# ECOLOGY OF THE SHARP-SHINNED HAWK (*Accipiter striatus*) IN SOUTHERN QUEBEC

by

Joanna L. Coleman

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements of the degree of Master of Science

> Department of Natural Resource Sciences Macdonald Campus of McGill University Montreal, Quebec

© Joanna L. Coleman, August, 2001



# National Library of Canada

Acquisitions and Bibliographic Services

395 Wellington Street Ottawa ON K1A 0N4 Canada

#### Bibliothèque nationale du Canada

Acquisitions et services bibliographiques

395, rue Wellington Ottawa ON K1A 0N4 Canada

Your file Votre référence

Our lile Notre rélérence

The author has granted a nonexclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of this thesis in microform, paper or electronic formats.

The author retains ownership of the copyright in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission. L'auteur a accordé une licence non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de cette thèse sous la forme de microfiche/film, de reproduction sur papier ou sur format électronique.

L'auteur conserve la propriété du droit d'auteur qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

0-612-78852-0

# Canadä

Early misty morning Dark, dense, damp forest Branches break as I brush past Spider spun handiwork tags along for the search

Eyes and ears open For a nearby nest Droppings dot the ground Plumes plucked from an unwary warbler

Fragile framework Carefully constructed and concealed Tiny twigs grapple, nodule to nodule Precariously perched in the bough, hugging the trunk

Sudden sunbeam Pierces gloom and alights To give but a glimpse of a blue-grey flash Negotiating a slalom course of twists and turns

Capricious cardinal song Turns to squawks and squeaks Last ditch, futile flutter and flap Effort to escape deadly grip of needle sharp talons

Breakfast for a Sharp-shinned Hawk

### ABSTRACT

The reproductive performance of Sharp-shinned Hawks (*Accipiter striatus*) nesting in southern Quebec was studied during the 1999 and 2000 breeding seasons. In 2000, 37.5% of breeders (equal numbers of males and females) were immature, whereas none were in 1999. In 2000, clutch size and hatching success were 4.4 and 3.1 eggs per nest, respectively. Of 10 pairs monitored in 2000, six hatched at least one chick and five raised young to a bandable age. However, only three pairs successfully fledged at least one young that year, whereas all seven nests observed in 1999 did so. Unseasonable weather in 2000 may have contributed to this decrease in nesting success.

In 2000, levels of organochlorines were measured in blood samples taken from sharpshin females and their young at five of the above-mentioned 10 nests. While most compounds were not detected at all, or at least not at levels likely to affect reproduction, concentrations of DDE and PCB's in these breeding females were much higher than in female migrants previously sampled in the eastern United States or Great Lakes. Whereas global contamination of the environment appears to be the source of PCB exposure, this population may be accumulating DDE on its wintering grounds.

Habitat assessments were conducted at 12 sharpshin nests over both years of the study. Means of the variables measured (among others) were nest tree height, 15.3 m; tree density, 1052/ha; total canopy cover, 86.7%; coniferous cover, 42.95%; and distance to the nearest opening, 17.5 m. Nests were found in a range of forested habitats, but this population did not exhibit a noteworthy degree of plasticity with respect to the measured parameters. That these sharpshins tended to use structurally older stands with more deciduous cover than other populations did may reflect regional differences in habitat availability and/or in the abundance of competitors.

# RÉSUMÉ

Le succès reproductif d'une population d'éperviers bruns (*Accipiter striatus*) nichant dans le sud du Québec a été étudié pendant les étés de 1999 et 2000. En 2000, 37.5% des nicheurs (un nombre égal de males et de femelles) étaient immatures, alors qu'aucun ne l'était en 1999. En 2000, une couvée moyenne comptait 4.4 œufs, parmi lesquels 3.1 ont éclos. Au moins un œuf a éclos dans six des 10 nids observés en 2000, et au moins un poussin a survécu jusqu'à l'âge où il pouvait être bagué dans cinq nids. Cependant en 2000, seulement trois couples ont réussi à élever au moins un oisillon jusqu'au point du premier envol, tandis qu'en 1999, chacun des sept couples observés l'ont fait. Le mauvais temps en 2000 (frais avec beaucoup de pluie) aurait peut-être contribué à cette baisse du taux de succès reproductif entre les deux années de l'étude.

En 2000, les taux d'organochlorés dans des échantillons de sang prélevés de femelles et de leurs poussins dans cinq des 10 nids mentionnés ci-haut ont été évalués. La plupart des composés n'ont pas été détectés du tout, ou du moins pas à des niveaux assez élevés pour affecter la reproduction. Cependant, ces femelles étaient beaucoup plus contaminées par le D.D.E. et les B.P.Cs que des femelles échantillonnées antérieurement lors de la migration dans l'Est des États-Unis ou les Grands Lacs. Il semble que cette population accumulerait des B.P.Cs à cause de la contamination globale de l'environnement, alors que les aires d'hivernage seraient la source de son exposition au D.D.E.

L'habitat a été évalué pour un total de 12 nids d'épervier brun en 1999 et 2000. Les moyennes des variables mesurées étaient (entre autres) la hauteur de l'arbre contenant le nid, 15.3 m; la distance à l'ouverture la plus proche, 17.5 m; la densité des arbres, 1052/ha; couvert canopé, 86.7%; couvert conifère, 42.95%. Les nids ont été trouvés dans plusieurs types de forêt, mais cette population n'a démontré aucune flexibilité remarquable dans les variables mesurées. Comparée aux autres populations, celle-ci avait tendance à utiliser des bosquets plus vieux structurellement, avec plus de feuillus, ce qui pourrait être indicatif de différences régionales dans la disponibilité d'habitat et/ou dans l'abondance des compétiteurs.

## ACKNOWLEDGEMENTS

First I would like to thank my principal supervisor, Dr. David Bird. Not only did he provide me with the opportunity to work on such a rewarding project, but he also allowed me to expand upon the original objectives and incorporate my own ideas for habitat and other investigations. I would also like to thank Dr. Rodger Titman, for his interest in my project, for coming out in the field, and helping me band birds. I owe a tremendous debt of gratitude to Mr. Eugene Jacobs, who travelled to Montreal to show me how to find Sharp-shinned Hawks, and then welcomed me into his own home in Wisconsin where he taught me to trap and handle them. These three people have been there for me throughout this project to offer constant encouragement and advice, and their passion for birds has certainly rubbed off on me.

Mr. Ian Ritchie, the technician for the Avian Science and Conservation Centre of McGill University, has been another invaluable source of guidance. He taught me and my research assistant how to draw blood samples, built field equipment for me and/or supervised me as I did so myself, and he helped me to provide the best care possible for my Great Horned Owl.

I would also like to express my heartfelt thanks to Ms. Stacey Jarema, my research assistant. Her conscientious, hard work, not to mention her positive attitude and friendship, all helped make the summer of 2000 highly productive and enjoyable. Ms. Kim Fernie must also be acknowledged for helping me and Stacey with the rather difficult task of obtaining blood samples from the chicks.

I am tremendously indebted to Mrs. Kay McKeever of the Owl Foundation for giving me my lure bird, Stevie, the Great Horned Owl. Without him sharpshin trapping would likely have been conducted with a far less effective stuffed decoy. Furthermore, the experience of working with such a wonderful bird has been immensely satisfying in and of itself.

Perhaps one of the most rewarding aspects of this project was having the participation of countless Montreal area birdwatchers, who provided me with tips about potential nest sites. The people belonging to the email forum Ornitho-Québec deserve specific recognition, as does Dr. Ron Zelt.

I would be remiss if I did not acknowledge the employees of les Parcs de la Montérégie, including (among others) Mme Danielle Chatillon, and especially M. Denis Henri and M. Pierre Wery. These people not only permitted me to conduct my research within provincial park boundaries, but also provided me with much information and numerous tips about possible nest sites (as well as free access). The same is true of les Parcs-Nature du C.U.M., which allowed me unlimited access to their parks, and one of their wildlife technicians, M. Denis Fournier. Similarly, I would like to thank M. Michel Robert and the Montreal Botanical Gardens for permitting me to work with sharpshins on their land.

Funding for this project was provided by the Province of Quebec Society for the Protection of Birds (Alfred B. Kelly Memorial Fund), the Avian Science and Conservation Centre of McGill University and the Canadian Wildlife Service. I owe special gratitude to the CWS, especially Dr. Laird Shutt, for conducting the chemical analyses on my blood samples and providing me with technical advice throughout the toxicology study.

Finally, I would like to thank my family. My parents helped me get to the point of pursuing a Master's degree by financing my undergraduate studies and providing me with the type of emotional support all children should have from their parents. My brother and grandmother also showed a remarkable interest in what I was doing and they too helped me to achieve my goals. My husband, Paul Payette, may come last, but most certainly not least. He put up with my crazy schedule, helped out with fieldwork, and did more than his share of housework and wedding planning when I was too busy or too tired. Even though I was sometimes too harried to pay him the attention he deserves, he has always been there arms open wide with love and encouragement.

# **CONTRIBUTIONS OF AUTHORS**

The body of this thesis consists of three chapters, each of which is a separate paper intended for publication in an as yet undetermined scientific journal. These papers are preceded by an introductory section, which itself consists of a literature review, a description of the various study objectives and a description of the study area. The articles are summarized and links between their results are put forth in the conclusion.

The thesis was entirely written by J. L. Coleman. In the toxicology study (Chapter 4), blood samples were collected by J. L. Coleman and analysed by L. Shutt of the Canadian Wildlife Service. He also provided editorial and technical advice, and appears as a co-author of that paper. The toxicology results were however, analysed by J. Coleman. In the nest habitat assessment (Chapter 5), data were collected and analysed by J. Coleman. E. A. Jacobs was a source of guidance and technical advice, and therefore appears as a co-author of that paper. D. M. Bird provided the basis for the entire project as well as editorial assistance and advice, and is a co-author of all three articles.

# TABLE OF CONTENTS

Chapte	er 1: Introduction			
	1.1 Introduction			
	1.2 Distinguishing characteristics			
	1.3 Foraging ecology			
	1.4 Predation			
	1.5 Habitat			
	1.6 Nesting ecology			
1.7 Nesting density, home range and territoriality				
	1.8 Lifespan and mortality			
	1.9 Migration	8		
	1.10 Population trends and study objectives	10		
Chapter 2: Study area and nest sites				
Chapte	er 3: Reproductive success of Sharp-shinned Hawks in Montreal	21		
	Abstract	21		
	3.1 Introduction	21		
	3.2 Methods	23		
	3.2.1 Location of potential nest sites	23		
	3.2.2 Location of nests	24		
	3.2.3 Clutch size	24		
	3.2.4 Hatching success	25		
	3.2.5 Nesting success	25		
	3.2.6 Age at first breeding	26		
	3.2.7 Data analysis - determination of nesting success	26		
	3.3 Results			
	3.3.1 Clutch size	27		
	3.3.2 Hatching success	27		
	3.3.3 Nesting success and causes of nest failure	28		

	3.3.4 Age at first breeding	29	
3.4 Dise	cussion	29	
Connecting sta	3.3.4 Age at first breeding 29   scussion 29   atement 35   ganochlorine levels in Sharp-shinned Hawks in Montreal 36   ict 37   ict 4.2.1 Trapping of breeders and retrieval of nestlings   ict. 4.2.2 Non-invasive manipulations of breeders and nestlings   ict. 4.2.3 Blood collection   ict. 4.2.4 Contaminant analysis   ict. 4.3.1 OC and PCB concentrations in plasma   ict. 57   st habitat use by Sharp-shinned Hawks in southern ebec. 58   act 52.1 Elimination of bias in nest searches 50   ict. 52.1 Elimination of bias in nest searc		
Chapter 4: Orga	anochlorine levels in Sharp-shinned Hawks in Montreal	36	
Abstrac	st in the second s	36	
4.1 Intro	oduction	36	
4.2 Met	thods	39	
	4.2.1 Trapping of breeders and retrieval of nestlings	39	
	4.2.2 Non-invasive manipulations of breeders and nestlings	40	
	4.2.3 Blood collection	40	
	4.2.4 Contaminant analysis	41	
	4.2.5 Data analysis	42	
4.3 Res	sults	42	
	4.3.1 OC and PCB concentrations in plasma	42	
	4.3.2 Estimated concentration of p,p'-DDE in eggs	48	
4.4 Dis	cussion	48	
Connecting statement			
Chapter 5: Nes Que	t habitat use by Sharp-shinned Hawks in southern bec	58	
Abstrac	ot la	58	
5.1 Intr	5.1 Introduction		
5.2 Me	thods	60	
	5.2.1 Elimination of bias in nest searches	60	
	5.2.2 Nest habitat assessments	60	
	5.2.3 Habitat variables and measurement techniques	61	
	5.2.4 Data analysis	62	
5.3 Res	sults	63	

5.4 Discussion	65
Chapter 6: Summary, conclusions and recommendations	71
Literature cited	77

2 -

# **Chapter 1: Introduction**

# 1.1 Taxonomy, status and distribution

The genus *Accipiter*, in the subfamily Accipitridae, includes approximately 50 species, more than any other genus of diurnal birds of prey in the world. Accipiters live in almost all wooded and scrub habitats on every continent except Antarctica. While the genus includes hawks that range in size from very small to medium, most species share common features of body shape and plumage. Like many other forest birds, they are rather slender, with long tails and short, broad wings, all features designed to enhance manoeuvrability. Long legs and toes are adapted for catching birds, an important part of the diet of many of these hawks. Except for some tropical and sub-tropical species, the majority of accipiters have bluish-grey backs and barred breasts (Newton, 1991).

The Sharp-shinned Hawk (A. striatus) or sharpshin, is the smallest of the three North American accipiters (Newton, 1991; Bildstein and Meyer, 2000) and the smallest diurnal forest raptor on the continent. There are 10 subspecies (Brown and Amadon, 1968), but only two are known to breed in North America. A. s. perobscurus is restricted to the Queen Charlotte Islands and possibly part of mainland British Columbia. A. s. velox is far more widespread, breeding over much of the continent (Godfrey, 1990); (Fig. 1.1).



Figure 1.1 Distribution of the Sharp-shinned Hawk in North and part of Central America

In Canada, the Sharp-shinned Hawk nests throughout the Yukon and Northwest Territories west of the Mackenzie River, and almost everywhere south of the 60<sup>th</sup> parallel. It is absent from most of Labrador and northwestern Newfoundland, from Quebec and Ontario north of the 55<sup>th</sup> parallel, and from parts of southern Alberta, Saskatchewan and Manitoba (Bildstein and Meyer, 2000).

At a more regional level, sharpshins nest throughout the province of Quebec south of the 51<sup>st</sup> parallel, particularly in the coniferous, mixed and deciduous forest zones. However, they are less commonly encountered in the region upstream from Trois-Rivières and in the St Lawrence lowlands, the most densely populated part of the province and the location of the current study area. In recent years on the island of Montreal, sharpshins have only been observed sporadically, although one observer in particular apparently discovered more than 200 nests in the greater Montreal area in the early part of the century (Ouellet and Bombardier, 1996).

Canadian populations (and individuals) may or may not be migratory, but those that are generally winter in North America south of the 50<sup>th</sup> parallel, i.e. the southern United States, although some go as far as Central America (Flood and Bortolotti, 1986).

The other two North American accipiters are the larger Cooper's Hawk (*A. cooperii*) and the still larger Northern Goshawk (*A. gentilis*). While the Cooper's Hawk's distribution is more southerly than the sharpshin's, the goshawk's distribution is more northerly (Dunn, 1987). Interestingly, neither of these birds is the sharpshin's closest relative. Rather, its closest cousin is the slightly larger Sparrowhawk (*A. nisus*), which breeds throughout much of Europe, the northern half of Asia and part of North Africa (Newton, 1991; Bildstein and Meyer, 2000).

In the United States, the Sharp-shinned Hawk is found on certain state lists of species requiring special protection. It does not however, currently appear on any provincial or federal lists of vulnerable, threatened or endangered species anywhere in Canada, and is likely one of the most numerous, though uncommonly seen raptors in the country (Kirk, 1997).

#### **1.2 Distinguishing characteristics**

Female sharpshins are roughly pigeon-sized, measuring 29-34 cm in length, with a wingspan of 58-65 cm and a mass of 150-218 g. Males are smaller at 24-27 cm in length, with a wingspan of 53-56 cm and a mass of 87-114 g. With males averaging about 57% of the body mass of their female counterparts, sharpshins exhibit the most extreme reverse sexual size dimorphism of all North American birds (Mueller and Berger, 1970).

This remarkable size difference allows for easy differentiation of the sexes, which otherwise diverge little, if at all in appearance (Bildstein and Meyer, 2000). Adults and juveniles however, are easily distinguished on the basis of colouration alone (Fig. 1.2). In adults, the upperparts are bluish-grey with a slightly darker cap. The underparts are whitish, with a pattern of fine, rufous, horizontal bands on the breast and belly. Adults also have red eyes, quite unlike the yellow eyes of immature individuals. Juveniles have brown to grey upperparts, often with white blotches and streaks, particularly on the head. Their underparts are white to cream with a bold, blurry pattern of mostly vertical brown streaking on the breast and belly. The undersides of the wings are whitish, with prominent dark bands that appear black in adults and dark brown in juveniles. In both adults and juveniles, the tail has several thick, dark horizontal bands and a narrow band of white at the tip, which, when folded, appears squared-off or notched (Bildstein and Meyer, 2000).

This tail shape is a crucial field mark because it can be used to distinguish sharpshins from Cooper's Hawks, with which they are frequently confused. Both species have nearly identical plumages, and while female Cooper's Hawks are roughly crow-sized, males are not appreciably larger than female sharpshins. However, when folded, a Cooper's Hawk's tail is rounded at the tip, and its head is proportionally larger than that of a sharpshin, with a prominent crest, or capital tract at the back that it erects when agitated (Rosenfield and Bielefeldt, 1993).



Figure 1.2 Plumage differences between adult (left) and yearling (right) Sharp-shinned Hawks

# 1.3 Foraging ecology

Although all three North American accipiters are bird-eaters, sharpshins are by far the most reliant upon avian prey (mostly small to medium-sized birds), which make up 97% of their diet (Storer, 1966). This may partly explain their degree of sexual size dimorphism, which tends to be most exaggerated in raptors that hunt the fastest-moving prey (Newton, 1979). The sexes differ significantly in type and mass of their prey, i.e. females capture prey that are on average 61% heavier than those taken by males (Storer, 1966).

Compared to their North American cousins, sharpshins also feed upon a wider range of bird species and genera. *Dendroica, Melospiza, Turdus, Hylocichla and Spizella* are among the most frequently taken (Storer, 1966). During the breeding season, they take advantage of the abundant supply of nestlings and fledglings, which therefore make up a significant proportion of their diet during this period. Other prey items include small mammals or large insects (Bildstein and Meyer, 2000).

The preferred hunting technique for sharpshins is the ambush. They spot their quarry from an elevated perch, and then use cover and the element of surprise to launch a rapid attack upon birds that are perched or in flight (Ouellet and Bombardier, 1996). With their very long legs and toes, and long, sharp, needle-like talons, they can easily reach into thick vegetation to seize their prey

(Bildstein and Meyer, 2000). They are just as adept at capturing birds at feeders, and actually kill more of them than any other predator, including the domestic cat

(*Felis catus*) (Dunn and Tessaglia, 1994). Sharpshins thoroughly pluck and dismember their prey before eating it, usually on a raised perch such as a log, branch or rock. During the nesting season they often have one or more habitual plucking perches (Fig. 1.3), normally within 30 m of the nest. The presence of piles of feathers, beaks, bird limbs and sometimes entire skeletons may therefore serve as a useful clue to the location of a sharpshin



# **1.4 Predation**

nest (E. Jacobs, pers. comm.).

Adult sharpshins are small and rather vulnerable to predation, particularly by other

Figure 1.3 Prey remains at sharpshin plucking perch

raptors, especially Great Horned Owls (*Bubo virginianus*) and goshawks (Newton, 1979; Moore and Henny, 1983). Even Cooper's Hawks will kill and eat them (Wiggers and Kritz, 1991). Other birds of prey that have been observed to take adult sharpshins, particularly on migration, include Bald Eagles (*Haliaeetus leucocephalus*) and Peregrine Falcons (*Falco peregrinus*) (Bildstein and Meyer, 2000).

Sharpshin nestlings and/or eggs are a common target for a wide variety of predators, which in the northeast include Blue Jays (*Cyanocitta cristata*), American Crows (*Corvus brachyrhynchos*), Grey Squirrels (*Sciurus carolinensis*), and Raccoons (*Procyon Lotor*). Both of the larger accipiters also depredate sharpshin nests, as do Great Horned Owls and Barred Owls (*Strix varia*) (E. Jacobs, pers. comm.).

## 1.5 Habitat

Of all aspects of sharpshin ecology, nest habitat use has probably been the subject of the greatest number of studies, according to Flood and Bortolotti (1986), although most of them have been conducted in the midwestern or western United States. It is difficult to extrapolate the results to northeastern populations, but overall, the literature indicates that breeding sharpshins inhabit dense, often young coniferous or mixed forests with a good deal of cover. Sharpshins in the St. Lawrence lowlands tend to frequent stands near bushy fields or clearings (Ouellet and Bombardier, 1996). Compared to Cooper's Hawks, sharpshins tend to nest in denser stands, with proportionally more evergreens and thicker canopies (Reynolds et al., 1982; Moore and Henny, 1983; Siders and Kennedy, 1996; Trexel et al., 1999). They also appear to build their nests in particularly dense areas within stands, perhaps in order to obtain protection from predators (Flood and Bortolotti, 1986).

Habitat use does not appear to change very much during migration, when individuals continue to demonstrate a tendency to frequent forests and their edges, probably because of the suitability of such areas for foraging (Sutton and Kerlinger, 1997; Bildstein and Meyer, 2000). Similarly, although relatively little is known about habitat use by wintering sharpshins, they do appear to maintain a certain consistency in this respect throughout the year. Furthermore, they tend to exploit the abundance of songbirds around bird feeders even more during the winter than they do during the summer months (Bildstein and Meyer, 2000)

#### 1.6 Nesting ecology

Although sharpshins occasionally reuse an old nest, they usually build a new one every year, and across much of the continent conifers tend to be their preferred nest trees (Bildstein and Meyer, 2000). The nest is normally placed in the live canopy, anywhere from 2.4 to 23 m above the ground, against the trunk and supported by one or more horizontal branches. It is a relatively flat platform, about 40-65 cm wide, made of small coniferous twigs and branches arranged in a rather untidy manner (Flood and Bortolotti, 1986; Ouellet and Bombardier, 1996;

Bildstein and Meyer, 2000). It appears that the male chooses the nesting area and uses display flights to attract passing females (E. Jacobs, pers. comm.). Both members of the pair gather nesting materials, while the female does most of the actual nest-building (Bildstein and Meyer, 2000).

There seems to be relatively little geographical variation in breeding phenology, and nesting activities usually get underway shortly after the return from spring migration (Flood and Bortolotti, 1986). Starting in late April to late May, the female lays anywhere from one to eight eggs (usually four or five), on alternate days. She begins to incubate them when the penultimate egg is laid, so that they all hatch within 48 hours (Reynolds and Wight, 1978). Throughout the 30-32 day incubation period, the male provides most, if not all of the female's food. Until the nestlings are roughly two weeks old, he continues to do all the hunting but does not actually feed the young. That responsibility falls to the female, as does that of brooding. After that point she begins to participate in food provisioning (Quellet and Bombardier, 1996; Bildstein and Meyer, 2000).

Depending upon latitude, male nestlings spend 21-24 days in the nest, while females take longer to develop and fledge after 24-27 days (Platt, 1976; Flood and Bortolotti, 1986). Although fledglings attempt to hunt after about two weeks, they continue to depend upon their parents for food (Mueller et al., 1981), and remain with them in the vicinity of the nest for about 3.5 weeks post-fledging. Little is known about the behaviour of fledglings after they are completely independent, except that most will not breed until they are at least two years old (Bildstein and Meyer, 2000).

Still, sharpshins are far more likely to breed as immature individuals than either of their North American congeners (Bednarz et al., 1990). Also, it appears that while their reproductive ecology may not be as well understood as that of the other two North American accipiters, sharpshins are on average the most productive of the three, particularly with respect to fledging success (Reynolds and Wight, 1978; Wiggers and Kritz, 1994).

# 1.7 Nesting density, home range and territoriality

Breeding sharpshins are highly territorial and both sexes vigorously defend the immediate area around the nest, especially against interspecific intruders. They also attack humans who approach too closely or linger for too long near the nest, although aggression levels vary considerably among individuals (Bildstein and Meyer, 2000). The distance between concurrently active nests ranges from 0.7 to 6.0 km, although the mean appears to be between 1.2 and 4.1 km, depending upon the region (Reynolds and Wight, 1978; Meyer, 1987). Radiotracking of breeders in New Brunswick showed that males and females ranged over areas of 1.2 to 2.7 km<sup>2</sup> and 0.9 to 1.4 km<sup>2</sup>, respectively. In North Carolina, home range sizes were 2.5 km<sup>2</sup> for males and 2.8 km<sup>2</sup> for females (Meyer, 1987).

#### 1.8 Lifespan and mortality

Although the maximum lifespan recorded for a wild sharpshin is close to 10 years (Clapp et al., 1982), most do not live past the age of three years. Two of the three principal factors in sharpshin mortality appear to be of human origin, i.e. collisions with vehicles and windows (especially near bird feeders), in addition to predation. Starvation likely accounts for a fair proportion of deaths, particularly in nestlings and in hatch-year birds, which experience the highest mortality rates in fall and winter (Bildstein and Meyer, 2000).

#### **1.9 Migration**

Sharpshins are more migratory than either of their North American congeners (Struve and Goodrich, 1992) and their autumn migration continues uninterrupted for longer than that of any other eastern raptor. They are actually best observed on their southward migration, and are often the most numerous hawks at migratory lookouts (Flood and Bortolotti, 1986), partly because they tend to migrate at low altitude (550-1000 m) (Ouellet and Bombardier, 1996).

Northeastern populations have two main fall flyways (Fig. 1.4); the inland route along the easternmost ridge of the Appalachians, used mainly by adults,



Figure 1.4 Migratory routes of northeastern sharpshin populations

and the Atlantic coastal route, flown mainly by juveniles (Viverette et al., 1996). In fact, 96% of the sharpshins trapped at Cape May Point are juveniles (Clark, 1985). Summer band recoveries show considerable overlap between these routes, indicating that both are likely used by members of the same populations, although individuals do not necessarily take the same route each year (Flood and Bortolotti, 1986). Not only do

juveniles and adult migrants apparently use separate migratory routes, but they also migrate at different times. Hatch-year birds leave the breeding grounds first (starting in August in Quebec), while breeders continue to abandon their nesting grounds into October. The fall flight through the St-Lawrence River valley peaks in mid-September (Ouellet and Bombardier, 1996). The sexes also segregate on migration, with females departing before males (Struve and Goodrich, 1992).

Migrating sharpshins often engage in soaring or flapping flight, alone or in small, sometimes interspecific kettles. They do not rely upon energy reserves to fuel their journey, but instead stop to hunt along the way (see section 1.5 for details on habitat use during migration), another tendency that increases the frequency with which they are seen during this time (Bildstein and Meyer, 2000).

Less is known about the spring migration, which is certainly less concentrated than the fall flight, but evidence suggests that northward migratory routes are basically the same as southward ones. The return flight in spring in the Montreal area peaks in late April to early May (Bildstein and Meyer, 2000).

## 1.10 Population trends and study objectives

Like many other raptors, sharpshin populations experienced declines from the 1940s to the early 1970s. Contributing factors may have included the shooting of thousands of individuals (especially migrants) every year during the first part of the 20<sup>th</sup> century and the taking of eggs (prized for their beauty) by collectors (Bildstein and Meyer, 2000). However, the widespread use of DDT, with its ability to impair reproduction, was almost certainly the principal agent of this trend (Snyder et al., 1973). Still, perhaps due to its more rapid generation time and comparatively high proportion of immature breeders, sharpshins recovered from their DDT-era lows more rapidly than Cooper's Hawks did, and appeared to have completely rebounded by 1970 (Bednarz et al., 1990).

Although the Sharp-shinned Hawk is not a listed species in Canada (see section 1.1) and is thought to number in the hundreds of thousands, the overwhelming message in the literature is that any evidence for trends in Canadian populations is quite equivocal (Kirk et al., 1995; Viverette et al., 1996; Kirk, 1997; Kirk and Hyslop, 1998). In fact, accurate population numbers for sharpshins over most of their extensive range are not known. This is largely due to their secretive nature and wide dispersal, both of which make it difficult and costly to census their populations (Bildstein, 1998; Kirk and Hyslop, 1998). In fact there is no information at all about the size of specific breeding populations, probably because their nests are extremely difficult to find (Kirk, 1997). Also since Canadian birds mix with others on their wintering grounds, it is impossible to count them accurately on non-breeding grounds (Kirk et al., 1995).

Nevertheless, population numbers and trends are inferred from various sources. One is the Breeding Bird Survey (BBS), a volunteer roadside count, conducted (in June) since 1966, along roughly 3000 randomly selected survey routes in all states and provinces. The BBS is the most comprehensive method for monitoring North American land bird populations, but it does have limitations. Thomas and Martin (1996) revealed how the development of new methods to analyse BBS data since the survey's inception have sometimes caused vastly

different population trends to be inferred from the same data sets. Kirk et al. (1995) mentioned regional variation in density and inconsistent coverage of routes as potentially important biases. However, the most problematic source of error, especially for sharpshins, is the uniqueness of roadside habitats, which contain different numbers of birds than points chosen at random. Certain predators, like American Kestrels (*F. sparverius*) and shrikes (*Lanius* spp.) commonly use telephone and power lines as hunting perches. Others, like eagles and Ospreys (*Pandion haliaetus*), build large, conspicuous nests. While these birds are often observed from the road, secretive forest-dwellers like accipiters are not (Kirk and Hyslop, 1998).

Christmas Bird Counts (CBC) are conducted annually in North America by volunteers, from December 11<sup>th</sup> to January 8<sup>th</sup>, within 25 km diameter circles. This method also has its drawbacks. One is regional and yearly variation in effort (Viverette et al., 1996). Dunn (1995) also noted that CBC totals are sometimes artificially inflated by feeder watchers, i.e. varying numbers of participants who simply count birds at their feeders. These people may record up to seven times more individuals of certain species than field observers do, mainly because birds are so visible at feeders. This is of particular concern for counts of sharpshins, which so often hunt around feeders. Finally, because of the cold, often inclement weather during this time, feeder watchers make up a greater proportion of CBC participants in northern areas, where more wintering birds also visit feeders due to the relative lack of natural food sources. Thus, the relative level of bias increases at higher latitudes, decreasing the reliability of CBCs for estimating trends in Canadian sharpshin (and other bird) populations.

Breeding bird atlases, which may elucidate the distribution and relative abundance of raptors, are less useful for discerning population trends, because they only represent a fixed period of time, usually five to 10 years. The information they provide may also be biased in much the same way as the BBS, i.e. a relative lack of coverage for areas far from well-populated areas and variation in observer effort (Kirk and Hyslop, 1998).

The Étude des Populations d'Oiseaux du Québec (EPOQ) is basically a compilation of checklist data that were collected between 1969 and 1989 for the province of Quebec. They were analysed by A. Cyr and J. Larivée in 1995, who determined population trends by the number of checklists in which the species were recorded (Kirk and Hyslop, 1998).

By far most of the available information about sharpshin populations comes from migration count data. While sharpshins are rarely seen during the breeding season, during migration they follow certain topographical features and concentrate in spectacular numbers along well-used corridors (Fig. 1.4). Lookouts or watch sites along these routes have been used as counting sites since early this century. While these counts are the single most important source of data about many raptor populations, their ability to discern trends has been guestioned. Bednarz et al. (1990) noted that while there is considerable variation in observer effort between years, a bigger problem is the influence of weather on migratory behaviour. Count data are generally presented in terms of numbers of birds observed per year or per hour of effort, and are not adjusted for natural seasonal, daily and hourly variations in the volume of migrants. Here, variation in observer effort combines with weather-related factors to create what may be a serious bias. Specifically, coverage has recently tended to be higher early and late in the migratory season, when there are normally fewer migrants. Thus, when these data are compared with totals per hour from earlier years, they may be misinterpreted as indicative of declines. Similarly, hawk-watching has become increasingly popular over the past two decades or so, and any increases in the counts of migrants may therefore result more from this increase in observer effort than from actual population growth (Flood and Bortolotti, 1986).

Some studies (Bednarz et al., 1990; Titus and Fuller, 1990) examined the concurrence between estimates of population trends made from migration counts at certain lookouts with those made from counts at other lookouts and by other methods, like the BBS. When combined, the data from different watch sites seem to be valuable indicators of trends over long periods of time and large geographical areas, but are less useful for detecting trends in specific breeding

populations. The problem is that individuals counted as they fly past the lookouts cannot be identified as to origin. Where sharpshins are concerned, sex and age-related differences in the routes and timing of migration (see section 1.9) lead to age and/or sex biases in the data from single lookouts, further discouraging efforts to use these data to infer population trends (Flood and Bortolotti, 1986).

Overall, the uncertainty associated with the interpretation of data obtained from all these methods of monitoring populations makes it difficult to determine whether discrepancies result from the methods and their limitations, or whether they reflect real population trends. In an effort to unravel this issue and pinpoint those species for which this has masked a lack of useful data, Kirk and Hyslop (1998) reviewed the population trends and status of numerous Canadian raptors according to all the above-mentioned data sources. Overall, the BBS, CBC and EPOQ recorded increasing sharpshin numbers over a roughly 30-year period, from the mid-1960s to the mid-1990s, although, according to the BBS, they declined from 1985-1994. This parallels data from Cape May Point indicating a significant decline (92% overall) from 1979 to 1992, while Hawk Mountain recorded a less marked decline (23% overall) for the same period (Viverette et al., 1996; N. Bolgiano, unpubl. data) (Fig. 1.5). Band recoveries indicate that both lookouts count sharpshins that breed in Quebec (Clark, 1985). Whereas counts at other eastern watch sites also declined, they did not do so at sites west of the Great Lakes, which instead reported stable or increasing numbers of migrating sharpshins over the same period of time (Kerlinger, 1993). Since 1992, sharpshin counts at Cape May Point have shown a general increasing trend. Perhaps there is a separate population in the northeast, e.g. in the Maritimes, that is rebounding from the effects of defoliation and spraying, including reduced songbird numbers, related to a spruce budworm (Choristoneura fumiferana) epidemic that occurred there in the late 1970s. On the other hand, counts of sharpshins at Hawk Mountain have decreased slightly since 1992 (N. Bolgiano, pers. comm.), which may corroborate some evidence of recent declines in Canadian sharpshin populations (Kirk and Hyslop, 1998).



Figure 1.5 Numbers of Sharp-shinned Hawks counted per hour at Hawk Mountain, PA and Cape May Point, NJ

This decline in counts of northeastern migrants (1980s to early 1990s) compared to their more western counterparts was initially attributed to various, mainly benign causes, such as changes in migratory and/or weather patterns. However, later hypotheses focussed on the possible roles of environmental contamination and habitat loss, among other problems.

In an attempt to resolve this issue, Viverette et al. (1996) compared combined data from Hawk Mountain and Cape May Point with eastern CBC and weather data, hypothesizing that the decline was related to a northward shift in overwintering populations. They determined that weather changes, particularly in the passage rates of cold fronts, which tend to increase the volume of migrants, could not have accounted for these declines. Instead, the numbers of sharpshins observed north of both lookouts had increased by more than 7% per year from 1979 to 1989, lending some support to their hypothesis. Viverette et al. (1996) suggested that northern populations had altered their migratory behaviour and were lingering on their breeding grounds, either not flying south at all, or not departing until early December when fall migration counts are already completed. They postulated that the growing popularity of bird-feeding in northern areas might be making them into profitable foraging grounds for wintering sharpshins.

However, it is significant that declines were first reported along the coastal route four years before a similar trend was first noticed at Hawk Mountain (as indicated by arrows in Fig. 1.5) (Laura, 1992). Viverette et al. (1996) interpreted this as possibly reflecting a comparatively greater tendency among juveniles to change their migratory patterns in response to changing conditions. Still, they did not rule out decreased productivity in eastern sharpshin populations as the reason for the delay and the declines.

If decreased reproductive performance was really to blame, Viverette et al. (1996) advanced the possibility that these populations were taking up significant levels of reproduction-impairing organochlorines on their breeding and/or wintering grounds. In support, Bohall Wood et al. (1996) found higher levels of certain pollutants, namely DDE, in tissue samples collected from migrating sharpshins at Hawk Mountain and Cape May Point than in those from their counterparts west of the Great Lakes.

Viverette et al. (1996) also identified habitat change as another possible agent in any extant decrease in the reproductive success of eastern populations. Specifically, urbanization, as well as forestry and/or forest aging, may have reduced the availability of suitable breeding habitat (see section 1.5) for eastern sharpshin populations.

The overall impetus for the current thesis project was two-pronged. First, despite their assertions that sharpshins are abundant in Canada, several authors acknowledged the uncertainty associated with data regarding actual population numbers (Titus and Fuller, 1990; Kirk et al., 1995; Kirk, 1997; Kirk and Hyslop, 1998). All of them called for investigations into the actual size and health of sharpshin populations. Second, the question of whether the declines in counts of fall migrants reflected real population trends or changes in migratory patterns and winter distributions remained unresolved. Many researchers (Bohall Wood et al., 1996; Viverette et al., 1996; Bildstein and Meyer, 2000) stressed the need to

conduct simultaneous studies of eastern sharpshin populations, examining their productivity and the extent to which they are affected by organochlorines and habitat changes. Accordingly, the overall aim of the present study was to look at the impact of various human activities, i.e. the presence of organochlorines in the environment and urbanization, on the reproductive performance of a northeastern (Montreal area) Sharp-shinned Hawk population.

Specific study objectives were as follows:

- 1. To evaluate and compare the reproductive success of this population with that of its counterparts elsewhere based upon information in the literature.
- To determine whether this population is indeed being exposed to elevated levels of organochlorines based upon levels measured in migrant individuals in the East and Midwest.
- To characterize and compare the nest sites used by this urban population with those used by others, based upon habitat assessments previously conducted by researchers in considerably less populated areas.

Of particular interest were any possible links between productivity and exposure to organochlorines and/or urbanization. Ultimately, the intent was to apply any pertinent findings to the development of recommendations as to the necessary measures for the preservation of this and other northeastern sharpshin populations.

#### Chapter 2: Study area and nest sites



Figure 2.1 Map showing approximate location of study area (box)

The study area was a rough square about 15,625 km<sup>2</sup> in size, in southwestern Quebec (box in Fig. 2.1). Its boundaries, specified in permit 10706GF accorded by the Société de la faune et des parcs du Québec, were as follows: 46° 02' N; town of Val David 45° 01' S; US border 72° 44' E; town of Granby 74° 25' W; Ontario border

The study area was located in the St. Lawrence lowlands ecoregion, in the Mixedwood Plains ecozone. The zone is typified mainly by deciduous trees including, Sugar Maple (*Acer saccharum*), Yellow Birch (*Betula alleghaniensis*), Beech (*Fagus grandifolia*), and Basswood (*Tilia americana*), among others. Conifers are less numerous, but Norway Spruce (*Picea abies*), White Pine (*Pinus strobus*), Eastern Hemlock (*Tsuga canadensis*), and White Cedar (*Thuja occidentalis*), among others, are all found here (Rouleau, 1990).

Glacial action was the major force that shaped the land here, depositing silt, sand and gravel, and creating a relatively constant physiography. The topography is generally level, or nearly so; the only relief around Montreal consists of the Laurentian Mountains to the north and the Monteregian Hills to the south. Glacial deposits also provided the parent material for the fertile clay soils that characterize most of the area. The climate is northern; the average January minimum temperature is -15°C and the average daytime high in July is 26°C.

The warm, humid summers are favourable to agriculture, which is practiced on 58% of the land in the ecozone (Government of Canada, 1996).

Until the area was settled, it was mostly forested, although more than 75% of it has since been cleared. Mainly woodlots, tree rows and remnant stands remain, but do not support much of the wildlife that once lived here.

As evident from Fig. 2.2, the study area is dominated by the city of Montreal, on an island situated at the confluence of the Ottawa and St. Lawrence Rivers. The city covers 177 km<sup>2</sup>, about one third of the island's total area, but the Montreal Urban Community (MUC), an association of 29 municipalities, extends over the entire island and a few others nearby, covering an area of 494 km<sup>2</sup>. The metropolitan area is even larger (4,024 km<sup>2</sup>; 26% of the study area), and comprises 102 municipalities that extend onto more islands as well as significant portions of the north and south shores of the St. Lawrence. The city of Laval on another island directly north of Montreal is Montreal's largest suburb and Quebec's second largest city (Linteau, 2000).



Figure 2.2 Map of study area (star indicates nest in St. Armand, outside Greater Montreal area.

Montreal is the second largest metropolitan area in Canada in terms of area and population (close to 3.5 million residents in 1999). It is also the second oldest city in the country, having been founded in 1642.

Today, a glance at any map of the city and the surrounding areas shows that they are well-developed and crisscrossed by several major highways and a few railroads. In terms of green space per person, Montreal has less than any other Canadian city, i. e. just over 4000 parcels of land, 91% of which are less than 10 ha in area (46% are less than one ha). These parcels cover about 44% of the city's total area, or slightly more than 68,800 ha, only about 10% of which is wooded (Government of Canada, 1996).



Figure 2.3 Map of Montreal area showing locations of sharpshin (numbered stars) nests found in 1999 and 2000

A brief description of each of the nest sites shown in Fig. 2.3 is given in Table 2.1, with an indication as to whether it was included in the habitat study in 1999 or 2000, and in the toxicology study (Chapters 5 and 4, respectively).

Table 2.1 Sharpshin nest sites included in current project. Circled sitenumbers represent nests included in toxicology study

SITE #	SITE	DESCRIPTION	HABITAT
1	Île Bizard	Large White Cedar ( <i>Thuja occidentalis</i> ) stand in regional park	1999
2	Lac des Bouleaux	Small grove of Jack Pine ( <i>Pinus banksiana</i> ) at summit of Mont St-Bruno in provincial park (total area of 7.3 km <sup>2</sup> )	2000
3	Terrebonne	Intermediate White Pine ( <i>P. strobus</i> ) plantation bordering sand pits, quarry and residential area	2000
4	Mt St- Bruno	Small spruce ( <i>Picea</i> spp.) plantation bordering picnic area and pond at base of Mt St-Bruno in provincial park	1999
5	Pte-aux- Prairies	Large mixed forest in regional park	2000
6	Pavillon de la Pomme	Small Red Pine ( <i>P. resinosa</i> ) and Norway Spruce ( <i>P. abies</i> ) plantation bordered by apple orchards on all sides	2000
7	Bois-de- Liesse	Several widely spaced Norway Spruce within deciduous forest in regional park	1999
8	Hudson	Intermediate Norway Spruce plantation bordered by golf course on one side, secondary road on opposite sides, houses on other sides.	1999
9	Botanical Gardens	Small grove of Blue Spruce ( <i>P. pungens</i> ) in North America's largest botanical gardens and Montreal's most popular tourist attraction	2000
10	St-Basile- le-Grand	Small mixed forest stand surrounded by soy fields on all sides	2000
11	Morgan Arboretum	Mixed stand within the mostly forested Morgan Arboretum which covers an area of 245 ha	1999
12	St-Armand	Small pine plantation bordered on one side by a secondary road in the town of St-Armand	1999

# Chapter 3: Reproductive success of Sharp-shinned Hawks in Montreal Abstract

During the summers of 1999 and 2000, various reproductive parameters were measured at 17 Sharp-shinned Hawk nests in the Montreal area in order to assess the productivity of this urban population. Overall, 21.4% of female and 23.1% of male breeders were immature, but whereas second-year individuals accounted for 37.5% of male and 37.5% of female breeders in 2000, no immature breeders were observed in 1999. Clutch size and hatching success were determined in 2000; mean values were 4.4 eggs and 3.1 eggs per nest (69.4%), respectively. Six of 10 pairs (60%) hatched at least one chick and five (50%) raised young to a bandable age, i.e. at least 10 days. In 2000, only three of 10 nests (30%) managed to fledge at least one young while in 1999, all seven nests (100%) could be considered successful.

#### 3.1 Introduction

Determining population statuses and trends for birds of prey is generally more problematic than for their non-raptorial counterparts. Raptors tend to be not only widely dispersed, but also highly secretive and thus difficult to find on their nesting grounds (Kirk et al., 1995; Kirk and Hyslop, 1998). This is especially true for Sharp-shinned Hawks, which are rarely seen during the breeding season and whose nests are very hard to locate. They are arguably the most difficult accipiters and among the most difficult of all North American birds to census (Bildstein and Meyer, 2000). While sharpshins are counted by several methods including hawk watches, Christmas Bird Counts and the Breeding Bird Survey among others, the data they provide are too often inadequate. In fact, there is a lack of information about the productivity of many forest-dwelling raptors, especially accipiters (Kirk et al., 1995). For many, autecological studies continue to be useful means of population monitoring.

Ongoing systematic measurements of reproductive success in specific breeding populations can yield valuable insight into their status in a way that

other monitoring techniques may not. Productivity can affect population growth, and information about reproductive success can be used to predict population trends. Breeding studies can also provide clues about the extent to which a population is exposed to environmental contaminants, as certain reproductive parameters may be affected by exposure to various chemicals (Newton, 1979).

A useful breeding study should measure certain parameters of productivity. Clutch size may be affected by habitat quality and/or food availability (Newton, 1979), and at least in the closely related Sparrowhawk (*A. nisus*), nests with more eggs fledge more young (Newton, 1991). Sharpshin nests in temperate regions typically contain three to eight eggs, usually four or five (Bildstein and Meyer, 2000).

Hatching success, or the percentage of eggs that hatch, is a valuable measure of population health, one that also relates to the effects of certain pollutants. For example, DDT has been shown to contribute to eggshell thinning, egg breakage and egg desertion, each of which can prevent eggs from hatching (Snyder et al., 1973). Of course, eggs may fail to hatch for other reasons, like infertility for example, and various proportions of infertile eggs are observed in wild raptor populations (Newton, 1979; Bird and Laguë, 1982).

Nesting success, or the percentage of nests that fledge young, is a vital parameter to the assessment of productivity, and so is the mean number of fledglings per nest, which was 2.7 in Oregon (Reynolds and Wight, 1978).

One last useful parameter is the age at first breeding. Newton (1991) explained that a bird's breeding success generally increases with age during the first years of life when it is honing its foraging and parenting skills, and later decreases due to aging. Many individuals do not breed in their first year either because some restriction in a critical resource prevents them from doing so, or because reproduction takes place at the expense of survival, especially early in life. Most sharpshins are at least two years old when they breed for the first time (Bohall Wood et al., 1996; Bildstein and Meyer, 2000), but some breeders are juveniles, and most of those are females.

While the literature yields some insight into the productivity of certain sharpshin populations, no authors have yet investigated the performance of birds in human-dominated (urban) landscapes. Nor have any such data been published for eastern North American populations, the ones purported to have exhibited migratory declines in the 1980s and early 1990s. Furthermore, some authors (Apfelbaum and Seelbach, 1983; Wiggers and Kritz, 1994) have clouded the issue of reproductive success by only publishing data on the number of nests that produce bandable young as opposed to fledglings.

This study therefore aims to assess productivity (necessitating a measurement of the percentage of nests that fledge young) in the sharpshin population in the greater Montreal area, a prevalently urban situation. The expectation was that if this population were truly declining, it would exhibit relatively low productivity.

## 3.2 Methods

In the summers of 1999 and 2000, seven and 10 sharpshin nests, respectively, were located using unbiased methods, and parameters of reproductive success were measured throughout the nesting season at each nest. In 2000, all parameters were measured, while in 1999, the only data recorded pertained to fledging success.

#### 3.2.1 Location of potential nest sites

Eliminating bias was important for the habitat assessment (Chapter 5). This was accomplished by obtaining information from several different sources, and not systematically searching for nests in habitat that would appear suitable according to the literature.

In March 1999, copies of all Quebec nest record cards for Sharp-shinned Hawks were obtained from the Canadian Museum of Nature in Ottawa. This information was sought based upon the knowledge that while actual nests are rarely reused, nest sites are often reoccupied (Platt, 1976; Bildstein and Meyer, 2000), and that other researchers have used historical records to find sharpshin

nests (Wiggers and Kritz, 1991; Garner, 1999). A total of 17 records was received; five described past nests located within the study area for this project, three of which were recent enough (within the past 20 years) to be useful. The observers, whose names and addresses are listed on the cards, were asked to provide additional details as to the exact locations of those three nests.

Another source of tips about potential nest sites was an e-mail forum for birdwatchers from all over the province of Quebec. All messages were read and when observations of sharpshins were reported, the authors were contacted and asked to provide further details, especially regarding the exact locations at which they had made their observations.

Finally, information about sharpshin sightings was solicited from local birdwatchers and wildlife technicians working in municipal and provincial parks. Other researchers have used similar sources to help find sharpshin nests (Moore and Henny, 1983; Wiggers and Kritz, 1991; Garner, 1999; Trexel et al., 1999).

# 3.2.2 Location of nests

Starting in late April at all potential sites, a minimum 200 m radius in all forest types was searched on foot. Imitations of the territorial call of the Barred Owl (*Strix varia*) were used to elicit defensive responses from any sharpshins that might be present. These defense responses along with visual evidence of nesting activity, such as whitewash, pluckings or moulted feathers, were used to determine the location of a nest. Other researchers have used these techniques in their searches for sharpshin (and other raptor) nests (Wiggers and Kritz, 1991; Garner, 1999; E. Jacobs, pers. comm.).

# 3.2.3 Clutch size

Eggs were counted in late May, well past the time when sharpshins nesting at this latitude have normally begun to incubate (Bildstein and Meyer, 2000; E. Jacobs, pers. comm.). To minimize disturbance, a pole-mounted mirror was used to attempt to see into nests that were within its reach (Fig. 3.1).

The device consisted of a wide-angle mirror, screwed into an elbow joint made of 381 mm ABS piping. The mirror could be elevated by screwing the elbow joint into a 1.83 m long, straight piece of piping, which could be screwed into another identical piece, and so on, to a maximum height of nine meters. One person holding the lowermost section of piping could raise the mirror to just above the nest and shift it to provide a view of its contents for an observer using



Figure 3.1. View of four chicks in pole-mounted mirror (nest no. 10)

binoculars. When the device could not be used, i.e. the nest was too high or the view in the mirror was obscured by foliage, the eggs were counted by a climber.

# 3.2.4 Hatching success

At this latitude, sharpshin eggs generally hatch around mid-June (E. Jacobs, pers. comm.), so nests were first checked for hatched eggs in early June, with repeat visits every few days until hatching was completed. Whenever possible the pole-mounted mirror was used. The chicks were visually aged to estimate the approximate hatching dates, and to decide accordingly upon the appropriate trapping dates for the toxicology study (Chapter 4).

# 3.2.5 Nesting success

Sharpshins fledge, i.e. leave the nest, after 21 to 32 days, depending upon latitude and sex (males fledge before females), and for the first two days or so afterwards, tend to remain on branches of the nest tree and other nearby trees (Bildstein and Meyer, 2000). This is the best time to count them, since they are likely to be together. Based upon the timetable for sharpshins in Wisconsin, the chicks were expected to spend about 27 days in the nest (E. Jacobs, pers. comm.), an overestimate that made accurate fledgling counts impossible at most
nests. The best data obtainable only established whether the nests had fledged any young at all, in which case they could be considered successful, although in some cases it was possible to determine that more than one chick had fledged, i.e. when at least two fledglings were seen or heard simultaneously.

For all nests that failed (to produce fledglings), an attempt was made to determine the cause of failure. This could only be done with any degree of certainty when the nest had clearly been depredated, which was sometimes evident from the presence of nestling remains around the nest. Even then however, the nest could have been depredated after having failed for some other reason. For instance, breeders may abandon their eggs if prey is in short supply, leaving them to be eaten by predators. In such a case, predation may be the apparent, but not the direct cause of nest failure (Newton, 1979).

## 3.2.6 Age at first breeding

In both 1999 and 2000, the putative parents at each sharpshin nest were aged, i.e. identified as yearling or mature, based upon the different plumages of both age classes (see section 1.2, Fig. 1.2).

## 3.2.7 Data analysis - determination of nesting success

Hatching success is expressed as a percentage; considering hatched eggs per clutch.

A successful nest has been defined as one in which at least one nestling reaches a bandable age (Rosenfield and Anderson, 1983; E. Jacobs, pers. comm.), but this does not give a true representation of nesting success because the nest can still fail after this point (Newton, 1979). Woolfenden and Fitzpatrick (1990) more accurately define a successful nest as one that contributes to the pool of individuals of breeding age. While various studies have expressed reproductive success in terms of the mean number of fledglings per successful nest, per complete clutch and per territorial pair, the most relevant measure of productivity is the last figure, the only one that accounts for all possible causes of nest failure (Newton, 1979).

However, an accurate count of fledglings was not always possible (see section 3.2.5). Overall nesting success was thus considered as the percentage of active nests that were successful, i.e. produced at least one fledgling.

An active nest was defined as one in which eggs were laid, upon which a female was observed in incubating posture, or one at which one or both members of a pair exhibited defensive behaviours. Traditional definitions of active nests refer to nests in which eggs are known to have been laid (E. Jacobs, pers. comm.). However, in the present study, difficulties in reaching two high nests prevented clutch counts from being completed until after the nests had been abandoned. That a female was observed in incubating posture would indicate that eggs had been laid (E. Jacobs, pers. comm.). The definition of a nesting attempt was thus expanded as described above so that these nests could be included in the present study.

## 3.3 Results

## 3.3.1 Clutch size

The mean clutch size in 2000 was 4.4 (n=7) and ranged between four and five eggs per nest. While 10 nests were located, two of them (nos. 5 and 7; Table 3.1) were empty by the time clutch counts were attempted. One (no. 4; Table 3.1) was already empty when it was found and there was a fresh, unbroken sharpshin egg (and a freshly moulted sharpshin feather) on the ground beneath it. The nest was in a precarious position and the egg was assumed to have fallen out. Whether more eggs had been laid in that nest was unclear, so this nest was not included in the calculation of mean clutch size.

## 3.3.2 Hatching success

The mean number of eggs hatched per active nest in 2000 was 3.1 (n=8) and mean hatching success was 69.4%. In this case the nest with the fallen egg was included in the calculation since hatching success would have been zero regardless of how many eggs were originally laid.

## 3.3.3 Nesting success and causes of nest failure

In the present study where, to be considered successful, a nest must have fledged young, nesting success was 30% (n=10) in 2000 and 100% (n=7) in 1999. For the sake of comparison, had a successful nest been more broadly defined as one that produced bandable young, nesting success in 2000 would have been 50%, with a mean of 3.6 bandable nestlings per successful nest. In 1999, four nests fledged at least two young, and in 2000, two nests fledged at least two young.

Of the nests that failed in 2000, two (nos. 3, 8; Table 3.1) failed after the young had reached a bandable age and evidence of predation was found at both. Upon a return visit to nest no. 8, a roughly three-week-old nestling was found alive on the ground below the nest. She was suffering from a severe infestation of maggots in her ear, but was in otherwise excellent condition and was later brought to a rehabilitation centre. Neither putative parent was seen or heard and a thorough search of the site revealed the remains of at least one other similarly aged chick. As the live nestling was neither emaciated nor dehydrated, it was highly unlikely that she had been out of the nest for more than a few hours. The most plausible explanation was that a predator had raided the nest that very morning, and the parents had either been killed or had abandoned their nest.

One nest (no. 10; Table 3.1) failed for unknown reasons after the eggs had hatched, but before the young reached a bandable age.

Two nests failed during the egg stage. Predation was the most likely cause of failure at nest no. 9 (Table 3.1), as broken eggshells were found beneath it. Shoddy nest construction or predation may have caused the egg to fall out of nest no. 4 (see section 3.3.1), and the parents to abandon it.

Two nests failed either before or during the egg stage (see section 3.2.7), both were empty and abandoned by the time clutch counts were attempted.

## 3.3.4 Age at first breeding

The proportion of immature breeders over both years of the study was 21.4% for females and 23.1% for males. In 2000, three of eight (37.5%) putative mothers and three of eight (37.5%) putative fathers were immature. At two of 10 nests (20%), both putative parents were identified as immature. In 1999, all six of the observed putative mothers and all five of the observed putative fathers were identified as mature.

Nest	Age at 1 <sup>st</sup> breeding		ge at 1 <sup>st</sup> breeding Clutch		Number of	Number of	
	Female	Male	size	eggs hatched	bandable young	fledglings	
1	Adult	Adult	5	4	4	≥2	
2	Adult	Adult	5	5	5	≥1	
3	Immature	Immature	5	4	4	0	
4	n/a	n/a	≥1	0	0	0	
5	Adult	Adult	n/a	n/a	n/a	n/a	
6	Immature	Adult	5	5	2	2	
7	Adult	Adult	n/a	n/a	n/a	n/a	
8	Immature	Immature	4	3	3	0	
9	n/a	Immature	4	0	0	0	
10	Adult	n/a	4	4	0	0	
Mean	n/a	n/a	4.43	3.13	3.60 (n=5)	n/a	

 Table 3.1 Reproductive parameters measured on Sharp-shinned Hawks in

 2000 in the Montreal area

## 3.4 Discussion

Clutch size was within the normal range for sharpshins breeding in temperate climates (Bildstein and Meyer, 2000). Mean clutch counts were 4.3 in Utah (Platt, 1976) and Wisconsin (E. Jacobs, unpubl. data), 4.5 in Missouri (Wiggers and Kritz, 1994) and 4.6 in Oregon (Reynolds and Wight, 1978). The North American mean was 3.9 (Apfelbaum and Seelbach, 1983).

Mean hatching success was perhaps low compared to the 87% success rate of sharpshins breeding in New Brunswick (Meyer, 1987), but still equivalent to the 70% reported in Oregon by Reynolds and Wight (1978). Mean brood size (number of young in nest on first visit after hatching) in Missouri was 3.5 chicks (Wiggers and Kritz, 1994) and the North American mean was 2.7 (Apfelbaum and Seelbach, 1983), although it is unclear whether this last figure refers to actual hatching success or brood size (Bildstein and Meyer, 2000).

The mean number of nestlings that reached a bandable age, i.e. at least 12 days old) was equal to the 3.6. bandable young per nest over a 13-year period in Wisconsin reported by E. Jacobs (unpubl. data).

The relatively high percentage of immature breeders is noteworthy. In Wisconsin, 28% of 65 breeding females and 11% of 65 breeding males observed over 10 seasons were immature, and 4.6% of pairings were between two yearlings (Jacobs and Semo, 1997). No yearling breeders were observed at 10 nests in Oregon (Reynolds and Wight, 1978) or at 12 nests in New Brunswick (Meyer, 1987).

Yearling males and females were equally likely to breed in 2000, and pairings between yearlings occurred at least (both putative parents were not aged at some nests) 20% of the time. In fact, while both immature pairs failed to fledge young, they did rear their chicks to a bandable age and did not have particularly small clutches or low hatching success. Over 10 years in Scotland, 18% of putative fathers and 15% of putative mothers at Sparrowhawk nests were immature, and as most pairings were between individuals of the same plumage class, few adult-immature pairs were observed. Productivity was lower for pairs containing yearlings than for pairings between adults, and lowest for pairings between yearlings (Newton, 1991). In contrast, Jacobs and Semo (1997) found that adult male-yearling female pairs in Wisconsin were no less productive than pairings between adults, and that both performed better than pairs containing immature males. They also found that immature females bred much (2.5 times) more frequently than immature males, which was different from Newton's finding that juvenile males bred only slightly (1.2 times) more often than juvenile females. Furthermore, only 4.6 and 6.3% of pairs in Wisconsin and Scotland, respectively, were composed of two yearlings, and in Scotland, the highest percentage of yearling-yearling pairs reported in any one year was 13.5%.

Certainly this phenomenon is intriguing, and a longer-term reproductive study could increase the sample size to examine whether this population consistently contains more immature breeders than others and if so, what this might reveal about environmental conditions in the area. Higher proportions of yearling breeders are often observed when environmental conditions are especially conducive to breeding, i.e. abundant food supply and/or good habitat quality (Newton, 1979).

Of critical importance is nesting success, particularly the disparity in results between both years. In 1999, all seven nests produced at least one fledgling, which translates into a 100% success rate, higher than rates reported by previous researchers (Bildstein and Meyer, 2000). In 2000 however, nesting success was only 30%, a considerably lower result. Nesting success has been measured at 91.7% in Oregon (Reynolds and Wight, 1978) and 95% in New Brunswick (Meyer, 1987)

Drawing inferences about population trends that may have contributed to this phenomenon is impossible from a two year study, and further studies may show that both years were anomalies. However, there was one major difference between the nests that were surveyed in both years. While observer effort in 1999 was limited to just that – observation – the nests in 2000 were more disturbed. Climbing nest trees, handling birds and nest visits can potentially affect their success. For example, climbing a tree may leave a scent trail to be followed by mammalian predators like Raccoons (*Procyon lotor*), which commonly prey upon sharpshin (and other bird) eggs and nestlings.

It is not possible to determine whether investigator disturbance was implicated in the higher failure rate in 2000, but careful analysis of the particular circumstances of each failure appears to suggest that this is unlikely. For example, had a nest failed after the young were banded as a result of this intervention, the failure would have been expected to occur very shortly afterwards. The feather pins that were found among the nestling remains at both nests that failed after banding allowed the ages of the chicks at the time of death

to be estimated. The feathers of sharpshin chicks grow at a predictable rate. Primaries appear after about one week and begin to grow out of their sheathes after about 10 days, at a rate of about 4 mm per day. The approximate age of the chick is calculated by dividing the length of the grown out feather by four and adding the quotient to 10 (E. Jacobs, pers. comm.). At both above-mentioned nests, the young died at least one week after having been banded.

The only nest (no. 10; Table 3.1) that failed during the nestling stage before the young could be banded experienced the least disturbance in the course of this study. It was found a few days before the eggs hatched, at which time the tree was climbed and the eggs counted. One week later the polemounted mirror was used to establish that all four eggs had hatched two to four days earlier. However, the nest was remarkably low which, combined with its location very close to the forest edge, could have made it an easy target for a wide variety of predators (see section 5.4 for details regarding the implications of proximity to forest edges).

The nest (no. 9; Table 3.1) that was predated during the egg stage was situated in the Montreal Botanical Gardens where, according to staff members, many bird nests had been depredated by Raccoons.

Since the other three failed nests had been abandoned before eggs were counted, the interventions in this study are not likely to have played any role.

Neither visit frequency for Black Eagles (*Aquila verreauxii*) nor climbing to nests to band the young of Bald Eagles (*Haliaeetus leucocephalus*) have been found to decrease the productivity of these large raptors (Gargett, 1977; Grier, 1969, respectively). The fact that sensitivity to human disturbance is positively correlated with raptor size (Newton, 1979) and that sharpshins are considerably smaller birds further supports the conclusion that researcher disturbance did not contribute to the high nest failure rate in 2000.

Weather conditions could be implicated in the increase in nest failures seen in the summer of 2000, which arrived late and was characterized by unseasonably cold temperatures and above average precipitation (A. Julien, pers. comm.). Inclement weather can reduce both prey availability and the

hunting efficiency of raptors, while increasing their energy requirements. Cold, wet weather can thus contribute to elevated mortality of nestlings, which may receive inadequate food, shelter and/or warmth. Wet weather has been linked to reduced productivity in Ospreys (*Pandion haliaetus*) and Black Eagles (Odsjö and Sondell, 1976; Gargett, 1977, respectively). Spring weather was the main cause of annual variation in productivity among Sparrowhawks, which performed more poorly in years when April had been wet and cool (Newton, 1991).

Food shortage appears to have contributed to nestling mortality in at least one nest (no. 6: Table 3.1). All five eggs hatched, but the nestlings were still completely down-covered and too small to be sexed (or banded) at 10 to 12 days old, when they should normally have begun to grow their feathers and exhibit sexual size dimorphism. Furthermore, while the putative mother was trapped, the male never showed up. Upon a return visit to band the nestlings when they were at least 17 days old, only two male chicks remained in the nest. Both were very small at about 85 g, when they normally should have weighed at least 100 g. Again, only the female was trapped and discussion with the landowner revealed that while she had been spotted on a daily basis, no male had been seen for at least two weeks. Possibly he died or abandoned the nest, leaving his mate to raise the five chicks, and as she was unable to feed them all in addition to herself, three died. Interestingly, both surviving males fledged.

One shortcoming of the present study is the small sample size of nests, which reduces the strength of statistical tests and of conclusions put forth in this study. However, small sample sizes seem to be characteristic of studies of this secretive species. Reynolds and Wight (1978) surveyed only 11 active nests over six years and Wiggers and Kritz (1994) monitored 13 nests over two years. Added difficulty in making useful comparisons between this and other studies stems from the fact that assessments of reproductive success have been expressed in different terms by different authors, as discussed in section 3.2.7. Still, based upon the available data, certain conclusions may be drawn about the productivity of this population compared to that of others elsewhere.

Overall, the results of this study do not necessarily indicate that sharpshins are declining in the Montreal area. The disparity in nesting success between both years of the study may be nothing more than artefact. Normal clutch sizes and hatching success rates bode well for this population, and such diverse raptor species as the Red-shouldered Hawk (*Buteo lineatus*), Eastern Screech Owl (*Otus asio*) and Mississippi Kite (*Ictinia Mississippiensis*) have been found to be equally or more productive in urban areas than in rural areas (Dykstra, 2000; Gehlbach, 1996; Parker, 1996, respectively). Rosenfield et al. (1996) found that not only did Cooper's Hawks breeding in an urban/suburban area of Wisconsin have mean clutch sizes and numbers of bandable young comparable to the most elevated values, but they also nested at the highest nesting density ever recorded for this species. Many nest sites were also used year after year for long periods of time. Ultimately they concluded that, contrary to suggestions made in some previous studies, urban Cooper's Hawk nests are no less productive than their rural counterparts.

While a short-term productivity study cannot reveal trends in this sharpshin population, by monitoring 17 nests over two years, it at least provides baseline data and potential nest site locations to serve as the starting point for a longerterm reproductive study. Such a project would be a useful endeavour, particularly because no reproductive studies have been conducted on sharpshin populations in any other large urban areas or in anywhere in northeastern North America.

## **Connecting statement**

Decreasing numbers in a population are usually associated with diminished recruitment and therefore, reduced reproductive success. Thus, a useful first step in determining whether Sharp-shinned Hawks breeding in southern Quebec are declining was to evaluate their productivity and compare it with that of their conspecifics across North America. While this type of study on its own can help to confirm or deny that a population is declining, it can do nothing to identify the possible reasons why, or propose necessary measures to solve the problem. Concurrent investigations into the extent to which various factors may be affecting reproduction in a population can increase the value of productivity studies. Accordingly, the current project included an attempt to evaluate whether these sharpshins are exposed to levels of organochlorine contaminants that could be associated with reproductive failure.

## **Chapter 4: Organochlorine levels in Sharp-shinned Hawks in Montreal**

## Abstract

During the summer of 2000, blood samples were collected from breeding Sharp-shinned Hawk (*Accipiter striatus*) females and their young at five nests in the Montreal area in order to assess the extent to which this population is exposed to persistent organic pollutants. Most compounds were not detected or were present at levels that would be unlikely to have any measurable impact upon individual or population health. However, concentrations of DDE and PCBs were higher in these breeding females than in their counterparts migrating through the eastern United States or Great Lakes.

#### 4.1 Introduction

The insidious effects of organochlorine (OC) pesticides and polychlorinated biphenyls (PCBs) on wildlife are well documented. Use of these chemicals, especially DDT, has been linked to dramatic declines in several North American raptors, i.e. Bald Eagles (*Haliaeetus leucocephalus*), Ospreys (*Pandion haliaetus*) and perhaps most notably, Peregrine Falcons (*Falco peregrinus*). In Europe, DDT contamination has been blamed for crashes in populations of Sparrowhawks (*A. nisus*), the sharpshin's closest relatives (Newton, 1979).

Because OCs are lipophilic they accumulate in animal tissues, where their concentrations increase as they move upward through successive trophic levels in a process known as biomagnification. This is aggravated by the tendency of many of these chemicals to resist biodegradation and persist for decades in the environment. As OC residues also travel long distances in air and water currents and in migrant animals, they are brought from their sources to animal populations all over the world (Newton, 1979). For these reasons, combined with the ongoing use of DDT and other OCs in some countries, North American birds of prey continue to be exposed to this suite of chemicals (Government of Canada, 1996).

The presence of OCs in the environment poses particular threats to raptors for two main reasons. First, activity levels of the enzymes that metabolize

these pollutants are very low in raptors, which are thus very inefficient at breaking them down (Walker and Stanley, 1987). Second, to varying degrees, female raptors (and other birds) rid themselves of OCs by laying eggs (Newton, 1979) and even low maternal body burdens of DDT and its primary metabolite, DDE can reduce breeding success in many species. They do so mainly by causing eggshell thinning, but there is evidence to implicate them in abnormal parental behaviour, including desertion and deliberate breakage of eggs, and embryo death. In any case, significant DDT/DDE contamination in eggs often results in hatching failure (Cooke, 1973; Snyder et al., 1973; Newton, 1979). In Cooper's Hawks (*A. cooperii*), this seems to occur when egg levels of DDE exceed 3-4 ppm (Snyder et al. 1973). These levels were associated with a 15% reduction in Sparrowhawk productivity (Newton et al., 1986), and while the critical level in sharpshins is unknown, it is likely very similar.

Unfortunately, sharpshins may be especially at risk for DDT-related reproductive failure mainly because they rely so heavily upon avian prey (see section 1.3), which generally contain higher levels of residues than mammalian or reptilian prey (Cooke, 1973; Snyder et al., 1973). Also, since they feed higher in the food chain than either of their North American congeners (Storer, 1966), sharpshins should be comparatively more contaminated (Snyder et al., 1973; Noble and Elliott, 1990).

Indeed, several studies have shown that sharpshins have greater body burdens of DDE than Cooper's Hawks and Northern Goshawks (*A. gentilis*). For instance, after DDT was used to control a moth outbreak in forests of the Pacific Northwest, sharpshins nesting in the area were 1.6, 2.3 and 6.1 times more contaminated than Cooper's Hawks, goshawks and American Kestrels (*F. sparverius*), respectively (Henny, 1977). Among accipiter eggs collected in southern Ontario in the 1980s, the mean level of DDE in sharpshin eggs was 8.3 ppm, about 1.8 and 8.3 times higher than levels in Cooper's Hawk and goshawk eggs, respectively (Noble and Elliott, 1990).

OC concentrations in the eggs of several raptors, including Sparrowhawks and Cooper's Hawks, are not only consistent among eggs from the same clutch, but are also strongly correlated with levels in certain maternal tissues, like blood plasma (Snyder et al., 1973; Newton and Bogan, 1978). In fact, Henny and Meeker (1981) demonstrated the existence of a clear, linear relationship between DDE levels in maternal plasma and egg levels for sharpshins and some other birds of prey. This allowed later researchers to predict egg levels and potential reproductive effects from concentrations measured in blood samples.

Levels of DDE in accipiter eggs do appear to demonstrate geographical variation, particularly in Cooper's Hawks, whose eggs were found to be much more contaminated in the eastern United States than in the west. Eastern populations also declined drastically during the DDT era while their western counterparts maintained relatively stable numbers (Snyder et al., 1973; Pattee et al., 1985). A similar geographic pattern of declines was exhibited by sharpshin populations during the DDT era and later, during the 1980s and early 1990s, when the numbers of migrants counted along eastern flyways decreased.

Whether this decline was related to elevated exposure to OCs is unclear, and several authors (Elliott and Shutt, 1993; Bohall Wood et al., 1996; Viverette et al., 1996) have called for simultaneous studies of productivity and exposure to pollutants to resolve this issue. Furthermore, individuals trapped on migration may belong to any one of several distinct breeding populations. While sampling them may provide a useful picture of the nature of contamination across a wide geographic area, it does not reveal the location of possible pollution hotspots within the breeding range. In fact, since the late 1980s, no studies have examined the degree of contamination in specific sharpshin populations.

If OCs did contribute to declines in counts of eastern migrants, the blood and eggs of northeastern populations might be expected to contain comparatively high levels. Accordingly, a toxicological study was conducted to investigate the extent to which sharpshins nesting in the Montreal area are exposed to various OCs by comparing residue levels in their blood and eggs with levels reported in other studies.

## 4.2 Methods

In the summer of 2000, blood samples were collected from breeding females and nestlings at five sharpshin nests in the greater Montreal area. These were submitted to the Canadian Wildlife Service (CWS) in Hull, which analyzed the levels of various OCs and PCBs they contained.

## 4.2.1 Trapping of breeders and retrieval of nestlings

The best time for trapping was when the chicks were 12 to 16 days old. By this age, reverse sexual size dimorphism should be apparent, allowing young sharpshins to be visually sexed and banded. They are also normally large enough to provide adequate blood samples (1 mL) for toxicological testing. Trapping when they are more than 16 days old is risky because they may fledge prematurely.

Trapping was conducted in the early morning (0500-0900) when the parents were most active, making frequent trips to and from the nest to feed their brood. A 4 m long, 60 mm mesh (black) mist net was erected in a relatively open area, between the nest and plucking perch if possible, and a live Great Horned Owl (*Bubo virginianus*) was tethered on a 30 cm high bow perch, about 60 cm in front of it. Imitations of the territorial call of the Barred Owl (*Strix varia*) were used to get the attention of the resident sharpshins. If a hawk stooped at the owl, it was caught in the net.

The first sharpshin to be caught (always the female in this study) was immediately removed from the net and placed in an aerated aluminium tube to keep her calm and immobile. If and when the male was caught, he was placed in a similar, but smaller tube.

Once the female was caught, the nestlings were removed from the nest by a climber, and lowered to the ground in a 7.5 L aerated cooler. At that point the female and her young could be processed, while the trap was left open in order to trap the male. Upon completion of blood sampling and measurements, the chicks were returned to the nest and their parents were released.

## 4.2.2 Non-invasive manipulations of breeders and nestlings

Breeders were aged and sexed as described in section 1.2. All individuals were banded with CWS aluminium leg bands; sizes 3A for females and 3B for males. Nestlings were aged based upon the length of feather protruding from the sheaths of the seventh or eighth right primaries, as described in section 3.4. The following body measurements were recorded for parents: wing chord, flattened wing length, tail length, and middle toe length. All individuals were weighed using a hand-held Pesola scale.

## 4.2.3 Blood collection

The mass of each bird was used to determine how much blood could be safely drawn from it. As a bird can give a maximum of 1% of its mass in blood, 1 mL may be collected from a 100g bird (I. Ritchie, pers. comm.). Samples were taken from the jugular vein, using a needle (27G½ for parents and 30G½ for chicks) and a heparin-coated 1 mL syringe.

Blood samples were immediately emptied into centrifuge tubes, and placed on ice for transport to the laboratory, where they were prepared for toxicological analyses (on the same day) as follows. Centrifugation at 14000 RPM for 8 minutes effectively separated red blood cells from the plasma, which was then pipetted into a separate, labelled tube and frozen at -20°C.

Blood samples were only obtained from sharpshins at the five nests where the young had reached a bandable age (Table 3.1). However, samples were not obtained from all individuals at nests where the male was not trapped (nos. 6 and 8; Table 3.1) and/or where inadequate volumes of blood were obtained from some individuals (nos. 1, 2 and 3; Table 3.1). Ultimately, of a possible total of 24 samples, 19 were sent to the CWS, and of those, 12 were analysed, i.e. all five maternal samples and at least one nestling sample from each nest. Two nestling samples from each of two nests (nos. 6 and 8; Table 3.1) were analyzed.

## 4.2.4 Contaminant analysis

Plasma samples were analyzed according to standard procedures, as described by Wakeford (2001).

Lipids were extracted from plasma samples, using the methods of Frings et al. (1972), as follows. First, formic acid (one part formic acid to one part plasma) was used to denature proteins, at which time the samples were spiked with a chlorobenzene/PCB internal standard solution. The OCs and PCBs were extracted on an activated  $C_{18}$  cartridge, from which analytes were removed by elution with 1:1 (dichloromethane) DCM/hexane.

Florisil column chromatography was used to remove any residual lipids from the samples. Next, PCB and OC levels were measured, using a HP 5890 high-resolution capillary gas chromatograph (GC) coupled with a HP 5970 mass selective detector (MSD) operated in selected ion monitoring mode. Each sample was injected twice into this system, first to determine OC content using an OC quantitation standard solution containing 21 OCs, and then to determine PCB content using a PCB quantitation standard solution of three Aroclors; 1242, 1254 and 1260 in a 1:1:1 ratio. The samples were injected in sequences that also included quantitation standards, a QA reference material and method blanks. Measuring OC and PCB levels in the samples involves the use of standard solutions with known quantities of these compounds. Retention times for samples reveal exactly which chemicals are present, and their levels are indicated by the intensity of specific mass fragments in the samples. The QA reference material was a homogenate made from Herring Gull (Larus argentatus) eggs collected from Lake Ontario in 1989. Use of the method blank allows the extent to which samples may have been contaminated during processing and analysis to be evaluated.

Concentrations of less than 0.0001 ppm were reported as not detected (ND) and those between 0.0001 and 0.0009 ppm were reported as trace (TR).

#### 4.2.5 Data analysis

Data were analysed using Microsoft Excel to calculate mean values and Pearson product-moment correlation coefficients. The significance of correlation coefficients was calculated using student-t tests (Freund and Wilson, 1997).

## 4.3 Results

## 4.3.1 OC and PCB concentrations in plasma

All results are reported in  $\mu$ g/g wet weight. The following compounds were not detected in any samples: 1,2,4,5-tetrachlorobenzene (TCIBz), 1,2,3,4-TCIBz,  $\alpha$ -hexachlorohexane (HCH),  $\beta$ -HCH,  $\gamma$ -HCH, octachlorostyrene, trans-chlordane and tris (4- chlorophenyl) methane. Cis-chlordane and pentachlorobenzene were only detected at trace levels in three and one maternal samples, respectively. For compounds that were detected at measurable levels, mean concentrations, ranges of values, and numbers of samples with measurable and trace levels are reported in Table 4.1 and the relative OC contaminant levels in maternal plasma samples are represented graphically in Fig. 4.1.

Sharp-shinned Ha nests in the Montr	wk breeding fema eal area in 2000	ales (F) and seven nestling	gs (N) at	five
COMPOLIND		PANCE OF VALUES	M	T

Table 4.1 Organochlorings (ug/g wet weight basis) in plasma from five

COMPOUND	<u>MEA</u>	N[]	RANGE OF VALUES			<u>M</u>		T	
	F	N	F	N	F	Ν	F	Ζ	
hexachlorobenzene	0.001				1	0	4	4	
heptachlor epoxide	0.011	0.001	0.004-0.015	0.001-0.002	5	3	0	2	
oxychlordane	0.026	0.003	0.008-0.039	0.001-0.005	5	6	0	1	
trans-nonachlor	0.029	0.004	0.009-0.056	0.002-0.008	5	5	0	2	
p,p'-DDE	0.460	0.048	0.184-0.741	0.021-0.091	5	7	0	0	
dieldrin	0.009	0.002	0.006-0.012	0.001-0.002	5	3	0	4	
p,p'-DDD	0.002	0.005	0.001-0.004	0.001-0.013	3	3	2	1	
cis-nonachlor	0.012		0.002-0.043		5	0	0	6	
p,p'-DDT	0.001				1	0	2	2	
photomirex	0.004	0.002	0.001-0.009	0.001-0.003	4	2	1	4	
mirex	0.019	0.011	0.004-0.056	0.005-0.016	4	2	1	1	

**M** = number of samples with measurable levels

T = number of samples with trace levels



Figure 4.1 Overall mean contaminant levels in plasma from Sharp-shinned Hawk mothers at nests in the Montreal area in 2000

Measurable levels of p,p'-DDE and various congeners of PCBs were detected in all samples. PCB levels are reported as the sum of all congeners. Individual and mean levels of p,p'-DDE and PCBs are reported in Table 4.2.

NEST SITE	p,p	'-DDE	PCBs		
	FEMALE	NESTLING	FEMALE	NESTLING	
Île Bizard	0.741	0.091	0.196	0.017	
Pavillon de la Pomme	0.600	0.071	0.073	0.001	
		0.029	1	0.001	
Terrebonne	0.425	0.055	0.164	0.018	
Lac des Bouleaux	0.349	0.034	0.199	0.018	
Hudson	0.184	0.035	0.106	0.024	
	_	0.021		0.022	
MEAN	0.460	0.048	0.148	0.014	

Table 4.2 Levels of p,p'-DDE and PCBs ( $\mu$ g/g wet weight basis) in plasma from five Sharp-shinned Hawk breeding females and seven nestlings at five nests in the Montreal area in 2000

Each maternal sample was scored according to the level of each of the various OCs it contained (1 = highest). The number of times it was assigned a particular score was counted and females were ranked from most to least contaminated, as follows: Île Bizard, Lac des Bouleaux, Terrebonne, Pavillon de la Pomme, Hudson (Fig. 4.2).



Figure 4.2 Rankings assigned to Sharp-shinned Hawk breeding females in the Montreal area in 2000 based upon contaminant levels in blood samples (for compounds detected at measurable levels in at least one sample)

The concentrations of the various PCB congeners in maternal samples were plotted on a graph and PCB profiles for the females were developed (Fig. 4.3). Each female's profile was compared to the profile for the Herring Gull QA reference material (see section 4.2.4) and correlation coefficients were calculated for each comparison. All maternal sharpshin profiles were significantly correlated with the Herring Gull profile (Table 4.3).

Table 4.3 Correlations between PCB profiles of female Sharp-shinned Hawks breeding in Montreal area in 2000 and Herring Gull QA reference material

Nest (maternal sample)	r value	t value	
Île Bizard	0.983	40.43	
Orchard	0.973	32.08	
Terrebonne	0.979	36.47	
Hudson	0.973	31.72	
Lac des Bouleaux	0.949	22.69	

For all above comparisons, df = 57 and p = 0.00. The profiles of two sharpshin females and of the reference material are presented in Fig. 4.3.

Nestling levels of DDE (older sibling for nests from which two chicks were tested) were strongly and positively correlated (r = 0.99) with maternal levels (Fig. 4.4). The relationship was statistically significant (t = 11.48, p = 0.0015, df = 3). Nestling levels were on average 11.64% ± 0.54% (range: 9.74-12.94%) those of their mothers.



Figure 4.4 p,p'-DDE levels in Sharp-shinned Hawk nestlings vs maternal levels at nests in the Montreal area in 2000



Figure 4.3 PCB profiles of female Sharp-shinned Hawks breeding in Montreal in 2000 and of Herring Gull (QA reference material) There was a highly significant (r = 0.98, t = 8.64, p = 0.003, df = 3) positive correlation between DDE levels and total OCs (except for PCBs) in maternal samples (Fig. 4.5). On average, DDE accounted for 78.2% of the total maternal body burden of OCs.



Figure 4.5 Total levels of OCs (except PCBs) vs levels of DDE in plasma samples from Sharpshinned Hawk mothers in the Montreal area in 2000

A highly significant (r = 0.976, t = 7.767, p = 0.005, df = 3) positive correlation was also found between PCB and oxychlordane levels in maternal plasma samples (Fig. 4.6).





## 4.3.2 Estimated concentration of p,p'-DDE in eggs

Henny and Meeker (1981) developed a regression equation that allows the concentrations of DDT and its metabolites in eggs to be predicted from plasma residues in adult sharpshins and other accipiters. The equation is appropriate for blood samples collected during the post-laying period (as were those in the present study) and is as follows.

[DDE] in eggs = 6.243 [DDE] in plasma <sup>1.033</sup> From this equation, the mean maternal plasma level of 0.460  $\mu$ g/g p,p'-DDE would result in mean egg levels of 2.80  $\mu$ g/g. While it would be interesting to be able to use this relationship to estimate egg levels of DDE in each nest, Henny and Meeker (1981) cautioned that this approach is inappropriate for determining individual DDT burdens.

## 4.4 Discussion

The majority of compounds were present at such low levels that they are unlikely to be affecting the health of this sharpshin population (L. Shutt, pers. comm.). Only oxychlordane, t-nonachlor, p,p'-DDE and total PCBs were detected at higher concentrations in these breeding females than in female fall migrants sampled by Elliott and Shutt (1993) in the Great Lakes. DDE and PCBs were also present at higher concentrations than all other contaminants in every blood sample. This is not unexpected and parallels the results of previous studies of pollutant exposure in North American raptors (Pattee et al., 1985; Noble and Elliott, 1990; Elliott and Shutt, 1993; Bohall Wood et al., 1996).

In this study, the predicted DDE content of eggs was 2.8 ppm. Among sharpshins trapped on migration through the Great Lakes in the 1980s, individuals flying south for the first time had very low plasma levels of DDE, but female fall migrants of breeding age had a mean level of 0.22 ppm (Elliott and Shutt, 1993) and predicted egg levels of 1.29 ppm. Adult female sharpshins flying south along eastern flyways in the United States had a similar mean plasma level of 0.21 ppm DDE, and a predicted egg level of 1.25 ppm (Bohall Wood et al., 1996). Meyer (1987) measured the DDE content of three eggs collected from sharpshin nests in New Brunswick in the 1980s. Levels ranged from 5.42 to 9.12 ppm (mean of 7.0 ppm) and shell thickness was 23% below average. Nine eggs collected in Ontario in the 1980s contained 3.52 to 18.6 ppm DDE, with a mean level of 8.2 ppm (Noble and Elliott, 1990). The egg level of DDE predicted from this data set was much lower, and clearly insufficient to cause significant eggshell thinning since all blood samples were collected at nests that hatched three or four eggs. While the shells of hatched eggs may not necessarily have been of normal thickness, they were not so thin as to prevent hatching. This is reasonable considering that this predicted level is below the critical level (3-4 ppm) at which reproduction in Cooper's Hawks and Sparrowhawks appears to be impaired.

What is perhaps more surprising is that the mean maternal concentration of plasma DDE in the present study was actually more than twice the mean levels found in female fall migrants of breeding age along either the Great Lakes or eastern United States fall flyways by Elliott and Shutt (1993) and Bohall Wood et al. (1996), respectively. It was also close to the highest level (0.49 ppm) recorded in the above-mentioned eastern migrants (Bohall Wood et al., 1996), which purportedly include members of this breeding population (Clark, 1985; Struve and Goodrich, 1992). Indeed, the correlation between total OC and DDE levels in maternal blood samples demonstrates that even though it has not been used in North America for nearly 30 years, DDT continues to account for the bulk of the body burden of OCs in these birds.

Food stress can inflate plasma DDE residues and so it is important to assess the body condition of birds being sampled (Henny and Meeker, 1981). Below normal weight is a reasonably good indicator of food stress (Newton, 1991), and breeding females in the current study weighed 180 to 214 g, well within the 150-218 g range (Bildstein and Meyer, 2000) and above the mean of 171 g reported as normal for female sharpshins (Storer, 1966). Weight alone however, may not always be indicative of body condition, and should thus be considered in the light of morphometric data. Wing chords in the present sample ranged from 195 to 206 mm, and averaged 199 mm, comparable to Storer's (1966) mean of 201.5 mm. Weight to wing chord ratios in these breeding females were 1:0.9 to 1:1.1, higher than the 1:0.85 ratio calculated from the data reported by Storer (1966), and the 1:0.86 and 1:0.89 in breeding age females trapped on fall and spring migration, respectively (Mueller et al., 1979). Also, in the present study maternal DDE levels were neither significantly correlated with weight (r = -0.54, t = -1.115, p = 0.17, df = 3) nor with the above-mentioned ratio (r = -0.72, t = -1.792, p = 0.1, df = 3), further indicating that food stress was unlikely to have contributed to the high levels of DDE that were observed.

Recent consumption of a very contaminated food item can also result in elevated plasma levels of DDE, and this must be acknowledged when sampling wild birds (Henny and Meeker, 1981). However, this is an unlikely explanation for the high maternal concentrations observed in this study. Of five individuals, only one (from Hudson; Table 4.2) had a DDE level below the means reported for female fall migrants of breeding age by Elliott and Shutt (1993) and Bohall Wood et al. (1996). It seems improbable that the other four would have all recently eaten something with a high DDE content.

If the results were not artificially inflated by either of the two aforementioned factors, the question is how and where these females acquired such high levels of DDE compared to migrants. While this greater contamination may point to a local source of pollutants, there is evidence for exposure (at least to DDE) on wintering grounds.

First, the significance and nature of the relationship between maternal and nestling levels of plasma DDE can reasonably be interpreted as an indication that the chicks are accumulating this compound via uptake from the yolk sac, the repository for OCs in the egg (Newton, 1979). To a certain extent and as long as they are not being fed contaminated prey, nestlings metabolize these chemicals as they grow, further diluting their body burdens by consuming "clean" food (Snyder et al., 1973). If the source of DDE contamination in nestlings were a local one, i.e. prey fed to them, such a consistent and significant correlation

probably would not have been observed. Some chicks might have been expected to have higher levels of DDE than others, and also to have levels closer to those of their mothers, particularly considering that lipid content did not differ significantly between nestlings and breeding females.

Second, chicks in the present study were consistently about one order of magnitude less contaminated than their mothers. As natal philopatry is common in sharpshins and other accipiters (Newton, 1979; Rosenfield and Bielefeldt, 1992; E. Jacobs, unpubl. data), these mothers may have hatched here and had similar levels themselves as nestlings. Indeed, the mean DDE level in nestlings (0.05 ppm) was close to the mean levels of 0.06 ppm and 0.05 ppm measured in first-time fall migrants sampled along the eastern and Great Lakes flyways, respectively (Elliott and Shutt, 1993; Bohall Wood et al., 1996). The implication is that those hatch-year birds sampled in both of the above-mentioned studies were no less exposed to DDE during the breeding season than the chicks tested in the current study.

Third, if this population were exposed to OCs mainly on its breeding grounds, certain females could be expected to be more contaminated than others depending upon land use in the vicinity of their nests. Two nestling samples from two particular nests (compared to one from each of the other three) were analysed because the potential for contamination was perceived to be higher at those sites. The first of these nests (no. 6; Table 2.1) was in a spruce and pine plantation, less than 25 m from an apple orchard that is just over 70 years old. Before Canada banned the use of DDT in the 1970's (Government of Canada, 1996), small quantities were used in the orchard, although they have not been in the past 30 years (M. Robert, pers. comm.). Indeed, the female from that nest had high levels of DDE. On the other hand, the second least contaminated female sample of all came from nest no. 2 (Table 2.1), which was also not far (within 2km) from an orchard. It was planted in the 1930s, and today contains less than 25% of its original stock of about 8000 apple trees, but as DDT was applied extensively to North American orchards in the 1950s and 1960s (Blus et al., 1987) this sizeable operation probably used large amounts of it.

Golf courses may also have high residue levels because DDT was widely promoted for the control of various turf pests in the 1950s and 1960s (e.g. Musser, 1962). The second nest (no. 8; Table 2.1) from which two nestling samples were tested was just over 30 m from Como Golf Course, which opened in 1902, and is likely to have used significant quantities of DDT, yet the female in question was the least contaminated of all. The most contaminated female sample came from nest no. 1 (Table 2.1), less than 1 km from St. Raphaël Golf Club, which was only built in 1994 and could not, at least not legally, have used DDT. Clearly no consistent relationship between land use patterns and maternal DDE levels is evident from the results of the current study.

Finally, adult female breeders were no more or no less contaminated than immature breeders. This is consistent with the findings of Elliott and Shutt (1993), who reported that concentrations of most pollutants increased significantly in sharpshins following their first winter in the south. After that, levels of the more persistent compounds did not change appreciably, indicating that prey consumed on the wintering grounds may be the primary source of exposure.

While the results of this investigation appear to point to the wintering grounds as the source of DDE exposure, this population could still be accumulating DDE during the breeding season. This scenario would not necessarily contradict these results if the songbird prey base in this area were consistently contaminated enough to account for the high maternal levels of DDE and their correlation with nestling levels. Collection of prey remains from nest sites in 1999 allowed for the rudimentary analysis of the diets of Montreal area sharpshins, which appear to feed upon a wide range of bird species. These include (but are not limited to) Yellow Warblers (*Dendroica petechia*), American Goldfinches (*Carduelis tristis*), Downy Woodpeckers (*Picoides pubescens*), American Robins (*Turdus migratorius*), Blue Jays (*Cyanocitta cristata*), Cedar Waxwings (*Bombycilla cedrorum*), various sparrows, Red-winged Blackbirds (*Agelaius phoeniceus*), Eastern Bluebirds (*Sialia sialis*), Northern Cardinals (*Cardinalis cardinalis*), Black-capped Chickadees (*Parus atricapillus*) and even Ruby-throated Hummingbirds (*Archilochus colubris*). If sharpshins breeding in

the Montreal area are accumulating DDE by preying upon these birds, the fact that some are migratory and others are not makes it difficult to infer the ultimate geographical source of contamination for this population.

Possibly the best way to resolve this question would be to determine the proportions of various birds in sharpshin diets (by collecting prey remains and pellets) in the Montreal area, and then sample those bird populations to assess their levels of DDE. Similar analyses could be carried out on the wintering grounds used by this population to compare its seasonal exposure regime.

Compared to their counterparts migrating through the Great Lakes, breeding females sampled in this study were nearly twice as contaminated with PCBs, which were not even detected by Bohall Wood et al. (1996) at measurable levels in plasma samples from migrants along eastern flyways. The possible impacts of PCBs upon reproduction in raptors are not completely clear (Cooke, 1973; Newton and Bogan, 1978), but certain congeners are associated with reduced clutch size, hatching success and fledging success in captive-dosed kestrels (Fernie et al., 2001). Reproductive performance was not compromised when the eggs of captive-dosed Screech Owls (Otus asio) contained 4-18 ppm PCBs (McLane and Hughes, 1980). The plasma levels associated with reproductive impairment in raptors are not known, and no equations to predict PCB levels in eggs from plasma levels have been published. However, the mean plasma level of total PCBs was only slightly higher than that of 0.140 ppm in two Broad-winged Hawks (Buteo platypterus) on spring migration through the Great Lakes in 1986. Merlins (F. columbarius) had a much higher mean plasma level of 0.233 ppm. Neither species was generally considered to be declining in Canada at the time (Noble et al., 1993). While it is difficult to apply these data to sharpshins, there is no evidence to suggest that PCBs are present in this population at high enough levels to impair reproduction.

As for the source of PCB exposure, Elliott and Shutt (1993) plotted the concentrations of the various congeners they measured in migrant sharpshins and compared the resulting profiles with those of Herring Gulls that had been sampled in the Great Lakes area over the same time period. The similarity

between the profiles of these two vastly different species (one terrestrial, one aquatic) led them to conclude that the source for both was global as opposed to local. The strong correlation between the PCB profiles of breeding females in this study and that of the Herring Gull reference material may also implicate worldwide contamination of the environment as the source of PCB exposure for this population.

Concerning other compounds, the only relationship that was revealed by this investigation was that between PCBs and oxychlordane. Pattee et al. (1985) found that the levels of certain OCs in Cooper's Hawk eggs were significantly related to one another. DDE, dieldrin, oxychlordane, t-nonachlor and mirex were all intercorrelated, and t-nonachlor and oxychlordane were correlated with PCBs. That most of these correlations were not evident from the results of this study may reflect the fact that relationships among certain pollutants may be unique to different geographical areas due to dissimilar spatial patterns of pesticide use, air currents, etc. Alternatively, this could simply be related to the fact that in this data set, all contaminants were present at much lower levels, perhaps too low to reveal these correlations. This is expected considering that eggs have a much higher fat content than plasma does, and thus contain higher contaminant levels.

One source of bias was the timing of blood sampling, i.e. that samples were only collected from females at nests in which eggs had hatched. While this allowed chicks to be sampled, the obvious consequence is that no toxicological data were collected from females that failed to hatch any eggs. It therefore becomes impossible to determine the extent to which OC contamination may have contributed to hatching failure. Although it would therefore seem appropriate to sample females during incubation, trapping them with a live lure and mist net would be difficult, and trapping an incubating female on the nest may lead to nest failure.

Another problem was encountered in attempting to compare the results of this and previous studies. While Henny and Meeker's (1981) regression equation for predicting egg levels of DDE from plasma residues was useful in this regard,

no analogous methods have been published for other pollutants, or for predicting DDE levels in tissues other than eggs. This is particularly unfortunate because Noble and Elliott (1990) published a very comprehensive account of contaminant levels in Canadian raptors, including temporal trends in various populations. It would have been most desirable to be able to use the information presented in their review in a more concrete manner, but they only reported egg, liver and brain residues, probably because these were the only data available.

While the results of this investigation fail to pinpoint the true source of DDE contamination, they appear to indicate that this population's wintering grounds are relatively contaminated. Bohall Wood et al. (1996) suggested that they may have found higher levels of DDE in eastern migrants than Elliott and Shutt (1993) did in Great Lakes migrants because of a difference in winter distribution. Most sharpshins using the eastern flyway apparently winter in the southeastern United States, whereas some using the Great Lakes flyway winter in Latin America where some countries continue to use DDT. Since eastern migrants reportedly include individuals that nest in the Montreal area, this fails to explain why this population was so contaminated. Instead this illustrates the need to develop a better understanding of the migratory habits of this population.

Furthermore, if females nesting in this area accumulate OCs primarily on their wintering grounds and dilute their body burdens during the breeding season, this population may be even more contaminated compared to previously sampled migrants than the results appear to demonstrate. Migrants were sampled in the fall, after the end of the nesting season, whereas females in the present study were sampled six to seven weeks after the onset of incubation.

OC levels in this population should therefore continue to be monitored on both the nesting and wintering grounds, as should levels in migrants. Because migratory watchsites are able to trap and sample many individuals, they can gather extensive and invaluable data about pollutant exposure in many raptor species. This information would be rendered even more useful by expanding programs to trap and band sharpshins at their nests, thus providing a means to

compare contaminant levels between breeding populations. Furthermore, winter band recoveries would help determine where this population spends the winter and make it possible to compare contaminant exposure between the breeding and wintering grounds by sampling the prey base in each locality.

## **Connecting statement**

Exposure to organochlorines has been shown to impair reproduction in various raptors, and it was identified as a potential contributor to any extant declines in Canadian Sharp-shinned Hawk populations. While it is important to examine the possibility that pollutants are decreasing the productivity of sharpshins breeding in southern Quebec, it is equally necessary to study the extent to which other factors may be involved. The nefarious effects of habitat fragmentation upon all kinds of wildlife are well documented and are especially likely to be felt in a human-dominated landscape as is the case throughout much of southern Quebec. Therefore, the current project included a comparison of this population's patterns of nest habitat use with that of others to study the effect of nesting in a mostly developed area on these patterns and the ability of this species to adapt to urbanization.

# Chapter 5: Nest habitat use by Sharp-shinned Hawks in southern Quebec Abstract

During the summers of 1999 and 2000, vegetational parameters of habitat quality were assessed at 12 Sharp-shinned Hawk nests (all but one in the greater Montreal area) in order to characterize nest habitat use by this prevalently urban population. Measured means (among others) were nest tree height, 15.3 m; tree density, 1052/ha; total canopy cover, 86.7%; coniferous cover, 42.95%; and distance to the nearest opening; 17.5 m. Sharpshins nested in a range of forest types, from mature conifer plantations to young, almost purely deciduous stands, but did not exhibit much flexibility with regards to the habitat features that were measured. They also used structurally older stands with more deciduous cover than those used by their counterparts elsewhere.

## 5.1 Introduction

Knowledge of the habitat requirements of Sharp-shinned Hawks is crucial to understanding their nesting ecology and developing recommendations for their conservation and management. As habitat fragmentation is the most important threat to the survival of most temperate zone species (Wilcove et al., 1986), efforts to understand how urban populations respond to the relative unavailability of large tracts of wilderness become especially pertinent.

Vegetational and structural characteristics are important cues for birds seeking nest sites (Reynolds et al., 1982). For accipiters, these features often reflect successional stage (Reynolds et al., 1982; Newton, 1991), and younger stands appear to provide the appropriate environmental conditions for breeding sharpshins. Their nest sites therefore tend to be dense, populated largely by small-diameter trees, and have relatively thick canopies with a good deal of coniferous cover (Reynolds et al., 1982; Moore and Henny, 1983; Wiggers and Kritz, 1991; Trexel et al., 1999; Bildstein and Meyer, 2000).

All these characteristics are important because they influence the ability of sharpshins to nest successfully. For instance, their typical nest structure would

appear to preclude them from using primarily deciduous stands. They build broad, flat nests, usually on horizontal branches, close to or touching the trunk (Bildstein and Meyer, 2000). Building materials consist almost entirely of coniferous twigs and branches, probably because their nodules grip each other and help hold the nest together (Newton, 1991). Also, as the smallest forest hawks, sharpshins are vulnerable to predation by many larger raptors, and so nesting in stands that offer some concealment and in which bigger birds may have difficulty manoeuvring provides protection (Bildstein and Meyer, 2000).

It is generally accepted that the vegetation or cover in a particular habitat meets the needs of the animals living there and altering that cover can have major impacts upon animal populations (Morrison et al., 1998). Previous studies (e.g. Viverette et al., 1996) acknowledged that the declines in counts of eastern migrants in the 1980s and early 1990s may reflect decreased productivity in eastern populations, and that this might be related to losses of suitable breeding habitat. Furthermore, the coincident increase in eastern Cooper's Hawks (*A. cooperii*) may indicate that habitat changes are benefiting this larger accipiter while reducing breeding opportunities for sharpshins (Viverette et al., 1996). Specifically, the ongoing pattern of forest aging and urbanization may favour Cooper's Hawks over sharpshins, particularly since Cooper's Hawk productivity has been shown to be unaffected by urbanization (Rosenfield et al., 1996).

While the nesting habitat of sharpshins breeding in urban areas has not been described, Newton (1991) observed that the closely related Sparrowhawk (*A. nisus*) in English and Scottish cities nested in "sub-standard" sites. He concluded that the birds use nest habitat according to what is available to them. Accordingly, urban sharpshins might also be expected to exhibit a certain degree of difference in nest habitat use from non-urban birds. A habitat study was thus initiated to investigate this issue for sharpshins nesting in the Montreal area. The goal was to compare certain vegetational features of their nest sites with those of other non-urban populations to test the afore-mentioned prediction.

## 5.2 Methods

## 5.2.1 Elimination of bias in nest searches

Previous studies have highlighted the importance of not conducting habitat studies in nest sites located by biased means, contending that biased search methods are one of the main shortcomings of other studies (Siders and Kennedy, 1996; Trexel et al., 1999). Biased search methods, such as searching in areas that, according to the literature, appear suitable for nesting accipiters, and using historical sites found by unknown techniques (Siders and Kennedy, 1996), were avoided in this study. The methods used to identify potential nest sites and to locate nests are described in sections 3.2.1 and 3.2.2, respectively. In addition, people who had completed nest record cards or posted relevant messages on the email forum were asked to explain how they made their observations. It was thus determined that they had done so in the course of random bird-watching activities, as opposed to systematic searches for nesting sharpshins or other birds. Similarly, while the various park officials and birdwatchers were asked to report any observations of sharpshins, they were specifically instructed not to deliberately look for nests.

## 5.2.2 Nest habitat assessments

At each nest site, after the young had fledged, habitat data were collected within 0.04 ha circular study plots (radius 11.3 m) centred on the nest trees. These had been similarly defined in previous studies (Moore and Henny, 1983; Garner, 1999; Trexel et al, 1999). Plots were delineated with four 11.3 m lengths of string to create four transects, each with a stake tied to each end. Using a compass, the trunk of the nest tree was marked with the four cardinal directions and a transect was laid down from the base of the tree, going outward in each direction. Each transect was divided into 10 equally spaced sections of 1.13 m by tying pieces of flagging tape around the string.

## 5.2.3 Habitat variables and measurement techniques

The nest tree species and four dominant canopy species were identified using (Rouleau, 1990), and the following data were recorded (Table 5.1).

Table 5.1. H	labitat variables.	description	and measurement	techniques

Variable	Description	Measurement technique	
Nest <sup>1</sup> or nest tree <sup>2</sup> height	Height (m) of nest <sup>1</sup> or nest tree <sup>2</sup>	Haga altimeter or measuring tape (for nest height)	
Nest height percent	Relative height of nest	Nest height /nest tree height × 100	
Nest tree condition	% nest tree dead or diseased	Visual estimate	
Nest tree dbh	Diameter (cm) at breast height of nest tree	dbh meter	
Canopy height	Mean height (m) of five canopy trees in study plot <sup>a</sup>	Haga altimeter	
Total canopy cover	% area over study plot occluded by canopy foliage	$\Sigma$ 40 readings ÷ 40 × 100: Readings taken at each transect	
Deciduous <sup>3</sup> ; Coniferous <sup>4</sup> ; Understory <sup>5</sup> cover	% area over study plot occluded by deciduous <sup>3</sup> ; coniferous <sup>4</sup> canopy; understory <sup>5</sup> foliage	section (see 5.2.2), with ocular tube (toilet paper roll with crosshairs at one end). Looking through it, what is directly over	
Ground cover	% ground in study plot covered by ground layer foliage	crosshairs is recorded.	
Shrub density <sup>6</sup> or index <sup>7</sup>	Shrubs < 3 cm DBH and above shoulder height <sup>6</sup> or between knee and shoulder height <sup>7</sup>	Number of shrubs within arms- reach along all transects meeting criteria	
Tree <sup>8</sup> or understory <sup>9</sup> density	Number of canopy <sup>8</sup> or understory <sup>9</sup> trees ≥ 9 cm DBH per ha	Number in study plot × 25	
Basal area	m <sup>2</sup> /ha of canopy trees	$\Sigma_i \pi (dbh_i / 200)^2$	
Mean dbh	Mean dbh of canopy trees in plot	dbh meter	
Distance to water10;Distance to nearest permanent water source10; opening $\geq 5$ ha11; or primary perch used by parents for plucking perch12plucking perch12parents for plucking prey (prior to egg hatching)12		measuring tape	
### 5.2.4. Data analysis

Although habitat data were collected at 16 nest sites in 1999 and 2000, only 12 sites were included in the habitat assessment. The remaining four were excluded because they could not be considered independent nesting areas.

Independent nesting areas are defined by two main criteria (Rosenfield and Bielefeldt, 1992, 1996). First, they should not be within what could reasonably be considered to be the range of previous nesters. This distance obviously depends on the species under consideration, and for sharpshins, the lowest recorded distance between two concurrently active nests was 0.7 km (Bildstein and Meyer, 2000). Accordingly, any nest found in 2000 that was within 0.7 km from a nest found in 1999 was excluded.

Second, for nesting areas to be considered independent, they should not be used by the same individuals. No birds were banded in 1999, so except in the cases of immature, obviously first-time breeders in 2000, it was impossible to determine whether any birds whose nest sites were assessed in 2000 had also used any of the nests assessed in 1999. The second criterion was therefore set aside and the birds from both years were assumed to be different.

Corel Quattro Pro, a spreadsheet program, was used to analyse the data and calculate mean values and measures of dispersion. An initial attempt to compare means between this and other published studies revealed that differences in methodology, sample size and regional vegetational characteristics made it difficult to infer conclusions. A between-study comparison of dispersion measures was thus initiated in the hope that it would yield some insight into interpopulation differences in variability of nest habitat use. It was expected that this urban population would be comparatively flexible in its use of nest habitat due to the relatively low availability of forested sites in the Montreal area.

Unfortunately however, the various published studies of nest habitat use by sharpshins express dispersion differently. While some authors provide this information in the form of standard errors (SE) (Wiggers and Kritz, 1991; Garner, 1999; Trexel et al., 1999), others provide standard deviations (SD) (Reynolds et

al., 1982; Moore and Henny, 1983). The only appropriate measure of dispersion for comparing variables measured on different populations with different sample sizes and different means is the coefficient of variation (CV). The CV is easily calculated from SE and SD values using the following mathematical formulae (Freund and Wilson, 1997; P. Dutilleul, pers. comm.).

 $CV = \frac{SD}{\overline{x}} \times 100$  and  $SD = SE(\sqrt{n})$ , where  $\overline{x}$  = mean, and n = sample size.

### 5.3 Results

All nests were in conifers. Seven pairs (58.3%) used spruce (*Picea spp.*) trees: three White (*P. glauca*), two Norway (*P. abies*), and two Black (*P. mariana*), and at most of those sites other evergreens were well represented in the canopy. Two nests were built in Jack Pine (*Pinus banksiana*), while White Pine (*P. strobus*), White Cedar (*Thuja occidentalis*), and Eastern Hemlock (*Tsuga canadensis*) were each used by one pair. The vast majority of stands were mixed, with canopies composed of a wide variety of other trees, and none were monospecific. Other important canopy species included Red and Sugar Maple (*Acer rubrum* and *A. saccharum*), Grey, Paper and Yellow Birch (*Betula populifolia, B. papyrifera* and *B. alleghaniensis*), Trembling Aspen (*Populus tremuloides*), American Beech (*Fagus grandifolia*), White Ash (*Fraxinus americana*), Red Oak (*Quercus rubra*), and Red Pine (*P. resinosa*).

Stands used by this population ranged in age from approximately 30 to 100 years, with a mean of 49.4 years. Means of the other variables measured are given in Table 5.2, along with their corresponding coefficients of variation. The variability comparison for selected variables is presented in Fig. 5.1.

Variable	Mean $\pm$ SE	<b>Coefficient of variation (%)</b>
Nest height (m)	$10.9 \pm 1.7$	54.3
Nest tree height (m)	15.3 ± 1.9	43.1
Nest height percent (%)	$68.7 \pm 3.3$	16.5
Nest tree condition (%)	54.6 ± 9.2	58.4
Nest tree DBH (cm)	$24.7\pm3.4$	47.2
Canopy height (m)	15.6 ± 1.9	41.6
Total canopy cover (%)	86.7 ± 2.2	8.9
Deciduous cover (%)	$44.6\pm8.6$	63.7
Coniferous cover (%)	$43.0 \pm 7.7$	59.5
Understory cover (%)	$30.7 \pm 7.19$	76.6
Ground cover (%)	36.4 ± 5. 5	49.7
Shrub density	$27.0 \pm 6.4$	75.0
Shrub index	59.6 ± 13.5	71.8
Tree density	$1052.1 \pm 180.3$	59.4
Understory density	$90.9 \pm 46.9$	171.0
Basal area m²/ha	$34.8 \pm 4.7$	46.8
Mean DBH (cm)	$18.5 \pm 2.8$	51.7
Dist. to water	$67.0 \pm 26.5$	104.7
Dist. to opening (m)	17.5 ± 3.2	63.2
Dist. to plucking perch (m)	$23.5 \pm 2.9$	34.6

Table 5.2 Mean values of habitat variables measured at Sharp-shinnedHawk nests in the Montreal area, 1999-2000.



# Figure 5.1 Coefficients of variation calculated for selected variables measured in present (first column, unlabelled) and previous studies of Sharp-shinned Hawks

1a Northwestern Oregon; 1b Eastern Oregon, both Reynolds et al. (1982) 2 Moore and Henny (1983) 3 Wiggers and Kritz (1991) 4 Garner (1999) 5 Trexel et al. (1999)

## **5.4 Discussion**

Sharpshins in the present study nested considerably closer to forest openings (mean distance of 17.5 m) than their conspecifics in Wisconsin (mean distance of 58.9 m; Trexel et al., 1999) or Arkansas (mean distance of 46.5 m; Garner, 1999). It also bears mentioning that two nests in 2000 were situated right along the edges of their respective stands. In many cases, the nearest openings were areas of considerable human activity, such as well used cycling and walking trails and even a golf course.

This proximity to edges may reflect the relative scarcity of large tracts of forest in this study area, which is apparent from topographical maps of the region (see Chapter 2 for details on study area). However, this does not adequately explain why several pairs nesting so close to open, disturbed areas did not use more interior sites, since no other breeding raptors seemed to be present. Breeding success in songbirds is negatively affected by proximity to forest openings, mainly due to the increased presence of common nest predators, such as Raccoons (*Procyon lotor*) and Blue Jays (*Cyanocitta cristata*) (Wilcove et al., 1986; Paton, 1994; Morrison et al., 1998). These and other species that concentrate near edges raid the nests of sharpshins, which could therefore be expected to build their nests away from openings. Perhaps nesting near openings confers a benefit to these sharpshins, i.e. proximity to the more diverse prey base in edge habitats (Morrison et al., 1998) that outweighs any increased risk of nest predation. Sharpshins in Quebec do hunt in clearings (Ouellet and Bombardier, 1996), and Montrealers often report them hunting in open backyards, which may be a sign of their increasing adaptation to foraging in open areas. An interesting avenue for future research might be a comparison of the microhabitat used for foraging between sharpshins nesting along edges and those using interior habitats. Collecting prey remains at plucking perches at both types of nests might also reveal whether the diversity of the prey actually consumed is greater at nests along edges.

This population tended to use stands with comparatively little coniferous cover (the lowest value across all other studies was 61.3% in Trexel et al., 1999), and extensive deciduous cover (the highest value across all other studies was 15.2% in Trexel et al., 1999). To a certain extent this may reflect regional differences in vegetation that occur across North America. The study area was located in the deciduous forest vegetation zone (Rouleau, 1990), where hardwoods naturally predominate. Further studies of nest habitat use by sharpshins elsewhere in this zone may elucidate whether this pattern is consistent among northeastern populations.

Regardless of the vegetative structure of the stands in which sharpshins nested, every nest was in a conifer. Trexel et al. (1999) reported a similarly disproportionate tendency for sharpshins to use conifers in mixed coniferhardwood habitat. This may reflect the suitability of the whorled branching pattern of many evergreens for supporting the relatively flat sharpshin nests, which in this study were all built against the tree trunks, on at least two branches growing out from the main stem.

The mean age of stands used by nesting sharpshins was roughly 50 years, which, at first glance, might not seem very different from the finding that most nests in Oregon were in young, i.e. 25-50 year-old, forests (Reynolds et al., 1982). However, as previously stated, the habitat characteristics of accipiter nest sites usually reflect successional stage, and 50-year-old stands in different parts of the continent can be at very different stages of succession. The Pacific Northwest is known for its forests of towering evergreens, most of which are still young at 50 years old, when many northeastern conifer species are approaching maturity. The Douglas Fir (*Pseudotsuga menziesii*) Western Hemlock (*T. heterophylla*) that predominate in northwestern Oregon only reach their maximum height after hundreds of years, and the Ponderosa Pine (*P. ponderosa*), the dominant species in eastern Oregon forests, only reaches maturity after 150 years (Burns and Honkala, 1990).

This illustrates that stand age is not always synonymous with successional stage. Furthermore, neither parameter is necessarily reflected in stand structure, which is presumably more important to birds choosing a nest site than either age or successional stage. This is especially true in managed stands or plantations, where succession does not occur naturally. Unfortunately, the three terms have often been used interchangeably in various studies, generating some confusion.

Semantics aside, the apparent willingness of this population to nest in stands having certain structural characteristics associated with mature, climax communities may be related to the status of the Cooper's Hawk in the area. While the Cooper's Hawk is not federally listed, it is on the provincial list of species that are susceptible to becoming vulnerable or threatened. No censuses have been conducted, but estimates place the provincial population at about 60 breeding pairs (Barnhurst et al., 1996; Bird, 1999), and only 15 nest sites have been found over the past 10 years in this study area. They do, however seem to be on the rise and are slated for removal from the afore-mentioned list in March of 2002 (F. Shaffer and P. Fradette, pers. comm.). Since they remain rare, many of the more open, structurally older stands in which they would ordinarily nest are unlikely to contain nests (Barnhurst et al., 1996), leaving room for sharpshins.

Low Cooper's Hawk numbers may similarly explain the comparatively high levels of deciduous canopy cover in this population's nest sites. The study by Trexel et al. (1999) provides a nice contrast, particularly because since its 1989 removal from the state list of threatened species (Rosenfield and Bielefeldt, 1993), the Cooper's Hawk may now be one of the most numerous hawks in Wisconsin. There, the stands used by nesting sharpshins were much more dense and had more coniferous cover than those used by Cooper's Hawks in the same region or by sharpshins in the present study. If Cooper's Hawk populations in Quebec are on the rise, revisiting this issue in the future might paint a very different picture of nest habitat use by sharpshins in the face of increased competition with their closest North American relatives.

Overall, the fact that many of this population's sites may be deemed suboptimal (more open, with more large, deciduous trees) may reveal something about the impact of urbanization on sharpshin nest habitat use. It is however, difficult to separate urbanization-related effects from natural differences in forest type owing to geography and conclusively make that connection. Furthermore, it is impossible to compare current patterns of nest habitat use by sharpshins in such an established urban environment with patterns they exhibited prior to the development of Montreal. To obtain a more accurate picture of differential patterns of nest habitat use between urban and rural populations, it might therefore be useful to compare the nest sites used by both types of populations in a single geographic area.

Ultimately, the results that best lend themselves to discussion are perhaps those of the variability comparison. Not only did this population demonstrate considerable flexibility, but also reworking the results of previous studies revealed considerable variability in nest habitat use by other populations. Clearly, mean values are useful, but it would seem equally important to look at dispersion as an indication of the degree to which a population is flexible in its use of nest habitat and can adapt to habitat changes. Thus, large CV values for a particular variable represent plasticity, while small values reflect a degree of uniformity in particular habitat features across nest sites. Contrary to the expectation that this urban population would exhibit more plasticity than more rural ones, the results of the present study are no more variable than those of others overall. In fact, no single population appears to be particularly flexible with respect to nest habitat use. What the results clearly indicate is that sharpshins do not confine themselves to nesting in any one type of forest, but rather use stands that differ widely in most of the vegetational characteristics that have been used to describe their nest sites. For example, despite many assertions to the contrary, sharpshins do not nest exclusively in dense stands. The CV for tree density in the present study was higher than previously reported, but values were above 40% in three other studies (Reynolds et al., 1982; Wiggers and Kritz, 1991; Trexel et al., 1999).

At the same time, the dispersion comparison revealed that despite their apparent willingness to nest in different types of forested habitat, sharpshins may be restricted throughout their breeding range to stands with well covered canopies. Whereas variation for most other measured variables was quite high, CV values for canopy cover range from 7.73% in Wisconsin (Trexel et al., 1999) to 35.53% in eastern Oregon (Reynolds et al., 1982), with an average for all studies combined of 16.93%. This supports the contention that a major limiting factor for the reproductive success of sharpshins is the vulnerability of the species to predation by other birds. Possibly the best strategy for this small hawk is to build its nest where a thick canopy allows it to remain unseen by other raptors flying overhead.

The CV for nest height percent was also quite low in the present study. Unfortunately, only one other group of researchers (Trexel et al., 1999) assessed this parameter, but their results also showed little dispersion (c.v. = 21.7%). Yet Reynolds et al. (1982) and Wiggers and Kritz (1991) also noted that sharpshins in their study areas tended to build their nests in the live canopy. Perhaps this also reflects the sharpshin's need for protection from predators; placing their nests up in the canopy where the thicker foliage reduces accessibility to larger raptors.

Nests used by this population were also far less variable in their proximity to the nearest openings than those used by conspecifics in Wisconsin (134.74%; Trexel et al., 1999) or Arkansas (156.99%; Garner, 1999). This may further support the conclusion that sharpshins in this urban area nest closer to openings just because the availability of large forested stands is lower than in other study areas where breeders can choose from a wider variety of suitable sites.

The issue of sample size should also be addressed. As Siders and Kennedy (1996) rightly contended, small sample sizes (fewer than 18 nests) in previous studies may have limited the interpretability of results and only 12 nests were included in the present habitat assessment. While some other studies benefited from larger sample sizes, those were achieved in part through the use of biased search methods (Wiggers and Kritz, 1991; Siders and Kennedy, 1996).

#### Chapter 6: Summary, conclusions and recommendations

Although the current project included three distinct research objectives (outlined in section 1.10), its ultimate goal was to discover how these different aspects of sharpshin ecology might be interrelated and how any such links might pertain to the preservation of this and possibly other populations.

The first objective was to evaluate the reproductive success of Sharpshinned Hawks breeding in southern Quebec, for the most part in the heavily developed Montreal area. While there was some, albeit equivocal evidence for recent declines in Canadian sharpshin populations, the paucity of productivity studies made it difficult at best to confirm or refute this contention. Certainly such a scenario could be expected to manifest itself in the results of these types of studies, for example, in relatively low clutch sizes, hatching success and/or fledging success. Yet, except for the gross, likely weather-related discrepancy in nesting success between years of this study, the reproductive performance of this population was normal or comparable to that of others elsewhere, at least in terms of clutch size and hatching rates.

The above parameters can be affected by exposure to organochlorines, which, due to their ability to impair reproduction, have been implicated as a possible cause of any extant population declines. However, most of the previous studies that evaluated contaminant exposure in sharpshins had been conducted on migrants of unknown origin, and so provided no means to isolate potential problem areas within the sharpshin's breeding range. Thus, the second objective of this project was to measure levels of OCs in blood samples from members of the same population monitored in the productivity study.

The majority of compounds analysed were not present at high enough levels to warrant concern. PCB concentrations however, were somewhat elevated, and the most likely source of exposure was determined to be global. Also, maternal levels of DDE were high enough in some females to have potentially resulted in decreased eggshell thickness, but clearly no such effects were observed. Even the most contaminated female hatched four of five eggs,

and the second most contaminated female hatched all five of hers. This could be an indication that DDE was not decreasing the reproductive performance of this population in any measurable way. However, the fact that toxicological data were only obtained from nests that persisted at least until the young reached a bandable age may have introduced a certain bias. In reality, the females whose eggs never hatched would probably have been most likely to exhibit significant contamination, but they were not sampled. Unfortunately, the potential risks associated with drawing blood at an earlier stage in the nesting season (see section 4.4) might have outweighed the benefits of doing so.

Unfortunately, this methodological limitation made it impossible to look for links between hatching failure and maternal OC levels, but it is still worthwhile to test for relationships to see if females with higher levels hatched fewer eggs or fledged fewer chicks. On the contrary, these analyses revealed that maternal DDE was neither correlated with hatching success nor with fledging success (r = 0.12 and r = 0.65, respectively). More contaminated females showed a weak tendency to hatch more eggs and were more likely to produce at least one fledgling. This could be related to the above-mentioned bias and/or to the small sample size. Yet, the results nonetheless have value, at least by establishing benchmark levels against which the results of future studies of productivity and pollutant levels can be measured. Such studies should be continued to obtain a larger sample size and an even more accurate picture of temporal trends in this population and the true extent to which it is exposed to contaminants. It might also be worthwhile to investigate organophosphate (OP) exposure in this population. OPs have largely replaced OCs in North America because they are not as persistent, and are used by orchards, golf courses and lawn care companies throughout Quebec. This study could not examine OP exposure because blood sample volumes were inadequate to permit such analyses.

Urbanization-related (and other) losses of suitable breeding habitat have also been implicated in the declines in northeastern migrant sharpshins seen in the 1980s and early 1990s, and in any declines in Canadian populations. Yet no

previous studies had focussed on habitat use by sharpshins breeding in humandominated landscapes, or attempted to find concrete evidence that such habitat changes negatively affect the reproductive performance of this species. This study therefore included a habitat assessment designed to quantify patterns of nest habitat use by this population and to compare them with those of other populations in North America.

The most significant findings were that these sharpshins nested closer to openings, in structurally older stands with more deciduous cover. While the proximity to edges may be an indication of the relative lack of extensive woodlands in the study area, the other two may reflect natural geographical differences in habitat type and/or in the presence of competitors like Cooper's Hawks. Furthermore, whereas this population was expected to be relatively flexible in habitat use, this was not found to be the case. On the contrary, a reanalysis of the results of previous studies demonstrated that in general, the habitat requirements of breeding sharpshins were less rigid than they were previously thought to be. Only canopy cover stood out as a universal feature of sharpshin nest sites, a possible reflection of the vulnerability of this little accipiter to larger avian predators.

As for the influence of habitat quality on nesting success, there were no significant correlations between productivity and any of the habitat variables that were measured. For example, if forest fragmentation were somehow impairing the ability of breeders to fledge young, as has previously been postulated, pairs that nested closer to edges might have been expected to perform more poorly than pairs that used more interior sites. Yet, the relationship between fledging success and distance to the nearest opening was insignificant, with a correlation coefficient of 0.42. Similarly, if forest aging in the northeast were truly reducing the productivity of sharpshins which, according to many studies, nest mainly in dense woods, breeders would tend to be less successful in more open stands. Again, there was no correlation (r = 0.34) between fledging success and tree density.

Finally, since high proportions of immature breeders in a population often reflect good conditions of habitat quality and availability, the fact that nearly 40% of breeders in 2000 were yearlings may further speak to the suitability of this diverse collection of forested habitats for nesting sharpshins.

Certainly, cities tend to support a lower diversity of raptors, as do smaller parcels of woodland. Yet this population showed that it could breed successfully in these fragments, as long as they were wooded and had well-covered canopies. As Montreal (like other cities) expands outward in a veritable explosion of suburban development, small fragments of forest are often razed, and sometimes their inherent value as wilderness areas may go unrecognized. Remaining stands of forest should be considered as potential nest sites for sharpshins and other raptors, and every effort must be made to protect them from being cleared.

Attempts were made to link the results of the toxicology and habitat studies. The most obvious possible correlation would be between the proximity of nests to various forms of land use, i.e. golf courses and orchards, with a relatively high potential for exposure to OCs, and actual levels in blood samples taken from those sites. However, no such relationships were apparent. Indeed, the female with the highest level of DDE nested close to a golf course, but one where persistent OCs were presumably never applied because it opened well after the use of these compounds was banned in Canada. In contrast, the least contaminated female nested even closer to a golf course, one that is almost a century old and very likely used significant quantities of these chemicals.

In any case, the fact that nestlings were consistently close to one order of magnitude less contaminated with DDE than their mothers points to the egg as the source of uptake for the young. Also, the breeding grounds are less likely to be the primary source of exposure because if the chicks were consuming contaminated food, they probably would have had much higher levels than they did. Overall, these birds appear to be accumulating OCs, DDE in particular, on their wintering grounds, but the nesting grounds can not be ruled out as a source of exposure. The best way to unravel this puzzle may be to measure and compare OC levels in prey on this population's breeding grounds with those on

its wintering grounds. However, doing so would require understanding of where these sharpshins spend the winter months.

Currently, the winter behaviour of this and other Canadian sharpshin populations is poorly understood, largely because individuals from many different breeding populations mix during the winter, making it impossible to identify individuals as to origin. One way to elucidate this aspect of sharpshin ecology might be to trap wintering sharpshins at various locations within their winter range, collect feathers from them, and then use stable hydrogen isotope analysis to infer breeding latitudes from those samples. Unfortunately, while satellite tracking would allow the whereabouts of sharpshins from this population to be monitored over a large geographic area for extended periods of time, the smallest transmitters available are still much too heavy for these birds.

The most realistic and inexpensive way to identify the wintering grounds of this population may therefore be through the analysis of banding data. Indeed, an important accomplishment of this project was the banding of 27 individuals; all those that survive will be identifiable as to natal origin or breeding grounds for the rest of their lives. Certainly this was not a major objective of this study, but winter recoveries of these bands can reveal where this population actually winters, thus opening the door for a more in-depth investigation into the source of contaminant exposure for these birds. These bands will also identify the origin of individuals that might be trapped on migration and subjected to blood sampling for toxicological analysis. This might then allow seasonal and yearly changes in individual pollutant levels to be monitored, and the levels in this population to be compared with those in others during a single sampling period at one location. Finally, having a number of banded sharpshins would, to a certain extent, allow natal philopatry and nest site fidelity in this population to be examined. This information would be useful in determining the importance of leaving previously occupied sharpshin nest sites intact, as opposed to felling trees for harvest or land clearing. If nothing else, breeding sharpshins and their young should continue to be banded on their breeding grounds in southern Quebec and elsewhere in North America.

On the whole, this project paints a picture of a sharpshin population that seems to be in good health in terms of productivity, but that continues to be exposed to pollutants. These birds also demonstrated an ability to nest successfully in a variety of wooded areas, even small ones with a high level of disturbance, and to live in an urban environment. It also seems that sharpshins in general may be far more adaptable than they were believed to be. At the same time, many questions about these birds and how they are affected by human activities, particularly the ongoing presence of DDE in the environment, remain unanswered. Hopefully the present study will serve as a source of potential sharpshin nest site locations and ideas for future research into the ecology of the Sharp-shinned Hawk (and other raptors) in this or any other human-dominated landscapes.

## LITERATURE CITED

- Apfelbaum, S. I. and P. Seelbach. 1983. Nest tree, habitat selection and productivity of seven North American raptor species based on the Cornell University nest record card program. *J. Raptor Res.* 17:97-113.
- Barnhurst, B., McIntosh, M. W. and D. Henderson. 1996. Epervier de Cooper.
  Pp. 376-379 *in* Atlas des oiseaux nicheurs du Québec méridional (J. Gauthier and Y. Aubry, eds.). Association québecoise des groupes d'ornithologues, Province of Quebec Society for the Protection of Birds, Canadian Wildlife Service, Environment Canada, Montreal, QC.
- Bednarz, J. C., Klem, D. Jr., Goodrich, L. J. and S. E. Senner. 1990. Migration counts of raptors at Hawk Mountain, Pennsylvania, as indicators of population trends, 1934-1986. *Auk* 107:96-109.
- Bildstein, K. L. 1998. Long-term counts of migrating raptors: a role for volunteers in wildlife research. *J. Wild. Manage.* 62:435-45.
- Bildstein, K. L. and K. Meyer. 2000. Sharp-shinned Hawk (*Accipiter striatus*). In The Birds of North America, no 482 (Poole, A. and F. Gill, eds.). The Birds of North America, Inc. Philadelphia, PA.
- Bird, D. M. 1999. Rapport sur la situation de l'épervier de Cooper (*Accipiter cooperii*) au Québec. Société de la faune et des parcs du Québec, Direction de la faune et des habitats. Quebec, QC.
- Bird, D. M. and P. C. Laguë. 1982. Fertility, egg weight loss, hatchability, and fledging success in replacement clutches of captive American Kestrels. *Can. J. Zool.* 60:80-88.
- Blus, L. J., Henny, C. J., Stafford, C. J. and R. J. Grove. 1987. Persistence of DDT and metabolites in wildlife from Washington state orchards. *Arch. Environ. Contam. Toxicol.* 16:467-476.
- Bohall Wood, P., Viverette, C., Goodrich, L., Pokras, M. and C. Tibbott. 1996. Environmental contaminant levels in Sharp-shinned Hawks from the eastern United States. *J. Raptor Res.* 30:136-44.
- Brown, L. and D. Amadon. 1968. Eagles, Hawks and Falcons of the World. McGraw-Hill Book Co., New York, NY.
- Burns, R. M. and B. H. Honkala, tech. coords. 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC. vol.2.

- Clapp, R. B., Klimkiewicz, M. K. and J. H. Kennard. 1982. Longevity records of North American birds: Gaviidae through Alcidae. J. Field Ornithol. 53:81-124.
- Clark, W. S. 1985. The migrating Sharp-shinned Hawk at Cape May Point: banding and recovery results. Pp. 137-138 *in* Proc. Hawk Migration Conf. IV (M. Harwood ed.). Hawk Migration Association of America. Washington Depot, CT.
- Cooke, A. S. 1973. Shell thinning in avian eggs by environmental pollutants. *Environ. Pollut.* 4:85-152.
- Dunn, E. H. 1995. Bias in Christmas Bird Counts for species that visit feeders. *Wilson Bull*. 107:122-130.
- Dunn, E. H. and D. L. Tessaglia. 1994. Predation of birds at feeders in winter. *J. Field Ornithol.* 65:8-16.
- Dunn, J., ed. 1987. Field Guide to the Birds of North America. Second edition. National Geographic Society. Washington, DC.
- Dykstra, C.R., J.L. Hayes, F.B. Daniel and M.M. Simon. 2000. Nest site selection and productivity of suburban red-shouldered hawks in southern Ohio. Condor 102:401-408.
- Elliott, J. E. and L. Shutt. 1993. Monitoring organochlorines in blood of Sharpshinned Hawks (*Accipiter striatus*) migrating through the Great Lakes. *Environ. Toxicol. Chem.* 12:241-250.
- Fernie, K. J., Smits, J. E., Bortolotti, G. R. and D. M. Bird. 2001. Reproduction success of American Kestrels exposed to dietary polychlorinated biphenyls. *Environ. Toxicol. Chem.* 20:776-781.
- Flood, N. J. and G. R. Bortolotti. 1986. Status Report on the Sharp-shinned Hawk (*Accipiter striatus*) in Canada. Unpubl. report for the Committee on the Status of Endangered Wildlife in Canada.
- Freund, R. J. and W. J. Wilson. 1997. Statistical Methods: revised edition. Academic Press. San Diego, CA.
- Frings, C. S., Fendley, T. W., Dunn, R. T. and C. A. Queen. 1972. Improved determination of total serum lipids by the sulfo-phospho-vanillin reaction. *Clin. Chem.* 18:673-674.
- Gargett, V. 1977. A 13-year population study of the Black Eagles in the Matapos, Rhodesia. *Ostrich* 48:17-27.

- Garner, H. D. 1999. Distribution and habitat use of Sharp-shinned and Cooper's Hawks in Arkansas. *J. Raptor Res.* 33:329-332.
- Gehlbach, F. R. 1996. Eastern Screech Owls in suburbia: a model of raptor urbanization. Pp. 69-74 *in* Raptors in Human Landscapes (Bird, D. M., Varland, D. E. and J. J. Negro, eds.). Academic Press, San Diego, CA.
- Godfrey, W. E. 1990. Encyclopédie des Oiseaux du Québec. Les Éditions de l'Homme. Ottawa, Canada.
- Government of Canada. 1996. The State of Canada's Environment. Minister of Public Works and Government Services. Gloucester, ON.
- Grier, J. W. 1969. Bald Eagle behaviour and productivity responses to climbing to nests. *J. Wildl. Manage*. 33:961-966.
- Henny, C. J. 1977. Birds of prey, DDT, and Tussock Moths in Pacific Northwest. *Trans. N. Am. Wildl. Nat. Res. Conf.* 42:397-411.
- Henny, C. J. and D. J. Meeker. 1981. An evaluation of blood plasma for monitoring DDE in birds of prey. *Environ. Pollut.* 25:291-304.
- Jacobs, E. A. and L. S. Semo. 1997. Reproductive performance and nesting phenology of adult and yearling Sharp-shinned Hawks (*Accipiter striatus*) in Wisconsin. Annual meeting of the Raptor Research Foundation, Savannah, GA. [abstract].
- Kerlinger, P. 1993. Sharp-shinned Hawk populations in free-fall. *Winging It* 5:10-11.
- Kirk, D. A. 1997. Update COSEWIC Status report on Sharp-shinned Hawk, *Accipiter striatus*. Unpubl. report for the Committee on the Status of Endangered Wildlife in Canada.
- Kirk, D. A., Hussell, D. and E. Dunn. 1995. Raptor population status and trends in Canada. *Bird Trends* 4:2-9.
- Kirk, D. A. and C. Hyslop. 1998. Population status and recent trends in Canadian raptors: a review. *Biol. Conserv.* 83:91-118.
- Laura, T. 1992. Northern Appalachians Regions Summary. *HMANA Hawk Migration Studies.* 17:40-54.
- Linteau, P. A. 2000. Histoire de Montréal depuis la confédération. 2<sup>e</sup> édition. Boréal. Montréal, QC.

- McLane, M. A. and D. L. Hughes. 1980. Reproductive success of screech owls fed Aroclor 1248. Arch. Environ. Contam. Toxicol. 9:661-665.
- Meyer, K. D. 1987. Sexual size dimorphism and the behavioural ecology of breeding and wintering Sharp-shinned Hawks (*Accipiter striatus*). Ph.D. dissertation, Univ. North Carolina, Chapel Hill, NC.
- Moore, K. R. and C. J. Henny. 1983. Nest site characteristics of three coexisting accipiter hawks in northeastern Oregon. *J. Raptor Res.* 17:65-76.
- Morrison, M. L., Marcot, B. G. and R. W. Mannan. 1998. Wildlife-habitat relationships. The University of Wisconsin Press. Madison, WI.
- Mueller, H. C. and D. D. Berger. 1970. Prey preferences in the Sharp-shinned Hawk: the roles of sex, experience and motivation. *Auk* 87:452-457.
- Mueller, H. C., Berger, D. D. and G. Allez. 1979. Age and sex differences in size of Sharp-shinned Hawks. *Bird-Banding* 50:34-44.
- Mueller, H. C., Mueller, N. S. and P. C. Parker. 1981. Observations of a brood of Sharp-shinned Hawks in Ontario, with comments on the functions of sexual dimorphism. *Wilson Bull*. 93:85-92.
- Musser, H. B. 1962. Turf Management. McGraw-Hill Book Company. New York, NY.
- Newton, I. 1979. Population ecology of raptors. Buteo Books. Vermillion, SD.
- Newton, I. 1991. The Sparrowhawk. T & A D Poyser Ltd. Staffs, GB.
- Newton, I. and J. Bogan. 1978. The role of different organo-chlorine compounds in the breeding of British Sparrowhawks. *J. Applied. Ecol.* 15:105-116.
- Newton, I., Bogan, J. and P. Rothery. 1986. Trends and effects of organochlorine compounds in Sparrowhawk eggs. *J. Applied. Ecol.* 23:461-478.
- Noble, D. G. and J. E. Elliott. 1990. Levels of contaminants in Canadian raptors, 1966 to 1988; effects and temporal trends. *Can. Field Nat.* 104:222-243.
- Noble, D. G., Elliott, J. E. and J. L. Shutt. 1993. Environmental contaminants in Canadian raptors, 1965-1989. Technical report no. 91. Canadian Wildlife Service. Ottawa, Canada.
- Odsjö, T. and J. Sondell. 1976. Reproductive success in Ospreys *Pandion haliaetus* in southern and central Sweden. 1971-1973. *Ornis. Scand.* 7:71-84.

- Ouellet, R. and M. Bombardier. 1996. Épervier brun. Pp. 372-375 in Atlas des oiseaux nicheurs du Québec méridional (Gauthier, J. and Y. Aubry, eds.). Association québecoise des groupes d'ornithologues, Province of Quebec Society for the Protection of Birds, Canadian Wildlife Service, Environment Canada, Montreal, QC.
- Parker, J. W. 1996. Urban ecology of the Mississippi Kite. Pp. 45-52 *in* Raptors in Human Landscapes (Bird, D. M., Varland, D. E. and J. J. Negro, eds.). Academic Press, San Diego, CA.
- Paton, P. C. 1994. The effect of edge on avian nest success: how strong is the evidence? *Conserv. Biol.* 8:17-26.
- Pattee, O. H., Fuller, M. R. and T. E. Kaiser. 1985. Environmental contaminants in eastern Cooper's Hawk eggs. *J. Wildl. Manage*. 49:1040-1044.
- Platt, J. B. 1976. Sharp-shinned Hawk nesting and nest site selection in Utah. *Condor* 78:102-3.
- Reynolds, R. T., Meslow, E. C. and H. M. Wight. 1982. Nesting habitat of coexisting *Accipiter* in Oregon. *J. Wild. Manage.* 46:124-38.
- Reynolds, R. T. and H. M. Wight. 1978. Distribution, density, and productivity of accipiter hawks breeding in Oregon. *Wilson Bull.* 90:182-196.
- Rosenfield, R. N. and R. K. Anderson. 1983. Final Report. Status of the Cooper's Hawk. Wisconsin Endangered and Threatened Species Investigations. Project no. E-1-5, study no. 208. Wisconsin Department of Natural Resources, Bureau of Endangered Resources. Madison, WI.
- Rosenfield, R. N. and J. Bielefeldt. 1992. Natal dispersal and inbreeding in the Cooper's Hawk. *Wilson Bull*. 104:182-184.
- Rosenfield, R. N. and J. Bielefeldt. 1993. Cooper's Hawk (*Accipiter cooperii*). In The Birds of North America, no 75 (Poole, A. and F. Gill, eds.). The Birds of North America, Inc. Philadelphia, PA.
- Rosenfield, R. N. and J. Bielefeldt. 1996. Lifetime nesting area fidelity in male Cooper's Hawks in Wisconsin. Condor 98:165-167.
- Rosenfield, R. N., Bielefeldt, J., Affeldt, J. L. and D. J. Beckmann. 1996. Urban nesting biology of Cooper's Hawks in Wisconsin. Pp. 41-44 *in* Raptors in Human Landscapes (Bird, D. M., Varland, D. E. and J. J. Negro, eds.). Academic Press, San Diego, CA.
- Rouleau, R., ed. 1990. Petite flore forestière du Québec. 2<sup>e</sup> édition. Les Publications du Québec. Quebec, QC.

- Siders, M. S. and P. L. Kennedy. 1996. Forest structural characteristics of accipiter nesting habitat: is there an allometric relationship? *Condor* 98:123-132.
- Snyder, N. F., Snyder, H. A., Lincer, J. F. and R. T. Reynolds. 1973. Organochlorines, heavy metals, and the biology of North American accipiters. *BioScience* 23:300-305.
- Storer, R. W. 1966. Sexual dimorphism and food habits in three North American accipiters. *Auk* 83:423-436.
- Struve, S. and L. Goodrich. 1992. Distribution of band recoveries for Sharpshinned Hawks (*Accipiter striatus*) banded in the eastern Appalachian flyway. Unpubl. report. Hawk Mountain Sanctuary. Kempton, PA.
- Sutton, C. and P. Kerlinger. 1997. The Delaware bayshore of New Jersey: a raptor migration and wintering site of hemispheric significance. *J. Raptor Res.* 31:54-58.
- Thomas, L. and K. Martin. 1996. The importance of analysis method for Breeding Bird Survey population trend estimates. *Conserv. Biol.* 10:479-490.
- Titus, K. and M. R. Fuller. 1990. Recent trends in counts of migrant hawks from northeastern North America. *J. Wildl. Manage*. 54:463-470.
- Trexel, D. R., Rosenfield, R. N., Bielefeldt, J. and E. A. Jacobs. 1999. Comparative nest site habitats in Sharp-shinned and Cooper's Hawks in Wisconsin. *Wilson Bull.* 111:7-14.
- Viverette, C. B., Struve, S., Goodrich, L. and K. L. Bildstein. 1996. Decreases in migrating Sharp-shinned Hawks (*Accipiter striatus*) at traditional raptormigration watch sites in eastern North America. *Auk* 113:32-40.
- Wakeford, B. 2001. Multiresidue method for the determination of chlorinated pesticides and polychlorinated biphenyls (PCBs) in wildlife tissues. National Wildlife Research Council Methods Manual, No. MET-CHEM-OC-04C
- Walker, C. H. and P. I. Stanley. 1987. Organochlorine insecticide residues in predatory birds – long-term trends and bioaccumulation. Pp 637-370. In Pesticide Science and Biotechnology (Greenhalgh, R. and T. R. Roberts, eds.). Blackwell Scientific Publications. Oxford, GB.

- Wilcove, D. S., McLellan, C. H. and A. P. Dobson. 1986. Habitat fragmentation in the temperate zone. Pp. 237-256 in Conservation Biology: The Science of Scarcity and Diversity (Soulé, M. E. ed.). Sinauer Associates. Sunderland, MA
- Wiggers, E. P. and K. J. Kritz. 1991. Comparison of nesting habitat of coexisting Sharp-shinned and Cooper's Hawks in Missouri. *Wilson Bull.* 103:568-77.
- Wiggers, E. P. and K. J. Kritz. 1994. Productivity and nesting chronology of the Cooper's Hawk and Sharp-shinned Hawk in Missouri. *J. Raptor Res.* 28:1-3.
- Woolfenden, G. E. and J. W. Fitzpatrick. 1990. Florida Scrub Jays: a synopsis after 18 years of study. Pp. 241-266 in Cooperative Breeding in Birds.
  Long-term studies of ecology and behavior (Stacey, P. B. and W. D. Koenig, eds.). Cambridge University Press.