COSEWIC
Assessment and Status Report

on the

Eastern Mole
Scalopus aquaticus

in Canada

SPECIAL CONCERN
2010

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

COSEWIC. 2010. COSEWIC assessment and status report on the Eastern Mole *Scalopus aquaticus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. x + 29 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Previous report(s):

COSEWIC. 2000. COSEWIC assessment and update status report on the Eastern Mole *Scalopus aquaticus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 25 pp.

Waldron, G.E. 1998. Update COSEWIC status report on the Eastern Mole *Scalopus aquaticus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-25 pp.

MacAulay, A. 1980. COSEWIC status report on the Eastern Mole *Scalopus aquaticus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 11 pp.

Production note:
COSEWIC would like to acknowledge Dr. Jennie L. Pearce and Dr. David Anthony Kirk for writing the status report on the Eastern Mole (*Scalopus aquaticus*) in Canada, prepared under contract with Environment Canada, overseen and edited by Mark Brigham, Co-chair, COSEWIC Terrestrial Mammals Species Specialist Subcommittee.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-953-3215
Fax: 819-994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la taupe à queue glabre (*Scalopus aquaticus*) au Canada.

Cover illustration/photo:
Eastern Mole —

Catalogue No. CW69-14/269-2011E-PDF
ISBN 978-1-100-18588-0

Recycled paper

COSEWIC
Assessment Summary

Assessment Summary – November 2010

Common name
Eastern Mole

Scientific name
Scalopus aquaticus

Status
Special Concern

Reason for designation
This small mammal has a Canadian range restricted to about 1000 hectares near Point Pelee National Park in southern Ontario. It has a restricted and fragmented distribution, but lack of adequate monitoring effort and quantification of threats underline the uncertainty of its conservation status. Although there is some evidence of decline, one third of the species' habitat is relatively secure in the park. Threats have not been evaluated elsewhere.

Occurrence
Ontario

Status history
Designated Special Concern in April 1980. Status re-examined and confirmed in April 1998, November 2000, and November 2010.

COSEWIC
Executive Summary

Eastern Mole
Scalopus aquaticus

Wildlife species information

The Eastern Mole (*Scalopus aquaticus*) is twice the size of a mouse, with a robust body, short, scantily-haired tail, large, broad front feet, and a long, pointed, hairless snout. The colour of the dense fur varies throughout the mole's range. The Eastern Mole can easily be distinguished from the Star-nosed Mole by the lack of fleshy appendages on its nose, and from the Hairy-tailed Mole by the absence of both webbed toes and hair on the tail.

Distribution

The Eastern Mole has the largest range of any mole species in North America. It occurs in most eastern and central states of the U.S., in extreme southern Canada, and in northern Mexico. In Canada, the species is restricted to southern Ontario, specifically three municipalities in Essex County, Ontario (Towns of Essex and Kingsville and the Municipality of Leamington) and the western portion of Romney Township in the Municipality of Chatham-Kent.

Habitat

Throughout its range, the Eastern Mole occupies a variety of habitats ranging from open woodlands to open fields, where the soil is sufficiently soft to allow tunnel construction. In Ontario, Eastern Moles are most frequently found in loam or sandy loam soils in forested areas, and along wooded or brushy hedgerows, water courses or open drains, where the soil is stone-free, coarse-textured, and generally fast-draining. In open habitat, mole tunnels generally radiate out from shady areas; cultivated fields are rarely used. Approximately 929 ha of potential habitat is estimated to occur in Canada.

Biology

Eastern Moles are mostly solitary and occupy relatively stable home ranges year-round. They excavate two types of tunnels: near-surface tunnels, which are used for foraging, and deep permanent gallery tunnels; digging the latter may produce the characteristic molehills, or “pushups”. Males have larger home ranges (1.1 ha) than females (0.3 ha).

The species likely has a polygynous mating system with breeding occurring after the first year. Breeding occurs once a year with the timing being later at northern latitudes. Mating takes place in late March-early April, and a litter of 2-5 young moles is produced in late April or early May. Moles feed on a wide variety of invertebrates, including earthworms, larvae and adult beetles, ants and vegetable matter (including mycorrhizal fungi). Because they live a largely subterranean existence, they are usually at low risk of predation, unless predators (e.g., snakes, weasels) enter or dig up tunnels (canids), or flooding or juvenile dispersal causes moles to come to the surface (where they are vulnerable to raptors and other predators).

Population sizes and trends

In 1997, Eastern Mole signs (defined as near-surface tunnels or push-ups) were recorded at 25 (52%) of 48 sites surveyed in southern Ontario which cover most of the potential distribution of the species except for Point Pelee National Park (PNPP). Forty-six of the 48 sites were resurveyed in 2008, and mole sign was recorded at 17 of the 23 sites that contained moles in 1997—a decline of 26%. One new site with mole sign was identified in 2009, increasing to 18 the number of places that have been surveyed outside Point Pelee National Park and are known to support Eastern Moles. Within Point Pelee National Park six sites were surveyed annually for mole sign between 1985 and 2000 and again in 2007 and 2008. Large year-to-year fluctuations in the number of mole signs occurred. The annual time series of mole sign had low statistical power, and yielded no significant trend.

Threats and limiting factors

The range of the Eastern Mole in Canada is likely limited by suitable soil types. Lands with suitable soils have been extensively modified or converted to intensive agriculture and residential development, with only a small percentage remaining that contains sufficient vegetative cover to provide suitable habitat. Habitat patches are frequently small and surrounded by unsuitable habitat. Eastern Moles likely have limited ability to move large distances across inhospitable habitat, resulting in isolation of populations in proximity to forest patches.

Special significance

Ontario is at the northernmost range for the species. Moles are important for mixing and turnover of soil, an ecological role that was even more important prior to the introduction of the earthworm from Europe. They may also act as important dispersal agents of mycorrhizal fungi. Moles are often considered as horticultural pests because their activities disfigure lawns and gardens.

Existing protection, status, and ranks

In Canada and Ontario, the Eastern Mole is listed under SARA and the Ontario *Endangered Species Act, 2007* as “a species of Special Concern”. One third of the remaining suitable habitat occurs within Point Pelee National Park, with the remainder scattered on both public and private land. The amount of habitat available to the Eastern Mole has remained relatively stable within the Park since 1997, and may also be stable outside of the park boundaries. NatureServe lists the Eastern Mole as Secure in the United States.

TECHNICAL SUMMARY

Scalopus aquaticus
Eastern Mole — Taupe à queue glabre
Range of occurrence in Canada:ON

Demographic Information

Generation time (Calculated using method 3 in IUCN guidelines (2008) and life table from Davis and Choate (1993))	1.5 yrs
Is there an inferred continuing decline in number of mature individuals? Based on the amount of potential habitat available.	No, based on available habitat
Estimated percent of continuing decline in total number of mature individuals within 5 years.	Unknown
Inferred percent reduction in total number of mature individuals over the last 10 years. Based on (a) amount of potential habitat available, or (b) reduced numbers of sites with mole sign outside of Point Pelee National Park.	(a) Likely none (b) 26%
Suspected percent [reduction or increase] in total number of mature individuals over the next 10 years.	Unknown, but based on the relative stability of potential habitat, population may be stable.
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown, but based on relative stability of potential habitat, population may be stable.
Are the causes of the decline clearly reversible and understood and ceased?	Unknown
Are there extreme fluctuations in number of mature individuals?	Unknown, although there is large annual variation in the number of mole signs in Point Pelee.

Extent and Occupancy Information

Estimated extent of occurrence (EO)	546 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value; other values may also be listed if they are clearly indicated (e.g., 1x1 grid, biological AO)).	Insufficient data to be able to calculate but must be <546 km²
Is the total population severely fragmented?	Unknown
Number of "locations".	Unknown
Is there an inferred continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Unknown
Is there an inferred continuing decline in number of populations?	No
Is there an inferred continuing decline in number of locations? Strictly speaking there is only one location but mole signs were detected at fewer sites outside PPNP in 2008 than 1997, although one new site was also reported (Ritchie and Nocera, 2010).	No
Is there an inferred continuing decline in area, extent and/or quality of habitat?	No inferred change in area or extent; unlikely change in quality
Are there extreme fluctuations in number of populations?	Unknown
Are there extreme fluctuations in number of locations*?	No

Are there extreme fluctuations in extent of occurrence?	Unlikely
Are there extreme fluctuations in index of area of occupancy?	Unlikely

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Impossible to estimate given current information.	unknown
Total	unknown
One population assumed	

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	None done

Threats (actual or imminent, to populations or habitats)

Habitat loss through flooding or vegetation removal. Habitat fragmentation. Nuisance trapping.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Secure in United States and adjacent states of Ohio and Michigan.	
Is immigration known or possible?	Immigration not likely
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Unknown
Is rescue from outside populations likely? Canadian population likely isolated by unsuitable habitat greater than the plausible dispersal distance of the Eastern Mole.	No

Current Status

COSEWIC: Special Concern (November 2010)

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Special Concern	Not applicable

Reasons for designation:
This small mammal has a Canadian range restricted to about 1000 hectares near Point Pelee National Park in southern Ontario. It has a restricted and fragmented distribution, but lack of adequate monitoring effort and quantification of threats underline the uncertainty of its conservation status. Although there is some evidence of decline, one third of the species' habitat is relatively secure in the park. Threats have not been evaluated elsewhere.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals):
Not applicable. While there was a 26% decline in occupied sites between two surveys in 1997 and 2008, the ephemeral nature of this animal combined with the lack of habitat decline means that it is unlikely this is indicative of a true population trend. Regular surveys in Point Pelee National Park suggest no decline.

Criterion B (Small Distribution Range and Decline or Fluctuation):
Not applicable. Meets Endangered criteria for B1 (EO < 5000) but does not meet any of sub-criteria a, b or c (severely fragmented/ 5-10 locations, continuing decline or fluctuations).

Criterion C (Small and Declining Number of Mature Individuals):
Not applicable. The quantitative data for mole numbers is based on surveys of signs (tunnels and push-ups) for which there is not strong evidence for correlation with population size.

Criterion D (Very Small or Restricted Total Population):
Not applicable. The size of the population is unknown. Further, there is no evidence that the species is prone to decline due to human or stochastic events within a very short time period.

Criterion E (Quantitative Analysis):
Not applicable.

PREFACE

Since the last Status report, there are some new survey data from outside Point Pelee National Park and annual monitoring data from within Point Pelee National Park have been analysed for trends. The characteristics of Eastern Mole habitat in Canada have been further described.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2010)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune
Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Eastern Mole
Scalopus aquaticus

in Canada

2010

TABLE OF CONTENTS

List of Figures

List of Tables

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and classification

Scientific name: *Scalopus aquaticus* (Linnaeus, 1758)

English name: Eastern Mole

French name: Taupe à queue glabre

Classification: Class Mammalia, Order Soricomorpha, Family Talpidae

The Eastern Mole is the only member of the genus *Scalopus*.

Wilson and Reeder (2005) accept 16 subspecies of Eastern Mole. All Eastern Moles in Canada are assumed to belong to the largest and most northern of these subspecies, *S. a. machrinus* (Banfield 1974; Yates and Schmidly 1978; van Zyll de Jong 1983).

Morphological description

The Eastern Mole is about twice the size of a mouse, with a robust body, short, scantily haired tail, large, broad front feet, and a long, pointed, hairless snout. The toes of the front and rear feet are webbed. The colour of the dense pelage varies with latitude throughout the mole's range from a greyish brown (almost black) to a light golden colour. Female Eastern Moles are 8-10% smaller in total body length and lighter in mass than males (see Leftwich 1972; Yates and Schmidly 1977).

Two other mole species occur in Ontario but neither overlaps in distribution with the Eastern Mole and they are easily distinguished (Dobbyn 1994). The Star-nosed Mole (*Condylura cristata)* can be easily distinguished from the Eastern Mole by the fleshy appendages on the snout. The Hairy-tailed Mole (*Parascalops breweri*) is easily distinguished by the un-webbed toes, the lateral rather than dorsal nostrils, and the densely-haired tail.

Population spatial structure and variability

There is no information on genetic variability or spatial structuring within the Canadian population. Little is known about dispersal ability of Eastern Moles; however, it is probably limited, similar to related species. The farthest movement documented for Townsend's Mole (*Scapanus townsendii)* is 722 m (see **Dispersal and Migration** section). Although roads, drainage ditches and small rivers did not prevent dispersal by juvenile Townsend's Moles (see **Dispersal and Migration** section) suitable habitat patches separated by more than 722 m may be isolated from each other.

Genetic variation may be greater in the southern parts of the range of the Eastern Mole; in the north, low levels of intra- and inter-population variation have been reported (Hartman 1996). In South Carolina, Hartman (1996) examined population-level genetic variability and found significant variation in mean direct-count heterozygosity, mean number of alleles per locus and percentage polymorphic loci, even over short distances. Eastern Moles have a diploid number of 34 chromosomes.

Designatable units

There is only one subspecies recognized in Canada and no distinctions that warrant assessment below this level. Thus this report is based on a single designatable unit.

Special significance

In Canada, the Eastern Mole is at the northernmost edge of the species range. *Scalopus a. machrinus* is the largest subspecies of Eastern Mole. Moles play an important role in mixing and turnover of soil, an ecological role that was likely even more important prior to the introduction of European earthworms.

Eastern Moles may act as dispersal agents of mycorrhizal fungi, which are important for soil processes and plant communities. Although fungal associations with moles in North America have not been examined, mycorrhizal fungi have been reported from the stomachs of Eastern Moles. In England and Japan, fruiting bodies of *Hebeloma* fungi are associated with mole nests and latrines (Sagara 1989; 1999; Sagara *et al.* 1989; cited in Hartman and Yates 2003).

Moles are often persecuted as they are considered horticultural pests because they disfigure lawns and gardens. There is widespread trapping in the U.S., often unreported. Some of this likely occurs in Canada. There is no information which suggests this species is of significance to First Nations people.

DISTRIBUTION

Global range

With the largest range of any North American mole species, the Eastern Mole occurs in most of the eastern and central states of the U.S., in northern Mexico and in extreme southern Canada (Figure 1). From northern Tamaulipus in Mexico the range extends north to southeastern South Dakota, Minnesota and Michigan, east to Massachusetts, and south to the southern tip of Florida (Yates and Schmidly 1978; Hartman and Yates 2003). The *machrinus* subspecies occurs in Ontario, Michigan, Ohio, Indiana, Illinois, and Wisconsin.

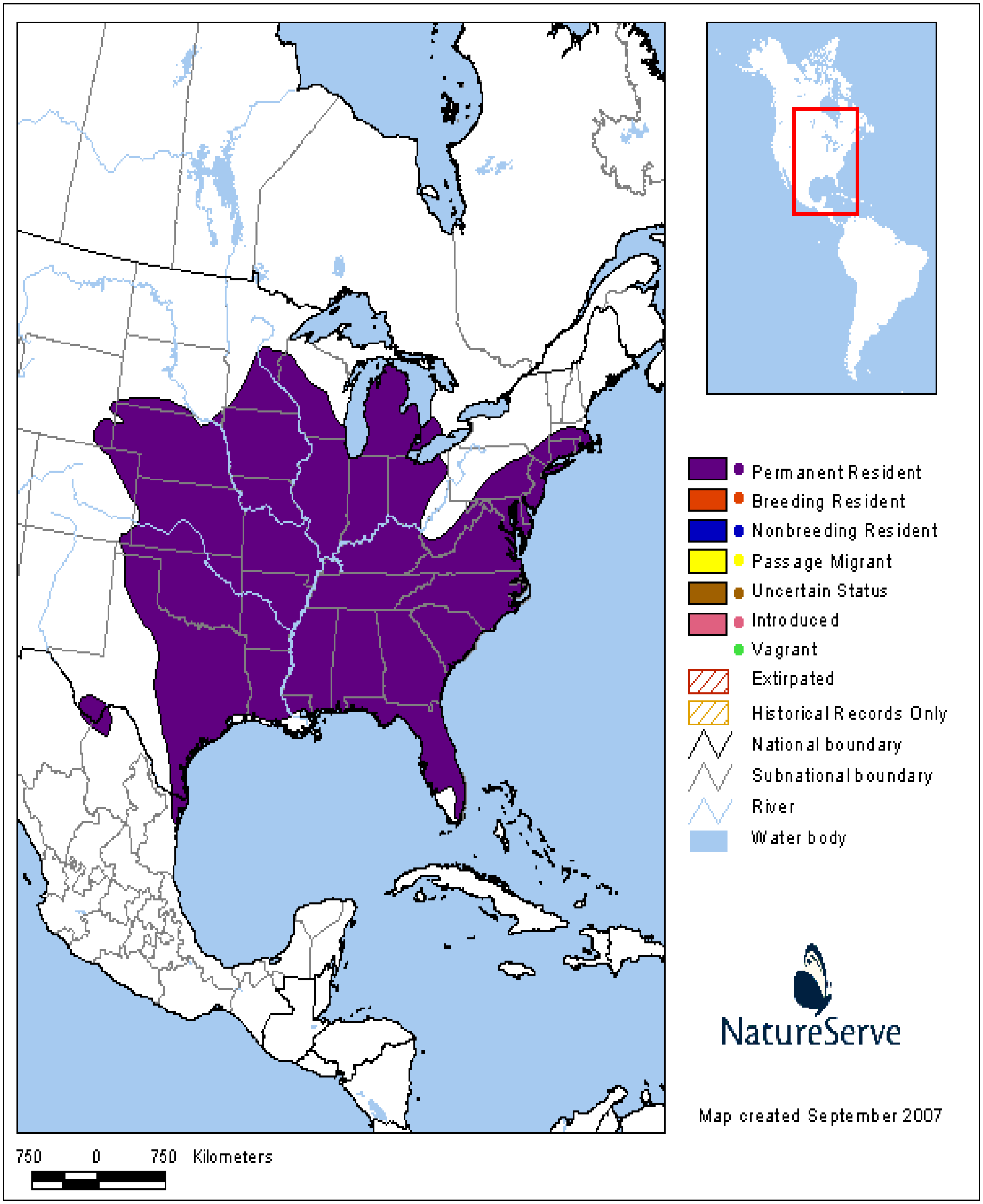

Figure 1. Range of Eastern Mole in North America (NatureServe 2009).

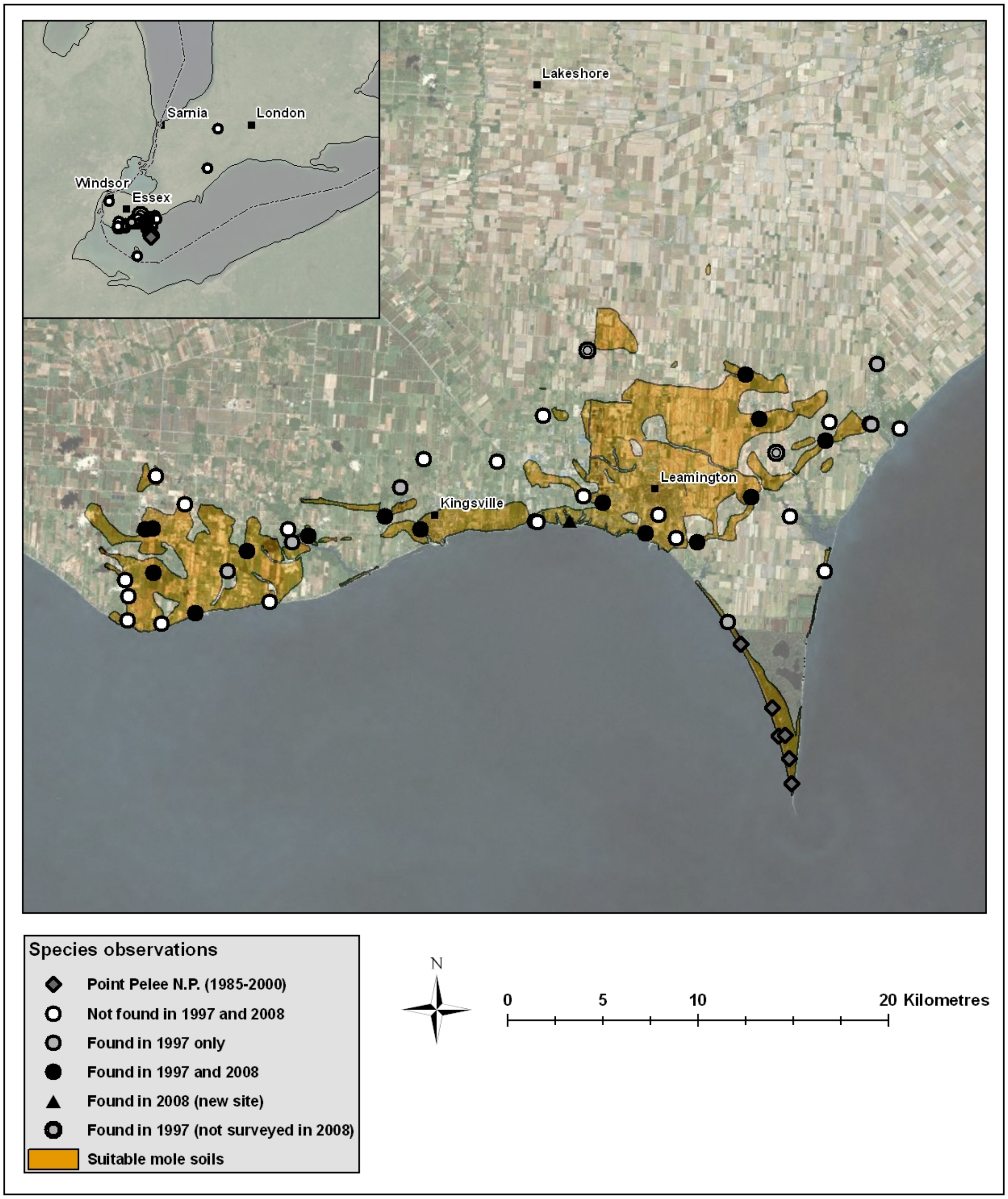

Figure 2. Map of occurrence of Eastern Moles and potential habitat in southern Ontario.

Canadian range

The Atlas of Mammals of Ontario project (Dobbyn 1994) reported that the Eastern Mole was limited to four townships in the south and east of Essex County: Colchester South (now the Town of Essex), Gosfield South and Gosfield North (now the Town of Kingsville) and Mersea (now the Municipality of Leamington) (Appendices 1 and 2 in Waldron 1998; see also Waldron *et al*. 2000). Fieldwork conducted in 1997 for the last COSEWIC update (Waldron 1998; Waldron *et al.* 2000) extended the known distribution of Eastern Moles easterly to include Kent County (now the Municipality of Chatham-Kent), and to the west to include Harrow, Essex County. The added extent of occurrence is approximately 350 km^2. The total extent of occurrence is 546 km^2. The data presently available preclude a reliable calculation of IAO but it must be < 546 km^2.

Historically, Saunders (1932; cited in Waldron 1998) recorded mole sign near Harrow in 1909. Saunders suggested that an Eastern Mole was collected near Rodney, Elgin County in 1910 (84 km from the main sites in Essex County). He also identified a specimen collected near Strathroy, Middlesex County (120 km from the main sites in Essex County) as an Eastern Mole but there have been no subsequent records from this or nearby localities. Based on trapping data, Waldron (1998) suggested that moles in Elgin and Middlesex Counties were likely Hairy-tailed Moles and not Eastern Moles.

Though searched for on Pelee Island and in the city of Windsor, Eastern Moles have never been recorded in those locations.

Search effort

Thirteen specimens are held at the Canadian Museum of Nature in Ottawa, which were collected between 1908 and 1919 from Point Pelee National Park (K. Kalidas, pers. comm.). Seventeen specimens are held by the Royal Ontario Museum, Toronto (Waldron *et al.* 2000). Eleven of these were collected from Point Pelee National Park between 1908 and 1950, three were collected near Kingsville between 1918 and 1935, and three were taken near Leamington in 1928 although methodology and therefore search effort was not the same for these sampling periods.

Forty-eight prospective sites across the entire known range of the species were searched for mole signs in 1997 for the 1998 Status report (Waldron 1998; Waldron *et al.* 2000). Search effort was not consistent among sites. One survey site was in Middlesex County, one in Elgin County, three in the Municipality of Chatham-Kent, and 43 in Essex County. Eastern Mole sign was found at 2 sites in the Municipality of Chatham-Kent and 22 sites surveyed in Essex County. None of the surveys was exhaustive, which combined with methodological limitations limits the inferences that can be made (see **POPULATION SIZES AND TRENDS** section).

Six sites in Point Pelee National Park (PNPP) that contained moles were surveyed annually for mole sign between 1985 and 2000. A 500 m long and 3 m wide transect was visually searched once each year, usually in April-early May with the number of mole tunnels and push-ups observed on each transect recorded (Michano 1991). Additional surveys in 2008 and 2009 found no substantive difference in the occupancy of the sites surveyed in 1985-2000 (PPNP unpub. data).

In 2008, Ritchie and Nocera (2010) resurveyed 46 of the 48 sites outside PNPP that Waldron (1998) had surveyed, using a similar level of search effort. At locations where there was a path or trail, Ritchie and Nocera followed the path/trail that allowed the largest portion of the site to be covered and/or walked the perimeter of the property. At locations where no trails were apparent, the authors walked a 500 m transect through the site or transect segments summing to 500 m in total at small sites. Eastern Mole sign was found at 17 of the 23 locations at which Waldron (1998) recorded Eastern Mole sign in 1997. No evidence of moles was found in 2008 at sites where no sign was found in the 1998 survey.

HABITAT

Habitat requirements

Throughout its range, the Eastern Mole occupies a variety of habitats from open woodlands to open fields, where the soil is sufficiently soft to allow tunnel construction. In Ontario, both shade and suitable soil types appear to be required. Cultivated land is used by Eastern Moles but only at the edges of hedgerows or forest, where tunnels may radiate up to 3 m from shaded areas into cultivated fields (Waldron *et al*. 2000).

In Ontario, Eastern Moles are five times more likely to occur at sites with loam or sandy loam soils than other soils (e.g., coarse sand, wetlands or clay; Ritchie and Nocera 2010). Loam and sandy loam soils are stone-free, coarse textured and generally fast draining (Waldron *et al.* 2000). Specific soil types in which Eastern Moles were recorded included Berrien sand, Berrien sandy loam, the sandy knolls of Brookston clay sand spot phase and Caistor sand spot phase, Eastport sand, Fox sandy loam, Harrow sand, Harrow sandy loam, Plainfield sand, and Tuscola fine sandy loam (Waldron *et al.* 2000).

Waldron *et al.* (2000) found Eastern Moles most often in suitable soils in forested areas, but also along wooded or brushy hedgerows, and water courses or open drains where a single tree or clump of bushes may have provided sufficient cover. Moles are more likely to occur at sites with suitable soils and with a high proportion of forest in the landscape (within 305 m); the amount of forest cover in the vicinity of mole tunnels appears less important (within 49 m; Ritchie and Nocera 2010). The probability of moles being recorded on suitable soils and with vegetation that was open and grassy increased with the amount of forest within the landscape (within 305 m; Ritchie and Nocera 2010).

Habitat trends

Waldron *et al.* (2000) estimated that 17,400 ha of suitable soils (excluding the Caistor and Brookston Clay sand spot soils because the sandy knolls used by the Eastern Mole could not be delineated) were present in Essex County, and that 4.2% of Essex County contained forest and hedgerows. Based on these data, they estimated that approximately 1,060 ha of suitable potential habitat for Eastern Moles occurred within Essex County in 1997. They noted that this estimate was likely variable because (1) the Eastern Mole had not been recorded in the northern part of Essex County, (2) the sandy knolls of the Caistor and Brookston Clay sand spot soils were used by Eastern Moles but were not included in the estimate, and (3) vegetated habitats other than forest and hedgerows, such as golf courses, orchards, suburban lawns and gardens, or vegetated watercourses were not included in the estimate.

Suitable habitat available to the Eastern Mole was recalculated (D. Kirk and J. Pierce, unpub. data) using digital soil data from the National Soil Database (CanSIS 2008) and updated forest cover data from interpretation of aerial photographs taken in 2006 for the three Municipalities in Essex County where Eastern Moles have been recorded. In total, 929 ha with suitable soils (excluding the Sand Spot phase of the Caistor and Brookston soils as per Waldron *et al.* (2000)) had forest cover (> 0.5 ha) in 2006. Thus, slightly less potential habitat may be available to the Eastern Mole than previously estimated by Waldron (1998) (although the amount of actual habitat may have remained unchanged since the first calculation). Unmapped habitat types such as golf courses, orchards, suburban lawns and gardens, and vegetated watercourses may provide additional potential habitat for the Eastern Mole.

The amount of suitable potential habitat within Point Pelee National Park has likely remained constant since 1997 (V. McKay, pers. comm.). Outside of the Park boundary, changes in forest cover have not been tracked in Essex Region. However, only small areas have been lost to residential, commercial or industrial developments during this time, amounting to an overall negligible loss of large forested woodlots since 1997 (M. Child, Essex Region Conservation Authority, pers. comm.). Ongoing tree planting in the Essex Region has resulted in approximately 81 ha of pastureland being reforested annually since 1997 (M. Child, Essex Region Conservation Authority, unpub. data), with most reforestation occurring within the southern part of the Region within the range of the Eastern Mole. It is not known whether these newly planted areas have been (or are able to be) colonized by Eastern Moles.

BIOLOGY

Life cycle and reproduction

Sex ratio

Sex ratio is often male-biased but this is likely due to a trapping bias. Arlton (1936) captured 125 Eastern Moles in Iowa and Nebraska with a male:female ratio of 1.88:1. Eastern Moles for which Conaway (1959) identified the sex had an overall ratio of 1.36:1 in a Wisconsin sample (*n* = 182) and 2.07:1 in a Missouri sample (*n* = 89). Of 800 Eastern Moles examined by Yates and Schmidly (1977), 66% were male, corresponding to a ratio of 1.94:1. In South Carolina, Hartman (1995a) also found the sex ratio was skewed in favour of males during the first six months of the year corresponding to the breeding season, 1.97:1 (*n* = 223). The bias during the breeding season is likely due to males being more active, and females being more wary and avoiding entering traps (Hartman 1995a). Outside the breeding season, the sex ratio did not differ from 1:1 (*n* = 119; Yates and Schmidly 1977).

In Missouri, Leftwich (1972) found the overall sex ratio was female-biased 1:1.23 (*n* = 201) and the young-of-the-year ratio to be female-biased 1:1.29, whereas the adult ratio was nearly 1:1.

In Kansas, Davis and Choate (1993) attributed a skewed ratio in favour of females, 1:1.8 (n = 174) to higher male mortality (see **Survival** section). The bias was more apparent as age increased (Juvenile, 0:1, n = 1; Post-juvenile, 1:1.8, n = 17; Subadult, 1.25:1, n = 42; First-year adult, 1:1, n = 56; Second-year adult, 1:1.3, n = 48; Old adult, 1:9, n = 10). One implication of a skewed ratio is that it affects the calculation of mole density, because males have larger home ranges than females (see **Activity and home range** section).

Timing

Eastern Moles, like other mole species, likely have a polygynous mating system (Hartman and Yates 2003). They breed once a year (Conaway 1959), with the timing varying over several months with geographical location. The peak breeding season appears to be during the last week in March and first week in April in Wisconsin and in mid-February in Arkansas, Missouri and Indiana (Conaway 1959). In Louisiana and Texas, breeding can begin in early February (Davis 1942; Lowery 1974; cited in Yates and Schmidly 1977), although it may start in January (Yates and Schmidly 1977). Few pregnant females were found in Wisconsin after 5 May, with one late individual caught on 4 July (Conaway 1959). In Canada, Banfield (1974) reported that moles were born in early May.

Conaway (1959) assessed reproductive status in Wisconsin, Arkansas, Indiana and Missouri. Testes began to enlarge in the fall, rapidly reaching maximum size in December in Missouri or late March-early April in Wisconsin; testes mass began to decrease immediately, reaching a minimum by mid-July. The first Missouri specimen with sperm in the testes was taken in December. Sperm disappeared from Wisconsin specimens by June. The vagina remained sealed until follicles with antra appeared in the ovary, at which time it opened in both virgin and parous animals. Given that most females taken were in oestrus and all females which had ovulated were pregnant, indicates that ovulation was induced.

There are no data on gestation length. Data from Wisconsin imply gestation may be four weeks or less because maximum breeding appeared to occur in late March and early April, and the majority of births occurred in the latter half of April (Conaway 1959). Scheffer (1910; cited in Conaway 1959) hypothesized that it was 5 weeks while Arlton (1936) reported it may be 6.

The onset of breeding does not appear to be triggered by temperature or day length (Conaway 1959; Hartman and Yates 2003) but the causal mechanism is unknown. Internal rhythms may regulate the timing of breeding (Conaway 1959). In the case of the European Mole (*Talpa europea*), Pévet *et al*. (1976) theorized the pineal gland played an important role.

<u>Age of breeding</u>

In Wisconsin, moles less than 1 year old possess infantile uteri or testes, suggesting they do not breed. All females older than one year were either pregnant or parous and males older than one year had sperm in the testes. All females > one year likely reproduce each year (Conaway 1959).

<u>Litter size</u>

In most mole species, litter size ranges from 2 to 5 (Hartman and Yates 2003). Conaway (1959) recorded 3 to 5 embryos in 33 Eastern Moles from Wisconsin and Missouri, with a mean of 3.9 per female. Arlton (1936) reported 4 to 5 embryos in 43 females from Iowa and Nebraska. Jones and Birney (1988) noted that litters in the north-central states average 4 young; Hartman and Yates (2003) reported that litters of 5 are rare.

Baker (1983) suggested that young leave the nest at about 50% of full size near 35 days of age. Hamilton (1943) reported young to be independent at about 28 days, while Mumford and Whitaker (1982) suggested it was not until they were almost full grown. The data for these accounts are unclear, as there are no published studies that identify the age when young leave the nest. Arlton (1936) captured 3 juveniles nearly as large as a small female, which he estimated to be about 4 weeks old who had milk in their stomachs.

Tunnel and nest characteristics

In Kentucky, mole tunnels were classified as either shallow (2-3 cm below the surface), or deep (10-40 cm below the surface; Harvey 1976). Two to seven nesting chambers 15-25 cm below the surface were associated with deep tunnels. Nesting chambers were 18-22 cm long and 10-12 cm in diameter. Only one nesting chamber was used at a time. In Michigan, Eastern Moles build a nest of grass, leaves and rootlets in a deep tunnel. Nests measure 10-20 cm in diameter and are often 5-30 cm below a rock or stump (Baker 1983).

Brown (1972) excavated 25 Eastern Mole tunnel systems in Florida. Shallow branching tunnels 25-38 mm diameter and 2.5-7.6 cm deep that interconnected formed 80-95% of each tunnel system. Deep tunnels were larger (up to 50 mm diameter) and averaged 20.3 cm in depth (to a maximum of 35.6 cm). One to 3 (mean = 2) nesting chambers were associated with deep tunnels in each system. Nest chambers were 8.8 to 15.0 cm in diameter, had 3 entrances (rarely 1 or 2). Nest chambers did not contain any bedding. Tunnel systems rarely had surface mounds or push-ups (2 of the 25 systems contained 1 surface mound each). Brown (1972) hypothesized that push-ups may not be required in Florida because 1) the body size of the Florida mole is small, 2) the tunnel systems are shallow, and 3) the loose sandy Florida soils are easily redistributed underground.

Arlton (1936) excavated Eastern Mole tunnels in Iowa and Nebraska. Deep tunnels were 10-35.5 cm on average (range 2.5-60 cm) and varied in length. Push-ups were usually between the deepest parts of a tunnel; with up to 20 per tunnel. Surface tunnels may be used once or for long periods of time. Tunnels varied from being <1 m to > 1 km long. In Missouri, mean tunnel length for 3 males was 254 m and 70 m for 2 females (Leftwich 1972).

Survival

Leftwich (1972) estimated that Eastern Moles in Missouri likely live only 1.5 years. Davis and Choate (1993) calculated maximum longevity in Kansas to be 3.5 years. The oldest male collected by Hartman (1995b) in South Carolina was estimated to be 5.9 years old and the oldest female was estimated at 6.2 years (Table 1). This estimate was based on assigning moles to relative age classes based on exposure of the external roots of maxillary teeth, tooth wear, and fusion of the interparietal suture.

Table 1. Static life tables for Eastern Moles captured during autumn. Column headings: n_x, number of survivors at start of age level x; l_x, proportion of animals surviving to start of age interval x; q_X, rate of mortality during age interval x to $x + 1$; e_x, mean expectation of life for animals alive at the start of age interval x.

Study	Age Class (yrs)	n_x	l_x	q_x	e_x
South Carolina	0-1	37	1.00	0.32	2.23
Hartman (1995b)	1-2	25	0.68	0.20	2.06
(males and females)	2-3	20	0.54	0.40	1.45
	3-4	12	0.32	0.50	1.08
	4-5	6	0.16	0.83	0.66
	5-6	1	0.02	1.00	0.50
Kansas	0-1	116	1.00	0.36	1.53
Davis and Choate	1-2	74	0.64	0.51	1.11
(1993) (males and	2-3	36	0.31	0.75	0.75
females)	3-4	9	0.08	1.00	0.50
Davis and Choate	0-1	48	1.00	0.35	1.42
(1993) (males only)	1-2	31	0.65	0.61	0.92
	2-3	12	0.25	0.92	0.58
	3-4	1	0.02	1.00	0.50
Davis and Choate	0-1	68	1.00	0.37	1.60
(1993) (females only)	1-2	43	0.63	0.44	1.24
	2-3	24	0.35	0.67	0.83
	3-4	8	0.12	1.00	0.50

Diet and foraging

Eastern Moles dig shallow tunnels in which they forage for invertebrates. Their diet is diverse and includes a wide range of invertebrate taxa such as earthworms (Annelida: Lumbricidae), larvae and adult beetles (Coleoptera), and ants (Hymenoptera: Formicidae), as well as vegetable material and mycorrhizal fungi. Diet composition may vary by geographic region and/or habitat (especially soil type). West (1910; cited in Hisaw 1923a) examined the stomach contents of 34 Eastern Moles from Illinois and found earthworms constituted 31%, adult insects 23%, insect larvae 29% and vegetable matter 13% of the food. Dyche (1903; cited in Hisaw 1923a) found earthworms comprised 50% or more of the stomach contents of 67 Eastern Moles. Scheffer (1910; cited in Hisaw 1923a) examined the stomach contents of 200 Eastern Moles collected in Kansas and found plant material in 43.

Whitaker and Schmeltz (1974; data cited in Hartman *et al.* 2000) examined stomach contents of 90 Eastern Moles from Indiana. The 4 most important food items were earthworms, Scarabaeidae larvae, vegetation and ants (frequency of occurrence of 87.8, 32.2, 40.0 and 48.9% respectively). Two other invertebrate taxa, centipedes and adult Carabidae, were common in stomach contents (21.1 and 28.9% respectively), but comprised only a small percentage by volume (3.1 and 5.6%). Mycorrhizal fungi in Eastern Mole stomachs comprised 1.1% of volume.

Hartman *et al*. (2000) examined the stomach contents of 374 Eastern Moles collected in South Carolina between August 1987 and June 1989. The three most important food items based on both mean percentage volume and frequency of occurrence were Scarabaeidae beetle larvae, ants and centipedes (mean % volume was 31.1, 15.4 and 12.4 respectively). Earthworms were in only 8.3% of the stomachs and represented about 3% of the mean volume. Mycorrhizal fungi and plant material were found in small amounts in 15 and 6.7% of stomachs, respectively.

Most authors report that earthworms are a major component of the diet of Talpidae moles (reviewed by Hartman *et al.* 2000), although the reliance on earthworms is unclear. There are no data on whether Eastern Moles in Canada eat European earthworms (probably introduced around 1800; Reynolds 1977; Gates 1982) but it is highly likely. Whitaker and Schmeltz (1974) and Hartman *et al.* (2000) both suggest that diet composition, and particularly the importance of earthworms in the diet, varies widely. In Ontario, Waldron *et al.* (2000) reported a large number of mole tunnels around anthills. Arlton (1936) found earthworms in the vicinity of 13 areas in Iowa containing Eastern Mole tunnels and 50% of these areas also contained ants.

Activity and home range

Eastern Moles are active year-round (Kentucky, Harvey 1976; Iowa, Arlton 1936), although activity may be limited by cold in winter (Arlton 1936). Construction of new surface tunnels is mainly during spring months when the ground is relatively soft, but may occur throughout the year, particularly after rain (Harvey 1976). Movements are restricted to existing surface and deep tunnels when the ground is dry or during winter when the soil is frozen. Deep tunnels, however, may be constructed when the ground is hard or frozen by packing excavated soil in other parts of the tunnel system (Hisaw 1923b).

Harvey (1976) inserted radioactive tags (pieces of ^{60}Co alloy wire) subcutaneously into 12 Eastern Moles (4 males, 8 females) in Kentucky, and released them where they had been captured. Moles were relocated once or twice per week between March 1963 and September 1966 for as long as they could be found. Most relocations occurred during daylight, but some nighttime observations were made. Mean home range of males calculated using the modified minimum area method was 1.09 ha (n = 4: 0.36 ha, 1.01 ha, 1.19 ha, 1.80 ha) and for females 0.28 ha (n = 3: 0.15 ha, 0.34 ha, 0.35 ha; Harvey 1976). These estimates were biased by the length of time that each animal was monitored (11 to 36 months); home range size increased with time monitored. Home ranges often overlapped. In one case, two moles extended the same surface tunnel at different times. No major shifts in home range were observed, and only one mole added a large area to its home range during the study. The nest site for this mole, however, did not change and the mole continued to use the rest of its home range in addition to the new area (Harvey 1976).

Harvey (1976) monitored the time spent in the nest during 24-hour periods between November and March by four Eastern Moles (2 females and 2 males), for 9, 41, 32 and 18 days, respectively. Females spent 39.2% of their time in the nest and males spent 35.7%. Most time out of the nest was from 0800 to1600 and 2300 to 0400 hr.

Harvey (1976) recorded the movements of one male and one female during four continuous 72-hr periods in September and November. For both moles, 31 periods of activity ranged from 45 min to 14 hr 15 min, averaging 4 hr 33 min. Thirty-five inactive periods ranged from 1 hr to 5 hr 55 min, averaging 3 hr 1 min. Moles typically used a single nest site when inactive during cold weather, but used more locations during warmer weather.

Moles rarely travel above ground. However, Arlton (1936) found that openings in mounds and surface tunnels were made at night, particularly during periods of drought, and on dark days, suggesting they are more likely to emerge during these times.

Physiology and adaptability

Due to their confined habitat (underground tunnels), moles like the Eastern Mole have relatively low metabolic rates and body temperatures relative to other mammals. Eastern Moles have lower body temperatures (36^{o} C; McNab 1979) than other North American moles (e.g., Star-nosed Mole, 37.7 ± 0.05^{o} C: Campbell et al. 2000; and the Shrew-mole (*Neurotrichus gibbsii)*, 38.4 ± 0.2^{o} C: Campbell and Hochachka 2000). Similar metabolic rates for Eastern Moles were reported by Leach et al. (1962; mean metabolic rate of 1.6 cm^3 O_2/g/hr (range 1.4-1.8)) and McNab (1979; mean rate of 1.41 cm^3 O_2/g/hr (± SE 0.05)).

Dispersal and migration

Little is known about dispersal by Eastern Moles. Harvey (1976) found one male 204 m from its nest. He recorded the mole to travel 278 m through tunnels when it returned to the nest. Leftwich (1972) followed 5 tagged juveniles including 3 females and 1 male from the same litter, suggesting that juveniles dispersed in July through foraging complexes extending from their natal tunnel system. Some young were trapped in tunnel complexes isolated from other tunnels indicating at least some dispersal may be above-ground. Some indirect evidence suggests that juvenile males disperse more widely than females, although Leftwich's data did not support this. Giger (1973) found that most above-ground dispersal by Townsend's Moles (*Scapanus townsendii*) likely involved juveniles, 61% of which dispersed < 152 m and 87% < 305 m from birth nests. The largest dispersal distance was 722 m. Male and female Townsend's Moles had similar dispersal distances and 3 individuals dispersed across paved roads (Giger 1973).

Other types of apparent dispersal may occur due to flooding events which displace moles from tunnels (Hartman and Yates 2003). Displaced moles may return when flooding subsides. Townsend's Moles returned to their home range when displaced by up to 450 m (Giger 1973). This includes displaced moles that successfully crossed a drainage canal (3.7 m wide and 1.2 m deep; 7 of 12 displaced moles), an elevated highway (1 of 5 moles), and a river (15 m wide and 1 m deep; 1 of 8 moles). Four moles naturally displaced by flooding returned to their home range. Leftwich (1972) moved 3 Eastern Moles up to 350 m and all returned to their home range.

To some extent, existing tunnels limit mole movements in that it may be more energetically profitable for a mole to use existing tunnels than to dig a new one unless it improves foraging success (Hartman and Yates 2003).

Eastern Mole movement may not be limited by water bodies, as they can swim (Arlton 1936); however, heavy clay soils or soils that are too wet or too dry to support tunnel construction may provide barriers to movement. Eastern Moles use gardens in some residential landscapes where there is sufficient shrub or tree cover, but do not adapt to open habitats such as cropland or pasture where there is no vegetative cover. The scale at which vegetative cover occurs is likely context-specific (e.g., degree of soil disturbance).

Interspecific interactions

Because most of their life cycle takes place underground, Eastern Moles and moles in general are infrequently exposed to predators (Hartman and Yates 2003). Certain weather conditions (heavy rainfall) may flood tunnels and cause moles to evacuate them, rendering individuals susceptible to predation.

Like shrews, moles are often discarded when caught due to their repellent odour (Mumford and Whitaker 1982). However, a wide variety of carnivorous mammals, diurnal raptors and owls have been recorded as predators (Baker 1983). Most predators likely take moles opportunistically when they come to the surface. Among recorded predators are the Red Fox (*Vulpes vulpes)*, Gray Fox (*Urocyon cinereoargenteus)*, Coyote (*Canis latrans)*, domestic Dog (*C. familiaris)*, domestic Cat (*Felis domesticus)*, Raccoon (*Procyon lotor),* Red-tailed Hawk (*Buteo jamaicensis)*, Red-shouldered Hawk (*B. lineatus)*, Broad-winged Hawk (*B. platypterus)*, Eastern Screech-owl (*Megascops asio)*, Barred Owl (*Strix varia)*, and Barn Owl (*Tyto alba*) (Baker 1983; Springer and Kirkley 1978; Zeveloff 2002).

Some predators are small enough to access Eastern Mole tunnels, especially the Least Weasel (*Mustela nivalis)* and various snakes (Jackson 1961) such as the Eastern Foxsnake (*Elaphe gloydi).* There is a record of an Eastern Foxsnake foraging for Eastern Moles at Point Pelee National Park (Sahanatien and Leggo 1989); however, no radio-tagged Eastern Foxsnakes in the Park have entered tunnels (J. Row, L. Ritchie pers. comm.). Northern Short-tailed Shrews (*Blarina brevicauda*) have been observed in or close to mole tunnels at PPNP (L. Ritchie pers. comm.) and could potentially prey on young moles (Eadie 1939). During extensive live-trapping in mole tunnels at PPNP, the only non-mole mammals caught were two Short-tailed Shrews.

Hartman and Yates (2003) list the known parasites of Eastern Moles.

POPULATION SIZES AND TRENDS

Sampling effort and methods

Waldron *et al.* (2000) surveyed 43 sites (of varying size) in Essex County, 3 in Chatham-Kent Municipality, 1 in Middlesex County and 1 in Elgin County for Eastern Moles in 1997. These sites represented the locations of all historical records as well as large forest patches occurring on sandy-loam soil types across the Canadian range of the species. Each site was searched opportunistically (G. Waldron, pers. comm., 28 April 2009) during summer and fall for fresh mole signs (surface tunnels or push-ups).

The sites in Essex County and Chatham-Kent municipality were resurveyed in mid-September 2008 (except for 1 site that was surveyed in mid-November) by Ritchie and Nocera (2010, total = 46 of Waldron's 48 sites). At sites where there was a path or trail, they followed the path/trail that allowed the largest portion of the site to be covered and/or walked the perimeter of the property. At locations with no trails, the authors walked a 500 m transect through the site or transect segments, which summed to 500 m, if the site was small. Fresh mole sign was recorded. The authors also employed live-trapping using pitfalls installed under a tunnel. They captured 10 moles and took toe-clippings and hair samples; however, none of the individuals was recaptured. It appeared that once captured, moles excavated around traps (Joe Nocera, pers. comm., 29 April 2009).

Surveys for Eastern Mole sign were conducted annually from 1985 to 2000 in PPNP along 6 transects. Each transect was 3 m wide and 500 m long (Michano 1991). Four transects were located in habitats having high habitat value (mature forest), and 2 in habitats with medium value (younger forest successional stages; Sahanatien and Leggo 1989). Transects were usually sampled in 1 day, although the timing of surveys varied between years (Michano 1991). Michano (1991) reported that surveys between 1985 and 1991 were not conducted within the recommended time period. Sahanatien and Leggo (1989) recommended surveys occur between late-March and early-April, preferably within 7 days of the ground becoming free of snow. Instead, the 1985-1991 surveys were generally conducted between April and early May. Michano (1991) recommended that all surveys be completed from April 1 to 5 to ensure consistency of data. This may not always be appropriate, however, depending on phenology.

Abundance

The density of Eastern Moles is not well-known in any part of its range. Harvey (1976) estimated the average home range size of male Eastern Moles to be 1.09 ha and for females to be 0.28 ha. Estimates of mole density range from 2-5 moles/ha (Baker 1983) to 7-12 moles/ha (Henderson 1983; cited in Waldron 1998) and 20-25 moles/ha (Jackson 1961). Based on a density of 2-12 moles/ha, Waldron (1998) estimated the mole population in Canada to number from 2,120 to 12,760 individuals (given a suitable habitat area of 1060 ha) but acknowledged the low reliability of this estimate.

In Missouri, Leftwich (1972) recorded mole densities of 0.59-1.55 moles/ha based on extensive trapping, and estimated that actual density may be 1.25-1.75 moles/ha after correcting for uncaptured moles. Hartman and Krenz (1993) calculated mole density to be 1.72-3.02 moles/ha from a trapping grid and assessment lines in South Carolina.

Minimal change in the amount of available habitat has likely occurred since 1997. Based on the amount of suitable soils near woodland, there may be 12% less now than in 1997 (929 vs. 1060 ha). Assuming similar densities, there is unlikely to be a difference in population size between Waldron (1998) and now. However, any current estimate of population size is at best a weak inference.

Fluctuations and trends

In a survey done outside Point Pelee National Park, Ritchie and Nocera (2010) found that of 23 sites with Eastern Mole sign in 1997, 17 had active signs of moles in 2008. This represents a 26% decline in number of sites having mole sign between the two surveys but high between-year variation is known to occur (Michano 1991). Locations where Eastern Moles were recorded during both surveys were more likely to be loam or sandy loam soils than sites where moles were recorded in 1997 only (Ritchie and Nocera 2010).

At Point Pelee National Park, annual counts of Eastern Mole surface tunnels and push-ups fluctuate widely between years (Fig. 3). Zorn (2003) calculated that the time series had low signal to noise ratio (Coefficient of variation = 0.78) and low power to detect trends (power = 0.45 with 80% confidence to detect a 10% decrease over 5 years). No statistical trend was apparent in the annual abundance of sign (tunnels and pushups).

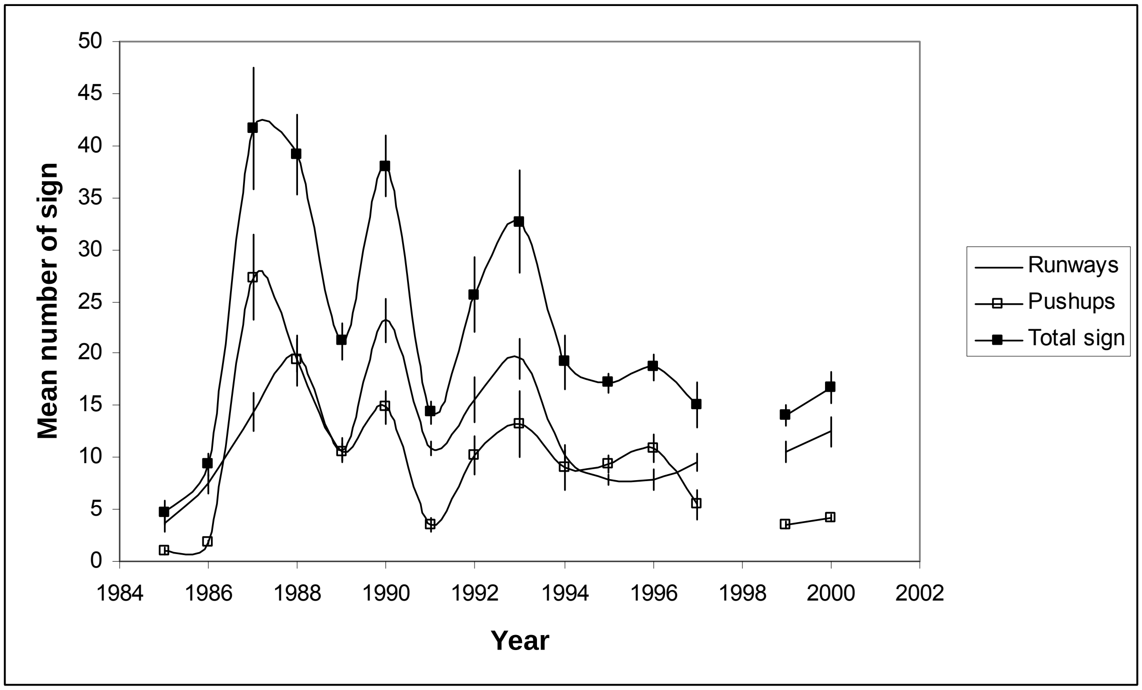

Figure 3. Mean (±standard error) counts of mole signs at Point Pelee National Park between 1985 and 2000 (Point Pelee National Park, unpub data). Note that the abundance/density of runways may not be correlated with mole abundance (Gorman and Stone 1990).

Michano (1991) suggested that inconsistent survey timing, changes in survey personnel, different weather patterns, changes in vegetation cover, and shifts in mole activity within the home range likely contributed to the large between-year variation in sign observed. However, no dramatic weather events occurred during the first 5 years of the survey and no changes in vegetation cover were apparent during the period (Michano 1991).

The number of tunnels and push-ups is likely a poor indicator of population size (Gorman and Stone 1990). Research in southern parts of the mole's range indicate that the length and complexity of tunnel networks varies widely between home ranges, perhaps as a function of food availability, habitat structure and/or soil moisture, and that the number of push-ups relative to the length of deep tunnels is also variable (see Tunnel and nest characteristics section). Surface tunnels may also belong to more than one home range, as mole home ranges (and use of surface tunnels) overlap. Male moles have larger home ranges than females, and thus mole density may be higher where several female territories occur together.

Monitoring fixed transects over time for the presence of mole sign is also likely an unreliable measure of population status. As outlined above, the number and location of surface tunnels and push-ups may depend on habitat structure and soil moisture. Although no published studies of Eastern Moles report frequent home range shifts, moles may concentrate activity in different parts of their home range depending on environmental conditions (see **BIOLOGY** section). This may result in some transects without active mole sign, despite their occurrence within a mole's home range. Transect length may also be problematic. Male Eastern Moles have relatively large home ranges (1.09 ha), and so a 500 m transect occupied in its entirety may conceivably intercept few unique Eastern Mole home ranges.

Reliable methods to estimate the population size of the Eastern Mole have not been developed. Surveys based on the presence of mole sign (as described by Waldron 1998 and Ritchie and Nocera 2010) may or may not provide useful information about changes in mole distribution over time. However, given the large year-to-year fluctuations in number of mole signs in PPNP, and an incomplete understanding of the factors that govern mole distribution in Ontario, surveys to assess mole distribution need to occur more frequently than every 10 years to provide useful data on mole distribution.

Rescue effect

Moles appear able to rapidly colonize natural habitat restoration projects. In Point Pelee National Park they colonized (within 3 years) areas where buildings and roads had been removed in the 1990s and the area revegetated. Prior to restoration, Eastern Moles occupied adjacent habitat (Waldron 1998; Waldron *et al.* 2000; G. Waldron, pers. comm., 31 January 2010).

The Canadian Eastern Mole population is separated from the one in Ohio by Lake Erie, and Eastern Moles have not been reported from islands between Point Pelee and Ohio (Waldron 1998, Waldron *et al*. 2000). Eastern Moles occur in Michigan; however, unsuitable soils separate the Detroit-Windsor corridor from the population in southern Essex County, Ontario by at least 20 km. Given the low dispersal potential of the Eastern Mole across inhospitable habitat (unsuitable soils, large water bodies), the Canadian Eastern Mole population is likely isolated from populations in the United States.

THREATS AND LIMITING FACTORS

The range of the Eastern Mole in Canada appears to be primarily limited by suitable soil types and forest cover. Regions with suitable soil have been extensively modified by intensive agriculture and residential development, with only a small percentage containing sufficient vegetative cover to provide suitable habitat for moles. Habitat patches are frequently small and isolated by unsuitable habitat, suggesting fragmentation may reduce the likelihood of colonization of unoccupied habitat, and may be restricting dispersal capacity and hence gene flow between isolated populations.

Macauley 1980 (cited in Waldron 1998) noted that moles are affected by fluctuations in the water table, and moles can be displaced by flooding of their tunnels. However, displaced Eastern Moles may return to their pre-flooding home range when water recedes (See **Dispersal and migration** section). Macauley 1980 (cited in Waldron 1998) estimated that the mole population in PPNP may decrease if water levels in Lake Erie rise and there is a continued absence of new dune creation and point enlargement. The 2006 State of the Park report (Parks Canada Agency 2006) identified disruption to natural lake and shoreline processes as a significant threat to coastal ecosystems within the Park. This disruption was associated with the intense human footprint along the greater ecosystem shoreline, resulting in, for example, altered rates of coastline erosion and deposition. The impact of changes to the western shoreline of PPNP on Eastern Moles is not known.

Mole traps and other means of lethal control are widely available in Ontario. Presumably, some Eastern Moles that are considered a nuisance in lawns, gardens and golf courses are killed by these.

PROTECTION, STATUS, AND RANKS

Legal protection and status

The Eastern Mole is listed as Special Concern under both the federal *Species at Risk Act* and the provincial (Ontario) *Endangered Species Act, 2007*. Species of Special Concern are identified under both Acts to prevent them from becoming endangered or threatened in Canada.

Non-legal status and ranks

Globally, the Eastern Mole is ranked as Least Concern by the IUCN and as Secure (G5) by NatureServe (NatureServe 2009). In Canada (and Ontario), NatureServe ranks the Eastern mole as Imperiled (N2, S2) and in the Wild Species report as Sensitive (CESCC 2006). In the United States the Eastern Mole is nationally ranked by NatureServe as Secure (N5). State ranks are listed in Table 2.

Table 2. NatureServe ranks for the Eastern Mole in the United States.

NatureServe rank	Description	U.S. state
S2	Imperiled	Colorado, Wyoming
S3	Vulnerable	West Virginia
S4	Apparently secure	Indiana, South Dakota
S4S5	Apparently secure-secure	Louisiana
S5	Secure	Alabama, Arkansas, Connecticut, Delaware, District of Columbia, Georgia, Illinois, Iowa, Kansas, Kentucky, Maryland, Massachusetts, Michigan, Mississippi, Nebraska, New Jersey, New York, North Carolina, Oklahoma, Pennsylvania, Tennessee, Texas, Virginia, Wisconsin
SNR	Not ranked	Florida, Missouri, Ohio, Rhode Island, South Carolina

Habitat protection and ownership

Thirty-three percent of suitable habitat (compared to Waldron 1998 who erroneously reported 66%) occurs within PPNP, which is managed and protected by the *National Parks Act*. Some suitable habitat also occurs on lands owned or managed by the Essex Region Conservation Authority and the Lower Thames Valley Conservation Authority, which are managed according to the Ontario *Conservation Authorities Act*. However, most suitable habitat outside of PPNP is privately owned. Some forested areas have been designated as Environmentally Significant Areas and receive some protection from development through municipal official plans and zoning bylaws.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

The status report writers thank Environment Canada for funding the preparation of this report. Special gratitude is extended to Gerry Waldron, Joe Nocera, Louise Ritchie, and Vicki McKay for sharing their knowledge about Eastern Moles, and to the Essex Region Conservation Authority for sharing knowledge and data on soils and land cover changes. The data for the North American range map was provided by NatureServe in collaboration with Bruce Patterson, Wes Sechrest, Marcel Tognelli, Gerardo Ceballos, The Nature Conservatory-Migratory Bird Program, Conservation International-CABS, World Wildlife Fund-US, and Environment Canada-WILDSPACE. Alain Filion prepared the distribution map for the Eastern Mole in Canada.

Authorities contacted – listed alphabetically

Mathew Child, Director Watershed Restoration, Essex Region Conservation Authority, Essex, Ontario.

Alan Dextrase, Senior Species at Risk Biologist, Ontario Ministry of Natural Resources, Peterborough, Ontario.

Tammy Dobbie, Parks Canada, Point Pelee National Park, Leamington, Ontario.

Jennifer Doubt, Chief Collections Manager-Botany, Canadian Museum of Nature, Ottawa, Ontario.

Lynn Gillespie, Research Scientist, Canadian Museum of Nature, Ottawa, Ontario.

Kamal Khidas, Chief Collections Manager – Vertebrates, Canadian Museum of Nature, Ottawa, Ontario.

Angela McConnell, Senior Species-At-Risk Biologist, Canadian Wildlife Service, Downsview, Ontario

Vicki McKay, Species at Risk Recovery Specialist, Parks Canada, Point Pelee National Park, Leamington, Ontario.

Fred Michano, Parks Canada, Pukaskwa National Park, Ontario.

Patrick Nantel, Conservation Biologist, Species at Risk Program, Parks Canada, Gatineau, Quebec

Michael Nelson, Restoration Biologist, Essex Region Conservation Authority, Essex, Ontario.

Joe Nocera, Research Scientist, Ontario Ministry of Natural Resources, Peterborough, Ontario.

Michael Oldham, Botanist, Ontario Natural Heritage Information Centre, Ontario Ministry of Natural Resources, Peterborough, Ontario.

Louise Ritchie, Wildlife Research Intern - Species At Risk, Ontario Ministry of Natural Resources, Peterborough, Ontario.

Jeff Row, PhD candidate, Department of Biology, Queen's University, Kingston, Ontario.

Sonia Schnobb, Administrative Assistant, COSEWIC Secretariat, Canadian Wildlife Service, Ottawa, Ontario.

Gilles Seutin, Coordinator Species at Risk Program, Parks Canada, Gatineau, Quebec

Gerry Waldron, Consultant, Gerry Waldron Ecological Consulting, Amherstburg, Ontario.

Paul Zorn, Ecologist, Parks Canada, Gatineau, Quebec.

INFORMATION SOURCES

Arlton, A. V. 1936. An ecological study of the mole. Journal of Mammalogy 17: 349-371.

Baker, R. H. 1983. Michigan Mammals. Michigan State University Press, East Lansing, Michigan, USA.

Banfield, A. W. F. 1974. The Mammals of Canada. National Museums of Canada. University of Toronto Press, Toronto, Ontario, Canada.

Brown, L. H. 1972. Unique features of the tunnel systems of the Eastern Mole in Florida. Journal of Mammalogy 53: 394-395.

Canada National Parks Act. 2010. Canada National Parks Act, 2000. Available at: http://laws.justice.gc.ca/en/N-14.01. Accessed: 29 March 2010.

Campbell, K. L. and P. W. Hochachka. 2000. Thermal biology and metabolism in the American Mole-Shrew *Neurotrichas gibbsii*. Journal of Mammalogy 81: 578-585.

Campbell, K.L., I.W. McIntyre and R.A. MacArthur. 2000. Postprandial heat increment does not substitute for active thermogenesis in cold-challenged star-nosed moles (*Condylura cristata*). Journal of Experimental Biology 203:301-310.

CanSIS. 2008. Canadian Soil Information System National Soil Database. Available at: http://sis.agr.gc.ca/cansis/nsdb/detailed/intro.html. Accessed 25 March 2010.

CESCC. 2006. Wild Species 2005: The General Status of Species in Canada. Canadian Endangered Species Conservation Council. Available at: http://www.wildspecies.ca/wildspecies2005/GS2005_site_e.pdf. Accessed: 3 February 2010.

Conaway, C. H. 1959. The reproductive cycle of the mole. Journal of Mammalogy 40: 180-194.

Davis, W. B. 1942. The moles (genus *Scalopus*) of Texas. American Midland Naturalist 27: 380-386.

Davis, F. W., and J. R. Choate. 1993. Morphologic variation and age structure in a population of Eastern Mole *Scalopus aquaticus*. Journal of Mammalogy 74: 1014-1025.

Dobbyn, J. 1994. Atlas of the Mammals of Ontario. Don Mills, Ontario, Federation of Ontario Naturalists.

Dyche, L I. 1903. Food habitats of the common garden mole. Transactions of the Kansas Academy of Science 18: 183-186.

Eadie, W. R. 1939. A contribution to the biology of *Parascalops breweri*. Journal of Mammalogy 20: 150-173.

Essex Region Conservation Authority. 2004. Accelerating the pace towards a sustainable community. Essex Region Conservation Authority Strategic Plan: Priorities 2005-2010. Essex Region Conservation Authority, Essex, Ontario. Available at: http://www.erca.org/downloads/sustainable_community.pdf. Accessed: 29 March 2010.

Gates, G.E. 1982 Farewell to North American Megadriles. Megadrilogica 4: 12-77.

Giger, R. D. 1973. Movements and homing in Townsend's mole near Tillamook, Oregon. Journal of Mammalogy 54: 648-659.

Gorman, M.L., and R.D. Stone 1990. The Natural History of Moles. Cornell University Press. Ithaca, New York, USA.

Hamilton, W. J. Jr. 1943. The Mammals of the Eastern United States. Cornstock, Ithaca, New York, USA.

Hartman, G. D. 1995a. "Seasonal effects on sex ratios in moles collected by trapping." American Midland Naturalist 133(2): 298-303.

Hartman, G. D. 1995b. Age determination, age structure and longevity in the mole *Scalopus aquaticus* (Mammalia). Journal of Zoology (London) 237: 107-222.

Hartman, G. D. 1996. Genetic variation in a subterranean mammal, *Scalopus aquaticus* (Insectivora: Talpidae). Biological Journal of the Linnaean Society 59: 115-125.

Hartman, G.D., and J. D. Krenz. 1993. Estimating population density of moles, *Scalopus aquaticus* using assessment lines. Acta Theriologica 38: 305-314.

Hartman, G. D., J. O. Whitaker, Jr, and J. R. Munsee. 2000. Diet of the mole *Scalopus aquaticus* from the Coastal Plain region of South Carolina. American Midland Naturalist 144: 342-351.

Hartman, G. D., and T. L. Yates. 2003. Moles (Talpidae). Pp 30-55 *in* Wild Mammals of North America: Biology, Management and Conservation. G. A. Feldhammer, B. C. Thompson and J. A. Chapman, Eds. John Hopkins University Press, Baltimore, Maryland.

Harvey, M. J. 1976. Home range, movements and diel activity of the Eastern Mole, *Scalopus aquaticus*. American Midland Naturalist 95: 436-445.

Henderson, F. R. 1983. Moles. Pp D53-D61 *in* Prevention and control of wildlife damage. R.M. Timm (Ed). Great Plains Agricultural Council and Wildlife Resources Committee, University of Nebraska, Lincoln, Nebraska.

Hisaw, F. L. 1923a. Feeding habits of moles. Journal of Mammalogy 4: 9-20.

Hisaw, F. L. 1923b. Observations on the burrowing habits of moles (*Scalopus aquaticus machrinoides*). Journal of Mammalogy 4, 79-88.

Jackson, H. H. T. 1961. Mammals of Wisconsin. University of Wisconsin Press, Madison, Wisconsin, USA.

Jones, J. K., and E. C. Birney. 1988. Handbook of the Mammals of the North-Central States. University of Minnesota Press, Minneapolis, Minnesota, USA.

Leach, B. J., T.R. Bauman, and C.W. Turner. 1962. Thyroxine secretion rate of Missouri Valley mole, *Scalopus aquaticus*. Proceedings of the Society for Experimental Biology and Medicine 110: 681-682.

Leftwich, B. H. 1972. Population dynamics and behavior of the Eastern Mole *Scalopus aquaticus machrinoides*. PhD dissertation, University of Missouri, Columbia.

Lower Thames Valley Conservation Authority. 2009. 2009 Annual report Lower Thames Valley Conservation Authority. Available at: http://www.lowerthames-conservation.on.ca/Publications/2009_LTVCA_AnnualReport.pdf. Accessed: 29 March 2010.

Lowery, G.H. 1974. The Mammals of Louisiana and Adjacent Waters. Louisiana State University Press, Baton Rouge, Louisiana.

McNab, B. K. 1979. The influence of body size on the energetics and distribution of fossorial and burrowing mammals. Ecology 5: 1010-1021.

Macauley, A. 1980. Status report on the Eastern Mole, Scalopus aquaticus. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Canada.

Michano, F. 1991. Point Pelee National Park Eastern Mole monitoring summary 1985-1991. Environment Canada, Parks Service, Point Pelee, Ontario.

Mumford, R. E., and J. O. Whitaker, Jr. 1982. Mammals of Indiana. Indiana University Press, Bloomington, Indiana.

NatureServe. 2009. NatureServe Explorer: an online encyclopaedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available at: http://www.natureserve.org/explorer. (Accessed April 8, 2009).

Parks Canada Agency. 2006. 2006 Point Pelee National Park of Canada State of the Park Report. Parks Canada Agency, Ottawa, Ontario.

Pévet, P. M. T. Juillard, A. R. Smith, and J. Kappeeers. 1976. The pineal gland of the mole *Talpa europea* L. Part 3. A fluorescence histochemical study. Cell and Tissue Research 65: 297-306.

Reynolds, J.W. 1977. The Earthworms (Lumbricidae and Sparganophilidae) of Ontario. Royal Ontario Museum, Toronto, ON.

Ritchie, L.E., and J.J. Nocera. 2010. Assessing the distribution of Eastern Moles (*Scalopus aquaticus*) in Canada in relation to loam soils and forest cover. American Midland Naturalist 164: 61-73.

Sagara, M. 1989. European record of the presence of a mole's nest indicated by a particular fungus. Journal of Mammalogy 47: 538.

Sagara, M. 1999. Mycological approach to the natural history of talpid moles – A review with new data and proposal of habitat-cleaning symbiosis. Pp 35-53 in Y. Yokohita and S. Nakamura, eds. Recent Advances in the Biology of Japanese Insectivora. Hiba Society of Natural History, Hiroshima, Japan.

Sagara, N, S. Kobayashi, H. Ota, T. Hsubo, and H. Okabe. 1989. Finding *Euroscaptor mizura* (Mammalia: Insectivora) and its nest from under *Hebeloma radicosum* (Fungi: Agaricales) in Ashiu, Kyoto with data of possible continuous occurrence of three talpine species in this region. Contributions of the Biology Laboratory of Kyoto University 27: 261-272.

Sahanatien, V. and J. Leggo. 1989. Natural resource management plan for the Eastern Mole (*Scalopus aquaticus machrinus*) Point Pelee National Park. Environment Canada Parks Service, Point Pelee, Ontario.

Saunders, W. E. 1932. Notes on the mammals of Ontario. Transactions of the Royal Canadian Institute 18(Part 2): 271-309.

Scheffer, T. H. 1910. The common mole. Kansas State Agricultural College Experimental Bulletin. 168: 19.

Springer, M. A., and J. S. Kirkley. 1978. Inter and intraspecific interactions between red-tailed hawks and great horned owls in central Ohio. Ohio Journal of Science 78(6): 323.

Van Zyll de Jong, C.G. 1983. Handbook of Canadian mammals. 1. Marsupials and Insectivores. National Museums of Canada, Ottawa, Ontario.

Waldron, G. E. 1998. Update COSEWIC status report on the Eastern Mole *Scalopus aquaticus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa.

Waldron, G., L. Rodger, G. Mouland, and D. Lebedyk. 2000. Range, habitat, and population size of the Eastern Mole, *Scalopus aquaticus*, in Canada. Canadian Field-Naturalist 114: 351-358.

West, J. A. 1910. A study of the food of moles of Illinois. Bulletin of the Illinois Laboratory of Natural History 9: 14-22.

Whitaker, J. O., Jr, and Schmelz, L. L. 1974. Food and external parasites of the eastern mole, *Scalopus aquaticus*, from Indiana. Proceedings of the Indiana Academy of Science 83: 478-481.

Wilson, D. E. and Reeder, D. M. (editors). 2005. Mammal Species of the World. A Taxonomic and Geographic Reference (3rd ed), Johns Hopkins University Press, Washington, DC. 2,142 pp.

Yates, T.L., and D. J. Schmidly. 1977. Systematics *of Scalopus aquaticus* in Texas and adjacent states. Occasional Papers, the Museum, Texas Technical University. 45: 1-36.

Yates, T. L., and D.J. Schmidly. 1978. *Scalopus aquaticus*. Mammalian Species 105: 1-4.

Zeveloff, S. I. 2002. Raccoons: A Natural History. UBC Press in association with Smithsonian Institution Press.

Zorn, P. 2003. Eastern Mole. Unpublished report to Point Pelee National Park, Parks Canada Agency, Ottawa, Ontario.

BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Dr. Jennie L. Pearce was born in Australia and immigrated to Canada in 1999. In both countries her research has focused on modelling the distribution, viability and habitat requirements of wildlife to inform and guide conservation efforts. Her company, *Pearce & Associates Ecological Research* utilizes the latest statistical techniques and computerized technology in the design, implementation and presentation of environmental data and research to a wide range of clients, including government, not-for-profit organizations and industry. She has led numerous research projects to develop spatial distribution models for mammal species with limited distribution records, developed population viability models for species with small populations at the edge of their geographic range and modelled the temporal population changes expected to occur in abundant, but ecologically sensitive species, when landscapes are modified due to human activities. She has written or co-authored 6 COSEWIC reports and has published more than 35 scientific papers in the area of conservation biology.

Born in the United Kingdom, Dr. David Anthony Kirk has been working for almost 20 years with the federal (Environment Canada and Parks Canada Agency) and provincial governments of Canada as well as non-government organizations (e.g., Bird Studies Canada, World Wildlife Fund and the Yellowstone to Yukon Conservation Initiative). He has a wide range of ecological and land use experience in different ecosystems from tropical to boreal. His company (*Aquila* Conservation & Environment Consulting) specializes in the use of multi-species and single species distribution models for use in conservation planning (integrating human resource use and biodiversity conservation), as well as literature reviews and objective analysis of a variety of human disturbance influences on biodiversity in anthropogenic landscapes. David is particularly interested in the spatial mapping of biodiversity and also works extensively on the status, recovery and management of species at risk. He has worked on small mammals in relation to their ecological role as prey for diurnal raptors and owls, as well as working extensively on lagomorphs. He has also reviewed sampling designs for rare species for Environment Canada, distribution models for identifying critical habitat for Parks Canada, and effects of raccoon predation on turtles and other species at risk at Point Pelee National Park of Canada. He has written or co-authored 20 COSEWIC status reports and updates, as well as 8 recovery plans, 2 action plans and a management plan for species at risk. *Aquila*'s emphasis is on peer-reviewed scientific articles in ecological and conservation journals as a forum for changing policy and management practices and David has co-authored 27+ papers in peer-reviewed scientific journals in the last 17 years.

COLLECTIONS EXAMINED

No collections were examined as part of this status report.