The distribution and conservation status of burrowing crayfishes *Fallicamabarus fodiens* and *Cambarus diogenes* in Canada.

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ABSTRACT

The distribution, density and status of the crayfishes *Cambarus diogenes* and *Fallicambarus fodiens* was evaluated in Canada. Surveys in possible habitats were conducted within and adjacent to the known Canadian ranges of the two species. The density (burrows/m^2), habitat type and potential threats were evaluated for each population studied. Overall, eighteen populations of *C. diogenes* and thirty-four populations of *F. fodiens* were surveyed.

The distribution of *F. fodiens* was extended north to the southeastern shores of Georgian Bay and East to the northeast shore of Lake Scugog. Eighteen percent of the populations occurred in protected areas and the burrow density ranged from 0.1 to 5.4/m^2. The distribution of *C .diogenes* was extended significantly east to the Niagara Peninsula as well as the northeastern shoreline of Lake Erie. Thirty nine percent of the populations occurred in protected areas and the burrow density ranged from 0.25 to 4.5/m^2.

There is sufficient evidence to suggest that both species should be considered as threatened in Canada as the probability of habitat destruction and thus of local extinctions is high throughout the vast majority of their relatively restricted Canadian ranges. In the future, it is important to recognize the proposed status of these two species officially (by federal and provincial authorities) as well as to monitor and manage the populations of both species particularly those not found on reserved lands. Private landowners need to be made aware of the presence and significance of the species and encouraged to conserve the remaining populations.

Keywords: Burrowing crayfish; Conservation status, Density, Distribution.

INTRODUCTION

Although invertebrates make up the largest portion of Canadian fauna their conservation status is largely unknown and only a few species are listed by COSEWIC. There exists therefore an urgent need to consider the status of at least some of the major invertebrate groups in Canada. Crayfish are an important part of aquatic ecosystems, which make up a very large portion of the overall biodiversity of Canada. In the case of some species, particularly the obligate burrowers, this role also extends to terrestrial systems. Because of their ability to affect the structure of the littoral zone at several levels, crayfish can be considered to be "Keystone species" and thus removing them or introducing them into aquatic environments can have a severe effect on the ecosystem.

The greatest area of crayfish species diversity in Canada centers on Southern Ontario where seven of the nine native species can be found, including the rarest burrowing species. It is important to note that this area has the highest human population in Canada and is therefore also the area where crayfish are under the greatest stress due to high levels of urbanization and intense agricultural activity. It has been recently shown that up to 45 % of the native crayfish species should be considered for some kind of protection within Canada (Hamr, 1998). Only two species of obligate burrowing crayfishes are found in Canada: *Cambarus diogenes* and *Fallicambarus fodiens*. Although neither is endemic, their populations are unique in that they represent the northern-most points of their distribution. As a result, they appear to have different life history patterns and ecological adaptations from their southern counterparts. It is therefore important to preserve their Canadian populations in order to conserve their overall genetic diversity in North America.

Crayfish can also act as biomonitors as they have been shown to accumulate toxins such as heavy metals and their presence or absence can be indicative of pollution (e.g. acidification). The distribution and

abundance of burrowing crayfishes may be particularly useful in reflecting the health, presence or loss of remaining (minor and major) wetlands. They may also be instrumental for studies relating to agricultural activities, as their habitats are often associated with farms, which may receive direct inputs of fertilizers and pesticides.

The principal objective of this study was to clarify the distribution and abundance of the two semi terrestrial burrowing freshwater crayfishes *Fallicambarus fodiens* and *Cambarus diogenes* found in Canada. Since these species have been identified in a WWF status report (Hamr 1998) as potentially threatened and endangered respectively, it is urgent that their present status, abundance and distribution are reevaluated. This is particularly true of *C. diogenes* which has been found only at six sites to date.

MATERIALS AND METHODS

Between May 1999 and May 2003, crayfish surveys in possible habitats were conducted within and adjacent to the Canadian ranges of the two species. (*F. fodiens* is restricted to southern Ontario where it occurs from south of Lake Simcoe and west of Lake Scugog to Lake St Clair and the Detroit River; *C. diogenes* is found only in southwestern Ontario where it is very rare as it has previously been reported from only six sites, mostly on or within a few kilometers of the north shore of Lake Erie).
Crayfish colonies were identified via presence of burrows or chimneys, which cap the burrow openings. The habitat for each colony was characterized, described (in terms of topography, soil and vegetation type) and its total area was estimated. At each site a number of burrows were excavated to identify the burrowing crayfish present and any other sympatric species were identified. Excavations were performed using a spade and small gardening trowel. All crayfish collected were examined for reproductive and moulting condition, sexed and measured. Carapace length or CPL was used as a standard measure of size. Ecological and life history data were also collected whenever possible. Several representative specimens were preserved (in 70% ethanol) from each site. In small or sensitive colonies, the number of excavated burrows was kept to a minimum. Appropriate permits/permission (Ministry of Natural Resources Ontario, Parks Canada, Environment Canada, Toronto Region Conservation Authority, etc.) were obtained prior to the start of this study.

Since each burrow system usually contains one adult individual, the number of individuals in a population was estimated by counting either the total number of burrow systems (in small populations) or the number of burrows in a 10 x 1m transect (in larger populations). The number of burrow systems per square metre were then estimated in each colony. Whenever possible the burrow water temperature was recorded and compared to ambient air temperature or the temperature of the water body adjacent or connected to burrows.

Upon the completion of this portion of the study, the obtained distributional and ecological data was summarized and compared to historical data/previous studies.

RESULTS

Thirty eight survey trips (1-3 day long) were conducted between May 1999 and August 2002. In total, eighteen populations of *Cambarus diogenes* and thirty-four populations of *Fallicambarus fodiens* were surveyed.

A . *Fallicambarus fodiens*

Distribution

F. fodiens is the only representative of its genus occurring in Canada where it is at the extreme northern end of its range. It is restricted to southern Ontario where it occurs from southern shores of Georgian Bay to just east of Lake Scugog in the east to Lake St Clair and the Detroit River in the west (This study; Barr, 1996; Crocker & Barr 1968; Hamr 1998, Guiasu et. al. 1996). In this study, the distribution of this species was extended north to the south-eastern shores of Georgian Bay and East to the north-east shore of Lake Scugog

(Figure 1.). The populations found in the Severn Sound region constitute the northernmost records for this species in Canada.

Habitat

Possible habitats of this species include roadside ditches, small, intermittent or temporary creek banks, agricultural ditches, reservoir shores, wet meadows, forest swamps. *F . fodiens* is most likely to be found in fine clay soils as 77 % of surveyed populations were found in clay soils. Vegetation associated with *F. fodiens* colonies included wetland plants such as cattails (49% of populations associated with *Typha* sp.), water plantain (*Alisma*), cursed crow foot-(*Ranunculus*), horsetails (Equisetum); ferns; various grasses and sedges (*Poa*, *Carex,, Phragmites*); various native and introduced wildflowers (periwinkle, garlic mustard, jewel weed, strawberry, poison ivy; milkweed, blackberry, wine (*Vitis*), purple loostrife, asparagus, golden rod, stinging nettles, milkweed, white asters, pigweed) ; various trees (sugar maple, Manitoba maple, red maple, beech, black cherry, basswood, yellow birch, red oak, white ash, black walnut, elm, willow, white cedar, choke cherry black , white pine, poplar, sumac); as well as agricultural crops such as corn.

Table 1 shows the burrow temperatures measured in various populations sampled during the study.

Life History

No females with eggs or broods were found during this study but females with visible glair glands were collected in May, June and August. One mating pair consisting of a form one (sexually active) male (CPL 36 mm) and a female with strong glair glands (CPL 31 mm) was found in the same burrow in Oakville on June 3, 1999. The smallest mature female (with glair measured 29.5 mm CPL) while the largest individuals collected were a female and a form 1 male, both measuring 36 mm in carapace length. Juveniles presumed to be one year old were collected in open water from May to June measured 15-19 mm CPL.

Burrow Density and Conservation Status

Overall, seven of thirty four or 18 % of the populations surveyed were found in protected areas which included 4 Conservation areas and a Provincial Park. The mean burrow density of all populations was 1.3/m^2 (standard deviation.: 1.3; range: 0.1/m^2 to 5.4/m^2). In unprotected populations the average density was 1.1 /m^2 (standard deviation.: 1.1) while in protected populations it was 2.1 /m^2 (standard deviation:1.9) (Figure 2).

Identified threats included agricultural activity (plowing, harvesting, fertilizers pesticides etc..), roads (construction, salting, cars), rail road (maintenance and pollution), general draining of wet areas and vegetation clearing, logging, water fluctuation in reservoirs, garbage dumping, pesticide and herbicide application in gardens and fields, lawn moving, habitat destruction due to construction in cemetery, urban housing development in rural areas adjacent to large cities and towns, and the construction of a septic bed for a visitors center in a conservation area.

On the basis of this and previous studies, this species should presently be considered as “Threatened” in Ontario (and therefore Canada), due to continuing habitat destruction, with the probability of local extinctions being high throughout the vast majority of its range.

B. *Cambarus diogenes*

Distribution

In Canada, *C. diogenes* is found only in southwestern Ontario from Welland River in the east to just west of Long Point where it is at the very extreme of its northernmost range (This study; Crocker & Barr 1968; Hamr 1998, Guiasu et. al. 1996). A single record also exists from the Rainy River District near Atikokan in northwestern Ontario (Crocker and Barr, 1968), which may be a genuine range extension from Minnesota. As a result of collections from this study, the distribution of this species was significantly extended east to The Niagara Peninsula as well as the northeastern shoreline of Lake Erie (Figure 3).

Habitat

Habitats of *C. diogenes* included coastal marshes, creek banks as well as roadside ditches. It can be found in both clay and sandy soils (56 % of surveyed populations found in clay soils). Vegetation associated with *C. diogenes* colonies included wetland plants such as cattails (67 % of populations were associated with *Typha* sp), arrowheads, water lily, burr reed; grasses (*Carex*, *Phragmites*; Bluejoint); wildflowers and various trees (willow, maple, basswood, red oak, pin cherry)

Table 1 shows the burrow temperatures measured in various populations sampled during the study.

Life History

During this study, form 1 males were found in May, June and September while form 2 males were collected in June and July females with strong glair glands were found in early May and females in berry were found on May 15 (CPL 33 and 37 with broods of 126 and 124 eggs respectively). One female extruded eggs in captivity on May 7th while moulting in captivity was observed in August.

The smallest mature female (with glair) measured 32 mm CPL, the smallest form 1 male measured 33 mm CPL and the largest individual collected was a form 1 male measuring 55 mm in carapace length.

Burrow Density and Conservation Status

Overall, seven of eighteen or 39 % of the populations surveyed were found in protected areas which included 2 Conservation areas, 2 Federal Wildlife refuges and 2 Provincial Parks.

The mean burrow density of all populations was 1.6/m^2 (standard deviation.: 1.0; range: 0.3/m^2 to 4.5 /m^2) (Figure 4) . The highest densities were observed in coastal marshes on Lake Erie (eg. Turkey Point and Long Point). In unprotected populations the average burrow density was 1.4 /m^2 (standard deviation: 1.1) while in protected populations it was 2.0 /m^2 (standard deviation: 0.7).

Identified threats included water fluctuation in reservoirs and lakes, litter from anglers and road (salt, gas; boat fuel), gas station runoff, channelization, habitat alteration due to boat club construction, erosion due to wave action from boats, lawn mowing, fertilization and pesticides.

On the basis of this and previous studies, this species should presently be considered as “Threatened” in Ontario (and therefore Canada), due to relatively restricted distribution, and the continued threat of habitat destruction and alteration.

DISCUSSION

Distribution

The distribution of the two species appears to be largely influenced by the presence of wetlands as well as soil type. *C diogenes* is found mainly in areas of clay and less so on sandy loam (Long Point Region) whereas *F. fodiens* is found in clay, clay loam and to a small extent on sandy loam (midland Region). *C .diogenes* and *F fodiens* were never found in sympatry during the course of this study (Figs. 1& 3) however the two species distributions appear to overlap in several areas of Southern Ontario (eg. the Long Point Region). Crocker and Barr (1968) and Guiasu et. al (1996) also found no sympatry in their surveys and suggested competition may occur and cause exclusion in Ontario but conversely Norrocky (1991) found the two species coexist and even share the same burrows in northern Ohio. *F fodiens* also does appear to occur in sympatry with *O. immunis* in roadside ditches in south western Ontario (Hamr unpublished data).

The distribution of *F. fodiens* was extended north to Severn Sound on the south-eastern shores of Georgian Bay and East to the north-east shore of Lake Scugog. The populations found in the Severn Sound region constitute the northernmost records for this species in Canada.

The Canadian range of *C. diogenes* was previously extended westward to the Niagara Peninsula (Guiasu,et.

al. 1996) where two populations were found. This study found new sites throughout Niagara Peninsula and the on the northern portion of Long Point peninsula (Fig. 3.). The northern limit of the species appears to be about 43 °N although one anomalous record exists from northern Ontario (Rainy River District near Atikokan, 48°N) (Crocker and Barr, 1968). This record (one small immature male) although valid, has never been reconfirmed and may be a result of an introduction. It is possible that this record is a genuine range extension from Minnesota where the species has been recorded by Jass and Hobbs, (1988) who propose the distribution to be continuous into northern Ontario. On the other hand, there are apparently no records for this species in north-eastern Minnesota, adjacent to the Canadian border (Helgen, 1990) and it has not been reported in Northern Ontario since despite numerous surveys (Momot pers. comm.). Similarly the present surveys revealed no populations of this species on Point Pelee peninsula and it is therefore most likely that this species range extends only as far as Long Point peninsula.

Habitat and ecology

F. fodiens is a semi-terrestrial burrower which spends most of its life within burrows consisting of a network of tunnels. The burrows have as many as four entrances and large terminal chamber which is usually located below the groundwater table. The entrances are usually made conspicuous by tall "chimneys" constructed from pellets of excavated mud. *Fallicambarus* burrows are found in wetlands (marshes and swamps) but also along roadside ditches and creek banks in moist clay, among rooted semi-aquatic plants and grasses. They can also be found far from permanent water in relatively hard, dry ground where the water table is far below the surface and the vegetation is primarily terrestrial (Barr, 1996; Crocker & Barr 1968). Such burrows may include deep vertical tunnels which can exceed one metre in length. Burrowing activity appears to be the greatest in the spring and following periods of heavy rainfall, in order to repair damaged burrows (Williams, 1974). Excavation also increases as water table drops and crayfish burrow to greater depths to reach groundwater. In a capture-recapture study, Norrocky (1991) found *F. fodiens* to be active and its home range was anywhere from 0.15 to 66 meters.

This species needs primarily clay soils in order to burrow (This study; Guiasu et al 1996; Crocker and Barr, 1968) and thus the hard rocks and thin soils of the Canadian Shield may limit the availability of suitable habitats and northward range expansion. It is not known whether *F. fodiens* is tolerant of low temperatures or whether winter burrows must be deep enough to go below the frost line. Norrocky (1991) showed that in Ohio, crayfish were active throughout the year, even under ice, and burrow temperatures ranged from 2.2 C in winter to 22.2 C in summer but remained relatively stable with respect to ambient air temperature fluctuation. The burrows of this species may have water with low oxygen concentrations (8-12% saturation) (Williams et. Al, 1974) and adults can survive for prolonged periods (up to several weeks) out of water if the humidity of the air is high enough (Hamr unpublished). *F. fodiens* is apparently prevented from colonizing faster flowing streams because of its inability to hold station in currents faster than 27 cm/second, a relatively low slip-speed value (Maude & Williams, 1983).

This study showed that it is most likely to be found in fine clay soils and is only sometimes associated with wetland plants. Summer burrow temperatures (14 - 23 C) were similar to those reported by other authors but this study also demonstrated the differences between surface water and burrow water (up to 10 C).
F. fodiens is probably an opportunistic omnivore, as demonstrated by captive individuals (Hamr unpublished data; Crocker Barr 1968), feeding on both vegetation and invertebrates associated with its burrows (Bovbjerg, 1952).

Cambarus diogenes is wide-ranging in North America which reflects a wide tolerance of ecological conditions. It appears to be an obligate burrower in Ontario, constructing burrows in coastal wetlands, mudflats, wet meadows and marshes (This study, Crocker& Barr, 1968; Barr, 1996; Guiasu et al. 1996). The burrows are usually capped with mud chimneys, but these may not be present where the ground is very soft and moist. In Ontario, burrows are generally shallower than those of *F. fodiens* and usually consist of a large resting chamber with two or three entrance tunnels (Crocker& Barr, 1968). The chimneys may be quite high (up to 15 cm) and the diameter of burrows may be very large depending on the size of the occupant. In the US, burrows as deep as 5 metres and covering as much as 12 m^2 have been recorded (Hobbs III&Jass, 1988). This species has enlarged gill chambers and can thus tolerate low oxygen conditions. Oxygen concentrations of burrow water can range between 0.1 and 8.8 mg/l (temp. 17 - 27 C pH from 5.2 to 9.0 and conductivity from 28 to 730 µmhos/cm (Hobbs III&Jass, 1988). *C. diogenes* can take oxygen directly from air by exposing its gill at he air-water interface or crawling into chimneys and/or tunnels which are above the water table. It can also survive in air for prolonged periods as long as its gills

are covered in a thin film of moisture.

This study showed that it is likely to be found in both clay and sandy soils and is often associated with wetland plants. The burrow density was found to be highest in coastal marshes. Summer burrow temperatures measured in this study were similar to those reported by other authors but this study demonstrated the large differences between surface water and burrow water (up to 15 C).
Little is known of the diet of this species but it is presumed to be omnivorous and feed on roots of vascular vegetation and earthworms (Crocker & Barr, 1986).

Life History

Little is known of the life history of the Canadian populations of *F. fodiens*. The only published study available (Williams et. al 1974), in a temporary stream bed near Waterloo, Ontario, reported that crayfish became active in early April and eggs were laid by the end of the month. An average of 85 eggs per female was counted. In early May, free-living juveniles measuring 6 mm CPL were found in open water. Mating was also observed in captivity at this time. In early August these young measured 12-14 mm CPL and by October they reached a size of 16-18 mm CPL. It was estimated therefore that in this population, crayfish reached sexual maturity after two summers (at a CPL of about 30 mm). Maximum size was 35 mm CPL. No mating occurred in the fall and little activity was observed from late October to early April.

During this study, observations of populations near Wheatley in south-west Ontario showed that mature females had not mated in early June. Captive individuals from this population were observed mating in mid June. Similarly, in the population from Norval near Toronto no young of the year or ovigerous females were found in mid May but many soft-shelled mature females were found suggesting a spring moult. Samples also included large form 1 males as well as juveniles from the previous year measuring 13 mm CPL. Females with glair glands and form 1 males are present in early summer and mating may therefore occur anytime between May and June. Since no ovigerous females were found it is difficult to estimate the time of ovipostion and it is possible that not all females participate in mating each year as some large females without glair are also present in the summer.

Berrill (unpublished data) found that populations in Holland Marsh, Ontario, sampled from May 16-30, included form I males (CPL> 30 mm), females with cement glands of various stage of development (CPL 27-30 mm), immature individuals of both sexes (CPL> 25) and young of the year (CPL 6 mm). No berried females were found but he witnessed copulations in captivity during May. The maximum size reported was 36 mm CPL. It appears therefore that this species in Ontario may breed from May to June, attain maturity at CPL of 25-30 mm and survive to 3-4 years maximum.. More detailed life history studies are needed to clarify the life history of the northern populations.

In southern U.S. populations, reproduction probably occurs throughout most of the year as females carry eggs or young from January to June and September to November. Form I males are found throughout the year so copulation can occur during any month. Maturity is reached at a minimum size of 19.5 mm CPL in males and 26.5 mm CPL in females (probably in the second year) and maximum size is 43 mm CPL. The sex ratio is approximately 1:1, fecundity ranges from to 48-201 eggs/young and the diameter of abdominal eggs is about 2 mm. As you go north through the species' range, populations tend to breed later in the spring or summer and have a larger size at maturity (Hobbs&Robinson, 1989; Page, 1985). The most recent and comprehensive study of a population in Northern Ohio by Norrocky (1991) found that occupancy of the same burrows occurred between Form I males and mature females from April to October but females with late stage cement glands and Form I males were present during all months. Some females extruded eggs in October and over wintered with eggs which then hatched from late March to April. Most ovigerous females were captured in March while most carried young in April. Fecundity was lower than in more southern populations (50-150 eggs) and there appeared little correlation with size. The smallest Form I male measured 30 mm CPL while the smallest ovigerous female measured 33.3 mm CPL. Individuals of both sexes molted no more than once a year and some less often, the average growth increase was 1.3 mm CPL and the maximum lifespan was estimated at 5-6 years.
Little is known of the life history of *C. diogenes* in Canada as no published studies exist. This study found ovipostion to occur in early to mid May while molting activity in adults was observed in August.

In more southern (US) populations mating occurs from late winter to early spring as well as in the fall but Form I males can be found from January to November suggesting that reproduction may take place in any

month (Hobbs III&Jass, 1988; Page, 1985). Copulation can occur within burrows or in open water. Prior to egg laying cement glands are prominent on the underside of the abdomen and tail fan (Hobbs III & Jass, 1988). Females with eggs were found from March to June and in September, October and January. Young are carried mainly from March to June and when free-living, live in open water until they reach about 10 mm CPL when they start burrowing. Maturity is reached probably at CPLs in excess of 40 mm and maximum size is 61 mm CPL. Fecundity ranges from 40 to 606 eggs/young and eggs are about 1.9 mm in diameter. (Page, 1985).

Conservation Status

Populations of *F. fodiens* are scattered over a wide geographic area but are never locally common and are restricted to isolated patches of wetland habitat, usually in the midst of extensive agricultural and urban areas: 93 collection records ranging over about 25 000 km^2 have been documented to date (Guiasu et. al 1996). The amount of available habitat suitable for *F. fodiens* is decreasing as this species' range coincides with heavily urbanized and industrialized areas (Barr, 1996) as well as the center of most of Ontario's agricultural production. As much as 70%-80% of the 2-2.4 million hectares of wetlands originally found in southern Ontario have been severely altered or destroyed altogether during the past 200 years (Reid 1989), with a probable parallel decline in populations of *F. fodiens*. Guiasu, Barr and Dunham (1996) found that several of the Toronto locations reported by Crocker and Barr (1968), which had *F. fodiens* colonies in the early and mid- 1960's, have since been developed for industrial or commercial purposes. Similarly, areas within the jurisdiction of the Metropolitan Toronto and Toronto Region Conservation Authority, which also used to support *F. fodiens* populations, have now become unsuitable for these crayfish, due to urban development (Guiasu et. al. 1996). Hobbs and Robinson (1989) found the species was conspicuously absent in rice growing regions of Arkansas suggesting that intense agricultural activities may also adversely affect this species. The recruitment of this species may also be low due to high mortality of juveniles in periods of dry weather or when habitat is disturbed (Guiasu et. al. 1996; Williams, 1974) and thus it may be particularly sensitive to disturbance.
This study found that protected sites had generally higher population densities than the unprotected sites. Populations within or adjacent to developing urban and suburban areas are under the most imminent threat of extirpation.

The range of *C. diogenes* overlaps areas of intense agricultural and recreational activity and as in the case of *F. fodiens*, much of its habitat outside reserves is likely under threat because of wetland destruction and alteration. To prevent further habitat shrinkage, populations of this species should be identified and their habitats should be further protected.

This study found that protected sites had generally higher population densities than the unprotected sites (Figure 4.) but the highest densities were observed at Turkey Point on land operated by the Turkey Point Company as a private waterfowl reserve. The Long Point/Turkey point Area is the area of highest densities while populations on the Niagara Peninsula especially those outside of reserves are potentially under the greatest threat of disappearance.

Burrowing crayfishes are good indicator species of wetland health and may also be particularly useful for studies relating to agricultural activities because their habitats include farm ponds, crop fields, as well as streams and ditches associated with farms which receive direct inputs of fertilizers and pesticides. Since the home range of these animals appears to be restricted to their burrow systems they should accurately reflect health conditions on a local scale and therefore help to pinpoint input sources. The range of habitats occupied by burrowing crayfishes includes wetlands, wet meadows, stagnant water, ponds, ditches, lakes, streams and even larger rivers. These habitats are included in urban, agricultural and natural areas and this therefore offers a possibility of comparing a wide range of populations/species/ecological types in terms of the effects of human disturbance/pollution.

In the future, it is important to recognize the proposed status of these two species officially (by federal and provincial authorities) as well as to monitor and manage the populations of both species particularly those not found on reserved lands. Landowners need to be made aware of the presence and significance of the species and encouraged to conserve the remaining populations.

ACKNOWLEDGEMENTS

Financial support for this study was provided by WWF (ESRF) Canada, Ontario Ministry of Natural Resources and Trent University. I would like to thank the following individuals for their help during the study: Lee, Sophie and Josef Hamr, Ed Paleczny, Al Dextrase, Brian Huis, Don Sutherland, and Dave Bell (MNR); Brian Huis, Rick Hornsby; Chuck Fawdry (Ontario Parks); Pam Martin, Paul Ashley and Jeff Robinson (CWS); Corey Lewis (The Wetland Specialists); David Dunham and Radu Guiasu (University of Toronto), Don Barber (Friends of the Kawthra Bush), Aleta Kaarstad and Fred Schueler (Eastern Ontario Biodiversity Museum), as well as Doug Blakey (Upper Canada College).

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TABLES

Table 1. Burrow water temperatures of selected populations surveyed.

Cambarus diogenes

SITE/DATE	BURROW WATER TEMPERATURE	SURFACE WATER TEMPERATURE	DIFFERENCE TEMPERATURE
9.6.99/Wainfleet bog	19	32	13
13.6.99/ Long point	22	37	15
21.6.99/Selkirk P.P.	19	34	15
23.6.99/Turkey Pt	24	28	4
23.6.99/Turkey Pt.	19	29	10
29.7.99/ Long point	24	30	6
30.6.00/ditch on rd. 42	20	30	10

Fallicambarus fodiens

SITE/DATE	BURROW WATER TEMPERATURE	SURFACE WATER TEMPERAURE	DIFFERENCE TEMPERATURE
26.5.99/Joshua creek	12	15	2
14.6.99/Kortright C.A.	20	20	0
17.6.99/Dunville Marsh	16	21	5
22.6.99/ Clairville dam	20	27	7
4.8.99/Wye Marsh	18	25	7
19.6.00/Morisson Ck.	20	21	1
19.6.00/UCC at Norval.	19	18	1
27.6.00/Teviotdale	19	19	0
30.6.00/Hankinson's drain	20	18	2
30.6.00/Cnt. rd. 42 ditch	23	30	7
30.6.00/Jacksonburg	22	25	3
5.6.02/Eberle line	15	22	7
6.6.02/point Pelee	17	17	0
6.6.02/Wheatley Prov, Pk.	15	15	0
6.6.02/Wheatley Prov, Pk.	16	16	0

FIGURES

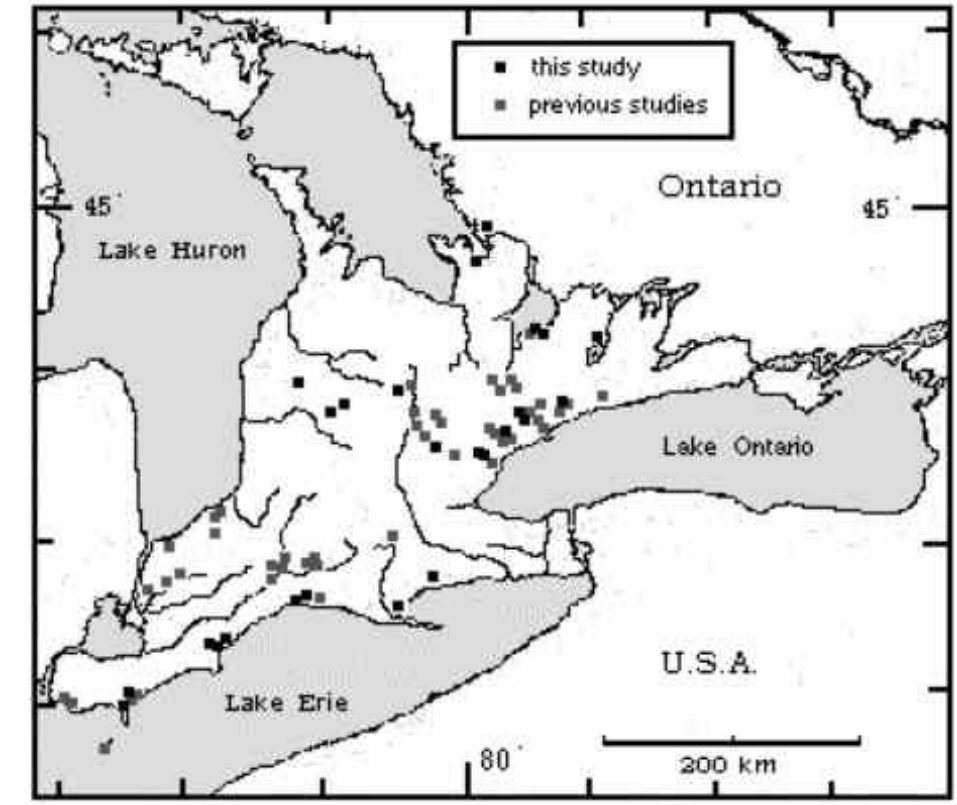

Figure 1. The known distribution of *Fallicambarus fodiens* in Canada.

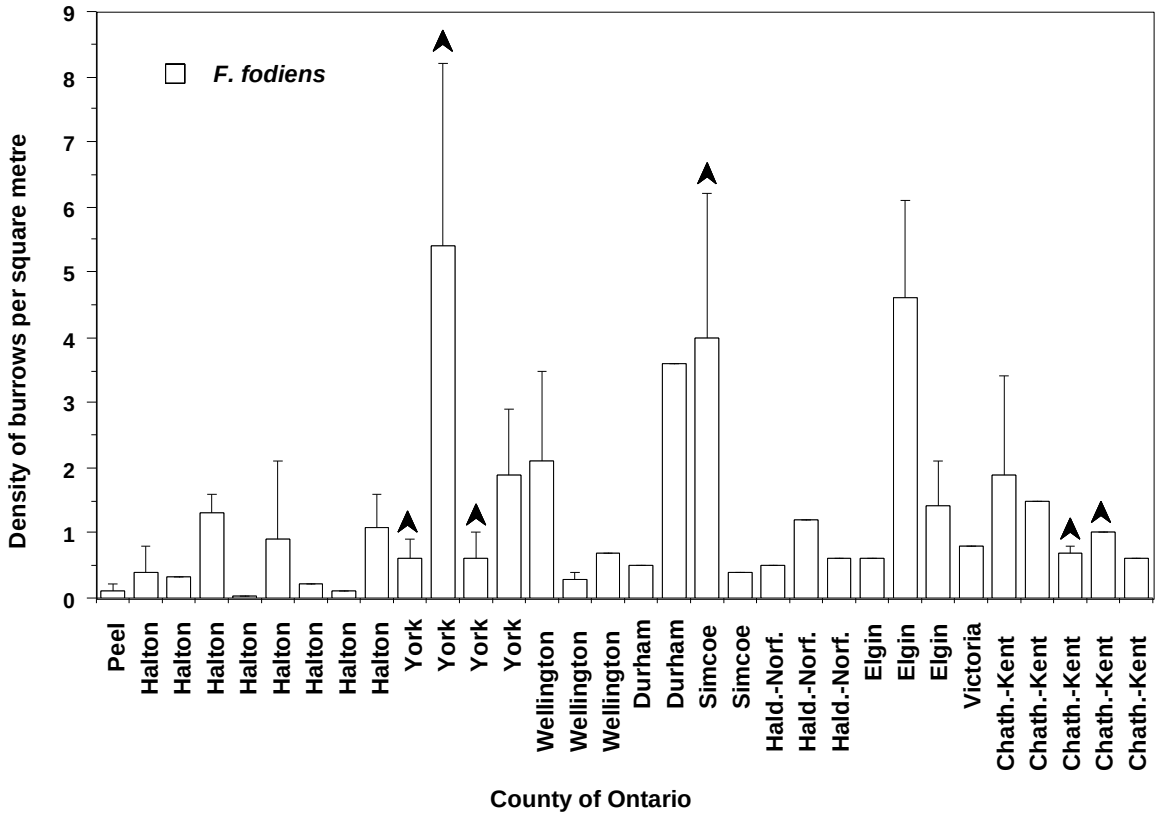

Figure 2. The mean burrow density of various populations of *F. fodiens* (grouped by county) sampled in this study. Arrows indicate population located in protected areas while error bars indicate the standard deviation of the mean.

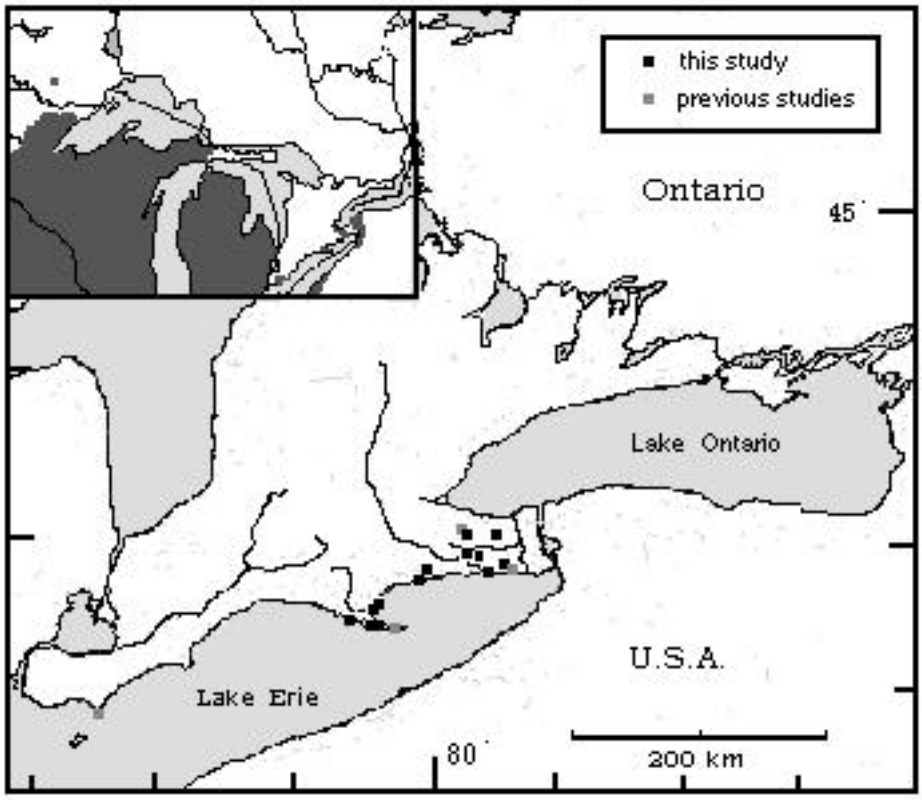

Figure 3. The known distribution of *Cambarus diogenes* in Canada. Inset shows the north eastern part of its North American range including the single record from Northern Ontario.

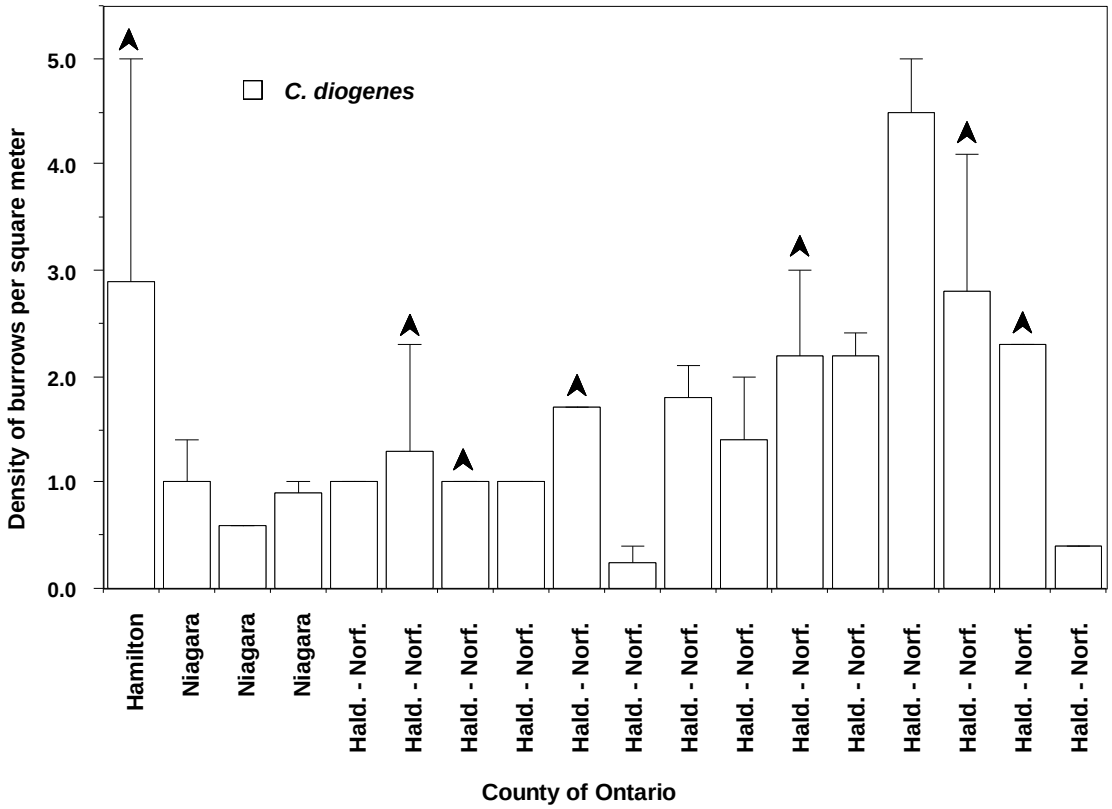

Figure 4. The mean burrow density of various populations of *C diogenes* (grouped by county) sampled in this study. Arrows indicate population located in protected areas while error bars indicate the standard deviation of the mean.