COMMITTEE ON THE
STATUS OF ENDANGERED
WILDLIFE IN CANADA

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COMITÉ SUR LE STATUT
DES ESPÈCES MENACÉES
DE DISPARITION AU CANADA

OTTAWA ON K1A 0H3
(819) 997-4991

STATUS REPORT ON THE LAKE ERIE WATER SNAKE
NERODIA SIPEDON INSULARUM

IN CANADA

BY

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AND EXPANDED WITH DATA AND COMMENTS FROM

RICHARD B. KING[1]

STATUS ASSIGNED IN 1991
ENDANGERED

REASON: DECLINING POPULATIONS CAUSED BY HUMAN PERSECUTION AND HABITAT DESTRUCTION MAY MAKE THIS UNIQUE ISLAND FORM, THAT HAS A VERY RESTRICTED DISTRIBUTION, VULNERABLE TO GENETIC SWAMPING BY EMIGRATING INDIVIDUALS FROM MAINLAND SUBSPECIES.

OCCURRENCE: ONTARIO

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1 REVISED AND EDITED (1991) BY FRANCIS R. COOK (THEN CHAIR, COSEWIC REPTILES AND AMPHIBIANS SUBCOMMITTEE).

Committee on the Status of Endangered Wildlife in Canada

Comité sur le statut des espèces menacées de disparition au Canada

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Contents

Abstract -- The Lake Erie Water Snake, Nerodia sipedon insularum, is a distinctive grey, patternless or partially patterned, insular form of the Northern Water Snake, N. sipedon. The other races of this species are strongly banded and widely distributed, collectively ranging from northeastern North America to western Mexico. N. s. insularum is confined to the archipelago of western Lake Erie and in Ohio and Ontario. In the latter it is recorded only on Pelee Island (the type locality of the subspecies) and on Middle, East Sister and Hen islands. It inhabits rocky shorelines, from which it forages for fish and other aquatic prey. Birds such as gulls may selectively prey on the banded form because it is more conspicuous in this habitat, thus favouring the survival of patternless or incompletely banded snakes. This has been widely cited as a example of the effects of natural selection balancing those of migration. Water snakes on some of these islands in both Ontario and Ohio have clearly declined in numbers during the past 40 years, due, at least in part, to human persecution and habitat destruction. An increase in the proportion of banded snakes is documented between the 1950s and the 1980s. Restoration of higher population levels may be critical to reversing this trend which is thought to be the result of genetic swamping by emigrants from the mainland into the reduced island populations. Protection for the subspecies and its habitat now exists under Ontario's Endangered Species Act and protection for species as a whole by its designation as a reptile under Ontario's Game and Fish Act (R.S.O. 1980, c.182). Endangered status is clearly justified.

Distribution

The Northern Water Snake, Nerodia sipedon Linnaeus, 1758, is one of 8 species in the genus Nerodia Baird and Girard, 1853, of the subfamily Natricinae of the family Colubridae. As presently defined, this genus is endemic to North America east of the Rocky Mountains and western Mexico. It was formerly included in Natrix Laurenti, 1768; the latter has been redefined to contain only 3 species which occur in Europe and Africa and east to Lake Baikal (Rossman and Eberle 1977). Nerodia sipedon has been divided into 4 subspecies which collectively occupy much of northern and south-central North America from Lake Superior south to northern Alabama, and from eastern Colorado to the Maine-New Brunswick border (Conant 1975: Map 99). The Northern Water Snake, N. s. sipedon is a widespread and abundant snake in southern Ontario (Figure 1) and occurs also in Canada in western and southern Quebec.

The Lake Erie Water Snake, Nerodia s. insularum, is restricted to the islands of the "Put-in-Bay" archipelago (Figure 2) in the west end of Lake Erie between the Catawba-Marblehead Peninsula (Ohio) and Point Pelee (Ontario). Its distribution is one of the smallest of any taxon on the continent (Conant (1938, 1951, 1958, 1975; Schmidt and Davis 1941: Figure 72; Wright and Wright 1957: Map 42; Mills 1948; Logier and Toner 1955, 1961; King 1986, 1987a, 1987b).

Morse (1904) first noted the presence of unique grey water snakes on the Lake Erie islands (as Natrix fasciata erythrogaster), and they were also mentioned by Conant (1934).

These populations were first described as Natrix sipedon insularum with Pelee Island, Ontario, as the type locality by Conant and Clay (1937). University of Michigan Museum of Zoology 80457 was designated as the type specimen. Four pattern types were defined by Conant and Clay (1937):

(A) gray above, essentially unpatterned dorsally and ventrally;
(B) imperfectly or obscurely patterned dorsally and ventrally, with a wide greyish dorsolateral stripe;
(C) narrowly and vaguely blotched or banded above, patterned below, dorsolateral stripe narrow;
(D) very like typical sipedon, with markings almost as extensive.

No notable differences in scale formulae were found between N. s. insularum and N. s. sipedon

Conant and Clay (1937) originally employed a "typological" subspecies shorthand not uncommon at the time, and referred to type A snakes as insularum, type D as sipedon, and types B and C as intergrades. Camin et al. (1954), Camin and Ehrlich (1958, 1979), Ehrlich and Camin (1960) subdivided the pattern variation further to produce 7 types: A, ab, B, bc, C, cd, and D. Conant and Clay (1963) reanalysed the variation and modernized their terminology by applying the subspecies name to the geographic population, referring to all the water snakes on these islands, regardless of their pattern, as N. s. insularum. They demonstrated that types A, B, and C together comprised 89.1% of a sample of 1258 water snakes pooled from all the islands.

In mark-release studies in 1980-1985 of 1247 individuals from the entire archipelago (336 of these from Canada: Pelee (306), Middle (27) and East Sister (3) islands), King (1986, 1987a, 1987b, 1989) simplified the variation to 3 categories: unbanded (= A), intermediate (= B + C), and banded (= D). In 1989-1990 an additional 268 individuals were examined from Pelee (246), Middle (12), and East Sister (10) islands (King, unpublished).

King (1987a, 1987b, 1988b) listed 10 islands, 1 to 20 km from the nearest mainland, where N. s. insularum occurs (Table 1). In Ontario, Pelee and Middle island populations are well documented (King 1986). Small numbers of Lake Erie Water Snakes have been taken on East Sister and Hen islands (Weller and Oldham 1988; Oldham and Weller 1989; King, unpublished data). Campbell (1977b) mentioned that there were no recorded populations on the small Canadian islands: North Harbour, Middle Sister and the Chicken Islands. King (unpublished data) searched Middle Sister and North Harbour islands in 1989-1990 and found no water snakes.

The major islands from which N. s. insularum has been recorded total 6617 hectares (Table 1). The Canadian portion of this is 4138 hectares or 62.3% of the total range (data from King (1987a). Pelee Island, the type locality, constitutes 61.5% of the range in total land area, but water snakes occur there now only along certain areas of the shoreline (Campbell 1977a; Oldham 1983a; King 1986 and unpublished data). Pelee Island had only 39.3% of the total population of Lake Erie Water Snakes in 1980-1985 estimates for all islands (King 1986). Campbell (1977a) lists 22 locations for the period 1970-1976. King (1986) censused only 3 major concentrations in 1980-85 but investigated 11 sites in 1980-

1990 (King, unpublished data).

The Catawba-Marblehead Peninsula has similar habitat to that of the islands (King 1987a, 1987b). Water snakes from there were reported as intergrades, N. s. sipedon x N. s. insularum, by Conant and Clay (1937) on the basis of a collection from Lakeside and Marblehead containing 1 type A and 5 D snakes and a second sample from the Catawba Peninsula with 2 A, 1 B, 7 C and 28 D.

Mainland sites in Ohio beyond the Catawba-Marblehead Peninsula have only type D individuals and are N. s. sipedon. Twenty taken at Port Clinton, at the base of the peninsula, pre-1937, were all type D (Conant and Clay 1937); as were 45 from Little Portage River and Sandusky Bay in 1979-1984 (King 1987b).

Conant and Clay (1937) included 63 individuals (all type D) from mainland Ontario in their analysis, but these apparently came from many localities in the province. The nearest Ontario mainland to the archipelago is Point Pelee National Park. This sand spit that juts into Lake Erie is largely forested but has extensive marshes on its western side. Neither Taverner (1914) nor Patch (1919), reported any water snakes on Point Pelee. Logier (1925), however, collected two in 1921 and reported that others were seen. Thirteen water snakes examined in 1963 from ditches on Point Pelee were all type D (F. R. Cook, unpublished data). King (unpublished data) collected 20 from the Hillman Marsh, Essex County, and 2 from the St. Clair Marsh, Kent County, on mainland Ontario in 1989-1990. He found one individual with an intermediate pattern at Hillman Marsh, but all others from both localities were banded and therefore both populations are assignable to N. s. sipedon.

There have been occasional reports of disjunct occurrences of snakes similar to type "A" elsewhere. Conant and Clay (1937) noted they had seen "insularum phenotype" individuals from Pennsylvania, Virginia, and West Virginia, but omitted them from the range of their new subspecies. Although these might demonstrate a hypothetical wider range of N. s. insularum in the past, they more likely are unique independent mutations at each site. Conant (1949), in assigning the faintly patterned type specimen of Nerodia agassizii Baird and Girard, 1853, (United States National Museum 1350 from "Lake Huron") to Natrix [now Nerodia] sipedon sipedon, remarked that it "in life, probably resembled some specimens of Natrix sipedon insularum." A Canadian Museum of Nature specimen (NMC 18882-9), a large adult, matches type A as it is uniformly grey dorsally with a virtually plain venter. It was collected 8 July 1977 on Vital Island, Manitoulin District, Ontario (Georgian Bay, Lake Huron), by Franklin D. Ross and Wayne Westman with 8 other large adults (NMC 18882-1 to -8) all of which have the distinct banded pattern typical of N. s. sipedon. Nickerson and Krager (1975) recorded 2 patternless watersnakes from one Missouri locality, and Lazell (1976) 2 from Cape Cod. However, in the latter report the snakes were brown, not grey.

Protection

In the United States, N. s. insularum occurs only in Ohio. It was considered endangered by Ashton (1976: 45) but has no legal protection although it is listed as a category 2 species by the U. S. Fish and Wildlife Service (Anonymous 1985).

In Canada, the subspecies was listed as endangered under Ontario's Endangered Species Act, R.S.O. 1980, c. 138, in 1977. In 1987 the entire species N. sipedon was included by Ontario Regulation 195/88, a regulation to amend Regulation 287 of Revised

Regulations of Ontario, 1980, made under the Endangered Species Act; and Ontario Regulation 113/88, a regulation to amend Ontario Regulation 397/84 made under the Game and Fish Act. Three areas owned by the Ontario Government contain populations of N. s. insularum. Two are on Pelee Island: Light House Point Nature Reserve (67 ha) and the Fish Point Nature Reserve (total acreage when fully assembled to be 114 ha). The other is East Sister Island Nature Reserve (26 ha). Not all of the 2 larger reserves is suitable Nerodia habitat. In 1980-1985, King (1986) made population estimates of 195 individuals or 80/km along 2.45 km of shoreline at Light House Point and 143/km or 99/km for 1.45 km of shoreline at Fish Point. At East Sister the estimate was only 25/km (King 1986).

A portion of Mill Point has been acquired by the Essex Conservation Authority. Important habitat on Sheridan Point, Pelee Island, and on Middle Island is not protected.

Population Size and Trend

General and United States' Trends

The abundance of water snakes in the area was noted in the lurid accounts of early travellers in the area and was doubtless part of the reason for the French name "Les Iles aux Serpents" in 1749 (Langois 1964). Wright and Wright (1957: 534) quote J. Carter's account of travels in 1778:

> There are several islands near the west end of [Lake Erie] ... It is impossible to believe that any place can produce a greater number of all kinds of reptiles than this does, particularly of the water snake. The lake is covered near the banks of the islands with the large pond-lily; the leaves of which lie on the surface of the water so thick, as to cover it entirely for many acres together; and on each of these lay, when I passed over it, wreaths of watersnakes basking in the sun, which amounted to myriads.

Another source repeats this:

> Numerous and enormous black water snakes, darting through the water, snaking out from under your every foot step, sunning themselves in heaps, knots and snarls [Ballou 1878; see also McDermott 1947].

In 1806 these islands were still noted for "myriads of watersnakes" (Langois 1964). The earliest museum specimens were nine from South Bass Island in 1893-1901 (King 1987b: 249).

As recently as the 1930s to 1960s water snakes were still thought to be remarkably numerous. The literature of this period reports many analyses of large series, giving an impression of repeated removal of large numbers of snakes by collectors. Often, however, the samples analyzed are markedly smaller than the numbers reported seen, so the capture reports do not necessarily equate with numbers actually removed from the population. As well, many samples include museum specimens and captive-bred snakes and relatively few wild-caught snakes (e.g. Conant and Clay 1937; Camin and Ehrlich 1958).

In his capture-mark-recapture study conducted over four years (1980-1984), King (1986) examined 1247 individual Island Water Snakes of all ages and made 202 recaptures from 13 sites on six islands: North Bass, Middle Bass, Pelee, Middle, Kellys, and Johnsons

(King 1986). In some analyses King uses figures for adult snakes only to provide an estimate the breeding population size. King (1986) averaged only 0.81 adult snakes per man-hour (although he did achieve a maximum of 19 per man-hour) and pointed out that:

> while hundreds of snakes were once captured in a single day ... a month or more of field work is now required to achieve similar sample sizes.

Water snakes were thought to have disappeared from some islands by the early 1980s (King 1986), but field work in 1989-1990 (King, unpublished data) has since demonstrated their presence on some of these (Table 1). Some populations now appear to be increasing (King, unpublished data), and perhaps recolonizing some islands. However, it is too early to determine if the increase is real and a response to greater protection or due to more intensive surveys, luck, or natural fluctuations.

Populations in Canada

Pelee Island: The first specific documentation of the occurrence of water snakes on this island was by Jones (1912). The Royal Ontario Museum has 2 specimens collected in 1933 and 1936 (ROM 3907, 5473, respectively). Conant and Clay (1937) documented the first significant sample, 36 specimens they and others had collected 9 June 1935. Fetherston (1949: 39) stated that "Water snakes were exceptionally common", and that 12 "stout ones" were found under one board and 27 were collected in one afternoon on Fish Point's east shore. Her specimens were deposited in the Cornell University collection. Hamilton (1951) records that they were collected in May 1947 and from April to July 1948. He adds that Robert Mengel took three additional specimens on 4 August 1947. Hamilton (1951) based his paper on 35 specimens (27 males and 8 females) but three included were not from Pelee Island. Watts (1951: 28) mentioned water snakes on the island as "still there in numbers". Conant and Clay (1963) included data on only 8 more specimens from Pelee Island than they had examined 26 years earlier.

In the 1970s, Campbell (1977a) and colleagues found that it was difficult to locate more than several dozen water snakes per day. A decline in numbers by 1976 was commented upon by M. Cowie (personal communication) and even earlier by Langlois (1954: 163). Campbell (1977a) gave a total of 102 snakes observed between 1970 and 1976. Oldham (1983), however, noted that he "consistently found 20 or more (mostly juveniles) during 2 to 3 hours of diligent rock flipping" at the quarry at Sheridan Point during 34 days of field work in 5 years (1979 to 1982). The Ontario Herpetofaunal Summary began to collect observations in 1984 and the records submitted to it until 1986 are given in Table 2.

King (1986) included Canadian populations in his studies in 1980-1985, with primary emphasis on Pelee Island. Over a combined total shoreline of 4.8 km, he captured 0.87 adult snakes per hour and obtained an population estimate of 489 (confidence interval between 205 and 1574) adults or 102 per km. Additional sites were examined in 1989-1990 and the island estimate revised to be closer to 1000 adults (King, unpublished data). In 1989-1990 King (unpublished data) had capture rates ranging from 0.90 to 3.20 adult snakes per man-hour for 6 intensively worked sites.

Middle Island: Thomas (1949) records that on 30 August 1945 his party that spent an hour or so there and noted:

> many very large individuals .... No attempt was made to count the total number of individuals, but in one place 7 were seen on the shelter of one clump of shrubbery. Such concentrations were fairly typical at close intervals along a stretch of several hundred yards of shore ... Middle Island has not been inhabited by human beings since about 1933 and the buildings on it are occupied only during the occasional inspection trips by a caretaker. The island is not otherwise visited except sporadically by fishermen or other persons who may pass by its shores. The population of snakes may represent the size normally attained in the absence of persecution.

Camin et al. (1954) recorded "several hundred" collected by 7 members of the Ohio Herpetological Society, 30 April 1949, on Middle Island and reported data on 254 (131 adults, 123 juveniles.

Camin and Ehrlich (1958) also collected there in 1957, but they documented only 21 adults additional to the totals given in the earlier paper. Ehrlich and Camin (1960) reported that 104 (84 adults 20 juveniles) were captured on Middle Island by 4 people in 2 days in early June 1958, and remarked on the summer reoccupation by humans and the snake destruction occurring.

King (1986) sampled Middle Island in 1980-1984 but captured only 0.27 snakes per man-hour over 1.10 km of shoreline and obtained a population estimate of 35 (15-112) adults or 32 per km of shoreline. During a half-day census on 31 May 1990, 13 water snakes, 12 of which were adults, were captured and 5 others seen in 4.5 hours, for a capture rate of 2.89 per man-hour (King, unpublished data).

East Sister Island: King (1986) found 0.21 adult snakes per hour over 1 km of shoreline and obtained an estimate of 25 (10-79) adults. This was based on 4 visits between 1980 and 1983 during which 3 water snakes were captured (King, unpublished data). During 3.7 hours census on 30 May 1990, 10 adult and one young-of-the-year were found (King, unpublished data).

Hen Island: In 35 minutes on 30 May 1990 between 10 and 15 water snakes seen along the shoreline (King, unpublished data).

Accounts of high numbers may be strongly biased because of the timing of collecting trips. Most large collections are recorded from April and early June when snakes would be clustered for mating (April) or most actively feeding (June) to recoup energy expenditures for mating (males) and early development of embryos (females). An exception is Thomas (1949) on the 30 August 1945 who noted that on Middle Island

> The 2 specimens taken were gravid females, and it is possible that all of the individuals in the population had gathered at this place preliminary to parturition. It is difficult otherwise to account for the absence of small specimens.

There is a discrepancy between the numbers of snakes recorded in the literature and the number actually preserved in museums. King (1987b) examined 1118 museum specimens

from the archipelago but when he excluded captive-born litters and wild-caught juveniles he was left with only 128 individuals in which sample sizes and collection interval were large and short enough, respectively, to be useable for comparison (Table 3).

Habitat

The bedrock of Pelee and Middle Islands is medium to light brown limestone of the Dundee Formation, whereas the Ohio Erie Islands are mainly composed of cream and tan dolomite of the Bass Islands Formation (Sanford 1969). Although Island Water Snakes may move inland to hibernate and give birth, they frequent the shorelines the majority of the year (Wright and Wright 1957: 533). The patternless grey coloration of "type A", and to some extent the intermediate patterns "type B" and "type C" (Conant and Clay 1937; Camin and Ehrlich 1958; King 1986), have been regarded as favoured by selection over the banded pattern. Grey snakes are cryptic against the bedrock exposures (limestone and dolomite) along shorelines. Pough (1976) has presented photographic documentation of the conspicuousness of a stationary banded form on rock substrates.

The preferred habitat on Pelee Island appears to be the shrub/tree line along beaches and rocky shores. Water snakes never seem to occur along the canals of Pelee Island (personal observations by Campbell and personal communications from residents).

On Middle Island Thomas (1949) noted:

> the north shore consists largely of limestone ledges ..., while the south shore slopes gently into the water, with frequent beaches of limestone rubble and gravel. Most of the island is forested. Dr. [N. Bayard] Green and the writer independently explored most of the island and failed to note any water snakes except on the ledges.

Hibernation sites may be near water or away from it (Camin et al. 1954; Anderson 1965; 143-144). In October, Campbell observed N. s. insularum on Pelee Island to have congregated in a large, abandoned quarry on Sheridan Point, in a deserted cistern on Fish Point, and along shore ledges. At Sheridan Point, many water snakes were under rocks during both April and October and associated with Eastern Garter (Thamnophis s. sirtalis) and Eastern Fox Snakes (Elaphe vulpina gloydi).

General Biology

Size, Maturity, and Longevity

Wright and Wright (1957, I: 533) gave the adult snout-vent length range as 56.2 to 115.1 cm for females and 68.5 to 90.0 cm for males. Thomas (1949) recorded 2 females from Middle Island regarded as exceptionally at 124.5 and 129 cm total length. King (1986) gave maximum total lengths of 144.0 cm for females and 110 cm for males for his sample from the entire archipelago.

King (1989) found he could divide his samples into age groups by snout-vent size (cm):

young-of-the-year	= either sex < 27cm
juveniles	= males 27-43cm, females 27-59cm
mature	= males > 43cm, females > 59cm

He recorded range of snout-vent length at maturity as 59 to 125 cm (mean 82.1) for females

and 43 to 86 cm (mean 62.5) for males, based on 373 and 435 individuals, respectively, measured in 1980-1984 on North and Middle Bass, Kellys and Johnsons islands in Ohio, and Pelee, Middle, and East Sister islands in Ontario.

Analysis of sexually mature water snakes (King 1986) showed the mean snout-vent length (in cm) of those on Pelee Island was 80.5 for 63 females and 58.8 for 103 males, whereas on Middle Island it was 85.7 for 13 females and 68.9 for 14 males. Variances (129.7, 78.5, 111.2 and 88.2, respectively) were relatively high and differences were not significant between these two islands.

King (1989) compared water and garter snakes on the Lake Erie archipelago and found a positive correlation in both species between mean adult snout-vent length with islands in females, but not in males. Body size of both species in the Lake Erie area appeared to be as large (garter snakes) or larger (water snakes) than those observed in mainland sites elsewhere (King 1989).

Hamilton (1951) reported that breeding took place after approximately 2 years. King's (1986) more extensive samples of 1449 captures of 1247 individual Island Water Snakes fixed attainment of maturity as 2 years for males but 3 years for females.

During 1988-1990, King (unpublished data) recaptured seven water snakes marked in his 1981-1984 studies. Four individuals were 3-4 years old when originally marked and over 10 years old when recaptured. He postulated from these results that recruitement of juveniles may be low in these populations. Growth shown by these recaptured snakes was variable, some showing virtually none whereas others showed considerable gains in both snout-vent length and weight (King, unpublished).

Breeding Aggregations

Many Nerodia mate in aggregations (Tinkle and Liner 1955) and it appears that N. s. insularum follows this pattern as well. During May, Langlois (1964) recorded and photographed breeding aggregations on the Erie Islands of 30 or more snakes, with as many as 12 males courting one female. King (1986) observed courtship between 0840 to 1550 h from 1 May to 11 June in 1980-1984. King (1986) also found that the proportion of males was significantly higher early in the season: 62% of snakes encountered were males from 25 April to 23 June whereas only 36% were males after that date to 4 October.

Number of Young

Hamilton (1951) reported the average number of young per litter (n=6) as 19, but Thomas (1949) had collected 2 large females containing 25 and 27 embryos. Some captive females (size unknown), on the other hand, have produced as few as 2 young (Ehrlich and Camin 1960). King (1986: 764-765) reported that litters obtained from 39 captive gravid females ranged from 9 to 50 and averaged 22.9 live young. Litter size was correlated with female snout-vent length and "not only did larger females produce more young, they produced larger young as well". The weight (in grams) of new-born snakes varied from 3.6 to 6.6; the average was 4.8 (King 1986: 765).

Movement

There are several reports of distances travelled by N. sipedon. Fitch and Shirer

(1971), record an average distance of 37 m. A large adult male N. sipedon remained within a space of 9 m for 23 days in June and July, along a pond in Kansas. A few gravid females within the same general area ranged less widely than other individuals. Newcomer et al. (1974) found that N. sipedon utilized the sun for compass orientation along a conditioned axis in the direction of water. Fraker (1970) reported that at least 20% of displaced N. sipedon were able to recognize their own home range possibly using waterborne chemical clues. Nerodia are believed to swim several kilometers (Cliburn 1961) and have been found "considerable distances from the islands" (Conant and Clay 1963:181, crediting Camin and Ehrlich 1958: 507 and a personal communication from Milton B. Trautman).

King (1987b: 248) recaptured 202 marked snakes from 2 to 1146 days after their capture and all were within about 300 m of their original capture site. Many were within 50 m of it. King (1987b) also released 317 captive-born newborns on Middle Bass Island (from females taken both on Middle Bass and North Bass islands) and 56 were recaptured the following spring and summer mostly within 25 m of the release site. An exceptional individual was 50 m from this site. King (unpublished data) recaptured 7 snakes in 1988-1990 that he had originally marked in 1981-1984. All were found in the study site in which they had been first marked. These data are very limited but do bring into question both the extent to which emigration and reconlonization of sites is likely. Both are important for management of populations and the theroretical base on which dynamics of Lake Erie Water Snakes have been interpreted.

Behaviour/Adaptability

During aggregation, especially at mating time, water snakes may not be very wary (Tinkle and Liner 1955). Langlois (1954: 163) and J. Harris (personal communication) reported that basking groups of insularum were killed by residents. At other times water snakes are shy or wary of human beings (Logier 1958: 26). They are also protected by their cryptic coloration and vigorous defensive behaviour consisting of flattening the body and head, so that it resembles a venomous snake, striking and biting, and releasing strong-smelling secretions from the vent.

Food

Using frequency of occurrence and bulk percentage, Hamilton (1951) showed that fish comprise 56.5 and 53.9 percent of the water snakes' diet on Pelee Island. Almost 50% of the fish were logperch and darters (Percina spp.). Other small fish and some amphibians comprised the rest of its diet. Conant (1951) thought that dead fish, perhaps those washed up on the beach, were an important source of food. King (1987b) observed feeding between 8 May and 28 September and reported on 37 snakes for which stomach contents could be identified. Thirty-four had eaten fish (including catfish and perch), one had eaten five toads (Bufo americanus), and 2 had eaten Mudpuppies (Necturus maculosus). King (1986) suggested that the island populations fed on more fish and fewer amphibians than mainland populations studied because frogs were scarcer along their shoreline habitat on the islands. In 1989-1990, King (unpublished data) recovered food items from 29 snakes; 25 had eaten fish (including sunfish, a spotfin shiner, and logperch), 6 (all from South Bass Island) Necturus, and 1 (a newborn taken at Sheridan Point, Pelee Island) Ambystoma larvae. The

latter is of particular interest because these salamanders themselves are a unique part of the island fauna and a pond in an abandoned quarry at the site is an breeding area for them (Bogart et al. 1985). These larvae might be an important food resource for newborns there (King, unpublished observations).

Limiting Factors

Habitat Loss

Ashton (1976) listed habitat destruction as the major cause of the race becoming endangered in Ohio. Since European settlement, the amount of suitable habitat for water snakes has diminished on the Lake Erie Islands.

In recent years, the American Erie islands have become increasingly altered and developed: marinas have been built, large quarries opened, lagoons filled, and shoreline/cottage developments created (Core 1948). The fish populations of western Lake Erie, a major food base of Nerodia, have been considerably reduced and/or altered (Scott 1967). High water levels have reduced the availability of suitable shoreline and possibly den sites.

Recent impoundment of water on Pelee Island (ie., "Lake Henry" at the north end) and shore protection with "armour stone", appear, from field observations, to have created some new habitat, and King (unpublished) found water snakes there in 1989-90. If shoreline recreational developments (cottages, proposed condominiums on Mill Point, see McLaren 1976) proceed on Pelee Island, there will likely be moderate loss/change of N. s. insularum habitat. Mill Point at one time was said to have a concentration of the water snakes (personal communication to Campbell from local residents), but King (unpublished data) found only 5 in 5 hours searching in 1989-1990.

In the 1970s, water levels fluctuated drastically in the western basin of Lake Erie. In Ontario, one suspected hibernaculum for N. s. insularum on Fish Point, Pelee Island, was flooded by high water levels. Much of the limestone shelving on Mill Point, formerly used by the snakes (personal observation, 1972) is now inundated. However, the flooded portion of Lighthouse Point (which was formerly fields), now known as "Lake Henry", has water snakes.

Should certain quarries, such as the one at Sheridan Point, be reactivated, there would be further loss of habitat. This is a major denning and birthing area (Campbell data). King (1986) obtained a population estimate of 138 adults, or 153 adults/km for 0.9 km of shoreline along the point.

Persecution, Predators and Competition

Numbers of water snakes have been occasionally collected on the Erie islands, and vehicle road-kills are a source of some mortality documented on Pelee Island (Campbell observations), but repeated slaughter by visitors and residents has likely contributed most to the species' decline. Conant (1982) records a systematic and, at the time apparently successful, extermination program on Rattlesnake Island, Ohio (but see footnote to Table 1). Populations on Middle Island, once a centre of abundance for this subspecies (Thomas 1949; Camin et al. 1954; Camin and Ehrlich 1958; Ehrlich and Camin 1960), have been clearly severely stressed. Ehrlich and Camin (1960) provided this sad comment:

> We regret to report that Middle Island, which was uninhabited for many years, is now once again occupied in the summer months. A campaign of extermination is being waged against the snakes, and for this reason we felt it would be foolish to initiate our planned program of marking and releasing snakes for long-term study

> Conant and Clay (1963) commented that
> Recent reports indicate that persecution by human predators is severe, and water snakes are becoming scarce, especially on those islands where there are concentrations of people in the summer months.

Major non-human predators on the Lake Erie Water Snake are presumed to be herons, gulls, and raptors (Camin et. al. 1954; Camin and Ehrlich 1958; Erlich and Camin 1960; Cliburn 1961). These birds were thought to prey on young water snakes swimming or exposed on rocks or otherwise in the open. Predation would logically be greater on banded or partly banded young snakes because they would be more conspicuous than grey ones against the shorelines. Differential selection could offset the effects of migration of banded forms from the mainland. This has often been used as a classic example natural selection in action (Ford 1975; Stebbins 1977; Futuyma 1979; King 1987b).

In decreasing order of abundance the herons which nest on the Canadian Erie Islands are: Black-crowned Night Heron, Great Blue Heron, Green Heron, Cattle and Great Egrets, and presumably the American Bittern. The egrets increased in the 1970s, while the night herons appeared to be decreasing (Campbell, unpublished data). The Night, Green and Great Blue herons, Great Egrets, and the American Bittern consume snakes elsewhere (Bent 1926: 208, 109, 190, 140, 78).

Herring Gulls, numerous about the Erie Islands, will also prey upon young water snakes (Camin et al. 1954; Camin and Ehrlich 1958), even taking snakes up to one metre long (Goldman 1971). In 1976, a Ring-billed Gull was observed capturing a young water snake (Campbell, unpublished data). Other island birds which may occasionally capture these snakes are the Double-crested Cormorant; and certain raptors, such as the Red-tailed and Red-shouldered Hawks and Osprey (Forbush and May 1939: 107; 109; 122).

King (1987b), however, found little evidence of contemporary extensive predation by birds. He cites analysis of the stomachs of nearly 800 herons and gulls (compiled by him from Ligas 1952; Jarvis and Southern 1976; Hoffman and Curnow 1979) where only one water snake was found. An experimental study with small and medium-small unbanded and banded models showed no significant difference between models in attempted predation in a field situation in shoreline habitat (King 1986). In an analysis of young and adult snakes collected in 1980-1984, King (1986) could not find a significant difference between their morph ratios and questioned the earlier hypothesis of differential survival of unbanded and banded forms.

Feral cats, which are common on Pelee Island, and the Blue Racer (Coluber constrictor foxii), which occurs sparingly there may account for minor additional predation. King (1986) cites an observation of a 105 cm (snout-vent length) Racer on Kellys Island eating an Island Water Snake that was 56 cm snout-vent length. Naturally occurring

mammalian carnivores do not seem to be plentiful on the islands. Fish may also be predators on young water snakes.

King (1986) analyzed the incidence of scarring as evidence of attempted, but unsuccessful, predator attacks and found nearly 17% of juvenile and adult snakes had scars or stub tails. However, these occurred with equal frequency among morphs suggesting that the predation attempts which may have caused them were not selective for one type or another.

The increasing numbers of some herons, like the egrets, and of gulls, might increase competition for a decreasing Lake Erie fish stock. Competition from other reptiles and mammals is not likely significant, on Pelee Island at least, since very few species which primarily eat fish occur on the island (Campbell observations).

The effects of large numbers of Carp (Cyprinus carpio) roiling the shallow waters, and increasing turbidity, and algal "blooms" in Lake Erie, might affect the foraging success of Nerodia, but no data are available.

Environmental Contamination

Aquatic-feeding snakes have shown higher pesticide residue levels than terrestrial ones (Fleet and Plapp 1978). Some species of Nerodia may survive even in areas of high residues of insecticides and PCB's. High activity of detoxifying enzymes in known for some species (Stafford et al. 1976). Paralysis and death of Nerodia may occur from sprays of DDT and oil, or from ingestion contaminated fish (Herald 1949). A Nerodia sipedon from Ohio had DDT-C1-36 residues up to 6.01 p.p.m. (Peterle 1966). In a study of DDT residues in the fat of aquatic animals, Nerodia sipedon had the highest amount, one specimen containing 364 p.p.m. (Meeks 1968). Four "Plain-bellied Water Snake" carcasses, found dead 3 weeks after treatment with Heptachlor Epoxide, had 113 p.p.m. of this pesticide (DeWitt et al. 1960). However, only traces of HE were found in Pelee Island Nerodia (0.01-0.04) (DeWitt et al. 1960).

Special Significance of the Subspecies

The taxonomic and evolutionary significance of this form has resulted in its wide discussion in the scientific literature. It has been an often used "text-book" example of polymorphism maintained by a balance between natural selection and migration (Ehrlich and Holm 1963; Ehrlich et al. 1974; Ford 1975; Hedrick et al. 1976; Stebbins 1977; Futuyma 1979; Ehrlich and Erlich 1981; King 1985). However, many unanswered questions and conflicting views about it remain.

Conant and Clay (1937) in naming the form as a subspecies suggested that isolation was important to the survival of the patternless (insularum) snakes on the archipelago and attributed the presence of a few banded (sipedon) individuals on the islands to migration from the mainland. Camin et al. (1954), Camin and Erlich (1958, 1977), and Erlich and Camin (1960) hypothesized that selective predation on banded snakes on the exposed rocky island shores balanced the effects of emigration from the mainland. On the mainland where shoreline habitats are generally more vegetated the banded form was judged to be more cryptic to predators. The banded pattern was more common in samples of newborns and less frequent in adult samples (Camin and Erlich 1960). Cliburn (1961) argued that the

water snakes on the islands were merely "an aberrant adult population of sipedon", and therefore subspecific recognition was not warranted. He contended that, as Nerodia are strong swimmers, the distances between the mainland and the islands of the archipelago constitute too narrow and imperfect a barrier to allow isolation from the influence of banded form.

Conant and Clay (1963), by pooling unbanded and intermediate patterns, showed that 89.1 per cent of 1258 individuals from the islands were distinct from the typical banded sipedon and argued that subspecific status was fully justified for the island form regardless of what factors maintained the observed frequencies. Camin and Ehrlich (1979) defended the hypothesis of selection in N. s. insularum against the contention of Pasteur (1977, 1979) that "snake migration could [not] be so great that it alone could balance the effects of bird predation."

King (1986: Table 5) demonstrated a change in the relative proportions of pattern types on the islands based on comparison of his 1979-1984 data with previous published studies and with museum collections. The proportion of banded snakes had clearly increased on Kellys and Middle Bass islands in Ohio and on Pelee and Middle islands in Ontario. This trend was also evident in 1989-1990 samples from Pelee and Middle islands; and although early samples are not available, East Sister Island also has a predominance of banded snakes now (King, unpublished data).

King (1986) concluded that selection pressure was now weak in the archipelago and that the reduction in numbers of snakes may have allowed the migration of banded morph from the mainland to have a greater effect than it had previously. He was not able, however, to demonstrate that emigration, either from the mainland or between islands, actually occurs (King 1986).

The origin of the patternless form has been only casually examined. Conant and Clay (1937: 8) suggested that "insularum and the mountain specimens of similar appearance may represent relics of an ancient wide-ranging form whose origin may or may not have been in sipedon" but this idea has received no further attention. There is implicit in the subsequent work an acceptance that the origin was simply as a chance mutation that then became common in the population. However, past hybridization of another species with a sipedon stock can not yet be rejected as a source of the patternless form. Large shifts of ranges likely occurred during both Wisconsin glaciation and post-glacial range expansions. The Lake Erie archipelago is well documented for the occurrence of extensive hybridization in the salamander genus Ambystoma (Bogart et al. 1985). A related water snake, Nerodia erythrogaster, is patternless, and one subspecies, N. e. neglecta Conant (1949), still occurs in disjunct populations in southern Michigan and northeastern Ohio (Conant 1975). Although it could have had a more northern range during a warmer period, the present variation makes it an unlikely direct source of a patternless gene in insularum. It is patterned at birth and loses this with maturity, whereas type A insularum is patternless at birth. Also, N. e. neglecta is dark brown or black, not gray, dorsally, and this pigment tends to invade the edges of the ventrals. It has an unpatterned venter as do some N. s. insularum, but this is red or orange-red in colour. Other races of N. erythrogaster do show gray dorsal colour and sometimes yellowish venters but they now occur south of N. e. neglecta (Conant 1949, 1975). However, the phenotypic expression of N. erythrogaster genes could be different

if introduced into the genome of N. sipedon and this has not yet been explored.

The inheritance of pattern types in Lake Erie Water Snakes has not been analyzed. Camin and Ehrlich (1958) presented separate histograms of the distribution of pattern type for 14 captive-born litters of females from the Bass complex (11) and Middle Island (3) together with the pattern type of the mother. However, in these data only one parent is known, and fertilization from a number of different males is possible for each litter. Two of 4 patternless females (type A) gave birth to litters without any type A young (Camin and Ehrlich (1958: Tables 5 and 6). Therfore a single dominent gene, which would have had to be expressed in some of the offspring, can be ruled out. Multiple genes, incomplete dominance, and recessives remain to be explored.

There is a somewhat parallel condition in a related natricine, the Common Garter Snake, Thamnophis sirtalis sirtalis. It also exhibits a geographically restricted unicoloured form in the same area, but this is black (melanistic). This morph is more widely distributed, being present not only on the archipelago but also in portions of the adjacent mainland, both at Point Pelee and further east on the lake, on Long Point. It has a frequency of as much as 59% in some populations (Gibson 1978; King 1988a). The melanistic morph is inherited in garter snakes as a single gene recessive to the normal striped pattern (Blanchard and Blanchard 1940). In contrast to the cryptic coloration explanation for survival of the insularum pattern, the black garter snakes are believed to be more conspicuous to predators then the normal form. It is hypothesized that black has, however, a thermoregulatory advantage in the habitat adjacent to Lake Erie area due to the thermal inertia of the lake which causes late cool springs: black snakes warm up faster and are more active at the critical time for breeding in these conditions (Gibson 1978; Gibson and Falls 1979, 1988; King 1988a).

Analysis of the degree of genetic variation in water snake populations in the Lake Erie region is underway but is still incomplete. However, earlier comparative studies on garter snakes may give some indication of the likelihood of gene flow in water snakes in the same area. Sattler and Guttman (1976) examined one albumin and 13 enzymatic loci electrophoretically in Thamnophis sirtalis. Samples containing both the melanistic morph and normal snakes taken on the southwest shore of Lake Erie near Bono were compared with samples from 130 km and 290 km to the south. No appreciable genetic differences were found either between black and normal or between these and populations to the south. They concluded that this indicated no significant genetic or geographical isolation between Lake Erie garter snakes and those to the south. This suggests that there are no physical barriers to gene flow for this species in the area, and this conclusion may apply also to the Lake Erie Water Snake which is probably at least nearly as capable of comparable dispersal. If so, this would favour the hypothesis that the uniqueness of the Lake Erie populations is maintained by natural selection rather than by geographical isolation.

Electrophoretic analysis of populations of Lake Erie Water Snakes is currently in progress by Robin Lawson, Osher Foundation Laboratory of Molecular Systematics, California Academy of Sciences, San Francisco, in cooperation with Richard B. King, as part of a larger study of the taxonomic relationships of Nerodia by Lawson. The extent of gene flow between islands and with the mainland populations will be accessed as part of these studies.

Evaluation

Because of its limited range and decreasing numbers, the Lake Erie Water Snake was listed by the Survival Service Commission of the International Union for Conservation of Nature and Natural Resources in the Red Data Book, Volume III (IUCN 1968, 1970, 1972).

The high level of scientific interest is demonstrated both by the number of papers published on these snakes, and their repeated use as a textbook example of the action of natural selection.

As well, almost all authors on Canadian reptiles in the past 30 years, since Cook (1964) first tentatively listed Canadian taxa of amphibians and reptiles in possible jeopardy, have indicated concern for the status of this form, listing it as uncommon, vulnerable or threatened (Cook 1970; 1977; Froom 1967; Campbell 1969; 1971; 1977a; 1977b; Simkin 1970; Stewart 1974; Canadian Wildlife Federation 1976; Federation of Ontario Naturalists 1976; Parsons 1976; Gregory 1977; McKeating and Bowman 1977; Bowman 1978; Cowan 1978).

The documented reduction in numbers of the Lake Erie Water Snake seems clearly due to human persecution and habitat modification. The uniqueness of the populations of these geographically semi-isolated snakes may be in jeopardy (King 1986). Although numbers on some islands in the Lake Erie Archipelago may still be greater than those for the species elsewhere in its range, populations have been seriously depleted on others. Diminished density may have made them vulnerable to genetic swamping by emigrating mainland water snakes (King 1986). On Pelee Island, fully banded snakes typical of mainland populations were absent in a sample of 36 water snakes reported by Conant and Clay (1937). Full banding was present in only 11 of 61 adult museum specimens (16%) collected between 1933 and 1961, but it was present in 71 of 171 (42%) adults examined in a mark-release study in 1980-1985 (King 1986), and 49 of 101 (49%) adults in 1989-1990 (King, unpublished data). However, the proportion of unbanded adults also increased between the 1980-1985 and 1989-1990 studies, from 12% to 20%, with a decline in intermediate snakes from 47% to 32% of the samples (King 1986 and unpublished data). On Middle Island the ratio in adult snakes of unpatterned:intermediate:banded snakes was 6:6:15 in 1980-1984 and 1:5:6 in 1990 (King 1986 and unpublished data). Collections from East Sister Island showed ratios of 0:1:2 in 1981-1983 samples and 0:4:6 in 1989-1990 (King 1986 and unpublished data).

If the 75% rule for recognition of subspecies is narrowly applied to present Canadian populations, Nerodia sipedon insularum could now be regarded as extirpated in Canada, and populations on Pelee, Middle and East Sister islands designated as intergrades, Nerodia sipedon sipedon x insularum. However, as Point Pelee is the type locality for the subspecies, it would be premature and confusing to take this step until further studies have been carried out. The influence of the grey and intermediate pattern types, which are the morphological markers for the subspecies, obviously remains strong, and if populations are allowed to build up again these patterns may be reasserted as the preponderant forms (King 1986).

This snake is too biologically interesting both in itself, and as one of several unique elements of the herpetofauna on these islands, to allow designation to be set aside by legalistic applications and taxonomic semantics. COSEWIC exists to designate status for unique populations at risk as well as subspecies and species, provided these populations are

geographically definable, at least semi-isolated, and at risk, as is the demonstrable the case here. As O'Brian and Mayr (1991) have pointed out in contrasting species and subspecies, interbreeding is a natural part of biological interaction between subspecies. Hybridization between intraspecific taxa should not diminish the need for population designation nor the priority attached to conservation of unique populations.

The recommended status is Endangered.

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Management Recommendations

- ON FILE WITH RANGE JURISDICTION -

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Fig. 1. The distribution of the Common Water Snake, Nerodia sipedon in North America: after Conant (1975). The large solid circle at the western end of lake Erie marks the distribution of the Island Water Snake, Nerodia sipedon insularum; cross-hatching shows the range of the Northern Water Snake, N. s. sipedon; dotted pattern the Midland Water Snake, N. s. pleuralis; and stippling the Carolina Salt Marsh Snake, N. s. williamengelsi.

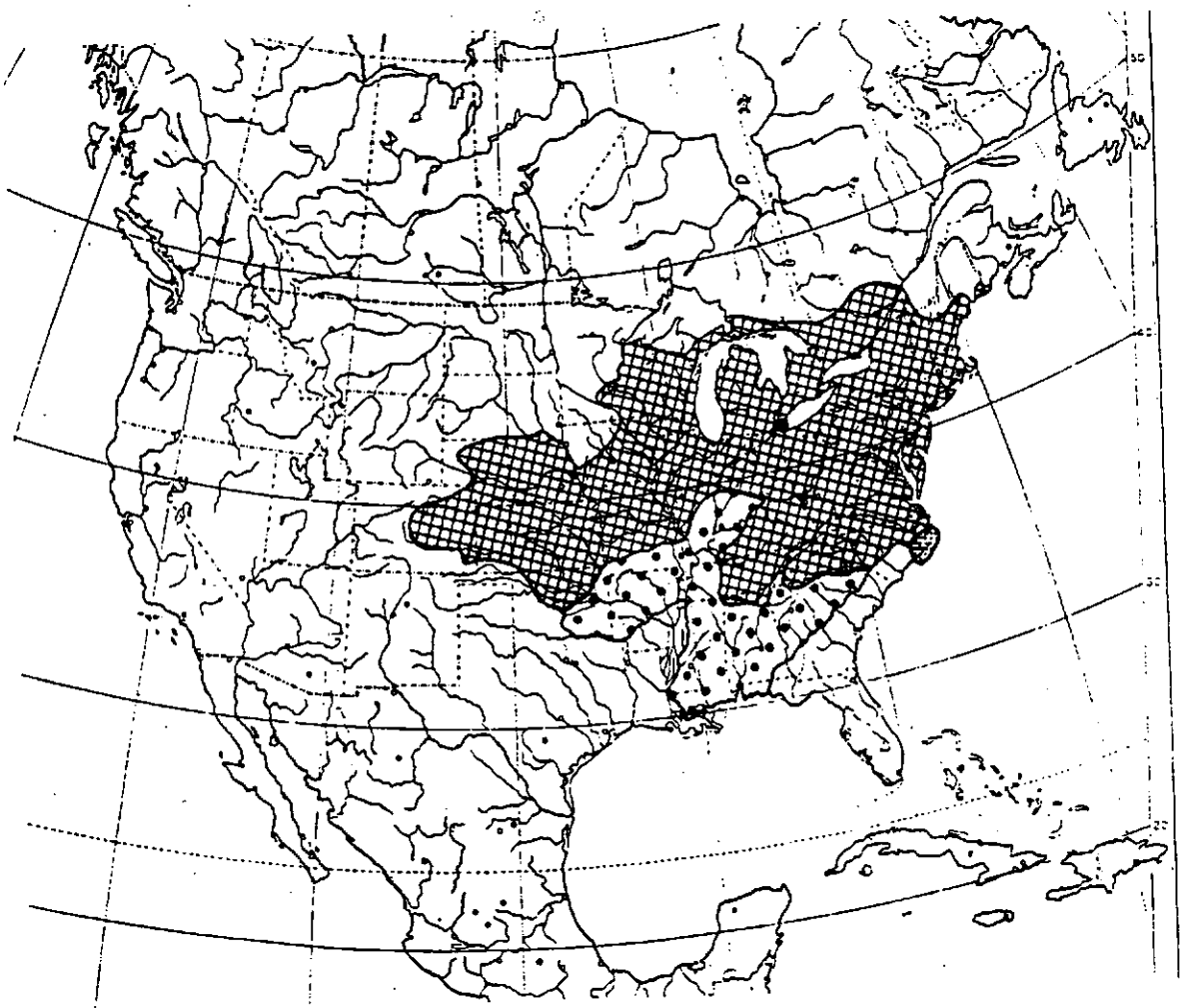

Fig. 2. Outline map of the major islands of the Put-in-Bay Archipelago, Ohio and Ontario, in the western end of Lake Erie. Point Pelee, Ontario, is in the upper right corner and the Catawba-Marblehead Peninsula, Ohio is in the middle at the bottom (from King, unpublished).

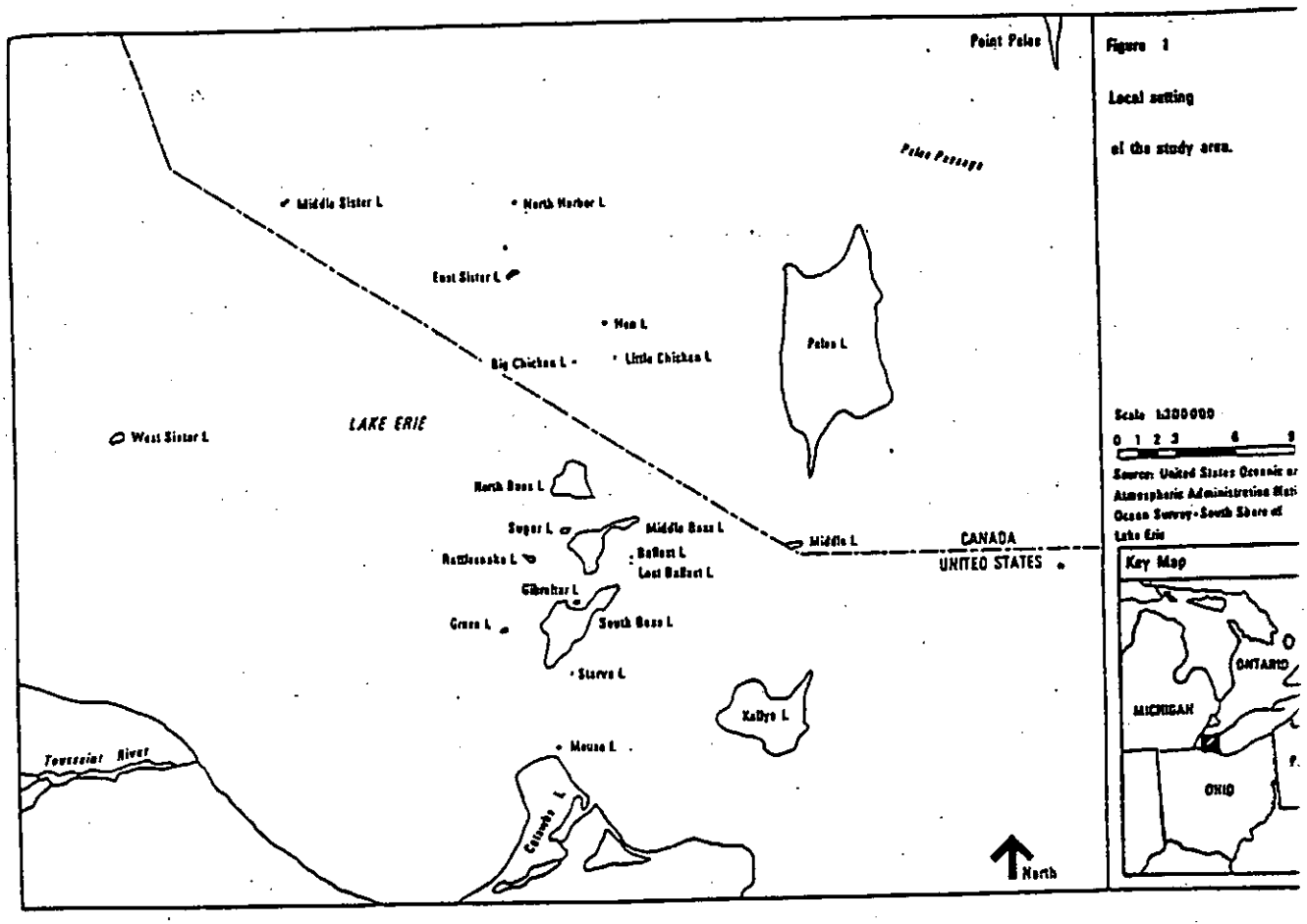

TABLE 1. Islands over 5 hectares in western Lake Erie where N. s. insularum has been recorded, based on King (1987a, 1987b, 1988b). On 6 other islands less than 5 hectares each, water snakes may also be absent or occur only in very small numbers. These were not searched in the initial years of study by King (1986) but see footnote.

Island	Area (hectares)	Remarks
OHIO		
Kellys	1169	
South Bass	673	
Middle Bass	300	
North Bass	282	
West Sister	28	None in 70 h searching (King 1986)
Johnsons	27	
Rattlesnake	24	Complete eradication (Conant 1982)*
ONTARIO:		
Pelee	4091	Type locality
East Sister	26	
Middle	21	

* Based on 1989 and 1990 field work, King (unpublished data) established that there are now water snakes on Rattlesnake Island and that they also occur on Sugar Island in Ohio. They also occur in Ontario on Hen Island but were not found on Middle Sister or North Harbour islands in searches during 1989-1990 (King, unpublished data).

TABLE 2. 1984-1986 Canadian observations published by the OHS.

Year	Island	Number	Source
1984	Middle	2	Oldham and Sutherland (1986)
	Pelee	20	
1985	Pelee	30	Oldham (1988)
1986	Pelee	50	Weller and Oldham (1988); and Oldham and Weller (1989)
	East Sister	1	
	Hen	6	

Although King (in Weller and Oldham 1988) remarked that those from Hen Island were the first from this locality, Campbell (1976, 1977a, 1977b) had noted earlier reports.

TABLE 3. Museum specimens larger > 27 cm snout-vent for which there were sizable samples (7-33) collected over relatively short intervals (3-13 years). Data from King 1987b.

		1933-37	1947-50	1959-61	Total
Pelee		21	33	7	61
			1945-58		
Middle			16		16
	1893-1901	1930-40	1948-53		
South Bass	9	21	21		51