

**LAKE ERIE WATER SNAKE ABUNDANCE AND HABITAT USE:
IMPLICATIONS FOR RECOVERY**

Project SG 196-03

**Final Report
to the
Ohio Lake Erie Commission**

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INTRODUCTION

A small grant from the Lake Erie Protection Fund of the Ohio Lake Erie Commission (SG 196-03) was provided to the Ohio Department of Natural Resources Division of Wildlife for research on the Lake Erie water snake, *Nerodia sipedon insularum*. Research was conducted under the direction of Dr. Richard B. King through a subcontract from the ODNR Division of Wildlife to Northern Illinois University. This document represents a final report to the Ohio Lake Erie Commission summarizing results obtained under this grant.

The Lake Erie watersnake occurs only on islands in western Lake Erie, giving it one of the most restricted distributions of any North American vertebrate taxon. Differences in color pattern between island populations of the Lake Erie watersnake and mainland populations of the northern watersnake (*N. s. sipedon*) provide a textbook example of the ways in which natural selection and gene flow influence population differentiation (King and Lawson 1997). However, its insular nature makes the Lake Erie watersnake vulnerable to population declines due to human activities and natural processes. Population declines during the mid- to late-1900's resulted in the Lake Erie watersnake being listed as endangered in Ontario in 1977, threatened in the U.S. in 1999, and endangered in Ohio in 2000. The research summarized here addresses two strategic actions of the *Lake Erie Protection & Restoration Plan*:

- B-2 Complete the inventory initiative of the Biological Diversity Strategic and Implementation Plan emphasizing identification of rare and endangered species and their habitat areas
- B-4 Maintain or restore viable populations of Lake Erie water snakes, institute specific management programs, identify and protect essential habitat refuge

Specific objectives were to:

1. Locate and characterize hibernation sites used by adult Lake Erie water snakes.
2. Characterize seasonal activity patterns of Lake Erie water snakes, especially the timing of entry into and emergence from hibernation.
3. Characterize movement patterns and habitat characteristics of adult Lake Erie water snakes throughout the active season.
4. Generate updated estimates of adult population size for Lake Erie water snakes.

Results pertaining to each of these four objectives are provided in the following sections.

LOCATION AND CHARACTERISTICS OF HIBERNATION SITES USED BY ADULT LAKE ERIE WATER SNAKES

A total of 61 adult Lake Erie water snakes were monitored using radiotelemetry between 2000 and 2003. Included were 26 males ranging in size from 118 – 347 g and 37 females ranging in size from 306 – 954 g. Detailed information about snake characteristics, surgical techniques dates of surgery and release, and monitoring can be found in King 2003. Measurements used to characterize the location of hibernation sites and movement patterns are shown in Fig. 1).

Data on hibernation sites were obtained for 49 individual Lake Erie water snakes (27 females, 22 males). Hibernation sites were located for two snakes in each of three years, for 10 snakes in each of two years, and for 36 snakes in a single year each. With one exception, snakes for which

hibernation sites were located in successive years consistently used the same hibernation location (within 10 m and often less). For these snakes, information on hibernation sites was pooled across years. In contrast, female E66 used hibernation sites separated by about 220 m in 2001 and 2002. These two hibernation sites were treated separately in the analyses below – thus, these analyses are based on 50 hibernation sites.

Of the 50 hibernation sites, 30 were located directly inland from shoreline areas used during the summer active season (details in table 2 of King 2003). The other 20 hibernation sites were located inland from shoreline areas outside of the extent of shoreline used during the summer active season (Fig. 1). To reach these hibernation sites, snakes apparently moved between 35 and 1410 m along the shore (estimated using ArcView) prior to selecting a hibernation site.

The distance between hibernation sites and shore was measured using a tape measure or distance-measuring wheel. Distance to shore exhibited a right-skewed distribution (Fig. 2) and was normalized by computing natural logarithms. Distance to shore did not differ significantly between males and so the sexes were pooled to generate a population-wide description of this variable. Distance to shore ranged from 1 – 580 m among individuals and averaged 27 m (back transformed from natural logarithms). The estimated upper limit for distance to shore for specific fractions of the population were: 50% of the population hibernated within 27 m of shore, 75% hibernated within 69 m of shore, 90% hibernated within 161 m of shore, 95% hibernated within 267 m of shore, and 99% hibernated within 700 m of shore (Fig. 2). The elevation above lake level of the ground surface over hibernating snakes was estimated to range from 1 – 10 m.

Characteristics of hibernation sites were variable. Most had soil and rock substrates and appeared to consist of natural openings or fissures. Access holes to some hibernation sites were apparent and may have been the result of burrowing by small mammals, shoreline erosion, or tree falls. In addition, some hibernation sites were found in or near human-made structures (e.g., in or near the remains of stone building foundations; near drainage tiles or sewer lines; in or near concrete shoreline protection, patio, or wall; the rock foundation of a cottage; inside an abandoned wine cellar. Vegetation around hibernation sites was also variable and included mature forest, woody scrub, and grass/herbaceous vegetation (sometimes including mown lawns).

SEASONAL ACTIVITY PATTERNS OF LAKE ERIE WATER SNAKES WITH SPECIAL REFERENCE TO THE TIMING OF ENTRY INTO AND EMERGENCE FROM HIBERNATION

Estimated dates of entry into hibernation were generated as follows. The latest date in the fall that each snake was observed within its summer active area and the earliest date that each snake was observed near its hibernation site were recorded. The mid-point between these dates was then used as an estimate of the date of entry into hibernation. Similarly, the latest date in the spring that each snake was observed near its hibernation site and the earliest date that each snake was observed within its summer active area were recorded. The mid-point between these dates was then used as an estimate of the date of emergence from hibernation.

Dates of entry into hibernation were estimated for a total 59 hibernation events. Dates of emergence from hibernation were estimated for a total of 28 hibernation events (the smaller

sample size for emergence reflects the fact that some snakes died in hibernation). Dates of entry into and emergence from hibernation did not differ significantly between sexes or among years (although sample sizes are small). Dates of entry into hibernation ranged from 12 September to 17 October (Fig. 3). Dates of emergence from hibernation ranged from 27 April to 31 May (Fig. 3). Comparison of these dates with mean daily minimum and maximum air temperatures (based on NOAA records for Put-in-Bay, Ohio; 1971–2001) suggests that entry into hibernation starts when the mean minimum daily temperature drops to about 60° F (Fig. 3). Entry into hibernation is largely complete by the time mean maximum daily temperature no longer rise above 60° F (Fig. 3). Emergence from hibernation starts when mean maximum daily temperature first exceeds 55° F and is largely complete by the time mean minimum daily temperature exceeds 57° F (Fig. 3).

MOVEMENT PATTERNS AND HABITAT CHARACTERISTICS OF ADULT LAKE ERIE WATERSNAKES THROUGHOUT THE ACTIVE SEASON

Data on movement patterns during the summer active season were obtained from 56 individual Lake Erie water snakes (34 females, 22 males). Data were obtained from five snakes during three summers and from 21 snakes during two summers. Locations used by individual snakes were recorded 5 – 18 times per active season (5 – 37 times across all active seasons). Each time a snake was located, GPS coordinates were recorded using a handheld Garmin *etrex* GPS receiver. GPS locations were plotted onto Digital Orthophoto Quarter Quadrangles (DOQQ) using ArcView GIS software. Amount of shoreline utilized during the summer active season was determined by using ArcView to estimate the maximum extent of shoreline between the any two locations used by a snake during the active season (Fig. 1). For snakes monitored during multiple summers, the maximum extent among all active season locations (regardless of year) was determined.

The distance each snake was from shore was estimated or measured using a tape measure or distance-measuring wheel each time a snake was located. Analysis focused on the maximum distance each snake was ever observed from shore during this time period (Fig. 1). For snakes monitored during multiple summers, the maximum distance in any summer was used for analysis.

Maximum extent of shoreline used and maximum distance to shore both exhibited right-skewed distributions (Fig. 4 & 5). Both variables were normalized for analysis by computing natural logarithms. Neither variable differed significantly between males and females. Therefore, the sexes were pooled to generate a population-wide description of active season movements.

Snakes consistently used the same areas during successive summers. Maximum extent of shoreline used ranged from 30 – 1360 m among individuals and averaged 252 m (back transformed from natural logarithms). The estimated upper limit of the extent of shoreline used by specific fractions of the population were: 50% of the population used 252 m or less, 75% used 437 m or less, 90% used 714 m or less, 95% used 960 m or less, and 99% used 1674 m or less (Fig. 4). Given that snakes were not monitored continuously and that some individuals were

monitored for only a portion of the active season, these distances may underestimate the true extent of shoreline used during the active season.

Maximum distance to shore ranged from 1 – 50 m among individuals and averaged 8 m (back transformed from natural logarithms). The estimated upper limit of the maximum distance from shore for specific fractions of the population were: 50% of the population ranged up to 8 m, 75% ranged up to 13 m, 90% ranged up to 21 m, 95% ranged up to 27 m, and 99% ranged up to 47 m (Fig. 5).

UPDATED ESTIMATES OF ADULT POPULATION SIZE FOR LAKE ERIE WATER SNAKES

Since 1980, water snakes have been individually marked by scale clipping and/or through the use of passive integrated transponders (PIT tags). Several techniques are available by which population size can be estimated from this kind of information (Caughley 1977). In general, these techniques involve marking and releasing animals during an initial census and recording the numbers of marked and unmarked animals in subsequent censuses. Techniques used here include Lincoln-Petersen, Schumacher-Eschmeyer, Bailey Triple-catch, and Jolly-Seber methods. Different methods have somewhat different data requirements and make somewhat different assumptions. Use of multiple methods of estimation is especially warranted when it is unknown how well assumptions are met.

Population estimates based on mark-recapture data from 1980 – 2003 can be found in King (2002). Updated estimates are currently being generated using data collected May – October 2003. A total of 1085 adult Lake Erie water snakes captures were recorded during 2003. Of these, 301 were recaptures of individuals marked in previous years or during earlier censuses within the 2003 field season. Most of these captures come from 7 long-term study sites on 4 islands (Table 1).

OTHER SIGNIFICANT OUTCOMES

Temporal Variation in Body Size, Growth Rate, and Diet Composition. – Data or now available from nearly yearly censuses of Lake Erie water snake populations from 1980 to the present. Julie Ray, a master's student at Northern Illinois University, has used these data to demonstrate significant year-to-year variation in snake morphology (maximum body size, condition) and growth rate. This variation does not correlate with weather conditions but instead appears to reflect the effect of a recent invader, the round goby. The round goby was first documented in Lake Erie in the early 1990's (Jude et al. 1992) and has since become the dominant bottom-dwelling fish in the island region. By 1998, gobies constituted 24% of the prey consumed by Lake Erie water snakes (King 1993, King et al. 1999). Recovery and identification of more than 140 prey items during 2003 revealed that gobies now constitute more than 92% of water snake prey – almost completely replacing native fishes from water snake diets. Furthermore, Ray's analyses demonstrate that Lake Erie water snakes achieve greater maximum adult body size and grow more rapidly since the goby invasion. Kristin Stanford, a PhD student at NIU, is using this long-term data set to test whether survivorship has also increased.

Lake Erie Water Snake Contaminant Analysis. – Change in water snake diet from native fish to round gobies causes concern about increased bioaccumulation of environmental toxins. Gobies feed on zebra mussels which themselves are filter feeders, increasing possible toxin uptake. During census work in May and June 2003, blood samples (up to 1 ml) were collected from 83 adult Lake Erie water snakes at eight locations on four islands. Samples were collected from at least five adult males and five adult females at each site and were separated into plasma and red blood cell components. Plasma samples will be pooled to produce 16 1.5 ml samples (males and females at each of 8 sites) and analyzed by the Canadian Wildlife Service to determine levels of PCBs and related compounds (Bishop and Rouse 2000).

U.S. Fish and Wildlife Service Lake Erie Watersnake Recovery Plan. – Researchers and ODNR Division of Wildlife staff worked cooperatively throughout 2003 to draft a recovery plan for the Lake Erie water snake. A draft recovery plan was approved in May 2003. Following public comment, peer review, and revision, this plan was approved in September 2003 (U. S. Fish and Wildlife Service 2003). Three criteria for delisting the Lake Erie watersnake were specified in this recovery plan. The first of these, *Population Persistence*, sets overall and island-specific population size requirements for the U.S. islands. The second criterion, *Habitat Protection and Management*, sets overall and island-specific habitat protection requirements. The third criterion, *Reduction of Human-induced Mortality*, seeks to reduce intentional and accidental human-induced mortality to the point where such mortality no longer represents a significant threat. Many of the results reported here were central to the development of these recovery criteria. Furthermore, these results have contributed to the development of habitat management plans being implemented by the ODNR Division of Parks and Recreation and in a USFWS approved Habitat Conservation Plan and available for use by private land owners.

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Table 1. Captures of adult Lake Erie water snakes during 2003 for use in generating population estimates. Estimates are based on recaptures of marked snakes from one day to another (day-to-day estimates), from one month to another (month-to-month estimates) or from one year to another (year-to-year estimates). Shown is the number of captures from 2003 to be used in generating these estimates.

Island	Site	Day-to-day Estimates		Month-to-month Estimates		Year-to-year estimates
		Daily Census Dates	Number of Captures	Monthly Census Dates	Number of Captures	Number of Captures
North Bass	South Shore					57
Kelleys	South Shore	1 June	16	early June	61	116
		2 & 4 June	19	late June	11	
		6 June	26	July August	34 10	
Kelleys	Southeast Shore	1 June	38			118
		2 June	43			
		6 June	37			
Middle Bass	State Park	26 May	24			73
		29 May	34			
Middle Bass	West End	26 May	33			76
		29 May	43			
South Bass	State Park	27 May	35	May	57	296
		30 May	22	July	98	
		9 & 10 July	72	August	33	
		15 & 17 July	26	September	108	
		15 August	21			
		18 & 19 August	12			
South Bass	East Shore	27 May	44	May	90	104
		30 May	46	July	10	

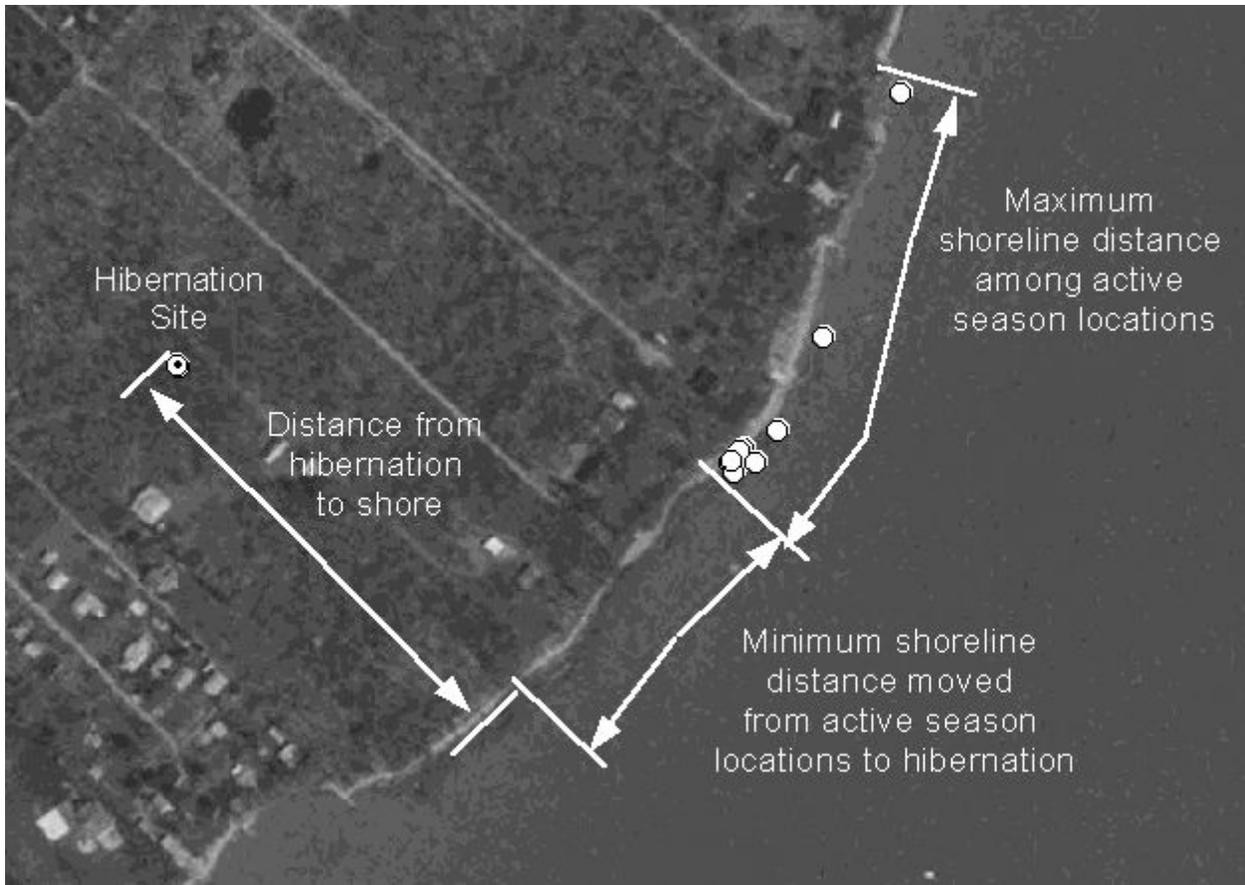


Figure 1. Movements of a representative Lake Erie water snake (female F7D), illustrating 'Maximum shoreline distance among active season locations', 'Minimum shoreline distance moved from active season locations to hibernation', and 'Distance from hibernation to shore'. Open circles are locations at which this snake was found between 19 June 2001 and 12 October 2001 (active season locations) and were recorded using a handheld GPS receiver. The 'bullseye' represents the hibernation site where this snake has remained since 23 October 2001. Maximum shoreline distance among active sites for this snake was 260 m. Sometime between 12 October and 23 October 2001, this snake moved about 135 m along the shore beyond where it spent the active season (= 'Minimum shoreline distance moved from active season locations to hibernation') and 280 m inland (= 'Distance from hibernation to shore') to hibernate.

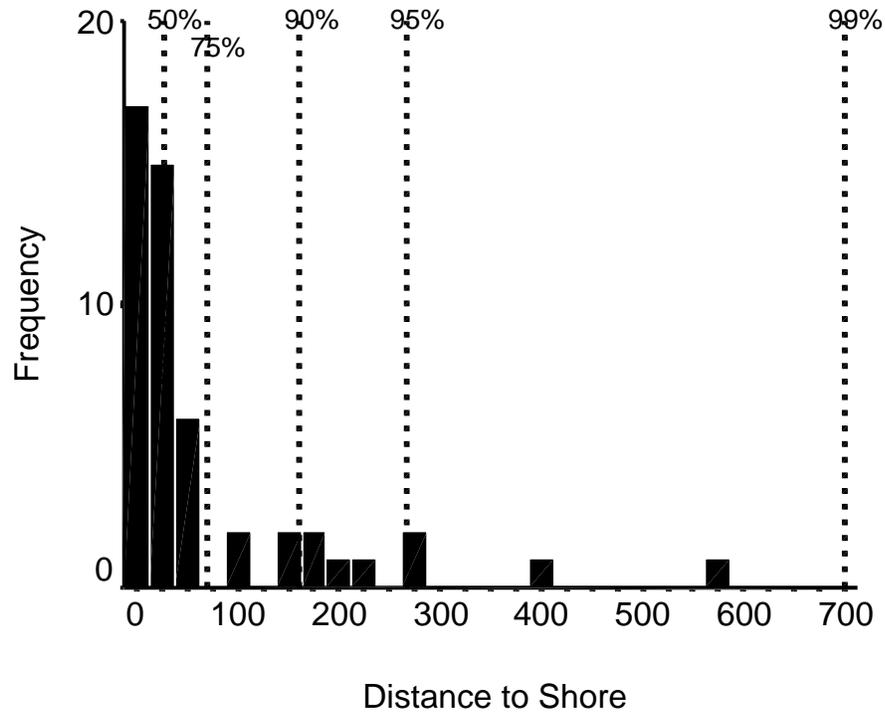


Figure 2. Distance from hibernation site to shore for 51 hibernation sites used by 50 adult Lake Erie water snakes monitored using radio telemetry. Distance ranged from 1 – 580 m and averaged 27 m (back transformed from natural logarithms). Dashed lines show the estimated upper limit of the maximum distance from shore for specific fractions of the population: 50% of the population hibernated within 27 m of shore, 75% hibernated within 69 m of shore, 90% hibernated within 161 m of shore, 95% hibernated within 267 m of shore, and 99% hibernated within 700 m of shore.

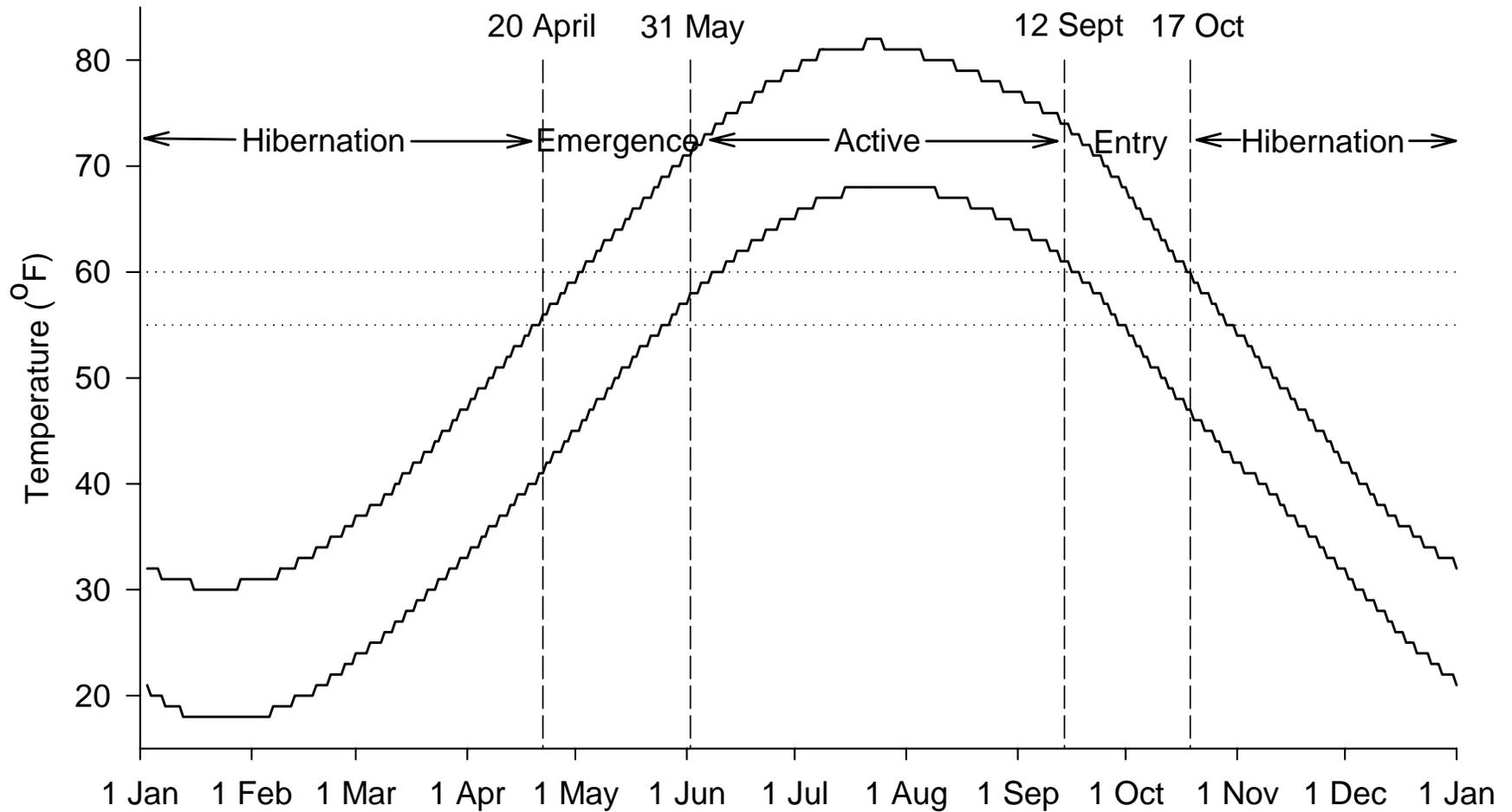


Figure 3. Estimated dates of hibernation, emergence from hibernation, summer activity, and entry into hibernation by adult Lake Erie water snakes. Also shown is the mean daily minimum temperature (lower solid line) and mean daily maximum temperature (upper solid line) for Put-in-Bay, Ohio 1971 – 2000 (from <http://www.ncdc.noaa.gov/oa/climate/normal/usnormals.html>). Vertical dashed lines delimit approximate dates of emergence from and entry into hibernation. Horizontal dotted lines correspond to 55° and 60° F.

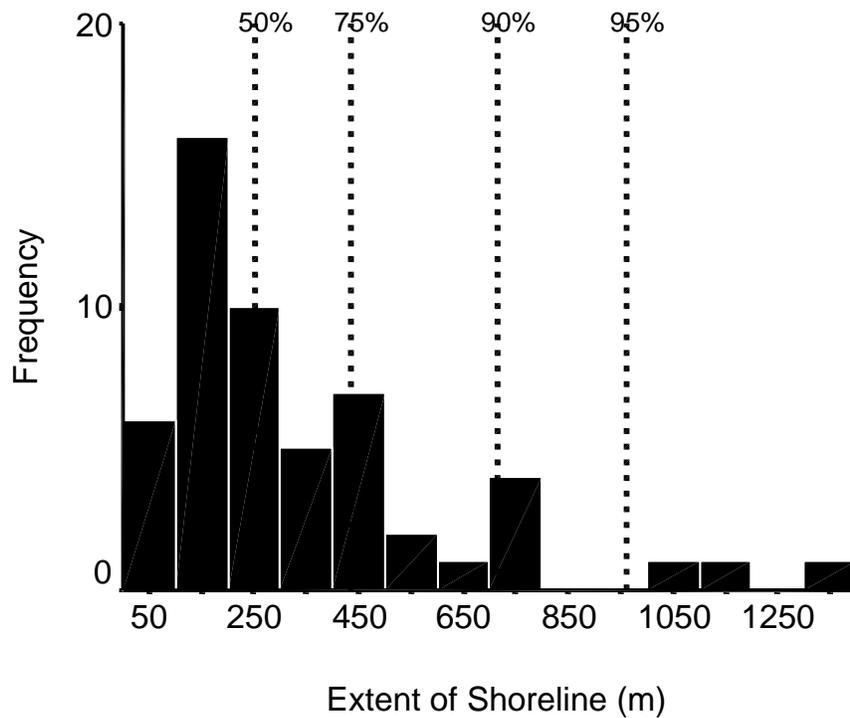


Figure 4. Extent of shoreline used during summer active seasons by 54 adult Lake Erie water snakes monitored using radio telemetry. Shoreline use ranged from 30 – 1360 m among individuals and averaged 252 m (back transformed from natural logarithms). Dashed lines show the estimated upper limit of the extent of shoreline used by specific fractions of the population: 50% of the population used 252 m or less, 75% used 437 m or less, 90% used 714 m or less, 95% used 960 m or less, and 99% (not shown) used 1674 m or less.

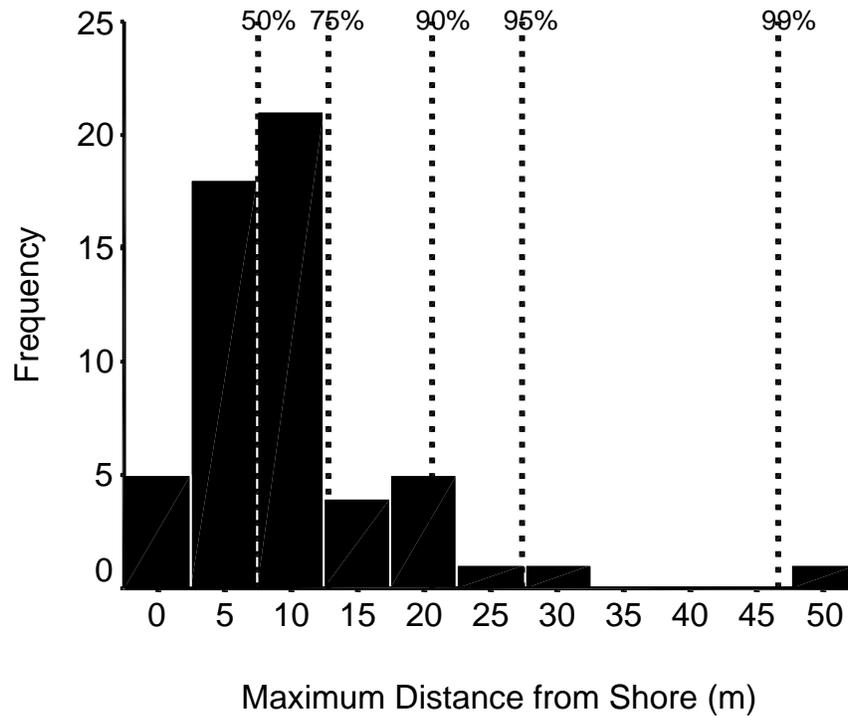


Figure 5. Maximum distance from shore moved during the summer active seasons by 50 adult Lake Erie water snakes monitored using radio telemetry. Maximum distance ranged from 1 – 50 m among individuals and averaged 8 m (back transformed from natural logarithms). Dashed lines show the estimated upper limit of the maximum distance from shore for specific fractions of the population: 50% of the population ranged up to 8 m, 75% ranged up to 13 m, 90% ranged up to 21 m, 95% ranged up to 27 m, and 99% ranged up to 47 m.