

Surveys for the Northern Ring-necked Snake
(*Diadophis punctatus edwardsii*) in Northeastern Minnesota:

Final Report

(Per Annual Plan Agreement 3000022980)

Prepared by: Gary S. Casper, Ph.D.
Great Lakes Ecological Services, LLC
P.O. Box 375, Slinger, WI 53086

Prepared for: Carol Hall, Amphibian and Reptile Specialist
MN DNR - Minnesota County Biological Survey
500 Lafayette Rd, Box 25, St. Paul, MN 55155

November 21, 2012



Northern Ring-necked Snake (*Diadophis punctatus edwardsii*), St. Louis County, MN. Photo by G.S. Casper

1. SUMMARY

The Northern Ring-necked Snake (*Diadophis punctatus edwardsii*) is a little known small reptile that reaches the northern limit of its range in northeastern Minnesota, where it has been recorded from only a few St. Louis and Lake county locations (Oldfield and Moriarty 1994; Carol Hall, personal communication 2012). It is a small, fairly secretive, animal with fossorial habits, and is often overlooked in biological surveys. In 2011, surveys performed for the Lake Superior Binational Program documented a few more records for this species in Lake County (G. Casper unpublished data). This study further evaluates known records in northeastern Minnesota, reports on surveys in May, June, July and September 2012, and discusses habitat features that may be important to the species. In sum, Northern Ring-necked Snakes are distributed from northern Carlton County (Jay Cooke State Park) to southwestern Cook County, with records hugging the north shore of Lake Superior, where climate moderation may explain the northern range limits. The maximum confirmed distance from the lake is approximately 5 miles (specimen GSC 787). The distribution of populations in this region is probably more or less continuous, although there are gaps expected where habitat conditions are less suitable and in developed areas (i.e., greater Duluth). More southern outlying records in Pine County may be disjunct or not – more surveys are needed in this area to assess distribution extent. Additional gap surveys are also warranted in southeastern St. Louis County (between Duluth and the county Two Harbors), south-central Lake County (between Two Harbors and Gooseberry Falls State Park), southeastern Lake County (between Tettegouche State Park and the Cook County line), and in southwestern Cook County (to determine the northern range limit). The status of populations remains unknown. Northern Ring-necked Snakes are certainly encountered much less frequently than the other two native snakes (Common Gartersnake, Northern Red-bellied Snake) on surveys in this area (G. Casper unpublished data). Whether this means they are less abundant, or simply less detectable due to differing or more secretive habits, is unknown. Several populations on public lands have been identified in this study which could be used to determine demographic parameters and conservation status through mark-recapture studies. Such studies are recommended in order to obtain baseline data for status assessment, and for monitoring the effects of ongoing climate change on the species.

2. METHODS

Museums (via www.herpnet.org), local naturalists, Minnesota State Park naturalists, the North American Field Herp Forum (www.naherp.com), and the Minnesota County Biological Survey were canvassed for Northern Ring-necked Snake records from Carlton, Cook, Lake, St. Louis and Pine counties. Most reported locations were then visited to conduct visual surveys, generally following the Lake Superior protocol for timed terrestrial searches (Casper and Hecnar 2011a), and usually searching complete habitat areas. Additional gap surveys were performed by searching for suitable habitat and surveying where accessible, and by road cruising. Road cruises were performed in September when snake migrations were underway to winter denning sites, and conducted when snakes were most likely to be moving (warm sunny days after cool nights). Weather conditions, habitat notes, and time spent were recorded on searches, and GPS coordinates taken (Appendices

A, B). Given the very large geographic area to be covered, and past experience in finding Northern Ring-necked Snakes most reliably in old quarries, along road cuts, and in beaver pond meadows, quarries were mapped from topo maps (Appendix C) and as many as possible were visited, while also searching other suitable habitat as encountered. Setting cover objects at some sites was considered, with surveys conducted by interested local volunteers following the Lake Superior protocol (Casper and Hecnar 2011b), but available volunteers were limited to the Wolf Ridge Environmental Learning Center (ELC), where snake surveys are being utilized in educational curricula. In addition, some state park naturalists and rangers agreed to watch for Northern Ring-necked Snakes and document any found. Therefore, given the time and funding available, the focus of this study was on visual searches of suitable habitat areas utilizing existing natural and anthropogenic cover items on the landscape (rocks, logs, mulch, and discarded items such as old carpet, silt fabric, metal and wood). This allowed for many more sites to be visited. Some tar paper cover objects were set on the first survey visit at sites where subsequent visits were planned. Voucher specimens and photographs were preserved where appropriate and have been deposited in the James Ford Bell Museum (JFBM) of Natural History at the University of Minnesota, Minneapolis.

The definition of suitable habitat to guide surveys was based on the author's experience with the species in Minnesota, Wisconsin and Upper Michigan, and published habitat descriptions (Vogt 1981, Oldfield and Moriarty 1994, Harding 1997, Holman 2012). The literature suggests that cool moist deciduous woodlands are the primary habitat (excepting flood prone bottomland), where they are secretive, nocturnal, and usually found hiding under rocks and logs in openings or along forest edges. My colleagues and I have conducted many forest interior surveys where Northern Ring-necked Snakes are found, searching under rocks and logs for salamanders, and have never found Northern Ring-necked Snakes except at forest edges where cover objects receive sun (G. Casper unpublished data). For this study, I considered suitable habitat to be forest edge, meadows or other openings (road cuts, gravel pits, quarries, etc.) in landscapes dominated by northern mixed or deciduous forest, with or near rocky outcrops or talus, and having southerly exposure.

3. RESULTS

3.1 Surveys

Naturalists at Jay Cooke, Gooseberry Falls and Tettegouche state parks, Wolf Ridge ELC, and Hawk Ridge Bird Observatory, were interviewed and training provided on search methods and snake identification. All state park naturalists were canvassed by email. Surveys were performed May 7-11, June 14-18, July 9-13, and September 13-19, 2012. Surveys were affected by unpredictable extreme weather. The May period was abnormally cold, with few snakes out. The June survey encountered heavy rains that washed out many roads and limited subsequent surveys in many areas (i.e., Jay Cooke State Park was closed for the season after the main road washed away, and portions of West Skyline Parkway and Seven Bridges Road in the Duluth area were closed for the rest of the season). The July surveys were abnormally hot and dry, limiting snake activity and our ability to detect them.

Weather on the September trip was suitable for road cruise surveys, the primary focus at that time, with sunny warm afternoons (50s to 60s F) and cool nights (40s). Sites visited are detailed in field notes (Appendix A) with waypoint coordinates provided in Appendix B. Survey sites are mapped in Figure 1.

Many suitable habitat areas were identified, from Jay Cooke State Park to southwestern Cook County (Figure 2; appendices A, B and F). The Appendix B and F shapefiles can be used to generate site-specific maps. Appendix F represents the subset of surveyed sites that appeared to have suitable habitat as defined above. Several new Northern Ring-necked Snake localities were verified (Figure 2). An old specimen collected by David Grosshuesch in 2004 at Hawk Ridge Bird Observatory was obtained and preserved (JFBM 18261). This was one of two road kills he found that year on East Skyline Parkway. On June 17, 2012, a shed skin was found at Rutherford Waypoint 504 in Cook County (Appendix B). This is an old gravel pit site (previously visited as Casper Waypoint 224), and the skin was in a large rotting log at the forest edge, high up on a west facing slope. We placed additional cover at the site (silt fabric, old carpeting) and continued surveys (including several independent visits by H Michael Casper) but no additional Northern Ring-necked Snakes were found. Since this represents the first Cook County record, this site warrants continuing surveys until a voucher specimen can be collected. We also obtained a sight report from the Temperance River gorge overlook at Temperance River State Park (GSC 2363) from September 2012, providing a second, but still undocumented, Cook County record. We collected a fresh specimen (JFBM 18236) north of Two Harbors at Casper Waypoint 638 on July 10, 2012, which fills a substantial range gap (ca. 40 mile gap between nearest verified records). Finally, we obtained a specimen (GSC 1140) from the Munger Trail southwest of Duluth in September 2012, verifying previous sight records (GSC 1135, MCBS 1352). Detailed field notes are provided in Appendix A. Many suitable habitat sites were found and are discussed further below.

3.2 Record Review

Records obtained are shown in Figure 2 and summarized in Table 1 (also see appendices A, B and D for additional details). Currently there are 33 records available, although MCBS 101 and 102 are probably duplicates of other records. Many records are unverifiable observational records. While most are probably accurate, there is potential for confusion with the Northern Red-bellied Snake (*Storeria occipitomaculata*), which is common in the study area (often under the local vernacular “Copperbelly Snake”), and occasionally exhibits fused nuchal spots which can appear as a neck ring (Brown and Phillips 2012). The ongoing collection of verifiable specimen and photo vouchers is important for documenting occurrences.

Table 1: Summarized Northern Ring-necked Snake Records (details in Appendix D)

Source	CatNo	Type	Year	County	Remarks
GSCS	744	specimen	2011	Lake	Tettegouche State Park
GSCS	779	specimen	2011	Lake	south of Silver Bay Municipal Airport
GSCS	787	specimen	2011	Lake	north of Crosby Manitou State Park
GSCS	1140	specimen	2012	St. Louis	DWP Trail near Elys Peak
JFBMR	1065	specimen	1940	Lake	Lax Lake
JFBMR	1237	specimen	1943	Lake	Palisade Head
JFBMR	1461	specimen	1948	St. Louis	Lester Park-Duluth
JFBMR	1774	specimen	1956	Lake	Lax Lake
JFBMR	3002	specimen	1968	Lake	Gooseberry Falls State Park
JFBMR	18236	specimen	2012	Lake	north of Waldo
JFBMR	18261	specimen	2004	St. Louis	E Skyline Parkway, Hawk Ridge Bird Observatory
MCBS	102	specimen		St. Louis	no locality data provided except county
GSCP	379	photograph	2011	Lake	south of Silver Bay Municipal Airport
JFBMP	134	photograph	1988	Pine	3 miles S of Sandstone near Government Rd.
JFBMP	389	photograph	2010	Pine	Banning State Park
MCBS	101	photograph		Pine	no locality data provided except county
NAFHF	52389	photograph	2005	Pine	Banning State Park
GSC	1107	observation	2012	Lake	Tettegouche State Park
GSC	1118	observation	2011	Lake	end of Co. Rd 132 north of Two Harbors
GSC	1119	observation	2012	Lake	end of Co. Rd 132 north of Two Harbors
GSC	1124	observation	2012	Carlton	Jay Cooke State Park
GSC	1129	observation	2000	Lake	Split Rock Lighthouse State Park
GSC	1130	observation	2000	Lake	Wolf Ridge ELC
GSC	1131	observation	2011	Lake	Wolf Ridge ELC
GSC	1132	observation	2002	Lake	Finland
GSC	1134	observation	2012	Lake	Superior Hiking Trail at Two Harbors
GSC	1135	observation	2012	St. Louis	along Munger Trail west of Smithville
GSC	2352	observation	2012	Lake	residence north of Wolf Ridge ELC
GSC	2363	observation	2012	Cook	Temperence River State Park
MCBS	1343	observation	2010	Lake	Tettegouche State Park
MCBS	1344	observation	2010	Lake	Tettegouche State Park
MCBS	1352	observation	2007	St. Louis	along Munger Trail west of Smithville
RURY	558	observation	2012	Cook	quarry along Forest Rd 166 east of Heartbreak Creek

4. DISCUSSION

4.1 Known Sites

The following sites warrant special mention, and waypoints marked in these areas represent some suitable habitat sites. All 133 suitable habitat sites in Appendix F may be considered for continuing followup surveys.

- Banning State Park: Photo vouchers are available from here, but additional surveys could contribute to a better understanding of status, distribution and habitat use.
- Jay Cooke State Park: Observations here still need confirmation with vouchers. Much good habitat exists. Park staff should eventually be able to obtain a voucher specimen if they remain alert, especially for snakes crossing roadways in the fall. Surveys could contribute to a better understanding of status, distribution and habitat use.
- Munger Trail, Smithville: includes most of West Skyline Parkway, the Munger Trail, and other trails on this ridge. Much good habitat exists along the south facing aspect of the ridge, and the two observations here are now confirmed with a 2012 voucher specimen. Additional surveys could contribute to a better understanding of status, distribution and habitat use. Several sites appropriate for cover object surveys are mentioned in Appendix A. Fall surveys during snake migrations by bicycle proved effective and are efficient.
- Hawk Ridge Bird Observatory, Duluth: A voucher specimen confirms presence here, along with an older “Lester Park” specimen. Additional surveys could contribute to a better understanding of status, distribution and habitat use. Much good habitat exists along East Skyline Parkway, various trails and the utility corridor, as well as along the Lester River (Seven Bridges Road) and at the north end of Lester Park Golf Course.
- Two Harbors area: A specimen and several observations are now available from this area. Additional surveys could contribute to a better understanding of status, distribution and habitat use in this region.
- Gooseberry Falls and Split Rock Lighthouse state parks: Observations here are supported by specimens collected in Gooseberry Falls State Park and a specimen from approximately 2.4 miles north of Split Rock State Park. Vouchers from Split Rock State Park are still needed.
- Tettegouche and George Crosby Manitou state parks, Wolf Ridge ELC: This is the “hot spot” for reports of the species. Voucher specimens document occurrence at Tettegouche State Park, and from approximately 1 mile north of George Crosby Manitou State Park. Observations from around Finland, Palisade Head, and the Wolf Ridge ELC warrant continuing surveys to better understand the local status, distribution and habitat preferences.
- Temperance River State Park: Our find of a shed skin approximately 1.7 miles north of this park, and an observation from near the Temperance River mouth, suggests that

Northern Ring-necked Snakes extend into at least southwestern Cook County. The shed skin site and other suitable areas, including within Temperance River State Park (and Carlton Peak), should be considered high priority sites for obtaining voucher specimens and for conducting additional surveys for better delineating the northern range limit of the species.

4.2 Other Amphibians and Reptiles Encountered on 2012 Surveys

One-hundred nineteen records of fourteen species encountered in 2012 surveys are provided in Appendix E and summarized in Table 2. Photos and specimens will be deposited at the James Ford Bell Museum in Minneapolis.

Table 2: Summary of other herp species encountered in 2012

Common Name	Scientific Name
Blue-spotted Salamander	<i>Ambystoma laterale</i>
Eastern American Toad	<i>Anaxyrus americanus americanus</i>
Eastern Snapping Turtle	<i>Chelydra serpentina serpentina</i>
Painted Turtle	<i>Chrysemys picta</i>
Northern Ring-necked Snake	<i>Diadophis punctatus edwardsii</i>
Eastern Gray Treefrog	<i>Hyla versicolor</i>
Northern Green Frog	<i>Lithobates clamitans melanota</i>
Mink Frog	<i>Lithobates septentrionalis</i>
Wood Frog	<i>Lithobates sylvaticus</i>
Eastern Red-backed Salamander	<i>Plethodon cinereus</i>
Spring Peeper	<i>Pseudacris crucifer</i>
Boreal Chorus Frog	<i>Pseudacris maculata</i>
Northern Red-bellied Snake	<i>Storeria occipitomaculata occipitomaculata</i>
Eastern Gartersnake	<i>Thamnophis sirtalis sirtalis</i>

4.3 Remaining Gaps

A number of areas stand out as remaining knowledge gaps for Northern Ring-necked Snake distribution. Here gap survey recommendations are made. The quarry and suitable habitat site layers developed in this study (appendices B and F) may be utilized in selecting sampling sites.

- South and west range limits: In the south, the gap between Jay Cooke and Banning state parks (Figure 2) should be considered for additional surveys. Other state parks (Moose Lake, St. Croix) and state forests (St. Croix, Nemadji, General C. C. Andrews, Fond Du Lac) provide opportunities for surveys to better define the southern and western range limits.
- St. Louis County: Here Northern Ring-necked Snakes are expected to be restricted to undeveloped areas of the lower elevations in the greater Duluth region (see Habitat Associations below). The gap between the east and west sections of Skyline Parkway (snakes are known from both ends, Hawk Ridge in the east, Munger Trail in the west) affords few

opportunities for surveys owing to extensive development. The most likely remaining habitat areas are associated with the bluffs, where many private quarries offer potential. The gap east of Hawk Ridge has less development, but few public lands. In these areas without public access, perhaps the best strategy will be autumn road and bicycle cruise surveys. To the north of Duluth, no records exist, but surveys in the Cloquet Valley State Forest could help confirm if this absence is real.

- Lake County: Here Northern Ring-necked Snakes are fairly well documented throughout the lower elevations along Lake Superior, extending northwards in some valleys. This suggests that the climate moderating effect of Lake Superior is associated with the northern range limit, and public lands here afford excellent opportunities for more intensive research on population demographics and ecology. Such surveys could contribute to a better understanding of status, distribution and habitat use. In particular, Tettegouche and George Crosby Manitou state parks, and Wolf Ridge ELC, should be considered for ecological studies. To the north of the lower lakeside elevations, no records exist, and surveys further inland in the Finland State Forest and Superior National Forest could help confirm if this absence is real.
- Cook County: This study provides the first evidence of Northern Ring-necked Snake occurrence in Cook County. These two sites should be high priority for followup surveys to obtain voucher specimens. Additional surveys further north should also be considered to determine the extent of the northern range limit, as this baseline data is needed for future generations to assess the effects of climate change on the species. Cascade River and Temperance River (including Carlton Peak) state parks should be initial survey targets, followed by suitable areas in the Superior National Forest, and Finland and Pat Bayle state forests.

4.4 Survey Method Recommendations

The cover object protocol developed for the Lake Superior Binational Program (Casper and Hecnar 2011b) remains a viable sampling method, albeit somewhat more expensive, requiring deployment of cover objects (plywood sheets) into suitable habitat, followed by up to ten site visits under suitable weather and time of day constraints. The logistics of proper sampling can therefore be challenging, waiting for the right weather to go, and best success is with local residents who can sample after their work day ends. This method is recommended for more permanent sampling sites, especially where local citizens or agency personnel can be recruited to perform the ten site visits. For example, cover objects at Wolf Ridge ELC can be checked by staff and used in educational programs, while cover objects at state parks may be suitable for volunteer groups to adopt.

Where only limited site visits can be made, we have demonstrated fair success simply searching natural and anthropogenic cover. Such cover includes rocks, logs, bark sheets, slash, and various metal, cardboard, wood and other junk. In these cases with limited repeat visits, spreading natural or artificial cover on the first site visit does increase the chances of snake detection on followup visits, and is recommended. Cover should be placed so that it receives afternoon sun, as detailed in

the cover object protocol (*op. cit.*). Special attention should be given to large downed logs that are exposed to afternoon sun during the breeding season (May-July). On several occasions my colleagues and I have found snakes and snake eggs within such logs by *carefully* peeling back the top layers of bark and rotting wood. Special care must be taken to replace layers into original positions so as to minimize micro-habitat disturbance, especially for eggs, as the humidity and temperature of the moist rotting wood is essential to proper incubation.

Road cruising is another technique useful for detecting Northern Ring-necked Snakes, although in my experience they do not seem to cross roads as readily as do Common Gartersnakes (*Thamnophis sirtalis*) and Northern-Red-bellied Snakes (*Storeria occipitomaculata*). Cruises should focus on gravel roads and bike paths, which are more readily crossed. Surveys can be by automobile, bicycle or foot, and should be conducted during periods in late September and early October with cool nights and sunny warm days. Spring surveys under similar cool night/warm day conditions may also prove fruitful, but numbers are typically higher in autumn with young of the year being especially mobile. If other snake species are found crossing roads during the survey, conditions should also be suitable for Northern Ring-necked Snakes.

A final survey technique worth mentioning is excavation of abandoned ant mounds. The naturalist at Jay Cooke State Park (Kristine Hiller) noted that a local resident often found Northern Ring-necked Snakes this way. These ant mounds are likely used for hibernation, so the most effective time of year for excavations may be in October, or immediately following the first frost.

4.5 Habitat Associations

Northern Ring-necked Snakes reach their northern range limit in northeastern Minnesota, where they are likely constrained by climate factors such as warmth and length of the growing season. They appear to be strongly associated with rock outcrops, especially where fractured rock provides underground retreats where snakes can survive temperature extremes, and sun-warmed surface rocks afford thermoregulation opportunities. This micro-habitat feature is not generally discoverable in GIS layers, but most observations are associated with south and southwest facing slopes of rock outcrops, typically where there are steep slopes and high topographic relief, such as talus slopes. The best sites are sun exposed, rather than under dense forest canopy. Road cuts often provide these conditions (i.e., Skyline Parkway in Duluth), as do quarries and other anthropogenic features which serve to expose bedrock and open slopes to sun exposure. The rocky ridges paralleling the north shore of Lake Superior provide many such habitat opportunities. Northern Ring-necked Snakes may be concentrated in the sugar maple/yellow birch dominated ridges that start a few miles inland from the lake, which moderates climate. Further north and away from the lake climate may become too cold.

All records from the north shore are within the North Shore Highlands ecological subsection (Figure 3). This ecoregion is a narrow strip 20 to 25 miles wide that follows the shoreline of Lake Superior from Duluth to the eastern tip of Minnesota. Lake Superior dominates the area and moderates its

climate. The terrain varies from gently rolling hills to steep cliffs. Most streams are short and run from the highland to the shore of Lake Superior, ending in waterfalls near the shoreline. The primarily forested habitat is heavily influenced by aspen-birch, with minor amounts of white and red pine, mixed hardwood-pine, and conifer bogs and swamp. Much of the white pine-red pine forests have been logged and replaced with quaking aspen-paper birch, but significant old-growth northern hardwood and upland northern white cedar forest remain. Recreation, tourism and forestry are the predominant land uses, with heavy development pressure along the sensitive Lake Superior shoreline, and inland bluffs overlooking the lake (above adapted from Minnesota DNR 2006a).

West and south from Duluth, records also appear in the Mille Lacs Upland and Glacial Lake Superior Plain ecological subsections, where more sandy soils predominate (Figure 3). The Mille Lacs Uplands is located in east-central Minnesota and contains several major rivers. Extensive wetlands and gently rolling hills are the dominant land forms, and glaciation has had a major influence on the landscape, resulting in moraines. Pre-settlement maple-basswood forests were prevalent in the south, and the north was a mix of conifer and hardwood forests (above adapted from Minnesota DNR 2006a). Northern Ring-necked Snake records are so far limited to the Kettle River valley, which may act as a conduit for snakes moving south.

The Glacial Lake Superior Plain Subsection occupies a small area just south of Duluth, but is part of a larger unit in Wisconsin (Figure 3). Topography is level to gently rolling except along rivers and streams where the Nemadji River and its tributaries have worn gorges up to 150 feet deep. There are no natural lakes, and pre-settlement the forest was mostly white spruce, white pine and aspen-birch. Following logging, today's forest is largely quaking aspen (above adapted from Minnesota DNR 2006a), except in protected areas such as Jay Cooke State Park where Northern Ring-necked Snake records currently cluster along an ecotone between highlands and lowlands with significant exposed bedrock outcropping.

Associations between snake records and presettlement vegetation (Minnesota DNR 2006b) are illustrated in Figure 4. In Pine County, records fall within Mixed Hardwood and Pine (Maple, White Pine, Basswood, etc.) and Aspen Birch (trending to conifers) communities. Around Duluth records fall within the Mixed Hardwood and Pine (Maple, White Pine, Basswood, etc.) community, and then within the Mixed White Pine and Red Pine community northwest of Duluth in St. Louis County. In Lake County records fall mostly within the Mixed White Pine and Red Pine community, then the Aspen Birch (trending to conifers) in eastern Lake County and all of Cook County. Whether these forest community associations are a primary influence on snake distribution, or simply the predominant forest type in areas limited by suitable climate for the snake, is not known.

Records are displayed over a digital elevation model (Minnesota DNR 2006c) in Figure 5. This suggests that snake distribution is limited to lower elevations along the shore of Lake Superior where the climate moderating lake effect is maximized, extending a longer growing season and moderating temperature extremes. Figure 6 zooms into the Lake-Cook county border region, showing how snake records further from the lake tend to follow valleys northward.

Figure 7 illustrates several climate variables that may be important to explaining Northern Ring-necked Snake distribution. Mean annual snowfall shows that snake records fall within higher snow depth regions, which usually means shallower frost depth. Normal precipitation December-February shows that snake records fall within lower precipitation regions, but this still results in higher snow depth due to colder temperatures in the same region – this balance may change with climate change. Normal annual precipitation, however, is on the high side in the region of the snake records, which may affect Northern Ring-necked Snake prey abundance (amphibians, earthworms) and the lushness of their habitat. Normal mean temperature June-August is relatively cool, while normal mean temperature December-February is moderated by Lake Superior. The narrow lakeside warmer December-February normal mean temperature band corresponds most closely with Northern Ring-necked Snake distribution, suggesting it may be the most critical limiting factor.

Climate Data Sources:

- Mean annual snowfall: For each annual snowfall year (July-June), one gridded map was generated based on the individual station observations using a kriging technique. Means for a given period length were then computed based for each gridpoint value rather than a per-station basis. This sequence allows for use of all possible data in a given year. Source: http://climate.umn.edu/snow_fence/Components/SFF/MeanSF/aveannual1971-2000.htm
- 1971-2000 Normal Precipitation Maps: A common misconception is that a climate “normal” describes the “typical” state of the atmosphere. “Normal” is simply a 30-year arithmetic mean, computed once per decade. The precipitation normals data presented in the maps below summarize the observation period 1971-2000. These values are benchmarks to be used throughout this decade as a measure of central tendency. Normals data can be useful in placing ongoing weather conditions in historical context. Additionally, normals data offer an excellent tool for describing climate variability across space. Source: http://climate.umn.edu/doc/historical/precip_norm.htm
- Normal Temperature Maps: A common misconception is that a climate “normal” describes the “typical” state of the atmosphere. “Normal” is simply a 30-year arithmetic mean, computed once per decade. The temperature normals data presented in the maps below summarize the observation period 1971-2000. These values are benchmarks to be used throughout this decade as a measure of central tendency. Normals data can be useful in placing ongoing weather conditions in historical context. Additionally, normals data offer an excellent tool for describing climate variability across space. Source: http://climate.umn.edu/doc/historical/temp_norm_adj.htm

The most parsimonious explanation for the pattern of Northern Ring-necked Snake distribution records we observe hugging the Lake Superior shoreline appears to be simple climate moderation, which is an important limiting factor for many poikilothermic animals. This species is assumed to have been expanding its range northward since the retreat of the Pleistocene glaciers, some 9,000 years ago. Lake Superior represents a significant physical barrier to this northward expansion, and Northern Ring-necked Snakes have successfully reached the south shore of the lake (Harding 1997), and presumably continue to expand northward around the east and west sides. There are no records from the Ontario north shore (Ontario Herp Atlas 2012). A likely scenario, then, is that these snakes have colonized Minnesota from Wisconsin, southwest of Lake Superior, and have relatively recently expanded their range around the west end of the lake and up the north shore. If this scenario is

accurate, then snakes may continue expanding northward with ongoing climate change if this raises average winter temperatures, and the north shore highlands may become increasingly hospitable for this species in future decades. However, if reduced snow cover results in more frequent and deeper frost depths, winter kills could increase. Also, if drier summers reduce prey abundance and change vegetative communities, this could negatively affect snakes. Therefore, the impacts of climate change on Northern Ring-necked Snakes are hard to predict, and both positive and negative outcomes are possible. Obtaining an accurate baseline of existing conditions will be necessary to assess such future change.

5. ACKNOWLEDGMENTS

Special thanks to Ryne and Jenny Rutherford for conducting June surveys, and H Michael Casper and Wolf Ridge ELC for providing lodging. For contributing records I thank Carol Hall, Christopher E. Smith, Gordon Hommes and H Michael Casper. Christopher E. Smith and Alan Resetar assisted with museum data. I thank Amy Funk and other contributing staff at state parks. Jenny Bushmaker, Pete Harris, Erin Manning and other staff at the Wolf Ridge ELC assisted with surveys and provided past observations. Janelle M. Long graciously allowed us to conduct surveys at Hawk Ridge Bird Observatory. Dave Grosshuesch kindly dug an old specimen out of his freezer for me. This work was contracted by the Minnesota County Biological Survey and conducted under State of Minnesota Department of Natural Resources (MNDNR), Division of Parks and Trails, Special Permit No. 201226, and MNDNR Fish management Section Division of Fish and Wildlife Special Permit No. 17192.

6. LITERATURE CITED

- Brown, L. E. And C. A. Phillips. 2012. Distribution, habitat, and zoogeography of the semi-fossorial red-bellied snake *Storeria occipitomaculata* (Storer) in Illinois. Illinois Natural History Survey Bull. 39(5):297-322.
- Casper, G. S. and S. J. Hecnar. 2011a. Standard operating procedure for: visual encounter surveys for amphibians in the Lake Superior Basin. Version 1. 10 pp. Access from: <http://flash.lakeheadu.ca/~shecnar/> under Research-Lake Superior
- Casper, G. S. and S. J. Hecnar. 2011b. Standard operating procedure for: cover board surveys for snakes in the Lake Superior Basin. Version 1. 7 pp. Access from: <http://flash.lakeheadu.ca/~shecnar/> under Research-Lake Superior
- Harding, J. H. 1997. Amphibians and Reptiles of the Great Lakes Region. University of Michigan Press, Ann Arbor. 378 pp.
- Holman, J. A. 2012. The Amphibians and Reptiles of Michigan. Wayne State University Press, Detroit, Michigan. 291 pp.
- Minnesota Department of Natural Resources. 2006a. Tomorrow's Habitat for the Wild and Rare: An Action Plan for Minnesota Wildlife, Comprehensive Wildlife Conservation Strategy. Division of Ecological Services, Minnesota Department of Natural Resources. Accessed online November 20, 2012, from

http://files.dnr.state.mn.us/assistance/nrplanning/bigpicture/cwcs/profiles/north_shore_highlands.pdf

- Minnesota Department of Natural Resources. 2006b. Minnesota DNR - Division of Forestry. Presettlement vegetation of Minnesota based on Marschner's original analysis of Public Land Survey notes and landscape patterns. Accessed 2011 from <http://deli.dnr.state.mn.us/>
- Oldfield, B. L. and J. J. Moriarty. 1994. Reptiles and Amphibians Native to Minnesota. University of Minnesota Press, Minneapolis. 240 pp.
- Ontario Herpetofaunal Summary Atlas. <http://nhic.mnr.gov.on.ca/herps/ohs.html>. Accessed July 21, 2012.
- Vogt, R. C. 1981. Natural History of Amphibians and Reptiles of Wisconsin. Milwaukee Public Museum, Milwaukee, WI. 205 pp.

7. APPENDICES

- Appendix A: Field Notes (attached Word doc)
- Appendix B: GPS Coordinates (attached ESRI shapefiles)
- Appendix C: Quarries (attached ESRI shapefile)
- Appendix D: Ring-necked Snake Records (attached ESRI shapefile and Excel file)
- Appendix E: All Herp Records (attached Excel spreadsheet)
- Appendix F: Suitable Habitat Sites Surveyed (attached ESRI shapefile)

8. FIGURES

- Figure 1: Survey locations
- Figure 2: Northern Ring-necked Snake records and suitable sites
- Figure 3: North Shore Highlands ecological subsection
- Figure 4: Presettlement vegetation
- Figure 5: Relief map
- Figure 6: Relief map Lake-Cook county border region
- Figure 7: Climate variables

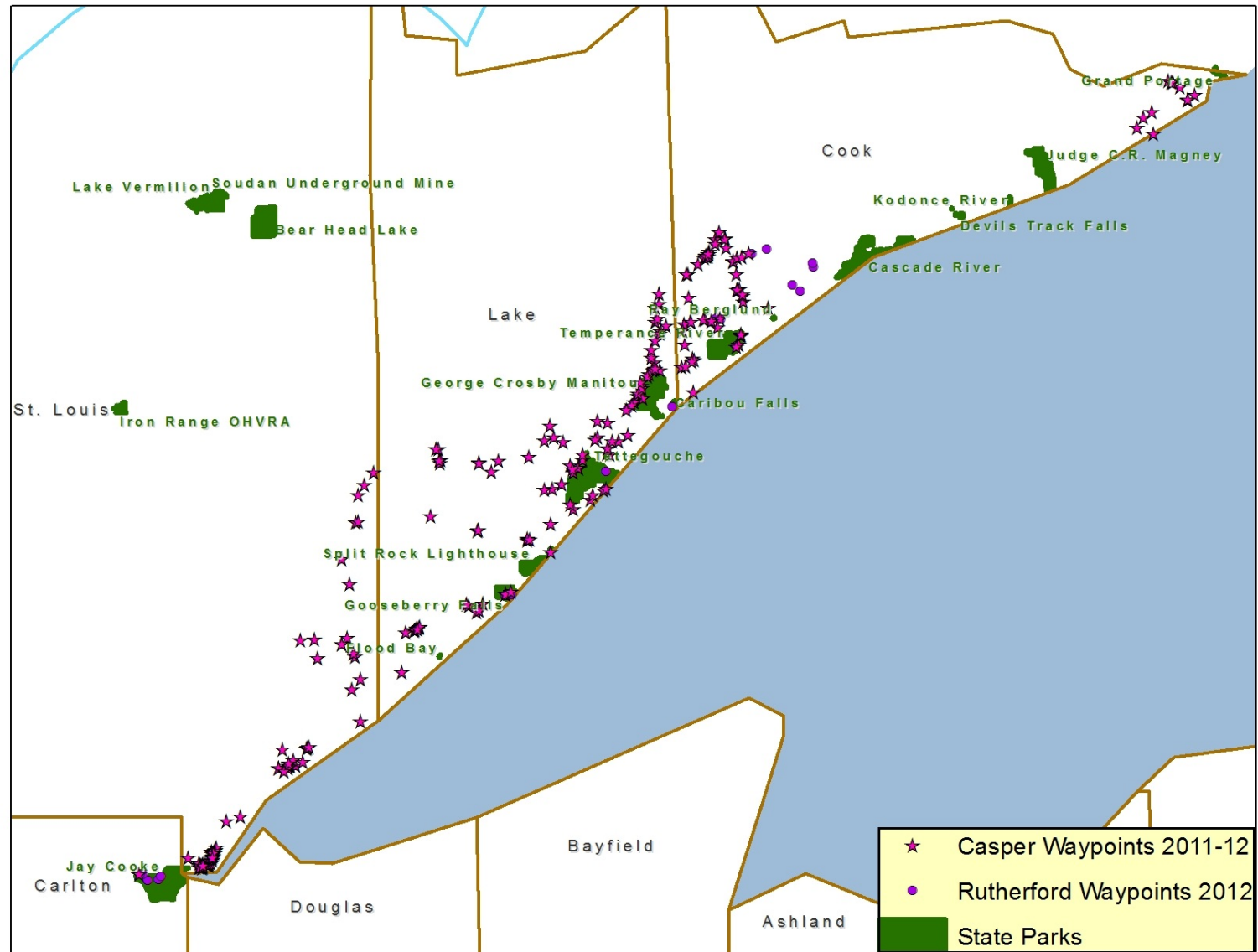


Figure 1: Survey locations

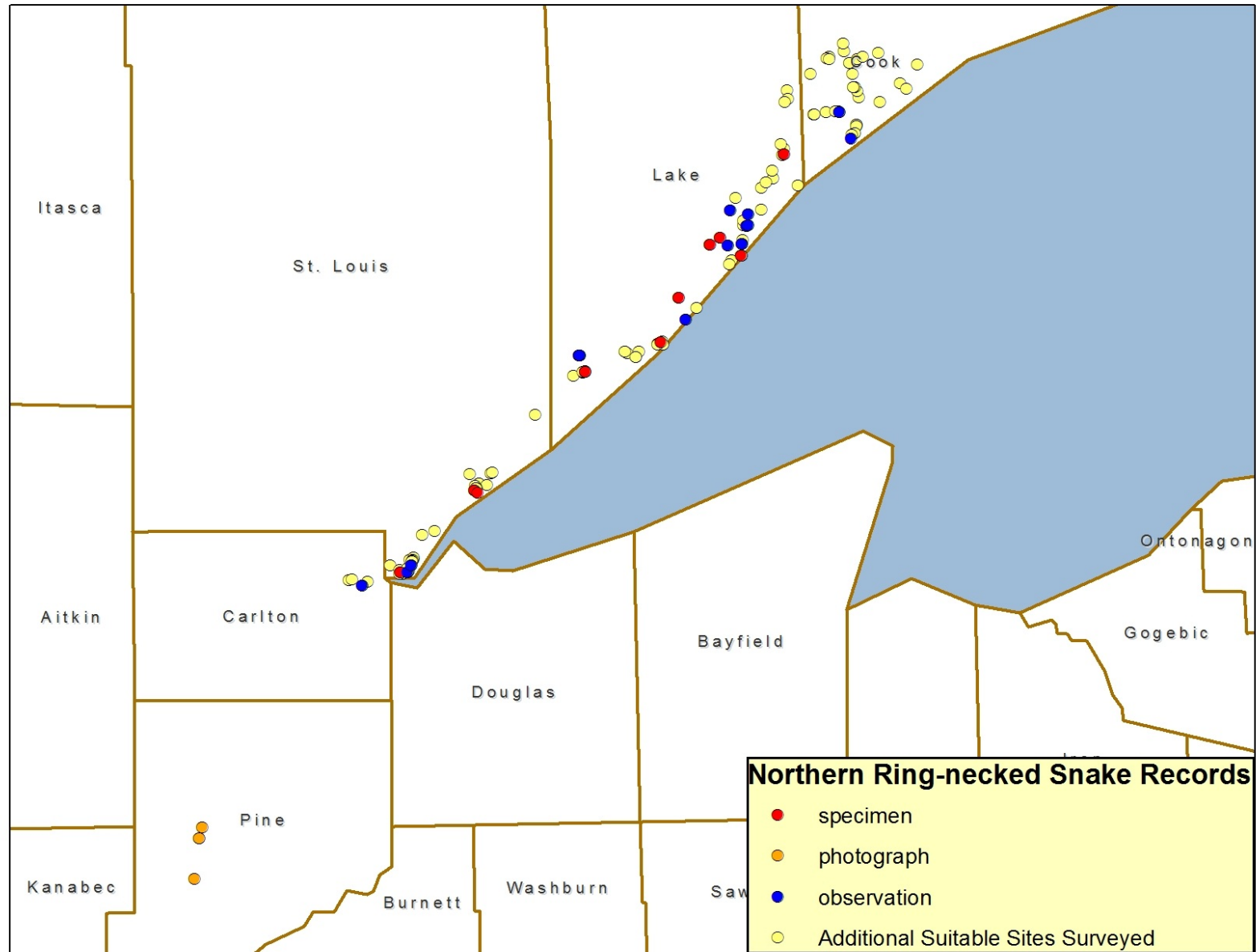


Figure 2: Northern Ring-necked Snake records and suitable sites

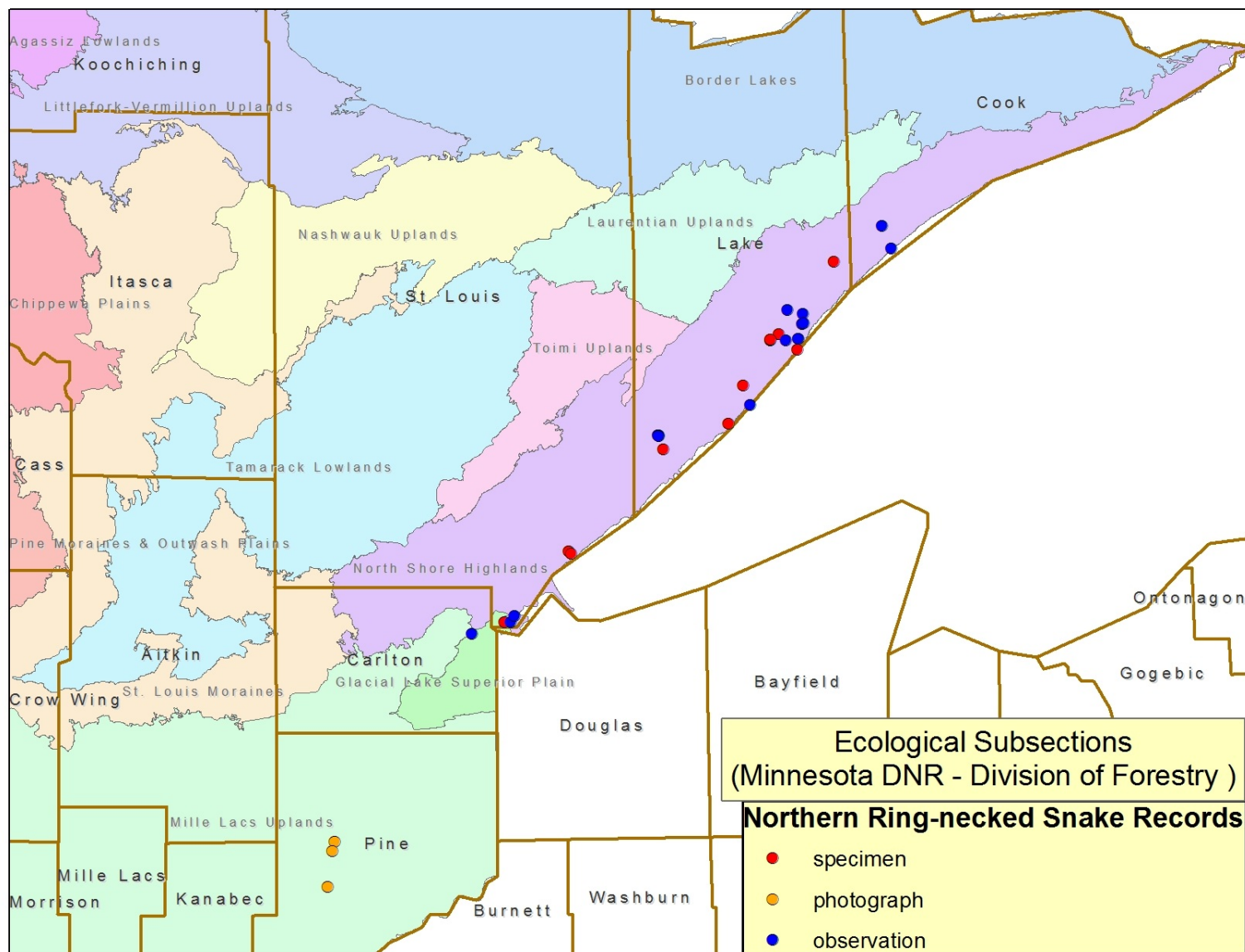


Figure 3: North Shore Highlands ecological subsection

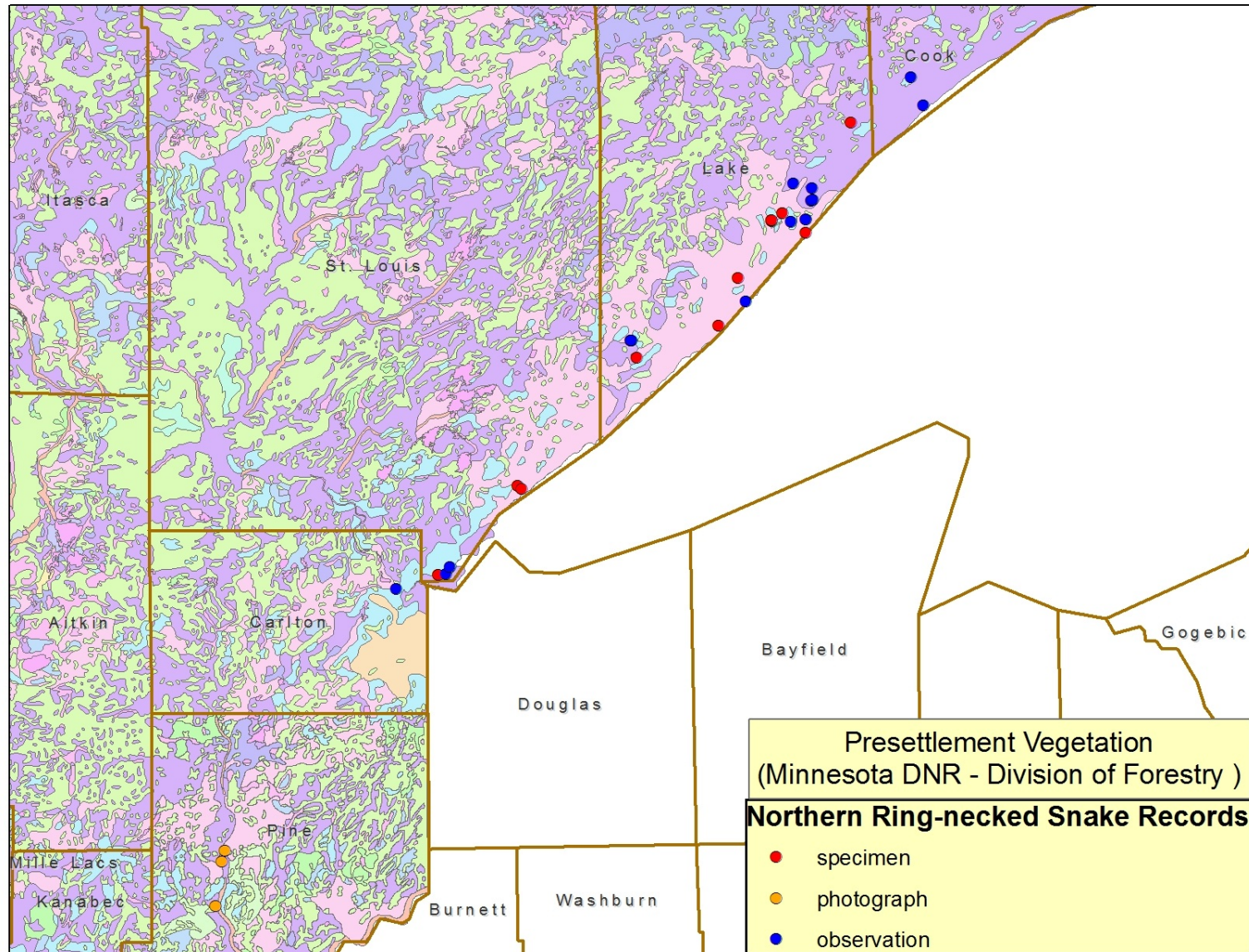


Figure 4: Presettlement vegetation

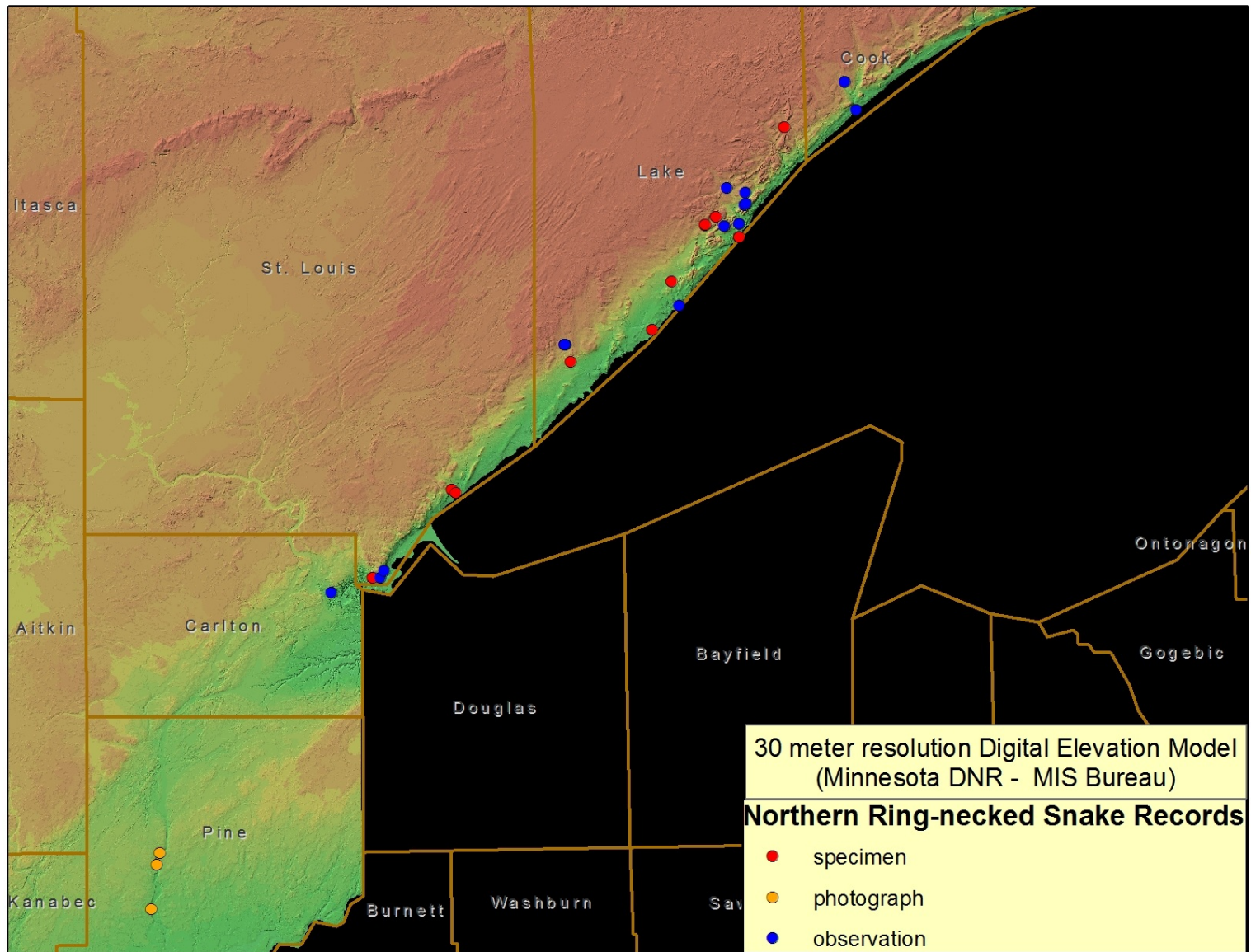


Figure 5: Relief map

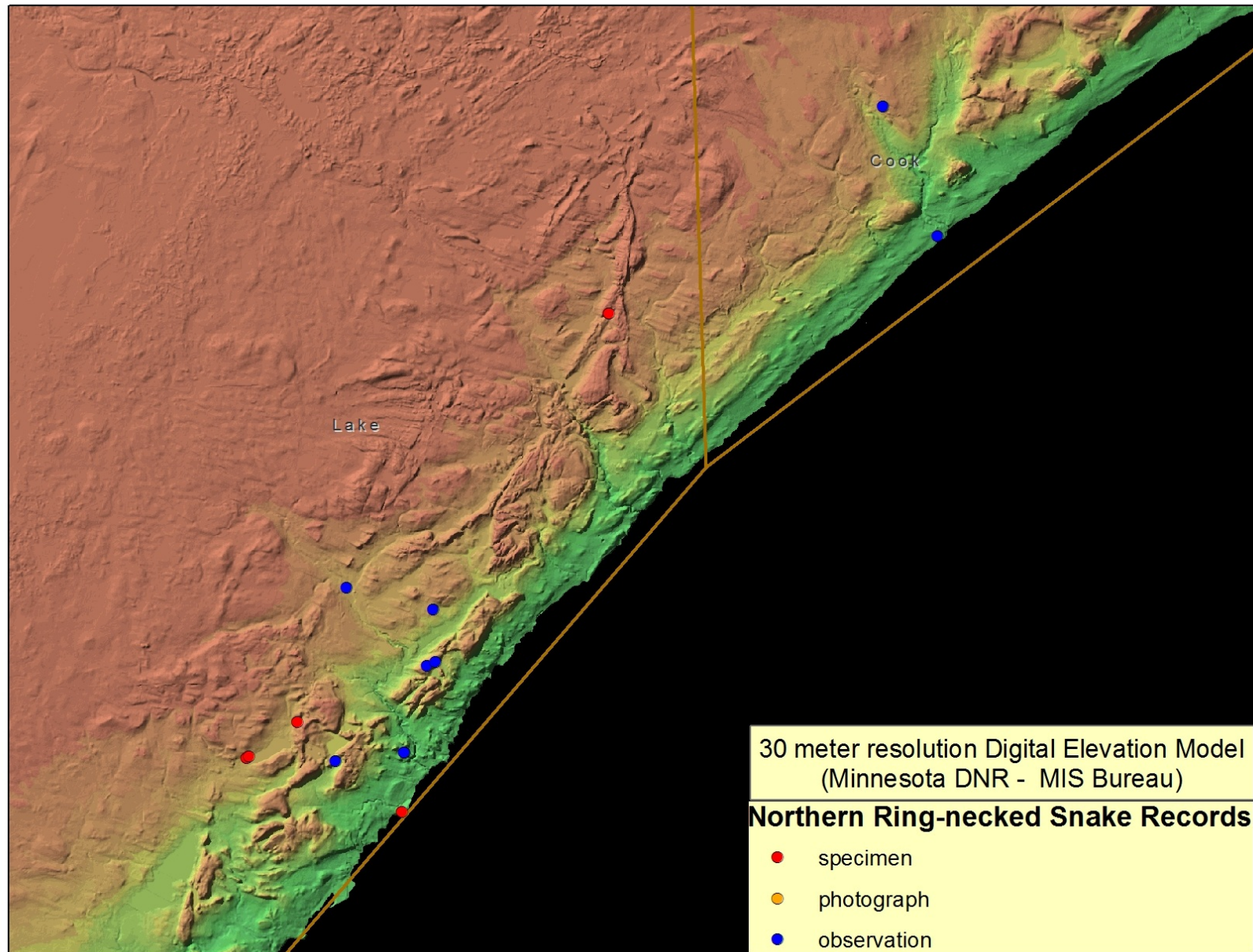


Figure 6: Relief map Lake-Cook county border region

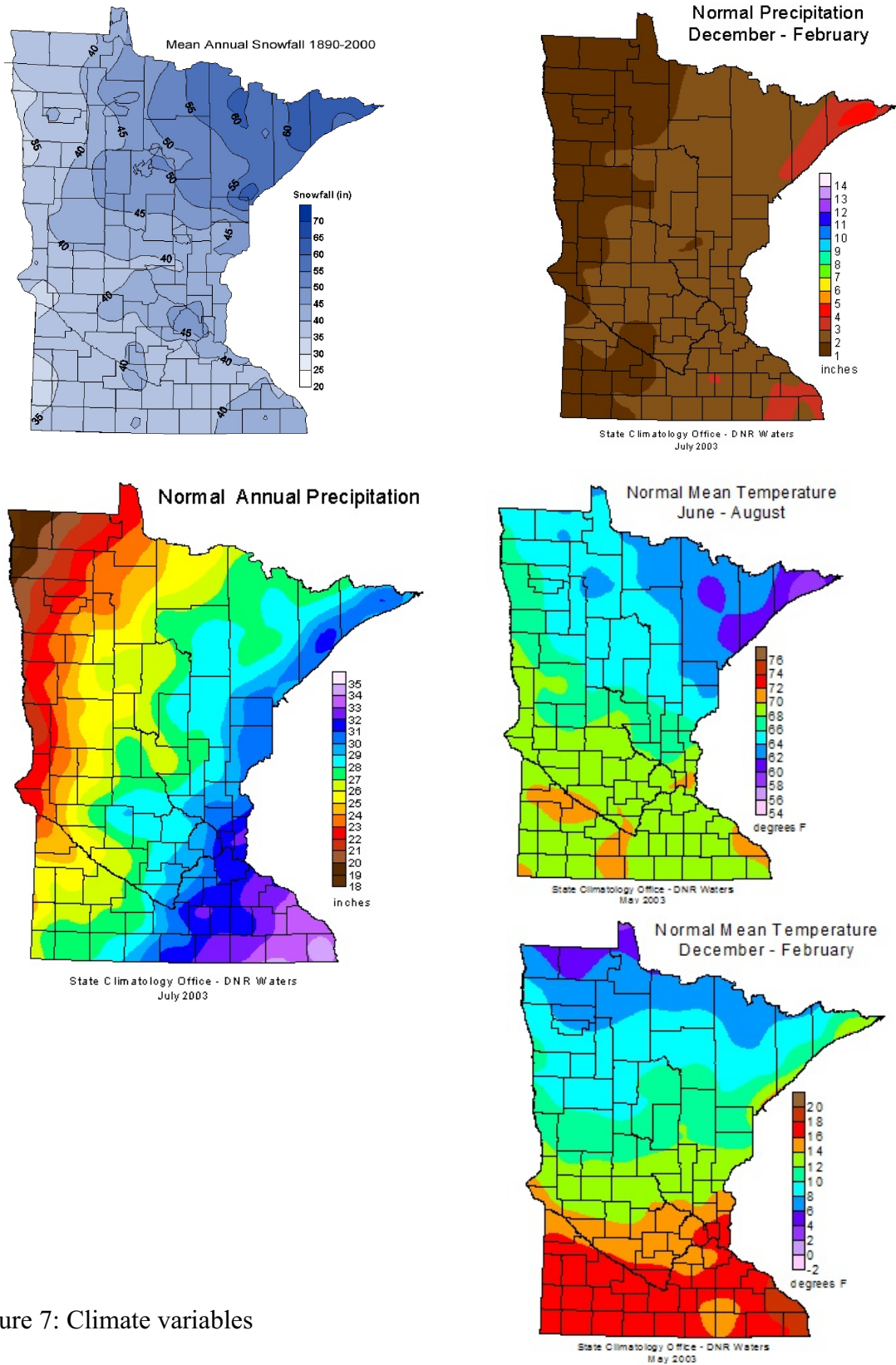


Figure 7: Climate variables