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Population loss of goldenseal, *Hydrastis canadensis* L. (Ranunculacaeae), in Ohio[1]

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MULLIGAN, M. R., AND D. L. GORCHOV. (Department of Botany, Miami University, Oxford, OH 45056). Population loss of goldenseal, *Hydrastis canadensis* L. (Ranunculaceae), in Ohio. J. Torrey Bot. Soc. 131: 305–310. 2004.—Goldenseal, *Hydrastis canadensis* L., is harvested from forests in the eastern U.S. for its rhizome, which is considered to have medicinal properties. While listed as rare or threatened in many states, its status in Ohio has not been assessed. To establish the status of historic goldenseal populations, we assessed 71 sites where voucher specimens had been collected from 1845 to 1998. Of these sites, 13% were deforested and no longer supported populations. Goldenseal was found on 65% of the remaining forested sites. Nearly half of documented goldenseal populations have become extinct, suggesting an overall decline of goldenseal in Ohio. The major cause of extinction appears to differ among Ecoregions, with deforestation important in the Eastern Corn Belt Plains, herbivory by white-tailed deer, in Erie/Ontario Drift and Lake Plain, and overcollection in the Western Allegheny Plateau.

Key words: goldenseal, *Hydrastis canadensis*, wild harvested plants, herbal plants, herbarium vouchers, local extinction, rarity, white-tailed deer.

Goldenseal, *Hydrastis canadensis* L. (Ranunculaceae), is a slow-growing perennial herb that is harvested for the medicinal properties of its rhizome (Foster 1991). Its historical range extends from Ontario south to Alabama and west to Kansas (Davis 1999). It still occurs in patches of moist soils in deciduous forests throughout its historical range, but the core range now appears to consist of Ohio, Indiana, Kentucky and West Virginia (Sinclair and Catling 2000a).

Populations of goldenseal have been dramatically reduced as a result of collection for medicinal use and deforestation during and since the mid 1800s (Lloyd and Lloyd 1884–5; Gagnon 1999). It is listed as rare in 7 states, threatened in 3, and ''of concern'' in 2. Furthermore, goldenseal is ranked ''vulnerable'' in 5 states, ''imperiled'' in 8 states and ''critically imperiled'' in 5 states by Natural Heritage Programs. However, even in areas where goldenseal is more prevalent, serious reductions of populations have been reported and attributed to overharvesting and deforestation (Davis 1999). These two impacts, as well as agricultural expansion, road intrusion, urbanization and recreational use, were listed as reasons why goldenseal is increasingly difficult to find in forests where plants were formerly abundant (Liebmann et al. 1998). Sinclair and Catling (2000a) proposed that the current distribution in Canada, small isolated patches, might be a result of loss of disturbance (such as flooding and fire) that benefits goldenseal, and extinction or extirpation of seed dispersers. Although many populations are small, inbreeding is probably not a cause of decline, as goldenseal reproduces vegetatively as well as sexually, and is self-compatible (Sinclair et al. 2000, Sanders and McGraw 2003, Christensen and Gorchov unpubl.).

Goldenseal was listed in 1997 on Appendix II of the Convention for International Trade on Endangered Species (CITES). The CITES program requires exporters of goldenseal rhizomes (but not finished products) to obtain permits, and encourages dealers and diggers to monitor populations and harvest sustainably (Robbins 2000). This listing recognizes that international trade may have a significant impact on wild goldenseal if the plant is not adequately managed (Liebmann et al. 1998).

Much of the information and government de-

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cisions concerning goldenseal are based on anecdotal rather than quantitative information on population status (Robbins 2000). Without organized or reported monitoring of historic wild populations of goldenseal in North America, it is difficult to quantify the extent of potential extirpation (Bannerman 1997). A recent survey of goldenseal in the central Appalachian region (consisting of populations mostly from West Virginia, with a few from Kentucky, Maryland, Ohio and Pennsylvania) encountered goldenseal infrequently, and found no particular elevation, aspect, land use or vegetation parameters that significantly affected presence or density of goldenseal (McGraw et al. 2003).

Although Ohio comprises a substantial part of the core of goldenseal's range, no comprehensive assessment has been made of the status of goldenseal populations in the state, where the Natural Heritage Program ranks it only as ''reported.'' Only one site in Ohio, Wayne National Forest (WNF), was included in McGraw et al.'s (2003) survey. Harvesting occurs on private land and in WNF, where a US$10 permit allows collection of 5 lb dry weight (Erin Larson, Forest Botanist, WNF, pers.comm. 5/11/03), which is equivalent to an estimated 5000 rhizomes (Christensen and Gorchov unpublished). Although collecting is illegal on all other public lands, some land managers report cases of poaching, a practice which is difficult to eliminate (Mulligan 2003). However, even though populations are not eliminated in a single harvest (Van der Voort et al. 2003), populations have been projected to go extinct if only 10% of the plants are harvested annually (Christensen and Gorchov 2002).

The purpose of this study was to establish the degree of population loss of goldenseal in Ohio and to examine some of the possible reasons for its decline.

Materials and Methods. SITE SELECTION AND LOCATION. The status of goldenseal in Ohio was assessed by determining what proportion of sites that contained goldenseal populations historically still support populations today. Loans of goldenseal collections were requested from all open herbaria in Ohio and received from BGSU, BHO, CINC, CLM, JHWU, KE, MU and OS. A total of 269 voucher specimens were received and examined for locality information. Records that gave specific locations (< 5 ha) were selected for this study ($N = 71$).

These sites were located using topographic maps and plat books.Landowners, land managers, or other knowledgeable individuals were then questioned by phone regarding site history and whether the site was still forested. If a site was determined to have been cleared or developed after the date of the voucher specimen, that population was scored extinct due to deforestation. For stands that were forested but currently lacked goldenseal, we evaluated whether the stand had been cleared subsequent to the year goldenseal was recorded by interviewing land managers, and where necessary, examining aerial photographs from each 10-year interval subsequent to the collection date.

To examine trends by region, sites were stratified by Ecoregion, using U.S. Environmental Protection Agency's Level III Ecoregions (Woods et al. 1998). A map of sites by Ecoregion was generated using ArcMap. Sites were also classified by ownership as private and public sectors. Privately owned sites were classified as corporate or private landowner. Public sites were classified as national, state, state-university, county, and municipality.

SAMPLING. Forested sites were surveyed for goldenseal between June 3rd and July 24th, 2002. Each site was searched by two people, allowing one hour per hectare up to a maximum of 4 hours per site. We traversed the area in parallel lines approximately 2–5 m apart. If goldenseal was found within 0.5 km of the original site description, the population was scored as extant. The number of goldenseal ramets with 1 leaf (non-reproductive), and 2–3 leaves (reproductive) were counted, following Gagnon's (1999) protocol for monitoring goldenseal populations. Counts were terminated at 200, in which case the total number of plants in the population was estimated. In sites that contained obviously over 200 plants, counts were not initiated, but the total was estimated. Observations were made on the structure of each stand, and in most stands the dominant species of herb, shrub, sub-canopy and canopy layers were recorded.

Herb-layer dominants were used to assess which forested sites had experienced excessive herbivory by white-tailed deer, enabling us to make inferences about the role of deer on goldenseal extinction. The abundance of deer in Ohio has increased nearly exponentially, from near zero in the 1940s to over 500,000 in 1996 (Iverson and Iverson 1999), and goldenseal is one of the most heavily browsed species of forest herbs at high densities (Frankland 2000;

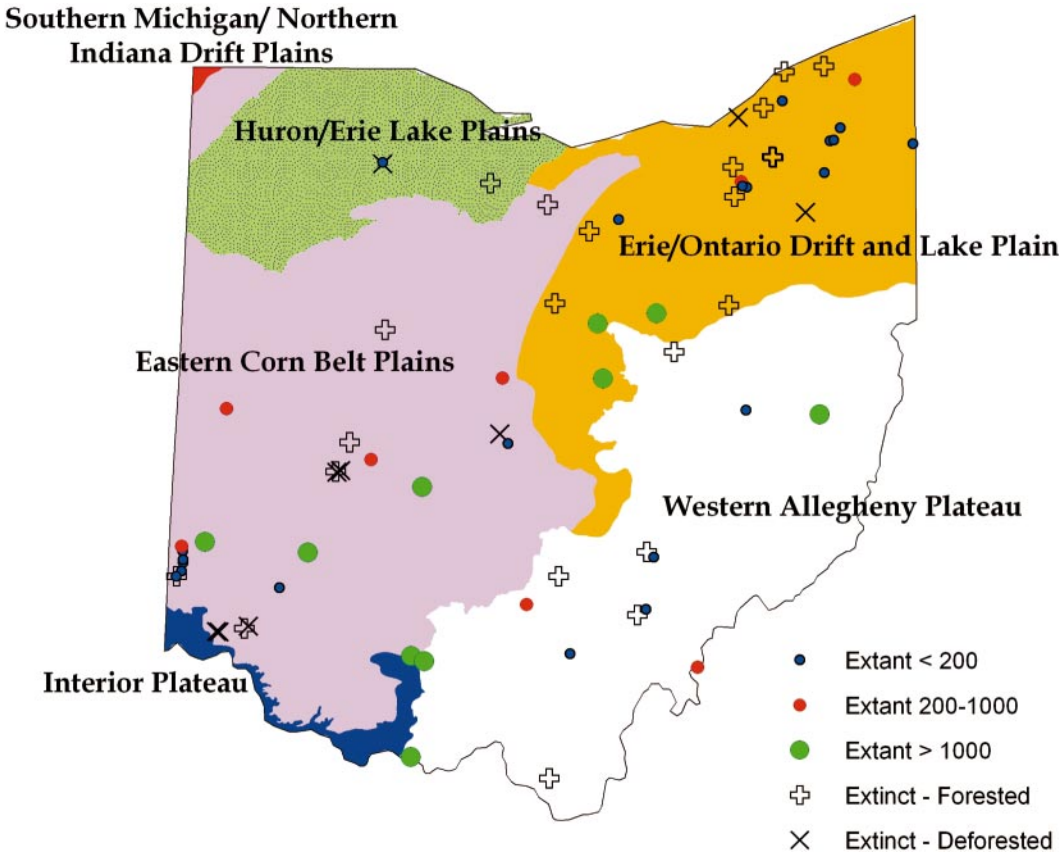

FIG. 1. An Ecoregions map of Ohio (from Wood et al. 1998) showing the locations of the 71 study sites and the current (2002) status of goldenseal at these sites.

Frankland and Nelson 2001). We compared the dominant herbaceous species to records of percent grazing for 55 herb species in an Illinois forest (Frankland 2000). We considered the 10 species with the highest percent grazing in Frankland's (2000) study to be ''preferred'' by deer, and the 24 species with 0% grazing to be ''avoided'' by deer.

Sites were classified as either goldenseal present or goldenseal absent. Goldenseal-absent sites were further classified as forested or deforested. In order to examine trends in occurrence and deforestation in different time periods, sites were classified by collection date of the original voucher, with three relatively distinct time periods recognized: early (1845–1949), intermediate (1957–1971) and recent (1977–1998). For each ownership class we assessed the number of sites forested with goldenseal, forested without goldenseal, and deforested.

CITES PERMITS. In order to assess where harvest is occurring, we requested copies of all CITES Export Permit applications submitted for wild goldenseal harvested in Ohio from the U.S. Fish and Wildlife Service.

Results. Locality data of 71 voucher specimens (dated 1845–1998) were sufficiently detailed for the collection site to be relocated (Fig. 1). Nine of the sites (13%) were determined to have been deforested and no longer supported populations. The remaining 62 forested sites were visited and 40 (65%) of these still contained goldenseal populations. None of the 22 forested sites that no longer contained goldenseal had been cleared or severely disturbed subsequent to the original collection date. These sites were similar in canopy tree composition to the 40 sites that contained goldenseal, with *Acer saccharum*, *Fagus grandifolia* and *Liriodendron tulipifera* as the most frequent canopy dominants in both categories (Mulligan 2003). Furthermore, goldenseal-present and goldenseal-absent forested sites did not show different patterns in

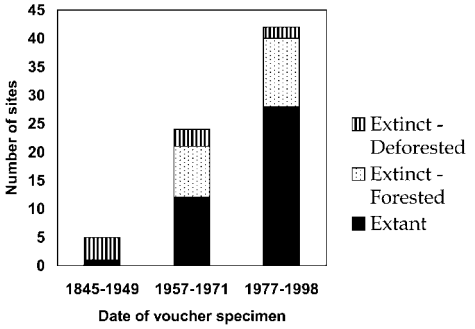

FIG. 2. Current (2002) status of goldenseal at 71 historic localities, stratified by date of the original voucher specimen.

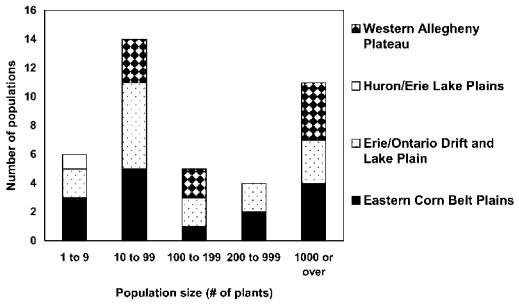

FIG. 3. Distribution of goldenseal population sizes (in 2002), stratified by Ecoregion.

dominant herbs, shrubs, or sub-canopy trees. Non-native invasive species, such as *Alliaria petiolata* and *Lonicera maackii*, were found in both goldenseal and goldenseal-absent sites.

Stratifying sites by age of the record, the proportion that still contained goldenseal was lowest for the sites with early records (1845–1933), intermediate for those dated 1957–1971 and highest for those with recent records (1977–1998; Fig. 2). Among sites that no longer contained goldenseal, none of the early, 75% of intermediate and 83% of recent sites were still forested.

While the number of sites differed among Ecoregions (Fig. 1), the proportion of these sites that still had goldenseal was similar; 56% on the Eastern Corn Belt Plains (N = 27 sites), 56% on the Erie/Ontario Drift and Lake Plain (N = 27), and 64% on the Western Allegheny Plateau (N = 14), and 33% on the Huron/Erie Lake Plains (N = 3). In sites where goldenseal was absent, 50% of Huron/Erie Lake Plains sites, 50% of the Eastern Corn Belt Plains sites, 83% of the Erie/Ontario Drift and Lake Plain sites, and all of the Western Allegheny Plateau sites were still forested.

The total number of goldenseal ramets in the 40 extant populations ranged from 1 to over 10,000 (Mulligan 2003). Most (62%) of these populations had fewer than 200 ramets, 10% had 200 to 1000 ramets and 28% had more than 1000 ramets. The proportion of populations falling into each of these size classes was similar among Ecoregions (Figs. 3).

Of the 27 populations where stage structure was determined, nine (33%) were comprised of ≥ 98% non-reproductive plants (Mulligan 2003). Six of these nine populations were located in the Erie/Ontario Drift and Lake Plain Ecoregion.

A total of seven CITES permits for export of goldenseal were received from U.S. Fish and Wildlife Service. Five of these permits, all dated 1998, specify the counties where the goldenseal was harvested. Of the 13 Ohio counties listed on one or more applications, 11 fall mostly in the Western Allegheny Plateau Ecoregion. One of the remaining counties was located in the Eastern Corn Belt Plains and the other spanned the Interior Plateau, Eastern Corn Belt and Western Allegheny Ecoregions.

Goldenseal was present in 55% of privately owned sites (N = 33) and 58% of public sites (N = 38). Among sites where goldenseal was no longer found, 53% of private and 78% of public sites were still forested. Comparing the two private ownership categories, sites owned by corporations more frequently contained goldenseal than those owned by individual landowners. Furthermore, for sites that were still forested, corporation-owned sites more frequently had goldenseal (88%) than did sites owned by individuals (61%). Among public ownership categories, national (67%) and state (69%) owned sites more frequently still had goldenseal than did sites owned by counties, municipalities, or universities.

Among the forested 20 goldenseal-absent sites where dominant herbs were determined, none had as a dominant one of the 10 herbs preferred by deer, based on Frankland (2000). In addition, for over half (64%) of these sites, one or more of the dominant herb species was one of the 24 species avoided by deer (Frankland 2000). However, among the 40 goldenseal-present sites where we determined dominants, 5 had a species preferred by deer as one of the dominants, and only 4 sites had a species avoided by deer as a dominant.

Discussion. STATUS OF GOLDENSEAL POPULATIONS IN OHIO. Assuming each site where goldenseal was not found represents a population that has gone locally extinct, nearly half of the Ohio goldenseal populations we investigated are now locally extinct. It is possible that one or a couple of these sites had a few small ramets or seedlings that went undetected, but we are confident we did not miss any healthy populations.

Our findings suggest an overall decline in the number of goldenseal populations in Ohio. It is conceivable that this extinction rate is mitigated somewhat by new populations colonizing other sites. We only surveyed historical populations, thus cannot assess such colonization. However, the rate at which other forest understory species colonize secondary forests has been shown to be quite low (Matlack 1994). Extinctions have been occurring throughout the past century, as the proportion of populations now extinct correlated with the age of the original collection.

Goldenseal populations in Ohio were more likely to be small (62% had < 200 ramets) compared to those in Ontario (30% < 200; Sinclair and Catling 2000b).

Causes of local extinctions. In general, deforestation has played a minor role in the decline of documented goldenseal populations in Ohio. Only 9 of the 71 sites had been deforested, and 4 of these were sites where goldenseal was vouchered prior to the 1930s. Forest cover in Ohio has increased since its nadir in 1910 (Griffith et al. 1991), although urban sprawl (Staley and Hisrich 2001) has reduced forested land in the periphery of metropolitan areas. Among Ecoregions, deforestation of goldenseal sites was most common in the Eastern Corn Belt Plains, where it was exclusively due to urban sprawl. Urban sprawl may explain why extinction rate was greater on private vs. public land. None of the forested sites without goldenseal showed evidence of excessive clearcutting or major disturbance in the canopy.

Our finding that stands without goldenseal were more commonly dominated by herbs avoided by white-tailed deer, and less commonly dominated by herbs preferred by deer, compared to stands with goldenseal, suggests that goldenseal extinction is associated with a history of heavy deer browse. Additional evidence suggests herbivory by deer has been a more important cause of goldenseal extinction in northeastern Ohio than elsewhere in the state. High densities of deer are characteristic in suburban areas in the northeastern counties (estimated 50–100/mi^2 ($= 20$–40/km^2), Mike Reynolds, Wildlife Biologist, Ohio Department of Natural Resources, pers. comm. 5/20/03). In 4 of our sites in this region, the shrub layer was lacking and the subcanopy and herb layers often sparse, suggesting excessive browse by deer. Goldenseal was extinct in 3 of these sites; biologists familiar with 2 of these sites considered deer to be responsible. The fourth site contained only one small non-reproductive plant. Combined with the heavy browse goldenseal experiences at high deer densities (Frankland 2000; Frankland and Nelson 2001), this evidence suggests herbivory by deer may have been an important cause of goldenseal extinctions in northeastern Ohio.

Since information on amounts of goldenseal harvested from the various sites is lacking, it is not possible to confirm whether overharvest is responsible for the decline or extinction of populations. However, overharvest is suggested by the greater prevalence of small populations in Ohio compared to Ontario, where harvesting is minimal (Sinclair and Catling 2000a), as well as by the extremely low proportion ($< 2\%$) of flowering ramets in 9 of the 27 populations where we determined population structure. In the year following harvest of a West Virginia population only 1% of ramets were reproductive, and this proportion increased over the next four years in the absence of harvest (Van der Voort et al. 2003). This compares to a range of 3% to 30% reproductive ramets in 6 Ohio populations not subjected to recent harvest (Christensen and Gorchov unpublished), and an overall average of 16% reproductive across 14 populations in Ontario (Sinclair and Catling 2002). Low frequency of flowering ramets following harvest can be attributed to the fact that plants with larger rhizomes are both more likely to flower and more likely to be removed in a harvest (Christensen and Gorchov unpublished).

Overharvest is probably currently a greater threat in the Western Allegheny Plateau than elsewhere in Ohio. Most of the CITES collections made in Ohio came from this Ecoregion, suggesting harvest is concentrated in this region. Anecdotal evidence also indicates that harvest is important in the Eastern Corn Belt Plains. In other regions of Ohio, harvest may have been intensive, and caused local extinctions, in the past. For example, one land manager claimed that harvesting had been prevalent in the Erie/Ontario Drift and Lake Plain, but has been much reduced in recent years (T. Curtin, pers. comm.).

Thus, the major cause of extinction appears to differ among Ecoregions, with deforestation important in the Eastern Corn Belt Plains, herbivory by white-tailed deer in Erie/Ontario Drift and Lake Plain, and overcollection in the Western Allegheny Plateau. Overall, nearly half of the historically documented goldenseal populations in Ohio have gone extinct. This rate of population decline, in the core of the historic range, indicates that current regulation of goldenseal harvest is not adequate, and that state listing of goldenseal should be considered.

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