ABSTRACT

POPULATION LOSS OF GOLDENSEAL, *HYDRASTIS CANADENSIS* L. (RANUNCULACEAE), IN OHIO

by Margie Mulligan

Goldenseal, *Hydrastis canadensis* L., is a slow-growing perennial herb that is harvested for the medicinal properties of its rhizome. It has become increasingly rare throughout its range, and in Ohio, the core of its range, it is believed to be declining. Voucher specimens from eight herbaria in Ohio were examined to determine what proportion of sites that historically supported goldenseal populations still support them today. Out of 269 voucher specimens reviewed, 71 had sufficient detail for the collection site to be relocated. Of these sites, 13% were deforested and no longer supported populations. The remaining sites were visited and goldenseal was found on 65% of these forested sites. This study revealed that nearly half of documented goldenseal populations have become extinct, suggesting an overall decline in the number of goldenseal populations in Ohio. Most of this population loss appears due to overharvest, rather than habitat loss or deer herbivory.

POPULATION LOSS OF GOLDENSEAL, *HYDRASTIS CANADENSIS* L.
(RANUNCULACEAE), IN OHIO.

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Introduction

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 is north into Canada, south to Alabama, and west to Kansas (Davis, 1999). It can still be found growing in patches of moist soils of deciduous forests throughout its historical range, but the core range now appears to consist of Ohio, Indiana, Kentucky and West Virginia (Sinclair and Catling, 2000b).

Populations of goldenseal have been dramatically reduced as a result of collection for medicinal use and deforestation (habitat loss) during and since the mid 1800s (Gagnon, 1999). Outside the core of its range, goldenseal is currently listed as rare in Connecticut, Georgia, Massachusetts, Minnesota, New Jersey, North Carolina and Vermont; threatened in Maryland, Michigan and New York; a species of concern in Tennessee and Wisconsin; and not state listed, but ranked (by state offices of the Heritage/Conservation Data Center Network) as “imperiled” in Alabama and “critically imperiled” in Mississippi (compiled from websites of state 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 populations in forests where plants were formerly abundant by Liebmann et al. (1998).

Much of the information known and government decisions concerning goldenseal are based on anecdotal rather than quantitative information on population status (Robbins, 2000). There is little economic incentive for the export industry to fund basic field population studies in the core of its range because these would be more costly than the value to the industry (Robbins, 2000). Therefore, there is no organized or reported monitoring of historic wild populations of goldenseal in North America, so it is difficult to quantify the extent of potential extirpation (Bannerman, 1997).

This combination of lack of information and possible threats to goldenseal populations has been the impetus for the “fragile ranking” of goldenseal by some interest

groups, such as the network of Natural Heritage Programs (Bannerman, 1997). This concern led to the 1997 listing of goldenseal on Appendix II of the Convention for International Trade on Endangered Species (CITES), an international treaty monitoring trade in threatened and endangered species (Davis, 1999). This program regulates the export of goldenseal 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).

Although Ohio comprises a substantial part of the core of goldenseal's range, no assessment has been made of the status of goldenseal populations in the state. Even the Natural Heritage Program ranks goldenseal as only "reported" in Ohio. The only information available is based upon anecdotal observations by botanists, land managers and naturalists who have witnessed the decline of local populations. In response to goldenseal's listing on CITES, the National Center for the Preservation of Medicinal Herbs is currently studying goldenseal in Ohio. The goal of their research is to alleviate pressures on wild populations across its range by developing cultivation methods for goldenseal and other medicinal herbs that are presently wild-harvested. Paul Strauss of United Plant Savers, in cooperation with Jan Salick of Missouri Botanical Garden, has initiated a controlled investigation into the impact of various wildharvesting techniques on indigenous goldenseal populations. This investigation will help identify what kinds of practices may assist the stand to return rapidly to optimal plant density. Deanna Christensen and Dave Gorchov of Miami University have also been studying the effects of harvesting on the population biology of goldenseal. They projected the effects of harvesting wild populations using a stage transition matrix model. While all this research is very important for minimizing the impact on wild populations of goldenseal, it does not address the current status of populations in the state.

The only attempt so far to determine distribution and abundance of goldenseal at a large scale was a recent study in the central Appalachian region (consisting of mostly West Virginia, but some Kentucky, Maryland, Ohio and Pennsylvania populations) (McGraw et al., 2003). Both goldenseal and *Panax quinquefolius* L. (ginseng) were surveyed simultaneously at sites to determine the specific niche requirements for each

species. It was found that ginseng was encountered more frequently than goldenseal. Goldenseal was encountered so infrequently that no particular elevation, aspect, land use or vegetation was found to significantly affect presence or density of goldenseal. Population decline was not investigated.

Because there is minimal research on the status of goldenseal there is not much information on the cause of its decline. There could be several causes for the putative decline across its range. Lloyd and Lloyd (1884-5) observed dramatic declines of goldenseal populations as a result of overharvest and habitat loss through deforestation. Sinclair and Catling (2000a, 2000b) proposed that the current distribution in Canada, small isolated patches, might be a result of loss of disturbance that benefits goldenseal, such as flooding and fire, and extinction or extirpation of seed dispersers.

Sanders and McGraw (2002) suggested that decline could be a result of overharvest, changes in land use, loss of seed dispersers, or constraints due to microhabitat requirements, breeding system or lack of genetic variability. Goldenseal typically reproduces vegetatively, often forming patches of individuals with the same genotype (ramets). However, goldenseal does sometimes reproduce sexually, producing seeds by self pollination and outcrossing (Sanders and McGraw, 2003). Genetic variability tends to be low in populations that are reproducing predominately asexually. Even when there is some genetic variability, in small and isolated populations, genetic drift can eliminate alleles leading to decline in genetic diversity. Populations that have less genetic variability have less potential to adapt to changes to the abiotic or biotic environment and are more likely to go extinct (Shaffer, 1981). This low genetic variation could cause extinctions in small, isolated populations of goldenseal, but such populations are likely to be more typical near the edge of its range than in core areas including Ohio.

Although seedlings are uncommon in natural populations, Sanders and McGraw (2003) determined that both selfed and outcrossed seeds were viable. Therefore, a lack of seed germination, rather than a breeding system constraint, is a possible cause of goldenseal decline. Sanders and McGraw (2003) speculate that changes in disturbance regimes or “faunal composition” of goldenseal habitat could be reducing the germination rate. I believe change in “faunal composition” includes the loss of seed dispersers or animals that disturb the soil. Although low germination rates could affect long-term

viability of goldenseal populations, there are more immediate threats to populations across its range. Overall trends in population decline in Ohio are more likely a result of overharvest, deforestation or herbivory.

In Ohio, harvesting goldenseal on public land is only permitted in Wayne National Forest (WNF) in the southeastern part of the state. Permit fees to harvest goldenseal in WNF are nominal, \$10 to collect up to 5 lb of dry weight (Erin Larson, Forest Botanist, WNF, pers.comm., 5/11/03), which is equivalent to an estimated 5000 rhizomes (Christensen and Gorchov, unpublished). WNF currently has a mandatory form for diggers to fill out which requests the location of harvested and the amount harvested. However, very few forms have been returned and WNF currently does not have the resources to enforce their return, but plans to improve the permit infrastructure in the next few years (Erin Larson, pers.comm., 5/11/03).

Although collecting is illegal on all other public lands, some land managers report cases of poaching, a practice which is difficult to eliminate (Keith Bengston, Park Manager for ODNR, pers.comm., 7/2/02; Larry Molen, Operations Assistant for private camp, pers. comm., 7/2/02). Without historic data on population sizes, it is difficult to quantify the effect of harvesting goldenseal from these populations. However, even though populations are not eliminated in a single harvest (Van der Voort et al., 2003), populations are projected to go extinct if only 10% of the plants are harvested annually (Christensen and Gorchov, 2002).

Deforestation is another threat to goldenseal populations. Ohio's forest cover during pre-settlement times was estimated at 95% of the state. By the end of 1910, Ohio was only 12% forested. Since then, the forest cover has increased to 30%, with 94% of the forest areas privately owned (Griffith et al., 1991). Despite this increase, urban sprawl (land development beyond the urban boundaries of existing cities, villages and urbanized rural areas) is a concern near Ohio's cities. The ongoing migration to low-density suburban locations and away from high-density urban areas has been occurred through most of the 20th century with the highest rates during the 1920s and 30s (Staley and Hisrich, 2001). This phenomenon has resulted in habitat loss and reduction of forested land for understory herbs in rural towns and in the periphery of metropolitan areas.

Deer, at high densities, are also a threat to goldenseal populations. The effects of white-tailed deer on 55 species of wildflowers were studied over two years in Beall Woods Nature Preserve in Illinois. In the first year, with high numbers of deer (estimated 58 deer/mi²), many of the species were heavily grazed, including goldenseal. Out of 55 herbs examined, goldenseal had the fifth highest percentage (45%) of plants grazed (Frankland, 2000). The next year, after deer numbers had been reduced, some species, such as *Delphinium tricornis* and *Trillium recurvatum* were still heavily grazed, while herbs such as goldenseal, *Polemonium reptans* and *Smilacina racemosa* did not have signs of herbivory. This suggests that goldenseal is not a preferred food for white-tailed deer, but at high densities deer will heavily browse it. Goldenseal and the other two herbs would be useful indicators for assessing impacts of deer densities on wildflower communities (Frankland and Nelson, 2001).

In Ohio, deer population densities have increased nearly exponentially from near zero in the 1940s to over 500,000 in 1996 (Iverson and Iverson, 1999). This was due to increases in forested land in the state, more shrubby habitat, few predators, mild winters, deer adaptation to human environments, and changes in deer population management. Deer densities were historically low in Ohio because most of the state was forested during pre-settlement times which is not ideal habitat for deer (Griffith et al., 1991).

Hunting on state public lands and national forests maintains deer population densities in these areas at 15-35 deer per square mile (Mike Reynolds, Wildlife Biologist, ODNR, pers. comm., 5/20/03). This range permits tree regeneration (Tilghman, 1989) and has minimal impacts on *Trillium grandiflorum* and other forest herbs (Anderson, 1994). In urban areas (especially metro parks) deer densities can be much greater, between 50 to 100 deer per square mile. This is a result of prohibitions on hunting, absence of large forest tracts and deer adaptation to the human environment (Mike Reynolds, Wildlife Biologist, ODNR, pers. comm., 5/20/03). Deer at high densities are a threat to goldenseal populations across the state, especially in urban areas or parks that do not allow hunting.

The purpose of this study was to quantify the population loss of goldenseal in Ohio and to examine some of the possible reasons for its decline. Herbarium voucher specimens were used to locate historic populations. Assessing the presence of goldenseal

at each record location was used to determine if goldenseal populations are declining across the state.

Habitat loss through extensive logging or deforestation was assessed by examining forest history of sites not containing goldenseal through historic aerial photos of sites combined with field observations. In order to assess population loss due to deer herbivory or overharvest, I examined understory vegetation, the stage structure of goldenseal populations, harvest data from CITES permit applications, and consulted land managers.

Methods

Site Selection

Decline of goldenseal populations was quantified by determining what proportion of sites that contained goldenseal populations historically still support populations today. Sites of historical goldenseal populations were compiled from herbarium voucher specimens. 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 labels were examined for information about the localities of the populations, such as coordinates, property ownership and nearby topographic features. Records that gave specific locations for sites (smaller than a 5 hectare area) were selected for this study (N=71).

Locating Sites and Determining if Forested

The 71 sites selected were located on county and topographic maps. In sites where the locality was specified by property ownership, plat books from county and local agencies were examined to determine the exact locations of sites. Next, local persons, such as curators, city employees, landowners and land managers who might know the status of the site containing the historic population were questioned by phone to determine whether the site was still forested and what they knew about the history of the site. If sites were determined to be cleared or developed subsequent to the date of the voucher specimen, that population was scored extinct due to deforestation.

Site Sampling

The sites that were determined to be still be forested were surveyed for populations of goldenseal between June 3rd and July 24th, 2002. Each site was searched with a field assistant, allowing one hour per hectare up to a maximum of 4 hours per site. We traversed the area in parallel lines approximately 2 -5 meters (depending on density of vegetation) apart. Following criterion used by Sinclair and Catling (2000b), I operationally defined a population as present if ramets were present in the same vicinity less than 0.5 km away from the description of the site.

Population Size

In sites where goldenseal was present, population size was determined using Gagnon's (1999) protocol for monitoring goldenseal populations. The number of plants in each leaf number stage-class (Table 1) was tallied. 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.

Site Observations

Stand structure and species composition were observed at most forested sites visited, whether goldenseal was present or not. The dominant species of herb, shrub, sub-canopy and canopy layers were recorded; nomenclature follows Gleason and Cronquist (1991). A general site description was written including the stratification of the layers, dominance of early successional tree species, the occurrence of an even-age stand, presence of exotic species, observations on disturbance such as deer browse or human impact, and site history compiled from communications with land manager or owner.

Site History

For stands that were forested but currently lacked goldenseal, I evaluated the possibility that the forest had been cleared subsequent to the year goldenseal was recorded and that a new forest stand had since regenerated. Aerial photos, approximately one photo for each 10-year increment from collection date to present, were requested from county agencies. Photos were compared and examined for evidence of clearcutting or extensive disturbance at any point during the time period.

Mapping

The location of each site was obtained from topographic maps. Maps of sites by county and by Ecoregion were generated using ArcMap, a GIS (Geographic Information Systems) software.

Ecoregions are areas distinguished by landscape-level characteristics that cause ecosystem components to reflect different patterns in different regions (Woods et al., 1998). The United States Environmental Protection Agency's (USEPA) Level III Ecoregions are a joint effort by multiple government agencies to standardize a common

framework on Ecoregions. The biotic and abiotic factors examined to determine these Ecoregions included geology, physiography, vegetation, climate, soils, land use, wildlife and hydrology. Different hierarchical levels of Ecoregions are recognized, with Level I dividing North America into 15 ecological Ecoregions and Level III into 99 Ecoregions (Woods et al., 1998).

The Nature Conservancy uses a different framework of Ecoregions, resulting in only four Ecoregions in Ohio compared to the six recognized by the USEPA. I chose the USEPA's classification because it was designed as a result of collaborations between the Ohio EPA, the Ohio Department of Natural Resources, the United States Department of Agriculture- Forest Service and Natural Resources Conservation Service, the United States Department of the Interior- U.S. Geological Survey, the Indiana Department of Environmental Management, USEPA Region IV and the USEPA National Health and Environmental Effects Research Laboratory (Woods et al., 1998).

Data Analysis

Sites were classified as either goldenseal present or goldenseal absent (=locally extinct). Goldenseal-extinct 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).

The occurrence of goldenseal and presence of forest were examined by Ecoregion to determine if there were any trends by region in Ohio. In sites where goldenseal was present, population size and stage structure were examined (Table 2).

In the fall of 2002, David Gorchov requested from the U.S. Fish and Wildlife Service all information available to the public on the export of goldenseal from Ohio since it was listed on CITES. The permit for export consists of the name and address of collector, date and county of collection, proof that the rhizomes were collected legally and, if rhizomes were purchased, the invoice of the sale. Permits only include the export of whole and sliced rhizomes because CITES does not regulate the export of finished products such as capsules, powders and tinctures that contain goldenseal. The

information received was from permits that involved plants collected prior to CITES (no county information) and plants collected in 1998 (Appendix III).

The ownership of each site was determined and sites were classified by ownership under the private (P) and public (B) sectors. Privately owned sites were classified as corporate (PC) or private landowner (PL). Public sites were classified as national (BN), state (BS), state-university (BU), county (BC) and municipality (BM). For each ownership class I assessed the number of sites forested with goldenseal, forested without goldenseal, and deforested.

Results

Out of 269 voucher specimens reviewed, 71 (dated 1845-1998) had sufficient detail for the collection site to be relocated (Figure 1 and Appendix I). Nine of the sites (13%) were determined 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 evidence of clearcutting. In seven of the sites, land managers stated that clearcutting had not occurred at the site. Of the remaining 15 sites, where forest history was gleaned from aerial photos, none experienced a major disturbance in the canopy. The dominant canopy trees (Appendix II) of all 22 sites were similar in composition to the 40 sites that contained goldenseal, and there was no evidence of successional trees dominating the forest in any of the sites. Most of the 40 sites with goldenseal, as well as most of the 22 sites without goldenseal, had canopies dominated by *Acer saccharum*, *Fagus grandifolia* and/or *Liriodendron tulipifera*. Furthermore, goldenseal-extant and goldenseal-extinct forested sites did not show different patterns in dominant herbs, shrubs, or sub-canopy trees. Invasive species, such as *Alliaria petiolata* and *Lonicera maackii*, were not associated with goldenseal-extinct sites, both were also found in sites with goldenseal.

Stratifying sites by age of the record, 20% of early (1845-1933), 50% of intermediate (1957-1971) and 58% of recent (1977-1998) sites still contained goldenseal (Figure 2). Among sites that no longer contained goldenseal, none of the early, 75% of intermediate and 83% of recent sites were still forested.

Placing the 71 sites on a map of Ecoregions of Ohio revealed that three sites were on the Huron/Erie Lake Plains, 27 on the Eastern Corn Belt Plains, 27 on the Erie/Ontario Drift and Lake Plain, and 14 were on the Western Allegheny Plateau (Figure 3). The remaining two Ecoregions in Ohio, Interior Plateau and Southern Michigan/Northern Indiana Drift Plains, did not contain any study sites. The proportion of sites that still had goldenseal was 33% on the Huron/Erie Lake Plains, 56% on the Eastern Corn Belt Plains, 56% on the Erie/Ontario Drift and Lake Plain, and 64% on the Western Allegheny Plateau. In sites where goldenseal was determined locally extinct, 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. Most (62%) of these populations had less than 200 ramets, 10% had 200 to 1000 ramets and 28% had more than 1000 ramets.

Assessing these population sizes by Ecoregion (Figure 4) showed that the only Huron/Erie Lake Plains site that contained goldenseal had less than 200 ramets. A majority (60%) of the Eastern Corn Belt Plains populations had less than 200 ramets, but 27% of populations in this Ecoregion exceeded 1000 ramets. The Erie/Ontario Drift and Lake Plain had slightly more (67%) of its populations in the smallest category and slightly fewer (20%) in the largest populations. The Western Allegheny Plateau had the greatest proportion (33%) of large populations and the lowest proportion (56%) of small populations.

Of the 27 populations where stage structure was determined, nine (33%) were comprised of $\geq 98\%$ non-reproductive plants (Table 2). Most (67%) of these nine populations were located in the Erie/Ontario Drift and Lake Plain Ecoregion. Of the remaining three sites, two were located in the Western Allegheny and one in the Eastern Corn Belt Plains.

A total of seven CITES permits for export of goldenseal were received from U.S. Fish and Wildlife Service (Appendix III). 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.

Out of the 71 sites, 33 were determined to be privately owned and 38 were public (Table 3). Goldenseal was extant in 55% of privately owned sites and 58% of public sites. 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 were more likely to still contain goldenseal than those owned by individual landowners. Furthermore, for sites that were still forested, corporation-owned sites were more likely to have goldenseal (88%) than were sites owned by individuals (61%). Among public ownership categories, national (67%) and state (69%) owned sites were more likely to still have goldenseal than were sites owned by other public entities. However, county lands did have a greater proportion (57%) of sites with goldenseal extant compared to university (33%) and municipal (33%) lands.

Figure 1. A county map of Ohio showing the 71 study sites that were surveyed for goldenseal in June and July 2002. Numbers refer to sites listed in Appendix I.

Figure 2. Current (2002) status of goldenseal at 71 historic localities in Ohio. Sites are stratified by date of the original collection.

Figure 3. An Ecoregions map of Ohio (from Wood et al., 1998) showing the location of the 71 study sites and the current (2002) status of goldenseal at these sites.

Figure 4. Extant populations classified by 2002 population size on an Ecoregion (Wood et al., 1998) map of Ohio.

Table 1. Leaf number size-classes of goldenseal (Gagnon, 1999, modified by Christensen, unpublished). Ramets, plants reproduced vegetatively, were counted individually and not grouped as one plant (following Sinclair and Catling, 2000b).

Size-class	Category	Description
1	one-leaved plant	plant with one basal leaf; non-reproductive
2	two-leaved plant	plant with two leaves from a single stem; reproductive
3	three-leaved plant	plant with two main leaves and one smaller leaf; reproductive

Table 2. The population stage structure and number of goldenseal ramets in 27 sites in Ohio. Twenty-five of the sites when searched for goldenseal contained less than 200 ramets per site. In two other sites (bold), counts were terminated before all plants were counted; in each of these sites the total population was estimated at 300.

Site#	1-leaf	2-leaf	3-leaf	Total Censused	% of 1-leaf Counted
4	28	3	1	32	88
6	12	6	0	18	67
7	2	1	0	3	67
8	6	3	0	9	67
9	38	9	0	47	81
10	23	0	0	23	100
19	131	9	0	140	94
20	44	44	0	88	50
24	43	2	1	46	93
39	89	11	0	100	89
42	82	0	0	82	100
45	90	13	0	103	87
46	75	48	0	133	61
50	22	0	0	22	100
51	54	10	0	64	84
55	27	0	0	27	100
58	9	0	0	9	100
59	182	1	0	183	99
60	74	0	0	74	100
61	1	0	0	1	100
63	23	5	0	28	82
64	64	21	3	88	73
65	156	31	0	187	83
66	180	17	0	197	91
67	60	1	0	61	98
69	7	2	0	9	78
71	3	2	0	5	60

Table 3. Current (2002) status of goldenseal and forest cover in 71 sites in Ohio stratified by type of land ownership.

Ownership	# of Sites Forested with Goldenseal	# of Sites Forested without Goldenseal	# of Sites Deforested	Total
Private- Corporate	7	1	2	10
Private- Individual Landowner	11	7	5	23
Public- National	4	2	0	6
Public- State	11	5	0	16
Public- State University	2	3	1	6
Public- County	4	3	0	7
Public- Municipal	1	1	1	3
Total	40	22	9	71

Discussion

Goldenseal's Status

This study revealed that nearly half of documented goldenseal populations are locally extinct, suggesting an overall decline in the number of goldenseal populations in Ohio. It is likely that extinctions have been occurring throughout the past century rather than only in recent decades. Had the decline occurred only in the early or intermediate time periods, then there should be no extinctions among the recently vouchered populations. If the decline had only occurred recently, the proportion of populations now extinct should have been similar for populations vouchered early (1845-1949), intermediate (1957-1971), or recent (1977-1998).

Most of the sites where goldenseal was found contained less than 200 ramets. This contrasts with population sizes in Ontario, Canada, on the edge of goldenseal's range, where only six (30%) of 20 relocated historic populations of goldenseal contained less than 200 ramets, 10 populations had 200-1000 ramets and four populations had over 1000 ramets (Sinclair and Catling, 2000a). Sinclair and Catling (2000a) reported no evidence of herbivory and only one site with evidence of digging, and suggested that collecting is more a problem in the U.S. Therefore, the greater frequency of smaller populations in Ohio could be a result of deer herbivory or collection.

Deforestation

Overall in the state, deforestation has played a minor role in the decline of goldenseal. Of the nine sites presently deforested, four had goldenseal collected prior to the 1930s. Even though I am unsure when these sites were actually deforested, this corresponded with the time period in which Ohio's forests were extensively cleared in the early part of the century. Three of the sites were from the late 1960s and have subsequently become sites of a subdivision, factory and farmland. The remaining two sites were from the mid-1980s and are now farmland and an upscale subdivision. Both of the farmland sites had streams through them that did not contain a forested riparian buffer which would have been ideal habitat for goldenseal.

One of the sites visited (#65) had been logged a few weeks prior to my visit. The canopy cover had almost entirely been removed except for *Acer saccharum* trees

comprising the landowner's sugarbush. Goldenseal was present but most plants were senescing as a result of the exposure to full sunlight. I predict this population will quickly go extinct.

None of the forested sites without goldenseal showed evidence of excessive clearcutting or major disturbance in the canopy. These sites were similar to the sites with goldenseal in terms of the dominant tree species in the canopy. The lack of differences between goldenseal-extant and goldenseal-extinct sites, in the dominants of the herb, shrub and sub-canopy layers, or in prevalence of invasive plant species, indicates that goldenseal extinction is not due to disturbance or other habitat changes. In addition, competition from invasive species does not appear to cause population demise. Sinclair and Catling (2000b), in sites in Ontario, also found goldenseal to be located in multiple habitats with a diversity of plant associates. They also suggested that disturbance (flooding and fire) is beneficial to growth and spread of goldenseal even though the disturbance may promote invasive alien species.

Among Ecoregions, deforestation of goldenseal sites was more prevalent in the Eastern Corn Belt Plains, where it was exclusively due to urban sprawl. This is not surprising since two of Ohio's four largest metropolitan areas, Cincinnati and Columbus (Staley and Hisrich, 2001), occur in this Ecoregion. The other two metropolitan areas, Cleveland and Akron/Canton, are located in Erie/Ontario Drift and Lake Plain, where the proportion of sites deforested was modest. Nevertheless, there was a site in this area that was cleared due to urban sprawl. In the Western Allegheny Plateau, where there are no major cities, there was no evidence of goldenseal population loss due to deforestation. The only site in Huron/Erie Lake Plains that was deforested was cleared for farmland and not as a result of urban sprawl.

More privately owned goldenseal sites were deforested than publicly owned goldenseal sites. Therefore forests that contain goldenseal are more likely to persist if they are public lands even though logging does occur on some of these lands (WNF and state forests). This could be a result of urban sprawl which almost solely affects private sites.

Herbivory by Deer

White-tailed deer herbivory has played a minor role in goldenseal extirpation in Ohio overall. However, in the northeast part of the state, herbivory appears to be more important. This part of Ohio includes the metropolitan areas of Cleveland and Akron, which have high densities of urban areas and roads. Deer in these northeastern counties are found locally at high densities in suburban areas (estimated 50-100/mi², Mike Reynolds, Wildlife Biologist at ODNR, pers. comm., 5/20/03). This is because deer populations are generally regulated by an open hunting season that, on most public land, occurs only in designated hunting areas. Hunting zones usually do not occur in urban and suburban settings, allowing deer densities in these areas to be high. Some land managers are forced to cull deer in their parks despite public opinion against it. This regulation of deer in all forests across the state is important for the survival of woodland herbs such as goldenseal.

Seven of the 71 historic sites were located in the Cleveland and Akron metropolitan areas. In four of these sites, I noted lack of a shrub layer and sometimes sparse sub-canopy and herb layers, which indicated excessive browse by deer. Three of these four sites (18, 37, 40) did not contain goldenseal and the fourth (61) contained only one small non-reproductive plant. Local biologists knowledgeable about sites 18 and 40 considered high deer densities the cause of goldenseal extinction. So, the demise of three populations in this area, and near extinction of a fourth, are most likely due to deer herbivory.

Comparing the dominant species in the herb layer of goldenseal-extinct versus goldenseal-extant sites supports the role of deer herbivory in population extinction of goldenseal. In this study, the ten most grazed herbs out of 55 from Frankland (2000) were considered to be the herbs most preferred by deer. The 24 herbs not grazed by deer were considered to be herbs avoided by deer. Among the 20 goldenseal-extinct sites where dominant herbs were determined, none had one of the herbs preferred by deer as a dominant. In addition, for over half (64%) of these sites, one or more of the dominant herb species was one that is avoided by deer. However, among the 40 goldenseal-extant sites where I determined dominants, five had a species preferred by deer as one of the dominants, and only four sites had a species avoided by deer as a dominant. Therefore,

severe deer browse was more evident in goldenseal-extinct sites than in extant sites. This pattern confirms that severe deer browse can result in goldenseal extinction.

Inference on the importance of deer herbivory on goldenseal extinction was based only on anecdotal information and my observations of dominant herbs and of recent excessive browse. It would be interesting to revisit all sites and more closely assess effects of deer at each site. Distribution and density of deer could be determined at sites by counting piles of fecal droppings. Then performing more intensive vegetation sampling, such as examining natural tree regeneration or documenting plants/trees that have been browsed, can show how deer are affecting the site.

Overharvest

In Ohio and throughout goldenseal's range, overharvest is commonly blamed for the demise of populations. Without initial population numbers, it is difficult to quantify this decline. However, some insights about harvest history of a goldenseal population can be made from examining population size and structure. Most of the Ohio sites in this study consisted of populations with <200 ramets, while, in Ontario, where harvesting is minimal, populations were typically between 200-1000 ramets (Sinclair and Catling, 2000a). This contrast in population sizes indicates that populations without harvesting pressures tend to be larger than populations where harvest has occurred.

The population structure of goldenseal tends to vary between recently harvested and not harvested sites. A West Virginia population censused after a harvest contained densely clustered small ramets, 99% of which were non-reproductive (Van der Voort et al., 2003). Although data prior to the harvest were not available, over the next four years the proportion of reproductive plants increased. This pattern 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).

However, populations dominated by non-reproductive plants don't always indicate that a population has been harvested. Christensen and Gorchov (unpublished) found that non-reproductive plants comprised 70%, 94%, 94%, 95%, 97% and 97% of six populations of goldenseal in Ohio that hadn't been harvested in recent times. Also, in Ontario, Sinclair and Catling (2002) visited 14 sites to examine population trends of

goldenseal. The population structure of individual sites were not reported, however, an average of all sites for two years comprised 86% non-reproductive plants

Of the 27 study sites in Ohio where I determined structure, non-reproductive plants comprised $\geq 98\%$ of the population in nine sites. Each of these populations had none or only one reproductive plant censused. This extreme scarcity of reproductive plants suggests that these nine populations were recently subjected to a severe harvesting event, but is not conclusive.

The effects of overharvest are not apparent in all parts of the state but vary by Ecoregion. Most of the CITES collections made in Ohio came from the Western Allegheny Plateau. This Ecoregion seems to have the greatest harvest pressure of all other Ecoregions, with deforestation and herbivory being minimal. The larger number of goldenseal populations and the larger sizes of these populations have made it an ideal harvest area. Also, two of the nine sites where population structure consisted of $\geq 98\%$ non-reproductive ramets were found in this Ecoregion which could indicate recent harvests. Erin Larson, botanist at Wayne National Forest, and Jim McCormac, botanist at ODNR, believe that goldenseal is not as common as it used to be in this part of the state.

In the Eastern Corn Belt Plains Ecoregion, overcollection may not have been as important as deforestation as a cause of local goldenseal extinction. Half of the study sites in this Ecoregion still contained goldenseal and some of these populations were large. And, of the 13 counties where a CITES permit was requested in 1998, only one was located in this Ecoregion. Also, only one of the nine sites where population structure was assessed had $\geq 98\%$ non-reproductive individuals.

In the Erie/Ontario Drift and Lake Plain and Huron/Erie Lake Plains Ecoregions harvest pressure is most likely minimal. Even though Erie/Ontario Drift and Lake Plain has the same number of sites with goldenseal as Eastern Corn Belt Plains, it also has the greatest proportion of smaller populations of all Ecoregions. Furthermore, Huron/Erie Lake Plains' only site that contains goldenseal has a small population. Erie/Ontario Drift and Lake Plain and Huron/Erie Lake Plains appear to have the least amount of goldenseal among Ecoregions. Because of this, collectors most likely do not bother with these parts of the state but concentrate in areas where there is more goldenseal. This is

reflected in the lack of CITES permits requested for both Ecoregions and in knowledge from land managers and botanists in these areas. A land manager at a site (#24) in Erie/Ontario Drift and Lake Plain stated that harvesting used to be prevalent in this part of the state but most of the diggers have eventually died so there is not much pressure in the area in recent years. However, out of the 9 sites where population structure consisted of $\geq 98\%$ non-reproductive ramets, six were found in the Erie/Ontario Drift and Lake Plain sites. This contradicts all other evidence pointing towards minimal collecting occurring in this Ecoregion.

Conclusions

This study has revealed that the number of populations of goldenseal in Ohio has declined and the most likely causes for extinction differ among Ecoregions. Deforestation was most prevalent in the Eastern Corn Belt Plains sites, but was not a problem in the Western Allegheny Plateau sites. Deer herbivory appeared to cause of population loss only in Erie/Ontario Drift and Lake Plain sites. The main cause of extinctions for Western Allegheny Plateau sites appears to be overcollection.

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Appendix I. Sites of 71 historic goldenseal populations selected for this study with information on herbarium record (locality, year of collection, herbarium), current land ownership, occurrence of goldenseal, presence of forest, Ecoregion, and population size of goldenseal. Precise locations are not listed in order to prevent poaching.

Site#	County	Township	Year	Herbarium	Ownership ¹	Goldenseal Presence in 2002 ²	Deforested ³	Ecoregion ⁴	Pop size
1	Adams	Green	1977	KE	PL	Y	N	W	~10,000s
2	Ashland	Ruggles	1980	KE	PC	N	N	E	0
3	Ashtabula	Morgan	1982	CLM	PC	Y	N	E	~ 400
4	Athens	Athens	1984	BHO	BM	Y	N	W	32
5	Athens	Athens	1993	BHO	BU	N	N	W	0
6	Butler	Hanover	1992	MU	PL	Y	N	C	18
7	Butler	Oxford	1933	MU	BS	Y	N	C	3
8	Butler	Oxford	1981	MU	BU	Y	N	C	9
9	Butler	Oxford	1989	MU	BU	Y	N	C	47
10	Butler	Reily	1980	MU	BC	Y	N	C	23
11	Butler	Reily	1982	MU	BC	N	N	C	0
12	Champaign	Urbana	1967	OS	BS	N	N	C	0
13	Clark	Pleasant	1977	KE	PL	Y	N	C	~ 500
14	Clark	Springfield	1969	JHWU	PC	N	Y	C	0
15	Clark	Springfield	1894	JHWU	BM	N	Y	C	0
16	Clark	Springfield	1969	JHWU	PC	N	N	C	0

¹ PC= Private/Corporate, PL= Private/Individual Landowner, BN= Public/National, BS= Public/State, BU= Public/State University, BC= Public/County, BM= Public/Municipal

² Y= Yes, N= No

³ Y= Yes, N= No

⁴ C= Eastern Corn Belt Plains, E= Erie/Ontario Drift and Lake Plain, H= Huron/Erie Lake Plains, W= Western Allegheny Plateau

Site#	County	Township	Year	Herbarium	Ownership	Goldenseal Present in 2002	Deforested	Ecoregion	Pop size
17	Cuyahoga	NA	1888	CLM	PC	N	Y	E	0
18	Cuyahoga	NA	1980	CLM	BC	N	N	E	0
19	Darke	Wayne	1986	MU	PC	Y	N	C	140
20	Franklin	Blendon	1980	OS	BC	Y	N	C	88
21	Franklin	NA	1925	OS	PL	N	Y	C	0
22	Geauga	Bainbridge	1959	OS	PC	N	N	E	0
23	Geauga	Bainbridge	1978	OS	PC	N	N	E	0
24	Geauga	Middlefield	1982	CLM	BC	Y	N	E	46
25	Hamilton	Sycamore	1980	OS	BU	N	N	C	0
26	Hamilton	NA	1845	CINC	PL	N	Y	C	0
27	Hamilton	NA	1965	CINC	BU	N	Y	C	0
28	Hamilton	NA	1986	MU	PL	N	Y	C	0
29	Hardin	Taylor Creek	1990	MU	PS	N	N	C	0
30	Harrison	Athens	1957	OS	PL	Y	N	W	~1000s
31	Highland	Brush Creek	1986	CINC	BS	Y	N	C	~1000s
32	Hocking	Laurel	1983	BHO	BS	N	N	W	0
33	Holmes	Killbuck	1968	KE	PC	N	N	W	0
34	Holmes	Ripley	1971	KE	PL	Y	N	E	~1000s
35	Huron	Greenfield	1997	CLM	PC	N	N	C	0
36	Knox	Harrison	1994	CLM	PL	Y	N	E	~1000s
37	Lake	Madison	1966	KE	BU	N	N	E	0
38	Lake	Willoughby	1962	OS	BC	N	N	E	0
39	Lake	NA	1980	CLM	PC	Y	N	E	100
40	Lake	NA	1980	CLM	BS	N	N	E	0
41	Lawrence	Elizabeth	1986	OS	BN	N	N	W	0

Site#	County	Township	Year	Herbarium	Ownership	Goldenseal Present in 2002	Deforested	Ecoregion	Pop size
42	Lorain	Huntington	1993	CLM	BC	Y	N	E	82
43	Madison	Union	1989	OS	BS	Y	N	C	~1000s
44	Meigs	NA	1961	BHO	BS	Y	N	W	~1000
45	Morgan	Union	1998	BHO	BN	Y	N	W	103
46	Morrow	Peru	1961	OS	PC	Y	N	C	~300
47	Perry	Monroe	1965	BHO	BM	N	N	W	0
48	Pike	Mifflin	1981	OS	PC	Y	N	W	~10,000s
49	Portage	Edinburg	1985	KE	PL	N	Y	E	0
50	Portage	Nelson	1977	OS	BS	Y	N	E	22
51	Preble	Israel	1981	MU	BS	Y	N	C	64
52	Preble	Somers	1981	MU	BS	Y	N	C	~1000s
53	Richland	Troy	1962	OS	BS	N	N	E	0
54	Richland	Worthington	1994	CLM	PC	Y	N	E	4000
55	Ross	Harrison	1991	CLM	BS	Y	N	W	27
56	Seneca	Adams	1962	OS	PL	N	N	H	0
57	Stark	Sugar Creek	1960	KE	PC	N	N	E	0
58	Summit	Boston	1957	OS	BN	Y	N	E	9
59	Summit	Boston	1959	OS	BN	Y	N	E	~300
60	Summit	Boston	1969	CLM	BN	Y	N	E	74
61	Summit	Boston	1979	KE	PC	Y	N	E	1
62	Summit	Northhampton	1979	KE	BN	N	N	E	0
63	Trumbull	Mesopotamia	1960	KE	PL	Y	N	E	28
64	Trumbull	Mesopotamia	1960	OS	PL	Y	N	E	88
65	Trumbull	Vernon	1977	KE	PL	Y	N	E	187
66	Tuscarawas	Washington	1987	MU	PL	Y	N	W	197

Site#	County	Township	Year	Herbarium	Ownership	Goldenseal Present in 2002	Deforested	Ecoregion	Pop size
67	Vinton	Clinton	1965	BHO	BS	Y	N	W	61
68	Warren	Wayne	1980	OS	BS	Y	N	C	~1000s
69	Warren	NA	1993	MU	PL	Y	N	C	9
70	Wood	Freedom	1967	OS	PL	N	Y	H	0
71	Wood	Liberty	1967	OS	BS	Y	N	H	5

Appendix II. The prominent herb, shrub, sub-canopy and canopy species of 63 forested sites in Ohio. Bold print represents the sites that contained goldenseal when they were searched in 2002. Nomenclature follows Gleason and Cronquist (1991).

Site #	Date Visited	Dominant Herb Species	Dominant Shrub Species	Dominant Sub-canopy Species	Dominant Canopy Species
1	7/3/2002	<i>Actaea pachypoda</i> , <i>Jeffersonia diphylla</i> , <i>Parthenocissus quinquefolia</i>	<i>Asimina triloba</i> , <i>Lindera benzoin</i>	<i>Acer saccharum</i>	<i>Liriodendron tulipifera</i>
2	6/4/2002	<i>Aster macrophyllus</i> , <i>Geranium maculatum</i> , <i>Hydrophyllum canadense</i>		<i>Acer saccharum</i>	<i>Acer saccharum</i> , <i>Carya ovata</i> , <i>Fagus grandifolia</i> , <i>Tilia americana</i>
3	7/10/2002	<i>Allium tricoccum</i> , <i>Geranium maculatum</i>		<i>Acer saccharum</i> , <i>Fagus grandifolia</i>	<i>Acer saccharum</i> , <i>A. rubrum</i> , <i>Fagus grandifolia</i> , <i>Liriodendron tulipifera</i>
4	6/19/2002	<i>Asarum canadense</i> , <i>Geranium maculatum</i>	<i>Asimina triloba</i> , <i>Hydrangea arborescens</i> , <i>Lindera benzoin</i>	<i>Acer saccharum</i> , <i>Aesculus flava</i> , <i>Fagus americana</i>	<i>Acer saccharum</i> , <i>Liriodendron tulipifera</i>
5	6/20/2003	<i>Lonicera japonica</i> , <i>Polystichum acrostichoides</i> , <i>Solidago</i> sp.	<i>Rosa multiflora</i> , <i>Rubus</i> spp.	<i>Acer saccharum</i> , <i>Fagus grandifolia</i> , <i>Ulmus americana</i> , <i>U. serotina</i>	mixed canopy
6	7/1/2002	<i>Impatiens</i> spp., <i>Panax quinquefolia</i> , <i>Parthenocissus quinquefolia</i> , <i>Smilacina racemosa</i>	<i>Lonicera maackii</i>	<i>Cercis canadensis</i> , <i>Fraxinus pennsylvanica</i> , <i>F. quadrangulata</i>	<i>Acer saccharum</i> , <i>Carya ovata</i> , <i>C. tomentosa</i> , <i>Quercus alba</i> , <i>Quercus velutina</i>

Site #	Date Visited	Dominant Herb Species	Dominant Shrub Species	Dominant Sub-canopy Species	Dominant Canopy Species
7	6/25/2002	<i>Amphicarpaea bracteata</i> , <i>Preanthes alba</i> , <i>Sanguinaria canadense</i>	<i>Lonicera maackii</i>	<i>Acer saccharum</i> , <i>Carya</i> spp.	<i>Acer saccharum</i> , <i>Quercus rubra</i> , <i>Q. muehlenbergii</i> , <i>Q. macrocarpa</i>
8	6/13/2002		<i>Lonicera maackii</i>	<i>Tilia americana</i> , <i>Acer saccharum</i>	<i>Quercus rubra</i> , <i>Fraxinus pennsylvanica</i>
9	6/13/2002	<i>Actaea alba</i> , <i>Cryptotaenia canadensis</i> , <i>Podophyllum peltatum</i> , <i>Sanicula</i> sp.	<i>Lonicera maackii</i>		<i>Acer saccharum</i> , <i>Fagus grandifolia</i> , <i>Quercus rubra</i>
10	7/17/2002	<i>Sanicula</i> sp.	<i>Lonicera maackii</i> , <i>Rosa multiflora</i>		<i>Acer saccharum</i> , <i>Platanus occidentalis</i>
11	7/17/2002	<i>Sanicula</i> sp.	<i>Lonicera maackii</i>		<i>Carya cordiformis</i> , <i>Quercus</i> spp.
12	6/26/2002	⁵ <i>Senecio aureus</i> , <i>Allium tricoccum</i> , <i>Thalictrum polygamum</i>	<i>Corylus americana</i>		<i>Fraxinus americana</i> , <i>Tilia americana</i> , <i>Quercus bicolor</i>
13	6/26/2002	<i>Parthenocissus quinquefolia</i> , <i>Sanicula</i> sp., <i>Uvularia grandiflora</i>	<i>Lonicera maackii</i>	<i>Celtis occidentalis</i> , <i>Prunus serotina</i>	<i>Carya cordiformis</i> , <i>Juglans nigra</i> , <i>Quercus muehlenbergii</i> , <i>Ulmus americana</i>
16	6/26/2002	<i>Impatiens</i> spp., <i>Laportea canadensis</i> , <i>Podophyllum peltatum</i> , <i>Sanguinaria canadense</i>		<i>Acer negundo</i>	<i>Acer saccharum</i> , <i>Platanus occidentalis</i> , <i>Populus deltoides</i>
18	7/16/2002	<i>Alliaria petiolata</i> , <i>Parthenocissus quinquefolia</i> , <i>Phytolacca americana</i> , <i>Rubus</i> spp.		<i>Fagus grandifolia</i> , <i>Fraxinus americana</i> ,	<i>Quercus alba</i> , <i>Q. velutina</i>

⁵ This site was located in a bog. The vegetation was not sampled but a species list is provided in Frederick (1974).

Site #	Date Visited	Dominant Herb Species	Dominant Shrub Species	Dominant Sub-canopy Species	Dominant Canopy Species
19	7/24/2002	<i>Jeffersonia diphylla</i> , <i>Geranium maculatum</i> , <i>Sanicula</i> sp.	<i>Lindera benzoin</i>	<i>Acer saccharum</i> , <i>Aesculus glabra</i> , <i>Fagus grandifolia</i>	<i>Acer saccharum</i> , <i>Fagus grandifolia</i>
20	6/27/2002	<i>Circaea lutetiana</i> , <i>Fraxinus</i> sp. seedlings, <i>Impatiens</i> spp.	open	open	<i>Acer saccharum</i> , <i>Fraxinus</i> sp., <i>Prunus serotina</i> , <i>Carya ovata</i> , <i>Quercus alba</i>
22	7/11/2002	<i>Alliaria petiolata</i> , <i>Parthenocissus quinquefolia</i> , <i>Tiarella cordifolia</i> , <i>Toxicodendron radicans</i>		<i>Acer saccharum</i> , <i>Tsuga canadensis</i>	<i>Acer saccharum</i> , <i>Betula lenta</i> , <i>Prunus serotina</i> , <i>Tsuga canadensis</i>
23	7/11/2002	<i>Alliaria petiolata</i> , <i>Circaea lutetiana</i> , <i>Polygonum virginianum</i> , <i>Toxicodendron radicans</i>		<i>Acer saccharum</i> , <i>Ostrya virginiana</i>	<i>Acer saccharum</i> , <i>Fagus grandifolia</i>
24	7/11/2002	<i>Arisaema triphyllum</i> , <i>Cimicifuga racemosa</i> , <i>Circaea lutetiana</i> , <i>Smilacina racemosa</i>	<i>Corylus</i> sp.	<i>Acer saccharum</i> , <i>Fagus grandifolia</i>	<i>Acer saccharum</i>
25	7/24/2002	<i>Vinca minor</i>	<i>Lonicera maackii</i>	<i>Acer saccharum</i> , <i>Carya</i> spp.	<i>Acer saccharum</i> , <i>Liriodendron tulipifera</i> , <i>Prunus serotina</i>
29	6/6/2002	<i>Alliaria petiolata</i> , <i>Impatiens</i> spp., <i>Laportea canadensis</i>	No data.	No data.	No data.
30	6/12/2002	<i>Acer saccharum</i> , <i>Podophyllum peltatum</i> , <i>Viola</i> spp.	open	open	<i>Acer saccharum</i> , <i>Prunus serotina</i>

Site #	Date Visited	Dominant Herb Species	Dominant Shrub Species	Dominant Sub-canopy Species	Dominant Canopy Species
31	7/2/2002	<i>Sanicula</i> sp., <i>Verbesina alternifolia</i>	<i>Asimina triloba</i> , <i>Lindera benzoin</i>	<i>Celtis occidentalis</i> , <i>Cercis canadensis</i> , <i>Prunus serotina</i>	<i>Liriodendron tulipifera</i>
32	6/21/2002	<i>Geranium maculatum</i> , <i>Podophyllum peltatum</i> , <i>Sanicula</i> sp.	No data.	No data.	No data.
33	6/11/2002	<i>Medeola virginiana</i> , <i>Podophyllum peltatum</i> , <i>Polygonum virginianum</i> , <i>Polystichum acrostichoides</i>		<i>Acer saccharum</i>	<i>Acer saccharum</i> , <i>Ulmus serotina</i> , <i>Fagus americana</i> , <i>Liriodendron tulipifera</i>
34	6/11/2002	<i>Parthenocissus quinquefolia</i> , <i>Preanthes alba</i> , <i>Sanicula</i> sp.	mixed	<i>Cornus florida</i> , <i>Ostrya virginiana</i> , <i>Sassafras albidum</i>	mixed canopy
35	6/4/2002	<i>Geranium maculatum</i> , <i>Parthenocissus quinquefolia</i>			<i>Acer saccharum</i> , <i>Fagus grandifolia</i> , <i>Populus heterophylla</i> , <i>Quercus palustris</i>
36	6/10/2002	<i>Alliaria petiolata</i> , <i>Parthenocissus quinquefolia</i>	<i>Lindera benzoin</i> <i>Rosa multiflora</i>	<i>Acer saccharum</i> , <i>Ulmus serotina</i> , <i>Carya cordiformis</i>	<i>Acer saccharum</i> , <i>Ulmus serotina</i>

Site #	Date Visited	Dominant Herb Species	Dominant Shrub Species	Dominant Sub-canopy Species	Dominant Canopy Species
37	7/10/2002	<i>Acer saccharum</i> , <i>Podophyllum peltatum</i>	open	open	<i>Acer saccharum</i> , <i>Prunus serotina</i>
38	7/9/2002	<i>Arisaema triphyllum</i> , <i>Podophyllum peltatum</i>	<i>Lindera benzoin</i>	<i>Acer saccharum</i>	Mixed canopy
39	7/9/2002	<i>Hepatica acutiloba</i> , <i>Polystichum acrostichoides</i>	<i>Lindera benzoin</i>	<i>Fagus grandifolia</i>	<i>Fagus grandifolia</i> , <i>Liriodendron tulipifera</i> , <i>Tsuga canadensis</i>
40	7/9/2002	<i>Arisaema triphyllum</i> , <i>Podophyllum peltatum</i>	open	open	<i>Acer saccharum</i> , <i>Quercus rubra</i>
41	6/18/2002	<i>Jeffersonia diphylla</i>	open	open	Mixed canopy
42	6/4/2002	<i>Asarum canadense</i> , <i>Geranium maculatum</i> , <i>Parthenocissus quinquefolia</i>	<i>Lindera benzoin</i>	<i>Alnus americana</i> , <i>Ostrya virginiana</i>	<i>Acer saccharum</i> , <i>Prunus serotina</i>
43	6/27/2002	<i>Parthenocissus quinquefolia</i> , <i>Sanicula</i> sp.	<i>Fraxinus pennsylvanica</i> , <i>Rosa multiflora</i> , <i>Ulmus serotina</i>	<i>Celtis occidentalis</i> , <i>Ulmus serotina</i>	Mixed canopy
44	6/19/2002	<i>Impatiens</i> spp., <i>Podophyllum peltatum</i> , <i>Polygonum virginianum</i> , <i>Smilacina racemosa</i>	<i>Lindera benzoin</i>	<i>Acer saccharum</i> , <i>Aesculus flava</i> , <i>Asimina triloba</i>	<i>Acer saccharum</i> , <i>Aesculus flava</i> , <i>Fagus grandifolia</i> , <i>Quercus rubra</i>
45	6/20/2002	<i>Parthenocissus quinquefolia</i> , <i>Polystichum acrostichoides</i>	<i>Fagus grandifolia</i>	<i>Acer saccharum</i> , <i>Fagus grandifolia</i>	<i>Acer saccharum</i> , <i>Aesculus flava</i> , <i>Fagus grandifolia</i> , <i>Quercus velutina</i>

Site #	Date Visited	Dominant Herb Species	Dominant Shrub Species	Dominant Sub-canopy Species	Dominant Canopy Species
46	6/10/2002	<i>Parthenocissus quinquefolia</i> , <i>Podophyllum peltatum</i> , <i>Sanguinaria canadense</i>		<i>Acer saccharum</i>	<i>Acer saccharum</i> , <i>Juglans nigra</i>
47	6/20/2002	<i>Adiantum pedatum</i> , <i>Parthenocissus quinquefolia</i>		<i>Acer saccharum</i> , <i>Fagus grandifolia</i> , <i>Ostrya virginiana</i>	<i>Acer saccharum</i> , <i>Aesculus flava</i> , <i>Fagus grandifolia</i> , <i>Prunus serotina</i>
48	7/2/2002	<i>Cimicifuga racemosa</i> , <i>Parthenocissus quinquefolia</i> , <i>Podophyllum peltatum</i>	<i>Fraxinus pennsylvanica</i>	<i>Acer saccharum</i> , <i>Tilia americana</i> , <i>Ulmus serotina</i>	<i>Acer saccharum</i> , <i>Tilia americana</i> , <i>Liriodendron tulipifera</i> , <i>Ulmus serotina</i>
50	7/11/2002	<i>Cimicifuga racemosa</i> , <i>Geranium maculatum</i>	<i>Rosa multiflora</i>	<i>Acer saccharum</i>	<i>Acer saccharum</i>
51	6/24/2002	<i>Asarum canadense</i> , <i>Circaea lutetiana</i> , <i>Parthenocissus quinquefolia</i>	<i>Asimina triloba</i> , <i>Lonicera maackii</i>	<i>Acer negundo</i>	<i>Quercus muehlenbergii</i> , <i>Tilia americana</i> , <i>Ulmus serotina</i> , <i>U.americana</i>
52	6/25/2002	<i>Parthenocissus quinquefolia</i> , <i>Polygonum virginianum</i> , <i>Ulmus serotina</i> seedlings	<i>Lindera benzoin</i> , <i>Ulmus serotina</i>	<i>Acer saccharum</i> , <i>Carpinus caroliniana</i> , <i>Celtis occidentalis</i>	<i>Acer saccharum</i> , <i>Fagus grandifolia</i> , <i>Fraxinus americana</i>
53	6/5/2002	<i>Alliaria petiolata</i> , <i>Impatiens</i> spp.		<i>Acer saccharum</i> , <i>Prunus serotina</i>	<i>Liriodendron tulipifera</i> , <i>Prunus serotina</i> , <i>Robinia pseudoacacia</i>

Site #	Date Visited	Dominant Herb Species	Dominant Shrub Species	Dominant Sub-canopy Species	Dominant Canopy Species
54	6/5/2002	<i>Circaea lutetiana</i> , <i>Impatiens</i> spp., <i>Osmorhiza longistylis</i> , <i>Parthenocissus quinquefolia</i>	<i>Rosa multiflora</i> , <i>Rubus</i> spp.	<i>Aesculus glabra</i> , <i>Crataegus</i> sp., <i>Fagus grandifolia</i>	<i>Acer saccharum</i> , <i>A. rubrum</i> , <i>Fraxinus pennsylvanica</i> , <i>Prunus serotina</i>
55	7/2/2002	<i>Asarum canadense</i> , <i>Circaea lutetiana</i> , <i>Geranium maculatum</i> , <i>Parthenocissus quinquefolia</i>	<i>Corylus</i> sp., <i>Lindera benzoin</i>	<i>Fraxinus pennsylvanica</i>	<i>Liriodendron tulipifera</i>
56	6/4/2002	<i>Parthenocissus quinquefolia</i> , <i>Podophyllum peltatum</i>		<i>Cornus</i> sp., <i>Fraxinus pennsylvanica</i>	<i>Acer saccharum</i> , <i>Tilia americana</i> , <i>Liriodendron tulipifera</i> , <i>Acer negundo</i>
57	6/12/2002	<i>Impatiens</i> spp., <i>Parthenocissus quinquefolia</i> , <i>Podophyllum peltatum</i> , <i>Rubus</i> spp.	<i>Cephalanthus occidentalis</i> , <i>Viburnum acerifolium</i>		Mixed canopy
58	7/15/2002	<i>Caulophyllum thalictroides</i> , <i>Cimicifuga racemosa</i> , <i>Circaea lutetiana</i>	<i>Lindera benzoin</i>	<i>Cornus</i> sp.	<i>Liriodendron tulipifera</i>
59	7/16/2002	<i>Adiantum pedatum</i> , <i>Arisaema triphyllum</i> , <i>Geranium maculatum</i> , <i>Fraxinus</i> seedlings		<i>Acer saccharum</i> , <i>Fagus grandifolia</i>	<i>Acer saccharum</i> , <i>Fagus grandifolia</i> , <i>Liriodendron tulipifera</i> , <i>Tilia americana</i>
60	7/16/2002	<i>Arisaema triphyllum</i> , <i>Circaea lutetiana</i>			<i>Acer saccharum</i> , <i>Fraxinus nigra</i> , <i>Liriodendron tulipifera</i> , <i>Quercus macrocarpa</i>

Site #	Date Visited	Dominant Herb Species	Dominant Shrub Species	Dominant Sub-canopy Species	Dominant Canopy Species
61	7/15/2002	<i>Geranium maculatum</i>	open	<i>Fagus grandifolia</i> , <i>Ostrya virginiana</i> , <i>Prunus serotina</i>	<i>Carya cordiformis</i> , <i>Quercus alba</i> , <i>Q. rubrum</i> , <i>Q. velutina</i>
63	7/10/2002	<i>Asarum canadense</i> , <i>Polystichum acrostichoides</i> , <i>Tiarella cordifolia</i>		<i>Acer saccharum</i> , <i>Tsuga canadensis</i> , <i>Ulmus serotina</i>	<i>Acer saccharum</i> , <i>Fagus grandifolia</i> , <i>Liriodendron tulipifera</i> , <i>Tilia americana</i>
64	7/11/2002	<i>Cimicifuga racemosa</i> , <i>Geranium maculatum</i> , <i>Parthenocissus quinquefolia</i> , <i>Polygonatum biflorum</i>	<i>Carpinus caroliniana</i> , <i>Lindera benzoin</i>	<i>Acer saccharum</i> , <i>Liriodendron tulipifera</i> , <i>Tilia americana</i>	<i>Acer saccharum</i> , <i>Quercus rubra</i>
65	7/10/2002	<i>Circaea lutetiana</i> , <i>Geranium maculatum</i> , <i>Impatiens</i> spp., <i>Podophyllum peltatum</i>		<i>Acer saccharum</i> , <i>Carpinus caroliniana</i> , <i>Carya ovata</i>	Logged spring 2002 leaving only <i>Acer saccharum</i>
66	6/12/2002	<i>Amphicarpaea bracteata</i> , <i>Impatiens</i> spp., <i>Osmorhiza longistylis</i> , <i>Polygonum virginianum</i>			Mixed canopy
67	6/18/2002	<i>Caulophyllum thalictroides</i> , <i>Cimicifuga racemosa</i> , <i>Geranium maculatum</i> , <i>Uvularia grandiflora</i>	<i>Hydrangea arborescens</i> , <i>Lindera benzoin</i>	<i>Acer saccharum</i> , <i>Fagus grandifolia</i>	<i>Acer saccharum</i> , <i>Fagus grandifolia</i>

Site #	Date Visited	Dominant Herb Species	Dominant Shrub Species	Dominant Sub-canopy Species	Dominant Canopy Species
68	7/1/2002	<i>Alliaria petiolata</i> , <i>Parthenocissus quinquefolia</i> , <i>Sanguinaria canadense</i> , <i>Smilacina racemosa</i>	<i>Lonicera maackii</i> , <i>Rosa multiflora</i>	<i>Asimina triloba</i> , <i>Cercis canadensis</i> , <i>Ulmus americana</i>	Mixed canopy
69	7/1/2002	<i>Hydrophyllum virginianum</i> , <i>Impatiens</i> spp., <i>Parthenocissus quinquefolia</i> , <i>Podophyllum peltatum</i>		<i>Ostrya virginianum</i> , <i>Prunus serotina</i> , <i>Sassafras albidum</i>	<i>Acer saccharum</i> , <i>Fraxinus americana</i> , <i>Quercus alba</i> , <i>Q. velutina</i>
70	6/3/2002	<i>Geranium maculatum</i> , <i>Laportea canadensis</i> , <i>Podophyllum peltatum</i>	<i>Hydrangea arborescens</i>		<i>Acer saccharum</i> , <i>Fagus grandifolia</i> , <i>Liriodendron tulipifera</i> , <i>Platanus occidentalis</i>
71	6/3/2002	<i>Aralia nudicaulis</i> , <i>Geranium maculatum</i> , <i>Parthenocissus quinquefolia</i> , <i>Podophyllum peltatum</i>	open	<i>Cornus</i> sp.	Mixed canopy

Appendix III. Data obtained from U.S. Fish and Wildlife Service on harvest of goldenseal rhizomes from Ohio from CITES permit applications including the dry weight in kg and the county where harvested. Counties primarily in Western Allegheny Plateau Ecoregion are in bold and those primarily in Eastern Corn Belt Plains are in *italics*. One county was divided equally in Interior Plateau, Western Allegheny and Eastern Corn Belt Plains Ecoregions and it is underlined. Note: The information related to MAFCO Natural Products comes from a single permit application.

Seller	Year	County	Harvest kg	Comments
Blessed Herbs	prior to CITES	unknown	500.0	pre-CITES collection, all from Ohio
Potter Fur and Roots	prior to CITES	unknown	273.0	pre-CITES collection, all from Ohio
MAFCO Natural Products	1998	Tuscarawas	25.0	
MAFCO Natural Products	1998	Gallia	57.0	
MAFCO Natural Products	1998	Ross	87.0	
Ohio River Ginseng & Fur	1998	multiple	682.0	<u>Adams</u> , Columbiana , Coshocton , Gallia , Guernsey , Jefferson , Monroe , <i>Preble</i> , Ross , Tuscarawas , Vinton counties.
The Herbal Exchange	1998	Muskingum	*28.0	Frazeysburg, Jacksonburg Twp; collected on owner's property
Wilcox Natural Products	1998	Lawrence	126.0	
Wilcox Natural Products	1998	Lawrence	82.1	

* = fresh weight