4. 0 Ecology of Great Lakes Alvars

4.1 Overview

Four key ecological processes that influence Great Lakes alvar communities needed to be studied in order to understand how best to manage and conserve alvar communities. The key processes identified by the Alvar Working Group were: 1) hydrology and soil moisture regime, 2) fire regime and land use history, 3) herbivory: browsing by deer and grazing by cattle, and 4) the invasion of exotic plant species. Initially the information that we had on these processes was spotty across the Great Lakes. Detailed data were available from one or two sites, and casual observations suggested these processes were active at other sites, but we had no idea how much these processes influenced alvar sites across the Great Lakes region.

We collected data on evidence of these four ecological processes as part of our initial community field surveys. Field workers looked for evidence of fire by searching for charred stumps, charred wood lying on the ground, or fire scars on trees. At many sites a few of the oldest-looking cedars were cored and aged. Evidence of hydrology and soil moisture regime were noted, such as standing pools of water, soil depth, soil texture, and bedrock structure. We looked for browse lines and nipped twigs for evidence of herbivory. We noted fence lines, farm machinery, cut stumps, or other evidence of land use history that might indicate past disturbance. And we noted any exotic species present.

These observations on ecological processes were used to refine several research hypotheses that would help us understand the role of the four key ecological processes. For each process, a team of collaborators was identified to refine research methods and evaluate work done to date. For the hydrology and soil moisture regime research, the team of collaborators included Tom Feeney, Ray Lougeay, Carol Reschke, Judith Jones, and Bruce Gilman. The fire and land use history team included Judith Jones, Claudia Schaefer, Bruce Gilman, Pat Comer, and Carol Reschke. The group working on herbivory included Dawn Bazely, Saewan Koh, Judith Jones, Don Cuddy, Janet Grand, Sandy Bonanno, Don Waller, and Carol Reschke. The group focusing on exotics included John Riley, Amy Samuels, and Judith Jones. Other collaborators in the Alvar Working Group provided suggestions and logistical support for research projects.

Summaries of the results to date are provided in this chapter. Some of the research is complete, and some is ongoing. The conclusions section at the end of each summary provides recommendations for management of alvar sites and suggestions for further research.

4.2 The Role of Alvar Hydrology and Soil Moisture Regime

4.2.1 Introduction

Most hydrologic studies of alvars in the Great Lakes region have concentrated on Chaumont Barrens in New York state (Reschke 1995a; Lougeay 1994, 1996; Tatnall 1996; Bertrand 1996; Feeney 1996, 1997). Reschke (1995a) found strong correlations between soil moisture conditions and vegetation types, with “alvar grasslands” (equivalent to tufted hairgrass wet alvar grassland) located in the wettest, seasonally flooded areas, and “calcareous pavement barrens” (equivalent to juniper alvar shrubland) in the drier, never-flooded areas. At the Limerick Cedars alvar, also in New York state, Gilman (1995) observed that alvar community structure was influenced by rapidly changing environmental conditions and differential tolerances of plants, especially to periodic drought.

Each alvar community type undoubtedly has its own special rhythm of seasonal wetness and dryness, and studies to date have only begun to document these patterns. Based on the Chaumont Barrens work, the hydrology of alvar grasslands has a considerable seasonal variation ranging from near-flooded conditions to near desiccation. Flooded conditions occur during March, April, May, and into June, and again in late September through November until snows accumulate (Figure A). These alvar grasslands achieve a near-wetland condition based upon the characteristics of the principal grassland soils, vegetation, and the spring and fall hydrologic conditions.

Figure A: Seasonal flooding conditions in alvar

Wet spring and fall conditions are usually interrupted by a very dry period in July and August in which all ponding ends and vegetation can be stressed to near, or beyond, the wilting point. Soils are very shallow (average is about 6 cm), and hold limited supplies of water; this limited soil moisture reservoir appears to be quickly depleted in dry periods. Surface temperatures on exposed rock within alvars can reach very high levels, from 43^{o} to 53^{o} C during summer periods (Schaefer and Larson 1997, Gilman 1995). Because of these factors, soils approach total desiccation in August and September, even during cool wet years (Lougeay 1996).

The rate of drying varies among different alvar community types, as outlined later in this section for sites on LaCloche Alvar as well as Chaumont Barrens. Shrubland alvars (in this case juniper alvar shrubland) consistently appear to dry more rapidly than grasslands (including tufted hairgrass wet alvar grassland and little bluestem alvar grassland) or adjacent woods.

The extreme range in hydrologic conditions appears to be a principal factor in limiting the invasion of woody species and maintaining grassland and other open alvar communities (Reschke 1995; Stephenson and Herendeen 1986). A hard summer drought on the Maxton Plains alvars on Drummond Island resulted in a die-back of woody plants that did not have their roots in moist bedrock cracks, along with an increased diversity of annual alvar plants the following year (Stephenson and Herendeen 1986).

Threats to alvar hydrology can come from within their site boundaries as well as beyond. Alvars have often served as open areas for off-road vehicle enthusiasts, snowmobilers, and timber harvesters, whose vehicles have created long-lasting ruts in the shallow soils. Ruts interfere with the natural soil moisture/surface water flow system by channeling water flow, thus changing the natural hydrologic system. Changes to off-site land use adjacent to alvars can also pose a threat to alvar hydrology in two ways. If the waters that flood the alvars are derived from a deeper groundwater source with an off-site recharge area, a change in the amount and timing of water recharge can alter the natural moisture regime. Also, off-site land use changes may cause an increase in surface water flow into an alvar site during normally droughty periods (Lougeay 1996).

Recognizing these threats, two studies of alvar hydrology and soil moisture regime were established. The first study focused on the regional hydrology of Chaumont Barrens. The term “regional hydrology” refers to how the hydrology of a site is influenced by hydrologic conditions of the surrounding landscape. The second study focused on the soil moisture regime and the effects of ruts on alvar grassland hydrology. It was conducted at two sites: LaCloche Island (north of Manitoulin Island in Ontario) and at Chaumont Barrens.

These studies provide only two examples, and the complete hydrologic story learned from each site does not necessarily apply to all alvars. Alvars across the Great Lakes occur in a variety of different geological settings. These two sites were selected to represent regional variation; however, study sites were also chosen based on where access for research was permitted and where local collaborators were available to conduct monitoring.

4.2.2 The Effect of Regional Hydrology on Alvars

Defining the source of flood waters for grassland alvars has proven difficult because alvars exist on carbonate rocks (limestone or dolostone) and in turn overlie karst aquifers. Groundwater flow to the land surface is a potential source of flooding that must be considered in these areas as many fen-like forms of vegetation exist in the alvars, suggesting a possible groundwater source (Reschke 1995). Collaborators have reported two instances, once at Belanger Bay on Manitoulin Island and once on Drummond Island, when water has been observed bubbling up from narrow rock crevices like a small water fountain. Other potential mechanisms of flooding exist, namely that surface water has simply become perched on the land surface. Understanding the hydrologic systems of alvars – and whether land use in surrounding areas may affect those systems – is fundamental to understanding how alvar ecosystems work and how best to protect them.

Regional hydrologic studies conducted at the Chaumont Barrens concentrated on identifying the source of seasonal waters ponded in the alvar grasslands by examining two principal hypotheses:

1. *Seasonal flooding of alvar grasslands stems from precipitation and snowmelt that becomes ponded on relatively impermeable bedrock.*
2. *Seasonal flooding of alvar grasslands stems from upwelling of deep groundwater derived from off-site recharge areas through the karst aquifer (modified from Reschke 1995a).*

Two methods were used to test these hypotheses in an effort to determine the source of alvar grassland floodwaters (Feeney 1996). First, groundwater and surface water elevations in the area were measured in order to determine whether sufficient hydraulic head was present to "drive" groundwater into the grasslands. Second, water chemistry was used to trace water through the system. Though hydrologic and chemical data were available for several places within Chaumont Barrens, this study focused on the grassland area called "Geum Prairie" because of the greater level of detailed data available for that area.

Physical Hydrology

Groundwater flow occurs because of differences in hydraulic head. In this study hydraulic head basically equates to elevation, with groundwater flowing from high to low elevation just as it does on the surface. For groundwater to discharge to an alvar grassland there must be a recharge area located upgradient at a higher elevation. The Chaumont Barrens preserve is actually situated on an interfluve, bounded by incised river valleys to the west, northwest, east, and southeast. Because the general dip, or tilt, of the bedrock and because the regional trend of the landscape is to the southwest, the region northeast of the site was recognized as the potential recharge area.

One characteristic common to all alvars is the generally flat nature of the landscape. Survey points were used to measure ground surface topography and dry-season water level elevations in two domestic water wells, a shallow spring, two abandoned wells, and the Chaumont/Lowville limestone contact, a recognized bedrock water-bearing zone in the region. Observed water levels upgradient of the grassland and the limited topographic relief suggested that there was not an adequate hydraulic head to drive water into the alvar grassland. This conclusion is somewhat tempered by the limited number of groundwater observations made during wet season conditions and the lack of knowledge about the magnitude of seasonal fluctuations in the water table. However, water levels would have to rise roughly 5 m above dry-season levels to enter the alvar grassland, which appears unlikely.

Water Chemistry

Analysis of flooding at Chaumont was also assessed by examining the water chemistry of different environments within and beyond the limits of the alvar grassland. Alvars in New York state occur on a limestone bedrock (the Chaumont Limestone) that is predominantly calcium carbonate, $CaCO_3$ (Table 4). Bedrock units that outcrop farther to the northeast (in the recharge area), and extend beneath the alvar because of the gentle regional dip, are slightly richer in magnesium (Mg). With this in mind, groundwaters entering the alvar grassland from the recharge area to the northeast would have dissolved a greater amount of magnesium than those waters that simply fell as precipitation and collected on the Chaumont Limestone surface within the alvar.

Table 4: Carbonate Composition of Black River Group Limestones

Formation Name	% $CaCO_3$	% $MgCO_3$ *
Chaumont Limestone	95.50	1.46
Lowville Limestone	87.06	5.68
Pamelia Dolomitic Limestone	59.10	12.69

*% weight from Johnsen 1971

Because the Chaumont Limestone is only about 9.1 m thick in this region, groundwater can encounter the Lowville, and even the Pamelia, strata at relatively shallow depths. Little carbonate is derived from the soil as the glacial sediment on the preserve is weathered and leached of carbonates. The finding that the alvar grassland waters are relatively low in magnesium indicates that the flood waters are not derived from a deeper groundwater flow system; instead, the alvar grassland waters result from water ponded at the surface and exposed only to the Chaumont Limestone bedrock.

Sodium (Na) was also used as a groundwater tracer because it has been observed in the groundwaters of these northern New York Ordovician limestones. Groundwater observed in wells and springs were found to have a greater concentration of sodium than water ponded at the alvar surface, proving sodium to be helpful in distinguishing groundwater from surface water and supporting the conclusion that deep waters had not risen to flood the alvar grasslands.

Findings

1. Alvar grassland flooding at Chaumont Barrens results from surface rainwater.

Analysis of groundwater elevations and water chemistry studied at the Chaumont Barrens alvar grassland indicates that flooding is the result of precipitation ponding at the surface on very thin soils over bedrock. Chemical analysis provided clear results: the lack of magnesium in the alvar grassland pools indicates that the waters did not circulate through the deeper Lowville and Pamelia Formations. This conclusion, however, does not rule out the presence of shallow groundwater flow through the upper 1 to 2 m of bedrock. Though this lateral flow through the near-surface bedrock (subcutaneous zone) has been observed at alvars, including the Chaumont Barrens, it would have limited areal extent and a source area relatively near the observed flow.

Bedrock fractures allowing water to rise to the surface are not readily visible at the locations where ponding appears; this is also true of many alvars across the Great Lakes. Large fractures have been observed along the periphery of the grasslands, but they appear filled with soils and organic matter. Bedrock pits and small solution conduits that once must have transmitted water now appear plugged after rains, supporting the idea that fractures at Chaumont Barrens are not as transmissive as they may have been in the geologic past.

4.2.3 Soil Moisture Regime and the Assessment of Grassland Ruts: On-Site Hydrology

Modification of the shallow soils is a potentially damaging threat to alvar hydrology. Trucks, tractors, off-road vehicles, and all-terrain vehicles traveling over an alvar grassland, particularly during wet periods, produce ruts that can remain for years (Figure B). Field observation has revealed water flow within the ruts, suggesting that the surface hydrology may be altered.

This study of alvar hydrology concentrated on the soil moisture regime, placing special emphasis on assessing ruts and their affect on alvar grassland soil moisture. Monitoring soil moisture requires manual observations over a long time period, thereby limiting the number of sites that could be studied across the region. Therefore, site selection was based upon the availability of dedicated individuals to make long-term field observations during a variety of

Figure B: Vehicle ruts in alvar grassland

seasonal conditions at a single alvar, from which more general conclusions could be drawn. The Chaumont Barrens and LaCloche Alvars were selected because they represent geographic extremes in the region, their geologic structure and rock type are different, and sites could be reliably monitored on a regular basis.

Soil moisture conditions were assessed both qualitatively and quantitatively at each alvar. Qualitative measures ranked soil moisture from 0 (very dry) to 4 (saturated) at each monitoring location. Quantitative soil moisture was measured with soil moisture sensors placed in a variety of habitats at each site: within undisturbed alvar grasslands, in alvar shrublands, in woods, and in grasslands disturbed by ruts or foot trails. The monitored habitats at Chaumont Barrens included tufted hairgrass wet alvar grassland, juniper alvar shrubland, sugar maple - shagbark hickory - hop-hornbeam deciduous forest, and white spruce - white pine conifer forest. At LaCloche, the habitats monitored included little bluestem alvar grassland, juniper alvar shrubland, and jack pine forest.

Soil moisture conditions were assessed at the Chaumont Barrens between 24 May and 15 August, 1996, involving 31 buried sensors. At LaCloche, soil moisture was monitored at 20 different stations over a 21-month period, from July 1996 to March 1998.

Findings

1. Alvar soils appeared to saturate almost completely after rainfall and then dry out more slowly to almost complete desiccation.

As shown in Figure C, soil moisture on alvar sites increased rapidly after summer rainfall events and then dried more slowly. Soil moisture is affected directly by summer weather patterns. During the summer of 1997 at LaCloche, there was a less pronounced wetting and drying cycle in soil moisture, stemming from a more consistent rainfall pattern.

2. Alvar soils remain saturated during the winter period and occasionally freeze.

From October onwards alvar soils are usually fully saturated, and they remain so until the following late spring. Reduced evaporation and transpiration and more consistent rainfall in the fall and winter months kept soils in a saturated state. At LaCloche Alvar, mean soil moisture conditions during the 1996/97 winter were generally wet and were considered much more representative of typical October-April conditions than the winter 1997/98, which was influenced by an El Nino event. The lack of snowpack caused by the mild winter conditions in 1997/98 allowed the ground to freeze. It is possible that ground freezing may also occur in extremely cold winters. Collaborators suspect that under typical winter conditions with a deep snowpack, the soil does not freeze and remains saturated.

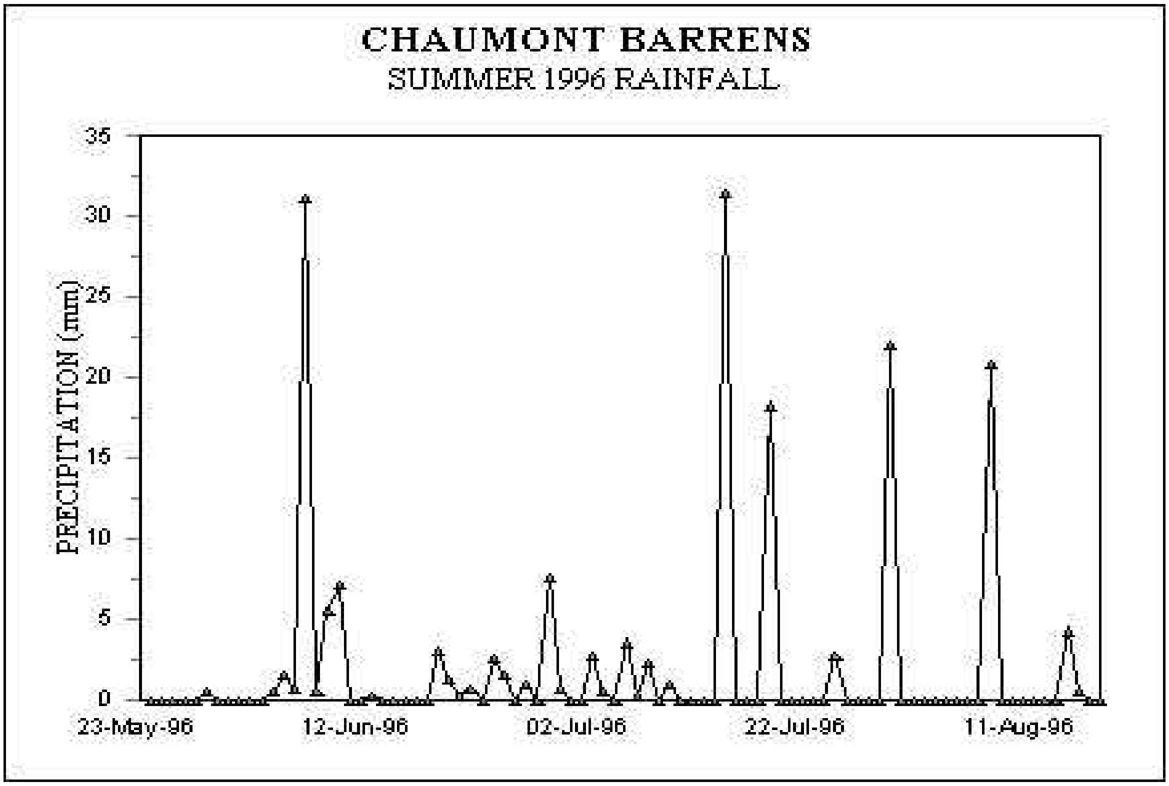
On alvar pavement communities especially, the winter frost cycle may be an important disturbance factor. The development of frost crystals and needle ice in shallow alvar soils has been shown to disrupt moss mats, uproot emerging seedlings, and change vegetation patterns at a very small scale (Gilman 1995).

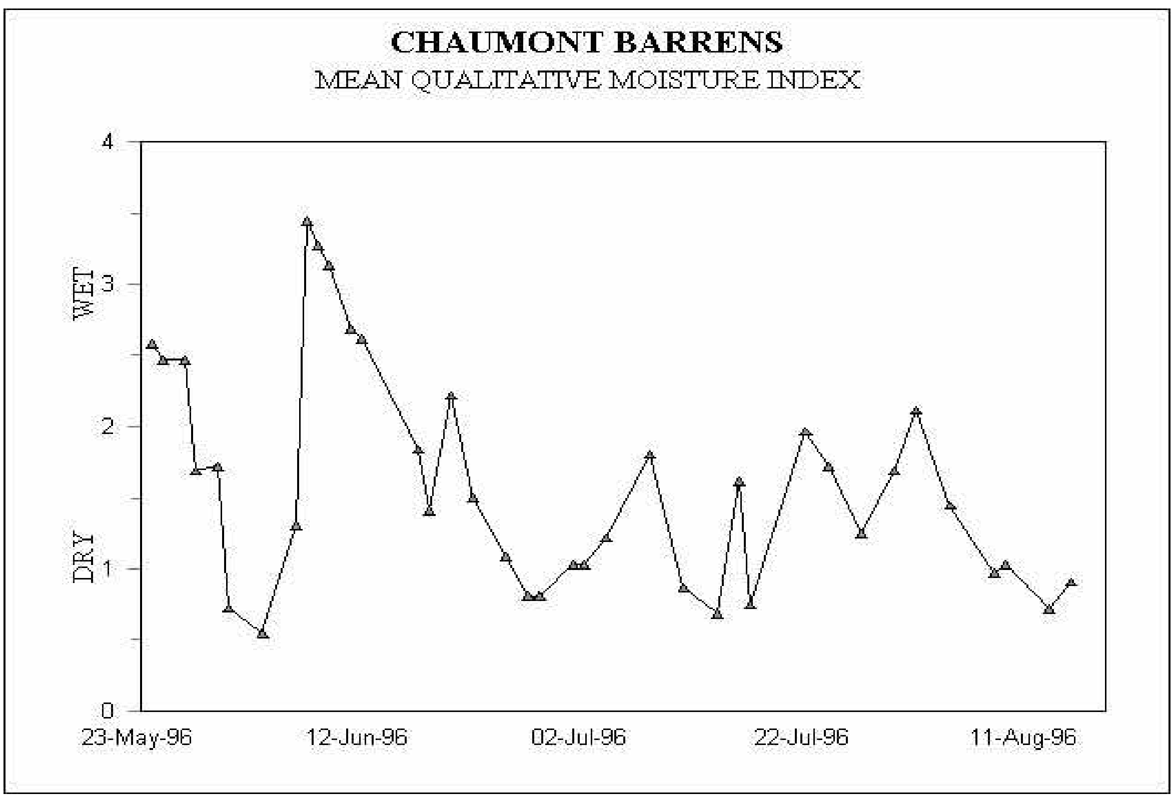
3. Different alvar community types show different patterns of soil moisture loss.

At both Chaumont Barrens and LaCloche, data from the soil moisture sensors were analyzed to trace desiccation rates over the entire summer period and for shorter periods without precipitation. In all cases, the alvar shrubland communities dried out more quickly than alvar grasslands, and usually more quickly than nearby woodlands. Desiccation rates over the entire summer period at Chaumont Barrens demonstrated that woodlands dried at the greatest rates, with alvar grasslands drying more slowly than other community types. However, over a shorter period without rain, the woodlands dried the slowest of all types measured (this result is less statistically reliable). At LaCloche, shrubland soils were found to desiccate more quickly and to a greater degree than either woods or grasslands.

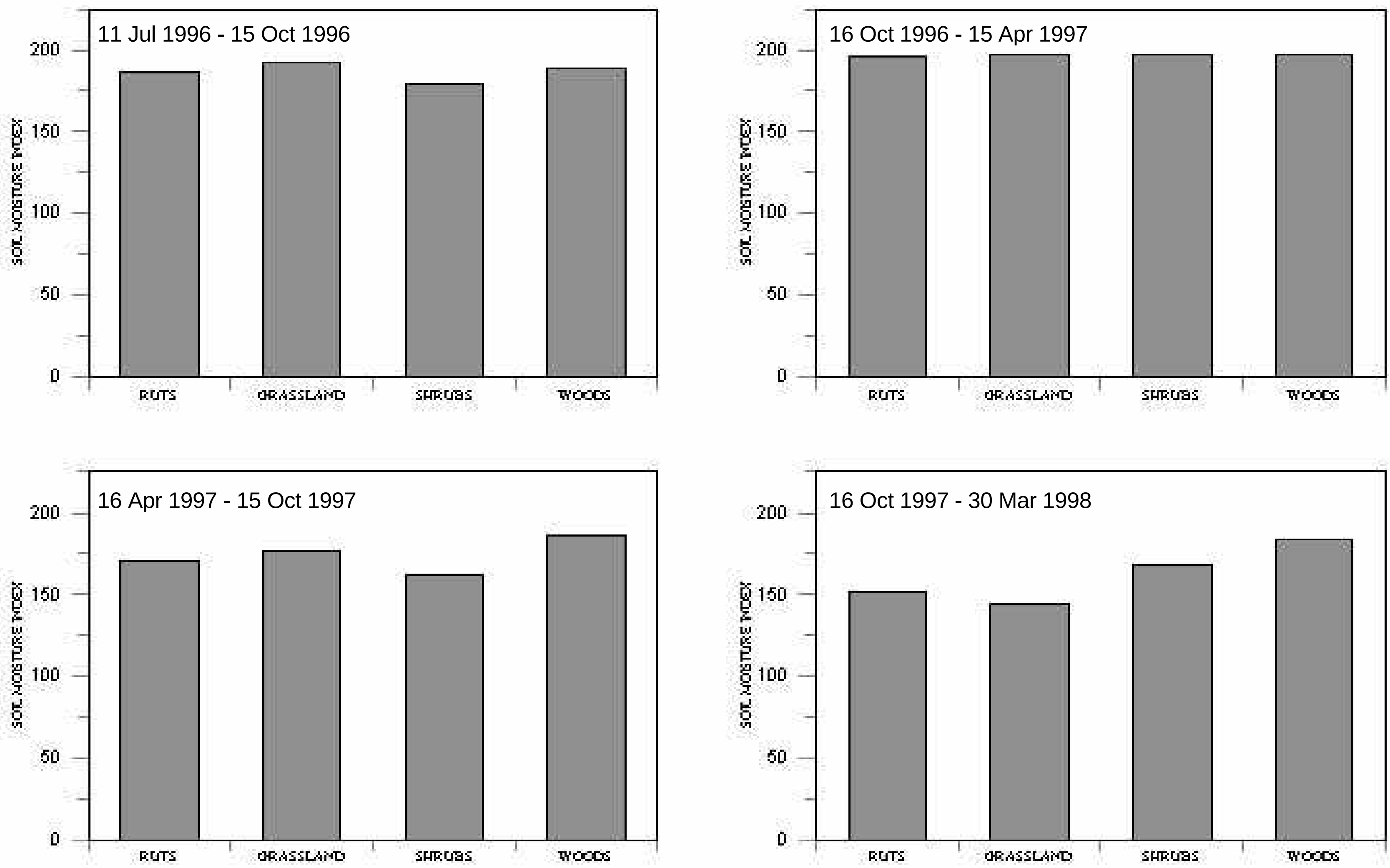
This pattern was similar when the mean soil moisture for these communities (plus ruts) was derived for the summer and winter seasons. During the summer months of 1996 and 1997, the shrubland soils were, on average, the driest among the community types (see Figure D).

Figure C


CHAUMONT BARRENS
SUMMER 1996 RAINFALL
PRECIPITATION (mm)
35
30
25
20
15
10
5
0
23-May-96
12-Jun-96
02-Jul-96
22-Jul-96
11-Aug-96


CHAUMONT BARRENS
MEAN QUALITATIVE MOISTURE INDEX
WET
DRY
4
3
2
1
0
23-May-96
12-Jun-96
02-Jul-96
22-Jul-96
11-Aug-96

MEAN SOIL MOISTURE



4. The presence of ruts causes nearby alvar soils to dry more rapidly and to a greater degree.

Ruts across alvar grasslands consistently result in soils desiccating more quickly and to a greater degree than adjacent undisturbed grasslands (see Figure E). This finding suggests that ruts have modified the surface hydrology. Sensors placed in a foot trail at Chaumont Barrens suggested a moderate increase in desiccation rate compared to undisturbed grassland soils.

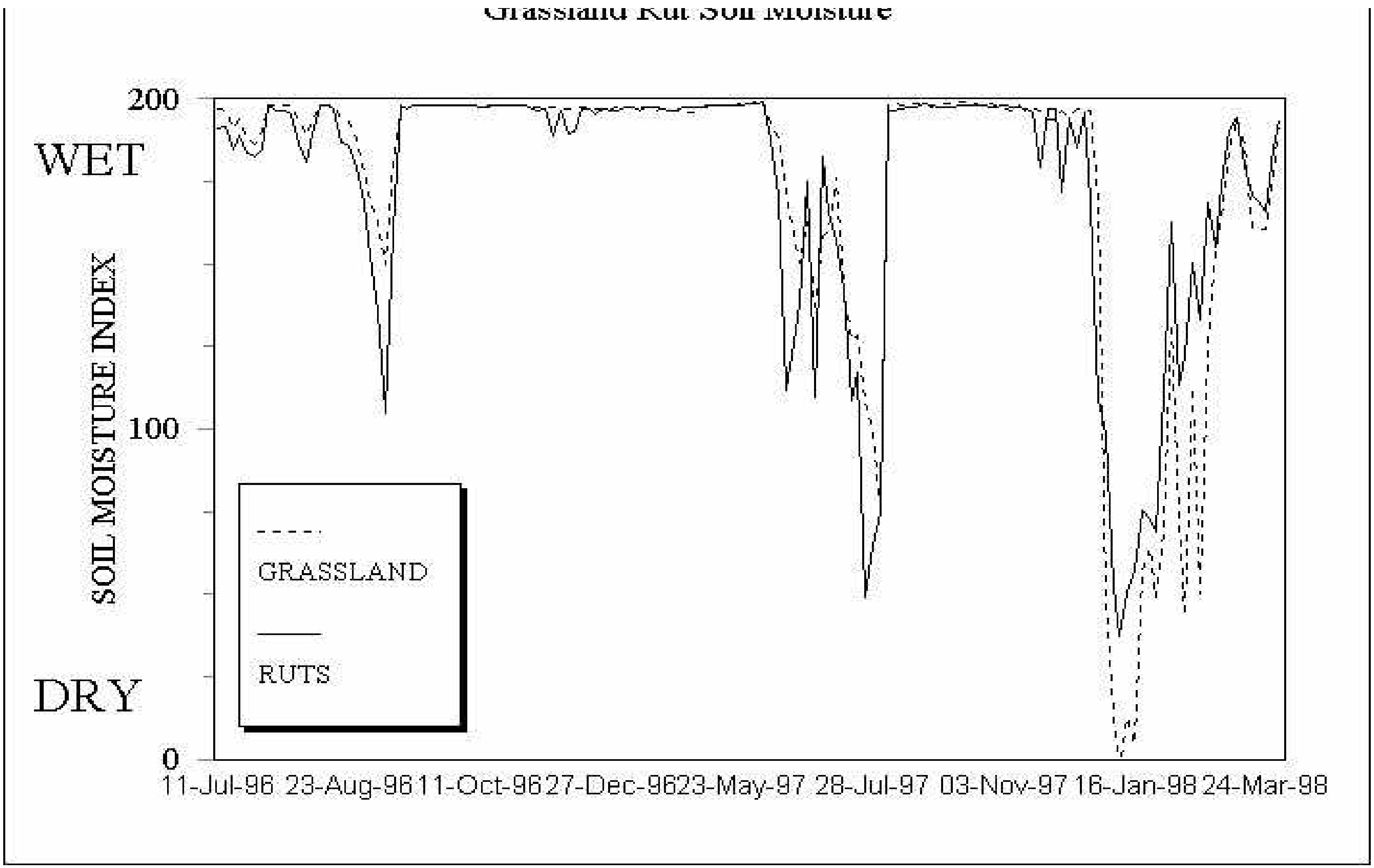
4.2.4 Conclusions

The study of regional hydrology conducted at the Chaumont Barrens revealed that water derived from beyond the boundaries of the alvar preserve was not responsible for flooding the grasslands. As a result, activities beyond the preserve boundaries do not appear to have an impact on the alvar grassland hydrology at that location. The regional hydrogeologic setting of New York alvars is fundamentally different than many alvars, including Carden, Smith Falls, the Bruce Peninsula, and Manitoulin and Drummond Islands. Field observation of waters bubbling to the surface at Belanger Bay on southern Manitoulin Island and on Drummond Island in Michigan attest to the need for site-specific studies.

Examination of water level data was helpful, and analysis of water chemistry proved to be a very useful tool in distinguishing surface water from groundwater. The success of water chemistry as a tool, however, was based largely on the variability of the bedrock geology at the Chaumont site. Because the geologic formations are relatively thin and differ in their chemical composition, the chemistry of water that circulated through different rocks was distinguishable. This chemical technique may be applicable at other alvar sites in the Great Lakes if the local bedrock geology has somewhat variable layers that can be chemically distinguished, like those at Chaumont Barrens.

Future study should anticipate the need to replace soil moisture sensors after roughly 18 months in the field. Other means of documenting soil moisture patterns, for example using remote sensing data such as radar imagery, may be useful tools for documenting soil moisture in a more continuous manner. Remote sensing techniques would also allow the study of more sites, since it would not be so dependent on the availability of someone willing to monitor sensors at alvar sites.

The study of alvar grassland soil moisture revealed that vehicle ruts do alter the soil moisture regime that is so important to alvar systems. Shallow alvar soils are most vulnerable to trampling and rut-formation when soils are saturated. Alvar grassland soils are also vulnerable when extremely dry because exposed dry soils, which often have a powdery texture, can easily be displaced from the bedrock. Management plans for alvar sites should prevent all vehicles from driving over alvars if at all possible, especially when the soils are saturated. Also, since the foot trail at Chaumont Barrens that follows the edge of a grassland showed a moderate increase in desiccation rate (compared to undisturbed grasslands), foot trails should be carefully located to avoid crossing areas with seasonally saturated soils.


WET
DRY
SOIL MOISTURE INDEX
200
100
0
GRASSLAND
RUTS
11-Jul-96
23-Aug-96
11-Oct-96
27-Dec-96
23-May-97
28-Jul-97
03-Nov-97
16-Jan-98
24-Mar-98

4.3 The Role of Fire Regime and Land Use History

4.3.1 Introduction

The history of Great Lakes alvars was examined from several angles to investigate three questions:

- Did alvars exist before European settlement times or are they the product of recent anthropogenic disturbance?
- Do alvars always remain open or do they grow in to some extent over an observable period of time?
- To what extent is fire involved in the origin and maintenance of alvars?

To address the first question, notes from the first surveys were used to reconstruct the presettlement vegetation of alvar areas on the Bruce Peninsula, Carden Plains, Manitoulin Island, and northern New York. Surveyors' comments such as "prairie," "plains," "rocky barrens," etc., were used to map the presence of alvars at the date of the survey. In addition, information about land use in alvar areas was collected from oral history interviews with older local residents. Topics of discussion dealt with logging activities, grazing practices, recollections of the alvars through the years, and memories and lore about local fire history.

To address the second question, a qualitative comparison was made of the size and openness of alvars on the Bruce Peninsula, Carden Plains, and Manitoulin Island in Ontario, and at Limerick Cedars in New York. The oldest available air photos were compared to the most recent ones available. In most cases, there were at least 45 years between sets of photos.

To address the third question, the presence or absence of burn evidence was recorded at each observation point made during alvar field work. Evidence included charcoal, burnt woody debris or stumps, and fire scars on trees. In addition, at each observation point a visual scan was made for eastern white cedar trees (*Thuja occidentalis*) that appeared to be exceptionally old. Some of these trees were cored and aged for further information on fire history. Also, local residents and old newspaper clippings were consulted to establish dates for burns. Finally, experts on fire history were escorted to several alvar sites, and they provided insights on fire history of alvars.

Work was done primarily by Claudia Schaefer on the Bruce Peninsula and the Carden Plain, Ontario with assistance in historical mapping by Helen

Godschalk of NHIC; by Bruce Gilman, Sandy Bonanno and Carol Reschke in New York; and by Judith Jones on Manitoulin Island, Ontario. Unpublished reports used in preparing this summary are listed in the references.

4.3.2 General Findings

1. All regions had some areas that were very likely to have been alvar at the time of the first surveys.

In New York, qualitative comments by the surveyors show that some alvar or substrate suitable for alvar did exist, in that there were some places described as "meadow," "rocky with limestone," or "poor land" in the survey of 1798. However, most of today's New York alvars had a cover of maple, beech and white pine in 1798. It is possible that pockets of alvar were under-represented because the surveyors were instructed to list timber species, and their comments were directed toward potential homesteaders who would be choosing parcels of land, sight unseen, for farms. Still, most New York alvars appear to have had more trees than they do today. Yet, on the whole the survey notes show that pockets of alvar did exist, even if the openings were small and scattered within the overall forest cover.

The story is very similar on the Flamborough Plain in Ontario (Goodban, 1995), with most of the current alvar areas listed as treed with maple, elm, basswood, etc. A few places were listed as having small trees or "broken land," and one area was listed as "meadow." However, while there are indications that there was suitable substrate for alvar, most of the land was forested.

Alvar was clearly described at Maxton Plains in Michigan in the survey of 1845. While the survey lines did not cross the majority of today's grasslands, several places were described by the surveyor as "naked rock with scattering of small trees growing in crevices" or some slight variation. At least two large areas of alvar existed (Comer et al. 1995).

On the Carden Plain, even a conservative estimate shows many patches of alvar existed at the time of the first survey in 1856. However, the patches, which were described as "plains," "prairie," "soil burnt off to rock," etc., appear to have been smaller than the alvar areas of today. Also, there appears to have been alvar in many places that are not now alvar. It is possible that some of these places have been altered by grazing or have grown up with trees.

The Bruce Peninsula also supported many areas that most likely were alvar at the time of the first survey in 1855. Many areas were described as "barren," "scarcely any timber," or "scattered trees." Fairly extensive areas at Burnt Lands alvar are described in the land survey as “rock burnt spruce plain” or “rocky burnt land.”

On Manitoulin Island, almost the entire Lake Huron shore from Portage Point (Taskerville) to the western tip of the island, and inland from the shore for 2 to 4 concession lines, was described in various ways as burnt, barren flat rock, no soil, or stunted timber. Over the course of this huge area, only a few intervening wetlands and areas of young secondary growth or slash existed. The area that was open or not forested was much more extensive than the area of the alvars today.

While the surveyors’ comments do not identify presettlement alvars with 100% certainty, the coincidence of locations and descriptions with current conditions leaves little doubt that alvars existed as a natural community in the Great Lakes basin 150 years ago in many of the same locations as they do today.

2. Alvars can be created by fire.

A few alvar areas exist today which were not alvar at the time of the early surveys. On Manitoulin, the Silverwater Radio Towers site, today a juniper alvar shrubland, was listed as "good level land with mixed timber" and "sandy loam of average depth and some large cedar." Interviews with older local residents brought out memories of fighting a huge fire at this site in 1925.

In New York, an area at Limerick Cedars which was tree-covered in a 1948 air photo burned in an intense fire in 1953. Photos in newspaper articles of the time show the location of the fire at what is now the barren nonvascular pavement at the Perch River Barrens portion of Limerick Cedars. Local residents described the fire as intense, burning deeply into moss and cracks, and requiring several days to extinguish. While it is not clear if this area supported an alvar community prior to the fire (probably a pavement savanna from the description of burning moss and the forest cover on the air photo), it is evident that fire removed most of the vegetation to create the alvar that exists today.

In addition, other sites such as Driftwood Cove and Hopkins Bay on the Bruce Peninsula, Alvar #4 at Carden, and the alvar west of South Baymouth on Manitoulin were listed as forested at the time of the first surveys. Driftwood

Cove, South Baymouth, and Carden #4 (no data is available for Hopkins Bay) have burn evidence present, making it likely that these alvars resulted from fires at or since settlement times.

3. Some alvars show no evidence of past fire.

The Bruce Peninsula alvars at Baptist Harbour, Bear's Rump Island, and parts of Pendall Lake, as well as part of the alvar on Great LaCloche Island, show no evidence of fire and support cedar trees several hundred years old. Even if fire occurred at these sites more than 500 years ago (and the evidence rotted away), the current sparse vegetation still testifies to an extremely slow growth rate at these sites. It is not inconceivable, therefore, that the past 3000-plus years that these sites have been exposed above Lake Huron would only have produced the growth we see today, and fire need not be a factor in explaining the barrenness of these alvars.

There are many other alvars which show no evidence of fire, although they lack the dramatic evidence of ancient cedar trees. These alvars occur throughout all regions, all alvar types, and in a range of conditions, such as along shores and inland.

4. Air photos show that shrublands and savannas appear to change or become wooded more quickly than grasslands or pavements.

This trend was noted independently by both Schaefer (1996a,c) and Jones (1996) and was observed at nearly every site where a comparison of historic air photos from the 1930s to the present was done (including a series of sites on Carden Plain, Flamborough Plain, Bruce Peninsula, and Manitoulin). At the very least, the comparisons show that some alvars or types of alvars do grow in over time, and it may happen in as little as 45 years. This also is supported anecdotally by interviews with older Manitoulin residents who pointed out wooded areas (limestone woodland) that had been open flat rock earlier in their lives.

Several hypotheses have been suggested to explain this trend, but none has been rigorously tested. Schaefer suggested that perhaps alvars grow in very slowly until some sort of threshold level of vegetation is reached and then they become wooded more quickly. Jones suggested that cracks and grikes in the bedrock, a common feature of shrublands, may favor growth of woody plants, allowing shrublands’ relatively rapid growth.

5. Air photos show that boundaries of most alvars changed little in 45 years, with some areas becoming more wooded.

This pattern of stable boundaries was noted many times, and may indicate that there is some underlying factor such as bedrock surface or lack of soil which causes an abrupt difference between alvar and adjacent land. This agrees well with Schaefer and Larson's (1997) finding that there is little transition zone between alvars and the surrounding communities. This trend also appears to show that alvars generally don't grow in from their margins, but rather from expansion of woody areas already present within the alvar openings.

6. Some alvar community types show a strong correlation with presence of burn evidence, while others do not.

Table 5 shows that some community types have an obvious correlation with past burning, for example bur oak limestone savanna and white cedar - jack pine / shrubby cinquefoil alvar savanna, where all observation points have burn evidence present. In addition, both the creeping juniper - shrubby cinquefoil alvar shrubland and the alvar nonvascular pavement types show a high percentage (71% and 75% of observation points, respectively) of burn evidence. This suggests that the sparseness of vegetation in these types may have something to do with past fires.

On the other hand, the tufted hairgrass wet alvar grassland and annual alvar pavement-grassland types show a lack of burn evidence, which makes sense since these types are usually on the wetter end of the moisture spectrum. Similarly, most of the observation points for the red cedar / early buttercup alvar woodland type had not burned, although the moisture regime here is unclear.

Burn evidence for other types show a fairly even split between presence and absence, perhaps indicating that fire occurs but is not necessarily a key maintaining process. However, since alvars can change very little over long periods of time, the occurrence of "alvar-maintaining fires" many centuries ago still cannot be ruled out. Little is known about how long burn evidence lasts before rotting away, and it is still possible that some alvars were created by fire centuries ago but that no evidence of burning remains.

Table 5. Observation points by community type showing presence/absence of burn evidence.

Points with only a fire scar are shown in the "present" column.

Alvar community type	Number of samples	Burn evidence present	Burn evidence absent

Tufted hairgrass wet alvar grassland	37	10 (+ 1 scar only)	26
Little bluestem alvar grassland	59	24 (+ 1 scar only)	35
Annual alvar pavement - grassland	15	2	13
Poverty grass dry alvar grassland	12	6 (+ 1 scar only)	5
Creeping juniper - shrubby cinquefoil alvar shrubland	21	15	6
Scrub conifer / dwarf lake iris alvar shrubland	7	3	4
Alvar nonvascular pavement	8	6 (+ 1 scar only)	1
Juniper alvar shrubland	42	25	16
Great Lakes limestone bedrock lakeshore	12	-	12
Chinquapin oak / nodding onion alvar savanna	3	3 - controlled burning	-
Bur oak limestone savanna	9	9	-
White cedar - jack pine / shrubby cinquefoil alvar savanna	16	16	-
Mixed conifer / common juniper alvar woodland	6	5	1
Red cedar / early buttercup alvar woodland	7	1	6

Another reason why a strong correlation with fire may not show up, at least in some grassland types, is that if fire occurred in a grassland, there would be very little evidence left behind, according to Tim Lynham, fire research officer with the Canadian Forest Service (personal communication, 1996). Reschke (1995) analyzed soil samples from Chaumont Barrens in New York to look for microscopic charcoal that would provide evidence of fires. She found no charcoal in alvar grassland soils, although charcoal was found in some areas of the adjacent juniper alvar shrubland.

Interestingly, Schaefer and Larson (1997) found little difference in composition and environmental variables between alvars with old trees showing no burn evidence and alvars which were known to have burned. Our data seems consistent with this conclusion. Our interpretation is that fire may be a necessary factor only in some types of alvars while it is merely an incidental occurrence in others.

7. Bur oak limestone savanna can result from hardwoods burned in catastrophic fire.

This community type occurs in Sheguiandah Township, among other places, on Manitoulin Island. A study of the history of the township shows that the area was surveyed in 1863, and then a catastrophic fire raged through most of the township in 1864, destroying most of the survey posts. The entire township had to be resurveyed in 1865; as a result, surveyors' notes are available for immediately before and after the fire.

Maps of vegetation before and after fire were made based on the two sets of notes and compared to the current locations of bur oak limestone savanna (field surveyed in 1997). The comparison shows that most areas currently supporting bur oak limestone savanna were described as hardwoods before the fire (usually predominantly maple), and that while these areas burned, not all vegetation was removed.

This study only speaks to the creation of bur oak limestone savanna and not to its maintenance, but this community type also exists in some areas of Foxy Prairie, where local people say there have been several fires in the last century and where repeated fire may keep the canopy open. However, the Sheguiandah Township savannas have not burned since the fire of 1864. Both sites have been continuously grazed by cattle since settlement times, and it is possible that in the absence of fire, grazing maintains their open savanna characteristics.

8. Grazing by cattle may be keeping some alvars open.

While grazing history was not investigated in depth, casual observations of fencelines where one side is used as pasture and the other side is not show drastic differences in the amount of alvar vegetation present and in the cover of woody plants. At Foxy Prairie, the grazed side is still alvar, while the side that is no longer grazed has grown up with tall Eurasian grasses. In Sheguiandah Township, the ungrazed side is a dense bur oak woodland with almost no alvar ground flora.

Many alvars in Carden Township and eastern Ontario (community types other than bur oak limestone savanna) have also served as pasture since settlement times. On the whole, alvars where grazing occurs have a higher than usual incidence of exotic plant species. Therefore, while grazing may keep some alvars open, it also seems to slowly degrade the natural community. Exclosures set up to look at what happens when grazing is stopped may not show results for several years, but future attention to this topic is needed since the results have implications for alvar restoration efforts (see section 4.4 below for further discussion of herbivory research).

9. Controlled burning may be beneficial to some alvar types but could harm others.

At the Stone Road Alvar site on Pelee Island, controlled burning has been very beneficial. Two controlled burns (1993 and 1997) have resulted in a die-back of 75% to 80% of the shrub cover and a reduction in the cover of weeds. The burns have also caused a resurgence of native species such as nodding onion (*Allium cernuum*), gray-headed coneflower (*Ratibida pinnata*), and whorled milkweed (*Asclepias verticillata*) (Dan Lebedyk, Essex Region Conservation Authority, personal communication). However, the Pelee Island alvar has a very different constellation of species from other alvar types and also has contiguous areas that are considered true prairie and savanna. Therefore, conclusions about the benefits of controlled burning at Pelee may not be transferable to other alvar types.

An upcoming article by Catling and Brownell (1998) concludes that a section of the Burnt Lands alvar which was cut and burned 37 years earlier had an unusually high species diversity of native vascular plants, including rare and/or restricted species. They argue that successional alvar burns are an important part of the alvar ecosystem and that burning is an appropriate management consideration for alvars.

In New York, at Limerick Cedars, Gilman (1997b) has shown that there may be detrimental effects from burning alvars. The Perch River Barrens was a pavement savanna prior to a catastrophic fire in 1953. Today, 45 years later, it remains a very barren pavement with only a sparse vegetative cover of lichens and mosses. Whether this pavement may someday be more highly diverse because of burning remains to be seen, but, if so, it may be on time scales that are difficult to regulate (or even correlate) with controlled burns.

Some collaborators have also expressed concern about the effects of burns on terrestrial molluscs, particularly on small, less robust (and often rarer) species (Wayne Grimm, personal communication).

Careful further study certainly must be done before controlled burning can be recommended for alvars (other than the Pelee Island site and possibly the alvar-related bur oak limestone savanna type). Most likely, recommendations will need to be developed on a site-by-site basis rather than on the basis of alvar community types as a whole.

4.3.3 Conclusions

From the alvars with old trees and no burn evidence, it is clear that not all alvars require fire to remain in an open state. If fire is at all required in some of these alvars, it could only be on the basis of a return cycle of many hundreds of years. Furthermore, at many other alvars, fire has probably been only an incidental occurrence, based on the fact that among many similar alvars some have burn evidence and some don't. Therefore, the use of fire as a management tool is not advised for all alvar community types, even though it may be beneficial for some sites such as Stone Road Alvar on Pelee Island.

Based on air photos, some alvars, especially shrublands and savannas, do grow in with trees. It is not known if low-intensity fire would maintain these more dynamic alvars in an open state, or if the only option is a larger fire which would reset the successional clock all the way to zero – to an extremely barren state. Clearly, some alvars have originated from large fires, so if low-intensity burning does not maintain these areas, management strategies might have to consider more intense burns at some future point.

Periodic fire may maintain bur oak limestone savannas and keep them from becoming woodlands, but grazing is probably obscuring this trend while degrading the ecosystem. Based on work in similar ecosystems with deeper soils (Tester, 1996), periodic burning should be studied as a management tool for this community type.

Certainly, given the long history of alvar communities from presettlement times, natural fires appear always to have been at least an incidental part of their history, and probably instrumental in maintaining some alvar types such as juniper alvar shrubland. This suggests that aggressive fire suppression is not needed on alvar habitats, although no alvar should be allowed to burn entirely in one fire event, to ensure the survival of invertebrate fauna. If fires do occur within alvars, researchers should use these occurrences as opportunities to gather much-needed data on subsequent ecological changes.

4.4 The Role of Browsing and Grazing

The effect of several kinds of herbivores on alvar plant communities was identified as a concern early in the Alvar Initiative, and information relating to browsing and grazing was collected from all field observation points. While information about browsing by rabbits and voles was gathered, their effects appear to be minor and a normal part of natural processes on alvar sites. The primary focus of research in this area has been browsing by white-tail deer (*Odocoileus virginianus*) and grazing by domestic cattle.

White-tail deer are a native species in the Great Lakes basin, but artificially high population levels across much of the basin, created and sustained by habitat modifications and management policies, are seriously impacting plant populations in many natural habitats (Waller and Rooney 1998). In some plant communities, such as Carolinian forests, intense deer grazing has significantly altered plant community composition and has resulted in the removal of a number of rare species (Bazely et al. 1997, Koh 1991, Pearl et al. 1995, Koh et al. 1994, Koh and Bazely 1994, Koh and Bazely 1992). There are concerns that excessive browsing by deer poses a threat to alvar communities by changing the composition and structure of shrub and herb layers. At the same time, some collaborators on the Alvar Working Group have questioned whether browsing by deer may benefit some alvar communities by limiting the growth of trees and shrubs (Alvar Working Group, 1996).

Alvars in the Great Lakes basin and elsewhere have long been influenced by grazing livestock. While this influence has been little studied in North America, the effects of grazing have been documented on alvar habitats of the Swedish island of Oland, where grazing by domestic animals has occurred since the first centuries A.D. (Titlyanova et al. 1988). In that location, grazing has been considered essential to prevent encroachment in closed grasslands occurring on silicious soils, where soil depth would potentially support woody vegetation (Rosen 1982, Bengtsson et al. 1988). A study of reproductive regeneration in grazed and ungrazed limestone grassland communities showed that the closed turf of ungrazed sites hindered the germination of perennial herbs, and that the short turf and gaps in grazed communities increased the abundance and persistence of some monocarpic plant species (Rusch 1988).

However, the intensity of grazing appears to be a critical factor. A comparison of ungrazed, moderately grazed, and overgrazed sites showed decreased biomass and floristic changes in the overgrazed area, with perennial and annual ruderal (quick-germinating, disturbed soil specialists) species replacing the dominant alvar grassland species. Alvar lichens had the highest biomass values in the moderately grazed community. (Titlyanova et al. 1988).

Brownell (1998) has noted that where grazing is intense on Great Lakes alvar grasslands, the grasses may be reduced and that species avoided by cattle such as flat-stemmed spike-rush *(Eleocharis compressa)* may increase in abundance. Rosette-forming species such as ciliolate aster *(Aster ciliolatus)* and goldenrod *(Solidago)* species also may increase. Early buttercup *(Ranunculus fascicularis)* is much more frequent on some alvars subject to grazing than on adjacent non-grazed sites. Nevertheless, even light grazing tends to result in elimination of certain species such as the disjunct clustered cancer-root *(Orobanche fasiculata)* (Catling and Brownell 1995).

As noted in the previous section, there is anecdotal evidence from several Great Lakes alvar sites that grazing by cattle may be keeping alvar areas open by preventing the invasion of trees or shrubs. This can be an important factor in maintaining suitable nesting habitat for rare alvar birds such as loggerhead shrike *(Lanius ludovicianus migrans)*, which depend on open, short grasslands for their prey (Chabot 1994).

These factors led the Alvar Working Group to hypothesize that cattle grazing is generally detrimental to alvar communities, but some light grazing may help to keep alvar areas open. Also, as the intensity of grazing increases, diversity of native species decreases and the number of exotics increases (Alvar Working Group 1996).

To address these questions about the role of browsing and grazing, a long-term research study was established. This study, coordinated by Dawn Bazely and Saewan Koh of York University, has two overall objectives:

- Establish permanent deer and cattle exclosures at sites in alvars in Ontario and in the United States.
- Collect baseline plant community composition data in order to allow the impact of mammalian herbivory to be assessed.

Permanent deer and cattle exclosures and adjacent control (grazed) plots were established in August and September 1997 in three Ontario locations (Misery Bay on Manitoulin Island; Burntlands, and Carden Plains) with varying grazing pressure. Exclosures were also built by TNC staff at Stony Point and Chaumont Barrens in New York state. Each exclosure (4.9 m x 4.9 m) consisted of four cattle panels.

Four paired plots (exclosure and grazed plot) were established in each of the Burntlands and Misery Bay locations and a total of eight paired plots at two sites in the Carden location. In New York, four exclosures were built at Stony

Point and four at Chaumont Barrens. This provides a total of 24 exclosures and 24 grazed control plots for the study.

As a general guideline, all plots are located in alvar grasslands with alvar savanna communities in the vicinity, since these are the most likely areas to detect herbivory effects. In the Misery Bay Preserve, the availability of this habitat was restricted, so research there will focus more on grassland/pavement areas. An important difference between the Ontario and U.S. sites was the inclusion of large red cedar (*Juniperus virginiana*) trees within the New York exclosures. This may affect subsequent plant community changes.

Manitoulin Island has a high deer density, while Burntlands is expected to have a low to intermediate deer density. Carden has two types of alvar sites: (i) alvars actively grazed by cattle and (ii) alvars not grazed by cattle but with intermediate deer density. The New York state sites are not recently grazed but have high deer densities.

Baseline data on the plant community composition of paired plots was collected in July/August 1996 and spring 1997, using the TNC field protocols and community field forms (Sneddon 1994) adopted by the Alvar Initiative.

Data from all plots have been entered into an Excel 5 database and will be statistically analyzed to examine relationships to all available environmental variables. Initially, grazed and exclosed plots are expected to be similar but with large differences in plant species composition among sites. However, in future years, depending on ungulate herbivory, grazed plots are expected to become rapidly different from ungrazed plots.

Funding to support periodic data collection and analysis of these changes is being sought, since the most valuable results of this project are likely to emerge only after repeated monitoring.

4.5 The Role of Exotic Plants

4.5.1 Introduction

The Alvar Working Group identified several exotic species that were invasive and problematic in alvar communities, including St. John's-wort (*Hypericum* *perforatum)* in Michigan, Canada bluegrass (*Poa compressa)* in Ontario and New York, and buckthorn *(Rhamnus cathartica)* and honeysuckle *(Lonicera tatarica, L. morrowii)* in New York. Several other exotic species were known to be present in alvar sites, but with little information about their abundance, frequency, or distribution.

Alvar survey methods included documentation of exotic species observed during field reconnaissance surveys (observation point data) and in plant species lists compiled for the six alvar structural types (described in section 2.1 above). Because the field information format varied slightly from year to year (e.g. recording species by abundance classes in 1995 and by percent cover in 1996), several different data sets were used for analysis.

Most of the analysis of exotics used a small data set (111 observation points) consisting of the 1996 observation points plus a few 1995 observation points that represented single community types. In places where a pattern occurred in the analysis, the full data set (291 observation points) was consulted to see if the pattern appeared consistently throughout.

For each observation point in the small data set (111 observation points), data compiled included a full list of all exotic species present, the number of exotics, the percent cover of *Poa compressa*, and the percent cover of all exotic species (excluding *P. compressa*). The large data set (291 observation points) included only the number of exotics, percent cover of *Poa compressa* and percent cover of other exotics.

Sample size for each community type was variable. In the small data set, there were from 22 to 25 examples of type 3 (little bluestem alvar grassland) and type 8 (juniper alvar shrubland); from 9 to 14 examples of type 2 (tufted hairgrass wet alvar grassland), type 4 (annual alvar pavement-grassland), and type 5 (creeping juniper - shrubby cinquefoil alvar pavement); 6 examples of type 7 (alvar nonvascular pavement); and only 2 or 3 examples of type 6 (scrub conifer / dwarf lake iris alvar shrubland), type 11 (Chinquapin oak / nodding onion alvar savanna), type 13 (poverty grass dry alvar grassland), type 16 (mixed conifer / common juniper alvar woodland), and type 17 (red cedar / early buttercup alvar woodland).

4.5.2 Findings on Common Exotic Species

1. Different species of exotic plants vary considerably in their frequency of occurrence on alvar habitats.

Overall, 109 exotic plant species (or taxa) were reported from all alvar observation points, and 64 exotic species were included in the small data set from 111 observation points. In this data set, there were 14 species that occurred in at least 9% of the observation points. These 14 taxa, in decreasing order of frequency are:

Canada bluegrass - *Poa compressa* (present at 62% of all observation points)

St. John's-wort - *Hypericum perforatum* (49%)

Rough-fruited cinquefoil - *Potentilla recta* (25%)

Common mullein - *Verbascum thapsus* (24%)

Common timothy - *Phleum pratense* (22%)

Ox-eye daisy - *Chrysanthemum leucanthemum* (17%)

Glaucous king devil - *Hieracium piloselloides* (17%)

Curly-leaf dock - *Rumex crispus* (14%)

Hawkweed - *Hieracium* sp. (13%)

Wild carrot - *Daucus carota* (11%)

Blueweed - *Echium vulgare* (11%)

White sweet-clover - *Melilotus alba* (10%)

Kentucky bluegrass - *Poa pratensis* (9%)

Buckthorn - *Rhamnus cathartica* (9%)

2. Whether or not Canada bluegrass is a native species, its presence is highly correlated with the frequency of exotic species at an alvar site.

Debate continues among many workers as to whether Canada bluegrass (*Poa compressa* L.) is a native or an exotic species. It is a common pasture grass in Europe and could have been introduced to North America either accidentally (e.g. in straw used for packing) or intentionally as a pasture grass. Many taxonomists consider *Poa compressa* an introduced species (Voss 1972; Dore and McNeill 1980; Cronquist 1991).

In contrast, it may have been a native species in certain habitats. Morton and Venn (1984, 1990) consider it native. Morton and Venn may have been influenced by familiarity with a collection of this grass by Bell in 1860 from "cracks in flat beds of limestone" on Great LaCloche Island (Bell 1870). However, by 1860 there had already been at least 100 years of periodic visits by Europeans in the Manitoulin region, especially in the area of Little Current (just south of LaCloche), so the collection does not show conclusively that *Poa compressa* is native in the area.

In early meetings of the Alvar Working Group, collaborators questioned whether *Poa compressa* should be considered an indicator of past disturbance and how this should influence evaluations of alvar community condition.

In our analyses, data on *Poa compressa* have been treated separately from data on known exotic species. Still, our results show that there is a connection between high percent covers of *P. compressa* and high numbers of exotic species; this is a statistically significant correlation. Whether or not it is native, this implies that in alvar communities *Poa compressa* is often more abundant where there has been past disturbance. This relationship to disturbed soils is consistent with the observations of Stephenson (1995) on Maxton Plains alvar, who noted that the species did not appear to be a competitive threat to other grassland components on the alvar, but that it aggressively colonized disturbed areas and formed dense swards on the deeper soils of road and drain berms.

3. Canada bluegrass and other exotic species are much more abundant in some alvar community types than in others.

Poa compressa occurred with a greater frequency (at a greater number of observation points) than any other exotic species. This was true in all alvar community types, with *P. compressa* being present at 62% of observation points. The frequency may actually be somewhat higher than is represented in our data since the greatest part of our samples were type 8 (juniper alvar shrubland), which is not a predominantly herbaceous type.

Community types 17 (red cedar / early buttercup alvar woodland), 4 (annual alvar pavement-grassland), and 11 (Chinquapin oak / nodding onion alvar savanna) had the highest percent covers of *Poa compressa* (Figure F). *Poa compressa* appeared at all observation points in each of these types.

Community types 6 (scrub conifer / dwarf lake iris alvar shrubland) and 16 (mixed conifer / common juniper alvar woodland) each had small sample sizes, but few of the observation points had any *Poa compressa* present, and when it was present, it had less than 1% cover. Of the five observation points in type 16 (mixed conifer / common juniper alvar woodland), none had more than 5% cover of *Poa compressa* in the community. None of the observations of type 14-15 (white cedar - jack pine / shrubby

Figure F Comparison of maximum and median values for percent cover of *Poa compressa* in different alvar community types, arranged in decreasing order of median values. The difference between median and maximum shows whether high numbers occur in most of the samples or in just a few samples with exceptionally high values.

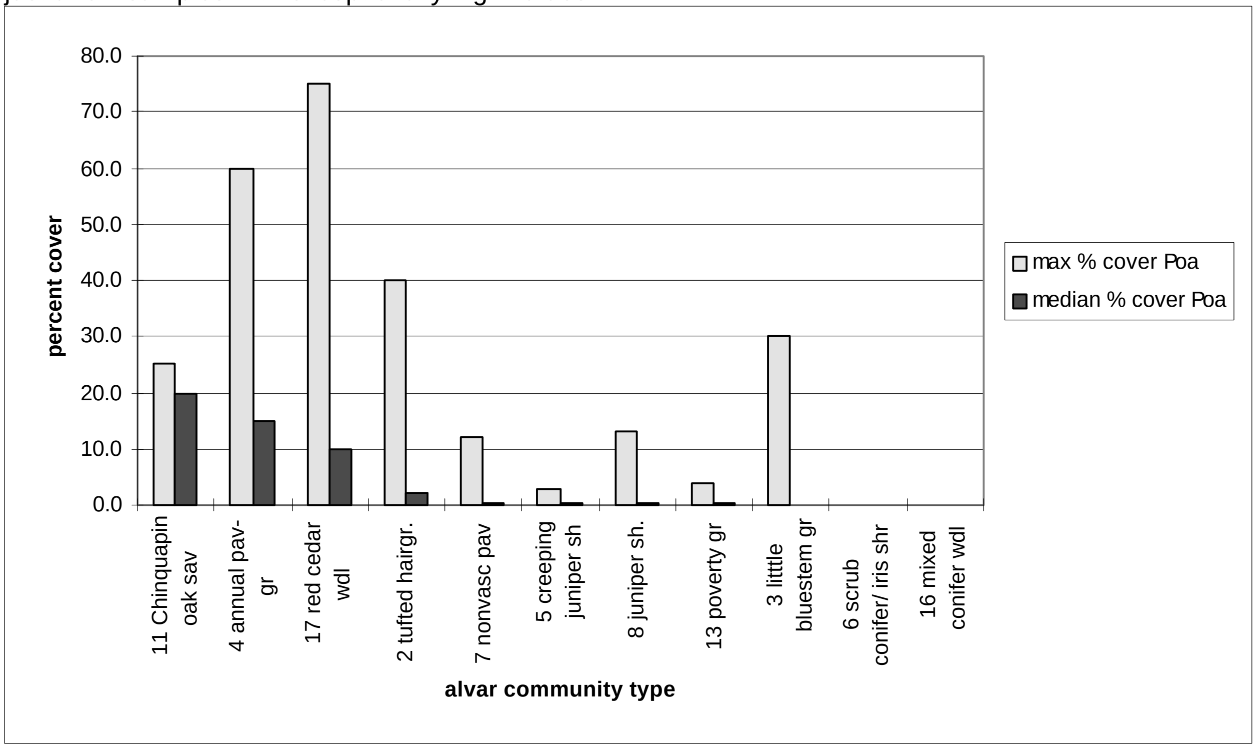
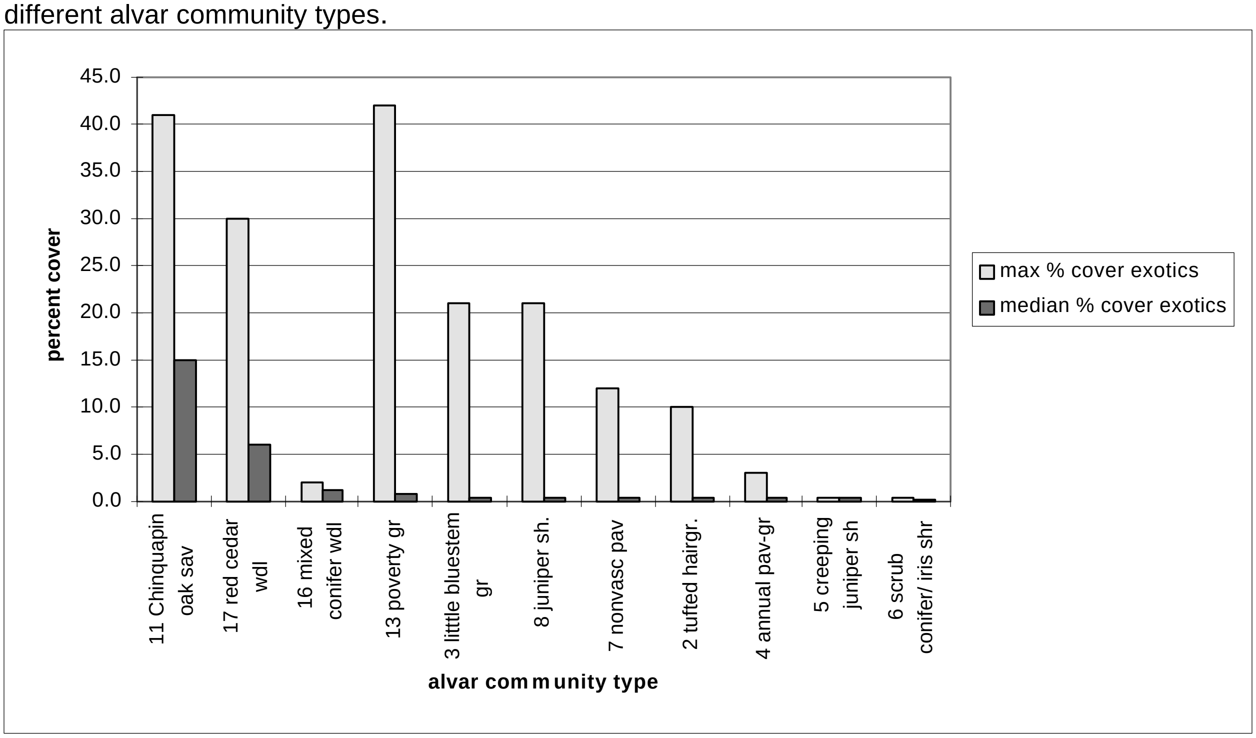


Figure G Comparison of maximum and median values of percent cover of exotic species in different alvar community types.



cinquefoil alvar savanna) had *Poa compressa* present at 1% or more cover, and only a few had this species present at all.

Therefore, *Poa compressa* does not appear to be an important plant, invasive or not, in our samples of alvar types 6 (scrub conifer / dwarf lake iris alvar shrubland), 14-15 (white cedar - jack pine / shrubby cinquefoil alvar savanna) or 16 (mixed conifer / common juniper alvar woodland).

A slightly different pattern was found for other exotic plant species. Community types 11 (Chinquapin oak / nodding onion alvar savanna) and 17 (red cedar / early buttercup alvar woodland) have the highest cover of exotics (Figure G), suggesting that these types tend to be weedier than other alvar types. Type 6 (scrub conifer / dwarf lake iris alvar shrubland) consistently ends up with the lowest cover of exotics, suggesting that this type has the fewest weeds.

4. St. John's-wort and a few other exotic herbs are also widespread in most alvar communities and are difficult to control.

After *Poa compressa,* St. John's-wort *(Hypericum perforatum)* is the most frequent exotic species in most alvar community types (except in types 6 and 16, where it is the most frequent exotic species). Overall, it occurred at 49% of the observation points. Community types 5 (creeping juniper - shrubby cinquefoil alvar pavement) and 3 (little bluestem alvar grassland) had the least *Hypericum perforatum* present. Types 11 (Chinquapin oak / nodding onion alvar savanna), 16 (mixed conifer / common juniper alvar woodland), and 17 (red cedar / early buttercup woodland) had *H. perforatum* present at all observation points.

The next most frequent species overall was rough-fruited cinquefoil (*Potentilla recta)* which occurred at 25% of observation points and was the next most frequent exotic species in most community types. Another widespread exotic presence was the hawkweeds of the genus *Hieracium*, which collectively constitute a large presence.

Some experimental attempts have been made to control St. John's-wort within alvar habitats on the Maxton Plains alvar on Drummond Island (Stephenson 1995). Preliminary results showed single removals by hand-pulling to be relatively ineffective since stored seeds in the soil replaced the removed plants. Multiple removals in a single season was more effective, especially within dense grass areas, but effectiveness was highly site-specific.

Burning was not an effective means of removing or reducing *Hypericum* populations, since the species resprouted vigorously from root systems. Experimental treatments with herbicides are highly effective at killing individual treated plants, but the longer-term response of alvar communities to this technique is uncertain.

4.5.3 Study Results Specific to Buckthorn

Buckthorn *(Rhamnus cathartica)* was the most frequently noted exotic shrub within alvar habitats. It was recorded from 9% of observation points, all from sites in New York and eastern Ontario (Burnt Lands, Gretna Alvar, and Massassauga Point Alvar). It occurred in three community types: juniper alvar shrubland, alvar nonvascular pavement, and annual alvar pavement-grassland.

A study of buckthorn conducted by Amy Samuels at Chaumont Barrens Preserve in New York (Samuels 1998) set out to address three main questions:

1. How are community type, soil depth, and land-use history related to the abundance of buckthorn at Chaumont Barrens?
2. How are the abundances of buckthorn, grey dogwood (*Cornus racemosa*), and common juniper (*Juniperus communis*) related to alvar community composition and species diversity?
3. How does buckthorn compare to grey dogwood and common juniper in terms of the relationship of each shrub species to associated herbaceous vegetation?

The answer to the first question should provide insight into factors that affect the establishment, spread, and control of buckthorn, while answers to the second and third questions will help determine whether or not buckthorn is enough of a problem to require some control measures. Buckthorn would be considered a problem if it alters community composition and species diversity, or if it is relatively abundant compared to the native shrubs. A second exotic shrub, honeysuckle *(Lonicera tatarica),* is also a problem on some of the same alvar sites, but to a lesser extent. In addition, black swallow-wort (*Vincetoxicum rossicum*) is a very aggressive exotic plant which is a management problem on New York state alvars.

The primary communities studied by Samuels were juniper alvar shrubland, tufted hairgrass wet alvar grassland, and adjacent woodlands that ranged from deciduous and mixed types (not represented in Alvar Initiative types) to coniferous woodlands and forests somewhat similar to mixed conifer / common juniper alvar woodland. The study examined relationships between buckthorn abundance and community type, soil depth, disturbance history, community composition, and abundance of native shrub species. An analysis of the age structure of buckthorn was completed and the abundance of seeds in the soil in different communities was examined. Sample plots near roads (within 80 paces) were also compared to plots in less disturbed interior shrublands.

Findings

1. The abundance of buckthorn varied between community types.

The highest abundance of buckthorn was found in the roadside shrublands, then in the woods, then in interior shrublands, with the lowest abundance in the alvar grasslands. Overall differences in frequency, density and percent cover between communities were found to be statistically significant. The study also found that the frequency and density of all ages of buckthorn were higher in coniferous and mixed woods than in deciduous woods.

Soils depths varied between communities, with deeper soils associated with shrublands and woods, and shallower soils in grasslands. This variation in soil depth is correlated to buckthorn abundance, with more buckthorn found in communities where soils are deeper.

2. Buckthorn abundance and seed density are related to the degree of disturbance in natural communities.

Disturbance as represented by distance from roads was strongly correlated with buckthorn abundance. The highest frequencies of buckthorn were found within 80 paces of a road.

Analysis of size and age class distributions indicated there was an uneven distribution of age classes, with many buckthorn seedlings and saplings, and fewer adults. Analysis of the distribution of seeds in the soil showed that there were significantly higher numbers of seeds near the roadside (where buckthorn abundance was also higher). Both seeds and adult buckthorn plants were found in the roadside and interior shrubland communities. Buckthorn seeds (but no adult plants) were found in deciduous woods. No seeds or buckthorn adults were found in grasslands

3. At Chaumont Barrens alvar, buckthorn is more problematic in woodland settings than in interior shrublands.

In shrublands, the comparison of buckthorn abundance to the abundance of native shrubs showed that buckthorn had a significantly lower abundance than the dominant shrubs: common juniper, grey dogwood, and downy arrowwood *(Viburnum rafinesquianum).* In contrast, the cover of buckthorn in woodlands was equivalent to the cover of the two most abundant native shrubs (grey dogwood and downy arrowwood), and significantly greater than any other native shrubs.

The overall trend that emerges across communities is that buckthorn and honeysuckle, the two exotic shrubs, have higher abundances in the woods and along the roadside than in the grasslands or interior shrublands. This tendency is much more pronounced for buckthorn than for honeysuckle.

4.5.4 Conclusions

The patterns presented here say something about the current state of weediness in different alvar community types but do little to explain the underlying causes. Most likely, the community types that are now the weediest were in the past the most desirable (or the most accessible) for human uses such as grazing. Land use history may have more to do with patterns of weediness than alvar community type. The majority of our data comparing exotics to alvar community types fail to show any strong pattern. This probably indicates that weediness of alvar communities is site specific and depends on local site disturbances rather than on some rangewide processes that consistently influence all occurrences of a community type.

More work needs to be done to determine appropriate management of exotic species and rehabilitation of weedy alvar sites. Developing techniques of applying herbicides without damaging native herbs is a challenge that still needs to be addressed. The effectiveness of manual removal of exotic plants, or of controlled burning as a restoration technique, also needs more study in a variety of alvar settings. Also, the role of *Poa compressa* in alvar communities should be studied in more detail to see whether this species is a threat.

One interesting question is whether the abundance of bird-dispersed seeds (such the seeds of buckthorn and honeysuckle) might be correlated with the abundance of perch sites for birds. Although that correlation was not specifically studied, it may have important management implications. For instance, if buckthorn or honeysuckle are cut as part of a management program and the cut brush left on site, this may be simply providing additional perch sites for birds that disperse the seeds. This could be an important question for future research.