Evaluation of Ozone Injury
on Vegetation in the
Seney National Wildlife Refuge
Michigan

2004 Observations

Submitted to

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INTRODUCTION

General

The Seney National Wildlife Refuge (NWR) is one of more than 500 refuges in the National Wildlife Refuge System (NWRS) administered by the U.S. Fish and Wildlife Service (FWS). The NWRS is a network of lands and waters managed specifically for the protection of wildlife and wildlife habitat and represents the most comprehensive wildlife management program in the world. Units of the system stretch across the United States from northern Alaska to the Florida Keys and include small islands in the Caribbean and South Pacific. The character of the refuges is as diverse as the nation itself.

Seney NWR is located in the Upper Peninsula of Michigan (Figure 1), and contains 95,500 acres that are managed to provide quality habitat for a diversity of wildlife species. On October 23, 1970, Congress conferred wilderness status on 25,150 acres of the Seney NWR.

Objectives

1). To identify ozone–sensitive plant species in the Seney NWR
2). To evaluate amount of ozone injury on vegetation in the Seney NWR

Justification

In 1970, Seney Wilderness was designated a Class I air quality area, receiving further protection under the Clean Air Act. Congress gave FWS and the other Federal land managers for Class I areas an "…affirmative responsibility to protect all those air quality related values (including visibility) of such lands..." Air quality related values include vegetation, wildlife, water, soils, visibility, and cultural resources. Despite this special protection, many of the resources in these wilderness areas are being impacted, or have the potential to be impacted, by air pollutants. Because many air pollutants can be carried long distances in the atmosphere, even rural and remote areas, including many wilderness areas, are affected by air pollution. To better understand how air pollution affects resources at the Seney NWR, annual surveys were conducted in 1999-2004 to evaluate ozone injury to vegetation within the refuge.

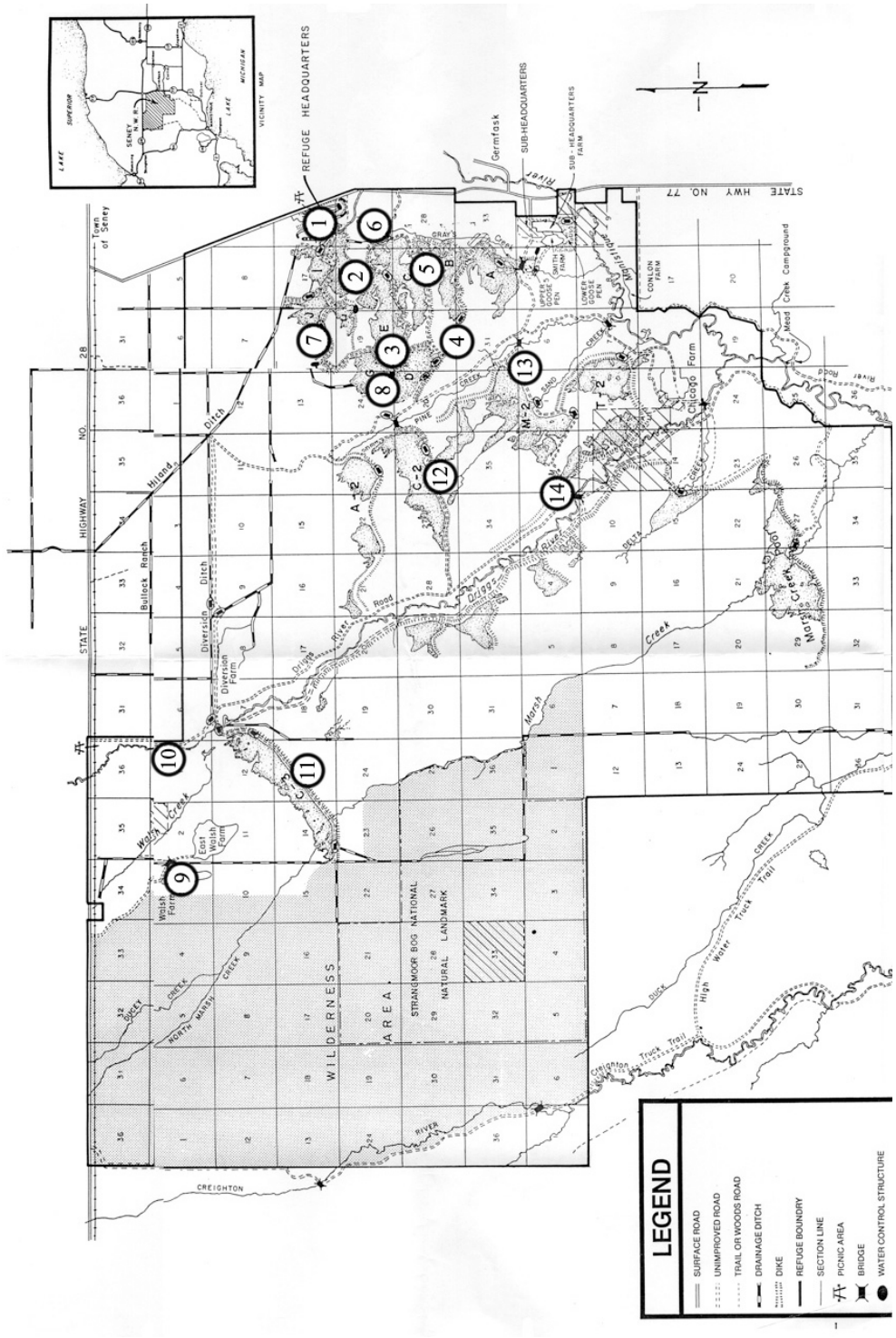

Figure 1. General location of the Seney National Wildlife Refuge and location of survey sites. Circled numbers denote survey site locations.

Diagnosis of Air Pollution Injury on Plants

Although many gaseous air pollutants are emitted into the atmosphere, only certain ones are phytotoxic and induce characteristic leaf symptoms that are useful during field surveys. The most important of these gaseous, phytotoxic air pollutants are ozone, sulfur dioxide, and fluorides. These pollutants, along with the normal constituents of the air, are taken into the plant leaf through the stomata. Once inside the leaf, the pollutant or its breakdown products react with cellular components causing tissue injury or death.

The resulting macroscopic symptoms, which are visible on the leaf surface, are classified as chronic or acute depending upon the severity of injury. Chronic symptoms imply tissue injury, whereas acute injury signifies tissue death. Chronic symptoms on foliage usually result a plant's exposure to low levels of pollution for an extended time, or occur when a plant is somewhat resistant to a pollutant. Visible ozone injury is usually considered to be chronic injury. Acute injury may be observed following a short-term, high concentration of pollution, or occurs when a plant is in a very sensitive condition. Sulfur dioxide injury as observed in the field is often acute.

Macroscopic leaf injury caused by air pollutants often represents an intermediate step between initial physiological events and decreases in plant productivity. Decreases in plant productivity (Pye 1988) may result in ecological changes, such as reduced diversity (Rosenberg et al. 1979). Visible leaf symptoms induced by phytotoxic pollutants serve as important diagnostic tools that allow observers to identify specific air pollutants as causal agents of vegetation damage (Davis 1984; Skelly et al. 1987, Skelly 2000). This knowledge can be used in the air pollution emissions permitting process for siting new industries (i.e. Prevention of Significant Deterioration Program), assessment of the secondary air quality standards, assessing the presence of air pollution injury in Class I areas, and in litigation involving air pollution injury.

Although ozone was the air pollutant of concern in this survey, it should be recognized that phytotoxic levels of air primary pollutants such as sulfur dioxide and fluorides might occur near industrial sources. Likewise, trace elements including metals may be found in excessive levels in vegetation growing in areas downwind from industrial or urban sources (Davis et al. 1984, Davis et al. 2001). Toxic elements such as arsenic, mercury (Davis 2002), and lead may be especially important in areas being managed for wildlife. Although such compounds are of more interest in mammalian and avian toxicity as compared to phytotoxicity, vegetation may sorb such

contaminants and become part of the contaminated food chain. However, the presence of excessive elements such as metals, as well as organic biohazards such as dioxins and furans, is determined with laboratory analysis of foliage, not with surveys dealing with macroscopic foliar injury.

Ozone

Ozone is probably the most important and widespread phytotoxic air pollutant in the United States, and is the air pollutant most likely to have an easily recognizable impact on vegetation within a NWR. Background levels of ozone exist naturally in the lower atmosphere, possibly originating from vertical downdrafts of ozone from the stratosphere, lightning, or chemical reactions of naturally occurring precursors. However, in many areas, precursors leading to phytotoxic levels of ozone originate from upwind urban areas. In those areas, hydrocarbons and oxides of nitrogen are emitted into the atmosphere from various industrial sources and automobiles. These compounds undergo photochemical reactions in the presence of sunlight forming photochemical smog, of which ozone is a major component. Ozone, or its precursors may travel downwind for hundreds of miles during long-range transport, as influenced by wind direction and movement of weather fronts. Thus, ozone impinging on refuges may originate in areas many miles upwind from the refuge. In fact, concentrations of ozone are often greater in rural areas downwind from urban areas, as compared to within an upwind urban area, due to the presence of reactive pollutants in the urban air that scavenge the ozone.

There are certain bioindicator plants in the East that are very sensitive to ozone and exhibit characteristic symptoms when exposed to ozone (Anderson et al. 1989, Davis and Coppolino 1976, Davis and Skelly 1992, Davis et al. 1981, Davis and Wilhour 1976, and Jensen and Dochinger 1989). The principal investigator in this survey routinely uses the following broad-leaved bioindicator species for evaluating ozone injury: black cherry (*Prunus serotina*), common elder (*Sambucus canadensis*), common milkweed (*Asclepias syriaca*), grape (*Vitis* spp), white ash (*Fraxinus americana*), and yellow-poplar (*Liriodendron tulipifera)*. The investigator also uses, but less commonly, Virginia creeper (*Parthenocissus quinquefolia*) and *Viburnum* spp.

Ozone-induced symptoms on broadleaved bioindicators usually appear as small 1-2 mm diameter "stipples" of pigmented, black or reddish-purple tissue, restricted by the veinlets, on the adaxial surface of mature leaves (see Skelly 2000, Skelly et al. 1987). Immature leaves seldom exhibit symptoms, whereas premature defoliation of mature leaves may occur on sensitive

species. To the casual observer, these symptoms are similar to those induced by other stresses (e.g., nutrient deficiency, fall coloration, heat stress, as well as certain insects, and diseases). However, the pigmented, adaxial stipple on plants of known ozone-sensitivity (i.e., black cherry or grape) is a reliable diagnostic symptom that can be used to evaluate ozone injury.

On eastern conifers, the most reliable symptom (current-year needles only) induced by ozone is a chlorotic mottle, which consists of small patches of chlorotic tissue interspersed within the green, healthy needle tissue. The mottle usually has a "soft edge" (as opposed to a sharply defined edge) to the individual mottled areas. An extremely sensitive plant may exhibit needle tip browning. However, this latter symptom can be caused by many stresses and therefore is not a reliable diagnostic symptom. Conifer needles older than current-growing season needles are not useful as monitors, since over-wintering and multi-year insect injuries may produce symptoms similar to that caused by ozone. Ozone injury to monocots, such as grasses (i.e., *Spartina* sp.), is also very difficult to diagnose in the field, as there are many causal agents that can result in tipburn and chlorotic mottle on grasses.

Description of Seney NWR
(Adapted from Seney NWR brochures)

Although it appears wild to the untrained eye, most of the 95,500 acres of the Seney NWR are carefully managed to provide quality habitat for a diversity of wildlife species. But like the timber wolf it harbors, Seney has an untamed spirit – the Wilderness Area the public seldom sees. On October 23, 1970, Congress conferred wilderness status on 25,150 acres of the Seney NWR. As part of the National Wilderness Preservation System this area is granted special protection that will insure the preservation of its wilderness characteristics.

History

Centuries ago, the lands of the Seney Wilderness Area within the refuge were overlain with sand in an extinct glacial lakebed. During drought periods, the sand from the lakebed was blown into dunes that, in time, became covered with trees and brush during the moist period. These dunes presently exist to form a necklace of islands in the midst of a vast bog. Today, these strangmoor bogs, or "string bogs," a sub-arctic formation rare at this latitude, characterizes two-thirds of the Seney Wilderness Area. These string bogs are now contained within the 9,500-acre Strangmoor Bog Registered National Landmark.

The present climate of the Seney NWR is characterized by cold winters and cool summers, with temperature extremes ranging from -47˚ to 103˚ F. Precipitation averages 31 inches annually, with about one-half received as snow in the winter months.

Vegetation

Much of the Seney NWR was once a white pine forest that was logged off during the late 1800's and then burned over many times. Although the refuge still boasts the giant stumps of white pines, it is now covered with second growth aspen and jack pine, and a variety of less prominent species. The bog islands are commonly dominated by a few red pines, with some jack pine and aspen. They are usually fringed with thick clumps of alder, and in some locations long stands of tamarack trail away on the tails of the islands. Black spruce swamps are also found along the edges of the bog. The bogs' unique habitat also supports such uncommon life forms as the carnivorous pitcher plant. A listing of Seney NWR vegetation, as supplied by refuge personnel, is given in the Appendix.

Wildlife

The Seney NWR today is managed for its two most important tenants: the endangered eastern timber wolf and the bald eagle. In addition to common fauna such as deer, fox, mink and muskrat, the refuge is home to beaver, moose, otter, black bear and coyote. Bird species include ospreys, as well as waterfowl such as geese, black duck, mallard, American widgeon and wood duck. Spruce, ruffed and sharp-tailed grouse, and numerous songbirds also dwell within the refuge.

Location

The Seney NWR is in Michigan's Upper Peninsula. The refuge headquarters is located off Highway M-77 near the villages of Seney and Germfask, and is approximately 80 miles northwest of the Mackinac Bridge.

METHODS

General Survey Areas

It had been predetermined that survey sites had to occur in open-areas (such as those occurring along roads or in fields) where ozone-sensitive plant species were found in sunlight and exposed to unrestricted air movement (Anderson et al. 1989; USDA Forest Service, 1990). Immediately prior to the first survey (1999), the investigator met with refuge personnel at refuge headquarters. (To the author's knowledge, there had been no recorded surveys prior to 1999 to document the level of ozone injury occurring to vegetation within this rural refuge). During this time, maps were viewed and discussed, which aided and influenced the preliminary selection of survey areas. Based on these initial discussions, tentative survey areas were selected throughout the refuge. Each area was visited, and its suitability determined in 1999. These general areas, with slight modifications, were also used in the 2000-2004 surveys.

Preliminary Selection of Bioindicator Species

FWS personnel furnished a list of refuge flora to the investigator (see Appendix). Prior to each survey, potential bioindicators that might exhibit ozone injury in the survey area were selected from this list. Plant species or genera on the list selected as potential bioindicators included: black cherry (*Prunus serotina*), blackberry (*Rubus* sp.), common milkweed (*Asclepias syriaca*), elderberry (*Sambucus canadensis*), pin cherry (*Prunus pensylvanica*), spreading dogbane (*Apocynum androsaemifolium*), and trembling aspen (*Populus tremuloides*). These species, with some modifications, were used in the 2004 survey.

Of course, many of the bioindicators grow in scattered localities through the NWR, and may not be present at desired survey areas; they may only be found with the help of local botanists. Also, most plant species growing in the more wet areas of the refuge have not been studied with regard to ozone-induced macroscopic symptoms. That is, the ozone-sensitivity of wetland species, as determined by controlled exposures of ozone, is generally unknown.

Air Quality

Ozone monitoring data are useful to complement the visual injury surveys, and as long as soil moisture is adequate and temperatures are moderate, more ozone-induced stipple is likely to occur in years with greater ozone concentrations. However, more consistent and long-term

monitoring datasets are needed to further understand the relationship between foliar symptoms, ambient ozone, and environmental conditions (e.g. droughts) in our parks and refuges.

During 1999 – 2001, ambient ozone levels were monitored only at Ellison Bay, Wisconsin (EPA AIRS site #55-029-0004), located approximately 75 miles southwest of the refuge. A new ozone monitor (EPA AIRS site #26-153-0001) was established within the refuge in 2001, and began collecting ambient ozone data on January 15, 2002. In my 2003 annual report, I emphasized that ambient ozone levels at Ellison Bay were not comparable to those monitored within the refuge. In this 2004 report, only data monitored (from 2002-2004) within the Seney NWR at AIRS site #26-153-0001 are presented. Ambient ozone levels in are expressed as "cumSUM60", the cumulative sum of all hourly ozone concentrations equaling or exceeding 60 ppb. Other researchers have found that this ozone statistic correlates with plant damage.

In 2004 the ambient ozone monitor within the Seney NWR revealed that cumSUM60 ozone levels had accumulated to only about 5,000 ppb.hrs at time of the August survey, and remained at this level throughout August (Figure 2). This reflected the general observation that ambient ozone values were at record lows throughout much of eastern United States in 2004, as associated with widespread cool, wet weather. During 2002 and 2003, the cumSUM60 ozone levels had accumulated to 13,000 ppb.hrs at time of the August surveys. In terms of phytotoxicity, even these are low levels of ambient ozone, and help explain the low levels of plant injury routinely observed at this location.

The ambient ozone levels monitored within the Seney NWR were less that other rural refuges such as the Moosehorn NWR in Maine, and much lower than ozone levels at the Mingo NWR in Missouri, Edwin B. Forsythe NWR in New Jersey, and Wichita Mountains NWR in Oklahoma. For example, the ozone levels at the Edwin B. Forsythe NWR reached about 80,000 ppb.hrs in 1991 (a very high ozone year), 60,000 ppb.hrs in both 1997 and 1998, and are often greater than 40,000 ppb.hrs by the summer's end. During 1999, ozone levels at the Mingo NWR likewise reached 80,000 ppb.hrs by late fall. In Oklahoma, ozone levels are routinely greater than 40,000 ppb.hrs by fall. In addition, at the more southerly refuges such as the Okefenokee, measurable ambient ozone occurs much earlier in the growing season than at the more northerly refuges. The ambient levels of ozone at Seney NWR are barely high enough to cause foliar injury, and only on very sensitive plant species such as common milkweed and spreading dogbane.

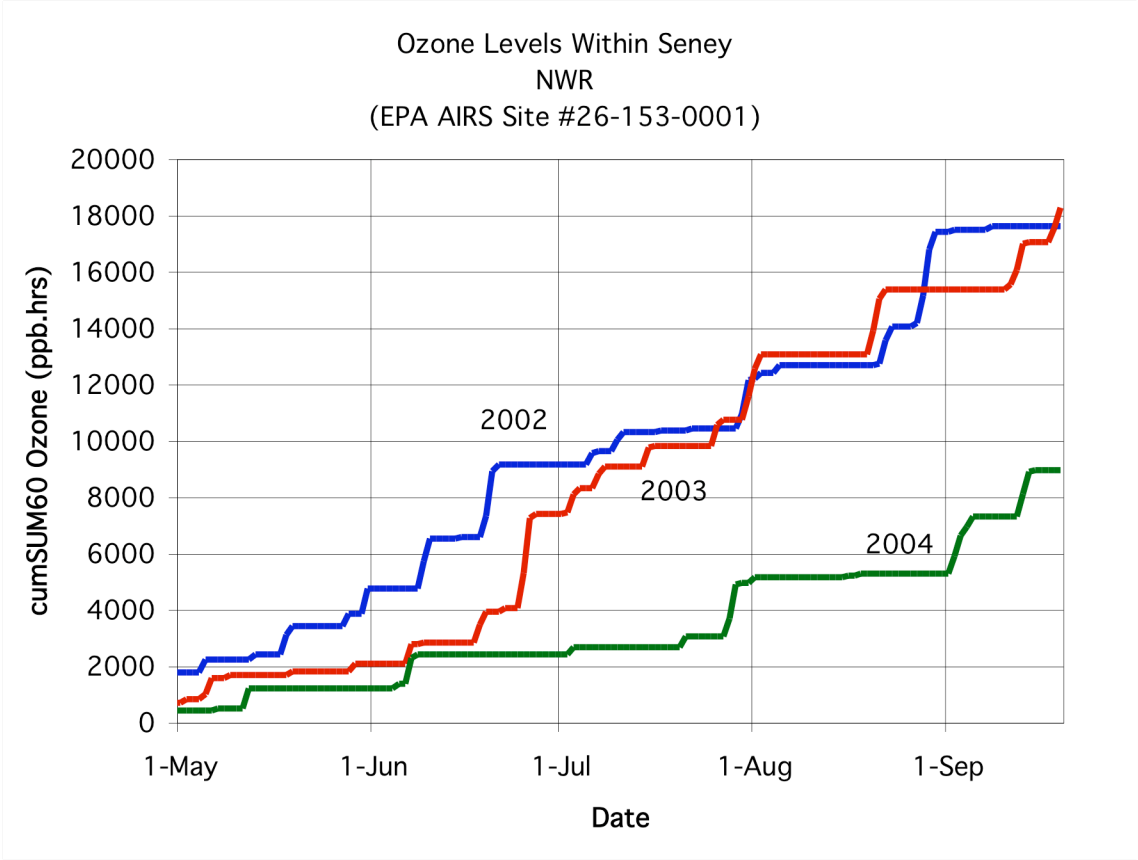

Figure 2. Cumulative sum of all hourly ozone concentrations equaling or exceeding 60 ppb (cumSUM60, ppb.hrs) in 2002-2004 as monitored within the Seney NWR (EPA AIRS Site # 26-153-0001).

Surveys Dates and Survey Locations

In 2004 the refuge was surveyed during August 13-16. All sites (Figure 1) were visited, but data was not necessarily taken at each site. In addition to these specific areas, vegetation was observed within other areas, and as the investigator traveled from location to location during the survey. This is a very large refuge, and other potential areas could be visited.

Severity Rating

Each broadleaved plant evaluated for ambient ozone injury had to have foliage within reach; that is, trees were not climbed nor were pole-pruners used. The main dataset taken was the number of plants (presented as a percentage) within a species that exhibited stipple.

In addition, the percentage of leaf tissue injured by ozone was estimated on one or two selected bioindicators. The ForestHealth Expert System had been used to train the investigator in estimating the amount of stipple on a leaf. For broadleaved tree species, the percentage of ozone injury was estimated on the oldest leaf on each of four branches, and the average value recorded. Then, the next oldest leaf was evaluated, and so on, until the five oldest leaves had been rated. For each herbaceous plant, each of the five (if present) oldest (basal) leaves of the plant was examined and the average percent stipple recorded. Each of the oldest five leaves on the current woody growth (canes) of vines was rated and the average percent stipple recorded. On all species, only adaxial leaf surfaces were evaluated. Symptom severity on the adaxial surface of each leaf evaluated was estimated by assigning severity classes, based on the percentage of surface injured, of 0, 5, 10, 20, 40, 60, 80, 90, 95 and 100 %.

If useful plant damage or scenic scenes were observed, digital images or slides were taken and forwarded to the FWS Air Quality Branch in Denver.

RESULTS AND DISCUSSION

Final Selection of Bioindicator Species

During each survey year, a re-evaluation of bioindicator species or genera (plants regarded as being sensitive to ozone) is made in the field. By 2004, the expanded list of potential bioindicators consisted of black cherry, blackberry, common milkweed, elderberry, pin cherry, serviceberry (*Amelanchier* sp.), spreading dogbane, and trembling aspen. These were among the most common of the ozone-sensitive species in the refuge, and usually occurred in open areas. Not all species/genera listed were present at all sites.

This list was amended to include raspberry (*Rubus idaeus*). Raspberry was selected as an indicator for sulfur dioxide (SO_2) injury, along with blackberry. However, since there was no point source of SO_2 readily evident, emphasis was placed on the ozone-sensitive bioindicators.

Foliar Symptoms

Common milkweed has been the most reliable ozone bioindicator within the Seney NWR. When milkweed injury (stipple) data was combined for all survey sites in 2004, the incidence of milkweed plants injured by ozone was 18 of 7,068 (0.25%) of the individuals evaluated (Table 1). The percentage of milkweed plants exhibiting ozone injury in 2004 was extremely low, as was the ambient ozone (Figure 2). The incidence of injured milkweed plants with ozone injury in August of the various survey years was as follows: 2000 (2.0%) > 1999 (1.6%) >2001 (1.5%) > 2002 (1.2%) > 2003 (0.6%) >2004 (0.2%). These very low levels of ozone injury are related to the very low levels of ambient ozone that the Seney NWR normally experiences. Detailed notes on severity of ozone severity, by leaf position, were recorded only for common milkweed. As in most years, the severity of ozone injury on milkweed foliage was very light in 2004 (Table 2).

Spreading dogbane may also be a useful ozone bioindicator in this refuge, but is not without problems. In 2004 ozone injury occurred on 14 of 47 (29.8%) spreading dogbane plants examined. However, as in most years, spreading dogbane leaves were showing severe chlorosis, leafspots, and defoliation at time of survey. Dogbane foliage begins to senesce very early in the growing season. These foliar symptoms greatly confounded evaluation of ozone injury (stipple). In fact, definite stipple could be evaluated only at survey Site 11. This site also had considerable ozone injury on spreading dogbane in 2002-2003, indicating that a very sensitive clone of

spreading dogbane is likely present at this site. In order to use spreading dogbane as a bioindicator at Seney NWR, surveys should be conducted much earlier in the growing season.

Sulfur dioxide injury was not observed on SO_2-sensitive bioindicators in 2004.

Site 1 (Refuge Headquarters Near "F" Pool). This survey site along the "Marshland Route" was located near the small, pullover, parking area adjacent to the "F Pool". The location was selected because of the openness and the number of bioindicators present. This is considered to be a good survey site, but does suffer from road dust. This location was designated as mile 0.0 in the field notes.

In 2004 stipple was noted on 2 of 200 (1.0%) of the common milkweed at this site (Table 1). The severity of the stipple on common milkweed was very light, never exceeding 10% of the upper leaf surface (Table 2). Dogbane plants were too chlorotic to evaluate at this location.

In 2003 stipple had been observed on 0.6% of the milkweeds and none of the spreading dogbane plants. In 2002 ozone injury had been observed on 1.2% of the milkweeds and on 23.1% of the spreading dogbane plants. During 2001, ozone injury occurred on 9.1% of the common milkweed plants, but not on spreading dogbane. In 2000, ozone-induced stipple was observed on 8.0% of the milkweeds, but not on any spreading dogbane plants at this location. During 1999, ozone injury had occurred on 8.6% of the common milkweeds and 9.5% of the dogbane plants at this survey site.

The ozone injury on the symptomatic milkweed plants in 2004 was very light in severity, never exceeding 10% of the upper leaf surface (Table 2). Older common milkweed and dogbane leaves were very chlorotic and undergoing premature defoliation. Although early leaf-fall has been common in late summer of many years, the intensity of defoliation was severe this year. Spreading dogbane also had severe chlorosis and leafspots.

Casual observations indicated that ozone injury did not occur on blackberry or serviceberry at Site 1 in 2004. Vegetative blackberry canes were examined, and found to be free of ozone-induced symptoms. Blackberry plants were not as red as in 2003. Blackberry plants were also not red in 2001, probably due to the plentiful rainfall that year. (In past years, the reddening often appeared to be related to water stress). Light black-knot infections were common on black cherry branches. Other common insect disorders (i.e., leaf chewing) and diseases (i.e., leafspots) were observed to occur in normal levels.

Blackberry and raspberry are both sensitive to SO_2. There was no SO_2 injury on these species at this site, nor other locations examined in the refuge. This finding was expected, as there were no apparent, large point sources of SO_2 upwind of the refuge.

The low level of ozone-induced symptoms, observed at this and other sites within the Seney NWR in 2004, was attributed mainly to the low levels of ambient ozone (Figure 2) present for the several months immediately prior to the survey, since rainfall (and therefore soil moisture) appeared to be adequate.

Site 2. Site 2 was located at mile 1.0 near a gated road along the edge of "Pool F". In 2004 ozone injury was not observed on common milkweed or elderberry (Table 1). The foliage of spreading dogbane was generally too chlorotic to evaluate. Raspberry plants had red leaves.

In 2003 ozone injury had not been observed on blackberry, common milkweed, elderberry, or spreading dogbane. However, the dogbane leaves had severe leafspot infections, chlorosis, and necrosis, making them difficult to rate regarding the amount of stipple present. Many of the lower leaves of common milkweed were red or yellow in 2003. Elderberry leaves exhibited small, red spots that included the veins and veinlets. Such symptoms were likely drought-related.

In 2002, only elderberry had exhibited ozone injury at Site 2, when stipple had been observed on approximately 18% of the plants. Stipple had not been observed on any bioindicator species at this site in 2001. In 2000, very light stipple was observed on less than 1% of the milkweeds. However, several viburnums (possibly *Viburnum cassinoides*) growing near this site had classic ozone-induced stipple in past years. No notes were taken regarding the foliage of the Viburnums in 2004.

Site 3. This site was near mile 2.0 near the pull-off just past the "Mile 2" marker at the "E-C Spillway". During the 2004 survey, ozone-induced stipple was not observed on any milkweed plants at this site (Table 1). Dogbane plants were too chlorotic to evaluate.

During the 2003 survey, stipple also was not observed on any bioindicators at this site. However, stipple could not be detected on many milkweed plants in 2003 since the lower leaves had fallen off, likely due to the drought. Blackberry leaves had marginal chlorosis, also likely related to the dry conditions. As in the dry year of 2002, spreading dogbane leaves exhibited chlorosis, leafspots, and initial senescence.

In 2002 ozone stipple had occurred on approximately 1% of the common milkweed plants, and on 40% of the spreading dogbane plants. During the 2001 survey, very light ozone

injury had been observed on approximately 2% of the common milkweeds. In 2000, ozone injury had also been noted on 2% of the milkweeds. In 1999, ozone injury was not observed on any bioindicators at this site.

Site 4. Site 4 was located near mile 4.0 between the "D Pool" and the "C Pool" at the "Loon Observation Deck". In 2004 stipple was observed on 6 of 120 (5.0%) of the common milkweed plants. The severity of the stipple was light (Table 2). Spreading dogbane plants were too chlorotic to rate.

In 2003 stipple had been observed on approximately 4% of the common milkweed plants at this survey site. Many milkweed leaves were completely red in 2003, and some milkweed plants had lost all their lower leaves. Spreading dogbane plants had severe chlorosis and leafspots. Such symptoms on both species complicated ozone injury evaluations. Ferns were brown in 2003.

During August 2002, ozone injury had occurred only on common milkweed, being observed approximately 4% of the plants. In 2001 very light ozone injury had occurred on approximately 2% of the black cherry trees, and 1% of the common milkweed plants. In 2000, very light ozone injury had been noted on approximately 4% of the common milkweed plants. In 1999, ozone injury had occurred on approximately 1% of the common milkweed plants at this survey site.

Site 5. Site 5 was located at mile 5.0, just before the eagle nest observation deck, near the "C-B Spillway" where the two ponds nearly meet. In 2004 definite ozone injury was not observed on any common milkweed plants (Table 1). However, two individual plants exhibited possible light stipple. However, this symptom was so indistinct that it was not rated as ozone injury. Spreading dogbane plants were very chlorotic with severe leafspot infections.

Ozone injury was not observed on any common milkweed plants in August 2002-2003. However, only the upper, remaining leaves could be evaluated in 2003. Spreading dogbane plants were chlorotic, had severe leafspots, were senescing, and were not rated in 2003.

In 2002 stipple had been noted on 15% of the spreading dogbane plants examined, in spite of their leaves becoming chlorotic. In 2001, ozone injury was not observed on any common milkweed plants at this site. In 2000, light ozone injury had been observed on 2% of the milkweed plants. In 1999, 4% of the milkweeds at this site had ozone injury.

Site 6. This site was located near the chained gate at mile 6.0 where thousands of common milkweed plants were growing. In 2004 stipple was not observed on any common milkweed or elderberry plants (Table 1).

In 2003 stipple had been observed on less than 1% of the common milkweed plants.

In August 2002, approximately 1% of the common milkweed plants had exhibited ozone-induced stipple. There was no ozone injury on the 10 elderberry plants examined. In 2001 light ozone injury had been observed on 2% of the common milkweed plants, but not on any elderberry plants. In 2000 light ozone injury had occurred on approximately 3% of the milkweed plants, and on 7% of the elderberry plants. In 1999, ozone injury had occurred on less than 1% of the milkweed plants, but not on elderberry. The aphid infestation, which was common on milkweed throughout the refuges in 2003, was especially severe at this site. Sooty mold on the milkweed leaves, associated with aphid exudates, complicated foliar evaluation.

Site 7. This site was located along the "Fishing Loop" to the "J-G Spillway", where a stand of milkweeds grew near a large red pine. In 2004, ozone injury was observed on 1 of 271 (0.4%) of the common milkweed plants examined (Table 1). The severity of the stipple on common milkweed was very light, never exceeding 10% of the upper leaf surface (Table 2).

The access road was closed in 2003 due to controlled burning and admittance was forbidden, so plants were not evaluated in that year.

In August 2002 ozone injury had been present on approximately 1% of the common milkweeds, but not on spreading dogbane or aspen. This site was not visited in 2001. In 1999-2000 ozone injury was not present on common milkweeds at this site.

Site 8. This site was located near the "E-D Spillway", where a stand of milkweeds was growing. This site was not visited in 2004.

In 2003 the access road was closed due to the controlled burn that had just taken place, and admittance was forbidden, so no observations were made.

During the August 2002 survey, ozone injury had occurred on approximately 7% of the common milkweed plants. Leaves of several milkweed plants at this site were reddish in 2002, but this symptom was not considered to be ozone-induced stipple. This site was not visited in 2001. In 2000, light ozone injury had been noted on approximately 15% of the milkweeds examined. Ozone injury was not observed at this site in 1999.

Site 9. This site was located at "Walsh Farm" where plants were examined along the edge of a large hayfield. In 2004 stipple was not observed on aspen or black cherry saplings

(Table 1). Dogbane was not present at this site in 2004, possibly having been mowed off or was being replaced through succession.

In 2003 stipple was noted on approximately 3% of the black cherry saplings examined, but not on aspen or spreading dogbane plants.

This site was not visited in August 2002. In 2001, light ozone injury had been observed on 5% of the aspen sprouts examined, and on approximately 12% of the spreading dogbane plants. In 2000, ozone injury did not occur on aspen, black cherry, or serviceberry at this site. In 1999 ozone injury had occurred on approximately 3% of the dogbane plants and 3% of the black cherry saplings.

Site 10. This site was located at the Driggs River Road gate. There are few bioindicators here. This site was not visited in 2001-2004 and should be abandoned in favor of a better bioindicator site. In 1999-2000 ozone injury was not observed on bioindicators (aspen only) at this site.

Site 11. This site was located along the very sandy dike of "Pool C-3", between the large red pine/drain pipe and the bridge, where thousands of common milkweeds were growing. There is also one large patch of spreading dogbane plants at this location. However, the sides of the road had been mowed, and many of the milkweed plants growing near the road were young sprouts. Such young milkweed sprouts seldom exhibit ozone injury at survey time and therefore were not evaluated. In addition, the spreading dogbane and common milkweed plants evaluated in past years were being overgrown with ferns, goldenrod, tall weeds, and brush. The dogbane plants, because of their short stature, were often completely overgrown, chlorotic, senescing, and had a very severe leafspot, making them extremely difficult to rate.

Nevertheless, selected common milkweed, black cherry, and spreading dogbane plants were evaluated for stipple in 2004. Ozone injury was not observed on common milkweed or black cherry (Table 1) plants deemed suitable for evaluation. Even so, weeds and brush often hid the basal leaves of the milkweed plants, and at times, entire milkweed plants were overgrown by weeds, making them difficult to evaluate. Black cherry saplings were generally taller than the weeds and brush and thus could be accurately evaluated. A total of 47 dogbane plants were deemed marginally suitable to rate for stipple. Of the 47 plants, 14 (29.8%) exhibited some stipple in 2004. However, leaf stipple evaluations may have been confounded by leaf chlorosis, senescence, and leafspots.

In 2003 more than 1,000 common milkweed plants in seven separate stands had been examined at this site. At that time, the stands were less overgrown. Stipple was not observed on any milkweeds, or on 30 black cherry saplings in 2003. However, stipple was noted on approximately 90% of the spreading dogbane plants.

In August 2002 ozone injury was observed on less than 1% of the common milkweeds, and on 90% of the spreading dogbane plants. The amount of ozone injury observed on spreading dogbane, both in 2002 and 2003, was much greater than anticipated. (In 1999 and 2000, the spreading dogbane plants at this site had lost their leaves by survey time, or the leaves were very yellow and spotted, and were therefore not evaluated. However, the foliage in 2001-2003 was suitable for evaluation). Most of the refuge likely receives approximately the same level of ambient ozone, and these dogbanes are growing on a sandy dike, typical of much of the refuge. Therefore, the most likely explanation for this high level of foliar injury is that this stand of spreading dogbanes is comprised of a clone that is highly susceptible to ozone.

In 2001 light ozone injury had been noted on approximately 1% of the common milkweed plants, and moderate to severe ozone injury was observed on 25% of the spreading dogbane plants. Ozone injury was not observed on aspen or blackberry in 2001. In 2000 light ozone injury had been observed on approximately 2% of the milkweed plants and 5% of the aspens at this site. Ozone injury had not been observed on blackberry, pin cherry, or serviceberry in 2000. In 1999, ozone injury had occurred on approximately 2% of the milkweed plants, but not on aspen.

Site 12. This site was located along the edge of "Pond C-2", where hundreds of common milkweed plants were growing. In 2004 a clone of 100 milkweeds growing between this site and survey Site 4 was also evaluated. Ozone-induced stipple was not observed on milkweeds growing at either site.

This site was not visited in 2003. In August 2002 stipple had been noted on approximately 2% of the common milkweeds, but not on the spreading dogbanes. In 2001 ozone injury was not observed on common milkweed. During 2000 light ozone injury had been observed on approximately 2% of the milkweeds. In 1999 stipple had been noted on about 1% of the milkweed plants at this survey site.

Sites 13-14. Site 13 was established along the edge of "Pool M-2" in 1999, and Site 14 was established immediately adjacent to the Driggs River Bridge. These sites were individually deemed too small, so the survey area was expanded in 2000. Sites 13 and 14 were combined and

the area between the two sites included in the survey area. Site 13-14 now (2004) encompasses the two original sites, plus a large number of common milkweed plants growing between the two original sites.

In 2004 more that 2,600 common milkweed plants were examined at this combined site. Only three individual plants (0.11%) exhibited stipple (Table 1). The severity of the stipple on common milkweed was very light, never exceeding 5% of the upper leaf surface (Table 2). Milkweed plants also were very chlorotic, defoliating, and had very severe leafspot infections. Lower leaves were missing on older plants. Many milkweeds had been mowed and resprouted; these smaller sprouts were generally dark green and healthy, as compared to the older, non-mowed plants. This healthy appearance was likely related to the younger age of the aboveground portion of the mowed plants. (This observation has been made in this refuge in most previous survey years). So many of the milkweed stands had been mowed in 2004, that sprouts in some of the mowed areas were evaluated in order to achieve an adequate number of plants.

In 2003 more than 2,000 common milkweed plants had also been examined at this site. None exhibited stipple. Many milkweeds in 2003 were very chlorotic, defoliating, and appeared drought-stressed. Some milkweeds had been mowed and young sprouts were evaluated. Aphid infestations were severe.

In August 2002 ozone stipple had occurred on less than 1% of the common milkweeds at this combined site, and stipple was very light in severity. Many of the milkweeds had been mowed prior to evaluation in 2002. In 2001, light ozone injury was noted on approximately 1% of the common milkweed plants examined, 7% of the spreading dogbanes, and on none of the black cherry trees. In 2000 approximately 2% of the milkweeds had exhibited light ozone injury, as did 1% of the aspens. Ozone injury was not observed on blackberry in 2000. In 1999 2% of the milkweed plants at the Site 13, and none of the milkweed plants at the Site 14, had ozone injury.

Site 15-15A. The original Site 15 was located at the old abandoned farm site at the edge of the refuge near the sign “Bear Hollow Loop Starts Here” of the Northern Hardwoods Cross-Country Ski Area. Thousands of milkweed plants grow in the field adjacent to the abandoned farm. In 2001, the plot was expanded to include a stand of common milkweeds growing immediately along the edge of the nearby lake. The combined new site is now designated as Site 15-15A. In 2004 ozone injury was observed on 6 of 806 (0.7%) of the milkweeds (Table 1). The

severity of the stipple on common milkweed was very light, never exceeding 10% of the upper leaf surface (Table 2). All symptomatic milkweeds were located along the edge of the lake, and not within the old farm site (which apparently had not been mowed in 2004).

In 2003 many of the milkweed plants had been mowed, and young sprouts were mainly evaluated; the most sensitive clone had been mowed off completely along the edge of the lake. Nevertheless, approximately 0.4% of the common milkweeds at this site showed stipple. The severity of the stipple on milkweed in 2003 was very light, never exceeding 5% of the upper leaf surface.

In August 2002, ozone injury was noted on approximately 1% of the common milkweed plants growing at this site. At this location, ozone injury was noted on 7% of the common milkweed plants in 2001. Ozone injury had not been observed at this site during surveys in 1999 or 2000.

Site 16. This site was located along Creighton Road, where many, scattered clumps of black cherry saplings were located in the very sandy soil. In 2004 ozone injury was not noted on black cherry or common milkweeds (clumps growing next to the two bridges) along this survey route. The foliage of dogbane plants was not suitable for evaluation.

In 2003 ozone stipple had been observed on 30% of the spreading dogbane plants, but not on black cherry or common milkweed. Leafspots were severe on black cherry and dogbane. About half of the milkweed plants had been removed by mowing.

This site was not visited in August 2002. In 2001, no ozone injury was noted on 20 black cherry trees examined. In 2000, the site was very dry and many of the plants had roadside dust on their leaves; data was not taken.

Site 17. This site is located on a dike at the edge of Marsh Creek Pool, a very remote location with a good stand of common milkweed. In 2004 ozone injury was not observed on milkweed at this survey site.

In 2003 ozone injury was not noted on the 75 milkweed plants examined. However, the site had been mowed, and the sprouts were fairly young, green, and healthy.

At the time of the survey in August 2002, the road was not passable and the site was not evaluated. In 2000 ozone injury was not observed on 50 milkweed plants. In 2001 ozone injury was observed on approximately 8% of the milkweed plants at this remote location.

Table 1. Summary of observations made during the August 2004 survey at the Seney National Wildlife Refuge. Numbers in table refer to number of plants with ozone-induced stipple as compared to the total number of plants evaluated for that species; also expressed as percentages. For comparison, summaries of August 1999 - 2003 data* are also presented.

Site	Aspen	Black-berry	Cherry		Common Milkweed	Elder-berry	Service-berry	Spreading Dogbane
			Black	Pin				
1					2/200			
2					0/600	0/10		
3					0/30			
4					6/120			
5					0/90			
6					0/1000	0/10		
7					1/271			
8								
9	0/20	0/20						
10								
11		0/30			0/410			14/47
12					0/460			
13-14					3/2633			
15-15A					6/806			
16		0/30	0/50		6/148			
17					0/300			
2004 Total	0/20	0/80	0/50		18/7068	0/20		14/47
2004%	0.0%	0.0%	0.0%		0.3%	0.0%		29.8%
2003 Total	0/20	0/40	1/90		39/7060	0/35	0/20	99/325
2003%	0.0%	0.0%	1.1%		0.6%	0.0%	0.0%	30.5%
2002 Total	0/20	0/40	0/36	1/12	64/5,416	5/42	0/30	111/480
2002%	0.0%	0.0%	0.0%	8.3%	1.2%	11.9%	0.0%	23.1%
2001 Total	2/70	0/110	1/62	0/30	51/3,514	0/20	0/140	15/108
2001%	2.8%	0.0%	1.6%	0.0%	1.5%	0.0%	0.0%	13.9%
2000 Total	2/300	0/140	0/22	0/10	44/2,228	2/48	0/150	3/50
2000%	0.7%	0.0%	0.0%	0.0%	2.0%	4.2%	0.0%	6.0%
1999 Total	0/90	0/70	1/49	0/20	33/2,055	0/21	0/100	3/51
1999%	0.0%	0.0%	2.0%	0.0%	1.6%	0.0%	0.0%	5.9%

*Survey dates were as follows: August 11-15, 1999; August 24-27, 2000; August 20-23, 2001; August 18-22, 2002; August 20-23, 2003; and August 15-17, 2004.

Table 2. Severity of ozone-induced stipple on leaves of symptomatic milkweed plants aat Seney NWR, August 2004.

Species	Site No.	Plant No.	Leaf Number				
			1*	2	3	4	5
C. Milkweed	**1**	**1**	5**	5	5	0	0
		2	10	5	5	5	5
	4	**1**	10	10	5	5	5
		2	10	10	10	5	5
		3	10	10	10	5	5
		4	5	5	5	5	0
		5	5	5	5	0	0
		6	5	5	5	5	5
	7	**1**	10	5	5	0	0
	13-14	**1**	5	0	0	0	0
		2	5	5	0	0	0
		3	5	0	0	0	0
	15-15A	**1**	5	5	5	0	0
		2	10	10	10	10	10
		3	10	10	5	10	10
		4	0	5	10	10	10
		5	10	0	0	0	0
		6	5	0	0	0	0

*Oldest leaf of the 5 leaves evaluated.
**Severity values = 0, 5, 10, 20, 40, 60, 80, 90, 95, and 100% of leaf tissue injured.

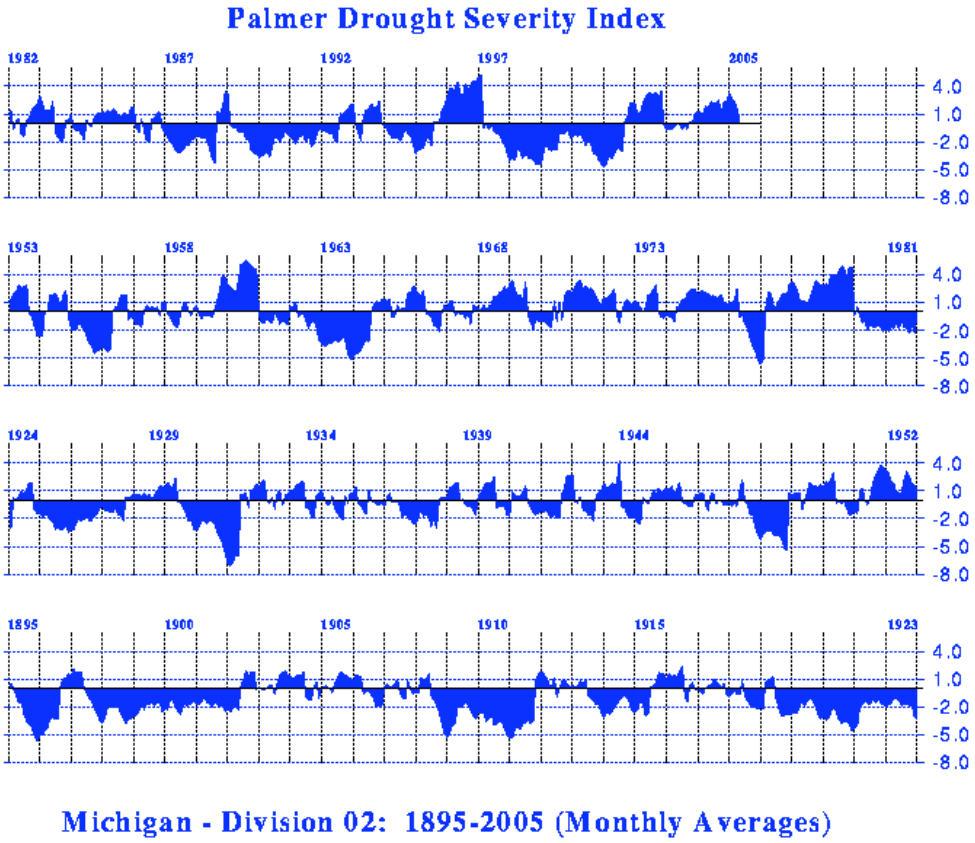

Figure 4. Palmer Drought Severity Index (PDSI) for the central portion of the Upper Peninsula of Michigan, including the Seney NWR, during 1895-2004. The horizontal line at "0" is considered normal moisture levels. Areas above the line represent adequate or surplus moisture for normal plant functioning, whereas areas below the line represent potential water stress. A drought severity index of -3 is generally considered to be a severe drought, likely reducing ozone uptake**.** The figure illustrates that a prolonged drought occurred in the general area of the Upper Peninsula during 1998–2000 and the first part of 2001. The year 2002 was wet; 2003 was dry, but not droughty; 2004 was cool and wet.

SUMMARY

In past reports ambient ozone data was obtained from the monitoring site located at Ellison Bay, WI, located 75 miles southwest of Seney NWR. On January 15, 2002, a new ozone monitor (EPA AIRS Site #26-153-0001) was established within the Seney NWR. As illustrated in my 2003 report, the ambient ozone data from the Ellison monitor are not comparable with ozone data monitored actually within the Seney NWR.

The 2002-2004 cumSUM60 ozone data from Seney refuge monitor (#26-153-0001) are presented in Figure 2. During the August 2002 and 2003 surveys, the cumSUM60 ozone levels had accumulated to only 13,000 ppb.hrs, a low level in terms of phytotoxicity. However, at the time of the 2004 survey, the cumSUM60 ozone levels within the refuge were even lower, accumulating to only 5,000 ppb.hrs, an extremely low level in terms of causing plant injury. For example, only 18 of 7,068 (0.25%) milkweeds examined exhibited ozone injury in 2004. This is the lowest incidence of ozone injury observed during any annual surveys at Seney. The monitored ozone data, along with the results of the field survey in the Seney NWR, indicated that the threshold dosage of ozone needed to cause injury on the foliage of ozone-sensitive plants such as common milkweed was lower than previously thought, perhaps as low as 5,000 ppb.hrs of cumSUM60 ozone.

In summary, the 2002-2004 ambient ozone values within the Seney NWR have been overall very low. This is to be expected, given the cool, remote environment of the Upper Peninsula of Michigan, the short summer season, and the lack of upwind nearby, major sources of ozone precursors.

The FWS should consider surveying the Seney NWR again in future years to follow the level of ozone-induced injury on vegetation over time, and to help further define ozone thresholds need to cause foliar injury in such remote locations.

There are a very high number of common milkweed plants present in the Seney NWR. This milkweed species is an excellent biomonitor to use in evaluating ozone injury in the refuge. In addition, ozone-induced stipple has been observed, but not quantified, on a *Viburnum* species (likely *V. cassinoides*) growing in the refuge. The investigator has observed ozone stipple on various species of *Viburnum* during several other surveys in the East, including within the Moosehorn NWR. The genus *Viburnum* is an under-used bioindicator with excellent potential, perhaps similar in utility to the genus *Sambucus*, for assessing ozone injury. Interestingly,

Viburnum and *Sambucus* are both in the same family (formerly, the Caprifoliaceae family). *Viburnum* could prove to be a valuable addition to the bioindicators already used for detecting ozone injury in the Seney NWR. Viburnums exhibit classic stipple symptoms, do not defoliate as early as spreading dogbane, and do not turn yellow, as do milkweed plants in late summer. In the future, consideration should be given to more use of *Viburnum* species in ozone-injury surveys, especially at the Seney refuge.

These results should prove useful to the FWS when making air quality management decisions, including those related to the review of Prevention of Significant Deterioration (PSD) permits.

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APPENDIX

Vegetation List for Seney National Wildlife Refuge
Furnished by the US FWS

Seney NWR Site Species List

Genus and species	Common name
Acer rubrum L.	(red maple)
Achillea lanulosa Nutt.	(Achillea millefolium var. occidentalis)
Actaea rubra (Ait.) Willd.	(red baneberry)
Adiantum pedatum L.	(northern maidenhair)
Agalinis tenuifolia (Vahl) Raf.	(slenderleaf false foxglove)
Agropyron repens (L.) Beauv.	(Elytrigia repens var. repens)
Agrostis gigantea Roth	(redtop)
Allium schoenoprasum L.	(wild chives)
Alnus rugosa (Du Roi) Spreng.	(Alnus incana ssp. rugosa)
Amelanchier interior Nielsen	(Pacific serviceberry)
Anaphalis margaritacea (L.) Benth. & Hook. f.	(western pearlyeverlasting)
Andromeda glaucophylla Link	(Andromeda polifolia var. glaucophylla)
Apocynum androsaemifolium L.	(spreading dogbane)
Apocynum cannabinum L.	(Indianhemp)
Arctostaphylos uva-ursi (L.) Spreng.	(kinnikinnick)
Arethusa bulbosa L.	(dragon's mouth)
Arisaema triphyllum (L.) Schott	(Jack in the pulpit)
Aronia X prunifolia (Marsh.) Rehd. (pro sp.)	(hybrid chokeberry)
Asclepias incarnata L.	(swamp milkweed)
Asclepias syriaca L.	(common milkweed)
Aster macrophyllus L.	(bigleaf aster)
Betula papyrifera Marsh.	(paper birch)
Betula pumila L.	(swamp birch)
Botrychium virginianum (L.) Sw.	(rattlesnake fern)
Brasenia schreberi J.F. Gmel.	(watershield)
Bromus inermis Leyss.	(smooth brome)
Campanula aparinoides Pursh	(marsh bellflower)
Campanula uliginosa Rydb.	(Campanula aparinoides)
Capsella bursa-pastoris (L.) Medik.	(shepherd's purse)
Carduus nutans L.	(nodding plumeless thistle)
Carex bebbii Olney ex Fern.	(Bebb's sedge)
Carex crawfordii Fern.	(Crawford's sedge)
Carex intumescens Rudge	(greater bladder sedge)
Carex lacustris Willd.	(hairy sedge)
Carex lasiocarpa Ehrh.	(woollyfruit sedge)
Carex oligosperma Michx.	(fewseed sedge)
Carex pensylvanica Lam.	(Pennsylvania sedge)
Carex pseudocyperus L.	(cypresslike sedge)
Carex rostrata Stokes	(beaked sedge)
Carex tuckermanii Dewey	(Tuckerman's sedge)
Castilleja coccinea (L.) Spreng.	(scarlet Indian paintbrush)
Centaurea diffusa Lam.	(white knapweed)
Centaurea maculosa auct. non Lam.	(Centaurea biebersteinii)

Cerastium vulgatum L. 1762,	(,)
Ceratophyllum demersum L.	(coon's tail)
Chamaedaphne calyculata (L.) Moench	(leatherleaf)
Chelone glabra L.	(white turtlehead)
Chenopodium capitatum (L.) Ambrosi	(blite goosefoot)
Chrysanthemum leucanthemum L.	(Leucanthemum vulgare)
Circaea alpina L.	(small enchanter's nightshade)
Cirsium arvense (L.) Scop.	(Canadian thistle)
Cirsium muticum Michx.	(swamp thistle)
Cirsium vulgare (Savi) Ten.	(bull thistle)
Claytonia caroliniana Michx.	(Carolina springbeauty)
Clematis virginiana L.	(devil's darning needles)
Comptonia peregrina (L.) Coult.	(sweet fern)
Convolvulus arvensis L.	(field bindweed)
Coptis groenlandica (Oeder) Fern.	(Coptis trifolia ssp. groenlandica)
Corallorrhiza maculata (Raf.) Raf.	(summer coralroot)
Corallorrhiza trifida Chatelain	(yellow coralroot)
Cornus alternifolia L. f.	(alternateleaf dogwood)
Cornus canadensis L.	(bunchberry dogwood)
Cornus stolonifera Michx.	(Cornus sericea ssp. sericea)
Cyperus esculentus L.	(chufa flatsedge)
Cyperus odoratus L.	(fragrant flatsedge)
Cypripedium acaule Ait.	(pink lady's slipper)
Dactylis glomerata L.	(orchardgrass)
Daucus carota L.	(Queen Anne's lace)
Dianthus deltoides L.	(maiden pink)
Dicentra canadensis (Goldie) Walp.	(squirrelcorn)
Dicentra cucullaria (L.) Bernh.	(dutchman's breeches)
Drosera rotundifolia L.	(roundleaf sundew)
Dryopteris intermedia (Muhl. ex Willd.) Gray	(intermediate woodfern)
Dryopteris spinulosa (O.F. Muell.) Watt	(Dryopteris carthusiana)
Dulichium arundinaceum (L.) Britt.	(threeway sedge)
Echinochloa muricata (Beauv.) Fern.	(rough barnyardgrass)
Eleocharis acicularis (L.) Roemer & J.A. Schultes	(needle spikerush)
Eleocharis smallii Britt.	(Small's spikerush)
Epigaea repens L.	(trailing arbutus)
Epilobium angustifolium L.	(fireweed)
Equisetum arvense L.	(field horsetail)
Equisetum hyemale L.	(scouringrush horsetail)
Equisetum palustre L.	(marsh horsetail)
Equisetum scirpoides Michx.	(dwarf scouringrush)
Equisetum sylvaticum L.	(woodland horsetail)
Eriocaulon septangulare Withering	(Eriocaulon aquaticum)
Eriophorum angustifolium Honckeny	(tall cottongrass)
Eriophorum virginicum L.	(tawny cottongrass)
Erythronium americanum Ker-Gawl.	(American troutlily)
Fragaria vesca L.	(woodland strawberry)
Fraxinus nigra Marsh.	(black ash)
Galeopsis tetrahit L.	(brittlestem hempnettle)
Galium tinctorium (L.) Scop.	(stiff marsh bedstraw)
Galium trifidum L.	(threepetal bedstraw)

Galium triflorum Michx.	(fragrant bedstraw)
Gaultheria procumbens L.	(eastern teaberry)
Gaylussacia baccata (Wangenh.) K. Koch	(black huckleberry)
Geranium robertianum L.	(Robert geranium)
Glyceria borealis (Nash) Batchelder	(northern mannagrass)
Glyceria canadensis (Michx.) Trin.	(rattlesnake mannagrass)
Gnaphalium macounii Greene	(Pseudognaphalium macounii)
Gymnocarpium dryopteris (L.) Newman	(western oakfern)
Habenaria clavellata (Michx.) Spreng.	(Platanthera clavellata)
Habenaria lacera (Michx.) R. Br.	(Platanthera lacera var. lacera)
Habenaria psycodes (L.) Spreng.	(Platanthera psycodes)
Helianthemum canadense (L.) Michx.	(longbranch frostweed)
Hepatica americana (DC.) Ker-Gawl.	(Hepatica nobilis var. obtusa)
Heteranthera dubia (Jacq.) MacM.	(grassleaf mudplantain)
Hieracium aurantiacum L.	(orange hawkweed)
Hieracium florentinum All.	(Hieracium piloselloides)
Hypericum ellipticum Hook.	(pale St. Johnswort)
Hypericum majus (Gray) Britt.	(large St. Johnswort)
Hypericum perforatum L.	(common St. Johnswort)
Impatiens capensis Meerb.	(jewelweed)
Iris versicolor L.	(harlequin blueflag)
Isoetes echinospora Durieu	(Isoetes tenella)
Isoetes muricata Durieu	(Isoetes tenella)
Juncus canadensis J. Gay ex Laharpe	(Canadian rush)
Juncus effusus L.	(common rush)
Juncus pelocarpus E. Mey.	(brownfruit rush)
Ledum groenlandicum Oeder	(bog Labradortea)
Lemna minor L.	(common duckweed)
Lilium philadelphicum L.	(wood lily)
Linaria vulgaris P. Mill.	(butter and eggs)
Linnaea borealis L.	(twinflower)
Listera convallarioides (Sw.) Nutt. ex Ell.	(broadlipped twayblade)
Lolium perenne L.	(perennial ryegrass)
Lonicera tatarica L.	(Tatarian honeysuckle)
Ludwigia palustris (L.) Ell.	(marsh seedbox)
Lychnis alba P. Mill.	(Silene latifolia ssp. alba)
Lycopodium annotinum L.	(stiff clubmoss)
Lycopodium clavatum L.	(running clubmoss)
Lycopodium obscurum L.	(rare clubmoss)
Lycopodium tristachyum Pursh	(deeproot clubmoss)
Lycopus uniflorus Michx.	(northern bugleweed)
Lysimachia terrestris (L.) B.S.P.	(earth loosestrife)
Lysimachia thyrsiflora L.	(tufted loosestrife)
Lythrum salicaria L.	(purple loosestrife)
Maianthemum canadense Desf.	(Canada beadruby)
Malva moschata L.	(musk mallow)
Matteuccia struthiopteris (L.) Todaro	(ostrich fern)
Medeola virginiana L.	(Indian cucumberroot)
Medicago lupulina L.	(black medick)
Megalodonta beckii (Torr. ex Spreng.) Greene	(aquatic beggartick)
Melilotus alba Medikus	(white sweetclover)

Mentha arvensis L.	(wild mint)
Mimulus ringens L.	(ringen monkeyflower)
Mitchella repens L.	(partridgeberry)
Monotropa uniflora L.	(Indianpipe)
Myrica gale L.	(sweetgale)
Myriophyllum exalbescens Fern.	(Myriophyllum sibiricum)
Myriophyllum verticillatum L.	(whorlleaf watermilfoil)
Najas flexilis (Willd.) Rostk. & Schmidt	(nodding waternymph)
Nepeta cataria L.	(catnip)
Nuphar variegata Dur.	(Nuphar lutea ssp. variegata)
Nymphaea odorata Ait.	(American white waterlily)
Oenothera biennis L.	(common eveningprimrose)
Oenothera fruticosa L.	(narrowleaf eveningprimrose)
Onoclea sensibilis L.	(sensitive fern)
Oryzopsis asperifolia Michx.	(roughleaf ricegrass)
Osmorhiza claytonii (Michx.) C.B. Clarke	(Clayton's sweetroot)
Osmorhiza longistylis (Torr.) DC.	(longstyle sweetroot)
Osmunda cinnamomea L.	(cinnamon fern)
Osmunda regalis L.	(royal fern)
Oxalis fontana Bunge	(Oxalis stricta)
Peltandra virginica (L.) Schott	(green arrow arum)
Phalaris arundinacea L.	(reed canarygrass)
Phleum pratense L.	(timothy)
Physocarpus opulifolius (L.) Maxim.	(common ninebark)
Plantago lanceolata L.	(narrowleaf plantain)
Plantago major L.	(common plantain)
Poa palustris L.	(fowl bluegrass)
Poa pratensis L.	(Kentucky bluegrass)
Pogonia ophioglossoides (L.) Ker-Gawl.	(snakemouth orchid)
Polygala paucifolia Willd.	(gaywings)
Polygonatum pubescens (Willd.) Pursh	(hairy Solomon's seal)
Polygonum amphibium L.	(water knotweed)
Polygonum cilinode Michx.	(fringed black bindweed)
Polygonum hydropiperoides Michx.	(swamp smartweed)
Polygonum orientale L.	(kiss me over the garden gate)
Populus tremuloides Michx.	(quaking aspen)
Potamogeton alpinus Balbis	(alpine pondweed)
Potamogeton amplifolius Tuckerman	(largeleaf pondweed)
Potamogeton berchtoldii Fieber	(Potamogeton pusillus var. tenuissimus)
Potamogeton confervoides Reichenb.	(Tuckerman's pondweed)
Potamogeton epihydrus Raf.	(ribbonleaf pondweed)
Potamogeton filiformis Pers.	(fineleaf pondweed)
Potamogeton foliosus Raf.	(leafy pondweed)
Potamogeton friesii Rupr.	(Fries' pondweed)
Potamogeton gramineus L.	(variableleaf pondweed)
Potamogeton illinoensis Morong	(Illinois pondweed)
Potamogeton natans L.	(floating pondweed)
Potamogeton obtusifolius Mert. & Koch	(bluntleaf pondweed)
Potamogeton praelongus Wulfen	(whitestem pondweed)
Potamogeton richardsonii (Benn.) Rydb.	(Richardson's pondweed)
Potamogeton robbinsii Oakes	(Robbins' pondweed)

Potamogeton strictifolius Benn.	(narrowleaf pondweed)
Potamogeton zosteriformis Fern.	(flatstem pondweed)
Potentilla anserina L.	(Argentina anserina)
Potentilla argentea L.	(silver cinquefoil)
Potentilla fruticosa auct. non L.	(Pentaphylloides floribunda)
Potentilla norvegica L.	(Norwegian cinquefoil)
Potentilla palustris (L.) Scop.	(Comarum palustre)
Potentilla simplex Michx.	(common cinquefoil)
Potentilla tridentata Ait.	(Sibbaldiopsis tridentata)
Prunella vulgaris L.	(common selfheal)
Prunus virginiana L.	(common chokecherry)
Pteridium aquilinum (L.) Kuhn	(western brackenfern)
Pyrola elliptica Nutt.	(waxflower shinleaf)
Ranunculus acris L.	(tall buttercup)
Rhamnus frangula L.	(Frangula alnus)
Ribes glandulosum Grauer	(skunk currant)
Rorippa islandica (Oeder) Borbas	(northern marsh yellowcress)
Rosa blanda Ait.	(smooth rose)
Rosa multiflora Thunb. ex Murr.	(multiflora rose)
Rosa palustris Marsh.	(swamp rose)
Rubus strigosus Michx.	(Rubus idaeus ssp. strigosus)
Rudbeckia hirta L.	(blackeyed Susan)
Rumex acetosella L.	(common sheep sorrel)
Sagittaria graminea Michx.	(grassy arrowhead)
Sagittaria latifolia Willd.	(broadleaf arrowhead)
Sambucus canadensis L.	(Sambucus nigra ssp. canadensis)
Sambucus racemosa L.	(scarlet elderberry)
Sarracenia purpurea L.	(purple pitcherplant)
Scirpus acutus Muhl. ex Bigelow	(Schoenoplectus acutus var. acutus)
Scirpus americanus Pers.	(Schoenoplectus americanus)
Scirpus cyperinus (L.) Kunth	(woolgrass)
Scutellaria epilobiifolia A. Hamilton	(Scutellaria galericulata)
Sedum purpureum (L.) J.A. Schultes	(Sedum telephium ssp. telephium)
Silene pratensis (Rafn) Godr. & Gren.	(Silene latifolia ssp. alba)
Sisyrinchium montanum Greene	(mountain blueeyed grass)
Smilacina racemosa (L.) Desf.	(Maianthemum racemosum ssp. racemosum)
Smilacina stellata (L.) Desf.	(Maianthemum stellatum)
Smilacina trifolia (L.) Desf.	(Maianthemum trifolium)
Solanum carolinense L.	(Carolina horsenettle)
Solanum dulcamara L.	(climbing nightshade)
Solidago canadensis L.	(Canada goldenrod)
Solidago graminifolia (L.) Salisb.	(Euthamia graminifolia var. graminifolia)
Solidago hispida Muhl. ex Willd.	(hairy goldenrod)
Solidago rugosa P. Mill.	(wrinkleleaf goldenrod)
Sonchus arvensis L.	(field sowthistle)
Sorbus americana Marsh.	(American mountainash)
Sparganium americanum Nutt.	(American burreed)
Sparganium angustifolium Michx.	(narrowleaf burreed)
Sparganium eurycarpum Engelm. ex Gray	(broadfruit burreed)
Sparganium fluctuans (Morong) B.L. Robins.	(floating burreed)
Sparganium minimum (Hartman) Wallr.	(Sparganium nutans)

Spartina pectinata Link	(prairie cordgrass)
Spiraea alba Du Roi	(white meadowsweet)
Spiraea tomentosa L.	(steeplebush)
Spiranthes cernua (L.) L.C. Rich.	(nodding ladiestresses)
Spiranthes lacera (Raf.) Raf.	(northern slender ladiestresses)
Stellaria longifolia Muhl. ex Willd.	(longleaf starwort)
Streptopus amplexifolius (L.) DC.	(claspleaf twistedstalk)
Tanacetum huronense Nutt.	(Tanacetum bipinnatum ssp. huronense)
Thalictrum dasycarpum Fisch. & Ave-Lall.	(purple meadowrue)
Tilia americana L.	(American basswood)
Toxicodendron radicans (L.) Kuntze	(eastern poison ivy)
Tragopogon major Jacq.	(Tragopogon dubius)
Tragopogon pratensis L.	(meadow salsify)
Trifolium agrarium L. p.p.	(Trifolium aureum)
Trifolium repens L.	(white clover)
Trillium cernuum L.	(whippoorwill flower)
Trillium grandiflorum (Michx.) Salisb.	(snow trillium)
Typha angustifolia L.	(narrowleaf cattail)
Typha latifolia L.	(broadleaf cattail)
Typha X glauca Godr. (pro sp.)	(white cattail)
Ulmus americana L.	(American elm)
Utricularia geminiscapa Benj.	(hiddenfruit bladderwort)
Utricularia gibba L.	(humped bladderwort)
Utricularia intermedia Hayne	(flatleaf bladderwort)
Utricularia vulgaris L. p.p.	(Utricularia macrorhiza)
Vaccinium macrocarpon Ait.	(cranberry)
Vaccinium oxycoccos L.	(small cranberry)
Vallisneria americana Michx.	(American eelgrass)
Verbascum thapsus L.	(common mullein)
Verbena hastata L.	(swamp verbena)
Veronica scutellata L.	(skullcap speedwell)
Viburnum cassinoides L.	(Viburnum nudum var. cassinoides)
Viburnum dentatum L.	(southern arrowwood)
Viburnum lentago L.	(nannyberry)
Vicia villosa Roth	(winter vetch)
Viola canadensis L.	(Canadian white violet)
Viola conspersa Reichenb.	(American dog violet)
Viola nephrophylla Greene	(Viola sororia)
Viola pallens (Banks ex DC.) Brainerd	(Viola macloskeyi ssp. pallens)
Zizania aquatica L.	(annual wildrice)