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STANDARD PROCEDURES FOR ESTABLISHING AND EVALUATING AIR POLLUTION BIOMONITORING GARDENS IN NATIONAL PARK UNITS

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BIOMONITORING GARDENS

Introduction

The Air Quality Division of the National Park Service has been actively researching the extent and severity of air pollution injury in park units since 1979. Air quality studies conducted in 1984 revealed that plant species in many park units were injured by air pollution, primarily O_3 and SO_2. The large area that many park units comprise makes it difficult and expensive to frequently evaluate biomonitoring plots scattered throughout the parks. Additionally, only a small percentage of each park flora has been experimentally tested for air pollution sensitivity. Consequently the air pollution sensitivity of most of each park flora is relatively unknown. Bioindicator species of known or suspected pollutant sensitivity should be co-located with ambient air quality monitoring stations so that the pollutant response of the indicator species can be correlated with ambient pollution concentrations. A planting of air pollutant sensitive species in a common area, preferably near an ambient pollutant monitoring station, is termed a biomonitoring garden. Biomonitoring gardens can be established to: (1) relate ambient pollution levels with visible injury thresholds for species of known pollutant sensitivity; (2) serve as a convenient, easily accessible grouping of native park species of known or suspected air pollution sensitivity; (3) provide a habitat where colonizing native species can be ranked for sensitivity to ambient air pollution. This increases our knowledge of the pollutant sensitivity of native species and consequently provides us with additional permanent residents for the biomonitor garden.

Plot Location

Plots should be located as close as possible to any continuous ambient pollutant monitoring station so that both plants and monitors are exposed to the same levels of pollutants. The gardens should be:

- o open to wind movement in the air shed (i.e., they should be in an open area)
- o away from any local sources of polluted air (sewage treatment plants, gasoline pumps, busy roadways, parking lots etc.)
- o strategically placed to discourage vandalism
- o accessible for frequent injury evaluations
- o near a reliable source of water

Plot Specifications and Installation

An area should be cleared of plant growth large enough to allow for the construction of a rectangular plot 26.0 by 13.0 meters (Figure 1). After clearing the area of plant growth, large rocks, debris, etc., a 4-6 foot high chain-link fence should be constructed around the enclosure (chain link is desirable but any fencing will suffice). The fence is needed to keep out large herbivores and deter vandalism. Ideally, the fence should be buried 6-12 inches beneath the soil surface. A finer mesh fence should be added to keep the upper 1-2 feet area above the soil surface free from entry by small rodents, lizards or other herbivores. Gates should be added where desired.

Ideally a vehicle-sized gate, and a person-sized gate, should be installed. After the fence is constructed, the individual plots can be laid out using meter tapes, stakes and string (Figure 1). Corner stakes should be placed in each plot to prevent damage to plants from watering hoses. Rocks, logs, etc., can be placed in a plot if such objects are a common part of the habitat of any species.

Biomonitoring Species

The garden is designed to utilize a variety of bioindicator species, from large shrubs to small annuals. Lichens can be easily added to the garden if air pollution-susceptible species are known to occur in the park. The air pollution susceptibility of some native species in our parks is known. In other cases species may be selected for inclusion in the plot based on air pollution susceptibility of other species in a genus, or based on foliar characteristics (i.e., mesophyllous foliage). In many cases there will be inadequate information on susceptible species and a biomonitoring garden composed of the most air pollution-susceptible vegetation in each park may take several years to evolve (replacing species with more susceptible species as new information becomes available). In all instances selection of species for inclusion in the plots and replacement of resident species with new species as new information becomes available should be coordinated with the Research Branch of the Denver Air Quality Division.

Some of the more important characteristics of a biomonitoring species are:

1. Native plants selected should be present in large numbers in specific habitats.

2. Plants should be reasonably free of serious pest and disease symptoms.

3. Plants should be easy to propagate or transplant.

4. The growing period of the plants should preferably coincide with the annual period of ozone formation for detecting ozone injury.

5. Annuals with an indeterminant growth habit are desirable as garden plants because their continuous formation of new leaves are good for long-term observations.

6. Plants should have an obvious and discernible air pollution response.

7. Plants should have a low injury threshold and a rapid response to air pollutants.

8. Plants should have simple leaves for leaf area injured and symptom evaluations.

9. For gaseous effects monitoring, plants with fewer leaves are preferred for better sampling.

10. For trace element effects monitoring, plants with many leaves are preferred for better sampling.

11. For biomonitoring gardens multiple species are preferred because of the differential sensitivities of various species to air pollutants.

One advantage of having different kinds of species (large perennials, small perennials, annuals, grasses) is that different types of plants are active at different times of the year to varying degrees. Annuals and grasses may respond more quickly to summer rains than perennials (thus becoming "active" biomonitors) whereas perennials may be slower to respond but their period of activity will usually supersede annual and grass activity due to a more extensive and deeper root systems. Having many types of plants is also, of course, more representative of the park flora. Since it is common for many parks to have a winter-spring and summer-fall flora, the garden is designed to reflect the natural cycles of park ecosystems. This is especially true of desert parks and parks with a pronounced summer rainfall pattern. Evergreen species that are air pollution-sensitive are desirable because they are physiologically active, to varying degrees, throughout the year. The garden can be designed to accomodate various plant types in some balanced design (the number of grass species is equal to the number of annual species, etc). However this plan is intended as a format only and substitution of plant types is recommended when appropriate, i.e., there may be only 1 or 2 grass species that are pollutant susceptible and 20-25 annual species of high pollutant-susceptibility. In such a case, annual plots should outnumber grass plots. It is recommended that the general format of large shrub/sapling tree, small shrub/seedling tree, grass, annual and colonizers be followed. Fifteen (15) plants of each species is desired.

The colonizer plots are intended to increase our knowledge of air pollution-sensitive species and hence serve as a source of new species to be added as permanent residents to the garden. Exotic species should be weeded out especially if they become numerous and crowd out native species. Species appearing in the colonizing plots should be evaluated for visible injury and ranked according to their pollution susceptibility. Species that are highly sensitive and display visible symptoms of injury should be transplanted or seeded into one of the appropriate plots for long-term inclusion as a biomonitor. Species that are relatively resistant to air pollution injury should be weeded out of the colonizer plots so that other species of unknown pollutant sensitivity can seed into the plot.

In general, the success of the biomonitor garden depends on neatness. Air pollution injury cannot be clearly evaluated in a plot overgrown with weeds and on plants that are drought stressed and full of senescent (dead) branches and leaves. A good biomonitoring garden therefore possesses the following attributes:

- o plots protected by adequate fencing
- o plots clearly demarcated with distinct buffer zones
- o adequately watered (different species will require different amounts of water)
- o plots free of weeds
- o plants pruned of dead branches and leaves
- o plots protected from watering hose injury (plot corner stakes)
- o consistent and timely evaluation of the resident species

Evaluation of Biomonitoring Species

Once the biomonitoring species have become established, as evidenced by new vegetative growth, the plants can be evaluated on a weekly, biweekly, or monthly schedule depending on the severity of air pollution episodes and the general rapidity of plant growth in the park. Biomonitoring gardens in parks receiving more air pollution should consequently be evaluated more frequently. Plants are evaluated on the basis of visible foliar injury - no growth measurements are required. Percentage of the total leaf surface area with visible air pollution injury should be recorded. Determination of ozone injury symptoms can be confirmed by sending pressed, dry leaves (unmounted) or fresh, green leaves in a sealed plastic bag (air express delivery) to the AQD contacts. Other injury symptoms should be noted (insect, fungal, heat, wind, etc.).

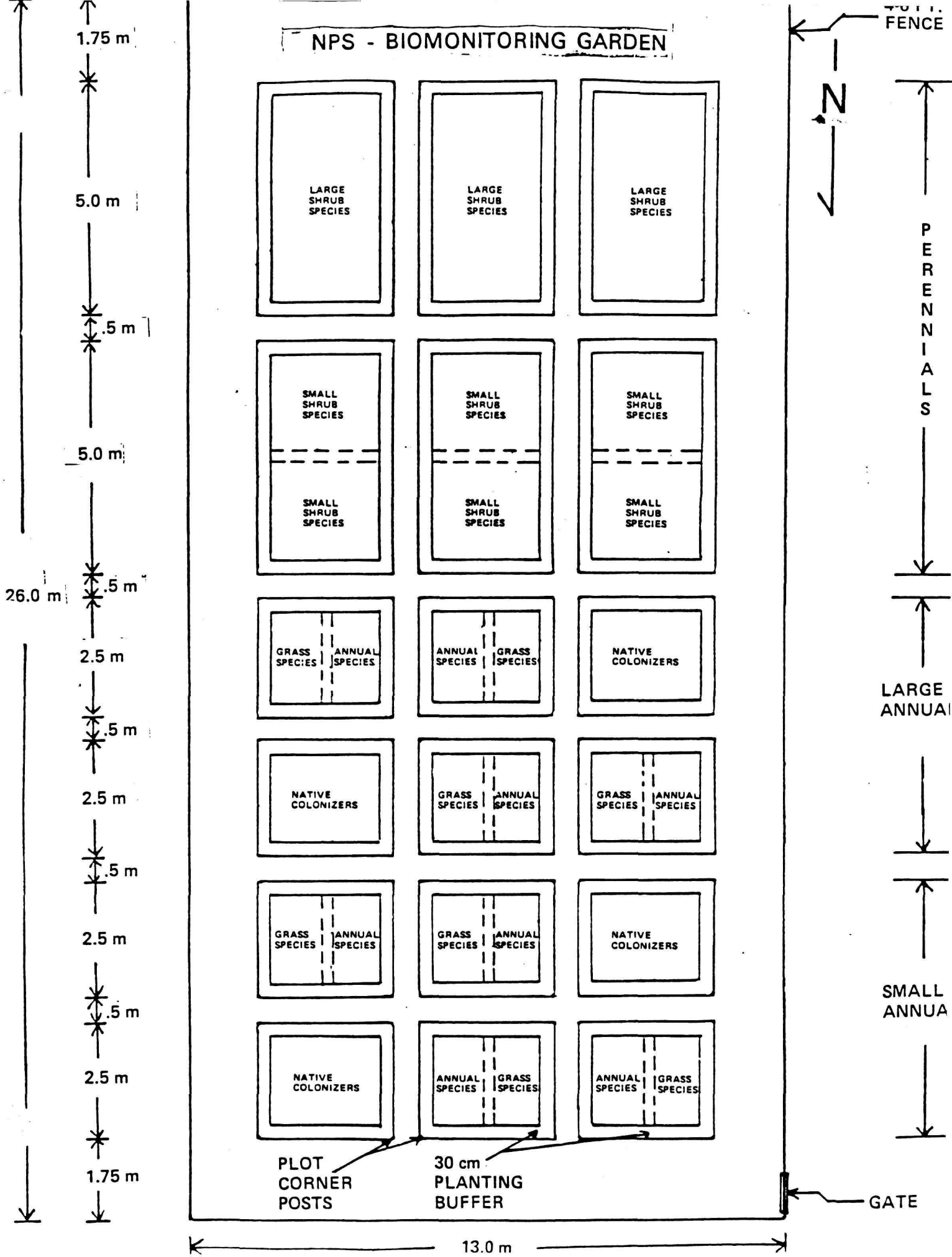
Score each plant for air pollution injury as follows:

1. Light Injury: Less than 25% of the leaves with any amount of pollution injury

2. Moderate Injury: Between 25-50% of the leaves with any amount of pollution injury

3. Severe Injury: More than 50% of the leaves with any amount of pollution injury

To summarize the data, calculate the mean score (sum of the 1, 2, 3 ratings divided by 15) for each species.


NPS - BIOMONITORING GARDEN
FENCE
N
1.75 m
5.0 m
.5 m
5.0 m
.5 m
26.0 m
2.5 m
.5 m
2.5 m
.5 m
2.5 m
.5 m
2.5 m
1.75 m
LARGE SHRUB SPECIES
SMALL SHRUB SPECIES
GRASS SPECIES
ANNUAL SPECIES
NATIVE COLONIZERS
PERENNIALS
LARGE ANNUA
SMALL ANNUA
PLOT CORNER POSTS
30 cm PLANTING BUFFER
GATE
13.0 m