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ENVIRONMENTAL INDICES FOR COMMON MICHIGAN TREES AND SHRUBS

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The floristic composition of a forest is the result of complicated interactions between flora and environment. To simplify this complex process, properties of an ecosystem important for sustaining plants can be grouped into four broad environmental factors: moisture, nutrients, heat, and light (Bakuzis 1959, Carleton 1982, Rowe 1956, Zedaker 1983). These factors influence the growth and survival of plants that are present despite, or because of, past natural or human-caused disturbance (Carleton 1982).

Environmental factors of a location influence how foresters manage a forest growing there (e.g. species to favor or species to plant). Ecologists also routinely report environmental factors or briefly characterize the environment (e.g. moist, cool, rich) as part of a description of forest communities. If environmental factors of a site and the corresponding requirements of forest species could be quantified, scientists and resource managers could make better descriptions and decisions. However, for several reasons, it is difficult to directly measure environmental variables and relate them to a given species' growth and survival (Daubenmire 1976, Rowe 1956, Zedaker 1983).

One possible solution is to use plants themselves as integrators and indicators of environmental factors (Bakuzis 1959, Daubenmire 1976, Rowe 1956, Zedaker 1983). This solution is not new to foresters. Site index (tree height at a standard age) integrates environmental factors to produce an indication of the potential productivity of an area.

Botanists and ecologists have frequently recorded the prevailing environmental conditions of forest species (Barnes and Wagner 1981, Fernald 1950, Gleason 1963, Rosendahl 1955). Based on these estimates and corrected by field measurements, semi-quantitative indices were determined for moisture, nutrients, heat, and light for forest species in Minnesota (Bakuzis 1959). The index for each factor is a discrete number from one to five. A value of one indicates the lowest level and five indicates the highest level for the factor. For example, a species with a moisture index of five occurs primarily in very wet environments. A species with a light index of one occurs primarily in dense shade. By calling these indices synecological coordinates, Bakuzis (1959) emphasized that they indicate environmental requirements when competing with other plants. Mean indices calculated from the individual indices of all species present provide an estimate of environmental factors of the plant community. Until more quantitative methods can be developed, species environmental indices provide a useful first approximation of their environmental requirements. The purpose of this paper is to present indices for Michigan trees and shrubs, compare them with Minnesota indices, and demonstrate how environmental indices might be used.

DETERMINING ENVIRONMENTAL INDICES

Bakuzis (1959) describes the approach for developing environmental indices. Environmental indices are first estimated from the literature and then adjusted based on field observations. Data[1] collected for the 1980 forest survey of Michigan (Raile and Smith 1983) provided the field observations. Each sample consisted of ten points uniformly spaced over an acre. At each point, trees 5.0 inches d.b.h. and larger were selected with a 37.5 factor prism. In addition, at the first three points, shrubs and small trees were sampled on fixed area subplots. Tree saplings (d.b.h. 1.0 to 4.9 inches) were recorded if they occurred within 6.8 feet of the point. Tree seedlings (d.b.h. less than 1.0 inches) and shrubs were recorded if they occurred in the northeast quadrant of the sapling subplot. Because field work occurred in every month from September 1977, to May 1981, and snow made it difficult to locate short plants, most of the the plots I selected were measured in May through October of each year. For each of the 3,943 plots selected, I recorded each species, regardless of size, that occurred.

The first step in developing environmental indices is to estimate indices as discrete numbers for each species encountered. For many species sampled in

[1] *W. Brad Smith provided information on accessing the survey data.*

Michigan, indices had already been determined or estimated in Minnesota (Bakuzis 1959, Bakuzis and Kurmis 1978). I used them as the estimate for Michigan (table 1). Some plants were only identified by genus in Michigan. For these I used indices of a commonly occurring member of the genus. Species without Minnesota indices ("NEW" in table 1) were assigned values on the basis of range maps and ecological information (Barnes and Wagner 1981, Fernald 1950, Gleason 1963, Harlow and Harrar 1969, Rosendahl 1955, Fowells 1965). For example, white ash was assigned a light index of 3 because it was described as intermediate in tolerance (Harlow and Harrar 1969), intermediate-intolerant to intolerant (Fowells 1965), and moderately tolerant (Barnes and Wagner 1981).

The second step is to compute plot indices. The plot light index is the average of the light indices of all species present on the plot. A plot with balsam fir, sugar maple, beech, hemlock, and striped maple has a plot light index of 1.4.

The third step is to calculate average plot indices for each species. Balsam fir was present on 1,395 plots. On these plots, 2.6 was the mean plot light index. Striped maple occurred on 105 plots and the mean plot light index was 2.2.

The fourth step is to form five groups for each environmental variable. Each group consists of species with the same index for an environmental variable. Balsam fir, with a preliminary light index of 2, was grouped with striped maple and other species with a light index of 2. Because balsam fir and striped maple did not have the same index for any other variable, they were not together in another group. For each group, the average of the mean plot indices is then calculated. For example, 2.4 was the average of light group 1 and 2.6 was the average of light group 2.

The final step adjusts Minnesota values to Michigan conditions. Mean plot indices calculated in step three are compared with the appropriate values from step four. Because balsam fir had a mean plot light index closer to 2.6 than 2.4, it was assigned to light group 2 (the same as in Minnesota). Striped maple, however, had a value closer to light group 1 and was assigned a value of 1.

COMPARING MICHIGAN AND MINNESOTA INDICES

Seventy-three tree and shrub species observed on plots in Minnesota also occurred on at least 10 plots in Michigan (table 1). Most of these species (89 percent) had similar sets of indices (at least two indices with no change and the rest of the four indices within one unit of the Minnesota indices). More species in Michigan had moisture indices increase (17) than decrease (7), nutrient indices decrease (12) than increase (5), heat indices increase (7) than decrease (4)., and light indices increase (14) than decrease (10). Because Michigan tends to be warmer (Rauscher 1984) and wetter (Merz 1978) than Minnesota, heat and moisture changes may reflect an adaptation to different climatic conditions.

Nine "NEW" species and eight Minnesota species (Bakuzis and Kurmis 1978) had indices estimated only from the literature (table 1). Only 29 percent of these had similar sets of indices (compared to 89 percent for species observed in Minnesota). This indicates that there is more uncertainty in going from estimated to field adjusted indices than in going from Minnesota to Michigan indices.

Paper birch and poison ivy, occurred frequently in Michigan and Minnesota and each had an index that changed two units. The Michigan light index for paper birch was three compared with five in Minnesota. This could indicate that paper birch has a greater tolerance to shade in Michigan or that more stands with paper birch were succeeding to tolerant species. Poison ivy was not as common in Michigan as in Minnesota. In addition, there was a pronounced shift toward wetter sites in Michigan that produced an increase of two units in the moisture index.

APPLYING ENVIRONMENTAL INDICES

Ecologists routinely label plant communities with the predominant plant species. Jack pine-oak is an example. Statements about moisture, nutrient, and light conditions further describe the community. A dry, open, jack pine-oak community provides a clearer description of the community. Grigal and Ohmann (1975) used Minnesota indices (Bakuzis 1959) to provide a more quantitative description of upland communities in the Boundary Waters Canoe Area. From a list of species occurring in each community, they calculated the average value for each environmental index. The jack pine-oak community had moisture, nutrient, and light indices of 2.0, 1.8, and 3.6 respectively.

Managers can use environmental indices to help evaluate regeneration possibilities. The manager visits stands scheduled for harvesting and records tree and shrub species present as well as other factors pertinent to regenerating the stand. Environmental indices are calculated from the species list and provide additional information for selecting tree species suitable for the site. As an example, two aspen stands, each with a site index of 67, are ready for harvest. On the basis of species present in each stand, one stand has moisture/

Table 1.--*Environmental indices for moisture (M), nutrients (N), heat (H), and light (L). Values of 1 for M, N, H, and L mean dry, poor, cool, and dark, respectively. EST — Estimated by Bakuzis and Kurmis (1978), NEW — New for Michigan. Plots examined in Minnesota--356, plots examined in Michigan--3,943.*

Minnesota					Michigan					Species	
M	N	H	L	No. of plots	M	N	H	L	No. of plots		
4	2	1	2	163	4	2	1	2	1,395	Balsam fir	*Abies balsamea*
3	5	5	3	36	3	5	5	3	16	Boxelder	*Acer negundo*
3	4	4	2	EST	4	4	3	1	105	Striped maple	*Acer pensylvanicum*
2	2	3	3	70	3	2	3	3	2,575	Red maple	*Acer rubrum*
3	5	5	4	5	3	5	5	3	78	Silver maple	*Acer saccharinum*
3	5	3	1	46	3	5	3	1	1,624	Sugar maple	*Acer saccharum*
3	2	2	1	110	4	2	2	1	364	Mountain maple	*Acer spicatum*
2	1	1	4	23	3	2	2	4	17	Green alder	*Alnus crispa*
5	2	1	4	58	5	1	1	4	486	Speckled alder	*Alnus rugosa*
3	2	2	4	14	2	2	3	4	824	Juneberry	*Amelanchier* spp.
5	1	1	5	9	5	1	1	5	11	Bog rosemary	*Andromeda glaucophylla*
1	1	2	5	26	1	1	2	5	19	Bearberry	*Arctostaphylos uva-ursi*
4	5	2	2	13	4	4	2	1	830	Yellow birch	*Betula alleghaniensis*
3	2	2	5	149	3	2	2	3	1,108	Paper birch	*Betula papyrifera*
2	5	5	1	<5	2	5	5	1	131	American hornbeam	*Carpinus caroliniana*
3	5	5	1	9	2	5	5	1	70	Bitternut hickory	*Carya cordiformis*
2	3	5	4	NEW	2	5	5	2	17	Pignut hickory	*Carya glabra*
4	5	5	1	<5	2	5	5	1	62	Shagbark hickory	*Carya ovata*
5	1	1	5	19	5	1	1	5	49	Leatherleaf	*Chamaedaphne calyculata*
1	1	2	5	9	1	1	2	5	363	Sweetfern	*Comptonia peregrina*
3	4	5	1	NEW	2	5	5	2	37	Flowering dogwood	*Cornus florida*
2	3	3	2	31	2	3	3	3	274	Dogwood — dry site	*Cornus rugosa*
4	2	2	3	82	4	2	2	4	326	Dogwood — wet site	*Cornus stolonifera*
2	1	2	3	121	3	2	2	2	421	Hazel	*Corylus* spp.
3	5	4	4	8	2	5	4	4	171	Hawthorn	*Crategus* spp.
1	2	2	3	119	2	2	2	3	86	Bush honeysuckle	*Diervilla lonicera*
3	5	4	1	11	3	5	4	1	21	Leatherwood	*Dirca palustris*
3	4	4	1	EST	3	5	4	1	536	Beech	*Fagus grandifolia*
3	4	5	3	NEW	3	5	4	2	810	White ash	*Fraxinus americana*
4	3	3	2	43	4	3	2	2	662	Black ash	*Fraxinus nigra*
3	5	4	4	62	3	5	4	3	230	Green ash	*Fraxinus pennsylvanica*
2	2	3	4	EST	1	2	3	5	28	Black huckleberry	*Gaylussacia baccata*
3	4	5	2	NEW	2	3	4	4	209	Witch hazel	*Hamamelis virginiana*
4	2	3	4	<5	4	1	2	4	21	Black alder	*Ilex verticillata*
3	5	5	1	<5	3	5	5	1	12	Butternut	*Juglans cinerea*
2	5	5	2	6	2	5	5	2	16	Black walnut	*Juglans nigra*
5	1	1	5	12	5	1	1	5	11	Bog laurel	*Kalmia polifolia*
5	1	1	5	33	5	1	1	5	153	Tamarack	*Larix laricina*
5	1	1	5	54	5	1	1	5	84	Labrador tea	*Ledum groenlandicum*
4	4	4	2	NEW	3	5	5	2	28	Spice bush	*Lindera benzoin*
3	2	2	1	61	3	2	2	2	471	Honeysuckle	*Lonicera* spp.
3	3	4	3	NEW	3	4	4	4	47	Apple	*Malus* spp.
2	5	4	1	39	3	5	4	1	660	Eastern hophornbeam	*Ostrya virginiana*
3	3	4	3	50	3	4	4	3	35	Virginia creeper	*Parthenocissus quinquefolia*
3	3	3	2	<5	4	2	2	3	10	Common ninebark	*Physocarpus opulifolius*
3	2	1	2	85	4	2	1	2	581	White spruce	*Picea glauca*

(Table 1 continued on next page)

(Table 1 continued)

Minnesota					Michigan						Species
M	N	H	L	No. of plots	M	N	H	L	No. of plots		
4	1	1	3	86	5	1	1	4	351	Black spruce	*Picea mariana*
1	1	2	5	55	1	1	2	5	353	Jack pine	*Pinus banksiana*
1	2	2	4	70	1	1	2	5	432	Red pine	*Pinus resinosa*
2	2	2	3	106	2	2	2	4	658	White pine	*Pinus strobus*
2	2	2	4	NEW	1	2	3	5	53	Scotch pine	*Pinus sylvestris*
4	3	2	3	17	4	2	2	3	365	Balsam poplar	*Populus balsamifera*
3	5	5	4	10	3	5	5	4	53	Eastern cottonwood	*Populus deltoides*
1	3	3	3	15	1	2	3	4	894	Bigtooth aspen	*Populus grandidentata*
2	2	2	4	129	3	2	2	4	1,762	Quaking aspen	*Populus tremuloides*
1	2	3	5	23	1	2	3	4	161	Pincherry	*Prunus pensylvanica*
2	3	4	3	<5	2	3	4	3	1,478	Black cherry	*Prunus serotina*
2	3	3	4	96	2	2	3	4	445	Chokecherry	*Prunus virginiana*
2	5	5	2	8	1	3	4	4	520	White oak	*Quercus alba*
4	2	4	3	NEW	3	5	5	3	41	Swamp white oak	*Quercus bicolor*
1	3	4	3	106	2	5	5	2	22	Bur oak	*Quercus macrocarpa*
1	4	3	3	70	1	3	3	4	1,192	Northern red oak	*Quercus rubra*
2	3	4	4	EST	1	3	4	5	144	Black oak	*Quercus velutina*
5	1	2	4	13	4	1	2	4	35	Alder buckthorn	*Rhamnus alnifolia*
1	3	3	4	72	3	3	3	4	124	Poison ivy	*Rhus radicans*
1	2	4	4	10	1	3	4	4	92	Sumac	*Rhus glabra, R. typhina*
4	4	2	2	120	4	3	3	2	374	Gooseberry-currant	*Ribes* spp.
3	2	5	4	EST	3	5	5	2	14	Black locust	*Robinia psuedoacacia*
1	2	3	5	39	2	2	3	5	85	Rose	*Rosa* spp.
3	2	2	3	69	3	2	3	3	1,371	Raspberry-blackberry	*Rubus* spp.
4	5	4	4	EST	4	4	4	4	42	Black willow	*Salix* nigra
4	1	2	5	<5	4	2	2	5	256	Willow shrubs	*Salix* spp.
2	5	4	1	<5	3	5	4	1	126	Elderberry	*Sambucus* spp.
3	4	4	4	NEW	1	4	5	4	140	Sassafras	*Sassafras albidum*
2	4	2	4	EST	3	2	2	4	13	Buffaloberry	*Shepherdia* spp.
2	5	4	2	34	2	5	5	3	18	Greenbriar	*Smilax* spp.
4	2	1	1	42	4	2	1	2	59	Mountain ash	*Sorbus americana*
4	3	3	3	<5	4	2	3	4	35	Spirea	*Spiraea* spp.
4	3	2	1	<5	4	3	2	1	52	Yew	*Taxus canadensis*
4	2	1	1	56	4	2	1	2	930	N. white-cedar	*Thuja occidentalis*
2	5	4	1	93	3	5	4	1	676	American basswood	*Tilia americana*
4	3	1	1	<5	4	3	2	1	588	Hemlock	*Tsuga canadensis*
3	5	4	2	79	3	5	4	1	820	American elm	*Ulmus americana*
3	5	5	3	24	3	5	5	2	95	Slippery elm	*Ulmus rubra*
2	5	5	4	EST	2	5	5	2	38	Rock elm	*Ulmus thomassii*
1	1	1	5	73	1	1	2	5	682	Blueberry — dry site	*Vaccinium angustifolium*
5	1	1	5	16	4	1	1	5	135	Cranberry — wet site	*Vaccinium oxycoccos*
3	3	3	3	16	3	3	3	3	408	Viburnum	*Viburnum* spp.
2	5	5	5	34	3	5	5	4	46	Grape	*Vitis* spp.
2	5	5	1	18	2	5	5	1	43	Prickly ash	*Zanthoxylum americanum*

nutrient indices of 3.8/2.5 and the other has 1.4/2.6. If the management objective is to convert hardwood stands to conifers and if other conditions are favorable, the high moisture index of the first stand should make it a good candidate for conversion to white spruce. The other stand with a low moisture index would more appropriately be converted to red pine.

Environmental indices can also be computed for clearcut stands using shrubs and tree seedlings present. However, because the variability of stand indices is greater when few species are recorded, estimates for clearcut stands may not be very reliable. Adding groundflora species, which are also important indicators (Bakuzis 1959, Coffman and Willis 1977, Daubenmire 1976, Rowe 1956), would reduce the variability. Groundflora species are not included in table 1, but adjusted environmental indices for Minnesota groundflora are available (Bakuzis and Kurmis 1978). Until field-adjusted indices are developed, these can serve as appropriate estimates.

CONCLUSION

For most species there was little difference between the adjusted Michigan and Minnesota moisture, nutrient, heat, and light indices. However, a few species had large differences. Field measurements are necessary for new species because estimated indices often must be adjusted. Environmental indices are a practical tool for estimating the environmental factors of moisture, nutrients, heat, and light. The assumption that, most field-adjusted indices for groundflora like those for trees and shrubs, will change little from Minnesota to Michigan needs to be verified.

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Plants are indicators of environmental factors like moisture, nutrients, heat, and light. Semi-quantitative indices for these four factors were developed for 90 Michigan trees and shrubs. The indices and a tally of species present provide a simple evaluation of the environment of a forest stand and a useful management aid.

KEY WORDS: Moisture, nutrients, heat, light, synecological coordinates.