Seven Years of Forest Succession in Happy Valley, Jefferson County, Indiana

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In April, 1974, a tornado severely damaged the forest in Happy Valley, Jefferson Co., Indiana. Pre-tornado data indicate that the forest was a near-mature, second-growth, sugar maple-Ohio buckeye community. A tree census in 1974 after the tornado revealed the loss of about one-third of the trees, and that sugar maple, white ash and white oak spp. had best survived the perturbation.

Seven years after the storm the portion of the forest most severely damaged in 1974 is dominated by sugar maple, elm spp., Ohio buckeye and redbud, and the sugar maple, white ash, and white oak spp. remain dominant only in the least disturbed portion of the valley. Mean distance between trees in the storm-affected area was 4.4 m pre-tornado (1973), 4.9 m post-tornado (1974) and 3.3 in 1981. The mean number of trees per hectare was 511 pre-tornado, 425 post-tornado and 927 in 1981. These changes in tree population provide evidence of secondary succession in Happy Valley.

Introduction

On the afternoon of April 3, 1974, a major tornado travelled across portions of Jefferson Co. in southeastern Indiana, traversed diagonally across the wooded Happy Valley, and created extensive damage. In the fall of 1974, Bailey & MacMillan (1) completed a census of those standing live trees (i.e., dbh ≥ 5 cm) which remained. Their findings indicated that the storm reduced the tree population in the valley by as much as one-third. With substantial areas of the canopy removed and a portion of the forest floor freed from supporting mature trees, Happy Valley became a natural laboratory for studying secondary succession.

Analysis of pre-tornado data, collected at different times by Dan Webster (pers. comm.) and John Davis (pers. comm.), suggests that the valley forest was a sub-climax sugar maple-Ohio buckeye community. Following the tornado, Bailey and MacMillan (1) described the forest as a sugar maple-white ash-white oak spp. community. The objectives of this study were to (1) catalog the present composition of the forest, (2) describe any quantitative changes that have occurred in the seven years following the storm, and (3) hypothesize about further succession in the valley.

Study Site

The study site is located at 38° 43′ N and 85° 27′ W, on the Hanover College campus, Jefferson County, Indiana. It is an area of rather sharp relief; from a plateau 230 m above sea level the wooded slopes descend 75 m to a narrow valley floor. An intermittent stream flows through the valley and empties into the Ohio River. The portion of the valley under consideration is approximately one-half of its total length (Figure 1).

Three line transects were made across the valley; two transects lay completely within the windthrown area while the third lay substantially south and out of this zone (Figure 1). These three transects were the same as those measured by Bailey and MacMillan (1).

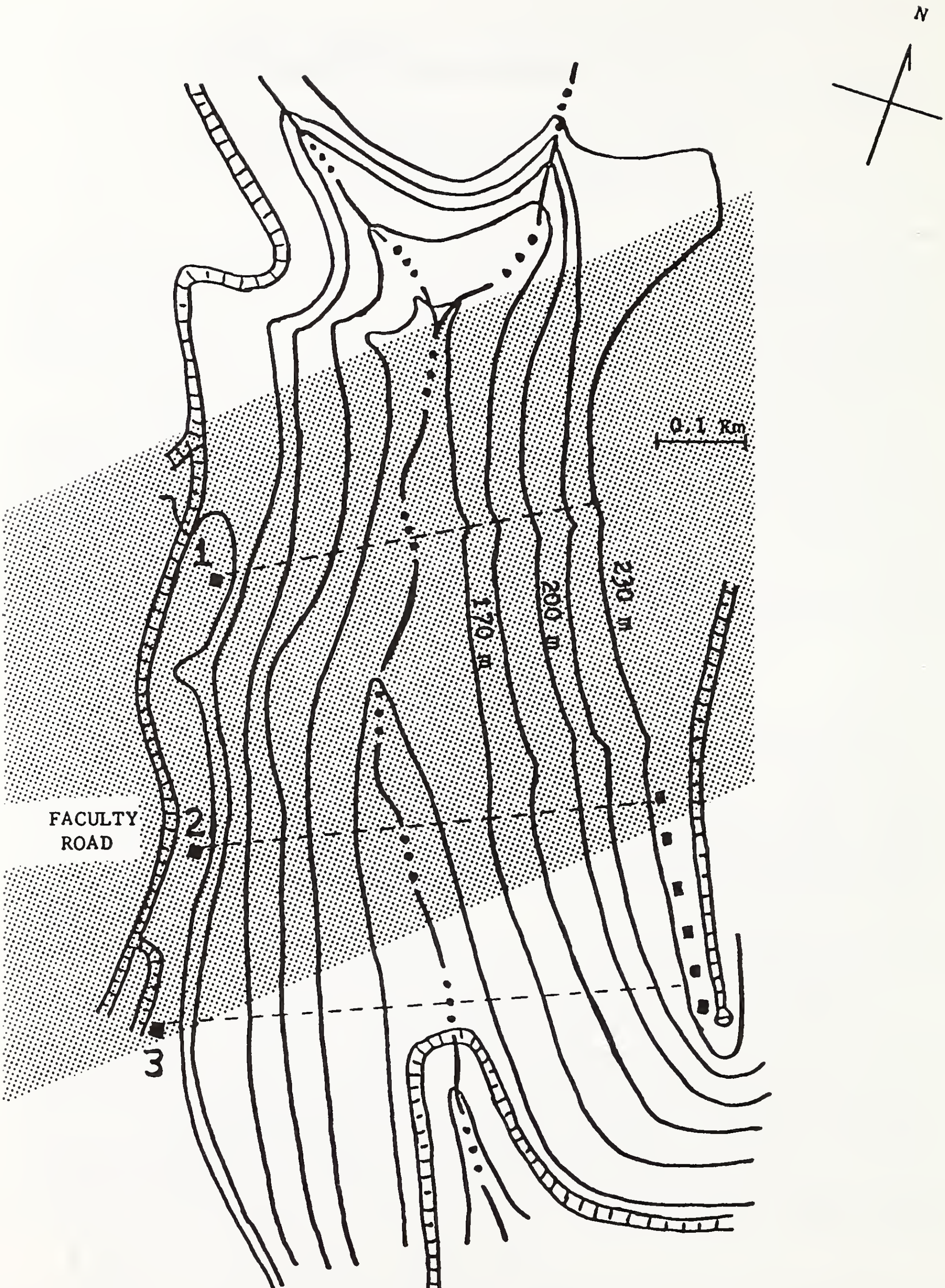

FIGURE 1. *Topographic map of Happy Valley study site. Numbers 1, 2 and 3 designate origins of the three transects. Contour intervals: 15 m. The shaded area represents the path of the tornado.*

Methods

Using the point-quarter method of Cottam and Curtis (3) with intervals of 15 m (50 ft), a random sample of the tree population was obtained. Data recorded in the field included point-to-tree distance, diameter at breast height (dbh), species identification and estimated tree height (i.e., small = < 3 m, medium = 3 to 9 m, tall = > 9 m).

Field data were analyzed using the methods of Bailey and MacMillan (1) and Cox (4). These methods use transect data to estimate mean distance and mean area per tree, and numbers of trees per hectare. To facilitate comparisons, the data were divided into four size classes based on dbh. These classes were: Class 1 = 5 to 10 cm dbh, Class 2 = 11 to 20 cm dbh, Class 3 = 21 to 30 cm dbh, and Class 4 = > 31 cm dbh. Computations were then performed to estimate relative density (RD), relative frequency (RF), relative basal area (RBA), and relative importance value (RIV) of each species within each of the four size classes (1).

Transects 1 and 2 represent that portion of the study site most seriously damaged by the tornado; data from these two transects were combined to yield specific information about this area, and are referred to as "woods" data. In the "woods" summary relative density and relative frequency were computed in the same manner as above, but without reference to the size classification. In addition, the following computations were used in place of RBA and RIV: Relative Dominance (RDom) of a species and Importance value (IV) of a species (1).

Criteria for Inclusion in Sample

One procedural problem in this study was how to judge whether or not an individual tree should be included in the sample. Any major wind-storm, such as the 1974 tornado, will result in a population of maimed survivors which are exceptions to the normal morphological definition of a tree (i.e., having a single vertical axis, commonly exceeding 3 m in height and usually devoid of low branches, but bearing a head or crown of branches and leaves). The standard tree is relatively uncommon in Happy Valley, where uprooted, wind-snapped, leaning and bent boles have survived and adapted to compensate for the structural damage suffered in the storm. New trunks have arisen from living root systems and from what were secondary branches. In addition, many trees exhibit scars as a result of being struck, bent or splintered during the storm.

To gather an unbiased sample, we established the following criteria. A "tree" must: (a) be at least 5 cm dbh, (b) be no more than 45° from vertical at the point of measurement, (c) show evidence of being alive (i.e., fresh buds, flexible twigs), and (d) not be so severely damaged by recent events (i.e., storms and fallen trees) that its survival is in doubt.

Results

General data describing the past and present tree population in Happy Valley are summarized in Table 1. The present mean point-to-tree distance and mean area of each tree are much lower than post-tornado values, and lower than pre-tornado means. The number of trees per hectare has increased by 165% in Transect 1, 75% in Transect 2 and 12% in Transect 3, as compared to the census data taken immediately following the tornado (1).

Tables 2 through 4 contain summaries of Transects 1, 2, and 3, respectively, by size classes. Species are ranked according to relative importance values (RIV). Overall, sugar maple (*Acer saccharum*) is the single most important tree species in the valley; it has the greatest RIV in size classes 1, 2, and 3, except in Transect 1, Class 1, where it is second to slippery elm (*Ulmus rubra*).

In Transect 1, Class 1 (Table 2), sugar maple and American elm (*Ulmus americana*) showed marked decreases in RIV, while slippery elm, American

TABLE 1. *Pre-Tornado (1973), Post-Tornado (1974), and Present (1981) conditions of the Happy Valley Forest, Jefferson County, Indiana.*

	Mean Distance (m)	Mean Area (m2)	Trees Per Hectare
Pre-Tornado Summary (J. Davis, Pers. Comm.)	4.4	19.5	512
Post-Tornado Summary (Bailey & MacMillan, 1977)	4.9(A)	23.6(A)	425(A)
	3.9(B)	15.2(B)	652(B)
1981 Summary	3.3(A)	11.0(A)	927(A)
	3.7(B)	13.7(B)	730(B)

(A) Mean Data From Transects 1 and 2 Through the More Damaged Portion of the Forest.
(B) Data From Transect 3 Through the Less Damaged Portion of The Forest.

TABLE 2. *Transect 1, Class 2. The Following Symbols are used in Tables 2 through 4: RD = Relative Density; RF = Relative Frequency; RBA = Relative Basal Area; RIV = Relative Importance Value; An Asterick (*) Denotes a Species Datum Discussed in the Text; Numbers Enclosed by Parentheses Indicate the Rank Given to the Species in 1974 (1).*

Species	RD	RF	RBA	RIV
*Slipperty Elm (10)	21.7	18.7	24.1	64.5
*Sugar Maple (1)	13.0	14.6	15.8	43.4
*American Basswood (11)	15.9	12.5	14.6	43.0
*Redbud	14.5	12.5	11.5	38.5
Black Maple (3)	8.7	8.3	10.3	27.3
*Wild Black Cherry	5.8	6.2	4.7	16.7
White Ash (5)	4.3	6.2	3.4	13.9
American Elm (2)	4.3	4.2	5.3	13.8
Hop-Hornbeam (4)	2.9	4.2	3.1	10.2
Rock Elm	2.9	4.2	2.2	9.3
Ohio Buckeye (6)	1.4	2.1	1.9	5.4
White Oak Spp. (8)	1.4	2.1	1.2	4.7
Hackberry (9)	1.4	2.1	1.0	4.5
Blue Ash	1.4	2.1	0.8	4.3
Totals	99.6	100.0	99.9	299.5

TABLE 2A. *Transect 1, Class 2.*

Species	RD	RF	RBA	RIV
*Sugar Maple (1)	36.4	36.4	25.2	98.0
*Ohio Buckeye (2)	27.3	27.3	38.3	92.9
*Slippery Elm (4)	18.2	18.2	10.2	46.6
Black Maple (5)	9.1	9.1	13.5	31.7
*White Oak Spp. (3)	9.1	9.1	12.8	31.0
Totals	100.1	100.1	100.0	300.2

TABLE 2B. *Transect 1, Class 3.*

Species	RD	RF	RBA	RIV
*Sugar Maple (2)	36.4	36.4	29.5	102.3
*White Oak Spp. (1)	27.3	27.3	30.5	85.1
Ohio Buckeye	9.1	9.1	11.9	30.1
Blue Ash	9.1	9.1	11.9	30.1
American Elm	9.1	9.1	8.4	26.6
Black Maple	9.1	9.1	7.7	25.9
Totals	100.1	100.1	99.9	300.1

TABLE 2C. *Transect 1, Class 4.*

Species	RD	RF	RBA	RIV
Sycamore (2)	25.0	25.0	43.7	93.7
Red Oak Spp. (3)	25.0	25.0	30.3	80.3
American Elm	25.0	25.0	14.9	64.9
Sugar Maple	25.0	25.0	11.1	61.1
Totals	100.0	100.0	100.0	300.0

TABLE 3. *Transect 2, Class 1.*

Species	RD	RF	RBA	RIV
*Sugar Maple (1)	20.8	20.0	26.1	66.9
*Slippery Elm (2)	19.4	18.3	20.3	58.0
*Ohio Buckeye (4)	8.3	8.3	9.8	26.4
*Redbud (2)	8.3	8.3	7.1	23.7
Rock Elm	6.9	5.0	7.8	19.7
Black Maple	5.6	5.0	4.4	15.0
*American Basswood (6)	4.2	5.0	4.3	13.5
Hackberry (6)	4.2	5.0	3.9	13.1
Hop-Hornbeam	4.2	5.0	3.0	12.2
Royal Paulownia	2.8	3.3	2.2	8.3
Blue Ash	2.8	3.3	1.8	7.9
Box Elder	2.8	3.3	1.7	7.8
Tulip Tree	2.8	3.3	1.5	7.6
Papaw	2.8	1.6	1.7	1.6
Honey Locust	1.4	1.6	1.9	4.9
*White Ash	1.4	1.6	1.9	4.9
Butternut	1.4	1.6	0.7	3.7
Totals	100.1	99.5	100.1	299.7

TABLE 3A. *Transect 2, Class 2.*

Species	RD	RF	RBA	RIV
*Sugar Maple (1)	65.2	53.3	60.0	178.5
*Ohio Buckeye	26.1	33.4	31.5	91.0
American Elm	4.3	6.7	5.3	16.3
Black Maple	4.3	6.7	3.3	14.3
Totals	99.9	100.1	100.1	300.1

TABLE 3B. *Transect 2, Class 3.*

Species	RD	RF	RBA	RIV
*Sugar Maple (1)	53.3	50.0	51.6	154.9
*Hackberry (4)	13.3	14.3	17.4	45.0
*Ohio Buckeye (3)	13.3	14.3	10.1	37.7
Sycamore	6.7	7.1	8.2	22.0
American Elm (6)	6.7	7.1	7.3	21.1
White Oak Spp.	6.7	7.1	5.4	19.2
Totals	100.0	99.9	100.0	299.9

TABLE 3C. *Transect 2, Class 4.*

Species	RD	RF	RBA	RIV
Ohio Buckeye	100.0	100.0	100.0	300.0

TABLE 4. *Transect 3, Class 1.*

Species	RD	RF	RBA	RIV
*Sugar Maple (1)	28.0	26.2	27.4	81.6
*Slippery Elm (5)	14.0	9.5	13.0	36.5
*Papaw	10.5	9.5	9.0	29.0
*Hop-Hornbeam	7.0	9.5	5.6	22.1
*Hackberry (3)	5.3	4.8	7.1	17.2
*Box Elder (8)	7.0	4.8	4.8	16.6
*Ohio Buckeye (6)	5.3	4.8	6.4	16.5
*White Oak Spp. (9)	3.5	4.8	6.2	14.5
*White Ash (10)	3.5	4.8	5.4	13.7
*American Elm (4)	3.5	4.8	2.4	10.7
Wild Black Cherry	1.8	2.4	2.3	6.5
Black Maple	1.8	2.4	2.0	6.2
Red Mulberry	1.8	2.4	2.0	6.2
American Basswood	1.8	2.4	2.0	6.2
Kentucky Coffeetree	1.8	2.4	1.8	6.0
Black Walnut	1.8	2.4	1.5	5.7
Flowering Dogwood	1.8	2.4	0.9	5.1
Totals	100.2	100.3	99.8	300.3

TABLE 4A. *Transect 3, Class 2.*

Species	RD	RF	RBA	RIV
*Sugar Maple (1)	36.4	38.1	28.2	102.7
*Box Elder (5)	13.6	14.3	18.2	46.1
*White Ash (3)	13.6	14.3	13.0	40.9
*White Oak Spp. (2)	13.6	9.5	14.8	37.9
Black Maple (9)	9.1	9.5	8.8	27.4
Ohio Buckeye	4.5	4.8	6.6	15.9
*Slippery Elm (4)	4.5	4.8	5.4	14.7
Wild Black Cherry	4.5	4.8	5.1	14.4
Totals	99.8	100.1	100.1	300.0

TABLE 4B. *Transect 3, Class 3.*

Species	RD	RF	RBA	RIV
*Sugar Maple (1)	32.0	33.3	31.4	96.7
*White Ash (2)	16.0	19.0	18.9	53.9
*White Oak Spp. (3)	20.0	14.3	19.3	53.6
Hackberry (6)	16.0	19.0	13.9	48.9
Box Elder	8.0	4.8	8.0	20.8
American Elm	4.0	4.8	4.8	13.6
Black Maple (9)	4.0	4.8	3.7	12.5
Totals	100.0	100.0	100.0	300.0

TABLE 4C. *Transect 3, Class 4.*

Species	RD	RF	RBA	RIV
*Sycamore (3)	27.8	20.0	41.4	89.2
*American Elm (4)	11.1	13.3	22.0	46.4
Sugar Maple	16.7	20.0	7.9	44.6
*Black Walnut (2)	16.7	13.3	8.4	38.4
*Red Oak Spp.	5.6	6.7	9.1	21.4
Hackberry (7)	5.6	6.7	4.4	16.7
Bitternut Hickory (8)	5.6	6.7	2.4	14.7
White Ash	5.6	6.7	2.3	14.6
Box Elder (6)	5.6	6.7	2.0	14.3
Totals	100.3	100.1	99.9	300.3

basswood (*Tilia americana*), and redbud (*Cercis canadensis*) showed dramatic increases since 1974. In Transect 1, Class 2, sugar maple decreased in RIV, but remained more important than Ohio buckeye (*Aesculus glabra*) which increased. In Transect 1, Class 3 (Table 2b) sugar maple was less important that the various white oak spp. (*Quercus bicolor, Q. michauxii, Q. muehlenbergii, Q. prinus*) in 1974, however, in 1981, white oak spp. showed a considerable decrease.

In 1981 sugar maple, slippery elm, Ohio buckeye and redbud remained the dominant species in Transect 2, Class 1 (Table 3); however sugar maple RIV had decreased since 1974. White ash (*Fraxinus americana*), which had ranked fourth in 1974, was located only once in the 1981 census. In Transect 2, Class 2 (Table 3a), sugar maple remained most important, while Ohio buckeye, not found in 1974, increased in RIV to second in 1981. Sugar maple, Ohio buckeye and hackberry (*Celtis occidentalis*) remained most important in Transect 2, Class 3 (Table 3b).

For the area less damaged by the storm, Transect 3, Class 1 (Table 4), eight of the ten species with highest RIV's in 1981 were the same as in 1974. Four of the five most important species in Transect 3, Class 2 (Table 4a) in 1974 had the highest RIV's again in 1981; however, sugar maple showed a decrease. In Transect 3, Class 3 (Table 4b) sugar maple, white ash and white oak spp. maintained RIV rankings of first, second and third, respectively, but sugar maple exhibited a decrease in RIV. Two large American elms measuring 89 and 56 cm dbh, established this species as second most important in Transect 3, Class 4 (Table 4c). In addition, a single red oak sp., measuring 67.5 cm dbh, placed this species fifth in RIV, while sycamore (*Platanus occidentalis*), sugar maple and black walnut (*Juglans nigra*) ranked first, third and fourth, respectively.

Table 5 contains "woods" data (a summary of all classes on Transects 1 and 2) from the present study, with comparisons to 1974. The 1981 "woods" data showed that while decreasing in RIV, sugar maple remained the most important species. Increased RIV's for Ohio buckeye, slippery elm and redbud placed these species second, third and fourth in importance, respectively. White oak spp. and white ash, which were second and third in 1974, decreased in 1981.

Discussion

The damage done to the forest in Happy Valley by the tornado of 1974 resulted in the loss of ca. 80% of the canopy trees (1). However, some trees remained (even though damaged) which could have provided seeds, understory trees which had been suppressed were released and many damaged canopy trees resprouted to some extent. Thus, there were ample sources for revegetation of the forest, which should have led to a moderate rate of succession (2). Bailey and MacMillan (1) found that the north end (Transect 1) of the study site was hit hardest by the tornado and cited as evidence the increase in mean distance between trees and the mean area per tree, going from south to north (Figure 1 and Table 1) up the valley. In the present study, a complete reversal of this mean distance and mean area gradient was found; mean distance and mean area per tree now decrease from south to north through the study site (Table 1). Areas of the site most disturbed by the storm of 1974 are now the areas of greatest tree density, albeit due primarily to trees in size Class 1. Clearly, a growth of trees passing 5 cm dbh minimum is suggested.

If we use the criteria of change in mean distance and mean area as an indicator of succession, we can now suggest that the area of Transect 3 was also affected by the tornado because we found decreases in mean distance between trees and in mean area per tree and an increase in the number of trees per hectare on this transect. These date substantiate the observation of downed trees in the area of Transect 3 after the tornado (pers. observ.).

Throughout the study site sugar maple continues to be the dominant tree. Stearns (5) suggested that sugar maple can maintain dominance in an area because of its ability to reproduce and grow successfully in shade as well as clearings. This doubtless accounts for its overall abundance in Happy Valley.

Transect 1 was extensively damaged in 1974 and the Class 1 trees (5 to 10 cm dbh) have greatly increased in density in the seven years since the tornado; this reflects both an increase in diversity and an increase in relative importance value (RIV) over those species present in 1974. Slippery elm and American basswood had RIV ranks of 10 and 11, respectively, in 1974, and redbud was not located during the 1974 census, but these three species are now three of the four most important species in this Transect and Class. According to Wharton and Barbour (7), slippery elm grows on dry slopes and moist, well-drained bottomlands. American basswood prefers well-drained soils; redbud is common on cut-over or wind-thrown areas in calcereous soils, while wild black cherry, also relatively important in this study area, becomes established readily in forest openings and is typical of the forest trees which regenerate rapidly when the vegetation is cleared (6). The Happy Valley study site, extensively damaged by the 1974 tornado, has provided prime habitat for all of these sun-tolerant, rapidly-growing trees.

Transect 1, Class 2 trees (11 to 20 cm dbh) were similar in 1974 and 1981. The same top five species were found and the order of imporatance remained much the same; however, rapid-growing Ohio buckeye increased its RIV ca. 100% while sugar maple decreased. In Transect 1, Class 3, sugar maple has replaced white oak spp. as the most important species due to a 37% decrease in RIV of white oak spp. In Transect 1, Class 4, only four trees > 31 cm dbh were found; thus all have large RIV's.

Transect 2 was also extensively damaged in the storm; since then growth of saplings into Class 1 has been rapid and species diversity has increased. White ash is an interesting exception; plentiful in 1974, it was much less important in 1981. A possible explanation is that a reduction in the supply of seeds has occurred in this part of the valley. During the course of study many large white ash boles were found, wind-thrown by the 1974 storm. These trees were once the primary source of white ash seeds along this transect, but in 1981 not one living white ash larger than 10 cm dbh was located along this transect. Combined with the better survival of sugar maple and slippery elm, a decrease in relative importance of white ash might be expected.

Transect 2, Classes 2, 3 and 4 showed little change in the seven years since the initial census by Bailey and MacMillan (1) due to the length of time required for smaller trees to grow into the larger size classes.

Transect 3 was least affected by the tornado, and relative stability is the most obvious characteristic of this transect. In Class 1, eight of the ten most important species were the same in 1974 and 1981. In Class 2, four of the five most important species in 1974 were also most important in 1981. In Class 3, the three most important species were the same in 1974 and 1981. However, in both classes 2 and 3 the RIV of slippery elm declined.

Transect 3, Class 4 contained several species which rated as relatively important because of their large diameter, rather than their abundance. Such a situation is typical of a more mature forest, which the southern end of the valley represents.

Table 5, "woods" data, represents a summary of that portion of the study site most heavily damaged by the tornado in 1974. Differences between the values

TABLE 5. *Summary of Data Collected From Transects 1 and 2, Through the Most Storm-Damaged Part of the Forest, Referred to as "Woods" Data. RDOM = Relative Dominance, Other Symbols the Same as in Tables 2 Through 4.*

Species	RD	RF	RDOM	RIV
*Sugar Maple (1)	27.1	22.3	32.1	81.5
*Ohio Buckeye (6)	10.1	12.8	11.7	34.6
*Slippery Elm (5)	15.0	14.9	4.2	34.1
*Redbud (14)	7.7	7.4	1.5	16.6
Black Maple (10)	6.3	6.1	3.7	16.1
*American Elm (8)	3.4	3.4	7.6	14.4
American Basswood (13)	6.8	6.1	1.5	14.4
Sycamore (4)	1.0	1.3	11.9	14.2
White Oak Spp. (2)	2.9	4.1	7.2	14.2
Hackberry (9)	2.9	4.1	4.4	11.4
Red Oak Spp.	0.5	0.7	7.0	8.2
Rock Elm	3.4	3.4	0.8	7.6
Blue Ash	1.9	2.7	2.2	6.8
Hop-Hornbeam	2.4	3.4	0.5	6.3
White Ash (3)	1.9	2.7	0.4	5.0
Wild Black Cherry	1.9	2.0	0.4	4.3
Royal Paulownia	1.0	1.3	0.2	2.5
Box Elder	1.0	1.3	0.1	2.4
Tulip Tree	1.0	1.3	0.1	2.4
Papaw	1.0	0.7	0.1	1.8
Honey Locust	0.5	0.7	0.2	1.4
Butternut	0.5	0.7	0.1	1.3
Totals	100.2	103.4	97.9	301.5

obtained by Bailey and MacMillan (1) and those obtained in 1981 indicate the trend of secondary succession here. In "woods" data, sugar maple remains most important although its RIV decreased by 33 since 1974. Ohio buckeye rose in RIV from sixth in 1974 to second in 1981; this change was not as dramatic in individual Transect/Class data (Tables 2 to 4). Thus, a definite trend toward restoration of Ohio buckeye as one of the dominant species in Happy Valley, as it was before the tornado (J. Davis, pers. comm.), is suggested. Slippery elm, which increased in importance in wind-thrown regions of the valley, appears to be entering a period of greater abundance. But judging from its disappearance from several of the larger diameter size classes since 1974, the ability of slippery elm to maintain its increased importance over the long-term is questionable. Redbud, which has increased vigorously since 1974 and now ranks fourth in importance, will probably decline in importance as taller species begin to close the canopy in this tornado-damaged portion of the valley.

In terms of secondary forest succession, the interval of time which has elapsed since Happy Valley was disturbed is quite short. Much of the windthrown region is still relatively open, and the forest canopy has not closed; however, the dramatic increase in trees per hectare (Table 1) in Transects 1 and 2, due almost entirely to saplings growing past the 5 cm dbh threshold, provides the first indication of a regenerating forest. Over the same period of time, the southern portion of the valley has changed much less. The area sampled by Transect 3 can still be described as a sugar maple-white ash-white oak spp. community, as it was by Bailey and MacMillan (1). However, the central and northern portions of the valley, sampled by Transects 1 and 2, no longer fit this description; the succession which has occurred since 1974 has resulted in what may best be described as a sugar maple-Ohio buckeye-slippery elm-redbud community. We expect that secondary succession will continue to alter some of the dominant species of this forest community. The data discussed reveals some changes which have occurred in Happy Valley over a relatively short period of time.

Acknowledgments

This study was made possible in part by grants from the Indiana Academy of Science and the Hanover College Research Committee.

Literature Cited

1. BAILEY, JOHN B. and P. C. MACMILLAN, 1977. A tree census of pre and post-tornado forest conditions of Happy Valley, Jefferson County, Indiana. Proc. Ind. Acad. Sci. *86*: 199-202.
2. CONNELL, JOSEPH H. and RALPH O. SLATYER. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. The Amer. Naturalist *111*:1119-1143.
3. COTTAM, GRANT and J. T. CURTIS. 1956. The use of distance measures in phytosociological sampling. Ecology *37*:451-460.
4. COX, GEORGE W. 1976. Laboratory manual for general ecology. Wm. C. Brown Co., Dubuque, IA, pp. 38-42.
5. STEARNS, FOREST W. 1949. Ninety years of change in a northern hardwood forest in Wisconsin. Ecology *30*:350-358.
6. U. S. Department of Agriculture—Forest Service. 1974. Important trees of eastern forests. U.S.D.A, Atlanta, GA.
7. WHARTON, MARY E. and ROGER W. BARBOUR. 1973. Trees and shrubs of Kentucky. Univ. of Kentucky Press, Lexington, KY.