CURRENT FOREST CONDITIONS OF OLDER STANDS OF THE MIXED MESOPHYTIC FOREST REGION ON THE APPALACHIAN PLATEAUS PROVINCE OF EASTERN KENTUCKY

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Abstract.—E. Lucy Braun coined the term “mixed mesophytic forest” in 1916. These forests are structurally complex and occur extensively across the Appalachian Plateaus Province. This region is considered the epicenter of highest development of the eastern deciduous forest. I used U.S. Forest Service, Forest Inventory and Analysis (FIA) data to study current forest conditions of this mixed mesophytic region on the Cumberland and Allegheny Plateaus in eastern Kentucky. A study population made up of 186 FIA plots with a quadratic mean diameter ≥30 cm, was used in the analysis. Across eastern Kentucky, these types of stands averaged 23.9 m^2 ha^{-1} in basal area and 277 stems ha^{-1} in the overstory. The McIntosh Evenness Index was used to quantify the degree of stand dominance, where 1.0 equaled an even representation of all species present on the plot. These 186 plots had an average evenness index of 0.84, indicating an expectedly high degree of species evenness in these structurally complex stands. Based on the dominant species, 10 forest communities were recognized. The most common community was *Quercus prinus*, occurring on 39 plots; second was the *Fagus grandifolia* community (29 plots), third was *Liriodendron tulipifera* (27 plots), and fourth was *Q. alba* (26 plots). Overstory species richness averaged 7.4 species per plot. The study, using a probability-based large-scale sample design, describes forest conditions across the Appalachian Plateaus Province in Kentucky. Defining FIA plots that represent stands that are mature associations of Braun’s mixed mesophytic forest poses problems because these stands are in various stages of recovery and succession from past disturbance.

INTRODUCTION

The Appalachian Plateaus Province of eastern Kentucky is considered to be the center of highest development of the eastern deciduous forest (Braun 1950). This area lies just west of the Appalachian Mountains and here the total environmental complex favors maximum complexity of forest development (Smith 1995). The forests of the mixed mesophytic forest region have been heavily disturbed over the last 100 years. Very few remnants of virgin forest remain (Quarterman and Turner 1972, Martin 1975, Muller 1982, McCarthy and others 1987, Braun 1950).

Braun labeled the complex forests of this region the “mixed mesophytic forest” because of the high degree of structural complexity and multitude of possible species combinations (Braun 1916). Her naming convention considered this as an association, a major climax unit of the formation. Examples of formations are the deciduous forest and the grassland. Examples of associations are mixed mesophytic and oak-hickory. The multitude of different forest communities in the mixed mesophytic forest association were defined as association-segregates (Braun 1950). Examples are beech-maple and white oak-red maple. Although Braun included all of the Cumberland and the unglaciated Allegheny Plateau of eastern Kentucky in the mixed mesophytic forest region she noted that the best development of these forests was in ravines, gorges,

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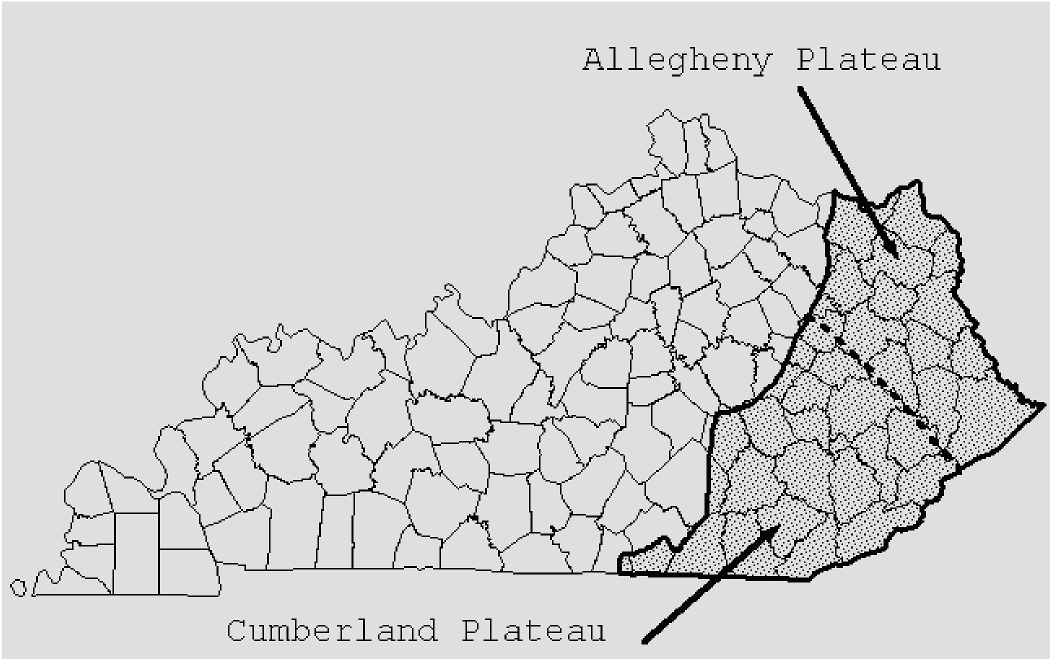

Figure 1.—The Appalachian Plateaus Province in eastern Kentucky with the unglaciated Allegheny Plateau Section in the north and the Cumberland Plateau Section in the south. After Fenneman (1938).

coves, and valleys on the Plateau where topography was mature enough to support the mesic species (Braun 1950). This observation suggests that she thought the mixed mesophytic variants would be more widespread across the plateau once the erosion cycle was complete.

Braun studied the eastern deciduous forests in the first half of the 20th century with many of her study sites located in eastern Kentucky. One of her goals was to study and document the complexity of the virgin remnants before all were lost to logging. The culmination of this work was the highly acclaimed treatise "Deciduous Forests of Eastern North America" (Braun 1950).

With most of the forests in eastern Kentucky in various stages of recovery from past disturbance, it is unknown what the current conditions are and how much older forest remains. Braun used preferential sampling to selectively choose sites for study. My approach was to use a post-stratified selection of plots from a landscape-level systematic sampling scheme and to use stand size as a surrogate for age. The purpose of the study was to describe the current composition and structure of older stands on the Appalachian Plateaus Province of eastern Kentucky.

METHODS

The study area is the Appalachian Plateaus Province of eastern Kentucky (Fig. 1). The study area contains 30,327 km^2 , of which 23,405 km^2 are forested. Included in this physiographic province is the Cumberland Plateau to the south, the unglaciated Allegheny Plateau to the north, and a small portion of the Cumberland Mountains in the southeast. The boundary between the Cumberland Plateau and the unglaciated Allegheny Plateau runs northwest to southeast and is mostly indeterminate (Fig. 1). The difference between the two is based upon the degree of topographic dissection (Fenneman 1938). The study population includes plots on forest land across 36 eastern Kentucky counties.

The data came from the U.S. Forest Service, Forest Inventory and Analysis (FIA) program. The plot placement is systematic, where one sample plot is located inside each hexagon of a hexagonal grid superimposed across the State. Each hexagon encompasses approximately 2,430 ha.

Across the state of Kentucky were 6,116 sample plots (sample units), measured between 1999 and 2005. I used GIS software to select 1,227 sample units in the hexagonal grid that fell within the Appalachian Plateaus Province boundary. Each plot consisted of a cluster of four circular 0.017-ha subplots (7.3 m radius); total sample unit area was 0.068 ha. Subplot 1 was the center of the cluster with the three remaining subplot centers located 36.6 m away at azimuths of 360°(subplot 2), 120°(subplot 3), and 240°(subplot 4). A perimeter circle that encloses the outer boundaries of the subplots' sample unit footprint is approximately 0.60 ha.

All trees with a diameter at breast height ≥12.7 cm (d.b.h.) were measured on each subplot. Nomenclature follows Little (1979). To satisfy elements of the study, I selected only plots that had a quadratic mean diameter (q.m.d.) (Avery and Burkhart 1994) ≥30.0 cm and that had homogeneous forest conditions across all four subplots. The homogeneity issue is important because the FIA program utilizes a sampling scheme that involves mapping and partitioning different forest and nonforest conditions across plots. This procedure could result in unequal-sized plots and unusually high variances, elements which weaken rigorous analysis (Bechtold and Scott 2005, Husch and others 1982). Eliminating plots with mapped situations or plots with a q.m.d. <30.0 cm left 186 plots for the study population.

Forest community identification and nomenclature was based upon the No. 1 ranked species, by basal area, on each plot. Species richness was the number of tree species ≥12.7 cm in d.b.h. on each plot. The McIntosh Index (McIntosh 1967) was used to assess the degree of species evenness on each plot, where 1.00 is perfect evenness and where numbers approaching 0.00 indicate less even representation of all species present, i.e., a large proportion of the dominance in one or two species (Pielou 1977, Causton 1988, Magurran 1988).

RESULTS

There were 3,480 trees ≥12.7 cm d.b.h. measured on the 186 study plots. Fifty-six tree species occurred across these plots (Table 1). Across all plots, basal area averaged 23.9 m^2 ha^{-1}; density averaged 277 trees ha^{-1}. Average species richness was 7.4 species per plot and the species evenness index was 0.84.

Site characteristics were documented by aspect and slope on each plot. Aspect was grouped into five classes (Lloyd and Lemmon 1970): (1) northeast facing; (2) north and east; (3) northwest and southeast; (4) west and south; and (5) southwest. These aspects are ranked from most favorable (northeast facing) for tree growth to least favorable (southwest). The aspect classes are uneven in size because they are grouped on the basis of productivity, so the northeast class does not cover as many degrees of aspect as the second best class, which covers the north and east aspects. Most of the FIA plots fell on the north and east class (60 plots). Sizable numbers were located on the northwest and southeast class, and the west and south class, 44 and 42 plots respectively (Table 2). Basal area, density, and species richness were lowest on the west- and south-facing class.

Table 1.—Basal area and density of individual tree species on the Appalachian Plateaus Province of eastern Kentucky, n = 186

Species	Basal Area	Density
	m^2 ha^{-1}	stems ha^{-1}
Pinus echinata Mill.	0.1	1.3
Pinus rigida Mill.	0.1	0.6
Pinus strobus L.	0.1	1.6
Pinus virginia Mill.	0.1	1.7
Tsuga canadensis (L.) Carr.	0.3	3.7
Acer nigrum Michx.f.	0.0	0.3
Acer pensylvanicum L.	0.0	0.2
Acer rubrum L.	1.5	29.0
Acer saccharum L.	1.1	14.7
Aesculus octandra Marsh.	0.1	1.4
Ailanthus altissima (Mill.) Swingle	0.0	0.1
Amelanchier spp.	0.0	0.4
Betula alleghaniensis Britton	0.0	0.2
Betula lenta L.	0.3	4.9
Betula nigra L.	0.0	0.1
Carpinus caroliniana Wait.	0.0	0.2
Carya cordiformis (Wangenh.) K.Koch	0.2	2.1
Carya glabra (Mill.) Sweet	0.9	12.5
Carya laciniosa (Michx.f.)Loud.	0.1	1.0
Carya ovata (Mill.) K. Koch	0.2	2.5
Carya tomentosa Nutt.	0.5	7.6
Celtis occidentalis L.	0.0	0.2
Cercis canadensis L.	0.0	0.4
Cornus florida L.	0.0	0.9
Diospyros virginninana L.	0.0	0.1
Fagus grandifolia Ehrh.	2.3	17.5
Fraxinus americana L.	0.2	2.7
Fraxinus pennsylvanica Marsh.	0.1	1.7
Gymnocladus dioicus (L.) K.Koch	0.0	0.1
Juglans nigra L.	0.1	0.9
Liquidambar styraciflua L.	0.0	0.3
Liriodendron tulipifera L.	3.1	33.0
Magnolia spp. L.	0.0	0.2
Magnolia acuminata L.	0.2	3.5
Magnolia macrophylla Michx.	0.0	0.2
Magnolia fraseri Walt.	0.0	0.5
Morus rubra L.	0.0	0.4
Nyssa sylvatica Marsh.	0.4	8.0
Ostrya virginiana (Mill.) K.Koch	0.0	0.2
Oxydendrum arboreum (L.) DC.	0.2	8.4
Platanus occidentalis L.	0.1	0.9
Prunus serotina Ehrh.	0.0	0.6

continued

Table 1.—continued.

Quercus alba L.	2.7	26.7
Quercus coccinea Muenchh.	1.1	8.6
Quercus falcata Michx.	0.1	0.7
Quercus muehlenbergii Engelm.	0.0	0.3
Quercus palustris Muenchh.	0.0	0.1
Quercus prinus L.	3.6	34.1
Quercus rubra L.	1.3	10.9
Quercus stellata Wangenh.	0.1	1.0
Quercus velutina Lam.	1.8	12.9
Robinia pseudoacacia L.	0.1	1.7
Sassafras albidum (Nutt.) Nees	0.2	5.6
Tilia americana L.	0.5	6.0
Ulmus americana L.	0.0	0.2
Ulmus rubra Muhl.	0.0	1.0
Unidentified trees	0.0	0.4
All species	23.9	276.7

0.0 = a value of > 0.0 but < 0.1 for the cell.

Table 2.—Stand attributes by aspect class on the Appalachian Plateaus Province of eastern Kentucky

Stand attribute	Aspect					
	NE[1]	N + E[2]	NW + SE[3]	W + S[4]	SW[5]	All
Number of plots	17	60	44	42	23	186
Basal area	25.1	24.1	25.4	21.9	23.5	23.9
Density	293.9	282.8	286.3	256.0	280.0	278.2
McIntosh Evenness	0.76	0.85	0.83	0.85	0.85	0.84
Species richness	7.8	8.0	7.1	6.7	7.3	7.4

[1] NE = 22.5 – 67.4 (degrees azimuth)
[2] N = 337.5 – 22.4; E = 67.5 – 112.4 (degrees azimuth)
[3] NW = 292.5 – 337.4; SE = 112.5 – 157.4 (degrees azimuth)
[4] W = 247.5 – 292.5; S = 157.5 – 202.4 (degrees azimuth)
[5] SW = 202.5 – 247.4 (degrees azimuth)

Most of the study plots (119) were on steep slopes (> 40 percent) (Table 3). Basal area, density, and species richness were highest on plots with slopes of 20-29 percent. Plots with slopes of 0-9 percent had the lowest average basal area and density (Table 3).

Of the 56 tree species tallied on the 186 study plots, *Q. prinus* had the highest basal area, averaging 3.6 m^2 ha^{-1}. (Table 1). Ranked next were *L. tulipifera, Q. alba*, and *F. grandifolia* with 3.1, 2.7, and 2.3 m^2 ha^{-1}, respectively. These four species accounted for 49 percent of total basal area across all plots.

Of the 3,480 trees ≥ 12.7 cm d.b.h. 329 were >50 cm d.b.h. Forty-one were >70 cm and 13 were >80 cm d.b.h. Ranked by d.b.h. the five largest trees were *Q. coccinea* (one tree), *A. saccharum* (one), and *F. grandifolia* (three). Their respective diameters were 122.2, 109.2, 97.0, 93.2, and 89.9 cm.

Table 3.—Stand attributes by slope class on the Appalachian Plateaus Province of eastern Kentucky

Stand attribute	Slope (percent)						
	0 - 9	10 - 19	20 - 29	30 - 39	40 - 49	≥50	All
Number of plots	9	14	17	27	49	70	186
Basal area (m^2 ha^{-1})	16.6	24.9	27.5	24.2	22.3	24.8	23.9
Density (stems ha^{-1})	191.7	274.0	321.9	294.7	259.8	286.2	278.2
McIntosh Evenness	0.84	0.85	0.82	0.82	0.85	0.83	0.84
Richness	7.4	7.2	8.4	7.1	7.1	7.5	7.4

The highest basal area recorded on any plot was 40.9 m^2 ha^{-1}. Overall, there were only 15 plots with a basal area >35.0 m^2 ha^{-1}. Highest ranked of these were four in the *F. grandifolia* community, three in the *Q. prinus* community, and two in the *A. rubrum* communities.

The highest q.m.d. recorded on any plot was 46.5 cm, which occurred in a *F. grandifolia* community on a slope of 24 percent at an aspect azimuth of 321 degrees. Only nine plots in the study population had a q.m.d. >40.0 cm.

The maximum species richness (14 species per plot) was recorded on two plots. Including the latter two plots, only 18 plots had more than 10 species: one plot with 13 species, four plots with 12 species, and 11 plots with 11 species.

Using a monomial naming convention, 10 forest communities were recognized in the study population (Table 4). The *Q. prinus* community was the most prevalent, occurring on 39 plots. The next most common communities were *F. grandifolia* , *L. tulipifera*, and *Q. alba*, occurring on 29, 27, and 26 plots, respectively. The *L. tulipifera* and *Q. velutina* communities had the lowest degree of species evenness, where both equaled 0.77. Lowest species richness was in the *F. grandifolia* and *Q. rubra* communities. Highest species richness was in the *Q. velutina* and *A. rubrum* communities (table 4). The highest average basal area was in the *A. rubrum* community, 27.0 m^2 ha^{-1}. The *C. glabra* and *Q. alba* communities had the lowest average basal areas, 22.1 and 22.7 m^2 ha^{-1}, respectively. While the *F. grandifolia* community had a relatively low basal area (22.8 m^2 ha^{-1}), it had the only plot with a q.m.d. of 46.5 cm, the highest recorded. Additionally, there were four plots in this community with a basal area >35.0 m^2 ha^{-1}.

DISCUSSION

The average basal area of the study plots was at the lower end of the range of older, mature stands in the Appalachian Mountains and Appalachian Plateaus Province. Stand basal area for eastern deciduous mesic old growth forests is typically in the range of 25 to 32 m^2 ha^{-1} (Held and Winstead 1975). Martin (1992) reported averages of 25 m^2 ha^{-1} at Lilley Cornett Woods on the southeast edge of the Cumberland Plateau in Kentucky. McCarthy and others (1987) reported an average of 29.6 m^2 ha^{-1} with a range of 21.7 to 41.0 m^2 ha^{-1} in Hawk Woods on the unglaciated Allegheny Plateau in southeast Ohio. In another study in Lilley Cornett Woods, Muller (1982) documented 27.0 m^2 ha^{-1} in the old-growth portion and 24.0 m^2 ha^{-1} in the secondary forest. It is important to note that many of the studies used in comparison had a minimum threshold for trees of 10 cm d.b.h. versus 12.7 cm d.b.h. in this study. In addition, many studies aggregated several sample plots when describing specific communities whereas this study had one sample plot representing each sample location.

Table 4.—Attributes of 10 forest communities on the 186 study plots on the Appalachian Plateaus Province of eastern Kentucky. The comparison is made between application of a monomial name versus binomial name (see text for details)

Forest community	Plots on which species is dominant	Forest communities resulting from use of a monomial name	Forest communities resulting from use of a binomial name	Percentage of plot basal area accounted for by the top 4 species			Richness	Evenness	Basal area
	No.	No.	No.	Min.	Max.	Avg.			(m^2 ha^{-1})
Chestnut oak	39	1	11	69	100	90	7.1	0.83	25.0
American beech	29	1	12	69	100	89	6.7	0.85	22.8
Yellow-poplar	27	1	14	73	100	89	7.4	0.77	23.4
White oak	26	1	9	62	100	87	7.2	0.84	22.7
Scarlet oak	12	1	9	75	95	81	7.5	0.87	24.1
Black oak	11	1	8	63	98	88	8.9	0.77	23.9
Northern red oak	9	1	6	71	100	89	6.8	0.88	23.7
Sugar maple	7	1	6	79	100	82	7.1	0.84	25.4
Red maple	7	1	6	68	94	85	8.6	0.83	27.0
Pignut hickory	4	1	4	75	96	85	8.0	0.84	22.1
Misc. others	15	--	--	--	--	--	--	--	--
All plots	186	10	85	54	100	88	7.4	0.84	23.9

The average density of the study plots was comparable to that reported in other studies in mature Appalachian and mixed mesophytic forests. Parker (1989) reported a range of 151 to 427 trees ha^{-1} while Martin (1992) documented > 250 trees ha^{-1} at Lilley Cornett Woods. McCarthy and others (1987) reported an average of 371 trees ha^{-1} at Hawk Woods in southeast Ohio with a range of 250 to 445 trees ha^{-1}. Muller (1982) reported an average of 428 trees ha^{-1} in the old-growth forest and 529 trees ha^{-1} in the secondary forest of Lilley Cornett Woods.

Although the species that were most dominant in the study plot population were similar to other studies, the ranking was slightly different. McCarthy and others (1987) ranked *Q. alba* as number one followed by *A. saccharum, L. tulipifera, Q. prinus*, and *Q. rubra*. Muller (1982) ranked *F. grandifolia* first, followed by *Q. prinus, A. saccharum*, and *A. rubrum* in an old-growth forest. In a secondary forest he ranked *F. grandifolia* as first, then *Q. prinus, L. tulipifera*, and *A. rubrum*. Galbraith and Martin (2005) reported six species that comprised 60 percent of total species importance: *F. grandifolia, Tsuga canadensis, A. rubrum, Q. alba, A. saccharum*, and *Q. prinus*. McEwan and Muller (2006) reported the top dominants as *F. grandifolia, Q. prinus, L. tulipifera*, and *Q. alba*. Braun (1942) noted that the mixed mesophytic forest is poorer on the Cumberland Plateau than in the Cumberland Mountains. In comparison, the forests of the plateau are more dominated by *F. grandifolia, Q. alba*, and *Q. prinus*. There is less dominance from *Tilia heterophylla*, *Aesculus octandra, A. saccharum, L. tulipifera*, and *Q. rubra*. Noticeably absent from the 186 study plots was *T. heterophylla*. Additionally, *Aesculus octandra* occurred on only nine plots. These two species are key indicators of Braun's mixed mesophytic forest association (Braun 1950).

Because of the subjectiveness in naming and describing forest communities, no meaningful comparisons could be made with existing studies. Unfortunately, vegetation classification suffers from overstatement, ambiguity, and misinterpretation. Most approaches are based on conceptions of pattern and overall character of the vegetation; therefore, any interpretation will often be based on personal choice, intuition, subjectivity, and experience (Shimwell 1971).

The nomenclature system used to identify specific communities can often cause problems and confusion, especially when trying to identify communities to finer degrees or levels. Baker (1950) lists several good reasons for this confusion: (1) the boundaries between communities may be vague; (2) extensive unlisted or unrecognized mixtures may occur; (3) local or rare types may not be included in the naming classification being used; and (4) it is difficult to determine whether a local area with a particular species is unique or just a phase of a broader mixed type. In addition, the various stages of stand succession are not always considered in naming or typing conventions.

Any, or all, of these issues may lead to inconsistencies between authors, resulting in descriptive work that is not comparable. I chose to use the monomial approach in naming the communities in this study because they are easier to consistently identify on the ground and classify using plot data. When the binomial naming convention is used, the number of unique forest communities balloons quickly to an unmanageable level; in this study, 85 possible communities would have resulted (Table 4). Subjective decisions would have been required on how to lump this large number of groups into meaningful and comprehensible communities. In addition, with sampling regimes that cover larger and larger areas, classification becomes complex because of the different roles the same character or indicator species may play in different habitats (Van der Maarel 2005).

Based on the plot data in the study, some of these stands may qualify as old-growth or late successional-mature forests. This conclusion holds especially true for the plots with trees >75 cm d.b.h. and basal areas >35 m^2 ha^{-1}. Martin (1975) suggests at least seven trees ha^{-1} >75.0 cm d.b.h. to indicate old-growth status. Because of the ruggedness of topography on the Cumberland and Allegheny Plateau (slopes >40 percent), some of these sites probably escaped logging. However, many did not and the impacted stands are still recovering from logging disturbance as well as the loss of *Castanea dentata*. This condition, plus burning and continued high grading, left some stands with poorly interpretable species patterns (Muller 1982). Natural disturbance is also an important factor in these systems, especially on steep slopes. Windthrow and slope slides are a significant component in modifying stand age and composition (Herman and See 1973). Unfortunately, it is not possible to interpret complexities of stand disturbance into the far past (>20 years) with FIA data.

This study used data from a very large landscape-scale sampling scheme. The sample provides a good account of current forest conditions over a large geographic area, which is in contrast to most studies where unique areas are selected for concentrated study. It is important to be mindful of this difference when comparing study results. The FIA data do provide valuable information on extent of forest conditions across a very wide area. Future studies with this dataset across the Appalachian Plateaus Province will develop more detail regarding the actual areas covered by different forest conditions along with refined forest community analysis. In addition, as future surveys are completed, plots can be tracked over time, providing a valuable record of trends in forest attribute dynamics.

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