A NUMERICAL ANALYSIS OF THE MORPHOLOGICAL VARIATION IN THE GENUS *ALETRIS* L. IN NORTH AMERICA

By

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PREFACE

This study was first proposed in 1975 and begun in 1977. Specimens on loan began arriving in early 1978, and categorization of the loan into physiographic provinces and species present within each province was the first step. Sampling and subsequent measuring required approximately one-half year, with computer analysis occupying another few months. It was not until all of the results of the analysis accumulated that I began to feel comfortable with the species as circumscribed. In a genus such as *Aletris* where the species seem to flow into one another, one begins to question the reliability of ranking taxa. Identification of an individual plant is sometimes possible with one or two characters, but with *Aletris*, as with many other genera, using as many characters as possible is the best rule. Because the species are so closely aligned, proper identification may continue to be a problem, since every plant cannot be subjected to the elaborate techniques of analysis employed in this study. I hope that the distribution maps will help narrow the choice of species present in any area, and I hope that the phenograms and PCA three-dimensional models will aid by showing affinities within the genus.

I would like to express my appreciation to my major adviser, Dr. Ronald J. Tyrl, not only for his assistance during the course of the study, but also for his encouragement and friendship during the past six years. Appreciation is also expressed to the other committee members, Dr. William Warde and Dr. Wilfred McMurphy. My thanks goes especially to Dr. Warde for his help in setting up computer programs at O.S.U. and for his help in analyzing the univariate results. A special note of thanks is given to Dr. Gary Schnell of the University of Oklahoma for his assistance in obtaining computer time there. Without his aid I would not have been able to experience the fine numerical techniques available with the Numerical Taxonomy System (NT-SYS).

Special thanks goes to Joe Bruner and Susan Barber for their friendship, encouragement, and support. Susan helped acquaint me with NT-SYS, and Joe constantly prodded me to finish.

Finally I want to express gratitude to my family for their support, assistance, and aid in every form. Thanks goes to my mother and father, Winnie and Dean Weigant, to my husband, John, and to my son, Brian. Without their understanding and sacrifices none of this would have been possible.

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CHAPTER I

INTRODUCTION

Aletris (Figure 1) is a lilaceous genus that has a disjunct distribution in eastern North America and eastern Asia. Of the 25-37 species that occur worldwide, five are native to North America. *Aletris farinosa*, a species with a white cylindric perianth, is the most wide-ranging of the five. It occurs from the southern Coastal Plain above Florida, along the east coast as far north as Rhode Island, west through the Appalachian Highlands, Interior Highlands, and Interior Plains, to Wisconsin and the southern tip of Ontario. *Aletris aurea*, with a yellow campanulate perianth, occurs primarily in the southern portion of the United States, ranging west into Texas and Oklahoma, and north in the Coastal Plain as far as New Jersey. *Aletris lutea*, which has a yellow cylindric perianth, is more restricted in its distribution, occurring in Florida and the southern portions of Georgia, Alabama, Mississippi, and Louisiana. *Aletris obovata* has a white obovate perianth and occupies a small area of northern Florida and the lower half of Georgia. *Aletris bracteata*, which is very similar to *A. farinosa* morphologically, is a disjunct, occurring in the everglades of southern Dade County, Florida, the Florida Keys, and the islands of Andros and Abaco in the Bahamas.

In addition to these species, a white color form of *A. lutea*

A—C Aletris lanuginosa Bur. et Franch. *A* Blühende Pflanze; *B* Blüte; *C* Tep. und Stam. — *D—E Aletris nepalensis* Hook. f.; *D* Blühende Pflanze; *E* Blüte. (Original.)

Source: Engler and Prantl (1930, p. 378)

Figure 1. Asian Species of Aletris

has been described, and natural hybrids of A. lutea and A. obovata occur in areas of sympatry for those species. Hybridization between A. farinosa and A. aurea has been postulated.

The exact distribution for each species of Aletris has not been well documented. This, combined with an unclear understanding of the morphological variation present in the genus and the presence of interspecific hybrids and introgressants has caused considerable taxonomic confusion and subsequent misidentification of specimens. Therefore, this study was undertaken to comprehensively describe and analyze the morphological variation of the five North American species and their putative natural hybrids and forms. It was hoped that the distribution of each species could be accurately determined and the effectiveness of the diagnostic characters currently being utilized be evaluated. Further, it was hoped that through correlation of the results of this study with the results of previous investigations, relationships within the genus could be elucidated.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

Aletris has been placed in the Haemodoraceae by Bentham and Hooker (1883), the Amaryllidaceae by Lawrence (1931), and the Liliaceae by Engler and Prantl (1930)--its currently accepted position. Classification into species has been based primarily on perianth color and shape, density of flowers along the raceme, and capsule attributes (Small, 1933; Correll and Johnston, 1970; Fernald, 1950; Northrop, 1902). These characters, as well as the other characters given in Table I, vary considerable with the age of the plant, environmental conditions, and collection locality. Alteration of perianth color and shape due to pressing, drying, and aging make these two characters reliable only in certain cases for herbarium specimens.

Nomenclature and Species Descriptions

Linnaeus was the first to use the name Aletris in Nov. Pl. Gen. in 1751 (Engler and Prantl, 1930). His description in Genera Plantarum (1754) was based on A. farinosa (Figure 2) and refers to the acaulescent nature of the plant. The perianth is composed of six fused tepals, is ovate-oblong-shaped, and is rugose. Lobes are lanceolate, acuminate, open, erect, and persistent. Stamens are

TABLE I

DESCRIPTIVE CHARACTERS USED
IN DIFFERENTIATING
SPECIES OF <u>ALETRIS</u>

Character	*Aletris obovata*	*Aletris* x *Tottenii*	*Aletris lutea*	*Aletris bracteata*	*Aletris farinosa*	*Aletris aurea*
Scape	5-7 dm	*	3-9 dm	3-8 dm	3-10 dm	3-8 dm
Leaf Length	6-8 cm	5-10 cm	4-12 cm	6-11 cm	5-30 cm	3-8 cm
Leaf Width	1-2 cm	.6-1.2 cm	*	6-10 cm	*	*
Leaf Shape	Elliptic, Obovate	*	Linear-lanceol.	Linear-lanceol.	Elliptic, Oblong	Elliptic, Oblong
Hyaline Margin	+	+	+	*	-	*
Raceme	20-40 cm	51-77 cm	4-20 cm	*	11-30 cm	10-40 cm
Number Flowers	*	Many	*	Many	Many	Few
Perianth Color	White	Cream to orange	Yellow	White	White	Yellow
Perianth Shape	Obovoid Obovate	*	Cylin-dric	Tubular-oblong	Cylin-dric	Campan-ulate
Flower Length	5-7 mm	*	8-9 mm	6-8 mm	7-9 mm	5-7 mm
Lobe Shape	Ovate, incurved	Not recurved	Triang., recurved	Lanceo-late	Ovate, recurved	Trian., erect
Capsule Shape	Ovate-conic	*	Conic-ovoid	Conic-oval	Ovoid	Ovoid
Beak Length	*	½ length caps. body	½ length cap. body	"stout"	as long as body	"short"
Style	Short	*	Elongate	Flat	*	Short
Pedicel Length	2 mm	*	*	0.1 mm	*	*
Epigyny	*	*	*	One-half	"Semi-"	*

* indicates no reference to character found in literature.

(Fernald, 1950; Correll and Johnston, 1970; Small, 1933; Northrop, 1902) six, subulate, as long as the corolla and inserted at the base of the corolla lobes. Anthers are oblong and erect. The pistil has an ovate ovary, subulate style as long as the stamens, and a three-lobed stigma. The many-seeded capsule is ovate, three-lobed, acuminate, and three-locular. Linnaeus also observed that the stamens are opposite the corolla segments, and the corolla is rugose and mealy. Small (1933) and Fernald (1950) report that the leaves are dark green and linear lanceolate to ovate. Racemes are densely flowered with thite cylindric-shaped flowers, and the anthers are exerted. The perianth adhers to the lower half of the capsule body, and beaks are slender and about as long as the capsule body.

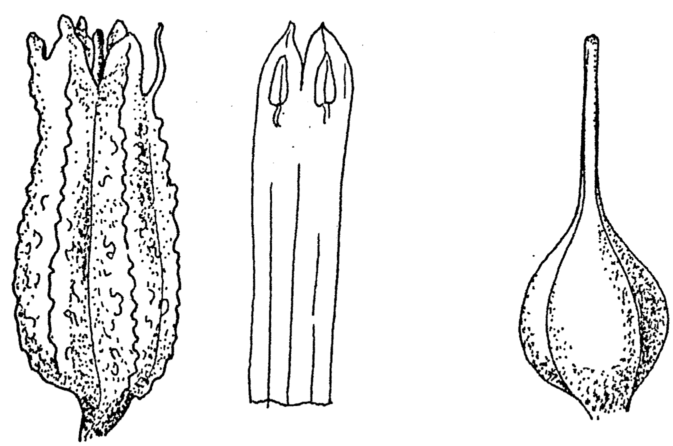


Figure 2. Aletris farinosa L. (Redrawn from N.Y. Botanical Garden Specimen)

It was not until 1788 that another North American species was reported--Aletris aurea (Figure 3). Thomas Walter, British-American botanist and Charleston planter, described A. aurea in Flora Caroliniana. Walter's description refers to A. aurea as differing from A. farinosa in the flowering time and light yellow perianth color. Small (1933) and Fernald (1950) describe A. aurea as differing from A. farinosa in its smaller yellow-green leaves, less dense inflorescence, and campanulate to obovate perianth. In addition, the lobes are erect, and the style or capsule beak is very short.

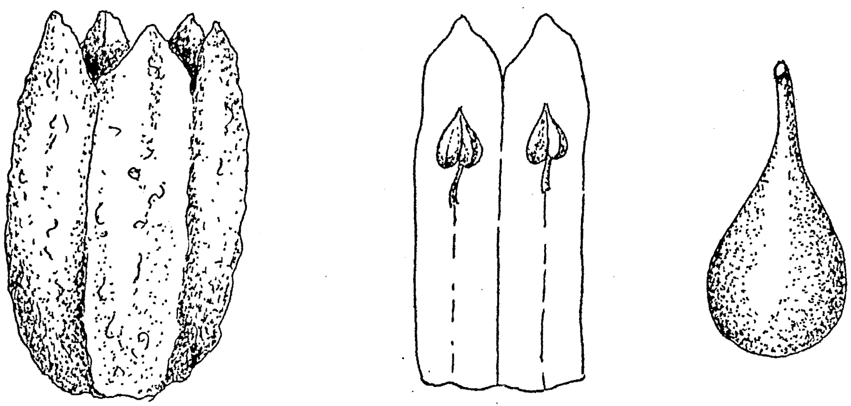


Figure 3. Aletris aurea Walter (Redrawn from N.Y. Botanical Garden Specimen)

In 1899 John Kunkel Small, an American botanist and head curator of the New York Botanical Garden, described another yellow-flowered Aletris for the United States. Aletris lutea (Figure 4) is similar in perianth color to A. aurea but is closer to A. farinosa in morphology and habit. Aletris lutea differs from A. farinosa, according to Small, in having shorter, narrower, yellow-green leaves, yellow flowers, a capsule body gradually, rather than abruptly, narrowed into beaks which are one-half, rather than equal to, the length of the capsule body.

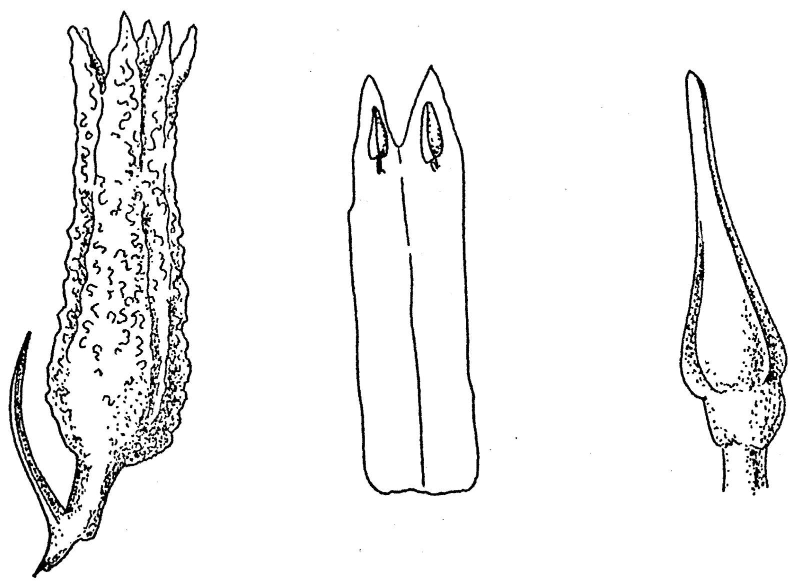


Figure 4. Aletris lutea Small (Redrawn from N.Y. Botanical Garden Specimen)

Alice R. Northrop described A. bracteata (Figure 5) in her 1902 article--Flora of New Providence and Andros (Bahama Islands). The species is similar to A. farinosa morphologically, differing slightly in the longer and narrower grayish-green leaves which have a more rigid apex and in the broader flattened style. The distribution--Andros, Abaco, and southern Florida--is disjunct with that of A. farinosa.

On July 25, 1903, G.V. Nash published a description of A. obovata (Figure 6), a new species which he and J.K. Small had discovered in Florida. Small had mentioned his and Nash's joint discovery in his preface to the Flora of the Southeastern United States, dated July 22, 1903. Because of the questionable publication date, Ward (1978) suggested that the authority for this species be amended to A. obovata Nash ex Small. The most complete description of A. obovata was by Nash, which referred to the distinctive obovate shape of the white perianth with incurved tips and leaves with a narrow hyaline margin.

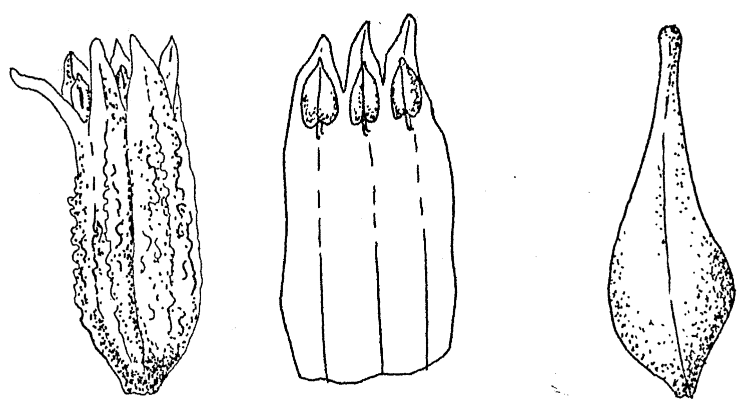


Figure 5. Aletris bracteata Northrop (Redrawn from N.Y. Botanical Garden Specimen)

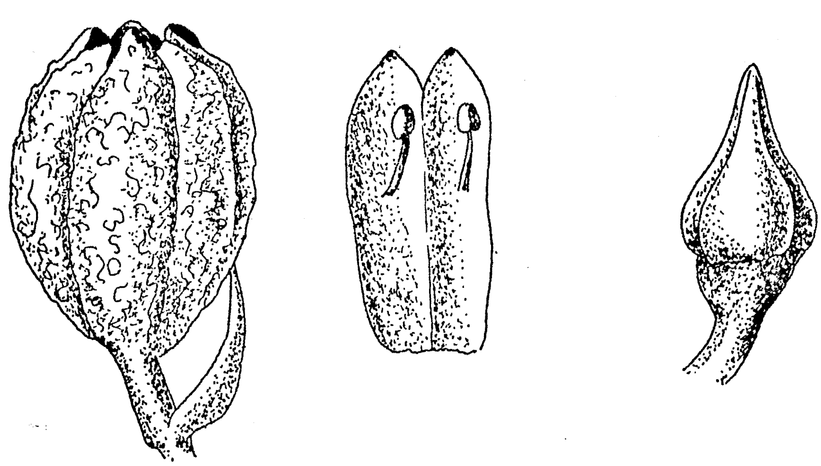


Figure 6. Aletris obovata Nash (Redrawn from N.Y. Botanical Garden Specimen)

In 1961, E.T. Browne, Jr. described a white-flowered form of *A. lutea* (*A. lutea* Small forma *alba* Browne) on the basis of observations made in Chatham County, Georgia. A population of equal numbers of white and yellow-flowered *Aletris* was discovered. Rather than identifying the white flowered plants as *A. farinosa*, they were designated as white forms of *A. lutea* because of their apparent lack of semi-epigynous flowers, a supposed diagnostic character for *A. farinosa*, and by the presence of a narrow hyaline margin on the leaves, considered typical of *A. lutea* by Browne.

Also in 1961, Browne designated the hybrid of *A. lutea* and *A. obovata* as *Aletris* x *Tottenii* Browne. Mixed populations were observed in the Georgia counties of Berrien, Colquitt, and Cook. Flowers of the hybrids were intermediate in color and shape but possessed the erect perianth tips of *A. obovata*. The binomial *Aletris* x *Tottenii* has not been encountered in the literature following its publication; the more descriptive *A. lutea* x *obovata* is the preferred designation.

It can be seen from the descriptions and figures that differentiation between species can be accomplished with certainty only by using a set of characters rather than giving weight to any one in particular. This is especially important when dealing with sympatric species and possible hybrids and in identifying herbarium specimens that have lost the reliable color character. Characters in Table I reiterate the morphological similarity of the species.

Hybridization in *Aletris*

Aletris bracteata is disjunct from the other four species of

Aletris, with a possible exception in Dade County, Florida. Its chromosome number has not been determined, nor have there been any reports in the literature of putative hybridizations involving this species. This taxon warrants further study.

Several factors favor hybridization among the remaining four species. Although their habitat requirements are slightly different, there are regions of geographical sympatry; mixed populations of parent species and intermediates have been reported in these areas. In addition, flowering times partially overlap, and the pollinators are the same (Sullivan, 1973). The haploid chromosome number for these four species is 13 (Browne, 1958; Browne, 1961; Sullivan, 1973).

Aletris obovata Nash and *A. lutea* Small were first reported to be hybridizing on the Coastal Plain of Georgia by Harper (1905, 1906). He observed only a few putative hybrids in one location and merely described them as being "intermediate in appearance." Browne (1961) described the hybridization of *A. obovata* and *A. lutea* occurring in several counties in southern Georgia and, as noted earlier, named the putative hybrid *Aletris* x *Tottenii* with n=13. Sullivan (1973) made an extensive biosystematic study of these two taxa and their hybrids in the southeastern states of Florida, Georgia, Alabama and Mississippi. She observed a one-week overlap in bloom time of the two taxa in areas of geographic sympatry. Disturbed habitats in these areas of sympatry were occupied by both parental species and hybrid swarms.

In addition, Sullivan observed a zonation of plants within these mixed populations, with *A. lutea* and *lutea*-like introgressants occupying the moister areas and *A. obovata* and *obovata*-like plants being found in the drier sandy areas. Fertility was high for both parents and hybrids, with mean pollen stainability ranging from 35-99%. Seed germination averaged 75% or less, but Sullivan postulated that the potential seed production capacity of 1000 seeds per flower, times 25-150 flowers per raceme, offsets this loss of seeds. Hybrids studied were intermediate in morphology, except that they were larger and more robust than either parent.

Hybridization between *A. farinosa* and *A. aurea* is not well documented. The two taxa were reported by Fernald (1937) to comingle at one location on the inner Coastal Plain of Virginia. Two plants of intermediate morphology were present and believed to be of hybrid origin. Fernald (1950) suggested that *A. lutea* might be a hybrid of *A. farinosa* and *A. aurea*, but there have been no subsequent investigations into this putative hybridization.

Anatomical Research

Completing a doctoral research program, Browne (1956) investigated the anatomy of *A. aurea*, *A. obovata*, and *A. farinosa*, with some references to *A. lutea* and *A. bracteata*. One of his principal concerns was the taxonomic position of the genus. He suggested that *Aletris* is an advanced member of the tribe Narthecieae of the Liliaceae, closely aligned with Narthecium and Metanarthecium. Although other genera in this tribe are polypetalous with no epipetaly, and *Aletris* is gamopetalous and epipetalous, Browne maintains that such an inconsistency is also present in other natural tribes of the Liliaceae. Pertinent results of his research and references made by him to the study of Holden and Krause (1936) are summarized in Table II.

TABLE II

ANATOMICAL FEATURES OF ALETRIS

	A. aurea	*A. obovata*	*A. farinosa*	*A. lutea*
Leaf Nerve Number	5-6(7)	7(8-9)	7-9	-
Palisade of Mesophyll	P	A	I	-
Stele	12-arch	10-arch	12-15-arch	-
Number Metaxylem Vessels	3	6	7-9	-
Perianth Adnation	P	P	A	-
Anthers	Inserted	Inserted	Exerted	Inserted
Anther Attachment	I	I	A	I
Epipetaly	P	P	A	I

P=Primitive A=Advanced I=Intermediate

Pharmacology

Browne (1956) also documented the pharmacological history of the genus. The rhizome of Aletris was, at one time, of some economic importance as a source of a number of folk cures, cathartics, and an estrogenic substance used as a uterine sedative and antispasmodic. It was also considered a source of diosgenin--a precursor for cortisone; however, Dioscorea is a more plentiful source.

CHAPTER III

METHODS AND PROCEDURES

Introduction

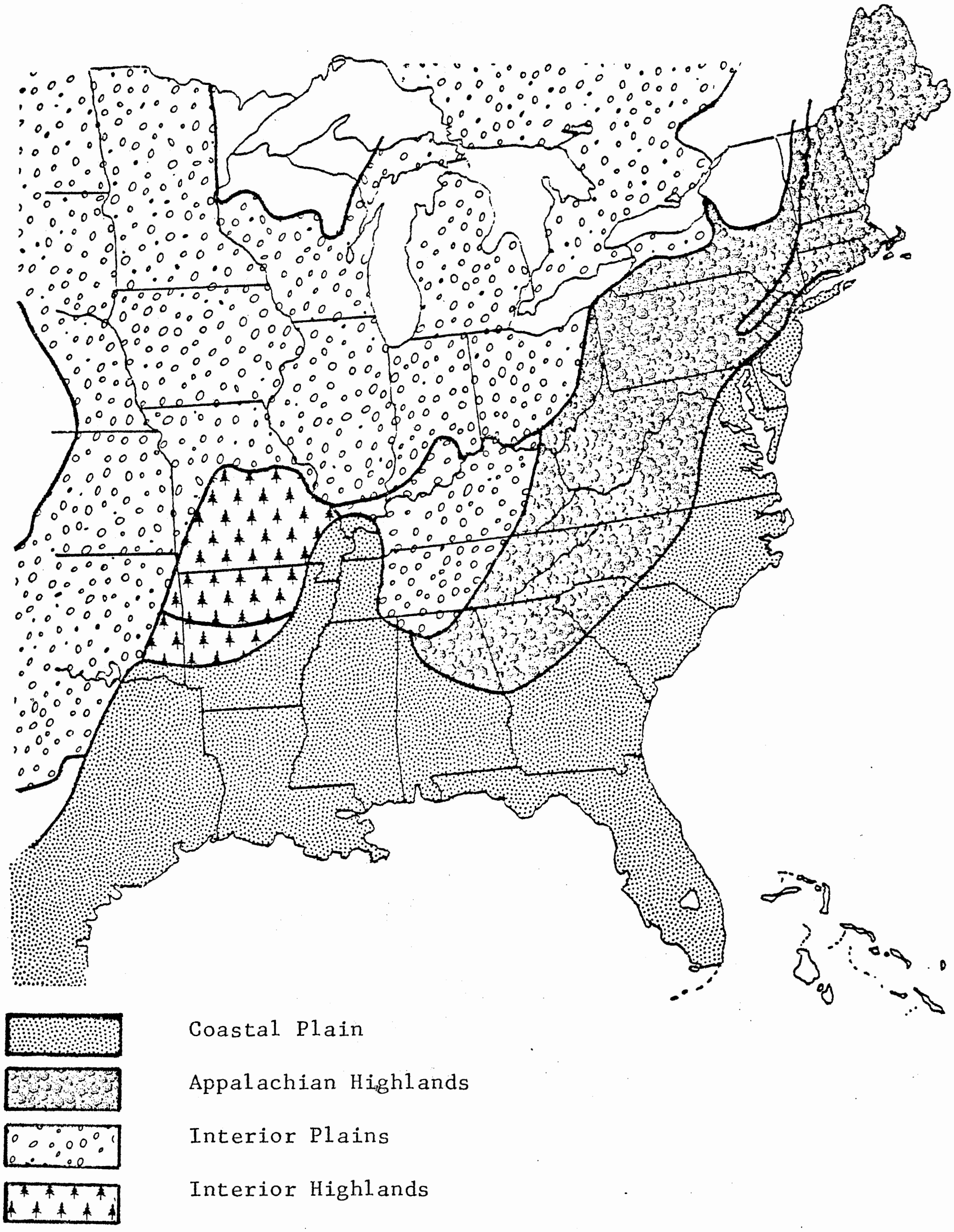
Since such a large geographic area was to be encompassed, a means was needed for logically dividing that area into subunits. Political divisions such as states have little relevance to the ecology of an area, and the same holds true for any arbitrary sectioning. Physiographic divisions, on the other hand, have a certain uniformity even though they may extend over a fairly wide range of latitudes and longitudes. *Aletris* occurs in four major physiographic divisions in North America which comprise ten provinces (Table III, Figure 7). In order to adequately determine the extent of variability of each species throughout its range, specimens were examined from each of the physiographic divisions. A total of 2,168 specimens were borrowed from herbaria at the following institutions: Florida State University (FSU), University of Georgia at Athens (GA), Harvard University (GH), Missouri Botanical Garden (MO), North Carolina State College (NCSC), University of North Carolina at Chapel Hill (NCU), New York Botanical Garden (NY), University of Oklahoma (OKL), Oklahoma State University (OKLA), University of Tennessee (TENN), University of Toronto (TRT), University of Arkansas at Fayetteville (UARK), University of Missouri at Columbia (UMO), Smithsonian (US), and University of Wisconsin (WIS).

TABLE III

REGIONS SAMPLED AND SPECIES COMPONENTS

Major Division	Province	Taxa Present	Symbol	N	Characteristics of Province *
Atlantic Plain	Coastal Plain	A. aurea	ACP	30	Broad plain rising inland; sandy beaches backed by estuaries and marshes; some limestone bluffs on west coast of Florida; inland ridges parallel the coast; altitudes less than 500 ft.
		A. bracteata	BCP	28	
		A. farinosa	FCP	30	
		A. lutea	LCP	30	
		A. obovata	OCP	30	
		A. lutea x obovata	XCP	13	
Appalachian Highlands	Piedmont	A. farinosa	FAH	29	500-2,000 ft. in the s., below 500 ft. n.
		A. aurea	AAH	5	
	Blue Ridge				Above 5,000 ft.
	Valley & Ridge				Parallel valleys and ridges; 1000-3000 ft.
	Appalachian Plateaus				Plateau, surface 2000-3,000 ft; deeply incised by valleys.
	New England	A. farinosa	FNE	30	Mostly hilly upland with altitudes above 5,000 ft.
Interior Plains	Central Lowland	A. farinosa	FIP	30	Vast plain; 500-2,000 ft.
	Interior Low Plateaus				Plateaus; less than 1,000 ft. Rolling uplands with moderate relief.
Interior Highlands	Ozark Plateaus	A. farinosa	FIH	18	Rolling upland; mostly above 1,000 ft.
		A. aurea	AIH	2	
	Ouachita Province				Like the valley and ridge province; 500-2,000 ft.

* Modified from Hunt, 1967



Coastal Plain

Appalachian Highlands

Interior Plains

Interior Highlands

Figure 7. Physiographic Regions Sampled

Sampling Technique

Samples were drawn from the specimens on loan, with care taken to represent the entire distributional range for each species within each physiographic division. The New England Province was separated from the Appalachian Highlands since it represents part of the northernmost limit of the distribution of *Aletris*. Specimens were chosen as randomly and objectively as possible, with the exception that only entire plants with adequate label information were used. Half the sample comprised fruiting specimens; the other half comprised flowering specimens. Duplicate sheets from the same population were not used.

Morphological Criteria

Each specimen was measured for 24 quantitative morphological characters (Table IV). Three are meristic and the remainder are continuous multistate characters. An additional eleven ratios were constructed from the data (Table V). Attempts were made via these ratios to quantify some of the more prevalent diagnostic characters. In addition, such ratios minimize effects due to size and age and eliminate units of measurements. Such measurements are sometimes transformed by putting them on a logarithmic scale which allows for growth being exponential. Clifford and Stephenson (1975) report that taking the square or cube root is a useful transformation, especially in measuring fruit.

TABLE IV

MORPHOLOGICAL CHARACTERS MEASURED FOR UNIVARIATE AND MULTIVARIATE ANALYSES

Character Symbol	Character
LL	Leaf Length
LA	Leaf Width at Top One-Fourth
LM	Leaf Width at Midpoint
LC	Leaf Width at Bottom One-Fourth
NERVE*	Number of Nerves per Leaf
SL	Scape Length
BR*	Number of Bracts per Scape
BRL	Length of Lowermost Bract
D	Diameter of Scape at Base
RAC	Raceme Length
FLS*	Number of Flowers per Raceme
BODY	Length of Capsule Body
BEAK	Length of Capsule Beak
FL	Flower Length
FT	Flower Width at Top
FA	Flower Width at Top One-Fourth
FM	Flower Width at Midpoint
FC	Flower Width at Bottom One-Fourth
EPIGF	Percent Perianth Adhering to Ovary
EPIGC	Percent Ovary Adhering to Perianth
AL	Anther Length
AWB	Anther Width at Base
AWM	Anther Width at Midpoint
AWT	Anther Width at Top

* Indicates those characters which are meristic

TABLE V

RATIOS CONSTRUCTED FROM MORPHOLOGICAL CHARACTERS MEASURED FOR UNIVARIATE AND MULTIVARIATE ANALYSES

Symbol	Name	Equivalent	Purpose
LI	Leaf Index	LL/LM	Reduces size effect
WI	Width Index	LA/LC	Quantifies leaf shape
RI	Raceme Index	RAC/SL	Indicates percent scape occupied by raceme
INFLI	Inflorescence Index	FLS/RAC	Quantifies density of raceme
CI	Capsule Index	BEAK/BODY	Quantifies relationship of beak and body
FLI	Flower Index	FL/FM	Reduces size effect
LOBEI	Lobe Index	FT/FA	Quantifies "lobes erect, recurved, or incurved"
CONI	Constriction Index	FA/FM	Quantifies amount of perianth constriction above middle
AI	Anther Index	AL/AWM	Reduces size effect
ABI	Anther Base Index	AWB/AWM	Quantifies shape of lower one-half of anther
AAI	Anther Apex Index	AWM/AWT	Quantifies shape of upper one-half of anther

Apriori Evaluation of Characters Included

Leaf Characters

Since the five species seemed to have a wide range of leaf lengths, this character seemed appropriate in order to determine whether there were any significant differences. Leaf Index Ratio (LI=LL/LM) gives an estimation of the length with the size effect reduced.

Leaf shape appeared to separate into two groups--those with either obovate or oblanceolate leaves and those with lanceolate to almost linear leaves. The ratio Width Index (WI=LA/LC) quantifies this dichotomy. If $WI<1.0$, the leaf in question is obovate or oblanceolate. If $WI=1.0$, the leaf is more or less linear. If $WI>1.0$, the leaf is lanceolate or ovate.

The presence or absence of a visible hyaline margin was evaluated to determine the reliability of applying this character to certain species. Since this was recorded as a dichotomy (+/-), it is not included in the analysis of variance; but it is listed in Appendix A as percent presence for each sample.

Nerve number has proven useful in morphological studies of other monocots, e.g. lemma nerve number and tribal affinities in the grasses. However, in <u>Aletris</u> this character proved to be a difficult one to objectively determine since primary veins only were counted, and the leaf bases were not always visible on herbarium specimens.

Scape Characters

Scape length (SL) overlapped considerably among the species, but was included as a measure of robustness. Number of bracts (BR) and length of the lowermost bract (BRL) were characters used by Sullivan (1973) to differentiate A. lutea, A. obovata, and hybrids. Again, herbarium specimens were sometimes damaged or had leaves obscuring a view of the entire scape and especially the lowermost bract. Diameter of the scape (D) was included as a general measure of the robustness of the plant.

Raceme Characters

Raceme length (RAC) and number of flowers (FLS) were used to construct the ratio inflorescence index (INFLI=FLS/RAC) which quantifies the diagnostic character "densely to sub-remotely flowered" used by Fernald (1950) and Correll and Johnston (1970.

Flower and Fruit Characters

Body and beak length yield the capsule index ratio (CI) to quantify "beaks as long as . . ." or ". . . half as long as the body" (Small, 1933; Fernald, 1950; Correll and Johnston, 1970). Flower measurements--flower length (FL), flower width at top (FT), flower width above midpoint (FA), flower width at midpoint (FM), and flower width below midpoint (FC)--were used independently and in various ratios to quantify perianth shape. Flower length index (FLI=FL/FM) reduces the size effect on length. Lobe index (LOBEI=FT/FA) quantifies whether the perianth lobes are erect, incurved, or recurved. If LOBEI=1.0, the lobes are erect. If LOBEI<1.0, the lobes are incurved. If LOBEI>1.0, the lobes are recurved. Constriction index (CONI=FA/FM) quantifies whether the perianth is constricted above the middle.

EPIGF and EPIGC indicate the amount of epigyny, EPIGF representing the percent perianth adhering to the ovary and EPIGC representing the percent ovary adhering to the perianth as used in "semi-epigynous;" i.e., 50% of the ovary is adnate to the perianth.

Anther Characters

Anther measurements and ratios--anther length (AL), anther width at base (AWB), anther width at midpoint (AWM), anther width at top (AWT), anther index (AI=AL/AWM), anther base index (ABI= AWB/AWM), and anther apex index (AAI=AWM/AWT)--were deemed useful since the species showed considerable variation in anther morphology.

Analyses Performed

The data were subjected to univariate analysis using an IBM/370-158 computer and the techniques of SAS (Barr, Goodnight, Sall, and Helwig, 1972, 1976) at Oklahoma State University.

Multivariate analysis was conducted on an IBM/370-158 computer using the NT-SYS program of Rohlf, Kishpaugh, and Kirk (1974) at the University of Oklahoma.

CHAPTER IV

RESULTS OF ONE-WAY ANALYSIS OF VARIANCE

Introduction

A one-way analysis of variance was performed on each character to elucidate the variability of each species throughout its range. Each set of herbarium sheets representing a particular species within a particular physiographic division was considered one sample; e.g., *A. aurea* in the Coastal Plain is one sample. Character means, standard deviations, standard errors of the means, variances, and coefficients of variability for the twelve samples are presented in Appendix A.

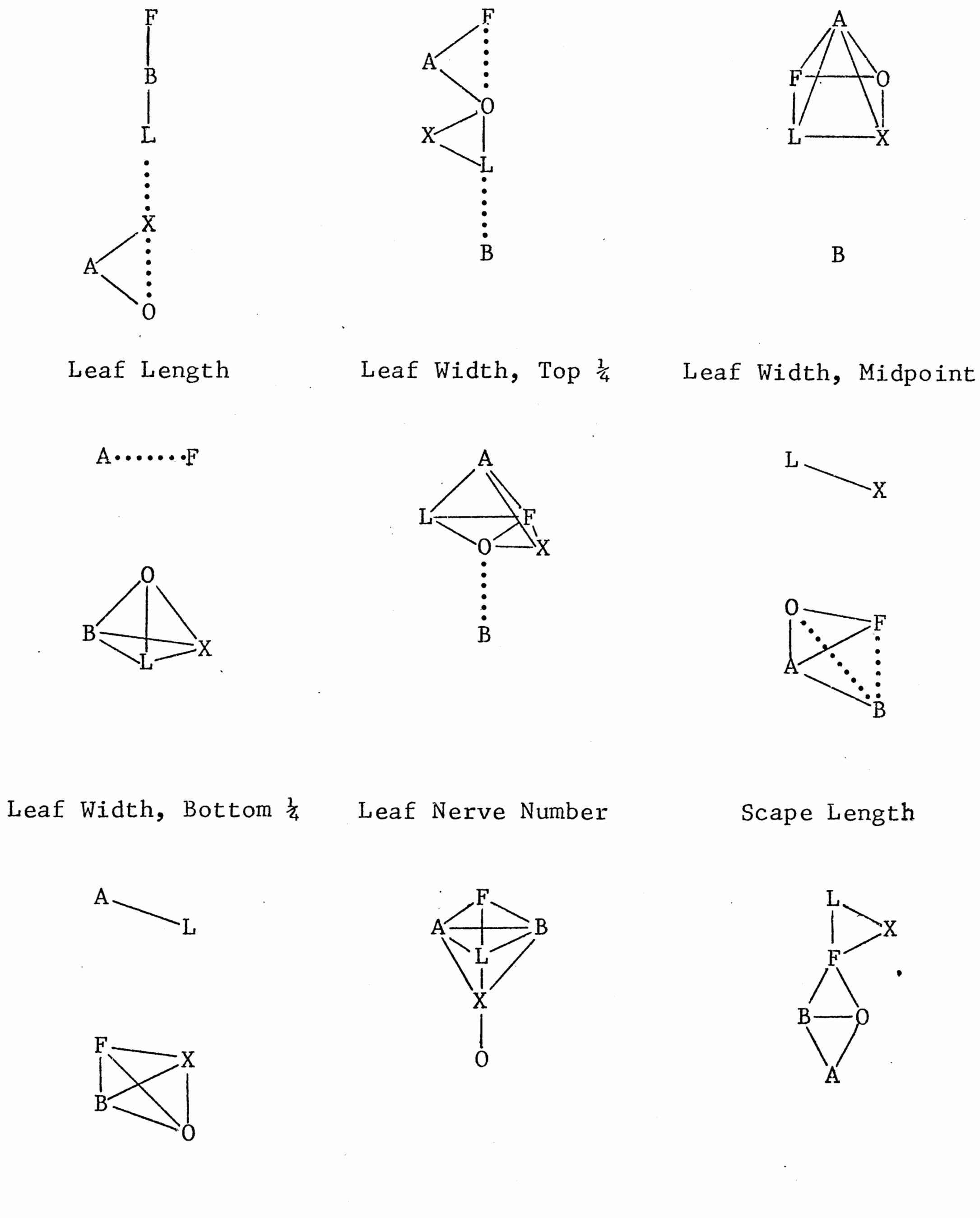
Variability Within a Sample

High variance and high coefficients of variability indicate variability from herbarium sheet to herbarium sheet within a physiographic sample. Characters that had the highest variances (greater than 100) and high coefficients of variability (40-69%) were leaf length, scape length, length of the lowermost bract, and number of flowers--all characters which are dependent on the age and/or robustness of the plant. By contrast, most of the ratios (except leaf index and width index) had small variances and coefficients of variability, indicating that they succeeded in reducing the age/size factor. Rather than dropping from the data-set characters that varied considerably, the sets were left intact to allow for the natural variability of those species that occur over large areas and over a wide range of environmental conditions and that were represented by specimens of different levels of maturity. All political states within a physiographic division were sampled if possible, but exact age and growing conditions were impossible to duplicate.

Variability of the Different Species Within the Coastal Plain

The one-way analysis of variance between species in the Coastal Plain showed a highly significant difference for practically all of the characters. Anther base index was the only character that did not differ significantly. Although *A. farinosa* and *A. aurea* also occur together in the Interior Highlands and the Appalachian Highlands, these two samples are eliminated from this discussion because of the extremely small sample size for *A. aurea*.

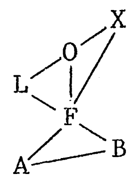
Least significant difference (LSD) comparisons allowed a means of constructing affinity diagrams of the six taxa for each character (Figure 8). A two dimensional approach devised by the author was employed rather than the traditional linear diagrams used in statistics. In general, it may be seen from the diagrams that *A. aurea* and *A. obovata* repeatedly showed affinities. *Aletris lutea*, *A. bracteata*, and *A. farinosa* constituted another close-knit group. *Aletris lutea* x *obovata* was almost always intermediate to *A. lutea* and *A. obovata*, as would be expected of a hybrid plant.



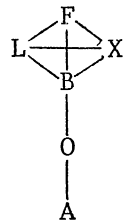
A=*Aletris aurea*, B=*Aletris bracteata*, F=*Aletris farinosa*,
L=*Aletris lutea*, O=*Aletris obovata*, X=*Aletris lutea* x *obovata*

—— Indicates no significant difference
•••••• Indicates significant difference at .10 level
Indicates significant difference at .05 level

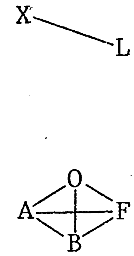
Figure 8. Least Significant Difference Comparisons Based on Means for Each Species, Coastal Plain



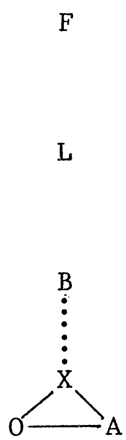
Raceme Length



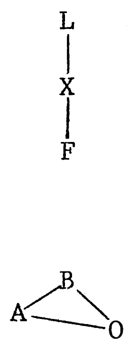
Number of Flowers



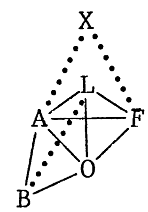
Capsule Body Length



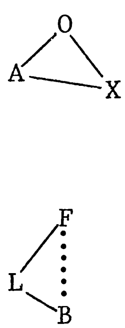
Capsule Beak Length



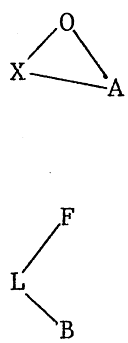
Flower Length



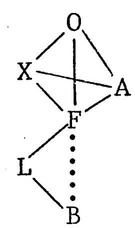
Flower Width, Top



Flower Width
Top One-half



Flower Width
Midpoint

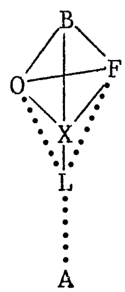


Flower Width
Bottom One-Half

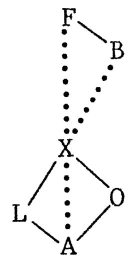
A=*Aletris aurea*, B=*Aletris bracteata*, F=*Aletris farinosa*,
L=*Aletris lutea*, O=*Aletris obovata*, X=*Aletris lutea* x *obovata*

—— Indicates no significant difference
...... Indicates significant difference at .10 level
Indicates significant difference at .05 level

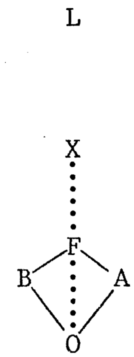
Figure 8 (Continued)



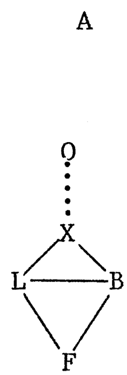
Percent Perianth Adnate



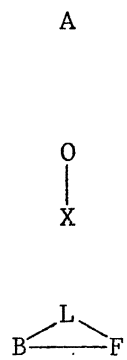
Percent Ovary Adnate



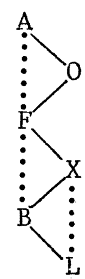
Anther Length



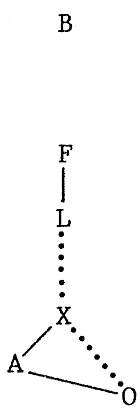
Anther Width, Base



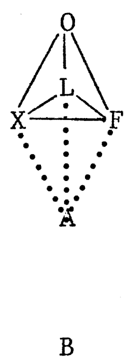
Anther Width, Midpoint



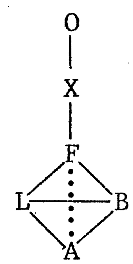
Anther Width, Top



Leaf Index



Width Index

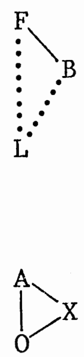


Raceme Index

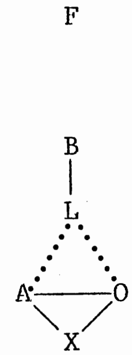
A=_Aletris aurea_, B=_Aletris bracteata_, F=_Aletris farinosa_, L=_Aletris lutea_, O=_Aletris obovata_, X=_Aletris lutea_ x _obovata_

——— Indicates no significant difference
•••••• Indicates significant difference at .10 level
Indicates significant difference at .05 level

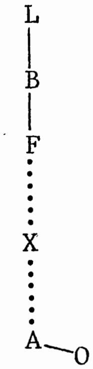
Figure 8 (Continued)



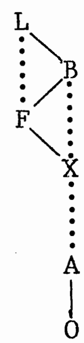
Inflorescence Index



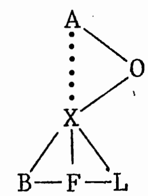
Capsule Index



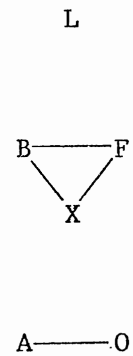
Flower Index



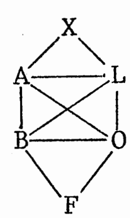
Lobe Index



Constriction Index



Anther Index



Anther Apex Index

A=*Aletris aurea*, B=*Aletris bracteata*, F=*Aletris farinosa*, L=*Aletris lutea*, O=*Aletris obovata*, X=*Aletris lutea* x *obovata*

——— Indicates no significant difference
...... Indicates significant difference at .10 level
Indicates significant difference at .05 level

Figure 8 (Continued)

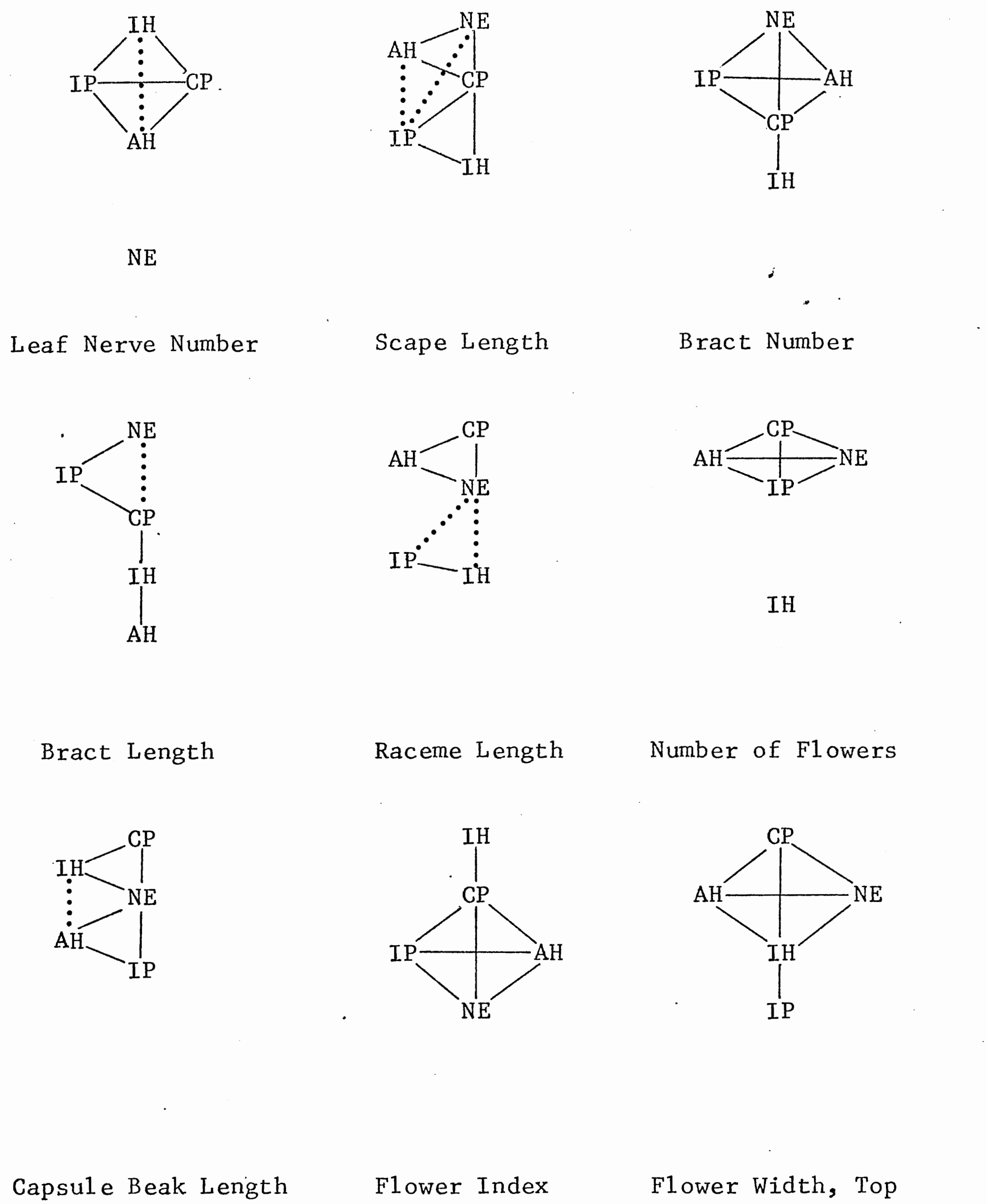
Variability of Aletris farinosa Throughout its Range

Variation of plants of A. farinosa throughout the range of its distribution, i.e., from physiographic division to division, was significant or highly significant for several characters (Figure 9). Least Significant Difference comparisons isolated the divisions with plants that exhibited the extreme values. A trend was evident in the affinity of plants of the New England Province for plants of the Appalachian Highlands and the Coastal Plain. Since the New England Province is the northernmost province of the Appalachian Highlands division, this nearness would be expected. The relationship of New England with the Coastal Plain is unclear, although they are contiguous in the extreme northern part of the Coastal Plain.

Another group showing affinities included the Interior Plains, the Coastal Plain, and the Interior Highlands. The Interior Highlands are geographically situated between the Interior Plains and the Coastal Plain, and the Interior Highlands do show some intermediacy with these two groups on the basis of this univariate analysis; but occasionally the Interior Highlands segregated out on the extremes or near the Appalachian Highalnds. The similarity of the two highland divisions would be expected. The sample size of the Interior Highlands (N=18) may account for the larger variability and therefore the changing affinites.

Variability of Aletris aurea Throughout its Range

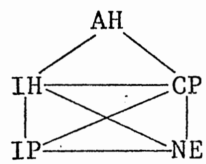
Aletris aurea differed significantly or highly significantly



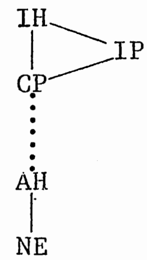
AH=Appalachian Highlands, CP=Coastal Plain, IH=Interior Highlands, IP=Interior Plains, NE=New England

——— Indicates no significant difference
...... Indicates significant difference at .10 level
Indicates significant difference at .05 level

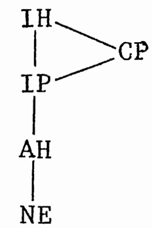
Figure 9. Least Significant Difference Comparisons Based on Means for Physiographic Regions, *Aletris farinosa*



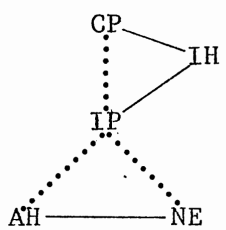
Percent Perianth Adnate



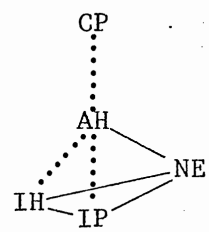
Anther Width, Base



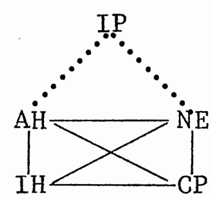
Anther Width, Midpoint



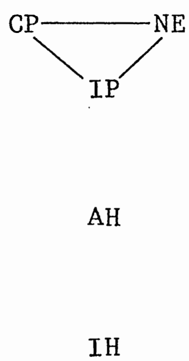
Anther Width, Top



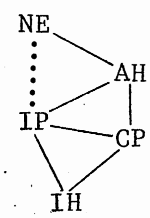
Raceme Index



Inflorescence Index



Constriction Index



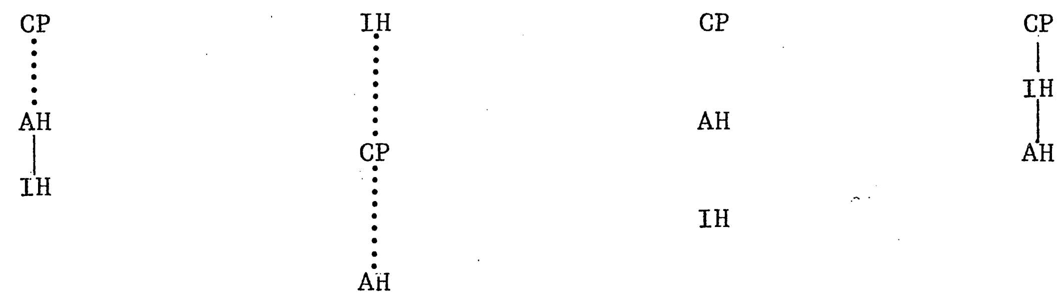
Anther Index

AH=Appalachian Highlands, CP=Coastal Plain, IH=Interior Highlands, IP=Interior Plains, NE=New England

—— Indicates no significant difference
...... Indicates significant difference at .10 level
Indicates significant difference at .05 level

Figure 9 (Continued)

from division to division in only four characters: anther width at top, anther width at base, raceme index, and anther apex index. Each affinity diagram (Figure 10) was different, and any conclusions based on such small samples would be suspect.



Flower Width, Top — Anther Width Base — Raceme Index — Anther Apex Index

CP=Coastal Plain AH=Appalachian Highlands IH=Interior Highlands

——— Indicates no significant difference
······ Indicates significant difference at .10 level
Indicates significant difference at .05 level

Figure 10. Least Significance Difference Comparisons Based on Means for Each Physiographic Region, Aletris aurea

Summary

Variability within a sample, i.e., from herbarium sheet to herbarium sheet, was greatest for characters that are dependent upon maturity and overall environmental conditions. Within the Coastal Plain six taxa occur together. LSD comparisons for each character revealed an affinity of A. aurea for A. obovata and of A. lutea, A. bracteata, and A. farinosa for each other. Aletris lutea x obovata formed the link between these two groups. Analysis of variance for A. farinosa throughout its range resulted in diagrams that show an affinity of plants in the Coastal Plain for plants in the New England Province and the Appalachian Highlands.

CHAPTER V

RESULTS OF MULTIVARIATE ANALYSIS OF VARIANCE

Introduction

All multivariate analyses were conducted using the NT-SYS program of Rohlf, Kishpaugh, and Kirk (1974). Analyses were performed either on sample means for each character with the ten samples being designated as operational taxonomic units (OTU's) or on individual specimens with each herbarium sheet an OTU. *Aletris aurea* in the Appalachian Highlands and *A. aurea* in the Interior Highlands were dropped because of their small sample sizes.

Cluster Analysis

Various methods of cluster analysis (Sneath and Sokal, 1973) were employed for comparative purposes (Table VI). Distance and correlation matrices were constructed using raw and standardized data. In each case a matrix of cophenetic correlation coefficients was used to compare the join levels of the phenogram with the values in the original matrix. These cophenetic correlation coefficients were all high, with the weighted pair-group method using arithmetic averages based on raw correlation data the lowest at 0.790. The highest correlation was obtained using the unweighted pair-group method using arithmetic averages based on the

TABLE VI

CLUSTER ANALYSIS METHODS EMPLOYED

Method	Cophenetic Correlation Coefficient
UPGMA, Correlation Raw	0.791
UPGMA, Distance Raw	0.876
UPGMA, Correlation Standardized	0.881
UPGMA, Distance Standardized	0.917
WPGMA, Correlation Raw	0.790
WPGMA, Distance Raw	0.872
WPGMA, Correlation Standardized	0.880
WPGMA, Distance Standardized	0.896
UPGMC, Distance Raw	0.876
UPGMC, Distance Standardized	0.905
WPGMC, Distance Raw	0.871
WPGMC, Distance Standardized	0.892
Single Linkage, Distance Raw	0.855
Single Linkage, Distance Standardized	0.874
Complete Linkage, Distance Raw	0.870
Complete Linkage, Distance Standardized	0.887

UPGMA: Unweighted Pair-Group Method Using Arithmetic Averages
WPGMA: Weighted Pair-Group Method Using Arithmetic Averages
UPGMC: Unweighted Pair-Group Method Using Centroid
WPGMC: Weighted Pair-Group Method Using Centroid

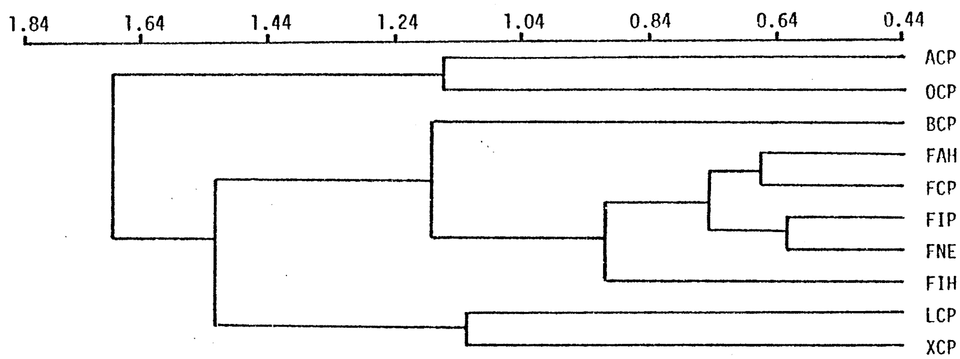
distance matrix generated from the standardized data, at 0.917. Phenograms of the cluster methods with the highest cophenetic correlation coefficients are presented in Figure 11. The remaining phenograms can be found in Appendix B.

All of the methods resulted in similar clustering. The *A. farinosa* group was persistent, with *A. bracteata* joining it either next or in conjunction with *A. farinosa* in the Interior Highlands. The group composed of *A. aurea*, *A. obovata*, and *A. lutea* showed changing affinities within the group, but the usual pattern was a clustering of *A. aurea* and *A. obovata*, then *A. lutea* and *A. lutea* x *obovata* clustering, finally these two clusters joining together before subsequent joining with the *farinosa-bracteata* group.

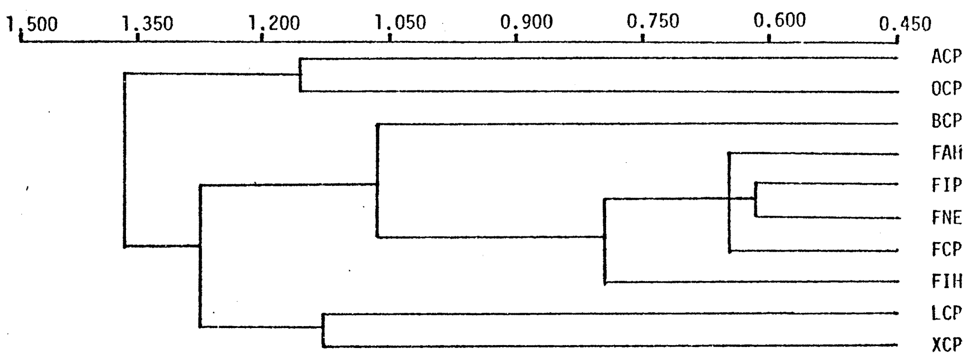
Evaluation of Cluster Methods

Without evaluating the mathematical implications of each cluster method, the results of Jardin's and Sibson's comparison (1971) shall be presented in Tables VII and VIII. It can be seen that each method has advantages and disadvantages, and results of many studies have shown that the most ideal method theoretically can be the least desirable method empirically, e.g., single linkage. Each method varies in effectiveness depending on the data being analyzed and whether it forms globular or long thin clusters. Results of 24 plots of raw data, two characters at a time revealed both types of clusters, with a preponderance of the long thin type; however, there was considerable overlap since the plots were based on raw data.

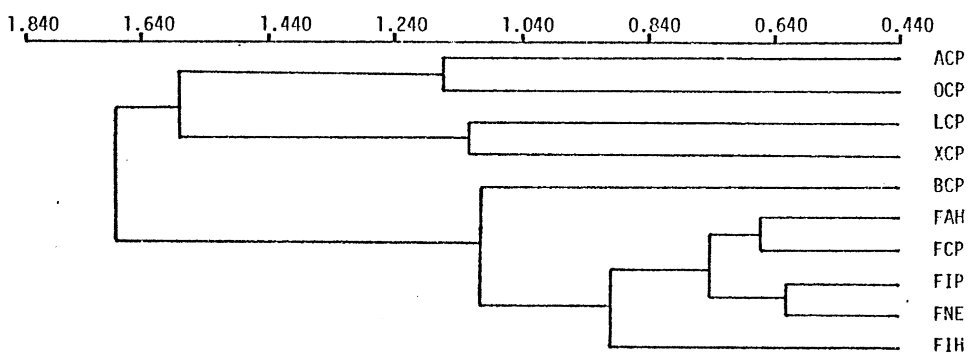
Since all of the phenograms are similar, the merits of any



a.) UPGMA, Standardized Distance



b.) UPGMC, Standardized Distance



c.) WPGMA, Standardized Distance

ACP: A. aurea, Coastal Plain
BCP: A. bracteata, Coastal Plain
LCP: A. lutea, Coastal Plain
OCP: A. obovata, Coastal Plain
XCP: A. lutea x obovata, Coastal Plain
FCP: A. farinosa, Coastal Plain
FAH: A. farinosa, App. Highlands
FIH: A. farinosa, Int. Highlands
FIP: A. farinosa, Int. Plains
FNE: A. farinosa, New England

Figure 11. Cluster Analysis of Aletris, Sample Means

TABLE VII

DESIRABLE PROPERTIES FOR CLUSTERING*

A.	A unique result should be obtained from the given data. (The tansformation should be 'well defined.')
B.	Small changes in the data should produce small changes in the dendogram. (The transformation should be continuous.)
C.	An ultrametric dissimilarity coefficient should be unchanged by the transformation.
D.	Results obtained should impose 'minimum distortion' subject to the other conditions (A, B, C).
E.	Transformation should be invariant to scale transformations.
F.	Transformation should commute with permutations of the OTU's.
G.	If a cluster is excised and the transformation applied to that cluster, the end result should be the restriction to that cluster of the original dendogram.

* Modified from Jardine and Sibson, 1971

TABLE VIII

EVALUATION OF CLUSTERING METHODS*

Linkage Type	Criteria Satisfied
Complete	Fails A, E-G are satisfied
Centroid	Fails B, E-G are satisfied
Medians	Fails B, E-G are satisfied
Group-average	Fails B, E-G are satisfied
Single	A-G are satisfied

* Modified from Jardine and Sibson, 1971

particular cluster method would be based on mathematical and aesthetic considerations, not on its taxonomic effectiveness. (1) Intuitively, the methods showing least chaining are most desirable for taxonomic studies requiring a delimitation of taxa. A method based on averages would overcome the chaining effect, yet minimize splitting. (2) The overlap shown in the raw data plots suggests that those methods utilizing the standardized data matrix would be more desirable. (3) Coefficients of association used as similarity measures do not take into account whether the attributes are independent or correlated. Since there was some correlation of characters, as discussed later in this chapter, those methods based on a correlation matrix would be inferior to those based on a distance matrix. These three criteria would suggest that UPGMA based on a standardized distance matrix would be best, and indeed its cophenetic correlation coefficient was highest at 0.917.

Correlation of Characters

A correlation matrix between characters was generated from the standardized data matrix (Appendix C). To facilitate evaluation of character correlations, a phenogram was constructed using the unweighted pair-group method with arithmetic averages (Figure 12). High negative correlations were not included on the phenogram, but these values may be found in Appendix C.

Vegetative characters that had high correlations were generally those that were affected by age and/or robustness of the plant. Therefore, when leaf length increased, so did bract length and density

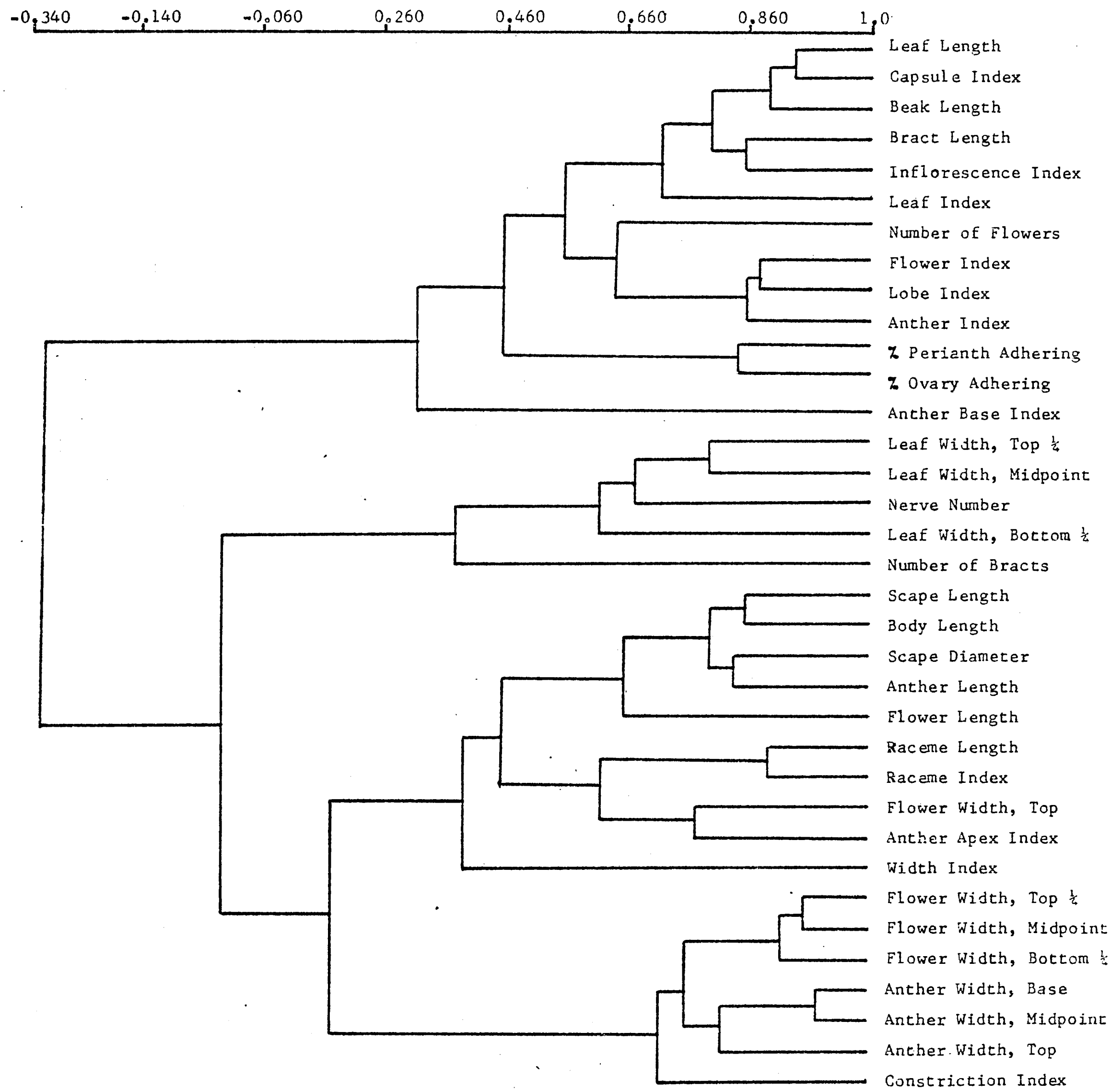


Figure 12. Phenogram of Correlation of Characters

of the flowers. Usually the high negative correlations involved alterations in the perianth and capsule with maturation; therefore as maturity progresses and leaf length and bract length increase, flower widths decrease due to the shrinking of the perianth. Constriction index (CONI) also increases with maturity, indicating more constriction above midpoint caused by distension of the perianth at the middle by the plump capsule body.

Reproductive characters that were correlated were grouped by structure, e.g. anther widths and flower widths. The ratios were generally more highly correlated with the reproductive characters and with themselves than with the vegetative characters. This most probably reflects the fact that nine of the eleven ratios involved reproductive characters.

Principal Components Analysis of Sample Means

Principal Components Analysis (PCA; Sneath and Sokal, 1973) yielded five factors with eigenvalues greater than one, accounting for a cummulative 93.48% of the trace (Table IX); therefore the characters appear to be highly correlated. The first three factors all had eigenvalues greater than ten and accounted for 80.25% of the variation, with the first latent vector alone accounting for 45%.

Most of the characters in factor one with loadings greater than 0.6 were reproductive, reflecting the perianth and inflorescence differences of the taxa; however, several characters with high loadings can be attributed to the stature of the different species, e.g. leaf length, bract length, raceme length, and leaf index. Characters

TABLE IX

LATENT VECTORS, PCA
OF SAMPLE MEANS

Factor Number	Eigen-Value	Percent of Trace	Cumulative Percent
Factor 1	15.66	44.74	44.74
Factor 2	7.91	22.60	67.35
Factor 3	4.52	12.90	80.25
Factor 4	3.21	9.17	89.42
Factor 5	1.42	4.06	93.48
Factor 6	0.97	2.77	96.24
Factor 7	0.65	1.84	98.09
Factor 8	0.35	0.99	99.08
Factor 9	0.32	0.92	100.00

in factor two with loadings greater than 0.6 repeat some of the stature/perianth differences plus anther length and anther index. Factor three had few characters with loadings greater than 0.6 including all of the leaf widths and nerve number (Table X).

The factor matrix was used to generate a projection matrix which then generated an euclidean distance matrix for three-dimensional models. The cophenetic correlation coefficient comparing the euclidean distance matrix with the standardized distance matrix was 0.984, therefore the 3-D models are an accurate representation of actual distances in the original standardized distance matrix. A minimum spanning tree was constructed and superimposed on one of the views. Through a combination of rotation, depression and elevation of the viewing plane, six views of the three-dimensional model were generated. Four of the views are reproduced in Figures 13-16. In

TABLE X

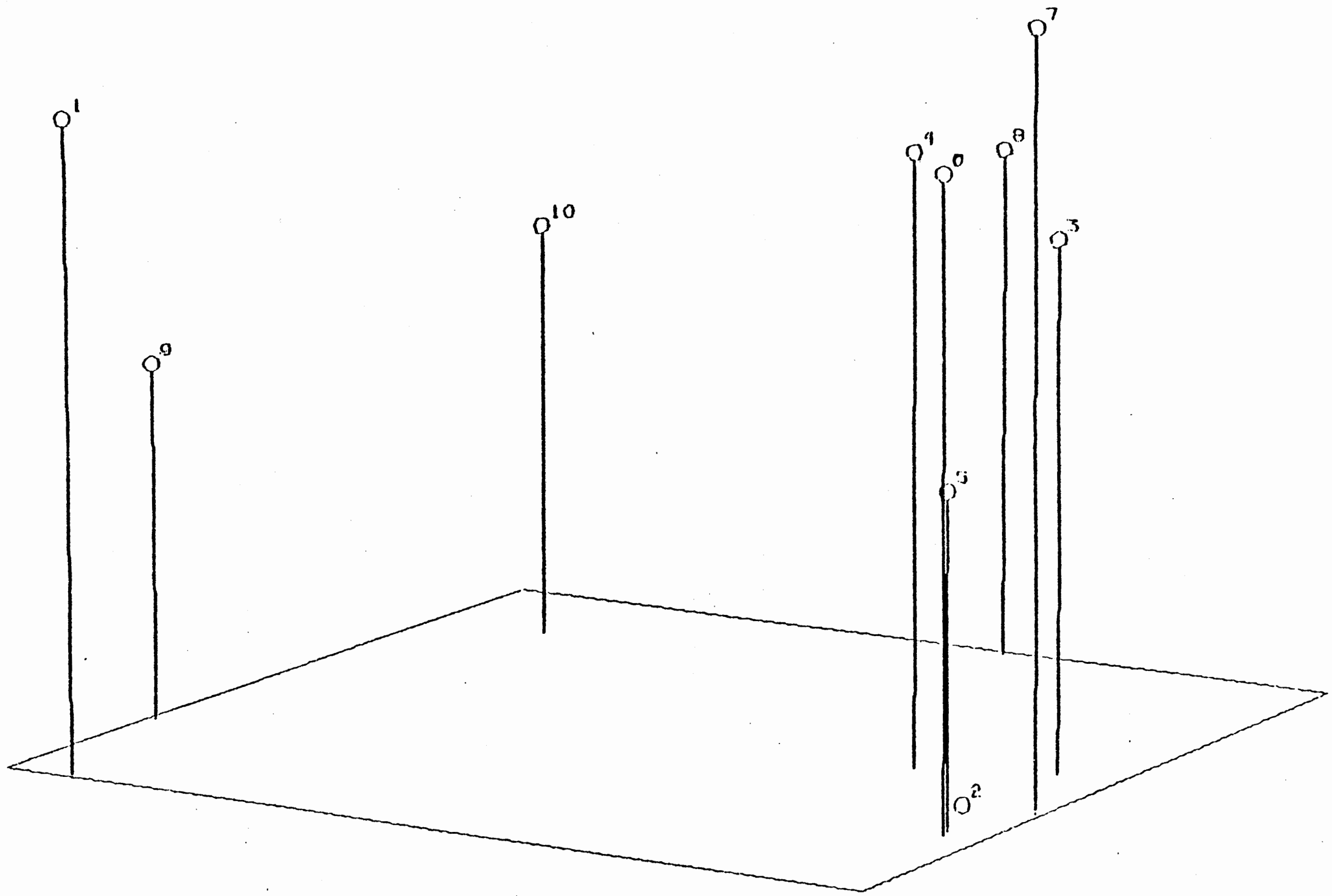
FACTOR LOADINGS, PCA
OF SAMPLE MEANS

Character	Factor 1	Factor 2	Factor 3
Leaf Length	0.968	-0.012	0.177
Leaf Width, Top ¼	0.113	0.333	0.860
Leaf Width, Midpoint	-0.409	0.137	0.858
Leaf Width, Bottom ¼	0.204	0.675	0.656
Leaf Nerve Number	0.106	-0.092	0.885
Scape Length	-0.306	-0.858	0.373
Bract Number	-0.264	-0.117	0.599
Bract Length	0.753	0.213	0.482
Scape Diameter	-0.007	-0.955	0.002
Raceme Length	-0.634	-0.673	-0.059
Flower Number	0.360	-0.741	0.187
Capsule Body Length	-0.444	-0.836	-0.016
Capsule Beak Length	0.850	-0.204	0.219
Flower Length	0.298	-0.722	0.037
Flower Width, Top	-0.662	-0.597	0.185
Flower Width, Top ¼	-0.961	0.144	0.103
Flower Width, Midpoint	-0.911	0.106	0.065
Flower Width, Bottom ¼	-0.881	-0.031	0.118
% Perianth Adherent	0.528	-0.100	-0.483
% Ovary Adherent	0.881	0.146	-0.211
Anther Length	-0.140	-0.854	0.087
Anther Width, Base	-0.849	0.372	-0.156
Anther Width, Midpoint	-0.926	0.240	-0.108
Anther Width, Top	-0.664	0.572	-0.065
Leaf Index	0.909	-0.005	-0.349
Width Index	-0.314	-0.447	0.378
Raceme Index	-0.645	-0.396	-0.320
Inflorescence Index	0.913	0.107	0.216
Capsule Index	0.913	0.128	0.158
Flower Index	0.803	-0.457	-0.091
Lobe Index	0.720	-0.565	-0.085
Constriction Index	-0.869	0.108	0.155
Anther Index	0.705	-0.628	0.231
Anther Base Index	0.584	0.411	-0.184
Anther Apex Index	-0.715	-0.433	-0.147

each view it is possible to see the A. farinosa group (3-7) with A. bracteata (2) nearer to it than to the other groups. Not only is A. bracteata near to A. farinosa in two dimensions, but separation by the third dimension (Factor 3) is based only on leaf widths and nerve number. The hybrid (10) of A. lutea and A. obovata is almost equidistant from the two respective parents (8 and 9). This precise intermediacy of a hybrid was unexpected, but the affinity diagrams of the univariate analysis and the results of cluster analysis corroborate it. Aletris aurea and A. obovata are similar to each other, but the distance is still fairly large. Aletris aurea (1) is the most remote of all the taxa.

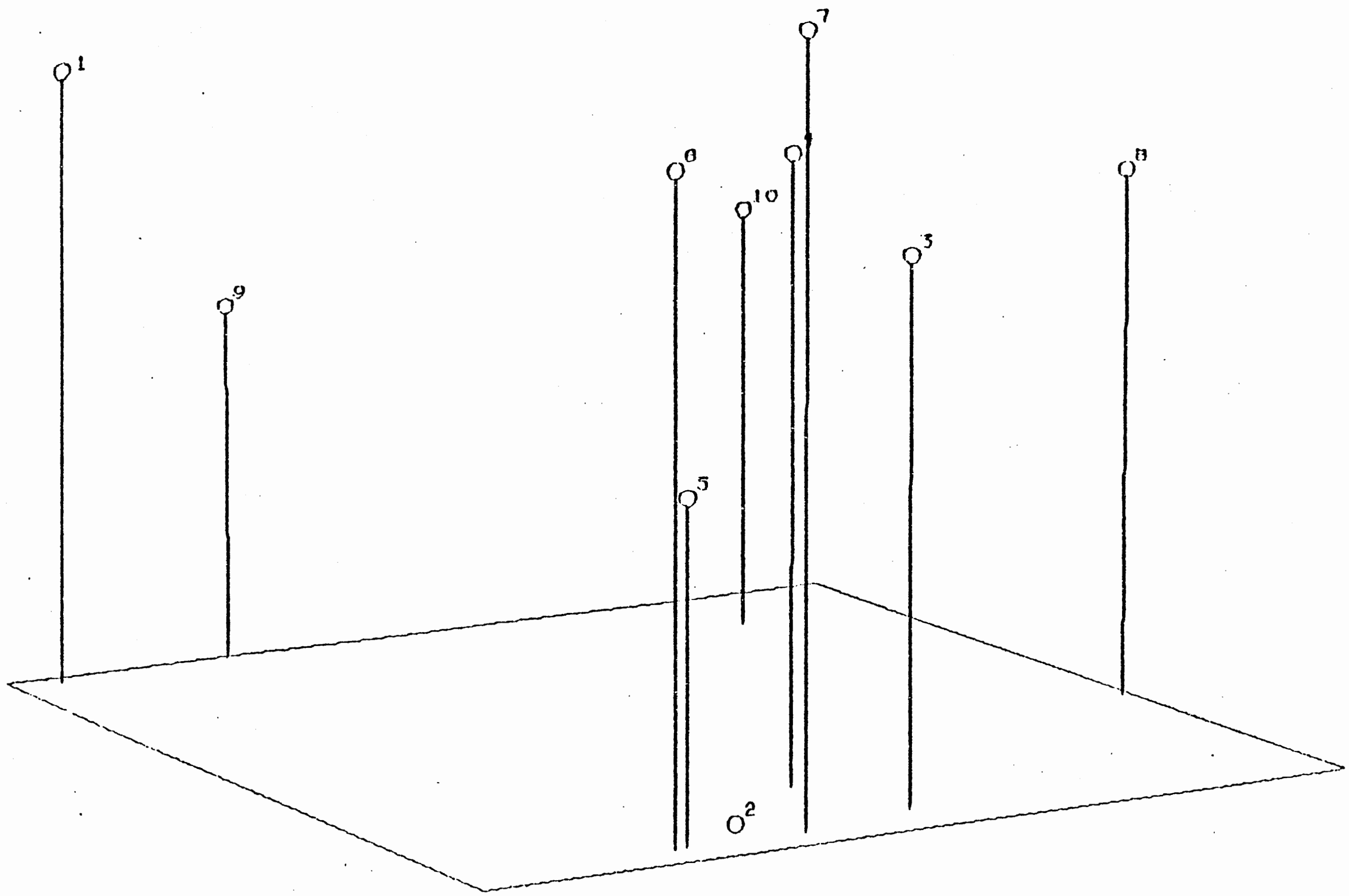
Summary

In general the clustering and principal components analysis segregated the groups along traditional taxonomic lines. Correlation of characters was usually attributable to the age/size factor or to a categorization of characters, e.g. reproductive characters being correlated.



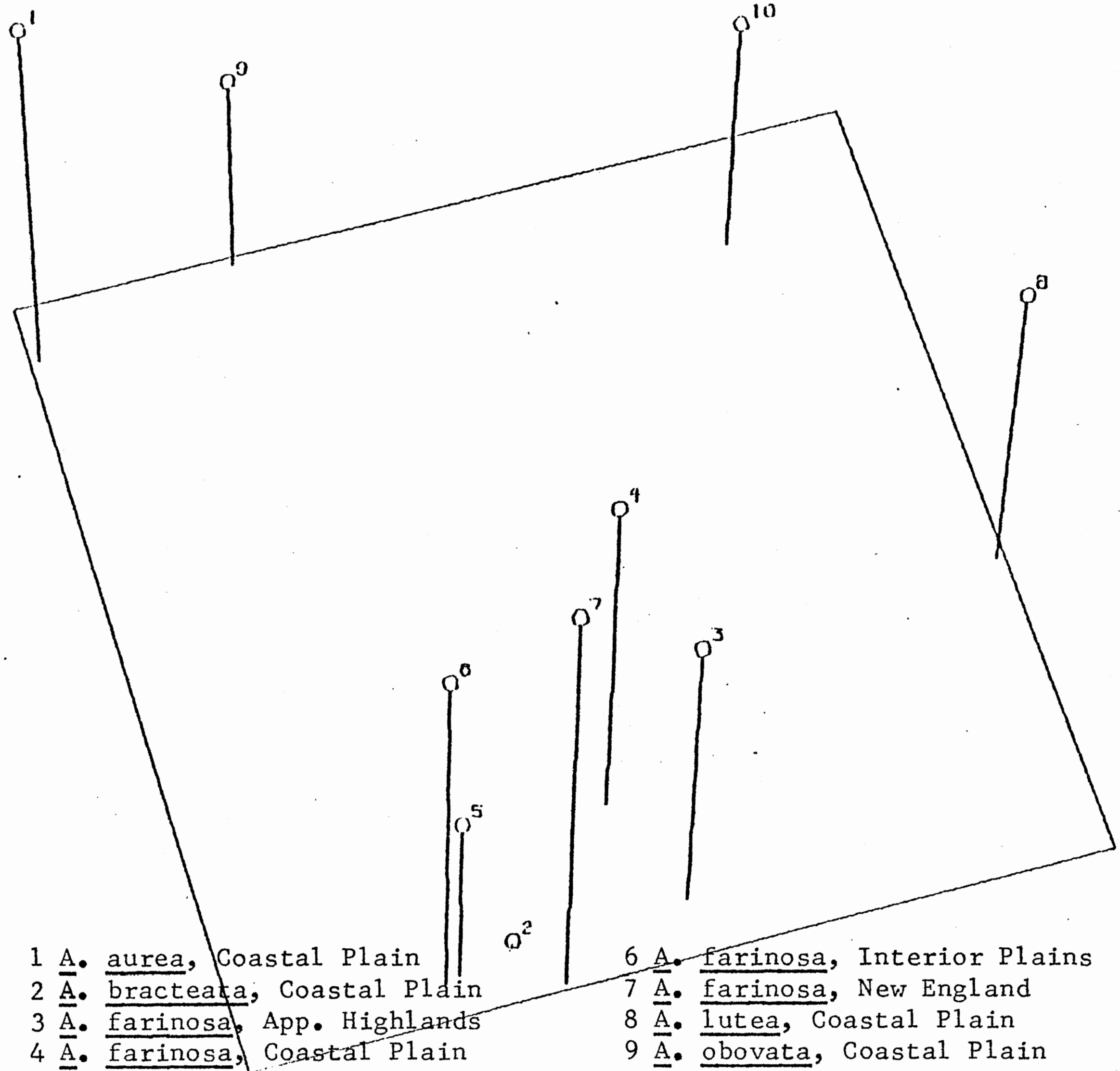
1 A. *aurea*, Coastal Plain
2 A. *bracteata*, Coastal Plain
3 A. *farinosa*, App. Highlands
4 A. *farinosa*, Coastal Plain
5 A. *farinosa*, Interior Highlands
6 A. *farinosa*, Interior Plains
7 A. *farinosa*, New England
8 A. *lutea*, Coastal Plain
9 A. *obovata*, Coastal Plain
10 A. *lutea* x *obovata*, Coastal Plain

Figure 13. Principal Components Analysis, Sample Means, View I



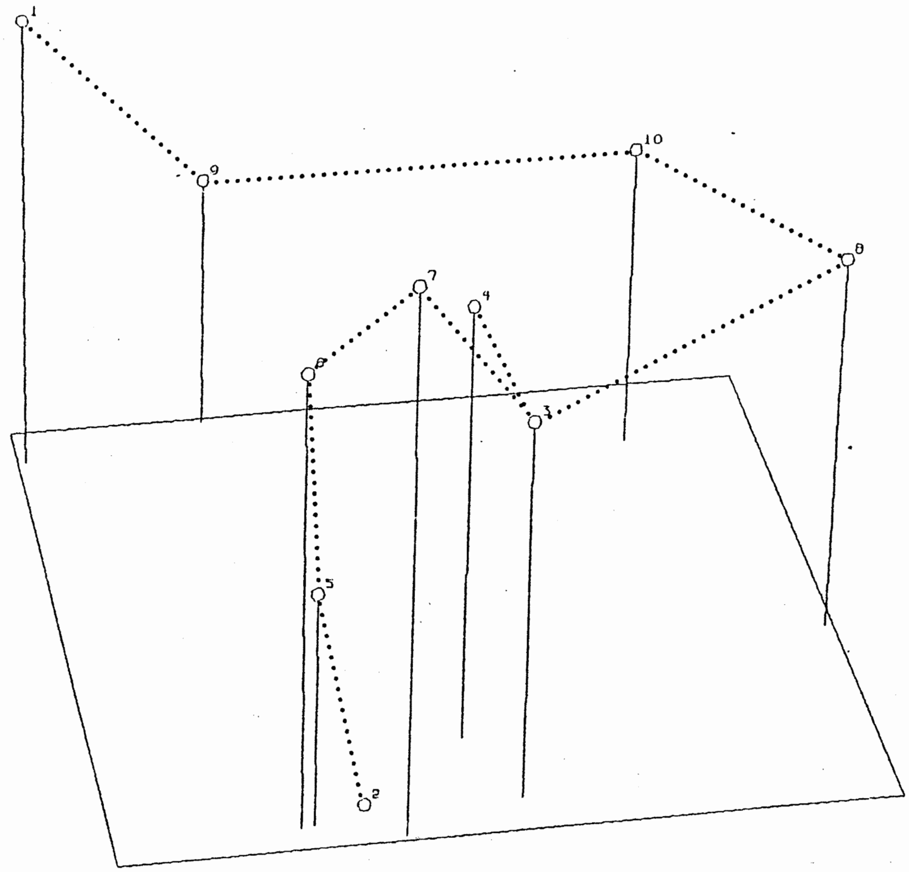
1 *A. aurea*, Coastal Plain
2 *A. bracteata*, Coastal Plain
3 *A. farinosa*, App. Highlands
4 *A. farinosa*, Coastal Plain
5 *A. farinosa*, Interior Highlands
6 *A. farinosa*, Interior Plains
7 *A. farinosa*, New England
8 *A. lutea*, Coastal Plain
9 *A. obovata*, Coastal Plain
10 *A. lutea* x *obovata*, Coastal Plain

Figure 14. Principal Components Analysis, Sample Means, View II



1 *A. aurea*, Coastal Plain
2 *A. bracteata*, Coastal Plain
3 *A. farinosa*, App. Highlands
4 *A. farinosa*, Coastal Plain
5 *A. farinosa*, Interior Highlands
6 *A. farinosa*, Interior Plains
7 *A. farinosa*, New England
8 *A. lutea*, Coastal Plain
9 *A. obovata*, Coastal Plain
10 *A. lutea x obovata*, Coastal Plain

Figure 15. Principal Components Analysis, Sample Means, View III



1 A. aurea, Coastal Plain
2 A. bracteata, Coastal Plain
3 A. farinosa, App. Highlands
4 A. farinosa, Coastal Plain
5 A. farinosa, Int. Highlands
6 A. farinosa, Interior Plains
7 A. farinosa, New England
8 A. lutea, Coastal Plain
9 A. obovata, Coastal Plain
10 A. lutea x obovata, Coastal Plain

OTU i	OTU j	Length
7	6	0.617
3	7	0.654
3	4	0.657
6	5	0.805
5	2	0.984
10	8	1.126
9	10	1.137
1	9	1.160
8	3	1.199

Figure 16. Principal Components Analysis, Sample Means, View IV and Minimum Spanning Tree

CHAPTER VI

EVALUATION OF DIAGNOSTIC CHARACTERS

Within the genus *Aletris*, two morphologically distinct groups exist: (I) the *farinosa*-*lutea*-*bracteata* group and (II) the *aurea*-*obovata* group. These two complexes each have a morphological homogeneity that is irrespective of perianth color.

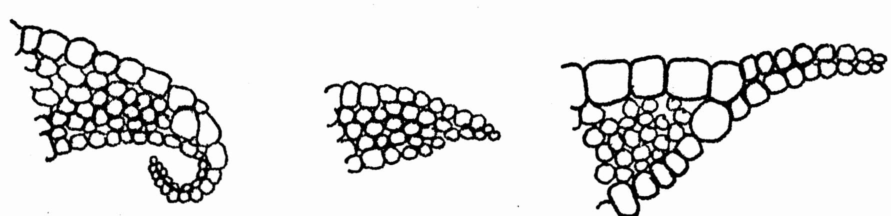
Plants of group I would generally be taller, with longer, more lanceolate leaves and densely-flowered racemes. The flowers would be longer than wide, approaching a cylindric shape and would tend to be constricted just above midpoint from the distended capsule body. They also would have a higher degree of adnation between perianth and ovary.

Within group I, classification into species is less precise. The obvious first dichotomy is perianth color, but this character may not be sufficient to categorize the three as separate entities. The capsule characters used by Northrop (1902) and Small (1933) are somewhat reliable, with *A. farinosa* having a long slender beak, *A. lutea* having a capsule gradually narrowed into a short beak, and *A. bracteata* having a short stout style. However, the range of variation of these characters was great enough that without perianth color as an aid, misidentification is possible. Defining *A. bracteata* and *A. farinosa* as the only species with half inferior ovaries is unwarranted, as all species have a degree of adnation, especially late in the growing season.

Group II plants would be smaller in stature with shorter more obovate leaves and a sub-remotely-flowered raceme. The perianth would be somewhat obovate, but as Ward (1978) suggested, it may not be as pronounced in *A. obovata* as presumed. Some specimens of *A. aurea* examined from the northwestern limit of its range had perianths approaching cylindric. The capsule beaks would tend to be very short and broad.

Classification into species of group II is best accomplished by flower color; but when this character is missing, the surface of the perianth is more roughly granular in *A. obovata* than in *A. aurea*. In addition *A. obovata* has a longer and less dense raceme; *A. aurea* has more bracts with the lowermost bract being longer and an extremely short style/beak.

A character that may have been over emphasized is the presence of a distinct visible hyaline margin. As Browne (1956) pointed out, even *A. farinosa* has a hyaline margin; however, its visibility is confounded by the fact that it tends to roll under (Figure 17). As the data in Appendix A show, all species of *Aletris* had a hyaline margin to some extent; so this character should not be ascribed only to *A. lutea*, *A. obovata*, and their hybrid.



A. farinosa *A. aurea* *A. obovata*

Figure 17. Leaf Margins (Redrawn from Browne, 1956)

CHAPTER VII

DISTRIBUTIONAL PATTERNS OF ALETRIS

Geographic information was recorded from the 2,168 herbarium specimens on loan. Mapping of the counties and states where each taxon occurred resulted in the distribution maps presented in Figures 18-23. The distributions as mapped will no doubt omit areas where *Aletris* does occur but which were not represented by specimens on loan.

Aletris farinosa occurs as far north as northeastern Wisconsin, southern Ontario, and southern New Hampshire and as far south as Louisiana, Mississippi, Alabama, and Georgia. No specimens were encountered from Florida, supporting Ward's conclusion (1978) that the species does not occur there. Although it is possible that questionable specimens were misidentified because of the morphological similarity of *A. farinosa* and *A. lutea*, the northward curving distributional pattern through Georgia and South Carolina supports the non-occurrence of *A. farinosa* in Florida. *Aletris* from the southeastern United States was well represented in the loans, so it is doubtful that this area was merely not collected.

Aletris lutea occupies almost exactly the area of the southeastern United States not occupied by *A. farinosa*. No specimens were encountered from as far north as South Carolina; Browne (1956) stated that although it was reported to occur there, he had seen none. Ward (1977) suggested that *A. lutea* does not occur west of Okaloosa County, Florida; however an accession by Browne (1956) was from Santa Rosa County, and the southeastern counties of Mississippi and Alabama form a continuum.

A. aurea is abundant in the Coastal Plain as far north as Maryland and possibly New Jersey. Specimens from the Appalachian Highlands and the Ouachita Province of the Interior Highlands were few.

The distribution as recorded for *A. obovata* agrees with Ward's (1978) statement that, in Florida, *A. obovata* occurs south to Citrus and Flagler counties; however, specimens were examined from as far west as Jackson and Gulf counties. Southeastern Georgia is also occupied by *A. obovata*.

Hybrids between *A. lutea* and *A. obovata* could possibly be found throughout the areas of sympatry; however, definite hybrids were examined from only eight counties in Georgia and Florida.

Specimens of *A. bracteata* were examined from southern Dade County, Long Key, Big Pine Key (Monroe County), Florida and Andros in the Bahamas. Northrop reports that the distribution also includes Abaco.

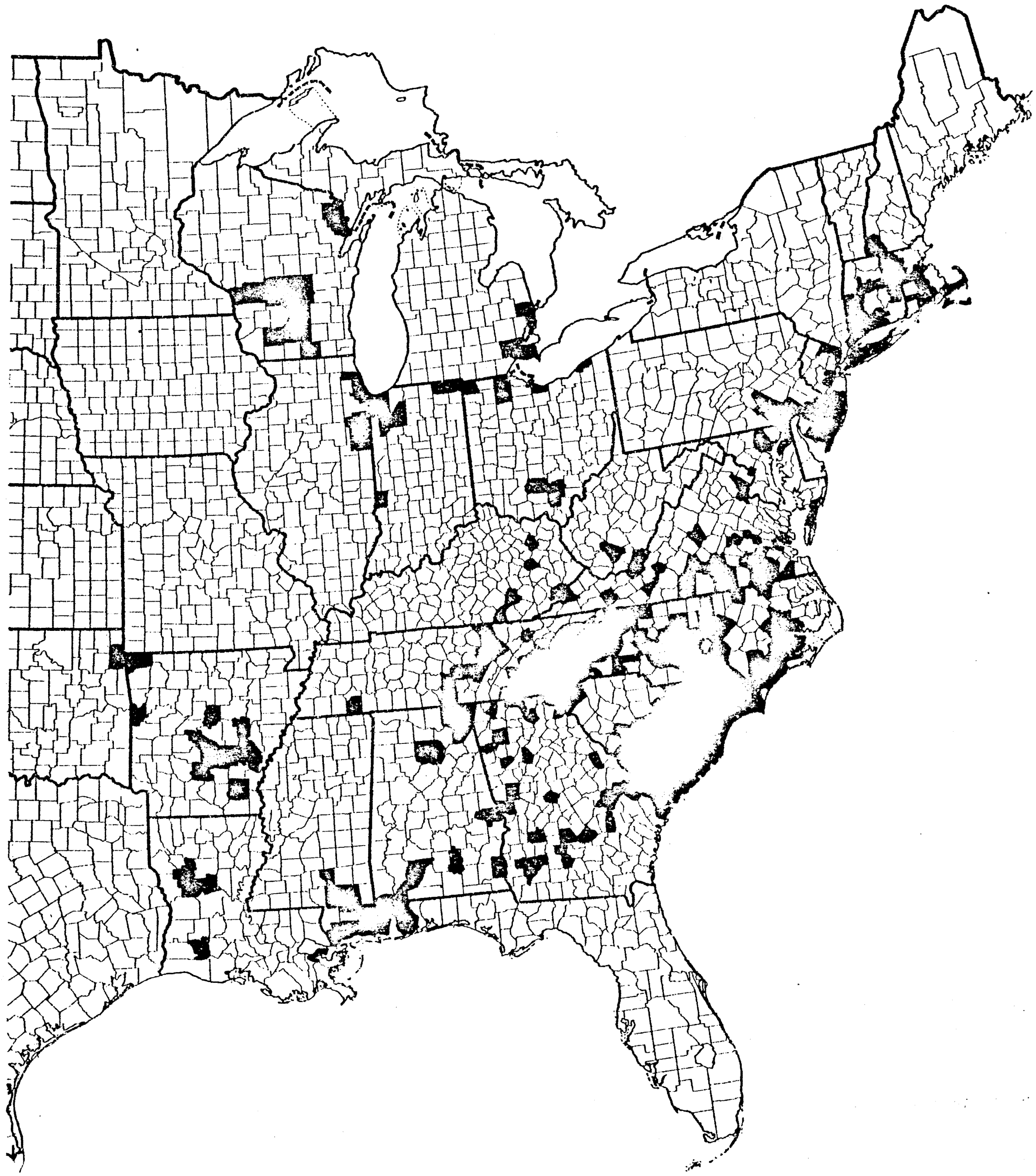


Figure 18. Partial Distribution of *Aletris farinosa* L.

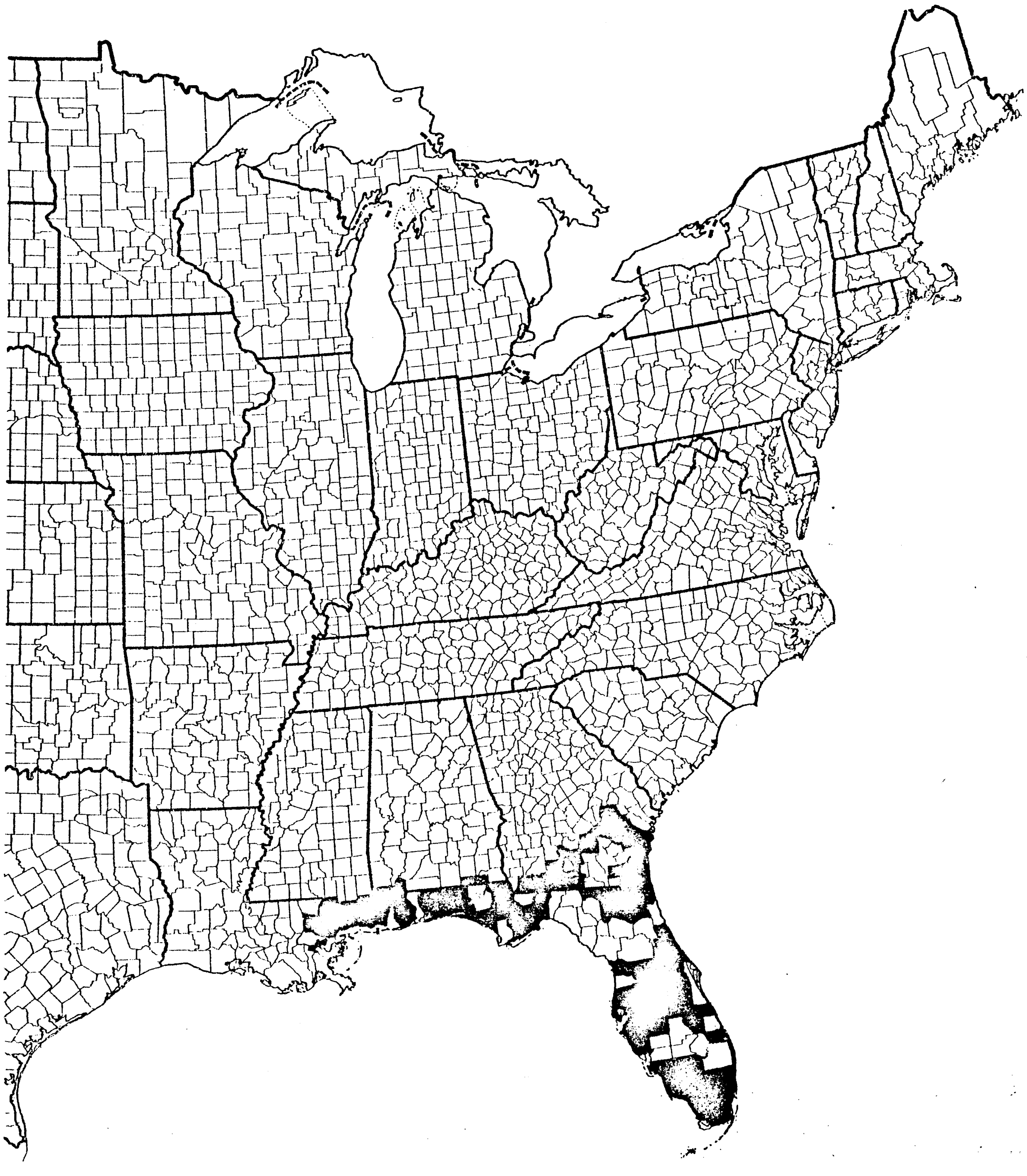


Figure 19. Partial Distribution of Aletris lutea Small

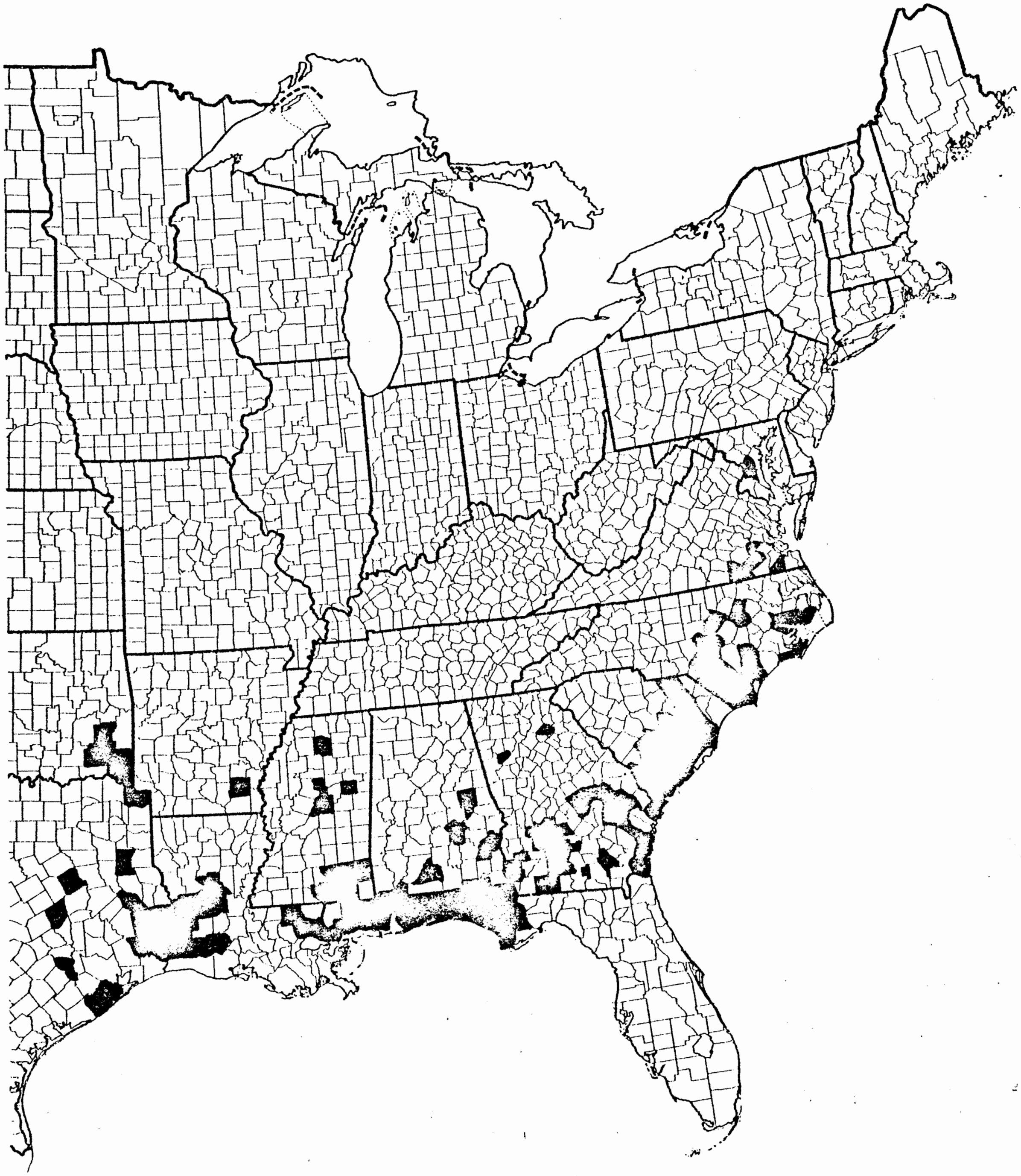


Figure 20. Partial Distribution of Aletris aurea Walter

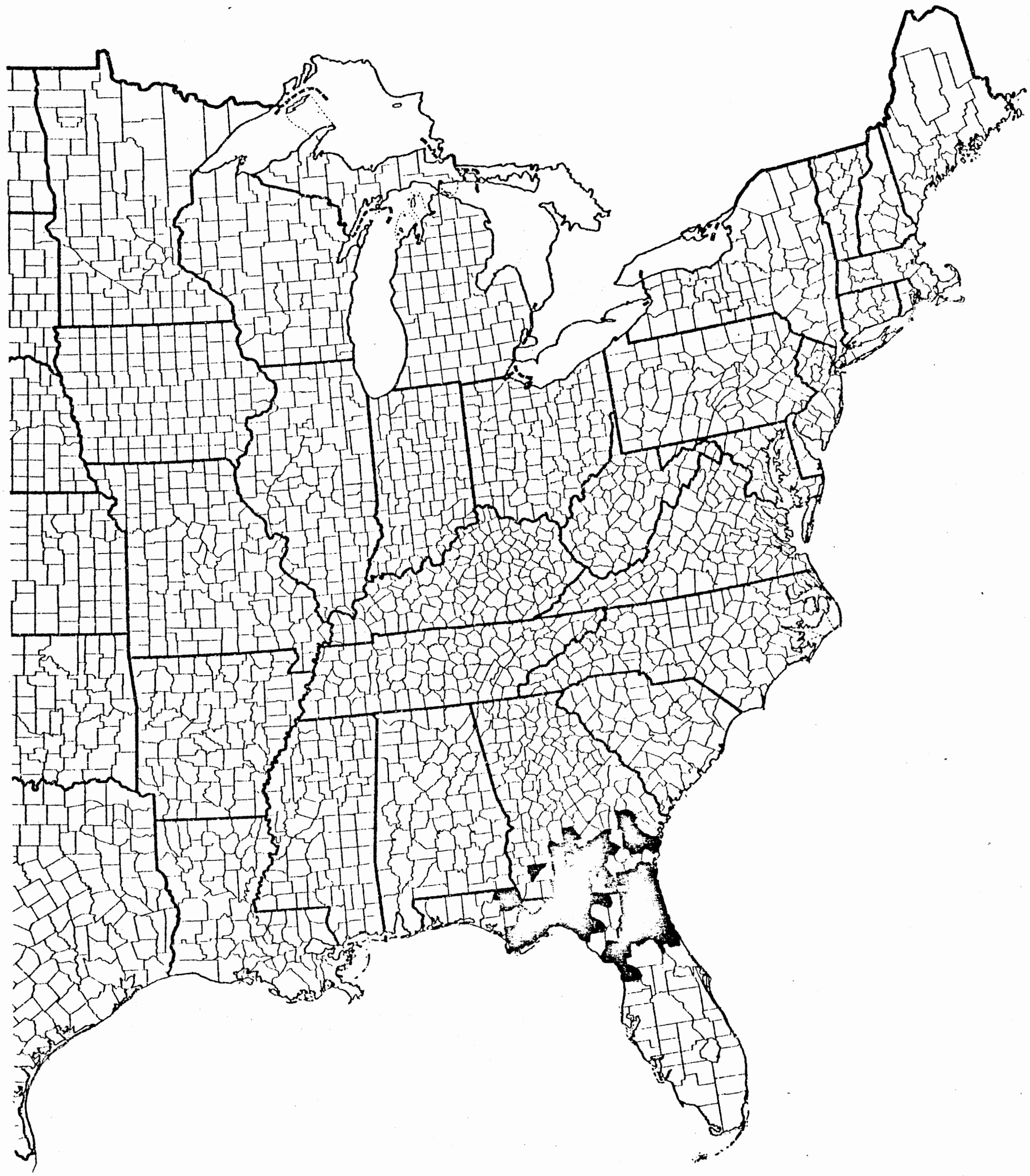


Figure 21. Partial Distribution of Aletris obovata Nash

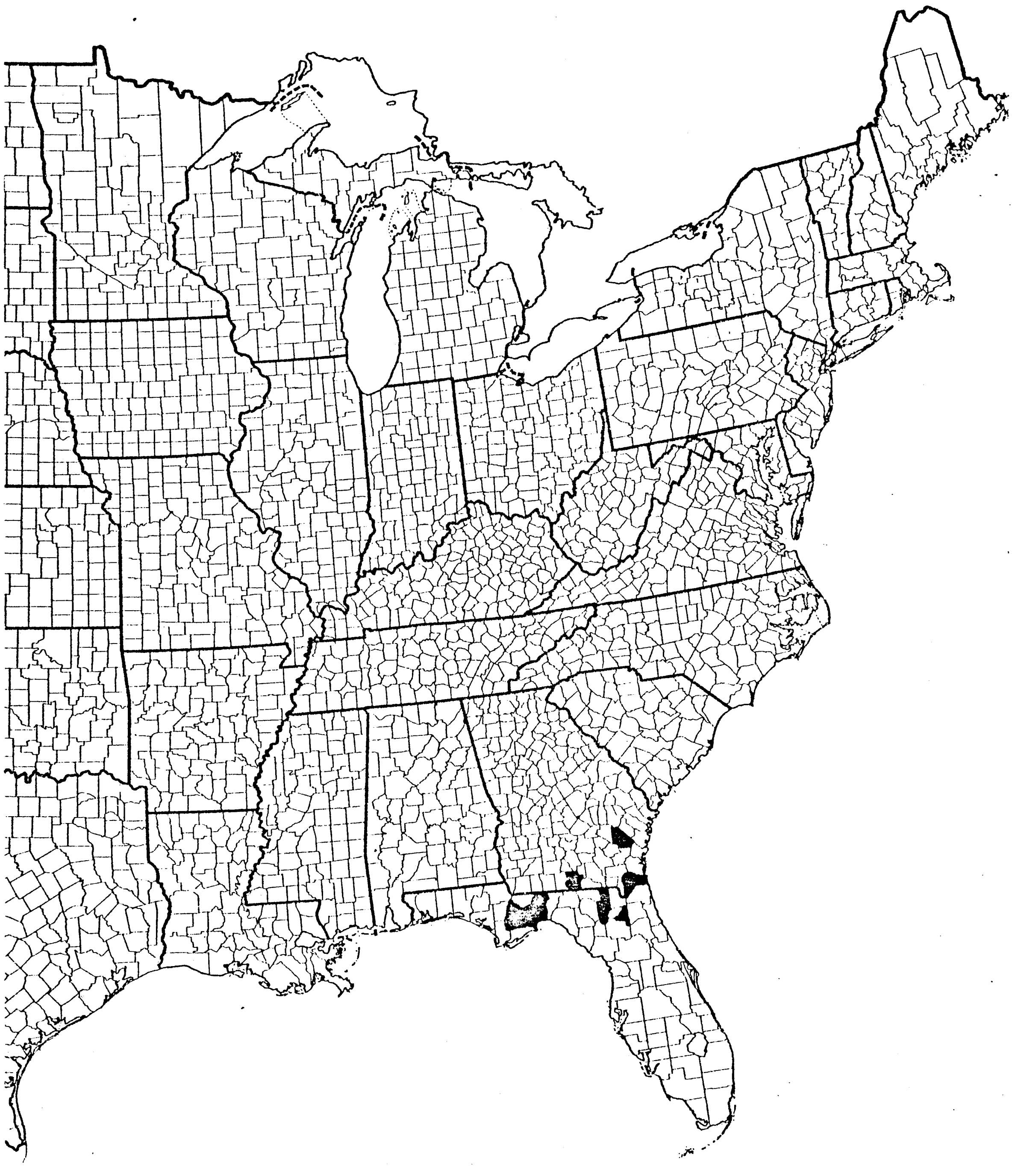


Figure 22. Partial Distribution of Aletris lutea x obovata

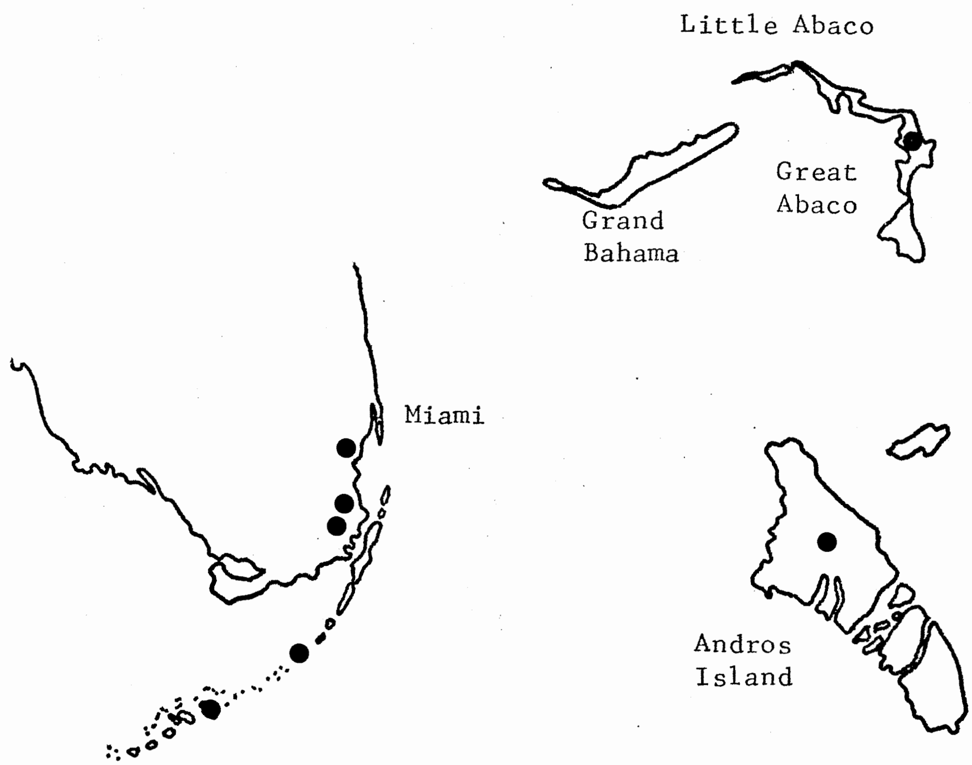


Figure 23. Partial Distribution of Aletris bracteata Northrop

CHAPTER VIII

EVALUATION OF INFRASPECIFIC, INTERSPECIFIC, AND PROBLEM TAXA

Aletris lutea forma *alba*

As noted above, semi-epigyny and the presence of a hyaline margin are unreliable in distinguishing *A. lutea* and *A. farinosa*; therefore it is possible that the designated *A. lutea* forma *alba* is actually *A. farinosa*. In an attempt to evaluate the taxonomic status of this color form the type specimen was examined for the same set of morphological characters and scored (+/-) for whether it was nearer to *A. lutea* or *A. farinosa*. Since *A. lutea* and *A. farinosa* had identical values for eight percent of the characters, the type specimen was equidistant from *A. lutea* and *A. farinosa* eight percent of the time. The remainder of the characters were nearer to *A. lutea* 46% of the time and nearer to *A. farinosa* 46% of the time. Browne's 1961 description of the population indicates equal numbers of white and yellow-flowered plants. In addition, he aludes to the initial tendency to identify the white-flowered plants as *A. farinosa*. Ultimately, he placed emphasis on two characters and designated the plant as a white color form of *A. lutea*. He states:

> . . . it was discovered that in neither of these types was there semi-epigyny, one of the most outstanding floral characters of *A. farinosa*. Microscopic and macroscopic examination of leaves of these plants revealed that both exhibited the narrow hyaline

margin which is typical of the leaves of A. lutea (p. 304-305). His collection date was June 13, and the type specimen was not in a mature fruiting stage--the most likely time for maximum perianth adnation. Therefore, it is possible that the population was composed of immature A. farinosa and A. lutea.

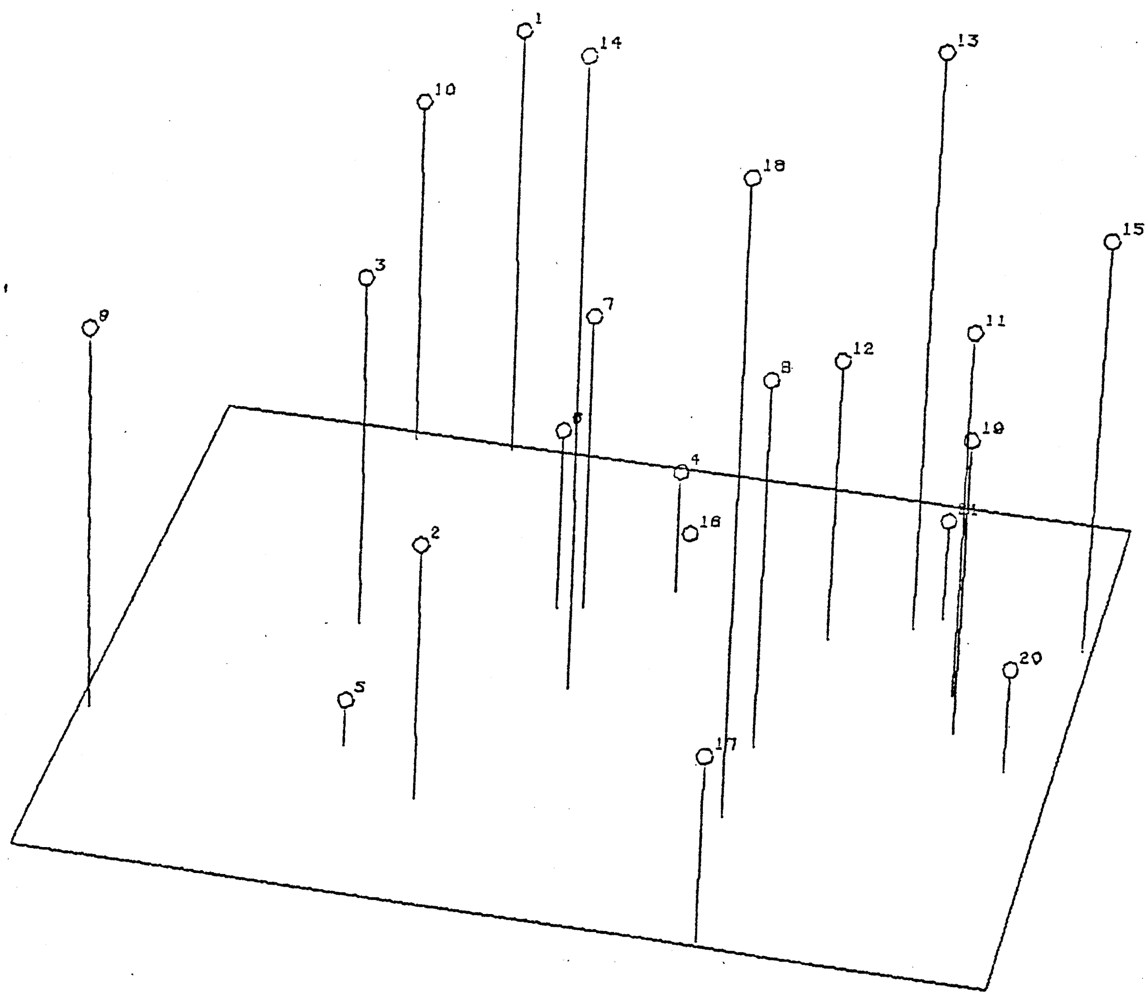
To further elucidate this relationship, principal components analysis was performed to utilize all of the 35 characters simultaneously in separating A. lutea and A. farinosa and in classifying the type specimen. Twenty-one OTU's were designated--10 A. lutea, 10 A. farinosa, and the type for A. lutea forma alba. Ten factors were extracted with eigenvalues greater than one, with the first three factors accounting for 49% of the trace. Factor loadings are given in Table XI.

Figures 28 and 29 show the scant separation of A. farinosa (1-10) and A. lutea (11-20). OTU's 4, 8, and 14 appear to segregate to the wrong groups. Number four is a specimen from Duval County, Florida and therefore may be A. lutea which was incorrectly identified as A. farinosa on the label. Examination and annotation of specimens prior to measurement upheld the identification as A. farinosa, however without perianth color information, error is possible. All other morphological characters were closer to A. farinosa. Number eight is a specimen from Perry Country, Mississippi. The capsule characters were intermediate to A. farinosa and A. lutea, but label information referred to the white perianth. OTU 14 is definitely A. lutea and was collected in Pasco County (peninsular), Florida. The type specimen for A. lutea forma alba (21) does segregate to the "lutea-side" and therefore designating this plant

TABLE XI

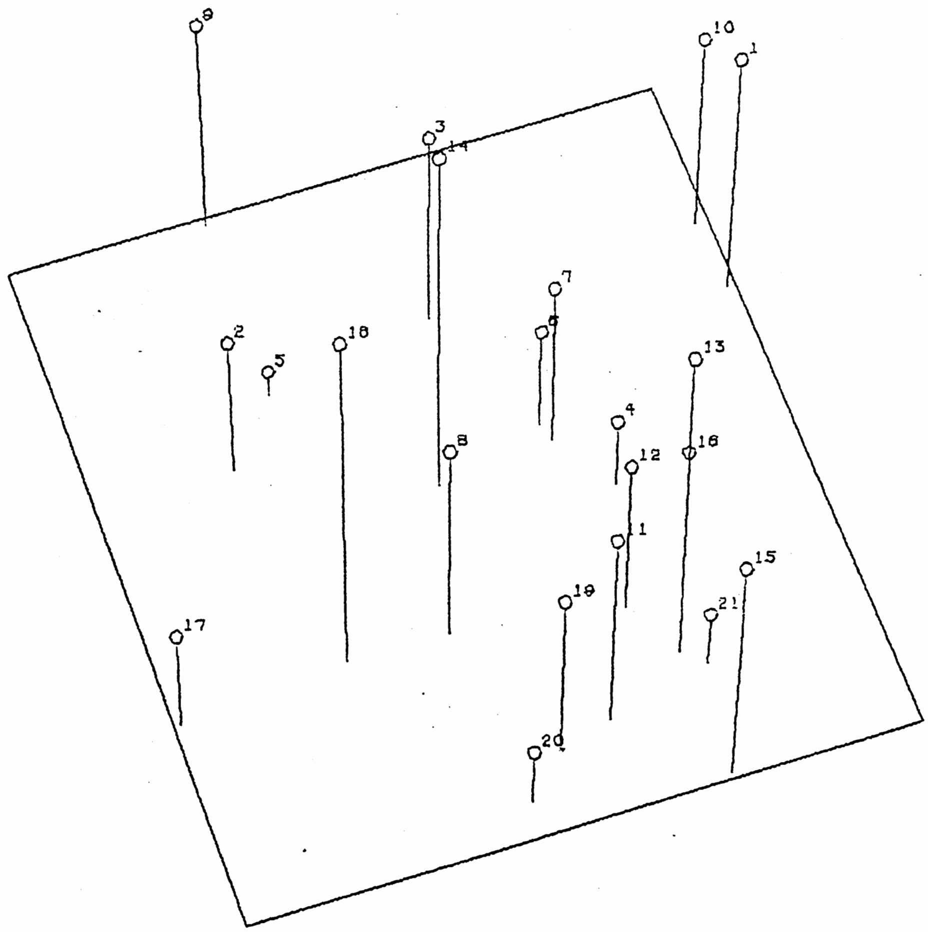
FACTOR LOADINGS, PCA OF *A. FARINOSA*, *A. LUTEA*, AND *A. LUTEA* FORMA *ALBA*

Character	Factor 1	Factor 2	Factor 3
Leaf Length	0.099	-0.742	0.207
Leaf Width, Top ¼	-0.047	-0.181	0.785
Leaf Width, Midpoint	0.169	-0.239	0.786
Leaf Width, Bottom ¼	-0.366	-0.573	0.220
Leaf Nerve Number	-0.033	-0.440	0.079
Scape Length	0.576	-0.157	0.197
Bract Number	0.522	-0.441	-0.130
Bract Length	0.050	-0.161	-0.124
Scape Diameter	0.208	-0.699	0.339
Raceme Length	0.219	-0.571	0.596
Flower Number	0.015	-0.683	0.386
Capsule Body Length	0.664	0.186	-0.045
Capsule Beak Length	-0.534	-0.353	-0.211
Flower Length	0.140	0.341	0.285
Flower Width, Top	0.216	0.317	0.428
Flower Width, Top ¼	-0.762	0.450	0.236
Flower Width, Midpoint	-0.911	0.124	0.164
Flower Width, Bottom ¼	-0.858	0.187	0.288
% Perianth Adherent	0.107	-0.292	-0.548
% Ovary Adherent	-0.416	-0.431	-0.439
Anther Length	0.545	-0.170	-0.141
Anther Width, Base	0.378	-0.217	-0.541
Anther Width, Midpoint	0.088	-0.341	-0.427
Anther Width, Top	-0.463	-0.289	0.038
Leaf Index	0.015	-0.388	-0.518
Width Index	0.351	0.347	0.588
Raceme Index	-0.042	-0.407	0.572
Inflorescence Index	-0.176	-0.429	-0.112
Capsule Index	-0.734	-0.379	-0.146
Flower Index	0.903	0.028	-0.037
Lobe Index	0.817	-0.146	0.101
Constriction Index	0.210	0.649	0.159
Anther Index	0.624	0.047	0.138
Anther Base Index	0.295	0.070	-0.139
Anther Apex Index	0.418	0.050	-0.301



1-10=A. farinosa 11-20=A. lutea 21=A. lutea froma alba

Figure 24. Principal Components Analysis of *Aletris farinosa*, *A. lutea*, and *A. lutea* forma *alba*, View I



1-10=A. farinosa 11-20=A. lutea 21=A. lutea forma alba

Figure 25. Principal Components Analysis of *Aletris farinosa*, *A. lutea*, and *A. lutea* forma *alba*, View II

as a white color form of A. lutea can be justified. This conclusion, however, is based on a sample of relatively small size and further study is warranted, especially of the original population

Aletris aurea x Aletris farinosa

Two of the specimens examined were labelled "Aletris aurea x farinosa" and were collected in areas where hybridization is possible. These two separate accessions, eleven years apart, were from what appears to be the same locality in Prince George County, Virginia. Label information for the two is as follows:

> N.Y. Prince George County, Virginia. Bog south end of Petersburg, Virginia. June 10, 1927. E.T. Wherry [no accession number]

> GH. Prince George County, Virginia. Flowers burnt orange or saffron-color. Argillaceous and siliceous boggy depressions, about three miles southeast of Petersburg, at head of Poo Run. June 19, 1936. M.L. Fernald, Bayard Long, and R.F. Smart 5720.

The 1927 Wherry accession was described in a note packet as the "Only one found, in colony of 1,000,000 A. farinosa and 1000 A. aurea (not yet in bloom)." Fernald's (1937) description of his collection indicates his opinion that the plant was indeed a hybrid:

> After a long-delayed lunch we were taken by Smart to a really wet portion of the bog, an area of inundated muddy swale and thicket. . .; and in one pastured corner of the swale, where Aletris aurea and A. farinosa comingled, two plants with flowers combining their distinctive traits and of a peculiar dull- or pinkish-orange color were evidently of hybrid origin. Luckily the cows had not eaten them! (p.328)

The plants collected by Wherry and Fernald may indeed be hybrids of A. aurea and A. farinosa, or they may be plants of A. lutea at the northern extreme of the species, or they may be aberrant pinkish-orange forms of A. farinosa.

In an attempt to classify these specimens, they were measured for the set of 35 characters. These values were then scored (+/-) for whether they were intermediate to the mean values for each putative parent and whether they were near to the mean value for A. lutea. This procedure had limited value since A. lutea is intermediate to A. farinosa and A. aurea in 43% of the morphological characters measured. Nevertheless, it was possible to score for those values that fulfilled one criterion only. Forty-three percent of the time, the values for the putative hybrid were either (1) both intermediate to A. farinosa and A. aurea and near to A. lutea or (2) larger or smaller than A. farinosa, A. aurea, and A. lutea. Twenty-six percent of the values were intermediate to A. farinosa and A. aurea and not near to values of A. lutea. Thirty-one percent of the values were near to A. lutea and not intermediate to A. aurea and A. farinosa.

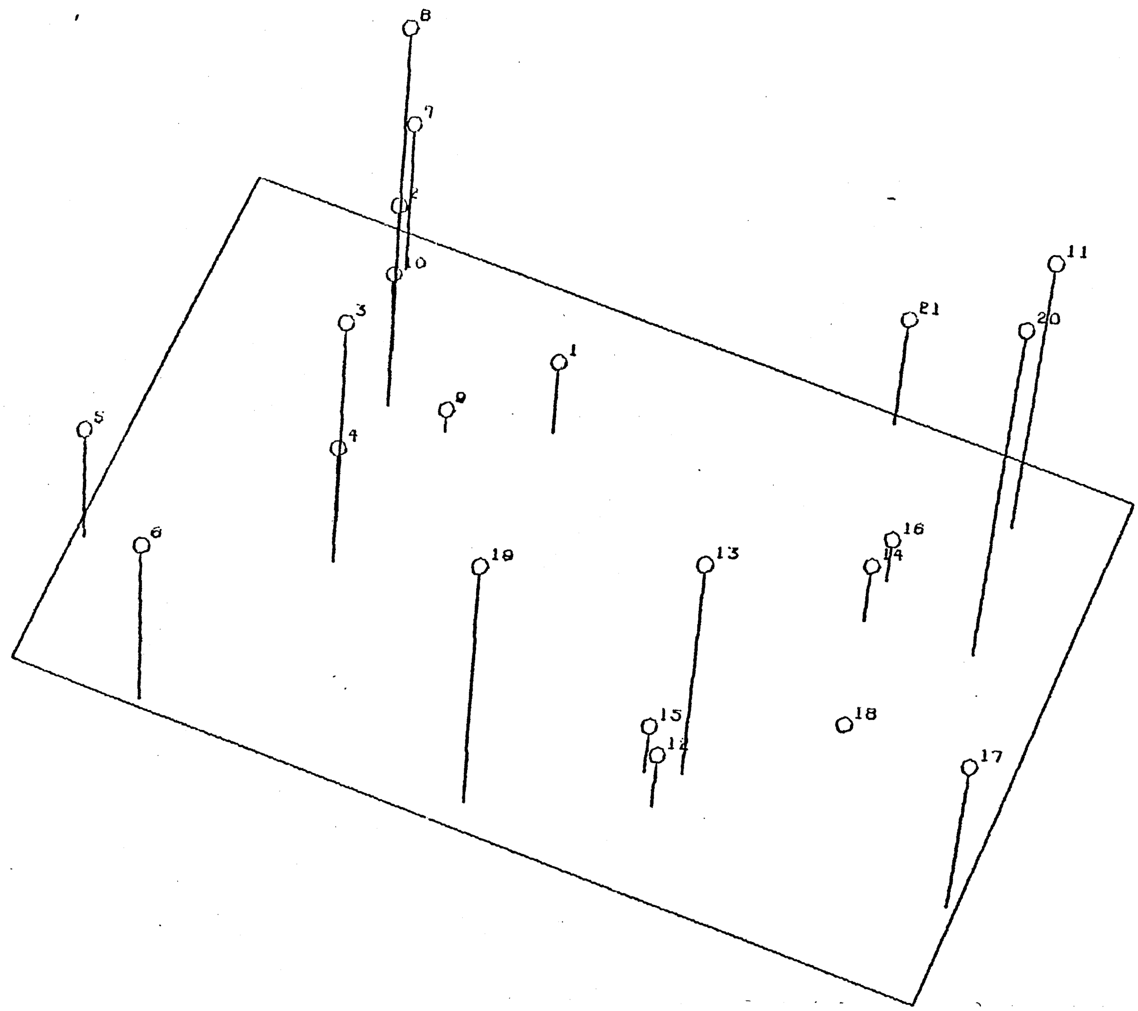
In an attempt to further elucidate this A. aurea-A. farinosa-unknown relationship, principal components analysis was performed on a sample from the Coastal Plain of 10 A. aurea, 10 A. farinosa and the unknown (21 OTU's). Nine latent vectors with a value greater than one were extracted accounting for 90% of the trace. The first three factors, however, accounted for only 55% of the trace. Factor loadings are presented in Table XII.

As can be seen in Figures 30 and 31, A. aurea (1-10) and A. farinosa (11-20) are separated from each other, but are highly variable. The unknown plant (21) is nearer to A. farinosa, but at the extreme. An additional PCA including ten OTU's of A. lutea would be useful, to see if the unknown segregates with A. lutea.

TABLE XII

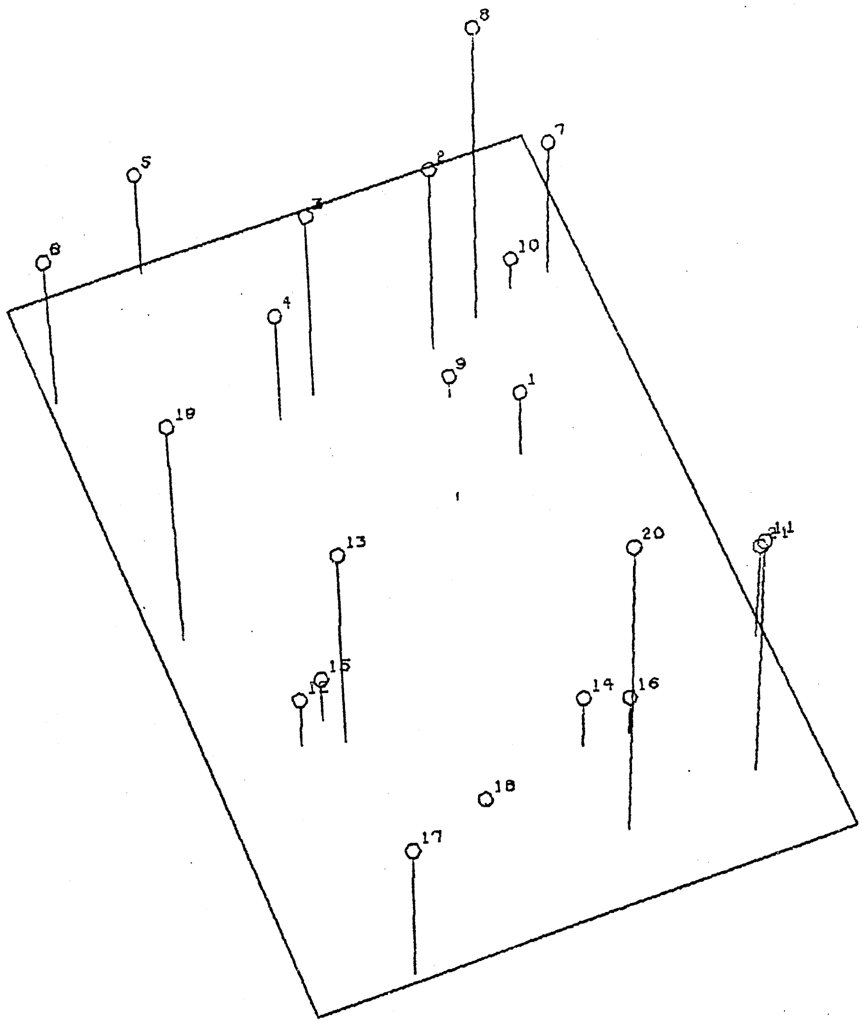
FACTOR LOADINGS, PCA OF A. AUREA, A. FARINOSA, AND PUTATIVE HYBRID

Character	Factor 1	Factor 2	Factor 3
Leaf Length	0.779	-0.240	0.158
Leaf Width, Top ¼	0.059	-0.579	0.330
Leaf Width, Midpoint	-0.166	-0.809	0.385
Leaf Width, Bottom ¼	0.103	-0.712	0.458
Leaf Nerve Number	0.086	-0.392	0.212
Scape Length	0.065	-0.230	-0.179
Bract Number	-0.205	-0.550	0.086
Bract Length	0.187	-0.218	-0.250
Scape Diameter	0.722	-0.412	0.280
Raceme Length	0.467	-0.145	0.612
Flower Number	0.671	-0.117	0.511
Capsule Body Length	0.299	-0.247	-0.282
Capsule Beak Length	0.926	0.137	0.051
Flower Length	0.802	0.091	-0.025
Flower Width, Top	-0.186	0.233	0.039
Flower Width, Top ¼	-0.797	0.301	0.408
Flower Width, Midpoint	-0.543	0.378	0.685
Flower Width, Bottom ¼	-0.045	0.502	0.698
% Perianth Adherent	0.683	-0.121	-0.165
% Ovary Adherent	0.474	-0.039	0.331
Anther Length	0.236	-0.675	-0.329
Anther Width, Base	-0.726	-0.473	-0.126
Anther Width, Midpoint	-0.740	-0.521	-0.008
Anther Width, Top	-0.396	-0.352	-0.049
Leaf Index	0.776	0.322	-0.071
Width Index	-0.120	0.465	-0.114
Raceme Index	0.390	-0.003	0.654
Inflorescence Index	0.593	-0.058	0.186
Capsule Index	0.858	0.185	0.171
Flower Index	0.806	-0.206	-0.468
Lobe Index	0.562	-0.085	-0.421
Constriction Index	-0.747	-0.076	-0.241
Anther Index	0.871	0.084	-0.220
Anther Base Index	0.135	0.197	-0.160
Anther Apex Index	-0.468	-0.214	0.028



1-10=A. aurea 11-20=A. farinosa 21=Unknown

Figure 26. Principal Components Analysis of *Aletris aurea*, *A. farinosa*, and Putative Hybrid, View I



1-10=A. aurea 11-20=A. farinosa 21=Unknown

Figure 27. Principal Components Analysis of Aletris aurea, A. farinosa, and Putative Hybrid, View II

However, as the previous PCA of *A. farinosa* and *A. lutea* showed (Figures 28-29), the two species are not readily distinguishable.

On the basis of the morphological measurements, and the fact that OTU 21 is at the very extreme of the *A. farinosa* group, it appears likely that the plant in question is either *A. lutea* or an aberrant color form of *A. farinosa*, and not a hybrid of *A.* farinosa and *A. aurea*.

Aletris lutea is reported by Fernald (1950) to occur as far north as southeastern Virginia; however, Fernald's statement that *A. lutea* is "presumably a hybrid" of *A. farinosa* and *A. aurea* may be based on his collection in Petersburg, Virginia. Geographical information collected in this study sets the northernmost limit for *A. lutea* at South Carolina.

Two accessions of *A. farinosa* from the northeastern United States Coastal Plain had label notations of pinkish- or cream-colored perianths:

> NY. Nantucket, Mass. Polpis, Nantucket Island, Mass. Amongst ericaceous shrubs, dry soil. Cream colored. Plants from Siasconset have pinkish flowers! June 28, 1961. Frank C. Mackeever 528.

> NY. Nantucket, Mass. Siasconset, Nantucket Island, Mass. Old, dry bog. All flowers in this colony--'pinkish'--color lost in drying. July 23, 1961. Frank C. MacKeever 536.

No species other than *A. farinosa* have been reported from Massachusettes; therefore, these specimens which were identified as *A. farinosa* are probably aberrant color forms. The occurrence of color forms of *A. farinosa* in the northeastern Coastal Plain supports the possibility of Wherry's and Fernald's collections being *A. farinosa*.

Aletris bracteata

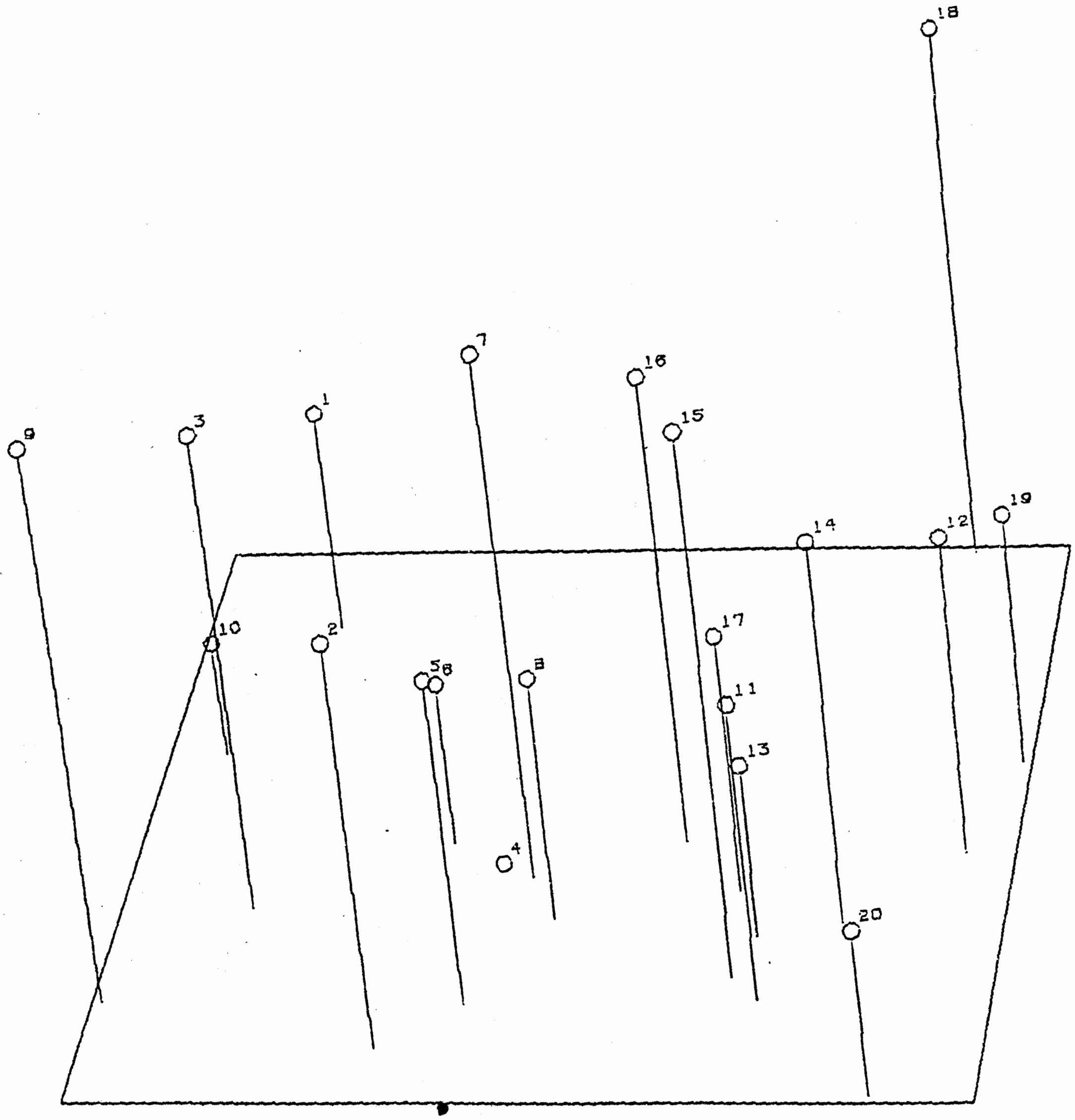
Cursory examination of *A. bracteata* and *A. farinosa* reveals a morphological similarity, and as PCA of mean values showed (Chapter V), separation of the *farinosa-bracteata* complex was tenuous and based on few characters. The distributions of the two species are widely disjunct, with *A. farinosa* not even occurring in Florida and *A. bracteata* only extending into Florida as far north as southern Dade County. Morphologically they have been separated by the longer and narrower grayish-green leaves of *A. bracteata* and by *A. bracteata*'s broader flattened style (Northrop, 1902). Small (1933) describes *A. bracteata* as having a less granular perianth and more conic capsule body. As mentioned previously, the chromosome number for *A. bracteata* is unknown. Without the disjunct distribution, separation of the two species would be difficult.

Principal components analysis was performed on 20 OTU's--10 *A. farinosa* and 10 *A. bracteata*. Figures 28 and 29 show that there is a slight degree of separation. Characters in the first factor with loadings greater than 0.6 were beak length, width index, capsule index, flower length, flower width at top one-fourth, flower width at midpoint, flower width at bottom one-fourth, and flower index (Table XIII). Width index differences corroborate Northrop's description of *A. bracteata* having a narrower leaf. The beak is broader and flat, and mean values for beak length suggest that it is also shorter. The flowers of *A. bracteata* measured in this study were smaller overall, but have the cylindric shape typical of *A. farinosa*.

TABLE XIII

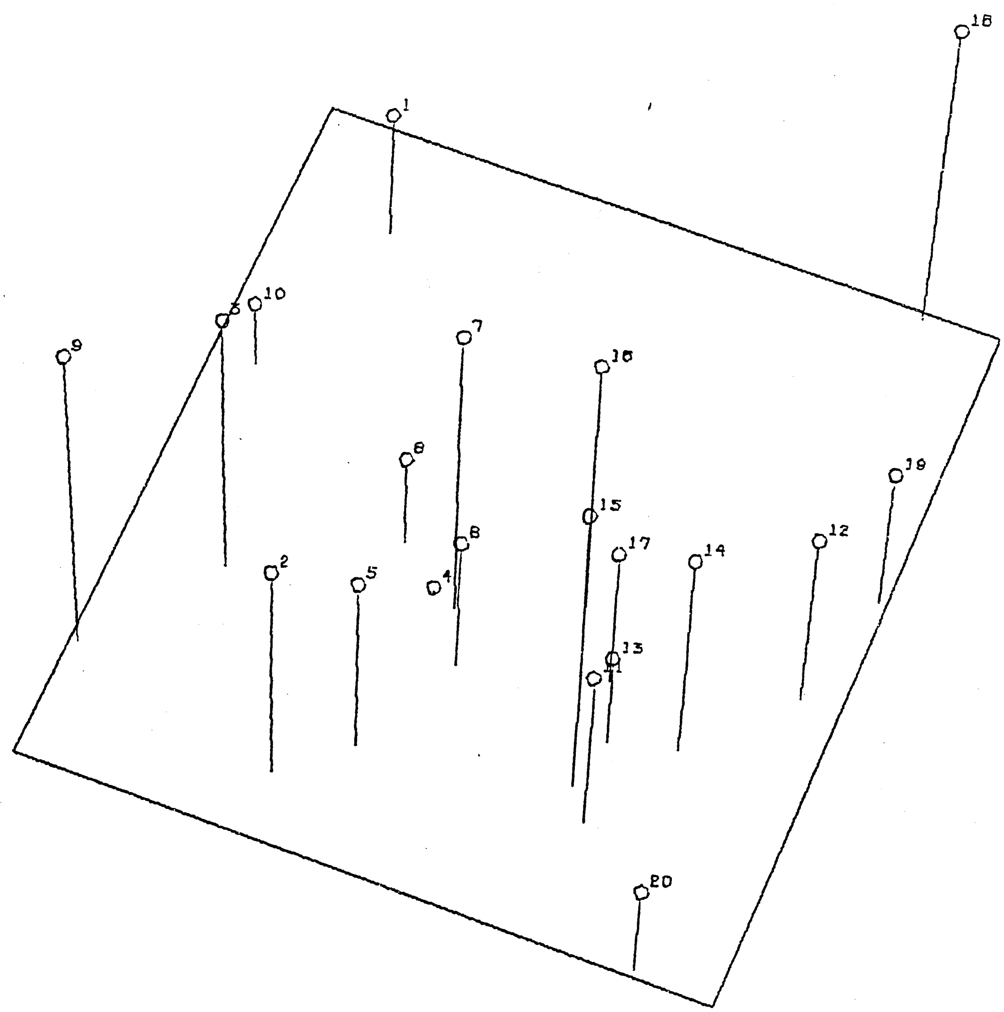
FACTOR LOADINGS, PCA OF *A. farinosa* AND *A. bracteata*

Character	Factor 1	Factor 2	Factor 3
Leaf Length	0.277	-0.663	0.304
Leaf Width, Top ¼	-0.742	-0.420	-0.188
Leaf Width, Midpoint	-0.562	-0.458	-0.276
Leaf Width, Bottom ¼	-0.368	-0.718	-0.351
Leaf Nerve Number	-0.583	-0.388	-0.279
Scape Length	0.185	-0.469	0.585
Bract Number	-0.267	-0.569	-0.173
Bract Length	-0.004	-0.566	0.451
Scape Diameter	-0.279	-0.758	0.083
Raceme Length	0.176	-0.803	0.352
Flower Number	-0.234	-0.677	0.000
Capsule Body Length	0.154	0.491	0.275
Capsule Beak Length	-0.824	-0.024	-0.062
Flower Length	-0.647	0.008	-0.045
Flower Width, Top	-0.324	0.677	0.057
Flower Width, Top ¼	-0.682	0.348	0.487
Flower Width, Midpoint	-0.827	0.185	0.371
Flower Width, Bottom ¼	-0.868	0.170	0.329
% Perianth Adherent	0.426	-0.228	0.139
% Ovary Adherent	-0.105	-0.009	0.092
Anther Length	-0.052	-0.075	-0.716
Anther Width, Base	0.449	-0.167	-0.433
Anther Width, Midpoint	0.032	-0.385	-0.292
Anther Width, Top	-0.349	-0.464	-0.051
Leaf Index	0.585	-0.102	0.456
Width Index	-0.611	0.234	0.238
Raceme Index	0.351	-0.531	0.168
Inflorescence Index	-0.440	-0.132	-0.378
Capsule Index	-0.821	0.194	-0.228
Flower Index	0.607	-0.208	-0.392
Lobe Index	0.433	0.242	-0.507
Constriction Index	0.080	0.537	0.420
Anther Index	-0.047	0.290	-0.346
Anther Base Index	0.323	0.292	0.062
Anther Apex Index	0.408	0.242	-0.171



1-10=A. farinosa 11-20=A. bracteata

Figure 28. Principal Components Analysis of Aletris farinosa and Aletris bracteata, View I



1-10=A. farinosa 11-20=A. bracteata

Figure 29. Principal Components Analysis of Aletris farinosa and Aletris bracteata, View II

Characters in the second factor with loadings greater than 0.6 were leaf length, leaf width at bottom one-fourth, scape diameter, raceme length, number of flowers per raceme, and flower width at top. A. bracteata's leaves are supposedly longer than A. farinosa's according to Northrop (1902), but the mean value for the sample of A. bracteata measured was shorter. Smaller values for scape diameter, raceme length, and number of flowers for A. bracteata could be attributed to less robust plants that happened to be sampled or to a species difference. Leaf width at the bottom one-fourth and flower width at top were characters in the third factor with high loadings, and they follow the trend of their counterparts in factor 1.

Long and Lakela of the University of South Florida do not separate A. farinosa and A. bracteata (Browne, personal communication), but these results would indicate that A. farinosa and A. bracteata should, at least tentatively, continue to be regarded as distinct taxa.

Long-Pedicelled Forms

Eight of the specimens examined had exceedingly long pedicels and/or secondary branching of the inflorescence:

NY. Aletris farinosa. Berks, Co., Pennsylvania. Scarlets Mill. September 13, 1916. Francis W. Pennell 8817.

NY. Aletris farinosa. Clifton, New Jersey. July 9, 1890. George V. Nash 1182.

GH. Aletris farinosa. Vineland, New Jersey. 1878. Miss Mary ___?___ [no accession number].

NY. Aletris farinosa. Morris County, New Jersey. Succasumua [?], New Jersey. July 15, 1910. R.C. Benedict [no accession number].

GH. *Aletris farinosa*. Nansemond County, Virginia. Dry, sandy woods and adjacent clearings, Kilby. September 11, 1935. M.L. Fernald, Bayard Long, and J.M. Fogg, Jr. 4845

US 327618. *Aletris farinosa*. Orange County, North Carolina. Collected near Chapel Hill. [no date] W.W. Ashe [no accession number].

NCSC 67164. *Aletris farinosa*. Orange County, North Carolina. Drive at airport, near house. Exact location unknown. Chapel Hill. May 29, 1966. David M. Dumond 138.

NY. *Aletris aurea*. (flor. racemis compos) Apalachicola, Florida. [no date, collector, or accession number].

None of these long-pedicelled forms were included in the samples measured; however, they were examined during the annotation process and appear to be aberrant *A. farinosa* except for the last specimen cited. The specimen from Apalachicola (Franklin County), Florida appears to be a hybrid of *A. lutea* and *A. obovata* and was so annotated. Both *A. lutea* and *A. obovata* occur in Franklin County, so hybridization is possible although no other specimens of hybrids were encountered from that county.

CHAPTER IX

CONCLUSIONS AND REMARKS

Various techniques of univariate and multivariate analyses reveal *Aletris* to be a rather homogeneous genus, with differentiation of species based mainly on perianth color, gross perianth shape, capsule attributes, and geographic location. The species, as recognized, appear to be appropriate, but considerable variation exists within each species; and some overlap occurs between the taxa. Care must be taken to identify any unknown plant on the basis of as many characters as available.

Aletris farinosa is the most wide-ranging of the species; and, in the Coastal Plain, exhibits variability in pedicel length, branching of the inflorescence, and perianth color. Areas of sympatry exist for *A. farinosa* with *A. obovata*, *A. lutea*, and *A. aurea*. Hybridization of *A. farinosa* with any of these three species is possible; therefore a biosystematic study of their inter-relationships would be valuable. PCA of *A. farinosa* and *A. bracteata* reveals their integrity morphologically; however classification is best accomplished by relying on the geographic location of any unknown plant. *Aletris lutea* is best distinguished from *A. farinosa* by its yellow perianth color; however PCA upholds the designation of a white form of *A. lutea*, so perianth color is not totally reliable. *Aletris lutea*'s capsule body gradually narrowed into a beak (Small, 1933) shows considerable variation, as does *A. farinosa*'s capsule body abruptly narrowed into a long slender beak. The replacement by *A. lutea* of *A. farinosa* in southern Georgia and Florida and their morphological similarity could indicate their close relationship. Merging the two species may be warranted.

Aletris aurea has the second-largest area of distribution, occurring primarily in the Coastal Plain. This species is morphologically distinct, and results of PCA indicate that it is not very closely related to the other species. Hybridization between *A. aurea* and *A. farinosa* appears to be unlikely.

Aletris obovata and *A. lutea* hybridize, and fertility is high (Sullivan, 1973). Hybridization between *A. farinosa* and *A. obovata* is here postulated because of the gradation of perianth shapes observed in specimens from areas in southern Georgia where the two species are sympatric. Indeed, if *A. lutea* and *A. farinosa* are close enough to merged, hybridization between *A. obovata* and *A. farinosa* would be expected.

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APPENDIX A

SIMPLE STATISTICS OF SAMPLES

APPALACHIAN HIGHLANDS

Aletris aurea

Variable	Units	N	Mean	St.D.	S.E.	Var.	C.V.
LL	mm	5	69.2	29.6	13.2	876.7	42.8
LA	mm	5	7.2	1.1	0.5	1.3	15.4
LM	mm	5	9.8	2.3	1.0	5.2	23.3
LC	mm	5	7.0	2.0	0.9	4.0	28.6
NERVE		5	7.2	1.3	0.6	1.7	18.1
SL	cm	5	60.3	20.8	9.3	430.9	34.4
BR		4	14.0	7.6	3.8	57.3	54.1
BRL	mm	3	14.0	5.3	3.1	28.0	37.8
D	mm	5	2.0	0.6	0.3	0.4	32.8
RAC	cm	5	11.5	7.3	3.2	52.6	62.9
FLS		5	31.0	9.4	4.2	88.0	30.3
BODY	mm	2	3.3	0.4	0.3	0.1	10.9
BEAK	mm	2	2.6	0.6	2.1	0.4	25.0
FL	mm	3	5.9	1.0	0.6	1.1	17.5
FT	mm	3	2.8	0.6	0.4	0.4	22.3
FA	mm	3	3.3	0.8	0.4	0.6	22.9
FM	mm	3	3.3	0.6	0.4	0.4	19.7
FC	mm	3	2.8	0.3	0.1	0.1	9.1
EPIGF		2	18.4	2.3	1.7	5.4	12.7
EPIGC		2	29.5	4.0	2.9	16.2	13.7
AL	Eyepiece Micrometer Units*	5	9.8	2.2	1.0	4.7	22.1
AWB		5	5.8	1.3	0.6	1.7	22.5
AWM		5	6.2	0.4	0.2	0.2	7.2
AWT		5	4.2	0.4	0.2	0.2	10.6
LI		5	7.3	3.2	1.4	10.0	43.0
WI		5	1.1	0.2	0.1	0.1	22.5
RI		5	0.2	0.1	0.0	0.0	32.8
INFLI		5	3.2	1.3	0.5	1.5	37.5
CI		2	0.8	0.1	0.1	0.0	14.3
FLI		3	1.8	0.2	0.1	0.0	9.6
LOBEI		3	0.8	0.1	0.1	0.0	11.4
CONI		3	1.0	0.1	0.1	0.0	13.5
AI		5	1.6	0.4	0.2	0.2	25.6
ABI		5	0.9	0.2	0.1	0.1	25.5
AAI		5	1.5	0.2	0.1	0.0	13.1

Percent Hyaline Margin: 100

* 0.08 mm/ unit

COASTAL PLAIN

<u>Aletris aurea</u>

Variable	Units	N	Mean	St.D.	S.E.	Var.	C.V.
LL	mm	30	70.0	21.7	4.0	470.4	31.0
LA	mm	30	9.4	3.9	0.7	15.1	41.3
LM	mm	30	11.1	3.5	0.6	12.5	31.9
LC	mm	30	7.3	2.6	0.5	6.8	35.8
NERVE		30	7.8	1.5	0.3	2.2	18.9
SL	cm	30	65.1	12.8	2.3	164.4	19.7
BR		28	10.7	3.9	0.7	14.9	36.0
BRL	mm	21	16.0	6.4	1.4	41.5	40.4
D	mm	29	2.1	0.6	0.1	0.4	31.2
RAC	cm	30	16.0	7.3	1.3	52.6	45.2
FLS		30	42.0	16.9	3.1	285.6	40.3
BODY	mm	15	3.6	0.4	0.1	0.1	9.9
BEAK	mm	15	2.2	0.3	0.1	0.1	14.3
FL	mm	15	6.0	0.5	0.1	0.3	9.0
FT	mm	15	3.9	0.7	0.2	0.5	18.3
FA	mm	15	3.7	0.5	0.1	0.3	14.6
FM	mm	15	3.5	0.6	0.1	0.3	16.3
FC	mm	15	2.9	0.6	0.2	0.4	22.5
EPIGF		19	13.3	3.8	0.9	14.5	28.7
EPIGC		15	27.1	7.9	2.0	61.8	29.0
AL	Eyepiece	30	10.2	1.9	0.3	3.4	18.1
AWB	Micrometer	30	6.7	1.1	0.2	1.1	15.8
AWM	Units*	30	6.8	1.1	0.2	1.2	16.3
AWT		30	3.5	0.8	0.1	0.6	22.2
LI		30	6.6	2.3	0.4	5.4	35.2
WI		30	1.3	0.4	0.1	0.2	30.9
RI		30	0.2	0.1	0.0	0.0	30.3
INFLI		30	2.8	0.7	0.1	0.5	26.6
CI		15	0.6	0.1	0.0	0.0	15.6
FLI		15	1.8	0.3	0.1	0.1	18.0
LOBEI		15	1.0	0.2	0.0	0.0	17.9
CONI		15	1.1	0.1	0.0	0.0	7.5
AI		30	1.5	0.3	0.1	0.1	18.7
ABI		30	1.0	0.1	0.0	0.0	14.3
AAI		30	2.0	0.4	0.1	0.1	17.7

Percent Hyaline Margin: 93.3

* 0.08 mm/ unit

INTERIOR HIGHLANDS

Aletris aurea

Variable	Units	N	Mean	St.D.	S.E.	Var.	C.V.
LL	mm	2	38.0	8.5	6.0	72.0	22.3
LA	mm	2	8.5	3.5	2.5	12.5	41.6
LM	mm	2	11.0	1.4	1.0	2.0	12.9
LC	mm	2	6.0	0.0	0.0	0.0	0.0
NERVE		2	7.0	0.0	0.0	0.0	0.0
SL	cm	2	52.1	2.6	1.9	6.8	5.0
BR		1	6.0	-	-	-	-
BRL	mm	1	11.0	-	-	-	-
D	mm	2	1.9	0.1	0.1	0.0	3.8
RAC	cm	2	6.1	0.2	0.2	0.0	3.5
FLS		2	19.0	0.0	0.0	0.0	0.0
BODY	mm	1	3.0	-	-	-	-
BEAK	mm	1	2.1	-	-	-	-
FL	mm	1	6.0	-	-	-	-
FT	mm	1	2.0	-	-	-	-
FA	mm	1	2.6	-	-	-	-
FM	mm	1	3.0	-	-	-	-
FC	mm	1	2.6	-	-	-	-
EPIGF		2	14.3	0.0	0.0	0.0	0.0
EPIGC		2	29.2	5.9	4.2	34.4	20.1
AL	Eyepiece Micrometer Units*	2	10.5	0.7	0.5	0.5	6.7
AWB		2	8.0	0.0	0.0	0.0	0.0
AWM		2	7.0	0.0	0.0	0.0	0.0
AWT		2	4.0	0.0	0.0	0.0	0.0
LI		2	3.4	0.3	0.2	0.1	9.6
WI		2	1.4	0.4	0.4	0.3	41.6
RI		2	0.1	0.0	0.0	0.0	1.5
INFLI		2	3.1	0.1	0.1	0.0	3.5
CI		1	0.7	-	-	-	-
FLI		1	2.0	-	-	-	-
LOBEI		1	0.8	-	-	-	-
CONI		1	0.9	-	-	-	-
AI		2	1.5	0.1	0.1	0.0	6.7
ABI		2	1.1	0.0	0.0	0.0	0.0
AAI		2	1.8	0.0	0.0	0.0	0.0

Percent Hyaline Margin: 100

* 0.08 mm/ unit

COASTAL PLAIN

Aletris bracteata

Variable	Units	N	Mean	St.D.	S.E.	Var.	C.V.
LL	mm	28	108.4	39.0	7.4	1524.4	36.0
LA	mm	28	5.0	1.2	0.2	1.3	23.1
LM	mm	28	6.4	2.0	0.4	3.8	30.4
LC	mm	28	4.8	1.3	0.2	1.7	27.3
NERVE		28	6.1	0.8	0.2	0.7	13.8
SL	cm	28	58.7	15.7	3.0	245/5	26.7
BR		25	7.2	2.4	0.5	5.7	32.9
BRL	mm	24	16.7	11.7	2.4	136.6	69.9
D	mm	28	2.4	0.7	0.1	0.5	29.0
RAC	cm	28	16.5	8.3	1.6	68.1	49.9
FLS		28	62.1	28.6	5.4	817.0	46.1
BODY	mm	13	3.4	0.8	0.2	0.7	23.8
BEAK	mm	13	3.1	0.7	0.2	0.4	21.5
FL	mm	15	6.4	0.5	0.1	0.2	7.4
FT	mm	15	3.1	0.6	0.2	0.3	18.9
FA	mm	15	2.0	0.5	0.1	0.3	25.7
FM	mm	15	2.3	0.4	0.1	0.1	17.0
FC	mm	15	2.3	0.3	0.1	0.1	13.7
EPIGF		14	21.0	3.8	1.0	14.4	18.1
EPIGC		15	41.8	8.7	2.3	76.4	20.9
AL	Eyepiece	27	10.1	1.5	0.3	2.3	15.1
AWB	Micrometer	27	4.8	0.8	0.2	0.7	17.7
AWM	Units*	27	4.7	0.9	0.2	0.8	18.8
AWT		27	2.7	0.6	0.1	0.4	22.5
LI		28	17.5	0.7	1.3	44.8	38.3
WI		28	1.1	0.2	0.0	0.0	18.5
RI		28	0.3	0.1	0.0	0.0	29.0
INFLI		28	3.9	1.1	0.2	1.1	27.1
CI		13	1.0	0.3	0.1	0.1	31.4
FLI		15	2.9	0.5	0.1	0.2	17.2
LOBEI		15	1.6	0.4	0.1	0.2	25.7
CONI		15	0.9	0.1	0.0	0.0	16.3
AI		27	2.2	0.5	0.1	0.3	23.1
ABI		27	1.0	0.2	0.0	0.0	19.3
AAI		27	1.8	0.5	0.1	0.2	26.4

Percent Hyaline Margin: 68.0

* 0.08 mm/ unit

APPALACHIAN HIGHLANDS

Aletris farinosa

Variable	Units	N	Mean	St.D.	S.E.	Var.	C.V.
LL	mm	29	115.6	33.3	0.2	1106.4	28.8
LA	mm	29	9.4	3.0	0.6	9.0	31.7
LM	mm	29	9.6	2.1	0.4	4.4	21.9
LC	mm	29	5.8	1.9	0.3	3.4	31.8
NERVE		28	8.0	1.6	0.3	2.7	20.5
SL	cm	29	71.3	12.7	2.4	161.3	17.8
BR		24	8.1	3.3	0.7	11.1	41.3
BRL	mm	24	16.1	5.7	1.2	32.5	35.4
D	mm	29	2.6	0.6	0.1	0.3	22.1
RAC	cm	29	17.7	5.5	1.0	30.7	31.3
FLS		29	70.2	23.5	4.4	549.0	33.4
BODY	mm	14	3.6	0.5	0.1	0.3	14.4
BEAK	mm	14	3.8	0.5	0.1	0.3	14.4
FL	mm	15	6.9	0.9	0.2	0.7	12.5
FT	mm	15	3.6	0.9	0.2	0.8	24.8
FA	mm	15	2.2	0.3	0.1	0.1	15.8
FM	mm	15	2.7	0.5	0.1	0.3	20.0
FC	mm	15	2.4	0.4	0.1	0.2	17.6
EPIGF		19	22.1	6.3	1.4	39.9	28.6
EPIGC		18	44.0	11.9	2.8	141.7	27.1
AL	Eyepiece Micrometer Units*	29	10.1	1.5	0.3	2.3	15.0
AWB		29	3.9	0.8	0.1	0.6	20.3
AWM		29	4.0	0.7	0.1	0.5	17.7
AWT		29	2.4	0.7	0.1	0.5	28.3
LI		29	12.3	3.7	0.7	13.5	29.8
WI		29	1.7	0.6	0.1	0.3	34.7
RI		29	0.2	0.1	0.0	0.0	22.4
INFLI		29	4.1	1.1	0.2	1.2	26.3
CI		14	1.1	0.3	0.1	0.1	26.2
FLI		15	2.6	0.4	0.1	0.2	14.7
LOBEI		15	1.7	0.4	0.1	0.2	25.2
CONI		15	0.8	0.1	0.0	0.0	15.9
AI		29	2.6	0.6	0.1	0.4	23.7
ABI		29	1.0	0.2	0.0	0.0	17.3
AAI		29	1.7	0.4	0.1	0.2	22.8

Percent Hyaline Margin: 86.2

* 0.08 mm/ unit

COASTAL PLAIN

Aletris farinosa

Variable	Units	N	Mean	St.D.	S.E.	Var.	C.V.
LL	mm	30	119.8	39.8	7.3	1586.9	33.3
LA	mm	30	10.3	3.8	0.7	14.8	37.4
LM	mm	30	10.2	3.3	0.6	10.7	32.2
LC	mm	30	6.2	1.9	0.3	3.6	30.7
NERVE		30	7.7	1.2	0.2	1.4	15.2
SL	cm	30	68.1	12.2	2.2	150.0	18.0
BR		23	7.8	3.0	0.6	9.2	38.7
BRL	mm	20	19.9	5.3	1.2	27.8	26.6
D	mm	30	2.8	0.8	0.1	0.6	27.2
RAC	cm	30	19.5	7.4	1.3	54.5	37.9
FLS		30	75.0	30.6	5.6	938.3	40.8
BODY	mm	15	3.6	0.5	0.1	0.2	13.5
BEAK	mm	15	4.4	0.7	0.2	0.5	15.6
FL	mm	15	7.2	0.7	0.2	0.5	9.3
FT	mm	15	3.7	0.8	0.2	0.6	20.9
FA	mm	15	2.6	0.7	0.2	0.4	24.8
FM	mm	15	2.9	0.6	0.2	0.4	21.5
FC	mm	15	2.8	0.6	0.1	0.3	20.2
EPIGF		26	19.8	3.8	0.7	14.6	19.3
EPIGC		20	42.3	8.1	1.8	65.7	19.2
AL	Eyepiece Micrometer Units*	29	10.7	2.0	0.4	4.2	19.1
AWB		30	4.4	0.7	0.1	0.5	16.5
AWM		30	4.6	0.8	0.1	0.7	17.5
AWT		30	3.1	0.7	0.1	0.5	21.7
LI		30	12.4	4.4	0.8	19.2	35.3
WI		30	1.7	0.5	0.1	0.2	28.9
RI		30	0.3	0.1	0.0	0.0	28.5
INFLI		30	4.0	1.2	0.2	1.4	29.9
CI		15	1.2	0.2	0.1	0.0	17.4
FLI		15	2.6	0.5	0.1	0.3	20.1
LOBEI		15	1.4	0.3	0.1	0.1	22.5
CONI		15	0.9	0.1	0.0	0.0	10.4
AI		29	2.3	0.4	0.1	0.2	18.2
ABI		30	1.0	0.2	0.0	0.0	20.9
AAI		30	1.5	0.3	0.1	0.1	22.1

Percent Hyaline Margin: 83.3

* 0.08 mm/ unit

INTERIOR HIGHLANDS

Aletris farinosa

Variable	Units	N	Mean	St.D.	S.E.	Var.	C.V.
LL	mm	18	119.5	42.5	10.0	1806.3	35.6
LA	mm	18	7.9	2.4	0.6	5.9	30.7
LM	mm	18	9.1	2.5	0.6	6.3	27.7
LC	mm	18	5.6	1.9	0.4	3.5	33.6
NERVE		18	7.2	1.1	0.2	1.1	14.7
SL	cm	18	62.8	8.2	1.9	66.9	13.0
BR		16	6.0	2.3	0.6	5.3	38.5
BRL	mm	16	18.1	6.0	1.5	36.0	33.1
D	mm	18	2.5	0.4	0.1	0.2	16.8
RAC	cm	18	13.1	3.4	0.8	11.8	26.2
FLS		18	46.9	10.7	2.5	113.8	22.7
BODY	mm	9	3.7	0.7	0.2	0.5	18.6
BEAK	mm	9	4.3	0.4	0.1	0.1	9.0
FL	mm	9	7.8	1.1	0.4	1.3	14.6
FT	mm	9	3.1	0.8	0.3	0.7	26.3
FA	mm	9	2.3	0.5	0.2	0.3	23.4
FM	mm	9	2.9	0.5	0.2	0.3	17.8
FC	mm	9	2.6	0.4	0.1	0.2	15.7
EPIGF		11	20.7	3.8	1.1	14.2	18.2
EPIGC		12	46.5	5.3	1.5	28.4	11.5
AL	Eyepiece	17	10.0	1.5	0.4	2.3	15.0
AWB	Micrometer	17	4.8	0.8	0.2	0.7	17.4
AWM	Units*	17	4.6	0.7	0.2	0.5	15.1
AWT		17	3.1	0.6	0.1	0.3	18.2
LI		18	14.1	6.0	1.4	36.5	42.8
WI		18	1.5	0.4	0.1	0.2	29.9
RI		18	0.2	0.0	0.0	0.0	22.0
INFLI		18	3.7	0.9	0.2	0.8	24.3
CI		9	1.2	0.2	0.1	0.0	14.8
FLI		9	2.7	0.3	0.1	0.1	12.6
LOBEI		9	1.4	0.3	0.1	0.1	19.7
CONI		9	0.8	0.2	0.1	0.0	19.3
AI		17	2.2	0.4	0.1	0.1	17.0
ABI		17	1.0	0.2	0.0	0.0	15.2
AAI		17	1.6	0.3	0.8	0.1	20.3

Percent Hyaline Margin: 55.6

* 0.08 mm/ unit

INTERIOR PLAINS

Aletris farinosa

Variable	Units	N	Mean	St.D.	S.E.	Var.	C.V.
LL	mm	30	128.2	31.9	5.8	1019.3	24.9
LA	mm	30	10.1	2.6	0.5	7.0	26.2
LM	mm	30	10.5	3.1	0.6	9.4	29.1
LC	mm	30	6.5	2.0	0.4	4.2	31.6
NERVE		30	7.5	1.1	0.2	1.2	14.8
SL	cm	30	64.8	9.7	1.8	93.3	14.9
BR		26	8.6	3.5	0.7	12.2	40.5
BRL	mm	24	24.2	8.2	1.7	67.5	34.0
D	mm	30	2.5	0.5	0.1	0.2	19.3
RAC	cm	30	13.5	3.7	0.7	14.0	27.8
FLS		30	64.5	18.1	3.3	328.2	28.0
BODY	mm	15	3.3	0.4	0.1	0.2	12.5
BEAK	mm	15	3.6	0.4	0.1	0.2	12.5
FL	mm	15	6.9	1.1	0.3	1.2	15.7
FT	mm	15	2.9	0.6	0.2	0.4	20.6
FA	mm	15	2.3	0.4	0.1	0.2	17.9
FM	mm	15	2.6	0.5	0.1	0.3	19.7
FC	mm	15	2.6	0.6	0.1	0.3	21.5
EPIGF		25	18.4	4.2	0.8	17.9	23.0
EPIGC		26	40.5	9.2	1.8	85.5	22.8
AL	Eyepiece Micrometer Units*	29	10.4	1.3	0.2	1.7	12.7
AWB	Eyepiece Micrometer Units*	29	4.5	0.6	0.1	0.3	12.7
AWM	Eyepiece Micrometer Units*	29	4.4	0.6	0.1	0.3	12.8
AWT	Eyepiece Micrometer Units*	29	2.8	0.4	0.1	0.2	14.8
LI		30	13.2	5.0	0.9	25.2	38.0
WI		30	1.6	0.4	0.1	0.2	27.4
RI		30	0.2	0.0	0.0	0.0	21.8
INFLI		30	4.9	1.4	0.3	2.0	28.9
CI		15	1.1	0.2	0.0	0.0	16.7
FLI		15	2.8	0.5	0.1	0.3	19.1
LOBEI		15	1.3	0.4	0.1	0.2	30.5
CONI		15	0.9	0.1	0.0	0.0	14.0
AI		30	2.4	0.4	0.1	0.2	16.2
ABI		30	1.0	0.1	0.0	0.0	13.8
AAI		30	1.6	0.3	0.1	0.1	18.2

Percent Hyaline Margin: 60.0

* 0.08 mm/ unit

NEW ENGLAND

<u>*Aletris farinosa*</u>

Variable	Units	N	Mean	St.D.	S.E.	Var.	C.V.
LL	mm	30	127.5	37.6	6.9	1413.2	29.5
LA	mm	30	9.9	2.9	0.5	8.4	29.4
LM	mm	30	10.4	2.8	0.5	7.8	26.9
LC	mm	30	6.9	2.5	0.5	6.3	36.6
NERVE		30	9.2	2.0	0.4	4.2	22.2
SL	cm	30	71.4	12.4	2.3	153.2	17.3
BR		30	8.8	3.0	0.5	8.7	33.6
BRL	mm	21	25.2	10.1	2.2	101.4	40.0
D	mm	30	2.4	0.7	0.1	0.4	27.1
RAC	cm	30	16.8	5.6	1.0	31.7	33.6
FLS		30	67.3	19.9	3.6	394.8	29.5
BODY	mm	15	3.5	0.3	0.1	0.1	8.4
BEAK	mm	15	4.0	0.5	0.1	0.2	11.7
FL	mm	15	6.7	0.6	0.2	0.4	9.3
FT	mm	15	3.3	0.7	0.2	0.6	22.5
FA	mm	15	2.4	0.7	0.2	0.4	27.0
FM	mm	15	2.6	0.5	0.1	0.3	20.6
FC	mm	15	2.4	0.4	0.1	0.2	17.2
EPIGF		22	18.3	3.8	0.8	14.3	20.7
EPIGC		22	40.5	8.2	1.7	66.6	20.1
AL	Eyepiece Micrometer Units*	24	9.8	1.2	0.2	1.4	12.2
AWB	Eyepiece Micrometer Units*	24	3.8	1.0	0.2	1.0	25.8
AWM	Eyepiece Micrometer Units*	24	3.8	0.9	0.2	0.8	23.9
AWT	Eyepiece Micrometer Units*	24	2.4	0.7	0.1	0.4	27.1
LI		30	13.0	5.5	1.0	30.1	42.0
WI		30	1.5	0.4	0.1	0.2	26.8
RI		30	0.2	0.1	0.0	0.0	24.1
INFLI		30	4.2	1.2	0.2	1.4	27.9
CI		15	1.1	0.2	0.0	0.0	15.5
FLI		15	2.6	0.4	0.1	0.2	16.0
LOBEI		15	1.5	0.6	0.1	0.3	39.1
CONI		15	0.9	0.1	0.0	0.0	11.2
AI		24	2.7	0.6	0.1	0.4	22.7
ABI		24	1.0	0.2	0.0	0.0	16.7
AAI		24	1.6	0.3	0.1	0.1	20.5

Percent Hyaline Margin: 46.7

* 0.08 mm/ unit

COASTAL PLAIN

<u>Aletris lutea</u>

Variable	Units	N	Mean	St.D.	S.E.	Var.	C.V.
LL	mm	30	95.8	35.1	6.4	1230.0	36.6
LA	mm	30	7.0	2.8	0.5	7.8	39.8
LM	mm	30	9.6	3.4	0.6	11.7	35.5
LC	mm	30	4.3	1.3	0.2	1.7	30.1
NERVE		30	7.6	2.0	0.3	3.6	24.9
SL	cm	30	82.6	15.4	2.8	238.6	18.7
BR		25	10.2	2.3	0.5	5.2	22.3
BRL	mm	27	15.1	6.0	1.2	36.6	40.0
D	mm	30	3.2	0.8	0.1	0.6	23.7
RAC	cm	30	22.3	7.5	1.4	56.8	33.8
FLS		30	75.2	24.0	4.4	574.8	31.9
BODY	mm	15	4.7	0.9	0.2	0.7	18.2
BEAK	mm	15	3.8	0.7	0.2	0.5	19.4
FL	mm	15	7.9	0.6	0.2	0.4	7.6
FT	mm	15	4.0	1.0	0.3	1.0	24.5
FA	mm	15	2.4	0.7	0.2	0.4	27.1
FM	mm	15	2.6	0.6	0.2	0.3	23.1
FC	mm	15	2.6	0.5	0.1	0.3	19.7
EPIGF		18	16.5	3.6	0.9	13.3	22.0
EPIGC		18	30.0	9.4	2.2	87.9	31.2
AL	Eyepiece Micrometer Units*	30	13.8	2.3	0.4	5.2	16.6
AWB		30	4.7	0.9	0.2	0.8	19.2
AWM		30	4.7	0.8	0.1	0.6	16.9
AWT		30	2.5	0.6	0.1	0.4	25.4
LI		30	10.8	4.3	0.8	18.6	39.8
WI		30	1.7	0.6	0.1	0.3	33.9
RI		30	0.3	0.1	0.0	0.0	27.4
INFLI		30	3.4	0.6	0.1	0.3	17.0
CI		15	0.8	0.3	0.1	0.1	32.7
FLI		15	3.2	0.6	0.2	0.4	19.5
LOBEI		15	1.7	0.5	0.1	0.2	26.8
CONI		15	0.9	0.1	0.0	0.0	11.5
AI		30	3.0	0.6	0.1	0.4	20.0
ABI		30	1.0	0.2	0.0	0.0	19.5
AAI		30	2.0	0.5	0.1	0.2	25.0

Percent Hyaline Margin: 83.3

* 0.08 mm/ unit

COASTAL PLAIN

Aletris obovata

Variable	Units	N	Mean	St.D.	S.E.	Var.	C.V.
LL	mm	30	58.6	19.0	3.5	362.0	32.5
LA	mm	30	8.2	2.3	0.4	5.1	27.4
LM	mm	30	10.5	2.8	0.5	7.8	26.6
LC	mm	30	4.8	1.7	0.3	3.0	35.7
NERVE		30	7.1	1.1	0.2	1.1	15.0
SL	cm	30	68.5	15.9	2.9	252.0	23.2
BR		25	7.2	2.5	0.5	6.3	35.1
BRL	mm	24	8.2	3.0	0.6	8.8	36.2
D	mm	30	2.5	0.7	0.1	0.4	26.4
RAC	cm	30	23.1	9.2	1.7	84.0	39.7
FLS		30	56.2	24.2	4.4	587.0	43.1
BODY	mm	15	3.7	0.6	0.1	0.3	15.1
BEAK	mm	15	2.3	0.4	0.1	0.1	16.8
FL	mm	15	6.0	0.5	0.1	0.2	7.9
FT	mm	15	3.5	1.1	0.3	1.3	33.1
FA	mm	15	4.1	0.7	0.2	0.5	16.3
FM	mm	15	4.0	0.6	0.2	0.4	15.7
FC	mm	15	3.1	0.4	0.1	0.2	12.7
EPIGF		16	19.6	4.9	1.2	24.0	25.0
EPIGC		16	33.4	8.7	2.2	75.9	26.1
AL	Eyepiece Micrometer Units*	30	9.5	1.4	0.3	2.1	15.1
AWB		30	5.9	1.0	0.2	1.1	17.4
AWM		30	6.0	0.8	0.1	0.7	13.4
AWT		30	3.4	0.6	0.1	0.3	16.6
LI		30	5.8	1.9	0.4	3.7	33.3
WI		30	1.9	0.7	0.1	0.5	36.8
RI		39	0.3	0.1	0.0	0.0	24.6
INFLI		30	2.5	0.7	0.1	0.5	28.8
CI		15	0.6	0.1	0.0	0.0	22.4
FLI		15	1.6	0.2	0.1	0.1	16.0
LOBEI		15	0.8	0.2	0.1	0.0	24.0
CONI		15	1.1	0.1	0.0	0.0	11.9
AI		30	1.6	0.3	0.1	0.1	18.8
ABI		30	1.0	0.2	0.0	0.0	17.3
AAI		30	1.8	0.4	0.1	0.1	19.6

Percent Hyaline Margin: 96.7

* 0.08 mm/ unit

COASTAL PLAIN

<u>*Aletris lutea* x *obovata*</u>

Variable	Units	N	Mean	St.D.	S.E.	Var.	C.V.
LL	mm	13	78.8	24.0	6.6	574.4	30.4
LA	mm	13	7.1	2.1	0.6	4.6	30.2
LM	mm	13	9.8	2.3	0.6	5.5	23.8
LC	mm	13	4.5	1.7	0.5	2.9	37.8
NERVE		13	7.6	1.4	0.4	2.1	19.0
SL	cm	13	80.3	13.1	3.6	171.5	16.3
BR		13	7.8	2.6	0.7	6.9	33.7
BRL	mm	13	12.8	4.8	1.3	23.0	37.6
D	mm	13	3.0	0.4	0.1	0.2	13.1
RAC	cm	13	24.9	5.3	1.5	27.7	21.1
FLS		13	66.6	16.4	4.6	269.3	24.6
BODY	mm	6	4.8	1.5	0.6	2.1	30.5
BEAK	mm	6	2.5	0.8	0.3	0.6	31.8
FL	mm	7	7.7	1.2	0.4	1.4	15.2
FT	mm	7	4.5	1.0	0.4	0.9	21.4
FA	mm	7	3.6	1.1	0.4	1.3	31.4
FM	mm	7	3.7	1.0	0.4	1.0	27.1
FC	mm	7	3.1	0.7	0.3	0.5	21.9
EPIGF		7	18.5	4.2	1.6	17.4	22.6
EPIGC		7	34.0	13.7	5.2	187.5	40.3
AL	Eyepiece Micrometer Units*	13	12.0	1.9	0.5	3.5	15.6
AWB	Eyepiece Micrometer Units*	13	5.2	1.2	0.3	1.5	23.6
AWM	Eyepiece Micrometer Units*	13	5.8	0.6	0.2	0.4	10.4
AWT	Eyepiece Micrometer Units*	13	2.8	0.6	0.2	0.3	19.5
LI		13	8.5	3.6	1.0	13.2	42.9
WI		13	1.7	0.7	0.2	0.4	39.4
RI		13	0.3	0.0	0.0	0.0	14.8
INFLI		13	2.7	0.7	0.2	0.5	24.8
CI		6	0.6	0.3	0.1	0.1	49.4
FLI		7	2.2	0.7	0.3	0.5	30.7
LOBEI		7	1.3	0.4	0.2	0.2	33.4
CONI		7	1.0	0.1	0.0	0.0	12.5
AI		13	2.1	0.4	0.1	0.2	18.8
ABI		13	0.9	0.2	0.0	0.0	19.8
AAI		13	2.1	0.5	0.1	0.2	21.9

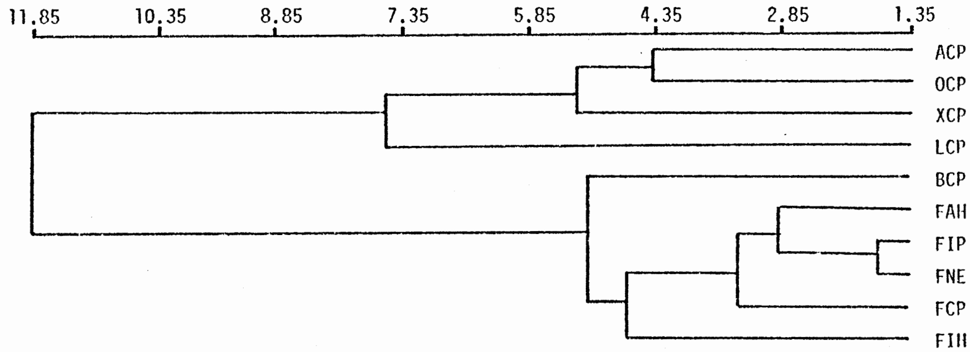
Percent Hyaline Margin: 92.3

* 0.08 mm/ unit

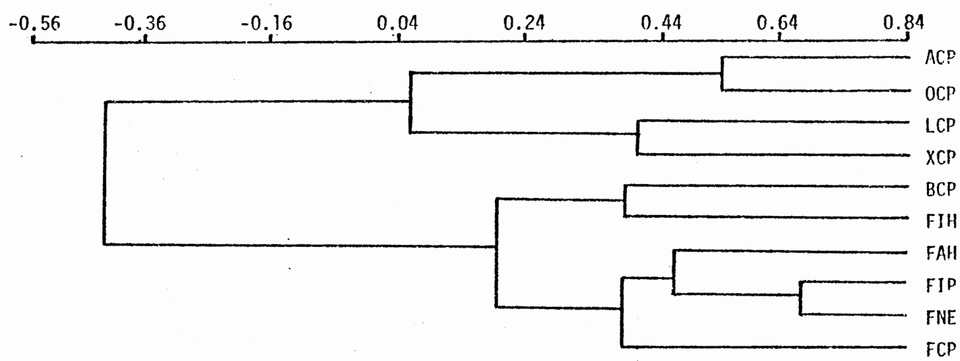
APPENDIX B

PHENOGRAMS OF VARIOUS

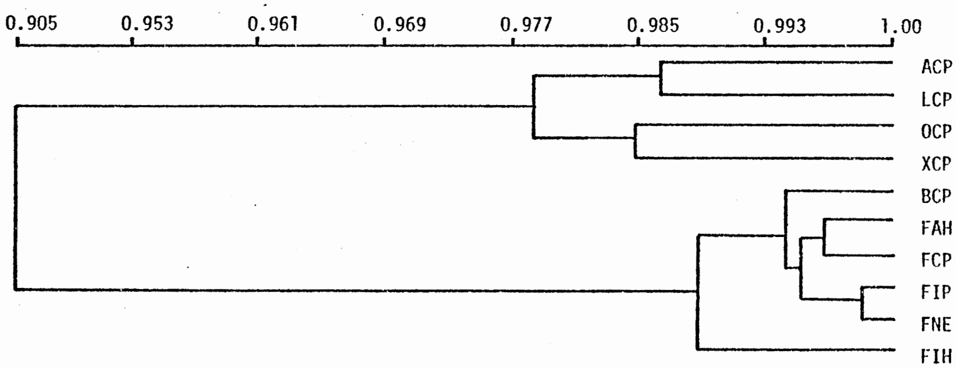
CLUSTERING METHODS



UPGMA, Distance Raw

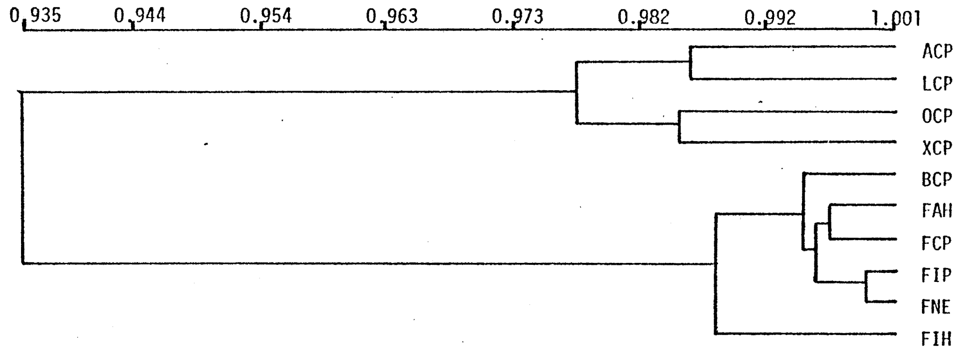


UPGMA, Correlation Standardized

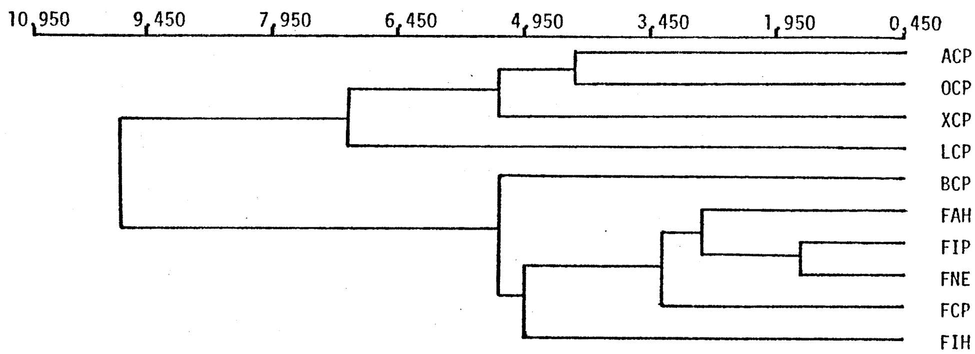


UPGMA, Correlation Raw

ACP: A. aurea, Coastal Plain
BCP: A. bracteata, Coastal Plain
LCP: A. lutea, Coastal Plain
OCP: A. obovata, Coastal Plain
XCP: A. lutea x obovata, Coastal Plain
FCP: A. farinosa, Coastal Plain
FAH: A. farinosa, App. Highlands
FIH: A. farinosa, Int. Highlands
FIP: A. farinosa, Int. Plains
FNE: A. farinosa, New England



WPGMA, Correlation Raw



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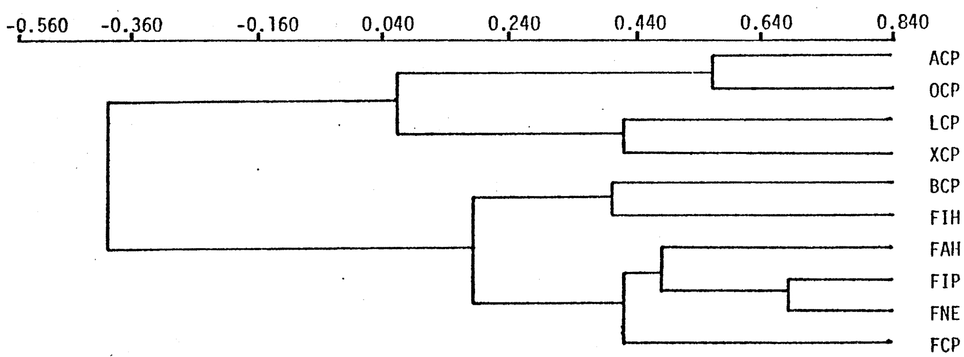

WPGMA, Correlation Standardized

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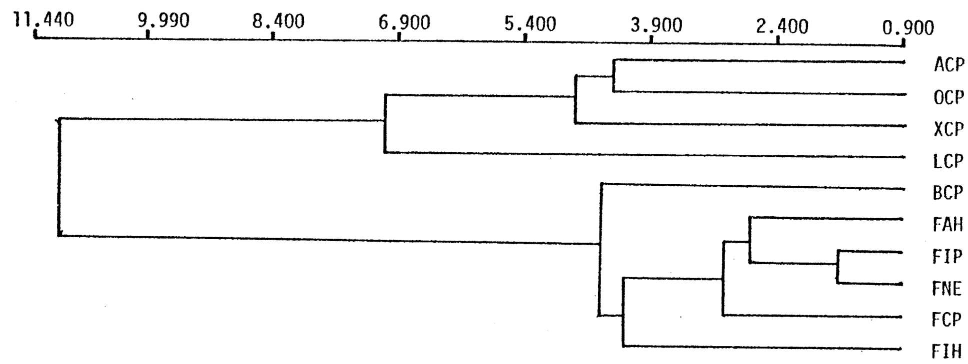
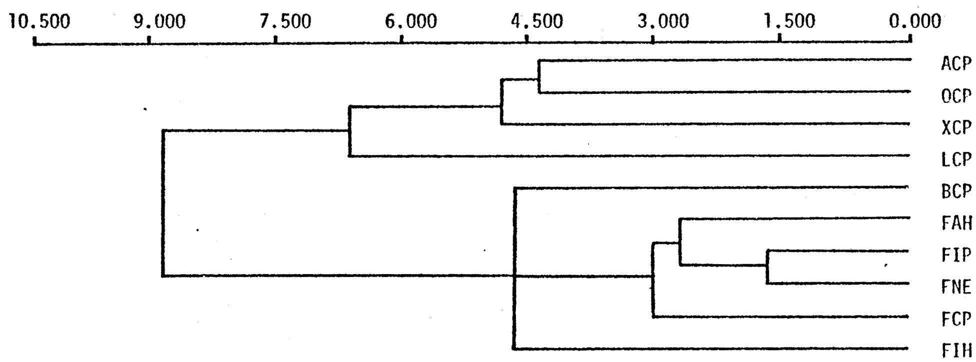
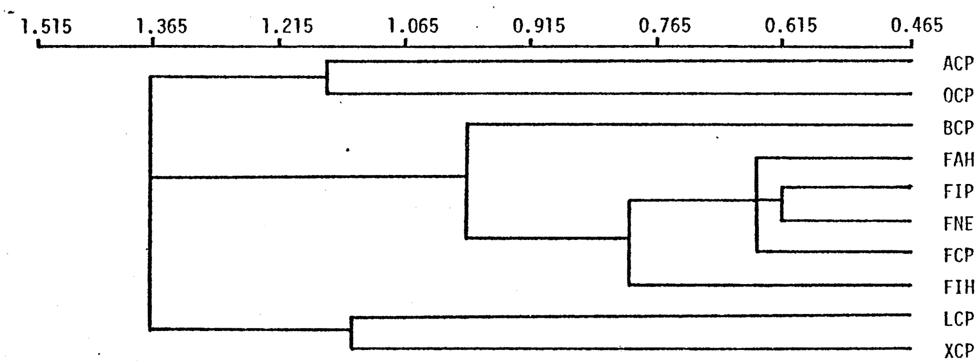


UPGMC, Distance Raw



WPGMC, Distance Raw



WPGMC, Distance Standardized

ACP: A. aurea, Coastal Plain
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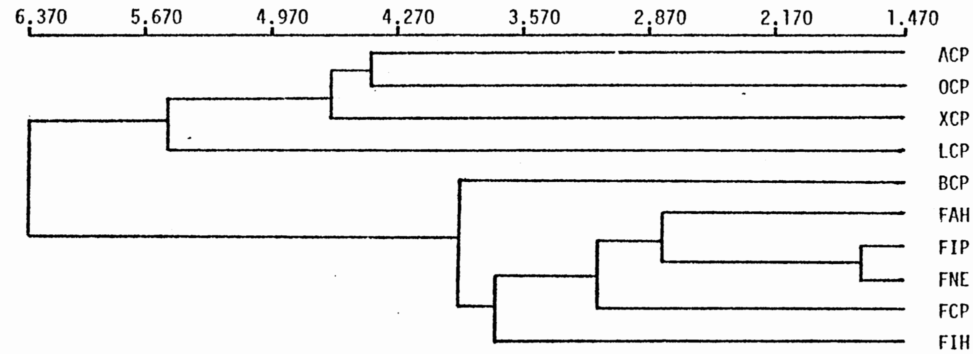
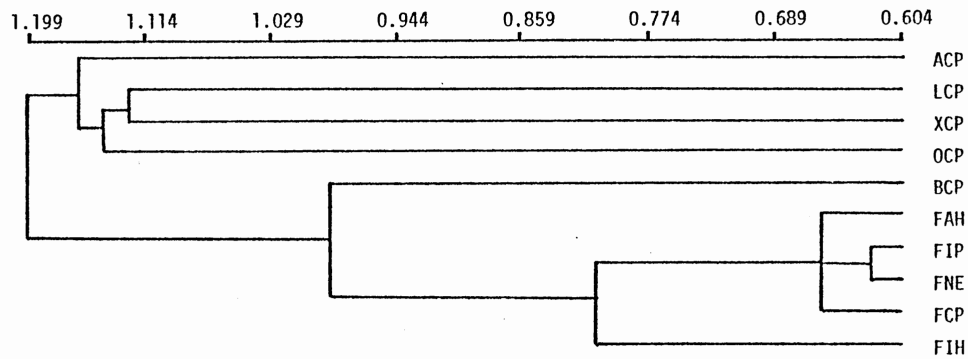
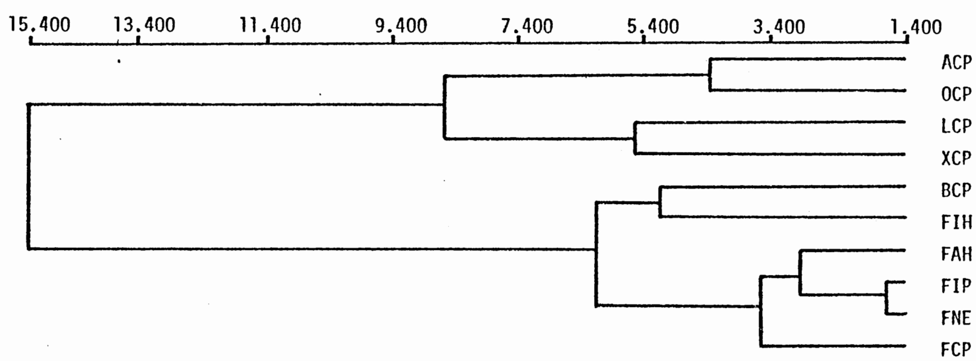


Single Linkage, Distance Raw



Single Linkage, Distance Standardized



Complete Linkage, Distance Raw

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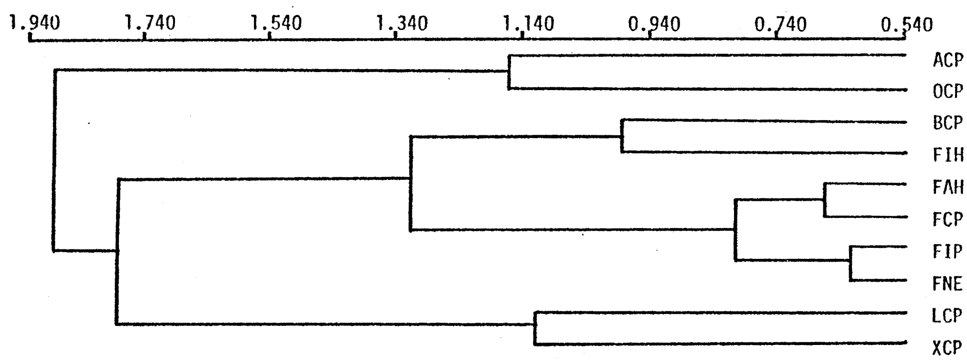

Complete Linkage, Distance Standardized

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APPENDIX C

CORRELATION COEFFICIENTS OF CHARACTERS

		1	2	3	4	5	6	7	8	9
1	Leaf Length	1.000								
2	Leaf Width, Top Quarter	0.275	1.000							
3	Leaf Width, Midpoint	-0.245	0.805	1.000						
4	Leaf Width, Bottom Quarter	0.321	0.782	0.512	1.000					
5	Leaf Nerve Number	0.259	0.700	0.672	0.556	1.000				
6	Scape Length	-0.234	-0.022	0.334	-0.413	0.432	1.000			
7	Bract Number	-0.222	0.262	0.461	0.341	0.428	0.392	1.000		
8	Bract Length	0.846	0.488	0.079	0.655	0.470	-0.251	0.136	1.000	
9	Scape Diameter	0.023	-0.259	-0.067	-0.689	0.002	0.796	0.013	-0.209	1.000
10	Raceme Length	-0.610	-0.286	0.121	-0.645	-0.004	0.743	0.094	-0.677	0.652
11	Flower Number	0.393	0.042	-0.103	-0.317	0.227	0.549	0.080	0.198	0.729
12	Capsule Body Length	-0.407	-0.399	0.056	-0.650	0.032	0.864	0.203	-0.476	0.799
13	Capsule Beak Length	0.887	0.287	-0.125	0.153	0.278	-0.025	-0.232	0.640	0.267
14	Flower Length	0.362	-0.156	-0.108	-0.408	0.077	0.536	-0.158	0.120	0.775
15	Flower Width, Top	-0.569	-0.120	0.285	-0.315	0.191	0.763	0.388	-0.518	0.516
16	Flower Width, Top Quarter	-0.898	0.068	0.533	-0.059	0.014	0.217	0.153	-0.654	-0.110
17	Flower Width, Midpoint	-0.835	0.083	0.520	-0.106	0.001	0.224	-0.019	-0.678	-0.053
18	Flower Width, Bottom Quarter	-0.772	0.102	0.544	-0.161	-0.052	0.308	0.038	-0.599	0.149
19	Percent Perianth Adnate	0.451	-0.177	-0.535	-0.345	-0.278	-0.242	-0.832	-0.014	0.128
20	Percent Ovary Adnate	0.799	0.110	-0.409	0.102	-0.053	-0.452	-0.726	0.469	-0.100
21	Anther Length	-0.122	-0.319	-0.016	-0.523	0.002	0.780	0.437	-0.167	0.844
22	Anther Width, Base	-0.862	-0.167	0.244	0.000	-0.345	-0.133	0.249	-0.598	-0.338
23	Anther Width, Midpoint	-0.907	-0.153	0.292	-0.054	-0.277	0.014	0.255	-0.649	-0.219
24	Anther Width, Top	-0.625	0.138	0.350	0.195	-0.311	-0.371	-0.027	-0.416	-0.425
25	Leaf Index	0.838	-0.242	-0.720	-0.004	-0.222	-0.423	-0.381	0.595	-0.015
26	Width Index	-0.241	0.366	0.565	-0.274	0.303	0.626	-0.015	-0.330	0.553
27	Raceme Index	-0.660	-0.374	-0.061	-0.633	-0.278	0.387	-0.135	-0.761	0.409
28	Inflorescence Index	0.923	0.351	-0.169	0.389	0.182	-0.316	-0.082	0.854	-0.077
29	Capsule Index	0.940	0.377	-0.170	0.359	0.191	-0.363	-0.331	0.745	-0.057
30	Flower Index	0.752	-0.219	-0.499	-0.191	-0.055	0.092	-0.006	0.527	0.447
31	Lobe Index	0.671	-0.236	-0.528	-0.207	0.076	0.229	0.028	0.375	0.446
32	Constriction Index	-0.841	-0.000	0.435	0.001	-0.006	0.212	0.519	-0.477	-0.112
33	Anther Index	0.698	0.009	-0.201	-0.140	0.356	0.428	0.144	0.510	0.564
34	Anther Base Index	0.437	-0.101	-0.357	0.212	-0.213	-0.571	0.020	0.441	-0.400
35	Anther Apex Index	-0.747	-0.487	0.006	-0.456	-0.156	0.556	0.467	-0.638	0.306

		10	11	12	13	14	15	16	17	18
10	Raceme Length	1.000								
11	Flower Number	0.421	1.000							
12	Capsule Body Length	0.750	0.296	1.000						
13	Capsule Beak Length	-0.400	0.458	-0.187	1.000					
14	Flower Length	0.153	0.411	0.633	0.557	1.000				
15	Flower Width, Top	0.783	0.198	0.819	-0.393	0.276	1.000			
16	Flower Width, Top Quarter	0.558	-0.405	0.294	-0.796	-0.373	0.546	1.000		
17	Flower Width, Midpoint	0.541	-0.415	0.330	-0.701	-0.228	0.552	0.968	1.000	
18	Flower Width, Bottom Quarter	0.598	-0.251	0.431	-0.600	-0.061	0.599	0.915	0.939	1.000
19	Percent Perianth Adnate	-0.073	0.322	-0.248	0.433	0.169	-0.401	-0.457	-0.309	-0.376
20	Percent Ovary Adnate	-0.518	0.181	-0.496	0.708	0.228	-0.630	-0.690	-0.541	-0.576
21	Anther Length	0.518	0.493	0.848	0.073	0.678	0.614	-0.061	-0.083	0.124
22	Anther Width, Base	0.192	-0.709	0.130	-0.814	-0.437	0.330	0.795	0.726	0.689
23	Anther Width, Midpoint	0.354	-0.595	0.261	-0.854	-0.373	0.504	0.872	0.816	0.792
24	Anther Width, Top	0.027	-0.672	-0.166	-0.524	-0.448	0.090	0.719	0.702	0.711
25	Leaf Index	-0.563	0.279	-0.380	0.664	0.256	-0.621	-0.925	-0.891	-0.851
26	Width Index	0.626	0.455	0.383	0.017	0.214	0.369	0.381	0.442	0.512
27	Raceme Index	0.904	0.267	0.473	-0.500	-0.120	0.577	0.598	0.573	0.599
28	Inflorescence Index	-0.659	0.387	-0.543	0.729	0.149	-0.674	-0.848	-0.836	-0.756
29	Capsule Index	-0.622	0.310	-0.536	0.919	0.261	-0.641	-0.807	-0.729	-0.669
30	Flower Index	-0.290	0.553	0.069	0.738	0.606	-0.295	-0.909	-0.895	-0.747
31	Lobe Index	-0.120	0.628	0.159	0.648	0.549	-0.037	-0.844	-0.811	-0.758
32	Constriction Index	0.521	-0.223	0.221	-0.820	-0.533	0.477	0.836	0.677	0.690
33	Anther Index	-0.044	0.756	0.200	0.734	0.592	-0.092	-0.766	-0.760	-0.661
34	Anther Base Index	-0.720	-0.199	-0.584	0.325	-0.214	-0.828	-0.598	-0.684	-0.711
35	Anther Apex Index	0.634	-0.060	0.729	-0.720	0.027	0.777	0.524	0.455	0.443

		19	20	21	22	23	24	25	26	27
19	Percent Perianth Adnate	1.000								
20	Percent Ovary Adnate	0.837	1.000							
21	Anther Length	-0.334	-0.451	1.000						
22	Anther Width, Base	-0.612	-0.722	-0.049	1.000					
23	Anther Width, Midpoint	-0.599	-0.757	0.028	0.974	1.000				
24	Anther Width, Top	-0.380	-0.389	-0.321	0.847	0.809	1.000			
25	Leaf Index	0.557	0.765	-0.110	-0.695	-0.770	-0.584	1.000		
26	Width Index	0.119	-0.155	0.248	-0.113	-0.002	0.005	-0.543	1.000	
27	Raceme Index	0.089	-0.394	0.217	0.309	0.438	0.245	-0.478	0.478	1.000
28	Inflorescence Index	0.365	0.687	-0.173	-0.772	-0.837	-0.561	0.771	-0.204	-0.677
29	Capsule Index	0.516	0.843	-0.267	-0.774	-0.842	-0.405	0.754	-0.143	-0.590
30	Flower Index	0.279	0.440	0.450	-0.721	-0.768	-0.745	0.799	-0.237	-0.430
31	Lobe Index	0.367	0.429	0.423	-0.760	-0.743	-0.858	0.716	-0.208	-0.280
32	Constriction Index	-0.686	-0.886	0.102	0.766	0.810	0.582	-0.795	0.202	0.554
33	Anther Index	0.241	0.334	0.489	-0.852	-0.838	-0.901	0.561	0.098	-0.300
34	Anther Base Index	0.055	0.276	-0.247	-0.190	-0.401	-0.176	0.575	-0.532	-0.617
35	Anther Apex Index	-0.500	-0.799	0.577	0.553	0.645	0.088	-0.548	0.060	0.492

		28	29	30	31	32	33	34	35
28	Inflorescence Index	1.000							
29	Capsule Index	0.860	1.000						
30	Flower Index	0.694	0.617	1.000					
31	Lobe Index	0.553	0.512	0.878	1.000				
32	Constriction Index	-0.680	-0.814	-0.689	-0.685	1.000			
33	Anther Index	0.621	0.546	0.868	0.863	-0.577	1.000		
34	Anther Base Index	0.544	0.449	0.474	0.214	-0.331	0.248	1.000	
35	Anther Apex Index	-0.712	-0.894	-0.269	-0.099	0.610	-0.210	-0.452	1.000

VITA [2]

Patricia Louise Weigant Risk

Candidate for the Degree of

Master of Science

Thesis: A NUMERICAL ANALYSIS OF THE MORPHOLOGICAL VARIATION IN THE GENUS <u>ALETRIS</u> L. IN NORTH AMERICA

Major Field: Botany

Biographical:

Personal Data: Born in Shawnee, Oklahoma, April 8, 1950, the daughter of Mr. and Mrs. Dean M. Weigant. Married to John L. Risk, with one son, Brian A. Risk.

Education: Graduated from Shawnee High School, Shawnee, Oklahoma, in May, 1968; enrolled in Bachelor of Arts program at Oklahoma State University, 1968-1970; enrolled in Bachelor of Science program at the University of Tulsa, 1970-1971; received Bachelor of Science degree in Botany from Oklahoma State University in 1974; enrolled in masters program at Oklahoma State University, 1974-1975; resumed masters program in 1977 and completed requirements for the Master of Science degree at Oklahoma State University in July, 1979.

Professional Experience: Graduate teaching assistant in Plant Biology and Plant Taxonomy, the School of Biological Sciences, Oklahoma State University, 1977-1979.

Professional Organizations: Member of Oklahoma Academy of Science and American Society of Plant Taxonomists.