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A Taxonomic Study of the Morphological Variation and Intergradation of Chrysemys picta (Schneider) (Emydidae, Testudines) in West Virginia

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A Taxonomic Study of the Morphological Variation and Intergradation of *Chrysemys picta* (Schneider) (Emydidae, Testudines) in West Virginia

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ABSTRACT

A Taxonomic Study of the Morphological Variation and Intergradation of *Chrysemys picta* (Schneider) (Emydidae, Testudines) in West Virginia

By Melissa Mann

Two subspecies of *Chrysemys picta* (*C. p. picta* and *C. p. marginata*) occur in West Virginia. The Allegheny Mountains have historically separated the distribution of *C. p. picta* and *C. p. marginata*; however, intergrades occur where ranges overlap. These intergrades display morphological characteristics that are often intermediate to the original subspecies. Morphological variation of *C. picta* was examined by comparing specimens from possible areas of *C. p. picta x C .p. marginata* intergradation in West Virginia to geographic areas that are not exposed to subspecies distribution overlap. Characters traditionally used to separate *C. p. picta* and *C. p. marginata* were measured on preserved specimens from museum collections. Additional character measurements were also taken for each specimen. Two characters, percent disalignment of the carapacial scutes and scute margin width, were analyzed for morphological variation in populations located across West Virginia. This analysis revealed clinal differences in turtle morphology within different watersheds across the state. Sixteen characters were subject to Canonical Discriminate Analysis, Principle Component Analysis, and Analysis of Variance. Range diagrams, bivariate scatterplots and polygonal diagrams were also constructed from the data. Results showed variation within the species and statistical differences between all groups for characters measuring scute disalignment, scute margin width, and supratemporal stripe width and ratio. Separation of *C. p. picta* and *C. p. marginata* was clearly defined, with intergrades intermediate to and overlapping both subspecies; however, intergrades displayed greater similarities to *C. p. picta*. Because the distribution of *C. picta* is widespread and complex with extensive morphological variation across its range, areas of intergradation where ranges overlap must be identified and studied for a more complete understanding of the distribution patterns and morphological variation of *C. picta* in West Virginia.

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS .... **i**
TABLE OF CONTENTS .... **ii**
LIST OF TABLES .... **iii**
LIST OF FIGURES .... **iv**

1.0 INTRODUCTION **1**
1.1 TAXONOMY 4
1.1.1 Nomenclature 4
1.1.2 Cytotaxonomy 10
1.2 NATURAL HISTORY 12
1.2.1 Morphology 12
1.2.2 Similar Genera and Species 15
1.3 GEOGRAPHIC DISTRIBUTION 18
1.3.1 Zones of Intergradation 18
1.3.2 Post-Glacial Dispersal 20
1.3.3 Habitat 20

2.0 MATERIALS AND METHODS **22**
2.1 SPECIMENS 22
2.2 STUDY METHODS 25
2.3 DATA ANALYSES 28
2.3.1 West Virginia Watershed Analyses 28
2.3.2 Intergrade Analyses 30

3.0 RESULTS AND DISCUSSION **31**
3.1 WEST VIRGINIA WATERSHED ANALYSES 31
3.1.1 Multivariate Statistical Analyses 31
3.1.2 Character Analyses 37
3.2 INTERGRADE ANALYSES 41
3.2.1 Multivariate Statistical Analyses 41
3.2.2 Analysis of Variance (ANOVA) 45
3.2.3 Character Analyes 47

4.0 CONCLUSIONS **58**

5.0 LITERATURE CITED **61**

APPENDIX A. *Chrysemys picta* Specimen Information
APPENDIX B. *Chrysemys picta* Data Sheets
APPENDIX C. Curriculum Vitae

LIST OF TABLES

Table 1. Published taxonomic studies of *Chrysemys picta* intergradation in the United States and Canada. 2
Table 2. Type localities for *Chrysemys picta*, *C. p. picta, C. p. bellii, C. p. dorsalis* and *C. p. marginata* reported in Ernst (1971). 5
Table 3. List of synonyms for *Chrysemys picta* (Schneider)*, C. p. picta* (Schneider), *C. p. bellii* (Gray), *C. p. dorsalis* Agassiz., and *C. p. marginata* Agassiz. All synonym citations are found in Ernst (1971). 6
Table 4. Character descriptions of *Chrysemys p. picta and C. p. marginata* from several published species accounts. 7
Table 5. Diploid number and source for *Chrysemys picta* listed in Bickham and Carr (1983). 10
Table 6. Diploid Number for *Chrysemys picta* as reported by Killebrew (1977). 11
Table 7. List of the morphological characters measured in the study and subjected to statistical analyses in SAS. 29
Table 8. Comparison of P values among *Chrysemys picta* watershed groups analyzed by Canonical Discriminant Analysis. 33
Table 9. Eigenvalues for Canonical Discriminant and Principal Component Analyses of the *Chrysemys picta* watershed analyses. 36
Table 10. Canonical Coefficients and Eigenvectors for Canonical Discriminant and Principal Component Analyses of the *Chrysemys picta* watershed analyses. 36
Table 11. Clinal differences in two *Chrysemys picta* characters based on watershed locality. 37
Table 12. Eigenvalues for Canonical Discriminant and Principal Component Analyses of the *Chrysemys picta* intergrade analyses. 45
Table 13. Canonical Coefficients and Eigenvectors for Canonical Discriminant and Principal Component Analyses of the *Chrysemys picta* intergrade analyses. 46
Table 14. Morphological characters and statistical results from Analysis of Variance,. 47
Table 15. Actual and relative maximum, minimum, and mean values for characters used in the polygonal graphical analysis. 48

LIST OF FIGURES

Figure 1. Copies of the original descriptions for (a) *Chrysemys picta* (Schneider, 1783) and (b) *C. p. picta* (Schneider, 1783)............ 8
Figure 2. Copies of the original descriptions for (a) *Chrysemys picta bellii* (Gray, 1873), and (b) *C. p. dorsalis* Agassiz (1857), and (c) *C. p. marginata* Agassiz (1857)....... 9
Figure 3. Karyotype of *Chrysemys picta*. 11
Figure 4. *Chrysemys picta picta* (dorsal view) with scutes arranged in straight lines across the carapace............ 13
Figure 5. *Chrysemys picta picta* (ventral view) with an unmarked yellow plastron. 13
Figure 6. *Chrysemys picta marginata* (dorsal view) with scutes arranged alternately across the carapace............ 14
Figure 7. *Chrysemys picta marginata* (ventral view) with a dark central plastral figure. 14
Figure 8. *Chrysemys picta* intergrade (dorsal view) with slightly misaligned scutes across the carapace............ 16
Figure 9. *Chrysemys picta* intergrade (ventral view) with a reduced plastral figure. 16
Figure 10. Phylogenetic relationships of emydid turtles............ 17
Figure 11. Geographic distribution of *Chrysemys picta* in North America. 19
Figure 12. Interpretation of Bleakney's hypothesis of the hybrid origin of *Chrysemys picta marginata*. 21
Figure 13. Map of *Chrysemys picta* specimens from West Virginia. 23
Figure 14. Map of *Chrysemys picta* specimen collection areas. 24
Figure 15. Examples of *Chrysemys picta* carapace measurements as described by Hartman (1958). 26
Figure 16. Supratemporal head stripe of *Chrysemys picta*. 27
Figure 17. Plot of *Chrysemys picta* Canonical Discriminant Analysis by West Virginia watershed: Can 1 vs. Can 2. 32
Figure 18. Plot of *Chrysemys picta* Principal Component Analysis by West Virginia watershed: Prin 1 vs. Prin 2. 34
Figure 19. Plot of *Chrysemys picta* Principal Component Analysis by West Virginia watershed: Prin 3 vs. Prin 2. 35
Figure 20. Mean percent disalignment of *Chrysemys picta* specimens based on watershed locality............ 38
Figure 21. Border width / carapace length ratio of *Chrysemys picta* specimens based on watershed locality............ 39
Figure 22. Distribution of *Chrysemys picta* populations within West Virginia, as determined by the watershed analyses. 40
Figure 23. Plot of *Chrysemys picta* Canonical Discriminate Analysis using West Virginia intergrades: Can 1 vs. Can 2. 42
Figure 24. Plot of *Chrysemys picta* Principal Component Analysis using West Virginia intergrades: Prin 1 vs. Prin 2. 43
Figure 25. Plot of *Chrysemys picta* Principal Component Analysis using West Virginia intergrades: Prin 3 vs. Prin 2. 44
Figure 26. Polygonal graph of relative character values for *Chrysemys picta picta*............ 49
Figure 27. Polygonal graph of relative character values for *Chrysemys picta* intergrades....... 50

Figure 28. Polygonal graph of relative character values for *Chrysemys picta marginata*........ 51
Figure 29. Polygonal graph of group means for *Chrysemys picta*... 52
Figure 30. Range diagram of percent disalignment (PD) for *Chrysemys picta*. 54
Figure 31. Range diagram of percent margin width (PM) for *Chrysemys picta*....................... 55
Figure 32. Range diagram of stripe ratio (SR) for *Chrysemys picta*.. 56
Figure 33. Bivariate scatterplot: of percent disalignment (PD) versus stripe ratio (SR) for *Chrysemys picta*. 57

1.0 INTRODUCTION

Chrysemys picta, the painted turtle, is one of the most common and widely distributed turtle species in North America (Pope, 1939). It is the only North American turtle whose range extends across the continent (Ernst et al., 1994). Because this turtle has such a broad geographic range and encompasses many different climatic and topographical regions across its distribution, its morphology varies according to the geographical area it inhabits. The high degree of morphological variation within the species has created problems when defining individuals or populations to the subspecific level, and as a result, many synonyms have been created. Four subspecies or geographical races are currently recognized in the United States: 1) *C. p. picta* (Schneider) along the Atlantic coast, 2) *C. p. bellii* (Gray) in western Canada and the United States, 3) *C. p. dorsalis* Agassiz in the south-central United States, and 4) *C. p. marginata* Agassiz in south-central Canada and the central United States, east of the Appalachian Mountains. Intergrades occur in areas of distribution range overlap, where morphology is often an intermediate or "mixed" form of the parental subspecies. It is often difficult to assign intergrades to a certain subspecific group. Therefore, areas of intergradation must be identified and studied for a more complete understanding of the distribution patterns and morphological variation of *C. picta*.

Numerous taxonomic studies have examined *Chrysemys picta* populations and/or preserved individuals from most of the major areas of intergradation in the United States and Canada (Table 1). No previous taxonomic studies have focused on *C. picta* intergradation in West Virginia, and few West Virginia specimens have been examined in published *C. picta* taxonomic research. Seidel (1981) examined *C. p. picta x C. p. marginata* intergrades in his taxonomic research of *Pseudemys* and confirmed the presence of intergrades in the upper New River system in West Virginia. In addition, Wright and Andrews (2002) examined *C. picta* specimens from West Virginia; however, the examined specimens were from populations far from possible areas of intergradation within the state. *C. p. picta*, from the James and Roanoke rivers, and *C. p. marginata* from the Ohio River Valley, come into contact with each other in the New River drainage, which enters the Ohio River Valley from Virginia, creating intergrade populations. The distribution of *C. picta* in West Virginia is also influenced by the Allegheny Mountains, a chain of the Appalachian Mountain range that has historically separated the distribution of *C. p. picta* and *C. p. marginata*. Intergradation may occur in certain areas of this region where the ranges come into contact. Therefore, intergradation greatly influences the morphological variation and distribution of *C. picta* in West Virginia.

Table 1. Published taxonomic studies of *Chrysemys picta* intergradation in the United States and Canada.

***Chrysemys picta* subspecies**	**Area of Intergradation**	**Author and Date of Publication**
C. p. picta x C. p. marginata	Tennessee	Johnson, 1954
C. p. picta x C. p. marginata	New York State and New England	Hartman, 1958
C. p. picta x C. p. marginata	Massachusetts	Waters, 1964
C. p. picta x C. p. dorsalis	Alabama	Ernst, 1967
C. p. picta x C. p. marginata	Northeastern United States (Massachusetts, New Jersey, New York, and Rhode Island)	Pough and Pough, 1968
C. p. picta x C. p. marginata	Massachusetts	Waters, 1969
C. p. picta x C. p. marginata	Tennessee	Ernst, 1970
C. p. dorsalis x C. p. marginata	Tennessee and Kentucky	Ernst, 1970
C. p. picta x C. p. marginata	Pennsylvania	Ernst and Ernst, 1971
C. p. bellii x C. p. marginata	Michigan (Northern Peninsula)	Ernst and Fowler, 1977
C. p. picta x C. p. marginata	Connecticut	Klemens, 1978
C. p. picta x C. p. marginata	Maryland	Groves, 1983
C. p. picta x C. p. marginata	Ontario and Quebec	Gordon, 1990
C. p. picta x C. p. marginata	Virginia, Pennsylvania, Massachusetts, Maine, New Hampshire and Nova Scotia	Rhodin and Butler, 1997
C. p. picta x C. p. marginata	Vermont	Wright and Andrews, 2002

Two subspecies of *Chrysemys picta*, *C. p. picta* and *C. p. marginata*, are present in West Virginia and will be examined in the study. Because *C. p. bellii* and *C. p. dorsalis* are not found in West Virginia, only the historical taxonomy of these subspecies are discussed in detail in this paper. The objectives of this study are to:

1) examine the morphological variation of *C. picta*,
2) compare morphological data from possible areas of *C. p. picta x C .p. marginata* intergradation in West Virginia to geographic areas that are not exposed to subspecies distribution overlap,
3) determine the extent of *C. p. picta* and *C. p. marginata* influence on the intergradation patterns in West Virginia, and
4) identify morphological characters that are useful in the separation of *C. p. picta, C. p. marginata* and *C. p. picta x C. p. marginata* intergrades.

1.1 TAXONOMY

1.1.1 Nomenclature

The genus *Chrysemys* (Gray) is in the family Emydidae, the largest family of turtles, with representatives on every continent except Australia and Antarctica (Conant and Collins, 1998). Family Emydidae includes 10 genera and 40+ species (Zug et al., 2001). Genus *Chrysemys* contains only a single species, *Chrysemys picta*; however, the species is composed of four geographical races, or subspecies, that are separated based on their morphological differences. Bishop and Schmidt (1931) were the first to recognize that *C. picta* consisted of a single species with different forms, or subspecies. The taxonomic classification of the species is defined below, with the taxonomic authority and original description cited:

- Kingdom Animalia
  - Phylum Chordata
    - Subphylum Vertebrata
      - Superclass Tetrapoda
        - Class Reptilia
          - Subclass Anapsida
            - Order Testudinata
              - Suborder Cryptodira
                - Family Emydidae
                  - Subfamily Deirochelyinae
                    - Genus *Chrysemys* Gray in Cat. Tort. Croc. Amphib. British Mus.(1844):27.
                      - Species *picta* (Schneider) in Allegem. Naturgesch. Schildkr. (1783):348.
                        - Subspecies *picta* (Schneider) in Allegem. Naturgesch. Schildkr.(1783):348.
                        - Subpecies *bellii* (Gray) in Synop. Reptil. (1831):31.
                        - Subspecies *dorsalis* Agassiz in Contrib. Nat. Hist. U.S.A. (1857):440.
                        - Subspecies *marginata* Agassiz in Contrib. Nat. Hist. U.S.A. (1857):439.

Type locality information for *Chrysemys picta* and the subspecies *C. p. picta, C. p. bellii, C. p. dorsalis* and *C. p. marginata* are indicated in Table 2. All synonyms present in the literature for *Chrysemys picta* and these subspecies are cited in Table 3. Over time, many synonyms have been created due to the morphological diversity within the species. Written subspecies accounts show similar character descriptions, with minor differences due primarily to morphological variation (Table 4). Original descriptions of *C. picta* and each subspecies are included in Figures 1 and 2.

Table 2. Type localities for *Chrysemys picta*, *C. p. picta, C. p. bellii, C. p. dorsalis* and *C. p. marginata* reported in Ernst (1971).

Chrysemys picta
Unknown; reported to have been in England (in error); designated as Lancaster, Pennsylvania,by Mittleman (1945) and vicinity of New York City, New York by Schmidt (1953:99).

Chrysemys picta picta
Unknown; Mittleman (1945) suggested that it be designated as Lancaster, Pennsylvania. Ernst (1971) found that Lancaster populations consist of intergrades, so the vicinity of New York City by Schmidt (1953:99) was accepted.

Chrysemys picta bellii
Not stated; designated as Manhattan, Kansas by Smith and Taylor (1950:34). Collector not stated. Original description based on a specimen at the Museum of the Royal College of Surgeons in England but was destroyed during the bombing of 1941.

Chrysemys picta dorsalis
Mississippi (market at Natchez, Adams County) and Louisiana (Lake Concordia); restricted to Natchez by Ernst (1967:133).

Chrysemys picta marginata
Racine, Wisconsin; Milwaukee, Wisconsin; Flint, Michigan; Ann Arbor, Michigan; Delphi, Indiana; and Burlington, Iowa. Restricted to Northern Indiana by Schmidt (1953:99).

Table 3. List of synonyms for *Chrysemys picta* (Schneider)*, C. p. picta* (Schneider), *C. p. bellii* (Gray), *C. p. dorsalis* Agassiz., and *C. p. marginata* Agassiz. All synonym citations are found in Ernst (1971).

Species/Subspecies	**Synonyms**
Chrysemys picta (Schneider)	*Testudo picta* Schneider, 1783
	Chrysemys cinerea Bonnaterre, 1789
	Emys bellii Gray, 1831
	Emys oregoniensis Harlan, 1837
	Chrysemys picta Gray, 1856
	Chrysemys marginata Agassiz, 1857
	Chrysemys dorsalis Agassiz, 1857
	Chrysemys nuttalli Agassiz, 1857
	Chrysemys pulchra Gray, 1873
	Chrysemys trealeasei Hurter, 1911
Chrysemys picta picta (Schneider)	*Testudo picta* Schneider, 1783
	Chrysemys cinerea Bonnaterre, 1789
	Chrysemys picta Gray, 1856
	Chrysemys picta picta Bishop and Schmidt, 1931
Chrysemys picta bellii (Gray)	*Emys bellii* Gray, 1831
	Emys oregoniensis, Harlan, 1837
	Chrysemys nuttalli Agassiz, 1857
	Chrysemys pulchra Gray, 1873
	Chrysemys trealeasei Hurter, 1911
	Chrysemys marginata bellii Stejneger and Barbour, 1917
	Chrysemys bellii bellii Ruthven, 1924
	Chrysemys picta bellii Bishop and Schmidt, 1931
	Chrysemys picta belli Schmidt, 1953
Chrysemys picta dorsalis Agassiz	*Chrysemys dorsalis* Agassiz, 1857
	Chrysemys marginata dorsalis Stejneger and Barbour, 1917
	Chrysemys picta dorsalis Bishop and Schmidt, 1931
Chrysemys picta marginata Agassiz	*Chrysemys marginata* Agassiz, 1857
	Chrysemys bellii marginata Ruthven, 1924
	Chrysemys picta marginata Bishop and Schmidt, 1931

Table 4. Character descriptions of *Chrysemys p. picta and C. p. marginata* from several published species accounts.

Character	Ernst et al., 1994	Pope, 1939	Carr, 1952	Conant and Collins, 1998	Green and Pauley, 1987
Chrysemys picta picta					
Carapace					
Size	-----	6 in	7 in	4.5-6 in	7 in
Depth	-----	Depressed	Low	-----	Somewhat flattened
Scute Alignment	Seams aligned	In a line with the margins	Aligned laminae	Scutes of the carapace in straight rows across the back	Seams are lined up
Anterior Scute Margin	Light borders	Broadly margined with yellow	Light fore margins	Light olive bands	Bordered in tan or yellow
Middorsal Stripe	Narrow; poorly developed or absent	-----	-----	-----	-----
Plastron					
Color/Figure	Plain yellow	Immaculately yellow	Plain yellow; rarely marked with black	Plain yellow or with a small dark spot or two	Yellow and mostly unmarked
Head					
Eye Stripe	-----	-----	Short bar	Bright yellow spots	Pair of yellow spots behind the eyes
Chrysemys picta marginata					
Carapace					
Size	-----	4.6 -5.6 in	6.2 in	4.5-5.5 in	Similar to C. p. picta
Depth	-----	-----	-----	-----	Similar to C. p. picta
Scute Alignment	Seams alternate	Scutes alternate	Staggered laminae	Scutes on the back alternating	Scutes alternate
Anterior Scute Margin	Dark borders	Not or only narrowly margined with yellow	Lack of light borders	-----	-----
Middorsal Stripe	Poorly developed or absent	-----	-----	-----	-----
Plastron					
Color/Figure	Dark; no more than half the width of the plastron and does not extend out along the seams	Longitudinal blotch that is half or less than half the width of the plastron	Dark, central figure that is half the width of the plastron and does not extend along the seams	Dark, oval figure that is half or less than the width of the plastron and does not send out extensions along the seams	Dark central figure that varies in shape and size
Head					
Eye Stripe	-----	-----	Similar to *C. p. picta*		-----

Figure 1. Copies of the original descriptions for a) *Chrysemys picta* (Schneider, 1783) and b) *C. p. picta* (Schneider, 1783).

a)

Schneider

kröten in einem großen Grabe. So weit Gmelin. In dieser ganzen Beschreibung ist kein Kennzeichen, welches eine eigne neue Art bezeichnete, die Farbe ausgenommen, welche mit dem Aufenthalte in trüben oder schlammichten Wasser und mit dem Fraße vielfache Abänderungen leiden muß, wie wir an den bunten Fischen sehn. Auch das Kupfer stimmt mit unsrer gemeinen Sumpfschildkröte überein, welche sich nach Schwenkfeld auch in einigen schlesischen Flüssen aufhält. Taf. X. stellt das Thier von oben, Taf. XI. von unten sehr gut vor, nur daß der Schluß der Augenlieder falsch und die Nasenlöcher undeutlich vorgestellt sind. Alles übrige stimmt darinne vollkommen mit dem Baue unserer gemeinen Art überein, bis auf folgende Puncte, welche allerdings eine neue Art bezeichnen, wenn die Zeichnung und der Stich getreu und genau sind. Erstlich ist der Kopf oben nicht platt, sondern gewölbt, und am Hintertheile so wie auch hinter den Augen geschuppt. Zweytens ist der Schwanz an beyden Zeichnungen geringelt und durch Puncte wie chagrinirt vorgestellt, da unsre Art den ganzen Schwanz mit kleinen harten Schuppen bedekt hat. Bis also dermaleinst von der kaiserlich russischen Akademie die vollständige Beschreibung der Thiere aus Persien und aus der Gegend der kaspischen See von Gmelin und Güldenstädt herausgegeben wird, habe ich

ich mittlerweile diese Art als eine neue mit den Kennzeichen, welche auf der Treue der Zeichnung beruhen, aufgeführt. Ein Pallas wird sie zu seiner Zeit wohl an ihren rechten Plaz stellen.

Noch will ich unter dieser Abtheilung einige mangelhafte Nachrichten von Arten einrücken, welche daraus nicht bestimmt werden können, damit doch wenigstens in Zukunft die Kenner diese Nachrichten sogleich bey der Hand haben, wenn ihnen neuere Nachrichten und neuere Arten aufstoßen, um sie damit zu vergleichen.

Hieher gehört zuerst die Beschreibung des Edward von der Morastschildkröte aus Pensylvanien. Ich kenne sie nur aus Seligmann Taf. 77. VIII Theil, wo auch eine Abbildung davon steht. Edward rechnet sie zu den Amphibien, weil sie an allen Füssen solche Auswüchse hat, welche Flossen gleichen; vorn 5 Zehen mit Krallen, hinten 4. Der Ober- und Unterschild hängen an beyden Seiten vermittelst zweyer Gelenke oder Angeln zusammen, welche die beyden Schaalen gänzlich schließen. Der kleine Schwanz hat eine scharfe Spitze von hornähnlicher Substanz, womit das Thier nach Edwards Meinung seine Bewegungen 1.ch Belieben hemmt, wenn es die Spitze unterwärts kehrt, indem es auf dem abschüssigen Theile steiler Schlammbänke fortschreitet. Sie soll lebendig einen sehr starken Moschusgeruch haben.

Noch unbestimmter ist die Nachricht, welche Catesby in seiner Beschreibung von Carolina (vor dem dritten Theile der Seligmannischen Vögel,

b)

Vögel, Bogen M) von einer besondern Schildkröte des Savannaflusses giebt, welche gesotten über und über weich und esbar seyn soll, obgleich die Schaale vor dem Kochen so hart zu seyn scheint, als bey andern Arten. Ich habe oben eine ähnliche Nachricht von den Schildkröten des Oronoque angeführt; ob die Art die nehmliche sey, mögen andre bestimmen.

Noch will ich einige Bemerkungen einrücken, welche mir der vortrefliche Professor Herrman in Strasburg mitgetheilt hat. Er besizt eine von ihm selbst ausgestopfte Schildkröte, einen halben Schuh lang. Die Schaale sieht gelb und schwarz, wie in der von Linne bey der Carolina angeführten Abbildung des Edward, und ziemlich gewölbt. Zähne sah er nicht an ihr. An den vordern Füssen sitzen so wie an den hintern vier Klauen. Die hintern Füsse sehn wie Elephantenfüsse. Der Schwanz endiget sich in einen krummen ½ Zoll langen knöchernen Haken. Demohngeachtet aber, sagt Herr Professor Herrmann, kann sie nicht scorpioides seyn. Die beyden hintersten Schildchen von den 24 des Randes sind gewölbter und hervorragender. Ob es eine Fluß- oder Landschildkröte sey, hat mein Freund vergessen anzumerken. Er besizt ferner eine obere Schaale gelb und schwarz geflekt, wie die vorige, welche er wegen der Körner im disco scutellorum, deren Grönov erwähnt, für den Schild einer Carolina hält.

Ferner meldet er mir, daß er aus England eine Schildkröte von der Größe eines kleinen Apfels in Spiritus unter dem Namen Testudo picta erhalten

halten habe. Sie hat Finger an den Füssen mit kurzen spitzigen Klauen, und einen kurzen Schwanz. Der Schild ist flach, die Felder durch einen gelben Rand von einander unterschieden. Unten ist sie gelb mit einer schwarzen Linie in der Mitte. Auf jeder Seite des Rückenschildes hat sie zwey dunkle blaulichte Flecken. Der Hals ist der Länge nach gelb und schwarz gestreift. Mein Freund meldet mir zugleich, daß das Thier schon längst für den Naturforscher des H. H. Schreber abgemalt sey, aber zu der Beschreibung habe er noch keine Zeit gehabt. Ich verweise also auch den Leser auf dieses Werk, worinne künftig eine umständlichere Beschreibung nebst der Abbildung erscheinen wird.

III. Testudines terrestres, pedibus clavatis unguiculatis, testa convexa cum sterno commissuris osseis iuncta.

Landschildkröten mit kolbigten Füssen, woran Nägel; die obergewölbte Schaale mit der untern durch Knochennähte verbunden.

Fimbriata, XII. Testudo testa striata et echinata, fronte callosa triloba.

Linne hat folgenden Charakter: pedibus subdigitatis, fronte callosa triloba, cauda unguiculata. In der Beschreibung heißt es, der Schild sey schwarz, länglicht eyförmig, und habe auf dem Rücken drey unmerkliche Winkel. Die Blätter desselben sollen

Figure 2. Copies of the original descriptions for a) *Chrysemys picta bellii* (Gray, 1873), b) *C. p. dorsalis* Agassiz (1857), and c) *C. p. marginata* Agassiz (1857).

a)

28. *Emys Bellii*, (*Bell's Terrapin.*)—Testa oblonga centro depressa lateribus convexis olivacea, fasciis irregularibus viridibus nigropunctatis reticulata, subtus nigrescente punctis maculisque luteis ornata, marginibus antico posticoque luteis maculis nigris flavo punctatis ad suturas positis, sterno margine irregulari luteo circumdato.

Inhab. (v. t. Mus. Col. Surg.)

The shell solid, oblong, the centre depressed, the sides rounded, the margin broad, centre slightly reflexed over the hinder legs, the nuchal shield long, linear, the vertebral shields nearly square, the first urnshaped, the others six-sided, with the sides straight; above olive, varied with irregular pale greenish lines dotted and edged with black, placed on the margin and across the middle of each of the shields, the centre band being most distinct on the marginal plates; the under side of the margin black dotted with yellow on the sides, and yellow on the ends, with irregular yellow dotted black spots placed on the suture between each of the plates, the symphysis with a broad longitudinal yellow spotted black band, separated from the margin, and divided down the middle by two pale yellow lines. The sternum nearly flat, its surface and upper edge black, dotted with yellow, and surrounded by an irregular yellow edge; the ends truncated, the front one denticulated, the hinder lobe broad, rounded on the sides. Length 9, breadth 8½, inches.

b)

CHRYSEMYS DORSALIS, *Ag.* I have seen only a few specimens of this species, the only one of the genus which I have not kept alive for a considerable time. They were sent to me by Prof. Wailes, who collected them in the States of Mississippi and Louisiana.[2] Lake Concordia is the locality whence most specimens were obtained. The Smithsonian Institution possesses specimens from the same source. This is the broadest and shortest species of the genus. It is easily distinguished by the great width of the median scales of the carapace; their form resembles more that of the scales of the young Ch. picta than that of the adults of other species. Margin of the costal scales plicated, as in Ch. marginata. As in Ch. picta, the sternum is uniformly golden yellow. The yellow median stripe along the back is broader than in any other species. The marginal scales are not so highly ornamented as in other species. Indeed, the characteristic, crescent-shaped figures of the margin occur only upon the lower surface, and are quite pale.

c)

... and in Louisiana and Mississippi, by *Chrysemys dorsalis*.

CHRYSEMYS MARGINATA, *Ag.* It is flatter, broader, and more rounded than Chrysemys picta; the bands between the scales of the carapace are either yellow or blood-red, narrower than in Ch. picta. but bordered with more distinct black lines. Their lateral margins exhibit parallel ridges, while in Chrysemys picta they are perfectly even. The ground color is bronze green, with a few red or yellow spots. Upon the sternum there is a black lyriform blotch, as in Chrysemys Bellii, but narrow and plain, and not mottled (see Pl. 5, fig. 3). This figure is, however, occasionally wanting. The young are represented Pl. 1, fig. 6. and Pl. 5, fig. 1–4; the eggs (Pl. 7a, fig. 4–6) are larger than in Ch. picta, though the animals are of the same size. I am indebted for specimens of this species to Dr. P. R. Hoy, of Racine, Wisconsin; to Mr. J. A. Lapham, of Milwaukee, Wisconsin; to Dr. Manly Miles, of Flint, Michigan; to Professor Alex. Winchell, of Ann-Arbor, Michigan; to Mr. Franklin Hill, of Delphi, Indiana; and to Dr. Rauch, of Burlington, Iowa. One specimen was sent to me from Rome, in the State of New York; but I cannot ascertain by whom, nor whether it had been found in that State.

1.1.2 Cytotaxonomy

The karyotype is not often mentioned in taxonomic studies of *Chrysemys picta* since published research is largely based on morphological studies. Morphological variation has been the main focus when separating the taxa. There are no known chromosomal races in turtles (Bickham and Carr, 1983); however turtle morphology varies extensively. Karyotypic data does not separate any of the turtle genera in the subfamily Deirochelyinae, which includes the genera *Chrysemys, Graptemys, Malaclemys, Trachemys, Pseudemys* and *Deirochelys*. All of these genera have the diploid number of 50 (Bickham and Carr, 1983), which is the most common diploid number in the family Emydidae (Killebrew, 1977). Diploid accounts of *C. picta* are listed in Tables 5 and 6, and the karyotype is pictured in Figure 3.

Table 5. Diploid number and source for *Chrysemys picta* listed in Bickham and Carr (1983).

Taxon	**Diploid Number**	**Source**
Chrysemys picta	50	Van Brink, 1959; Forbes, 1966; Killebew, 1977
C. p. picta	50	Van Brink, 1959; Forbes, 1966; Killebew, 1977
C. p. bellii	50	Glascock, 1915; Van Brink, 1959; Forbes, 1966; Stock, 1972; DeSmet, 1978
C. p. dorsalis	50	Forbes, 1966
C. p. marginata	50	Jordan, 1914; Forbes, 1966

Table 6. Diploid Number for *Chrysemys picta* as reported by Killebrew (1977).

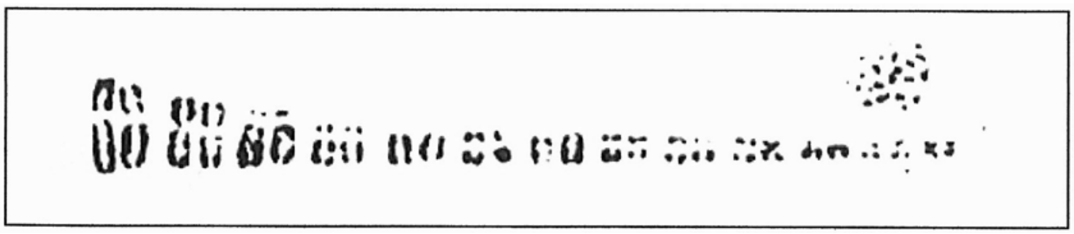
Abbreviations in the table include: M = macrochromosomes, m = microchromosomes, and 2n = diploid number

Species	**Diploid Number**		
	M	m	2n
Chrysemys picta	26	24	50

Source: McKowen (1972)

Figure 3. Karyotype of *Chrysemys picta*.

2n = 50 (Killebrew, 1977)



Only two known intergradation studies have addressed genetic variation in *Chrysemys picta*. In additional to morphological analyses, Waters (1969) compared serum protein patterns of several *C. picta* populations in Massachusetts using immunoelectrophoresis. Waters (1969) demonstrated that island samples closely resembled each other and differed strikingly from mainland samples. Most recently, Starkey et al. (2003) analyzed mitochondrial DNA sequences from *C. p. picta, C. p. bellii, C. p. dorsalis, and C. p. marginata*. Based on molecular data, Starkey et al. (2003) recommended that *Chrysemys* be recognized as the following taxa: *C. picta* (including *C. p. picta, C. p. bellii,* and *C. p. marginata*) and *C. dorsalis* (including *C. p. dorsalis*). These results are pending further evidence from nuclear genetic analysis; therefore, the traditional classification is used throughout this research study.

1.2 NATURAL HISTORY

1.2.1 Morphology

Chrysemys picta are medium-sized turtles characterized by a smooth, unkeeled carapace, narrow notch on the upper jaw, and conspicuous markings of yellow and red on the head, neck, and limbs (Carr, 1952). The head is black with yellow stripes on the sides and bright yellow blotches above. The limbs and marginal scutes (marginals) of the carapace are decorated with red markings, and the background color of the carapace ranges from black to olive (Conant and Collins, 1998).

1.2.1.1 *Chrysemys picta picta*

Chrysemys p. picta are only known turtles with the scutes arranged in straight lines across the back (Conant and Collins, 1998; Figure 4). The margins between the vertebral and costal scutes (vertebrals and costals) are often bordered in tan or yellow and follow the straight alignment of the scutes (Green and Pauley, 1987). The plastron is light yellow and unmarked with occasional small dark spots (Conant and Collins, 1998; Figure 5).

1.2.1.2 *Chrysemys picta marginata*

Chrysemys picta marginata are similar in appearance to *C. p. picta* except that the scutes on the carapace are alternately arranged and the width of the margins between the vertebral and costal scutes (vertebral and costals) is reduced and often darker in color (Pope, 1939; Figure 6). There is a dark central figure on the plastron that is normally oval in shape and takes up half or less than half the plastral width (Conant and Collins, 1998; Figure 7).

Figure 4. *Chrysemys picta picta* (dorsal view) with scutes arranged in straight lines across the carapace.

Figure 5. *Chrysemys picta picta* (ventral view) with an unmarked yellow plastron.

Figure 6. *Chrysemys picta marginata* (dorsal view) with scutes arranged alternately across the carapace.

Figure 7. *Chrysemys picta marginata* (ventral view) with a dark central plastral figure.

1.2.1.3 Intergrades vs. Hybrids

Intergrades exhibit morphological characteristics that are often intermediate or mixed between the parental subspecies. Intergrades are formed from genetic exchange between members of the same species that are often morphologically distinct (such as subspecies or varieties), where hybrids are a result of the genetic exchange between two different species that are closely related. Fertility is not compromised in intergrades, since they are formed from the same species. In contrast, male and/or female hybrids are usually partially or completely sterile (Gilbert, 1961). Intergrades of *Chrysemys p. picta and C. p. marginata* typically have slightly misaligned scutes (Figure 8) and a plastral figure that is reduced in size (Figure 9). Intergradation in *C. picta* has been studied more extensively than in any other North American turtle species (Ernst, 1971).

1.2.2 Similar Genera and Species

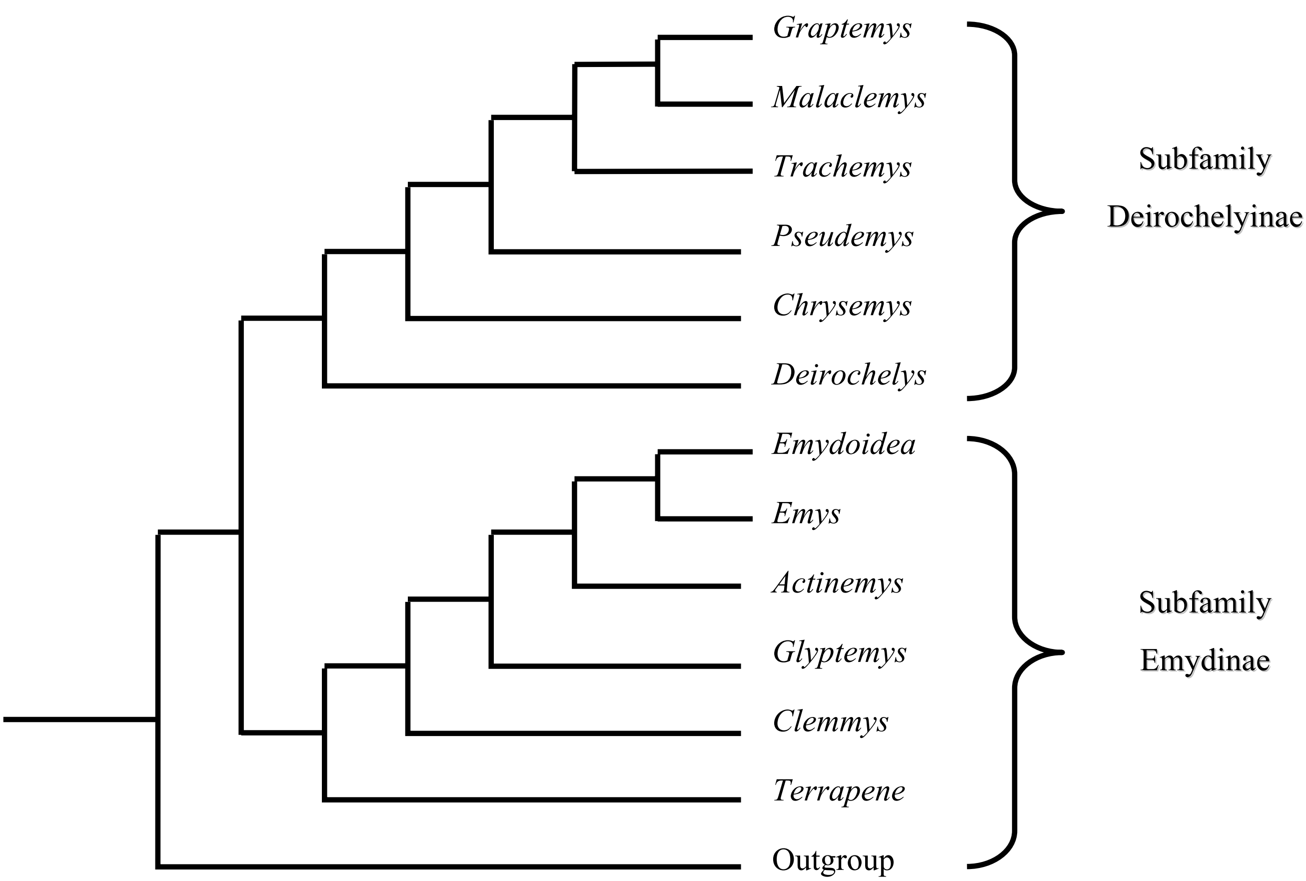
Turtle genera that have a close phylogenetical relationship include *Pseudemys, Trachemys, Malaclemys, Graptemys, and Deirochelys* (Figure 10). The two most closely related genera, *Pseudemys* and *Trachemys,* are so similar that both genera were at one time grouped in the genus *Chrysemys,* but were later split into separate genera (Carr, 1952). All three genera (*Chrysemys, Pseudemys* and *Trachemys*) are basking turtles that are often seen sitting on rocks and logs in the open sunlight for thermoregulation (Conant and Collins, 1998). *Pseudemys* and *Trachemys* resemble *Chrysemys picta,* but are much larger in size and have well-developed longitudinal ridges along the carapacial surface (Ernst et al., 1994).

Deirochelys, the chicken turtles, are much closer in size to *Chrysemys* turtles and have a smooth, unkeeled carapace; however, *Deirochelys* have a much longer neck, webbed carapacial pattern, and are found in the southern-most regions of United States (Ernst et al., 1994). Map turtles of the genus *Graptemys* are also similar in appearance and size but have a sharply keeled carapace and serrated marginal scutes.

Figure 8. *Chrysemys picta* intergrade (dorsal view) with slightly misaligned scutes across the carapace.

Figure 9. *Chrysemys picta* intergrade (ventral view) with a reduced plastral figure.

Figure 10. Phylogenetic relationships of emydid turtles.



Modified from Stephens and Wiens (2003)

1.3 GEOGRAPHIC DISTRIBUTION

The distribution of *Chrysemys picta* extends from Oregon and Washington in the western United States to Ontario, Canada in the north and reaches as far south as Mexico and east to the Atlantic coast (Figure 11). *C. p. picta* occur from Nova Scotia to Alabama in the eastern region of the United States (Green and Pauley, 1987), and *C. p. marginata* occur from Quebec and southern Ontario to Tennessee and northern Georgia and Alabama (Conant and Collins, 1998). *C. p. dorsalis* range from southern Illinois through Louisiana and west to Alabama, while *C. p. bellii* extend northwest toward the Pacific (Conant and Collins, 1998). The latter two subspecies are not present in West Virginia and were not examined in the study. In West Virginia, the distribution of *C. p. picta* and *C. p. marginata* has been historically separated by the Allegheny Mountains (part of the Appalachian Mountain range) in the eastern part of the state. The Allegheny Mountains naturally separated the two subspecies by dividing their original routes of dispersal via the Potomac River drainage in the east and the Ohio River drainage in the west (Green and Pauley, 1987).

1.3.1 Zones of Intergradation

Intergrades with characteristics that are intermediate in form or a mixture of *Chrysemys p. picta* and *C. p. marginata* reportedly occur in "zones" where the ranges overlap, particularly in the Allegheny Mountain region and the eastern panhandle (Green and Pauley, 1987). The James River drainage in Monroe County has also been cited as an area of intergradation in West Virginia (Hoffman, 1949). Seidel (1981) studied the influence of the James and Roanoke River drainages in the area of the Upper New River on the distribution of turtle fauna in the state. This area is another region of documented *C. p. picta x C. p. marginata* intergradation (Seidel, 1981). Intergradation between *C. p. picta* and *C. p. marginata* have been studied throughout much of the east, (Johnson, 1954; Hartman, 1958; Waters, 1964, 1969; Pough and Pough, 1968; Ernst and Ernst, 1971; Klemen, 1978; Groves, 1983; Rhodin and Butler, 1997; Wright and Andrews, 2002), but no formal studies have been conducted in West Virginia.

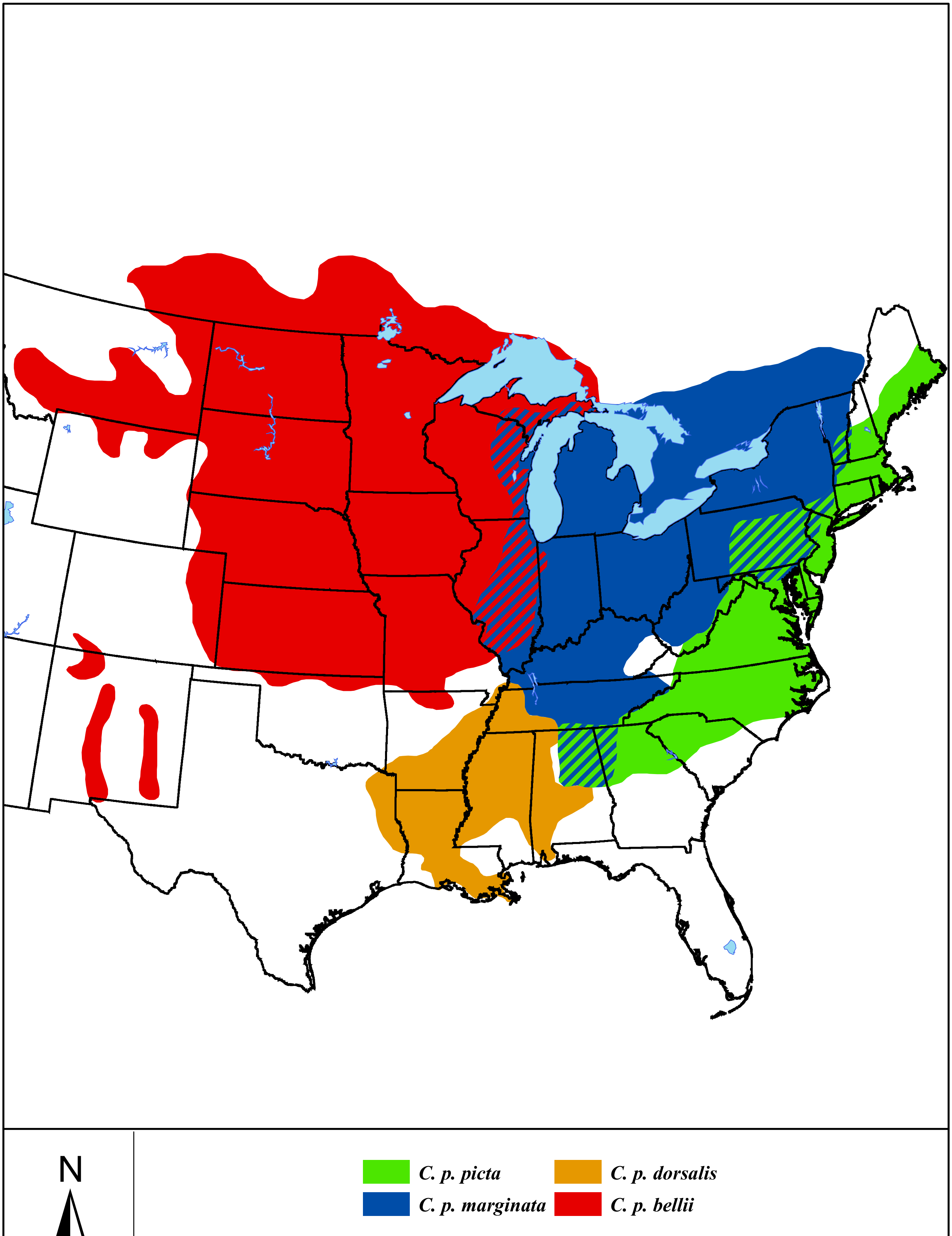


Figure 11. Geographic distribution of *Chrysemys picta* in North America.

1.3.2 Post-Glacial Dispersal

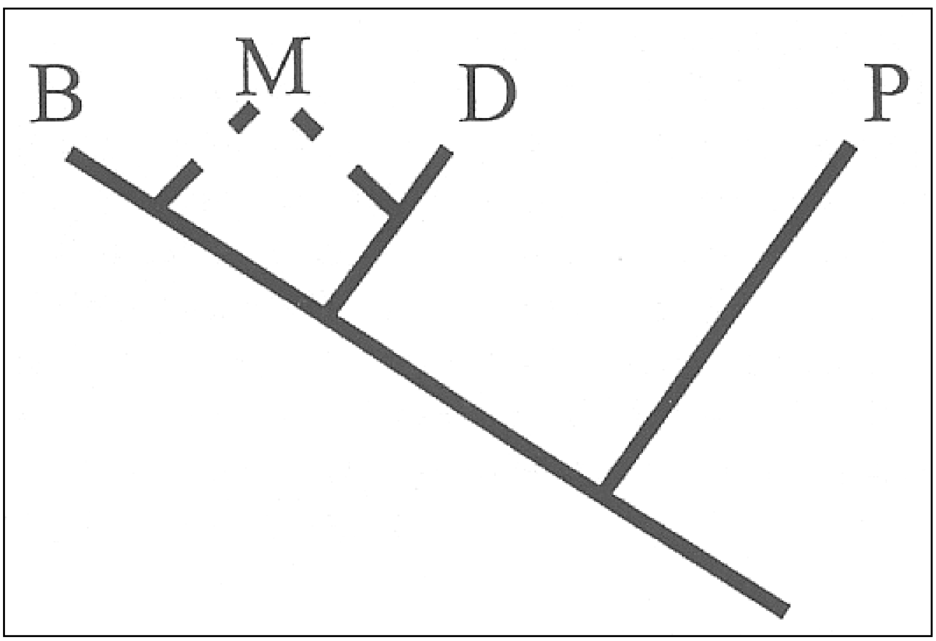
Bleakney (1958) suggested that during the last Wisconsinan glaciation of 20,000 years ago, *Chrysemys picta* was divided into three separate and genetically isolated populations: *C. p. picta* in the Atlantic coastal region, *C. p. dorsalis* in the lower Mississippi region, and *C. p. bellii* in the southwest. With the retreat of the glaciers, subspeciation occurred. Bleakney hypothesized that *C. p. dorsalis* was created from a refuge population in the lower Mississippi regions, while *C. p. picta* was formed from a retreat in the Atlantic Costal region, and *C. p. bellii* was formed in the west. When the three populations expanded northward, *C. p. marginata* was formed when *C. p. dorsalis* and *C. p. bellii* came into contact with each other and "hybridized" (Figure 12). *C. p. picta x C. p. marginata* intergrades were formed when *C. p. marginata* spread into the Ohio River Valley and eventually met *C. p. picta* as it spread to the north and west. Bleakney's hypothesis has been widely accepted (Groves, 1983; Wright and Andrews, 2002; Waters, 1964; Pough and Pough, 1968; Ernst, 1970) but has been recently debated by Starkey et al. (2003) based on molecular data. However, Starkey et al. (2003) noted that more molecular tests are needed before any definite conclusions can be made, particularly considering the hybrid origin of *C. p. marginata*.

1.3.3 Habitat

Chrysemys picta spend much of their time basking on logs in shallow bodies of water such as lakes and ponds (Conant and Collins, 1998) or slow-moving streams and rivers. Pools with a soft and muddy substrate that are rich in aquatic vegetation are also widely preferred (Green and Pauley, 1987). Detailed habitat information is not known for most of the specimens measured in the study, for preserved specimens from museum collections were used. Specimen locality data were limited to information received from the databases at the Carnegie Museum (CMNH) and West Virginia Biological Survey (WVBS). Geographic locations of measured specimens were plotted on distribution maps based on information provided in the databases. All museum numbers and locality notes for preserved specimens are listed in Appendix A.

Figure 12. Interpretation of Bleakney's hypothesis of the hybrid origin of *Chrysemys picta marginata.*

(Starkey et al., 2003)



(B = *C. p. bellii,* D = *C. p. dorsalis,* M = *C. p. marginata,* and P = *C. p. picta*)

2.0 MATERIALS AND METHODS

2.1 SPECIMENS

One hundred and fourteen adult painted turtles were examined from museum collections at the West Virginia Biological Survey (WVBS) and the Carnegie Museum of Natural History (CMNH). Juveniles (individuals less than 90 mm in length; Pough and Pough, 1968) were excluded since the significance of their morphological characters is not well understood (Klemens, 1978).

Fifty-three specimens from West Virginia were examined. These specimens were grouped into areas based on watersheds, including the Lower Ohio / Kanawha rivers (Boone, Cabell, Jackson, Ritchie, Roane, Mason, Putnam, and Wood counties), New River (Mercer, Monroe, and Summers counties), Greenbrier River (Greenbrier and Pocahontas counties), Tygart River (Randolph County), Cheat River (Preston County) and Potomac River (Berkeley, Hampshire, Hardy, and Jefferson counties) (Figure 13). Painted turtles in West Virginia were originally distributed throughout the state via two main drainage systems: the Ohio in the west and the Potomac in the east. West Virginia specimens were grouped into the smaller watershed areas mentioned above to examine levels of intergradation throughout the state. The Ohio / Kanawha group was not divided into smaller watershed areas, since intergradation is much less likely to occur in this region. Since intergradation is thought to occur in numerous areas within the state, smaller groups allow for better comparison between hypothetical "populations" of these turtles in West Virginia.

Specimens collected far from possible regions of intergradation were chosen to represent "pure" populations of *Chrysemys p. picta* and *C. p. marginata.* These included 28 *C. p. picta* specimens from North Carolina, South Carolina, and Virginia and 22 *C. p. marginata* specimens from Indiana, Michigan, and Ohio (Figure 14). As demonstrated in Section 2.3.1, specimens from Greenbrier and New River watersheds were grouped together as "intergrades."

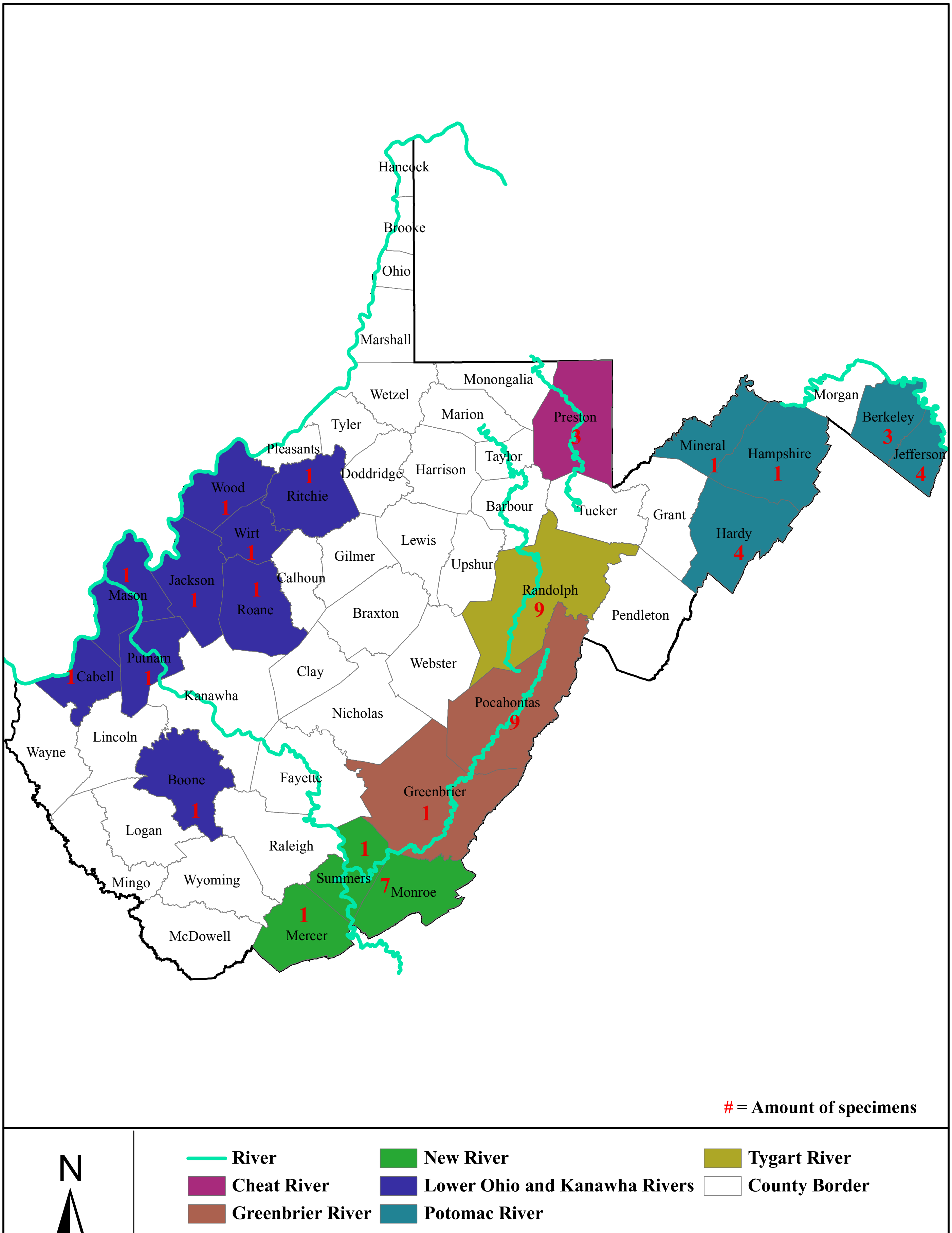


Figure 13. Map of *Chrysemys picta* specimens from West Virginia.

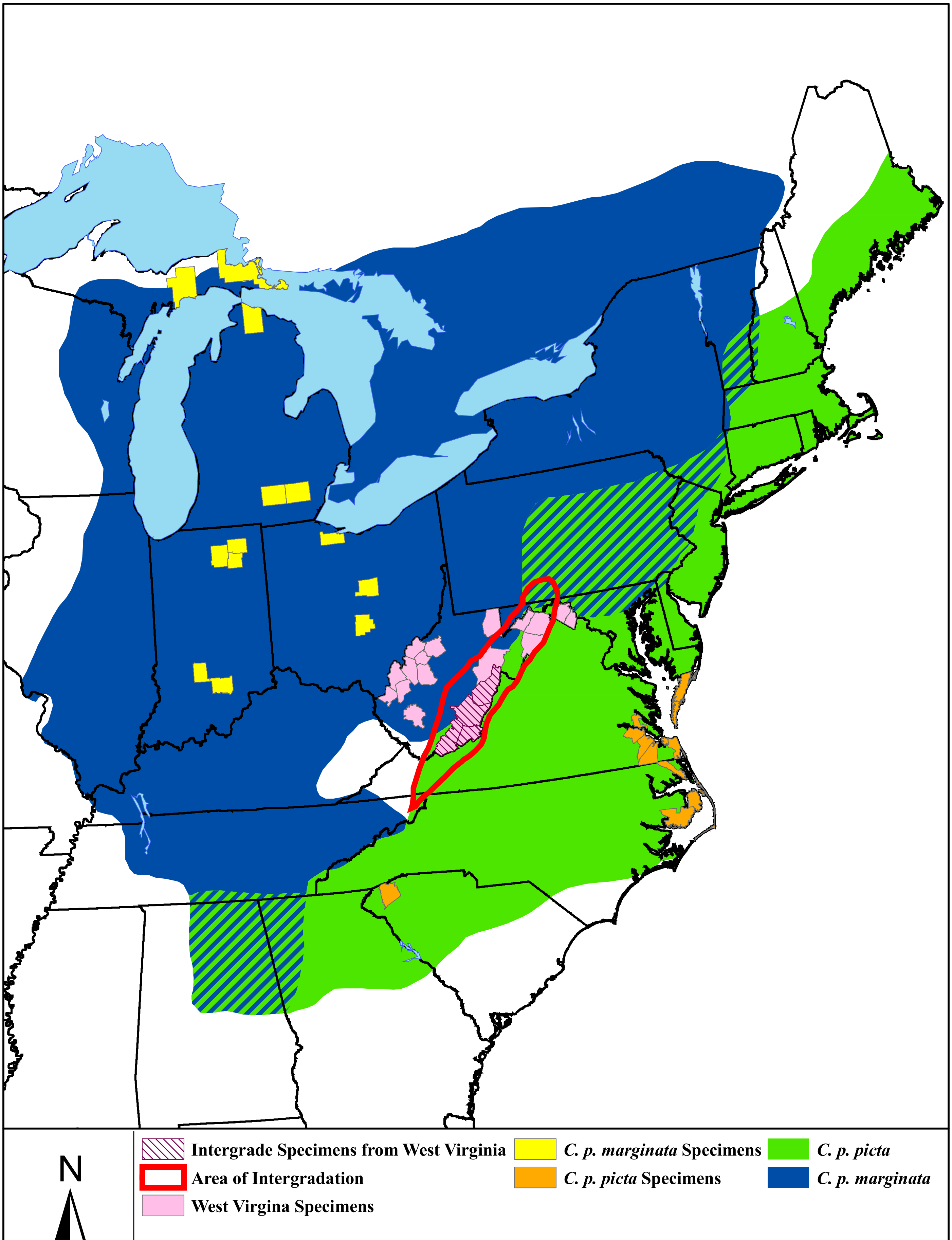


Figure 14. Map of *Chrysemys picta* specimen collection areas.

2.2 STUDY METHODS

Twenty-five morphological characters were measured and recorded for each specimen. Measurements were taken with a PRO-MAX electronic digital caliper accurate to 0.01 millimeters. When pertinent, measurements were taken on the left and right side of each specimen and then averaged. In addition, the carapace and plastron of each turtle were photographed. Claw length was measured to determine the sex of each individual, but was not included in any analyses.

Important characters used to separate the subspecies were chosen based on those outlined by Hartman (1958; Figure 15). Hartman (1958) identified several significant distinguishing characters to separate *Chrysemys p. picta* and *C. p. marginata*; most taxonomic studies of *C. picta* have relied on Hartman's methods since his initial study. Hartman's characters included: 1) percent disalignment of the second costal scutes and second vertebral scutes, 2) width of the anterior border of the second costal scutes at the midpoint, and 3) size of plastral figure, if present. Ratio of disalignment was used to determine the degree of disalignment of the carapacial scutes. When the seams are 100 % disaligned, the scutes are exactly alternate (*C. p. marginata*), and scutes that are 0 % disaligned lie in the same transverse line (*C. p. picta*); however, very few *C. picta* specimens have completely aligned or exactly alternate costal scutes.

Characters were also chosen on the basis of their importance for identification in field guides and other taxonomic keys. Additional measurements were taken to determine possible new distinguishing characteristics that are taxonomic characters measured in other Emydid species (Seidel and Palmer, 1991; Seidel, 1994 and 1999). New character measurements included supratemporal eye stripe length, width, and width/length ratio (Figure 16). Plastral markings were not quantified or analyzed for this study. Plastral pattern data has not been a reliable character in many *C. picta* studies (including this study), for the markings are often faded and indistinct on preserved specimens (Ultsch, et al., 2001).

Figure 15. Examples of *Chrysemys picta* carapace measurements as described by Hartman (1958).

1) Second costal scute width
2) Width of the anterior border of the second costal scute at the midpoint
3) Disalignment of the posterior edge of the second costal scute and posterior edge of the second vertebral scute
4) Straight-line length of the carapace

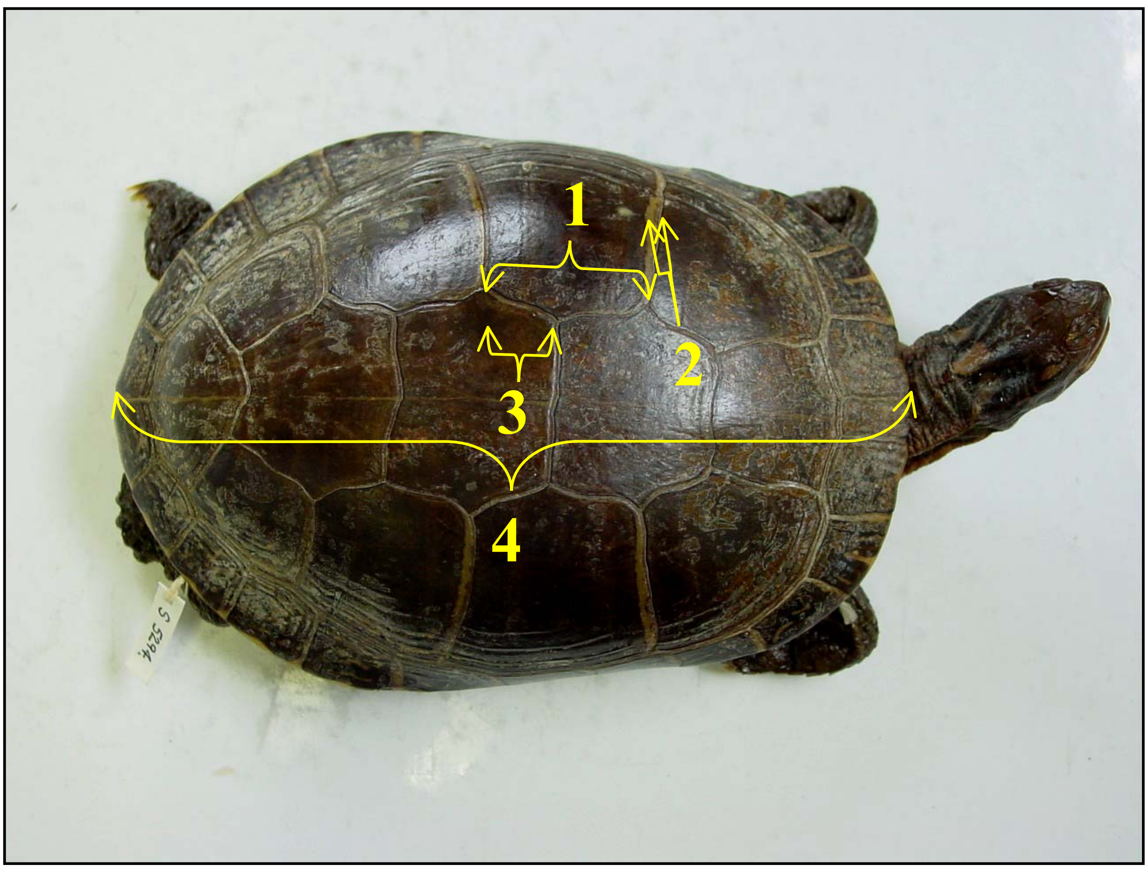
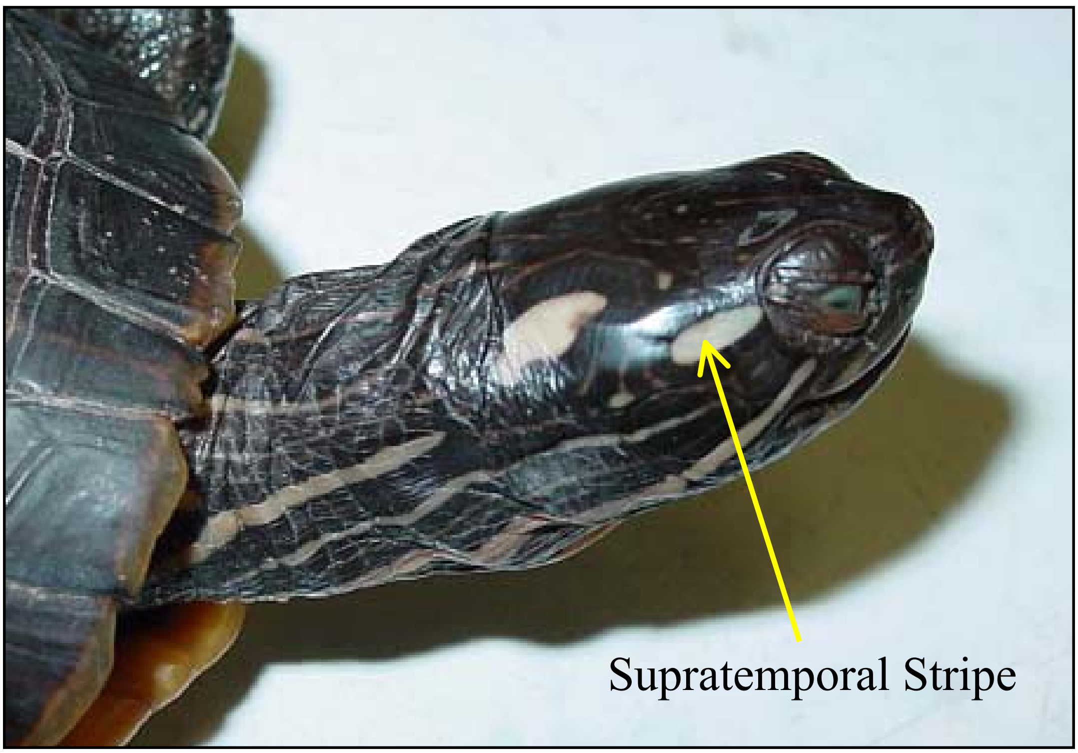


Figure 16. Supratemporal head stripe of *Chrysemys picta.*



2.3 DATA ANALYSES

2.3.1 West Virginia Watershed Analyses

One hundred and three specimens were evaluated to analyze potential clinal variation of morphological characters within West Virginia. Specimens were separated into groups based on their respective watersheds of origin. For the purposes of this study, those watersheds were based on counties of collection..

Sixteen of the 25 measured characters were determined to be important for multivariate statistical analyses (Table 7). Characters derived from ratios were calculated from original measurements in Microsoft Excel (2000 Version). Using SAS Version 9.1 for Windows, Canonical Discriminant Analysis (CDA) and Principal Component Analysis (PCA) were performed on 101 specimens. Two of the 103 specimens were previously decapitated and did not possess any values for certain characters (CW, SL, SW, SR). Since SAS is unable to analyze specimens with missing data, these individuals were eliminated from the multivariate statistical analysis. West Virginia watershed populations were compared to "pure" populations of both subspecies.

Key distinguishing characters from all 103 specimens, including 53 from West Virginia, were analyzed and compared to the "pure" populations of both subspecies (Figures 13 and 14). Using Microsoft Excel, two characters, 1) percent disalignment of the carapacial scutes (PD), and 2) ratio width of the second costal scute margin versus carapace length (PM), were plotted on column graphs for each population or watershed group (Table 7). These column graphs gave visual representations of group means among West Virginia watersheds and pure subspecies populations.

Table 7. List of the morphological characters measured in the study and subjected to statistical analyses in SAS.

	Character Abbreviation and Name	Description
1	**SLC**- Straight-line carapace length	length of the carapace along the midline of the body at the greatest distance (mm)
2	**CW-** Carapace width	width of the carapace at the midline of the body (mm)
3	**CLL-** Second costal scute width (left)	width of the second costal scute of the carapace that lies between the marginals and the vertebrals (mm)
4	**CLR-** Second costal scute width (right)	width of the second costal scute of the carapace that lies between the marginals and the vertebrals (mm)
5	**DL-** Scute disalignment (left)	posterior edge of the second costal scute to the posterior edge of the second vertebral scute (mm)
6	**DR-** Scute disalignment (right)	posterior edge of the second costal scute to the posterior edge of the second vertebral scute (mm)
7	**PD-** Percent disalignment	disalignment ratio of the second costal scutes and the second vertebral scutes (%) (**DL/CLL) + (DR/CLR)**; (Hartman, 1958)
8	**MWL-** Anterior margin width (left)	width of the anterior margin of the second costal scute at the midpoint (mm)
9	**MWR-** Anterior margin width (right)	width of the anterior margin of the second costal scute at the midpoint (mm)
10	**PM-** Margin/carapace ratio	ratio of second costal margin width average (for both sides) versus straight-line carapace length (%) (Utlsch, et al., 2001)
11	**SH-** Shell height	distance from the highest point on the carapace to the lowest point on the plastron (mm)
12	**SLP-** Straight-line plastron length	length of the plastron along the midline of the body at the greatest distance (mm)
13	**HW-** Head width	width of the head at the widest point (mm)
14	**SL-** Supratemportal stripe length	length of the yellow stripe extending from the anterior portion of the left eye (mm)
15	**SW-**Supratemportal stripe width	width of the yellow stripe extending from the anterior portion of the left eye (mm)
16	**SR-** Supratemportal stripe ratio	ratio of the supratemporal stripe width versus length

2.3.2 Intergrade Analyses

Eighty specimens were used to compare West Virginia intergrade populations to "pure" populations of both subspecies. Intergrade populations included 19 *Chrysemys p. picta* x *C. p. marginata* specimens from distinct areas of intergradation in West Virginia. Based on results of the watershed analyses (Section 2.3.1), only specimens from Pocahontas, Greenbrier, Mercer, Monroe and Summers counties (Greenbrier and New River watersheds) were examined as intergrades; therefore, specimens from all other counties were excluded. Specimens from the Greenbrier and New River watersheds were significantly different from "pure" population groups. All other watersheds showed an affinity to either "pure" *C. p. picta* or *C. p. marginata* populations. All specimens representing "pure" populations outside of West Virginia were used again for this portion of the study (Figure 14).

Using SAS, Canonical Discriminant Analysis (CDA), Principle Component Analysis (PCA), and Analysis of Variance (ANOVA) were performed on 16 characters that were measured on each specimen (Table 7). Eigenvalues, canonical coefficients, eigenvectors, and squared distances (D) were used to interpret the statistical significance of the results. Using Microsoft Excel, polygonal graphs (radiate indicators), population range diagrams, and bivariate scatterplots were constructed from the character data and analyzed visually for trends.

3.0 RESULTS AND DISCUSSION

3.1 WEST VIRGINIA WATERSHED ANALYSES

A watershed analysis was performed to determine trends in *Chrysemys p. picta* and *C. p. marginata* morphology across West Virginia.

3.1.1 Multivariate Statistical Analyses

CDA accounts for variations in the sample data based on the pre-defined groups that were assigned prior to the analysis. Compared to PCA, it has the most powerful discriminatory ability; however, it is also the most biased, for it analyzes variation in the sample based on differences from pre-defined group means. Therefore, graphical analysis can at times indicate greater morphological variation than what is actually present in the sample.

CDA showed selective clustering of *C. picta* populations within West Virginia (Figure 17). Some populations were significantly different, while others overlapped greatly. Pure populations of *C. p. picta* and *C. p. marginata* were significantly different ($D=57.05$; $P<0.0001$; Table 8). Some groups showed close affiliations with these pure subspecies populations. For example, Ohio/Kanawha River specimens were closely related to pure *C. p. marginata* specimens ($D=2.82$; $P>0.5$), while Potomac River specimens were closely related to pure *C. p. picta* specimens ($D=4.27$; $P=0.245$). West Virginia populations from the Cheat, Greenbrier, New, and Potomac River watersheds were significantly different ($P<0.001$) from pure *C. p. marginata* populations. Populations from the Greenbrier, New, Ohio/Kanawha, and Tygart River watersheds were significantly different ($P<0.001$) from pure *C. p. picta* populations. Therefore, only those specimens from the Greenbrier and New River watersheds were significantly different from both pure subspecies populations. Table 8 shows the statistical relationships among groups of study specimens. Those with P values less than 0.05 are considered significantly different from one another.

Figure 17. Plot of *Chrysemys picta* Canonical Discriminant Analysis by West Virginia watershed: Can 1 vs. Can 2.

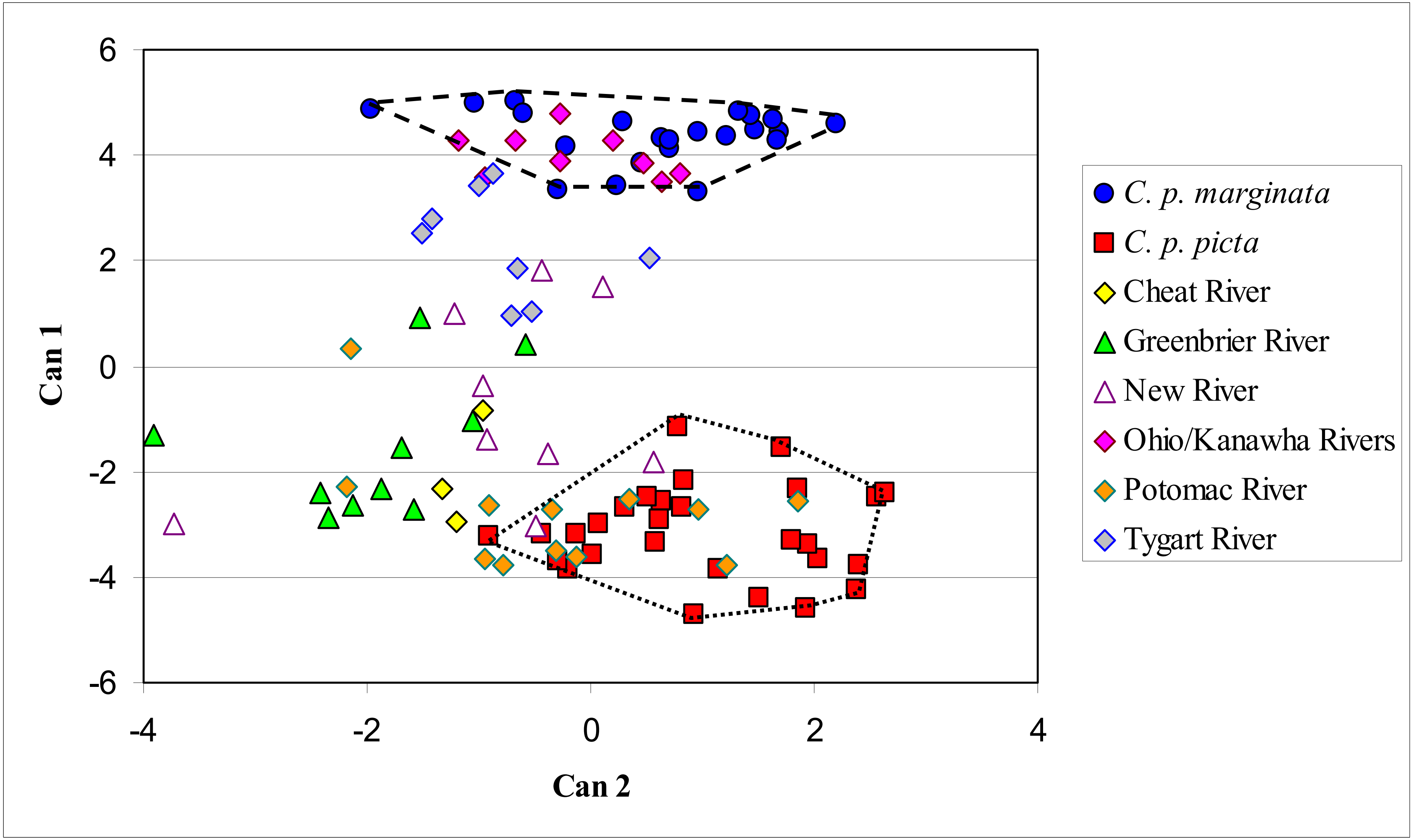


Table 8. Comparison of P values among *Chrysemys picta* watershed groups analyzed by Canonical Discriminant Analysis.

Groups	C	E	G	M	N	O	P	T
C	1	0.316	0.9613	<.0001	0.8518	<.0001	0.9189	0.0011
E	0.316	1	<.0001	<.0001	<.0001	<.0001	0.2449	<.0001
G	0.9613	<.0001	1	<.0001	0.2184	<.0001	0.0348	<.0001
M	<.0001	<.0001	<.0001	1	<.0001	0.5229	<.0001	0.0004
N	0.8518	<.0001	0.2184	<.0001	1	<.0001	0.0382	0.0008
O	<.0001	<.0001	<.0001	0.5229	<.0001	1	<.0001	0.0515
P	0.9189	0.2449	0.0348	<.0001	0.0382	<.0001	1	<.0001
T	0.0011	<.0001	<.0001	0.0004	0.0008	0.0515	<.0001	1

1) C = Cheat River, E = Pure Eastern, G = Greenbrier River, M = pure Midland, N= New River, O = Ohio/Kanawha, P = Potomac River, T = Tygart River
2) Groups with $P<0.05$ are significantly different from one another
3) Groups with $P>0.05$ are not significantly different from one another

Despite the lack of group-selection bias, PCA also showed clustering of *C. picta* populations (Figures 18 and 19). Relationships among West Virginia watershed groups were similar to those distinguished by CDA. Ohio/Kanawha and Potomac River watersheds showed the closest affinities to pure *C. p. marginata* and *C. p. picta*, respectively. Greenbrier and New River groups separated more completely from either group, potentially showing more thorough intergradation in those areas.

Eigenvalues represent the amount of variation that is accounted for in CDA or PCA (Table 9). Eigenvalues express variation as a mathematical value and are a measurement of the amount of variation used in the separation of the taxa or groups. Eigenvalues showed that most of the variation (86%) in CDA was in Can 1. The number of canonical variables is equal to the number of assigned groups, minus one. One hundred percent of the variation in CDA was achieved after seven canonical variables; however, over 95 percent was accounted for on the first three variables. Standardized canonical coefficient values showed that PD, PM, DL, MWR, and CLL accounted for most variation on Can 1, while CW, DL, SR, and SLC accounted for most variation on Can 2 (Table 10).

Figure 18. Plot of *Chrysemys picta* Principal Component Analysis by West Virginia watershed: Prin 1 vs. Prin 2.

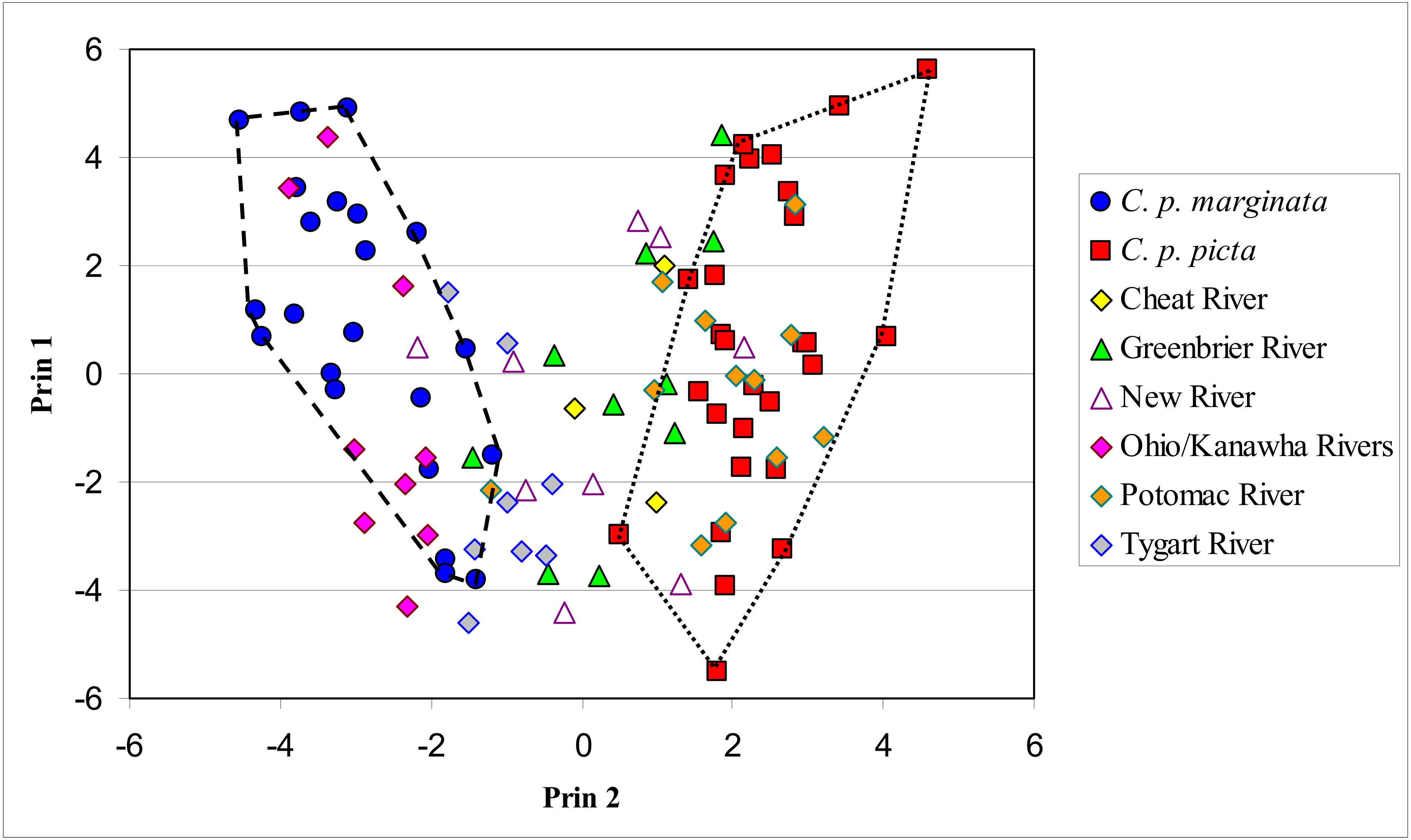


Figure 19. Plot of *Chrysemys picta* Principal Component Analysis by West Virginia Watershed: Prin 3 vs. Prin 2.

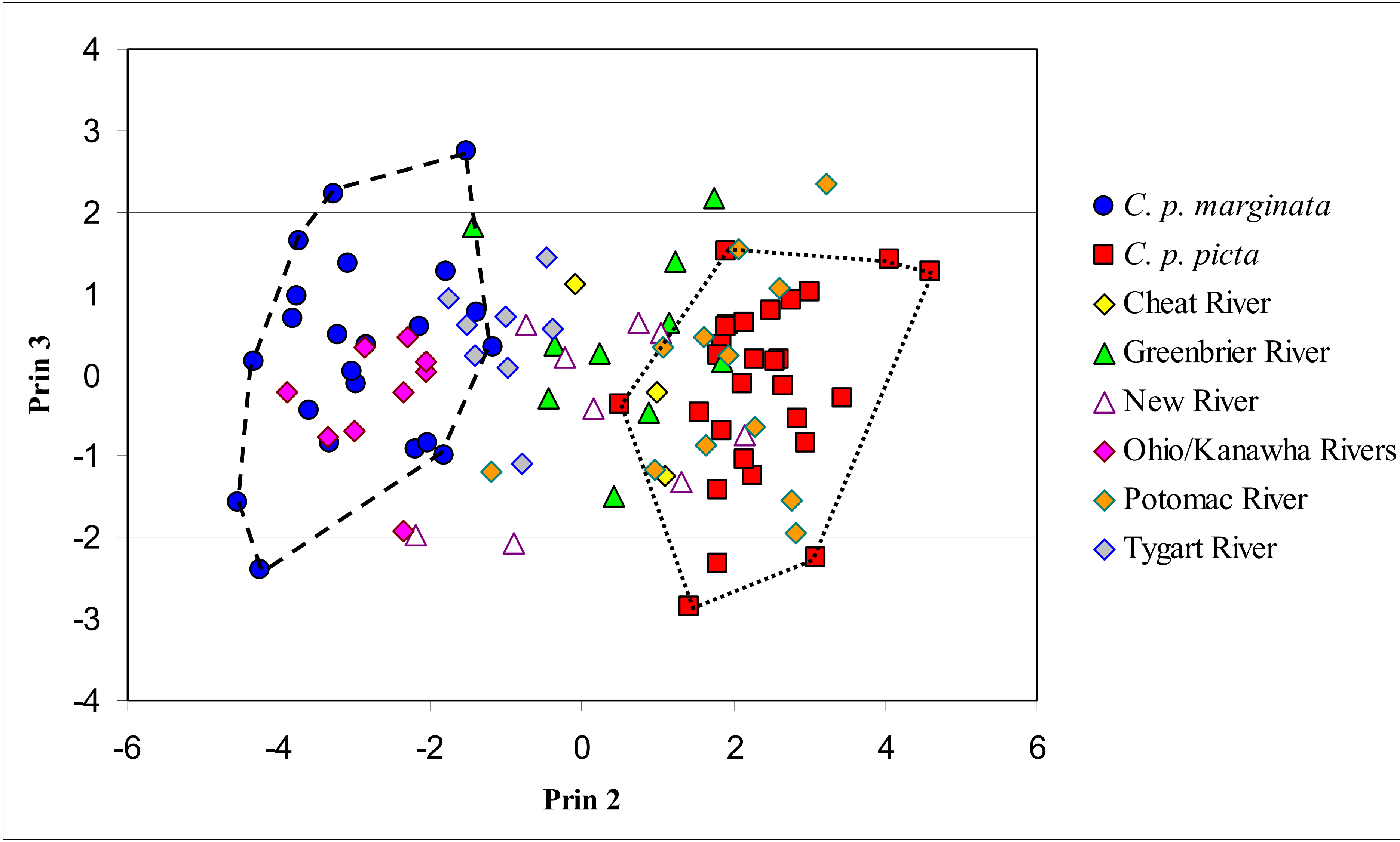


Table 9. Eigenvalues for Canonical Discriminant and Principal Component Analyses of the *Chrysemys picta* watershed analyses.

Test		**Eigenvalue**	**Difference**	**Proportion**	**Cumulative**
CDA	Can 1	10.9596	10.0112	0.8611	0.8611
	Can 2	0.9484	0.5965	0.0745	0.9356
	Can 3	0.3519	0.1818	0.0276	0.9632
	Can 4	0.1701	0.0184	0.0134	0.9766
	Can 5	0.1517	0.0649	0.0119	0.9885
	Can 6	0.0868	0.0274	0.0068	0.9953
	Can 7	0.0593		0.0047	1.0000
PCA	Prin 1	2.9891	1.0261	0.2299	0.2299
	Prin 2	1.9629	0.6351	0.1510	0.3809
	Prin 3	1.3278		0.1021	0.4831

Table 10. Canonical Coefficients and Eigenvectors for Canonical Discriminant and Principal Component Analyses of the *Chrysemys picta* watershed analyses.

Characters	CDA Canonical Coefficients		PCA Eigenvectors		
	Can 1	Can 2	Prin 1	Prin 2	Prin 3
SLC	-0.9875	-1.8989	0.3645	-0.0303	-0.0944
CW	0.4740	2.8753	0.3554	-0.0331	-0.0543
CLL	1.1838	-0.0751	0.3628	0.0084	-0.0686
CLR	-0.7017	0.5541	0.3618	0.0036	-0.0715
DL	-1.3702	-2.3908	0.0771	-0.3769	0.0327
DR	0.3970	1.7002	0.0714	-0.3759	0.0461
PD	3.4483	1.2395	-0.0038	-0.3807	0.0567
MWL	-0.1223	0.5993	0.1693	0.3227	0.3547
MWR	1.2054	-0.8123	0.1763	0.3036	0.3884
PM	-1.4745	0.3978	0.0686	0.3451	0.4417
SH	0.0620	0.4453	0.3433	-0.0083	-0.1385
SLP	-0.1828	-1.1766	0.3468	0.0189	-0.1478
HW	-0.0577	0.0042	0.3554	-0.0114	-0.0704
SL	0.1608	0.8617	0.1772	-0.2259	0.2288
SW	0.0638	-0.6182	0.0238	0.3111	-0.4655
SR	-0.7176	1.9943	-0.0798	0.3254	-0.4303

Unlike CDA, the most visible difference between population groups for PCA was seen on the second principal component. Eigenvalues for PCA showed that approximately 48 percent of the variation was accounted for on three principal components (Table 9). Eigenvector values showed that no specific characters contributed significantly higher weight to account for the variation on Prin 1, Prin 2, or Prin 3 (Table 10).

3.1.2 Character Analyses

Column graphs revealed clinal differences in *C. picta* morphology within different watersheds across the state (Table 11; Figures 20 and 21). Moving eastward, there was an increase in similarity to *C. p. picta* morphology from watersheds in the western part of the state across to the eastern panhandle. From west to east, both the mean percent disalignment (PD) and scute margin width ratio (PM) measurements became increasingly *C. p. picta* in character (Figures 20 and 21). Figure 22 shows the distribution of *Chrysemys picta* populations within the state of West Virginia, as determined by all components of the watershed analyses.

Table 11. Clinal differences in two *Chrysemys picta* characters based on watershed locality.

	Pure *marginata*	**Ohio / Kanawha Rivers**	**Tygart River**	**New River**	**Greenbrier River**	**Potomac River**	**Cheat River**	**Pure *picta***
Scute Disalignment (%)								
Number	22	9	9	9	10	13	3	28
Mean	91.30	86.29	75.09	35.83	27.17	26.33	26.59	18.96
SD	6.85	5.04	15.80	23.98	16.35	16.90	5.43	10.85
Min	77.63	74.45	43.22	7.09	11.48	4.17	20.97	5.82
Max	110.03	92.68	90.96	74.91	64.46	54.12	31.82	47.97
Border Width/Carapace Ratio (%)								
Number	22	9	9	9	10	13	3	28
Mean	1.29	1.01	1.54	1.51	1.84	2.19	1.74	2.37
SD	0.51	0.25	0.51	0.51	0.50	0.72	0.17	0.57
Min	0.00	0.55	0.62	0.58	1.05	0.84	1.57	1.15
Max	2.25	1.36	2.31	2.19	2.73	3.88	1.90	3.54

*Format modified from Wright and Andrews, 2002.

Figure 20. Mean percent disalignment of *Chrysemys picta* specimens based on watershed locality.

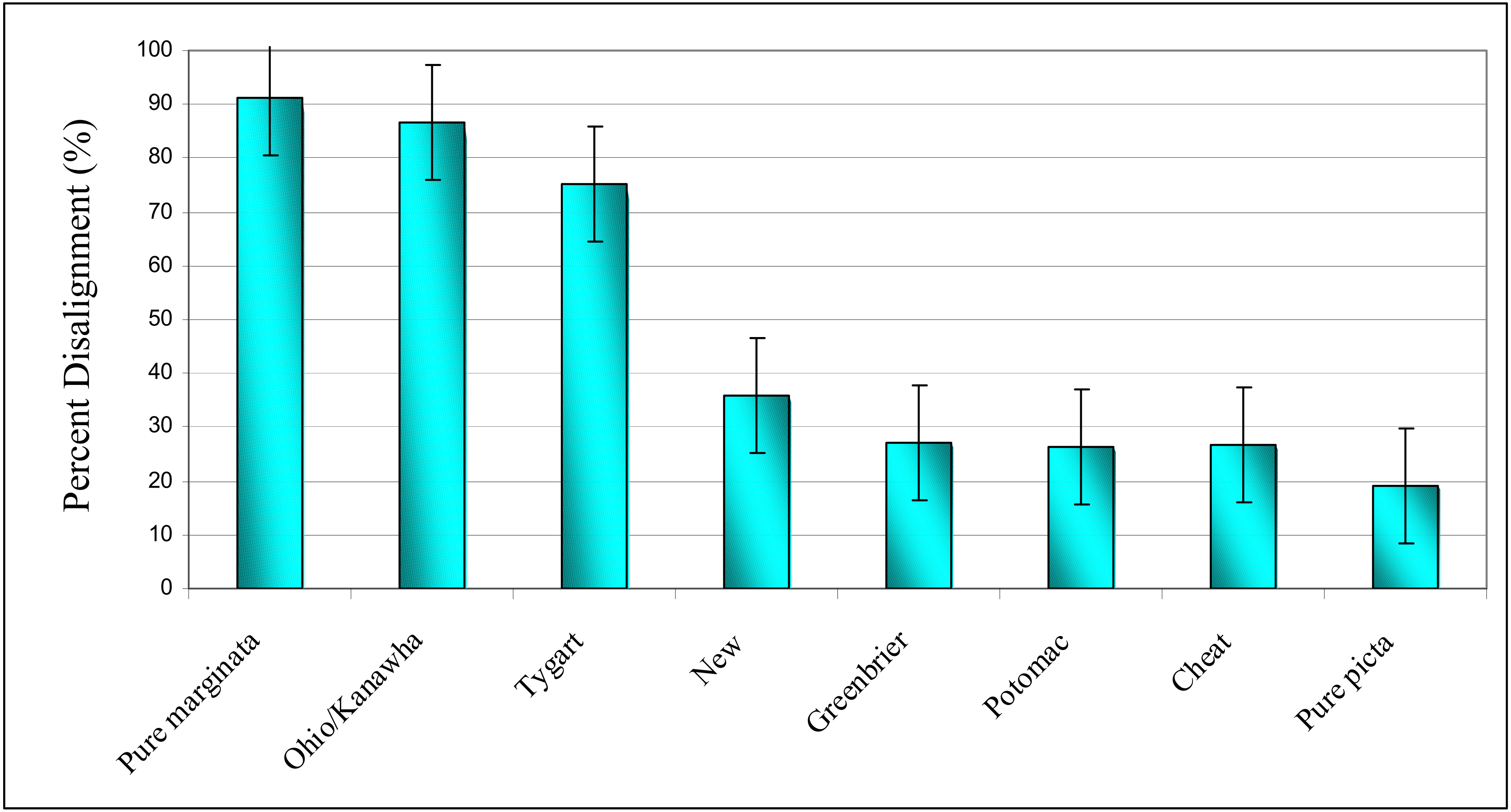
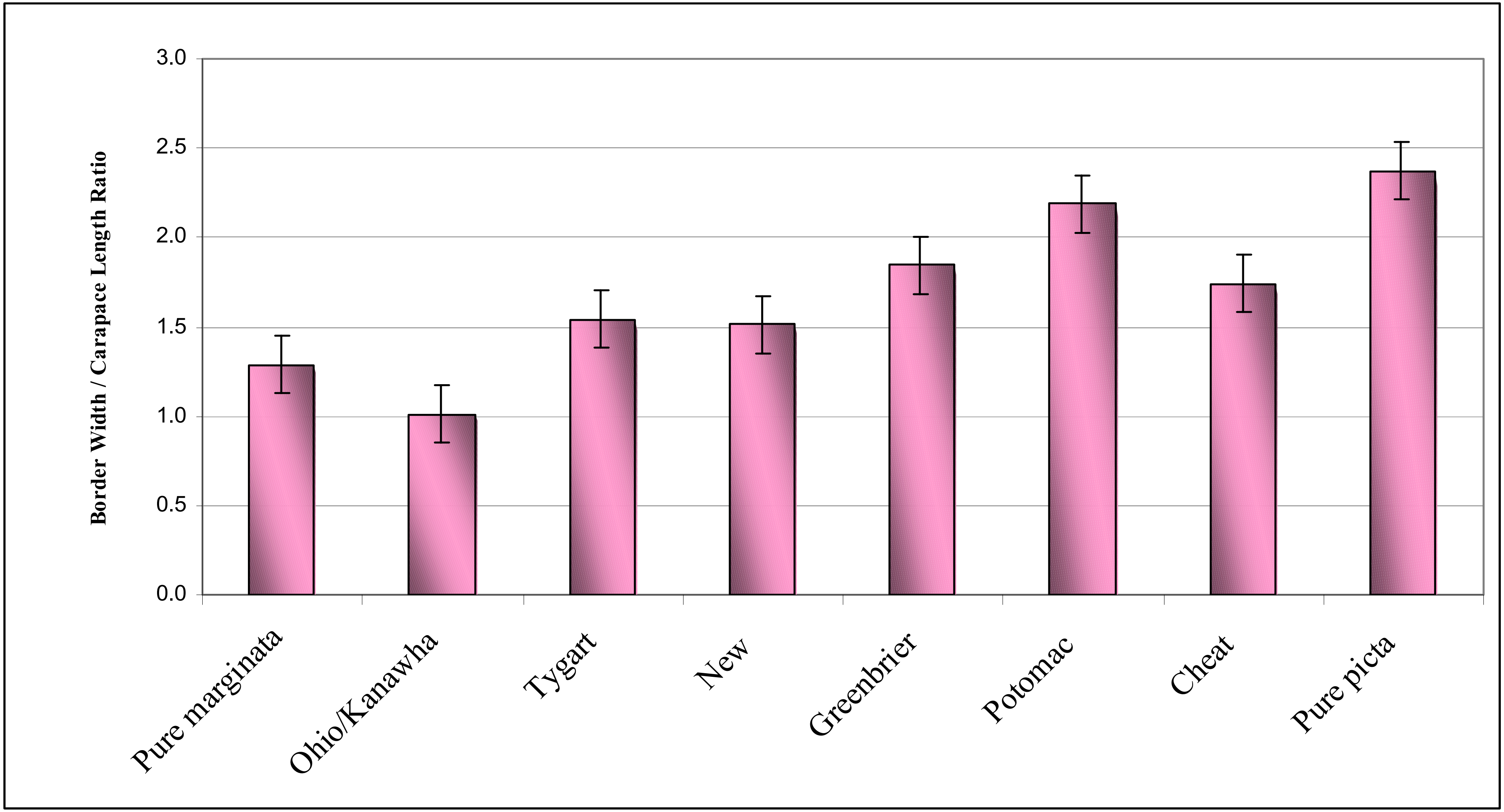


Figure 21. Border width / carapace length ratio of *Chrysemys picta* specimens based on watershed locality.



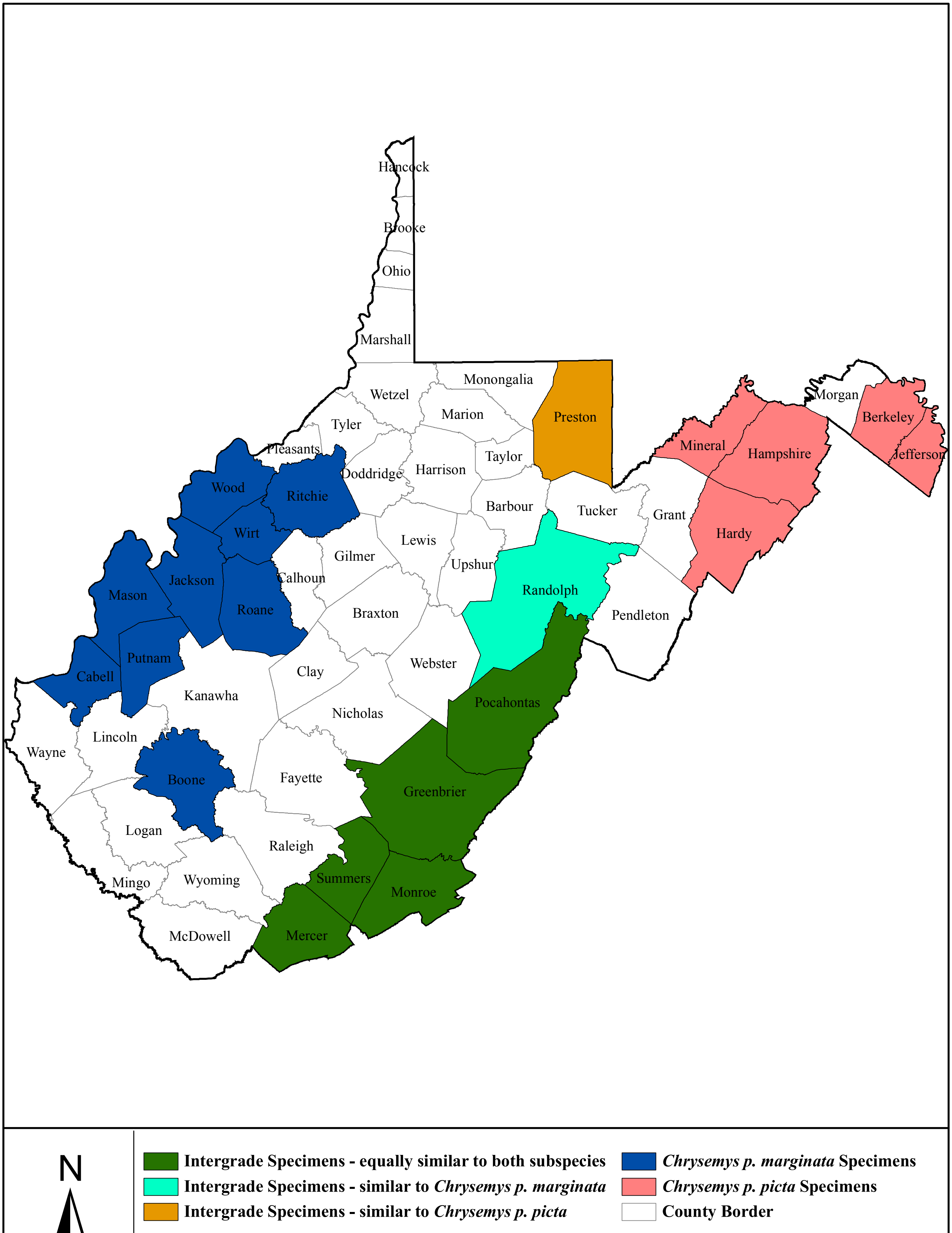


Figure 22. Distribution of *Chrysemys picta* populations within West Virginia, as determined by the watershed analyses.

3.2 INTERGRADE ANALYSES

Specimens from Greenbrier and New River watersheds were significantly different from both pure subspecies populations; therefore, they were chosen as typical representatives of intergrade populations in West Virginia.

3.2.1 Multivariate Statistical Analyses

3.2.1.1 Canonical Discriminant and Principal Component Analyses

CDA showed significant separation of the subspecies *Chrysemys p. picta* and *C. p. marginata* (D=48.430; P<0.0001), with *C. p. picta x C. p. marginata* intergrades as a significantly different group between the two subspecies (P<0.0001;Figure 23), This is expected for intermediate populations, for although they are essentially a combination of the two subspecies, their differences set them apart from either group. Data indicated that intergrades measured in the study are more *C. p. picta* in character, since the intergrades are positioned nearer to *C. p. picta* (D=9.539) than *C. p. marginata* (D=26.512). Some of the character measurements were not converted to ratios; therefore, CDA also accounted for size variation in the character measurement data.

Principle Component Analysis (PCA) is a more reliable test for variation, for it does not incorporate user bias of distinguishing data into set groups or taxa. PCA and CDA graphical analyses showed similar arrangements, with *Chrysemys p. picta* and *C. p. marginata* separating completely (Figures 23 to 25). PCA graphs indicated that the intergrades do not separate completely from the two subspecies but occur as a clustered series of points located almost exactly between the two groups, but overlapping *C. p. picta* to a greater extent (Figures 24 and 25). Based on the characters measured in the study, PCA graphs illustrated that the intergrades more closely resemble *C. p. picta*.

Figure 23. Plot of *Chrysemys picta* Canonical Discriminant Analysis using West Virginia intergrades: Can 1 vs. Can 2.

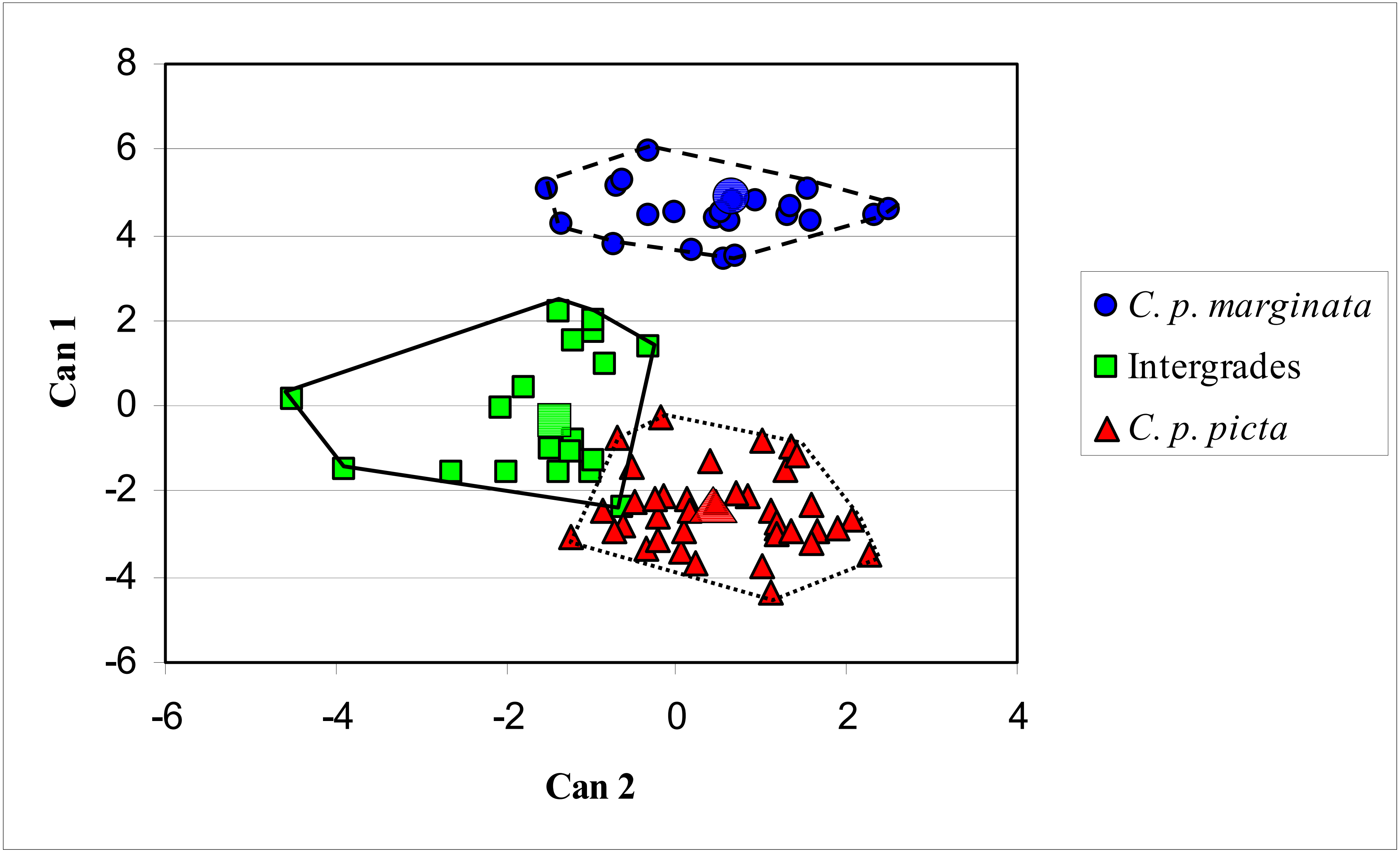


Figure 24. Plot of *Chrysemys picta* Principle Component Analysis using West Virginia intergrades: Prin 1 vs. Prin 2.

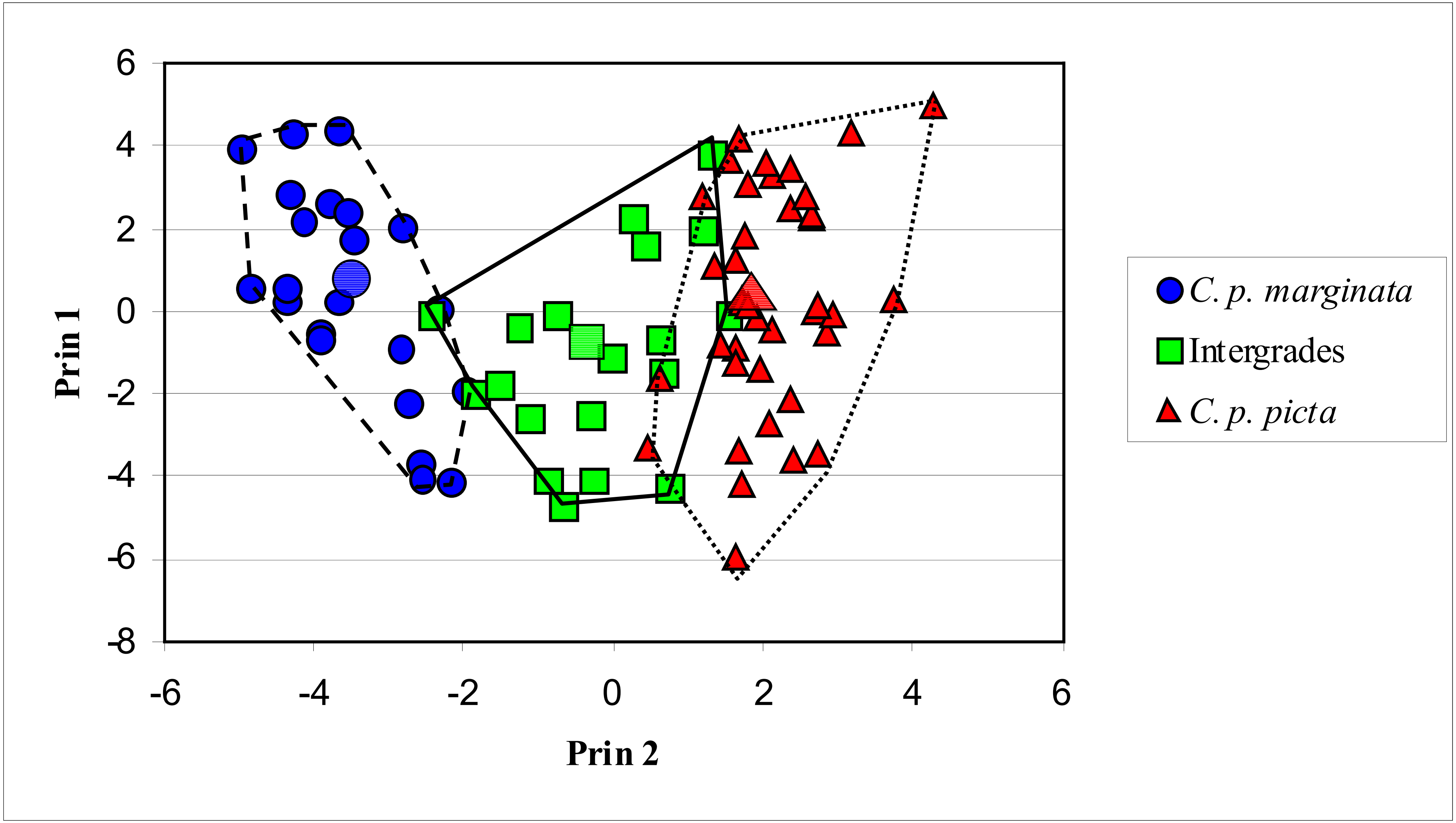
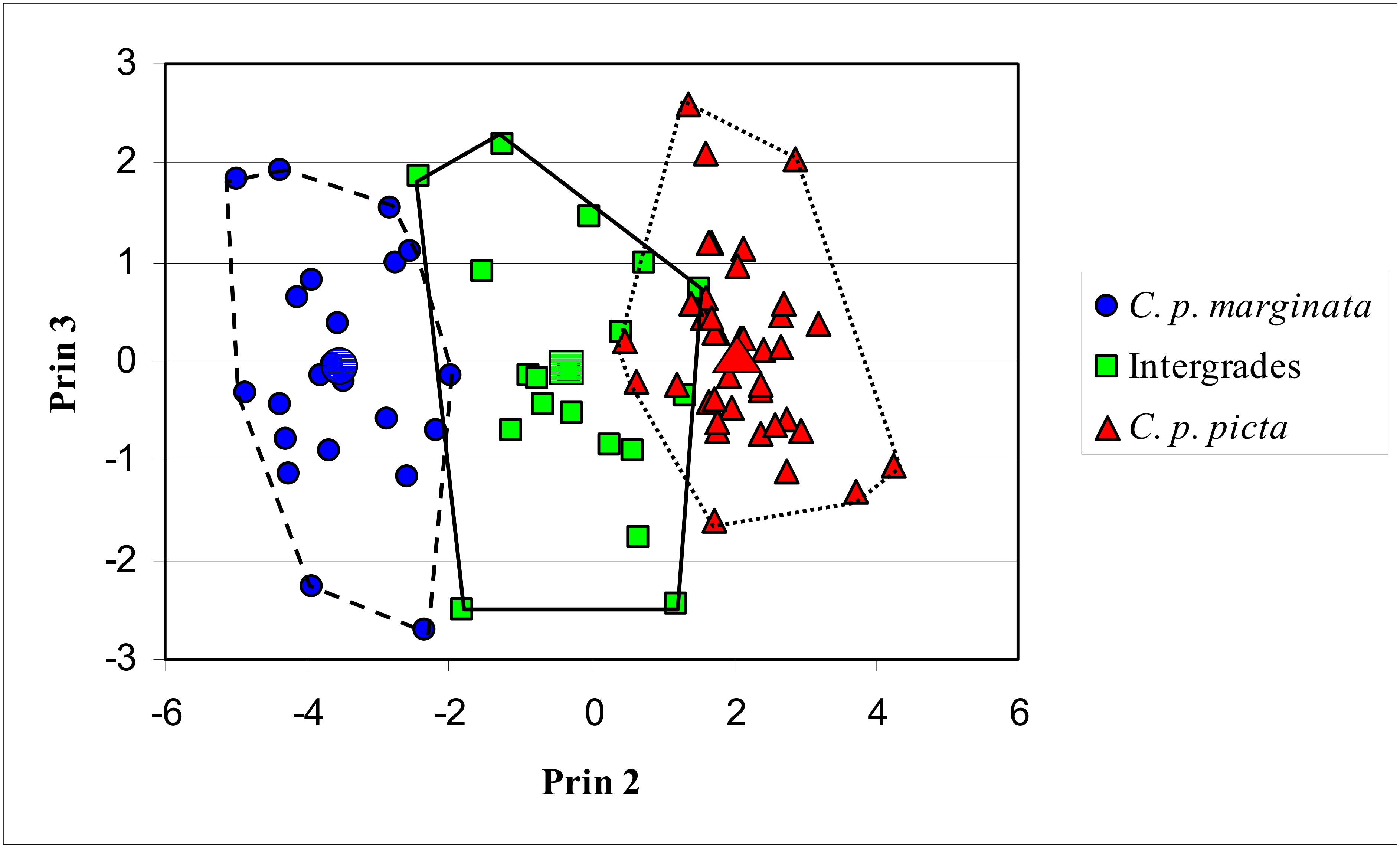


Figure 25. Plot of *Chrysemys picta* Principle Component Analysis using West Virginia intergrades : Prin 3 vs. Prin 2.



Eigenvalues for CDA showed that 100% of the variation in the data was used to separate the taxa (Table 12). All of the variation was accounted for as expected, due to the high level of the test's discriminatory power. PCA eigenvalues show that a high percentage (85.79%) of the variation was used in the statistical analysis (Table 12). Additional PCA tests could be added, but only a very small percentage of the variation in the sample would be added to the original analysis.

Table 12. Eigenvalues for Canonical Discriminant and Principal Component Analyses of the *Chrysemys picta* intergrade analyses.

Test		**Eigenvalue**	**Difference**	**Proportion**	**Cumulative**
CDA	Can 1	8.8596	8.0271	0.9141	0.9141
	Can 2	0.8325		0.0859	1.0000
PCA	Prin 1	6.9946	0.5967	0.4114	0.4114
	Prin 2	6.3978	5.2060	0.3763	0.7878
	Prin 3	1.1918		0.0701	0.8579

One hundred percent of the variation in CDA was achieved on two canonical variables; over 91 percent was accounted for on the first variable. Standardized canonical coefficient values showed that PD, PM, and DL accounted for most variation on Can 1, while PM, SR, PD, CW, and DL accounted for most variation on Can 2 (Table 13). PD and PM are very important characters for separating taxa using this statistical test. Eigenvector values showed that no specific characters contributed significantly higher weight to account for most of the variation on Prin 1, Prin 2, or Prin 3 (Table 13).

3.2.2 Analysis of Variance (ANOVA)

Analysis of Variance (ANOVA) determined the significance of the characters measured in separating the pre-defined groups or taxa by producing "F" values for each character. The defined "taxa" were *Chrysemys p. picta, C. p. marginata*, and *C. p. picta x C. p. marginata* intergrades.

Table 13. Canonical Coefficients and Eigenvectors for Canonical Discriminant and Principal Component Analyses of the *Chrysemys picta* intergrade analyses.

Characters	CDA Canonical Coefficients		PCA Eigenvectors		
	Can 1	Can 2	Prin 1	Prin 2	Prin 3
SLC	-0.4352	0.8587	0.3337	-0.0177	0.0895
CW	-0.3303	2.4992	0.3597	-0.0290	0.1035
CLL	0.3627	-1.0370	0.3639	0.0077	0.0724
CLR	-0.2044	0.9825	0.3634	0.0065	0.0582
DL	-1.2638	-2.1640	0.0849	-0.3744	0.0765
DR	0.6506	-0.0009	0.0734	-0.3792	0.0523
PD	2.7997	2.6623	0.0172	-0.3836	0.0524
MWL	0.5293	-0.7716	0.1896	0.3172	-0.2954
MWR	0.4853	-1.7995	0.1953	0.2972	-0.3176
PM	-1.2470	2.8440	0.0822	0.3438	-0.3780
SH	0.5646	0.4219	0.3438	0.0054	0.1467
SLP	-0.4715	-1.0976	0.3449	0.0247	0.1682
HW	0.1707	-0.7672	0.3517	-0.0197	0.0657
SL	0.2141	1.1389	0.1717	-0.2360	-0.3474
SW	-0.3385	-1.3501	0.0041	0.3169	0.4663
SR	-0.4760	2.7055	-0.1036	0.3216	0.4880

(see Table 7 for defined character abbreviations)

Significant differences ($P<0.05$) show strong separation among the taxa. Ten of the sixteen morphological characters measured were significantly different among the groups (Table 14). These included: CW, DL, DR, PD, MWL, MWR, PM, SL, SW and SR (see Table 7 for defined abbreviations). The strongest characters measured variation in scute disalignment (DL, DR, PD), margin width (MWL, MWR, PM), and supratemporal stripe (SL, SW, SR). The F value of carapace width (CW) was significant, but not as strong as the other significant characters (with P values <0.0001) and is not as important as the other characters in separating the groups.

Table 14. Morphological characters and statistical results from Analysis of Variance,.

Character	ANOVA	
	F Value	P Value
SLC	1.19	0.3107
CW	4.46	*0.0147
CLL	1.21	0.3039
CLR	0.98	0.3782
DL	133.42	*<0.0001
DR	156.26	*<0.0001
PD	192.58	*<0.0001
MWL	26.10	*<0.0001
MWR	19.52	*<0.0001
PM	32.21	*<0.0001
SH	2.82	0.0648
SLP	1.00	0.3743
HW	0.93	0.3990
SL	13.76	*<0.0001
SW	41.26	*<0.0001
SR	42.96	*<0.0001

(see Table 7 for defined character abbreviations)
*P Values <0.05 were considered significant.

3.2.3 Character Analyes

3.2.3.1 Polygonal Graphical Analysis

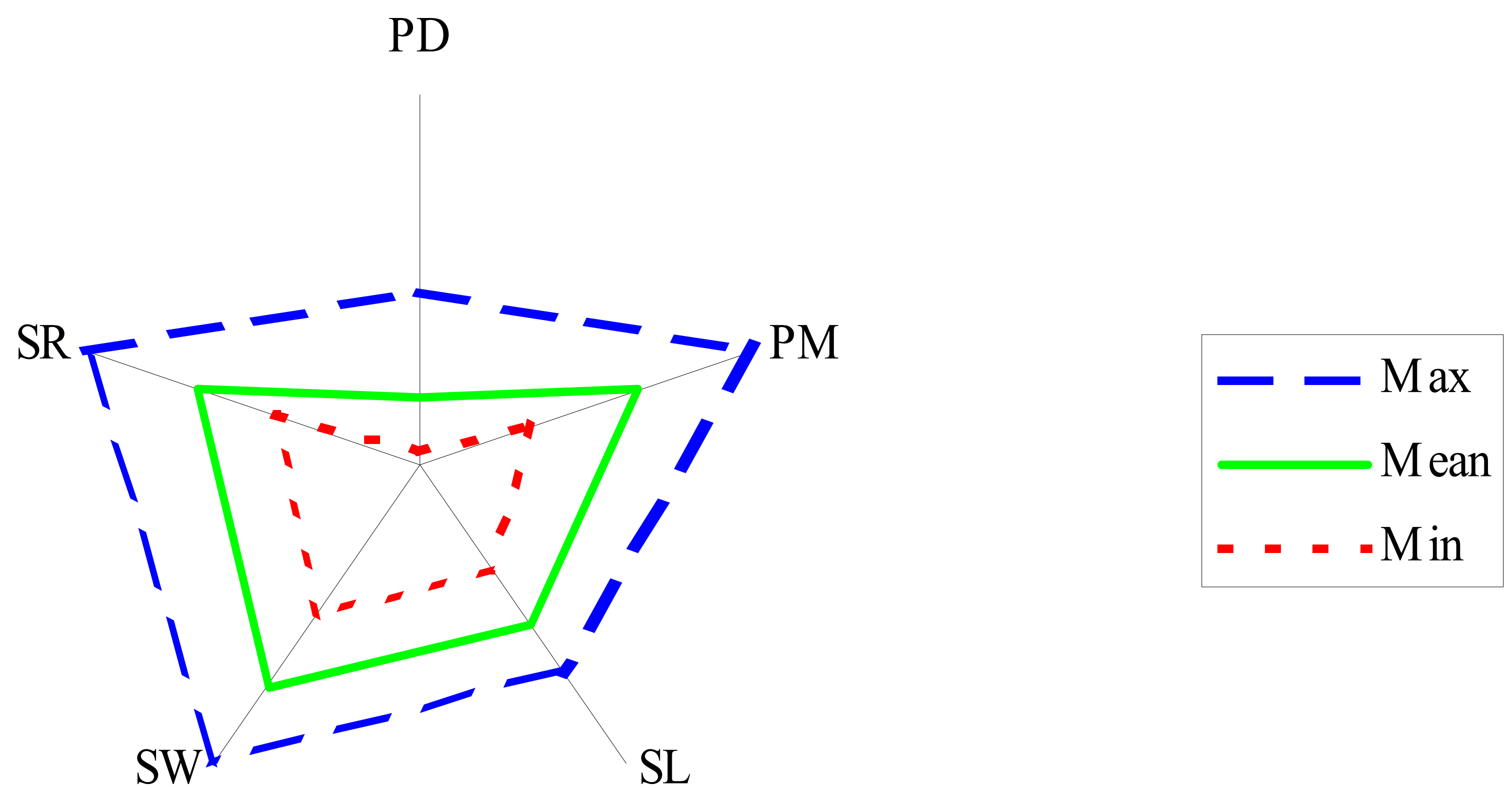
Polygonal graphs (or radiate indicators) were constructed to represent the most significant characters measured in the study on separate axes (radii) and compare relative maximum, minimum and mean values to show the limits of variability within each group (Table 15). Characters were chosen based on whether the "F" value was significant. Also, the total canonical structure data in the SAS output were used to define characters that were important in the separation of the groups. Polygonal graphs showed considerable variation in the characters for each group (Figures 26 to 28). Intergrades had the highest levels of variation, which can also be seen from Figure 27. Mean character values were also plotted for each group (*Chrysemys p. picta, C. p. marginata,* and intergrades) to illustrate character differences between the "taxa." *C. p. marginata* has significantly greater mean values for percent disalignment (PD) and supratemporal stripe length (SL), while the mean values of *C. p. picta* are larger for percent margin width (PM), stripe width (SW), and stripe ratio (SR) (Figure 29). Intergrade means are between the means of the other groups (*C. p. picta* and *C. p. marginata*) for all characters graphed.

Table 15. Actual and relative maximum, minimum, and mean values for characters used in the polygonal graphical analysis.

	Character									
	PD		PM		SL		SW		SR	
	A	R	A	R	A	R	A	R	A	R
					Total Sample (n=80)					
Max	110.03	100	3.54	100	10.69	100	3.37	100	0.67	100
Mean	42.90	38.99	1.89	53.39	6.22	58.19	2.12	62.91	0.36	53.73
Min	3.74	3.40	0.29	8.19	3.71	34.71	0.60	17.80	0.08	11.94
					C. p. picta (n=39)					
Max	50.81	46.18	3.54	100	7.29	68.19	3.37	100	0.67	100
Mean	19.72	17.92	2.34	66.10	5.66	52.95	2.50	74.18	0.45	67.16
Min	3.74	3.40	1.15	32.49	3.71	34.71	1.74	51.63	0.29	43.28
					C. p. marginata (n=22)					
Max	110.03	100	2.25	63.56	9.53	89.15	2.17	64.39	0.43	64.18
Mean	91.31	82.99	1.30	36.72	7.25	67.82	1.57	46.59	0.23	34.33
Min	77.63	70.55	0.29	8.19	4.42	41.35	0.60	17.80	0.08	11.94
					Intergrades (n=19)					
Max	74.91	68.08	2.73	77.12	10.69	100	2.88	85.46	0.53	79.10
Mean	34.43	31.29	1.65	46.61	6.15	57.53	1.97	58.46	0.34	50.75
Min	7.09	6.44	0.58	16.38	4.58	42.84	1.44	43.73	0.13	19.40

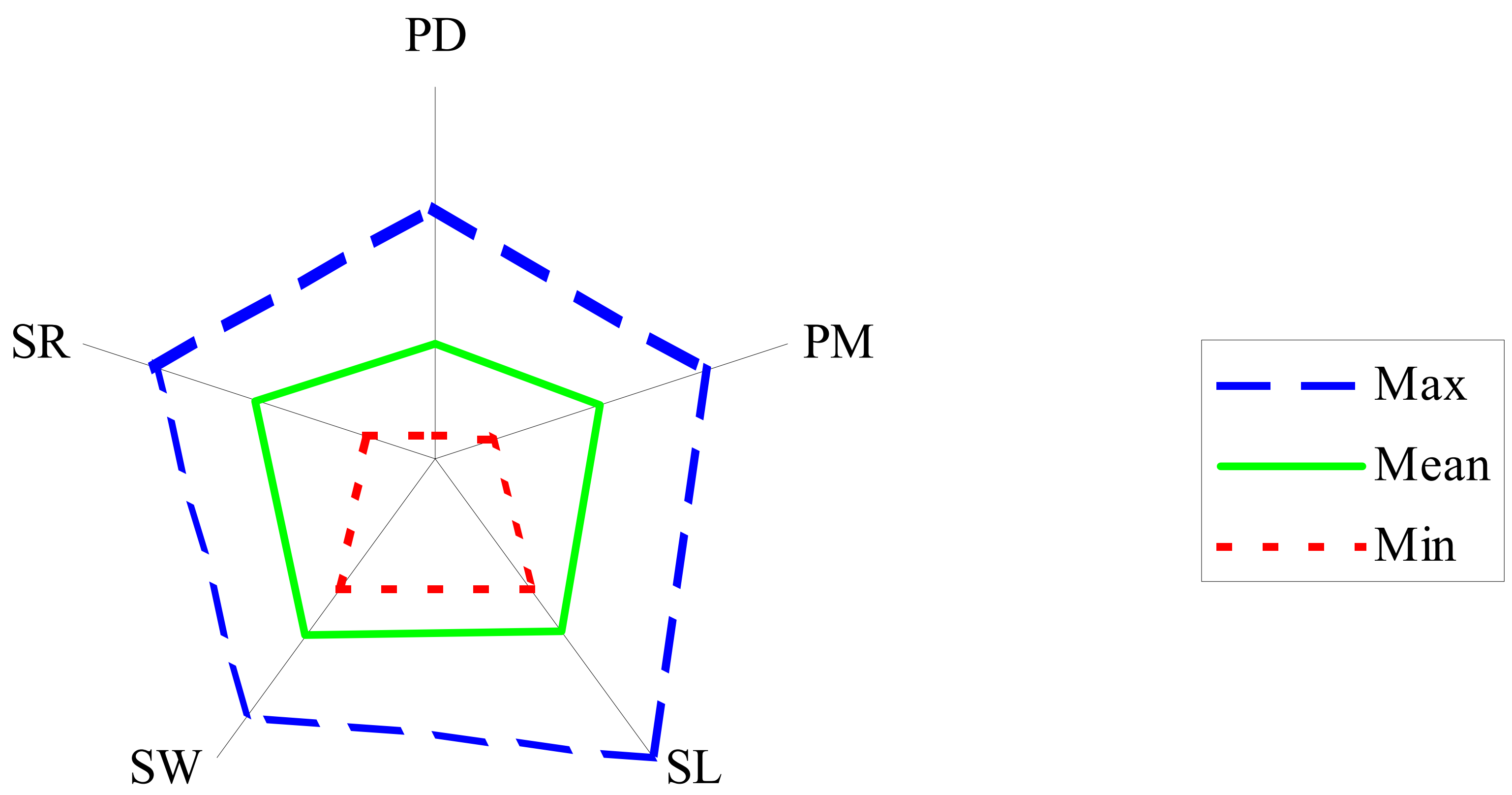
(see Table 7 for defined character abbreviations)
A = actual value
R = relative value

Figure 26. Polygonal graph of relative character values for *Chrysemys picta picta*.



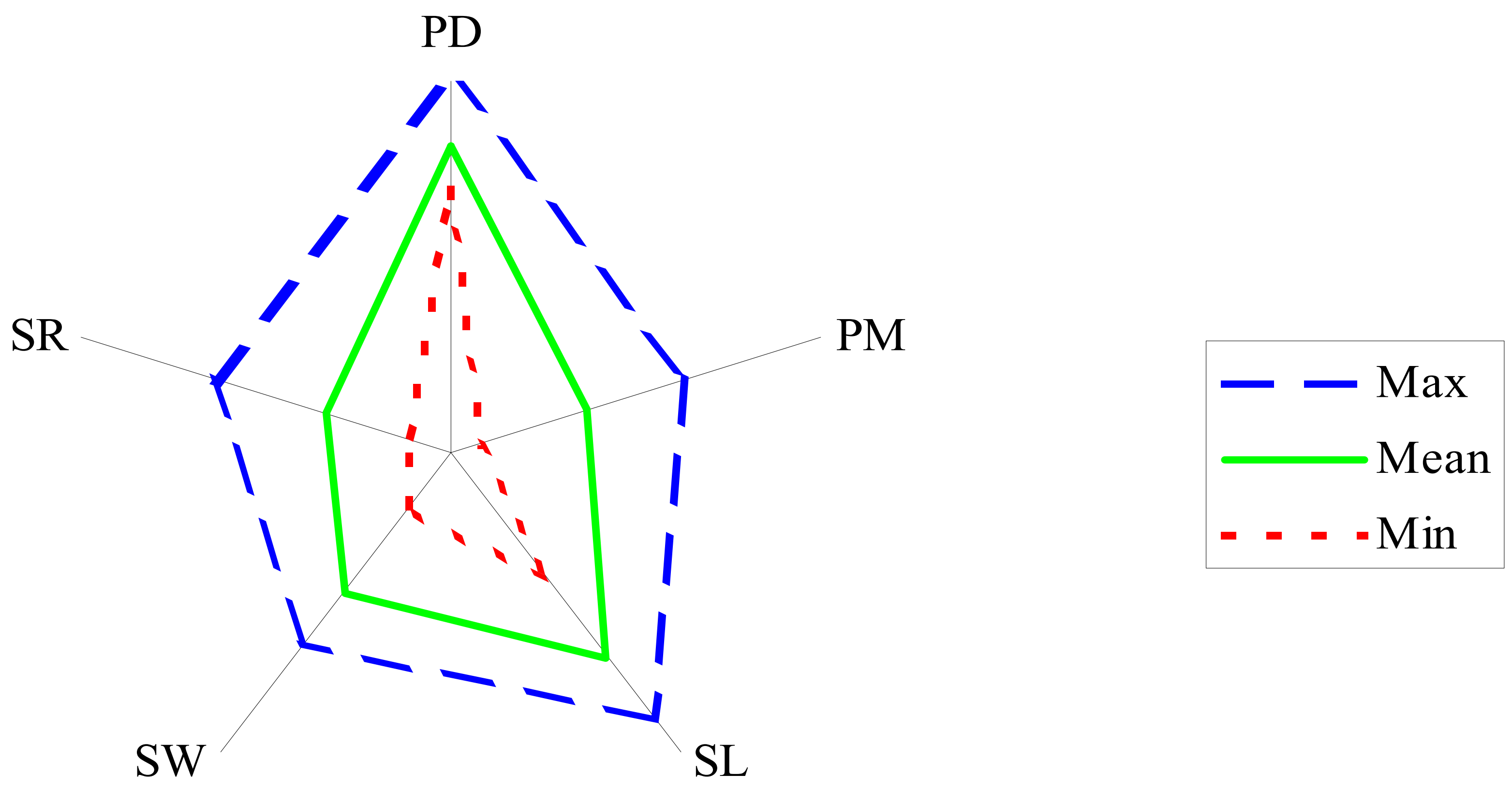
PD = Percent Disalignment; **PM** = margin width ratio; **SL** = supratemporal stripe length; **SW** = supratemporal stripe width; **SR** = supratemporal stripe ratio

Figure 27. Polygonal graph of relative character values for *Chrysemys picta* intergrades.



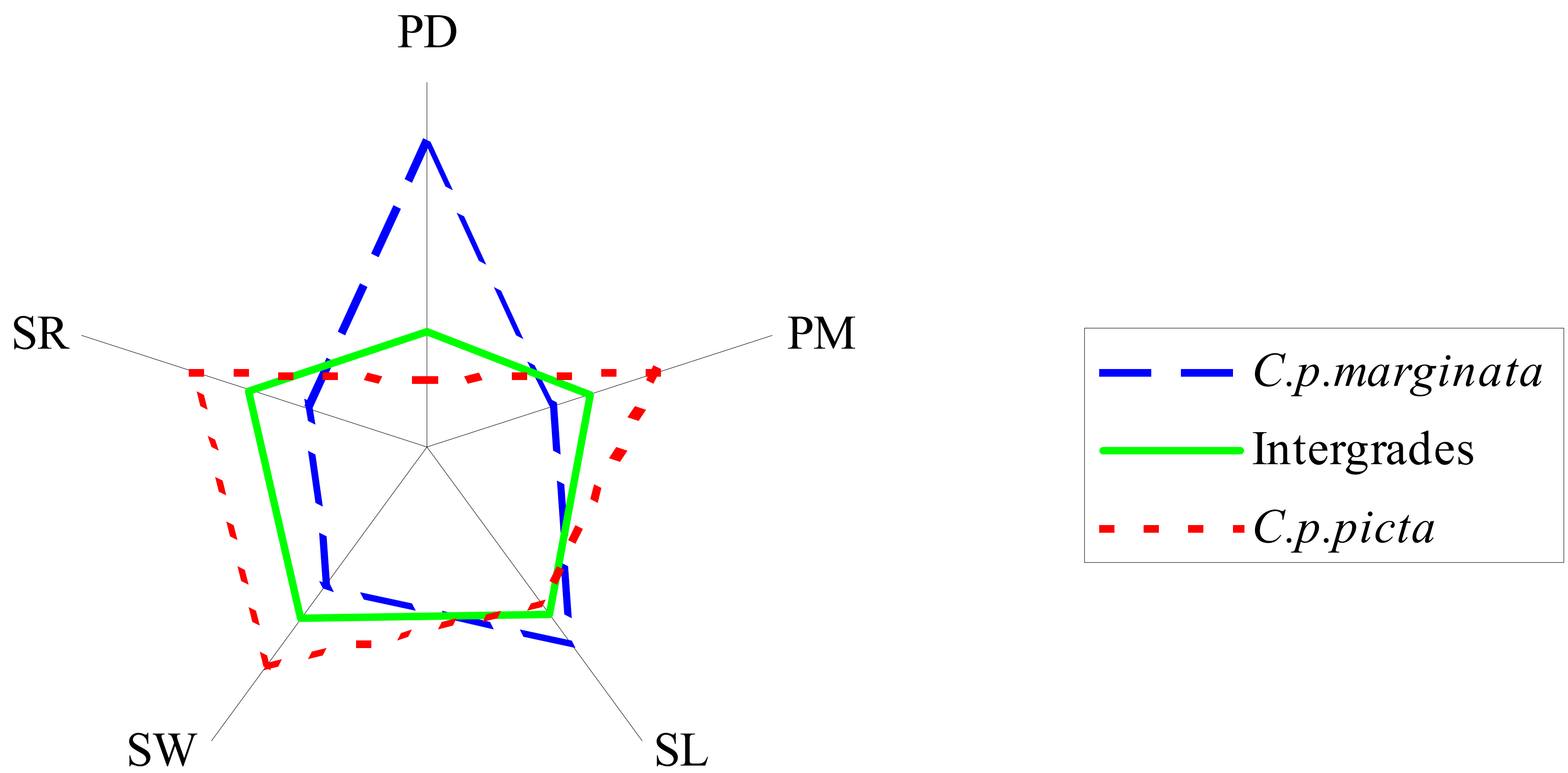
PD = Percent Disalignment; **PM** = margin width ratio; **SL** = supratemporal stripe length;
SW = supratemporal stripe width; **SR** = supratemporal stripe ratio

Figure 28. Polygonal graph of relative character values for *Chrysemys picta marginata*.



PD = Percent Disalignment; **PM** = margin width ratio; **SL** = supratemporal stripe length; **SW** = supratemporal stripe width; **SR** = supratemporal stripe ratio

Figure 29. Polygonal graph of group means for *Chrysemys picta.*



PD = Percent Disalignment; **PM** = margin width ratio; **SL** = supratemporal stripe length;
SW = supratemporal stripe width; **SR** = supratemporal stripe ratio

3.2.3.2 Range Diagrams

Range diagrams were used to plot the mean value, minimum and maximum values (range), standard deviation, and standard error for selected characters within each "taxa" or group (*Chrysemys p. picta, C. p. marginata* and intergrades). Range diagrams that do not show overlap between groups indicate greater significant differences. High levels of variation (represented by the thick horizontal black lines) were evident on each character graph (Figures 30 to 32). Percent disalignment for *C. p. picta* was the least variable character on the graphs (Figure 30). Percent disalignment showed complete separation and the highest significant difference between *C. p. picta* and *C. p. marginata*. *C. p. picta* and *C. p. marginata* differences were evident by the separation on percent margin width (PM) and stripe ratio (SR) graphs (Figures 31 and 32). The intergrade group is intermediate between *C. p. picta* and *C. p. marginata* on all graphs. Because the intergrade group is skewed toward *C. p. picta* on the range diagram for percent scute disalignment (Figure 30), *C. p. picta* strongly influences the intergrade group in that character.

3.2.3.3 Bivariate Scatterplot Analysis

The bivariate scatterplot showed the relationship between percent disalignment (PD) and supratemporal stripe ratio (SR) by plotting them against each other on x,y coordinates (Figure 33). Character ratios allow for comparison of a larger number of characters since ratios compare two or more measurements. Intergrades were between *C. p. picta* and *C. p. marginata,* but indicated a closer relationship to *C. p. picta (*as in CDA and PCA analyses). The diagram does not show a strong linear correlation between the characters.

Figure 30. Range diagram of percent disalignment (PD) for *Chrysemys picta*.

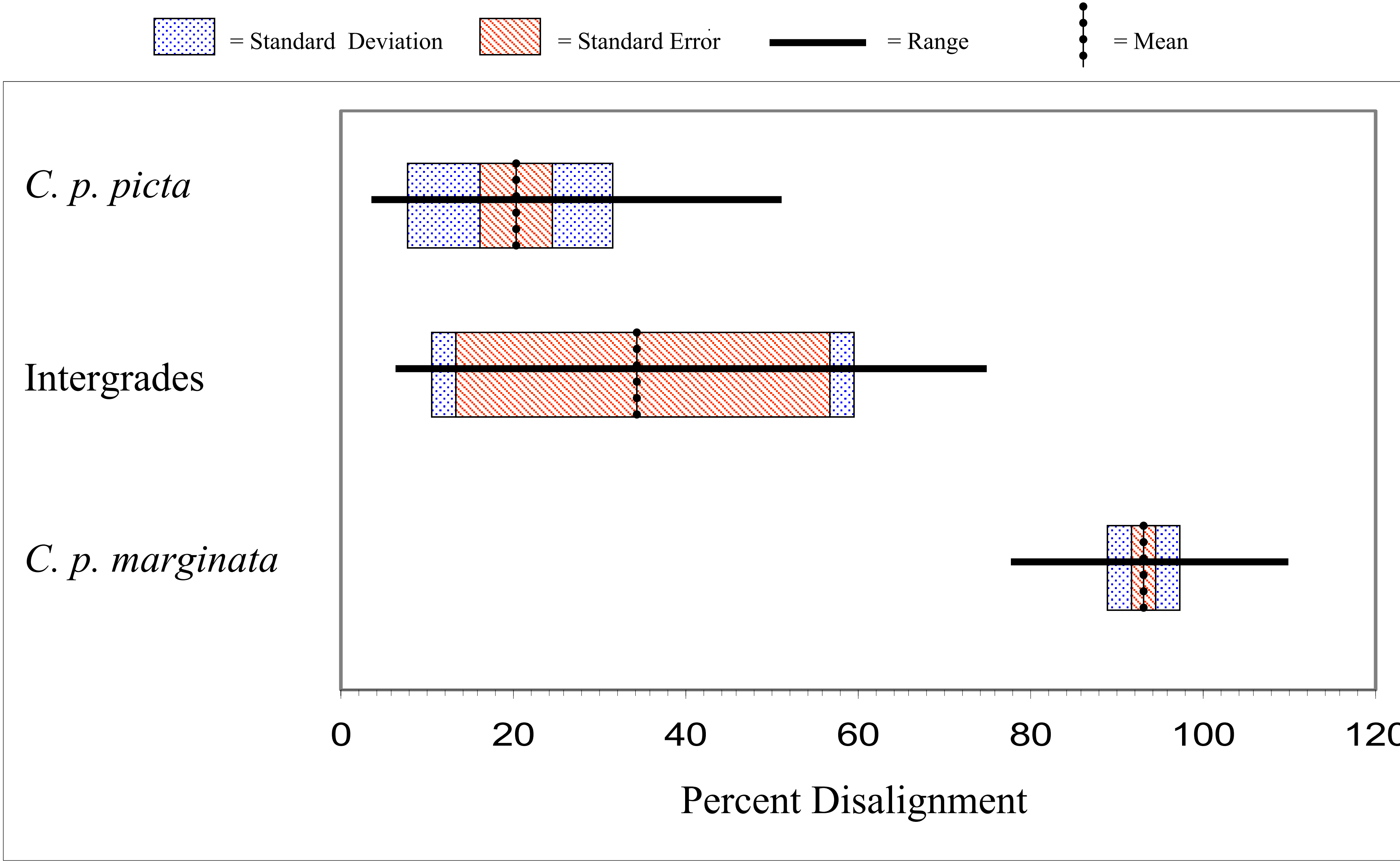


Figure 31. Range diagram of percent margin width (PM) for *Chrysemys picta*.

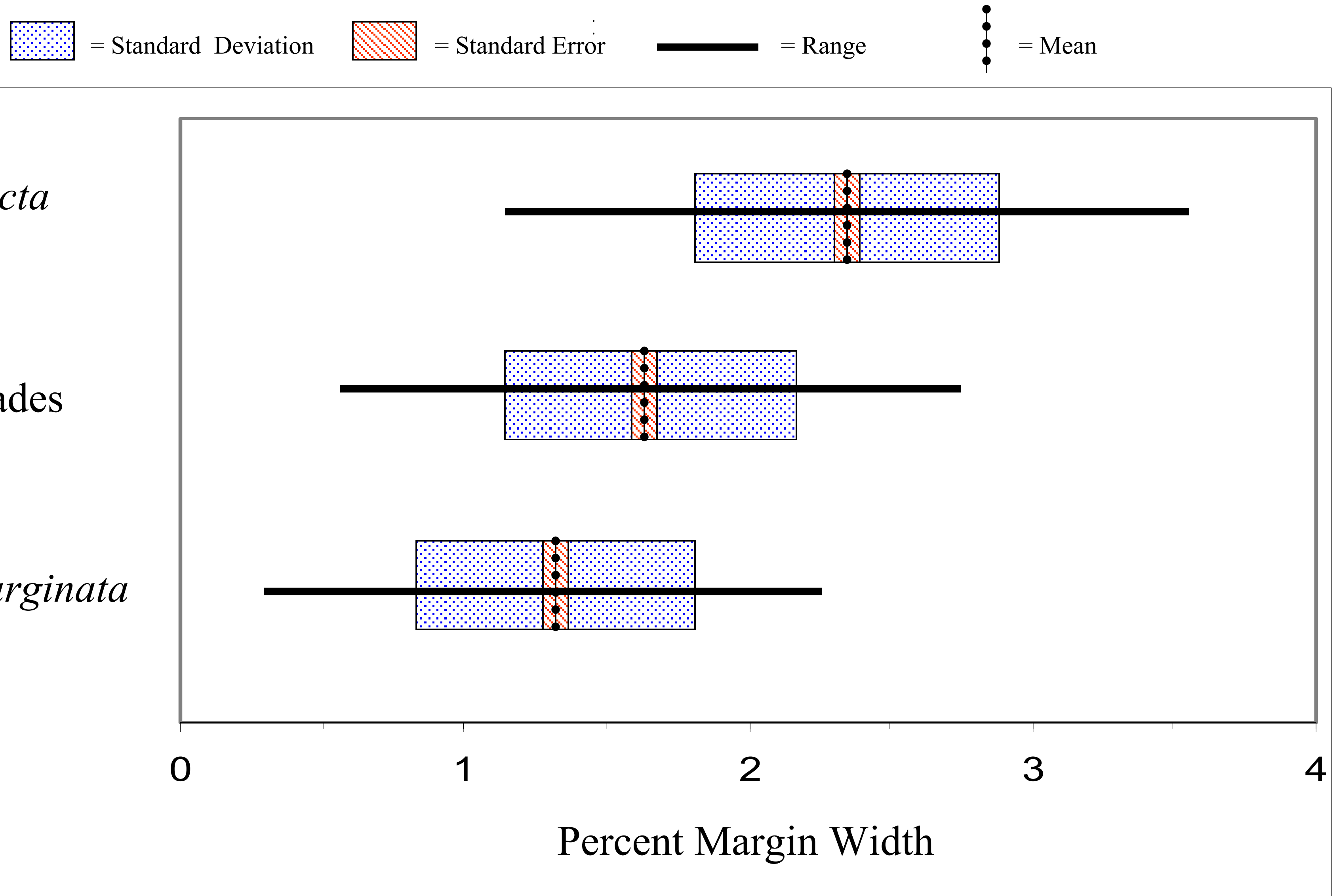


Figure 32. Range diagram of stripe ratio (SR) for *Chrysemys picta*.

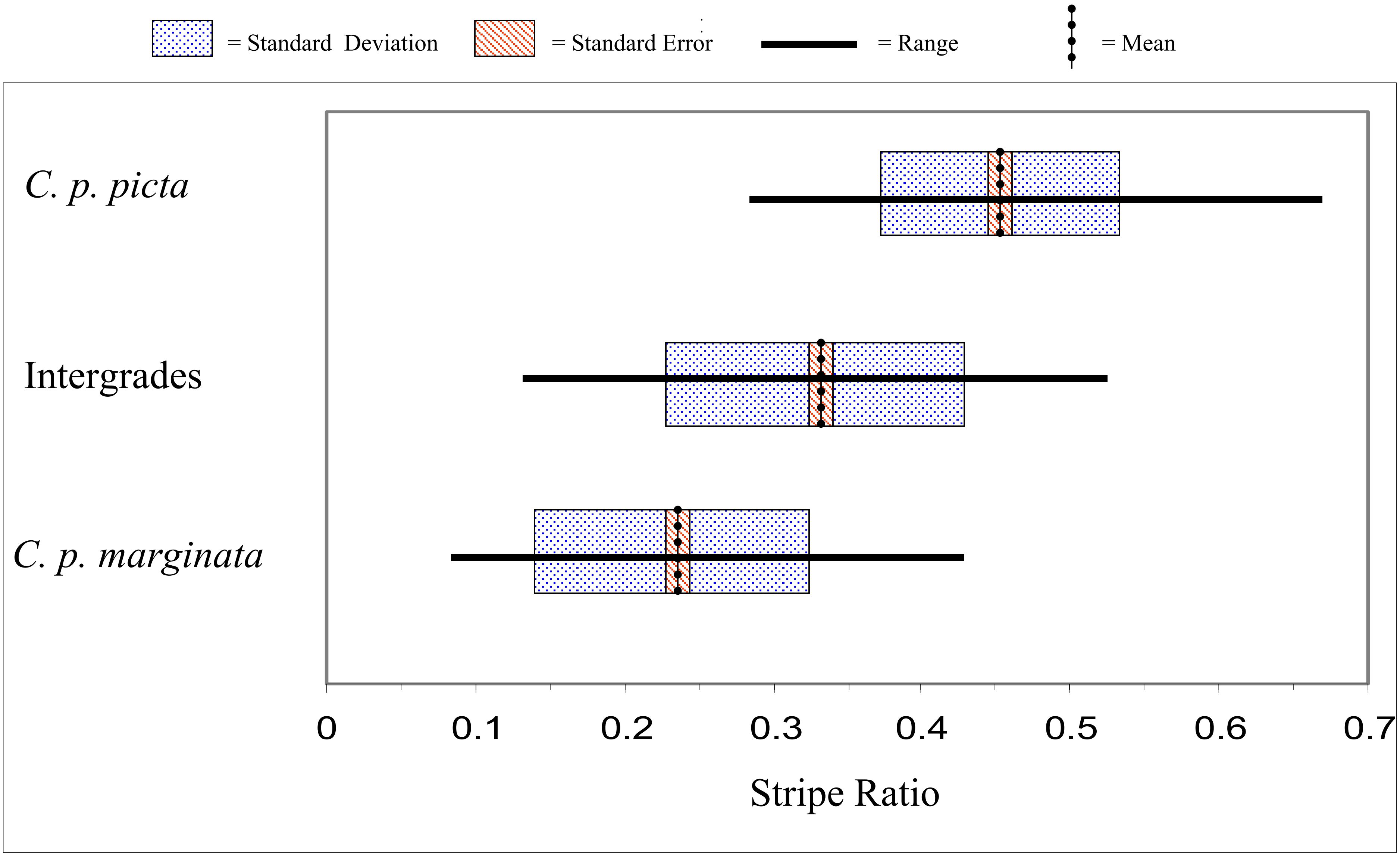
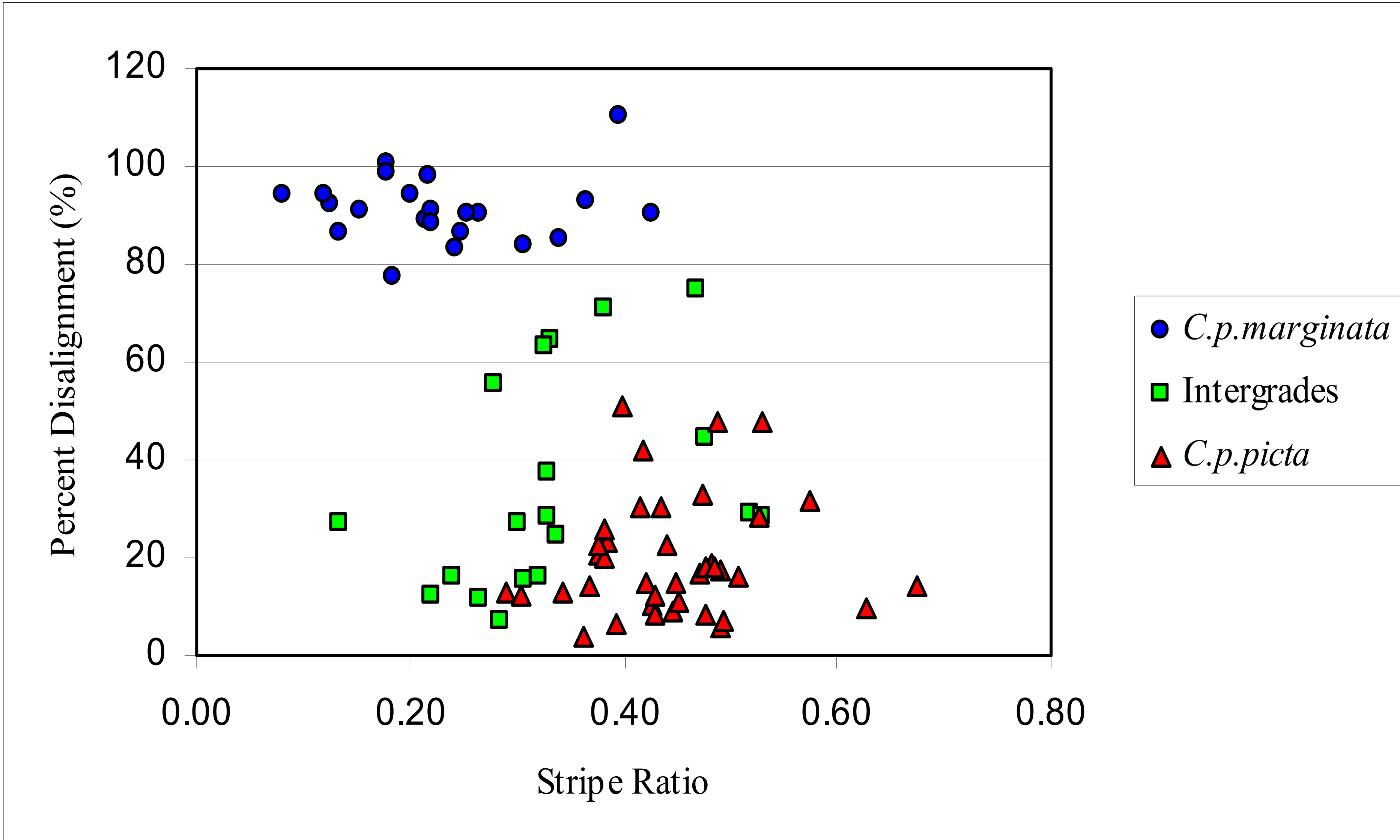


Figure 33. Bivariate scatterplot of percent disalignment (PD) versus stripe ratio (SR) for *Chrysemys picta*.



4.0 CONCLUSIONS

1. Ultsch et al. (2001) suggested values to determine intergrades based on statistics of large "true" *Chrysemys picta marginata* and *C. p. picta* populations in which *C. p. marginata* should show a percent scute disalignment of 85 to 93 percent and mean border width of 1.1 to 1.7 percent (of carapace length). True *C. p. picta* populations should have values that are less than or equal to 43 percent disalignment and mean border widths of 1.9 to 2.9 percent. Intergrades have values that fall between the values given for either subspecies. However, "populations" in the New River and Greenbrier River watersheds had large disalignment ranges (Table 8), indicating intergrade populations. An increase in *C. p. picta* characteristics was observed from the western part of the state to the eastern panhandle. This trend has been seen in other *picta/marginata* studies (Hartman, 1958; Pough and Pough, 1968; Ernst and Ernst, 1971; Groves, 1983, and Wright and Andrews, 2002). The postglacial dispersal hypothesis suggested by Bleakney (1958) is validated in this study. During the Wisconsinan glacial period (at the end of the Pleistocene) in the northeastern regions of the United States, the subspeciation of *C. picta* occurred, due to the isolation of Atlantic costal region populations. When the glaciers retreated, populations of *C. p. picta* moved north and west, while populations of *C. p. marginata* were dispersed to the northeast following the Ohio River drainage.

2. Analysis of variance (ANOVA) was used to examine the morphological variation of *Chrysemys picta*. Results indicated significant variation in characters used to analyze scute disalignment and margin width, as many other taxonomic studies of *C. picta* (Table 1) previously demonstrated. These are also distinguishing characters that are defined in the literature (Table 4). However, results also indicated significant variation in the supratemporal stripe character measurements (SL, SW and SR) that may prove to be a good diagnostic character in separating the subspecies. This character has not been documented in previous *C. picta* taxonomic studies, but has been shown to separate other turtle genera (Seidel, 1981). Polygonal graphs and range graphs also illustrated the morphological variation of *C. picta*.

3. Morphological data from regions of possible *Chrysemys picta. picta x C .p. marginata* intergradation in West Virginia were compared to morphological data from geographic areas that are not exposed to subspecies distribution overlap (defined as *C. p. picta* and *C. p. marginata* groups). Data were compared from the three groups using Canonical Discriminate Analysis (CDA), Principle Component Analysis (PCA), and Analysis of Variance (ANOVA). Polygonal graphs (radiate indicators), population range diagrams, and bivariate scatterplots were also used to compare data from the three groups. *C. p. picta* and *C. p. marginata* showed the highest degree of morphological separation, with specimens from areas of intergradation falling between the two groups, confirming that the specimens are, in fact, intergrades.

4. Canonical Discriminate Analysis (CDA), Principle Component Analysis (PCA), range diagrams, and polygonal graphs indicate that West Virginia intergrade populations examined in the study more closely resemble *Chrysemys picta picta* based on the morphological characters measured in the study. This conclusion supports the suggestion (Seidel, 1981; Green and Pauley, 1987) that *C. p. picta* from Virginia may have entered the New River system and formed areas of intergradation when the populations contacted *C. p. marginata* from the Ohio River Valley. Additional supporting data includes the bivariate scatter diagram of percent disalignment (PD) vs. stripe ratio (SR). Intergrades were plotted between *C. p. picta* and *C. p. marginata*, again showing a closer relationship to *C. p. picta* as in CDA and PCA.

5. Data from ANOVA validate characters that strongly separate *Chrysemys picta picta*, *C. p. marginata,* and intergrades. Scute disalignment (DL, DR, PD), percent margin width (PM) and supratemporal stripe width and width/length ratio (SW and SR) characters were significantly different among all three groups. Since percent disalignment (PD), percent margin width (PM), and supratemportal stripe width are ratios that account for specimen size differences, they are the strongest characters used to separate the taxa. Polygonal graphical analyses confirm that *C. p. marginata* have greater scute disalignment and longer

supratemporal stripes, and *C. p. picta* have wider scute margins and supratemporal stripes. Intergrades show intermediate forms for all characters (PD, PM, SL, SW and SR).

6. Although scute disalignment, margin width and supratemporal stripe characters strongly separated the three groups defined in this study (*Chrysemys picta picta*, *C. p. marginata* and intergrades), a dichotomous key would not accurately define the groups due to the high degree of intergradation and morphological variation of the species. Intergrades are not distinct taxa, so it would be impossible to completely separate the groups. However, morphological variation between the subspecific groups and intergrades can be evaluated with the statistical methods outlined in the paper.

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Appendix A

Chrysemys picta Specimen Information

Chrysemys picta picta specimens from CMNH (n=39):

<u>North Carolina</u>-
Camden: McCoy (1970) #53004, #53005, #53006, #53007
Dare: McCoy (1977) #64977
Hyde: Clanton (1938) #12965

<u>South Carolina</u>-
Pickins: Ewert (1976) #61492, #61493, #87419, #87420

<u>Virginia</u>-
Accomack: Mitchell and Censky (1986) #125758, #125759
Mitchell (1986) #146553, #146554, #146555
City of Norfolk: Warney (1986) #125750
City of Suffolk: Mitchell and Pague (1984) #125048, #125051, #125052, #125054, #125061, #125062, #125064, #125065, #125073, #125075
Mitchell (1986) #125108, #125114
City of Virginia Beach: Mitchell (1981) #125100, #125101
Isle of Wight: Norman (1987) #148200
James City: Wood (1949) #35396
Northhampton: Mitchell (1986) #125753, #125754, #125755, #125757, #125762, #146549
Surry: Mitchell (1987) #146587

Chrysemys picta marginata specimens from CMNH (n=22):

<u>Indiana</u>-
Jackson: Ewert (1976) #87417, #87418
Kosciusko: Iverson (1987) #115931, #115932, #115933, #115934, #115935
Monroe: Ewert (no date) #117894
Noble: Williamson (1907) #R3085
Whitley: Atkinson (1903) #R3174B, #R3174C, #R3174D

<u>Michigan</u>-
Cheboygan: Freed and Grady (1978) #68119
Chippewa: Ewert (1976) #87416
Jackson: Hahn (1972) #62099
Schoolcraft: Ewert (1976) #87413, #87414, #87415
Washtenaw: Freed and Grady (1978) #68200

<u>Ohio</u>-
Fairfield: Barnebey (1952) #35136
Knox: Freed (1978) #68173
Sandusky: Swanson (1931) #S5294

Chrysemys picta specimens from areas of intergradation in West Virginia (n=19):

CMNH specimens
Greenbrier: Green (1940) #19420
Monroe: Richmond (1938) #14391
Hall and Hamilton (1939) #16741, #16743, #16744, #16746
Scott (1950) #29417
Pocahontas: Netting (1931) #S5324, #S5325, #S5328, #S5346, #S5348
Richmond (1933) #S6916
Netting (1935) #S8860
Hicks (1948) #28499
Swanson (1931) #S5347

WVBS specimens
Mercer: Collector unknown (1970) #4238
Monroe: Collector unknown (1971) #4220
Summers: Collector unknown (1970) #4234

Chrysemys picta specimens from other counties in West Virginia (n=34)

CMNH specimens
Berkeley: Llewellyn (1934) #S7135, #7138
Netting and Scott (1949) #30068,
Cabell: Collector unknown #17515
Hardy: Wilson (1945) #24092,
Pauley (1985) #113398
Jefferson: Poland (1940) #18684, #18690, #18691,
Scott (1949) #30074,
Mineral: Llewellyn (1939) #18514
Randolph: Richmond (1936) #9413, #9414, #9478
Green (1936) #9599,
Collector unknown #15581, #15605, #15609, #15614, #15638

WVBS specimens
Boone: Collector unknown (1963) #3085
Hampshire: Collector unknown (1935) #245
Hardy: Collector unknown (1945) #1790, (1966) #3385
Jackson: Collector unknown (1965) #3225
Mason: Collector unknown (1967)#3655
Preston: Collector unknown (1969) #3963, #4126, #4127
Putnam: Collector unknown (1965) #3227
Ritchie: Collector unknown (1963) #3078
Roane: Collector unknown (1965) #3224
Wirt: Collector unknown (1954) #2631
Wood: Collector unknown (1966) #3310

Appendix B

Chrysemys picta Data Sheets

1.

$$\frac{DL}{CLL} + \frac{DR}{CLR} = PD$$

Specimen #	Subspecies	Museum	Museum #	State/County	NLC	SLC	CW	VSL	VSW	CLL	CW2
1-F	marg '	CM	S 5294	OH-SAND	141.13	142.43	101.18	14.20	6.14	27.60	103.22
2-F	pict (I)	CM	S 5348	WV-POCA	120.77	124.87	87.08	13.01	6.27	25.63	88.35
3-F	pict (I)	CM	S 5328	WV-POCA	141.81	143.03	97.30	15.03	6.74	26.99	
4-F	pict	CM	S 7135	WV BERK	145.15	145.95	92.44	14.46	6.62	30.46	
5-F	pict	CM	S 5325	WV-POCA	134.51	138.09	92.23	13.54	6.07	26.91	
6-F	pict	CM	S 5346	WV-POCA	148.01	149.66	96.48	15.16	7.22	31.44	
7-M	pict	CM	30074	WV-JEFF	111.56	112.76	80.89	11.82	4.96	22.24	
8-F	pict	CM	16744	WV-MONR	140.52	141.03	103.95	14.86	6.61	28.15	
9-F		CM	18514	WV-MINE	130.91	133.39	92.37	14.64	8.39	23.75	
10-M	intg	CM	5324	WV-POCA	100.58	101.02	76.34	8.83	4.91	18.91	
~~11-F~~	~~pict~~	~~CM~~	~~35130~~	~~ME-OXFO~~	~~147.51~~	~~148.91~~	~~104.57~~	~~13.44~~	~~8.02~~	~~28.60~~	
12-M	pict	CM	18690	WV-JEFF	123.30	125.26	89.39	13.42	4.60	24.12	
13-M	marg '	CM	68173	OH-KNOX	132.52	134.36	97.59	16.96	4.49	25.24	
14-J		CM	5327	WV-POCA	83.85	84.31	68.61	7.87	5.17	—	
15-M	marg '	CM	35136	OH-FAIR	126.01	128.12	97.10	13.79	3.86	24.23	
16-F	pict	CM	30068	WV-~~BERK~~	130.71	132.24	96.12	14.41	6.65	25.73	
17-F		CM	9414	WV-RAND	98.98	100.80	71.18	8.10	6.08	19.38	
18-F	marg	CM	17515	WV-CABE	115.13	116.00	85.76	12.19	6.07	20.90	
19-M		CM	14391	WV-MONR	93.23	94.76	75.44	7.21	7.72	18.79	
20-M		CM	5347	WV-POCA	111.56	117.24	82.38	8.24	3.91	22.04	
21-M	marg	CM	15581	WV-RAND	102.45	104.05	75.30	11.10	4.71	19.85	
22-M	pict	CM	18691	WV-JEFF	107.89	110.36	80.72	10.65	4.43	21.30	
23-M	pict	CM	8860	WV-POCA	103.19	104.07	70.96	11.13	5.90	19.25	
24-M	marg	CM	9599	WV-RAND	103.23	104.38	76.76	11.03	5.60	20.85	
25-F	pict	CM	18684	WV-JEFF	123.79	124.49	89.88	12.57	4.86	25.80	
26-	pict	CM	16746	WV-MONR	116.56	117.76	79.69	10.72	4.02	22.33	
27-M	int	CM	19420	WV-GREEN	127.88	129.64	87.69	15.04	7.03	24.90	
28-M	marg	CM	29417	WV-MONR	128.09	132.07	90.94	13.84	6.10	24.62	
29-M		CM	13398	WV-HARD	102.78	103.70	82.41	10.37	5.72	21.26	
30-M	marg	CM	15605	WV-RAND	99.24	100.64	15.61	9.70	3.85	19.32	
31-F	marg	CM	15638	WV-RAND	133.19	134.34	93.25	13.15	5.91	26.77	
32-F		CM	16741	WV-MONR	127.52	128.57	88.75	13.00	7.49	26.25	
33-M		CM	15609	WV-RAND	104.35	105.79	80.45	10.82	3.81	21.13	
34-F	marg	CM	15614	WV-RAND	103.56	105.93	84.55	10.17	6.75	20.27	
35-		CM	16743	WV-MONR	109.49	111.71	81.57	10.79	6.04	20.93	
36		CM	9413	WV-RAND	126.31	127.06	93.11	12.87	7.49	24.14	

36 - WV
31 - PICTA
3 - MARG

Z.

	CLR	DL	DR	MWL	MWR	DSW	CCL	CTL	ACL	PCL	ACR	PCR	SH
1	27.84	15.08	15.42	2.15	2.30	0.49	7.15	26.24	—	—	8.49	6.37	50.50
2	25.43	1.89	2.08	2.50	2.51	—	6.09	22.97	9.13	6.37	9.56	5.68	38.85
3	26.74	4.07	2.45	2.80	2.30	0.63	3.01	32.63	6.76	9.40	7.18	8.12	48.56
4	31.26	4.31	3.51	2.99	3.35	0.48	5.22	31.81	7.06	9.64	7.12	10.48	53.26
5	26.43	1.87	1.48	3.78	3.77	1.05	2.41	29.00	6.71	8.61	7.08	9.69	50.57
6	31.76	2.91	2.23	3.63	3.34	0.44	1.79	31.63	7.61	8.66	7.84	9.81	59.93
7	21.20	6.12	5.64	4.67	4.08	0.64	8.12	19.57	11.11	6.56	9.10	7.07	37.25
8	27.27	1.48	1.54	2.40	3.16	0.34	3.40	26.27	7.04	9.41	6.61	8.81	47.51
9	26.16	4.92	4.14	2.71	2.80	0.67	2.66	27.09	6.14	9.87	5.78	9.62	45.41
10	18.66	1.95	3.33	1.57	1.54	—	1.88	19.90	10.11	6.72	9.74	7.11	35.78
11	29.15	3.12	2.85	3.19	3.28	0.47	3.90	32.69	5.22	7.54	6.31	7.62	50.90
12	23.84	0.50	0.50	2.40	2.60	0.60	7.86	23.97	10.92	7.66	10.64	6.56	41.24
13	24.83	11.64	10.92	0.32	0.47	0.66	10.33	16.40	10.59	7.79	12.37	7.50	46.92
14													
15	23.27	10.90	10.28	1.41	1.45	—	13.37	23.21	11.30	5.94	12.09	6.40	47.66
16	25.48	1.25	0.48	2.54	2.53	—	7.55	↓	6.65	8.97	4.80	8.76	47.89
17	19.74	8.49	8.53	2.17	2.48	0.52	1.94		5.04	5.48	4.98	6.08	34.53
18	21.53	9.75	9.91	1.26	1.81	1.13	1.85		4.67	4.83	5.09	5.92	40.35
19	19.00	3.06	2.46	1.27	1.74	0.66	5.65		9.61	7.12	9.53	4.60	37.29
20	22.36	1.15	1.40	2.61	2.61	0.48	10.81		9.15	6.76	9.50	6.81	37.84
21	19.99	7.92	7.65	1.34	1.55	0.42	5.71		9.60	7.00	9.95	5.97	37.05
22	21.70	1.52	1.54	3.00	3.17	0.49	6.70		9.79	7.83	10.79	6.87	37.41
23	20.26	3.03	2.36	1.04	1.14	0.86	5.71		9.06	8.26	9.21	6.65	36.29
24	19.99	7.93	6.92	1.25	1.25	—	5.81		8.96	5.98	9.07	5.77	33.17
25	26.17	2.19	1.47	2.47	2.83	0.68	0.85		7.29	9.07	7.26	8.34	48.53
26	22.60	0.93	0.66	1.48	1.18	—	6.98		8.07	4.46	8.04	5.23	39.18
27	24.46	8.07	7.84	2.54	2.44	—	4.36		9.94	7.72	9.56	6.97	44.29
28	25.13	9.39	9.24	1.38	1.62	—	9.87		11.85	9.20	11.99	8.66	40.73
29	20.41	4.03	3.63	2.92	2.20	0.62	5.83		8.98	6.08	8.96	6.59	33.98
30	19.24	9.41	8.13	0.62	0.62	—	4.04		8.93	4.81	10.08	5.03	35.72
31	26.52	11.67	11.37	2.32	2.70	—	3.42		6.50	8.41	9.22	9.63	46.05
32	25.45	4.33	2.97	2.73	2.89	0.73	5.65		5.86	7.56	5.96	7.63	41.57
	20.71	6.59	5.07	2.02	1.91	0.69	5.45		9.13	6.10	8.92	4.76	37.00
	20.05	5.01	3.71	1.16	1.47	0.55	1.48		4.71	5.33	4.90	5.89	40.99
	21.32	5.63	6.07	1.89	1.76	0.48	5.12		9.62	6.43	10.42	7.19	36.39
	24.95	10.31	9.50	2.75	2.33	—	2.60	↓	5.81	8.04	5.83	7.22	40.93

SH → middle 2nd vert.

3.

#	NLP	SLP	PW (2nd seam)	PD	~~SCR~~ L (cranial)	~~PFA~~ HL (cranial length)	~~CPH#~~ SL (strip length)	~~PPH#~~ SW (stripe width)	~~PC~~ HW (width cranial)	Notes
1	130.85	131.24	85.66			29.06	5.49	2.17	21.25	
2	107.43	111.10	70.99			27.36	5.70	1.74	19.70	
3	134.59	135.15	83.40			24.97	6.13	2.06	21.55	head in neck
4	128.86	129.69	78.58			23.68	5.38	3.23	21.80	head little in neck
5	126.82	127.23	80.30			—	7.79	1.71	20.56 yellow	tail very difficult to bend
6	136.60	137.02	80.98			26.70	6.88	2.21	21.86 yellow	tail very difficult to bend
7	103.80	105.82	69.82			22.19	4.01	2.09	18.46 brown/orange	penis extended; plastron discolored; head in neck
8	132.80	133.71	86.37			27.48	6.44	1.65	21.11 brown/orange	plastron discolored
9	124.25	125.47	80.61			25.48	5.59	2.69	20.68 brown/orange	tail diff to bend
10	91.37	95.30	63.18			21.67	5.06	1.66	17.22 yellow	scute more disaligned right side; deformed nuchal
11	137.72	138.61	88.43			26.77	6.92	2.60	23.72	
12	114.47	115.74	72.17			23.98	6.21	2.68	20.22	deformed anterior plastron (broken?) head in neck → Straight-line plastral 102.87
13	120.36	121.81	76.19			26.63	7.42	1.97	21.19	
14										carapace decaying - diff to meas. head not measurable
15	112.97	116.90	76.39			25.13	8.16	1.75	20.02	
16	122.43	123.06	80.08			—	7.39	1.96	22.15	
17	93.14	93.87	62.87			18.41	4.74	1.66	17.37	head in neck
18	111.67	112.05	75.47			—	5.53	1.66	18.40	
19	89.69	91.96	61.79			29.65	5.54	2.88	17.29	penis extended
20	102.50	105.65	69.79			25.59	6.51	1.72	20.01	nuchal scute unusually small & short
21	91.93	94.52	62.79			24.07	4.90	1.58	17.83	penis extended
22	103.29	104.60	70.32			20.77	6.21	2.48	18.76	front claws very long, DS well defined
23	93.33	95.86	61.43			21.92	5.86	1.76	17.32	front claws long
24	97.80	98.40	63.31			—	5.24	2.35	17.94	diff" meas head
25	113.90	114.44	74.80			27.47	5.35	3.01	21.12	back claws longer
26	107.18	109.67	70.37			23.33	5.93	1.68	17.80	
27	115.48	118.51	77.96			26.83	5.65	1.87	19.52	
28	114.42	117.79	75.41			25.97	6.08	2.85	20.94	
29	96.75	99.70	65.79			28.28	4.61	2.32	17.26	
30	92.89	94.65	62.11							front claws longer, head not measurable - stuck in neck
31	110.01	117.45	75.27			27.16	5.84	1.46	20.90	plastron extends more ant left
32	114.37	115.25	74.57			—	4.58	2.43	21.54	head in neck
33	98.33	101.60	65.26			—	8.36	2.53	17.68	
34	99.71	101.26	69.83			[illegible]	6.67	1.74	17.89	margins dark brown
35	103.84	105.35	69.24			23.30	6.12	1.71	17.76	
36	115.28	116.85	78.87			24.44	6.77	2.05	19.79	

4.

Specimen #	Subspecies	Museum	Museum #	State/County	NLC	SLC	CW	VSL	VSW	CLL
37		CM	24092	WV- HARD	113.01	114.19	79.68	11.74	5.60	21.86
38	marg	CM	284.99	WV-POCA	125.90	126.90	87.36	13.75	5.49	25.02
39		CM	7138	WV-BERK	117.23	119.57	91.96	13.51	6.01	22.62
40	marg	CM	9478	WV-RANO	91.34	92.24	74.61	8.06	5.42	18.26
41		CM	6916	WV-POCA	110.95	111.70	84.32	10.62	4.38	20.13
42	pict	CM	148200	✓VA- ISLE OF WIGHT	146.47	147.59	109.75	16.29	5.06	29.12
43	pict	CM	125754	VA-NORTH HAMPTON	140.82	142.16	105.38	16.64	7.09	27.04
44-F	pict	CM	146554	VA-ACCOMA	141.86	142.13	103.48	16.55	8.74	29.10
45-M	pict	CM	129925	VA-ROCKING	101.97	103.02	80.89	9.75	5.57	18.29
46-F	picta	CM	125075	✓VA-City of SUFFOLK	136.69	138.22	104.22	14.43	6.43	28.82
47-	pict	CM	125101	✓VA-BEACH	130.98	135.49	97.58	13.92	5.48	26.03
48	pict	CM	125100	✓VA BEACH	152.72	153.02	108.03	17.48	7.77	32.08
49	pict	CM	146555	VA ACCOM	146.51	148.21	106.85	14.71	8.22	30.29
50	pict	CM	125052	✓VA CITY OF SUFFOLK	128.96	130.51	91.83	13.35	5.93	24.76
51	pict	CM	125108	✓VA SUFFOLK	136.94	139.79	99.16	12.11	7.22	31.89
52-M	pict	CM	125065	✓VA SUFF	93.51	94.22	76.17	10.97	5.01	15.63
53-F	pict	CM	125757	VA NORTH HAMP	107.99	108.66	82.21	11.69	6.92	21.25
54-M	pict	CM	35396	✓VA JAMES CITY CO.	125.36	125.74	90.72	14.96	5.42	25.02
55-F	pict	CM	125051	✓VA SUFF	119.23	120.07	87.71	13.68	6.87	23.59
56	pict	CM	125755	VA NORTH HAMP	115.53	116.73	85.58	12.38	5.79	23.50
57	pict	CM	125054	✓VA SUFF	116.64	117.84	85.23	11.65	6.94	23.64
58	pict	CM	146549	VA NORTH HAMP	98.44	99.13	77.92	9.47	6.98	19.30
P 59	pict	CM	125762	VA NORTH HAMP	120.05	121.46	86.68	13.33	7.46	25.23
60	pict	CM	125753	VA NORTH HAMP	120.90	122.37	87.39	14.04	5.32	25.94
61	pict	CM	146553	VA ACCO	148.58	149.47	109.73	16.96	8.32	32.36
62	pict	CM	125758	VA ACCO	140.30	141.29	103.48	17.53	6.94	25.67
63	pict	CM	125064	✓VA SUFF	94.94	95.78	77.85	9.30	4.82	19.30
64	pict	CM	125759	VA ACCO	143.41	145.54	105.01	16.19	6.34	27.96
65	pict	CM	✓ 125061	✓VA SUFF	116.71	119.06	93.30	13.38	5.61	23.99
66	pict	CM	125114	✓VA SUFF	141.91	143.45	102.82	17.01	6.39	28.15
67	pict	CM	125048	✓VA SUFF	109.23	110.16	81.29	11.63	6.10	22.39
68	pict	CM	125750	✓VA CITY OF NORFOLK	95.75	96.37	73.76	10.94	5.62	18.70
69	pict	CM	146587	✓VA SURRY CO.	116.68	117.67	89.24	11.71	6.67	23.39
70	pict	CM	125062	✓VA SUFF	143.36	144.23	109.42	15.20	6.42	30.80
71	pict	CM	125073	✓VA SUFF	118.25	119.35	90.47	13.36	6.83	23.06
72	pict	CM	53005	NC-CAMD	143.02	144.16	108.76	14.40	5.63	28.57

no 125119

HEAD SHOTS
H1 - 125067
H2 - 146553 #61
H3 - 125053
H4 125048 #67

5.

CLR	DL	DR	MWL	MWR	DSW	CCL	CTL	ACL	PCL	ACR	PCR	SH
21.60	6.29	4.99	1.12	0.80	0.68	9.36		12.03	7.24	10.98	8.22	43.31
25.06	6.90	4.19	1.80	1.80	—	5.38		9.14	7.02	8.43	7.04	39.85
21.75	1.92	2.03	3.32	3.28	1.02	4.77		10.08	6.94	10.65	6.67	42.97
18.11	7.81	6.90	1.02	1.56	—	5.47		8.68	5.69	8.96	5.79	32.85
20.50	2.85	2.69	1.50	1.73	—	7.79		8.84	3.35	8.98	6.15	35.65
29.59	1.92	1.03	3.24	2.72	—	5.51		6.79	9.47	7.39	10.30	54.56
27.27	3.62	2.77	4.03	3.90	0.76	14.11		9.57	7.63	11.77	8.05	46.65
30.28	1.84	1.92	2.82	2.97	0.77	3.85		6.11	9.47	6.11	9.58	53.75
18.23	1.68	1.71	2.62	2.30	0.88	6.16		7.41	6.66	8.00	6.61	38.90
28.17	1.48	1.12	3.72	2.94	0.80	4.91		6.49	9.03	6.48	8.99	49.95
26.52	1.91	1.46	3.11	2.84	1.11	13.48		8.14	6.59	10.08	6.63	43.32
31.28	1.93	1.55	5.25	5.55	0.69	5.32		5.73	9.72	5.97	8.52	53.07
30.22	6.45	6.16	3.66	3.66	0.73	5.10		6.51	7.16	6.40	8.28	52.17
24.70	1.59	0.74	2.44	2.52	0.60	9.46		10.40	8.26	10.39	7.66	43.95
31.57	2.31	1.61	3.75	3.07	0.81	5.27		7.06	7.75	5.40	9.00	53.06
13.82	1.14	0.91	1.32	0.85	—	8.33		8.52	4.41	8.54	5.75	36.79
20.83	3.58	2.34	2.61	2.55	1.10	4.92		6.28	7.39	5.90	6.82	38.72
24.91	0.00	1.45	2.88	2.84	0.80	6.85		11.76	5.04	12.07	7.90	42.85
22.95	5.93	5.24	2.77	2.93	0.93	7.28		5.98	7.00	6.18	7.66	43.75
22.41	6.98	4.73	2.56	2.49	0.68	6.30		10.19	6.35	10.69	6.92	40.83
23.54	3.39	4.30	2.93	3.24	0.69	8.18		9.32	7.33	10.08	7.43	40.22
19.66	0.87	0.57	2.81	2.56	0.82	5.03		4.84	6.09	5.63	6.37	39.15
24.86	2.11	1.53	3.57	3.53	0.71	3.04		6.14	7.04	6.67	6.28	43.78
26.35	2.34	2.07	2.61	2.97	1.00	10.74		11.77	8.06	11.26	7.27	42.90
31.28	7.19	2.54	3.23	3.32	0.75	5.14		7.85	11.00	8.17	10.88	55.94
26.62	0.41	0.57	2.51	2.99	0.79	4.54		10.84	8.55	10.37	8.01	49.33
18.97	3.83	2.18	2.57	2.59	—	5.00		5.52	6.11	5.16	6.28	39.32
27.95	1.49	0.87	3.59	3.41	0.66	14.44		10.85	8.47	10.97	8.41	43.68
24.13	0.84	0.67	3.88	3.07	—	9.65		12.10	6.44	10.92	7.26	46.44
27.69	4.67	3.73	4.36	4.15	0.62	3.38		7.85	8.93	8.10	8.54	48.90
21.95	2.27	1.83	2.82	2.81	0.70	8.91		10.50	5.87	9.68	7.56	39.39
18.70	2.10	1.76	2.58	2.55	0.56	10.02		9.24	5.52	8.97	5.83	34.36
23.57	6.17	5.00	2.97	2.49	1.09	4.69		5.90	6.73	5.90	6.73	42.79
30.80	2.65	2.00	3.09	3.10	0.82	5.70		6.86	8.41	6.84	8.42	55.81
23.06	2.79	2.45	3.09	3.41	0.57	10.20		10.64	6.41	10.51	6.30	40.33
29.30	2.50	1.52	4.04	3.39	0.82	4.02		6.79	9.82	6.75	9.25	51.09

6.

NLP	SLP	PW	PD	SCR	~~PFA~~ cranial length	CPH# L	PPH# W	PC W (cranial)	Notes
104.34	105.16	65.83			23.64	5.00	1.74	18.52	
112.50	114.60	73.34			25.36	5.17	2.46	18.99	margins dark, white plaster covering specimen
109.72	112.05	73.43			21.99	6.12	1.96	20.22	~~margins~~
85.12	86.95	62.87			20.37	4.42	1.37	16.42	margins dark
101.91	103.55	66.73			24.97	10.69	1.44	19.00	PCL deformed foot w/one short nail
138.64	141.27	88.89			31.18	6.10	2.61	22.84	
128.25	130.47	85.68			32.93	6.73	2.58	21.96	good DSW, penis extended
130.72	131.01	91.11			30.61	6.66	1.93	22.01	~~penis extended~~
97.13	98.51	67.28			23.92	4.36	1.97	17.19	penis extended
131.42	132.44	87.45			31.32	5.96	2.66	21.66	
125.24	125.82	83.57			33.47	6.44	2.20	22.21	cloacal bulge
146.95	147.79	93 29			32.55	5.88	2.65	23 53	
135.85	137.21	93.32			30.81	6.08	2.54	22.97	
116.90	118.16	74.11			27.28	5.38	3.37	19.71	penis extended
127.45	129.58	81.59			29.72	6.40	1.95	21.80	right side head used
88.42	89.97	61.30			22.57	3.71	2.50	16.32	penis extended, slight post keel
102.84	103.98	66.04			24.53	4.90	2.58	16.93	
115.98	116.85	76.70			29.45	6.24	3.06	21.26	good DSW
111.52	113.04	72.14			27.43	4.93	2.61	19.14	
106.26	107.53	69.25			26.71	4.91	1.96	17.92	penis extended
103 47	104.56	69.52			26.38	4.30	2.04	18.46	penis extended
94.11	95.86	63.58			23.12	5.17	2.55	16.69	
113.28	114.04	75.84			27.93	6.37	2.86	19.25	
112.15	113.28	71.61			27.43	4.98	2.34	19.37	penis extended, good DSW
137.04	138.24	94.21			33.31	6.31	2.75	23.34	
136.32	137.03	84.13			32.18	4.79	1.74	23.27	penis extended
89.91	91.98	63.18			25.40	4.87	2.79	17.43	
130.10	131.73	87.05			29.86	6.27	2.69	23.22	cloacal bulge
111.03	113.92	7604			3016	5.38	2.12	20.84	penis extended, 3 claw missing, 2nd meas left post
133.77	135.05	88.12			30.77	5.83	2.42	21.71	
102.56	103.72	67.34			25.31	5.32	2.57	17.82	penis extended
86.18	87.74	58.51			21.57	5.03	1.89	16.20	penis extended
111.68	112.24	76.90			26.67	5.95	2.91	19.04	good DSW
136.30	137.27	91.72			30.98	6.43	2.70	22.51	
107.95	109.92	75.90			26.82	5.02	2.21	18.97	penis extended
140.71	141.91	91.34			25.59	7.29	2.68	22.32	♀

LEFT

7.

Specimen #	Subspecies	Museum	Museum #	State/County	NLC	SLC	CW	VSL	VSW	CLL
73	pict	CM	53006	NC-CAMDEN	122.63	127.52	97.28	11.64	3.92	24.91
74	pict	CM	53004	NC-CAMD	111.30	112.64	83.69	11.72	5.50	20.77
75	pict	CM	87420	SC-pickens	121.74	122.34	85.58	11.81	6.05	23.50
76	pict	CM	53007	NC-Camden	128.63	131.36	95.06	16.24	6.74	23.56
77	pict	CM	12965	NC-Hyde	147.51	148.89	108.90	14.85	6.12	32.43
78	pict	CM	64977	NC-Dare	123.14	124.02	90.87	13.62	5.13	24.87
79	pict	CM	61492	SC Pickens	103.15	105.34	79.44	10.65	3.98	21.24
80	pict	CM	87419	SC pick	135.71	136.49	95.46	11.89	7.00	28.72
81	marg	CM	R3174B	IN-Whitley	120.20	121.66	91.89	10.28	3.69	23.81
82	marg	CM	87417	IN-Jack	151.43	152.89	113.18	15.68	6.36	30.71
83	marg	CM	87418	IN-Jack	160.87	163.35	117.16	19.95	7.35	30.68
84	marg	CM	117894	IN-Monroe	132.99	135.43	95.71	16.07	4.08	25.20
85	marg	CM	87414	MICH-Schoolcraft	145.92	146.72	106.78	13.91	6.79	31.30
86	marg	CM	3174D	IN-Whit	121.93	123.64	90.64	12.57	5.85	25.11
87	marg	CM	87416	MICH-chippa	142.71	145.10	110.97	15.27	5.13	26.01
88	marg	CM	R3174C	IN-Whit	135.51	135.98	97.68	13.80	5.58	27.90
89	marg	CM	62099	MICH JACK	138.27	139.57	100.93	13.43	7.44	28.59
90	marg	CM	68119	MICH-Chesboy	130.94	132.57	94.07	16.59	5.95	25.84
91	marg	CM	115935	IN-Kos	130.90	132.99	91.30	12.56	6.16	28.26
92	marg	CM	87413	MICH-School	146.79	148.86	99.52	14.79	4.61	27.70
93	marg	WVBS	3227	PUTN	142.09	142.56	101.01	15.13	5.37	29.46
94	marg	WVBS	3078	RITC	153.30	154.82	106.28	16.30	8.55	29.93
95	marg	WVBS	3385	HARD	128.80	129.49	85.33	14.87	5.17	25.18
96	marg	WVBS	3310	WOOD	116.23	117.45	87.01	12.32	5.02	21.47
→ 97	pict	WVBS	3963	PRES	143.94	145.80	99.96	17.37	6.60	27.32
→ ~~98~~	~~marg~~	~~WVBS~~	~~3078~~	~~RITC~~	~~153.27~~	~~155.05~~				~~29.90~~
→ 99	marg	WVBS	3655	MASO	134.22	136.62	96.50	15.58	4.20	26.56
→ 100	marg	WVBS	3225	JACK	109.01	110.19	81.90	11.87	5.59	20.36
→ 101	marg	WVBS	3085	BOON	110.90	111.76	81.56	10.89	4.95	23.57
102	marg	WVBS	3224	ROAN	104.28	104.90	79.88	10.27	5.02	19.95
103	pict	WVBS	4220	MONR	137.79	138.68	101.53	14.00	15.19	29.86
104	marg	WVBS	2631	WIRT	96.31	97.05	74.98	8.51	5.24	17.11
105	marg (I?)	WVBS	8562	GREE	113.92	115.41	86.97	11.80	4.90	23.36
106	marg (I?)	WVBS	4234	SUMM	129.55	132.27	93.79	13.28	6.53	25.62
107	pict	WVBS	245	HAMP	99.62	100.25	78.56	10.21	5.95	20.34
108	pict	WVBS	1790	HARD	96.69	97.68	78.27	8.42	4.05	18.90

#14782 WVBS not measurable - road kill?

WVBS - #3204 #949 #252
JUV #3656 #253
#1183 #8526
#2001 #1182

8.

	CLR	DL	DR	MWL	MWR	DSW	CCL	CTL	ACL	PCL	ACR	PCR	SH
	24.25	2.89	2.05	3.10	2.84	0.73	8.45		9.67	7.58	11.17	7.58	43.00
	20.97	1.39	1.23	2.61	2.29	0.62	15.24		10.25	6.04	10.60	7.24	38.51
	23.69	2.14	1.99	2.10	2.09	0.57	3.61		5.38	6.99	5.86	6.88	44.40
	24.05	3.02	2.40	3.32	3.01	0.75	9.30		10.50	7.38	8.33	8.54	43.06
	32.78	3.01	2.82	4.03	4.40	1.01	2.05		4.81	7.80	4.61	7.04	54.53
	24.08	2.45	2.04	4.74	4.04	0.79	9.22		12.01	6.62	11.87	6.80	44.53
	21.06	1.05	0.77	1.81	1.92	0.60	5.38		9.55	6.60	9.42	6.09	35.07
	28.17	2.45	2.13	1.65	1.83	0.47	8.34		6.28	9.00	6.82	8.71	52.22
	23.61	10.23	9.43	1.75	1.86	0.72	6.84		6.17	7.82	5.96	7.49	40.30
	31.40	14.37	14.88	2.81	2.25	0.58	1.06		7.32	8.86	7.37	8.88	52.69
	30.24	14.61	14.13	0.84	0.91	—	4.32		7.37	10.14	8.12	10.13	55.12
	24.40	11.07	10.31	0.73	1.00	0.61	15.93		10.16	7.21	10.36	7.09	42.50
	31.76	16.49	15.30	2.83	2.93	0.68	1.92		7.21	9.11	6.92	9.46	52.44
	25.00	11.62	10.02	0.87	0.84	—	9.33		12.46	8.91	10.32	9.34	42.73
	26.03	12.92	10.77	1.92	1.92	0.43	4.79		6.49	8.29	6.87	8.30	53.65
	27.60	13.07	12.26	2.00	1.99	0.92	3.10		6.59	8.21	6.39	8.10	49.27
	29.22	12.63	12.98	1.60	2.05	0.63	7.96		5.47	9.05	5.90	8.76	52.78
	25.84	10.43	9.63	2.17	3.79	1.94	12.01		12.27	9.05	12.49	9.25	41.00
	28.26	14.06	13.92	1.74	[illegible]	0.70	2.76		7.47	8.38	6.68	8.56	37.39
	27.62	13.25	12.35	1.54	2.35	—	3.00		7.66	9.96	7.98	10.17	51.80
	28.85	13.14	12.24	1.44	1.31	—	5.83		5.95	8.31	6.37	7.71	56.96
→	29.75	13.31	13.02	1.60	1.70	.68	10.81		5.67	7.16	5.63	7.36	57.04
	24.55	3.67	3.13	2.03	1.96	1.05	7.14		11.03	7.41	10.88	8.08	40.10
	21.60	9.62	9.48	0.70	0.60	—	—		11.64	7.90	—	7.82	38.87
→	26.77	3.56	3.29	2.39	2.18	1.19	8.48		10.75	6.72	10.84	6.99	46.01
→	~~29.08~~	~~13.30~~	~~12.88~~	~~1.73~~	~~1.59~~				~~5.87~~	~~7.26~~	~~5.35~~	~~7.69~~	
→	26.97	11.42	12.16	1.98	1.74	.42	11.45		12.64	9.12	12.29	8.27	42.77
	19.98	8.69	7.85	.98	.92	.63	12.69		10.39	5.63	9.12	5.29	34.26
	23.37	10.43	10.55	.81	.93	.50	6.43		4.62	5.83	4.23	5.54	44.11
	20.12	8.89	8.35	1.27	1.27	.63	4.10		4.88	5.88	5.17	5.49	37.49
	29.42	2.73	2.10	2.86	2.67	.63	6.19		6.85	9.08	7.29	9.21	46.39
104	18.43	6.63	6.58	.85	.95	—	7.99		9.80	7.16	9.70	7.17	34.78
105	23.10	8.41	8.05	1.40	1.52	.81	2.26		6.49	6.39	6.42	6.26	37.07
106	25.39	8.53	7.64	.80	.74	.90	10.24		11.58	8.88	11.79	7.05	45.40
107	19.48	1.22	.80	2.40	1.80	.72	2.05		6.23	6.48	6.02	6.60	37.88
108	18.23	5.16	2.88	1.68	1.77	.76	4.05		10.84	6.21	11.25	6.69	31.72

is left side more disaligned?

9.

	NLP	SLP	PW	~~PD~~ PWA	SCR	PFA	CPH#	PPH#	PC	Notes
	117.26	117.50	79.41			31.98	5.58	2.13	20.67	small portion of penis coming forth
	105.02	106.28	70.00			26.34	6.11	2.63	18.90	cloacal bulge
	109.06	110.11	74.94			29.69	5.79	2.84	19.01	
	114.98	116.94	74.72			29.74	5.80	2.18	20.36	penis extended
	138.07	139.01	90.60			31.24	6.32	3.02	21.91	
	114.68	115.32	74.39			26.74	5.62	2.73	18.90	penis extended
	95.41	96.12	65.59			23.97	4.94	2.35	18.15	penis extended
	125.15	125.93	78.97			31.31	6.02	3.06	20.83	
	108.43	109.95	76.16			25.06	7.46	1.81	18.05	see thru turtle
	143.74	144.78	91.28			29.20	7.32	0.60	21.77	
	136.46	139.55	88.70			32.37	7.54	1.52	23.35	
	117.37	119.34	75.42			30.12	9.34	1.24	22.18	large cloacal bulge
	134.24	135.39	84.46			28.98	8.94	1.60	22.57	
	109.66	110.31	76.86			29.21	7.51	1.86	20.37	see thru brother or sister
	132.76	133.64	90.56			28.27	6.54	1.00	22.63	
	123.79	124.31	76.30			20.53	8.49	1.87	20.05	
	127.86	128.87	82.84			28.43	7.04	1.56	21.61	
	63.05	64.54	20.35			27.95	8.33	1.54	20.71	penis extended
	108.99	110.32	62.43			29.62	7.48	1.33	21.17	
	134.10	134.55	79.13			25.16	8.82	1.11	22.53	
93	122.56	128.80	89.08	76.49		29.42	7.80	1.23	22.79	midline seam not straight; plastron malformed
94	138.04	138.41	87.87	73.55		21.38	8.39	1.86	22.65	penis extended
95	114.58	115.75	73.09	55.66		28.37	5.74	2.50	19.89	weird scute alignment 3.67 (L) 2.83 (R) claws long
	106.27	106.55	71.61	58.95		—	5.51	2.21	18.36	cannot bend tail badly preserved & dried, def male, head strip diff to meas
	131.10	132.93	84.95	67.78		20.66	5.08	2.10	21.98	stripe weird runs into other thick head stripe measure on right
	121.08	124.00	80.10	64.73		29.94	7.41	2.04	21.07	def male
	97.61	98.77	67.86	49.92		20.87	7.25	1.52	17.65	
	102.01	103.33	67.63	51.49		26.96	6.41	1.74	18.74	
	94.84	96.69	67.19	52.20		24.78	5.92	1.71	17.27	
	123.21	127.07	83.10	64.54		29.87	6.37	1.53	22.66	
	87.68	88.07	60.30	48.67		21.58	6.19	1.41	16.70	def male
	103.32	105.64	72.90	55.82		27.05	5.38	2.05	20.05	Anthony Creek
	116.65	117.86	79.12	61.64		22.58	6.65	2.16	21.01	def male - intergrade ♂
	91.40	92.48	66.93	48.98		18.38	4.90	1.86	17.83	
	88.43	89.18	63.03	47.41		—	—	—	—	head not measureable

Appendix C

Curriculum Vitae

Melissa R. Mann

Curriculum Vitae

EDUCATION

Marshall University, Huntington, WV
Master of Science in Biology
Concentration: Herpetology
Summa Cum Laude, May 2007

Thomas More College, Crestview Hills, KY
Bachelor of Arts in Biology/ Associate of Arts in Microcomputer Applications Systems
Cum Laude, 2000

KNOWLEDGE & SKILLS

- Environmental education ranging from students in a camp setting to lab coursework at a university level
- Public speaking to a variety of age groups regarding biological topics and wildlife
- Presentation of research at scientific conventions to professionals and students
- Handling and caring for a variety of wild and domestic animals
- ArcGIS mapping and analysis, MS Windows, MS Office, MS Access database design, Adobe Products (Acrobat, DreamWeaver, InDesign)
- Physiology, taxonomy, natural history and ecology of extant vertebrate species, specializing in reptiles, amphibians, birds and bony fishes
- Physiology, taxonomy and ecology of native vascular plants
- Field identification of vertebrates (by sight or call) and terrestrial vegetation
- Research collection techniques such as electroshocking, gillnetting, seining, as well as live-capture trapping and habitat surveys
- Certified Open-Water SCUBA diver (PADI)
- Kentucky Project WET and Project WILD certification (2004)
- CPR Certification (2007)

WORK EXPERIENCE

Adjunct Professor

Thomas More College Biology Department – (August 2005-Present)

- Teach local high school students college level general Biology lab course
- Prepare lecture material and assist with lab set-up and procedures
- Prepare and administer quizzes, examinations, and laboratory practicals

Public Information/Education Specialist

Ohio River Valley Sanitation Commission (ORSANCO) – (August 2005-present)

- Manage student water quality monitoring program
- Develop curriculum for the ORSANCO River Education Center
- Participate in various educational programs throughout the Ohio River Basin
- Travel, setup and present mobile aquarium for environmental education programs and other special events
- Respond to information requests regarding ORSANCO and the Ohio River
- Edit and write technical/public documents

WORK EXPERIENCE (continued)

Solid Waste Enforcement Officer

Boone County Public Works Department - (January 2004-August 2005)

- Enforce solid waste, litter and environmental ordinances in Boone County, Kentucky
- Work closely with the Solid Waste Coordinator on the implementation of the Solid Waste Plan which includes projects such as public education, state and local clean-ups and recycling programs
- Coordinate and present litter and recycling education programs at North-Central 4-H camp for Boone County fifth graders
- Coordinate 2005 River Sweep Event for Boone County, Kentucky
- Present with other area environmental educators at the 2004 Waterific Event – hosted by Northern Kentucky Sanitation District
- Work closely with organizations such as the Northern Kentucky Conservation District, Northern Kentucky Household Hazardous Waste Coalition, Northern Kentucky Technical Advisory Committee, Sierra Club and other local environmental organizations

Environmental Education Intern

- University of Kentucky Cooperative Extension Service - (September - November 2003)
- Designed, organized and taught classes concerning natural resources and the environment to approximately 1750 students from grades 4 through 8
- Instructed the following classes on a regular basis: birding (by sight and call), forestry, mammal skins, animal tracks, pond study (water quality assessment) and a nature night-hike
- Maintained outdoor and indoor classroom areas
- Worked cooperatively with 4-H agents, teachers, chaperones, other instructors and camp staff

4-H Camp Instructor

Barboursville 4-H Camp, Barboursville, West Virginia - (June 2002)

- Taught one-week course on local small stream ecology to 20 grade-school students
- Lead expeditions into the field to collect and study native aquatic organisms

Animal Caretaker

Thomas More College Department of Biology - (January 1997 - August 2001)

- Shared responsibility for the welfare of numerous species of reptiles, amphibians, fishes, and arthropods
- Gained valuable experience teaching to a variety of age groups concerning wildlife and nature

BIOLOGICAL EXPERIENCE

Herpetology Research Assistant, under Dr. Thomas K. Pauley

Marshall University Department of Biological Sciences – (August 2001-May 2003)

a) Database Designer

Inventory and Monitoring Program (Funded by National Park Service)

- Created functional database for NPS studies conducted in West Virginia using MS Access
- Organized and entered data from previous research conducted on NPS land

b) Teaching Assistant

Taught and moderated Herpetology and Ornithology laboratory sessions

- Chaperoned students on trips to the field
- Prepared supplemental learning material for students

BIOLOGICAL EXPERIENCE (continued)

c) Animal Caretaker

- Maintained health and well-being of live animals located at school
- Educated students, children and visitors using live animal displays
- Traveled when necessary to give live animal presentations

d) Herpetologist

West Virginia Stream Salamander Survey - (funded by USGS and EPA) –

- Surveyed for diversity and abundance of aquatic plethodontid salamanders in 1st and 2nd order streams of West Virginia, to be used as an indication of stream health
- Sampled using quadrat and transect methods
- Assisted in data collection, data analysis, report and technical paper writing

e) Field Herpetologist

West Virginia Herp Atlas - (funded by WV Division of Natural Resources)

- Inventoried reptiles and amphibians statewide for two years to help form a complete statewide Herp Atlas for West Virginia
- Used various field techniques across the state and helped compile information into the database

Aquatic Biologist, under Dr. Thomas G. Jones

Marshall University Department of Integrated Science and Technology - (August 2002-May 2003)

- Completed controlled collections of freshwater fish on large rivers and smaller streams
- Operated boat-mounted electro-shocking units
- Sampled benthic organisms and examined water chemistry

Volunteer Herpetologist

- Ohio Frog and Toad Calling Survey (sponsored by Ohio DNR) - (March 2004-present)
- Currently volunteering in statewide program to inventory anurans calling at different times of year
- Established permanent routes to be monitored on yearly basis
- Visit sites monthly during early and late spring, identify species, and record calling data.

Volunteer Field Assistant

Environmental Solutions and Innovations, Inc. - (funded by Indiana DNR) - (Sept. 2004)

- Assisted with capture and radiotelemetry studies of the Federally-endangered Indiana bat (*Myotis sodalis*) at Wyandotte Cave, on Harrison-Crawford State Forest
- Employed a harp trap to catch bats and learned to identify the species before processing

Museum Volunteer

Cincinnati Museum of Natural History - (January 1997-May 2000)

- Identified vertebrate species and curate the herpetological specimen collection
- Partook in research opportunities concerning the collection

Biology Research Assistant

Thomas More College Ohio River Biology Field Station - (Summers 1997-1999)

- Collected and analyzed research data on large river and small stream ecosystems
- Achieved extensive knowledge of fish and other aquatic organisms
- Assisted teaching of Big River Ecosystems course to other undergraduate students

BIOLOGICAL EXPERIENCE (continued)

Biology Research Associate, under Dr. John W. Ferner
(Funded by Cinergy Earth Day Environmental Grant) - (May 1997-May 2000)

- Surveyed and collect live reptile specimens to investigate population and distribution of reptiles in Northern Kentucky (Boone, Kenton and Campbell Counties)
- Prepared a database using MS Access to combine current survey records and past museum records
- Presented research at scientific conventions

PUBLICATIONS

Obermeyer (Mann), M. R., J.W. Ferner, and P. J. Krusling. 2000. A Survey and Review of Snake Populations in Boone, Kenton, and Campbell Counties, Kentucky. Final Report: Cinergy Earth Day Environmental Grant.

Mann, A., M.R. Obermeyer (Mann), and J.W. Ferner. 2000. Geographic Distribution. *Opheodrys aestivus*. Herpetological Review 31(2): 114.

Ferner, J.W., C. Lorentz, M. Obermeyer (Mann), and P.J. Krusling. 2000. Geographic Distribution. *Apalone spinifera spinifera*. Herpetological Review 31(1): 51.

PUBLISHED ABSTRACTS

Mann, M. R. and T. K. Pauley. Marshall University Department of Biological Sciences – Intergradation of the turtle *Chrysemys picta* in West Virginia. Southeastern Biology Vol. 50, No. 2, April 2003.

Tackett, Fred, Eric Emory, Melissa Mann, Adam Mann and Thomas Jones. Marshall University, Huntington, West Virginia and ORSANCO, Cincinnati, Ohio – Fish community structure of the Kanawha River. Southeastern Biology Vol. 50, No. 2, April 2003.

PROFESSIONAL SOCIETIES

Sigma Xi Scientific Research Society
Delta Epsilon Sigma National Honor Society
Greater Cincinnati Herpetological Society

GRADUATE COURSEWORK

Herpetology
Conservation Biology
Seminar I & II
Ornithology
Economic Botany
Spatial Analysis for the Environment
Independent Study (Fish Sampling Kanawha/Ohio River)
Taxonomy of Vascular Plants II
Aquatic Diversity