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IMPLICATIONS OF CLAW MORPHOLOGY FOR POSSIBLE AQUATIC LOCOMOTION IN *PTERANODON*

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AMY C SMITH

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IMPLICATIONS OF CLAW MORPHOLOGY FOR POSSIBLE AQUATIC LOCOMOTION IN *PTERANODON*

By

Amy C. Smith

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ABSTRACT

IMPLICATIONS OF CLAW MORPHOLOGY FOR POSSIBLE AQUATIC LOCOMOTION IN *PTERANODON*

By

Amy C Smith

Previous studies (Bennett 2001, Bramwell and Whitfield 1974) have suggested that *Pteranodon* may have been capable of aquatic locomotion in the epicontinental seaway that covered Kansas during the Cretaceous. Quantitative morphometrics were employed here to examine pteranodont pes claw morphology to ascertain how the morphologies of the claws of this genus relate morphometrically to the claws found on the pedes of various birds and crocodylians, which served as extant phylogenetic bracketing taxa for pterosaurs. These taxa included four species of swimming birds, one wading bird, one terrestrial/perching bird, two species of crocodile, and one species of alligator, along with one species of *Pteranodon*.

Homologous landmarks were placed on digital photographs of avian, crocodylian, and pteranodont claws. Once these landmarks were transformed into Bookstein coordinates, morphometric data were derived for all specimens. These data were then analyzed through the use of the programs SYSTAT and Excel in search of statistically significant differences between homologous claws at significance level $\alpha = 0.05$.

ANOVA calculations indicated that pteranodont claws are most statistically similar to those of Scarlet Ibis and the Peacock, somewhat similar to those of *Crocodylus acutus* and the Great Auk, and least similar to the Pelican, Whistling Swan, and alligator. These results indicate that *Pteranodon* did not actively propel through the water, but may have been capable of floating or treading water at the surface.

Dedicated to Dr. William Chaisson, whose continued support has always helped me maintain focus and persistence in pursuing my career.

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INTRODUCTION

As with any extinct organism, the various aspects of the functional morphology of *Pteranodon* must be inferred through multiple studies and testable hypotheses. One convention for such a study is the use of an extant phylogenetic bracket (Witmer 1995). Using this technique with the relatively novel technique of quantitative morphometrics, this thesis explores the possibility that *Pteranodon* was capable of swimming on the epicontinental seaway that covered the Western Interior of North America during the Cretaceous period.

Pteranodont Habitat and Food

Two lines of evidence indicate that *Pteranodon* lived and fed in an oceanic environment. First, *Pteranodon* fossils to date have been found only in the Cretaceous chalk beds of Kansas. All four pteranodont specimens used in this study came from the Niobrara Chalk Formation (Bennett 1994), which has also yielded fossils of mosasaurs (the most commonly found vertebrate fossils in this formation), fish, the piscivorous birds *Hesperornus* and *Enionus* (Bramwell and Whitfield 1974), plesiosaurs, and turtles (Bennett 2000). Secondly, fossil evidence indicates that *Pteranodon* fed on fish in the epicontinental seaway. This evidence includes a pteranodont specimen that contains fish scales and bones in its stomach (Bramwell and Whitfield 1974), and a second specimen that has a bolus of fish caught between its mandibular rami (Bennett 2001, part 2).

Proposed Terrestrial and Aerial Locomotion of *Pteranodon*

One of the more frequently discussed aspects of pteranodont terrestrial locomotion has been the issue of plantigrade versus digitigrade stance. Although all birds are digitigrade (Ede 1964), it was determined that *Pteranodon*, like crocodylians (Parrish 1987), was plantigrade (Bennett 2001, part 2). This is supported by the morphology of the tarsal, metatarsal, and interphalangeal joints. For example, the joint found between the distal tarsals and metatarsals (which were not fused to each other as is the condition in birds (Padian 1983)) are thought to have permitted flexion of the pes in the vertical plane, as well as permitting some lateral flexion. Furthermore, the metatarsal and interphalangeal joints are simple ginglymoid joints that could not only permit flexion, but probably extension as well (Bennett 2001, part 2).

The question of whether *Pteranodon* was bipedal or quadrupedal has been more intensely debated. The argument for bipedalism can be supported first by examining the terrestrial locomotion of large birds. For example, the limb disparity (the ratio of wing length to leg length) of *Pteranodon*, which is 9:1, is closest to that of the albatross, which is 8:1 (Padian 1983). Although the hind limbs of both the albatross and *Pteranodon* are small compared to their respective wingspans, the albatross is able to walk normally with a bipedal gait. The possible bipedalism of *Pteranodon* can also be compared to the bipedalism of birds with regards to the positioning of the femur. If the pteranodont femur were positioned horizontally and parasagittally, then most of the puboischiadic would lie behind and below the femur and the acetabulum, as is the condition in birds (Padian 1983). Additionally, it is possible that the weight of the body of *Pteranodon* could be held over its feet, giving it adequate balance in a bipedal stance. To further promote

balance in a bipedal stance, flexion of the carpus and the subsequent rotation of the radius, ulna, and humerus may have allowed for the wing to fold against the body with the fourth manus digit directed posterodorsally (Bennett 2001, b).

On the other hand, several lines of evidence support the argument for a quadrupedal stance in *Pteranodon*. Such evidence includes the reduction of the post-acetabular part of the pelvis, which is thought to eliminate the possibility of bipedalism in *Pteranodon*. This structure, in addition to the posterior position of the acetabulum, hypothetically allowed the femur to move dorsally and ventrally, so that *Pteranodon* could move along the ground by sliding on its stomach and pulling itself forwards with its feet (Bramwell and Whitfield 1974).

Although Bramwell and Whitfield (1974) have suggested that *Pteranodon* could hang from cliff edges like a bat, it has since been concluded that its claws were unsuitable for climbing or perching, and were instead more suited to terrestrial locomotion due to their minimal curvature (Bennett 2001, a). Furthermore, *Pteranodon* lacks the uniformly parallel foot bones used for grasping branches as seen in bats (Padian 1983). These evidences strongly indicate that *Pteranodon* could not perch or grab onto any surface.

Hypotheses of pteranodont aerial locomotion tend to correlate with hypotheses of terrestrial locomotion. If *Pteranodon* were strictly quadrupedal, then it would not have been able to run in order to take off for flight (Bramwell and Whitfield, 1974). Because its wing finger was four times the length of its humerus and radius combined (Padian 1983), *Pteranodon* would have needed to take off from an object that was high enough to prevent its wings from hitting the ground on the first downwards stroke. Moreover, Bramwell and Whitfield (1974) hypothesized that *Pteranodon* could take off from the

ground by facing winds at speeds of at least seven meters per second and spreading its wings, similar to the method of take-off used by the albatross.

The Possibility of Pteranodont Aquatic Locomotion

The possibility that *Pteranodon* landed on the water to feed has been mentioned briefly (Bramwell and Whitfield 1974, Bennett 2001, b), but until now it has not been examined as a hypothesis. The aquatic feeding habits of *Pteranodon* are most often involved in the argument for pteranodont aquatic locomotion. Originally, most hypotheses regarding methods of feeding suggested that *Pteranodon* fed by plunge diving, or by sticking the beak into the water as it glided above the surface.

Plunge diving and feeding while gliding are congruent with the structure of the jaws, which indicate that prey was caught between the jaws (Bennett 2001, b). Furthermore, *Pteranodon* had strong neck bones with flexion thought to be suitable for striking into the water (Bramwell and Whitfield 1974). However, both methods of feeding seem improbable due to the lack of teeth or other structures in the jaw that would facilitate catching fish in this manner. Additionally, the premaxilla extends forwards beyond the tip of the mandible (Bennett 2001, b). If *Pteranodon* were a glider, it would not have been able to gain enough speed necessary to plunge into the water (Bramwell and Whitfield 1974).

An alternative hypothesis suggests that *Pteranodon* fed by floating on the surface of the water and plunging its beak below the surface in order to grab fish (Bramwell and Whitfield 1974). It is presumed that *Pteranodon* could dip its head 90 centimeters (Bennett 2001, b) below the water's surface with a range of roughly 1.2 meters

(Bramwell and Whitfield 1974), and could have used its elongate maxilla to slash through the water and disorient fish (Bennett 2001, b). The disadvantages to this style of feeding are that *Pteranodon* would be vulnerable to underwater predators and would not be able to pursue quickly moving fish (Bramwell and Whitfield 1974).

The means by which *Pteranodon* may have launched into the air are also used in the argument for possible aquatic locomotion. It is proposed that if *Pteranodon* could take off directly from the ground, then it could probably take off from the surface of the water in like manner (Bennett 2001, b). For example, if there were sufficient wind to facilitate lift, *Pteranodon* may have either flapped its wings from the crest of a wave, or launched itself form the crest of a wave as a glider (if *Pteranodon* could indeed glide). In these two cases, the large expanse of the wings would permit a flapping downwards without hitting the surface of the water or catching unfavorable air currents (Bramwell and Whitfield 1974).

The Extant Phylogenetic Bracket Surrounding *Pteranodon*

The Extant Phylogenetic Bracket (EPB) method was developed by Witmer (1995) primarily to test hypotheses regarding placement and/or functional morphologies of the soft tissues of fossil organisms by comparing the tissues of at least two extant outgroups to the fossil under study. However, an EPB can also be used to test hypotheses regarding other topics of paleobiology, including the hypothesis that pteranodont claws have functionally morphological characteristics similar to claws of the extant groups Aves and Crocodylia (in regards to aquatic locomotion). In this case, the hypothesis was tested by first examining the known swimming behaviors of the extant taxa, and then by making

inferences of the swimming ability of *Pteranodon* by comparing and contrasting claw morphologies. These inferences are considered to be Level I inferences, due to the homologies of the claws studied across all taxa. Level I inferences can generate a decisive positive assessment, which minimizes speculation through the presence of morphological congruence (Witmer 1995).

Class	Order	Family	Genus/species
Reptilia	Crocodylia	Crocodylidae	*Crocodylus porosus*
Reptilia	Crocodylia	Crocodylidae	*Crocodylus acutus*
Reptilia	Crocodylia	Alligatoridae	*Alligator mississippiens*
Reptilia	Pterosauria	Pterodontidae	*Pteranodon*
Reptilia	Pterosauria	Pterodontidae	*Pteranodon longiceps*
Aves	Pelecaniformes	Pelecanidae	*Pelecanus*
Aves	Pelecaniformes	Pelecanidae	*Pelecanus conspicillatus*
Aves	Anseriformes	Anatidae	*Olor columbianus*
Aves	Charadriiformes	Laridae	*Larus marinus*
Aves	Charadriiformes	Alcidae	*Pinguinis*
Aves	Ciconiiformes	Threskionithidae	*Eudocimus ruber*
Aves	Galliformes	Phasianidae	*Pavo cristatus*

TABLE 1. Classifications of animals used in study (Brochu 2003, Raikow 1985, Bennett 1994).

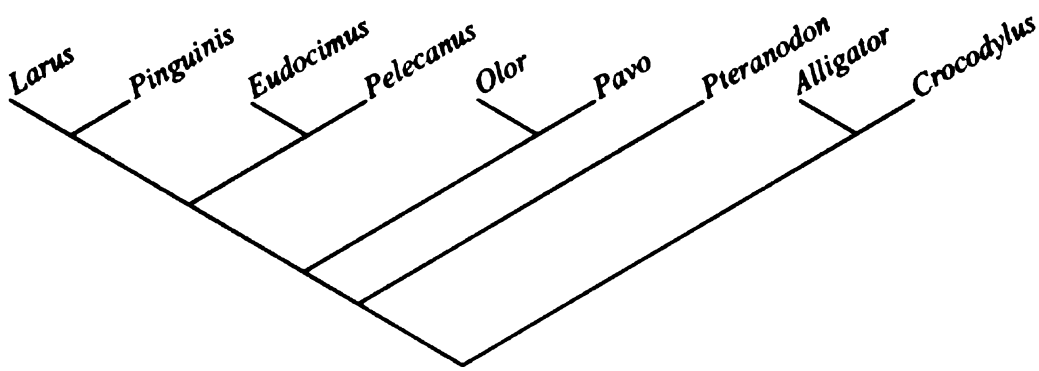

FIGURE 1. Relationships of genera used in study (Compiled from Thomas et. al 2004, Brochu 2003, Mayr 2003, Hedges and Sibley 1994, and Bennett 2003).

Genus/species	Number of Digits on Pes	Phalangeal Formula of Pes	Webbing Present on Pes?	Foot type (birds)
Crocodylus porosus	4	2-3-4-4	significant webbing	N/A
Crocodylus acutus	4	2-3-4-4	significant webbing	N/A
Alligator mississippiens	4	2-3-4-4	~2/3 webbed	N/A
Pteranodon	4	2-3-4-5	N/A	N/A
Pteranodon longiceps	4	2-3-4-5	N/A	N/A
Pelecanus	4	2-3-4-5	totipalmate	ectropodactyl
Olor columbianus	4	2-3-4-4	palmate	anisodactyl
Larus marinus	3	0-3-4-5	palmate	tridactyl
Pinguinis	3	0-3-4-5	palmate	tridactyl
Eudocimus ruber	4	2-3-4-4	basally	anisodactyl
Pavo cristatus	4	2-3-4-4	none	anisodactyl

TABLE 2. Specimen pes types and characteristics (Raikow 1985, Bennett 2001 part 1, Bellairs 1969).

It should be here noted that although *Pinguinis* (the Great Auk) is now extinct, it is used as part of the EPB because its behavior has been observed and documented before its extinction.

Avian Locomotion

Of the six different bird species used in this study (assuming that the two Pelican specimens are either similar in functional morphology to each other, or are the same species), two species swim by paddling along the water's surface, two species swim/swam both along the water's surface and under the water, one species wades in marshy areas, and one species is a terrestrial bird that occasionally perches.

Olor columbianus and *Larus marinus* perform most of their aquatic locomotion at the surface of the water. *Olor columbianus*, the Whistling Swan, swims at the surface and feeds by dipping its beak down into the water, usually in shallow areas (Wallace and

Mahan 1975). *Larus marinus*, the Great Black-Backed Gull, floats on the water more than it actively swims (Wallace and Mahan 1975). However, when it does swim, it does so by paddling along the surface with its legs. Gulls occasionally dive into the water, reaching depths no deeper than one to two meters below the water's surface. When gulls walk on the ground, it is with a lumbering gait, but they can sometimes hop onto perches (Good 1998).

Pinguinis, the Great Auk, swam mostly underwater by propelling itself with its flightless wings. The Auk could also flap its wings efficiently to plane along the surface of the water. In spite of its skill in the water, however, the Auk walked clumsily on land (Montevecchi and Kirk 1996). Like *Pinguinis*, *Pelecanus* has broad feet and webbing between the toes that allow fast underwater swimming (Lockley 1974). However, Pelicans feed mostly by flying close over the water and suddenly plunge diving into the water to scoop up fish (Géroudet 1965).

Eudocimus ruber, the Scarlet Ibis, is similar to the White Ibis in both behavior and choice of habitat. It walks slowly when feeding in shallow marshes, but walks more quickly when feeding in aquatic habitats. The Scarlet Ibis can fly, and does so with rapid beats of the wing; however, it swims only when pressed by danger (Kushlan and Bildstein 1992).

Pavo cristatus, the Peacock, is a mostly terrestrial, non-swimming bird that is used as a control in this study. It travels mainly by walking on the ground, but can run when threatened. Furthermore, the Peacock flies only when crossing a ravine or alighting into roost trees. Thus, the peacock spends most of its time on the ground, perching in trees only when roosting (Ragupathy 1998).

Crocodylian Locomotion

Extant crocodylians are secondarily aquatic, in contrast to their terrestrial ancestors (Parrish 1987). They perform many of their daily activities such as feeding, social interactions, and reproduction, in the water (Seebacher et al. 2003). As such, crocodylian feet are webbed as an adaptation to their aquatic environment. Although both the crocodylian manus and pes have webbing between the digits, the pes is extensively more webbed than is the manus (Bellairs 1969). For example, the manus digits of *Alligator mississippiens* are webbed almost halfway, whereas the pes digits are webbed along two-thirds of their length. Similarly, *Crocodylus acutus* has slight webbing on the third and fourth digits of its manus, whereas it has more extensive webbing on the outer digits of its pes (Cope 1900).

Despite the presence of webbing, the feet are not the main source of propulsion in adult crocodylian aquatic locomotion. Only hatchling crocodylians swim entirely by paddling their feet, using their hind limbs to do so between 77% and 98.9% of the time. On the other hand, medium-sized crocodylians paddle with their feet only at very slow speeds, using their hind limbs between 71.3% and 92.9% of the time. Large crocodylians do not use their feet for aquatic propulsion at all. Instead, the webbed feet of large and medium-sized crocodylians that are swimming quickly are used to help maintain balance and facilitate maneuverability in the water, while the tail facilitates propulsion (Seebacher et al. 2003).

The Use of Quantitative Morphometrics

In contrast to qualitative descriptions, morphometrics are a quantitative way to examine and compare shape data of organisms. These data can be then be analyzed using algebra and statistics based on homologous landmarks placed on images of specimens. Furthermore, using landmarks for shape comparison when performing morphometrics better assures homology of data across specimens or taxa. However, landmarks can omit data about curvature, unless another method is used to study curvature. Variation of the coordinates of landmarks across studied specimens is removed by mathematically removing the differences in specimen positions, sizes, and orientations (Zelditch et al 2004). Morphometrics were used in this thesis to maintain homology across specimens, and permit statistical analyses of these data.

MATERIALS AND METHODS

Specimens Studied

The two extant outgroups used in the EPB with the extinct genus *Pteranodon* were Aves and Crocodylia. From one to four homologous claws were compared and contrasted among the nine genera in this study. Sixteen total specimens (photographs of which are shown in Appendix I) were examined, as described in Table 3. The four pteranodont claws of unknown articulation were not used in the study, and were retained in the overall data set (their data listed in Appendix VII) only for the creation of the tangential claw phenograms in Appendix VIII.

Specimen	Specimen Location	Genus or Species	Description	Body Parts Used in Study
FHSM-VP2062	Fort Hays Sternberg Museum	*Pteranodon longiceps*	articulated foot in chalk block	claws 1, 2, 3, & 4
KU49399	University of Kansas Museum	*Pteranodon*	disarticulated left tibia, tarsals, metatarsals, and phalanges in chalk	two disarticulated claws
YPM2554	Yale Peabody Museum	*Pteranodon*	articulated tarsals metatarsals, and disarticulated claws in chalk	one distarticulated claw
YPM2436	Yale Peabody Museum	*Pteranodon*	disarticulated metatarsals and claw in chalk	one distarticulated claw
(UM-P)	University of Michigan Zoological Museum	*Pelecanus*	articulated skeleton	claws 1, 2, 3, & 4
(UM-WS)	University of Michigan Zoological Museum	*Olor columbianus*	articulated skeleton	claws 2, 3, & 4
(C-GBBG)	Chicago Field Museum	*Larus marinus*	articulated skeleton	claws 2, 3, & 4
(C-PI)	Chicago Field Museum	*Pinguinis*	articulated skeleton	claws 2, 3, & 4
(C-SI)	Chicago Field Museum	*Eudocimus ruber*	articulated skeleton	claws 1, 2, 3, & 4
(C-PC)	Chicago Field Museum	*Pelecanus conspicillatus*	articulated skeleton	claws 3 & 4
(MSU-PA)	Michigan State University Museum	*Pavo cristatus*	articulated skeleton	claws 1, 2, 3, & 4
C22026	Chicago Field Museum	*Crocodylus porosus*	articulated skeleton	claws 1, 2 & 3
C213395	Chicago Field Museum	*Crocodylus acutus*	articulated skeleton	claw 1
(C-CAD)	Chicago Field Museum	*Crocodylus acutus*	articulated skeleton	claws 2 & 3
C31011	Chicago Field Museum	*Alligator mississippiens*	articulated skeleton	claw 3
C31321	Chicago Field Museum	*Alligator mississippiens*	articulated skeleton	claws 1 & 3

TABLE 3. Specimens examined. Specimens that have no catalog number are given an informal abbreviation for reference in this paper (shown above in parentheses).

Photograph Acquisition and Organization

All photographs of specimens used in this study were taken with a Canon Powershot A40 Digital Camera. Photographs were taken of the fronts of the specimens,

and where possible, also of both the left and right side and of the back of the specimen. A Geological Society of America cardboard scale (in centimeters) was placed in the photographs of many of the specimens. All photographs were taken in color, with the highest possible resolution and with the camera set to automatically adapt to the lighting conditions. Once acquired, the photographs were then labeled and organized according to their location and catalog number or label on a computer hard drive. Notes about these photographs can be found in Appendix II.

Photograph Manipulation

Single elements of avian, crocodylian, and pteranodont feet had to be isolated and then oriented in a manner that would allow for the placing of landmarks and for morphometric measurement. Adobe Photoshop CS1 was used for all manipulations and calculations performed on the avian, crocodylian, and pteranodont claws. This program has the advantages of the ability to adjust brightness, contrast, and other aspects of photographs, a tool that measures distances between two points, and a built-in XY coordinate system.

The first step was to load the photograph of a crocodylian, avian, or pteranodont pes into Adobe Photoshop. Next, in instances where the cardboard scale was present in the photograph, the photograph was first increased or decreased in percentages until one centimeter of the scale measured as one centimeter in the program. (It should be noted, however, that this is not a necessary step, as all size data were removed once certain morphometric calculations of the landmarks were performed as shown below.) Each claw image was then cropped and placed in its own file, and labeled by the specimen to which

it belonged and the number of the digit to which it corresponds. In order to define the edges of the claw as precisely as possible, the brightness and contrast aspects of the image were adjusted to make the claw stand out against its background, then the edges of the claw were sharpened using the sharpen tool. The pictures remained in color because it was easier to see the claw edges in color than in black and white. This method was applied to 36 claws from 15 specimens.

Raw Landmark Placement and Claw Orientation

Once the claw image has been isolated and its edges had been sharpened, landmarks were placed on homologous areas on each claw. Four landmarks were placed on every claw (Figure 1); one landmark each was placed on the two proximal corners of each claw where the claw meets the digit, a third was placed at the distal tip of the claw, and the fourth was placed at the middle of the proximal edge of the claw where the claw meets the digit. The claws were examined under a high magnification in order to place the landmarks on the most specific coordinates possible. Although landmarks 1, 2, and 3 were of the most interest, landmark 4 was included in morphometric computations and was used to help determine the centroid coordinates and size.

Once landmarks were placed on the claw, the image was then reoriented so that landmarks 1 and 2 rested parallel to each other on a horizontal baseline. This was done with each claw. Furthermore, claws that curved upwards and towards the right were left in this orientation, but claws that curved upwards to the left were flipped horizontally so that all claws were in the same orientation. An assumption held here is that a horizontally

flipped image of one side of the claw appears similar enough to the other side of said claw that calculations will not significantly vary.

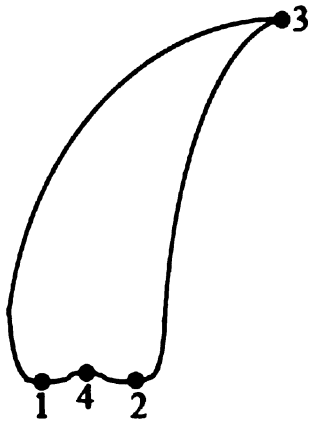

FIGURE 2. Locations of the four landmarks on avian, crocodylian, and pteranodont claws after reorientation.

Raw Landmark Coordinate Input and Transformation

With the claws in their homologous orientation, the next step was to record the XY coordinates of the landmarks from Photoshop's XY display (see Appendix III). This step was also performed in high zoom for accuracy in landmark coordinates. The line along which landmarks 1 and 2 rested was the baseline, which was then considered to occur at Y=0. The pencil tool and the measure tool work equally as well for pinpointing the coordinates of landmarks; the XY coordinates are shown in the Info window. Y coordinates for landmarks 3 and 4 were determined by subtracting the Y coordinate of landmark 1 from the Y coordinates of landmark 3 and 4 respectively. The raw landmark coordinates for each claw were placed in a Microsoft Excel spreadsheet, organized by specimen and digit number.

Although equations exist to directly transform raw landmark data to Bookstein (shape) data, the raw coordinates of each claw were first transformed into standardized coordinates with Equation 1. This equation was placed directly into the cells of an Excel spreadsheet for each set of coordinates. Transformation of landmarks from raw coordinates to standardized coordinates placed all of the claws in a common plane of existence, with all the landmarks 1 occurring at the coordinate (0, 0). Shape differences, however, had not yet been removed from the landmark data.

$$X_S = X - X_1 \qquad Y_S = Y - Y_1$$

EQUATION 1. Transformation from raw coordinates to standardized coordinates in any given claw.

Next, the standardized coordinates of the claw landmarks were transformed into Bookstein coordinates with Equation 2. This equation was also placed directly into the Excel worksheet and the calculations were carried out by the program. Transformation of landmarks from standardized coordinates to Bookstein coordinates removed differences between claw sizes by placing their baseline landmarks within a plane between X = 0 and X = 1, as shown in Figure 3.

$$X_B = X_S/S_{S2} \qquad Y_B = Y_S/X_{S2}$$

EQUATION 2. Transformation from standardized coordinates to Bookstein coordinates in any given claw.

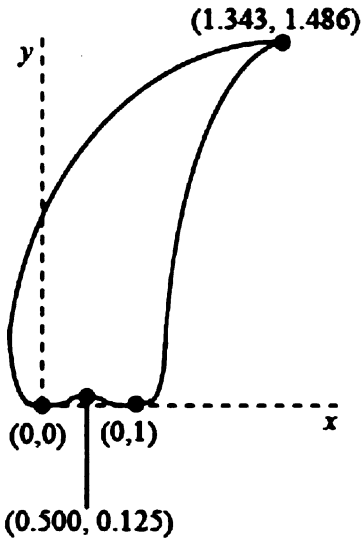

FIGURE 3. Claw landmarks with an example set of Bookstein coordinates. The Bookstein coordinates of landmark 1 and landmark 2 for every claw involved in the study are (0,0) for landmark 1, and (0,1) for landmark 2.

Morphometric Calculations

Several variables to be used in later calculations were extracted from geometric and trigonometric calculations made with the Bookstein coordinates of the claw landmarks. All of the equations for these calculations were placed directly into Excel and computed by the program. First, the locations of the centroid coordinates in the center of each claw were calculated, followed by the calculation of centroid size (Zelditch et al 2004). The centroid coordinates of each claw were calculated by averaging the X and Y coordinates of the four landmarks, as demonstrated in Equation 3. The centroid size of each claw was then determined by taking the square root of the sum of distances from each of the four landmarks to the centroid, as in Equation 4.

$$X_{CT} = \frac{X_{B1} + X_{B2} + X_{B3} + X_{B4}}{4} \qquad Y_{CT} = \frac{Y_{B1} + Y_{B2} + Y_{B3} + Y_{B4}}{4}$$

EQUATION 3. Calculation of coordinates of centroid location in any given claw (Zelditch et al 2004).

$$\text{centroid size} = \sqrt{\sum [(X_B - X_{CT})^2 + (Y_B + Y_{CT})^2]}$$

EQUATION 4. Calculation of the size of the centroid in any given claw (Zelditch et al 2004).

The next set of calculations made with the Bookstein coordinates were the distances between the four landmarks of each claw. The distances between landmarks 1 and 2, 1 and 3, 1 and 4, 2 and 3, and 3 and 4 were determined using the general distance formula given in Equation 5. It should be noted that because size data were removed once the landmark coordinates were transformed into Bookstein coordinates, the centimeter was no longer an accurate metric for these distances. Instead, these distances represented a set of data that was compared to the homologous distances of other claws, as apposed to an absolute measurement.

$$D = \sqrt{[(X_{B1} - X_{B2})^2 + (Y_{B1} - Y_{B2})^2]}$$

EQUATION 5. Equation used to determine the distance between any two landmarks.

Once the distances between landmarks were calculated, the angles between landmarks 1, 2 and 3 were calculated. Angle 312 was labeled as angle α, angle 123 was labeled as angle β, and angle 132 was labeled as angle γ, as demonstrated in Figure 4. All angles were calculated and recorded in degrees; the equations used to calculate these angles are shown in Equations 6, 7 and 8.

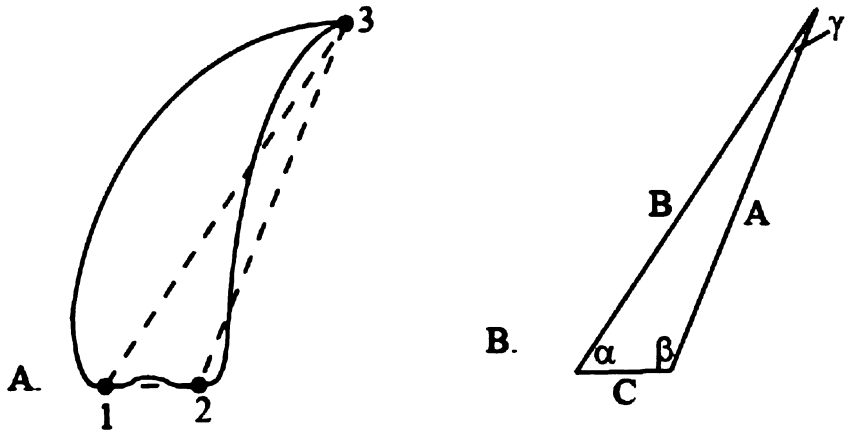

FIGURE 4. A. Example of superposition of a triangle (shown in dashed lines) drawn from connecting landmarks 1, 2, and 3. B. Locations of angle and line designations in the triangle between landmarks 1, 2, and 3.

$$\text{Cos}\alpha = \frac{B^2 + C^2 - A^2}{2BC}$$

EQUATION 6. Calculation of angle α in any given claw (in degrees).

$$\text{Cos}\beta = \frac{A^2 + C^2 - B^2}{2AC}$$

EQUATION 7. Calculation of angle β in any given claw (in degrees).

$$\text{Cos}\gamma = \frac{A^2 + B^2 - C^2}{2AB}$$

EQUATION 8. Calculation of angle γ in any given claw (in degrees).

Another variable used for claw comparison was the ratio of angle α to angle β. This was calculated by dividing angle α by angle β (Equation 9). This ratio represents the

amount of slant towards the right in each claw; for example, a smaller ratio implies that the claw leans less towards the right, whereas a larger ratio implies that the claw leans more towards the right.

$$\alpha : \beta \text{ ratio} = \alpha/\beta$$

EQUATION 9. Calculation oF-Ratio of angle α to angle β.

The last variable determined from the Bookstein landmarks of each claw was the aspect ratio of the claw (Equation 10). For this variable, the X coordinate of landmark 2 was used to represent the width of the claw (which in all cases equaled one due to the previous step of transforming all landmarks into Bookstein coordinates), and the Y coordinate of landmark 3 was used to represent the height of the claw. It was assumed that that any points on the claw outline that were higher than the Y coordinate of landmark 3, or farther than the X coordinate of landmark 2, would not significantly change the outcome of this calculation. Thus, an approximate ratio of width to height of each claw was determined.

$$\text{aspect ratio} = \frac{X_{B2}}{Y_{B3}} = \frac{1}{Y_{B3}}$$

EQUATION 10. Aspect ratio of any given claw.

Curvature Equations

Each claw was recognized as having two curves; the inner curve was the curve that formed the right side of the claw, and the outer curve was the curve that formed the left side of the claw (Figure 5). For each curve of each claw, raw coordinates of the curve were extrapolated under high magnification in Photoshop and then recorded in the Excel

spreadsheet. The top and bottom ends of the curve were determined to occur at coordinates where the curve began to change its direction (as shown in Figure 5). Once a set of coordinates for a curve had been recorded, each coordinate was transformed into Bookstein coordinates by placing Equation 11 (Zelditch et al 2004) into the spreadsheet.

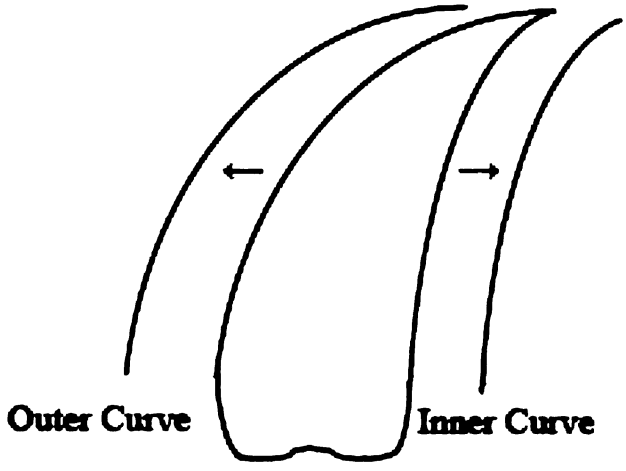

FIGURE 5. The inner and outer curve of any given claw.

$$X_B = \frac{(X_2 - X_1)(X_3 - X_1) + (Y_2 - Y_1)(Y_3 - Y_1)}{(X_2 - X_1)^2 + (Y_2 - Y_1)^2}$$

$$Y_B = \frac{(X_2 - X_1)(Y_3 - X_1) - (Y_2 - Y_1)(Y_3 - Y_1)}{(X_2 - X_1)^2 + (Y^2 - Y_1)^2}$$

EQUATION 11. Transformation of raw coordinates to Bookstein coordinates (Zelditch et al 2004) used in curvature calculations. These calculations are based on the raw coordinates of landmarks 1, 2 and 3.

The resulting Bookstein coordinates of each separate curve were plotted on their own XY Scatter graph in Excel (listed in Appendix IV). Next, a polynomial ($Y = AX^2+BX^1+CX^0$) trend line of the data was plotted, with the equation for the trend line and its R^2 value shown on the graph. The coefficients of X^2, X^1, and X^0 were then recorded as variables for both curves of every claw.

Variable Correlation Calculations

Before any statistical comparisons among variables could be completed, all variables found from the above calculations (for all claws) had to be processed to identify which variables significantly correlated with each other, in order to eliminate redundant data. This process was carried out in a statistical analysis computer program called SYSTAT. In the ANALYSIS menu, the command CORRELATIONS → SIMPLE... was selected. A Pearson analysis was selected, with the options continuous data, two sets, and list wise deletion checked. All morphometric variables were added with the exception of the X and Y baseline coordinates of landmarks 1 and 2, and the distance between these coordinates. These five variables were excluded because they were identical throughout all taxa, and thus could not be included in the correlation analysis. When the analysis was run, a Pearson correlation value was produced for every combination of variable pairs. The absolute values of these numbers were then compared to values found on the Pearson correlation coefficient table (Upton and Cook 2004) at 26 degrees of freedom (see Equation 12) and $p = 0.05$. Any pair of variables with an absolute value equal to or above 0.374, the correlation coefficient, denoted a significant correlation with each other. These pairs are listed in Appendix V.

$$\text{degrees of freedom} = \text{sample size} - 2$$

EQUATION 12. Calculation of degrees of freedom for use in Pearson correlation coefficient table.

Organization of Samples for Statistical Analyses

Because this study examines the morphometric similarities and differences between homologous claws across taxa, it was necessary to separate the data from digits

1, 2, 3, and 4 of all taxa into four data files to be used in statistical analyses. Each file was individually processed in the following statistical procedures to ensure a comparison of the same digit across taxa in each analysis. As an aside, statistical analyses were performed on the data file that includes all digits from all taxa except the pteranodont claws of unknown articulation, as well as the data files that include all digits from all taxa with the pteranodont claws of unknown articulation; however, because these tests do not compare strictly homologous structures, they are present in this study only for tangential speculation.

Creation of Principal Components

In SYSTAT, a factor analysis was used to create uncorrelated principal component variables to be used in later statistical comparisons within each of the six data files. This step removed redundant data by producing mathematical variables that did not correlate with each other. Analysis → Multivariate Analysis → Factor Analysis... was selected from the menu bar. In the Model tab, the principal components method was used with the correlation method of extraction. In the Rotation tab, varimax was selected; in the Save tab, Factor Scores were selected to be saved with the option checked to save data with scores. All other settings were left at their defaults. Next, all claw variables except the X and Y values of the Bookstein coordinates of landmarks 1 and 2 as well as the distance between these landmarks (these five variables omitted because they remain constant throughout taxa) were added to the Model variable(s) field. When OK was clicked, a data file containing the new principal component variables was created. This process was performed on each of the individual digit data sets, yielding 4 new data files containing principal component variables for each digit.

Claw Phenogram Creation

In order to create a phenogram of claw morphologies for each digit, a cluster analysis was run in SYSTAT for each data file containing the newly created principal components. Analysis → Multivariate Analysis → Cluster Analysis → Hierarchical... was selected from the menu bar. In the Main tab, Ward Linkage, Euclidean Distance, and Join: Rows were selected. Next, the principal component variables were entered into the Selected Variables field. All other settings in this window were left at their defaults. When OK was clicked, a dendrogram was created that had the taxa as its endpoints, with a measure of distance below. This distance described where clusters joined together in the dendrogram, in the sense that the shorter the distance was before two clusters joined, the morphometrically closer to each other the clusters were. This process was performed for all four individual claw data sets. It was also performed for the two all-inclusive data sets for speculative purposes.

ANOVA Analyses

ANOVA was used to look for statistically significant similarities and differences between the clusters produced within each of the four claw dendrograms. Each principal component was analyzed individually, and all calculations were performed by entering the necessary formulas into an Excel spreadsheet. Within each principal component, each cluster was listed as an individual sample, and then calculations were performed in order to find the degrees of freedom within each cluster (Equation 13), the mean of the cluster (Equation 14), the variance within the cluster (Equation 15), and the sum of squared deviations in the cluster (Equation 16).

$$df = n-1, \text{ where n is the cluster sample size}$$

EQUATION 13. Calculation of degrees of freedom of each cluster.

$$\overline{x}_j = \frac{\sum_{i=1}^{n} x_i}{n}$$

EQUATION 14. Calculation of the mean of a single cluster.

$$s^2 = \frac{\sum (x_i - \overline{x})^2}{n-1} = \frac{\sigma^2}{df_{wc}}$$

EQUATION 15. Calculation of variance within a single cluster.

$$\sum \sigma^2 = s^2 \bullet df_{wc}$$

EQUATION 16. Calculation of the sum of squared deviations within a single cluster.

Next, seven calculations involving all of the clusters together were performed. The sums of all cluster sums of squared deviations (Equation 17), as well as the sum of all cluster degrees of freedom (Equation 18) were calculated. The variance within clusters was then calculated using Equation 19.

$$\text{sum of all clusters}' \sum \sigma^2 = \sum_{j=1}^{k} \sum_{i=1}^{n_j} (x_{ij} - \overline{x}_j)^2$$

EQUATION 17. Calculation of the sum of all cluster sums of squared deviations.

$$df_{wc} = \sum df$$

EQUATION 18. Calculation of the sum of the degrees of freedom within clusters.

$$s_{wc}^2 = \sum \frac{\sigma^2}{df_{wc}}$$

EQUATION 19. Calculation of the variance within all clusters.

The four remaining calculations yielded values between the clusters. The mean between all clusters was first found with Equation 20. The between clusters sum of squared deviations weighted by the clusters' sample sizes was then found for the group of clusters with Equation 21. Once the between clusters degrees of freedom was determined with Equation 22, the between clusters variance was calculated using Equation 23 (Kachigan 1991). With these calculated values, it was then possible to determine and analyze the F-ratios of cluster pairs for each principal component variable.

$$\overline{\overline{X_{bc}}} = \sum_{i=1}^{n} \frac{\overline{X_j}}{\#\,\text{clusters}}$$

EQUATION 20. Calculation of the mean between all clusters.

$$\sum \sigma_{bc}^2 = \sum_{j=1}^{k} n_j(\overline{X_j} - \overline{\overline{X_{bc}}})^2$$

EQUATION 21. Calculation of the between clusters sum of squared deviations weighted by the clusters' sample sizes.

$$df_{bc} = \#\,\text{clusters} - 1$$

EQUATION 22. Calculation of the degrees of freedom between clusters.

$$s_{bc}^2 = \frac{\sum \sigma_{bc}^2}{df_{bc}}$$

EQUATION 23. Calculation of the variance between clusters.

The F-ratio for a group of clusters within a principal component variable was calculated by dividing the variance between clusters by the variance within clusters (Equation 24). Accordingly, the degrees of freedom for the F-ratio were the degrees of freedom between clusters as the first number, followed by the degrees of freedom within clusters as the second number. Upon holding the null hypothesis to be that there are no significant differences between the clusters under each principal component variable, all calculated F-ratios were compared to the F distribution values (at α =0.05) generated by the **>calc fif(0.95, df_{bc}, df_{wc})** command in SYSTAT, where df_{bc} represents the degrees of freedom between clusters, and df_{wc} represents the degrees of freedom within clusters. In the cases that the absolute value of the F-ratio was less than the critical value, the null hypothesis was supported and the clusters were found not to be statistically different from one another. However, in the cases when the absolute value of the calculated F-ratio was equal to or greater than the critical value, the alternative hypothesis that the clusters are significantly different from one another was instead supported (Kachigan 1991). Clusters that yielded statistically significant F-ratio values within their first comparison to the rest of the clusters as a group underwent analyses individually paired with every other cluster in order to determine specific F-ratio values between pairs of clusters.

$$F = \frac{s_{bc}^2}{s_{wc}^2}$$

EQUATION 24. Calculation of the F-ratio of two or more clusters.

RESULTS

Bookstein Coordinates of Claw Landmarks

Once homologous landmarks were placed on all claws used in the study, their coordinates were transformed into standardized coordinates, which were then transformed into Bookstein coordinates (Table 4). Because the Bookstein coordinates of landmarks 1 and 2 are constant in all claws, only the Bookstein coordinates of landmarks 3 and 4 of all claws have been plotted on Figures 6 and 7 respectively for visual comparison. (NOTE: Images in this thesis are presented in color.)

Specimen	Pes	Claw	Bookstein Coordinates							
			Landmark 1		Landmark 2		Landmark 3		Landmark 4	
			X	Y	X	Y	X	Y	X	Y
FHSM-VP2062	Left	1	0	0	1	0	0.500	3.321	0.464	0.107
		2	0	0	1	0	0.973	3.405	0.459	-0.081
		3	0	0	1	0	0.065	2.848	0.500	-0.130
		4	0	0	1	0	0.529	3.706	0.471	0.176
UM-P	Left	1	0	0	1	0	1.313	2.813	0.500	0.125
		2	0	0	1	0	2.300	3.600	0.500	0.133
		3	0	0	1	0	1.707	0.634	0.439	-0.085
		4	0	0	1	0	1.692	1.173	0.577	0.135
UM-WS	Left	2	0	0	1	0	0.630	4.074	0.593	-0.148
		3	0	0	1	0	1.941	3.765	0.471	-0.147
		4	0	0	1	0	0.795	4.077	0.590	-0.256
C-GBBG	Left	2	0	0	1	0	0.900	2.500	0.500	-0.100
		3	0	0	1	0	1.179	2.128	0.436	-0.154
		4	0	0	1	0	0.565	2.826	0.565	-0.174
C-PI	Left	2	0	0	1	0	1.000	4.143	0.429	-0.476
		3	0	0	1	0	1.061	4.182	0.485	-0.242
		4	0	0	1	0	1.667	6.333	0.583	-0.167
C-SI	Left	1	0	0	1	0	-2.650	3.450	0.600	-0.300
		2	0	0	1	0	1.588	3.059	0.412	-0.353
		3	0	0	1	0	1.550	3.400	0.450	-0.400
		4	0	0	1	0	1.333	2.500	0.556	-0.333
C-PC	Left	3	0	0	1	0	0.719	2.063	0.500	-0.094
		4	0	0	1	0	1.261	3.261	0.478	-0.217
MSU-PA	Left	1	0	0	1	0	2.537	0.642	0.493	0.045
		2	0	0	1	0	2.136	4.955	0.409	0.000
		3	0	0	1	0	3.859	1.592	0.423	-0.070
		4	0	0	1	0	3.170	1.274	0.481	0.113
C22026	Left	1	0	0	1	0	1.566	2.823	0.496	0.142
		2	0	0	1	0	1.944	3.204	0.500	0.000
		3	0	0	1	0	1.810	2.983	0.569	-0.069
C213395	Left	1	0	0	1	0	1.282	2.373	0.473	-0.109
C-CAD	Left	2	0	0	1	0	0.896	2.167	0.573	0.156
		3	0	0	1	0	0.392	2.608	0.431	-0.314
C31011	Left	3	0	0	1	0	1.465	2.433	0.446	-0.015
C31321	Left	1	0	0	1	0	1.505	3.126	0.526	-0.137
		3	0	0	1	0	0.449	3.808	0.385	-0.077

TABLE 4. The Bookstein coordinates of claw landmarks.

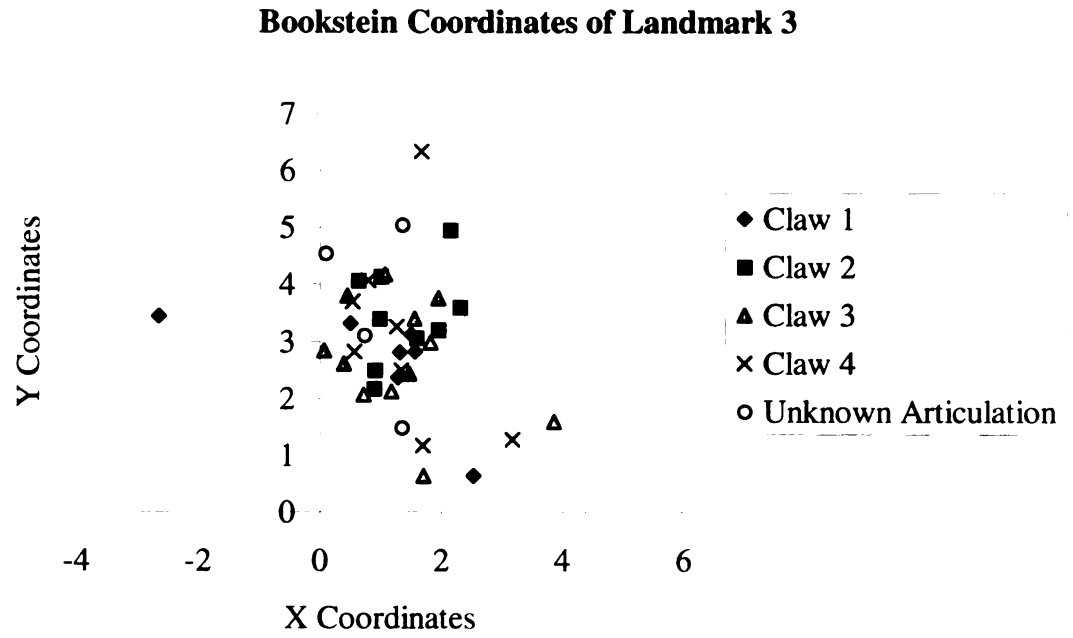

FIGURE 6. Bookstein coordinates of landmark 3 of all claws (data from Table 4).

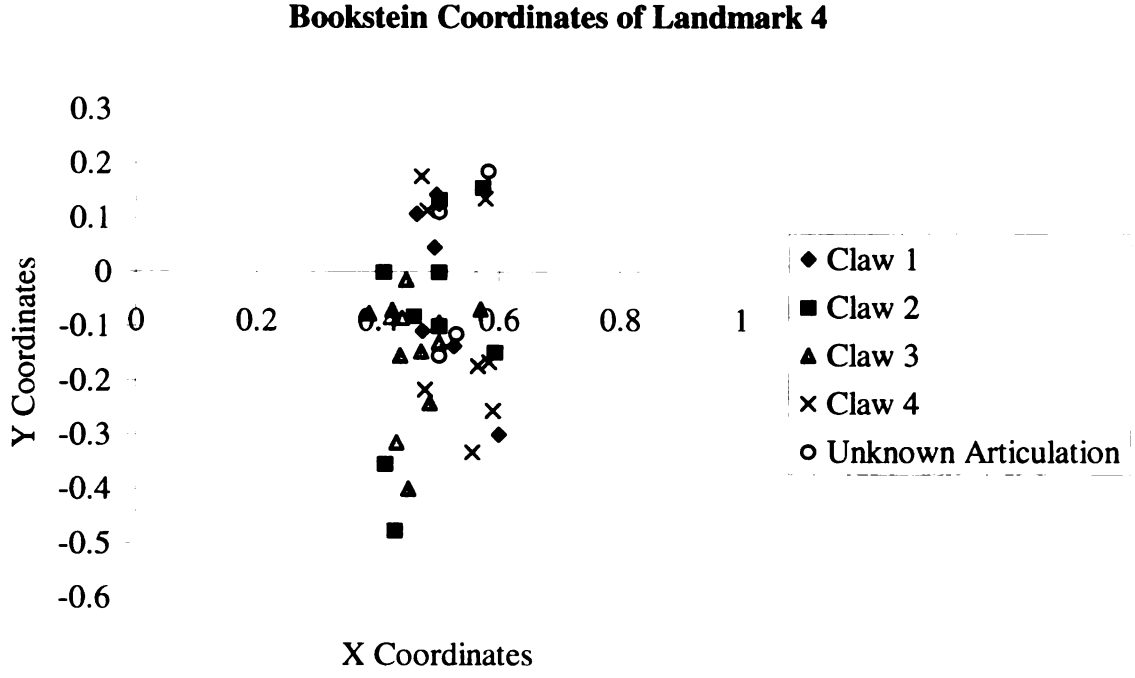

FIGURE 7. Bookstein coordinates of landmark 4 of all claws (data from Table 4).

Claw Centroid Locations and Sizes

The (X, Y) coordinates and the size of the centroid of the claws (based on Bookstein coordinates) yielded two more variables for each claw, shown in Table 5.

Specimen	Pes	Claw	Centroid Location		Centroid Size
			X	Y	
FHSM-VP2062	Left	1	0.491	0.857	2.934
		2	0.608	0.831	3.085
		3	0.391	0.679	2.631
		4	0.500	0.971	3.240
UM-P	Left	1	0.703	0.734	2.601
		2	0.950	0.933	3.525
		3	0.787	0.137	1.402
		4	0.817	0.327	1.578
UM-WS	Left	2	0.556	0.981	3.644
		3	0.853	0.904	3.606
		4	0.596	0.955	3.687
C-GBBG	Left	2	0.600	0.600	2.332
		3	0.654	0.494	2.109
		4	0.533	0.663	2.601
C-PI	Left	2	0.607	0.917	3.839
		3	0.636	0.985	3.796
		4	0.813	1.542	5.667
C-SI	Left	1	-0.263	0.788	4.197
		2	0.750	0.676	3.015
		3	0.750	0.750	3.290
		4	0.722	0.542	2.487
C-PC	Left	3	0.555	0.492	1.957
		4	0.685	0.761	3.051
MSU-PA	Left	1	1.007	0.172	1.979
		2	0.886	1.239	4.583
		3	1.320	0.380	3.325
		4	1.163	0.347	2.651
C22026	Left	1	0.765	0.741	2.673
		2	0.861	0.801	3.125
		3	0.845	0.728	2.920
C213395	Left	1	0.689	0.566	2.309
C-CAD	Left	2	0.617	0.581	1.994
		3	0.456	0.574	2.468
C31011	Left	3	0.728	0.605	2.384
C31321	Left	1	0.758	0.747	2.967
		3	0.458	0.933	3.396

TABLE 5. Claw centroid locations and sizes.

Distances Between Claw Bookstein Landmarks

The morphometric distances between each landmark yielded a total of 6 variables (shown in Table 6) to be used in statistical analyses. Because the coordinates of landmarks 1 and 2 remained constant throughout all claws, the distance between these landmarks also remained constant.

Specimen	Pes	Claw	Distances Between Landmarks (Bookstein)					
			L1-L2	L2-L3	L1-L3	L3-L4	L1-L4	L2-L4
FHSM-VP2062	Left	1	1	3.359	3.359	3.214	0.476	0.546
		2	1	3.406	3.542	3.524	0.467	0.547
		3	1	2.997	2.849	3.010	0.517	0.517
		4	1	3.736	3.744	3.530	0.503	0.558
UM-P	Left	1	1	2.830	3.104	2.808	0.515	0.515
		2	1	3.828	4.272	3.906	0.517	0.517
		3	1	0.950	1.821	1.458	0.447	0.567
		4	1	1.362	2.059	1.524	0.592	0.444
UM-WS	Left	2	1	4.091	4.122	4.222	0.611	0.434
		3	1	3.881	4.236	4.179	0.493	0.549
		4	1	4.082	4.154	4.338	0.643	0.484
C-GBBG	Left	2	1	2.502	2.657	2.631	0.510	0.510
		3	1	2.136	2.433	2.400	0.462	0.585
		4	1	2.859	2.882	3.000	0.591	0.468
C-PI	Left	2	1	4.143	4.262	4.654	0.641	0.744
		3	1	4.182	4.314	4.462	0.542	0.569
		4	1	6.368	6.549	6.590	0.607	0.449
C-SI	Left	1	1	5.022	4.350	4.962	0.671	0.500
		2	1	3.115	3.447	3.609	0.542	0.686
		3	1	3.444	3.737	3.956	0.602	0.680
		4	1	2.522	2.833	2.938	0.648	0.556
C-PC	Left	3	1	2.082	2.184	2.167	0.509	0.509
		4	1	3.271	3.496	3.565	0.525	0.565
MSU-PA	Left	1	1	1.666	2.617	2.130	0.495	0.509
		2	1	5.083	5.396	5.247	0.409	0.591
		3	1	3.272	4.174	3.817	0.428	0.582
		4	1	2.516	3.416	2.928	0.494	0.531
C22026	Left	1	1	2.879	3.228	2.887	0.515	0.524
		2	1	3.340	3.748	3.514	0.500	0.500
		3	1	3.091	3.489	3.295	0.573	0.437
C213395	Left	1	1	2.389	2.697	2.610	0.485	0.538
C-CAD	Left	2	1	2.169	2.345	2.036	0.594	0.455
		3	1	2.678	2.637	2.922	0.533	0.649
C31011	Left	3	1	2.477	2.840	2.651	0.446	0.554
C 31321	Left	1	1	3.167	3.470	3.407	0.544	0.493
		3	1	3.847	3.834	3.885	0.392	0.620

TABLE 6. Distances between the Bookstein landmarks of each claw.

Angles Between Claw Bookstein Landmarks

The angles described in Figure 4 were found by using the distances calculated in Table 6. These yield three additional variables for each claw and are presented in Table 7.

Specimen	Pes	Claw	Angles (degrees)		
			α	β	γ
FHSM-VP2062	Left	1	81.439	81.439	17.122
		2	74.055	89.545	16.400
		3	88.688	71.828	19.484
		4	81.870	82.763	15.367
UM-P	Left	1	64.983	96.340	18.677
		2	57.426	109.855	12.719
		3	20.376	138.122	21.501
		4	34.729	120.548	24.723
UM-WS	Left	2	81.215	84.806	13.980
		3	62.723	104.036	13.241
		4	78.968	87.120	13.913
C-GBBG	Left	2	70.201	87.709	22.089
		3	61.004	94.821	24.175
		4	78.690	81.254	20.056
C-PI	Left	2	76.430	90.000	13.570
		3	75.769	90.830	13.401
		4	75.256	96.009	8.735
C-SI	Left	1	127.528	43.386	9.085
		2	62.560	100.886	16.554
		3	65.493	99.189	15.319
		4	61.928	97.595	20.478
C-PC	Left	3	70.787	82.235	26.978
		4	68.860	94.574	16.566
MSU-PA	Left	1	14.195	157.341	8.456
		2	66.675	102.918	10.408
		3	22.412	150.897	6.691
		4	21.890	149.589	8.522
C22026	Left	1	60.976	101.344	17.680
		2	58.745	106.425	14.830
		3	58.745	105.199	16.056
C213395	Left	1	61.621	96.774	21.606
C-CAD	Left	2	67.537	87.248	25.216
		3	81.448	76.880	21.672
C31011	Left	3	58.948	100.819	20.233
C31321	Left	1	64.290	99.181	16.529
		3	83.279	81.762	14.959

TABLE 7. Angle calculations (in degrees) between Bookstein landmarks 1, 2, and 3 of each claw.

Aspect and Angle Ratios of Claws

The aspect ratio and the ratio of α to β yielded one variable each for all claws and are presented in Table 8.

Specimen	Pes	Claw	Aspect Ratio	Ratio of α to β
FHSM-VP2062	Left	1	0.301	1.000
		2	0.294	0.827
		3	0.351	1.235
		4	0.270	0.989
UM-P	Left	1	0.356	0.675
		2	0.278	0.523
		3	1.577	0.148
		4	0.852	0.288
UM-WS	Left	2	0.245	0.958
		3	0.266	0.603
		4	0.245	0.906
C-GBBG	Left	2	0.400	0.800
		3	0.470	0.643
		4	0.354	0.968
C-PI	Left	2	0.241	0.849
		3	0.239	0.834
		4	0.158	0.784
C-SI	Left	1	0.290	2.939
		2	0.327	0.620
		3	0.294	0.660
		4	0.400	0.635
C-PC	Left	3	0.485	0.861
		4	0.307	0.728
MSU-PA	Left	1	1.558	0.090
		2	0.202	0.648
		3	0.628	0.149
		4	0.785	0.146
C22026	Left	1	0.354	0.602
		2	0.312	0.552
		3	0.335	0.558
C213395	Left	1	0.421	0.637
C-CAD	Left	2	0.462	0.774
		3	0.383	1.059
C31011	Left	3	0.411	0.585
C31321	Left	1	0.320	0.648
		3	0.263	1.019

TABLE 8. Aspect ratios and ratios of α to β of each claw.

Claw Curvature Polynomial Coefficients

The coefficients for functions in the format of $Y = AX^2+BX^1+CX^0$ that when plotted, most closely match the inner and outer curvature of the claws, are detailed in Table 9. The R^2 value is also listed with the coefficients as a measure of accuracy.

Specimen	Pes	Claw	Curvature Equation Coefficients							
			Outer Curve				Inner Curve			
			X^2 Coeff. (A)	X Coeff. (B)	X^0 Coeff. (C)	R^2 Value	X^2 Coeff. (A)	X Coeff. (B)	X^0 Coeff. (C)	R^2 Value
FHSM-VP2062	Left	1	-15.455	7.681	2.625	0.836	-0.595	-3.749	5.024	0.969
		2	-3.515	4.931	1.571	0.934	-28.809	48.784	-18.602	0.055
		3	6.265	-0.0681	1.569	0.014	0934	-5.999	3.540	0.966
		4	-4.664	6.368	2.091	0.799	3.077	-11.171	9.538	0.957
UM-P	Left	1	-1.819	3.559	0.968	0.923	-3.088	7.371	-2.425	0.039
		2	-0.955	3.205	0.884	0.968	2.330	-7.246	7.878	0.260
		3	-0.552	1.190	0.172	0.984	-1.172	4.941	-2.914	0.971
		4	-0.334	1.179	0.169	0.985	0.844	-1.180	0.829	0.608
UM-WS	Left	2	-3.86	2.815	3.278	0.876	-11.562	17.706	-3.753	0.325
		3	-1.034	3.404	0.785	0.982	-9.132	35.312	-30.955	0.935
		4	-1.640	3.394	2.764	0.856	-27.085	41.063	-12.265	0.236
C-GBBG	Left	2	-4.340	4.756	0.700	0.891	24.194	-51.157	27.556	0.863
		3	-1.809	3.496	0.243	0.965	-34.266	69.085	-33.466	0.101
		4	-4.950	3.494	2.197	0.644	12.141	-19.406	8.749	0.571
C-PI	Left	2	-3.088	4.842	2.034	0.923	-2.278	1.816	2.713	0.341
		3	-3.622	5.538	1.936	0.869	-11.757	21.063	-6.011	0.117
		4	-1.495	4.055	3.382	0.932	-3.427	8.851	-1.171	0.315
C-SI	Left	1	-0.014	-1.246	0.059	0.996	0.010	-0.805	1.151	0.994
		2	-0.629	2.546	0.671	0.986	1.031	0.817	-0.217	0.552
		3	-1.022	3.451	0.515	0.997	1.894	-0.789	0.719	0.581
		4	-1.262	3.164	0.465	0.989	4.087	-6.873	4.199	0.115
C-PC	Left	3	-5.311	4.867	0.863	0.704	-3.715	2.715	1.270	0.678
		4	-2.422	3.795	1.660	0.820	-2.165	2.736	1.209	0.069
MSU-PA	Left	1	-0.472	1.370	0.269	0.994	-0.747	2.950	-2.168	0.993
		2	-0.829	2.076	3.794	0.831	-1.111	4.511	0.379	0.649
		3	-0.231	1.159	0.687	0.996	-0.233	1.473	-0.812	0.992
		4	-0.032	1.147	0.822	0.994	-0.496	2.429	-1.689	0.976
C22026	Left	1	-1.084	3.322	0.120	0.987	-1.966	9.825	-7.914	0.966
		2	-0.682	2.848	0.174	0.996	-0.408	3.836	-3.152	0.989
		3	-0.994	3.082	0.455	0.989	2.177	-2.723	0.834	0.977
C213395	Left	1	-1.569	3.392	0.472	0.991	-1.570	7.826	-5.119	0.646
C-CAD	Left	2	0.171	1.888	0.279	0.996	6.754	-7.017	1.696	0.418
		3	6.975	3.398	0.488	0.977	-3.751	2.004	2.436	0.931
C31011	Left	3	-0.830	2.557	0.547	0.998	-0.634	4.310	-3.095	0.982
C31321	Left	1	-0.669	2.303	1.176	0.946	1.618	-0.718	0.753	0.607
		3	3.371	5.436	2.326	0.763	7.725	-16.428	9.065	0.755

TABLE 9. Coefficients from polynomial ($Y = AX^2+BX+CX^0$) equations of outside and inside curves with their R^2 values, derived from Bookstein coordinates.

Principal Component Variables Generated for Each Claw

A principal component analysis run in SYSTAT for each individual claw from the above variables rendered principal component variables (shown in the data as PC1, PC2, etc.) for each claw. These variables, listed in Tables 10 through 13, were later used in ANOVA analyses.

Specimen	PC1	PC2	PC3
FHSM-VP2062	0.332	-1.974	1.024
UM-P	0.067	-0.219	-0.900
C-SI	1.519	1.197	1.010
MSU-PA	-1.871	0.667	1.036
C22026	0.024	0.109	-1.170
C213395	-0.229	-0.158	-0.800
C31321	0.158	0.379	-0.199

TABLE 10. Principal component variables generated for claw 1 using SYSTAT.

Specimen	PC1	PC2	PC3	PC4	PC5
FHSM-VP2062	-0.376	-0.349	-0.082	1.969	-1.632
UM-P	0.308	1.302	-0.503	-0.389	-0.100
UM-WS	0.948	-1.622	-1.027	0.236	0.705
C-GBBG	-0.830	-0.561	-0.233	-1.906	-1.463
C-P	0.591	-0.962	1.834	-0.256	0.217
C-SI	-0.611	0.593	1.513	0.194	0.731
MSU-PA	1.781	0.786	-0.362	-0.254	0.010
C22026	-0.338	1.119	-0.256	0.331	0.082
C-CAD	-1.473	-0.305	-0.884	0.075	1.449

TABLE 11. Principal component variables generated for claw 2 using SYSTAT.

Specimen	PC1	PC2	PC3	PC4	PC5
FHSM-VP2062	0.019	1.396	-1.032	0.613	-0.615
UM-P	-2.002	-1.103	-0.254	-0.225	-0.216
UM-WS	1.116	-0.381	1.163	0.250	-0.230
C-GBBG	-0.899	0.298	2.492	-0.408	-0.318
C-P	1.384	0.267	0.603	0.369	0.743
C-SI	0.418	-0.339	-0.574	-1.247	2.013
C-PC	-0.993	0.630	0.178	1.211	0.547
MSU-PA	0.606	-2.247	-0.439	-0.417	-0.745
C22026	0.216	-0.485	-0.475	2.094	0.705
C-CAD	-0.553	0.973	-0.565	-1.381	0.850
C31011	-0.328	0.111	-0.899	-0.009	-1.318
C31321	1.016	0.881	-0.199	-0.849	-1.416

TABLE 12. Principal component variables generated for claw 3 using SYSTAT.

Specimen	PC1	PC2	PC3	PC4	PC5
FHSM-VP2062	0.171	1.251	-0.943	-0.446	-1.386
UM-P	-1.338	-0.594	1.396	0.021	-0.718
UM-WS	0.083	0.674	0.396	2.237	0.261
C-GBBG	-0.349	0.901	0.816	-1.155	0.049
C-P	2.161	-0.424	0.883	-0.370	0.211
C-SI	-0.615	-0.168	-0.399	-0.539	1.932
C-PC	-0.070	0.245	-1.284	0.156	0.397
MSU-PA	-0.043	-1.884	-0.865	0.096	-0.746

TABLE 13. Principal component variables generated for claw 4 using SYSTAT.

Claw Phenograms

The principal component variables underwent cluster analyses in SYSTAT and a phenogram for each individual claw was produced. In the phenograms, taxa were paired first to other taxa with the most morphometrically similar claws, then to other taxa or clusters with claws in the order of decreasing morphometric similarity. The distance metrics below the phenograms show at what distances the taxa and clusters join, and represent the phenetic distances between the claws of the taxa.

The phenogram of claw 1, shown in Figure 8, pairs the claw of *Pteranodon longiceps* most closely with that of the Scarlet Ibis. This cluster is then joined to the

Peacock, and these three claws are then joined to a group of clusters containing the two crocodile species, the alligator, and the Pelican.

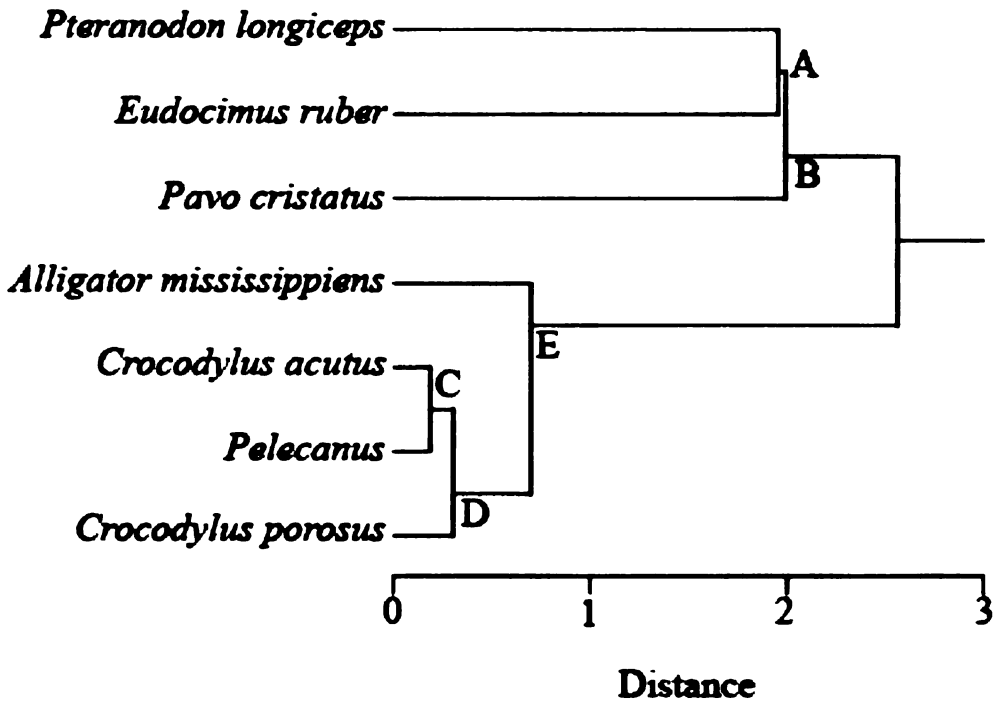

FIGURE 8. Phenogram of digit 1 claws based on principal components. Clusters are labeled with capital letters.

The phenogram of claw 2, shown in Figure 9, pairs *P. longiceps* with the Great Black-Backed Gull. This cluster is then paired most closely with the cluster containing one species of crocodile and the Whistling Swan. The next closest cluster to these contains the Great Auk and Scarlet Ibis, and this cluster, combined with the aforementioned clusters, joins group of nested clusters containing the Peacock, Pelican, and the other species of crocodile.

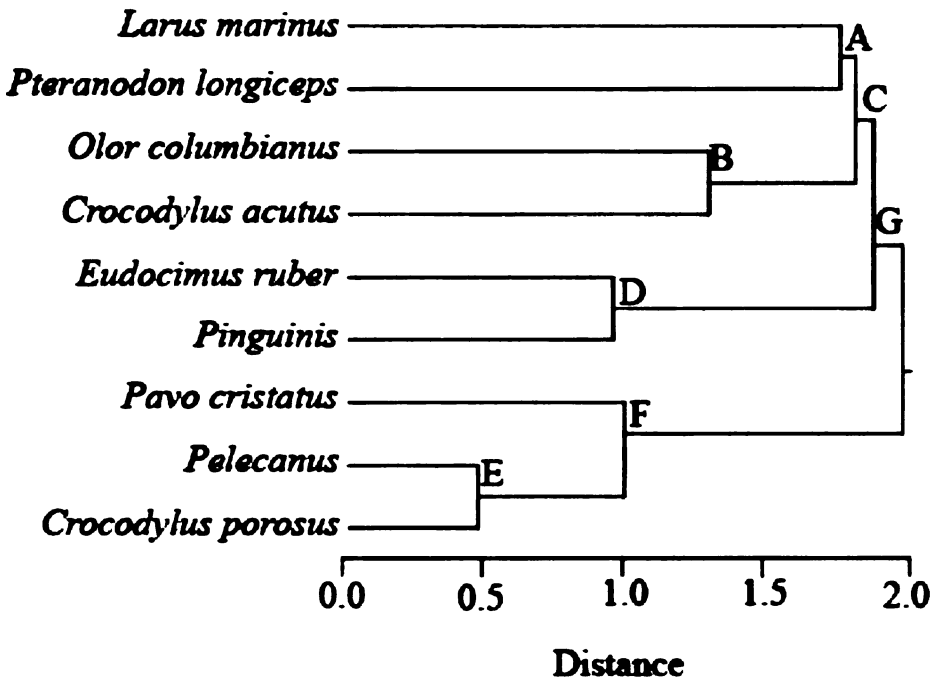

FIGURE 9. Phenogram of digit 2 claws based on principal components. Clusters are labeled with capital letters.

P. longiceps is most closely joined to the two specimens of alligator in the third claw phenogram (Figure 10). These nested clusters are equally joined to the clusters containing the Pelican and Peacock and *Crocodylus acutus* and the Scarlet Ibis. The combination of these clusters is then joined to clusters containing the other crocodile and Pelican specimens, as well as the Great Black-Backed Gull, the Great Auk, and the Whistling Swan, in nested configurations.

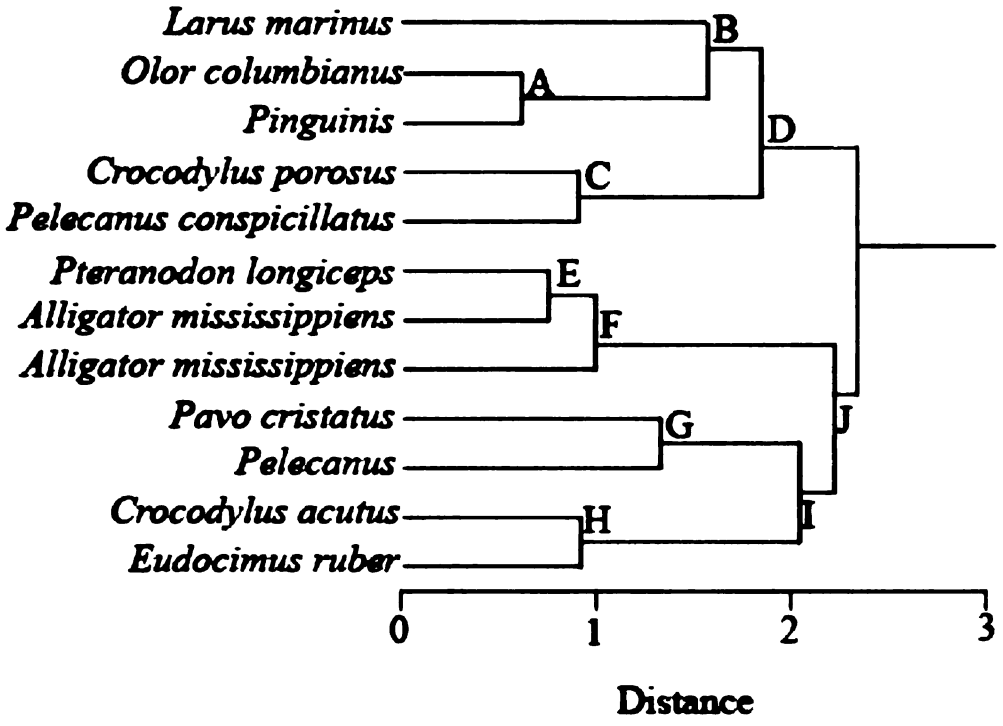

FIGURE 10. Phenogram of digit 3 claws based on principal components. Clusters are labeled with capital letters.

The phenogram of the fourth claw, shown in Figure 11, places the fourth claw of *P. longiceps* mostly closely to the cluster containing the fourth claws of the Pelican and the Great Black-Backed Gull. These three taxa are joined at equal distances to the cluster containing that Great Auk and the Whistling Swan, and the cluster containing the Peacock, the Scarlet Ibis, and the other specimen of Pelican.

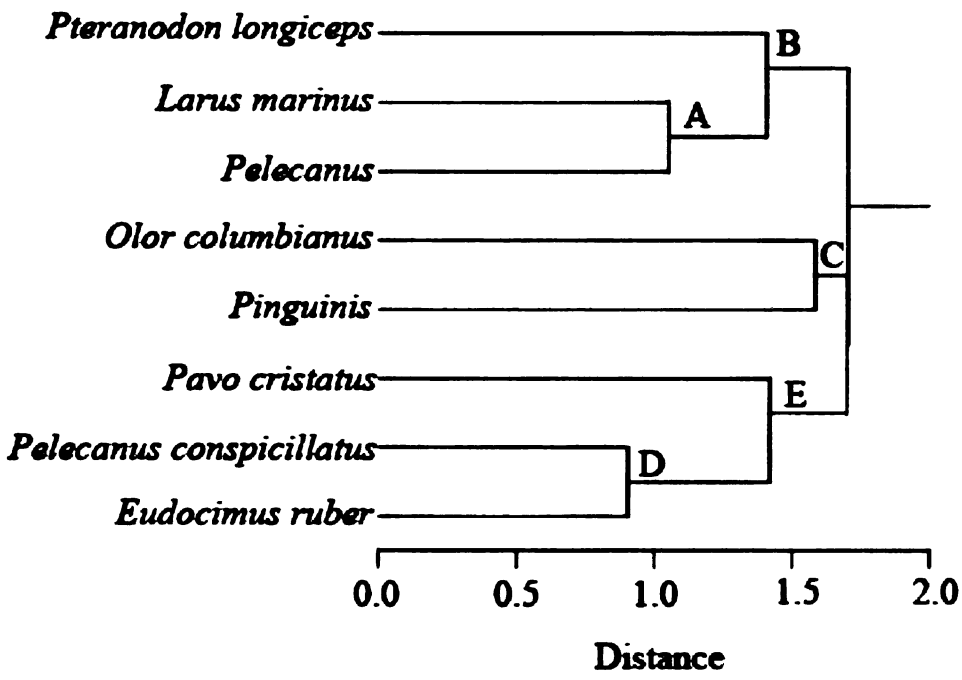

FIGURE 11. Phenogram of digit 4 claws based on principal components. Clusters are labeled with capital letters.

ANOVA Results

In order to determine which clusters of claws were significantly similar or different to each other, ANOVA was performed on groups of clusters within each phenogram (see Appendix VI for the cluster data used in these analyses). These analyses were performed individually for each principal component variable.

In the phenogram for claw 1, all of the clusters were found to be statistically similar to each other for two of the three principal components, as shown in Table 14A. However, principal component 3 contained a statistically significant difference somewhere within the group of all of the clusters in the phenogram. Narrowing down the clusters tested for statistical differences yielded data in Table 14B, which shows a statistically significant difference only for the group of clusters that contains cluster B. Table 14C shows the ANOVA results for all clusters paired with clusters A and B. Of

these pairs, only clusters A and B were found to be significantly similar to each other; all other tested cluster pairs revealed a significant difference.

A.

Claw 1

Principal Components	**PC1**	**PC2**	**PC3**
F-Ratio of {A, B, C, D, E}	0.527	0.056	43.993
F-Ratio Degrees of Freedom	4, 9	4, 9	4, 9
At α = 0.05, Significant Value is	3.630	3.630	3.630
Statistically Different?	no	no	yes

B.

Claw 1, Principal Component 3

F-Ratio of {B, C, D, E}	36.439
F-Ratio Degrees of Freedom	3, 8
At α = 0.05, Significant Value is	4.070
Statistically Different?	yes

F-Ratio of {C, D, E}	0.321
F-Ratio Degrees of Freedom	2, 6
At α = 0.05, Significant Value is	5.140
Statistically Different?	no

F-Ratio of {D, E}	0.544
F-Ratio Degrees of Freedom	1, 5
At α = 0.05, Significant Value is	6.610
Statistically Different?	no

C.

Claw 1, Principal Component 3

Clusters in Comparison	A+B	A+C	A+D	A+E	B+C	B+D	B+E
F-Ratio of {A, B, C, D, E}	0.356	1358.293	199.609	37.959	2452.385	320.375	55.719
F-Ratio Degrees of Freedom	1, 3	1, 2	1, 3	1, 4	1, 3	1, 4	1, 5
At α = 0.05, Significant Value is	10.13	18.51	10.13	7.71	10.13	7.71	6.61
Statistically Different?	no	yes	yes	yes	yes	yes	yes

TABLE 14. ANOVA results of claw 1. A. ANOVA results of all clusters in phenogram, for all principal components. B. ANOVA results for decreasing groups of clusters for principal component 3. C. ANOVA results of cluster pairs for principal component 3.

Table 15A shows that all of the principal components except principal component 2 had statistical similarities among all of the clusters in the phenogram of claw 2. In spite of narrowing down the clusters in each ANOVA analysis shown in Table 15B, all groups

of clusters in this table contain a statistically significant difference. Among the specific pairs of clusters that were analyzed (their results shown in Table 15C), several pairs of clusters show statistical differences between the two tested clusters.

A.

Claw 2

Principal Component	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
F-Ratio of {A, B, C, D, E, F, G}	0.441	4.562	2.716	0.012	1.156
F-Ratio Degrees of Freedom	6, 14	6, 14	6, 14	6, 14	6, 14
At α = 0.05, Significant Value is	2.850	2.850	2.850	2.850	2.850
Statistically Different?	no	yes	no	no	no

B.

Claw 2, Principal Component 2

F-Ratio of {B, C, D, E, F, G}	5.077
F-Ratio Degrees of Freedom	5, 13
At α = 0.05, Significant Value is	3.030
Statistically Different?	yes

F-Ratio of {C, D, E, F, G}	6.254
F-Ratio Degrees of Freedom	4, 12
At α = 0.05, Significant Value is	3.260
Statistically Different?	yes

F-Ratio of {D, E, F, G}	6.253
F-Ratio Degrees of Freedom	3, 9
At α = 0.05, Significant Value is	3.860
Statistically Different?	yes

F-Ratio of {E, F, G}	12.478
F-Ratio Degrees of Freedom	2, 8
At α = 0.05, Significant Value is	4.460
Statistically Different?	yes

F-Ratio of {F, G}	14.154
F-Ratio Degrees of Freedom	1, 7
At α = 0.05, Significant Value is	5.590
Statistically Different?	yes

C.

Claw 2, Principal Component 2

Clusters in Comparison	A+B	A+C	B+C	A+E	A+F	B+E	B+F	C+E
F-Ratio of {A, B, C, D, E}	0.581	0.331	0.192	141.831	54.766	10.691	15.429	18.979
F-Ratio Degrees of Freedom	1, 2	1, 4	1, 4	1, 2	1, 3	1, 2	1, 3	1, 4
At α = 0.05, Significant Value is	18.51	7.71	7.71	18.51	10.13	18.51	10.13	7.71
Statistically Different?	no	no	no	yes	yes	no	yes	yes

Clusters in Comparison	C+F	E+F	A+D	B+D	C+D	D+E	D+F	A+G
F-Ratio of {A, B, C, D, E}	21.534	0.488	0.119	0.585	0.701	3.176	4.380	0.027
F-Ratio Degrees of Freedom	1, 5	1, 3	1, 2	1, 2	1, 4	1, 2	1, 3	1, 6
At α = 0.05, Significant Value is	6.61	10.13	18.51	18.51	7.71	18.51	10.13	5.99
Statistically Different?	yes	no	no	no	no	no	no	no

Clusters in Comparison	B+G	C+G	D+G	E+G	F+G
F-Ratio of {A, B, C, D, E}	0.615	0.158	0.373	13.329	14.154
F-Ratio Degrees of Freedom	1, 6	1, 8	1, 6	1, 6	1, 7
At α = 0.05, Significant Value is	5.99	5.32	5.99	5.99	5.59
Statistically Different?	no	no	no	yes	yes

TABLE 15. ANOVA results of claw 2. A. ANOVA results of all clusters in phenogram, for all principal components. B. ANOVA results for decreasing groups of clusters for principal component 2. C. ANOVA results of cluster pairs for principal component 2.

In the phenogram of claw 3 (Figure 10), two of the five principal components contained statistically significant differences within the group of all ten clusters (Table 16A). When this group was repeatedly narrowed down and analyzed, principal components 3 and 4 showed significant differences only in groups that included clusters B, C, and D (Table 16B and 16C). Table 16D shows which cluster pairs yielded significant differences between the clusters.

A.

Claw 3

Principal Component	PC1	PC2	PC3	PC4	PC5
F-Ratio of {A, B, C, D, E, F, G, H, I, J}	0.646	1.261	5.263	4.093	1.790
F-Ratio Degrees of Freedom	9, 22	9, 22	9, 22	9, 22	9, 22
At α = 0.05, Significant Value is	2.340	2.340	2.340	2.340	2.340
Statistically Different?	no	no	yes	yes	no

B.

Claw 3, Principal Component 3

F-Ratio of {B, C, D, E, F, G, H, I, J}	5.170
F-Ratio Degrees of Freedom	8, 21
At α = 0.05, Significant Value is	2.420
Statistically Different?	yes

F-Ratio of {C, D, E, F, G, H, I, J}	3.559
F-Ratio Degrees of Freedom	7, 19
At α = 0.05, Significant Value is	2.540
Statistically Different?	yes

F-Ratio of {D, E, F, G, H, I, J}	4.083
F-Ratio Degrees of Freedom	6, 18
At α = 0.05, Significant Value is	2.660
Statistically Different?	yes

F-Ratio of {E, F, G, H, I, J}	1.372
F-Ratio Degrees of Freedom	5, 14
At α = 0.05, Significant Value is	2.960
Statistically Different?	no

F-Ratio of {F, G, H, I, J}	0.605
F-Ratio Degrees of Freedom	4, 13
At α = 0.05, Significant Value is	3.180
Statistically Different?	no

F-Ratio of {G, H, I, J}	0.563
F-Ratio Degrees of Freedom	3, 11
At α = 0.05, Significant Value is	3.590
Statistically Different?	no

F-Ratio of {H, I, J}	0.255
F-Ratio Degrees of Freedom	2, 10
At α = 0.05, Significant Value is	4.100
Statistically Different?	no

F-Ratio of {I, J}	0.449
F-Ratio Degrees of Freedom	1, 9
At α = 0.05, Significant Value is	5.120
Statistically Different?	no

C.

Claw 3, Principal Component 4

F-Ratio of {B, C, D, E, F, G, H, I, J}	4.308
F-Ratio Degrees of Freedom	8, 21
At α = 0.05, Significant Value is	2.420
Statistically Different?	yes

F-Ratio of {C, D, E, F, G, H, I, J}	4.596
F-Ratio Degrees of Freedom	7, 19
At α = 0.05, Significant Value is	2.540
Statistically Different?	yes

F-Ratio of {D, E, F, G, H, I, J}	3.072
F-Ratio Degrees of Freedom	6, 18
At α = 0.05, Significant Value is	2.660
Statistically Different?	yes

F-Ratio of {E, F, G, H, I, J}	1.900
F-Ratio Degrees of Freedom	5, 14
At α = 0.05, Significant Value is	2.960
Statistically Different?	no

F-Ratio of {F, G, H, I, J}	1.421
F-Ratio Degrees of Freedom	4, 13
At α = 0.05, Significant Value is	3.180
Statistically Different?	no

F-Ratio of {G, H, I, J}	1.289
F-Ratio Degrees of Freedom	3, 11
At α = 0.05, Significant Value is	3.590
Statistically Different?	no

F-Ratio of {H, I, J}	1.711
F-Ratio Degrees of Freedom	2, 10
At α = 0.05, Significant Value is	4.100
Statistically Different?	no

F-Ratio of {I, J}	0.610
F-Ratio Degrees of Freedom	1, 9
At α = 0.05, Significant Value is	5.120
Statistically Different?	no

D.

Claw 3, Principal Component 3

Clusters in Comparison	A+B	A+C	A+D	A+E	A+F	A+G	A+H	A+I	A+J	B+C	B+D	B+E	B+F	B+G	B+H
F-Ratio of Cluster Pair	0.529	5.749	0.014	41.185	17.081	17.364	26.866	48.217	45.139	4.398	0.681	11.277	27.659	6.158	7.880
F-Ratio Degrees of Freedom	1, 3	1, 2	1, 5	1, 2	1, 3	1, 2	1, 2	1, 4	1, 7	1, 3	1, 6	1, 3	1, 4	1, 3	1, 3
At α = 0.05, Significant Value is	10.13	18.51	6.61	18.51	10.13	18.51	18.51	7.71	5.59	10.13	5.99	10.13	7.71	10.13	10.13
Statistically Different?	no	no	no	yes	yes	no	yes	yes	yes	no	no	yes	yes	no	no

Clusters in Comparison	B+I	B+J	C+D	C+E	C+F	C+G	C+H	C+I	C+J	D+E	D+F	D+G	D+H	D+I	D+J
F-Ratio of Cluster Pair	15.825	32.074	1.472	6.016	1.930	0.342	1.665	2.058	3.485	5.350	4.975	2.243	3.217	4.818	9.850
F-Ratio Degrees of Freedom	1, 5	1, 8	1, 5	1, 2	1, 3	1, 2	1, 2	1, 4	1, 4	1, 5	1, 6	1, 5	1, 5	1, 7	1, 10
At α = 0.05, Significant Value is	6.61	5.32	6.61	18.51	10.13	18.51	18.51	7.71	7.71	6.61	5.99	6.61	6.61	5.59	4.96
Statistically Different?	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	yes

Claw 3, Principal Component 4

Clusters in Comparison	A+B	A+C	A+D	A+E	A+F	A+G	A+H	A+I	A+J	B+C	B+D	B+E	B+F	B+G	B+H
F-Ratio of Cluster Pair	0.600	9.099	0.362	0.001	0.530	31.254	327.161	7.469	3.430	12.695	1.174	0.370	0.408	1.559	20.009
F-Ratio Degrees of Freedom	1, 3	1, 2	1, 5	1, 2	1, 3	1, 2	1, 2	1, 4	1, 7	1, 3	1, 6	1, 3	1, 4	1, 3	1, 3
At α = 0.05, Significant Value is	10.13	18.51	6.61	18.51	10.13	18.51	18.51	7.71	5.59	10.13	5.99	10.13	7.71	10.13	10.13
Statistically Different?	no	no	no	no	no	yes	yes	no	no	yes	no	no	no	no	yes

Clusters in Comparison	B+I	B+J	C+D	C+E	C+F	C+G	C+H	C+I	C+J	D+E	D+F	D+G	D+H	D+I	D+J
F-Ratio of Cluster Pair	5.059	1.947	1.908	6.259	7.694	19.101	44.162	26.100	21.464	0.358	1.534	2.440	9.487	7.657	6.447
F-Ratio Degrees of Freedom	1, 5	1, 8	1, 5	1, 2	1, 3	1, 2	1, 2	1, 4	1, 4	1, 5	1, 6	1, 5	1, 5	1, 7	1, 10
At α = 0.05, Significant Value is	6.61	5.32	6.61	18.51	10.13	18.51	18.51	7.71	7.71	6.61	5.99	6.61	6.61	5.59	4.96
Statistically Different?	no	no	no	no	no	yes	yes	yes	yes	no	no	no	yes	yes	yes

TABLE 16. ANOVA results of claw 3. A. ANOVA results of all clusters in phenogram, for all principal components. B. ANOVA results for decreasing groups of clusters for principal component 3. C. ANOVA results for decreasing groups of clusters for principal component 4. D. ANOVA results of cluster pairs for principal components 3 and 4.

The phenogram for claw 4 showed no significant differences between any of the five clusters analyzed (shown in Table 17). Thus, it was not necessary to perform further ANOVA analyses on these clusters.

Claw 4

Principal Component	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
F-Ratio of {A, B, C, D, E}	1.952	0.549	3.204	1.032	1.454
F-Ratio Degrees of Freedom	4, 7	4, 7	4, 7	4, 7	4, 7
At $\alpha = 0.05$, Significant Value is	4.120	4.120	4.120	4.120	4.12
Statistically Different?	no	no	no	no	no

TABLE 17. ANOVA results of all clusters in phenogram, for all principal components of claw 4.

Tables 18 through 20 summarize the number of statistically different principal components for each cluster pairs with one or more differences. One or more significantly different principal components indicate a statistical difference between the morphologies of the claws within those clusters.

In the phenogram of claw 1 (Figure 8), cluster A was found to be statistically different from every other cluster except for cluster B; likewise, cluster B was found to be statistically different from all clusters except cluster A. However, clusters C, D, and E are statistically similar to each other. These results separate the phenogram into two groups: the group containing *Pteranodon*, the Scarlet Ibis, and the Peacock, and the group containing two species of crocodile, the alligator, and the Pelican.

Cluster	**Number of Different PCs (out of 3)**
A+C	1
A+D	1
A+E	1
B+C	1
B+D	1
B+E	1

TABLE 18. List of pairs of clusters in the phenogram of the first claw with one or more statistically different principal components.

Table 19 shows that in the phenogram of claw 2 (Figure 9), clusters E and F are significantly different from clusters A, B, C, and G in one principal component. This indicates a difference between the claws of the Peacock, Pelican, and *Crocodylus porosus* and those of the Great Black-Backed Gull, *Pteranodon*, Whistling Swan, and *Crocodylus acutus*. Furthermore, because cluster D is not found to be statistically different from any of the other clusters, the second claws of the Great Auk and the Scarlet Ibis are statistically similar to those of all other taxa in the analysis.

Cluster	Number of Different PCs (out of 5)
A+E	1
A+F	1
B+F	1
C+E	1
C+F	1
E+G	1
F+G	1

TABLE 19. List of pairs of clusters in the phenogram of the second claw with one or more statistically different principal components.

Table 20 shows all of the pairs of clusters in the phenogram of claw 3 (Figure 10) that have significant differences. Cluster pairs A+H and D+J are different in two principal components, but the rest of the pairs listed in Table 20 are different in only one principal component.

Clusters	Number of Different PCs (out of 5)
A+E	1
A+F	1
A+H	2
A+I	1
A+J	1
B+E	1
B+F	1
B+I	1
B+J	1
D+J	2
A+G	1
B+C	1
B+H	1
C+G	1
C+H	1
C+I	1
C+J	1
D+H	1
D+I	1

TABLE 20. List of pairs of clusters in the phenogram of the third claw with one or more statistically different principal components.

DISCUSSION

Conclusions Drawn from ANOVA Analyses

The ANOVA results between clusters for each of the four claws are graphically summarized in Table 21 to facilitate comparison.

Taxon	Claw 1	Claw 2	Claw 3	Claw 4
Pavo cristatus	●	☒	●	●
Eudocimus ruber	●	●	●	●
Larus marinus	■	●	☒	●
Olor columbianus	■	●	☒	●
Pinguinis	■	●	☒	●
Pelecanus	☒	☒	●	●
Pelecanus conspicillatus	■	■	●	●
Alligator mississippiens	☒	■	●	■
Crocodylus acutus	☒	●	●	■
Crocodylus porosus	☒	☒	●	■

KEY

■ Claw not analysed
☒ Found in cluster statistically different from cluster containing pteranodont claw
● Found in cluster statistically similar to cluster containing pteranodont claw

TABLE 21. Summary of ANOVA results for clusters containing claws of other taxa in comparison with clusters containing the claws of *Pteranodon longiceps*, with key.

As shown in Table 21, the Scarlet Ibis (*Eudocimus ruber*) is the only taxon that has all four claws in clusters found to be significantly similar to clusters containing the pteranodont claws. The next taxon with the most similarity in pes claw morphometrics to that of *Pteranodon* is the Peacock (*Pavo cristatus*), as its first, third, and fourth claws are found in clusters that are statistically similar to those containing the homologous pteranodont claws. Two out of three claws of the Great Black-Backed Gull (*Larus*

marinus), the Great Auk (*Pinguinis*), and *Crocodylus acutus* are morphometrically similar to their pteranodont counterparts. Of the examined claws, the Whistling Swan (*Olor columbianus*) and both specimens of Pelican (*Pelecanus* and *Pelecanus conspicillatus*) were found to have only two out of four possible claws in clusters that were statistically similar to clusters containing homologous pteranodont claws. The remaining two specimens, *Alligator mississippiens* and *Crocodylus acutus*, each have only one out of three possible claws (of the claws tested) in clusters found to be statistically similar to clusters containing the homologous claws of *Pteranodon.*

One should bear in mind the both the various pes structures of different taxa as well as their differing methods of aquatic locomotion when comparing and contrasting claw morphometrics. For example, in spite of the similarities in claw morphometrics, it is necessary to bear in mind that *Pteranodon* and the Scarlet Ibis have differing pes structures, because the first digit of the Scarlet Ibis's pes points backwards and is elevated from the ground (Raikow 1985), whereas the first digit of the pteranodont pes points forwards with the rest of the digits. The Scarlet Ibis has basally webbed pes, and although it can swim, does so quite rarely (Kushlan and Bildstein 1992). Moreover, like that of the Scarlet Ibis, the first digit of the Peacock's pes is fully reversed and elevated (Raikow 1985). However, there is no webbing present on the pes of the Peacock, and it cannot swim under any circumstance (Ragupathy 1998).

Of the Great Black-Backed Gull, the Great Auk, and the crocodile, only the Great Black-Backed Gull uses its webbed feet to paddle at the surface of the water. The Great Auk instead propelled itself underwater with its wings (Montevecchi and Kirk 1996), and the crocodile uses its tail for propulsion (Seebacher et al. 2003). The Whistling Swan and

the Pelican, in contrast, use their fully webbed feet to paddle through the water (Wallace and Mahan 1975). Although *Alligator mississippiens* and *Crocodylus acutus* have extensively webbed pes like the Whistling Swan and the Pelican, adult crocodiles and alligators propel themselves in water with their tails, using their feet for balance and stability (Seebacher et al. 2003).

If conclusions in regards to aquatic locomotion can be made from the comparison of pteranodont claw morphometrics to those of extant organisms with known methods of locomotion, then the significant similarities and differences among these claws indicate that *Pteranodon* did not habitually paddle at or under the water's surface with its pes. First, the morphometrics of its claws most closely resemble those of the Scarlet Ibis, which only swims when in danger, and second most closely resemble those of the Peacock, which does not swim at all. Furthermore, clusters containing pteranodont claws have found to be statistically different for two out of four claws for the Pelican and Whistling Swan specimens, which use their feet to actively paddle through the water. Therefore, it is highly unlikely that *Pteranodon* actively swam in the epicontinental seaway that once covered Kansas.

On the other hand, it is possible that *Pteranodon* may have floated and/or treaded water at the surface of the seaway. This is suggested because *Crocodylus acutus* and the Great Auk, which both swim/swam by methods other than propulsion with the pes, have two of their three claws in clusters that are statistically similar to clusters containing pteranodont claws. These similarities indicate the option of some aquatic locomotion, even if that locomotion is not actively traveling. Hypothetically, *Pteranodon* could alight upon the water's surface to feed, then float or tread water efficiently enough to not sink

but without forward motion, and then take off from the water with a method discussed in the introduction.

Not all results of this analysis are exactly consistent with the above explanation. For example, in contrast with *Crocodylus acutus*, *Crocodylus porosus* and *Alligator mississippiens* only have one claw each in clusters statistically similar to clusters containing pteranodont claws. It is presently unknown if part of this inconsistency is due to the data missing from the missing claw 2 of *Alligator mississippiens*. This inconsistency contradicts the idea that *Pteranodon* probably used its pes only for balance in the water, and not for propulsion. A second inconsistency is that two of the three claws of the Great Black-Backed Gull being in clusters that are statistically similar to those containing pteranodont claws. Although the Great Black-Backed Gull floats at the suface more often than it paddles through the water with its feet, these similarities somewhat contradict the idea that *Pteranodon* probably did not actively paddle at the water's surface.

Consistencies and Inconsistencies of the Study

Several consistencies in the claw phenograms lend support to the validity of this study. For example, in the phenogram of claw 1, the two species of crocodile and one species of alligator are clustered closely together, as would be expected (in spite of the presence of the Pelican in that cluster). A similar consistency is present in the phenogram of claw 3, where the two alligator specimens are clustered closely together.

However, some inconsistencies are present in this study as well. One such inconsistency lies in the significant difference between the cluster containing the second Peacock claw and the cluster containing the second pteranodont claw. Examination of the

second Peacock claw in different lighting offers the possibility that the second and fourth landmarks may be misplaced on the claw. If this is indeed the case, then this mistake may have affected the data enough to cause the second claw of the Peacock to differ morphometrically from that of *Pteranodon.*

Other apparent inconsistencies lie within the placement of taxa within the claw phenograms. Although the phenogram of claw 3 has the two alligator specimens clustered closely together, the two species of crocodile are in separate, different clusters. Likewise, the phenogram of claw 4 places the two Pelican specimens in separate clusters. The phenogram of claw 2 shares a similar situation with the two crocodile species. However, since claws can be some variable in shape, it should be considered that no two specimens from a single taxon will have identically-shaped claws, and this may account for the apparent separation of phenotypically close taxa in the phenogram clusters.

Potential sources of error in this study lie in the missing data that are represented in Table 21 as solid black boxes. It was not possible to obtain clear, useful photographs of *Olor columbianus* claw 1, *Pelecanus conspicillatus* claws 1 and 2, and *Alligator mississippiens* claw 2 because these specimens were stored in glass case, which made photography difficult. Furthermore, some data were missing due to a lack of homologous claws among some of the taxa. *Larus marinus* and *Pinguinis* did not have their first claw analyzed because these taxa do/did not possess a first digit. Likewise, the three crocodylian taxa do not have a claw on their fourth digit.

Arguments for Other Pterosaur Aquatic Locomotion: Soft Part Preservation Evidence

Aquatic locomotion has been suggested as a possibility for at least three species in

addition to *Pteranodon*. These three suggestions stem from the observation of soft tissue preservation found in specimens of *Rhamphorhynchus muensteri*, *Pterodactylus* sp., and a specimen of *?Azhardichidae indet.* studied by Frey et al (2003). All three of these specimens show what appear to be imprints of webbing between the pes digits. The *Rhamphorhynchus muensteri* specimen shows distinct traces of webbing between metatarsals I through IV and digits I through V of the right pes. This webbing extends all the way to the bases of the claws. The webbing found in the pes of the *Pterodactylus sp.* specimen extends to the base of the ungula phalanx, and is thickest between digits III and IV. The *?Azhardchidae indet.* specimen shows traces of webbing on its pes in the form of a geotithic stain. It also shows these traces on its manus, implying that the manus was webbed as well (Frey et al 2003).

The formations that yielded these three specimens are consistent with aquatic paleoenvironments. The *Rhamphorhynchus muensteri* and *Pterodactylus sp.* specimens were both found in the Solnhofen formation (Frey et al 2003), which was deposited in a marine environment during the Jurassic (Kemp and Trueman 2003). The *?Azhardchidae indet.* specimen was found in the Crato Formation (Frey et al 2003), which consists of lacustrine sediments deposited in the Early Cretaceous (Heimhofer et al 2006).

It is logical that webbing present between the pes digits implies the capability for aquatic locomotion in pterosaurs within different clades and from different formations, because although most aquatic birds have independently evolved, they all tend to have feet that are expanded with partial or full webbing between the toes (Wallace and Mahan 1975). In fact, pterosaur phylogeny lends support to the idea of independent evolution of pes structures designed for aquatic locomotion. *Rhamphorhynchus* and *Pterodactylus* are

primitive clades found closely together at the base of the pterosaur phylogeny. In contrast, *Azhdarcho* is found in a separate, more derived clade (6 steps from *Pterodactylus*) (Bennett 1994). Since it is improbable that webbing on the pes has persisted throughout pterosaur evolution, this condition was likely an independently acquired adaptation to aquatic environments in these taxa. This information does not indicate whether or not *Pteranodon* also had webbing on the pes, but it does suggest a possibility of webbing and/or some other form of adaptation to its aquatic environment.

Arguments for Other Pterosaur Aquatic Locomotion: Ichnological Evidence

Ichnofossils found in the western United States have also been proposed as evidence supporting the possibility that some pterosaurs could swim or float in water. The late Jurassic Sundance and Summerville formations contain tracks proposed by Lockley and Wright (2003) to be the traces of pterosaurs floating in the shallow sea that was regressing from the area at that time. The most definitive swim tracks were found at the Del Monte Mines and Alcova lake localities. Some of these tracks show what appear to be impressions of claws, phalangeal pads, and heels of floating pterosaurs. Other tracks are proposed to be between one and four short toe impressions and elongate scratch marks. These parallel scratch marks are interpreted as toe-tip traces in the substrate. Additionally, some rocks containing these traces also show ripple marks. The combination of these structures present in the rock are interpreted by Lockley and Wright (2003) as the tracks of a buoyant pterosaur floating in shallow water.

It would be impossible to find any such ichnofossils in the Niobrara chalk, since the Cretaceous epicontinental seaway was deep enough to serve as a habitat for

mososaurs and plesiosaurs (Bennett 1994, 2000). However, the interpretation of pterosaur swim traces in the Sundance and Summerville formations opens the possibility that some pterosaurs may have been able to float in the water. If this were to be the case, then it is not unreasonable that *Pteranodon* could tread the water's surface.

Summary and Future Work

The similarities of the morphometrics of pteranodont claws to those of the Scarlet Ibis and the Peacock, along with the dissimilarities to those of the Whistling Swan and the Pelican indicate that *Pteranodon* could not propel itself through the water with its feet. However, the similarities between the morphometrics of pteranodont claws and those of *Crocodylus acutus* and the Great Auk suggest the possibility that *Pteranodon* could stay afloat and/or tread water at the surface, without necessarily moving forward. This possibility is not unique to *Pteranodon*, as other pterosaurs (*Rhamphorhynchus*, *Pterodactylus*, and *?Azhdarcho indet.*) have shown what appear to be traces of webbing on the pes. Proposed ichnofossils of pterosaurs treading water in what were once shallow seas during the Jurassic also suggest the possibility of aquatic locomotion in pterosaurs.

Continuations of this work can be taken in several different directions. For example, the techniques of morphometrics with use of an EPB can be applied to the morphological analysis of the metatarsals and/or digits of *Pteranodon* in the question of its potential for aquatic locomotion. However, the study of possible pteranodont aquatic locomotion does not have to focus only on the pes of *Pteranodon*. The femoral index of *Pteranodon* may be compared to that of swimming birds, birds of prey, wading birds, etc., as presented in Zeffer et al (2003). It may also be possible to compare the beak of

Pteranodon to those of extant birds who feed in the water, to see if *Pteranodon* was capable of plunging or diving based on beak morphology.

A tangential project could be performed on the pteranodont claws of unknown articulation. These claws, included in the phenogram in Figure 69, can be compared to the claws of known articulations in the phenogram in order to propose to which digit each unknown claw may correspond. The morphometrics of the unknown claws may also be included in digit-specific cluster analyses so that a more specific examination of their possible placements may be performed.

APPENDIX I

PHOTOGRAPHS OF CLAWS WITH LANDMARKS

Note: The following images are not to scale.

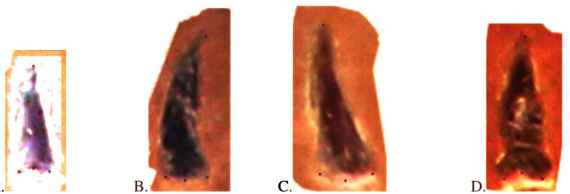

FIGURE 12. Photographs of FHSM-VP2062 left pes claws with landmarks. A. Claw 1. B. Claw 2. C. Claw 3. D. Claw 4.

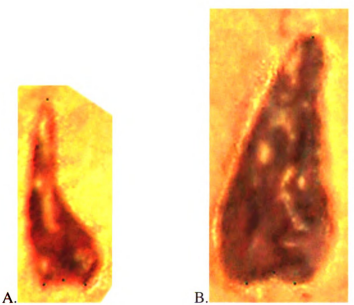

FIGURE 13. Photographs of KU49399 left pes claws with landmarks. A. Unknown Claw 1. B. Unknown Claw 2.

FIGURE 14. Photograph of YPM2554 left pes Unknown Claw 3 with landmarks.

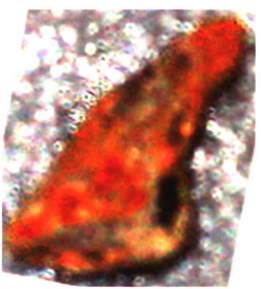

FIGURE 15. Photograph of YPM2436 left pes Unknown Claw 4 with landmarks.

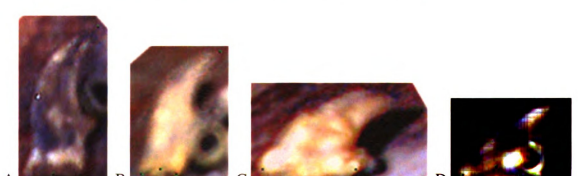

FIGURE 16. Photographs of UM-P left pes claws with landmarks. A. Claw 1. B. Claw 2. C. Claw 3. D. Claw 4.

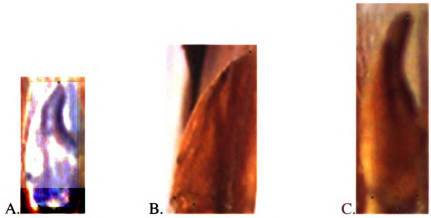

FIGURE 17. Photographs of UM-WS left pes claws with landmarks. A. Claw 1. B. Claw 2. C. Claw 3.

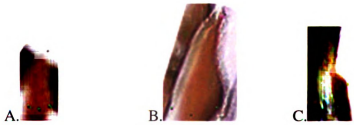

FIGURE 18. Photographs of C-GBBG left pes claws with landmarks. A. Claw 2. B. Claw 3. C. Claw 4.

FIGURE 19. Photographs of C-P left pes claws with landmarks. A. Claw 2. B. Claw 3. C. Claw 4.

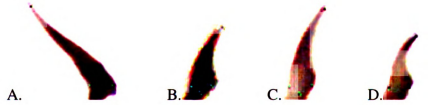

FIGURE 20. Photographs of C-SI left pes claws with landmarks. A. Claw 1. B. Claw 2. C. Claw 3. D. Claw 4.

FIGURE 21. Photographs of C-PC left pes claws with landmarks. A. Claw 3. B. Claw 4.

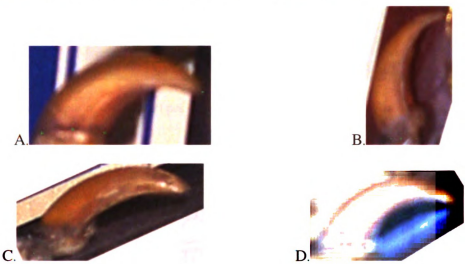

FIGURE 22. Photographs of MSU-PA left pes claws with landmarks. A. Claw 1. B. Claw 2. C. Claw 3. D. Claw 4.

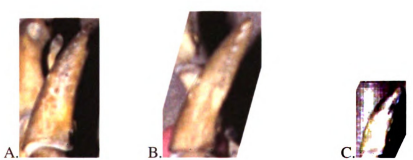

FIGURE 23. Photographs of C22026 left pes claws with landmarks. A. Claw 1. B. Claw 2. C. Claw 3.

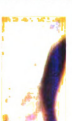

FIGURE 24. Photograph of C213395 left pes Claw 1 with landmarks.

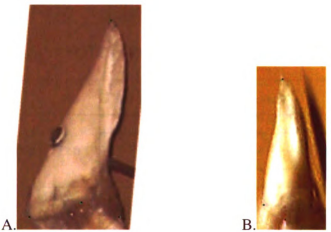

FIGURE 25. Photographs of C-CAD left pes claws with landmarks. A. Claw 2. B. Claw 3.

FIGURE 26. Photograph of C31011 left pes Claw 3 with landmarks.

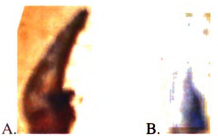

FIGURE 27. Photographs of C31321 left pes claws with landmarks. A. Claw 1. B. Claw 3.

APPENDIX II

NOTES ON PHOTOGRAPHS

Specimen	Pes	Claw	Notes
FHSM-VP2062	Left	1	
		2	
		3	
		4	
KU49399	Unknown	UNK1	
	Unknown	UNK2	
YPM2554	Unknown	UNK3	Image flipped horizontally
YPM2436	Unknown	UNK4	
UM-P	Left	1	Image flipped horizontally
		2	Image flipped horizontally
		3	
		4	
UM-WS	Left	2	
		3	Image flipped horizontally
		4	Image flipped horizontally
C-GBBG	Left	2	
		3	Image flipped horizontally
		4	Image flipped horizontally
C-PI	Left	2	Image flipped horizontally
		3	Image flipped horizontally
		4	Image flipped horizontally
C-SI	Left	1	Strange shaped claw
		2	
		3	Image flipped horizontally
		4	Image flipped horizontally
C-PC	Left	3	Image flipped horizontally; no scale
		4	Image flipped horizontally; no scale
MSU-Pa	Left	1	
		2	
		3	Image flipped horizontally
		4	Image flipped horizontally
C22026	Left	1	No scale
		2	No scale
		3	No scale
C213395	Left	1	Image flipped horizontally; no scale
C-CAD	Left	2	Image flipped horizontally; no scale
		3	Image flipped horizontally; no scale
C31011	Left	3	No scale
C31321	Left	1	Image flipped horizontally; no scale
		3	Image flipped horizontally; no scale

TABLE 22. Notes on photographs used in study.

APPENDIX III

RAW COORDINATES OF CLAW LANDMARKS

Specimen	Pes	Claw	Raw Coordinates							
			Landmark 1		Landmark 2		Landmark 3		Landmark 4	
			X	Y	X	Y	X	Y	X	Y
FHSM-VP2062	Left	1	1.58	0	1.86	0	1.72	0.93	1.71	0.03
		2	1.74	0	2.11	0	2.1	1.26	1.91	-0.03
		3	2.81	0	3.27	0	2.84	1.31	3.04	-0.06
		4	0.36	0	0.7	0	0.54	1.26	0.52	0.06
KU49399	Unknown	UNK1	1.2	0	1.56	0	1.23	1.64	1.38	0.04
	Unknown	UNK2	0.52	0	0.95	0	1.1	2.17	0.77	0.08
YPM2554	Unknown	UNK3	0.71	0	1.23	0	1.09	1.62	0.97	-0.08
YPM2436	Unknown	UNK4	0.4	0	1.8	0	2.28	2.08	1.14	-0.16
UM-P	Left	1	0.83	0	1.31	0	1.46	1.35	1.07	0.06
		2	0.76	0	1.06	0	1.45	1.08	0.91	0.04
		3	0.6	0	1.42	0	2	0.52	0.96	-0.07
		4	0.75	0	1.27	0	1.63	0.61	1.05	0.07
UM-WS	Left	2	0.54	0	0.81	0	0.71	1.1	0.7	-0.04
		3	0.32	0	0.66	0	0.98	1.28	0.48	-0.05
		4	0.36	0	0.75	0	0.67	1.59	0.59	-0.1
C-GBBG	Left	2	0.41	0	0.61	0	0.59	0.5	0.51	-0.02
		3	0.25	0	0.64	0	0.71	0.83	0.42	-0.06
		4	0.75	0	0.98	0	0.88	0.65	0.88	-0.04
C-PI	Left	2	0.31	0	0.52	0	0.52	0.87	0.4	-0.1
		3	0.26	0	0.59	0	0.61	1.38	0.42	-0.08
		4	0.22	0	0.34	0	0.42	0.76	0.29	-0.02
C-SI	Left	1	1.05	0	1.25	0	0.52	0.69	1.17	-0.06
		2	0.5	0	0.67	0	0.77	0.52	0.57	-0.06
		3	0.5	0	0.7	0	0.81	0.68	0.59	-0.08
		4	0.46	0	0.64	0	0.7	0.45	0.56	-0.06
C-PC	Left	3	0.24	0	0.56	0	0.47	0.66	0.4	-0.03
		4	0.23	0	0.46	0	0.52	0.75	0.34	-0.05
MSU-PA	Left	1	0.32	0	0.99	0	2.02	0.43	0.65	0.03
		2	0.86	0	1.3	0	1.8	2.18	1.04	0
		3	2.32	0	3.03	0	5.06	1.13	2.62	-0.05
		4	1.23	0	2.29	0	4.59	1.35	1.74	0.12
C22026	Left	1	0.57	0	1.7	0	2.34	3.19	1.13	0.16
		2	0.56	0	1.64	0	2.66	3.46	1.1	0
		3	1.93	0	2.51	0	2.98	1.73	2.26	-0.04
C213395	Left	1	0.63	0	1.73	0	2.04	2.61	1.15	-0.12
C-CAD	Left	2	1.02	0	1.98	0	1.88	2.08	1.57	0.15
		3	0.87	0	1.38	0	1.07	1.33	1.09	-0.16
C31011	Left	3	1.02	0	2.59	0	3.32	3.82	1.72	-0.023
C31321	Left	1	1.12	0	2.07	0	2.55	2.97	1.62	-0.13
		3	0.84	0	1.62	0	1.19	2.97	1.14	-0.06

TABLE 23. Raw coordinates of all claw landmarks.

APPENDIX IV

CLAW CURVATURE COORDINATES AND PLOTS

Note: In the following tables, "outer" refers to the left side curve of each claw, whereas "inner" refers to the right side curve of each claw.

FHSM-VP2062 Claw 1							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
1.700	0.910	0.429	3.250	1.720	0.910	0.500	3.250
1.650	0.890	0.250	3.179	1.740	0.860	0.571	3.071
1.600	0.860	0.071	3.071	1.740	0.790	0.571	2.821
1.590	0.810	0.036	2.893	1.740	0.750	0.571	2.679
1.570	0.750	-0.036	2.679	1.720	0.730	0.500	2.607
1.570	0.710	-0.036	2.536	1.740	0.720	0.571	2.571
1.570	0.650	-0.036	2.321	1.750	0.690	0.607	2.464
1.560	0.620	-0.071	2.214	1.760	0.660	0.643	2.357
1.550	0.550	-0.107	1.964	1.760	0.610	0.643	2.179
1.540	0.510	-0.143	1.821	1.780	0.570	0.714	2.036
1.540	0.430	-0.143	1.536	1.780	0.540	0.714	1.929
1.530	0.370	-0.179	1.321	1.800	0.510	0.786	1.821
1.540	0.330	-0.143	1.179	1.800	0.490	0.786	1.750
1.540	0.290	-0.143	1.036	1.810	0.430	0.821	1.536
1.550	0.220	-0.107	0.786	1.830	0.370	0.893	1.321
1.540	0.180	-0.143	0.643	1.830	0.330	0.893	1.179
1.530	0.130	-0.179	0.464	1.840	0.290	0.929	1.036
1.530	0.090	-0.179	0.321	1.850	0.240	0.964	0.857
				1.860	0.200	1.000	0.714
				1.860	0.150	1.000	0.536
				1.870	0.110	1.036	0.393
				1.890	0.070	1.107	0.250

TABLE 24. Raw and Bookstein coordinates taken from the outer and inner curves of FHSM-VP2062, claw 1.

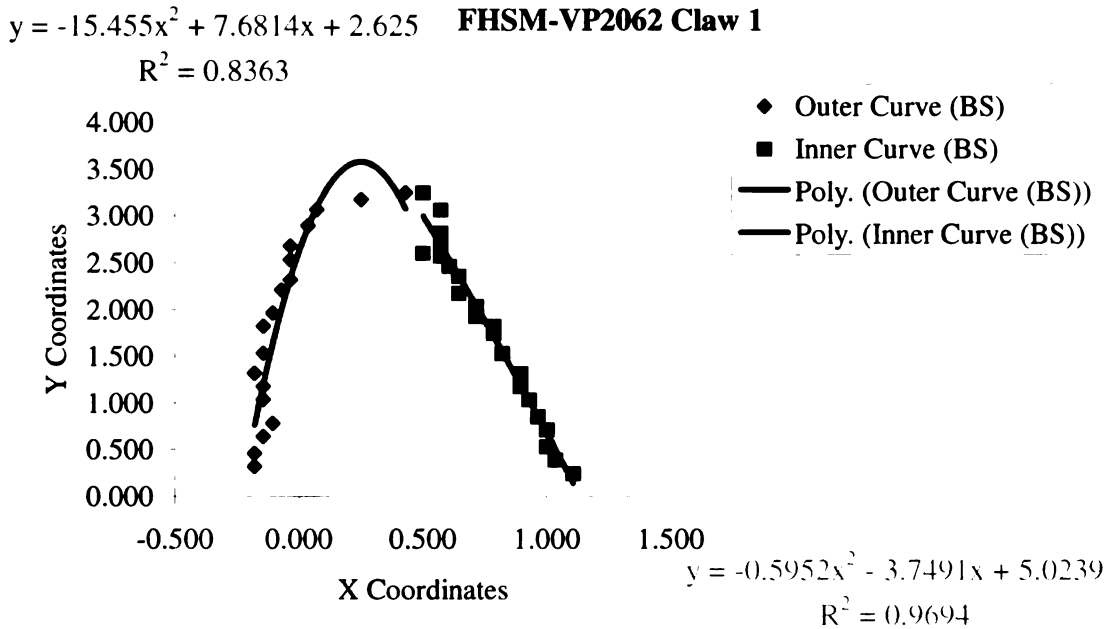

FIGURE 28. Plotted Bookstein coordinates taken from the inner and outer curves of FHSM-VP2062 claw 1, with trend lines and matching equations.

FHSM-VP2062 Claw 2							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
2.050	1.260	0.838	3.405	2.110	1.220	1.000	3.297
2.020	1.240	0.757	3.351	2.080	1.200	0.919	3.243
2.000	1.220	0.703	3.297	2.060	1.170	0.865	3.162
1.970	1.200	0.622	3.243	2.040	1.140	0.811	3.081
1.950	1.180	0.568	3.189	2.020	1.090	0.757	2.946
1.940	1.150	0.541	3.108	2.020	1.050	0.757	2.838
1.920	1.120	0.486	3.027	2.020	0.990	0.757	2.676
1.910	1.090	0.459	2.946	2.020	0.910	0.757	2.459
1.890	1.060	0.405	2.865	2.020	0.840	0.757	2.270
1.870	1.020	0.351	2.757	2.020	0.810	0.757	2.189
1.840	0.990	0.270	2.676	2.020	0.740	0.757	2.000
1.830	0.960	0.243	2.595	2.020	0.700	0.757	1.892
1.820	0.920	0.216	2.486	2.030	0.640	0.784	1.730
1.810	0.880	0.189	2.378	2.010	0.590	0.730	1.595
1.790	0.840	0.135	2.270	2.010	0.550	0.730	1.486
1.780	0.800	0.108	2.162	2.000	0.510	0.703	1.378
1.760	0.770	0.054	2.081	2.010	0.460	0.730	1.243
1.750	0.700	0.027	1.892	1.990	0.420	0.676	1.135
1.740	0.650	0.000	1.757	2.010	0.390	0.730	1.054
1.730	0.610	-0.027	1.649	2.020	0.330	0.757	0.892
1.720	0.570	-0.054	1.541	2.020	0.270	0.757	0.730
1.710	0.520	-0.081	1.405	2.030	0.260	0.784	0.703
1.700	0.480	-0.108	1.297	2.050	0.180	0.838	0.486
1.690	0.430	-0.135	1.162	2.080	0.150	0.919	0.405
1.690	0.400	-0.135	1.081	2.090	0.120	0.946	0.324
1.700	0.340	-0.108	0.919	2.120	0.100	1.027	0.270
1.700	0.290	-0.108	0.784				
1.680	0.240	-0.162	0.649				
1.680	0.170	-0.162	0.459				
1.690	0.120	-0.135	0.324				
1.710	0.070	-0.081	0.189				

TABLE 25. Raw and Bookstein coordinates taken from the outer and inner curves of FHSM-VP2062, claw 2.

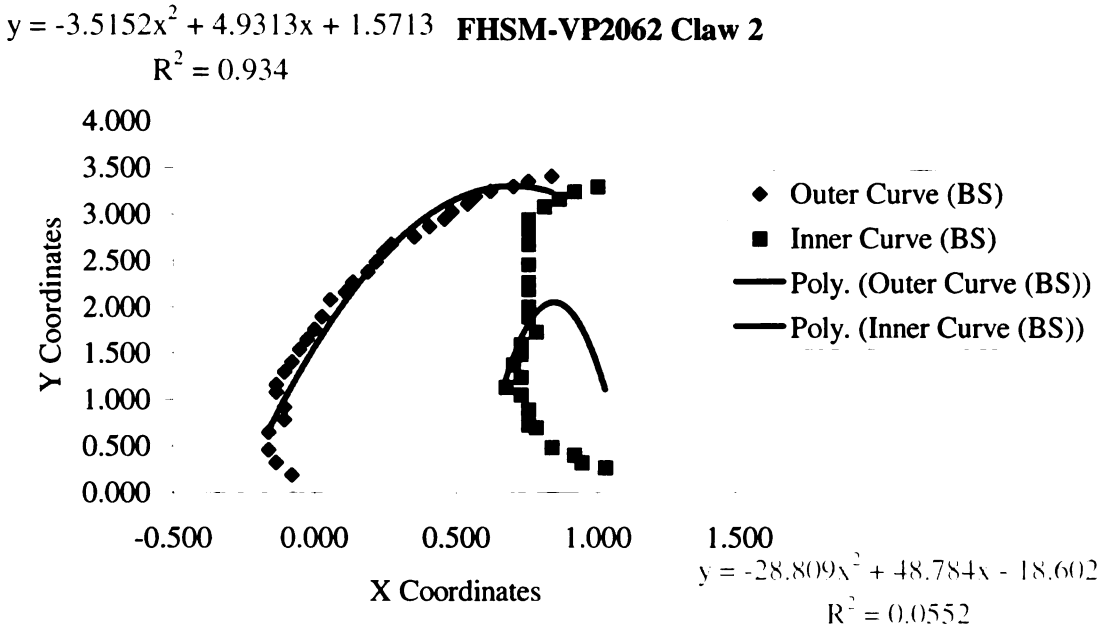

FIGURE 29. Plotted Bookstein coordinates taken from the inner and outer curves of FHSM-VP2062 claw 2, with trend lines and matching equations.

FHSM-VP2062 Claw 3							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
2.810	1.300	0.000	2.826	2.900	1.290	0.196	2.804
2.790	1.260	-0.043	2.739	2.890	1.250	0.174	2.717
2.760	1.230	-0.109	2.674	2.900	1.210	0.196	2.630
2.750	1.190	-0.130	2.587	2.910	1.180	0.217	2.565
2.750	1.150	-0.130	2.500	2.910	1.150	0.217	2.500
2.740	1.120	-0.152	2.435	2.920	1.110	0.239	2.413
2.750	1.080	-0.130	2.348	2.920	1.070	0.239	2.326
2.740	1.040	-0.152	2.261	2.920	1.040	0.239	2.261
2.730	1.000	-0.174	2.174	2.930	1.000	0.261	2.174
2.730	0.970	-0.174	2.109	2.920	0.970	0.239	2.109
2.720	0.930	-0.196	2.022	2.920	0.940	0.239	2.043
2.730	0.910	-0.174	1.978	2.920	0.910	0.239	1.978
2.730	0.880	-0.174	1.913	2.940	0.880	0.283	1.913
2.730	0.840	-0.174	1.826	2.940	0.850	0.283	1.848
2.730	0.800	-0.174	1.739	2.960	0.810	0.326	1.761
2.730	0.760	-0.174	1.652	2.970	0.780	0.348	1.696
2.730	0.710	-0.174	1.543	2.980	0.750	0.370	1.630
2.720	0.660	-0.196	1.435	3.000	0.720	0.413	1.565
2.730	0.620	-0.174	1.348	3.010	0.680	0.435	1.478
2.730	0.580	-0.174	1.261	3.020	0.650	0.457	1.413
2.720	0.510	-0.196	1.109	3.020	0.620	0.457	1.348
2.740	0.480	-0.152	1.043	3.040	0.590	0.500	1.283
2.770	0.450	-0.087	0.978	3.060	0.570	0.543	1.239
2.790	0.430	-0.043	0.935	3.070	0.530	0.565	1.152
2.800	0.390	-0.022	0.848	3.090	0.490	0.609	1.065
2.790	0.310	-0.043	0.674	3.100	0.450	0.630	0.978
2.780	0.250	-0.065	0.543	3.120	0.420	0.674	0.913
2.760	0.150	-0.109	0.326	3.140	0.370	0.717	0.804
				3.160	0.320	0.761	0.696
				3.190	0.290	0.826	0.630
				3.230	0.240	0.913	0.522
				3.260	0.200	0.978	0.435
				3.280	0.170	1.022	0.370

TABLE 26. Raw and Bookstein coordinates taken from the outer and inner curves of FHSM-VP2062, claw 3.

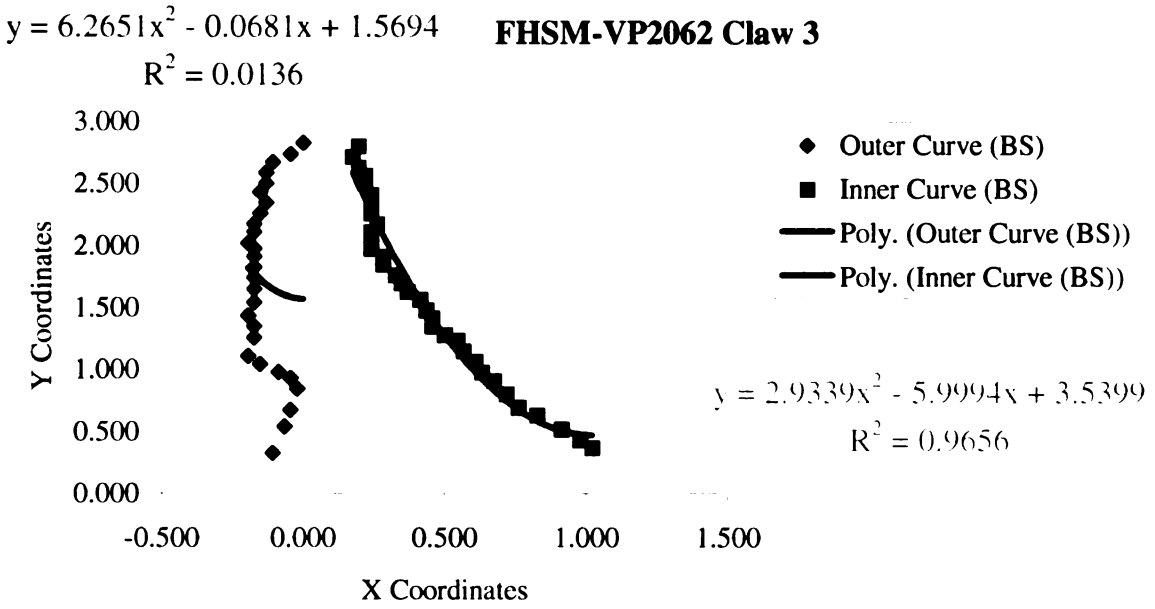

FIGURE 30. Plotted Bookstein coordinates taken from the inner and outer curves of FHSM-VP2062 claw 3, with trend lines and matching equations.

FHSM-VP2062 Claw 4							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.480	1.240	0.353	3.647	0.590	1.220	0.676	3.588
0.460	1.200	0.294	3.529	0.590	1.190	0.676	3.500
0.450	1.170	0.265	3.441	0.580	1.160	0.647	3.412
0.430	1.140	0.206	3.353	0.590	1.130	0.676	3.324
0.420	1.100	0.176	3.235	0.600	1.100	0.706	3.235
0.430	1.060	0.206	3.118	0.600	1.060	0.706	3.118
0.420	1.030	0.176	3.029	0.610	1.030	0.735	3.029
0.410	1.000	0.147	2.941	0.620	1.000	0.765	2.941
0.380	0.980	0.059	2.882	0.620	0.970	0.765	2.853
0.380	0.940	0.059	2.765	0.620	0.940	0.765	2.765
0.380	0.900	0.059	2.647	0.620	0.900	0.765	2.647
0.370	0.860	0.029	2.529	0.630	0.840	0.794	2.471
0.380	0.810	0.059	2.382	0.640	0.790	0.824	2.324
0.360	0.790	0.000	2.324	0.650	0.750	0.853	2.206
0.340	0.760	-0.059	2.235	0.660	0.700	0.882	2.059
0.340	0.730	-0.059	2.147	0.690	0.670	0.971	1.971
0.330	0.680	-0.088	2.000	0.700	0.640	1.000	1.882
0.330	0.640	-0.088	1.882	0.700	0.590	1.000	1.735
0.320	0.590	-0.118	1.735	0.710	0.540	1.029	1.588
0.330	0.550	-0.088	1.618	0.700	0.490	1.000	1.441
0.320	0.510	-0.118	1.500	0.700	0.440	1.000	1.294
0.320	0.470	-0.118	1.382	0.700	0.400	1.000	1.176
0.320	0.410	-0.118	1.206	0.710	0.350	1.029	1.029
0.320	0.370	-0.118	1.088	0.720	0.290	1.059	0.853
0.340	0.340	-0.059	1.000	0.730	0.250	1.088	0.735
0.350	0.310	-0.029	0.912	0.760	0.200	1.176	0.588
0.360	0.270	0.000	0.794	0.790	0.160	1.265	0.471
0.330	0.230	-0.088	0.676				
0.300	0.190	-0.176	0.559				
0.280	0.150	-0.235	0.441				

TABLE 27. Raw and Bookstein coordinates taken from the outer and inner curves of FHSM-VP2062, claw 4.

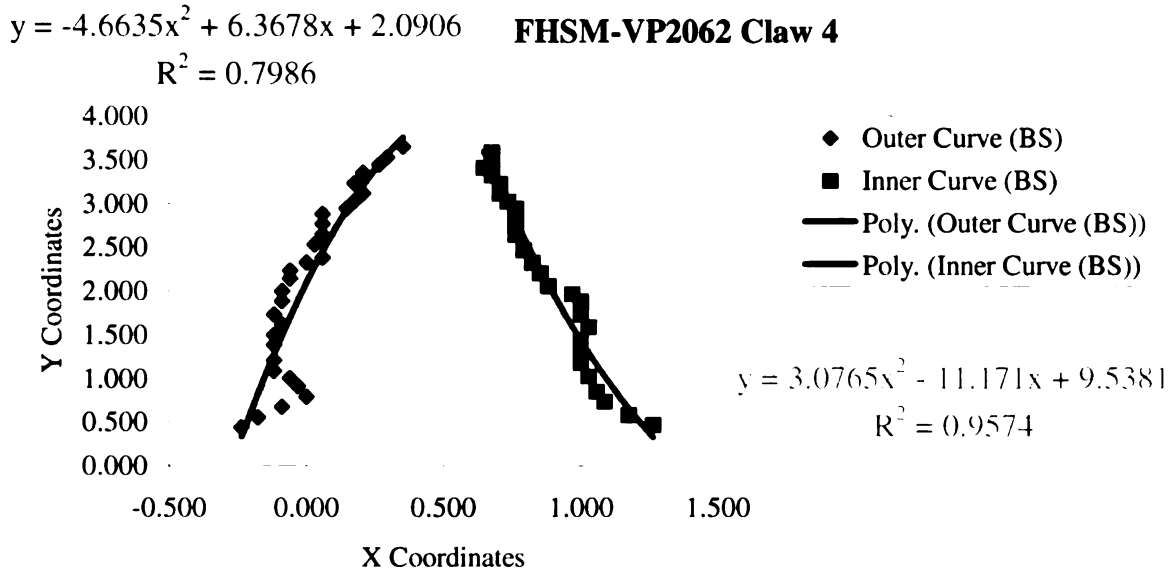

FIGURE 31. Plotted Bookstein coordinates taken from the inner and outer curves of FHSM-VP2062 claw 4, with trend lines and matching equations.

UM-P Claw 1							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
1.410	1.330	1.208	2.771	1.440	1.320	1.271	2.750
1.390	1.320	1.167	2.750	1.420	1.280	1.229	2.667
1.360	1.300	1.104	2.708	1.400	1.260	1.188	2.625
1.330	1.290	1.042	2.688	1.390	1.230	1.167	2.563
1.300	1.270	0.979	2.646	1.380	1.200	1.146	2.500
1.280	1.260	0.938	2.625	1.370	1.170	1.125	2.438
1.250	1.250	0.875	2.604	1.360	1.150	1.104	2.396
1.220	1.230	0.813	2.563	1.340	1.120	1.063	2.333
1.200	1.220	0.771	2.542	1.340	1.090	1.063	2.271
1.180	1.200	0.729	2.500	1.320	1.070	1.021	2.229
1.160	1.180	0.688	2.458	1.310	1.030	1.000	2.146
1.150	1.170	0.667	2.438	1.290	1.010	0.958	2.104
1.130	1.160	0.625	2.417	1.280	0.970	0.938	2.021
1.110	1.140	0.583	2.375	1.280	0.950	0.938	1.979
1.080	1.110	0.521	2.313	1.260	0.920	0.896	1.917
1.060	1.100	0.479	2.292	1.260	0.890	0.896	1.854
1.040	1.080	0.438	2.250	1.260	0.860	0.896	1.792
1.020	1.040	0.396	2.167	1.260	0.860	0.896	1.792
1.000	1.020	0.354	2.125	1.260	0.810	0.896	1.688
0.990	0.990	0.333	2.063	1.260	0.770	0.896	1.604
0.970	0.960	0.292	2.000	1.270	0.740	0.917	1.542
0.950	0.930	0.250	1.938	1.270	0.720	0.917	1.500
0.940	0.910	0.229	1.896	1.290	0.680	0.958	1.417
0.930	0.870	0.208	1.813	1.300	0.650	0.979	1.354
0.910	0.830	0.167	1.729	1.320	0.630	1.021	1.313
0.910	0.800	0.167	1.667	1.330	0.600	1.042	1.250
0.900	0.760	0.146	1.583	1.350	0.570	1.083	1.188
0.890	0.730	0.125	1.521	1.370	0.550	1.125	1.146
0.890	0.700	0.125	1.458	1.380	0.520	1.146	1.083
0.880	0.680	0.104	1.417	1.420	0.510	1.229	1.063
0.880	0.650	0.104	1.354	1.450	0.490	1.292	1.021
0.870	0.620	0.083	1.292				
0.870	0.590	0.083	1.229				
0.860	0.550	0.063	1.146				
0.870	0.510	0.083	1.063				
0.870	0.480	0.083	1.000				
0.880	0.430	0.104	0.896				
0.890	0.390	0.125	0.813				

TABLE 28. Raw and Bookstein coordinates taken from the outer and inner curves of UM-P, claw 1.

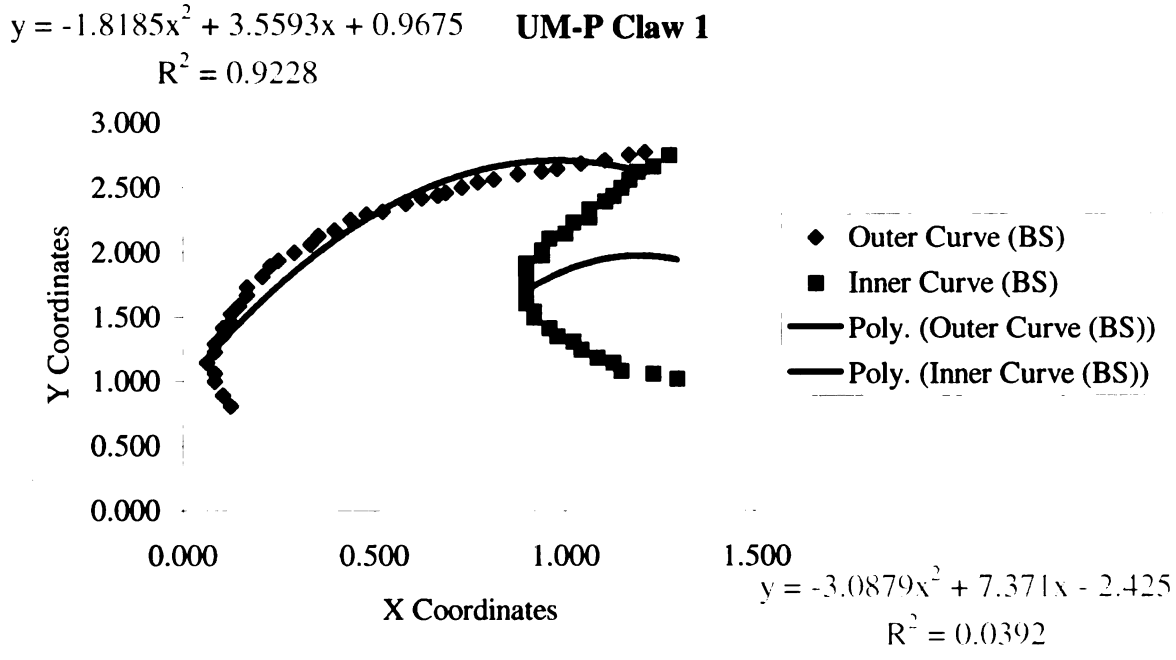

FIGURE 32. Plotted Bookstein coordinates taken from the inner and outer curves of UM-P claw 1, with trend lines and matching equations.

UM-P Claw 2							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
1.380	1.090	2.067	3.633	1.420	1.010	2.200	3.367
1.340	1.080	1.933	3.600	1.400	1.000	2.133	3.333
1.320	1.070	1.867	3.567	1.390	0.970	2.100	3.233
1.290	1.060	1.767	3.533	1.370	0.940	2.033	3.133
1.260	1.050	1.667	3.500	1.350	0.930	1.967	3.100
1.230	1.040	1.567	3.467	1.340	0.910	1.933	3.033
1.200	1.020	1.467	3.400	1.320	0.880	1.867	2.933
1.180	1.000	1.400	3.333	1.290	0.860	1.767	2.867
1.150	0.990	1.300	3.300	1.270	0.830	1.700	2.767
1.130	0.970	1.233	3.233	1.250	0.810	1.633	2.700
1.090	0.960	1.100	3.200	1.240	0.790	1.600	2.633
1.070	0.930	1.033	3.100	1.220	0.750	1.533	2.500
1.040	0.920	0.933	3.067	1.210	0.710	1.500	2.367
1.010	0.890	0.833	2.967	1.210	0.690	1.500	2.300
0.990	0.860	0.767	2.867	1.200	0.650	1.467	2.167
0.970	0.830	0.700	2.767	1.210	0.620	1.500	2.067
0.950	0.800	0.633	2.667	1.210	0.590	1.500	1.967
0.930	0.780	0.567	2.600	1.230	0.570	1.567	1.900
0.920	0.750	0.533	2.500	1.260	0.550	1.667	1.833
0.910	0.710	0.500	2.367	1.280	0.530	1.733	1.767
0.900	0.680	0.467	2.267	1.320	0.520	1.867	1.733
0.880	0.650	0.400	2.167	1.350	0.510	1.967	1.700
0.870	0.610	0.367	2.033	1.380	0.500	2.067	1.667
0.860	0.570	0.333	1.900				
0.850	0.530	0.300	1.767				
0.840	0.500	0.267	1.667				
0.830	0.460	0.233	1.533				
0.820	0.430	0.200	1.433				
0.830	0.380	0.233	1.267				
0.820	0.340	0.200	1.133				

TABLE 29. Raw and Bookstein coordinates taken from the outer and inner curves of UM-P, claw 2.

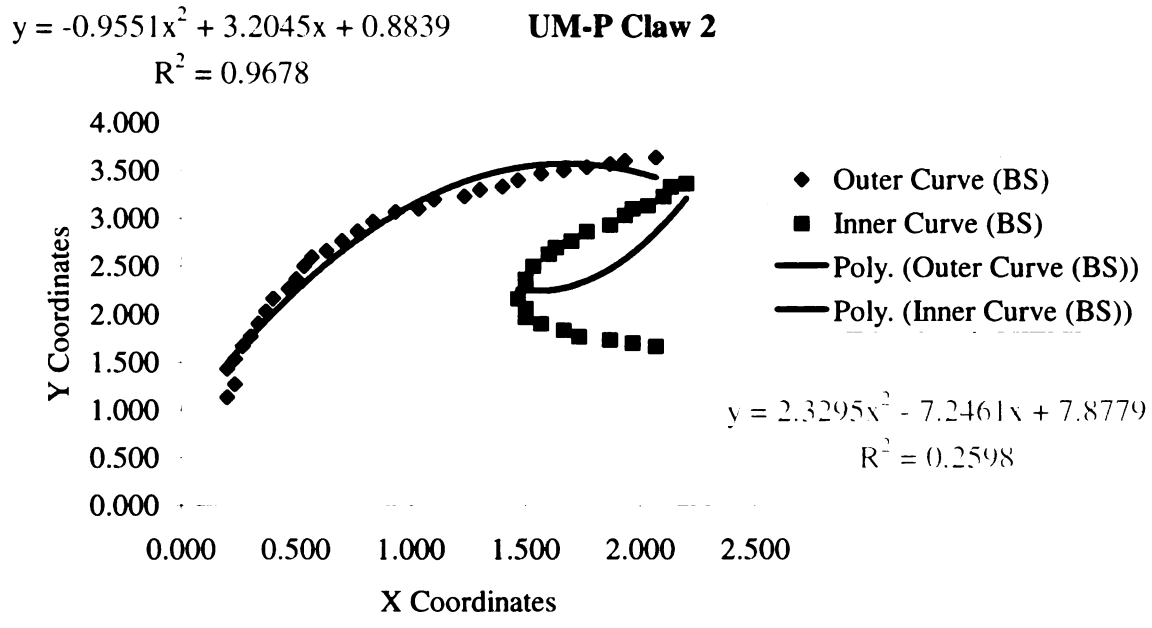

FIGURE 33. Plotted Bookstein coordinates taken from the inner and outer curves of UM-P claw 2, with trend lines and matching equations.

UM-P Claw 3							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
1.860	0.560	1.537	0.683	1.940	0.510	1.634	0.622
1.830	0.580	1.500	0.707	1.900	0.520	1.585	0.634
1.800	0.580	1.463	0.707	1.860	0.510	1.537	0.622
1.770	0.600	1.427	0.732	1.820	0.510	1.488	0.622
1.740	0.620	1.390	0.756	1.790	0.510	1.451	0.622
1.710	0.630	1.354	0.768	1.770	0.510	1.427	0.622
1.690	0.650	1.329	0.793	1.720	0.520	1.366	0.634
1.650	0.660	1.280	0.805	1.690	0.510	1.329	0.622
1.630	0.660	1.256	0.805	1.670	0.500	1.305	0.610
1.600	0.660	1.220	0.805	1.650	0.490	1.280	0.598
1.570	0.670	1.183	0.817	1.620	0.480	1.244	0.585
1.540	0.680	1.146	0.829	1.590	0.460	1.207	0.561
1.520	0.690	1.122	0.841	1.570	0.440	1.183	0.537
1.480	0.690	1.073	0.841	1.540	0.430	1.146	0.524
1.450	0.680	1.037	0.829	1.530	0.410	1.134	0.500
1.420	0.690	1.000	0.841	1.510	0.400	1.110	0.488
1.390	0.670	0.963	0.817	1.490	0.380	1.085	0.463
1.360	0.670	0.927	0.817	1.470	0.350	1.061	0.427
1.330	0.660	0.890	0.805	1.460	0.330	1.049	0.402
1.300	0.640	0.854	0.780	1.450	0.310	1.037	0.378
1.290	0.630	0.841	0.768	1.440	0.270	1.024	0.329
1.260	0.620	0.805	0.756	1.420	0.250	1.000	0.305
1.230	0.600	0.768	0.732	1.410	0.220	0.988	0.268
1.210	0.600	0.744	0.732	1.400	0.190	0.976	0.232
1.170	0.590	0.695	0.720				
1.150	0.570	0.671	0.695				
1.120	0.560	0.634	0.683				
1.100	0.540	0.610	0.659				
1.060	0.520	0.561	0.634				
1.040	0.500	0.537	0.610				
1.010	0.500	0.500	0.610				
0.980	0.490	0.463	0.598				
0.940	0.490	0.415	0.598				
0.920	0.470	0.390	0.573				
0.910	0.460	0.378	0.561				
0.880	0.450	0.341	0.549				
0.850	0.420	0.305	0.512				
0.830	0.400	0.280	0.488				
0.810	0.380	0.256	0.463				
0.780	0.350	0.220	0.427				
0.750	0.320	0.183	0.390				
0.740	0.290	0.171	0.354				
0.710	0.260	0.134	0.317				
0.690	0.230	0.110	0.280				

TABLE 30. Raw and Bookstein coordinates taken from the outer and inner curves of UM-P, claw 3.

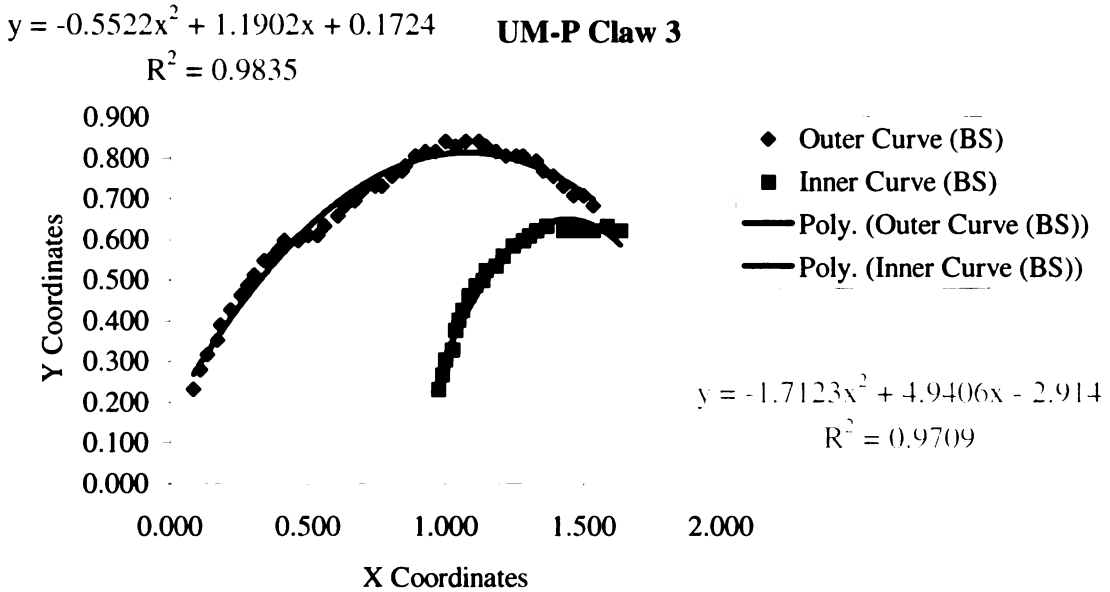

FIGURE 34. Plotted Bookstein coordinates taken from the inner and outer curves of UM-P claw 3, with trend lines and matching equations.

UM-P Claw 4							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
1.580	0.620	1.596	1.192	1.620	0.590	1.673	1.135
1.540	0.620	1.519	1.192	1.580	0.570	1.596	1.096
1.510	0.620	1.462	1.192	1.560	0.550	1.558	1.058
1.480	0.620	1.404	1.192	1.530	0.530	1.500	1.019
1.440	0.600	1.327	1.154	1.500	0.510	1.442	0.981
1.420	0.600	1.288	1.154	1.480	0.490	1.404	0.942
1.390	0.580	1.231	1.115	1.450	0.470	1.346	0.904
1.360	0.570	1.173	1.096	1.420	0.440	1.288	0.846
1.330	0.550	1.115	1.058	1.400	0.420	1.250	0.808
1.310	0.540	1.077	1.038	1.380	0.400	1.212	0.769
1.280	0.510	1.019	0.981	1.350	0.390	1.154	0.750
1.260	0.500	0.981	0.962	1.330	0.350	1.115	0.673
1.230	0.480	0.923	0.923	1.330	0.320	1.115	0.615
1.190	0.470	0.846	0.904	1.340	0.290	1.135	0.558
1.150	0.450	0.769	0.865	1.360	0.250	1.173	0.481
1.100	0.430	0.673	0.827	1.380	0.220	1.212	0.423
1.060	0.420	0.596	0.808	1.400	0.200	1.250	0.385
1.030	0.390	0.538	0.750	1.420	0.170	1.288	0.327
1.010	0.370	0.500	0.712				
0.980	0.340	0.442	0.654				
0.950	0.320	0.385	0.615				
0.930	0.300	0.346	0.577				
0.920	0.270	0.327	0.519				
0.900	0.240	0.288	0.462				
0.880	0.210	0.250	0.404				
0.870	0.180	0.231	0.346				

TABLE 31. Raw and Bookstein coordinates taken from the outer and inner curves of UM-P, claw 4.

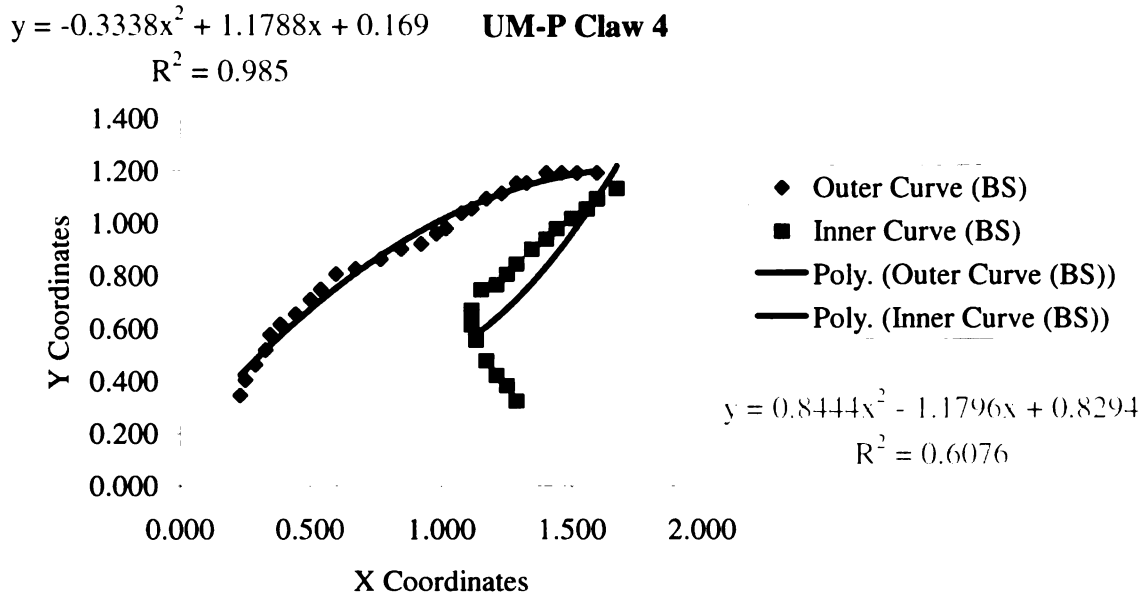

FIGURE 35. Plotted Bookstein coordinates taken from the inner and outer curves of UM-P claw 4, with trend lines and matching equations.

UM-WS Claw 2							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.700	1.060	0.593	3.926	0.770	0.980	0.852	3.630
0.680	1.040	0.519	3.852	0.760	0.940	0.815	3.481
0.660	1.010	0.444	3.741	0.760	0.920	0.815	3.407
0.650	0.990	0.407	3.667	0.760	0.900	0.815	3.333
0.640	0.970	0.370	3.593	0.740	0.870	0.741	3.222
0.620	0.950	0.296	3.519	0.730	0.840	0.704	3.111
0.600	0.930	0.222	3.444	0.730	0.810	0.704	3.000
0.570	0.910	0.111	3.370	0.740	0.780	0.741	2.889
0.550	0.880	0.037	3.259	0.740	0.750	0.741	2.778
0.540	0.860	0.000	3.185	0.750	0.720	0.778	2.667
0.520	0.840	-0.074	3.111	0.760	0.690	0.815	2.556
0.510	0.820	-0.111	3.037	0.770	0.670	0.852	2.481
0.500	0.800	-0.148	2.963	0.780	0.650	0.889	2.407
0.480	0.770	-0.222	2.852	0.810	0.630	1.000	2.333
0.480	0.730	-0.222	2.704	0.820	0.620	1.037	2.296
0.470	0.710	-0.259	2.630				
0.460	0.670	-0.296	2.481				
0.460	0.630	-0.296	2.333				
0.450	0.590	-0.333	2.185				
0.450	0.550	-0.333	2.037				
0.430	0.530	-0.407	1.963				
0.430	0.490	-0.407	1.815				
0.430	0.440	-0.407	1.630				
0.420	0.400	-0.444	1.481				
0.430	0.360	-0.407	1.333				
0.430	0.310	-0.407	1.148				
0.430	0.260	-0.407	0.963				
0.430	0.220	-0.407	0.815				
0.440	0.180	-0.370	0.667				

TABLE 32. Raw and Bookstein coordinates taken from the outer and inner curves of UM-WS, claw 2.

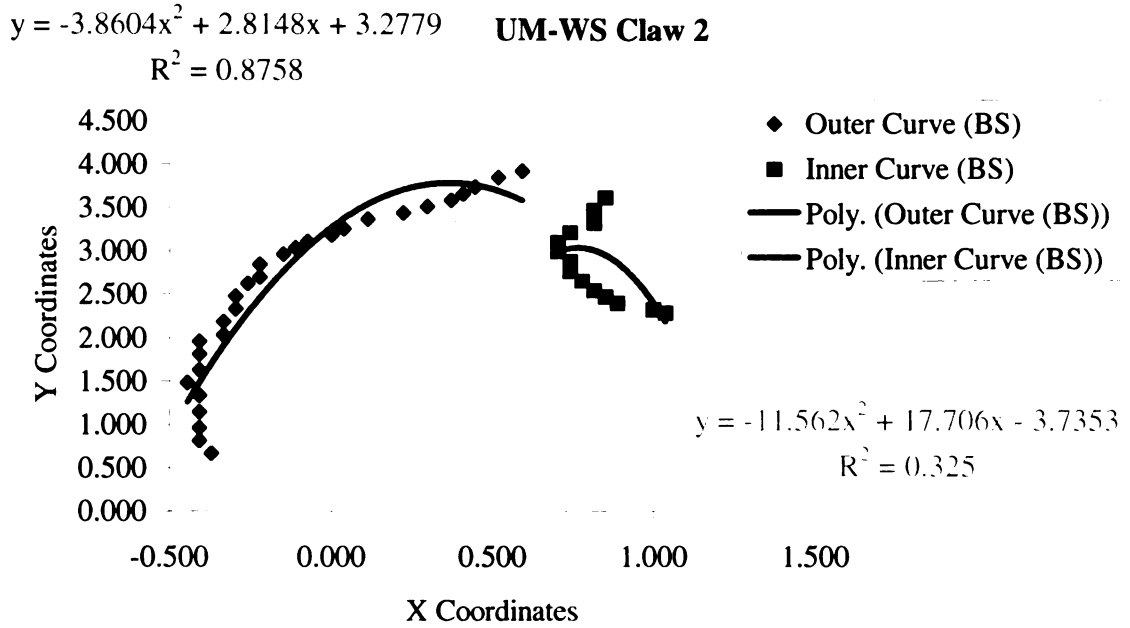

FIGURE 36. Plotted Bookstein coordinates taken from the inner and outer curves of UM-WS claw 2, with trend lines and matching equations.

UM-WS Claw 3							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.950	1.270	1.853	3.735	1.010	1.160	2.029	3.412
0.920	1.250	1.765	3.676	0.990	1.120	1.971	3.294
0.900	1.240	1.706	3.647	0.990	1.070	1.971	3.147
0.870	1.230	1.618	3.618	0.980	1.040	1.941	3.059
0.840	1.210	1.529	3.559	0.960	1.010	1.882	2.971
0.820	1.200	1.471	3.529	0.940	0.970	1.824	2.853
0.800	1.180	1.412	3.471	0.920	0.930	1.765	2.735
0.780	1.160	1.353	3.412	0.910	0.890	1.735	2.618
0.760	1.130	1.294	3.324	0.890	0.860	1.676	2.529
0.730	1.110	1.206	3.265	0.890	0.820	1.676	2.412
0.710	1.090	1.147	3.206	0.870	0.790	1.618	2.324
0.690	1.070	1.088	3.147	0.860	0.750	1.588	2.206
0.680	1.050	1.059	3.088	0.850	0.720	1.559	2.118
0.660	1.030	1.000	3.029	0.850	0.680	1.559	2.000
0.640	1.010	0.941	2.971	0.840	0.640	1.529	1.882
0.620	1.000	0.882	2.941	0.830	0.600	1.500	1.765
0.600	0.970	0.824	2.853	0.820	0.560	1.471	1.647
0.580	0.940	0.765	2.765	0.820	0.520	1.471	1.529
0.560	0.930	0.706	2.735	0.820	0.490	1.471	1.441
0.550	0.900	0.676	2.647	0.810	0.440	1.441	1.294
0.540	0.880	0.647	2.588	0.810	0.400	1.441	1.176
0.520	0.850	0.588	2.500	0.810	0.380	1.441	1.118
0.510	0.820	0.559	2.412	0.810	0.350	1.441	1.029
0.500	0.790	0.529	2.324	0.810	0.320	1.441	0.941
0.480	0.760	0.471	2.235	0.810	0.290	1.441	0.853
0.460	0.730	0.412	2.147	0.810	0.250	1.441	0.735
0.440	0.690	0.353	2.029	0.810	0.200	1.441	0.588
0.430	0.670	0.324	1.971	0.800	0.150	1.412	0.441
0.420	0.630	0.294	1.853	0.800	0.100	1.412	0.294
0.410	0.600	0.265	1.765	0.800	0.060	1.412	0.176
0.400	0.560	0.235	1.647				
0.390	0.540	0.206	1.588				
0.380	0.500	0.176	1.471				
0.360	0.460	0.118	1.353				
0.360	0.430	0.118	1.265				
0.350	0.390	0.088	1.147				
0.340	0.340	0.059	1.000				
0.340	0.300	0.059	0.882				
0.330	0.260	0.029	0.765				
0.320	0.240	0.000	0.706				
0.310	0.200	-0.029	0.588				
0.320	0.160	0.000	0.471				
0.320	0.110	0.000	0.324				

TABLE 33. Raw and Bookstein coordinates taken from the outer and inner curves of UM-WS, claw 3.

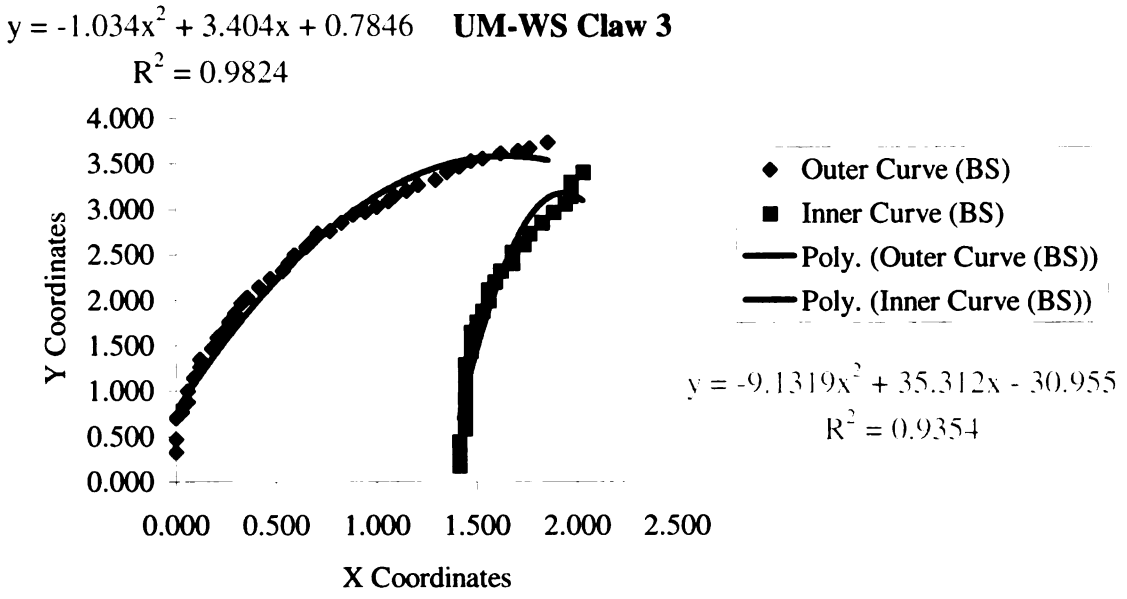

FIGURE 37. Plotted Bookstein coordinates taken from the inner and outer curves of UM-WS claw 3, with trend lines and matching equations.

UM-WS Claw 4							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.580	1.590	0.564	4.077	0.700	1.520	0.872	3.897
0.560	1.570	0.513	4.026	0.680	1.500	0.821	3.846
0.540	1.550	0.462	3.974	0.670	1.470	0.795	3.769
0.520	1.530	0.410	3.923	0.660	1.440	0.769	3.692
0.510	1.500	0.385	3.846	0.650	1.400	0.744	3.590
0.500	1.470	0.359	3.769	0.640	1.370	0.718	3.513
0.490	1.440	0.333	3.692	0.630	1.320	0.692	3.385
0.480	1.410	0.308	3.615	0.630	1.290	0.692	3.308
0.470	1.390	0.282	3.564	0.620	1.250	0.667	3.205
0.450	1.370	0.231	3.513	0.620	1.230	0.667	3.154
0.440	1.340	0.205	3.436	0.610	1.200	0.641	3.077
0.430	1.310	0.179	3.359	0.610	1.170	0.641	3.000
0.420	1.260	0.154	3.231	0.610	1.140	0.641	2.923
0.410	1.270	0.128	3.256	0.620	1.120	0.667	2.872
0.400	1.240	0.103	3.179	0.620	1.080	0.667	2.769
0.390	1.190	0.077	3.051	0.640	1.060	0.718	2.718
0.380	1.150	0.051	2.949	0.650	1.040	0.744	2.667
0.370	1.130	0.026	2.897	0.670	1.000	0.795	2.564
0.360	1.090	0.000	2.795	0.680	0.970	0.821	2.487
0.340	1.060	-0.051	2.718	0.700	0.950	0.872	2.436
0.330	1.030	-0.077	2.641	0.720	0.920	0.923	2.359
0.310	1.000	-0.128	2.564	0.730	0.890	0.949	2.282
0.310	0.970	-0.128	2.487				
0.300	0.940	-0.154	2.410				
0.280	0.910	-0.205	2.333				
0.260	0.870	-0.256	2.231				
0.260	0.840	-0.256	2.154				
0.250	0.800	-0.282	2.051				
0.250	0.770	-0.282	1.974				
0.230	0.720	-0.333	1.846				
0.230	0.680	-0.333	1.744				
0.220	0.640	-0.359	1.641				
0.210	0.600	-0.385	1.538				
0.200	0.550	-0.410	1.410				
0.200	0.520	-0.410	1.333				
0.210	0.470	-0.385	1.205				
0.220	0.430	-0.359	1.103				
0.220	0.370	-0.359	0.949				
0.230	0.310	-0.333	0.795				
0.240	0.280	-0.308	0.718				
0.260	0.240	-0.256	0.615				
0.290	0.200	-0.179	0.513				

TABLE 34. Raw and Bookstein coordinates taken from the outer and inner curves of UM-WS, claw 4.

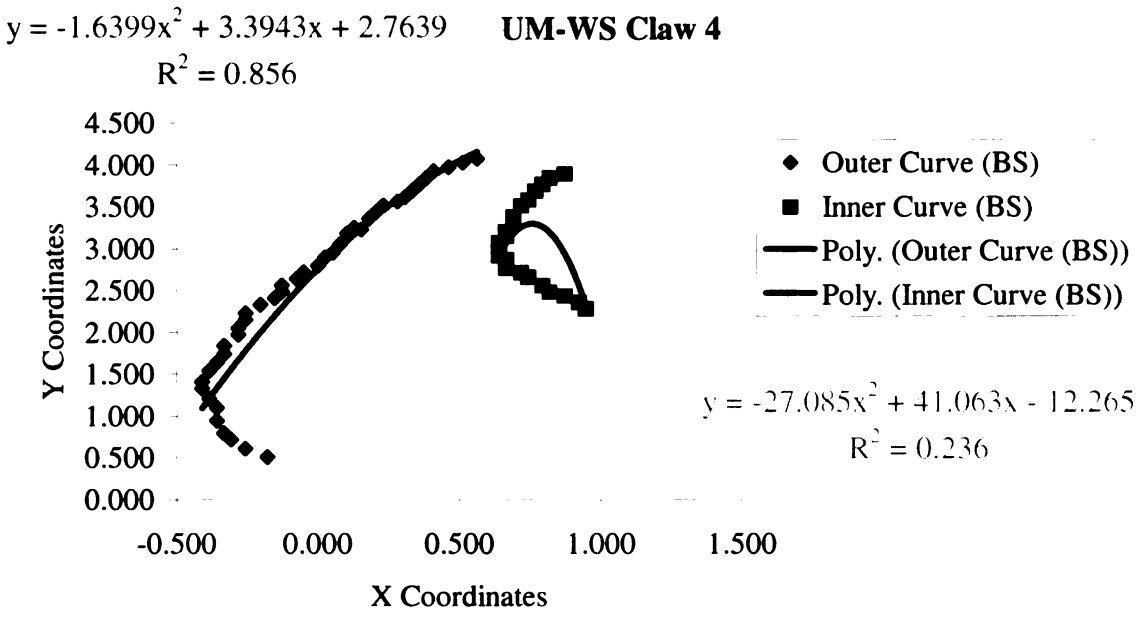

FIGURE 38. Plotted Bookstein coordinates taken from the inner and outer curves of UM-WS claw 4, with trend lines and matching equations.

C-GBBG Claw 2							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.540	0.410	0.650	2.050	0.570	0.450	0.800	2.250
0.520	0.400	0.550	2.000	0.570	0.420	0.800	2.100
0.510	0.380	0.500	1.900	0.580	0.380	0.850	1.900
0.490	0.370	0.400	1.850	0.580	0.350	0.850	1.750
0.480	0.350	0.350	1.750	0.580	0.300	0.850	1.500
0.470	0.330	0.300	1.650	0.580	0.260	0.850	1.300
0.450	0.310	0.200	1.550	0.580	0.220	0.850	1.100
0.430	0.280	0.100	1.400	0.600	0.180	0.950	0.900
0.420	0.230	0.050	1.150	0.610	0.130	1.000	0.650
0.410	0.200	0.000	1.000	0.620	0.090	1.050	0.450
0.410	0.170	0.000	0.850				
0.410	0.140	0.000	0.700				
0.410	0.110	0.000	0.550				
0.410	0.090	0.000	0.450				
0.410	0.050	0.000	0.250				

TABLE 35. Raw and Bookstein coordinates taken from the outer and inner curves of C-GBBG, claw 2.

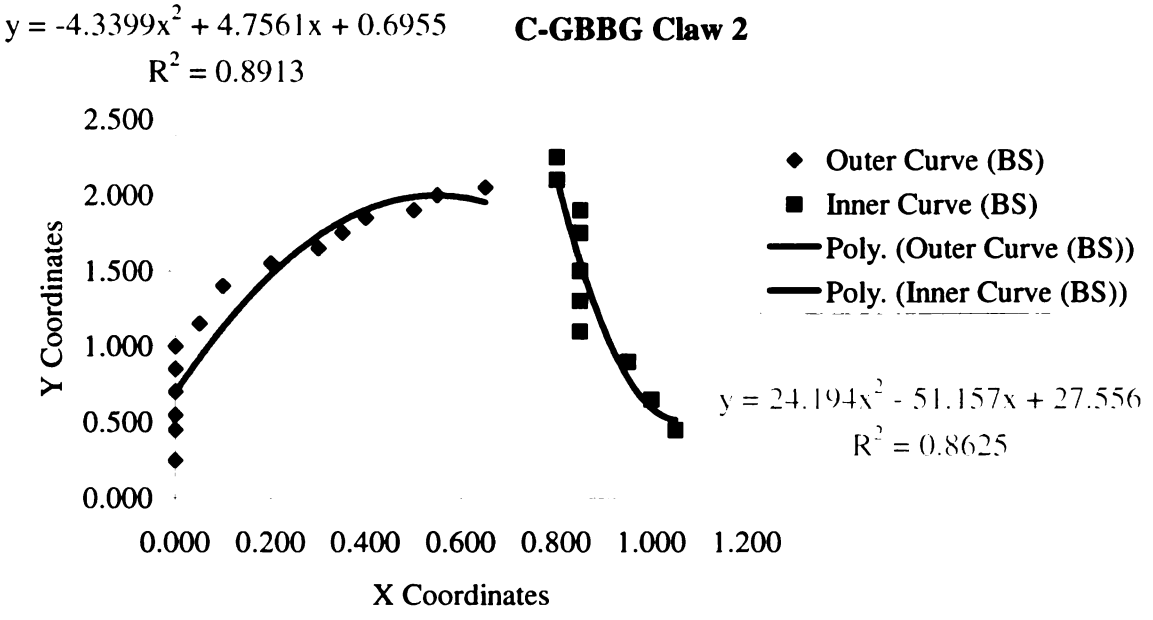

FIGURE 39. Plotted Bookstein coordinates taken from the inner and outer curves of C-GBBG claw 2, with trend lines and matching equations.

C-GBBG Claw 3							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.630	0.770	0.974	1.974	0.680	0.790	1.103	2.026
0.600	0.760	0.897	1.949	0.670	0.760	1.077	1.949
0.580	0.740	0.846	1.897	0.650	0.730	1.026	1.872
0.540	0.720	0.744	1.846	0.640	0.700	1.000	1.795
0.510	0.700	0.667	1.795	0.640	0.670	1.000	1.718
0.500	0.690	0.641	1.769	0.640	0.630	1.000	1.615
0.480	0.670	0.590	1.718	0.630	0.590	0.974	1.513
0.450	0.650	0.513	1.667	0.630	0.550	0.974	1.410
0.440	0.630	0.487	1.615	0.610	0.510	0.923	1.308
0.430	0.600	0.462	1.538	0.610	0.490	0.923	1.256
0.420	0.570	0.436	1.462	0.610	0.460	0.923	1.179
0.410	0.450	0.410	1.154	0.610	0.430	0.923	1.103
0.400	0.520	0.385	1.333	0.620	0.400	0.949	1.026
0.490	0.490	0.615	1.256	0.620	0.370	0.949	0.949
0.380	0.460	0.333	1.179	0.630	0.340	0.974	0.872
0.360	0.430	0.282	1.103	0.640	0.320	1.000	0.821
0.350	0.390	0.256	1.000	0.650	0.300	1.026	0.769
0.340	0.370	0.231	0.949	0.650	0.260	1.026	0.667
0.330	0.340	0.205	0.872	0.670	0.240	1.077	0.615
0.320	0.300	0.179	0.769	0.690	0.210	1.128	0.538
0.300	0.280	0.128	0.718	0.690	0.180	1.128	0.462
0.290	0.250	0.103	0.641				
0.290	0.230	0.103	0.590				
0.270	0.190	0.051	0.487				
0.270	0.160	0.051	0.410				
0.260	0.120	0.026	0.308				
0.270	0.110	0.051	0.282				

TABLE 36. Raw and Bookstein coordinates taken from the outer and inner curves of C-GBBG, claw 3.

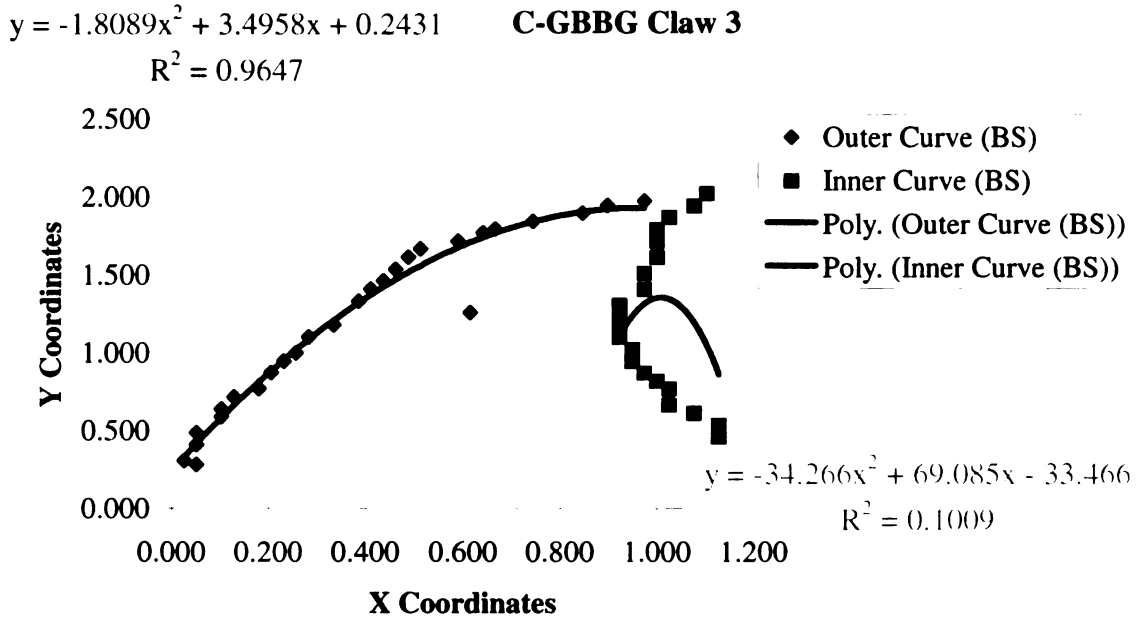

FIGURE 40. Plotted Bookstein coordinates taken from the inner and outer curves of C- GBBG claw 3, with trend lines and matching equations.

C-GBBG Claw 4							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.840	0.640	0.391	2.783	0.870	0.620	0.522	2.696
0.810	0.630	0.261	2.739	0.870	0.570	0.522	2.478
0.790	0.610	0.174	2.652	0.860	0.530	0.478	2.304
0.780	0.590	0.130	2.565	0.870	0.470	0.522	2.043
0.760	0.580	0.043	2.522	0.870	0.450	0.522	1.957
0.750	0.560	0.000	2.435	0.870	0.410	0.522	1.783
0.740	0.530	-0.043	2.304	0.870	0.380	0.522	1.652
0.730	0.500	-0.087	2.174	0.870	0.360	0.522	1.565
0.720	0.470	-0.130	2.043	0.870	0.330	0.522	1.435
0.710	0.430	-0.174	1.870	0.880	0.300	0.565	1.304
0.700	0.390	-0.217	1.696	0.900	0.290	0.652	1.261
0.700	0.350	-0.217	1.522	0.910	0.270	0.696	1.174
0.700	0.320	-0.217	1.391	0.930	0.260	0.783	1.130
0.700	0.300	-0.217	1.304	0.960	0.250	0.913	1.087
0.700	0.260	-0.217	1.130				
0.700	0.220	-0.217	0.957				
0.700	0.180	-0.217	0.783				
0.710	0.150	-0.174	0.652				
0.730	0.120	-0.087	0.522				

TABLE 37. Raw and Bookstein coordinates taken from the outer and inner curves of C-GBBG, claw 4.

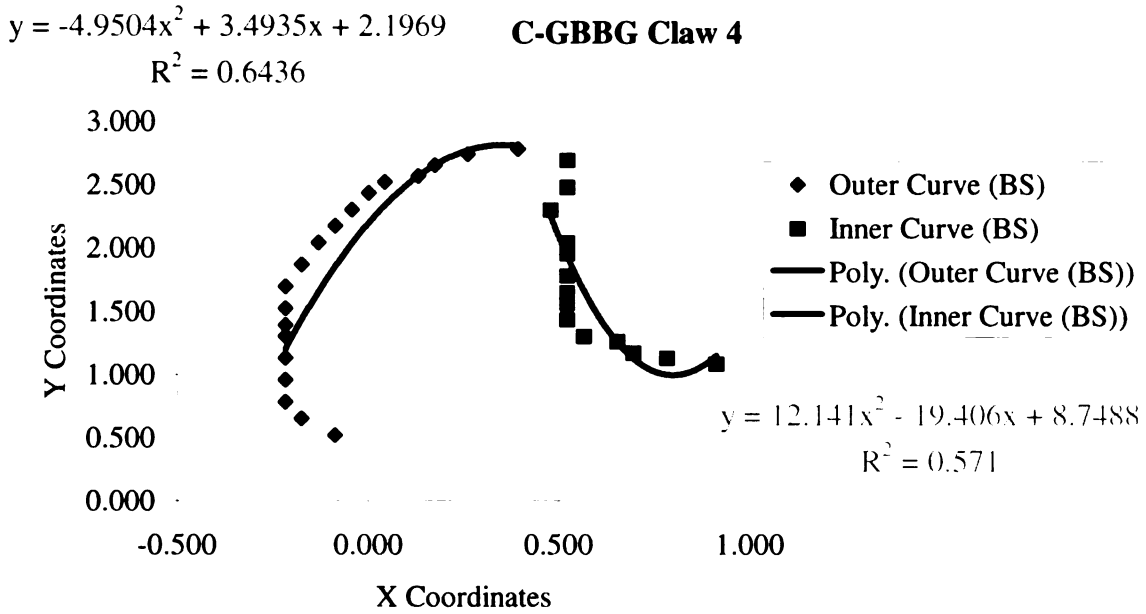

FIGURE 41. Plotted Bookstein coordinates taken from the inner and outer curves of C-GBBG claw 4, with trend lines and matching equations.

C-PI Claw 2							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.490	0.850	0.857	4.048	0.510	0.830	0.952	3.952
0.480	0.840	0.810	4.000	0.500	0.810	0.905	3.857
0.460	0.800	0.714	3.810	0.490	0.780	0.857	3.714
0.440	0.790	0.619	3.762	0.490	0.760	0.857	3.619
0.430	0.780	0.571	3.714	0.470	0.740	0.762	3.524
0.410	0.760	0.476	3.619	0.480	0.720	0.810	3.429
0.410	0.740	0.476	3.524	0.410	0.700	0.476	3.333
0.390	0.710	0.381	3.381	0.470	0.670	0.762	3.190
0.370	0.680	0.286	3.238	0.470	0.640	0.762	3.048
0.370	0.650	0.286	3.095	0.460	0.620	0.714	2.952
0.360	0.630	0.238	3.000	0.460	0.590	0.714	2.810
0.340	0.610	0.143	2.905	0.450	0.570	0.667	2.714
0.340	0.570	0.143	2.714	0.460	0.530	0.714	2.524
0.330	0.530	0.095	2.524	0.460	0.500	0.714	2.381
0.320	0.500	0.048	2.381	0.460	0.470	0.714	2.238
0.320	0.470	0.048	2.238	0.470	0.450	0.762	2.143
0.300	0.440	-0.048	2.095	0.480	0.420	0.810	2.000
0.300	0.410	-0.048	1.952	0.470	0.400	0.762	1.905
0.290	0.390	-0.095	1.857	0.490	0.370	0.857	1.762
0.280	0.270	-0.143	1.286	0.500	0.340	0.905	1.619
0.280	0.340	-0.143	1.619	0.510	0.310	0.952	1.476
0.270	0.310	-0.190	1.476	0.530	0.290	1.048	1.381
0.270	0.280	-0.190	1.333	0.550	0.260	1.143	1.238
0.270	0.260	-0.190	1.238	0.580	0.230	1.286	1.095
0.270	0.230	-0.190	1.095	0.610	0.200	1.429	0.952
0.270	0.190	-0.190	0.905				
0.280	0.150	-0.143	0.714				
0.280	0.100	-0.143	0.476				
0.280	0.060	-0.143	0.286				

TABLE 38. Raw and Bookstein coordinates taken from the outer and inner curves of C-PI claw 2.

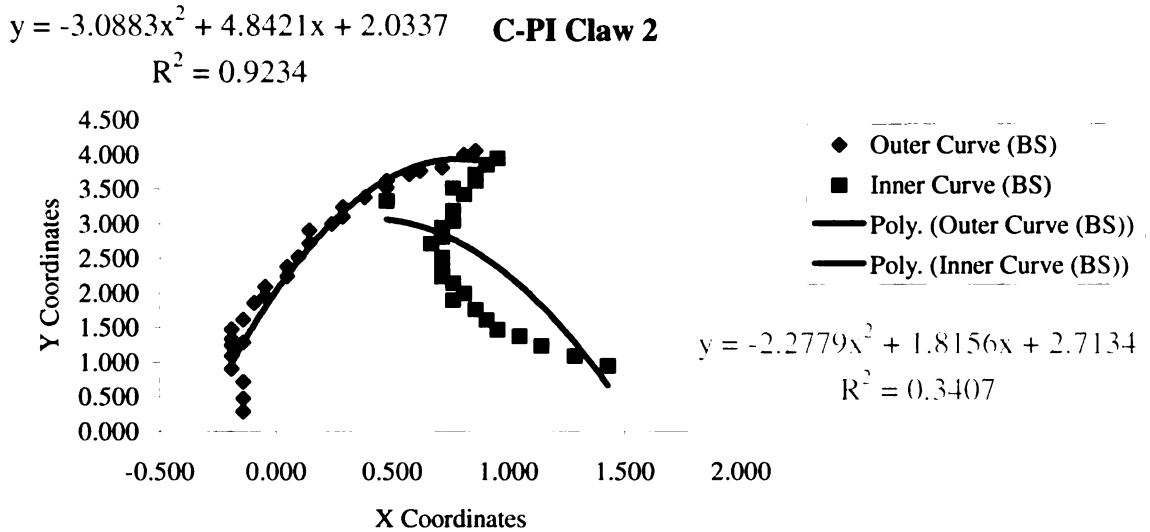

FIGURE 42. Plotted Bookstein coordinates taken from the inner and outer curves of C-PI claw 2, with trend lines and matching equations.

C-PI Claw 3							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.590	1.370	1.000	4.152	0.600	1.360	1.030	4.121
0.560	1.350	0.909	4.091	0.590	1.330	1.000	4.030
0.550	1.330	0.879	4.030	0.580	1.320	0.970	4.000
0.520	1.310	0.788	3.970	0.570	1.290	0.939	3.909
0.510	1.290	0.758	3.909	0.550	1.260	0.879	3.818
0.480	1.270	0.667	3.848	0.540	1.240	0.848	3.758
0.470	1.260	0.636	3.818	0.530	1.210	0.818	3.667
0.450	1.240	0.576	3.758	0.520	1.170	0.788	3.545
0.430	1.220	0.515	3.697	0.510	1.140	0.758	3.455
0.420	1.190	0.485	3.606	0.500	1.130	0.727	3.424
0.400	1.170	0.424	3.545	0.500	1.110	0.727	3.364
0.390	1.140	0.394	3.455	0.490	1.080	0.697	3.273
0.380	1.120	0.364	3.394	0.490	1.050	0.697	3.182
0.360	1.100	0.303	3.333	0.490	1.020	0.697	3.091
0.350	1.060	0.273	3.212	0.490	0.990	0.697	3.000
0.340	1.030	0.242	3.121	0.490	0.960	0.697	2.909
0.320	1.000	0.182	3.030	0.500	0.930	0.727	2.818
0.320	0.980	0.182	2.970	0.510	0.910	0.758	2.758
0.310	0.950	0.152	2.879	0.510	0.880	0.758	2.667
0.300	0.930	0.121	2.818	0.520	0.850	0.788	2.576
0.290	0.890	0.091	2.697	0.530	0.830	0.818	2.515
0.290	0.860	0.091	2.606	0.550	0.820	0.879	2.485
0.280	0.830	0.061	2.515	0.580	0.800	0.970	2.424
0.270	0.900	0.030	2.727	0.610	0.790	1.061	2.394
0.270	0.780	0.030	2.364	0.640	0.780	1.152	2.364
0.250	0.740	-0.030	2.242				
0.250	0.700	-0.030	2.121				
0.250	0.670	-0.030	2.030				
0.240	0.640	-0.061	1.939				
0.230	0.600	-0.091	1.818				
0.220	0.560	-0.121	1.697				
0.220	0.530	-0.121	1.606				
0.220	0.480	-0.121	1.455				
0.220	0.440	-0.121	1.333				
0.220	0.400	-0.121	1.212				
0.220	0.360	-0.121	1.091				
0.220	0.320	-0.121	0.970				
0.220	0.290	-0.121	0.879				
0.230	0.240	-0.091	0.727				
0.240	0.210	-0.061	0.636				
0.240	0.160	-0.061	0.485				
0.250	0.120	-0.030	0.364				

TABLE 39. Raw and Bookstein coordinates taken from the outer and inner curves of C-PI claw 3.

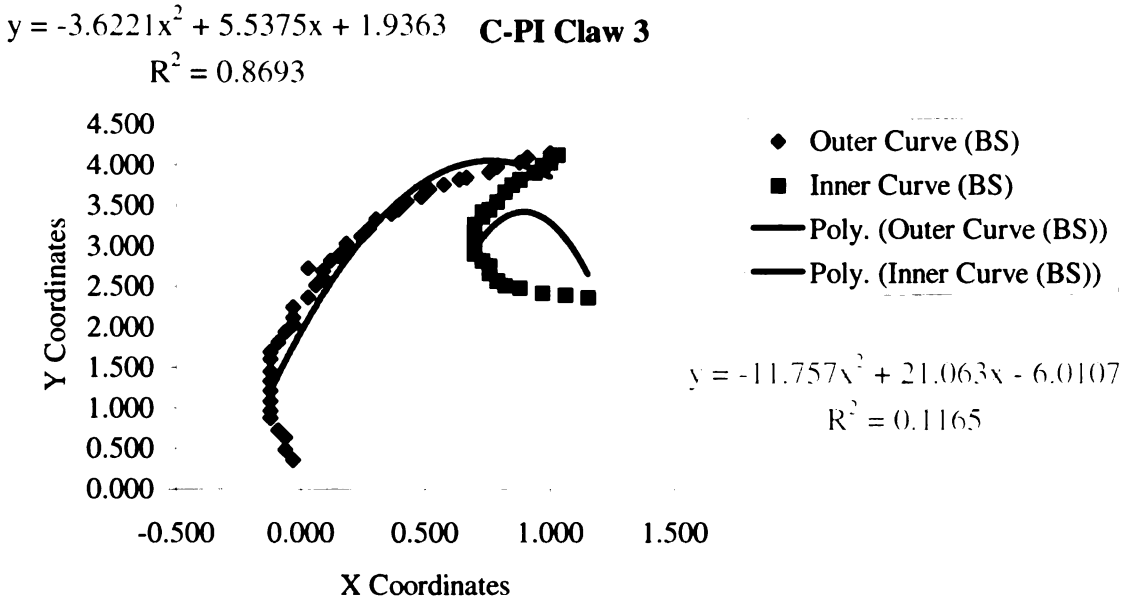

FIGURE 43. Plotted Bookstein coordinates taken from the inner and outer curves of C-PI claw 3, with trend lines and matching equations.

C-PI Claw 4							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.390	0.760	1.417	6.333	0.400	0.740	1.500	6.167
0.370	0.740	1.250	6.167	0.390	0.720	1.417	6.000
0.360	0.730	1.167	6.083	0.380	0.710	1.333	5.917
0.350	0.710	1.083	5.917	0.380	0.690	1.333	5.750
0.330	0.690	0.917	5.750	0.370	0.680	1.250	5.667
0.320	0.660	0.833	5.500	0.370	0.650	1.250	5.417
0.300	0.640	0.667	5.333	0.360	0.620	1.167	5.167
0.290	0.620	0.583	5.167	0.350	0.590	1.083	4.917
0.280	0.590	0.500	4.917	0.350	0.560	1.083	4.667
0.270	0.560	0.417	4.667	0.340	0.530	1.000	4.417
0.250	0.530	0.250	4.417	0.330	0.500	0.917	4.167
0.240	0.500	0.167	4.167	0.330	0.470	0.917	3.917
0.230	0.470	0.083	3.917	0.330	0.450	0.917	3.750
0.220	0.450	0.000	3.750	0.340	0.420	1.000	3.500
0.210	0.420	-0.083	3.500	0.350	0.390	1.083	3.250
0.210	0.390	-0.083	3.250	0.360	0.370	1.167	3.083
0.200	0.350	-0.167	2.917	0.380	0.350	1.333	2.917
0.190	0.320	-0.250	2.667	0.400	0.340	1.500	2.833
0.180	0.290	-0.333	2.417	0.420	0.310	1.667	2.583
0.180	0.260	-0.333	2.167	0.420	0.280	1.667	2.333
0.170	0.210	-0.417	1.750	0.470	0.270	2.083	2.250
0.180	0.180	-0.333	1.500	0.490	0.250	2.250	2.083
0.180	0.130	-0.333	1.083				
0.190	0.080	-0.250	0.667				

TABLE 40. Raw and Bookstein coordinates taken from the outer and inner curves of C-PI claw 3.

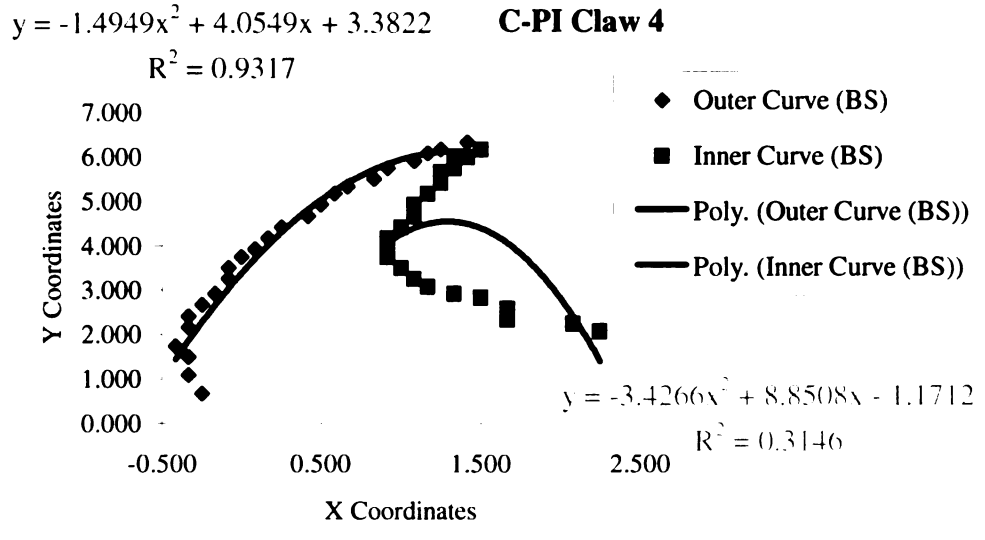

FIGURE 44. Plotted Bookstein coordinates taken from the inner and outer curves of C-PI claw 4, with trend lines and matching equations.

C-SI Claw 1							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.530	0.660	-2.600	3.300	0.540	0.680	-2.550	3.400
0.550	0.630	-2.500	3.150	0.550	0.660	-2.500	3.300
0.560	0.610	-2.450	3.050	0.580	0.630	-2.350	3.150
0.570	0.590	-2.400	2.950	0.590	0.610	-2.300	3.050
0.580	0.580	-2.350	2.900	0.620	0.590	-2.150	2.950
0.600	0.560	-2.250	2.800	0.630	0.560	-2.100	2.800
0.610	0.530	-2.200	2.650	0.660	0.540	-1.950	2.700
0.630	0.510	-2.100	2.550	0.680	0.510	-1.850	2.550
0.650	0.490	-2.000	2.450	0.710	0.490	-1.700	2.450
0.670	0.460	-1.900	2.300	0.730	0.480	-1.600	2.400
0.690	0.440	-1.800	2.200	0.770	0.450	-1.400	2.250
0.710	0.420	-1.700	2.100	0.790	0.430	-1.300	2.150
0.730	0.400	-1.600	2.000	0.830	0.410	-1.100	2.050
0.750	0.370	-1.500	1.850	0.860	0.380	-0.950	1.900
0.780	0.350	-1.350	1.750	0.900	0.360	-0.750	1.800
0.800	0.330	-1.250	1.650	0.920	0.340	-0.650	1.700
0.820	0.300	-1.150	1.500	0.950	0.320	-0.500	1.600
0.850	0.280	-1.000	1.400	0.980	0.300	-0.350	1.500
0.870	0.250	-0.900	1.250	1.010	0.280	-0.200	1.400
0.900	0.220	-0.750	1.100	1.030	0.260	-0.100	1.300
0.910	0.190	-0.700	0.950	1.050	0.240	0.000	1.200
0.930	0.160	-0.600	0.800	1.070	0.220	0.100	1.100
0.940	0.140	-0.550	0.700	1.110	0.190	0.300	0.950
0.960	0.110	-0.450	0.550	1.140	0.170	0.450	0.850
0.980	0.080	-0.350	0.400	1.160	0.140	0.550	0.700
1.010	0.060	-0.200	0.300	1.190	0.100	0.700	0.500
				1.220	0.070	0.850	0.350

TABLE 41. Raw and Bookstein coordinates taken from the outer and inner curves of C-SI claw 1.

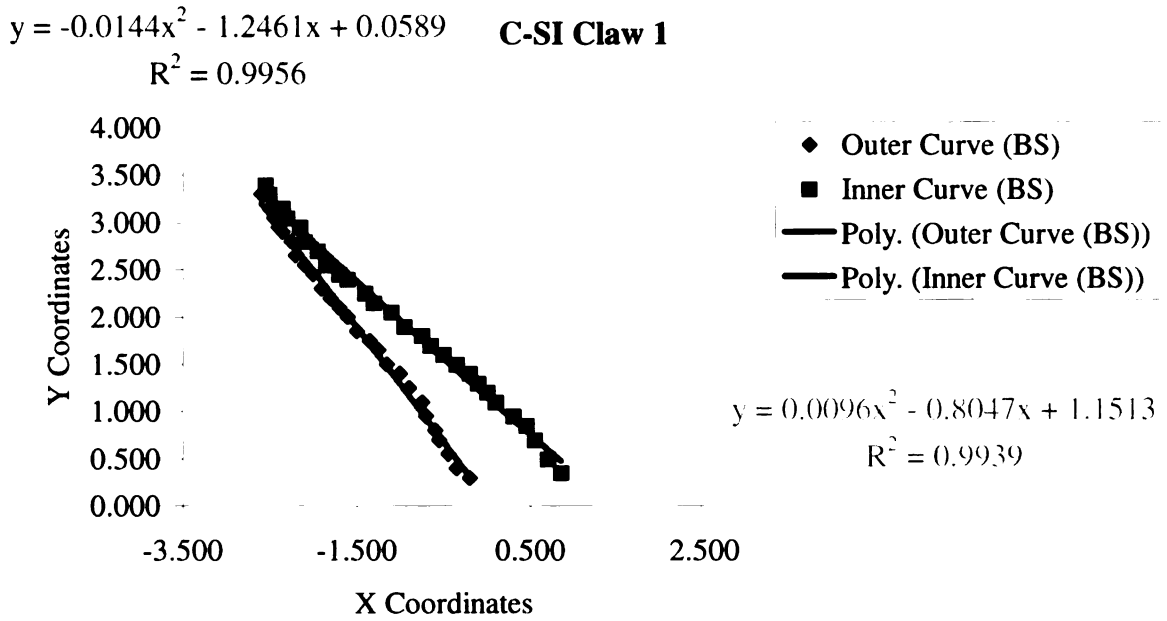

FIGURE 45. Plotted Bookstein coordinates taken from the inner and outer curves of C-SI claw 1, with trend lines and matching equations.

C-SI Claw 2							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.720	0.500	1.294	2.941	0.740	0.490	1.412	2.882
0.710	0.490	1.235	2.882	0.730	0.470	1.353	2.765
0.700	0.480	1.176	2.824	0.730	0.460	1.353	2.706
0.690	0.460	1.118	2.706	0.710	0.440	1.235	2.588
0.670	0.440	1.000	2.588	0.700	0.420	1.176	2.471
0.660	0.420	0.941	2.471	0.690	0.410	1.118	2.412
0.650	0.400	0.882	2.353	0.680	0.390	1.059	2.294
0.630	0.370	0.765	2.176	0.670	0.350	1.000	2.059
0.610	0.350	0.647	2.059	0.670	0.350	1.000	2.059
0.600	0.330	0.588	1.941	0.660	0.330	0.941	1.941
0.580	0.310	0.471	1.824	0.660	0.300	0.941	1.765
0.570	0.290	0.412	1.706	0.650	0.280	0.882	1.647
0.560	0.260	0.353	1.529	0.650	0.260	0.882	1.529
0.550	0.220	0.294	1.294	0.640	0.230	0.824	1.353
0.530	0.200	0.176	1.176	0.640	0.200	0.824	1.176
0.510	0.170	0.059	1.000	0.640	0.170	0.824	1.000
0.510	0.130	0.059	0.765	0.650	0.150	0.882	0.882
0.510	0.100	0.059	0.588	0.660	0.130	0.941	0.765
				0.670	0.100	1.000	0.588
				0.680	0.080	1.059	0.471

TABLE 42. Raw and Bookstein coordinates taken from the outer and inner curves of C-SI claw 2.

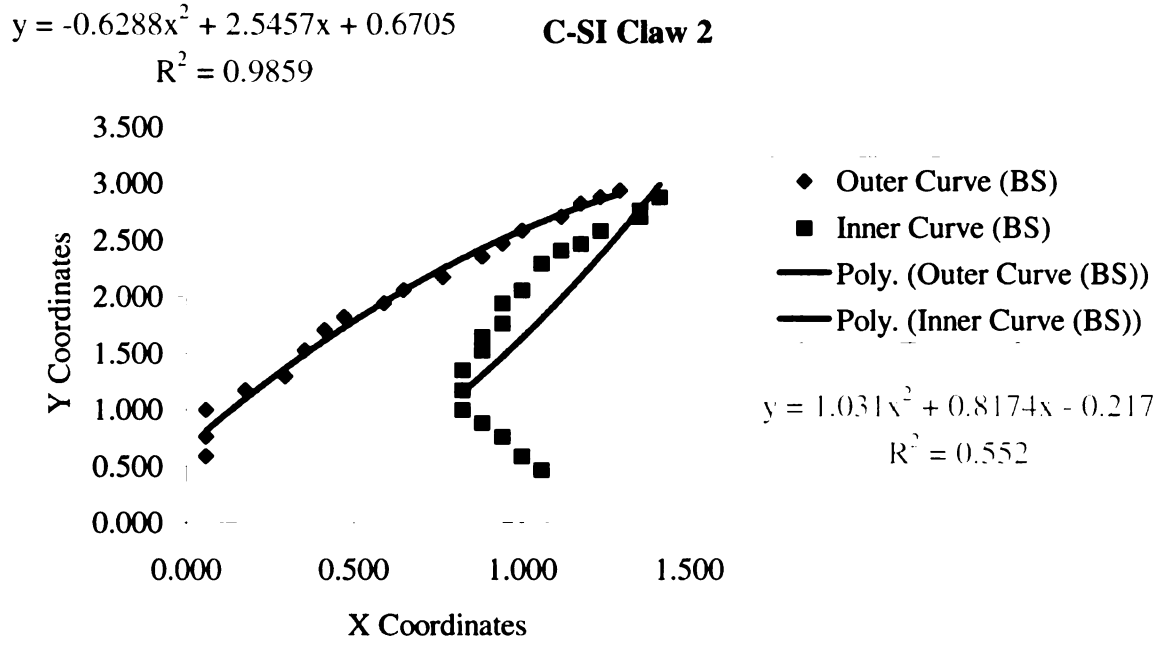

FIGURE 46. Plotted Bookstein coordinates taken from the inner and outer curves of C-SI claw 2, with trend lines and matching equations.

C-SI Claw 3							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.790	0.690	1.450	3.450	0.790	0.670	1.450	3.350
0.770	0.670	1.350	3.350	0.780	0.650	1.400	3.250
0.760	0.650	1.300	3.250	0.770	0.640	1.350	3.200
0.740	0.630	1.200	3.150	0.760	0.630	1.300	3.150
0.730	0.610	1.150	3.050	0.760	0.610	1.300	3.050
0.720	0.600	1.100	3.000	0.750	0.590	1.250	2.950
0.700	0.580	1.000	2.900	0.740	0.570	1.200	2.850
0.680	0.560	0.900	2.800	0.730	0.540	1.150	2.700
0.670	0.540	0.850	2.700	0.720	0.520	1.100	2.600
0.660	0.530	0.800	2.650	0.710	0.490	1.050	2.450
0.650	0.510	0.750	2.550	0.700	0.470	1.000	2.350
0.640	0.490	0.700	2.450	0.690	0.440	0.950	2.200
0.630	0.470	0.650	2.350	0.690	0.410	0.950	2.050
0.610	0.440	0.550	2.200	0.680	0.380	0.900	1.900
0.600	0.410	0.500	2.050	0.680	0.350	0.900	1.750
0.590	0.380	0.450	1.900	0.680	0.320	0.900	1.600
0.580	0.360	0.400	1.800	0.680	0.290	0.900	1.450
0.580	0.340	0.400	1.700	0.680	0.260	0.900	1.300
0.570	0.310	0.350	1.550	0.680	0.230	0.900	1.150
0.560	0.280	0.300	1.400	0.690	0.190	0.950	0.950
0.550	0.250	0.250	1.250	0.710	0.170	1.050	0.850
0.540	0.220	0.200	1.100	0.730	0.140	1.150	0.700
0.530	0.200	0.150	1.000				
0.520	0.170	0.100	0.850				
0.510	0.140	0.050	0.700				
0.500	0.110	0.000	0.550				

TABLE 43. Raw and Bookstein coordinates taken from the outer and inner curves of C-SI claw 3.

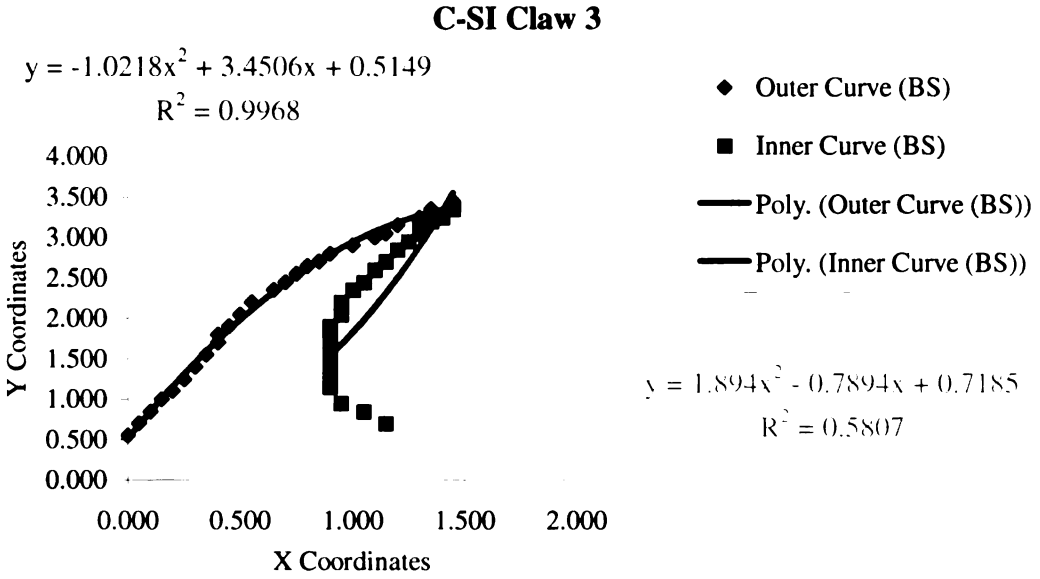

FIGURE 47. Plotted Bookstein coordinates taken from the inner and outer curves of C-SI claw 3, with trend lines and matching equations.

C-SI Claw 4							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.680	0.450	1.222	2.500	0.690	0.430	1.278	2.389
0.670	0.440	1.167	2.444	0.680	0.420	1.222	2.333
0.650	0.420	1.056	2.333	0.670	0.410	1.167	2.278
0.630	0.410	0.944	2.278	0.660	0.390	1.111	2.167
0.610	0.400	0.833	2.222	0.640	0.370	1.000	2.056
0.590	0.380	0.722	2.111	0.640	0.360	1.000	2.000
0.580	0.370	0.667	2.056	0.630	0.350	0.944	1.944
0.570	0.340	0.611	1.889	0.620	0.330	0.889	1.833
0.550	0.320	0.500	1.778	0.600	0.310	0.778	1.722
0.540	0.300	0.444	1.667	0.590	0.290	0.722	1.611
0.530	0.270	0.389	1.500	0.590	0.270	0.722	1.500
0.520	0.250	0.333	1.389	0.580	0.260	0.667	1.444
0.510	0.230	0.278	1.278	0.580	0.230	0.667	1.278
0.510	0.200	0.278	1.111	0.590	0.220	0.722	1.222
0.480	0.170	0.111	0.944	0.590	0.190	0.722	1.056
0.480	0.140	0.111	0.778	0.610	0.160	0.833	0.889
0.470	0.100	0.056	0.556	0.620	0.130	0.889	0.722
				0.640	0.110	1.000	0.611
				0.660	0.090	1.111	0.500
				0.670	0.060	1.167	0.333

TABLE 44. Raw and Bookstein coordinates taken from the outer and inner curves of C-SI claw 4.

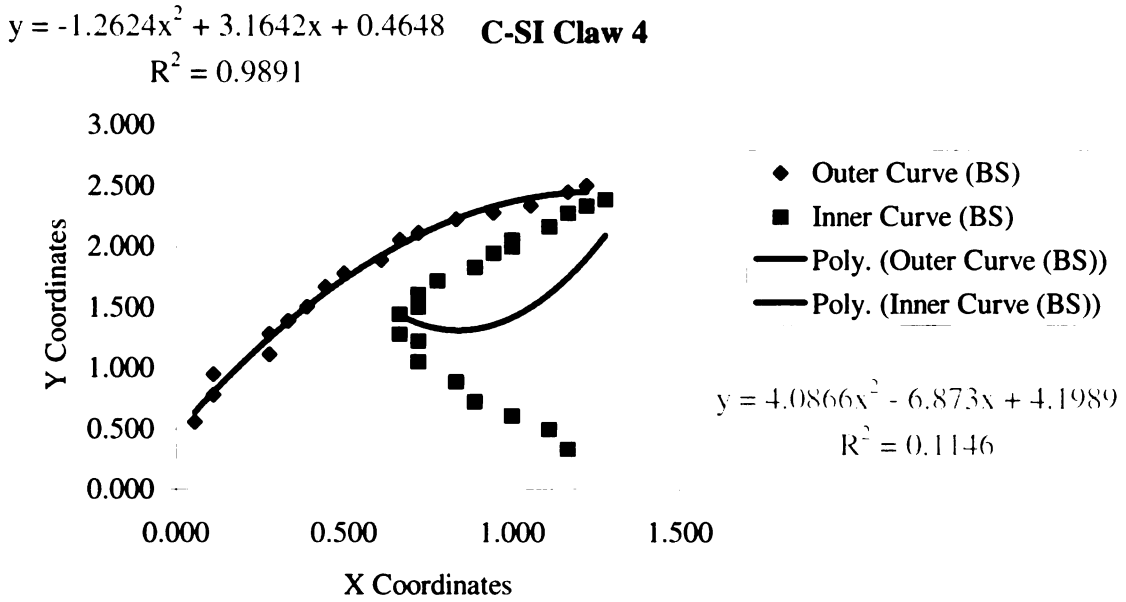

FIGURE 48. Plotted Bookstein coordinates taken from the inner and outer curves of C-SI claw 4, with trend lines and matching equations.

C-PC Claw 3							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.430	0.630	0.594	1.969	0.460	0.640	0.688	2.000
0.410	0.610	0.531	1.906	0.440	0.600	0.625	1.875
0.380	0.600	0.438	1.875	0.430	0.580	0.594	1.813
0.350	0.590	0.344	1.844	0.420	0.550	0.563	1.719
0.330	0.570	0.281	1.781	0.420	0.510	0.563	1.594
0.310	0.550	0.219	1.719	0.430	0.490	0.594	1.531
0.300	0.530	0.188	1.656	0.430	0.460	0.594	1.438
0.290	0.510	0.156	1.594	0.430	0.420	0.594	1.313
0.280	0.490	0.125	1.531	0.440	0.390	0.625	1.219
0.260	0.460	0.063	1.438	0.450	0.360	0.656	1.125
0.240	0.430	0.000	1.344	0.470	0.420	0.719	1.313
0.240	0.400	0.000	1.250	0.490	0.310	0.781	0.969
0.240	0.350	0.000	1.094	0.500	0.280	0.813	0.875
0.230	0.310	-0.031	0.969	0.520	0.250	0.875	0.781
0.240	0.250	0.000	0.781	0.530	0.220	0.906	0.688
0.230	0.200	-0.031	0.625	0.540	0.200	0.938	0.625
0.240	0.150	0.000	0.469				
0.240	0.110	0.000	0.344				
0.250	0.070	0.031	0.219				

TABLE 45. Raw and Bookstein coordinates taken from the outer and inner curves of C-PC claw 3.

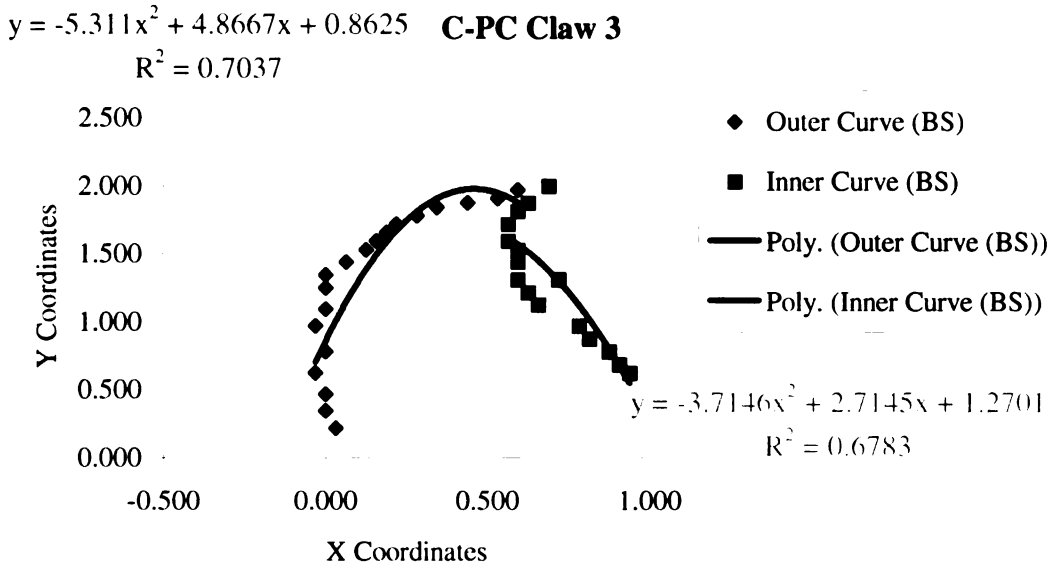

FIGURE 49. Plotted Bookstein coordinates taken from the inner and outer curves of C-PC claw 3, with trend lines and matching equations.

C-PC Claw 4							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.470	0.730	1.043	3.174	0.500	0.730	1.174	3.174
0.440	0.720	0.913	3.130	0.470	0.710	1.043	3.087
0.410	0.710	0.783	3.087	0.450	0.690	0.957	3.000
0.390	0.690	0.696	3.000	0.430	0.680	0.870	2.957
0.370	0.670	0.609	2.913	0.410	0.650	0.783	2.826
0.350	0.640	0.522	2.783	0.400	0.620	0.739	2.696
0.330	0.630	0.435	2.739	0.390	0.590	0.696	2.565
0.320	0.620	0.391	2.696	0.380	0.560	0.652	2.435
0.300	0.600	0.304	2.609	0.370	0.530	0.609	2.304
0.290	0.580	0.261	2.522	0.370	0.510	0.609	2.217
0.270	0.570	0.174	2.478	0.370	0.470	0.609	2.043
0.260	0.550	0.130	2.391	0.370	0.450	0.609	1.957
0.250	0.530	0.087	2.304	0.370	0.410	0.609	1.783
0.230	0.500	0.000	2.174	0.380	0.380	0.652	1.652
0.230	0.470	0.000	2.043	0.390	0.350	0.696	1.522
0.220	0.430	-0.043	1.870	0.400	0.320	0.739	1.391
0.210	0.400	-0.087	1.739	0.420	0.290	0.826	1.261
0.200	0.340	-0.130	1.478	0.430	0.260	0.870	1.130
0.210	0.310	-0.087	1.348	0.450	0.230	0.957	1.000
0.210	0.270	-0.087	1.174	0.460	0.210	1.000	0.913
0.210	0.230	-0.087	1.000	0.470	0.170	1.043	0.739
0.210	0.190	-0.087	0.826	0.490	0.150	1.130	0.652
0.210	0.160	-0.087	0.696	0.510	0.120	1.217	0.522
0.220	0.130	-0.043	0.565				

TABLE 46. Raw and Bookstein coordinates taken from the outer and inner curves of C-PC claw 4.

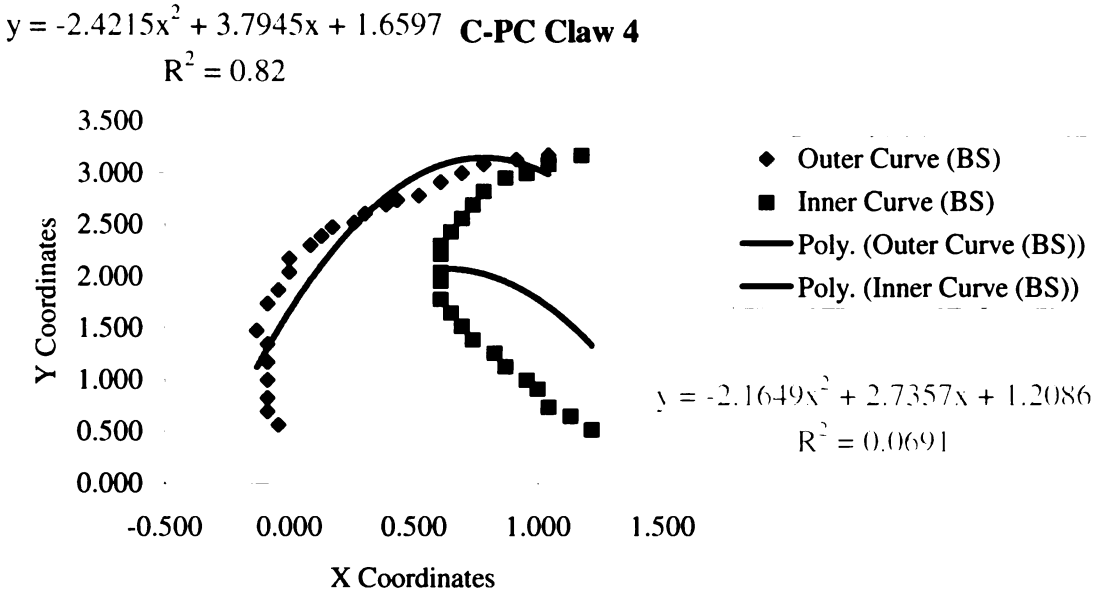

FIGURE 50. Plotted Bookstein coordinates taken from the inner and outer curves of C-PC claw 4, with trend lines and matching equations.

MSU-PA Claw 1							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
1.980	0.490	2.478	0.731	1.960	0.400	2.448	0.597
1.970	0.510	2.463	0.761	1.910	0.420	2.373	0.627
1.940	0.540	2.418	0.806	1.880	0.440	2.328	0.657
1.910	0.570	2.373	0.851	1.860	0.450	2.299	0.672
1.890	0.590	2.343	0.881	1.830	0.450	2.254	0.672
1.860	0.610	2.299	0.910	1.800	0.460	2.209	0.687
1.830	0.640	2.254	0.955	1.770	0.470	2.164	0.701
1.800	0.660	2.209	0.985	1.740	0.480	2.119	0.716
1.770	0.690	2.164	1.030	1.720	0.490	2.090	0.731
1.740	0.710	2.119	1.060	1.690	0.490	2.045	0.731
1.720	0.730	2.090	1.090	1.650	0.500	1.985	0.746
1.690	0.740	2.045	1.104	1.600	0.500	1.910	0.746
1.650	0.760	1.985	1.134	1.560	0.500	1.851	0.746
1.620	0.780	1.940	1.164	1.520	0.480	1.791	0.716
1.580	0.790	1.881	1.179	1.490	0.470	1.746	0.701
1.550	0.810	1.836	1.209	1.450	0.450	1.687	0.672
1.510	0.820	1.776	1.224	1.420	0.440	1.642	0.657
1.480	0.830	1.731	1.239	1.390	0.430	1.597	0.642
1.440	0.840	1.672	1.254	1.370	0.410	1.567	0.612
1.400	0.860	1.612	1.284	1.330	0.390	1.507	0.582
1.350	0.860	1.537	1.284	1.300	0.380	1.463	0.567
1.320	0.860	1.493	1.284	1.280	0.350	1.433	0.522
1.270	0.860	1.418	1.284	1.250	0.320	1.388	0.478
1.220	0.850	1.343	1.269	1.220	0.310	1.343	0.463
1.170	0.840	1.269	1.254	1.200	0.280	1.313	0.418
1.140	0.830	1.224	1.239	1.160	0.260	1.254	0.388
1.110	0.820	1.179	1.224	1.140	0.230	1.224	0.343
1.070	0.810	1.119	1.209	1.130	0.210	1.209	0.313
1.030	0.790	1.060	1.179	1.110	0.180	1.179	0.269
0.990	0.760	1.000	1.134	1.090	0.140	1.149	0.209
0.960	0.750	0.955	1.119	1.070	0.110	1.119	0.164
0.930	0.730	0.910	1.090				
0.900	0.720	0.866	1.075				
0.870	0.700	0.821	1.045				
0.850	0.680	0.791	1.015				
0.820	0.670	0.746	1.000				
0.790	0.650	0.701	0.970				
0.770	0.640	0.672	0.955				
0.740	0.620	0.627	0.925				
0.720	0.600	0.597	0.896				
0.680	0.590	0.537	0.881				
0.640	0.570	0.478	0.851				

TABLE 47. Raw and Bookstein coordinates taken from the outer and inner curves of MSU-PA claw 1.

TABLE 47 (cont'd)

0.630	0.550	0.463	0.821
0.600	0.520	0.418	0.776
0.580	0.490	0.388	0.731
0.550	0.460	0.343	0.687
0.530	0.440	0.313	0.657
0.510	0.420	0.284	0.627
0.470	0.390	0.224	0.582
0.440	0.360	0.179	0.537
0.420	0.330	0.149	0.493
0.400	0.290	0.119	0.433
0.380	0.260	0.090	0.388
0.350	0.220	0.045	0.328
0.340	0.180	0.030	0.269

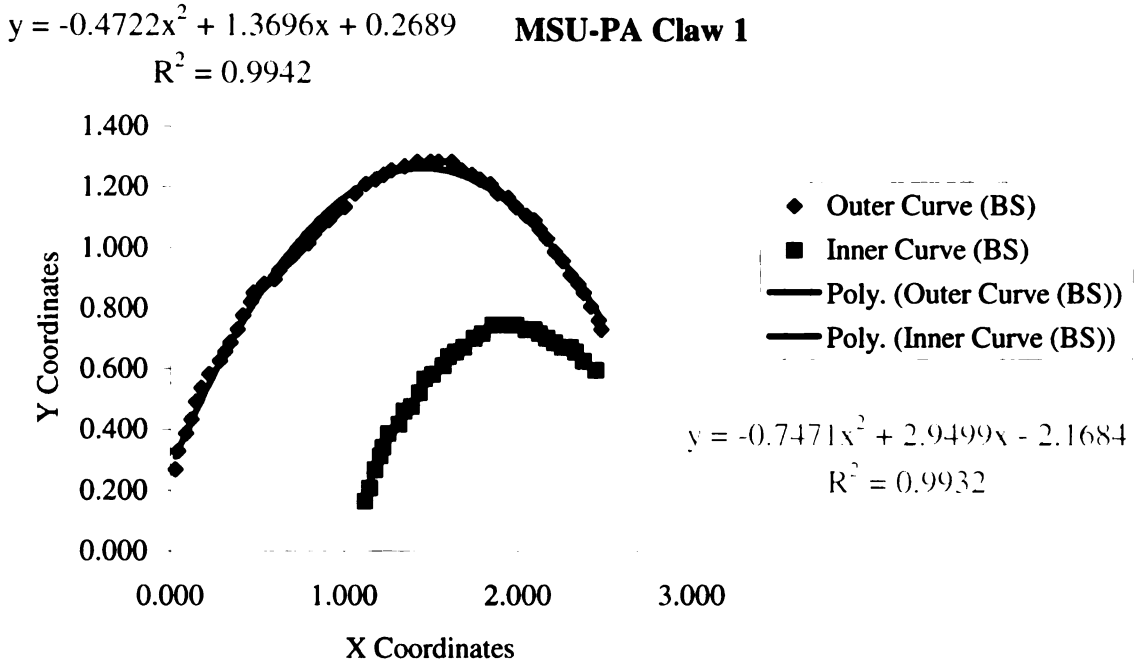

FIGURE 51. Plotted Bookstein coordinates taken from the inner and outer curves of MSU-PA claw 1, with trend lines and matching equations.

MSU-PA Claw 2							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
1.720	2.230	1.955	5.068	1.650	2.100	1.795	4.773
1.670	2.220	1.841	5.045	1.610	2.080	1.705	4.727
1.630	2.220	1.750	5.045	1.580	2.060	1.636	4.682
1.590	2.220	1.659	5.045	1.540	2.030	1.545	4.614
1.540	2.210	1.545	5.023	1.520	2.010	1.500	4.568
1.510	2.190	1.477	4.977	1.480	2.000	1.409	4.545
1.460	2.180	1.364	4.955	1.460	1.980	1.364	4.500
1.420	2.170	1.273	4.932	1.430	1.960	1.295	4.455
1.380	2.160	1.182	4.909	1.400	1.930	1.227	4.386
1.350	2.150	1.114	4.886	1.370	1.910	1.159	4.341
1.310	2.130	1.023	4.841	1.360	1.870	1.136	4.250
1.270	2.100	0.932	4.773	1.330	1.840	1.068	4.182
1.220	2.080	0.818	4.727	1.310	1.820	1.023	4.136
1.190	2.050	0.750	4.659	1.290	1.780	0.977	4.045
1.160	2.020	0.682	4.591	1.270	1.750	0.932	3.977
1.130	2.010	0.614	4.568	1.250	1.730	0.886	3.932
1.110	1.990	0.568	4.523	1.230	1.700	0.841	3.864
1.080	1.970	0.500	4.477	1.220	1.660	0.818	3.773
1.050	1.940	0.432	4.409	1.200	1.630	0.773	3.705
1.020	1.910	0.364	4.341	1.180	1.590	0.727	3.614
0.990	1.880	0.295	4.273	1.160	1.550	0.682	3.523
0.970	1.860	0.250	4.227	1.140	1.510	0.636	3.432
0.940	1.830	0.182	4.159	1.110	1.470	0.568	3.341
0.910	1.800	0.114	4.091	1.100	1.440	0.545	3.273
0.860	1.770	0.000	4.023	1.080	1.400	0.500	3.182
0.840	1.740	-0.045	3.955	1.070	1.360	0.477	3.091
0.810	1.710	-0.114	3.886	1.060	1.310	0.455	2.977
0.780	1.670	-0.182	3.795	1.060	1.270	0.455	2.886
0.750	1.650	-0.250	3.750	1.060	1.230	0.455	2.795
0.730	1.620	-0.295	3.682	1.060	1.200	0.455	2.727
0.710	1.580	-0.341	3.591	1.060	1.160	0.455	2.636
0.690	1.540	-0.386	3.500	1.060	1.130	0.455	2.568
0.680	1.500	-0.409	3.409	1.060	1.080	0.455	2.455
0.670	1.460	-0.432	3.318	1.060	1.040	0.455	2.364
0.650	1.420	-0.477	3.227	1.060	0.990	0.455	2.250
0.630	1.390	-0.523	3.159	1.050	0.960	0.432	2.182
0.620	1.360	-0.545	3.091	1.050	0.920	0.432	2.091
0.600	1.320	-0.591	3.000	1.050	0.880	0.432	2.000
0.580	1.270	-0.636	2.886	1.050	0.850	0.432	1.932
0.580	1.220	-0.636	2.773	1.050	0.810	0.432	1.841
0.560	1.180	-0.682	2.682	1.060	0.770	0.455	1.750
0.560	1.140	-0.682	2.591	1.060	0.740	0.455	1.682

TABLE 48. Raw and Bookstein coordinates taken from the outer and inner curves of MSU-PA claw 2.

TABLE 48 (cont'd)

0.540	1.090	-0.727	2.477	1.080	0.720	0.500	1.636
0.540	1.040	-0.727	2.364	1.090	0.680	0.523	1.545
0.540	1.010	-0.727	2.295	1.100	0.660	0.545	1.500
0.540	0.970	-0.727	2.205	1.120	0.620	0.591	1.409
0.530	0.920	-0.750	2.091	1.140	0.600	0.636	1.364
0.530	0.880	-0.750	2.000	1.150	0.570	0.659	1.295
0.520	0.840	-0.773	1.909	1.170	0.540	0.705	1.227
0.520	0.800	-0.773	1.818	1.180	0.510	0.727	1.159
0.510	0.750	-0.795	1.705				
0.510	0.720	-0.795	1.636				
0.520	0.680	-0.773	1.545				
0.520	0.630	-0.773	1.432				
0.520	0.580	-0.773	1.318				
0.520	0.550	-0.773	1.250				
0.540	0.500	-0.727	1.136				
0.540	0.460	-0.727	1.045				
0.560	0.420	-0.682	0.955				
0.560	0.380	-0.682	0.864				
0.570	0.330	-0.659	0.750				
0.580	0.290	-0.636	0.659				
0.600	0.260	-0.591	0.591				
0.620	0.210	-0.545	0.477				

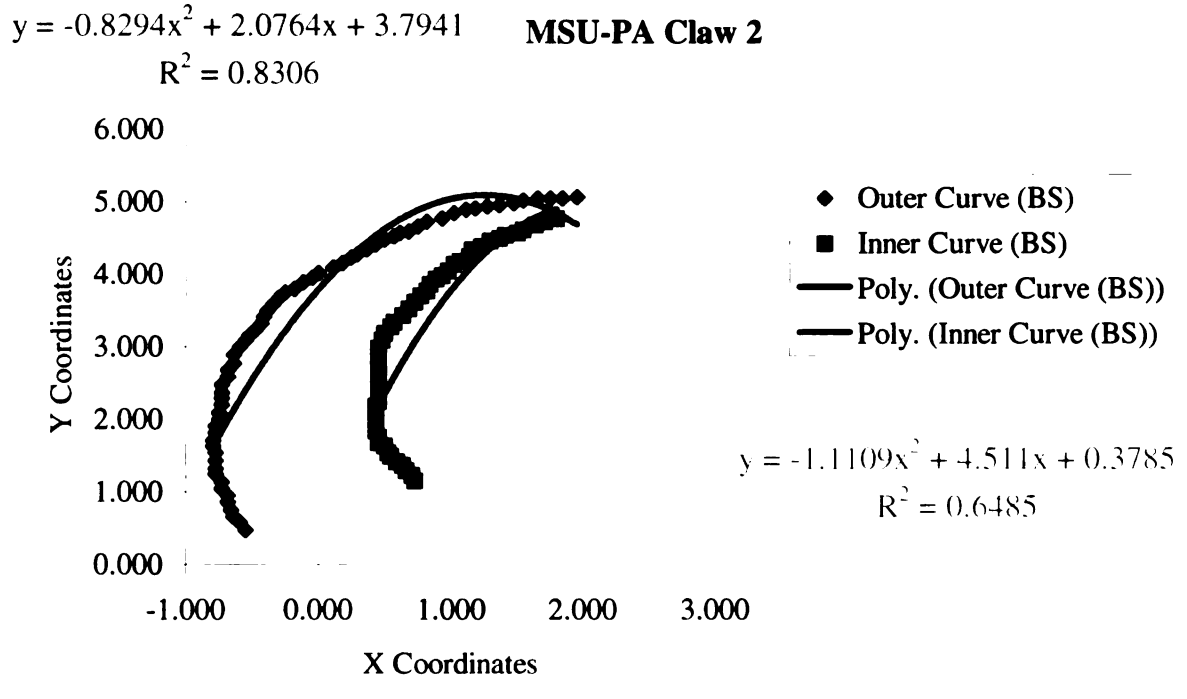

FIGURE 52. Plotted Bookstein coordinates taken from the inner and outer curves of MSU-PA claw 2, with trend lines and matching equations.

MSU-PA Claw 3							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
5.020	1.200	3.803	1.690	4.930	1.060	3.676	1.493
4.990	1.240	3.761	1.746	4.890	1.060	3.620	1.493
4.960	1.260	3.718	1.775	4.850	1.060	3.563	1.493
4.930	1.280	3.676	1.803	4.820	1.060	3.521	1.493
4.890	1.320	3.620	1.859	4.770	1.060	3.451	1.493
4.860	1.340	3.577	1.887	4.730	1.060	3.394	1.493
4.830	1.370	3.535	1.930	4.680	1.070	3.324	1.507
4.800	1.390	3.493	1.958	4.640	1.060	3.268	1.493
4.770	1.390	3.451	1.958	4.590	1.070	3.197	1.507
4.720	1.410	3.380	1.986	4.550	1.070	3.141	1.507
4.680	1.430	3.324	2.014	4.500	1.070	3.070	1.507
4.650	1.440	3.282	2.028	4.440	1.070	2.986	1.507
4.620	1.450	3.239	2.042	4.390	1.070	2.915	1.507
4.590	1.470	3.197	2.070	4.340	1.070	2.845	1.507
4.550	1.480	3.141	2.085	4.290	1.060	2.775	1.493
4.500	1.490	3.070	2.099	4.210	1.040	2.662	1.465
4.470	1.480	3.028	2.085	4.220	1.040	2.676	1.465
4.430	1.490	2.972	2.099	4.190	1.020	2.634	1.437
4.380	1.490	2.901	2.099	4.150	1.010	2.577	1.423
4.340	1.500	2.845	2.113	4.110	1.010	2.521	1.423
4.300	1.510	2.789	2.127	4.070	1.000	2.465	1.408
4.250	1.520	2.718	2.141	4.040	0.980	2.423	1.380
4.210	1.520	2.662	2.141	4.000	0.970	2.366	1.366
4.170	1.520	2.606	2.141	3.970	0.950	2.324	1.338
4.130	1.520	2.549	2.141	3.940	0.940	2.282	1.324
4.100	1.520	2.507	2.141	3.900	0.920	2.225	1.296
4.060	1.510	2.451	2.127	3.860	0.910	2.169	1.282
4.020	1.510	2.394	2.127	3.830	0.890	2.127	1.254
3.980	1.510	2.338	2.127	3.790	0.880	2.070	1.239
3.950	1.510	2.296	2.127	3.750	0.860	2.014	1.211
3.910	1.500	2.239	2.113	3.720	0.850	1.972	1.197
3.880	1.490	2.197	2.099	3.680	0.830	1.915	1.169
3.860	1.490	2.169	2.099	3.650	0.800	1.873	1.127
3.820	1.490	2.113	2.099	3.620	0.790	1.831	1.113
3.800	1.480	2.085	2.085	3.580	0.780	1.775	1.099
3.770	1.470	2.042	2.070	3.560	0.760	1.746	1.070
3.750	1.460	2.014	2.056	3.520	0.740	1.690	1.042
3.700	1.450	1.944	2.042	3.490	0.720	1.648	1.014
3.680	1.440	1.915	2.028	3.460	0.700	1.606	0.986
3.650	1.440	1.873	2.028	3.440	0.680	1.577	0.958
3.620	1.430	1.831	2.014	3.400	0.650	1.521	0.915
3.590	1.420	1.789	2.000	3.370	0.620	1.479	0.873

TABLE 49. Raw and Bookstein coordinates taken from the outer and inner curves of MSU-PA claw 3.

TABLE 49 (cont'd)

3.560	1.410	1.746	1.986	3.330	0.600	1.423	0.845
3.530	1.400	1.704	1.972	3.310	0.570	1.394	0.803
3.510	1.390	1.676	1.958	3.280	0.540	1.352	0.761
3.470	1.380	1.620	1.944	3.250	0.500	1.310	0.704
3.440	1.380	1.577	1.944	3.230	0.460	1.282	0.648
3.410	1.360	1.535	1.915	3.230	0.410	1.282	0.577
3.380	1.340	1.493	1.887				
3.340	1.330	1.437	1.873				
3.310	1.320	1.394	1.859				
3.280	1.300	1.352	1.831				
3.250	1.280	1.310	1.803				
3.220	1.270	1.268	1.789				
3.190	1.260	1.225	1.775				
3.170	1.240	1.197	1.746				
3.140	1.220	1.155	1.718				
3.110	1.210	1.113	1.704				
3.080	1.200	1.070	1.690				
3.060	1.180	1.042	1.662				
3.030	1.160	1.000	1.634				
3.010	1.150	0.972	1.620				
2.980	1.140	0.930	1.606				
2.960	1.110	0.901	1.563				
2.920	1.090	0.845	1.535				
2.890	1.060	0.803	1.493				
2.860	1.040	0.761	1.465				
2.840	1.020	0.732	1.437				
2.820	1.000	0.704	1.408				
2.780	0.970	0.648	1.366				
2.760	0.950	0.620	1.338				
2.730	0.920	0.577	1.296				
2.710	0.900	0.549	1.268				
2.690	0.880	0.521	1.239				
2.660	0.850	0.479	1.197				
2.630	0.820	0.437	1.155				
2.610	0.790	0.408	1.113				
2.580	0.760	0.366	1.070				
2.550	0.730	0.324	1.028				
2.530	0.700	0.296	0.986				
2.500	0.680	0.254	0.958				
2.490	0.640	0.239	0.901				
2.470	0.590	0.211	0.831				

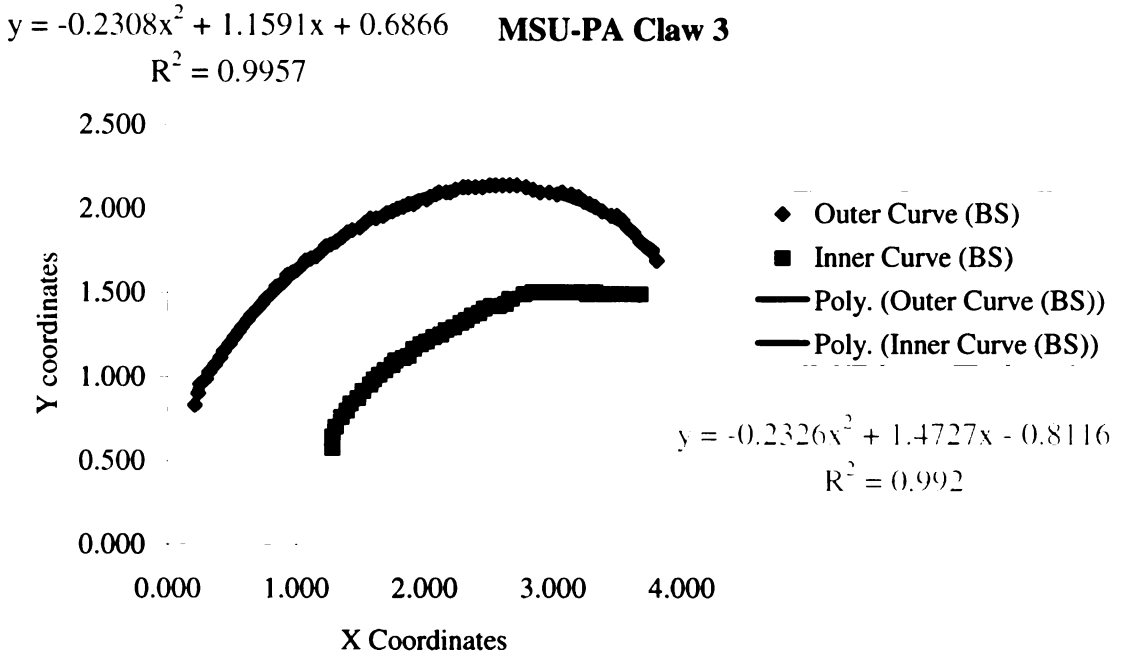

FIGURE 53. Plotted Bookstein coordinates taken from the inner and outer curves of MSU-PA claw 3, with trend lines and matching equations.

MSU-PA Claw 4							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
4.530	1.530	3.113	1.443	4.450	1.210	3.038	1.142
4.500	1.570	3.085	1.481	4.400	1.240	2.991	1.170
4.450	1.600	3.038	1.509	4.340	1.260	2.934	1.189
4.420	1.630	3.009	1.538	4.310	1.270	2.906	1.198
4.380	1.660	2.972	1.566	4.280	1.280	2.877	1.208
4.340	1.690	2.934	1.594	4.250	1.280	2.849	1.208
4.290	1.720	2.887	1.623	4.210	1.300	2.811	1.226
4.260	1.750	2.858	1.651	4.170	1.300	2.774	1.226
4.210	1.760	2.811	1.660	4.130	1.310	2.736	1.236
4.170	1.780	2.774	1.679	4.090	1.310	2.698	1.236
4.120	1.810	2.726	1.708	4.040	1.320	2.651	1.245
4.090	1.820	2.698	1.717	4.000	1.330	2.613	1.255
4.040	1.850	2.651	1.745	3.960	1.330	2.575	1.255
3.990	1.860	2.604	1.755	3.900	1.330	2.519	1.255
3.960	1.880	2.575	1.774	3.870	1.330	2.491	1.255
3.910	1.890	2.528	1.783	3.830	1.340	2.453	1.264
3.870	1.900	2.491	1.792	3.790	1.340	2.415	1.264
3.830	1.920	2.453	1.811	3.750	1.340	2.377	1.264
3.790	1.930	2.415	1.821	3.700	1.340	2.330	1.264
3.740	1.940	2.368	1.830	3.650	1.340	2.283	1.264
3.710	1.960	2.340	1.849	3.600	1.330	2.236	1.255
3.660	1.980	2.292	1.868	3.550	1.310	2.189	1.236
3.620	1.990	2.255	1.877	3.510	1.300	2.151	1.226
3.570	2.000	2.208	1.887	3.470	1.290	2.113	1.217
3.510	2.010	2.151	1.896	3.420	1.270	2.066	1.198
3.450	2.030	2.094	1.915	3.380	1.260	2.028	1.189
3.410	2.040	2.057	1.925	3.350	1.240	2.000	1.170
3.370	2.040	2.019	1.925	3.310	1.230	1.962	1.160
3.320	2.030	1.972	1.915	3.260	1.210	1.915	1.142
3.280	2.030	1.934	1.915	3.220	1.190	1.877	1.123
3.240	2.030	1.896	1.915	3.190	1.170	1.849	1.104
3.190	2.030	1.849	1.915	3.150	1.150	1.811	1.085
3.130	2.030	1.792	1.915	3.110	1.140	1.774	1.075
3.100	2.030	1.764	1.915	3.080	1.120	1.745	1.057
3.050	2.030	1.717	1.915	3.040	1.100	1.708	1.038
2.990	2.030	1.660	1.915	3.000	1.080	1.670	1.019
2.910	2.040	1.585	1.925	2.960	1.060	1.632	1.000
2.870	2.020	1.547	1.906	2.930	1.030	1.604	0.972
2.830	2.010	1.509	1.896	2.900	1.000	1.575	0.943
2.790	1.990	1.472	1.877	2.860	0.980	1.538	0.925
2.750	1.970	1.434	1.858	2.830	0.940	1.509	0.887
2.700	1.950	1.387	1.840	2.790	0.920	1.472	0.868

TABLE 50. Raw and Bookstein coordinates taken from the outer and inner curves of MSU-PA claw 4.

TABLE 50 (cont'd)

2.660	1.920	1.349	1.811	2.760	0.890	1.443	0.840
2.620	1.900	1.311	1.792	2.730	0.850	1.415	0.802
2.600	1.880	1.292	1.774	2.710	0.820	1.396	0.774
2.570	1.860	1.264	1.755	2.690	0.770	1.377	0.726
2.530	1.840	1.226	1.736	2.660	0.740	1.349	0.698
2.500	1.820	1.198	1.717	2.650	0.690	1.340	0.651
2.460	1.800	1.160	1.698	2.630	0.640	1.321	0.604
2.420	1.780	1.123	1.679	2.610	0.600	1.302	0.566
2.370	1.760	1.075	1.660	2.600	0.560	1.292	0.528
2.320	1.750	1.028	1.651	2.590	0.520	1.283	0.491
2.290	1.740	1.000	1.642				
2.260	1.710	0.972	1.613				
2.230	1.690	0.943	1.594				
2.200	1.680	0.915	1.585				
2.160	1.660	0.877	1.566				
2.120	1.640	0.840	1.547				
2.090	1.620	0.811	1.528				
2.040	1.600	0.764	1.509				
2.000	1.570	0.726	1.481				
1.960	1.550	0.689	1.462				
1.920	1.530	0.651	1.443				
1.870	1.500	0.604	1.415				
1.830	1.470	0.566	1.387				
1.780	1.450	0.519	1.368				
1.750	1.420	0.491	1.340				
1.710	1.400	0.453	1.321				
1.680	1.380	0.425	1.302				
1.650	1.350	0.396	1.274				
1.610	1.320	0.358	1.245				
1.590	1.280	0.340	1.208				
1.560	1.260	0.311	1.189				
1.530	1.230	0.283	1.160				
1.490	1.190	0.245	1.123				
1.460	1.170	0.217	1.104				
1.430	1.130	0.189	1.066				
1.400	1.100	0.160	1.038				
1.380	1.050	0.142	0.991				
1.350	1.010	0.113	0.953				
1.300	0.970	0.066	0.915				
1.270	0.930	0.038	0.877				
1.230	0.890	0.000	0.840				
1.210	0.840	-0.019	0.792				
1.190	0.810	-0.038	0.764				
1.160	0.760	-0.066	0.717				
1.150	0.720	-0.075	0.679				
1.130	0.670	-0.094	0.632				

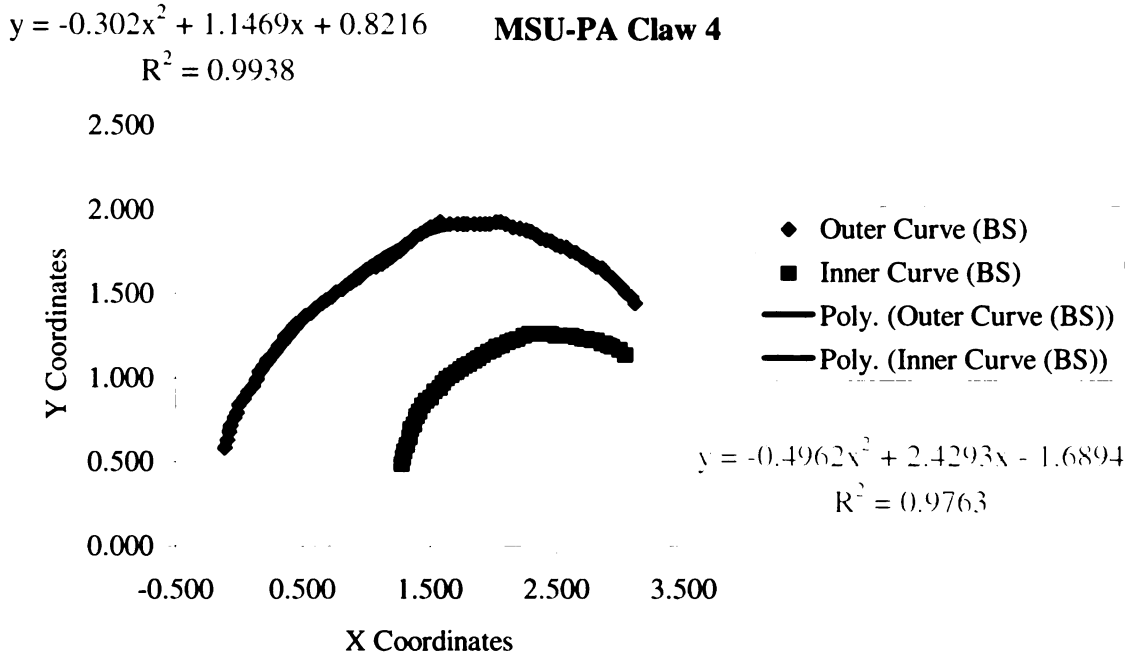

FIGURE 54. Plotted Bookstein coordinates taken from the inner and outer curves of MSU-PA claw 4, with trend lines and matching equations.

C22026 Claw 1							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
2.240	3.210	1.478	2.841	2.350	3.090	1.575	2.735
2.210	3.190	1.451	2.823	2.340	3.040	1.566	2.690
2.170	2.170	1.416	1.920	2.310	3.000	1.540	2.655
2.140	3.150	1.389	2.788	2.300	2.970	1.531	2.628
2.130	3.120	1.381	2.761	2.260	2.930	1.496	2.593
2.100	3.100	1.354	2.743	2.240	2.880	1.478	2.549
2.080	3.070	1.336	2.717	2.250	2.830	1.487	2.504
2.070	3.030	1.327	2.681	2.250	2.780	1.487	2.460
2.050	3.000	1.310	2.655	2.230	2.730	1.469	2.416
2.020	2.980	1.283	2.637	2.220	2.680	1.460	2.372
2.000	2.960	1.265	2.619	2.210	2.650	1.451	2.345
1.970	2.930	1.239	2.593	2.200	2.590	1.442	2.292
1.950	2.900	1.221	2.566	2.210	2.550	1.451	2.257
1.920	2.870	1.195	2.540	2.210	2.500	1.451	2.212
1.890	2.850	1.168	2.522	2.220	2.470	1.460	2.186
1.870	2.820	1.150	2.496	2.240	2.440	1.478	2.159
1.840	2.800	1.124	2.478	2.260	2.400	1.496	2.124
1.820	2.770	1.106	2.451	2.240	2.370	1.478	2.097
1.800	2.740	1.088	2.425	2.230	2.330	1.469	2.062
1.770	2.720	1.062	2.407	2.220	2.300	1.460	2.035
1.750	2.680	1.044	2.372	2.200	2.270	1.442	2.009
1.720	2.650	1.018	2.345	2.180	2.240	1.425	1.982
1.710	2.620	1.009	2.319	2.170	2.200	1.416	1.947
1.690	2.600	0.991	2.301	2.160	2.150	1.407	1.903
1.680	2.570	0.982	2.274	2.150	2.120	1.398	1.876
1.650	2.540	0.956	2.248	2.140	2.080	1.389	1.841
1.630	2.510	0.938	2.221	2.130	2.040	1.381	1.805
1.610	2.490	0.920	2.204	2.130	2.000	1.381	1.770
1.590	2.460	0.903	2.177	2.110	1.970	1.363	1.743
1.570	2.430	0.885	2.150	2.100	1.920	1.354	1.699
1.550	2.400	0.867	2.124	2.080	1.890	1.336	1.673
1.520	2.380	0.841	2.106	2.070	1.860	1.327	1.646
1.490	2.350	0.814	2.080	2.060	1.810	1.319	1.602
1.460	2.320	0.788	2.053	2.060	1.770	1.319	1.566
1.440	2.270	0.770	2.009	2.040	1.730	1.301	1.531
1.400	2.240	0.735	1.982	2.030	1.690	1.292	1.496
1.380	2.200	0.717	1.947	2.010	1.640	1.274	1.451
1.350	2.160	0.690	1.912	2.000	1.600	1.265	1.416
1.340	2.140	0.681	1.894	1.980	1.560	1.248	1.381
1.310	2.090	0.655	1.850	1.960	1.520	1.230	1.345
1.290	2.060	0.637	1.823	1.950	1.470	1.221	1.301
1.270	2.030	0.619	1.796	1.940	1.430	1.212	1.265

TABLE 51. Raw and Bookstein coordinates taken from the outer and inner curves of C22026 claw 1.

TABLE 51 (cont'd)

1.240	1.980	0.593	1.752	1.940	1.390	1.212	1.230
1.230	1.950	0.584	1.726	1.930	1.350	1.204	1.195
1.210	1.920	0.566	1.699	1.920	1.300	1.195	1.150
1.200	1.880	0.558	1.664	1.910	1.270	1.186	1.124
1.180	1.850	0.540	1.637	1.910	1.220	1.186	1.080
1.160	1.820	0.522	1.611	1.900	1.180	1.177	1.044
1.150	1.790	0.513	1.584	1.900	1.140	1.177	1.009
1.140	1.760	0.504	1.558	1.890	1.090	1.168	0.965
1.120	1.710	0.487	1.513	1.890	1.050	1.168	0.929
1.100	1.670	0.469	1.478	1.890	1.010	1.168	0.894
1.080	1.640	0.451	1.451	1.880	0.970	1.159	0.858
1.070	1.600	0.442	1.416	1.880	0.930	1.159	0.823
1.060	1.570	0.434	1.389	1.870	0.880	1.150	0.779
1.050	1.530	0.425	1.354	1.860	0.830	1.142	0.735
1.040	1.490	0.416	1.319	1.850	0.800	1.133	0.708
1.030	1.430	0.407	1.265	1.840	0.760	1.124	0.673
1.010	1.400	0.389	1.239	1.830	0.710	1.115	0.628
0.990	1.350	0.372	1.195	1.830	0.670	1.115	0.593
0.980	1.320	0.363	1.168	1.820	0.620	1.106	0.549
0.970	1.270	0.354	1.124	1.830	0.580	1.115	0.513
0.950	1.240	0.336	1.097	1.830	0.540	1.115	0.478
0.930	1.200	0.319	1.062	1.830	0.500	1.115	0.442
0.910	1.160	0.301	1.027	1.850	0.450	1.133	0.398
0.900	1.120	0.292	0.991	1.850	0.400	1.133	0.354
0.870	1.080	0.265	0.956				
0.850	1.040	0.248	0.920				
0.840	0.990	0.239	0.876				
0.830	0.950	0.230	0.841				
0.810	0.900	0.212	0.796				
0.800	0.860	0.204	0.761				
0.790	0.820	0.195	0.726				
0.780	0.790	0.186	0.699				
0.770	0.740	0.177	0.655				
0.750	0.700	0.159	0.619				
0.730	0.670	0.142	0.593				
0.720	0.640	0.133	0.566				
0.710	0.590	0.124	0.522				
0.710	0.550	0.124	0.487				
0.690	0.530	0.106	0.469				
0.690	0.490	0.106	0.434				
0.670	0.440	0.088	0.389				
0.660	0.400	0.080	0.354				
0.640	0.360	0.062	0.319				
0.630	0.310	0.053	0.274				
0.620	0.270	0.044	0.239				
0.610	0.230	0.035	0.204				

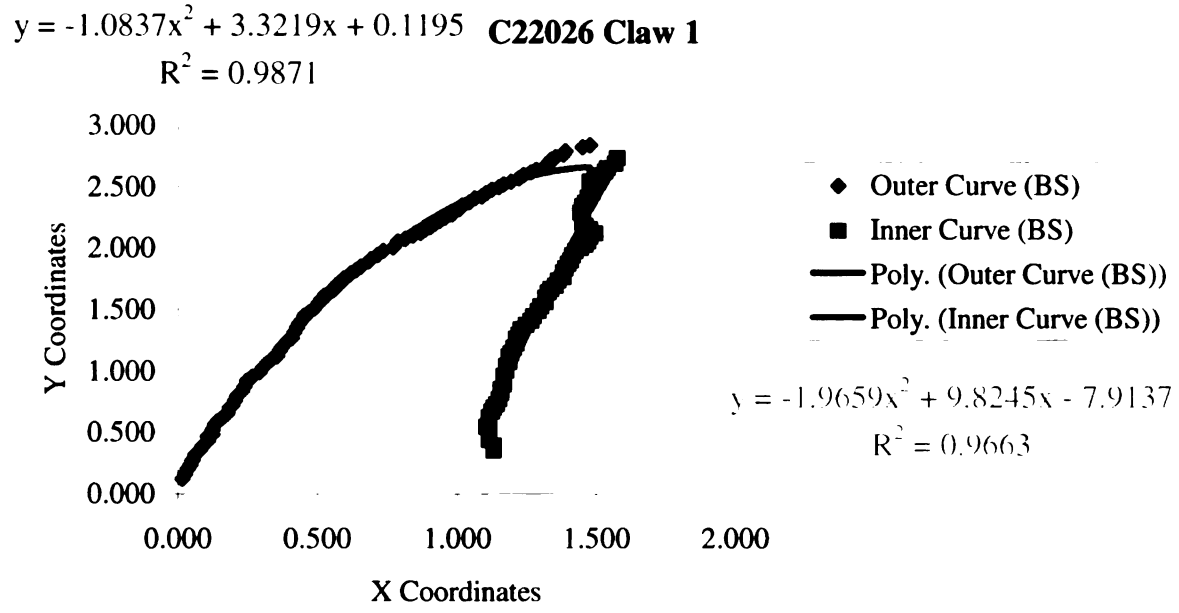

FIGURE 55. Plotted Bookstein coordinates taken from the inner and outer curves of C22026 claw 1, with trend lines and matching equations.

C22026 Claw 2							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
2.520	3.410	1.815	3.157	2.720	3.340	2.000	3.093
2.480	3.390	1.778	3.139	2.730	3.310	2.009	3.065
2.440	3.370	1.741	3.120	2.730	3.260	2.009	3.019
2.410	3.350	1.713	3.102	2.730	3.210	2.009	2.972
2.370	3.320	1.676	3.074	2.720	3.180	2.000	2.944
2.350	3.290	1.657	3.046	2.720	3.130	2.000	2.898
2.320	3.280	1.630	3.037	2.710	3.090	1.991	2.861
2.290	3.250	1.602	3.009	2.700	3.050	1.981	2.824
2.250	3.220	1.565	2.981	2.700	3.020	1.981	2.796
2.220	3.190	1.537	2.954	2.680	2.990	1.963	2.769
2.190	3.150	1.509	2.917	2.660	2.960	1.944	2.741
2.170	3.120	1.491	2.889	2.650	2.930	1.935	2.713
2.130	3.080	1.454	2.852	2.630	2.900	1.917	2.685
2.110	3.050	1.435	2.824	2.620	2.850	1.907	2.639
2.080	3.030	1.407	2.806	2.600	2.810	1.889	2.602
2.050	3.000	1.380	2.778	2.590	2.770	1.880	2.565
2.020	2.960	1.352	2.741	2.570	2.750	1.861	2.546
1.990	2.930	1.324	2.713	2.560	2.720	1.852	2.519
1.970	2.900	1.306	2.685	2.540	2.690	1.833	2.491
1.930	2.850	1.269	2.639	2.530	2.660	1.824	2.463
1.910	2.820	1.250	2.611	2.510	2.630	1.806	2.435
1.890	2.780	1.231	2.574	2.500	2.600	1.796	2.407
1.860	2.740	1.204	2.537	2.490	2.560	1.787	2.370
1.830	2.710	1.176	2.509	2.480	2.530	1.778	2.343
1.790	2.680	1.139	2.481	2.470	2.490	1.769	2.306
1.760	2.640	1.111	2.444	2.460	2.460	1.759	2.278
1.740	2.610	1.093	2.417	2.440	2.440	1.741	2.259
1.710	2.570	1.065	2.380	2.420	2.410	1.722	2.231
1.680	2.530	1.037	2.343	2.410	2.380	1.713	2.204
1.650	2.490	1.009	2.306	2.390	2.350	1.694	2.176
1.630	2.460	0.991	2.278	2.380	2.330	1.685	2.157
1.600	2.420	0.963	2.241	2.370	2.290	1.676	2.120
1.560	2.370	0.926	2.194	2.350	2.260	1.657	2.093
1.540	2.330	0.907	2.157	2.340	2.220	1.648	2.056
1.510	2.290	0.880	2.120	2.330	2.180	1.639	2.019
1.470	2.260	0.843	2.093	2.320	2.150	1.630	1.991
1.450	2.220	0.824	2.056	2.310	2.110	1.620	1.954
1.430	2.190	0.806	2.028	2.290	2.070	1.602	1.917
1.410	2.160	0.787	2.000	2.280	2.030	1.593	1.880
1.390	2.120	0.769	1.963	2.260	1.990	1.574	1.843
1.370	2.090	0.750	1.935	2.240	1.940	1.556	1.796
1.350	2.050	0.731	1.898	2.220	1.890	1.537	1.750

TABLE 52. Raw and Bookstein coordinates taken from the outer and inner curves of C22026 claw 2.

TABLE 52 (cont'd)

1.330	2.030	0.713	1.880	2.200	1.840	1.519	1.704
1.310	2.010	0.694	1.861	2.180	1.800	1.500	1.667
1.290	1.980	0.676	1.833	2.170	1.760	1.491	1.630
1.280	1.960	0.667	1.815	2.150	1.720	1.472	1.593
1.260	1.930	0.648	1.787	2.140	1.680	1.463	1.556
1.240	1.900	0.630	1.759	2.130	1.640	1.454	1.519
1.230	1.880	0.620	1.741	2.100	1.600	1.426	1.481
1.220	1.860	0.611	1.722	2.080	1.550	1.407	1.435
1.200	1.820	0.593	1.685	2.060	1.510	1.389	1.398
1.180	1.790	0.574	1.657	2.040	1.460	1.370	1.352
1.160	1.760	0.556	1.630	2.020	1.410	1.352	1.306
1.140	1.730	0.537	1.602	2.000	1.370	1.333	1.269
1.120	1.700	0.519	1.574	1.980	1.330	1.315	1.231
1.100	1.650	0.500	1.528	1.950	1.300	1.287	1.204
1.080	1.610	0.481	1.491	1.930	1.260	1.269	1.167
1.070	1.560	0.472	1.444	1.920	1.240	1.259	1.148
1.060	1.520	0.463	1.407	1.900	1.200	1.241	1.111
1.040	1.480	0.444	1.370	1.880	1.160	1.222	1.074
1.030	1.450	0.435	1.343	1.870	1.110	1.213	1.028
1.020	1.420	0.426	1.315	1.850	1.080	1.194	1.000
1.020	1.390	0.426	1.287	1.830	1.030	1.176	0.954
1.020	1.360	0.426	1.259	1.840	0.990	1.185	0.917
1.010	1.330	0.417	1.231	1.830	0.930	1.176	0.861
1.000	1.230	0.407	1.139	1.800	0.890	1.148	0.824
0.990	1.240	0.398	1.148	1.780	0.850	1.130	0.787
0.970	1.210	0.380	1.120	1.780	0.830	1.130	0.769
0.970	1.170	0.380	1.083	1.770	0.780	1.120	0.722
0.950	1.130	0.361	1.046	1.770	0.750	1.120	0.694
0.920	1.100	0.333	1.019	1.760	0.710	1.111	0.657
0.900	1.070	0.315	0.991	1.740	0.660	1.093	0.611
0.880	1.040	0.296	0.963	1.740	0.630	1.093	0.583
0.860	1.000	0.278	0.926	1.730	0.600	1.083	0.556
0.860	0.960	0.278	0.889	1.720	0.550	1.074	0.509
0.860	0.920	0.278	0.852	1.730	0.510	1.083	0.472
0.820	0.880	0.241	0.815	1.730	0.470	1.083	0.435
0.800	0.840	0.222	0.778	1.720	0.420	1.074	0.389
0.770	0.790	0.194	0.731	1.720	0.390	1.074	0.361
0.750	0.750	0.176	0.694	1.720	0.350	1.074	0.324
0.740	0.710	0.167	0.657	1.730	0.310	1.083	0.287
0.730	0.680	0.157	0.630	1.730	0.260	1.083	0.241
0.710	0.680	0.139	0.630	1.720	0.220	1.074	0.204
0.700	0.590	0.130	0.546				
0.690	0.540	0.120	0.500				
0.680	0.510	0.111	0.472				
0.670	0.450	0.102	0.417				
0.660	0.420	0.093	0.389				

TABLE 52 (cont'd)

0.650	0.380	0.083	0.352
0.640	0.330	0.074	0.306
0.640	0.290	0.074	0.269
0.640	0.260	0.074	0.241

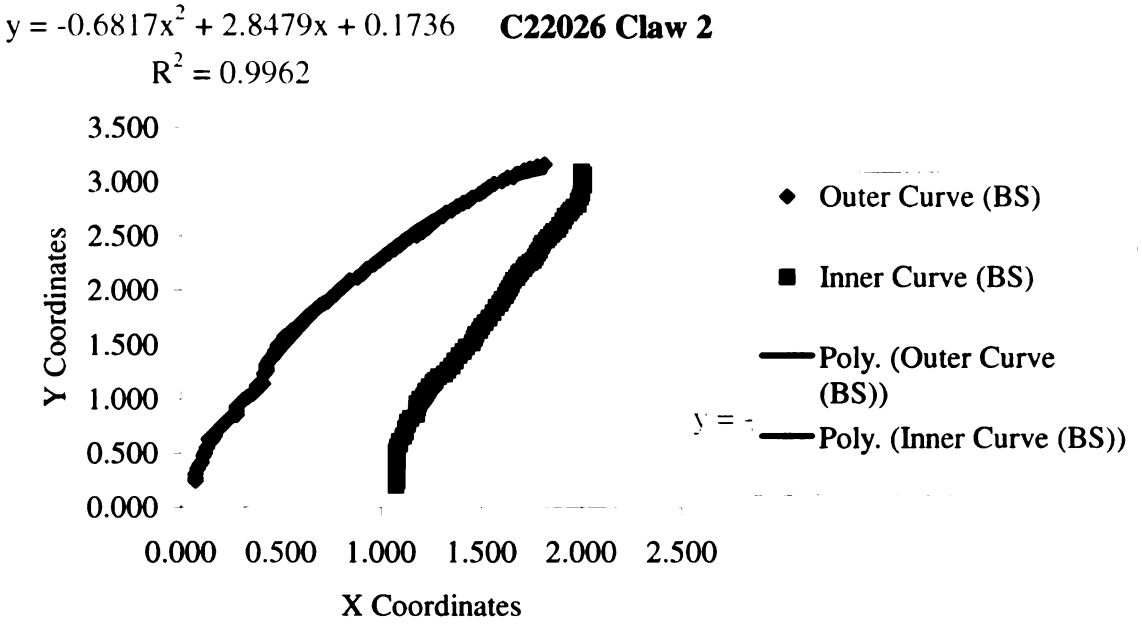

FIGURE 56. Plotted Bookstein coordinates taken from the inner and outer curves of C22026 claw 2, with trend lines and matching equations.

C22026 Claw 3							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
2.930	1.720	1.724	2.966	2.980	1.670	1.810	2.879
2.890	1.710	1.655	2.948	2.970	1.630	1.793	2.810
2.870	1.690	1.621	2.914	2.960	1.590	1.776	2.741
2.840	1.670	1.569	2.879	2.950	1.570	1.759	2.707
2.800	1.650	1.500	2.845	2.930	1.530	1.724	2.638
2.770	1.630	1.448	2.810	2.920	1.490	1.707	2.569
2.740	1.600	1.397	2.759	2.910	1.450	1.690	2.500
2.720	1.590	1.362	2.741	2.900	1.420	1.672	2.448
2.690	1.580	1.310	2.724	2.890	1.400	1.655	2.414
2.660	1.560	1.259	2.690	2.890	1.370	1.655	2.362
2.630	1.540	1.207	2.655	2.880	1.340	1.638	2.310
2.610	1.520	1.172	2.621	2.860	1.320	1.603	2.276
2.600	1.510	1.155	2.603	2.870	1.280	1.621	2.207
2.580	1.500	1.121	2.586	2.870	1.250	1.621	2.155
2.550	1.480	1.069	2.552	2.850	1.220	1.586	2.103
2.540	1.460	1.052	2.517	2.840	1.180	1.569	2.034
2.520	1.440	1.017	2.483	2.840	1.160	1.569	2.000
2.350	1.410	0.724	2.431	2.830	1.130	1.552	1.948
2.470	1.390	0.931	2.397	2.820	1.100	1.534	1.897
2.450	1.360	0.897	2.345	2.820	1.070	1.534	1.845
2.420	1.330	0.845	2.293	2.810	1.040	1.517	1.793
2.400	1.300	0.810	2.241	2.800	1.010	1.500	1.741
2.370	1.270	0.759	2.190	2.800	0.980	1.500	1.690
2.350	1.260	0.724	2.172	2.790	0.960	1.483	1.655
2.330	1.230	0.690	2.121	2.800	0.930	1.500	1.603
2.320	1.200	0.672	2.069	2.800	0.900	1.500	1.552
2.290	1.180	0.621	2.034	2.800	0.860	1.500	1.483
2.290	1.150	0.621	1.983	2.790	0.830	1.483	1.431
2.260	1.120	0.569	1.931	2.790	0.800	1.483	1.379
2.240	1.090	0.534	1.879	2.770	0.760	1.448	1.310
2.230	1.060	0.517	1.828	2.760	0.730	1.431	1.259
2.220	1.030	0.500	1.776	2.740	0.690	1.397	1.190
2.200	1.000	0.466	1.724	2.730	0.660	1.379	1.138
2.190	0.970	0.448	1.672	2.730	0.620	1.379	1.069
2.170	0.940	0.414	1.621	2.710	0.580	1.345	1.000
2.160	0.910	0.397	1.569	2.700	0.550	1.328	0.948
2.150	0.880	0.379	1.517	2.670	0.530	1.276	0.914
2.130	0.860	0.345	1.483	2.640	0.490	1.224	0.845
2.110	0.830	0.310	1.431	2.630	0.440	1.207	0.759
2.100	0.800	0.293	1.379	2.600	0.400	1.155	0.690
2.090	0.760	0.276	1.310	2.590	0.360	1.138	0.621
2.080	0.720	0.259	1.241	2.580	0.320	1.121	0.552

TABLE 53. Raw and Bookstein coordinates taken from the outer and inner curves of C22026 claw 3.

TABLE 53 (cont'd)

2.070	0.680	0.241	1.172	2.580	0.290	1.121	0.500
2.060	0.640	0.224	1.103				
2.050	0.610	0.207	1.052				
2.030	0.580	0.172	1.000				
2.020	0.550	0.155	0.948				
2.010	0.520	0.138	0.897				
2.000	0.490	0.121	0.845				
1.990	0.450	0.103	0.776				
1.990	0.420	0.103	0.724				
1.970	0.380	0.069	0.655				
1.960	0.350	0.052	0.603				
1.960	0.300	0.052	0.517				
1.950	0.260	0.034	0.448				
1.950	0.220	0.034	0.379				
1.950	0.180	0.034	0.310				

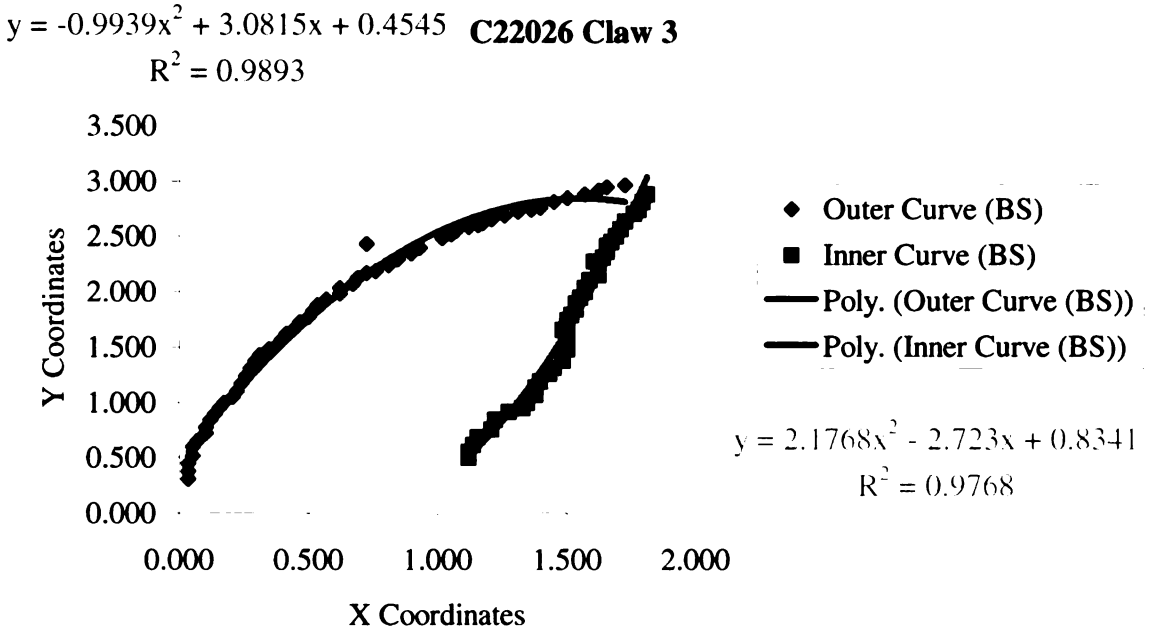

FIGURE 57. Plotted Bookstein coordinates taken from the inner and outer curves of C22026 claw 3, with trend lines and matching equations.

C213395 Claw 1							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
1.940	2.610	1.191	2.373	2.060	2.550	1.300	2.318
1.910	2.600	1.164	2.364	2.040	2.520	1.282	2.291
1.870	2.590	1.127	2.355	2.030	2.500	1.273	2.273
1.830	2.580	1.091	2.345	2.020	2.470	1.264	2.245
1.800	2.560	1.064	2.327	2.020	2.430	1.264	2.209
1.770	2.540	1.036	2.309	2.010	2.380	1.255	2.164
1.750	2.520	1.018	2.291	1.990	2.360	1.236	2.145
1.720	2.490	0.991	2.264	1.980	2.330	1.227	2.118
1.700	2.470	0.973	2.245	1.970	2.300	1.218	2.091
1.670	2.460	0.945	2.236	1.950	2.260	1.200	2.055
1.640	2.430	0.918	2.209	1.940	2.230	1.191	2.027
1.600	2.410	0.882	2.191	1.910	2.190	1.164	1.991
1.550	2.380	0.836	2.164	1.890	2.160	1.145	1.964
1.510	2.360	0.800	2.145	1.880	2.130	1.136	1.936
1.490	2.340	0.782	2.127	1.850	2.090	1.109	1.900
1.460	2.300	0.755	2.091	1.830	2.040	1.091	1.855
1.430	2.270	0.727	2.064	1.820	2.010	1.082	1.827
1.410	2.240	0.709	2.036	1.820	1.960	1.082	1.782
1.380	2.220	0.682	2.018	1.800	1.930	1.064	1.755
1.350	2.180	0.655	1.982	1.790	1.870	1.055	1.700
1.320	2.150	0.627	1.955	1.780	1.830	1.045	1.664
1.300	2.110	0.609	1.918	1.770	1.800	1.036	1.636
1.280	2.080	0.591	1.891	1.770	1.760	1.036	1.600
1.250	2.040	0.564	1.855	1.760	1.720	1.027	1.564
1.220	2.020	0.536	1.836	1.750	1.690	1.018	1.536
1.200	1.980	0.518	1.800	1.740	1.640	1.009	1.491
1.190	1.940	0.509	1.764	1.730	1.590	1.000	1.445
1.170	1.900	0.491	1.727	1.720	1.560	0.991	1.418
1.140	1.870	0.464	1.700	1.720	1.510	0.991	1.373
1.120	1.840	0.445	1.673	1.710	1.470	0.982	1.336
1.090	1.800	0.418	1.636	1.710	1.430	0.982	1.300
1.070	1.770	0.400	1.609	1.700	1.390	0.973	1.264
1.040	1.720	0.373	1.564	1.700	1.350	0.973	1.227
1.030	1.690	0.364	1.536	1.690	1.320	0.964	1.200
1.010	1.660	0.345	1.509	1.690	1.280	0.964	1.164
0.980	1.620	0.318	1.473	1.680	1.230	0.955	1.118
0.970	1.590	0.309	1.445	1.680	1.190	0.955	1.082
0.950	1.540	0.291	1.400	1.670	1.150	0.945	1.045
0.930	1.500	0.273	1.364	1.650	1.110	0.927	1.009
0.920	1.450	0.264	1.318	1.650	1.060	0.927	0.964
0.900	1.410	0.245	1.282	1.640	1.010	0.918	0.918
0.900	1.370	0.245	1.245	1.640	0.980	0.918	0.891

TABLE 54. Raw and Bookstein coordinates taken from the outer and inner curves of C213395 claw 1.

TABLE 54 (cont'd)

0.880	1.340	0.227	1.218	1.630	0.930	0.909	0.845
0.870	1.300	0.218	1.182	1.630	0.890	0.909	0.809
0.860	1.260	0.209	1.145	1.630	0.850	0.909	0.773
0.840	1.220	0.191	1.109	1.620	0.800	0.900	0.727
0.820	1.170	0.173	1.064	1.640	0.760	0.918	0.691
0.800	1.140	0.155	1.036	1.650	0.720	0.927	0.655
0.790	1.090	0.145	0.991	1.660	0.680	0.936	0.618
0.790	1.050	0.145	0.955	1.660	0.630	0.936	0.573
0.790	1.000	0.145	0.909	1.660	0.600	0.936	0.545
0.760	0.970	0.118	0.882	1.670	0.560	0.945	0.509
0.750	0.920	0.109	0.836	1.680	0.510	0.955	0.464
0.730	0.880	0.091	0.800	1.690	0.470	0.964	0.427
0.730	0.830	0.091	0.755	1.710	0.430	0.982	0.391
0.720	0.790	0.082	0.718	1.730	0.390	1.000	0.355
0.710	0.760	0.073	0.691	1.750	0.350	1.018	0.318
0.710	0.730	0.073	0.664	1.770	0.310	1.036	0.282
0.700	0.670	0.064	0.609	1.780	0.280	1.045	0.255
0.680	0.630	0.045	0.573	1.800	0.250	1.064	0.227
0.680	0.580	0.045	0.527				
0.680	0.530	0.045	0.482				
0.680	0.480	0.045	0.436				

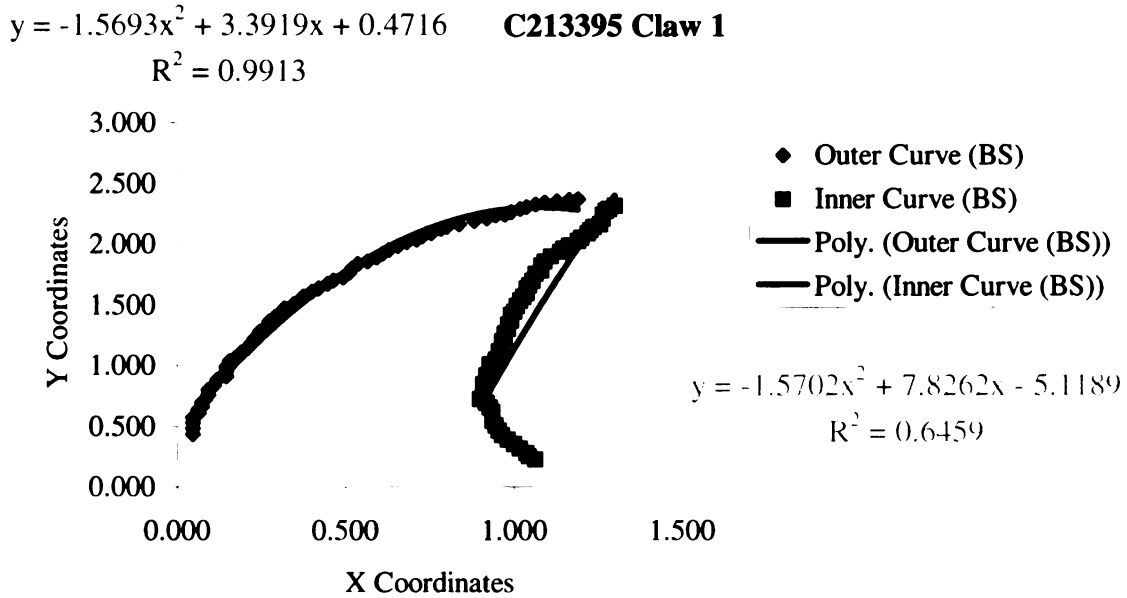

FIGURE 58. Plotted Bookstein coordinates taken from the inner and outer curves of C213395 claw 1, with trend lines and matching equations.

C-CAD Claw 2							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
1.870	2.040	0.885	2.125	1.910	2.030	0.927	2.115
1.860	2.000	0.875	2.083	1.930	2.000	0.948	2.083
1.830	1.960	0.844	2.042	1.940	1.980	0.958	2.063
1.830	1.930	0.844	2.010	1.960	1.960	0.979	2.042
1.810	1.910	0.823	1.990	1.980	1.940	1.000	2.021
1.760	1.870	0.771	1.948	1.990	1.900	1.010	1.979
1.790	1.830	0.802	1.906	1.990	1.860	1.010	1.938
1.770	1.780	0.781	1.854	2.000	1.840	1.021	1.917
1.760	1.740	0.771	1.813	2.000	1.810	1.021	1.885
1.760	1.710	0.771	1.781	2.010	1.780	1.031	1.854
1.740	1.670	0.750	1.740	2.010	1.750	1.031	1.823
1.730	1.640	0.740	1.708	2.010	1.730	1.031	1.802
1.710	1.610	0.719	1.677	2.010	1.700	1.031	1.771
1.690	1.570	0.698	1.635	2.020	1.660	1.042	1.729
1.680	1.530	0.688	1.594	2.020	1.620	1.042	1.688
1.640	1.490	0.646	1.552	2.020	1.560	1.042	1.625
1.620	1.440	0.625	1.500	2.020	1.520	1.042	1.583
1.590	1.400	0.594	1.458	2.020	1.460	1.042	1.521
1.590	1.360	0.594	1.417	2.020	1.420	1.042	1.479
1.570	1.340	0.573	1.396	2.020	1.370	1.042	1.427
1.550	1.300	0.552	1.354	2.010	1.320	1.031	1.375
1.530	1.270	0.531	1.323	2.010	1.280	1.031	1.333
1.510	1.240	0.510	1.292	2.000	1.240	1.021	1.292
1.500	1.220	0.500	1.271	2.000	1.200	1.021	1.250
1.490	1.190	0.490	1.240	1.990	1.160	1.010	1.208
1.470	1.160	0.469	1.208	1.990	1.100	1.010	1.146
1.450	1.130	0.448	1.177	1.990	1.090	1.010	1.135
1.430	1.110	0.427	1.156	1.970	1.060	0.990	1.104
1.410	1.070	0.406	1.115	1.970	1.030	0.990	1.073
1.390	1.030	0.385	1.073	1.950	0.990	0.969	1.031
1.370	1.000	0.365	1.042	1.940	0.960	0.958	1.000
1.360	0.970	0.354	1.010	1.920	0.930	0.938	0.969
1.250	0.710	0.240	0.740	1.910	0.910	0.927	0.948
1.220	0.670	0.208	0.698	1.900	0.870	0.917	0.906
1.210	0.630	0.198	0.656	1.880	0.850	0.896	0.885
1.190	0.590	0.177	0.615	1.870	0.820	0.885	0.854
1.170	0.560	0.156	0.583	1.870	0.790	0.885	0.823
1.160	0.530	0.146	0.552	1.860	0.760	0.875	0.792
1.140	0.490	0.125	0.510	1.860	0.730	0.875	0.760
1.110	0.440	0.094	0.458	1.860	0.700	0.875	0.729
1.090	0.390	0.073	0.406	1.860	0.670	0.875	0.698
1.080	0.370	0.063	0.385	1.850	0.620	0.865	0.646

TABLE 55. Raw and Bookstein coordinates taken from the outer and inner curves of C-CAD claw 2.

TABLE 55 (cont'd)

1.060	0.330	0.042	0.344	1.850	0.580	0.865	0.604
1.040	0.290	0.021	0.302	1.850	0.550	0.865	0.573
1.020	0.260	0.000	0.271	1.860	0.500	0.875	0.521
				1.860	0.460	0.875	0.479
				1.880	0.420	0.896	0.438
				1.910	0.380	0.927	0.396
				1.930	0.350	0.948	0.365
				1.940	0.320	0.958	0.333
				1.950	0.270	0.969	0.281
				1.960	0.220	0.979	0.229

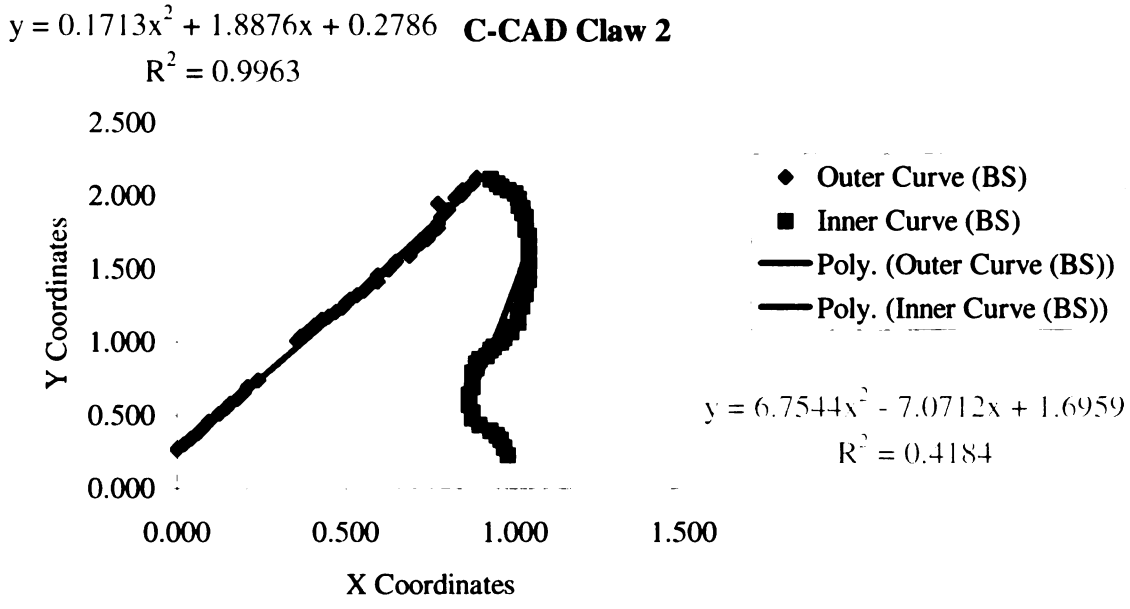

FIGURE 59. Plotted Bookstein coordinates taken from the inner and outer curves of C-CAD claw 2, with trend lines and matching equations.

C-CAD Claw 3							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
1.050	1.290	0.353	2.529	1.080	1.290	0.412	2.529
1.050	1.270	0.353	2.490	1.100	1.270	0.451	2.490
1.040	1.240	0.333	2.431	1.120	1.240	0.490	2.431
1.030	1.210	0.314	2.373	1.140	1.210	0.529	2.373
1.030	1.180	0.314	2.314	1.160	1.180	0.569	2.314
1.020	1.150	0.294	2.255	1.190	1.160	0.627	2.275
1.020	1.120	0.294	2.196	1.220	1.120	0.686	2.196
1.020	1.100	0.294	2.157	1.230	1.100	0.706	2.157
1.010	1.070	0.275	2.098	1.240	1.060	0.725	2.078
1.010	1.040	0.275	2.039	1.260	1.020	0.765	2.000
1.010	1.010	0.275	1.980	1.260	1.000	0.765	1.961
1.010	0.980	0.275	1.922	1.270	0.970	0.784	1.902
1.010	0.940	0.275	1.843	1.280	0.940	0.804	1.843
1.010	0.920	0.275	1.804	1.290	0.910	0.824	1.784
1.000	0.890	0.255	1.745	1.290	0.880	0.824	1.725
1.000	0.860	0.255	1.686	1.290	0.860	0.824	1.686
1.000	0.840	0.255	1.647	1.300	0.830	0.843	1.627
0.990	0.810	0.235	1.588	1.300	0.800	0.843	1.569
0.990	0.790	0.235	1.549	1.310	0.760	0.863	1.490
0.990	0.760	0.235	1.490	1.310	0.740	0.863	1.451
0.980	0.740	0.216	1.451	1.310	0.700	0.863	1.373
0.970	0.720	0.196	1.412	1.310	0.670	0.863	1.314
0.970	0.700	0.196	1.373	1.320	0.640	0.882	1.255
0.960	0.670	0.176	1.314	1.320	0.610	0.882	1.196
0.950	0.650	0.157	1.275	1.320	0.590	0.882	1.157
0.940	0.590	0.137	1.157	1.320	0.550	0.882	1.078
0.930	0.560	0.118	1.098	1.320	0.530	0.882	1.039
0.930	0.540	0.118	1.059	1.330	0.500	0.902	0.980
0.930	0.520	0.118	1.020	1.330	0.470	0.902	0.922
0.920	0.490	0.098	0.961	1.340	0.430	0.922	0.843
0.910	0.470	0.078	0.922	1.340	0.400	0.922	0.784
0.910	0.430	0.078	0.843	1.350	0.380	0.941	0.745
0.910	0.400	0.078	0.784	1.350	0.340	0.941	0.667
0.890	0.380	0.039	0.745	1.370	0.320	0.980	0.627
0.890	0.340	0.039	0.667	1.370	0.290	0.980	0.569
0.890	0.320	0.039	0.627	1.390	0.270	1.020	0.529
0.890	0.290	0.039	0.569	1.400	0.240	1.039	0.471
0.880	0.270	0.020	0.529	1.410	0.210	1.059	0.412
0.880	0.230	0.020	0.451	1.430	0.170	1.098	0.333
0.880	0.200	0.020	0.392	1.440	0.150	1.118	0.294
				1.440	0.120	1.118	0.235

TABLE 56. Raw and Bookstein coordinates taken from the outer and inner curves of C-CAD claw 3.

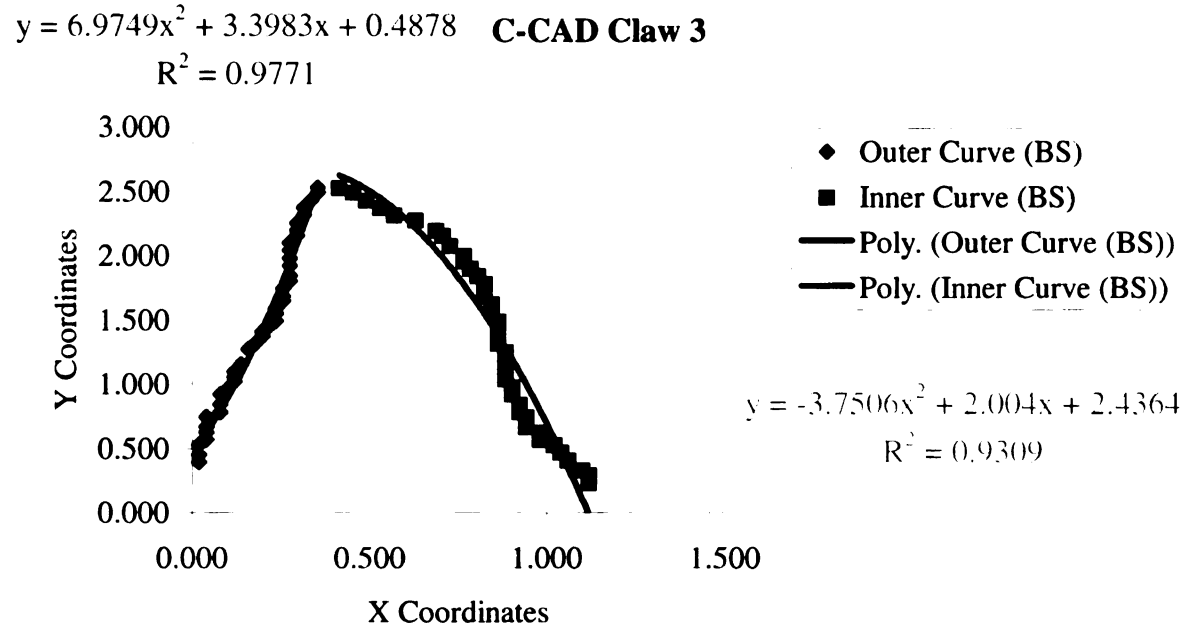

FIGURE 60. Plotted Bookstein coordinates taken from the inner and outer curves of C-CAD claw 3, with trend lines and matching equations.

C31011 Claw 3							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
2.960	3.840	1.236	2.446	3.510	3.440	1.586	2.191
2.920	3.820	1.210	2.433	3.510	3.370	1.586	2.146
2.870	3.800	1.178	2.420	3.510	3.330	1.586	2.121
2.820	3.780	1.146	2.408	3.490	3.290	1.573	2.096
2.790	3.750	1.127	2.389	3.480	3.270	1.567	2.083
2.740	3.720	1.096	2.369	3.460	3.230	1.554	2.057
2.700	3.690	1.070	2.350	3.430	3.190	1.535	2.032
2.650	3.670	1.038	2.338	3.410	3.160	1.522	2.013
2.620	3.610	1.019	2.299	3.390	3.110	1.510	1.981
2.610	3.570	1.013	2.274	3.380	3.070	1.503	1.955
2.580	3.530	0.994	2.248	3.350	3.020	1.484	1.924
2.560	3.500	0.981	2.229	3.330	2.960	1.471	1.885
2.520	3.470	0.955	2.210	3.310	2.910	1.459	1.854
2.490	3.430	0.936	2.185	3.280	2.850	1.439	1.815
2.450	3.410	0.911	2.172	3.260	2.800	1.427	1.783
2.400	3.380	0.879	2.153	3.250	2.750	1.420	1.752
2.370	3.340	0.860	2.127	3.230	2.700	1.408	1.720
2.350	3.290	0.847	2.096	3.210	2.640	1.395	1.682
2.310	3.270	0.822	2.083	3.190	2.580	1.382	1.643
2.290	3.230	0.809	2.057	3.180	2.510	1.376	1.599
2.260	3.180	0.790	2.025	3.160	2.430	1.363	1.548
2.220	3.150	0.764	2.006	3.140	2.400	1.350	1.529
2.190	3.090	0.745	1.968	3.110	2.350	1.331	1.497
2.150	3.050	0.720	1.943	3.100	2.300	1.325	1.465
2.110	3.010	0.694	1.917	3.070	2.240	1.306	1.427
2.070	2.970	0.669	1.892	3.050	2.180	1.293	1.389
2.040	2.930	0.650	1.866	3.020	2.130	1.274	1.357
2.010	2.880	0.631	1.834	3.000	2.070	1.261	1.318
1.980	2.830	0.611	1.803	2.970	2.020	1.242	1.287
1.950	2.790	0.592	1.777	2.930	1.990	1.217	1.268
1.920	2.740	0.573	1.745	2.910	1.940	1.204	1.236
1.900	2.680	0.561	1.707	2.890	1.900	1.191	1.210
1.870	2.650	0.541	1.688	2.860	1.850	1.172	1.178
1.850	2.600	0.529	1.656	2.850	1.820	1.166	1.159
1.830	2.560	0.516	1.631	2.830	1.760	1.153	1.121
1.810	2.530	0.503	1.611	2.820	1.710	1.146	1.089
1.790	2.490	0.490	1.586	2.810	1.650	1.140	1.051
1.750	2.440	0.465	1.554	2.790	1.600	1.127	1.019
1.730	2.400	0.452	1.529	2.780	1.540	1.121	0.981
1.710	2.350	0.439	1.497	2.780	1.490	1.121	0.949
1.680	2.320	0.420	1.478	2.770	1.450	1.115	0.924
1.660	2.280	0.408	1.452	2.770	1.400	1.115	0.892

TABLE 57. Raw and Bookstein coordinates taken from the outer and inner curves of C31011 claw 3.

TABLE 57 (cont'd)

1.630	2.240	0.389	1.427	2.770	1.370	1.115	0.873
1.610	2.210	0.376	1.408	2.780	1.320	1.121	0.841
1.590	2.170	0.363	1.382	2.800	1.290	1.134	0.822
1.570	2.140	0.350	1.363	2.820	1.240	1.146	0.790
1.540	2.100	0.331	1.338				
1.520	2.060	0.318	1.312				
1.510	2.020	0.312	1.287				
1.480	1.960	0.293	1.248				
1.460	1.920	0.280	1.223				
1.430	1.870	0.261	1.191				
1.410	1.830	0.248	1.166				
1.380	1.780	0.229	1.134				
1.360	1.740	0.217	1.108				
1.350	1.680	0.210	1.070				
1.330	1.630	0.197	1.038				
1.320	1.580	0.191	1.006				
1.310	1.530	0.185	0.975				
1.290	1.490	0.172	0.949				
1.270	1.450	0.159	0.924				
1.260	1.400	0.153	0.892				
1.240	1.340	0.140	0.854				
1.220	1.290	0.127	0.822				
1.200	1.240	0.115	0.790				
1.180	1.190	0.102	0.758				
1.150	1.150	0.083	0.732				
1.130	1.110	0.070	0.707				

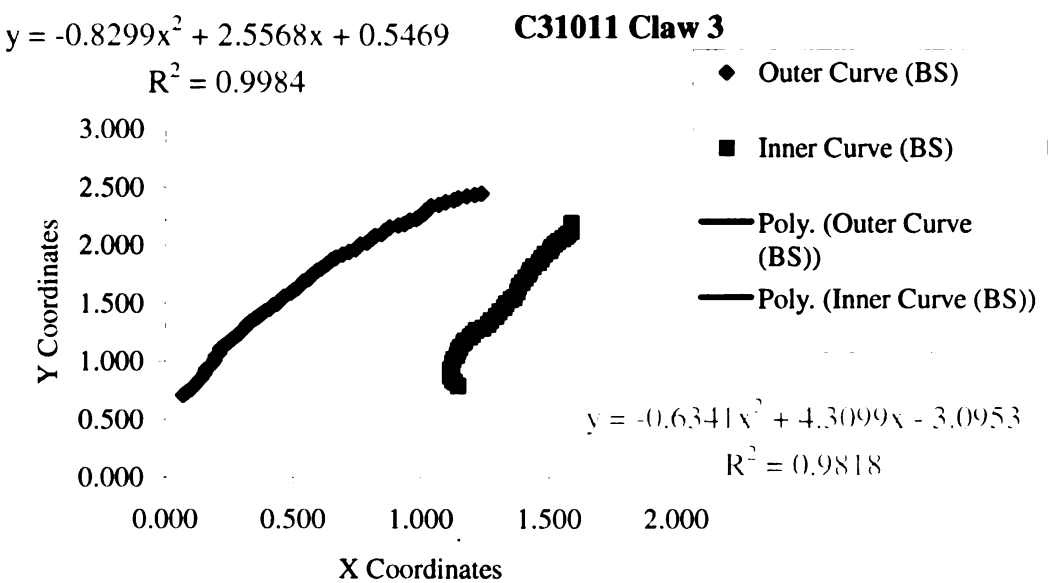

FIGURE 61. Plotted Bookstein coordinates taken from the inner and outer curves of C31011 claw 3, with trend lines and matching equations.

C31321 Claw 1							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
2.420	2.950	1.368	3.105	2.530	2.930	1.484	3.084
2.400	2.930	1.347	3.084	2.510	2.880	1.463	3.032
2.370	2.910	1.316	3.063	2.490	2.840	1.442	2.989
2.340	2.890	1.284	3.042	2.470	2.810	1.421	2.958
2.310	2.860	1.253	3.011	2.460	2.780	1.411	2.926
2.270	2.840	1.211	2.989	2.440	2.760	1.389	2.905
2.240	2.820	1.179	2.968	2.420	2.720	1.368	2.863
2.220	2.800	1.158	2.947	2.410	2.680	1.358	2.821
2.190	2.770	1.126	2.916	2.390	2.660	1.337	2.800
2.170	2.750	1.105	2.895	2.380	2.620	1.326	2.758
2.130	2.720	1.063	2.863	2.360	2.580	1.305	2.716
2.100	2.700	1.032	2.842	2.340	2.560	1.284	2.695
2.070	2.680	1.000	2.821	2.330	2.530	1.274	2.663
2.050	2.650	0.979	2.789	2.310	2.500	1.253	2.632
2.020	2.620	0.947	2.758	2.300	2.470	1.242	2.600
2.000	2.590	0.926	2.726	2.290	2.450	1.232	2.579
1.970	2.560	0.895	2.695	2.270	2.410	1.211	2.537
1.940	2.530	0.863	2.663	2.260	2.370	1.200	2.495
1.910	2.510	0.832	2.642	2.250	2.340	1.189	2.463
1.890	2.480	0.811	2.611	2.240	2.310	1.179	2.432
1.860	2.460	0.779	2.589	2.220	2.280	1.158	2.400
1.830	2.430	0.747	2.558	2.200	2.230	1.137	2.347
1.810	2.400	0.726	2.526	2.180	2.200	1.116	2.316
1.800	2.360	0.716	2.484	2.170	2.160	1.105	2.274
1.780	2.320	0.695	2.442	2.160	2.120	1.095	2.232
1.780	2.280	0.695	2.400	2.140	2.080	1.074	2.189
1.750	2.250	0.663	2.368	2.130	2.050	1.063	2.158
1.740	2.220	0.653	2.337	2.120	2.020	1.053	2.126
1.720	2.180	0.632	2.295	2.110	1.990	1.042	2.095
1.700	2.140	0.611	2.253	2.100	1.940	1.032	2.042
1.670	2.100	0.579	2.211	2.080	1.900	1.011	2.000
1.650	2.050	0.558	2.158	2.070	1.860	1.000	1.958
1.620	2.020	0.526	2.126	2.050	1.810	0.979	1.905
1.590	1.990	0.495	2.095	2.040	1.770	0.968	1.863
1.560	1.960	0.463	2.063	2.030	1.730	0.958	1.821
1.530	1.920	0.432	2.021	2.010	1.690	0.937	1.779
1.500	1.890	0.400	1.989	2.000	1.650	0.926	1.737
1.480	1.850	0.379	1.947	1.990	1.610	0.916	1.695
1.450	1.790	0.347	1.884	1.980	1.560	0.905	1.642
1.420	1.760	0.316	1.853	1.980	1.520	0.905	1.600
1.400	1.720	0.295	1.811	1.960	1.480	0.884	1.558
1.380	1.680	0.274	1.768	1.940	1.440	0.863	1.516

TABLE 58. Raw and Bookstein coordinates taken from the outer and inner curves of C31321 claw 1.

TABLE 58 (cont'd)

1.360	1.660	0.253	1.747	1.940	1.410	0.863	1.484
1.340	1.620	0.232	1.705	1.940	1.380	0.863	1.453
1.310	1.600	0.200	1.684	1.920	1.340	0.842	1.411
1.280	1.570	0.168	1.653	1.910	1.300	0.832	1.368
1.260	1.540	0.147	1.621	1.890	1.270	0.811	1.337
1.230	1.510	0.116	1.589	1.890	1.220	0.811	1.284
1.220	1.480	0.105	1.558	1.880	1.190	0.800	1.253
1.200	1.440	0.084	1.516	1.890	1.160	0.811	1.221
1.170	1.390	0.053	1.463	1.890	1.130	0.811	1.189
1.160	1.340	0.042	1.411	1.900	1.100	0.821	1.158
1.140	1.300	0.021	1.368	1.890	1.060	0.811	1.116
1.110	1.260	-0.011	1.326	1.910	1.000	0.832	1.053
1.080	1.220	-0.042	1.284	1.920	0.960	0.842	1.011
1.050	1.190	-0.074	1.253	1.920	0.930	0.842	0.979
1.030	1.150	-0.095	1.211	1.940	0.890	0.863	0.937
1.020	1.110	-0.105	1.168	1.960	0.860	0.884	0.905
1.000	1.070	-0.126	1.126	2.120	0.530	1.053	0.558
0.970	1.030	-0.158	1.084	2.150	0.490	1.084	0.516
0.970	1.000	-0.158	1.053	2.170	0.460	1.105	0.484
0.940	0.950	-0.189	1.000	2.190	0.430	1.126	0.453
0.930	0.900	-0.200	0.947	2.210	0.400	1.147	0.421
0.930	0.870	-0.200	0.916				
0.910	0.820	-0.221	0.863				
0.910	0.770	-0.221	0.811				
0.910	0.710	-0.221	0.747				
0.910	0.660	-0.221	0.695				
0.910	0.610	-0.221	0.642				
0.920	0.570	-0.211	0.600				
0.930	0.530	-0.200	0.558				
0.930	0.480	-0.200	0.505				
0.950	0.440	-0.179	0.463				
0.960	0.380	-0.168	0.400				
0.980	0.340	-0.147	0.358				
0.990	0.300	-0.137	0.316				
1.000	0.260	-0.126	0.274				
1.020	0.220	-0.105	0.232				
1.040	0.180	-0.084	0.189				

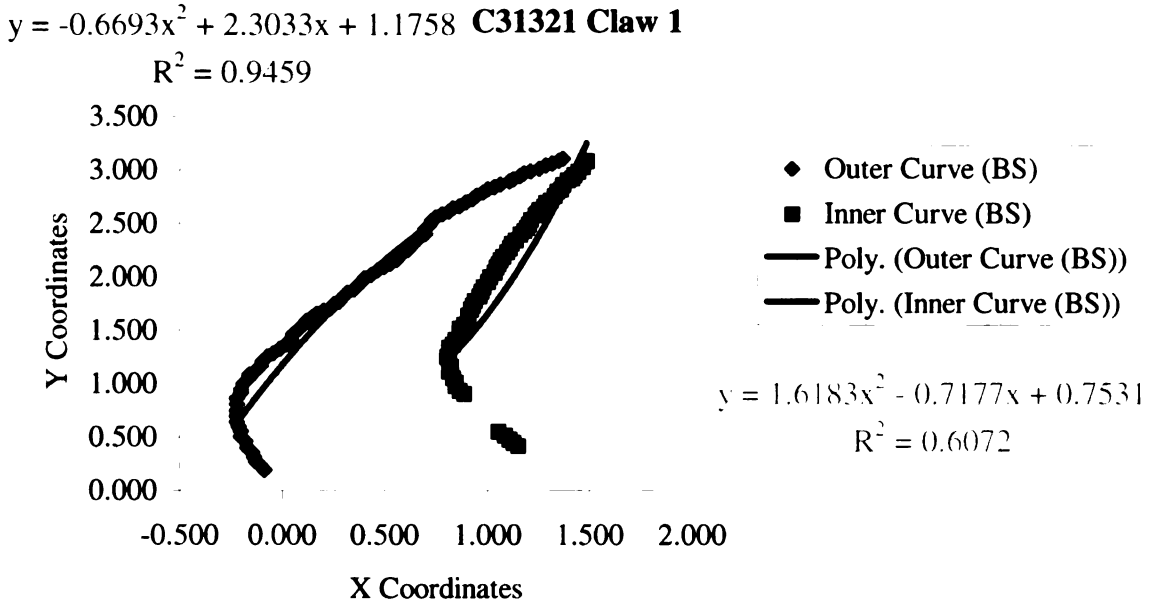

FIGURE 62. Plotted Bookstein coordinates taken from the inner and outer curves of C31321 claw 1, with trend lines and matching equations.

C31321 Claw 3							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
1.060	2.850	0.282	3.654	1.270	2.790	0.551	3.577
1.020	2.810	0.231	3.603	1.280	2.750	0.564	3.526
1.010	2.770	0.218	3.551	1.270	2.710	0.551	3.474
0.990	2.730	0.192	3.500	1.270	2.670	0.551	3.423
0.980	2.680	0.179	3.436	1.270	2.620	0.551	3.359
0.970	2.630	0.167	3.372	1.260	2.560	0.538	3.282
0.960	2.590	0.154	3.321	1.270	2.500	0.551	3.205
0.970	2.540	0.167	3.256	1.260	2.420	0.538	3.103
0.950	2.500	0.141	3.205	1.250	2.370	0.526	3.038
0.940	2.450	0.128	3.141	1.250	2.320	0.526	2.974
0.940	2.390	0.128	3.064	1.250	2.270	0.526	2.910
0.920	2.360	0.103	3.026	1.240	2.230	0.513	2.859
0.910	2.310	0.090	2.962	1.240	2.190	0.513	2.808
0.900	2.270	0.077	2.910	1.230	2.140	0.500	2.744
0.880	2.230	0.051	2.859	1.230	2.090	0.500	2.679
0.870	2.190	0.038	2.808	1.230	2.060	0.500	2.641
0.850	2.130	0.013	2.731	1.230	2.000	0.500	2.564
0.850	2.090	0.013	2.679	1.240	1.940	0.513	2.487
0.840	2.040	0.000	2.615	1.250	1.880	0.526	2.410
0.840	1.990	0.000	2.551	1.250	1.830	0.526	2.346
0.830	1.950	-0.013	2.500	1.260	1.790	0.538	2.295
0.830	1.910	-0.013	2.449	1.270	1.750	0.551	2.244

TABLE 59. Raw and Bookstein coordinates taken from the outer and inner curves of C31321 claw 3.

TABLE 59 (cont'd)

0.820	1.860	-0.026	2.385	1.270	1.700	0.551	2.179
0.800	1.830	-0.051	2.346	1.280	1.650	0.564	2.115
0.780	1.790	-0.077	2.295	1.280	1.610	0.564	2.064
0.770	1.750	-0.090	2.244	1.270	1.570	0.551	2.013
0.760	1.710	-0.103	2.192	1.270	1.530	0.551	1.962
0.750	1.670	-0.115	2.141	1.260	1.480	0.538	1.897
0.740	1.630	-0.128	2.090	1.270	1.450	0.551	1.859
0.720	1.570	-0.154	2.013	1.260	1.400	0.538	1.795
0.710	1.510	-0.167	1.936	1.260	1.350	0.538	1.731
0.700	1.460	-0.179	1.872	1.260	1.320	0.538	1.692
0.690	1.420	-0.192	1.821	1.260	1.270	0.538	1.628
0.690	1.350	-0.192	1.731	1.270	1.230	0.551	1.577
0.680	1.290	-0.205	1.654	1.290	1.180	0.577	1.513
0.680	1.250	-0.205	1.603	1.310	1.120	0.603	1.436
0.680	1.210	-0.205	1.551	1.320	1.080	0.615	1.385
0.670	1.170	-0.218	1.500	1.330	1.030	0.628	1.321
0.650	1.150	-0.244	1.474	1.350	1.000	0.654	1.282
0.640	1.110	-0.256	1.423	1.370	0.960	0.679	1.231
0.620	1.060	-0.282	1.359	1.390	0.920	0.705	1.179
0.600	1.020	-0.308	1.308	1.410	0.880	0.731	1.128
0.590	0.970	-0.321	1.244	1.440	0.840	0.769	1.077
0.590	0.930	-0.321	1.192	1.450	0.790	0.782	1.013
0.610	0.870	-0.295	1.115	1.470	0.760	0.808	0.974
0.630	0.820	-0.269	1.051	1.490	0.730	0.833	0.936
0.640	0.770	-0.256	0.987	1.510	0.680	0.859	0.872
0.640	0.720	-0.256	0.923	1.520	0.640	0.872	0.821
0.670	0.660	-0.218	0.846	1.530	0.590	0.885	0.756
0.680	0.600	-0.205	0.769	1.530	0.550	0.885	0.705
0.700	0.540	-0.179	0.692	1.530	0.510	0.885	0.654
0.700	0.490	-0.179	0.628	1.540	0.470	0.897	0.603
0.700	0.440	-0.179	0.564	1.560	0.420	0.923	0.538
0.710	0.380	-0.167	0.487	1.560	0.380	0.923	0.487
0.730	0.330	-0.141	0.423	1.560	0.350	0.923	0.449
0.750	0.290	-0.115	0.372	1.570	0.310	0.936	0.397
0.770	0.250	-0.090	0.321	1.580	0.270	0.949	0.346
				1.600	0.230	0.974	0.295
				1.620	0.180	1.000	0.231
				1.640	0.130	1.026	0.167

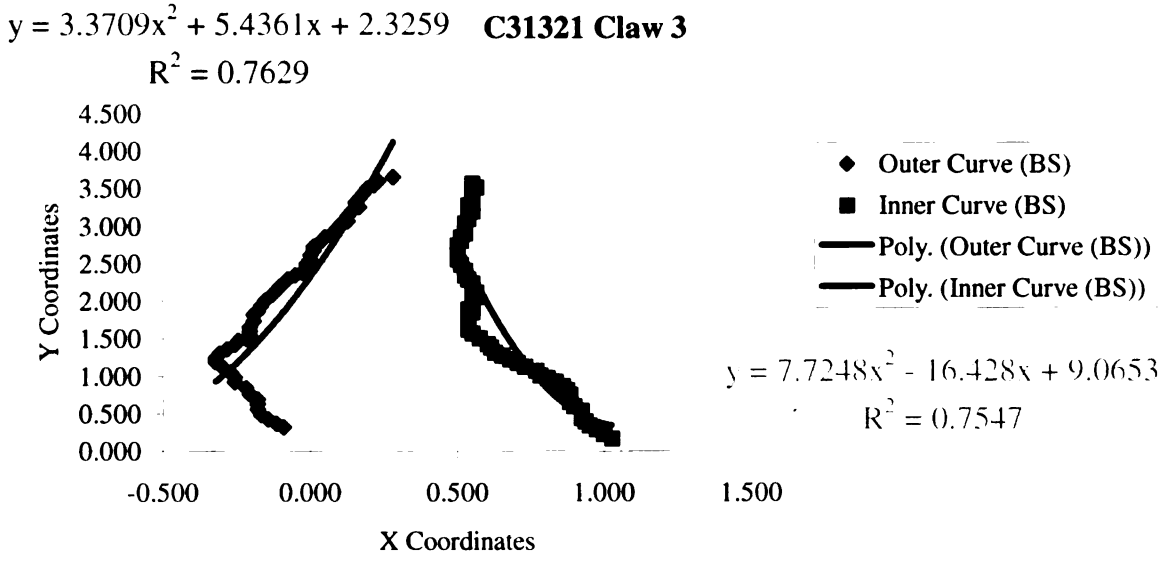

FIGURE 63. Plotted Bookstein coordinates taken from the inner and outer curves of C31321 claw 3, with trend lines and matching equations.

APPENDIX V

LIST OF PAIRS OF CORRELATED VARIABLES

Positively Correlated Variable Pairs	
centroid X coordinate	Bookstein L3 X coordinate
beta	Bookstein L3 X coordinate
centroid Y coordinate	Bookstein L3 Y coordinate
centroid size	Bookstein L3 Y coordinate
distance from L2 to L3	Bookstein L3 Y coordinate
distance from L1 to L3	Bookstein L3 Y coordinate
distance from L3 to L4	Bookstein L3 Y coordinate
alpha	Bookstein L3 Y coordinate
alpha/beta ratio	Bookstein L3 Y coordinate
outer curve C coefficient	Bookstein L3 Y coordinate
distance from L1 to L4	Bookstein L4 X coordinate
centroid X coordinate	beta
centroid Y coordinate	centroid size
distance from L2 to L3	centroid Y coordinate
distance from L1 to L3	centroid Y coordinate
distance from L3 to L4	centroid Y coordinate
centroid Y coordinate	alpha
centroid Y coordinate	alpha/beta ratio
centroid Y coordinate	outer curve B coefficient
centroid Y coordinate	outer curve C coefficient
distance from L2 to L3	centroid Size
distance from L1 to L3	centroid Size
distance from L3 to L4	centroid Size
alpha	centroid Size
alpha/beta ratio	centroid Size
outer curve C coefficient	centroid Size
distance from L1 to L3	distance from L2 to L3
distance from L3 to L4	distance from L2 to L3
alpha	distance from L2 to L3
alpha/beta ratio	distance from L2 to L3
outer curve C coefficient	distance from L2 to L3
distance from L1 to L3	distance from L3 to L4
outer curve C coefficient	distance from L1 to L3
alpha	distance from L3 to L4
alpha/beta ratio	distance from L3 to L4
outer curve C coefficient	distance from L3 to L4
alpha/beta ratio	distance from L1 to L4

TABLE 60. List of pairs of positively correlated morphometric variables.

TABLE 60 (cont'd)

alpha/beta ratio	alpha
outer curve C coefficient	alpha
aspect ratio	beta
outer curve coefficient A	outer curve coefficient B
outer curve coefficient C	outer curve coefficient B
inner curve coefficient A	inner curve coefficient C

Negatively Correlated Variable Pairs	
Bookstein L3 X coordinate	alpha
Bookstein L3 X coordinate	alpha/beta ratio
Bookstein L3 Y coordinate	beta
Bookstein L3 Y coordinate	gamma
Bookstein L3 Y coordinate	aspect ratio
Bookstein L4 X coordinate	distance from L2 to L4
Bookstein L4 Y coordinate	distance from L1 to L4
Bookstein L4 Y coordinate	distance from L2 to L4
centroid X coordinate	alpha
centroid X coordinate	alpha/beta ratio
centroid Y coordinate	beta
centroid Y coordinate	gamma
centroid Y coordinate	aspect ratio
centroid size	gamma
centroid size	aspect ratio
distance from L2 to L3	beta
distance from L2 to L3	gamma
distance from L2 to L3	aspect ratio
distance from L1 to L3	gamma
distance from L1 to L3	aspect ratio
distance from L3 to L4	gamma
distance from L3 to L4	aspect ratio
alpha	beta
alpha	aspect ratio
beta	alpha/beta ratio
gamma	outer curve C coefficient
aspect ratio	alpha/beta ratio
aspect ratio	outer curve C coefficient
inner curve coefficient A	inner curve coefficient B
inner curve coefficient B	inner curve coefficient C

TABLE 61. List of pairs of negatively correlated morphometric variables.

APPENDIX VI

PRINCIPAL COMPONENT DATA WITHIN EACH CLUSTER OF EACH CLAW PHENOGRAM

Claw 1

Principal Component 1					
Cluster	A	B	C	D	E
Principal Component Data	0.332	0.332	0.067	0.067	0.067
	1.519	1.519	-0.229	-0.229	-0.229
		-1.871		0.024	0.024
					0.158
Principal Component 2					
Cluster	A	B	C	D	E
Principal Component Data	-1.974	-1.974	-0.219	-0.219	-0.219
	1.197	1.197	-0.158	-0.158	-0.158
		0.667		0.109	0.109
					0.379
Principal Component 3					
Cluster	A	B	C	D	E
Principal Component Data	1.024	1.024	-0.900	-0.900	-0.900
	1.010	1.010	-0.800	-0.800	-0.800
		1.036		-1.170	-1.170
					-0.199

TABLE 62. Principal component data within each cluster in the phenogram of claw 1.

Claw 2

Principal Component 1							
Cluster	A	B	C	D	E	F	G
Principal Component Data	-0.376	0.948	-0.376	0.591	0.308	1.781	0.591
	-0.830	-1.473	-0.830	-0.611	-0.338	0.308	-0.611
			0.948			-0.338	-0.376
			-1.473				-0.830
							0.948
							-1.473
Principal Component 2							
Cluster	A	B	C	D	E	F	G
Principal Component Data	-0.349	-1.622	-0.349	-0.962	1.302	1.302	-0.962
	-0.561	-0.305	-0.561	0.593	1.119	1.119	0.593
			-1.622			0.786	-0.349
			-0.305				-0.561
							-1.622
							-0.305
Principal Component 3							
Cluster	A	B	C	D	E	F	G
Principal Component Data	-0.082	-1.027	-0.082	1.834	-0.503	-0.503	1.834
	-0.233	-0.884	-0.233	1.513	-0.256	-0.256	1.513
			-1.027			-0.362	-0.082
			-0.884				-0.233
							-1.027
							-0.884
Principal Component 4							
Cluster	A	B	C	D	E	F	G
Principal Component Data	1.969	0.236	1.969	-0.256	-0.389	-0.389	-0.256
	-1.906	0.075	-1.906	0.194	0.331	0.331	0.194
			0.236			-0.254	1.969
			0.075				-1.906
							0.236
							0.075
Principal Component 5							
Cluster	A	B	C	D	E	F	G
Principal Component Data	-1.632	0.705	-1.632	0.217	-0.100	-0.100	-1.632
	-1.463	1.449	-1.463	0.731	0.082	0.082	-1.463
			0.705			0.010	0.705
			1.449				1.449
							0.217
							0.731

TABLE 63. Principal component data within each cluster in the phenogram of claw 2.

Claw 3

Principal Component 1										
Cluster	A	B	C	D	E	F	G	H	I	J
Principal Component Data	1.116	1.116	-0.993	1.116	0.019	1.016	-2.002	0.418	-2.002	1.016
	1.384	-0.899	0.216	-0.899	-0.328	0.019	0.606	-0.553	0.606	0.019
		1.384		1.384		-0.328			0.418	-0.328
				-0.993					-0.553	-2.002
				0.216						0.606
										0.418
										-0.553
Principal Component 2										
Cluster	A	B	C	D	E	F	G	H	I	J
Principal Component Data	-0.381	-0.381	0.630	-0.381	1.396	0.881	-1.103	0.973	-1.103	0.881
	0.267	0.298	-0.485	0.298	0.111	1.396	-2.247	-0.339	-2.247	1.396
		0.267		0.267		0.111			0.973	0.111
				0.630					-0.339	-1.103
				-0.485						-2.247
										0.973
										-0.339
Principal Component 3										
Cluster	A	B	C	D	E	F	G	H	I	J
Principal Component Data	1.163	1.163	0.178	1.163	-1.032	-0.199	-0.439	-0.574	-0.439	-0.439
	0.603	2.492	-0.475	2.492	-0.899	-1.032	-0.254	-0.565	-0.254	-0.254
		0.603		0.603		-0.899			-0.574	-0.574
				0.178					-0.565	-0.565
				-0.475						-0.199
										-1.032
										-0.899
Principal Component 4										
Cluster	A	B	C	D	E	F	G	H	I	J
Principal Component Data	0.250	0.250	1.211	0.250	0.613	-0.849	-0.225	-1.381	-0.225	-0.225
	0.369	-0.408	2.094	-0.408	-0.009	0.613	-0.417	-1.247	-0.417	-0.417
		0.369		0.369		-0.009			-1.381	-1.381
				1.211					-1.247	-1.247
				2.094						-0.849
										0.613
										-0.009

TABLE 64. Principal component data within each cluster in the phenogram of claw 3.

TABLE 64 (cont'd)

Principal Component 5										
Cluster	A	B	C	D	E	F	G	H	I	J
Principal Component Data	-0.230	-0.230	0.547	-0.230	-0.615	-1.416	-0.745	2.013	-0.745	-0.745
	0.743	-0.318	0.705	-0.318	-1.318	-0.615	-0.216	0.850	-0.216	-0.216
		0.743		0.743		-1.318			2.013	2.013
				0.547					0.850	0.850
				0.705						-1.416
										-0.615
										-1.318

Claw 4

Principal Component 1					
Cluster	A	B	C	D	E
Principal Component Data	-1.338	-1.338	0.083	-0.615	-0.615
	-0.349	-0.349	2.161	-0.070	-0.070
		0.171			-0.043
Principal Component 2					
Cluster	A	B	C	D	E
Principal Component Data	-0.594	1.251	0.674	-0.168	-0.168
	0.901	-0.594	-0.424	0.245	0.245
		0.901			-1.884
Principal Component 3					
Cluster	A	B	C	D	E
Principal Component Data	1.396	1.396	0.396	-0.399	-0.399
	0.816	0.816	0.883	-1.284	-1.284
		-0.943			-0.865
Principal Component 4					
Cluster	A	B	C	D	E
Principal Component Data	0.021	0.021	2.237	-0.539	-0.539
	-1.155	-1.155	-0.370	0.156	0.156
		-0.446			0.096
Principal Component 5					
Cluster	A	B	C	D	E
Principal Component Data	-0.718	-0.718	0.261	1.932	1.932
	0.049	0.049	0.211	0.397	0.397
		-1.386			-0.746

TABLE 65. Principal component data within each cluster in the phenogram of claw 4.

APPENDIX VII

MORPHOMETRIC DATA FOR THE FOUR PTERANODONT CLAWS OF UNKNOWN ARTICULATION

Specimen	Pes	Claw	Centroid Location		Centroid Size
			X	Y	
KU49399	Unknown	UNK1	0.396	1.167	3.994
	Unknown	UNK2	0.733	1.308	4.435
YPM2554	Unknown	UNK3	0.558	0.74	2.842
YPM2436	Unknown	UNK4	0.718	0.343	1.665

TABLE 66. Claw centroid locations and sizes of the four claws of unknown articulations.

Specimen	Pes	Claw	Distances between Landmarks (Bookstein)					
			L1-L2	L2-L3	L1-L3	L3-L4	L1-L4	L2-L4
KU49399	Unknown	UNK1	1	4.647	4.556	4.464	0.512	0.512
	Unknown	UNK2	1	5.059	5.224	4.921	0.61	0.458
YPM2554	Unknown	UNK3	1	3.127	3.2	3.277	0.523	0.523
YPM2436	Unknown	UNK4	1	1.525	2.003	1.795	0.541	0.485

TABLE 67. Distances between the Bookstein landmarks of each claw of unknown articulation.

Specimen	Pes	Claw	Angles (degrees)		
			α	β	γ
KU49399	Unknown	UNK1	88.952	78.623	12.425
	Unknown	UNK2	75.036	93.954	11.01
YPM2554	Unknown	UNK3	76.799	85.061	18.14
YPM2436	Unknown	UNK4	47.891	102.995	29.114

TABLE 68. Angle calculations (in degrees) between Bookstein landmarks 1, 2, and 3 of each claw of unknown articulation.

Specimen	Pes	Claw	Aspect Ratio	Ratio of α to β
KU49399	Unknown	UNK1	0.22	1.131
	Unknown	UNK2	0.198	0.799
YPM2554	Unknown	UNK3	0.321	0.903
YPM2436	Unknown	UNK4	0.673	0.465

TABLE 69. Aspect ratios and ratios of α to β of each claw with unknown articulation.

Specimen	Pes	Claw	Curvature Equation Coefficients							
			Outer Curve				Inner Curve			
			X^2 Coeff. (A)	X Coeff. (B)	X^0 Coeff. (C)	R^2 Value	X^2 Coeff. (A)	X Coeff. (B)	X^0 Coeff. (C)	R^2 Value
KU49399	Unknown	UNK1	24.814	20.535	5.804	0.51	2.215	-5.851	4.716	0.829
	Unknown	UNK2	-0.931	2.908	2.876	0.928	-8.348	19.477	-6.933	0.521
YPM2554	Unknown	UNK3	-2.771	4.188	1.492	0.991	-0.501	-3.169	5.12	0.884
YPM2436	Unknown	UNK4	-0.48	1.54	0.325	0.998	-2.888	9.447	-6.254	0.598

TABLE 70. Coefficients from polynomial ($Y = AX^2+BX+CX^0$) equations of outside and inside curves of the four claws with unknown articulations (with their R^2 values), derived from Bookstein coordinates.

KU49399 UNK1							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
1.190	1.590	-0.028	4.417	1.270	1.600	0.194	4.444
1.170	1.570	-0.083	4.361	1.270	1.560	0.194	4.333
1.160	1.530	-0.111	4.250	1.290	1.520	0.250	4.222
1.160	1.490	-0.111	4.139	1.290	1.500	0.250	4.167
1.160	1.450	-0.111	4.028	1.290	1.450	0.250	4.028
1.160	1.420	-0.111	3.944	1.300	1.400	0.278	3.889
1.150	1.400	-0.139	3.889	1.300	1.330	0.278	3.694
1.140	1.350	-0.167	3.750	1.310	1.280	0.306	3.556
1.130	1.310	-0.194	3.639	1.310	1.220	0.306	3.389
1.120	1.270	-0.222	3.528	1.290	1.140	0.250	3.167
1.120	1.230	-0.222	3.417	1.290	1.090	0.250	3.028
1.110	1.190	-0.250	3.306	1.290	1.070	0.250	2.972
1.110	1.150	-0.250	3.194	1.300	1.030	0.278	2.861
1.110	1.110	-0.250	3.083	1.290	1.010	0.250	2.806
1.100	1.060	-0.278	2.944	1.290	0.940	0.250	2.611
1.100	1.020	-0.278	2.833	1.300	0.910	0.278	2.528
1.100	0.980	-0.278	2.722	1.310	0.860	0.306	2.389
1.100	0.930	-0.278	2.583	1.330	0.820	0.361	2.278
1.100	0.900	-0.278	2.500	1.350	0.780	0.417	2.167
1.100	0.850	-0.278	2.361	1.360	0.750	0.444	2.083
1.080	0.810	-0.333	2.250	1.380	0.720	0.500	2.000
1.070	0.770	-0.361	2.139	1.400	0.690	0.556	1.917
1.060	0.730	-0.389	2.028	1.430	0.660	0.639	1.833
1.060	0.700	-0.389	1.944	1.460	0.630	0.722	1.750
1.060	0.660	-0.389	1.833	1.480	0.600	0.778	1.667
1.060	0.610	-0.389	1.694	1.520	0.560	0.889	1.556
1.070	0.570	-0.361	1.583	1.570	0.510	1.028	1.417
1.090	0.530	-0.306	1.472	1.610	0.480	1.139	1.333
1.080	0.500	-0.333	1.389	1.640	0.440	1.222	1.222
1.070	0.470	-0.361	1.306	1.660	0.390	1.278	1.083
1.080	0.430	-0.333	1.194	1.680	0.340	1.333	0.944
1.080	0.390	-0.333	1.083	1.700	0.300	1.389	0.833
1.110	0.350	-0.250	0.972	1.710	0.250	1.417	0.694
1.120	0.320	-0.222	0.889	1.720	0.200	1.444	0.556
1.110	0.270	-0.250	0.750	1.700	0.150	1.389	0.417
1.100	0.230	-0.278	0.639				
1.110	0.190	-0.250	0.528				
1.120	0.150	-0.222	0.417				

TABLE 71. Raw and Bookstein coordinates taken from the outer and inner curves of KU49399, unknown claw 1.

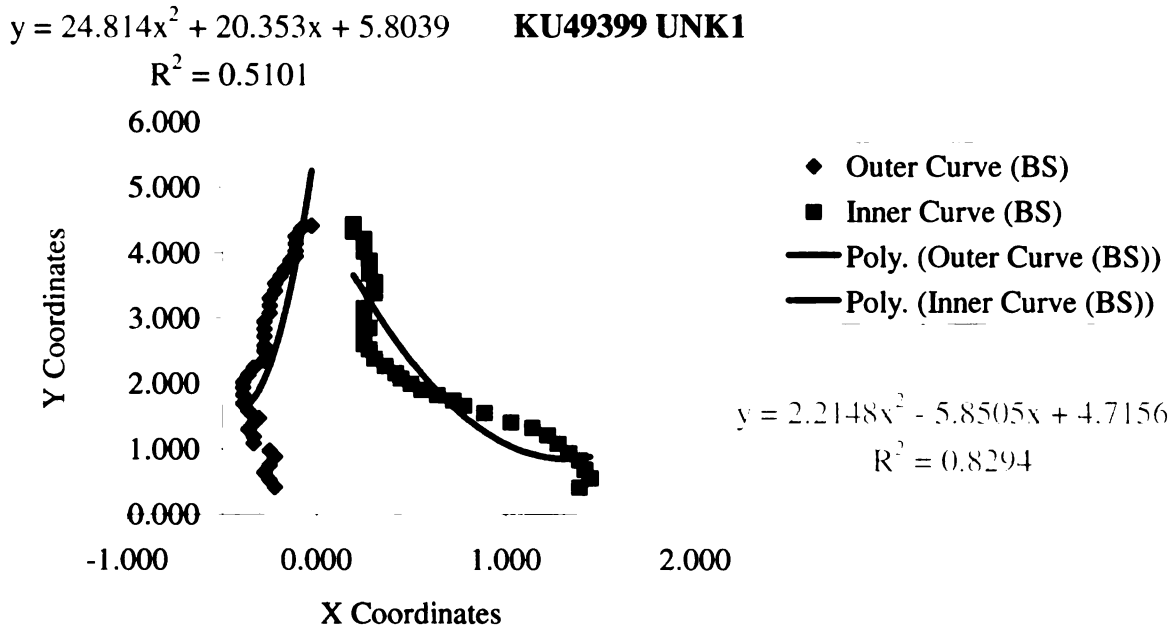

FIGURE 64. Plotted Bookstein coordinates taken from the inner and outer curves of KU49399 unknown claw 1, with trend lines and matching equations.

KU49399 UNK2							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
0.970	2.140	1.047	4.977	1.190	2.080	1.558	4.837
0.940	2.110	0.977	4.907	1.200	2.030	1.581	4.721
0.920	2.080	0.930	4.837	1.200	1.990	1.581	4.628
0.900	2.050	0.884	4.767	1.200	1.910	1.581	4.442
0.890	2.020	0.860	4.698	1.180	1.880	1.535	4.372
0.870	1.990	0.814	4.628	1.180	1.850	1.535	4.302
0.870	1.960	0.814	4.558	1.170	1.810	1.512	4.209
0.850	1.940	0.767	4.512	1.180	1.770	1.535	4.116
0.830	1.900	0.721	4.419	1.180	1.730	1.535	4.023
0.810	1.880	0.674	4.372	1.180	1.710	1.535	3.977
0.790	1.850	0.628	4.302	1.170	1.680	1.512	3.907
0.790	1.830	0.628	4.256	1.150	1.650	1.465	3.837
0.760	1.790	0.558	4.163	1.140	1.620	1.442	3.767
0.740	1.750	0.512	4.070	1.140	1.580	1.442	3.674
0.720	1.730	0.465	4.023	1.150	1.540	1.465	3.581
0.710	1.690	0.442	3.930	1.160	1.500	1.488	3.488
0.700	1.670	0.419	3.884	1.170	1.460	1.512	3.395
0.680	1.630	0.372	3.791	1.180	1.420	1.535	3.302
0.660	1.590	0.326	3.698	1.180	1.380	1.535	3.209
0.650	1.540	0.302	3.581	1.170	1.350	1.512	3.140
0.630	1.510	0.256	3.512	1.170	1.310	1.512	3.047

TABLE 72. Raw and Bookstein coordinates taken from the outer and inner curves of KU49399, unknown claw 2.

TABLE 72 (cont'd)

0.610	1.480	0.209	3.442	1.170	1.280	1.512	2.977
0.600	1.450	0.186	3.372	1.170	1.250	1.512	2.907
0.580	1.410	0.140	3.279	1.180	1.210	1.535	2.814
0.570	1.360	0.116	3.163	1.180	1.180	1.535	2.744
0.550	1.320	0.070	3.070	1.180	1.140	1.535	2.651
0.520	1.290	0.000	3.000	1.190	1.100	1.558	2.558
0.490	1.250	-0.070	2.907	1.190	1.060	1.558	2.465
0.480	1.210	-0.093	2.814	1.180	1.020	1.535	2.372
0.470	1.170	-0.116	2.721	1.180	0.980	1.535	2.279
0.450	1.120	-0.163	2.605	1.190	0.950	1.558	2.209
0.440	1.080	-0.186	2.512	1.190	0.910	1.558	2.116
0.430	1.040	-0.209	2.419	1.190	0.860	1.558	2.000
0.420	1.000	-0.233	2.326	1.210	0.830	1.605	1.930
0.400	0.940	-0.279	2.186	1.230	0.790	1.651	1.837
0.390	0.920	-0.302	2.140	1.240	0.740	1.674	1.721
0.370	0.880	-0.349	2.047	1.260	0.700	1.721	1.628
0.360	0.840	-0.372	1.953	1.270	0.650	1.744	1.512
0.340	0.800	-0.419	1.860	1.270	0.610	1.744	1.419
0.320	0.760	-0.465	1.767	1.290	0.560	1.791	1.302
0.310	0.710	-0.488	1.651	1.300	0.500	1.814	1.163
0.280	0.670	-0.558	1.558	1.300	0.460	1.814	1.070
0.270	0.610	-0.581	1.419	1.300	0.410	1.814	0.953
0.270	0.560	-0.581	1.302				
0.270	0.520	-0.581	1.209				
0.270	0.470	-0.581	1.093				
0.260	0.410	-0.605	0.953				
0.270	0.370	-0.581	0.860				
0.270	0.310	-0.581	0.721				
0.280	0.260	-0.558	0.605				
0.280	0.210	-0.558	0.488				
0.300	0.160	-0.512	0.372				
0.320	0.120	-0.465	0.279				
0.330	0.070	-0.442	0.163				
0.360	0.030	-0.372	0.070				

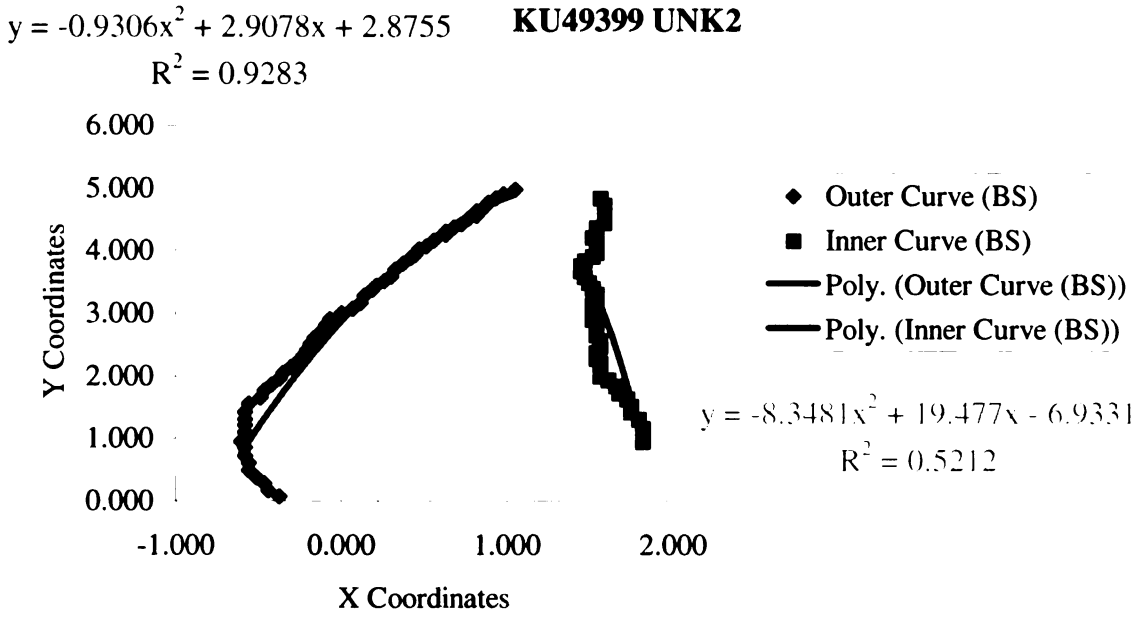

FIGURE 65. Plotted Bookstein coordinates taken from the inner and outer curves of KU49399 unknown claw 2, with trend lines and matching equations.

YPM2554 UNK3							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
1.010	1.590	0.577	3.058	1.100	1.580	0.750	3.038
0.990	1.570	0.538	3.019	1.110	1.540	0.769	2.962
0.980	1.530	0.519	2.942	1.110	1.500	0.769	2.885
0.960	1.510	0.481	2.904	1.110	1.470	0.769	2.827
0.960	1.480	0.481	2.846	1.110	1.430	0.769	2.750
0.950	1.450	0.462	2.788	1.100	1.380	0.750	2.654
0.950	1.420	0.462	2.731	1.100	1.340	0.750	2.577
0.930	1.400	0.423	2.692	1.090	1.290	0.731	2.481
0.900	1.370	0.365	2.635	1.090	1.250	0.731	2.404
0.880	1.330	0.327	2.558	1.070	1.210	0.692	2.327
0.870	1.290	0.308	2.481	1.080	1.170	0.712	2.250
0.850	1.250	0.269	2.404	1.090	1.130	0.731	2.173
0.830	1.220	0.231	2.346	1.110	1.090	0.769	2.096
0.830	1.170	0.231	2.250	1.120	1.050	0.788	2.019
0.810	1.140	0.192	2.192	1.140	1.020	0.827	1.962
0.790	1.110	0.154	2.135	1.150	1.000	0.846	1.923
0.780	1.080	0.135	2.077	1.150	0.960	0.846	1.846
0.770	1.050	0.115	2.019	1.160	0.930	0.865	1.788
0.770	1.020	0.115	1.962	1.170	0.900	0.885	1.731
0.770	0.990	0.115	1.904	1.190	0.860	0.923	1.654
0.760	0.950	0.096	1.827	1.200	0.830	0.942	1.596
0.760	0.910	0.096	1.750	1.220	0.800	0.981	1.538
0.740	0.860	0.058	1.654	1.230	0.770	1.000	1.481
0.720	0.830	0.019	1.596	1.240	0.740	1.019	1.423
0.710	0.800	0.000	1.538	1.260	0.700	1.058	1.346
0.690	0.770	-0.038	1.481	1.270	0.670	1.077	1.288
0.700	0.720	-0.019	1.385	1.280	0.640	1.096	1.231
0.680	0.680	-0.058	1.308	1.280	0.600	1.096	1.154
0.660	0.640	-0.096	1.231	1.280	0.550	1.096	1.058
0.660	0.610	-0.096	1.173	1.270	0.510	1.077	0.981
0.650	0.570	-0.115	1.096	1.290	0.460	1.115	0.885
0.660	0.530	-0.096	1.019	1.300	0.440	1.135	0.846
0.650	0.480	-0.115	0.923	1.320	0.410	1.173	0.788
0.640	0.430	-0.135	0.827	1.330	0.380	1.192	0.731
0.640	0.380	-0.135	0.731	1.330	0.340	1.192	0.654
0.630	0.340	-0.154	0.654	1.330	0.300	1.192	0.577
0.620	0.290	-0.173	0.558	1.310	0.250	1.154	0.481
0.600	0.260	-0.212	0.500				
0.590	0.210	-0.231	0.404				

TABLE 73. Raw and Bookstein coordinates taken from the outer and inner curves of YPM2554, unknown claw 3.

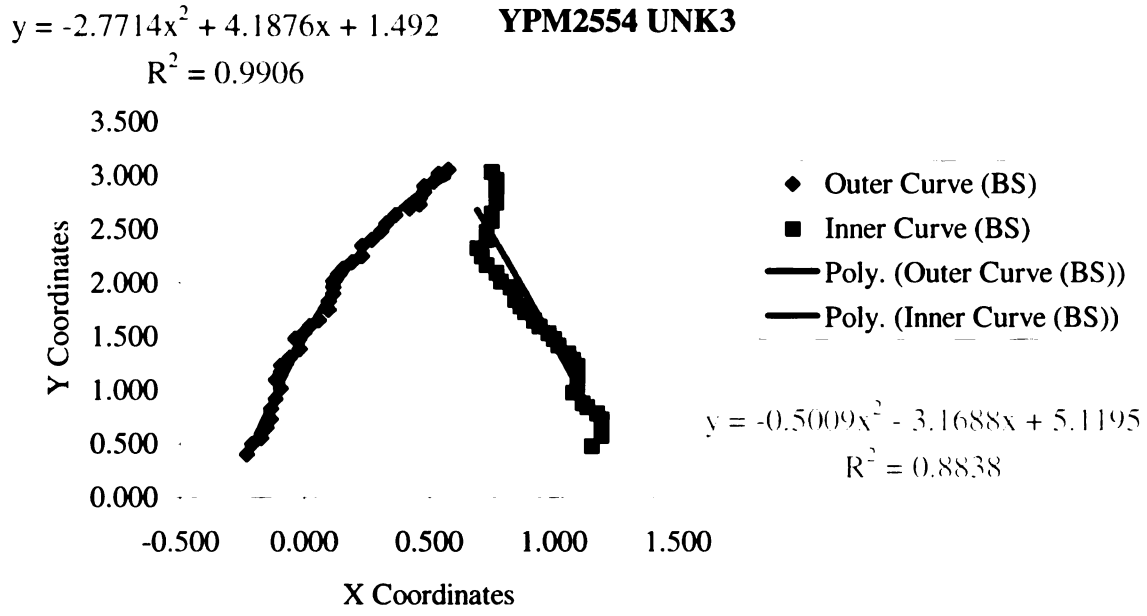

FIGURE 66. Plotted Bookstein coordinates taken from the inner and outer curves of YPM2554 unknown claw 3, with trend lines and matching equations.

YPM2436 UNK4							
Outer Raw		Outer Bookstein		Inner Raw		Inner Bookstein	
X	Y	X	Y	X	Y	X	Y
2.190	2.100	1.279	1.500	2.360	1.790	1.400	1.279
2.160	2.100	1.257	1.500	2.340	1.740	1.386	1.243
2.120	2.100	1.229	1.500	2.320	1.720	1.371	1.229
2.080	2.110	1.200	1.507	2.280	1.690	1.343	1.207
2.040	2.100	1.171	1.500	2.240	1.660	1.314	1.186
2.010	2.070	1.150	1.479	2.220	1.620	1.300	1.157
1.980	2.060	1.129	1.471	2.190	1.590	1.279	1.136
1.960	2.030	1.114	1.450	2.150	1.560	1.250	1.114
1.920	2.030	1.086	1.450	2.120	1.530	1.229	1.093
1.900	1.980	1.071	1.414	2.090	1.510	1.207	1.079
1.860	1.960	1.043	1.400	2.060	1.470	1.186	1.050
1.830	1.940	1.021	1.386	2.030	1.440	1.164	1.029
1.810	1.930	1.007	1.379	2.020	1.420	1.157	1.014
1.760	1.920	0.971	1.371	1.990	1.380	1.136	0.986
1.720	1.910	0.943	1.364	1.970	1.330	1.121	0.950
1.700	1.890	0.929	1.350	1.960	1.270	1.114	0.907
1.670	1.840	0.907	1.314	1.960	1.200	1.114	0.857
1.650	1.820	0.893	1.300	1.920	1.150	1.086	0.821
1.630	1.790	0.879	1.279	1.910	1.090	1.079	0.779
1.590	1.760	0.850	1.257	1.890	1.020	1.064	0.729
1.560	1.740	0.829	1.243	1.860	0.960	1.043	0.686
1.530	1.710	0.807	1.221	1.860	0.870	1.043	0.621
1.490	1.700	0.779	1.214	1.840	0.810	1.029	0.579
1.470	1.670	0.764	1.193	1.860	0.750	1.043	0.536
1.450	1.660	0.750	1.186	1.880	0.700	1.057	0.500
1.420	1.640	0.729	1.171	1.890	0.650	1.064	0.464
1.390	1.620	0.707	1.157	1.890	0.600	1.064	0.429
1.350	1.590	0.679	1.136	1.880	0.560	1.057	0.400
1.320	1.570	0.657	1.121	1.880	0.520	1.057	0.371
1.300	1.540	0.643	1.100	1.910	0.480	1.079	0.343
1.270	1.520	0.621	1.086	1.940	0.430	1.100	0.307
1.250	1.510	0.607	1.079	1.950	0.380	1.107	0.271
1.220	1.510	0.586	1.079	1.950	0.320	1.107	0.229
1.190	1.480	0.564	1.057	1.970	0.260	1.121	0.186
1.160	1.460	0.543	1.043	1.980	0.220	1.129	0.157
1.140	1.440	0.529	1.029				
1.120	1.420	0.514	1.014				
1.090	1.390	0.493	0.993				
1.080	1.360	0.486	0.971				
1.050	1.350	0.464	0.964				

TABLE 74. Raw and Bookstein coordinates taken from the outer and inner curves of YPM2436, unknown claw 4.

TABLE 74 (cont'd)

1.020	1.320	0.443	0.943
1.000	1.290	0.429	0.921
0.980	1.260	0.414	0.900
0.960	1.230	0.400	0.879
0.950	1.210	0.393	0.864
0.920	1.180	0.371	0.843
0.900	1.150	0.357	0.821
0.890	1.120	0.350	0.800
0.830	1.100	0.307	0.786
0.820	1.070	0.300	0.764
0.790	1.040	0.279	0.743
0.780	1.000	0.271	0.714
0.770	0.960	0.264	0.686
0.720	0.910	0.229	0.650
0.710	0.880	0.221	0.629
0.690	0.860	0.207	0.614
0.660	0.830	0.186	0.593
0.640	0.790	0.171	0.564
0.620	0.770	0.157	0.550
0.610	0.740	0.150	0.529
0.590	0.710	0.136	0.507
0.570	0.690	0.121	0.493
0.540	0.650	0.100	0.464
0.530	0.610	0.093	0.436
0.510	0.590	0.079	0.421
0.480	0.570	0.057	0.407
0.450	0.540	0.036	0.386
0.430	0.500	0.021	0.357
0.400	0.470	0.000	0.336
0.370	0.410	-0.021	0.293

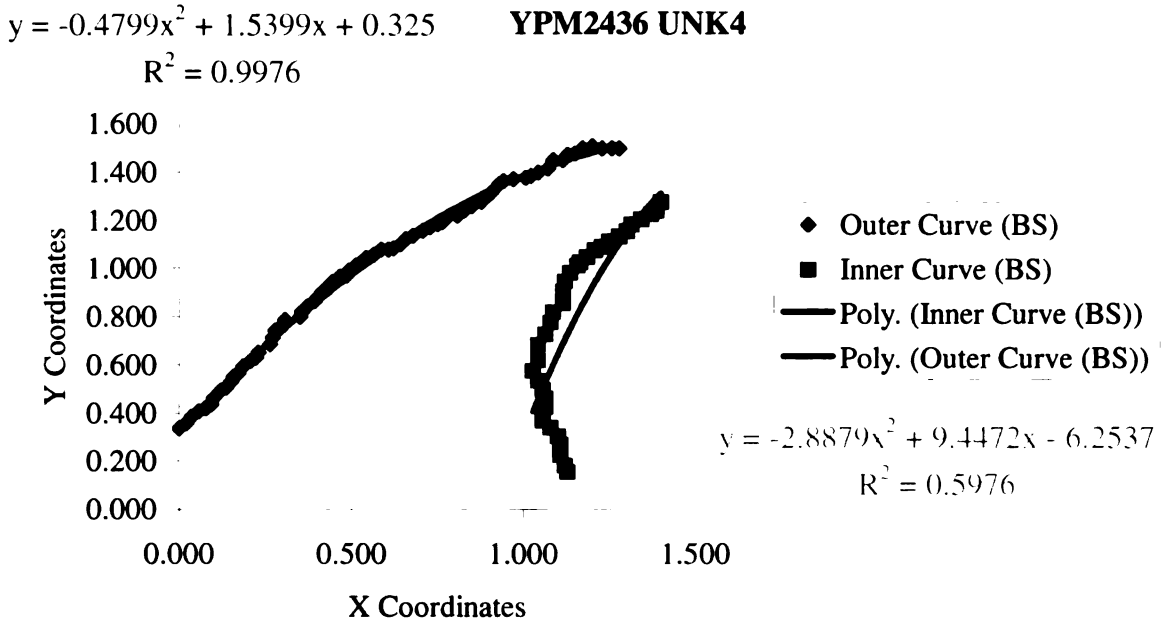

FIGURE 67. Plotted Bookstein coordinates taken from the inner and outer curves of YPM2436 unknown claw 4, with trend lines and matching equations.

APPENDIX VIII

TANGENTAL CLAW PHENOGRAMS

Figures 68 and 69 are claw phenograms calculated without regard to homologous articulation. They are provided here as tangential ideas.

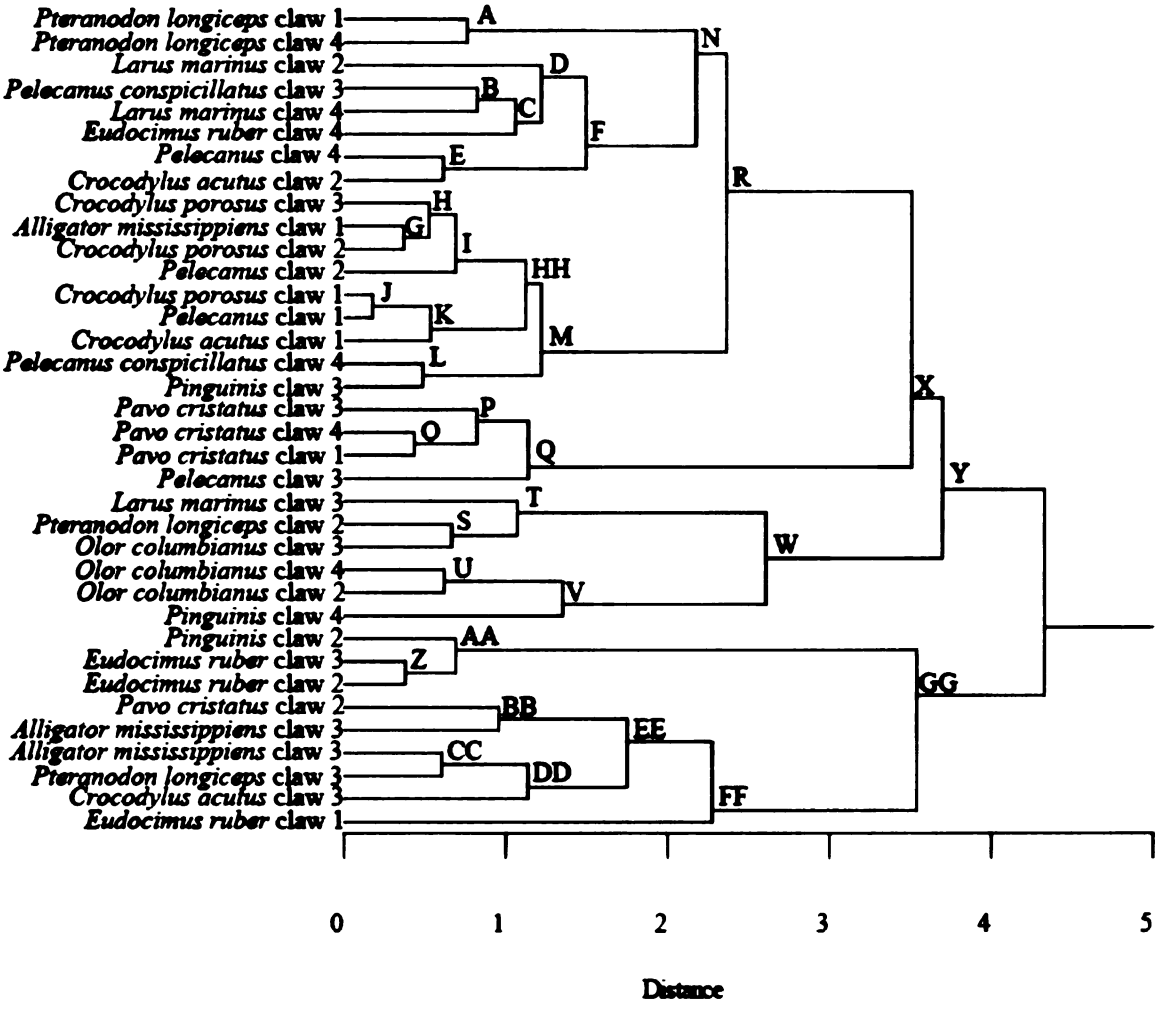

FIGURE 68. Phenogram of all claws regardless of articulation, without the four pteranodont claws of unknown articulation. Clusters are labeled with capital letters.

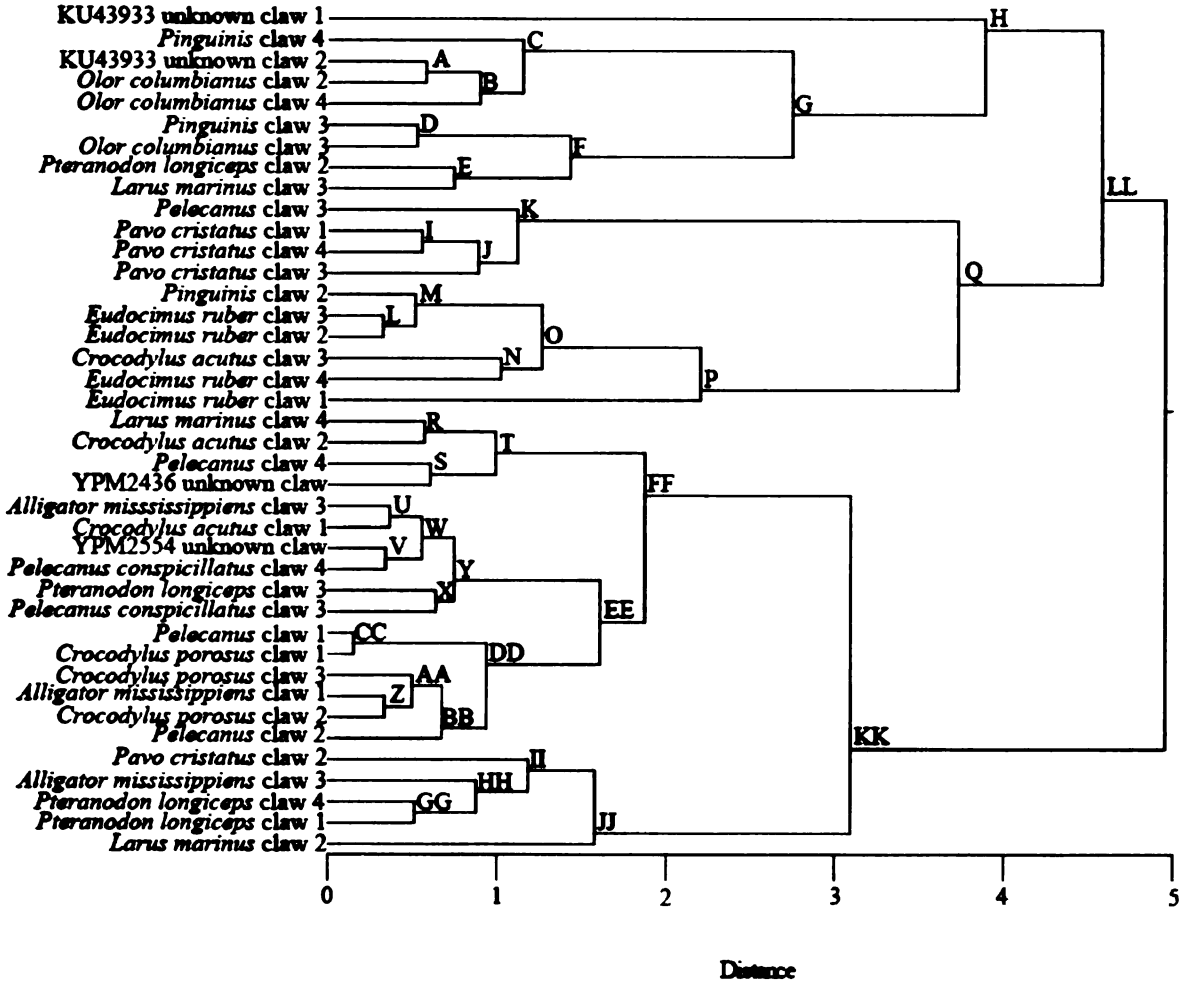

FIGURE 69. Phenogram of all claws regardless of articulation, with the four pteranodont claws of unknown articulation. Clusters are labeled with capital letters.

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