MORPHOLOGY OF *ASTARTE BOREALIS* (MOLLUSCA: BIVALIVA) OF CAMDEN BAY, NORTHERN ALASKA

by

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This thesis was prepared under the direction of the candidate's thesis advisor, Dr. Anton Oleinik, Department of Geosciences, and has been approved by the members of her supervisory committee. It was submitted to the faculty of the Charles E. Schmidt College of Science and was accepted in partial fulfillment of the requirements for the degree of Master of Science.

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ABSTRACT

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The genus *Astarte* is known for variable shell morphology and polymorphism within living and fossil species. *Astarte borealis*, the most common living species, is recognizable and common among mid-to-high latitude North Pacific, Arctic Ocean and North Atlantic waters, and has been divided into many subspecies and varieties based on overall shell shape. A collection of recent *A. borealis* specimens from Camden Bay, northern Alaska (641 specimens) with outline intact were used for analyses. Bivariate analysis of height vs. length and morphometric analysis of shell outline determined variants within a population of *A. borealis*, and then compared to Pliocene *A. borealis* and Oligocene *A. martini*. The computer program SHAPE uses elliptic Fourier coefficients of shell outline to evaluate and visualize shape variations. The multivariate

outline analysis indicates that *A. borealis* intraspecies variation is based upon a common shape that grades into other shapes, rather than grade between two or more end-forms.

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CHAPTER 1

1.0 INTRODUCTION

Of the over 1200 genera within the Class Bivalvia, the genus *Astarte* Sowerby, 1816 is known to be one of the more complex to classify. The genus *Astarte* is recorded as early as the Jurassic and in recent times prolific in circumpolar panarctic waters and known for polymorphism in species (Zettler, 2001). One of the more successful species is the *Astarte borealis* Schumacher, 1817, which provides evidence for the earliest opening of the Bering Strait (Marincovich et al., 2002). The species is known to have a high degree of shell shape variability and has been often called a species complex owing to numerous subspecies and named varieties. Although there are several synonyms attributed to the polymorphic species, there have been few morphological studies on the species. The shell varies from ovate to subtrigonal to quadrangular among the genus; Bernard (1979) stated that reproduction is non-pelagic and a possible primary cause of the vast polymorphism exhibited within *Astarte borealis* populations. One of the ways to examine the amount of variation and possible presence of different shape morphs with gradation for both recent and fossil *Astarte* is to use statistic techniques to study shell shape variability.

1.1 Objectives

The objective of this study is to quantitatively determine the degree of morphological variability in shell shape among a population of recent *Astarte borealis* within a single location. The second objective of this study is to compare the outline analysis of modern *Astarte borealis* to the fossil *A. borealis* on loan from the CAS Paleontology collection. The fossil and modern are thought to have the same shape and the use of elliptical Fourier analysis will attempt to show that the outline of fossil clams match the modern and fall into the same distribution.

1.2 Hypothesis

The hypothesis for this study is that a population of *Astarte borealis* in the Camden Bay of Northern Alaska shows a high degree of variation in shell outline morphology. The variation is attributed to a central form that grade into a range of variants rather than the presence of two or more forms within the species. The Pliocene *A. borealis* specimens show a similar extent of variation when compared to the recent specimens.

1.3 Relevance

This study will be the first to comprehensively study the shell outline variation within a single population of *Astarte borealis*. Although the *A. borealis* has been studied in comparison to other *Astarte* species (Gardner & Thompson, 1999;Ockelmann, 1958; Schaefer, Trutschler, & Rumohr, 1985; Selin, 2007; Zettler M. L., 2002), they have never been studied using the shell outline to determine the degree and type of variability within the *A. borealis* species. The genus lacks in depth examination of the morphology of shell outline and an investigation into the degree of variability within one population will provide insight into the polymorphic characteristic of the genus *Astarte*. The importance of understanding the shape variation in the *A. borealis* is significant for systematic studies of both recent and fossil species.

1.4 Thesis Organization

Following the introduction, this thesis is organized into these subsequent chapters: Overview of *Astarte* Morphology; Previous Studies of Genus *Astarte* Morphology; Approaches to Study of Bivalve Shape; Methods and Materials; Results and Analysis; and Discussion and Conclusion.

Chapter 2, Overview of *Astarte* Morphology, will discuss the problems inherent with the shell outline of the Genus *Astarte*, in particular the *A. borealis* species.

Chapter 3, Previous Studies of the Genus *Astarte* Morphology, will discuss all prior studies of *Astarte borealis* in regards to shape, genetics and the shell periostracum.

Chapter 4, Approaches to the Study of Shape, will discuss previous studies of *A. borealis* and the genus and introduce the typical shape measurement methods used in paleontology of bivalves and their applicability to *A. borealis*.

Chapter 5, Methods and Materials, will describe the collection and handling of the materials. It will also detail the software used in the analysis of the shell outline of the specimens.

Chapter 6, Results and Analysis, will contain descriptive and graphical analysis performed by the author.

Chapter 7, Discussion and Conclusion, provides the conclusion, problems with the study and ideas for future study.

Chapter 7 is followed by appendices, raw and statistical data, and bibliography.

CHAPTER 2

2.0 OVERVIEW OF *ASTARTE* MORPHOLOGY

2.1 Genus Overview

Abbott (1974) lists the genus *Astarte*, class Bivalvia, as having many species that are widely distributed throughout the Northern Hemisphere, occurring throughout the Arctic Ocean, the east and west of the North Atlantic, and from Japan east towards the Pacific and Alaskan coasts (**Figure 1**). Lubinsky (1980) explains that the group *Astarte* is ecologically complex with each species having different requirements of salinity, temperature, depth and bottom sediments and furthermore, the distribution of the genus is wide, with some species being endemic to the high Arctic while others are known only from southern Labrador. The genus is important in its realm of shallow subtidal and continental shelf soft substrate habitats, however, relatively little study has been conducted regarding the morphology of the shell. The genus is known to be highly variable and polymorphic; as a result several of the species possess numerous synonyms. Coan (2000) notes that the astartid line emerged in the Lower Devonian and living members differ little from the fossil forms. The characteristics of the family Astartidae include gross morphologies that overlap between species causing difficulty in finding distinct traits in which to delineate species. The members are known to be polymorphic within species and display range in the characteristics used to define them. In addition to the lack of distinguishable features among the genus, Kriz (1996) remarks that *Astarte* has been used as a “wastebasket” for species found in the Prague basin that were unable to be placed into then existing genera. Today, *Astarte borealis* is considered a widespread benthic boreal-arctic bivalve found in the Arctic and North Atlantic and North Pacific Oceans and is commonly found in Northern Alaska’s Camden Bay, part of the Beaufort Sea (Zettler, 2001).

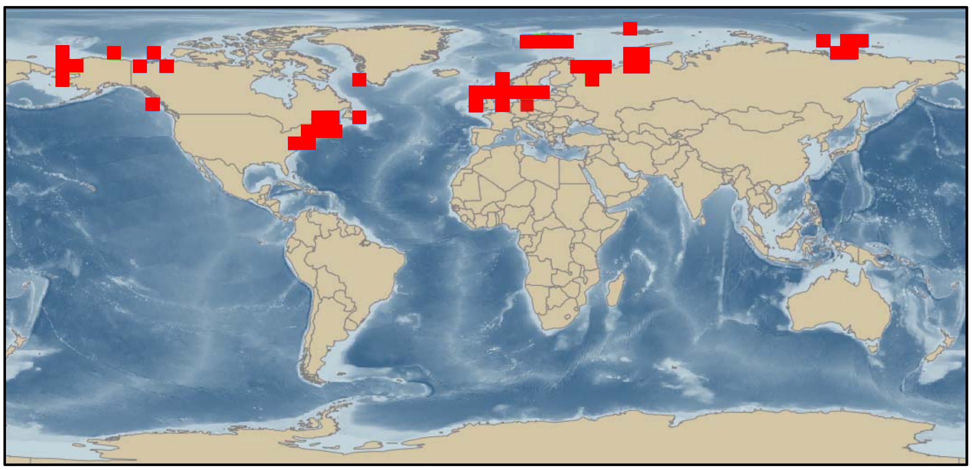

Figure 1. Recent distribution of *Astarte borealis* from OBIS (Ocean Biogeographic Information System) and Abbott (1974).

2.2 Genus *Astarte* and *A. borealis* Morphology

Bivalve mollusks can be identified though several physical characteristics within genera that indicate the differences between members of separate species. Examples include hinge structure, surface sculpture, number of teeth, umbo shape, color of periostracum, pallial sinus shape, and several others. The members of the genus *Astarte* share gross morphologies that overlap within the genus causing difficulty in differentiating the separate species from one another. Descriptions of the genus and *A. borealis* have come from several sources including: Abbott, 1974; Bernard, 1979; Coan, 2000; Dall, 1903; Dall, 1920; Lubinsky, 1980, Ockelmann, 1958; Saleuddin, 1965; Zettler, 2001.

2.2.1 Shell Morphology of Genus

The exterior characteristics of genus *Astarte* include the periostracum, ribs and overall shell shape. The genus has a shell outline that is primarily trigonal with variations that are elliptical, ovate or subquadrate. The genus is equivalve and the length is equal to or greater than the height. The sculpture of the genus is comprised of commarginal ribs, most of which are equally spaced and vary from fine to broad-sized ribs; *A. esquimalti* has irregular, wavy ribs. The umbones are mostly broad and inflated; a few species have pointed umbones that are generally just dorsal of the midline. The umbones are prone to erosion in older specimens, which causes a difference in the appearance between juvenile and adult individuals. The periostracum is thick to this and varies from shiny to silky to dull across the genus. It is generally a yellow to black to reddish-brown and adherent.

The shell shape of *Astarte borealis* is ovate to subquadrate to subtrigonal with umbones subcentral, just dorsal of midline, and often eroded in older individuals. The sculpture consists of fine, commarginal ribs or striae, and may possibly have raised ribs around the first 6-8 mm of the umbones. The periostracum is fibrous and adherent, thick, and yellow to black.

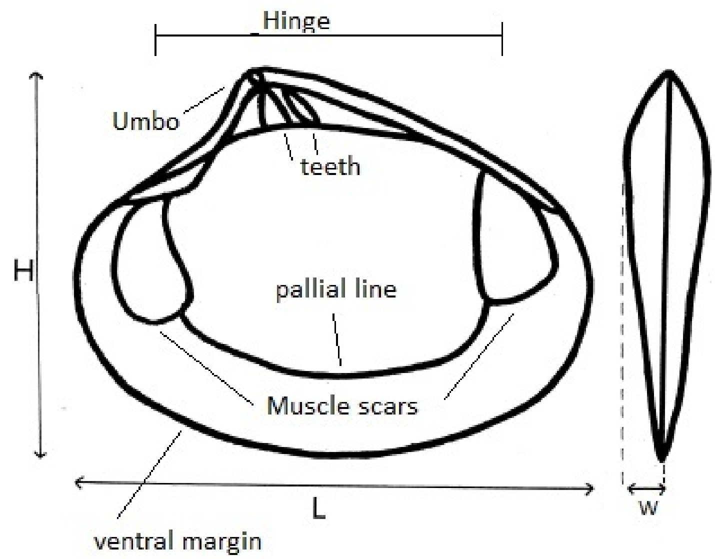

Figure 2. Interior of *Astarte*, with hinge, umbo, teeth, ventral margin, and muscle scars shown. Dimensions used for measurements shown as *H* – height, *L*- length and *W* – width. Modified from Gardner and Thompson (1999).

The interior characteristics of the genus *Astarte* shell include the hinge, teeth, pallial line, muscles scars and inner margin (**Figure 2**). The hinge varies from strong to narrow across the genus. There is a single, large cardinal tooth in the right valve and two smaller cardinal teeth in the left valve; no lateral teeth present in the genus. Large external ligament attached to strong, prominent nymph. The pallial line in the genus is narrow and faint, without pallial sinus. The muscle scars are deeply impressed. The inner margin is crenulated to some degree across the genus, except for *Astarte borealis.* The fossil *A. martini* displays different degrees of crenulation, weak to strongly crenulate.

2.2.2 *A. borealis* Morphology

Astarte borealis has a strong hinge as well as strong ligament attached to two prominent nymphs. The left valve has three teeth, two are larger cardinal teeth and the third is very small and inconspicuous. The right valve has right valve has two teeth, the anterior much larger and broader than the posterior tooth. The adductor muscle scar is deeply impressed and the anterior pedal retractor scar is prominent. No pallial sinus and the pallial line is narrow and sometimes faint. The interior margin is smooth and uncrenulated in most, in a very few they may be some very light crenulations present. Almost always, the lack of crenulations will differentiate *A. borealis* form other *Astarte* species.

2.3 Advantages and Disadvantages of Selected Morphological Features

2.3.1 Interior Markings and General Shape

The shape found in the Genus *Astarte* varies little among the species described in literature. The overall shell outline of the genus is trigonal, pertaining to or in the form of a triangle (Abbott, 1974), with some of the species exhibiting an elliptical shape. The similar shape and description of *Astarte* species can cause confusion when the illustrations of the shells are not available.

The hinge and teeth are strong and large and do not have an adequate amount of distinction in form to determine the different species as most of the genus *Astarte* has the same number and type of teeth, but rather work in identification of the genus form others. The interior markings of *Astarte borealis* are insufficient for landmark analysis which requires multiple, easily identifiable marks in rapid succession. The interior lines are faint and as stated above the pallial sinus is lacking.

2.3.2 The Periostracum

Okcelmann (1958) introduces the concept that the microstructure of the periostracum is very characteristic in some species and that it may be useful as an indicator of speciation in the genus. Saleuddin (1965, 1967) described the microstructure of periostracum in the Genus *Astarte* and in 1974 used SEM to qualify it further. The periostracum of 6 species of *Astarte* were studied and found to have microscopically different structures. This study is only a qualification of the periostracum, he did not use it to quantify or distinguish the genus further. Saleuddin (1967, 1974) did two studies on the periostracum of the Genus *Astarte*, but did not go in depth in using it for the categorization of the genus.

Bernard (1979) lists some of the microstructure of the *Astarte* periostracum; however, for the *A. borealis* the appearance of periostracum is not consistent and thus is not a good choice for studies with this particular species. Bernard goes on to confirm that the easiest way to distinguish *A. borealis* from other *Astarte* is the “always uncrenulated shell margins”. Schafer, Trutschler and Rumohr (1985) concludes that when the microscopic periostracum structure is absent, and is the only distinguishing feature between the two species when other features are similar, some *A. montagui* may be identified as *A. borealis*. This signifies that the periostracum is not always a reliable source of distinction between species. Skazina, Sofronova and Khaitov (2013) used the periostracum of three adult *Astarte* to identify the juveniles of the species from one another in a long term population study (**Figure 3**).

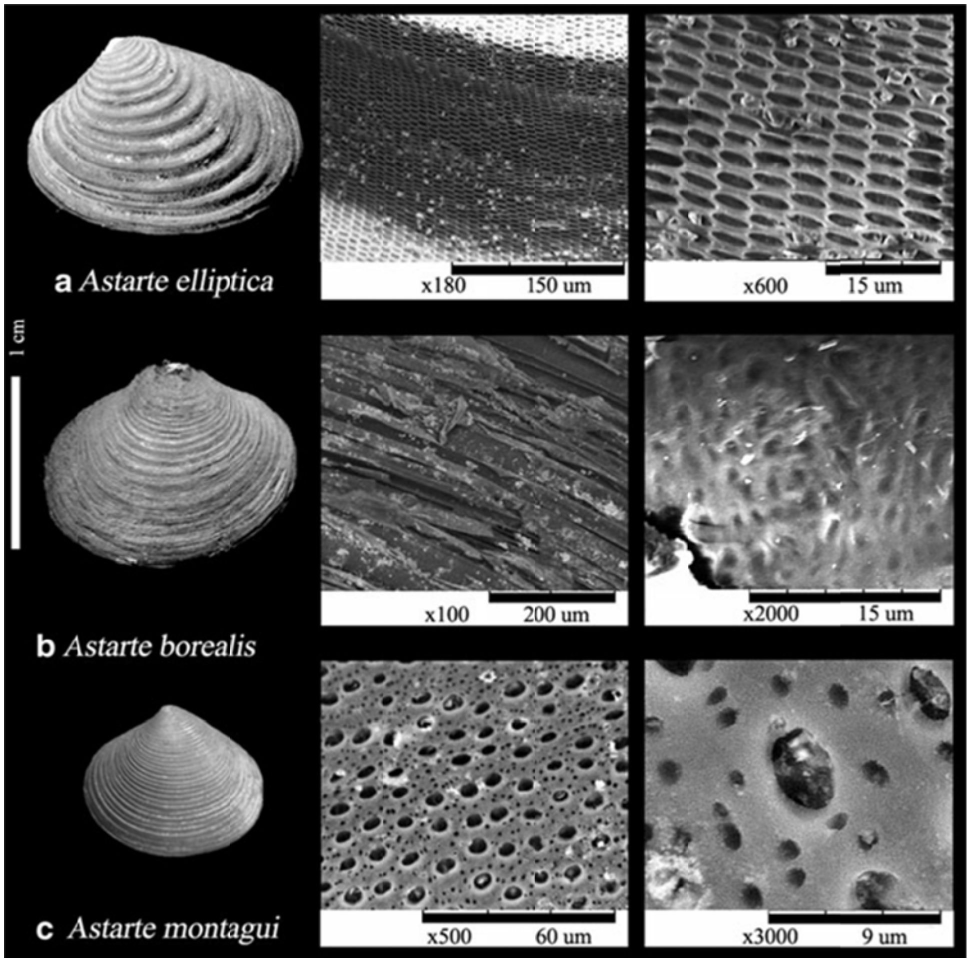

Figure 3. From Skazina, Sofronova and Khaitov (2013) “External view and periostracum microstructure of adult White Sea astartids: *A. elliptica* (a), *A. borealis* (b) and *A. montagui* (c)”

2.3.3 Crenulated Margins

The genus *Astarte* has crenulated margins ranging from strong to weak, except for the *Astarte borealis* which has none to extremely weak crenulations. As confirmed by Bernard (1979), the lack of crenulated margins can be used to differentiate *A. borealis* form the other species. If they were more strongly present they could be used as a tool to find the differences in crenulation patterns. The crenulations are geographically and temporally distributed in respect to the movement of the genus from the Atlantic and Arctic into the Pacific after the opening of the Bering Strait. The warm water Astarte species that originated in the Atlantic have crenulate margins and ancestral *A. borealis* that moved into the Arctic developed into a cold water species with smooth margin. Thus the Astarte species found in the Atlantic have crenulate margin and the Arctic and Pacific *A. borealis* are found to have a smooth margin, which also did not appear until after the late Miocene (Marincovich et al., 2002).

2.4 Synonyms of *Astarte borealis*

Being highly morphologically variable, the genus *Astarte* has many synonymized taxa for each species. Table 1 lists the 7 most common species of *Astarte* and the number of synonymized taxa found for each, *A. borealis* has the most, 38. Zettler (2001) provides insight into the complexity of the *Astarte borealis* species complex by collecting all the literature worldwide that have mentioned the species. Zettler (2001) cited well over 100 papers that show the great number of synonyms assigned to the species as well as the geographical extent of the species. Table 2 contains a complied list of all synonyms found in Zettler (2001), World Register of Marine Species (WoRMS), Malacolog (Rosenberg, 2009) and additional literature to date.

***Astarte* Species**	**Synonymized taxa**
A. borealis	38
A. montagui	19
A. arctica	11
A. crenata	8
A. elliptica	7
A. esquimalti	5
A. compacta	3

Table 1: The 7 most common species of genus *Astarte* and taxa synonymized with them. Data from Coan (2000), Zettler (2001, 2002), Selin (2007), Malacolog (Rosenberg, 2009) and WoRMS.

Genus	Species	Form	Recent (R) Fossil (F)	Author	Year
Astarte	*borealis*	*crassa*		Pfeffer	1886
Astarte	*borealis*	*placenta*	R	Leche	1878
Astarte	*borealis*	*rhomboidalis*		Leche	1878
Astarte	*borealis*	*sericea*		Posselt	1895
Astarte	*bornholmi*		R	Hopner Petersen	2001
Astarte	*cyprinoides*			Duval	1841
Astarte	*fabula*			Reeve	1855
Astarte	*fjordi*		R	Hopner Petersen	2001
Astarte	*islandica*			Deshayes in d'Orbigny	1849
Astarte	*jenseni*		R	Hopner Petersen	2001
Astarte	*lactea*			Broderip & G.B. Sowerby I	1829
Astarte	*leffingwelli*			Dall	1920
Astarte	*moerchi*		R	Hopner Petersen	2001
Astarte	*nordi*		R	Hopner Petersen	2001
Astarte	*nortonensis*			MacNeil	1943
Astarte	*nuuki*		R	Hopner Petersen	2001
Astarte	*olchovica*			Petrov	1982
Astarte	*ovata*			Filatova	1957
Astarte	*plana*			Sowerby	1917
Astarte	*producta*			G.B. Sowerby II	1874
Astarte	*pseudoactis*			Merklin & Petrov	1962
Astarte	*richardsonii*			Reeve	1855
Astarte	*saintjohnensis*			Verkrüzen	1877
Astarte	*semisulcata*		R	Leach in Ross	1819
Astarte	*semisulcata*	*placenta*		Mörch	1869
Astarte	*sibirica*			Posselt	1896
Astarte	*silki*		R	Hopner Petersen	2001
Astarte	*subtrigona*			G.B. Sowerby II	1874
Crassina	*corrugata*			T. Brown	1827
Crassina	*depressa*			T. Brown	1827
Crassina	*multicostata*			J. Smith	1839
Crassina	*semisulcata*			Leach in Ross	1819
Crassina	*uddevalensis*			J. Smith	1839
Crassina	*withami*			J. Smith	1839
Mactra	*veneriformis*			Wood	1828
Tridonta	*borealis*		R	Schumacher	1817
Tridonta	*cavalli*			Pollonera	1901
Venus	*borealis*			Chemnitz	1784

Table 2: List of all available synonyms and varieties/form, with author and year published, of *Astarte borealis* found in literature, following Zettler (2001).

CHAPTER 3

3.0 PREVIOUS STUDIES OF *ASTARTE BOREALIS* MORPHOLOGICAL VARIATION

There have been previous studies concerning the variation found in the genus *Astarte* and *Astarte borealis*. Most have been comparisons of morphology between different species, rather than study of variations within the single species. There are four studies that compare the traditional bivariate measurements of *A. borealis* with other *Astarte* species. A genetic study of *A. borealis* compared to two other species, *A. elliptica* and *A. striata*. The other type of study done with *Astarte* species has to do with the periostracum of the shell.

3.1 Shape Studies of *Astarte borealis* Using Bivariate Analysis

There are four previous biometric studies that include the *Astarte borealis* in comparison to other members of the genus *Astarte*, the methods used are traditional linear measurements with bivariate analysis. The first remarks of bivariate measurements come from Ockelmann (1958) who measured the length, height and width of 22 *A. borealis* specimens collected from East Greenland. Ockelmann (1958) calculated the length/height ratio to be 1.28 and the width/height ration to be 0.23. The shells collected are on the whole, much larger than the other three studies and have some of the highest ratios of length to height. Ockelmann (1958) notes that there is inconsistency within the shape variation among *A. borealis*, and though some of the recovered samples may be referred to as var. *placenta* (Mörch) which is compressed and elongated, there are other specimens that resemble var. *sericea* (Posselt) or var. *withami* ((Wood) Leche) and numerous intermediate forms. After observing about 3000 specimens, he concludes that "on the whole, considering the intraspecific variation within the large material at hand, there seems to be no regular tendency" and sub-specific rank should not be applied to the forms observed (Ockelmann, 1958). After examining four other species of the genus, *Astarte montagui*, *A. elliptica*, *A. crentata* and *A. sulcata*, Ockelmann (1958) assesses that the genus possesses considerable variation and for the most part, should not distinguish between the subspecies based on shape alone.

The second study was performed by Schaefer, Trutschler and Rumhor in 1985 on the biometrics of *A. borealis*, as well as *A. elliptica* and *A. montagui*, from the western Baltic Sea. In this study the purpose was to ultimately determine if the shell shape was enough to determine the differences between the species. The shell length and breadth (Schaefer et al., 1985) were collected from 4121 species and compared with the various weights of the specimens; the weights were taken with live, wet samples; again after the soft tissue taken out of the shells; and again when shells were dried in an oven. The analysis suggested that in samples over 5 mm, it was possible to determine the difference between most of *A. borealis* and the *A. montagui* when using the length and breadth (**Figure 4**), however there was problems with some of the bivalves classified as *A. borealis* that may have in fact been *A. montagui* when periostracum was taken into account. Schaefer et al. (1985) also asserts that the variability of the shape with relation to salinity (Remane, 1940) called into question whether the distinction by length and breadth relationship is a reliable method when applied to other areas.

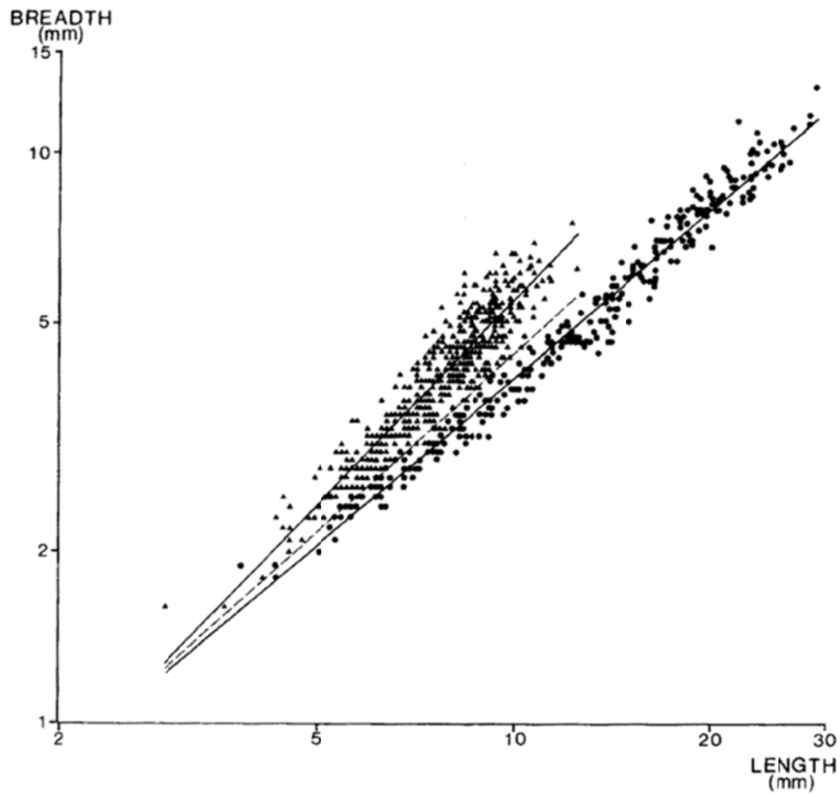

Figure 4. Fig 4 from Schaefer et al. (1985), "Shell length to shell breadth relations of *Astarte borealis* (●; n = 305) and *A. montagui* (▲; n = 504) and graphically fitted separation line (---), plotted double logarithmically ($\log_e$)"

The third study by Zettler in 2002 was the only to focus solely on the *A. borealis* population characteristics of a particular geographical area. Zettler (2002) distinguishes his study as "the first extensive study of this important indicator species near its geographical range" and identifies the Baltic *A. borealis* as an outpost of the mainly Arctic distribution of the species. The collection from Mecklenburg Bight of the Baltic Sea yielded 414 specimens that were measured for shell length and weight of shell. 217 of the 414 shells collected were measured for shell height and length and plotted to show the linear relationship (Figure 5). Bivariate analysis of the collection found a mean length to height ratio of 1.15, varying from 1.05 to 1.25. The results from Zettler (2002) can be compared to the results from the bivariate analysis in this study, located in Chapter 6, using the equation found in the graph from Zettler (2002) (Figure 5).

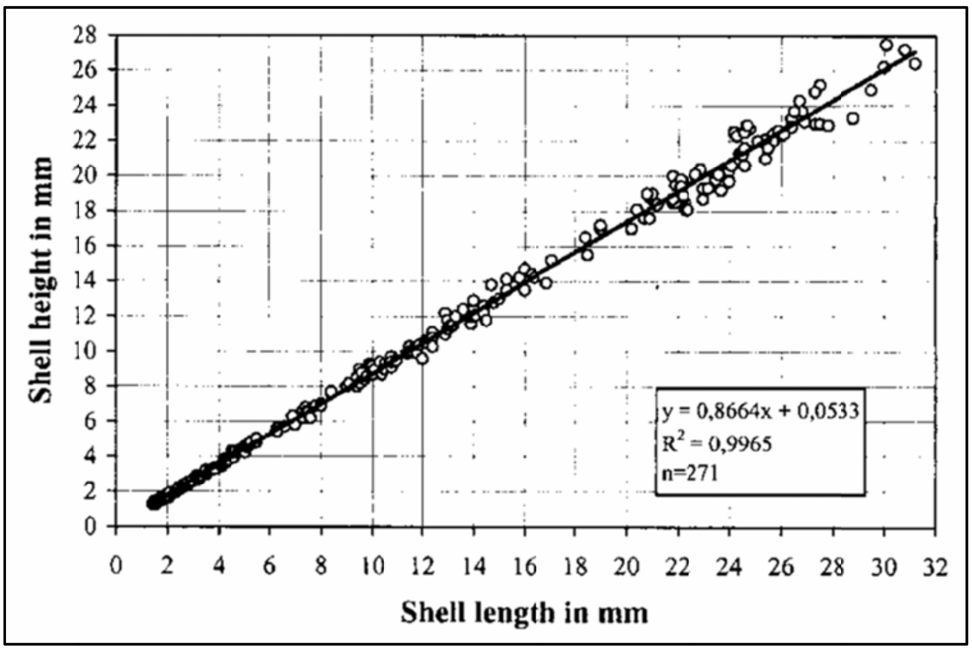

Figure 5. Figure 7 from Zettler (2002), "Shell height-length relationship of *Astarte borealis* from the Mecklenburg Bight"

The fourth study by Selin in 2007 compared *A. borealis* and *A. arctica* from Sakhalin, North Pacific by using linear measurements of length, width and height of the shells. 145 specimens, 70 *A. borealis* and 75 *A. arctica*, were analyzed and found to have different proportions with respect to the two species. Although they had similar physical features the height vs. length and width vs. length relationships, as well as the height/length and width/height ratios, of the shells were enough to differentiate between these two species (**Figure 6**).

Table 1. Characteristics of the initial material

Species	*L*, mm			*H*, mm			*D*, mm			W_{tot} ± SE, g
	min	max	av.	min	max	av.	min	max	av.	
Astarte arctica	5.6	42.7	21.8	5.1	40.0	20.0	2.6	21.6	10.4	5.2 ± 1
A. borealis	5.8	52.4	23.3	5.1	48.7	21.2	2.5	23.2	9.5	6.5 ± 1

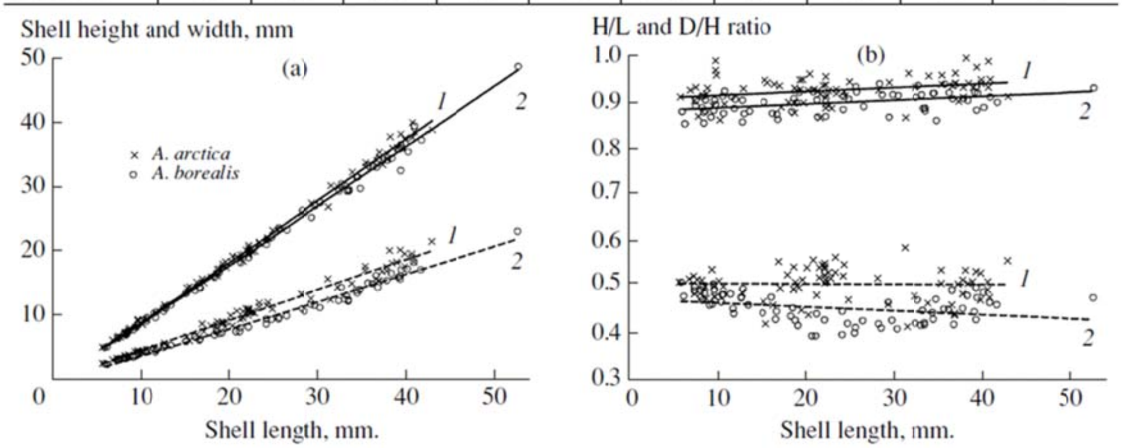

Figure 6. From Selin (2007), Top: Table 1 with characteristics of *A. arctica* and *A. borealis*; Bottom left: Linear shell measurements of *Astarte arctica* (*1*) and *A. borealis* (*2*), relationship between shell length and shell height (solid lines), shell length and shell width (dashed lines); Bottom right relationship of H/L (solid lines) and D/H (dashed lines) ratios to shell length.

All four of the studies mentioned above have taken place in the Atlantic and North Pacific, leaving the Arctic Ocean with no shape studies to date. Three of the studies are from the densely populated Baltic Sea region where there is ease in collecting samples. The Arctic Ocean is remote and the collection of sufficient material is difficult, thus the lack of in depth studies to populations of Arctic *Astarte borealis*.

3.2 The Genetic Study of *Astarte borealis*

In 1999, Gardner and Thompson investigated the genetic variation of three species of *Astarte,* including *A. borealis*, found in the North Atlantic Ocean. The purpose was to compare sympatrically occurring *Astarte* in order to determine the level of shared genetics within the genus. The shells were collected from the east coast of Newfoundland, Canada and then Gardner and Thompson (1999) identified the shells based upon the descriptions found in Lubinsky (1980) and assigned to three species *A. borealis* (n=175), *A. elliptica* (n=35) and *A. striata* (n=29). Twelve allozyme loci were selected in order to find genetic variation among the species specific population. They used Principal Component Analysis (PCA) of the allozyme loci to determine if the genetic differentiation was able to allow for identification of random specimens to the correct species designation (**Figure 7**). Gardner and Thompson (1999) also calculated Nei's (1978) genetic distance (*D*) and genetic identity (*I*) for the pairs of the three species to find the degree of "genetic relatedness". The genetic test found similarities among the species (Figure 4) and indicated that the two other *Astarte* species, *A. elliptica* and *A. striata*, had descended from the *A. borealis*. Using data found for *I* and *D* (**Table 3**), Gardner and Thompson (1999) estimate the time of divergence at 2.25 Myr for *A.*

borealis and *A. elliptica*; 2.65 Myr for *A. borealis* and *A. striata*; and 2.45 Myr for *A. elliptica* and *A. striata*. Gardner and Thompson (1999) conclude "the three species arose at much the same time from an ancestral stock or from the oldest of the three species, which is likely to be *A. borealis* (Lubinsky, 1980)".

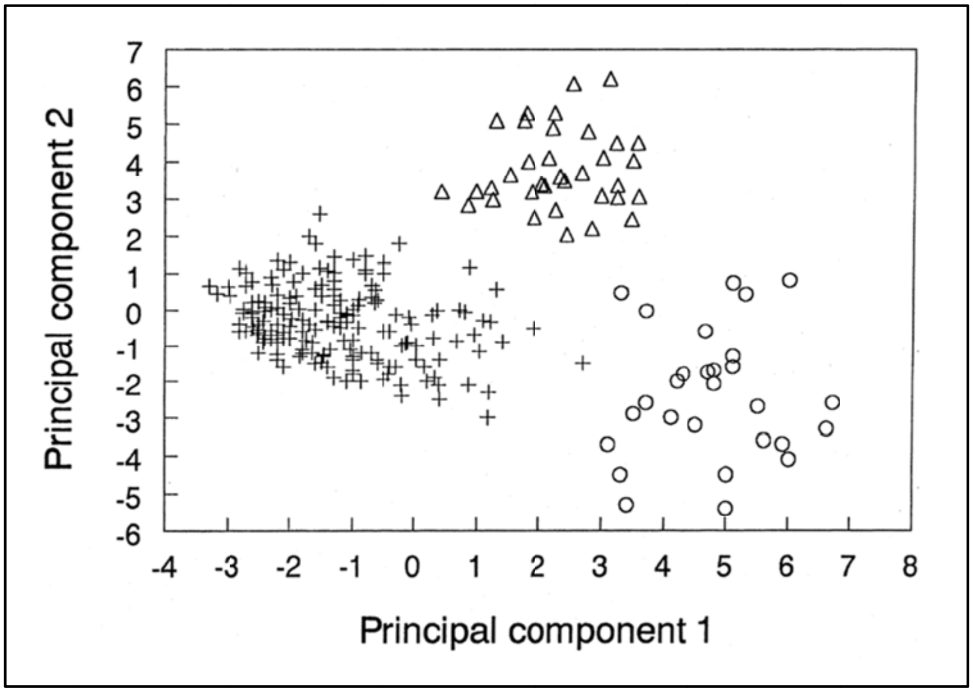

Figure 7. Fig 2 from Gardner and Thompson (1999), "Principal component (PC2) as a function of principal component 1 (PC1) for allozyme variation in *Astarte* (+ *Astarte borealis*; Δ *A. elliptica*; ○ *A. striata*)".

Species	*A. borealis*	*A. elliptica*	*A. striata*
A. borealis	—	0.64	0.59
A. elliptica	0.45	—	0.61
A. striata	0.53	0.49	—

Table 3. Table 4 from Gardner and Thompson (1999), "Nei's *I* (above diagonal) and *D* (below diagonal) values calculated for pairwise species comparisons between *Astarte borealis*, *A. elliptica*, *A. striata*."

In addition to genetic study, there was multivariate analysis of distance measurements of the shells. Gardner and Thompson (1999) selected 14 morphometric traits (Figure 8) that were measured to nearest 0.1mm for all 239 specimens. Data was examined with PCA to determine if the morphometric characteristics could be used to identify each species (**Figure 8**). Multivariate analysis of variance (MANOVA) of 13 characteristics, standardized by the 14th - length, was assessed to find correlation of morphometric features with species designation (**Figure 9**). The multivariate analysis showed overlap in shell shape between the three species (**Table 4**), and was useful for the speciation only when combined with the genetic analysis. The downfall of genetic study is that the living tissue must be preserved during collection, a difficult task if collections are performed in remote areas and in cases of fossil study; it is not preserved at all.

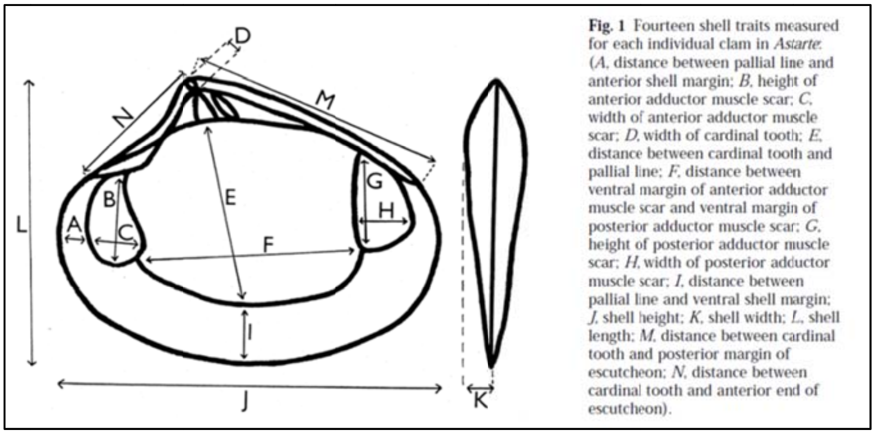

Figure 8. Fig 1 from Gardner and Thompson (1999), 14 measured distance traits of *Astarte* shells.

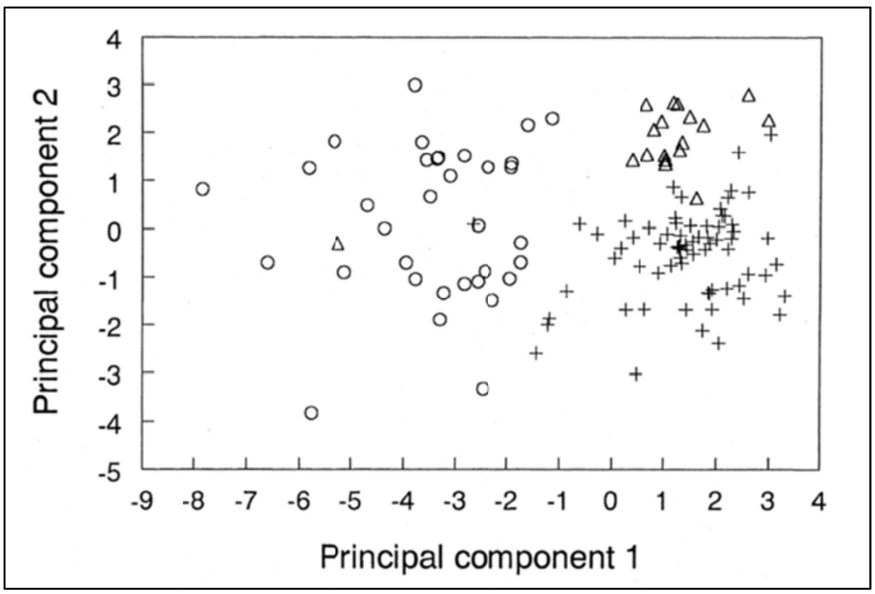

Figure 9. Fig 3 from Gardner and Thompson (1999), "Principal component (PC2) as a function of principal component 1 (PC1) for morphometric variation in *Astarte* (+ *Astarte borealis*; ∆ *A. elliptica*; ○ *A. striata*)".

Table 6 Multivariate analysis of variance (MANOVA) of variation in 13 morphometric traits as a function of species

Statistic	Value	F	Numerator d.f.	Denominator d.f.	Significance (P)
Wilks's Lambda	0.021	48.6	26	216	0.0001
Pillai's Trace	1.571	30.7	26	218	0.0001
Hotelling–Lawley Trace	18.148	74.7	26	214	0.0001
Roy's Greatest Root	16.456	138.0	13	109	0.0001

		Univariate ANOVAS		
Trait	F-value	Significance (P)	R^2	REGWQ
A	61.73	0.0001	0.507	B > E = S
B	65.18	0.0001	0.521	E = B > S
C	59.86	0.0001	0.499	B = E > S
D	18.81	0.0001	0.239	E > B > S
E	50.02	0.0001	0.455	B > E > S
F	42.80	0.0001	0.416	B > E > S
G	47.32	0.0001	0.440	E = B > S
H	108.60	0.0001	0.644	E = B > S
I	74.84	0.0001	0.555	B > E > S
J	0.59	0.5579	0.010	E = B = S
K	259.28	0.0001	0.812	S > B > E
M	29.31	0.0001	0.328	E > S = B
N	7.05	0.0013	0.105	E > S = B

Trait, length-standardized $\log_{10}$-transformed trait (see Fig. 1 for trait designations). REGWQ, Ryan–Einot–Gabriel–Welsch multiple range test for species-specific differences in mean trait value (B, *Astarte borealis*; E, *A. ellipuca*; S, *A. striata*).

Table 4. Table 6 from Gardner and Thompson (1999), "Multivariate analysis of variance (MANOVA) of variation in 13 morphometric traits as a function of species"

3.3 Periostracum Studies of the Genus *Astarte*

Ockelmann (1958) was the first to notice that the finer periostracum structure, viewed at 80x magnification, of the genus *Astarte* varied among its species and could be used to identify the smaller shells when the other morpho-features were inconclusive for identification purposes. Ockelmann describes the periostracum of *Astarte borealis*, *A. elliptica*, *A. montagui* and four varieties of *A. crenata* (*A. c. crenata*, *A. c. subequilatera*, *A. c. inflata* and *A. c. acusticostata*) (

Figure 10 and **Table 5**).

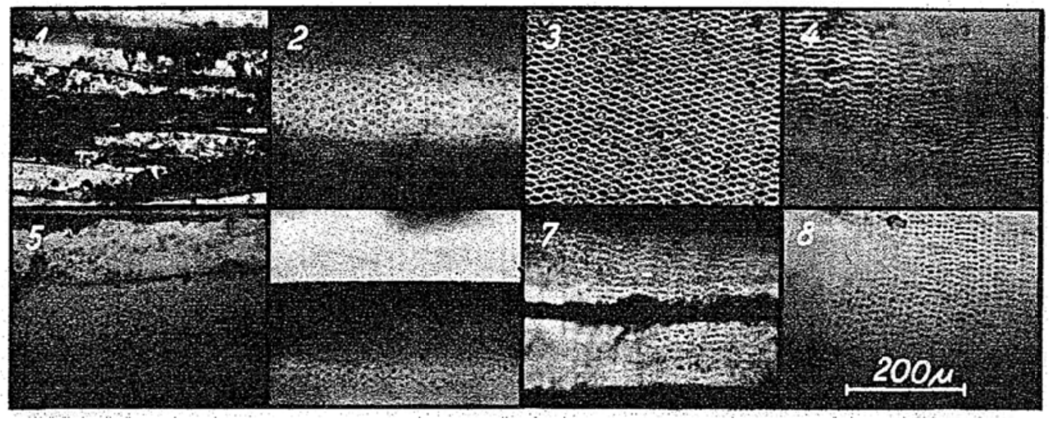

Figure 10. From Plate 1 in Ockelmann, 1958: "Microphotographs of the periostracum of the East Greenland species and subspecies of *Astarte*. Transillumination through the shell-substance. About 80 x." From top left: 1-*A. borealis*, 2 – *A. montagui*, 3 – *A. elliptica*, 4 – *A. sulcata*, 5 – *A. crenata*, 6 – *A. c. acusticostata*, 7 – *A. c. subequilatera*, and *A. c. inflata*.

Species	Periostracum
A. borealis	highly variable, fibrous and more or less frayed
A. montagui	irregular, radiating rows of faint, dot-like depressions
A. elliptica	fine, mesh-like structure
A. crenata	var. *crenata* - very fine, dot-like depressions, irregular grooves var. *subequilatera* - fine, dot structure, more marked var. *inflata* - dot like depressions arranged radially, irregular concentric rows var. *acusticostata* almost smooth

Table 5. Descriptions of the microscopic *Astarte* periostracum by Ockelmann (1958) at 80x magnification.

Ockelmann (1958) recommends further study of the fine structure as a possible way to clarify some of the systematics of this polymorphic genus.

Saleuddin (1967) was able to differentiate between three species of *Astarte*, *A. undata*, *A. castanea* and *A. esquimalti*, excluding *Astarte borealis*, and found that each had a characteristic microscopic texture of periostracum, viewed at 50x magnification (**Figure 11**).

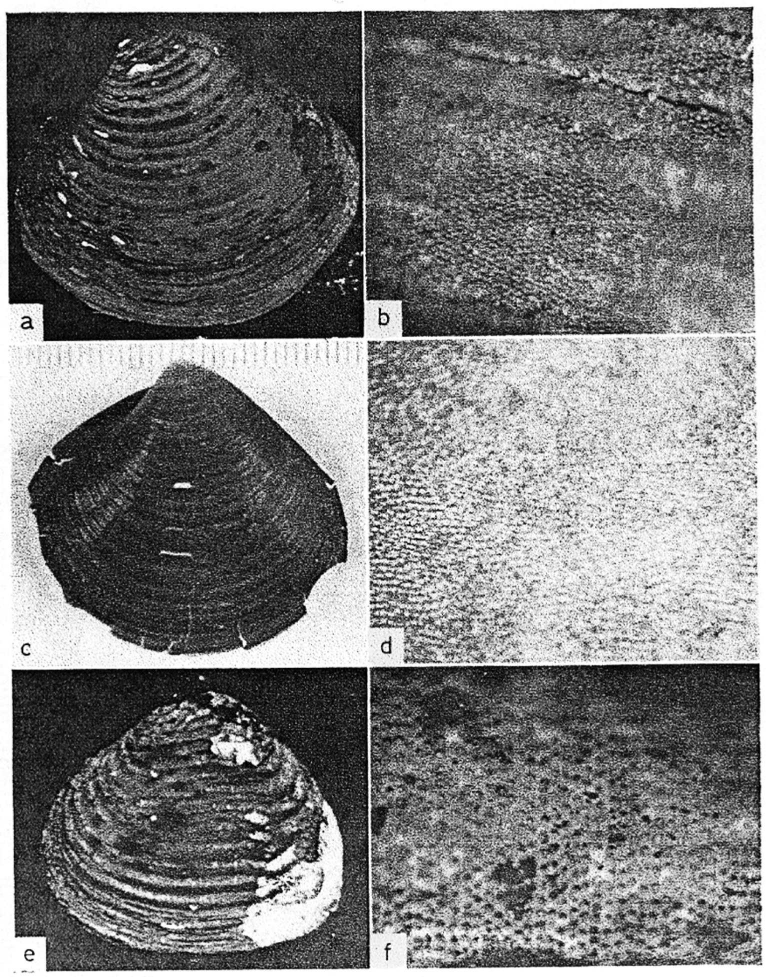

Figure 11. From Plate 40 in Saleuddin (1967): "Shell valves (a,c,e) and the surface view of the periostracum (b,d,f). (a and b) *A. undata* (a x 1.5; b x 50); (c and d) *A. castanea* (c x 1.15; d x 50); (e and f) *A. esquimalti* (e x 1.6, f x 50)"

In 1974, he continued the work using a Scanning Electron Microscope (SEM) and *A. castanea* and *A. elliptica* samples. When viewed at 450x and 500x magnification, Saleuddin (1974) found that though the periostracum appears uniformly pitted in both species, there were differences in the shape of the pits (**Figure 12**).

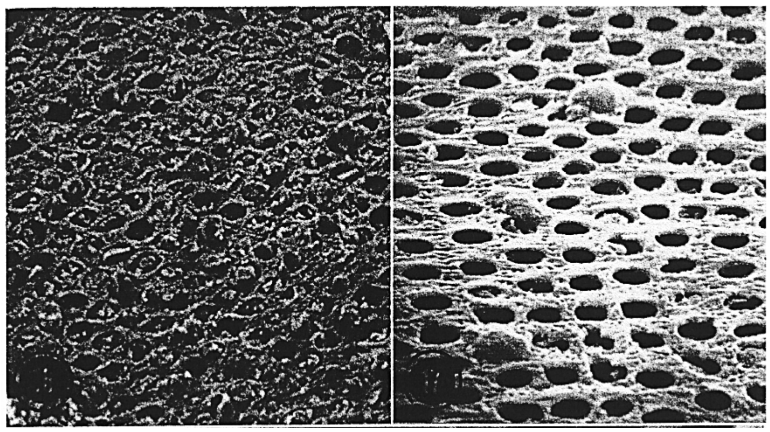

Figure 12. From Fig 16 & 17 in Saleuddin (1974), Left: SEM of the periostracum of *A. elliptica* x 450; Right: SEM of *A. castanea* x 500.

Skazina, Sofronova and Khaitov (2013) examine the use of periostracum to differentiate juvenile astartids based on the adult periostracum structure of *A. borealis*, *A. elliptica*, and *A. montagui*. The juveniles lack distinguishing shell morphology to exactly describe the species, therefore the SEM examination of the periostracum is needed to differentiate between the species. Skazina, Sofronova and Khaitov (2013) describes the periostracum as follows: *A. elliptica* has a fine reticulum, resembling hexagons; *A. montagui* surface is covered with uniform pits in a radial pattern, which at higher magnification are large pits surrounded by smaller ones; *A. borealis* has a complicated pattern of different shaped pits in no particular order, and looks cracked (**Figure 3**). Although there is success using the fine periostracum structure to differentiate between species of *Astarte*, there is no study that covers variation of periostracum microstructure within one species of *Astarte*. A point of contention with the use of this feature for study is that the periostracum is organic and often not preserved in fossil specimens and would therefore not serve to link the recent and fossil studies.

CHAPTER 4

4.0 APPROACHES TO THE STUDY OF BIVALVE SHAPE

Shape in systematic descriptions is often defined using subjective terms that vary depending upon researcher and are often open to reader interpretations. Statistical shape analysis provides an objective mean to describe the overall shape of an object and, in case of zoology or paleontology, provides a potential to differentiate between species by using statistical parameters in a mathematical formulae. Shape is inherently important in the study of any species, particularly the ones where a variety of potential shapes is somewhat limited. The shape of a bivalve may make it immediately recognizable to the observer and shell outline is important in genus and species identifications. The shape study of an organism is referred to as morphometrics, the quantitative analysis of form. The shape of a bivalve can be studied in various ways and is usually analyzed using three key methods: traditional, landmark, and outline.

4.1 Traditional Measurements

The bivariate measurements composed of length and height of a bivalve are the basis for the traditional study of shape; however the real component being measured is size (Raup and Stanley, 1978). The two are not mutually exclusive, nor carry the same meaning when dealing with morphology (Bookstein, 1989). The application of bivariate measurements provides a ratio of height to length that many other similarly sized bivalves can also possess. This allows for the analysis of the size of the bivalve but does not take into account the outline. When shape is described in measurements that are perpendicular to one another, the shape is assumed to be rectangular (Raup and Stanley, 1978) (**Figure 13**). The attempt to observe nuanced differences within a species cannot be determined by only comparing the size of the "rectangle" that the shell occupies when measured as a product of the length versus height.

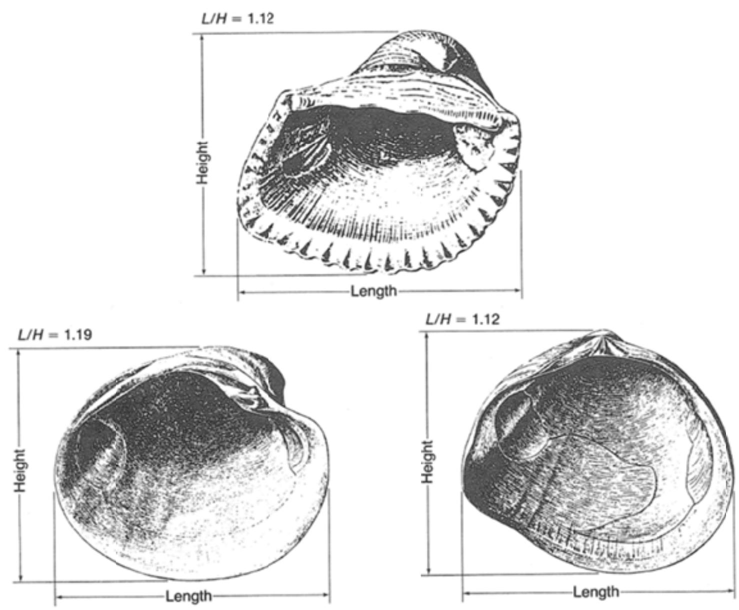

Figure 13. Length vs. height ratios for three different bivalves all nearly equal (clockwise from top, L/H = 1.12, 1.12, and 1.19). Reproduced from Stanley and Raup (1978).

For this study there will be an analysis of the height to length ratios compared with previous studies (Ockelmann, 1958; Schafer, Trutschler and Rumhor, 1985; Selin 2007; Zettler, 2001) to see if *Astarte borealis* from Northern Alaska have similar height/length/width relationships as *A. borealis* from other-regions.

4.2 Landmark Measurements

The use of landmarks in multivariate analysis allows for a more detailed examination of the differences in morphology. The landmarks are homologues among the specimens studied as well as easily identified (Bookstein, 1991). The number of landmarks may depend on the size of the specimen as well as the detail in change needed to be observed. The landmark distances are measured and compared using Bookstein or Procrustes coordinates (Raup and Stanley, 1978). Typically for a bivalve, the landmarks would include around 10 points about the shell, as seen in Figure 14, that include the beak of the shell (1), posterior and anterior cardinal tooth position (2,9), the limits of the posterior and anterior adductor muscle scars (3,4,7,8) and the tip of the pallial sinus (5) (Rufino et al., 2006) .

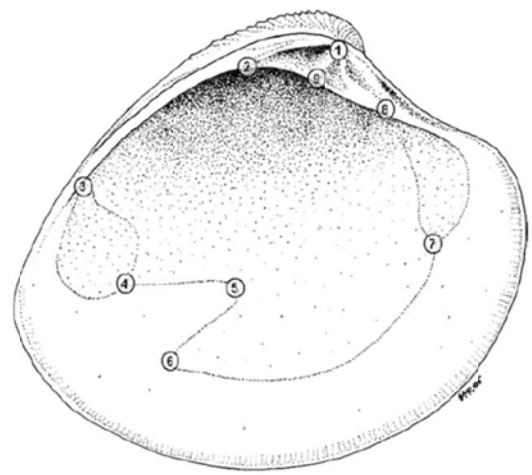

Figure 14. Fig 1 from Rufino et al., 2006, landmarks shown on the interior of *Chamelea striatula*.

In the genus *Astarte*, there are few landmarks available for study. The option is to use the hinge and teeth, which is if they are available in the species. The muscle scars are deeply impressed, but the pallial line is weak and there is no pallial sinus, which limits the amount of landmarks available to about 7, the use of these proves difficult in the ability to rapidly and easily identify these landmarks in multiple specimens. There are several bivariate linear measurement analyses of *Astarte*; however there are no available landmark analysis studies of the genus. The use of landmarks for analysis in the case of *Astarte borealis* proves to be challenging and too time consuming given the lack of distinction in, and rapid identification of, landmarks for a study of numerous (hundreds) specimens. Crampton (1995) remarks that another caveat of landmark analysis is that there may be information lost when using only a few homologous points rather than the outline analysis. Since the Astarte lack numerous significant landmarks, the used of outline analysis demonstrates to be a more useful tool in the quantitative assessment of the species.

4.3 Outline Measurements

Scott (1980) asses that outlines are used in visual recognition of species and thusly the examination of the outline can add to the qualitative analysis done by the researcher. The most recent and rapidly advancing method of multivariate morphometric analysis is done by tracing the outline of the shape and quantifying differences. The first way this was done was by fitting the curve of the outline to a polynomial curve, the method has been updated to eigenshape and Elliptic Fourier (EFD) methods. The former uses a number of points around the outline at equal intervals to obtain a basic line, the deviations of these points from a simple circle are analyzed to find differences (Scott, 1980). The EFD uses the entire outline of the object and finds the sum of the minimum amount of ellipses required to mimic the shape by decomposing the original outline (Kuhl and Giardina, 1982; Rohlf 1986). The decompositions of each outline can be compared by using the principal components of each deviation. Both of these methods have weaknesses, the eigenshape methods require the selection of starting points for each individual outline, whereas the EFD does not. The method chosen for this study is dependent upon the software selected to process that data, in this study the elliptical Fourier method is employed (Iwata and Ukai, 2002).

CHAPTER 5

5.0 MATERIALS AND METHODS

5.1 Field Collections and Museum Collections

The recent bivalve specimens were collected during a research trip to the North Slope of Alaska in July of 2005. The locality is remote and hard to access. The shells were initially observed on July 13, 2005 in a locality in the North Slope of Alaska, the gravel beach of Camden Bay to the east of the Carter Creek mouth. On this first date, 22 complete bivalves and 18 single valves were collected and noted to have differing morphology, but all initially identified as *Astarte borealis*. Researchers returned to the site on July 17, 2005 and collected all of the shells during a span of two days along a 5.5 km stretch of beach along Camden Bay, between Marsh Creek and the Sadlerochit River (**Figure 15**). The beach is made up of mostly gravel with occasional sand bars; average width of the beach is 30 meters (**Figure 16**).

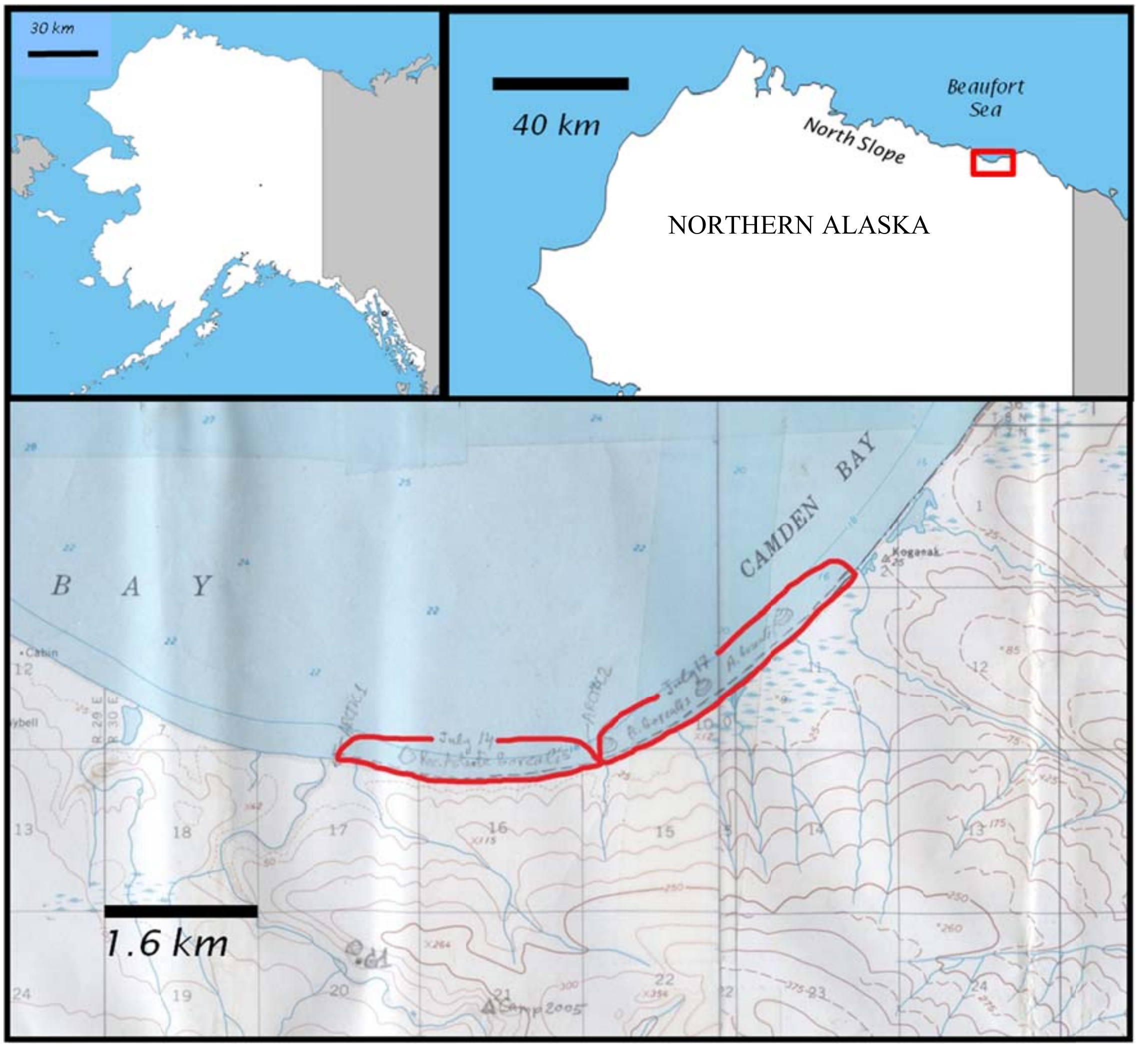

Figure 15: Area of shell collection. Top left image shows Alaska for spatial reference. Top right image shows the location of the Camden Bay in northern Alaska, the highlighted area is expanded in the image beneath. The bottom image is a depiction of the site where the shells were collected from along Camden Bay.

Figure 16: Left: Area of shell collection. 30 m wide stretch of gravel and sand bar beach in Camden Bay, northern Alaska. Right: *Astarte borealis* on the beach (lens cap for scale).

The fossil Pliocene *Astarte borealis* used in this study were obtained on loan from the California Academy of Sciences, Department of Invertebrate Zoology and Geology fossil collections. Specimen locality and formation are the Sandy Ridge section, Alaska Peninsula, marine facies of the Milky River formation (**Figure 17**). 13 specimens were used for the distance measurement analysis based on completeness with respect to the distance measurements needed. 11 specimens were used from this collection for the outline analysis and chosen based on degree of outline completion. The fossil specimens were all identified as *Astarte borealis* and collected from Alaska.

Figure 17. Left: Alaska with location (1) of the recent *A. borealis* and location (2) the Sandy Ridge section, Alaska Peninsula where the fossil *A. borealis* were collected. Right: three of the fossil *A. borealis*, note the bottom shell with incomplete outline was not included in sampling.

The fossil *Astarte martini* specimens were also collected during a research trip to the North Slope of Alaska in July of 2005, from the Oligocene Nuwok Member of the Tertiary Sagavanirktok Formation (Location 1 in **Figure 17**). Thirty-three specimens were used for distance and outline analysis.

5.2 Sample Sorting and Preparation

All of the shells collected from the site were sorted to separate left from right valves to eliminate duplication of outline. The left valves were retained and sorted again; retaining only specimens with complete outline available, any valves with large chips or partial outlines were removed from the study sample. A total of 641 recent left valves and 11 Pliocene specimens were used for this study. Left valves were chosen, with no preference over right valves, to eliminate duplication of a specimen in the quantitative analyses.

All left valves were soaked in sodium hypochlorite, 10% solution for approximately 48 hours to remove organic matter (periostracum), then rinsed with de-ionized water and dried. Fossil specimens were unaltered for this study; due to limited number of samples, both left and right valves of fossil *Astarte borealis* were used when outline was visible.

5.3 Photography and Image Processing

Recent shells were prepared for photography by coating the exterior surface with water based tempera paint to remove any image interference from rust staining on the surfaces. The shells were photographed with Canon EOS 20D digital camera and processed in Adobe Photoshop 7.0 to retain the outline of the image. All shells with incomplete outlines were removed. 11 Pliocene *A. borealis* and 33 *A .martini* were photographed with Optronix Magna Fire Firewire digital camera in and edited in Photoshop to retain only shell outline. The fossil shells had no processing prior to digital imaging, and any right valves were transposed to represent left valves. The last step was possible due to the equivalve *A. borealis* characteristic.

5.4 Distance Measurements

A third of the recent specimens that were selected for outline analysis were selected randomly for the distance measurements, amounting to 225 in total. There were also 13 Pliocene fossil samples available for measurement. Three distance measurements were taken using a Mitutoyo Absolute Digimatic digital caliper; height, length and width were taken in millimeters to the hundredth place (0.01 mm).

5.5 SHAPE Software

SHAPE ver. 1.3, a software package for Quantitative Evaluation of Biological Shapes Based on elliptical Fourier descriptors, developed by Iwata and Ukai in 2002, was used in this study for the quantitative analysis of the bivalve outline. The valve outline shape variation is studied by the Elliptic Fourier descriptors (EFDs) which are obtained by decomposing a curve into a sum of harmonically related ellipses (Kuhl and Giardina, 1982). The SHAPE ver. 1.3 software package contains four programs: ChainCoder, Che2Nef, PrinComp and PrinPrint.

5.5.1 Image Analysis

Image analysis was performed by the ChainCoder program, by extraction of the contours of the valve outline from a digital image and preserving the relative information as a chain code. The images of the left valves were obtained by photographing specimens. The image of the left valves were taking next to a scale marker (30mm x

30mm), aligned with the hinge oriented at the top of the photo. 9 left valves were captured in each image. The left valves were placed interior downward on a dark background to obtain the most contrast. Images were imported into Photoshop 7.0 to retain only outline and to change images to full color (24-bit) BITMAP images for processing in SHAPE (**Figure 18**).

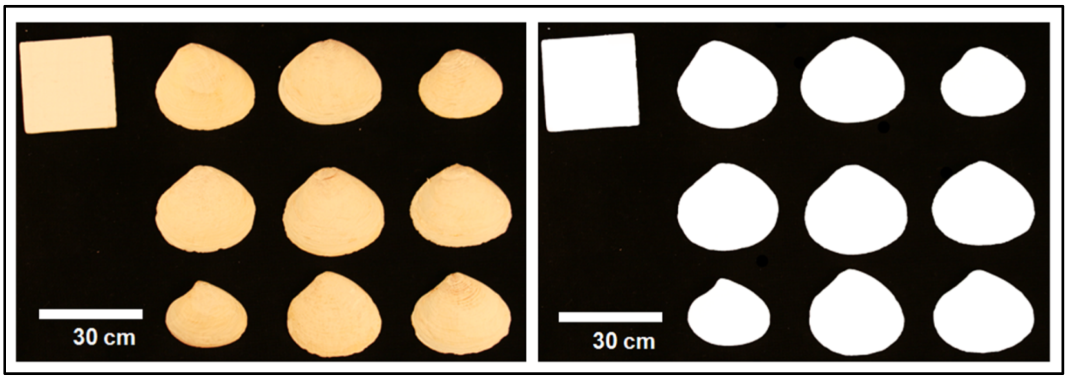

Figure 18. Left: Photo of 9 *A. borealis* left valves with scale marker (30mm x 30mm). Right: Same photo processed in Adobe Photoshop 7.0 to retain only outline and change image format.

The ChainCoder program converts the full color image to black and white by splitting the image into three colors with gray scale, converting the image with clearest contrast to black and white. The noise is reduced and the closed contour of the valve was extracted by edge detection which is described as chain code. Chain code is a coding system for describing geometrical information about contours using numbers 0-7 (figure 4), indicating direction as measured counterclockwise from *X* axis of *X* - *Y* coordinate system to represent the position of each successive point in relation to the previous (Kuhl and Giardina, 1982) (**Figure 19**). The area of each valve was also recorded.

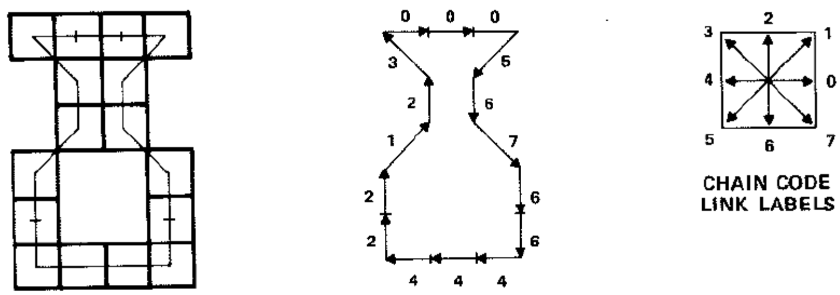

Figure 19. Example of chain coding process where points on the outline are selected and analyzed, from top left, V_1 = 0005676644422123. From Kuhl and Giardina, 1982.

5.5.2 Derived Elliptic Fourier Descriptors

The program called Chc2Nef used the chain code obtained from ChainCoder to calculate normalized Elliptic Fourier descriptors (EFDs) following the procedures suggested by Kuhl and Giardina (1982) (Eq. 1 Fourier series expansion for the chain code of contour. From Kuhl and Giardina, 1982.Eq. 1 and Eq. 2). Kuhl and Giardina (1987) define Eq. 2 as follows: n is the nth harmonic; p is the number of steps in trace around the outline; Δx_p is the displacement along the x-axis of the contour between the steps p-1 and p; Δt_p is the length of the linear segments between the steps; t_p is the length sum of all the segments; and $T = t_k$ is the total length of the contour as approximated y the trace polygon. The EFDs are normalized to be invariant with respect to size, rotation and starting point and is based on the first harmonic ellipse that corresponds to the contour information's first Fourier approximation. The Elliptic Fourier descriptors are used to find the principal components of the shape variation.

$$x(t) = A_0 + \sum_{n=1}^{\infty} a_n \cos\frac{2n\pi t}{T} + b_n \sin\frac{2n\pi t}{T}$$

Eq. 1 Fourier series expansion for the chain code of contour. From Kuhl and Giardina, 1982.

$$a_k = \frac{T}{2n^2\pi^2}\sum^{p}(\Delta x_p/\Delta t_p)\left(\cos 2\pi k t_i\sqrt{T} - \cos 2\pi k t_{i-1}\sqrt{T}\right)$$

$$b_k = \frac{T}{2n^2\pi^2}\sum^{p}(\Delta x_p/\Delta t_p)\left(\sin 2\pi k t_i\sqrt{T} - \sin 2\pi k t_{i-1}\sqrt{T}\right)$$

Eq. 2. Elliptical Fourier decomposition of the x coordinates, with components a_k and b_k. From Kuhl and Giardina, 1982. The equations substitute c_k for a_k and d_k for b_k when calculating the y coordinate projections.

5.5.3 Principal Component Analysis

In PrinComp, principal component analysis of the normalized EFDs is done to efficiently summarize the information contained in these coefficients (Rohlf and Archie 1984) in order to be more easily interpreted. The principal component analysis converts a set of observed correlated variables and by means of orthogonal transformations, produces a set of values that are linearly uncorrelated variables or principal components. The first principal component produced has the highest possible variance with respect to the data set. Each successive principal component has the highest possible variance with respect to the preceding component.

5.5.4 Visualization of Variations

The visualization program, PrinPrint, outputs the shape variation accounted by the most effective principal components that will be determined by the pervious program. Following the procedure in Iwata and Ukai (2002), the coefficients of the elliptic Fourier descriptors are calculated where the score for a particular principal component is equal to + 2 or- 2 times the standard deviation from the mean, the square root of the eigenvalue of the particular component and the scores of the remaining components are zero. The coefficients are used to execute an inverse Fourier transform and create contour shapes that are visual representations of the data. This visual output will aid in interpreting the variation associated with each principal component.

CHAPTER 6

6.0 RESULTS AND ANALYSIS

6.1 Distance Measurements

Appendix 2 contains the raw measurements taken from the recent and Pliocene *Astarte borealis*. When the height and length of both were examined, the averages for both were quite similar. The large sample size of the recent *A. borealis* can be an accurate representation of the population, however the small number of Pliocene shells is limiting in the comparisons that can be made and should be used merely as an idea of the correlation between the recent and Pliocene shape variation of *Astarte borealis*. The ratios of length to height and width to height were examined for both groups as well as the previous studies done by Ockelmann (1958), Selin (2007) and Zettler (2001) (**Table 6**). The width to height ratio was not available from the 2001 study by Zettler. For the length to height ratio, the two populations studied here and those by Selin and Zettler were quite similar, whereas the population studied by Ockelmann has a much higher ratio, indicating that the shells were much narrower in that area. However, for all four populations, the width to height ratios were very similar indicating that the size of the shells is consistent geographically and spatially.

Specimen	L/H
recent *A. borealis*	1.16
Fossil *A. borealis*	1.12
Ockelmann 1958	1.28
Selin 2007	1.10
Zettler 2001	1.15
Fossil *A. martini*	1.21

Specimen	W/H
recent *A. borealis*	0.21
Fossil *A. borealis*	0.24
Ockelmann 1958	0.23
Selin 2007	0.22
n/a	n/a
Fossil *A. martini*	0.27

Table 6: L/H (length to height) and W/H (width to height) ratios of the recent and Fossil groups in this study, compared to data of Ockelmann (1958), Selin (2007) and Zettler (2001).

The measurements of height and length were plotted on a scatter plot for both the recent and fossil specimens with linear trend lines (**Figure 20**). The correlation coefficient for height to length ratio is 0.7393 for the recent and 0.7363 for the fossil specimens. This is not a strong correlation value within the sample sets; however, it is nearly identical for both sets, indicating that the correlation factor within the species is the same for the fossil and recent populations.

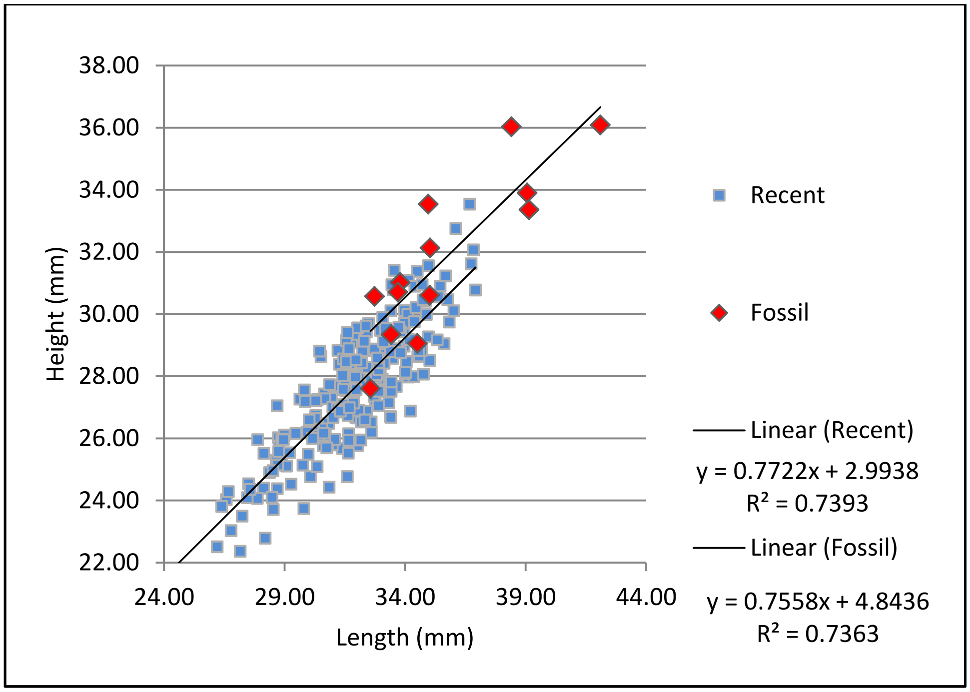

Figure 20: Recent and Fossil specimen scatter plot showing the similar coefficient correlation between the two series. The data obtained by measurement was recorded into Excel to create graphs.

The fossil *Astarte martini* measurement data was compared to the *A. borealis* data and found to have a higher correlation coefficient, 0.8977 vs. 0.7393 (recent) and 0.7363 (Fossil) (**Figure 21**).

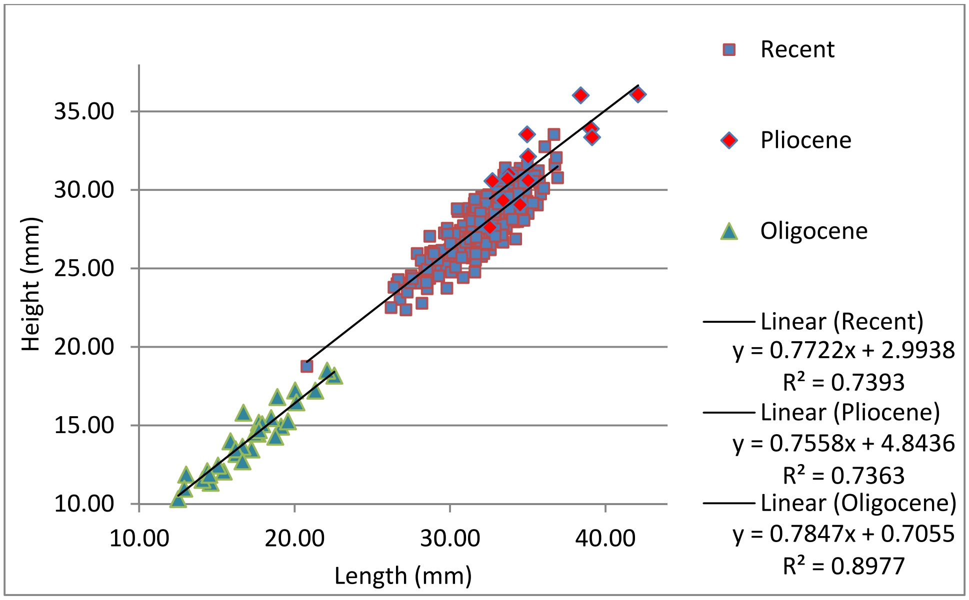

Figure 21. Recent and Fossil *A. borealis* and fossil *A. martini* are shown on scatter plot showing the similar coefficient correlation between the two *A. borealis* series and the smaller *A. martini* that have a similar H/L proportion.

6.2 Outline Shape Analysis

6.2.1 Recent Specimens

The outline analysis shows the areas where the variability was found in the shell outline as well as the proportion of variance that could be attributed to each component of variation among the population. The results of the statistical computation by the SHAPE software package PrinComp and the first 7 principal components are visualized by PrinPrint are shown in **Figure 22** and in more detail in Appendix 3.

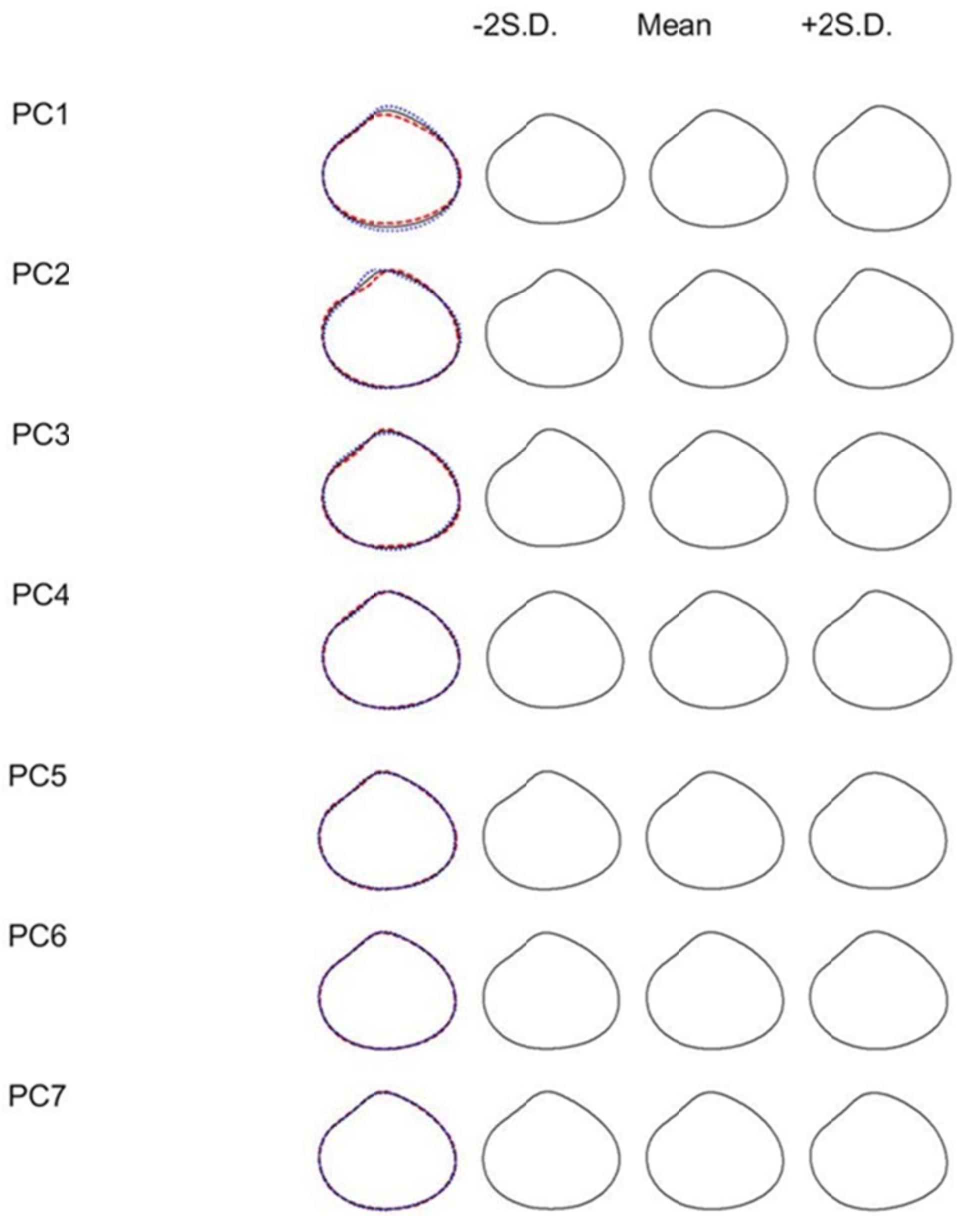

Figure 22. The PrinPrint visualization of the mean shape and the + 2 and – 2 standard deviation from the mean in outlines for the first 7 significant principal components. The blue dotted line in the first overlay are the + 2 standard deviation, the black, solid line is the mean form; the red, dashed line is the – 2 standard deviation.

Principal components that represent the variance in the outline were calculated from the symmetric and asymmetric aspects of the shell. **Table 7** has first 10 principal components (PC) of the recent *A. borealis* outline analysis as computed by SHAPE software program PrinComp. The 10 PC account for about 94.94% of the variance found in the population, and the first three PCs represent 83.21% of variance.

Principal Component	Eigenvalue	Proportion (%)	Cumulative (%)
Prin1	7.36E-04	47.4171	47.4171
Prin2	3.53E-04	22.7443	70.1614
Prin3	2.02E-04	13.0451	83.2065
Prin4	5.23E-05	3.3717	86.5782
Prin5	4.26E-05	2.7436	89.3218
Prin6	2.68E-05	1.7263	91.0482
Prin7	2.04E-05	1.3167	92.3649
Prin8	1.65E-05	1.0634	93.4282
Prin9	1.29E-05	0.8343	94.2625
Prin10	1.05E-05	0.6759	94.9384

Table 7: The first 10 principal components of the recent specimens of *Astarte borealis* outlines analysis with eigenvalues, the proportion that each component describes variance for and the cumulative of variance accounted.

The PCs were plotted against one another to show where the concentration of variance in outline shapes. The greatest variation is represented by the first PC, the second greatest variation by the second PC and so forth. The distribution of variation can be visualized by plotting the PCs against one another, since the first two PCs comprise the most variation; they are plotted with the PC 1 on the x-axis and the PC 2 on the y-axis. **Figure 23** shows the first and second principal components plotted with the outline contours drawn by the PrinPrint program in the SHAPE software; **Figure 24** shows the first and third principal components.

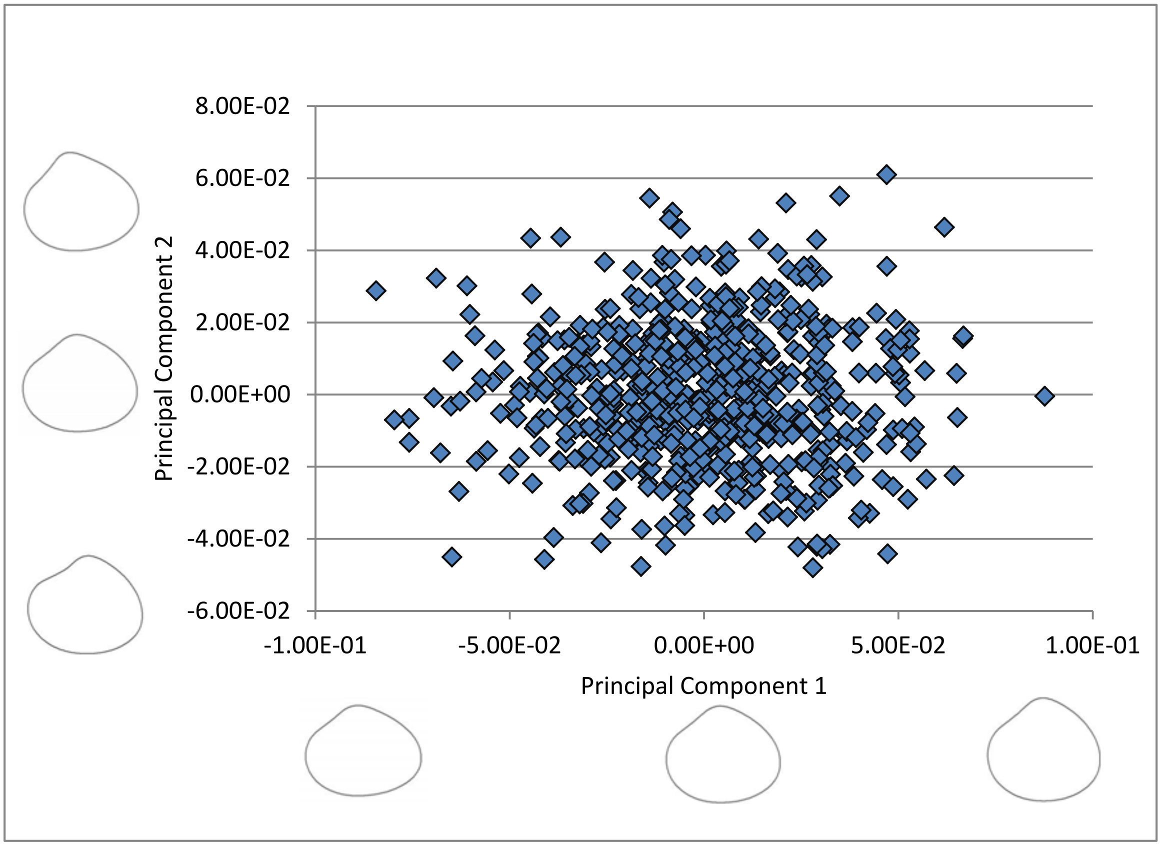

Figure 23: Scatter plot of Principal Component scores 1 versus 2 for the recent *A. borealis* specimens. The contours recreated by PrinPrint of SHAPE have been placed with respect to the trend of variation. The data obtained in SHAPE software was imported into Excel to make graphs.

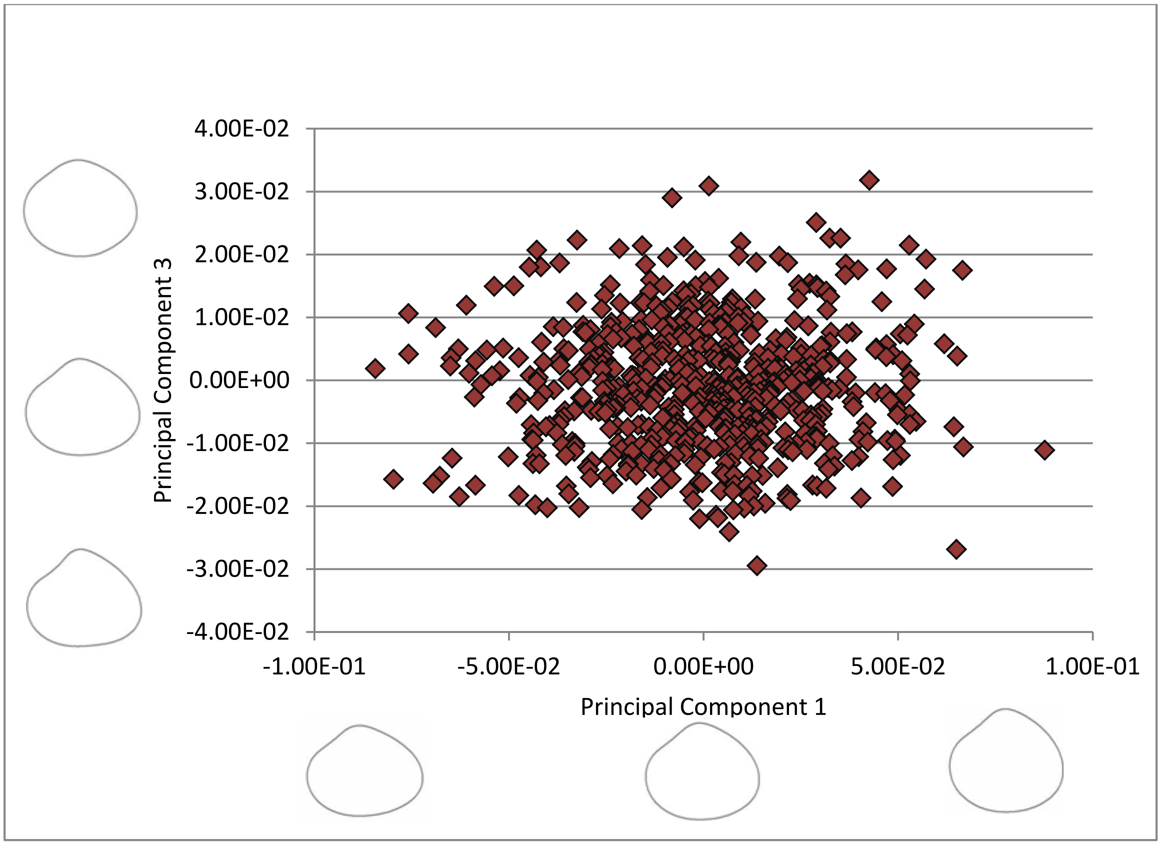

Figure 24: Scatter plot of Principal Component scores 1 versus 3 for the recent *A. borealis* specimens. The contours recreated by PrinPrint of SHAPE have been placed with respect to the trend of variation.

The PrinPrint program provides the visual interpretation of the -2 and +2 standard deviation of the shape variation represented by the principal components. Appendix 4 shows the first seven principal components visualized with the mean shape in black with the negative deviation in red dashed contour line and the positive deviation in blue dotted line. The PC 1 accounts for 47.42 % of the variance found in the recent specimens and based on the visualization this is representative of the overall shell height (**Figure 25**).

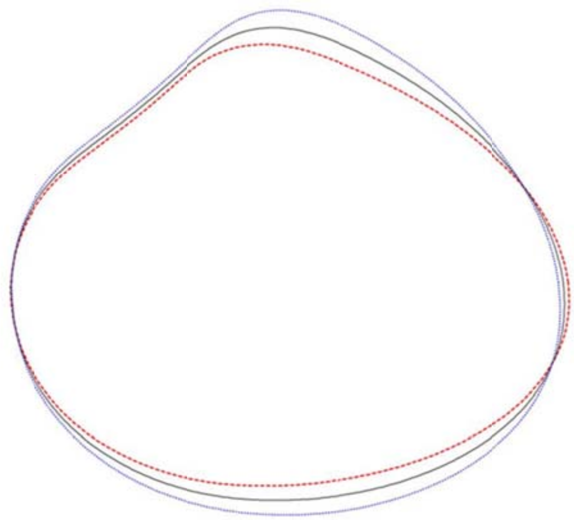

Figure 25: Reconstruction of contours of PC 1 by PrinPrint, variation visible with respect to shell height to length ratio. The blue dotted line is the + 2 standard deviation, the black, solid line is the mean form; the red, dashed line is the – 2 standard deviation.

From the positive to the negative standard deviations, the shell length only varies about 1% whereas the shell height varies about 15%. The positive standard deviation has a height to length ratio of 1.09, the mean shape ratio is 1.17 and the negative standard deviation has a ratio of 1.26. The mean ratio of 1.17 is consistent with the distance measurements examined in the previous section. The PC 2 accounts for 22.74 % of the variance and represents the position of the umbones with respect to the central line (**Figure 26**).

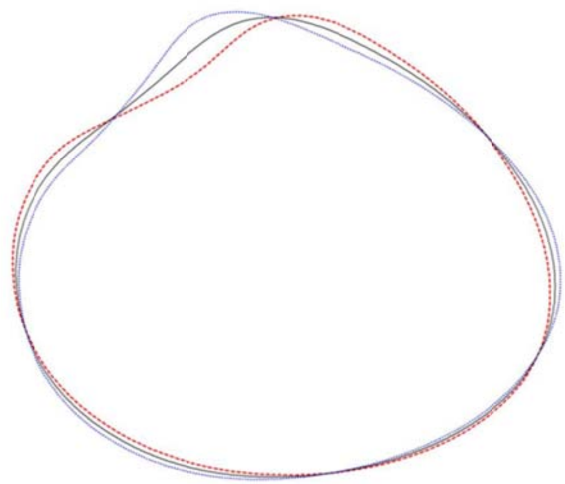

Figure 26: Reconstruction of contours of PC 2 by PrinPrint, variation with respect to position of umbo. The blue dotted line is the + 2 standard deviation, the black, solid line is the mean form; the red, dashed line is the – 2 standard deviation.

The mean shape has an umbo nearly on the midline, the positive deviation has the umbo quite dorsal to the midline and the negative deviation has the umbo slightly dorsal of the midline. The PC 3 accounts for 13.05 % of the variance and is representative of the overall shell shape (**Figure 27**).

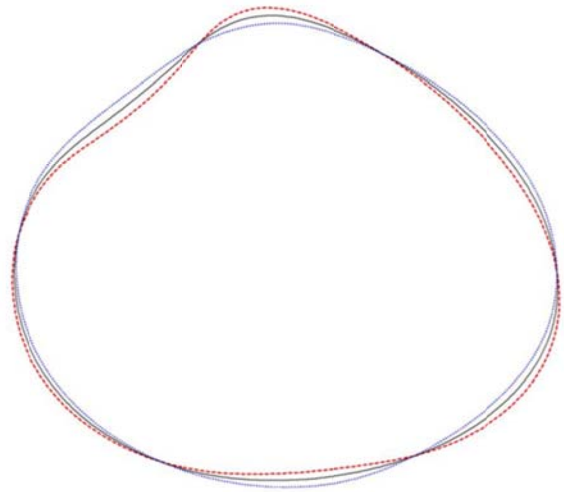

Figure 27: Reconstruction of the contours of PC 3 by PrinPrint, variation with respect to the overall shell shape. The blue dotted line is the + 2 standard deviation, the black, solid line is the mean form; the red, dashed line is the – 2 standard deviation.

The positive deviation has a rounded, subquadrate figure ranging to the negative valve with a compressed subtrigonal shape. This is consistent with the various descriptions available in literature.

6.2.2 Fossil Specimens

The 11 fossil specimens had the outline analyzed and results were plotted over the recent graphs for correlation (**Figure 28**). The fossil specimen data falls entirely into the range of the recent specimens' data. The small number of fossil specimens available poses a problem in regards to outline analysis. Therefore there are only used as an indication of whether the fossils are similar to the recent specimens' morphological variability and not a direct indicator of correspondence.

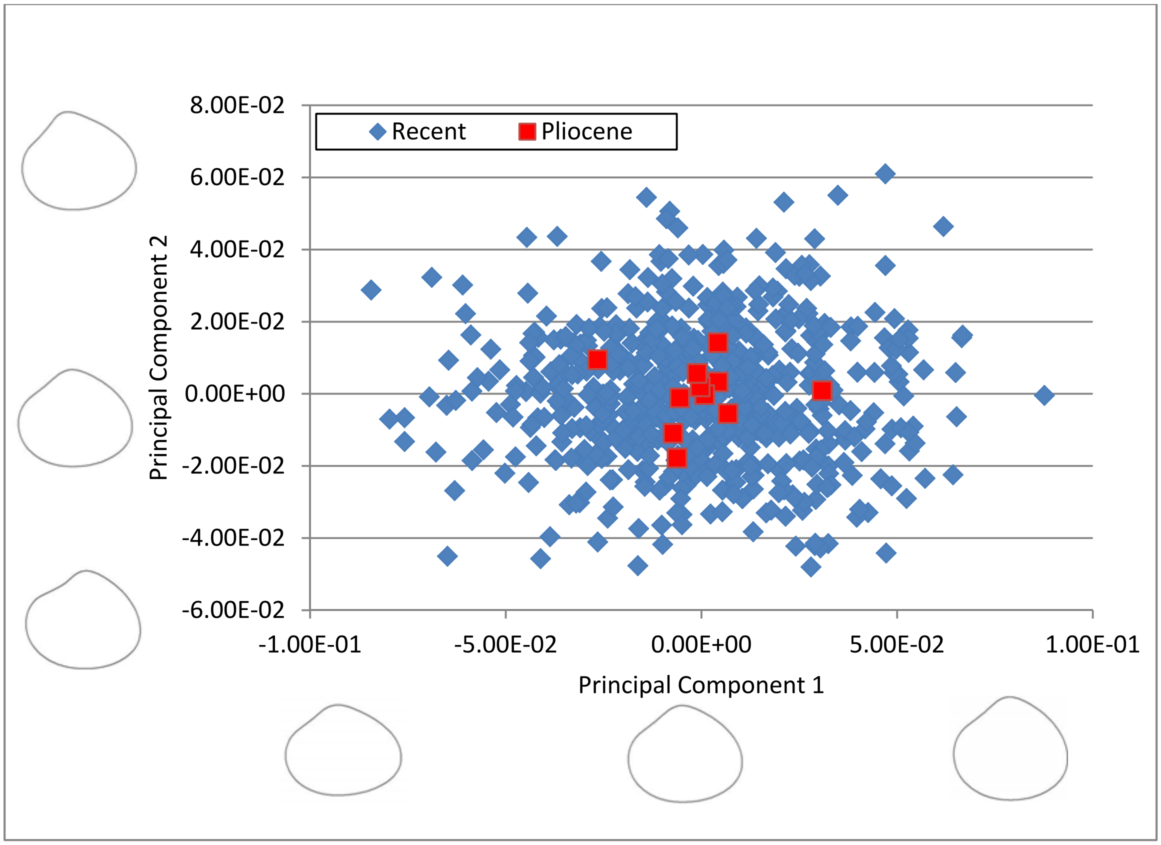

Figure 28: Scatter plot of Principal Component scores 1 versus 2 for the recent (blue) and fossil (red) *A. borealis* specimens. The contours recreated by PrinPrint of SHAPE have been placed with respect to the trend of variation.

CHAPTER 7

7.0 DISCUSSION AND CONCLUSIONS

Outline Shape analysis clearly indicate that *Astarte borealis* has a high morphological variability within the species which can be a potential source of much confusion among researchers during species identification. The bivariate analysis comparison between fossil and recent population shows that there is continuity in the species and the variation has been a characteristic of the species for a long time. The multivariate outline analysis indicates that the intraspecies variation is based upon a common shape that grades into other shapes evenly. Two areas of concentration that are separate or grade into each other are the indication of two distinct varieties/forms such as in the study by Gardner and Thompson (1999) where the plot of *A. borealis*, *A. elliptica* and *A. striata* are concentrated in three areas on the graph (**Figure 7**). Since this was absent in both the PC 1 vs. PC2 and the PC1 vs. PC 3 plots, the result indicates a correlated population centered on a common form. The PrinPrint plots show the most significant principal components and their interpretations show where the variation is found. This study does not support the idea that the variation within certain species is a continuum between two end-forms. In the case of the genus *Astarte*, *Astarte borealis* in particular, forms and varieties assignment would be at best problematic without population study based on the statistically significant data. Assignment of fossil species, that may not be available in quantities should not be based solely on the shell outline and should include other diagnostic characteristics, if found.

The study of geographical distribution of the species by Zettler (2002) emphasized and confirms the polymorphism of *A. borealis*. The polymorphism of the species has been attributed to the non-pelagic reproduction that causes the eggs to attach to the substrate near the parents (Ockelmann, 1958). Since there is a lack of diversity in the reproduction, the variation could accelerate depending upon environmental conditions such as substrate composition, salinity, temperature, nutrients, and so forth. The slight differences in environment may influence the changes in the shell height to length ratio or perhaps the ventral margin that affect a certain portion of the population but do not separate it from the species. Changes can probably be detected in shell thickness and overall size which could be a function of water temperature. That, in turn would be a function of changing climate.

Further research should include study of several populations, particularly focusing at the differences in outline form from the Arctic to the North Atlantic. The investigation can also include several fossil *Astarte borealis* and/or other species to gain an insight into the spatial and temporal patterns in shape changes within the genus and species. Ideally a full study would be done, that follows the spatial and temporal variation of the shell outline of the genus to track the changes and evolutionary radiation of the genus *Astarte* we can gain an insight into the succession of species, and in a number of cases, determine if we are looking at a different species or just the same one. The use of DNA analysis between the Arctic, Atlantic, Baltic and Pacific populations could also be useful in determining the amount of correlation between the regional populations when used in combination with outline and, for recent specimens, periostracum analysis.

APPENDIX 1

This appendix contains all the raw distance measurements and data for the recent and Pliocene *Astarte borealis* and Oligocene *A. martini* used for the bivariate analysis in table format.

All Specimens Distance Measurements (mm) Raw Data Page 1

Specimen	sample number	height (mm)	length (mm)	width (mm)	length/height ratio	width/length ratio
A. borealis	AB0001	26.20	32.60	6.39	1.24	0.20
A. borealis	AB0002	29.27	34.97	6.15	1.19	0.18
A. borealis	AB0003	31.23	35.68	5.67	1.14	0.16
A. borealis	AB0004	30.79	33.50	5.65	1.09	0.17
A. borealis	AB0005	27.57	33.18	5.62	1.20	0.17
A. borealis	AB0006	25.68	31.40	5.98	1.22	0.19
A. borealis	AB0007	29.42	33.53	6.54	1.14	0.20
A. borealis	AB0008	31.38	34.50	5.89	1.10	0.17
A. borealis	AB0009	25.49	29.98	6.14	1.18	0.20
A. borealis	AB0010	31.09	34.13	6.29	1.10	0.18
A. borealis	AB0011	28.63	30.51	5.52	1.07	0.18
A. borealis	AB0012	28.03	31.79	5.82	1.13	0.18
A. borealis	AB0013	26.23	30.59	5.04	1.17	0.16
A. borealis	AB0014	26.87	32.40	6.55	1.21	0.20
A. borealis	AB0015	28.05	32.08	6.11	1.14	0.19
A. borealis	AB0016	27.27	29.63	5.49	1.09	0.19
A. borealis	AB0017	27.91	33.05	5.63	1.18	0.17
A. borealis	AB0018	29.48	32.97	6.45	1.12	0.20
A. borealis	AB0019	27.98	32.79	6.33	1.17	0.19
A. borealis	AB0020	30.47	35.76	6.02	1.17	0.17
A. borealis	AB0021	28.42	32.87	5.31	1.16	0.16
A. borealis	AB0022	30.90	35.45	5.02	1.15	0.14
A. borealis	AB0023	26.25	30.69	5.80	1.17	0.19
A. borealis	AB0024	28.63	34.52	5.33	1.21	0.15
A. borealis	AB0025	27.90	31.55	5.29	1.13	0.17
A. borealis	AB0026	25.77	32.03	5.36	1.24	0.17
A. borealis	AB0027	30.42	34.84	6.91	1.15	0.20
A. borealis	AB0028	27.25	30.36	5.34	1.11	0.18
A. borealis	AB0029	29.83	34.01	6.84	1.14	0.20
A. borealis	AB0030	28.97	33.96	5.95	1.17	0.18
A. borealis	AB0031	26.53	32.59	5.50	1.23	0.17
A. borealis	AB0032	24.38	28.70	5.82	1.18	0.20
A. borealis	AB0033	31.56	34.97	6.04	1.11	0.17
A. borealis	AB0034	29.05	35.62	5.74	1.23	0.16
A. borealis	AB0035	25.53	31.64	6.02	1.24	0.19
A. borealis	AB0036	30.78	36.92	6.33	1.20	0.17
A. borealis	AB0037	28.39	31.27	5.90	1.10	0.19
A. borealis	AB0038	28.06	31.42	6.01	1.12	0.19
A. borealis	AB0039	30.92	33.52	6.28	1.08	0.19
A. borealis	AB0040	24.40	28.13	5.01	1.15	0.18
A. borealis	AB0041	24.77	31.60	5.77	1.28	0.18
A. borealis	AB0042	28.26	31.62	6.36	1.12	0.20
A. borealis	AB0043	25.95	32.17	5.20	1.24	0.16
A. borealis	AB0044	29.18	34.18	5.49	1.17	0.16
A. borealis	AB0045	27.50	31.88	5.06	1.16	0.16
A. borealis	AB0046	28.29	32.44	5.96	1.15	0.18
A. borealis	AB0047	26.68	31.95	5.88	1.20	0.18
A. borealis	AB0048	27.72	32.31	5.97	1.17	0.18

All Specimens Distance Measurements (mm) Raw Data Page 2

Specimen	sample number	height (mm)	length (mm)	width (mm)	length/height ratio	width/length ratio
A. borealis	AB0049	27.29	30.94	5.47	1.13	0.18
A. borealis	AB0050	32.76	36.10	6.69	1.10	0.19
A. borealis	AB0051	28.70	32.93	5.76	1.15	0.17
A. borealis	AB0052	27.86	32.58	5.95	1.17	0.18
A. borealis	AB0053	30.12	33.98	5.88	1.13	0.17
A. borealis	AB0054	25.26	28.87	4.91	1.14	0.17
A. borealis	AB0055	26.48	30.82	5.43	1.16	0.18
A. borealis	AB0056	25.14	29.76	5.29	1.18	0.18
A. borealis	AB0057	25.79	30.98	5.29	1.20	0.17
A. borealis	AB0058	26.57	32.28	5.68	1.21	0.18
A. borealis	AB0059	24.07	27.87	5.35	1.16	0.19
A. borealis	AB0060	24.77	30.07	5.95	1.21	0.20
A. borealis	AB0061	24.03	26.58	4.81	1.11	0.18
A. borealis	AB0062	31.62	36.74	6.80	1.16	0.19
A. borealis	AB0063	25.96	27.88	6.02	1.07	0.22
A. borealis	AB0064	28.83	32.75	5.23	1.14	0.16
A. borealis	AB0065	27.26	32.76	5.28	1.20	0.16
A. borealis	AB0066	27.53	31.54	5.45	1.15	0.17
A. borealis	AB0067	28.43	32.19	5.93	1.13	0.18
A. borealis	AB0068	25.30	28.65	4.99	1.13	0.17
A. borealis	AB0069	32.07	36.84	5.69	1.15	0.15
A. borealis	AB0070	23.03	26.78	4.37	1.16	0.16
A. borealis	AB0071	29.99	34.11	6.16	1.14	0.18
A. borealis	AB0072	27.43	30.65	5.25	1.12	0.17
A. borealis	AB0073	18.76	20.79	4.82	1.11	0.23
A. borealis	AB0074	26.02	28.74	5.80	1.10	0.20
A. borealis	AB0075	25.83	30.78	4.52	1.19	0.15
A. borealis	AB0076	25.97	31.07	5.62	1.20	0.18
A. borealis	AB0077	25.77	30.60	6.06	1.19	0.20
A. borealis	AB0078	27.64	31.13	5.17	1.13	0.17
A. borealis	AB0079	30.95	33.45	6.34	1.08	0.19
A. borealis	AB0080	23.74	29.80	5.27	1.26	0.18
A. borealis	AB0081	28.83	31.21	5.95	1.08	0.19
A. borealis	AB0082	29.48	33.96	5.19	1.15	0.15
A. borealis	AB0083	29.11	31.91	5.64	1.10	0.18
A. borealis	AB0084	29.99	34.88	5.64	1.16	0.16
A. borealis	AB0085	26.66	32.03	6.88	1.20	0.21
A. borealis	AB0086	27.56	29.82	6.27	1.08	0.21
A. borealis	AB0087	26.15	31.65	6.47	1.21	0.20
A. borealis	AB0088	26.53	32.19	5.05	1.21	0.16
A. borealis	AB0089	26.74	30.29	6.09	1.13	0.20
A. borealis	AB0090	30.90	34.40	6.18	1.11	0.18
A. borealis	AB0091	22.51	26.20	5.17	1.16	0.20
A. borealis	AB0092	29.09	31.77	5.93	1.09	0.19
A. borealis	AB0093	29.71	33.97	6.58	1.14	0.19
A. borealis	AB0094	30.21	34.45	5.71	1.14	0.17
A. borealis	AB0095	27.07	31.58	6.12	1.17	0.19
A. borealis	AB0096	29.32	32.25	5.48	1.10	0.17
A. borealis	AB0097	29.35	31.89	5.30	1.09	0.17

All Specimens Distance Measurements (mm) Raw Data Page 3

Specimen	sample number	height (mm)	length (mm)	width (mm)	length/height ratio	width/length ratio
A. borealis	AB0098	26.09	30.33	5.64	1.16	0.19
A. borealis	AB0099	30.11	33.41	6.18	1.11	0.18
A. borealis	AB0100	28.47	32.91	5.55	1.16	0.17
A. borealis	AB0101	27.72	31.25	5.73	1.13	0.18
A. borealis	AB0102	28.40	31.69	5.53	1.12	0.17
A. borealis	AB0103	28.19	32.97	6.34	1.17	0.19
A. borealis	AB0104	26.91	32.07	6.55	1.19	0.20
A. borealis	AB0105	27.36	32.71	6.05	1.20	0.18
A. borealis	AB0106	24.54	27.50	5.42	1.12	0.20
A. borealis	AB0107	31.41	33.55	5.73	1.07	0.17
A. borealis	AB0108	26.88	34.22	5.87	1.27	0.17
A. borealis	AB0109	29.43	32.39	5.79	1.10	0.18
A. borealis	AB0110	24.29	26.67	5.14	1.10	0.19
A. borealis	AB0111	25.94	31.66	5.88	1.22	0.19
A. borealis	AB0112	28.05	32.81	5.43	1.17	0.17
A. borealis	AB0113	28.88	32.74	5.39	1.13	0.16
A. borealis	AB0114	27.77	33.35	5.85	1.20	0.18
A. borealis	AB0115	26.64	30.27	5.56	1.14	0.18
A. borealis	AB0116	28.58	33.49	6.11	1.17	0.18
A. borealis	AB0117	29.56	32.03	5.89	1.08	0.18
A. borealis	AB0118	28.81	30.45	6.01	1.06	0.20
A. borealis	AB0119	28.90	32.25	5.85	1.12	0.18
A. borealis	AB0120	27.93	31.51	6.05	1.13	0.19
A. borealis	AB0121	28.04	31.65	5.53	1.13	0.17
A. borealis	AB0122	28.42	33.13	5.30	1.17	0.16
A. borealis	AB0123	27.69	31.04	5.49	1.12	0.18
A. borealis	AB0124	26.11	28.98	5.88	1.11	0.20
A. borealis	AB0125	28.89	33.64	5.57	1.16	0.17
A. borealis	AB0126	27.98	34.14	6.23	1.22	0.18
A. borealis	AB0127	24.90	28.37	4.70	1.14	0.17
A. borealis	AB0128	25.76	28.77	4.45	1.12	0.15
A. borealis	AB0129	26.31	30.54	5.70	1.16	0.19
A. borealis	AB0130	28.28	32.84	6.09	1.16	0.19
A. borealis	AB0131	27.66	33.46	5.73	1.21	0.17
A. borealis	AB0132	24.43	30.85	5.52	1.26	0.18
A. borealis	AB0133	28.65	34.60	5.62	1.21	0.16
A. borealis	AB0134	29.70	32.48	5.23	1.09	0.16
A. borealis	AB0135	28.80	33.40	5.47	1.16	0.16
A. borealis	AB0136	28.56	31.43	5.59	1.10	0.18
A. borealis	AB0137	22.37	27.16	5.18	1.21	0.19
A. borealis	AB0138	29.43	33.82	6.38	1.15	0.19
A. borealis	AB0139	22.79	28.19	5.30	1.24	0.19
A. borealis	AB0140	27.99	34.36	6.01	1.23	0.17
A. borealis	AB0141	27.67	33.63	5.79	1.22	0.17
A. borealis	AB0142	27.52	33.42	5.04	1.21	0.15
A. borealis	AB0143	29.15	31.56	5.70	1.08	0.18
A. borealis	AB0144	25.09	30.35	4.98	1.21	0.16
A. borealis	AB0145	27.73	30.86	5.61	1.11	0.18
A. borealis	AB0146	26.24	30.21	6.61	1.15	0.22

All Specimens Distance Measurements (mm) Raw Data Page 4

Specimen	sample number	height (mm)	length (mm)	width (mm)	length/height ratio	width/length ratio
A. borealis	AB0147	27.28	30.67	5.40	1.12	0.18
A. borealis	AB0148	26.71	33.38	5.89	1.25	0.18
A. borealis	AB0149	29.76	34.38	7.06	1.16	0.21
A. borealis	AB0150	29.90	33.07	5.07	1.11	0.15
A. borealis	AB0151	30.95	34.71	6.00	1.12	0.17
A. borealis	AB0152	27.05	28.69	5.36	1.06	0.19
A. borealis	AB0153	25.11	29.08	5.10	1.16	0.18
A. borealis	AB0154	28.51	35.02	5.78	1.23	0.17
A. borealis	AB0155	26.21	29.95	5.98	1.14	0.20
A. borealis	AB0156	28.09	34.00	6.04	1.21	0.18
A. borealis	AB0157	26.85	31.14	6.03	1.16	0.19
A. borealis	AB0158	25.99	30.20	5.63	1.16	0.19
A. borealis	AB0159	27.14	31.86	5.90	1.17	0.19
A. borealis	AB0160	29.62	32.38	5.99	1.09	0.18
A. borealis	AB0161	23.81	26.39	5.19	1.11	0.20
A. borealis	AB0162	28.22	32.91	5.39	1.17	0.16
A. borealis	AB0163	30.46	34.74	5.82	1.14	0.17
A. borealis	AB0164	29.75	35.83	7.12	1.20	0.20
A. borealis	AB0165	26.60	32.33	6.05	1.22	0.19
A. borealis	AB0166	27.09	31.42	6.27	1.16	0.20
A. borealis	AB0167	26.09	30.67	5.47	1.18	0.18
A. borealis	AB0168	28.03	31.84	5.23	1.14	0.16
A. borealis	AB0169	25.15	28.71	4.98	1.14	0.17
A. borealis	AB0170	23.50	27.24	5.38	1.16	0.20
A. borealis	AB0171	28.47	31.56	6.54	1.11	0.21
A. borealis	AB0172	33.54	36.68	5.83	1.09	0.16
A. borealis	AB0173	26.09	30.41	5.59	1.17	0.18
A. borealis	AB0174	24.09	27.45	4.90	1.14	0.18
A. borealis	AB0175	27.21	30.29	5.40	1.11	0.18
A. borealis	AB0176	28.82	32.24	6.05	1.12	0.19
A. borealis	AB0177	25.52	28.14	5.42	1.10	0.19
A. borealis	AB0178	27.82	33.42	6.80	1.20	0.20
A. borealis	AB0179	27.58	31.43	5.50	1.14	0.17
A. borealis	AB0180	27.01	31.00	6.08	1.15	0.20
A. borealis	AB0181	23.71	28.53	5.09	1.20	0.18
A. borealis	AB0182	26.95	31.19	5.58	1.16	0.18
A. borealis	AB0183	28.43	32.91	5.93	1.16	0.18
A. borealis	AB0184	28.84	34.68	6.31	1.20	0.18
A. borealis	AB0185	29.13	32.30	6.04	1.11	0.19
A. borealis	AB0186	26.17	30.62	5.13	1.17	0.17
A. borealis	AB0187	27.57	31.97	6.25	1.16	0.20
A. borealis	AB0188	28.59	32.85	5.66	1.15	0.17
A. borealis	AB0189	27.19	29.85	5.94	1.10	0.20
A. borealis	AB0190	26.68	33.41	5.62	1.25	0.17
A. borealis	AB0191	28.07	34.76	5.61	1.24	0.16
A. borealis	AB0192	26.00	30.15	5.37	1.16	0.18
A. borealis	AB0193	25.98	28.88	5.98	1.11	0.21
A. borealis	AB0194	26.74	31.63	5.67	1.18	0.18

All Specimens Distance Measurements (mm) Raw Data Page 5

Specimen	sample number	height (mm)	length (mm)	width (mm)	length/height ratio	width/length ratio
A. borealis	AB0195	28.47	34.05	5.24	1.20	0.15
A. borealis	AB0196	28.89	31.67	5.53	1.10	0.17
A. borealis	AB0197	29.57	33.73	6.37	1.14	0.19
A. borealis	AB0198	28.03	31.41	6.44	1.12	0.21
A. borealis	AB0199	28.76	33.81	5.91	1.18	0.17
A. borealis	AB0200	29.41	31.60	5.42	1.07	0.17
A. borealis	AB0201	30.56	35.37	5.62	1.16	0.16
A. borealis	AB0202	27.15	33.33	5.52	1.23	0.17
A. borealis	AB0203	25.70	30.75	5.38	1.20	0.17
A. borealis	AB0204	24.96	28.52	4.65	1.14	0.16
A. borealis	AB0205	26.68	31.01	5.79	1.16	0.19
A. borealis	AB0206	28.53	31.96	5.84	1.12	0.18
A. borealis	AB0207	27.98	31.94	6.19	1.14	0.19
A. borealis	AB0208	28.82	34.55	6.11	1.20	0.18
A. borealis	AB0209	29.17	35.33	6.17	1.21	0.17
A. borealis	AB0210	26.88	31.31	5.34	1.16	0.17
A. borealis	AB0211	24.53	29.27	5.14	1.19	0.18
A. borealis	AB0212	27.52	32.90	6.07	1.20	0.18
A. borealis	AB0213	30.11	36.02	5.71	1.20	0.16
A. borealis	AB0214	26.16	29.47	5.02	1.13	0.17
A. borealis	AB0215	26.99	31.68	5.58	1.17	0.18
A. borealis	AB0216	26.60	30.02	4.94	1.13	0.16
A. borealis	AB0217	27.05	32.89	5.94	1.22	0.18
A. borealis	AB0218	29.12	33.10	6.44	1.14	0.19
A. borealis	AB0219	25.58	28.75	5.88	1.12	0.20
A. borealis	AB0220	25.54	29.20	5.58	1.14	0.19
A. borealis	AB0221	25.96	28.95	5.05	1.12	0.17
A. borealis	AB0222	28.13	34.02	5.83	1.21	0.17
A. borealis	AB0223	24.36	27.57	5.85	1.13	0.21
A. borealis	AB0224	29.54	33.19	6.58	1.12	0.20
A. borealis	AB0225	24.11	28.48	5.33	1.18	0.19
A. borealis (fossil)	ABF01	29.34	33.42	6.86	1.14	0.21
A. borealis (fossil)	ABF02	29.06	34.51	7.58	1.19	0.22
A. borealis (fossil)	ABF03	36.09	42.10	10.61	1.17	0.25
A. borealis (fossil)	ABF04	32.13	35.03	7.84	1.09	0.22
A. borealis (fossil)	ABF05	31.02	33.79	7.46	1.09	0.22
A. borealis (fossil)	ABF06	33.54	34.96	6.72	1.04	0.19
A. borealis (fossil)	ABF07	30.57	32.73	8.20	1.07	0.25
A. borealis (fossil)	ABF08	30.71	33.70	7.64	1.10	0.23
A. borealis (fossil)	ABF09	36.03	38.41	7.77	1.07	0.20
A. borealis (fossil)	ABF10	30.61	35.02	7.39	1.14	0.21
A. borealis (fossil)	ABF11	33.90	39.06	7.42	1.15	0.19
A. borealis (fossil)	ABF12	27.61	32.56	5.56	1.18	0.17
A. borealis (fossil)	ABF13	33.36	39.14	8.49	1.17	0.22
A. martini	RAM01	15.17	17.70	4.42	1.17	0.29
A. martini	RAM02	16.81	18.90	4.46	1.12	0.27
A. martini	RAM03	14.93	19.13	3.94	1.28	0.26
A. martini	RAM04	13.47	17.23	3.07	1.28	0.23

All Specimens Distance Measurements (mm) Raw Data Page 6

Specimen	sample number	height (mm)	length (mm)	width (mm)	length/height ratio	width/length ratio
A. martini	RAM05	11.87	13.03	2.71	1.10	0.23
A. martini	RAM06	11.35	14.60	2.89	1.29	0.25
A. martini	RAM07	12.06	15.45	3.26	1.28	0.27
A. martini	RAM08	12.44	15.08	2.68	1.21	0.22
A. martini	RAM09	11.53	14.08	2.95	1.22	0.26
A. martini	RAM10	13.64	16.65	3.79	1.22	0.28
A. martini	RAM11	17.23	20.04	6.09	1.16	0.35
A. martini	RAM12	18.17	22.56	5.55	1.24	0.31
A. martini	RAM13	13.99	15.88	3.41	1.14	0.24
A. martini	RAM14	13.18	16.26	4.81	1.23	0.36
A. martini	RAM15	13.48	16.21	3.35	1.20	0.25
A. martini	RAM16	14.28	18.76	3.68	1.31	0.26
A. martini	RAM17	18.49	22.10	5.25	1.20	0.28
A. martini	RAM18	15.46	18.49	4.45	1.20	0.29
A. martini	RAM19	12.08	14.39	2.73	1.19	0.23
A. martini	RAM20	14.48	17.62	3.89	1.22	0.27
A. martini	RAM21	15.81	16.71	4.52	1.06	0.29
A. martini	RAM22	17.22	21.34	5.02	1.24	0.29
A. martini	RAM23	10.31	12.51	2.17	1.21	0.21
A. martini	RAM24	14.50	17.45	3.72	1.20	0.26
A. martini	RAM25	12.72	16.65	3.33	1.31	0.26
A. martini	RAM26	11.86	14.52	2.54	1.22	0.21
A. martini	RAM27	10.97	12.91	2.53	1.18	0.23
A. martini	RAM28	16.47	20.12	4.18	1.22	0.25
A. martini	RAM29	15.08	17.92	4.73	1.19	0.31
A. martini	RAM30	15.26	19.58	4.15	1.28	0.27
A. martini	RAM31	14.70	17.70	3.70	1.20	0.25

APPENDIX 2

This appendix contains all the principal component scores produced by SHAPE software in table format.

All Specimens Effective Principal Component Scores Page 1

Specimen	PC1	PC2	PC3	PC4	PC5	PC6	PC7
A. borealis	-3.25E-02	-3.71E-03	2.23E-02	4.17E-03	5.86E-03	-1.08E-03	5.83E-03
A. borealis	3.06E-02	-2.46E-03	2.23E-03	1.04E-02	-1.39E-02	-4.98E-03	3.64E-03
A. borealis	3.13E-03	1.84E-02	4.45E-03	-3.96E-03	1.26E-02	-2.85E-03	-1.43E-03
A. borealis	4.86E-02	7.77E-03	-1.69E-02	1.97E-03	-2.66E-03	1.15E-03	9.28E-04
A. borealis	-1.34E-02	-1.89E-03	-1.02E-02	-3.33E-03	3.71E-04	3.37E-03	3.69E-03
A. borealis	1.04E-02	7.72E-04	-2.03E-02	4.28E-03	-7.80E-03	1.62E-03	5.55E-03
A. borealis	-1.62E-02	-4.77E-02	1.23E-02	-1.25E-02	9.39E-04	-1.44E-02	4.43E-03
A. borealis	1.85E-02	-4.59E-04	6.61E-03	1.37E-02	-7.13E-03	-1.00E-02	4.58E-04
A. borealis	-3.88E-03	-2.54E-02	1.13E-02	-2.99E-03	5.31E-03	2.05E-03	-6.38E-03
A. borealis	3.01E-02	-4.16E-03	5.39E-03	8.55E-03	7.38E-03	6.46E-03	-6.26E-03
A. borealis	4.83E-03	-6.96E-03	-1.61E-03	2.45E-03	2.13E-03	-6.80E-03	-2.73E-03
A. borealis	-1.71E-02	-9.45E-03	-2.90E-03	5.38E-03	-1.50E-02	-2.30E-03	-3.65E-03
A. borealis	1.41E-02	-1.39E-03	-1.24E-02	1.13E-02	-1.61E-02	7.83E-04	-2.26E-03
A. borealis	1.19E-02	7.28E-03	-1.20E-02	1.80E-03	-4.16E-04	8.16E-03	2.20E-03
A. borealis	1.02E-02	5.84E-03	-9.75E-03	-1.48E-03	-9.43E-04	2.78E-03	6.12E-03
A. borealis	1.29E-02	-2.30E-02	-7.96E-03	-6.69E-03	-4.23E-03	-1.73E-04	1.88E-03
A. borealis	-3.20E-02	-3.03E-02	-2.02E-02	7.29E-04	-6.04E-03	-9.49E-05	9.30E-04
A. borealis	-2.22E-02	-9.76E-03	-7.32E-03	-7.02E-03	2.60E-03	5.10E-03	6.47E-03
A. borealis	-5.38E-03	9.24E-03	7.36E-03	6.66E-03	3.99E-03	-1.82E-03	-4.37E-03
A. borealis	6.16E-03	-1.13E-02	1.14E-02	-2.19E-03	-4.61E-03	-2.42E-03	1.66E-03
A. borealis	2.14E-02	-4.89E-03	-1.87E-02	3.78E-05	7.40E-03	2.29E-03	3.19E-03
A. borealis	-3.38E-02	-3.07E-02	-9.71E-03	1.35E-03	-4.47E-03	-3.56E-03	2.40E-03
A. borealis	-4.43E-02	2.79E-02	-7.04E-03	-5.60E-03	-7.02E-03	-2.73E-03	-2.17E-04
A. borealis	5.30E-02	1.15E-02	1.00E-03	1.26E-02	1.03E-02	6.70E-04	-1.07E-03
A. borealis	-6.49E-02	-4.50E-02	3.58E-03	-2.77E-03	2.43E-03	-3.78E-03	1.06E-03
A. borealis	-3.55E-02	-1.08E-02	-1.19E-02	-1.58E-02	-1.73E-03	2.73E-04	-2.98E-03
A. borealis	-9.99E-03	3.04E-02	-1.41E-02	1.70E-02	-2.39E-03	-1.07E-02	2.02E-04
A. borealis	-1.04E-02	1.40E-02	8.50E-03	3.80E-03	2.00E-03	-1.44E-03	-7.12E-05
A. borealis	-2.41E-03	1.33E-02	-7.31E-03	-3.81E-03	7.71E-03	1.44E-03	-1.56E-03
A. borealis	1.11E-02	-9.42E-03	-4.59E-03	6.21E-03	-1.76E-03	1.92E-03	5.52E-03
A. borealis	-4.16E-02	1.57E-02	6.08E-03	-9.67E-03	8.89E-03	-5.84E-03	5.13E-03
A. borealis	-1.41E-02	1.14E-02	-7.42E-03	-3.17E-03	-4.44E-05	6.42E-03	3.04E-03
A. borealis	4.04E-02	-3.20E-02	-1.87E-02	9.21E-03	8.75E-03	-7.65E-03	-3.78E-03
A. borealis	-6.56E-03	2.57E-02	8.99E-03	-6.88E-03	-3.95E-03	-3.02E-03	5.89E-03
A. borealis	-1.07E-02	3.86E-02	-1.09E-03	3.40E-03	-2.81E-03	2.42E-03	2.66E-03
A. borealis	1.23E-02	1.13E-03	-8.51E-03	8.07E-03	-2.83E-03	2.08E-03	3.59E-03
A. borealis	-5.15E-03	1.81E-02	1.42E-02	-8.57E-03	-9.02E-03	-2.17E-03	-3.41E-03
A. borealis	-1.95E-02	-1.51E-02	-7.52E-03	-5.32E-03	1.50E-03	3.92E-03	-5.21E-04
A. borealis	-2.32E-02	1.27E-02	-4.40E-03	1.32E-03	1.56E-02	2.04E-03	3.75E-03
A. borealis	3.21E-03	1.27E-03	-2.15E-02	6.14E-03	-4.66E-04	7.09E-03	-5.53E-03
A. borealis	1.34E-03	-3.66E-03	3.09E-02	6.25E-03	8.08E-03	-4.85E-03	-1.73E-03
A. borealis	6.43E-02	-2.25E-02	-7.38E-03	-6.43E-04	-1.12E-03	-1.27E-02	-3.08E-03
A. borealis	1.73E-03	2.07E-02	-4.70E-03	8.57E-03	5.99E-03	-6.21E-04	-1.16E-03
A. borealis	-2.18E-02	1.67E-02	-3.98E-03	1.44E-02	-5.21E-03	-5.30E-03	-2.89E-04
A. borealis	-1.37E-02	3.22E-02	1.59E-02	6.98E-04	6.65E-04	-2.46E-03	-3.35E-03
A. borealis	2.00E-02	-2.12E-02	4.14E-03	-1.04E-02	-5.15E-03	-1.95E-03	4.20E-03
A. borealis	-2.67E-03	-1.95E-02	1.19E-02	4.73E-03	1.15E-03	-1.18E-03	4.02E-03
A. borealis	1.45E-02	2.30E-02	-1.75E-03	1.26E-02	-5.13E-04	-4.57E-03	5.93E-03
A. borealis	3.25E-02	-2.00E-02	6.13E-03	-1.01E-02	6.20E-04	-1.55E-03	-1.33E-03
A. borealis	1.29E-02	7.46E-03	2.13E-03	8.18E-03	-3.04E-03	-4.53E-03	-2.75E-03
A. borealis	3.10E-02	1.37E-02	-1.32E-02	9.78E-04	3.08E-03	1.21E-03	7.53E-03
A. borealis	6.23E-03	-5.82E-03	7.29E-03	3.52E-03	1.46E-03	-9.98E-04	-1.28E-03
A. borealis	5.02E-03	6.37E-03	-3.66E-03	-2.00E-06	-4.88E-03	-3.94E-03	-9.74E-03
A. borealis	-1.87E-02	7.22E-03	-4.31E-03	-1.91E-04	1.88E-03	-4.39E-04	-1.38E-02
A. borealis	-4.30E-02	1.67E-02	-1.19E-02	8.67E-03	1.01E-03	-2.46E-04	-4.65E-03
A. borealis	1.40E-02	4.31E-02	-3.93E-04	1.83E-02	6.86E-03	-7.74E-03	-2.33E-03

All Specimens Effective Principal Component Scores Page 2

Specimen	PC1	PC2	PC3	PC4	PC5	PC6	PC7
A. borealis	-1.19E-02	4.73E-03	-7.93E-03	-5.04E-03	8.87E-04	-1.35E-03	6.91E-03
A. borealis	1.32E-02	2.29E-03	-3.16E-03	8.01E-03	-1.81E-02	1.81E-03	4.52E-04
A. borealis	5.30E-02	-1.07E-02	-7.00E-03	2.47E-04	7.33E-03	-1.73E-03	-4.32E-03
A. borealis	1.09E-02	-6.86E-03	-1.64E-03	6.99E-03	-3.73E-03	8.06E-04	-1.36E-03
A. borealis	-8.44E-02	2.88E-02	1.88E-03	3.48E-05	5.96E-03	-4.84E-03	2.69E-03
A. borealis	-8.12E-03	5.06E-02	2.90E-02	-2.24E-02	5.82E-03	-2.06E-02	-3.98E-03
A. borealis	-1.02E-02	-3.64E-02	-1.43E-02	3.77E-03	1.99E-02	1.03E-03	2.62E-03
A. borealis	8.20E-03	-2.77E-02	-1.16E-02	3.12E-03	-4.97E-04	-3.31E-03	5.21E-04
A. borealis	5.02E-02	5.45E-03	-4.78E-03	4.20E-04	2.02E-03	5.44E-03	1.90E-03
A. borealis	-2.32E-02	1.17E-03	-1.18E-02	3.50E-03	-1.26E-03	7.85E-03	-8.65E-03
A. borealis	-9.90E-03	-4.18E-02	1.68E-04	-9.68E-03	5.99E-03	-6.74E-03	3.11E-03
A. borealis	1.22E-02	8.98E-03	7.23E-03	5.25E-03	-3.66E-03	1.40E-03	-4.97E-03
A. borealis	2.95E-02	1.44E-02	-6.55E-04	-5.13E-03	3.97E-03	8.50E-04	9.74E-04
A. borealis	2.19E-02	3.22E-03	-1.03E-02	-4.89E-03	-4.98E-03	1.95E-03	1.06E-03
A. borealis	3.82E-02	1.47E-02	-3.39E-03	9.35E-04	-2.39E-03	-3.62E-04	2.04E-03
A. borealis	4.14E-03	2.60E-03	-1.05E-02	-2.30E-03	6.84E-04	4.83E-03	5.46E-03
A. borealis	4.10E-02	-1.60E-02	-8.15E-03	8.12E-03	5.11E-03	4.52E-03	6.75E-03
A. borealis	3.04E-02	3.27E-02	-5.34E-03	8.98E-03	5.40E-03	-5.43E-04	6.37E-03
A. borealis	-7.12E-04	-1.59E-02	-1.22E-02	1.45E-02	-3.69E-03	-2.96E-03	-1.96E-03
A. borealis	-8.73E-03	7.44E-03	8.76E-03	4.25E-03	-6.20E-03	3.33E-03	5.05E-03
A. borealis	3.24E-02	-2.58E-02	1.33E-02	-3.44E-03	-9.70E-03	-5.98E-04	-4.60E-03
A. borealis	-1.32E-02	1.70E-02	2.81E-03	2.10E-03	-2.11E-04	-2.49E-03	2.20E-03
A. borealis	-1.41E-02	-1.42E-02	6.29E-03	-8.48E-03	-8.91E-03	-3.71E-04	-6.64E-06
A. borealis	-5.86E-02	7.58E-04	-1.67E-02	1.67E-03	1.92E-03	1.42E-03	1.54E-03
A. borealis	1.62E-03	2.47E-02	1.13E-02	1.16E-02	-8.94E-03	-2.20E-04	4.80E-03
A. borealis	-4.16E-03	-7.29E-03	1.00E-02	-5.35E-04	-1.33E-02	8.98E-04	-4.40E-03
A. borealis	-2.87E-02	1.81E-02	-1.29E-02	-9.28E-03	-4.04E-03	3.59E-03	1.97E-03
A. borealis	1.13E-02	-3.79E-03	-1.14E-02	-6.35E-05	-9.55E-04	1.81E-04	1.80E-03
A. borealis	-3.53E-02	1.47E-03	-1.68E-02	9.31E-03	-1.31E-02	-4.98E-03	3.78E-03
A. borealis	5.41E-02	-8.99E-03	8.96E-03	-7.23E-04	-1.35E-03	-1.01E-02	-3.65E-03
A. borealis	4.41E-03	3.56E-02	8.47E-03	5.26E-03	3.87E-03	-6.50E-03	2.54E-03
A. borealis	8.77E-02	-4.29E-04	-1.11E-02	-7.37E-03	3.28E-03	-2.58E-03	-2.98E-04
A. borealis	1.42E-03	-2.29E-02	-1.78E-04	-7.19E-03	4.24E-04	-7.10E-03	-1.86E-03
A. borealis	2.34E-02	-2.80E-02	9.51E-03	-8.74E-03	-7.19E-03	-2.99E-03	3.65E-04
A. borealis	2.38E-02	-6.81E-03	1.53E-03	6.50E-03	-1.52E-03	-3.06E-03	-9.71E-04
A. borealis	-8.12E-04	8.44E-03	7.37E-04	-7.83E-03	1.01E-02	2.31E-03	4.12E-03
A. borealis	-4.58E-03	1.07E-02	1.36E-02	6.11E-04	-1.36E-03	3.83E-03	-8.78E-03
A. borealis	-1.87E-02	-2.10E-02	-1.00E-02	-5.98E-03	5.90E-03	-4.31E-03	5.21E-03
A. borealis	-4.75E-02	7.98E-04	-1.83E-02	1.36E-03	-2.54E-04	3.71E-03	7.13E-03
A. borealis	-6.51E-02	-3.20E-03	2.28E-03	8.49E-03	-1.03E-02	4.63E-03	-1.62E-03
A. borealis	3.15E-02	1.95E-02	1.42E-02	7.55E-03	-9.34E-03	1.13E-02	-9.43E-03
A. borealis	-1.40E-02	5.45E-02	4.44E-02	-2.35E-02	-1.39E-03	-2.15E-02	-1.53E-03
A. borealis	5.51E-03	-1.66E-02	9.20E-03	-5.56E-03	3.60E-04	3.18E-04	-8.00E-03
A. borealis	-4.39E-02	1.42E-02	-1.32E-02	1.69E-02	3.99E-03	-7.53E-03	2.24E-03
A. borealis	-2.70E-02	-3.82E-03	5.88E-03	-1.21E-02	2.68E-03	9.43E-04	5.80E-04
A. borealis	7.00E-03	7.90E-03	3.95E-03	-4.46E-03	-8.71E-04	2.17E-03	-3.68E-03
A. borealis	-3.85E-02	6.12E-03	-1.48E-03	-8.91E-03	-4.23E-03	4.23E-04	-5.25E-03
A. borealis	-3.68E-02	-2.00E-03	-6.26E-03	6.30E-03	-3.07E-03	1.89E-03	-3.83E-03
A. borealis	-2.20E-02	-1.23E-02	-9.97E-03	4.81E-03	9.29E-03	-1.96E-03	3.87E-03
A. borealis	2.15E-02	1.72E-02	3.90E-04	1.13E-03	-4.42E-03	1.39E-03	-8.56E-03
A. borealis	2.88E-02	1.90E-02	-7.00E-03	-2.66E-03	1.07E-03	2.93E-03	1.35E-03
A. borealis	4.44E-03	1.57E-02	8.73E-03	-3.27E-03	-4.94E-04	3.66E-03	-4.37E-03
A. borealis	-3.47E-02	5.66E-03	4.73E-03	-7.12E-03	3.45E-04	3.31E-04	7.41E-04
A. borealis	3.49E-02	5.50E-02	-1.32E-03	2.68E-03	5.73E-03	-7.71E-03	8.05E-03
A. borealis	-3.47E-02	1.59E-02	-1.80E-02	1.53E-02	-1.78E-03	-2.97E-03	-4.11E-03
A. borealis	4.18E-02	-9.74E-03	-6.76E-03	7.05E-03	6.11E-03	6.07E-03	2.50E-03

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Specimen	PC1	PC2	PC3	PC4	PC5	PC6	PC7
A. borealis	1.37E-02	2.86E-02	-2.95E-02	-1.06E-02	-2.30E-03	1.81E-03	1.09E-02
A. borealis	-1.73E-02	-4.85E-03	-1.50E-02	2.27E-03	-2.22E-03	-4.31E-03	-2.84E-03
A. borealis	-1.66E-02	2.38E-02	8.06E-03	-4.43E-03	3.15E-03	-3.62E-03	1.92E-03
A. borealis	3.21E-02	-2.60E-02	-1.41E-02	-1.71E-02	8.01E-03	1.55E-02	-4.73E-03
A. borealis	2.38E-02	3.29E-02	-4.71E-03	1.36E-03	-7.41E-03	-1.69E-03	2.85E-03
A. borealis	4.16E-03	4.44E-03	3.00E-03	-2.00E-03	-7.73E-03	4.19E-03	-2.34E-03
A. borealis	7.64E-03	2.41E-02	-2.06E-02	6.57E-03	1.18E-03	-5.80E-03	-1.93E-03
A. borealis	-3.58E-02	-6.00E-03	-5.75E-03	1.02E-02	-3.52E-03	6.80E-03	-1.49E-04
A. borealis	-2.40E-02	-3.45E-02	1.52E-02	-2.41E-03	8.38E-03	-8.87E-03	2.29E-03
A. borealis	-1.84E-02	-8.22E-03	-1.13E-02	3.49E-03	8.41E-04	2.22E-03	-3.75E-03
A. borealis	-3.19E-03	2.38E-02	7.33E-03	2.76E-03	9.56E-04	2.70E-03	-6.16E-04
A. borealis	5.64E-03	5.11E-03	3.61E-03	1.42E-03	-5.41E-03	1.58E-03	-2.48E-03
A. borealis	2.82E-02	5.87E-03	1.11E-03	-5.71E-03	2.50E-04	2.33E-03	5.15E-04
A. borealis	-2.61E-02	-8.24E-03	1.68E-03	-1.22E-02	-7.09E-03	7.39E-03	3.01E-03
A. borealis	9.59E-03	1.19E-02	2.20E-02	-4.85E-03	3.26E-03	1.07E-03	8.24E-04
A. borealis	2.16E-02	1.74E-02	-3.55E-03	-1.32E-03	1.15E-03	-5.30E-04	3.02E-03
A. borealis	1.17E-02	-1.23E-02	-1.84E-02	3.56E-05	-7.28E-03	-7.37E-03	-6.47E-03
A. borealis	4.40E-02	-5.24E-03	-1.94E-03	-2.46E-04	-4.39E-05	-6.44E-04	-1.25E-03
A. borealis	8.91E-03	-2.10E-02	1.01E-02	1.47E-02	-1.44E-03	-1.83E-03	-5.49E-04
A. borealis	3.84E-04	3.86E-02	1.57E-02	-5.11E-03	6.07E-03	-8.04E-03	1.14E-03
A. borealis	4.98E-02	1.24E-02	-5.48E-03	-1.88E-03	2.83E-03	5.98E-03	-2.25E-03
A. borealis	1.35E-02	-2.26E-02	-6.30E-03	-6.49E-03	-9.48E-03	-4.68E-03	-9.55E-03
A. borealis	-2.93E-02	6.29E-03	2.02E-03	-3.86E-03	2.48E-03	5.28E-04	2.20E-03
A. borealis	-1.00E-02	2.37E-02	-8.78E-03	-6.06E-03	1.89E-03	-2.70E-03	8.08E-04
A. borealis	-2.08E-02	6.53E-03	9.34E-03	-5.58E-03	-1.36E-03	5.49E-03	-4.02E-03
A. borealis	1.62E-02	-1.05E-02	-2.82E-03	-1.82E-03	-1.02E-02	4.62E-03	4.07E-03
A. borealis	1.90E-02	2.08E-02	-1.39E-02	-9.68E-03	1.15E-02	3.74E-03	5.76E-03
A. borealis	4.47E-03	1.09E-02	3.22E-03	1.49E-03	-8.82E-04	1.00E-03	-2.97E-03
A. borealis	-1.44E-03	-1.41E-03	-3.40E-03	1.62E-02	4.14E-03	-6.95E-03	6.49E-03
A. borealis	2.96E-02	1.71E-02	-1.21E-03	-8.93E-03	2.89E-03	1.15E-03	9.34E-03
A. borealis	-8.90E-03	2.83E-02	-1.30E-02	8.31E-03	-7.65E-03	-2.16E-03	-8.63E-04
A. borealis	-3.87E-02	-3.96E-02	8.54E-03	-1.29E-02	4.91E-03	-1.02E-02	4.53E-03
A. borealis	-1.69E-02	2.69E-02	-7.12E-03	9.22E-03	2.35E-03	-1.15E-02	4.68E-03
A. borealis	-6.46E-02	9.32E-03	-1.24E-02	7.95E-03	6.16E-03	-2.57E-03	4.86E-03
A. borealis	-1.33E-02	-1.72E-02	-9.25E-03	-6.14E-03	-3.19E-03	4.90E-03	1.29E-03
A. borealis	-5.52E-03	-3.56E-03	-7.82E-04	6.44E-03	4.92E-03	-6.10E-03	-1.21E-03
A. borealis	-1.94E-02	-5.04E-03	-1.35E-02	2.86E-03	2.00E-03	-4.95E-03	-5.55E-06
A. borealis	1.26E-02	1.01E-02	-7.62E-03	2.48E-03	-8.02E-03	1.76E-03	8.36E-03
A. borealis	-3.70E-02	2.22E-03	1.87E-02	3.54E-03	-2.27E-03	-2.58E-03	2.84E-03
A. borealis	2.63E-02	-3.01E-02	-9.81E-03	-4.43E-03	1.36E-02	6.59E-03	6.29E-04
A. borealis	1.53E-02	-1.08E-02	-1.07E-04	-1.81E-03	-1.75E-03	-6.37E-03	-4.26E-04
A. borealis	6.90E-03	1.30E-02	2.99E-03	-1.80E-02	7.32E-03	7.19E-03	-3.24E-03
A. borealis	-8.49E-03	3.75E-02	-1.33E-02	7.99E-03	1.36E-02	-1.16E-02	4.28E-03
A. borealis	-2.89E-02	-2.70E-04	-4.77E-03	-1.83E-03	-2.91E-03	3.12E-03	-6.14E-03
A. borealis	-6.52E-03	-1.84E-02	2.60E-03	4.52E-03	3.35E-03	5.12E-03	-6.32E-04
A. borealis	-3.04E-02	8.57E-03	7.60E-03	1.03E-02	4.36E-04	4.72E-03	1.46E-03
A. borealis	-2.51E-02	-3.63E-05	3.27E-03	-1.10E-03	-3.05E-03	1.01E-02	-1.58E-03
A. borealis	-4.29E-02	4.56E-03	-1.85E-04	9.08E-03	1.38E-03	-1.82E-03	-1.28E-03
A. borealis	-8.95E-03	4.86E-02	1.16E-02	5.78E-03	1.56E-03	-8.46E-03	1.34E-03
A. borealis	1.52E-02	-3.79E-03	-1.51E-02	3.43E-03	8.76E-03	-4.62E-03	3.49E-03
A. borealis	-1.12E-02	-1.28E-02	1.07E-02	-4.52E-03	-7.85E-03	-6.25E-03	-4.52E-03
A. borealis	3.98E-02	5.99E-03	-1.21E-02	-1.52E-02	-4.69E-04	4.15E-03	2.86E-03
A. borealis	2.93E-02	-1.53E-02	1.48E-02	-1.01E-02	-3.87E-03	-1.73E-03	-3.42E-03
A. borealis	-2.41E-02	2.39E-02	-7.69E-03	1.34E-02	-2.36E-03	-6.68E-03	8.90E-04
A. borealis	-2.48E-02	-1.35E-02	-4.68E-03	8.75E-04	-5.20E-03	2.10E-04	3.89E-04
A. borealis	5.28E-02	1.77E-02	2.15E-02	7.43E-03	-2.76E-03	1.70E-03	-2.36E-03

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Specimen	PC1	PC2	PC3	PC4	PC5	PC6	PC7
A. borealis	-2.67E-03	-6.44E-03	-1.90E-02	1.92E-02	2.07E-03	-1.08E-02	4.95E-03
A. borealis	-2.17E-02	1.63E-02	2.10E-02	-2.39E-03	-2.82E-03	1.48E-02	-4.76E-03
A. borealis	-4.29E-02	1.06E-02	2.07E-02	-2.78E-03	-1.13E-03	-1.96E-03	-4.57E-03
A. borealis	-4.38E-02	9.07E-03	-9.52E-03	-1.15E-02	5.83E-03	9.64E-04	3.80E-03
A. borealis	6.26E-03	-1.17E-02	-1.85E-03	-1.95E-03	-5.72E-03	8.32E-03	-2.52E-03
A. borealis	2.10E-02	2.17E-02	-8.21E-03	2.24E-03	-6.73E-03	1.87E-03	-5.90E-04
A. borealis	6.54E-03	-1.04E-02	7.73E-04	-1.00E-02	-7.57E-03	-1.01E-03	-4.07E-03
A. borealis	-2.37E-02	2.44E-05	1.93E-03	4.94E-04	3.61E-03	2.35E-03	-2.43E-04
A. borealis	-3.48E-02	-1.35E-03	1.12E-04	-2.16E-03	-5.89E-03	-3.33E-04	-5.04E-03
A. borealis	-2.77E-03	-2.03E-02	-9.06E-03	-4.21E-03	6.66E-03	-6.10E-03	1.73E-03
A. borealis	-3.13E-02	-1.76E-02	5.97E-04	1.52E-03	-6.80E-04	-2.20E-03	6.58E-03
A. borealis	7.82E-03	7.14E-03	6.03E-03	8.11E-03	-1.28E-03	-1.10E-04	-3.06E-03
A. borealis	5.36E-03	7.82E-03	-1.49E-02	-8.13E-03	-2.99E-03	2.94E-03	4.78E-03
A. borealis	2.80E-02	3.14E-02	-5.86E-03	-1.01E-02	1.50E-02	3.97E-03	-6.07E-03
A. borealis	1.14E-02	1.83E-02	-4.80E-03	8.48E-03	6.58E-03	-3.43E-03	-1.57E-03
A. borealis	1.65E-02	-3.30E-02	3.60E-03	-1.51E-03	-5.73E-03	5.79E-03	-4.70E-03
A. borealis	1.70E-02	-1.94E-02	-2.22E-03	-2.95E-03	3.63E-03	2.74E-03	5.99E-03
A. borealis	-6.27E-03	7.74E-03	-7.62E-03	9.97E-03	-7.87E-03	9.65E-03	2.26E-03
A. borealis	-3.59E-02	1.52E-02	5.03E-03	-7.93E-03	-2.64E-03	2.15E-03	-2.67E-03
A. borealis	-1.48E-02	7.92E-03	3.38E-04	4.58E-03	-2.52E-03	-4.37E-03	-5.82E-04
A. borealis	-4.81E-02	-6.44E-03	-3.65E-03	2.59E-03	-3.13E-03	-8.85E-03	1.33E-03
A. borealis	2.93E-04	-2.06E-02	1.17E-01	1.95E-02	1.20E-02	2.11E-02	-1.77E-03
A. borealis	-2.32E-02	-8.36E-04	-1.22E-03	1.35E-03	-4.89E-03	2.00E-03	2.16E-03
A. borealis	1.29E-02	-8.66E-03	-2.00E-02	6.26E-04	-5.07E-03	-7.83E-03	-6.89E-03
A. borealis	1.49E-03	-1.29E-02	-5.18E-03	-7.69E-03	4.33E-03	3.61E-03	4.16E-03
A. borealis	-1.03E-02	3.68E-02	1.51E-02	6.51E-03	7.96E-03	-1.29E-03	-1.34E-03
A. borealis	4.93E-02	2.09E-02	-9.67E-03	2.40E-03	1.16E-02	-4.13E-04	-6.11E-05
A. borealis	-4.49E-03	8.29E-05	7.71E-03	-7.19E-03	-2.20E-03	6.73E-04	-2.21E-03
A. borealis	-2.25E-02	6.43E-03	7.62E-03	5.17E-03	-7.67E-03	-6.20E-03	-3.16E-03
A. borealis	-2.85E-03	1.47E-02	3.48E-03	9.72E-04	-6.92E-03	1.51E-03	-2.82E-03
A. borealis	-1.90E-02	-9.23E-04	-3.43E-03	-2.27E-03	-9.09E-03	9.60E-03	1.57E-03
A. borealis	-3.63E-02	8.09E-03	-1.02E-02	-5.12E-04	3.88E-03	4.30E-03	-6.31E-03
A. borealis	-4.26E-02	1.71E-02	-3.20E-03	-2.32E-03	-2.97E-03	-6.88E-04	7.92E-03
A. borealis	2.90E-02	-4.21E-02	1.52E-02	-8.99E-03	-3.56E-03	-1.26E-02	2.43E-03
A. borealis	9.98E-03	-5.60E-03	-6.52E-04	1.45E-02	-8.74E-03	6.62E-03	-4.60E-03
A. borealis	-8.00E-03	1.09E-02	1.25E-02	-2.27E-03	4.94E-03	-1.48E-03	-5.05E-03
A. borealis	-6.10E-02	3.02E-02	1.20E-02	-8.31E-03	5.59E-03	-5.69E-03	-4.19E-03
A. borealis	-2.62E-02	-6.60E-04	1.13E-02	-4.35E-03	4.41E-03	-3.77E-03	1.79E-03
A. borealis	-4.88E-02	-2.94E-03	1.50E-02	2.43E-03	-1.42E-03	-3.16E-03	-1.91E-03
A. borealis	7.09E-03	1.66E-03	-1.31E-02	4.23E-03	5.92E-03	1.48E-02	-4.44E-04
A. borealis	2.16E-02	3.47E-02	1.87E-02	-3.53E-03	-7.44E-04	-4.96E-03	8.91E-04
A. borealis	8.78E-03	-2.45E-02	4.98E-04	1.59E-05	1.09E-03	-4.94E-03	1.21E-03
A. borealis	2.50E-02	3.26E-02	1.45E-02	-6.48E-03	9.41E-03	-7.37E-03	-3.22E-03
A. borealis	-3.77E-02	1.49E-02	-8.38E-03	-8.95E-03	4.44E-05	4.73E-03	1.24E-03
A. borealis	2.51E-02	-1.86E-02	4.14E-03	-7.70E-03	-1.26E-03	4.89E-03	4.21E-03
A. borealis	-1.77E-02	1.41E-02	6.37E-04	-1.38E-03	-9.65E-03	-6.92E-04	-6.53E-03
A. borealis	-4.37E-02	-9.34E-03	-8.38E-03	-5.03E-03	1.26E-03	-1.09E-03	-1.60E-03
A. borealis	-7.52E-03	-9.96E-03	-3.88E-03	-2.03E-04	-4.50E-04	4.53E-03	5.18E-04
A. borealis	1.41E-02	1.51E-02	1.03E-03	2.86E-03	-1.10E-03	3.89E-03	-1.63E-03
A. borealis	7.81E-03	-2.12E-02	-1.50E-02	-1.30E-02	1.16E-04	-2.76E-03	1.16E-03
A. borealis	-2.95E-02	-2.73E-02	2.96E-03	-3.14E-04	7.37E-04	-1.02E-03	-4.92E-03
A. borealis	5.33E-03	1.16E-02	-8.40E-03	-5.11E-03	-1.73E-03	4.60E-03	-3.54E-03
A. borealis	-1.80E-02	-1.21E-02	-1.71E-03	-1.01E-02	-5.17E-04	8.16E-04	3.65E-03
A. borealis	-2.56E-02	3.67E-02	4.45E-03	-5.05E-03	1.10E-02	-7.28E-03	5.50E-03
A. borealis	1.06E-02	-2.90E-02	-8.01E-03	-5.63E-03	-3.21E-03	5.77E-04	9.38E-03
A. borealis	-2.07E-03	2.99E-02	1.50E-02	-1.22E-02	-9.65E-03	-4.55E-03	1.33E-04

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Specimen	PC1	PC2	PC3	PC4	PC5	PC6	PC7
A. borealis	-5.72E-02	4.49E-03	-6.58E-04	5.70E-04	-1.02E-02	4.14E-03	4.61E-03
A. borealis	-2.55E-02	2.37E-02	1.35E-02	-8.41E-03	2.19E-03	4.71E-04	-3.62E-03
A. borealis	-4.81E-03	-5.06E-03	1.01E-02	-5.96E-03	3.59E-03	6.16E-03	-6.20E-03
A. borealis	-6.03E-02	2.22E-02	1.13E-03	-5.44E-04	-1.05E-03	5.03E-03	3.14E-03
A. borealis	-1.87E-02	2.78E-02	7.48E-04	7.58E-03	4.31E-03	-8.34E-03	-9.30E-03
A. borealis	-3.96E-02	2.16E-02	-7.19E-03	2.33E-03	5.78E-03	9.86E-03	7.57E-03
A. borealis	9.57E-03	-1.20E-02	1.15E-02	2.20E-03	-1.28E-02	-5.71E-03	-4.71E-03
A. borealis	5.36E-03	-3.27E-02	-3.18E-03	2.54E-04	-3.77E-03	-8.27E-03	-3.88E-03
A. borealis	-2.39E-02	6.42E-05	8.52E-03	-6.30E-04	-2.47E-03	-3.98E-03	3.69E-03
A. borealis	5.06E-02	1.51E-02	-1.19E-02	8.31E-03	5.14E-03	1.67E-03	-4.08E-03
A. borealis	5.18E-03	1.96E-02	-6.43E-03	-4.70E-03	-1.84E-03	4.13E-03	-2.52E-03
A. borealis	2.23E-02	2.48E-02	-1.91E-02	8.83E-03	4.87E-04	-6.12E-03	1.42E-03
A. borealis	2.75E-02	-1.02E-02	3.33E-04	-5.52E-03	-5.82E-03	-3.86E-03	4.83E-04
A. borealis	2.17E-02	-1.94E-02	-1.10E-02	-8.02E-03	-5.70E-03	1.70E-03	9.94E-04
A. borealis	5.40E-03	-2.67E-02	9.25E-03	-1.04E-02	1.81E-03	-9.01E-03	-6.36E-04
A. borealis	-3.56E-02	-1.33E-02	-4.84E-03	-2.83E-03	9.30E-04	4.67E-03	-1.47E-03
A. borealis	-5.15E-02	6.64E-03	5.13E-03	9.06E-03	-5.53E-03	-4.10E-03	-5.77E-03
A. borealis	-2.18E-02	1.92E-02	-1.01E-03	3.89E-03	2.74E-03	-3.14E-03	3.00E-03
A. borealis	-3.30E-02	-9.61E-03	-1.04E-02	4.22E-03	2.39E-03	-1.09E-02	-1.29E-03
A. borealis	-2.99E-02	-1.54E-02	-1.38E-02	-1.05E-02	1.03E-02	-3.50E-03	-4.79E-03
A. borealis	-3.61E-02	-3.21E-03	8.42E-03	2.54E-03	-3.67E-03	4.59E-03	-1.91E-03
A. borealis	3.99E-02	1.87E-02	-9.42E-03	-1.04E-02	4.48E-03	-1.59E-03	6.51E-03
A. borealis	2.95E-02	3.32E-03	-1.90E-04	5.14E-03	5.52E-03	2.39E-03	4.07E-03
A. borealis	-3.32E-02	-1.79E-02	-1.13E-02	2.90E-03	-4.54E-03	5.81E-04	-1.85E-03
A. borealis	-1.36E-02	1.46E-02	2.05E-03	-5.07E-03	-7.41E-03	-4.75E-03	6.05E-03
A. borealis	5.62E-03	2.71E-02	-1.31E-02	7.54E-03	-1.36E-03	6.33E-03	-4.37E-03
A. borealis	2.76E-02	3.58E-02	-5.49E-03	4.01E-03	4.85E-03	3.91E-03	1.23E-03
A. borealis	2.57E-02	3.56E-02	-6.36E-03	2.07E-03	-2.39E-04	1.59E-03	7.25E-03
A. borealis	7.48E-03	4.56E-03	-1.76E-02	1.67E-02	-1.69E-02	-6.54E-03	7.61E-04
A. borealis	1.14E-02	1.69E-02	-7.61E-03	8.49E-03	1.43E-03	-5.03E-03	-3.75E-03
A. borealis	5.99E-03	-1.10E-02	-4.41E-03	1.46E-02	-2.82E-03	2.77E-04	2.72E-03
A. borealis	-4.11E-02	1.83E-04	2.90E-03	2.23E-03	-1.63E-03	-1.47E-03	-5.12E-03
A. borealis	2.06E-02	5.44E-03	-1.19E-05	-6.85E-03	1.48E-03	-1.50E-03	-1.23E-03
A. borealis	1.94E-02	2.85E-02	1.98E-02	-2.83E-04	6.69E-03	-6.46E-03	4.11E-03
A. borealis	6.50E-02	5.88E-03	-2.69E-02	2.32E-03	-8.06E-03	5.11E-03	6.59E-04
A. borealis	-4.32E-02	-8.50E-03	-1.98E-02	-9.95E-03	-2.93E-03	-1.88E-03	2.35E-03
A. borealis	-1.05E-02	4.07E-03	-5.95E-03	1.15E-02	8.16E-03	4.30E-03	3.60E-03
A. borealis	-2.33E-02	-2.39E-02	-1.64E-02	2.42E-04	-1.36E-03	-9.90E-04	2.86E-03
A. borealis	-2.53E-02	-7.27E-03	-3.74E-03	9.99E-03	-1.09E-02	-1.77E-03	-5.37E-03
A. borealis	5.31E-02	-1.59E-02	-8.17E-05	8.41E-03	-6.12E-03	-7.34E-03	1.89E-03
A. borealis	-6.78E-03	1.20E-02	-8.23E-03	7.26E-03	1.07E-03	-4.01E-03	4.15E-03
A. borealis	-1.25E-02	1.49E-02	-9.47E-04	-6.89E-03	1.16E-02	-6.89E-04	6.28E-03
A. borealis	7.70E-03	-4.13E-03	-2.62E-03	-3.91E-03	5.91E-03	5.84E-03	2.89E-03
A. borealis	3.36E-02	1.00E-03	-1.36E-02	-2.81E-04	2.90E-03	6.65E-03	3.88E-03
A. borealis	8.85E-03	2.42E-02	-4.73E-03	-2.45E-03	-8.84E-03	1.44E-03	3.81E-04
A. borealis	1.50E-03	2.67E-02	9.13E-03	-9.36E-03	-4.29E-03	3.99E-03	-5.24E-04
A. borealis	2.41E-02	-4.23E-02	1.30E-02	-1.61E-02	7.97E-03	-8.80E-03	7.28E-03
A. borealis	2.94E-02	-1.75E-02	-5.84E-03	-1.01E-04	-6.31E-03	-2.59E-03	3.26E-03
A. borealis	1.19E-02	-1.89E-03	-6.99E-03	6.48E-03	1.70E-02	-2.40E-03	2.29E-03
A. borealis	1.41E-02	1.55E-02	-6.23E-03	-1.63E-02	-6.98E-03	4.17E-03	-4.59E-03
A. borealis	-5.02E-02	-2.20E-02	-1.22E-02	-3.04E-03	5.67E-03	8.15E-03	-5.92E-04
A. borealis	-2.68E-02	-1.16E-02	3.84E-03	-6.07E-03	1.06E-03	3.83E-03	3.03E-03
A. borealis	-4.05E-02	1.62E-03	-7.38E-03	-8.24E-03	4.56E-03	3.41E-04	-5.88E-03
A. borealis	6.52E-02	-6.37E-03	3.85E-03	1.06E-03	-3.62E-03	9.68E-03	6.96E-04
A. borealis	-2.60E-02	-8.61E-03	-1.66E-04	1.32E-03	4.75E-03	7.95E-03	-1.14E-03
A. borealis	3.68E-02	-1.28E-02	3.32E-03	6.41E-04	-6.44E-04	2.00E-03	-2.14E-03

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Specimen	PC1	PC2	PC3	PC4	PC5	PC6	PC7
A. borealis	-2.47E-02	-4.40E-03	7.25E-03	3.18E-03	7.21E-03	9.96E-04	-7.27E-03
A. borealis	-1.07E-03	-1.49E-02	-2.20E-02	-4.84E-03	8.46E-03	-1.58E-03	1.09E-03
A. borealis	2.91E-02	-4.14E-02	-1.68E-02	1.25E-02	-9.97E-03	-4.25E-03	-2.57E-03
A. borealis	-2.33E-02	-2.75E-03	6.54E-03	-1.30E-03	-6.66E-03	3.36E-03	1.85E-04
A. borealis	2.58E-02	3.48E-02	1.57E-03	-9.05E-03	-1.48E-03	-1.49E-03	-1.55E-03
A. borealis	-1.93E-02	-9.30E-03	-1.33E-02	2.45E-03	-3.76E-03	-3.87E-04	-1.30E-03
A. borealis	-1.98E-03	-1.65E-03	-9.27E-04	2.50E-03	4.85E-03	5.46E-04	6.25E-04
A. borealis	-3.37E-04	-1.80E-02	-1.63E-02	-1.24E-03	7.44E-03	-1.75E-03	5.02E-04
A. borealis	-1.33E-02	2.18E-03	9.61E-03	6.02E-03	3.54E-03	6.68E-03	4.05E-03
A. borealis	-5.44E-02	3.52E-03	7.18E-04	-9.65E-03	8.09E-03	3.18E-06	-6.02E-03
A. borealis	1.15E-03	-6.94E-03	1.26E-02	-2.96E-04	-4.31E-03	-1.97E-03	-3.81E-03
A. borealis	1.94E-03	-4.77E-03	-4.46E-03	-3.68E-04	-5.91E-03	-3.64E-03	9.63E-03
A. borealis	-1.59E-02	3.66E-03	-2.05E-02	1.20E-02	7.72E-03	-3.73E-03	3.67E-03
A. borealis	1.04E-02	-2.90E-02	-9.10E-04	1.70E-03	-4.36E-03	-7.99E-04	-1.96E-03
A. borealis	-9.33E-04	-1.55E-03	-9.76E-03	4.28E-03	2.29E-03	1.09E-04	-5.09E-03
A. borealis	-1.22E-02	-4.29E-03	-1.79E-03	1.29E-02	-8.19E-03	-1.04E-02	-1.90E-05
A. borealis	-1.53E-02	1.39E-02	1.23E-02	1.82E-03	3.66E-03	-2.86E-04	2.96E-03
A. borealis	1.50E-03	1.40E-02	1.48E-02	-6.42E-03	6.77E-03	1.12E-03	-7.47E-03
A. borealis	-1.59E-02	2.39E-03	-1.29E-03	2.36E-03	7.58E-03	9.81E-03	3.84E-03
A. borealis	3.04E-02	-4.27E-02	5.52E-03	-7.43E-03	5.14E-05	-1.00E-02	4.76E-03
A. borealis	-6.89E-02	3.23E-02	8.39E-03	-5.44E-04	-2.55E-03	-1.99E-03	-8.94E-03
A. borealis	8.80E-03	6.02E-03	-7.43E-03	5.79E-03	4.93E-03	6.22E-04	-4.31E-03
A. borealis	-5.10E-03	-7.55E-04	2.12E-02	-1.81E-03	6.93E-04	-4.12E-03	-5.94E-04
A. borealis	3.86E-03	-4.88E-03	8.80E-03	6.08E-03	-3.01E-03	5.37E-03	-7.28E-04
A. borealis	-1.10E-02	1.81E-02	-1.18E-02	-2.08E-03	-1.21E-02	7.12E-03	-4.73E-03
A. borealis	-4.46E-02	4.34E-02	7.80E-04	-9.89E-03	-4.13E-03	-2.69E-03	2.83E-03
A. borealis	-1.41E-02	-8.67E-03	-1.10E-02	-1.28E-03	7.22E-03	4.38E-03	8.06E-03
A. borealis	6.38E-03	4.72E-03	2.86E-03	3.49E-03	5.06E-03	-2.38E-03	-2.08E-03
A. borealis	2.76E-02	5.62E-03	3.96E-03	-6.61E-03	1.51E-02	-6.35E-03	1.56E-04
A. borealis	8.68E-03	1.18E-03	-8.36E-04	-5.22E-03	-1.29E-03	-1.15E-03	8.78E-03
A. borealis	-4.08E-03	1.46E-02	3.13E-03	1.63E-02	3.06E-03	4.40E-04	7.97E-03
A. borealis	8.68E-04	-6.92E-04	-4.54E-03	-1.09E-03	-7.37E-03	-9.99E-03	-6.56E-03
A. borealis	-4.02E-02	-6.59E-03	-2.03E-02	-3.94E-03	-2.03E-03	7.53E-03	2.09E-03
A. borealis	1.21E-02	-9.15E-03	-5.81E-03	9.11E-03	7.85E-03	9.84E-03	-6.50E-03
A. borealis	1.89E-02	3.92E-02	-9.93E-04	-1.21E-02	-4.47E-04	-2.65E-03	4.53E-03
A. borealis	-6.28E-02	-1.81E-03	-1.85E-02	-9.63E-04	1.06E-03	1.42E-02	3.03E-03
A. borealis	3.23E-02	-1.03E-02	-1.00E-02	6.41E-03	-1.06E-02	-1.26E-03	-2.15E-03
A. borealis	6.96E-04	-1.45E-02	5.66E-03	2.56E-03	-6.14E-03	1.49E-03	9.18E-03
A. borealis	2.85E-03	1.34E-02	-3.78E-03	-7.60E-03	4.62E-03	-3.43E-04	-7.27E-03
A. borealis	2.15E-02	-3.39E-02	-1.81E-02	4.53E-03	3.67E-03	4.23E-03	3.86E-03
A. borealis	1.92E-02	5.64E-03	1.92E-03	-1.07E-02	7.52E-04	5.44E-04	5.05E-04
A. borealis	-6.31E-03	-3.30E-02	1.81E-03	1.91E-03	-4.46E-03	-1.98E-03	-3.30E-03
A. borealis	1.03E-02	-7.85E-03	-1.05E-02	-5.65E-03	-9.12E-03	1.16E-02	6.84E-03
A. borealis	-1.21E-02	5.85E-04	1.18E-02	-7.00E-03	-9.79E-03	-3.92E-03	4.80E-03
A. borealis	4.01E-03	9.89E-03	-7.32E-03	1.51E-03	-1.04E-02	9.90E-03	-5.44E-04
A. borealis	-2.55E-02	-1.79E-02	-3.33E-03	-1.04E-02	-1.31E-02	-3.38E-03	3.17E-03
A. borealis	5.66E-03	3.62E-02	4.45E-03	5.17E-03	1.56E-02	-3.29E-03	6.94E-03
A. borealis	3.31E-02	-2.52E-02	-1.20E-02	-2.58E-03	-2.95E-03	-3.83E-03	2.84E-03
A. borealis	2.74E-02	-1.10E-02	-6.38E-03	1.72E-04	-3.37E-03	-3.82E-03	-1.20E-03
A. borealis	2.93E-02	-3.01E-03	-8.08E-03	-7.47E-03	-6.50E-03	6.79E-03	3.97E-03
A. borealis	5.68E-02	6.66E-03	1.45E-02	-5.16E-03	6.59E-03	-2.05E-03	-3.23E-03
A. borealis	-4.97E-03	-3.63E-02	-1.16E-02	-5.09E-03	1.65E-03	7.27E-03	5.10E-03
A. borealis	-2.06E-02	-1.25E-02	-2.25E-03	-1.35E-04	-8.55E-04	3.15E-03	-7.90E-04
A. borealis	1.82E-02	5.06E-03	-2.22E-04	1.33E-02	2.20E-02	-1.49E-03	2.66E-03
A. borealis	-1.84E-02	1.82E-02	7.34E-03	-3.34E-03	-1.77E-03	-1.21E-03	1.01E-03
A. borealis	3.25E-02	-1.38E-02	2.76E-03	5.88E-04	1.20E-03	-1.50E-03	1.91E-03

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Specimen	PC1	PC2	PC3	PC4	PC5	PC6	PC7
A. borealis	-3.11E-02	-3.02E-02	-2.76E-03	4.91E-04	-4.82E-03	2.09E-04	4.63E-03
A. borealis	8.26E-03	2.08E-02	-1.11E-03	3.63E-03	-4.03E-03	4.16E-03	5.53E-04
A. borealis	1.16E-02	1.32E-03	-5.92E-03	5.61E-03	-7.65E-03	4.15E-03	-1.09E-03
A. borealis	-2.15E-02	8.42E-03	1.23E-02	5.05E-03	-3.96E-03	2.32E-03	-6.17E-03
A. borealis	1.62E-02	2.68E-03	-6.03E-03	3.59E-03	3.15E-03	3.21E-03	-2.62E-03
A. borealis	2.80E-02	-4.80E-02	-1.66E-02	1.12E-02	4.43E-03	1.71E-05	2.80E-03
A. borealis	3.82E-02	1.85E-02	7.70E-03	-1.33E-02	-4.12E-04	-2.76E-03	-4.96E-03
A. borealis	-1.36E-03	-2.25E-02	3.14E-03	1.17E-02	1.31E-02	-1.97E-03	3.05E-03
A. borealis	1.56E-02	4.60E-03	-1.38E-03	-1.15E-02	1.21E-02	-7.13E-03	2.91E-03
A. borealis	-7.24E-03	1.93E-03	-1.20E-02	2.64E-03	4.39E-04	6.84E-03	9.11E-05
A. borealis	2.92E-02	-2.93E-02	1.48E-02	6.51E-03	8.11E-03	3.12E-03	-4.50E-03
A. borealis	2.44E-02	-4.04E-03	1.52E-02	-2.43E-04	-5.41E-05	5.97E-04	1.02E-03
A. borealis	-1.09E-03	-5.91E-03	-4.94E-03	3.29E-03	3.03E-03	-2.49E-03	1.84E-03
A. borealis	-2.90E-02	-1.79E-02	2.48E-03	4.50E-03	6.71E-03	1.15E-03	-4.00E-03
A. borealis	3.43E-03	-4.76E-03	-1.07E-03	3.57E-03	-4.48E-03	-2.86E-03	-7.02E-04
A. borealis	2.27E-02	-1.11E-02	-3.21E-03	6.81E-03	-7.26E-03	5.16E-03	1.97E-03
A. borealis	3.68E-02	-1.13E-02	7.42E-03	4.52E-03	-1.01E-02	3.77E-03	-7.26E-03
A. borealis	1.17E-02	4.00E-03	-3.57E-04	4.03E-05	6.11E-03	1.27E-03	2.74E-03
A. borealis	4.34E-03	-9.62E-03	-1.76E-02	-6.35E-03	6.44E-03	2.90E-03	-5.36E-03
A. borealis	-7.63E-03	-1.13E-02	-7.22E-03	-4.39E-03	-6.52E-03	-1.33E-03	3.26E-03
A. borealis	1.40E-02	1.06E-02	9.40E-03	-7.29E-03	-3.12E-03	3.23E-03	-8.70E-05
A. borealis	1.31E-02	7.24E-03	2.87E-03	3.27E-03	-8.84E-04	3.10E-03	-3.79E-03
A. borealis	-1.58E-02	8.77E-03	2.14E-02	1.62E-03	5.17E-03	-3.54E-03	-5.07E-03
A. borealis	-3.30E-02	5.34E-03	-1.00E-02	-1.48E-03	-3.50E-03	1.35E-03	-2.15E-03
A. borealis	-1.51E-02	-2.13E-02	9.50E-02	2.21E-02	6.38E-03	6.06E-03	7.01E-03
A. borealis	-1.39E-02	-2.08E-02	1.42E-02	-1.68E-02	4.71E-03	3.95E-03	3.28E-03
A. borealis	1.90E-02	-7.85E-03	2.36E-03	-3.72E-03	3.43E-03	7.15E-04	-4.54E-03
A. borealis	-2.64E-02	6.90E-03	4.08E-03	1.04E-03	-2.29E-03	6.78E-03	-7.27E-04
A. borealis	-3.74E-02	-1.83E-02	3.05E-03	8.39E-03	4.98E-04	5.15E-03	3.70E-03
A. borealis	4.68E-02	1.55E-02	-2.13E-03	-4.38E-03	-6.25E-03	-5.24E-05	-5.11E-03
A. borealis	1.48E-02	2.99E-02	-9.38E-03	3.91E-03	-1.52E-03	4.30E-03	3.45E-03
A. borealis	4.52E-03	-5.49E-04	-2.56E-03	4.39E-03	-1.22E-03	8.80E-03	8.64E-04
A. borealis	3.06E-02	-1.56E-02	-1.72E-03	-3.60E-03	1.18E-02	1.70E-03	-1.14E-02
A. borealis	-6.95E-02	-8.60E-04	-1.64E-02	3.89E-03	-6.42E-03	3.19E-03	1.02E-02
A. borealis	-1.73E-02	2.68E-03	-4.31E-04	-1.74E-03	2.87E-03	2.18E-03	-1.83E-03
A. borealis	1.46E-02	2.48E-02	-8.07E-03	-1.12E-02	-7.61E-04	-9.78E-05	1.45E-03
A. borealis	-2.29E-02	8.43E-03	1.81E-03	-2.27E-03	3.68E-03	1.63E-03	-1.48E-03
A. borealis	4.70E-02	6.10E-02	5.69E-03	-2.10E-02	3.86E-03	-6.13E-03	5.05E-03
A. borealis	-2.53E-02	-5.62E-03	-5.14E-03	-2.77E-03	-4.66E-04	2.95E-03	-6.78E-04
A. borealis	3.85E-02	-2.26E-02	-4.17E-03	-7.15E-03	2.74E-04	1.39E-03	4.66E-03
A. borealis	-1.28E-02	1.45E-03	-2.80E-03	3.70E-03	-5.53E-03	5.12E-03	2.68E-03
A. borealis	-3.59E-03	-1.72E-02	-1.77E-02	9.12E-03	1.03E-02	5.52E-03	5.34E-03
A. borealis	1.66E-02	-1.22E-02	1.93E-03	2.99E-03	-8.98E-03	-5.78E-03	-2.73E-03
A. borealis	4.58E-02	-2.36E-02	1.25E-02	-6.62E-03	1.52E-03	-4.15E-03	-2.38E-03
A. borealis	2.79E-02	1.62E-02	1.20E-03	-8.96E-04	6.25E-03	-2.92E-03	-3.17E-03
A. borealis	5.50E-03	1.01E-02	-7.66E-03	4.10E-03	-3.42E-03	-7.50E-03	-1.04E-03
A. borealis	2.31E-02	1.25E-02	3.74E-03	-1.10E-02	-4.02E-03	1.26E-04	1.88E-03
A. borealis	3.24E-02	-4.15E-02	2.26E-02	-2.48E-03	-5.85E-04	-1.10E-02	-3.05E-03
A. borealis	1.70E-02	1.15E-02	-1.51E-03	1.06E-02	6.84E-03	1.48E-02	4.05E-04
A. borealis	-6.78E-02	-1.61E-02	-1.52E-02	1.10E-02	-3.27E-03	-2.73E-03	9.32E-03
A. borealis	-1.43E-02	-2.45E-02	5.96E-03	2.21E-03	-2.87E-03	-1.04E-02	-8.21E-04
A. borealis	-1.61E-02	-4.61E-03	-1.03E-02	-6.22E-03	8.80E-03	-1.53E-03	-3.80E-04
A. borealis	-1.59E-03	-7.23E-03	1.03E-01	1.39E-02	-8.48E-03	5.50E-03	1.01E-02
A. borealis	1.83E-02	2.93E-02	-4.06E-03	-5.52E-04	-6.82E-03	6.41E-03	3.12E-03
A. borealis	-2.91E-02	-1.99E-02	-1.55E-02	-7.26E-03	1.02E-02	-1.04E-02	-2.06E-03
A. borealis	-1.63E-02	-1.60E-02	9.01E-04	-2.45E-03	-8.27E-03	3.60E-03	1.83E-04

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Specimen	PC1	PC2	PC3	PC4	PC5	PC6	PC7
A. borealis	-3.60E-03	-4.31E-03	-9.19E-03	-7.35E-03	1.08E-02	-3.23E-03	-8.36E-04
A. borealis	2.47E-02	1.13E-02	5.15E-05	4.84E-03	-4.52E-03	-1.35E-03	2.24E-03
A. borealis	-8.27E-03	-2.32E-02	-1.57E-02	6.15E-03	8.38E-03	-1.08E-02	2.67E-03
A. borealis	-2.10E-03	1.34E-02	1.68E-04	1.08E-02	-8.15E-03	3.83E-03	-4.62E-03
A. borealis	2.05E-02	-2.42E-02	-4.43E-03	-5.83E-03	6.25E-04	2.41E-03	1.97E-03
A. borealis	2.58E-02	-3.23E-02	-1.72E-03	-4.67E-03	3.72E-03	4.85E-03	3.24E-03
A. borealis	2.39E-02	-2.88E-02	-1.01E-02	2.22E-03	6.63E-03	7.04E-04	6.87E-03
A. borealis	1.10E-02	-1.13E-03	1.03E-02	5.57E-03	-5.88E-03	1.38E-03	-5.43E-03
A. borealis	-1.08E-02	1.75E-02	5.83E-03	-6.33E-03	-4.02E-03	2.64E-03	2.50E-03
A. borealis	2.32E-03	-3.33E-02	-2.19E-03	-4.91E-04	-2.18E-03	-1.13E-02	-2.96E-03
A. borealis	2.94E-02	-1.86E-02	-5.20E-03	7.03E-04	1.19E-02	5.01E-03	-4.60E-03
A. borealis	1.99E-02	6.56E-03	1.83E-03	4.87E-03	9.95E-03	1.49E-03	3.27E-04
A. borealis	1.12E-02	7.11E-03	-2.44E-03	3.76E-03	8.35E-03	-2.88E-03	2.11E-04
A. borealis	2.29E-02	2.04E-02	-1.14E-02	-1.17E-03	6.06E-04	-1.28E-03	1.41E-03
A. borealis	-4.22E-02	-1.44E-02	-1.32E-02	-5.19E-03	2.35E-03	-7.10E-04	2.29E-03
A. borealis	2.62E-03	-4.31E-03	1.06E-02	-5.78E-03	-3.28E-03	8.83E-03	-8.22E-03
A. borealis	7.19E-03	9.07E-03	-4.72E-03	3.97E-03	-8.13E-04	7.90E-03	-6.70E-04
A. borealis	-9.23E-03	9.81E-03	7.45E-03	6.54E-03	3.74E-03	-1.13E-02	-6.92E-03
A. borealis	-3.69E-02	4.37E-02	2.41E-03	-6.98E-04	-1.65E-03	-4.73E-03	-4.72E-03
A. borealis	-5.24E-02	-5.18E-03	1.53E-03	-6.43E-03	1.64E-03	5.16E-03	-5.67E-03
A. borealis	9.98E-03	-8.37E-03	-7.18E-03	6.46E-03	-1.20E-02	3.74E-03	1.58E-03
A. borealis	-4.18E-02	-6.66E-03	1.81E-02	-3.90E-03	4.00E-03	1.19E-03	-2.28E-03
A. borealis	6.60E-03	2.39E-02	-2.41E-02	1.86E-02	2.52E-03	-3.24E-04	9.24E-03
A. borealis	-2.49E-02	-4.51E-04	-1.34E-03	1.38E-02	-8.46E-03	-8.35E-03	-7.04E-03
A. borealis	-2.27E-02	-2.38E-02	-3.61E-03	-1.54E-04	-2.37E-03	5.10E-03	-3.77E-03
A. borealis	9.04E-03	-8.11E-03	1.98E-02	2.06E-03	2.74E-03	-1.69E-03	-8.26E-04
A. borealis	-7.58E-03	-4.01E-03	3.38E-03	-8.27E-03	-8.96E-03	-2.60E-04	-3.88E-03
A. borealis	1.34E-03	-5.33E-03	-2.02E-03	-4.01E-04	-3.06E-03	-4.56E-03	-4.42E-03
A. borealis	-2.11E-02	1.08E-02	-1.09E-02	8.02E-04	4.00E-03	6.75E-03	-5.44E-03
A. borealis	5.30E-03	-1.19E-02	1.09E-01	7.44E-03	-1.33E-02	6.48E-03	2.48E-02
A. borealis	-1.15E-02	1.79E-02	-1.27E-02	2.45E-03	-2.74E-03	9.22E-03	-8.29E-05
A. borealis	-2.37E-02	-5.86E-03	9.21E-03	1.03E-02	-5.08E-03	3.67E-03	2.53E-03
A. borealis	-1.66E-02	-7.31E-03	3.58E-03	-4.40E-03	-2.91E-03	-1.21E-03	-1.85E-03
A. borealis	1.66E-02	4.26E-03	-6.56E-03	8.22E-03	1.34E-03	-9.99E-04	5.33E-03
A. borealis	1.33E-02	-2.64E-02	-4.21E-03	-3.50E-03	8.44E-03	-3.47E-04	-2.93E-04
A. borealis	-9.94E-03	-1.21E-02	-5.88E-03	8.88E-03	1.45E-03	4.18E-03	-1.22E-03
A. borealis	1.34E-03	1.16E-03	5.85E-03	-4.73E-04	1.42E-03	-4.95E-03	-1.41E-04
A. borealis	-2.76E-02	1.78E-03	3.90E-03	-6.53E-03	4.34E-03	8.89E-04	1.20E-03
A. borealis	3.97E-02	-3.42E-02	1.76E-02	5.56E-03	2.66E-03	-7.76E-03	-2.86E-03
A. borealis	-7.97E-02	-7.02E-03	-1.57E-02	-7.18E-05	-3.72E-03	-3.02E-03	5.42E-03
A. borealis	-1.79E-02	-1.43E-02	5.43E-03	-1.08E-02	-3.88E-03	2.57E-03	3.05E-03
A. borealis	-1.10E-03	-3.44E-03	-1.61E-02	-3.73E-03	-5.04E-03	7.54E-05	4.18E-03
A. borealis	1.58E-02	1.37E-02	-1.95E-02	2.92E-03	-1.53E-04	-2.05E-03	-3.86E-03
A. borealis	-1.60E-02	-3.74E-02	-3.32E-03	2.47E-03	6.49E-03	1.41E-03	8.26E-03
A. borealis	1.71E-02	1.07E-02	4.79E-03	-8.56E-04	2.97E-03	8.82E-03	-6.14E-03
A. borealis	2.82E-02	-2.03E-02	-8.80E-03	-1.96E-03	5.42E-03	-7.70E-04	1.96E-03
A. borealis	4.26E-02	-3.29E-02	3.18E-02	-2.13E-02	6.56E-03	-1.08E-02	1.73E-03
A. borealis	3.40E-03	-4.60E-03	-4.85E-03	-3.12E-03	-8.88E-03	6.09E-03	1.32E-02
A. borealis	6.31E-03	1.81E-02	2.46E-03	1.83E-03	-3.48E-03	-1.71E-03	-3.34E-03
A. borealis	8.63E-03	-3.57E-03	2.48E-04	-9.48E-03	9.50E-03	5.85E-03	8.35E-03
A. borealis	1.78E-02	-3.23E-02	-4.57E-04	3.73E-05	-9.03E-03	-8.13E-03	9.27E-05
A. borealis	2.72E-03	1.08E-02	-1.09E-02	-1.86E-02	-6.38E-03	5.67E-03	4.59E-03
A. borealis	1.24E-02	-3.16E-03	-2.80E-03	-4.94E-03	-4.33E-03	2.10E-03	2.03E-05
A. borealis	2.26E-02	6.00E-03	-3.82E-04	3.67E-03	-1.53E-02	1.19E-03	-6.23E-03
A. borealis	3.07E-02	6.06E-03	-4.54E-03	-3.78E-03	-1.45E-02	-1.63E-03	-3.25E-03
A. borealis	-1.06E-02	1.06E-03	-9.00E-03	2.45E-03	-7.22E-03	2.18E-03	-5.00E-03

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Specimen	PC1	PC2	PC3	PC4	PC5	PC6	PC7
A. borealis	4.41E-03	-6.48E-03	1.01E-02	1.38E-03	7.61E-03	-2.61E-03	-3.22E-03
A. borealis	-1.15E-02	1.98E-02	6.20E-03	9.87E-03	-7.45E-03	-1.12E-05	-9.68E-03
A. borealis	-1.29E-02	-7.45E-03	1.08E-01	3.81E-03	-1.13E-02	1.17E-02	1.33E-02
A. borealis	3.36E-03	4.30E-03	-2.91E-03	9.36E-03	-2.40E-03	6.20E-03	-7.87E-04
A. borealis	-6.30E-02	-2.68E-02	4.99E-03	-4.60E-03	1.81E-02	-4.52E-03	-2.36E-03
A. borealis	-7.47E-03	1.88E-02	-5.43E-03	-8.68E-03	1.07E-03	2.01E-03	-7.52E-03
A. borealis	-5.89E-02	1.63E-02	-2.66E-03	-3.25E-03	4.29E-03	-1.05E-03	4.33E-04
A. borealis	1.83E-02	2.69E-02	1.83E-03	-2.31E-03	1.06E-03	1.10E-03	3.38E-03
A. borealis	5.52E-04	3.22E-03	-6.06E-03	-4.18E-03	-1.01E-02	-1.43E-03	2.63E-03
A. borealis	-1.04E-02	-5.28E-03	-4.97E-04	3.90E-03	2.70E-03	8.34E-04	-9.75E-03
A. borealis	-2.93E-02	1.49E-02	4.98E-03	-4.64E-03	3.07E-03	2.43E-03	-2.00E-03
A. borealis	-1.61E-02	7.15E-03	9.62E-03	1.93E-03	8.32E-03	1.65E-03	1.31E-03
A. borealis	3.64E-02	-1.91E-02	1.68E-02	-1.57E-02	1.51E-03	-1.90E-03	4.66E-03
A. borealis	-3.24E-03	3.85E-02	1.24E-03	3.41E-03	-3.80E-03	-2.35E-03	3.95E-03
A. borealis	4.91E-02	5.86E-03	-9.37E-03	3.35E-03	-4.53E-03	2.15E-03	-4.94E-03
A. borealis	9.93E-03	-1.01E-02	-8.49E-03	1.17E-03	-6.80E-03	-2.44E-03	-1.40E-03
A. borealis	-1.60E-02	-1.19E-02	-1.33E-02	1.02E-02	4.84E-03	-2.76E-03	4.10E-03
A. borealis	-4.86E-03	1.58E-02	-9.75E-03	-5.85E-03	-1.14E-03	2.62E-03	-1.78E-04
A. borealis	-4.48E-02	6.21E-04	1.80E-02	-5.43E-04	-4.35E-03	8.53E-04	2.49E-04
A. borealis	5.82E-03	2.20E-03	-7.69E-03	-3.31E-03	-3.96E-03	9.79E-03	1.31E-03
A. borealis	-2.11E-02	1.16E-02	6.77E-03	-6.54E-04	3.87E-04	6.96E-03	-4.97E-03
A. borealis	-2.91E-02	1.33E-02	8.05E-03	-1.06E-02	-1.52E-02	1.99E-03	8.71E-04
A. borealis	8.86E-03	-4.27E-03	9.13E-03	-2.25E-03	-3.78E-03	1.89E-03	-6.97E-03
A. borealis	1.31E-03	-1.51E-02	8.07E-03	-8.95E-04	1.20E-02	7.40E-03	7.74E-03
A. borealis	-4.11E-02	-4.57E-02	-2.04E-03	-7.04E-03	5.56E-03	-5.92E-03	-9.75E-03
A. borealis	-6.00E-03	-1.70E-02	6.96E-03	6.25E-03	-1.17E-02	-3.82E-03	6.03E-04
A. borealis	3.64E-03	-4.34E-03	-2.18E-02	-5.30E-03	1.69E-02	8.14E-03	-9.61E-04
A. borealis	-5.45E-03	-2.24E-03	-2.03E-03	-4.51E-03	-6.05E-03	3.09E-03	-2.82E-03
A. borealis	1.24E-02	-2.01E-02	-1.52E-02	6.13E-04	-1.70E-03	3.73E-03	3.67E-03
A. borealis	1.88E-03	-1.20E-02	5.40E-03	-3.04E-03	3.05E-03	2.70E-03	3.76E-03
A. borealis	2.91E-02	1.10E-02	-9.27E-03	1.26E-03	-5.72E-03	9.79E-04	-5.59E-03
A. borealis	8.04E-03	9.04E-03	-8.56E-03	5.53E-03	1.52E-03	6.90E-03	-2.72E-03
A. borealis	9.25E-04	5.85E-03	-1.04E-02	-5.80E-03	2.51E-03	4.42E-03	1.66E-03
A. borealis	-4.25E-02	1.02E-02	4.86E-04	6.62E-03	-6.23E-03	-1.44E-03	5.90E-04
A. borealis	2.69E-02	2.37E-02	8.67E-03	-8.87E-03	-5.54E-03	5.00E-03	-1.63E-03
A. borealis	5.50E-03	2.50E-03	3.39E-03	-5.17E-03	3.61E-03	-3.24E-03	-8.28E-03
A. borealis	-1.49E-02	-4.67E-03	1.84E-02	-2.86E-03	3.31E-03	3.70E-03	-3.71E-03
A. borealis	5.72E-02	-2.34E-02	1.93E-02	-1.01E-03	9.25E-03	9.51E-06	-1.11E-02
A. borealis	2.89E-02	8.68E-03	-8.97E-03	-4.38E-04	-1.45E-02	5.89E-04	8.29E-03
A. borealis	-2.84E-02	-1.03E-02	3.37E-03	1.91E-03	1.01E-02	-4.01E-04	-6.78E-04
A. borealis	4.87E-02	-9.79E-03	4.09E-03	-8.67E-03	1.01E-03	-1.73E-03	-4.73E-03
A. borealis	-1.89E-03	-1.68E-02	-7.96E-03	1.21E-03	-4.85E-03	-1.02E-03	-6.20E-03
A. borealis	4.44E-02	2.26E-02	5.15E-03	-2.09E-03	-1.68E-06	6.57E-03	-7.75E-04
A. borealis	2.95E-02	-2.51E-02	-8.46E-04	2.37E-03	-4.57E-03	-2.61E-03	-1.27E-03
A. borealis	3.54E-03	-1.96E-02	-1.24E-03	-3.66E-03	9.10E-03	3.03E-03	-2.33E-03
A. borealis	3.27E-02	2.44E-03	7.64E-03	-2.93E-06	-2.19E-03	2.41E-03	-4.37E-03
A. borealis	-8.59E-04	1.48E-02	5.48E-03	4.37E-03	6.38E-03	-1.39E-04	-3.14E-03
A. borealis	-9.44E-04	9.07E-03	-2.64E-03	1.43E-02	3.65E-03	-7.35E-03	3.58E-04
A. borealis	5.52E-03	4.30E-03	-5.60E-03	1.09E-02	1.20E-02	-4.34E-03	-2.51E-04
A. borealis	-2.25E-02	-3.14E-02	-4.37E-03	9.06E-03	1.54E-03	3.08E-03	3.12E-03
A. borealis	-7.58E-02	-1.32E-02	1.06E-02	-2.38E-03	7.27E-03	-6.96E-03	-2.33E-03
A. borealis	6.69E-03	-1.02E-02	-1.03E-02	-6.62E-03	9.37E-03	5.72E-03	-2.38E-03
A. borealis	-2.59E-02	1.86E-02	-1.60E-03	-8.25E-04	-5.24E-03	-5.75E-03	1.78E-03
A. borealis	6.65E-02	1.56E-02	1.75E-02	8.13E-03	7.19E-03	8.94E-04	3.17E-04
A. borealis	-2.15E-03	-2.34E-02	1.91E-02	2.82E-03	-1.00E-02	-5.94E-03	3.68E-03
A. borealis	5.10E-02	-9.42E-03	3.12E-03	2.34E-03	5.62E-03	-1.01E-03	1.31E-03

All Specimens Effective Principal Component Scores Page 10

Specimen	PC1	PC2	PC3	PC4	PC5	PC6	PC7
A. borealis	-1.07E-02	-2.67E-02	3.90E-03	6.46E-03	-5.68E-03	-5.46E-03	5.36E-03
A. borealis	1.62E-02	-1.10E-02	-7.37E-03	-3.67E-03	-5.82E-03	-6.26E-03	-1.95E-03
A. borealis	3.09E-02	-6.02E-03	3.36E-03	-4.69E-03	-2.69E-03	-1.91E-03	-1.09E-02
A. borealis	-1.45E-02	-2.56E-02	-1.86E-02	7.24E-03	8.11E-03	6.84E-03	-2.81E-03
A. borealis	-2.60E-02	-1.63E-02	2.63E-03	1.87E-03	-2.26E-03	1.59E-03	-2.57E-03
A. borealis	7.13E-03	-2.60E-02	1.24E-02	-8.93E-03	1.82E-03	-2.66E-03	8.21E-03
A. borealis	-2.42E-02	2.13E-04	-1.25E-02	-2.44E-03	2.81E-03	6.40E-03	-1.97E-03
A. borealis	5.46E-02	-1.37E-02	-6.52E-03	1.26E-02	-3.18E-04	-9.09E-03	-2.30E-03
A. borealis	-4.93E-03	-2.61E-02	6.36E-03	8.55E-03	-1.13E-02	-6.81E-03	6.56E-03
A. borealis	3.87E-03	2.27E-02	1.62E-02	-1.92E-03	1.19E-03	-2.37E-03	-4.47E-04
A. borealis	3.15E-02	6.37E-03	-1.71E-02	1.81E-04	1.05E-02	2.19E-03	-2.16E-04
A. borealis	-5.57E-02	-1.55E-02	4.82E-03	-8.80E-03	-1.96E-03	-5.60E-03	4.32E-03
A. borealis	2.14E-02	-9.67E-03	6.82E-03	-1.61E-02	-1.29E-02	-5.06E-03	-3.27E-03
A. borealis	-1.38E-02	2.55E-02	-3.90E-03	1.23E-03	1.28E-02	-6.72E-03	9.21E-03
A. borealis	1.70E-03	4.70E-03	1.23E-02	1.23E-02	5.47E-03	-3.99E-03	1.34E-03
A. borealis	6.42E-03	4.33E-03	-9.38E-03	9.26E-03	-1.01E-02	-1.08E-02	-8.03E-03
A. borealis	3.21E-02	1.83E-02	-1.16E-03	1.25E-03	6.25E-03	6.93E-04	-7.24E-03
A. borealis	-3.23E-03	-1.53E-02	1.38E-02	3.73E-03	-1.50E-03	-2.22E-03	1.07E-03
A. borealis	-7.10E-03	-2.15E-02	-9.56E-03	7.35E-03	1.49E-03	-5.59E-03	5.23E-04
A. borealis	-4.75E-03	-4.28E-03	-1.10E-02	-7.32E-03	2.44E-03	4.64E-03	3.62E-03
A. borealis	5.20E-03	-9.16E-03	-4.50E-03	-4.78E-03	-9.01E-04	8.19E-03	-2.06E-03
A. borealis	-7.58E-02	-6.63E-03	4.19E-03	1.75E-03	-8.18E-03	2.15E-03	4.64E-04
A. borealis	-4.94E-03	-3.35E-02	9.10E-02	2.17E-02	3.02E-02	8.35E-03	-1.45E-02
A. borealis	1.35E-02	-2.01E-02	1.88E-02	3.83E-03	2.98E-03	-5.37E-03	2.82E-03
A. borealis	-3.10E-02	-9.41E-03	7.73E-03	-1.16E-03	-7.78E-03	3.37E-03	4.48E-04
A. borealis	-1.99E-02	-1.02E-02	-1.44E-02	-6.13E-03	1.86E-03	-1.11E-02	2.31E-03
A. borealis	-6.84E-03	-5.04E-03	-6.56E-03	-3.07E-03	-1.34E-03	-1.36E-03	-6.25E-03
A. borealis	-3.10E-02	1.38E-02	8.73E-03	9.54E-04	-4.43E-03	2.35E-03	-7.03E-03
A. borealis	-8.79E-03	-8.92E-03	6.09E-03	3.21E-03	1.46E-02	2.30E-03	-6.11E-03
A. borealis	3.17E-02	7.95E-04	1.12E-02	-1.56E-02	-1.10E-02	-6.72E-04	-1.72E-03
A. borealis	-1.59E-02	-7.32E-03	-6.97E-03	-1.50E-02	2.52E-03	2.08E-03	7.84E-03
A. borealis	-1.55E-02	5.65E-04	3.31E-03	6.63E-03	-2.87E-03	-2.45E-04	7.84E-03
A. borealis	-3.16E-02	5.49E-03	-2.75E-03	7.96E-03	5.99E-03	3.09E-03	-6.79E-03
A. borealis	-2.37E-02	-2.34E-03	2.14E-03	2.61E-03	7.33E-04	4.05E-03	6.32E-04
A. borealis	-3.19E-02	1.92E-02	1.27E-03	2.84E-04	6.78E-03	-4.06E-03	-7.02E-03
A. borealis	2.75E-02	2.40E-03	2.43E-03	-6.55E-05	-8.75E-04	1.52E-02	-3.60E-03
A. borealis	1.39E-02	-5.83E-05	-1.08E-02	-6.78E-03	-8.01E-04	-3.16E-03	-7.18E-03
A. borealis	1.54E-02	-5.63E-03	-9.83E-03	-1.43E-03	-2.98E-03	1.76E-03	-4.55E-03
A. borealis	-5.86E-02	-1.85E-02	3.12E-03	-1.17E-02	-3.48E-03	-8.82E-04	1.26E-03
A. borealis	-2.66E-03	7.48E-03	-3.68E-03	-5.45E-03	3.62E-04	6.86E-04	-4.28E-03
A. borealis	1.69E-02	-5.37E-03	-1.76E-03	8.41E-04	2.77E-03	3.92E-03	-2.29E-03
A. borealis	-3.19E-02	1.33E-02	1.17E-03	1.47E-02	6.32E-03	-3.12E-03	1.06E-04
A. borealis	2.54E-02	-7.64E-03	-4.78E-03	6.49E-03	-1.52E-03	-1.27E-03	-4.14E-03
A. borealis	7.99E-03	1.62E-02	-1.66E-02	-8.73E-03	3.27E-03	7.93E-03	-5.48E-04
A. borealis	-5.38E-02	1.24E-02	1.49E-02	-6.07E-03	-1.08E-02	1.44E-03	8.69E-04
A. borealis	-1.93E-03	1.54E-02	6.84E-03	-1.56E-03	1.08E-02	-3.23E-03	2.18E-03
A. borealis	5.56E-03	-1.18E-02	-5.87E-03	3.26E-03	5.23E-03	-2.97E-03	6.57E-04
A. borealis	4.26E-03	-1.30E-02	-5.13E-03	-2.92E-03	-1.16E-03	-9.45E-04	3.18E-04
A. borealis	2.11E-02	5.31E-02	6.37E-03	-1.30E-03	7.61E-04	-7.02E-03	7.42E-03
A. borealis	-3.72E-02	-1.85E-02	-6.94E-03	-1.65E-03	-5.05E-03	-3.05E-03	-6.43E-03
A. borealis	4.70E-02	3.56E-02	1.77E-02	2.48E-03	-1.30E-03	-3.97E-03	7.52E-03
A. borealis	1.03E-02	-4.98E-03	9.29E-03	8.36E-03	-6.33E-03	-6.65E-04	-6.42E-03
A. borealis	4.69E-02	-1.38E-02	3.76E-03	4.24E-04	3.81E-03	5.50E-03	7.10E-03
A. borealis	2.89E-02	4.30E-02	2.51E-02	-5.52E-03	-8.26E-03	1.18E-02	6.86E-03
A. borealis	3.52E-02	-3.06E-03	2.26E-02	-1.90E-02	-6.06E-03	-8.35E-03	5.17E-03
A. borealis	-1.83E-02	3.44E-02	3.68E-04	-5.50E-03	1.03E-02	9.18E-04	4.44E-03

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Specimen	PC1	PC2	PC3	PC4	PC5	PC6	PC7
A. borealis	3.60E-03	2.52E-02	-3.40E-03	1.01E-02	1.09E-02	-4.10E-03	8.43E-03
A. borealis	5.46E-03	2.82E-02	5.42E-03	-2.64E-03	3.09E-03	-9.22E-04	4.28E-04
A. borealis	5.29E-02	1.55E-02	-5.40E-03	5.66E-03	-5.44E-03	-7.25E-04	4.85E-03
A. borealis	2.72E-02	2.23E-02	1.54E-02	-1.20E-02	-7.13E-03	1.66E-03	-3.81E-03
A. borealis	9.21E-03	2.68E-02	4.79E-03	-5.87E-04	-1.64E-03	-3.29E-03	7.34E-03
A. borealis	7.41E-03	3.89E-03	1.29E-02	-1.90E-03	4.22E-03	-4.57E-03	-3.25E-03
A. borealis	6.39E-03	-2.13E-02	-1.40E-03	-3.76E-03	-7.60E-05	6.34E-03	-4.03E-04
A. borealis	6.68E-02	1.63E-02	-1.06E-02	-4.38E-04	-3.18E-03	4.23E-03	1.35E-03
A. borealis	4.72E-02	-4.41E-02	-9.58E-03	1.38E-02	1.75E-02	2.11E-04	-3.15E-03
A. borealis	5.77E-03	3.98E-02	1.08E-02	3.72E-03	4.65E-03	-5.06E-03	-7.95E-03
A. borealis	-6.03E-03	4.60E-02	8.83E-03	-5.20E-03	3.82E-03	-4.42E-03	-2.60E-03
A. borealis	1.98E-02	-2.74E-02	-4.85E-03	8.58E-03	-4.91E-03	-1.33E-03	5.46E-04
A. borealis	-2.94E-02	-8.86E-03	-1.42E-02	-5.79E-03	2.79E-04	3.84E-03	1.04E-02
A. borealis	2.71E-03	1.74E-02	3.31E-03	-6.02E-03	6.83E-03	-1.85E-03	-3.08E-04
A. borealis	-9.28E-03	-2.54E-02	1.96E-02	1.78E-03	1.49E-04	-5.11E-03	1.86E-03
A. borealis	2.11E-02	-2.66E-02	1.01E-03	-3.82E-03	-4.95E-04	-5.56E-03	2.46E-03
A. borealis	2.49E-02	2.08E-02	5.16E-03	-6.44E-03	-1.50E-02	7.32E-04	-9.68E-03
A. borealis	-8.46E-03	-1.35E-02	-7.83E-03	4.22E-03	-1.23E-03	4.62E-03	6.62E-05
A. borealis	1.25E-02	-1.49E-02	-1.76E-02	1.45E-02	3.56E-03	6.01E-04	-1.36E-03
A. borealis	4.62E-03	2.04E-02	-1.47E-02	1.47E-03	1.27E-02	1.18E-02	-1.26E-02
A. borealis	-9.02E-03	-5.85E-03	-4.28E-03	5.99E-04	-4.47E-03	-1.00E-03	-8.78E-04
A. borealis	4.80E-02	1.28E-02	-3.21E-03	-4.11E-03	-1.46E-02	3.83E-03	-4.50E-03
A. borealis	1.43E-02	-1.02E-02	4.26E-03	2.94E-03	-8.02E-03	-9.07E-04	-2.46E-03
A. borealis	-6.43E-03	9.99E-03	-2.46E-04	-1.96E-03	-4.61E-03	-2.46E-03	4.40E-03
A. borealis	4.22E-02	-7.75E-03	-9.80E-03	3.88E-03	1.85E-03	-1.69E-03	9.33E-04
A. borealis	1.21E-02	-1.86E-02	-5.76E-03	2.56E-03	-1.01E-03	1.04E-03	4.17E-03
A. borealis	-1.28E-02	-1.12E-02	-1.40E-02	2.65E-03	5.88E-03	8.95E-03	7.46E-04
A. borealis	6.52E-03	3.71E-02	-4.35E-03	-1.33E-02	-1.06E-03	1.48E-03	3.50E-03
A. borealis	4.87E-02	-2.55E-02	-1.26E-02	-5.61E-03	7.24E-04	1.74E-03	2.64E-03
A. borealis	-2.18E-03	1.24E-02	-1.34E-02	-1.04E-02	-6.11E-04	1.17E-02	3.62E-03
A. borealis	1.32E-02	-3.82E-02	1.29E-02	1.80E-03	4.68E-03	1.24E-03	3.89E-03
A. borealis	2.65E-02	3.33E-02	-1.10E-02	6.01E-03	5.18E-03	-5.99E-03	3.02E-03
A. borealis	3.30E-02	1.84E-02	-1.58E-03	-2.26E-03	3.98E-03	5.47E-03	1.98E-04
A. borealis	-1.83E-02	8.76E-03	8.06E-04	2.43E-03	-9.01E-03	-3.06E-03	-1.51E-03
A. borealis	2.90E-03	1.20E-02	-2.97E-04	-5.05E-03	4.20E-03	1.48E-03	-2.03E-03
A. borealis	5.05E-02	3.30E-03	7.39E-03	7.99E-03	-3.48E-03	-1.61E-03	-2.20E-03
A. borealis	-1.10E-02	1.06E-02	-1.71E-02	5.36E-03	-3.48E-03	5.91E-03	6.01E-04
A. borealis	-1.15E-02	-6.48E-03	4.70E-03	2.84E-03	-3.94E-03	-2.42E-04	1.23E-03
A. borealis	4.42E-02	5.93E-03	4.91E-03	-8.10E-03	3.18E-03	4.75E-04	4.85E-03
A. borealis	3.91E-02	-1.20E-02	-1.99E-03	-1.62E-04	-5.25E-03	-3.08E-03	-1.28E-03
A. borealis	-1.22E-02	2.92E-05	-2.09E-03	-7.81E-03	1.12E-02	2.75E-03	-8.22E-03
A. borealis	-4.75E-02	-1.75E-02	3.59E-03	-7.16E-03	8.48E-04	-2.85E-03	-4.56E-04
A. borealis	2.48E-02	-7.65E-03	9.60E-04	4.61E-03	1.24E-03	-2.29E-03	6.95E-03
A. borealis	3.66E-02	-1.14E-02	1.85E-02	-1.63E-03	-5.55E-03	3.40E-03	-8.23E-04
A. borealis	5.17E-02	-5.99E-04	-2.32E-03	-2.82E-03	-7.53E-03	-2.74E-03	4.22E-03
A. borealis	-2.22E-03	-1.28E-02	9.60E-03	2.66E-03	-3.70E-03	-1.05E-03	-8.32E-03
A. borealis	-1.35E-02	-2.07E-02	4.50E-03	-6.01E-05	-4.94E-04	3.18E-03	-7.23E-03
A. borealis	-2.70E-02	-1.68E-02	-4.97E-03	-3.43E-03	-7.07E-04	1.05E-02	-6.83E-04
A. borealis	-1.04E-02	-9.71E-04	4.69E-03	-7.09E-03	3.18E-03	-5.84E-03	-4.74E-03
A. borealis	2.14E-03	4.46E-03	-3.25E-03	2.63E-03	-9.14E-03	-1.22E-03	-7.23E-03
A. borealis	1.98E-02	-1.20E-02	1.88E-03	2.06E-04	-7.99E-04	2.68E-04	-4.26E-04
A. borealis	1.38E-02	6.44E-03	-1.02E-02	1.50E-02	1.27E-02	-2.66E-03	7.40E-03
A. borealis	2.73E-03	-3.68E-03	-2.47E-03	-4.68E-03	-1.27E-04	3.22E-03	1.13E-03
A. borealis	-2.41E-02	-1.73E-02	2.08E-03	-1.35E-03	3.99E-04	-2.00E-03	8.17E-04
A. borealis	-3.26E-02	1.41E-02	1.24E-02	3.50E-03	2.01E-03	2.60E-03	-5.45E-03
A. borealis	-7.52E-03	3.20E-02	-4.62E-03	-3.11E-03	3.54E-03	-3.79E-03	-6.20E-05

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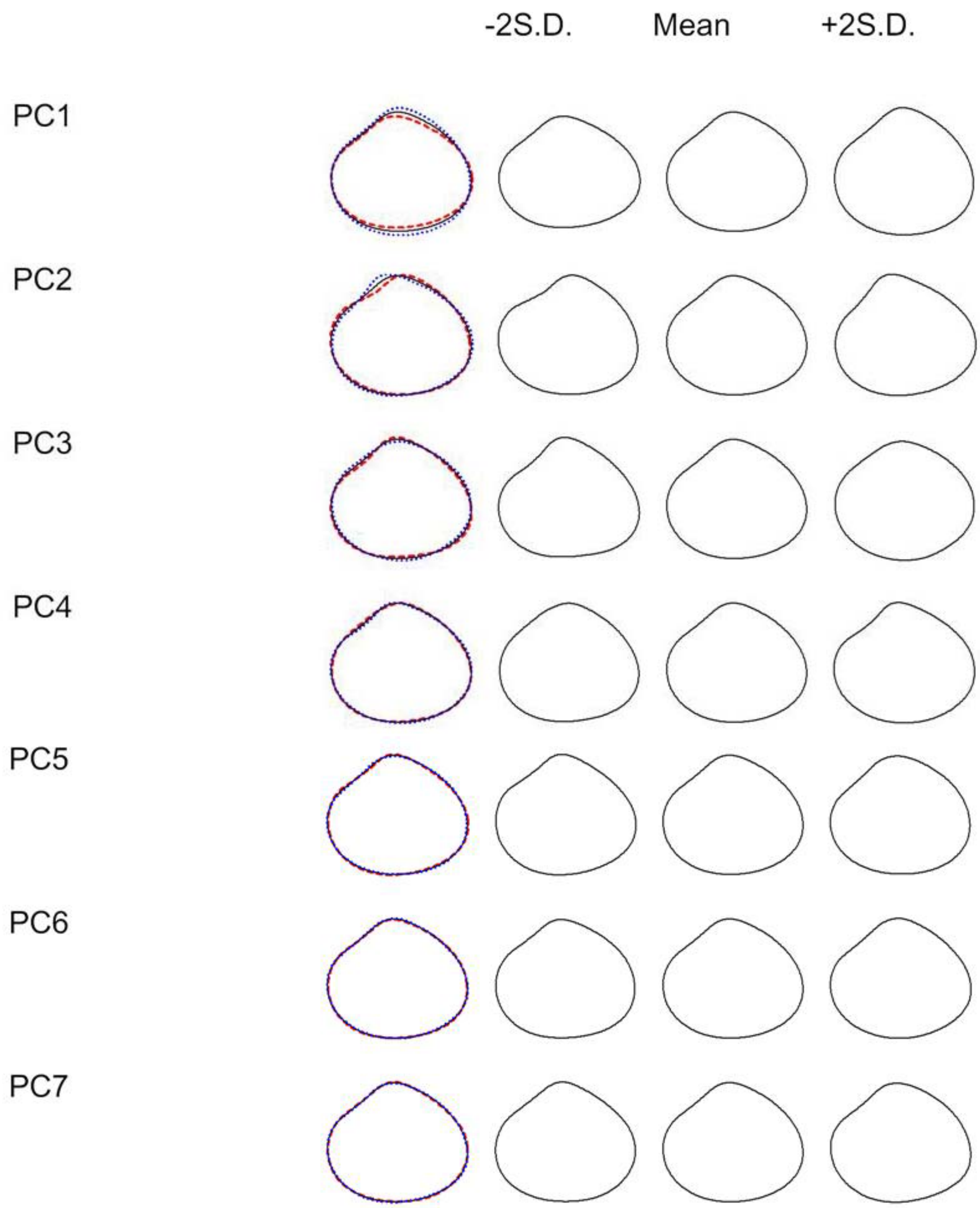
Specimen	PC1	PC2	PC3	PC4	PC5	PC6	PC7
A. borealis	2.04E-02	-8.10E-03	-1.07E-02	1.65E-02	-3.35E-03	-3.88E-03	3.43E-03
A. borealis	1.11E-02	4.55E-05	-1.67E-02	1.78E-02	-1.11E-02	-6.43E-03	6.84E-03
A. borealis	2.61E-02	-1.83E-02	-8.40E-03	-6.43E-03	-3.71E-04	1.81E-03	2.98E-03
A. borealis	-4.69E-03	6.12E-03	-9.83E-03	1.24E-02	-1.52E-02	-1.91E-03	-5.25E-04
A. borealis	-1.09E-02	-4.12E-03	-9.51E-04	-5.97E-04	-5.57E-03	4.18E-03	2.77E-03
A. borealis	5.24E-02	-2.90E-02	7.20E-03	-7.70E-03	-1.39E-04	-4.86E-03	1.94E-03
A. borealis	-1.06E-02	2.09E-02	1.11E-02	1.76E-03	3.83E-03	2.03E-03	-3.02E-03
A. borealis	-4.42E-02	-2.46E-02	-9.39E-03	4.09E-03	-3.41E-03	-5.27E-03	-1.84E-03
A. borealis	-4.77E-03	-2.19E-02	4.02E-03	-6.26E-03	5.41E-03	-3.19E-03	-1.11E-02
A. borealis	1.29E-02	4.20E-03	-1.94E-03	1.03E-03	1.21E-02	4.41E-03	2.15E-03
A. borealis	-3.94E-03	-3.09E-04	1.20E-02	-1.15E-03	-6.17E-03	-6.02E-03	-3.32E-03
A. borealis	3.81E-02	-4.67E-03	-1.28E-02	1.17E-02	8.01E-03	5.65E-03	-3.28E-03
A. borealis	-6.66E-03	5.11E-03	-6.82E-03	-7.41E-03	-6.26E-03	-2.38E-03	1.88E-03
A. borealis	1.78E-03	2.00E-02	3.54E-03	5.24E-03	8.59E-03	-2.68E-03	1.09E-03
A. borealis	-3.33E-02	1.06E-02	-4.86E-03	6.11E-04	-2.11E-03	1.05E-03	7.33E-04
A. borealis	-4.73E-02	2.31E-03	-2.76E-03	-5.56E-03	9.46E-03	6.30E-03	-5.16E-03
A. borealis	-2.65E-02	-4.11E-02	-4.80E-03	-1.13E-02	9.68E-03	-4.80E-03	1.82E-03
A. borealis	6.18E-02	4.64E-02	5.82E-03	-5.37E-03	-1.81E-03	-3.80E-03	2.38E-03
A. borealis	3.25E-02	-2.21E-02	3.14E-03	2.88E-03	-9.46E-03	-1.88E-04	2.72E-03
A. borealis	-5.29E-03	-2.90E-02	2.17E-03	-1.07E-03	-3.54E-03	4.65E-03	2.44E-03
A. borealis	2.66E-03	-1.16E-02	2.07E-04	-3.14E-03	9.27E-03	3.01E-03	6.46E-04
A. borealis	-4.28E-03	-1.27E-02	1.11E-03	3.44E-03	-1.41E-03	8.70E-03	5.77E-03
A. borealis	3.67E-02	-1.02E-02	5.14E-04	1.19E-03	-1.94E-03	3.48E-03	-4.45E-03
A. borealis	-2.49E-02	1.74E-02	-1.51E-02	1.39E-03	-3.99E-03	3.89E-03	3.90E-03
A. borealis	-8.69E-03	-3.13E-04	2.75E-05	1.12E-04	-2.33E-03	-5.97E-03	9.46E-04
A. borealis (fossil)	-6.21E-03	-1.78E-02	-1.83E-03	-1.18E-02	-4.05E-03	3.81E-03	-9.34E-04
A. borealis (fossil)	6.79E-03	-5.47E-03	-9.86E-03	2.25E-03	-4.88E-03	1.23E-03	6.11E-04
A. borealis (fossil)	4.25E-03	3.31E-03	-4.94E-03	7.25E-03	-7.50E-03	-4.77E-03	-4.68E-03
A. borealis (fossil)	8.21E-04	-2.28E-04	9.16E-03	6.00E-03	-5.37E-03	-6.58E-04	3.62E-03
A. borealis (fossil)	-7.23E-03	-1.09E-02	1.00E-02	7.68E-03	4.87E-03	-2.24E-03	3.31E-03
A. borealis (fossil)	-2.65E-02	9.50E-03	-1.42E-02	-8.95E-04	2.07E-03	-6.05E-04	3.46E-03
A. borealis (fossil)	-5.56E-03	-1.10E-03	3.07E-03	-3.27E-03	1.01E-02	-5.95E-03	-4.66E-03
A. borealis (fossil)	-3.17E-04	1.95E-03	2.24E-03	6.26E-04	-1.85E-03	-3.84E-03	-1.97E-03
A. borealis (fossil)	4.24E-03	1.42E-02	1.16E-02	-1.14E-02	-3.72E-03	-4.52E-04	1.37E-03
A. borealis (fossil)	-1.09E-03	5.69E-03	3.15E-03	5.34E-03	3.50E-03	1.39E-02	-2.95E-03
A. borealis (fossil)	3.08E-02	8.64E-04	-8.49E-03	-1.83E-03	6.80E-03	-4.33E-04	2.83E-03
A. martini	3.84E-02	-3.68E-02	-9.44E-03	-4.90E-03	1.18E-03	3.28E-03	6.59E-04
A. martini	-6.47E-02	3.80E-03	-7.86E-03	1.59E-03	-1.16E-02	5.03E-03	-6.27E-04
A. martini	-7.60E-02	2.73E-03	-2.55E-02	-6.62E-03	5.67E-03	-5.19E-03	-8.02E-03
A. martini	-7.32E-02	-2.02E-02	1.25E-02	-1.39E-03	4.19E-03	9.08E-03	1.24E-03
A. martini	-3.75E-03	-5.91E-02	3.00E-03	1.79E-02	-2.11E-03	9.31E-04	-5.93E-04
A. martini	-2.48E-02	1.07E-02	2.35E-02	4.27E-03	-5.65E-04	-6.31E-03	8.57E-04
A. martini	-8.41E-03	-7.45E-03	3.42E-03	-1.03E-02	-2.59E-03	-7.81E-03	-7.92E-03
A. martini	-2.12E-02	5.22E-03	1.12E-02	-2.36E-03	8.73E-03	1.23E-02	2.76E-03
A. martini	-3.76E-02	6.13E-02	-1.48E-03	2.23E-02	9.50E-03	6.99E-04	-2.68E-03
A. martini	-5.87E-02	2.76E-03	-2.81E-03	5.40E-03	-4.15E-03	-5.20E-03	5.18E-03
A. martini	-5.35E-03	-6.03E-03	1.53E-02	-4.61E-03	-8.94E-03	5.06E-03	-6.30E-03
A. martini	4.01E-02	-2.52E-02	-2.15E-03	6.18E-03	-1.01E-02	-4.50E-04	-1.08E-02
A. martini	7.58E-03	3.48E-02	8.38E-03	1.33E-03	-2.59E-03	-2.90E-03	1.33E-03
A. martini	3.04E-02	4.11E-02	-2.28E-03	-6.83E-03	-8.90E-03	-1.29E-03	-2.56E-03
A. martini	-2.99E-03	4.48E-02	-4.58E-03	-1.03E-02	-9.96E-03	6.56E-03	7.57E-03
A. martini	1.44E-02	-4.02E-03	2.78E-03	4.69E-03	4.99E-03	5.71E-03	-8.35E-04
A. martini	6.31E-02	1.22E-02	5.78E-03	1.48E-02	-1.32E-02	-6.41E-03	6.99E-03
A. martini	4.15E-02	2.37E-02	-1.34E-02	-7.13E-03	1.47E-03	9.72E-04	2.60E-03
A. martini	4.91E-02	1.55E-02	-2.68E-03	1.47E-03	1.51E-02	-8.48E-03	-3.78E-03
A. martini	-8.70E-02	-1.67E-02	-1.99E-02	2.38E-03	-6.87E-03	-2.80E-03	3.74E-03

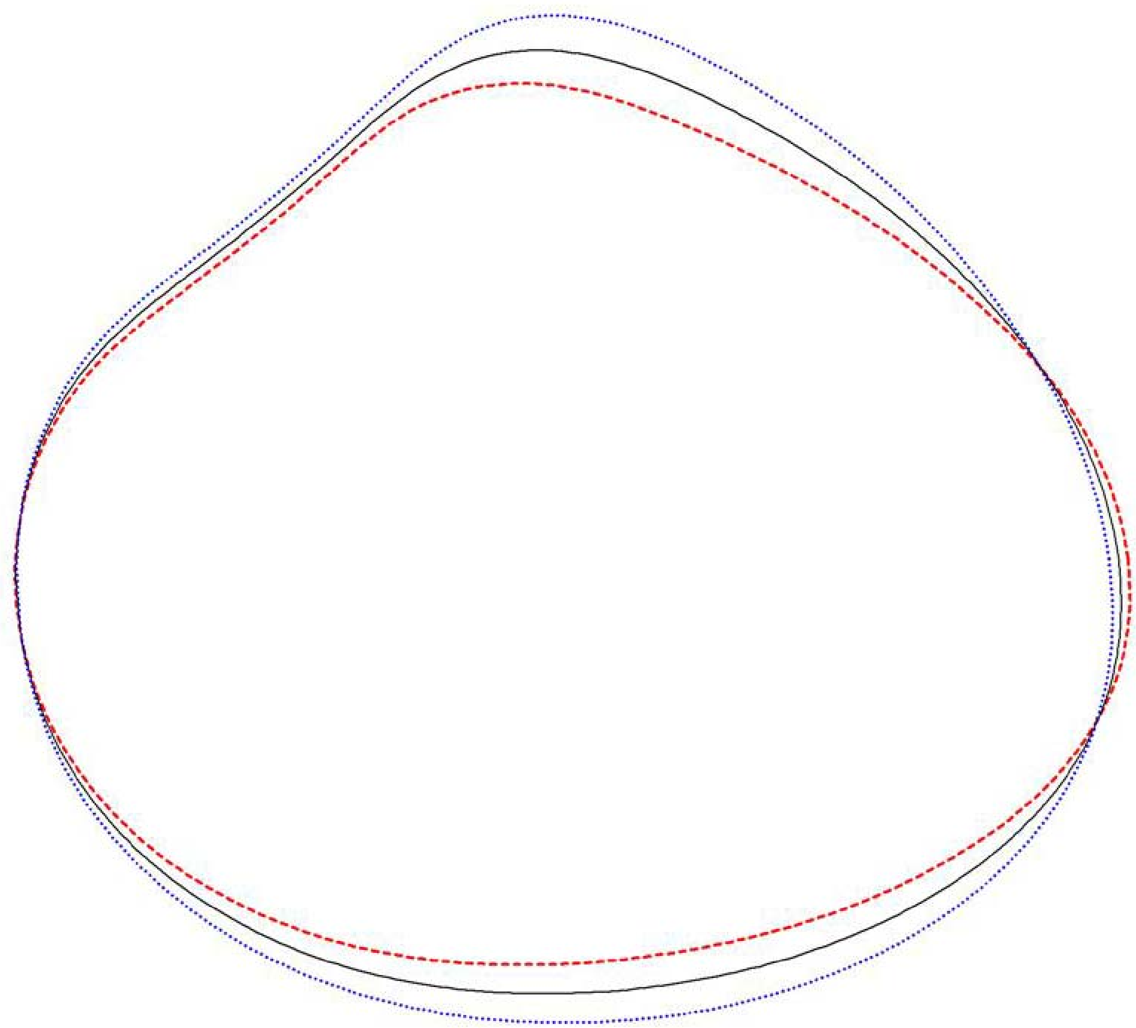
All Specimens Effective Principal Component Scores Page 13

Specimen	PC1	PC2	PC3	PC4	PC5	PC6	PC7
A. martini	4.34E-02	-3.30E-02	-6.44E-03	-1.26E-04	4.52E-03	-1.77E-03	1.50E-02
A. martini	3.27E-03	-1.90E-02	2.90E-05	-6.23E-03	1.72E-03	-6.36E-03	7.85E-03
A. martini	5.66E-02	-8.65E-03	-1.99E-02	-7.44E-03	2.45E-03	6.68E-03	-2.53E-03
A. martini	-1.24E-02	1.58E-04	1.13E-02	-9.05E-03	1.11E-02	8.77E-04	6.71E-05
A. martini	4.28E-02	1.70E-02	3.77E-03	-1.08E-02	1.17E-04	-6.82E-04	-1.63E-03
A. martini	-5.03E-03	6.10E-05	6.48E-03	-3.37E-03	4.65E-03	4.79E-03	2.87E-03
A. martini	8.60E-03	-2.44E-02	1.74E-02	-1.03E-02	-4.18E-03	-2.53E-03	-5.34E-03
A. martini	-1.51E-02	-1.34E-02	2.46E-03	4.79E-04	7.83E-03	-1.15E-02	2.61E-04
A. martini	5.71E-02	-1.73E-03	-8.88E-03	1.89E-02	2.61E-03	7.74E-03	-5.36E-03

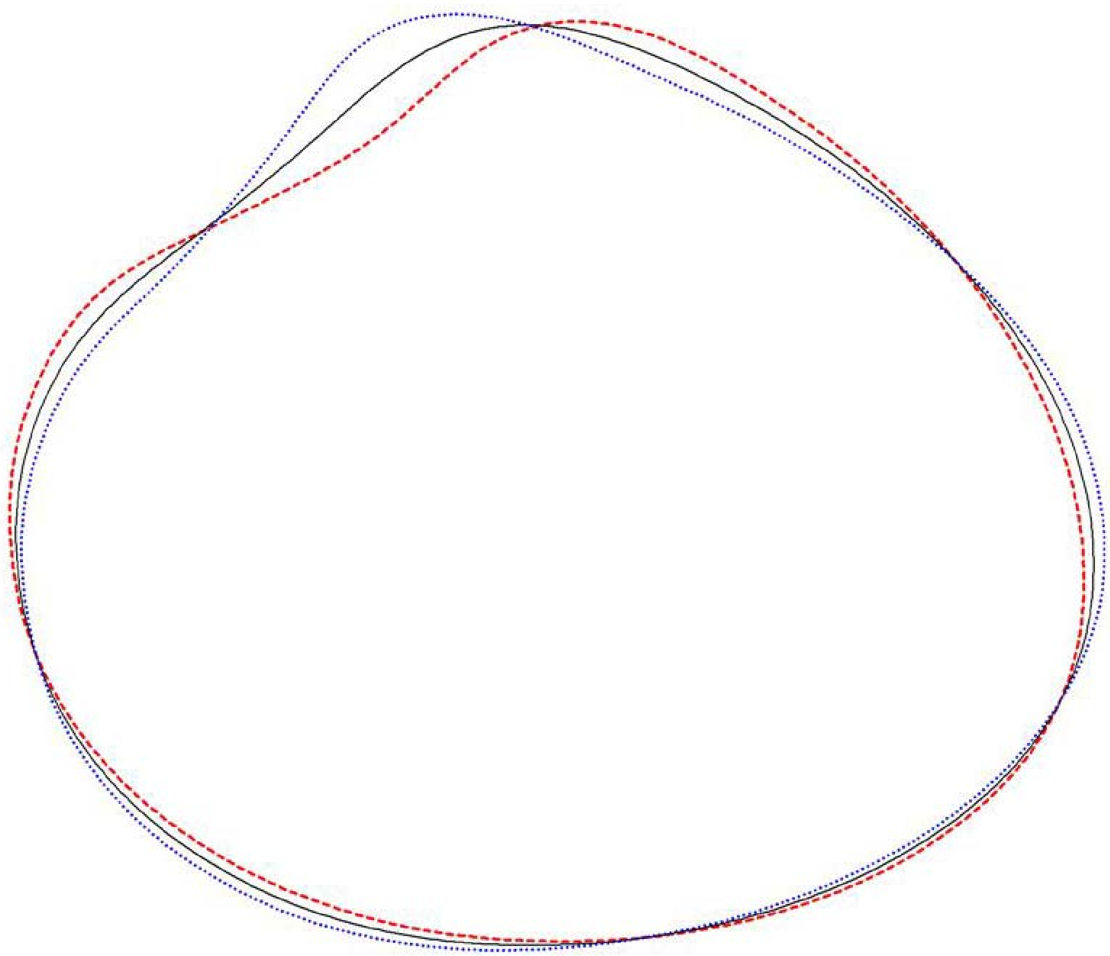
APPENDIX 3

This appendix contains the visual reconstruction of the effective principle component scores for *Astarte borealis* as outlines. PrinPrint visualization of the mean shape and the + 2 and – 2 standard deviation from the mean in outlines for the first 7 significant principal components. The blue dotted line in the first overlay are the + 2 standard deviation, the black, solid line is the mean form; the red, dashed line is the – 2 standard deviation. Enlarged images of the overlain outlines for the 7 principal components follow.

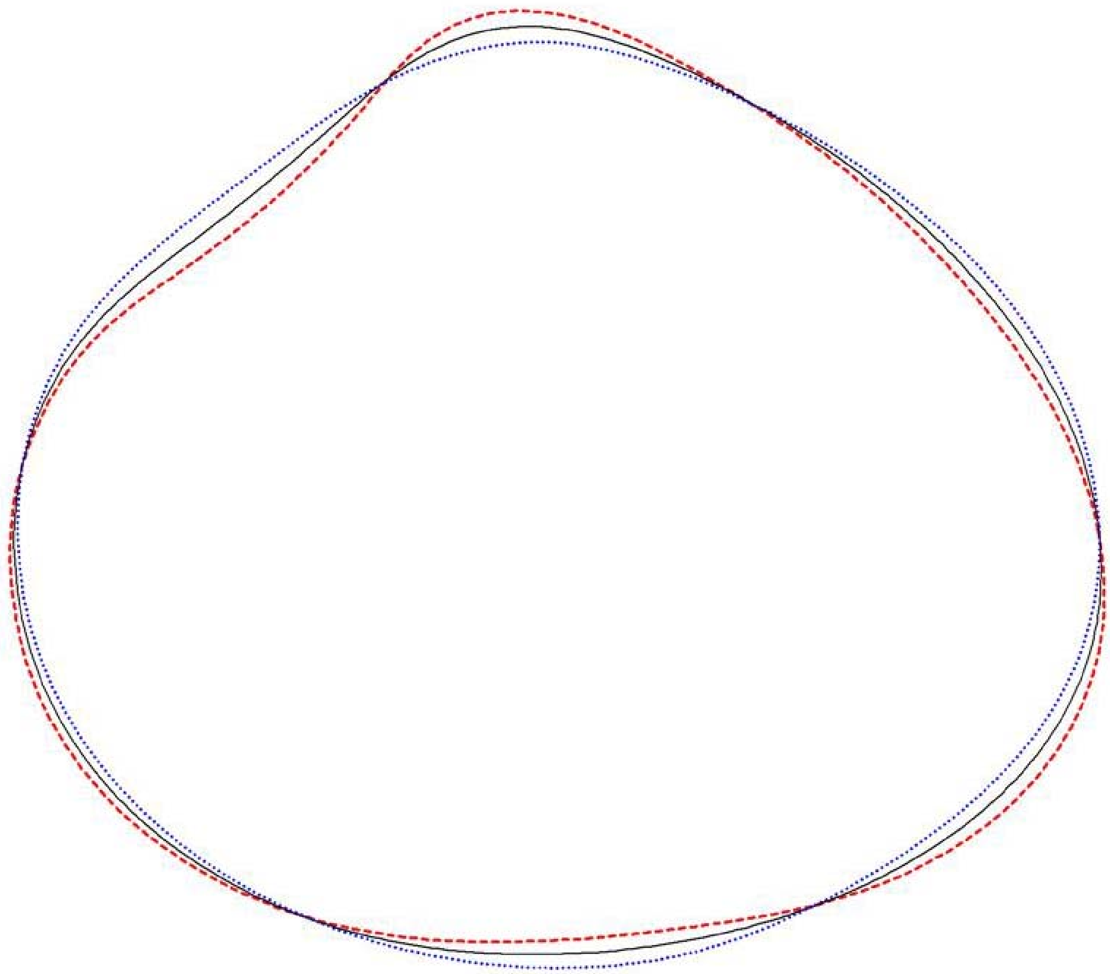

-2S.D.
Mean
+2S.D.
PC1
PC2
PC3
PC4
PC5
PC6
PC7



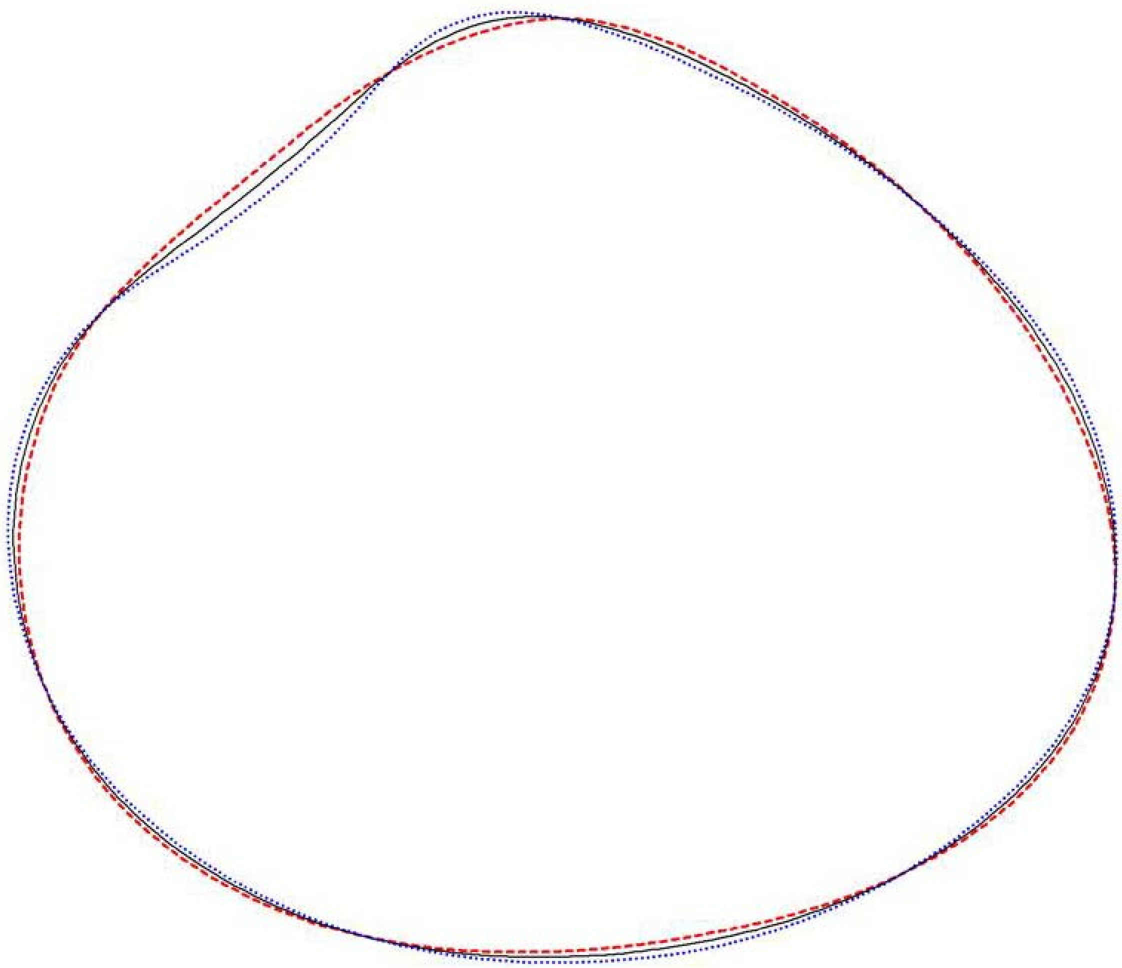
Principal Component 1



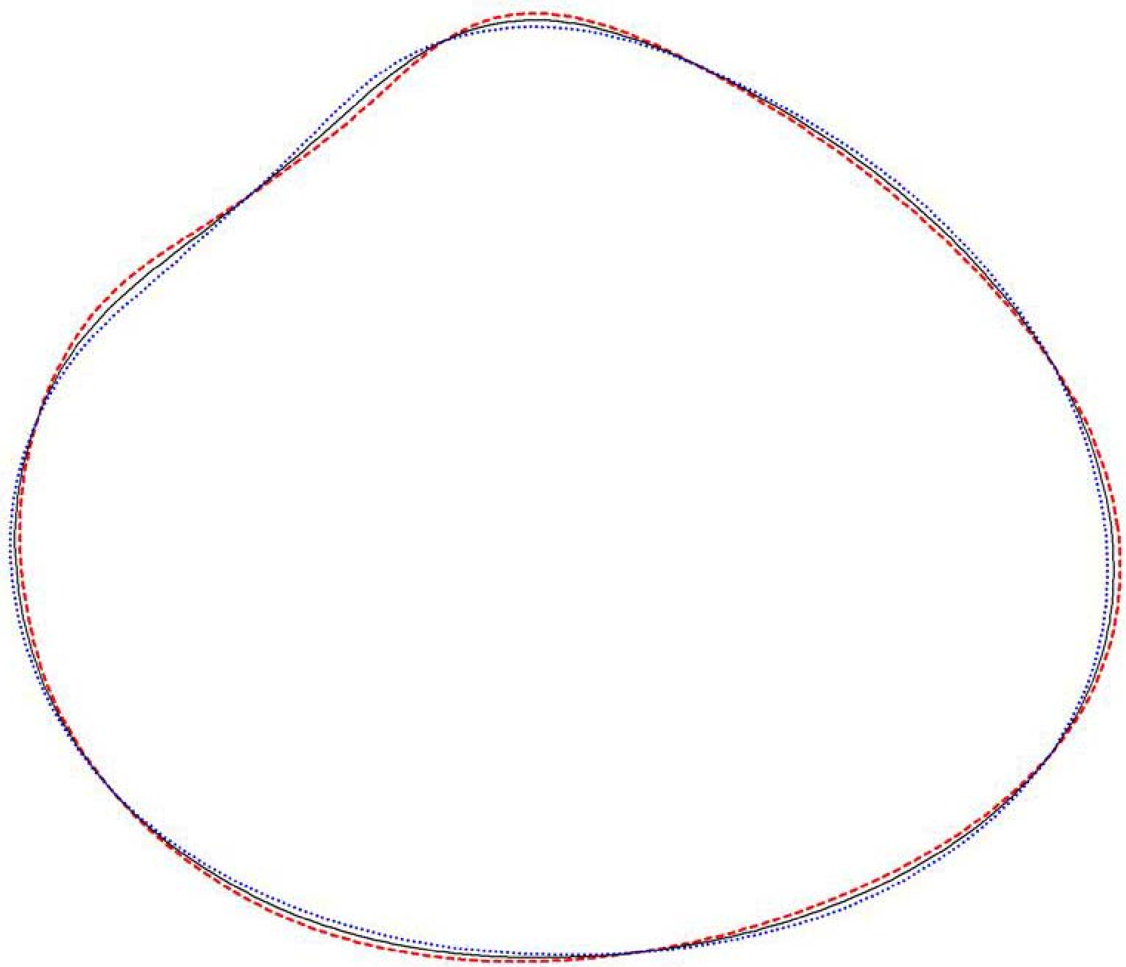
Principal Component 2



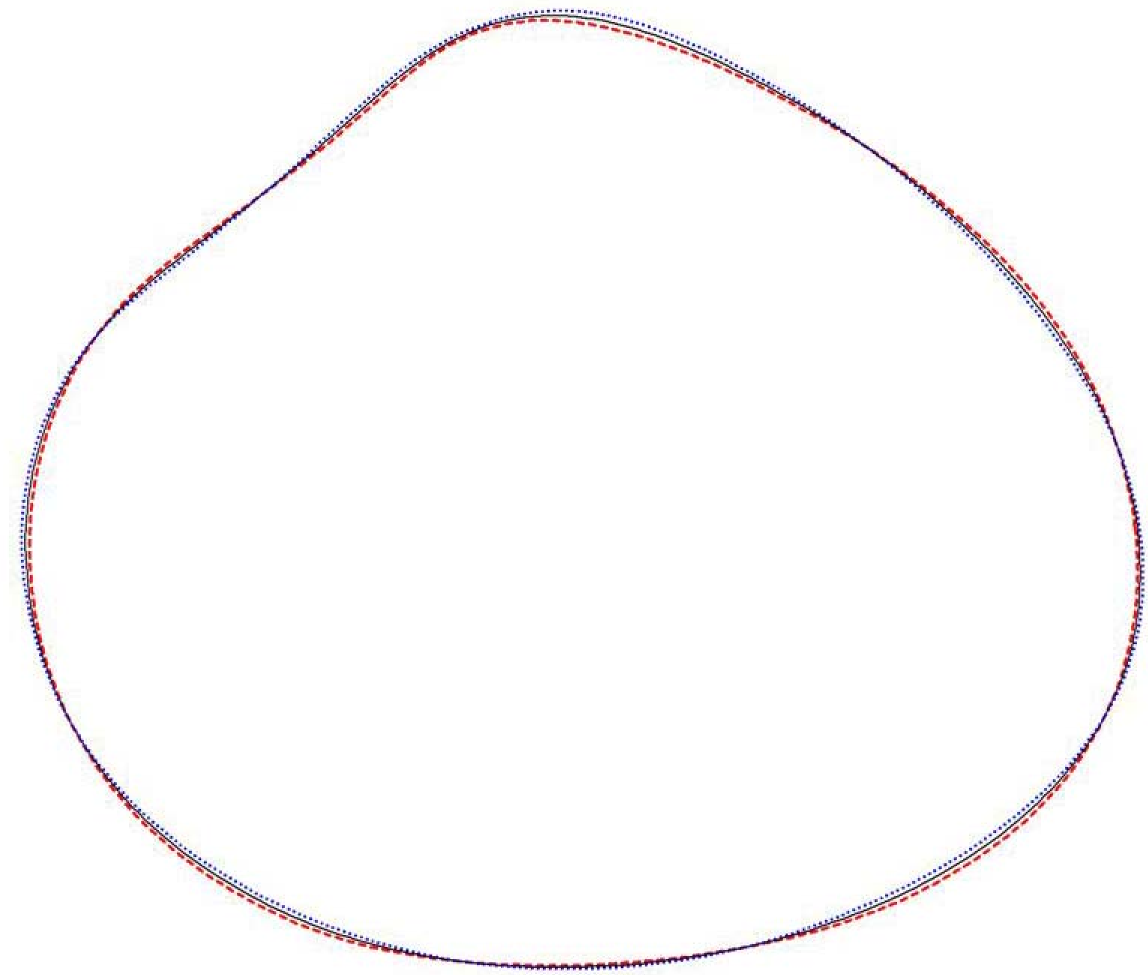
Principal Component 3



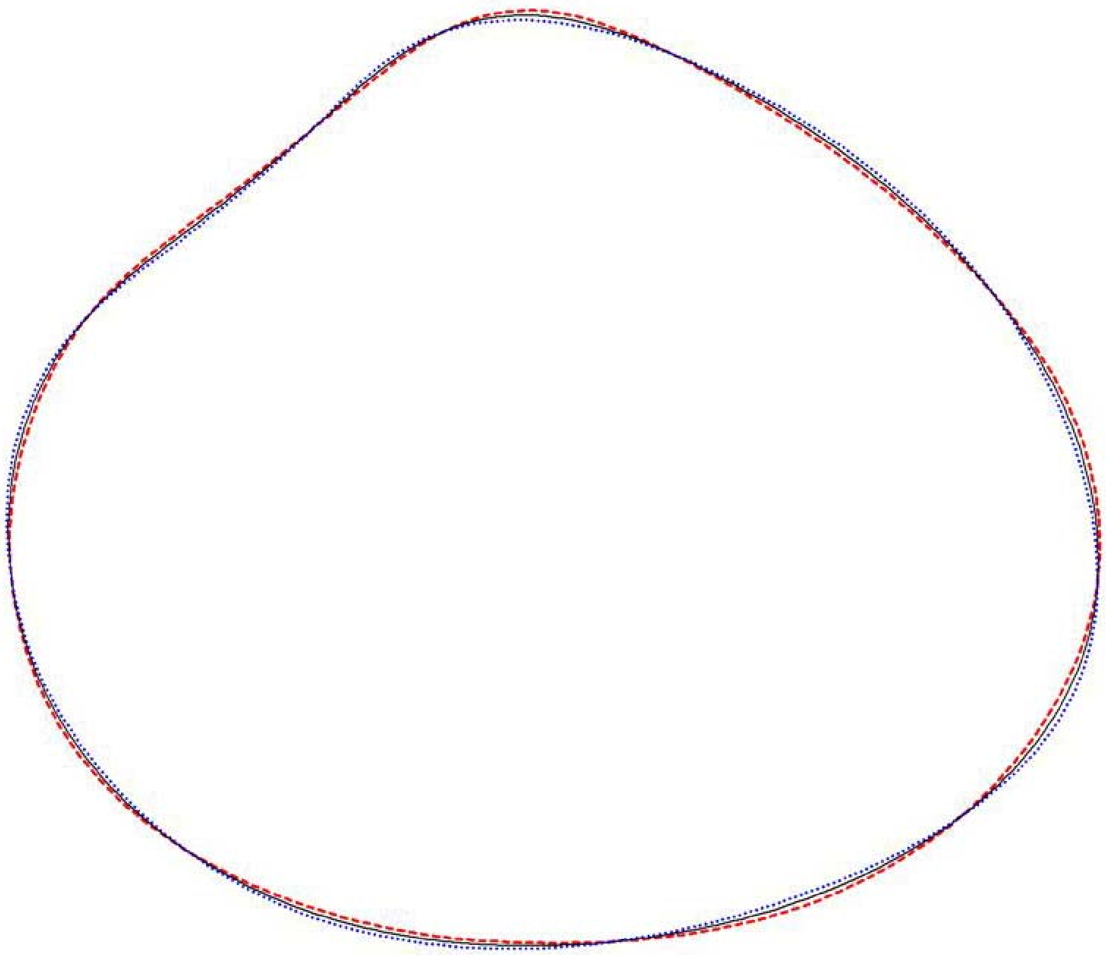
Principal Component 4



Principal Component 5



Principal Component 6



Principal Component 7

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