Charles E. Schmidt College of Science

Morphological Variability of Astarte borealis (Mollusca, Bivalvia) in the Camden Bay, Northern Alaska

Michelle Chrpa, Dr. Anton Oleinik

Geosciences/Geology; Florida Atlantic University

The genus Astarte is well known for variable shell morphology and polymorphism within living and fossil species. Astarte borealis, the most common living species, has been divided into many subspecies and varieties based on overall shell shape. The A. borealis is easily recognizable and common among mid to high latitude North Pacific, Arctic Ocean and North Atlantic waters making determination of species varieties a complex issue. Ascertaining the variability based on shell shape within an A. borealis population may reduce use of subjective interpolation of potential subspecies or varieties within the species. A collection of A. borealis specimens from the Camden Bay, Alaska yielding 635 specimens with outline intact were used to find shell shape variability. Morphometric analysis of shell outline seeks to determine variants within a population of A. borealis. The computer program package SHAPE uses elliptic Fourier descriptor coefficients of A. borealis outline to evaluate and visualize the shape variation among the specimens. The principal component analysis of the coefficients showed the majority of the variation was summarized by 5 components; the asymmetrical and symmetrical variations had cumulative contributions of 83.1% and 90.0% respectively. The overall coefficient analysis showed the 1st principal component accounted for 38.3% of variance related to the aspect ratio of the shell, ranging from 1.07:1 to 1.23:1. The 2nd principal component relating to overall shell roundness from trigonal to subrounded explains 15.9% variance and the 3rd principal component relating to convexness of ventral margin explains 9.0% variance.

Morphological Variability Of *Astarte borealis* (Mollusca, Bivalvia) in the Camden Bay, Northern Alaska

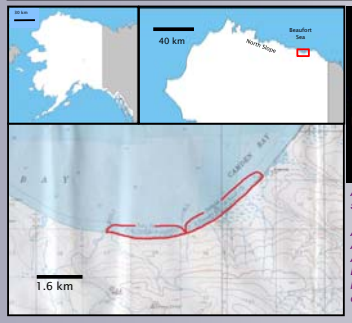
CHRPA, Michelle and OLEINIK, Anton
Geosciences Department, Florida Atlantic University, Boca Raton 33431

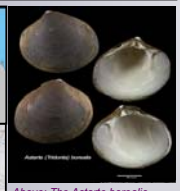
ABSTRACT

The genus *Astarte* is well known for variable shell morphology and polymorphism within living and fossil species. *Astarte borealis*, one of the most common living *Astarte*, has been divided into many subspecies and varieties merely based on overall shell shape. The *A. borealis* is easily recognizable and common among mid to high latitude North Pacific, Arctic Ocean and North Atlantic waters making the determination of species varieties a complex issue. No published study of *A. borealis* shell outline variability is available. Ascertaining the morphological variability based on shell shape within an *A. borealis* population may reduce the use of subjective interpolation of potential subspecies or varieties within the species. A collection of Recent *A. borealis* specimens from the Camden Bay, Alaska yielding 980 specimens with outline intact were used in this study to find shell shape variability. 11 Pliocene *A. borealis* from the collection California Academy of Sciences, Department of Invertebrate Zoology and Geology were also used in the analysis to determine the correlation of shape in fossil and recent Astarte from the same locality.

COLLECTION AREA

The collection area is located in the Camden Bay of Northern Alaska near the Beaufort Sea. The shells were collected along a 5.5 km stretch of beach in Camden Bay between Marsh Creek and the Sadlerochit River. The beach is made up of mostly gravel with occasional sand bars; average width of the beach is 30 meters.





Above: The Astarte borealis shown with exterior and interior

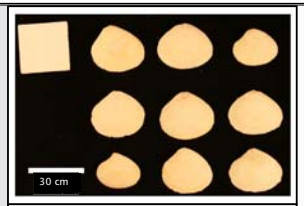
At Left , clockwise from top left: Alaska in white; Northern Alaska shown with Camden Bay of Beaufort Sea highlighted in red; area of shell collection highlighted in red

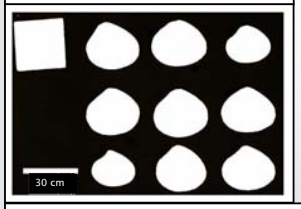
REFERENCES

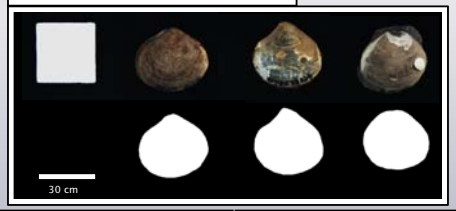
- Iwata, H. and Y. Ukai, 2002. SHAPE: A computer program package for quantitative evaluation of biological shapes based on elliptic Fourier descriptors. Journal of Heredity 93: 384-385
- Marincovich Jr., L., Barinov, K.B. and Oleinik, A.E., 2002. The Astarte (Bivalvia: Astartidae) That Document the Earliest Opening of Bering Strait. Journal of Paleontology, 76(2): 239-245
- Zettler, M.L., 2001. Recent geographical distribution of the *Astarte borealis* species complex, its nomenclature and bibliography (Bivalvia; Astartidae). Schriften zur Malakozoologie, 18:1-14

MATERIALS AND METHODS

All shells collected in the Camden Bay were processed by cleaning with bleach, sorting out left valves and retaining complete outline shells numbering 1070 specimens. The shells were pictured with Canon EOS 20D and processed in Adobe Photoshop 7.0 to retain the outline of the image and any shells with incomplete outlines were removed. 11 Pliocene *A.borealis* were photographed with digital camera in MagnaFire program and edited in Photoshop to retain only outline. The program Shape version 1.3 (Iwata and Ukai, 2002) was used for all analyses. A chain code was calculated for each of the outlines, and the chain codes were translated into sine and cosine variables in an elliptic Fourier analysis. A principal components analysis on the resulting elliptic Fourier descriptors resulted in principal components describing various aspects of the variation among the thirty outlines. These principal components were visualized as PC plots.



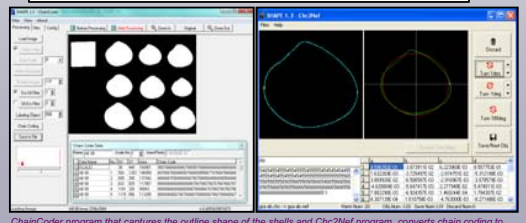




At left: Astarte borealis left valves cleaned to remove periostracum. Astarte borealis image taken with Canon EOS 20D and 30 mm marker for scale.

Image then processed in Photoshop to retain only outline.

Below: Pliocene A. borealis images processed in Photoshop to retain only outline, last image is a right valve flipped 180° to represent a left valve.

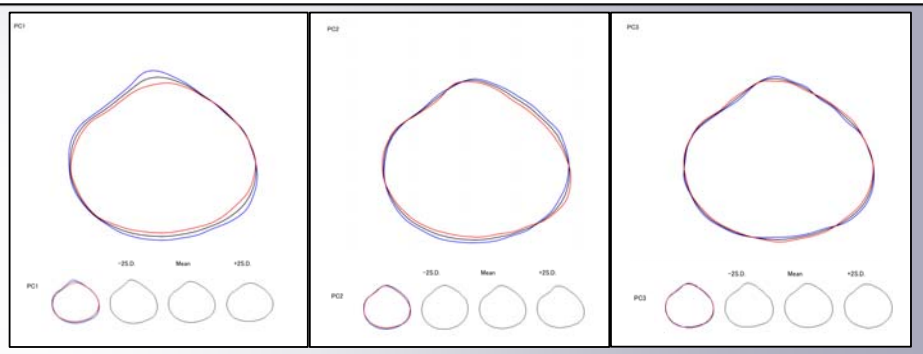


ChainCoder program that captures the outline shape of the shells and Chc2Nef program, converts chain coding to normalized elliptical Fourier descriptors.

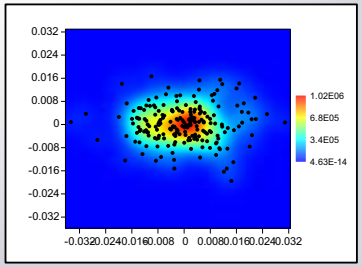
RESULTS

Results were plotted with the PrinPrint program from SHAPE by plotting the mean shell shape of the Recent specimens and the mean -2 and mean +2 standard deviations of the square root of the eigenvalue of the respective components. The eigenvalues of each Recent specimen for the first, second and third principal components (PC) were plotted in a graph as well as the first and second PC of the Pliocene specimens.

The PC plots of the Recent *A. borealis* indicate that the shape variation in the shells is not linear and, in most cases, the third and second PC do not correlate among the population. The shape variations are also present in the Pliocene shells, but unable to confirm similar shape trends as the number of specimens is limited. The principal component analysis of the coefficients showed that the majority of the variation was summarized by 5 components; the asymmetrical and symmetrical variations had cumulative contributions of 83.1% and 90.0% respectively.



The overall coefficient analysis showed the 1st principal component accounted for 38.3% of the variance related to the aspect ratio of the shell, ranging from 1.07:1 to 1.23:1. The 2nd principal component relating to the overall shell roundness from trigonal to subrounded explains 15.9% variance and the 3rd principal component relating to the convexness of the ventral margin explains 9.0% variance.

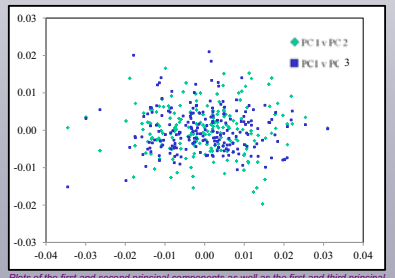


The density map of the graph showing the 1st PC and 2nd PC shows that the shape variation is not evenly distributed among the population. The concentration of correlation is skewed to the right of the graph where shells have a smaller height to width ratio.

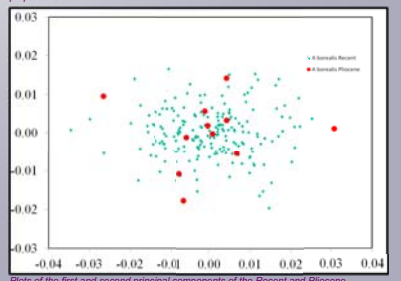
Astarte borealis Principal Component Analysis

Component	Eigenvalue	Proportion(%)	Cumulative(%)
1	2.18E-04	38.30	38.30
2	9.04E-05	15.87	54.17
3	5.11E-05	8.97	63.14
4	4.54E-05	7.97	71.11
5	3.77E-05	6.63	77.74
6	2.79E-05	4.90	82.65
7	2.07E-05	3.64	86.29
8	2.05E-05	3.60	89.89
9	1.60E-05	2.82	92.70
10	1.42E-05	2.49	95.19
11	8.30E-06	1.46	96.65
12	8.26E-06	1.45	98.10
13	6.49E-06	1.14	99.24

Table of the first thirteen principal components with eigenvalues and proportion of variance explained by the respective component, and the cumulative percentages of proportions.



Plots of the first and second principal components as well as the first and third principal components of the principal components analysis. Shows the variations of each specimen with respect to principal components.



Plots of the first and second principal components of the Recent and Pliocene collections of A. borealis.

Morphometric analysis of the shell outline will seek to determine the variants within a population of *A. borealis*. The computer program package SHAPE uses elliptic Fourier descriptor coefficients of the *A. borealis* shell outline to evaluate and visualize the shape variation among the sample specimens. The principal component analysis of the coefficients showed that the majority of the variation was summarized by 5 components; the asymmetrical and symmetrical variations had cumulative contributions of 83.1% and 90.0% respectively. The overall coefficient analysis showed the 1st principal component accounted for 38.3% of the variance related to the aspect ratio of the shell, ranging from 1.07:1 to 1.23:1. The 2nd principal component relating to the overall shell roundness from trigonal to subrounded explains 15.9% variance and the 3rd principal component relating to the convexness of the ventral margin explains 9.0% variance.