

## MORPHOMETRICAL ANALYSIS OF RADULAE OF NATICID GASTROPODS (GASTROPODA: CAENOGASTROPODA) FROM THE EURASIAN ARCTIC

L. S. Tursunova<sup>1,2</sup>, I. O. Nekhaev<sup>2</sup>

<sup>1</sup> Saint Petersburg State Academy of Veterinary Medicine,  
196084, Saint Petersburg, Chernigovskaya Str., 5, e-mail: vivapomba@yandex.ru

<sup>2</sup> Saint Petersburg State University,  
199034, Saint Petersburg, Universitetskaya Emb., 7–9, e-mail: inekhaev@gmail.com

The taxonomy of family Naticidae gastropods inhabiting the Eurasian Arctic and adjacent regions is mainly based on shell features while anatomical data is used rarely. The aim of this study is to describe inter- and intraspecific variability of some radular characters and to estimate their suitability for species-level taxonomy. In total eighteen radulae of four naticid species (*Amauropsis islandicus*, *Cryptonatica affinis*, *Euspira pallida*, *Euspira tenuistriata*) were studied using a scanning electron microscopy. Statistical analysis of six morphometric characters describing shape of radular teeth did not reveal any significant differences between species. Three specimens of *Cryptonatica affinis* were separated on scatterplot from the other snails. Previous suggestions on the change in the number of denticles in the central and marginal teeth during the snails' growth were not confirmed.

**Keywords:** Gastropoda, Arctic, morphology, radula, Naticidae

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### INTRODUCTION

The mollusks of the Naticidae family are marine bottom predators. The natural range of the family encompasses the entirety of the World Ocean. The family includes a large number of species and there are still some difficulties in terms of species classification.

The taxonomy of the Naticidae snails from the Eurasian Arctic at the species level is based on the shell morphology, however, there are radulae descriptions for each species [Golikov, Sirenko, 1983 (Golikov, Sirenko, 1983); Golikov, Sirenko, 1988]. Golikov and Sirenko [1983 (Golikov, Sirenko, 1983)] indicate that the radula may be useful for determining species in some cases, however, there is a large individual variability of radula traits, including that related to the size of the gastropod. Data were obtained using light microscopy.

Photographs of radulae obtained using an electron microscope were published by Bouchet and Warén [Bouchet, Warén, 1993] for mollusks

from the North Atlantic. The authors believe that differences in the morphology of the radules are insignificant and mollusks cannot be used for species classification.

A work on the morphology of the superfamily Naticoidea, which includes several Arctic representatives, describes the difference in the structure of male reproductive apparatus, which may be suitable for species classification [Shileyko, 1977 (Schileyko, 1977)]. The author believes that the characteristics of radula cusps are variable within one species.

The aim of our work is to study the intraspecific variability of radulae, as well as their suitability for species classification. The objectives of the study were to study the of radulae using scanning microscopy, the analysis of morphology and comparison of the obtained results with the existing classification of Naticidae in the Arctic [Golikov, Sirenko, 1983 (Golikov, Sirenko, 1983)].

### MATERIALS AND METHODS

The study used mollusks from the Laptev, Barents and Kara Seas, belonging to four species (the minimum and maximum shell heights in mm are given in brackets): *Cryptonatica affinis* (Gmelin, 1791) (2.2–19.5), *Euspira pallida* (Broderip et G.B. Sowerby I, 1829) (10.5–18.4), *Euspira tenuistriata* (Dautzenberg et H. Fischer, 1911) (11.8–16.4), *Amauropsis islandicus* (Gmelin, 1791) (4–19) (table). Materials are taken from the collection of St. Petersburg State University.

Radulae were extracted from mollusks, cleaned of soft tissues using water sodium hypochloride solution, then washed with distilled

water and placed on a stub. The samples were coated with silver for the electron microscopy.

The following parameters were described for the central teeth of the radula: the presence of one or two angles on the basal denticle (a1 and a2), the angle of the outer basal denticle (b), width (c), the length of the plate of the entire tooth (d), which consists of the length of the tooth (d1) and the length of the bent part of the tooth (d2) before the dissection of the tooth plate into three teeth, and the height of the central (k1) and lateral (k2) denticles on the cutting edge (fig. 1). Two-three central teeth of each radula, were measured in a image editor, then the data of these measurements were averaged and the proportions were

calculated using average values. In addition, the number of denticles on the inner marginal tooth were used for the analysis. External marginal teeth did not differ from each other, and the lateral

teeth were located at different angles on the analyzed photographs, which did not allow for reliable assessment of their variability.

Studied material

Water body	Date of sampling	N	E	Depth	Number of the specimen
<i>Amauropsis islandicus</i>					
The Barents Sea	23.06.2015	74°34'	41°24'	223	303
The Kara Sea	13.10.2000	74°05',746'	70°25',787'	14	297, 332
<i>Cryptonatica affinis</i>					
Svalbard	18.06.2011	78°05'	14°09'	10-20	237
The Laptev Sea	05.10.2014	75°10,7'	115°43'	21	231, 333
The Laptev Sea	04.10.2014	74°34,9'	115°45,1'	15	230, 298
The Kara Sea	12.09.12	73°27,1'	69°08,5'	19,8	300, 301, 299
The Barents Sea	16.04.2016	78°04'	48°54'	307	334
The Barents Sea	9.08.2013	70°30'	33°30'	-	335
<i>Euspira pallida</i>					
The Laptev Sea	20.08.2014	76°15,3'	139°00,8'	16	292
The Barents Sea	03.06.2009	69°07,80'	36°02,11'	80	302
<i>Euspira tenuistriata</i>					
The Barents Sea	18.08.2006	71°11,061'	45°10,012'	250	294
The Kara Sea	12.09.2012	73°39,0'	69°58,3'	19,8	234, 244

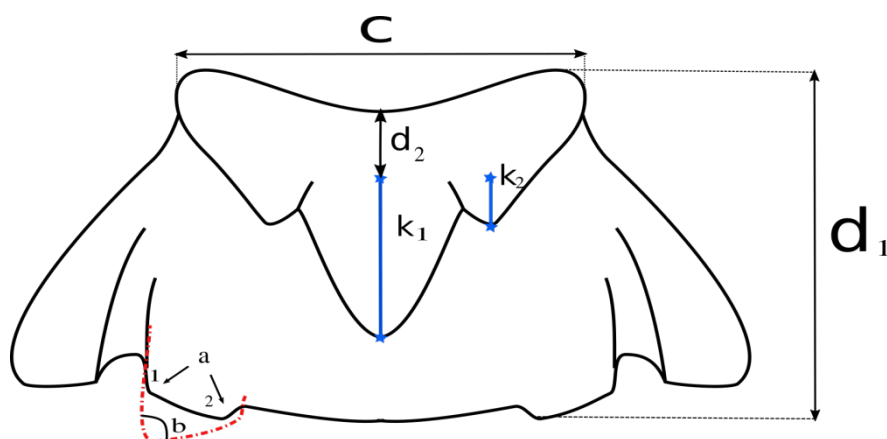


Fig. 1. Measurement scheme of central radula tooth.

The principal component analysis (PCA) was used for the analysis. Box plots were built for graphic representation. The calculations were performed using Past ver. 3.24 and Jasp ver. 0.9.2 software.

Six parameters were used for PCA analysis: the ratio of length to width ( $d/c$ ), the ratio of the length of the central small denticle to the central large ( $k_1 / k_2$ ), the number of external angles on

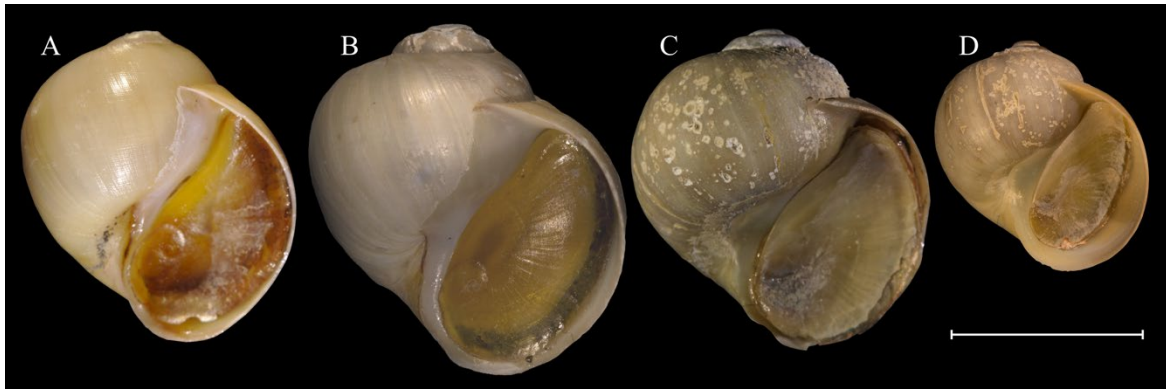
the denticle of the base ( $a = 1$  or  $a = 2$ ), the lateral angle on the denticle of the base ( $b$ ) in degrees and the number of denticles on the inner marginal tooth.

Mollusks were identified according to the system proposed by Golikov and Sirenko [Golikov, Sirenko, 1983 (Golikov, Sirenko, 1983); Golikov, Sirenko, 1988] (fig. 2).

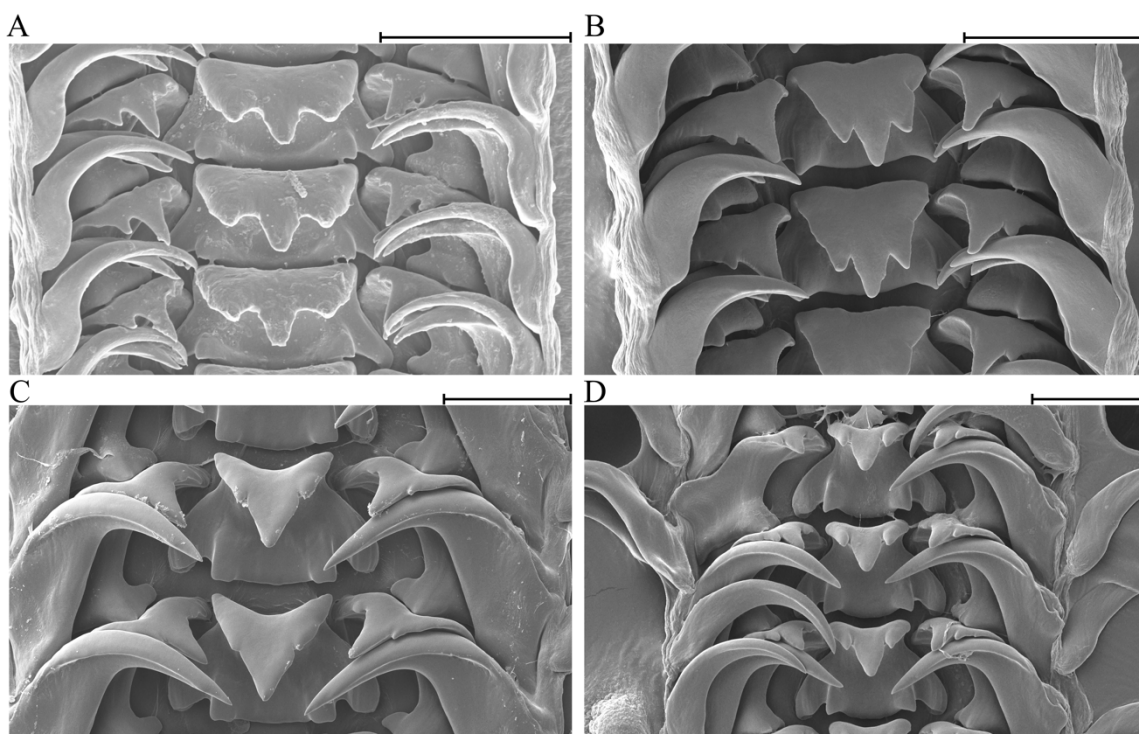
RESEARCH RESULTS AND DISCUSSION

All studied radulae were typical of the family and had three denticles on the cutting edge of the central tooth (fig. 3). The exception was

one specimen of *Cryptonatica affinis* (No. 333), which had only one denticle on the cutting edge. This individual was not used for the analysis.



**Fig. 2.** Shells of Naticidae, used for the study. A – *Euspira tenuistriata*, № 244, B – *Euspira pallida* № 292, C – *Cryptonatica affinis* № 230, D – *Cryptonatica affinis* № 298. Scale bar = 10 mm.



**Fig. 3.** Radulae of Naticidae, used for the study. A – *Euspira tenuistriata*, № 244, B – *Euspira pallida* № 292, C – *Cryptonatica affinis* № 230, D – *Cryptonatica affinis* № 298. Scale bars = 50  $\mu$ m.

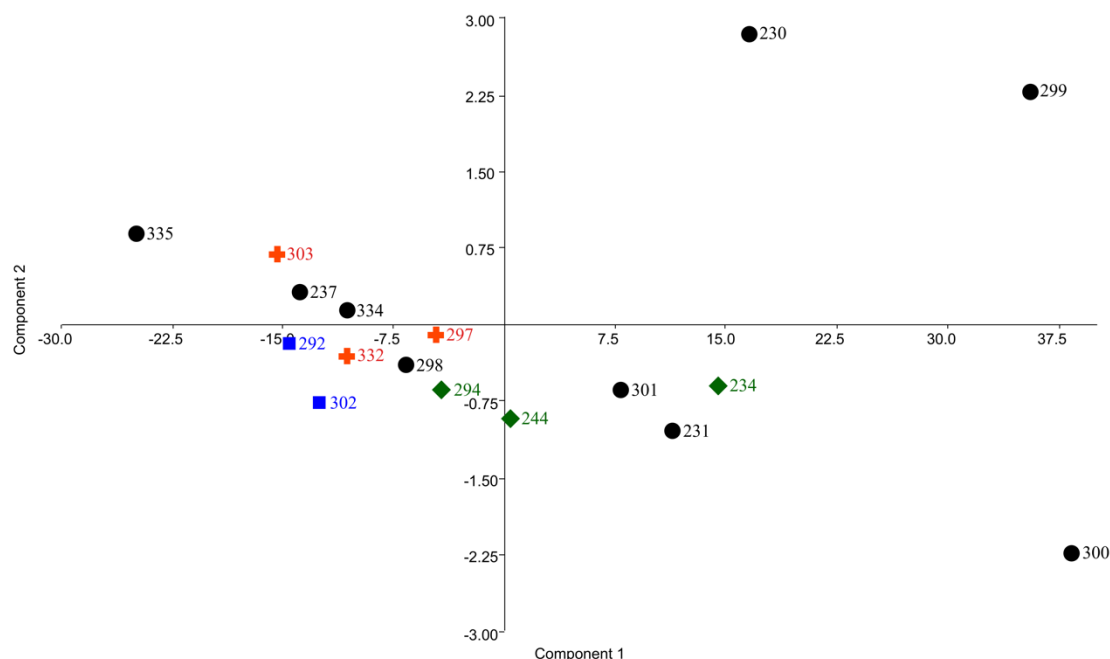
In the PCA analysis, the majority of the variability (99.416%) was taken by axis 1, which correlates with the values of angle (b). The second most important was axis 2 (0.447%), which correlated with k1/k2 ratio.

In the PCA scatterplot (Fig. 4), the species were not grouped by the analyzed parameters. Three specimens of *Cryptonatica affinis* (230, 299, 300) were located on the right side of the PCA scatter plot. *Euspira tenuistriata*, *Euspira pallida*, and *Amauropsis islandicus* are combined in one group with the rest of *Cryptonatica affinis*. According to the selected features of the central tooth, the radula cannot be used for species determination of the Naticidae gastropods. Based on statistical results comparing the features of the

radula, it is possible to assume the presence of two forms of *Cryptonatica affinis*, which may indicate the presence of more than one species. In the future, this assumption should be verified by independent traits (shell, molecular phylogenetic analysis, anatomy of the soft body).

Distinctive features of the genera are not distinguished being overlapped by specific features.

Golikov and Sirenko [Golikov, Sirenko, 1988] indicated age-related variability in the number of denticles on the cutting edge of the central and external marginal teeth in *Cryptonatica affinis*, which is not confirmed by our data.



**Fig. 4.** PCA Scatterplot of radular characters. Crosses – *Amauropsis islandicus*, circles – *Cryptonatica affinis*, squares – *Euspira pallida*, diamonds – *Euspira tenuistriata*. Numbers as in the table.

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