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Anomalies in radulae of Albinaria species from the Greek islands of Kephallinia and Ithaka (Mollusca: Gastropoda Pulmonata: Clausiliidae)

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While studying 108 radulae of *Albinaria* species in search for diagnostic characters, we kept record of the observed malformations, which were classified into seven categories. Next to longitudinal anomalies, only a single non-longitudinal one was found. The results suggest that there might be (sub)species specific differences in the percentage of anomalies.

Key words: Pulmonata, Clausiliidae, *Albinaria*, radula, anomalies, Greece.

INTRODUCTION

In a paper on abnormalities in the radula of *Drymaeus virgulatus* (Férussac, 1821) Venmans & Verdcourt (1950: 1) stated that "very few references concerning abnormal radulae are to be found in the literature on non marine mollusca...". Anomalies in radula structures of other molluscan groups had been described by e.g. Adam (1933), Cawston (1940) and Peile (1922, 1932). At present, more than forty years later, not much seems to have changed. We could find only five additional papers on, or with references to, abnormal features of radulae (Schilder, 1963; Solem, 1974; Runham, 1975; Falniowsky, 1979; Marshall, 1983: fig. 8d). This is surprising, because the use of the Scanning Electron Microscope (= SEM) has made it considerably easier to study radulae in much detail.

While studying the systematics and the evolutionary history of the species of the clausiliid genus *Albinaria* Vest, 1867, from the Greek islands Kephallinia and Ithaka, attention was paid to the structure of the radulae. The main results of this investigation were published by Kemperman (1992: 81-120). The various kinds of radular anomalies that were noticed unexpectedly, are dealt with in this paper.

The pulmonate radula has transverse rows with a central tooth and several lateral and marginal teeth. In principle, the central tooth consists of a basal plate with a mesocone, which may be accompanied by a pair of more or less obsolete side-cusps. The lateral teeth may also have these side-cusps, which are called endo- or ectocones, depending on their position relative to the central tooth. The marginal teeth have both kinds of side-cusps, with an ectocone often split up into a series of separate cones.

Counting in a transverse row from the central, bilaterally symmetrical tooth (= C) on, the adjoining asymmetrical tooth (on both sides) is the first lateral (= L1), followed by the second lateral (= L2) etc. The transition between lateral and marginal (= M) teeth is

not always clear. In *Albinaria* we used the size of the basal plate to distinguish between both kinds. In a transverse row of radular teeth, the C and L teeth have relatively large basal plates, provided with denticles that enable them to perform a hinge-function. By definition counting from the central tooth on, the first tooth with a basal plate decreasing disproportionally in size, is considered to be the last lateral. The adjoining one is the first marginal tooth (= M1).

Breure & Gittenberger (1982) described the rock-scraping radula type, characterised by a reduction of the side-cusps on both sides of the central tooth and several adjoining lateral teeth, resulting in a central zone with unicuspid teeth. The *Albinaria* radula belongs to this rock-scraping type.

MATERIAL AND METHODS

During field trips on Kephallinia and Ithaka living snails were collected at many localities and fixated and conserved in 70% alcohol. The radulae of specimens belonging to the following (sub)species were studied:

A. adrianae adrianae Gittenberger, 1979;
A. a. dubia Gittenberger, 1979;
A. contaminata contaminata (Rossmässler, 1835);
A. c. periporon Kemperman & Gittenberger, 1992;
A. c. samiensis Kemperman & Gittenberger, 1992;
A. c. odysseus (Boettger, 1878);
A. c. muraria (A. Schmidt, 1868);
A. senilis senilis (Rossmässler, 1836);
A. s. flavescens (Boettger, 1878);
A. s. kolpomyrtensis Kemperman & Gittenberger, 1990;
A. jonica jonica (Pfeiffer, 1866);
A. j. assicola Kemperman & Gittenberger, 1990.

Anomalies were found in material from the following localities (unless stated otherwise, the locality is on Kephallinia island); the material was collected by E. Gittenberger (053, 055, 060), G.J.M. Visser (033) and the third author (remaining localities).

033 *A. contaminata contaminata* — along road to Oros Aenos (ca. 13 km ESE. of Argostoli), 1200 m alt., DH6923; 10-11-1985

053 *A. adrianae adrianae* — coastal rocks 1 km N. of Poros, 50 m alt., DH7924; 09-05-1987

055 *A. adrianae adrianae* — gorge W. of Poros (type loc.) (= 25.1 km E. of Argostoli), 25 m alt., DH8023; 08-05-1979, 21-03-1988

060 *A. adrianae dubia* — ca. 2.5 km SE. of Xenopoulon, 300 m alt., 08-05-1979

294 *A. contaminata contaminata* — between Metaxata and Travliata near junction to Mon. Andreou (= 7.6 km SE. of Argostoli), on rock-bases along road, 145 m alt., DH6021; 23-04-1987

467 *A. senilis senilis* — 500 m SW. of Tsarkasianos (= 16.3 km E. of Argostoli), on small rocks along road, 570 m alt., DH7125; 03-05-1987

507 *A. adrianae adrianae* — gorge 3.8 km SE. of Poros (28.3 km ESE. of Argostoli), on rocks of N.-face gorge along road, 10 m alt., DH8220; 08-05-1987

539 *A. senilis senilis* — Mavrata (= 24 km ESE. of Argostoli), on vineyard-wall in village along road to Thiramones, 160 m alt., DH7514; 09-05-1987

544 *A. adrianae adrianae* — 200 m N. of Poros (= 25 km E. of Argostoli), on isolated rock between houses along coastal road, 1 m alt., DH8023; 09-05-1987

568 *A. adrianae dubia* — 1.5 km N. of Arginia along the road to Kapandriti (= 22.3 km ESE. of Argostoli), 520 m alt., DH7618; 10-05-1987

578 *A. adrianae dubia* — 2.5 km NW. of Ag. Georgios (type loc.) (= 22.8 km ESE. of Argostoli), on high rock-faces, 400 m alt., DH7618; 11-05-1987

579 *A. adrianae dubia* — 1.5 km NW. of Ag. Georgios, 275 m alt., DH7717; 11-05-1987

585 *A. contaminata muraria* — Ithaka Isl., 3 km NNW. of Vathi, on rocks along coast of N.-side bay of Vathi, 5-10 m alt., DH7448; 12-05-1987

604 *A. contaminata odysseus* — Ithaka Isl., along road to highland-planes 2 km S. of Moni Taxiarchon (= 5.6 km S. of Vathi), 510 m alt., DH4174; 13-05-1987

614 *A. contaminata odysseus* — Ithaka Isl., 600 m S. of Agros (= 4.5 km W. of Vathi) on rock-face along road, 160 m alt., DH7147; 13-05-1987

From 108 specimens the buccal masses were removed, macerated in a 20% KOH-solution, cleaned ultrasonically and mounted for SEM studies. For more detailed information on these procedures, see Kemperman (1992: 85).

RESULTS

In 108 specimens we found one or more anomalies in 20% of the radulae (table 1). Seven categories of anomalies are distinguished, concerning the central, the lateral, as well as the marginal teeth. In all cases but one, the anomaly is repeated in all transverse rows. Thus nearly always entire longitudinal teeth-rows are involved. The following anomaly types were listed.

(1). Fusion of teeth. — This was found five times. In four cases two teeth were involved: L8 and L9 in *A. a. adrianae* (507) (fig. 1), L5 and L6 in *A. c. contaminata* (033), M3 and M4 in *A. a. adrianae* (544) (fig. 2), and M9 and M10 in *A. a. dubia* (579) (fig. 12). In a specimen of *A. a. dubia* (578) three mesocones and three ectocones were present on a single element (fig. 3), which can be interpreted as a fusion of three marginal teeth.

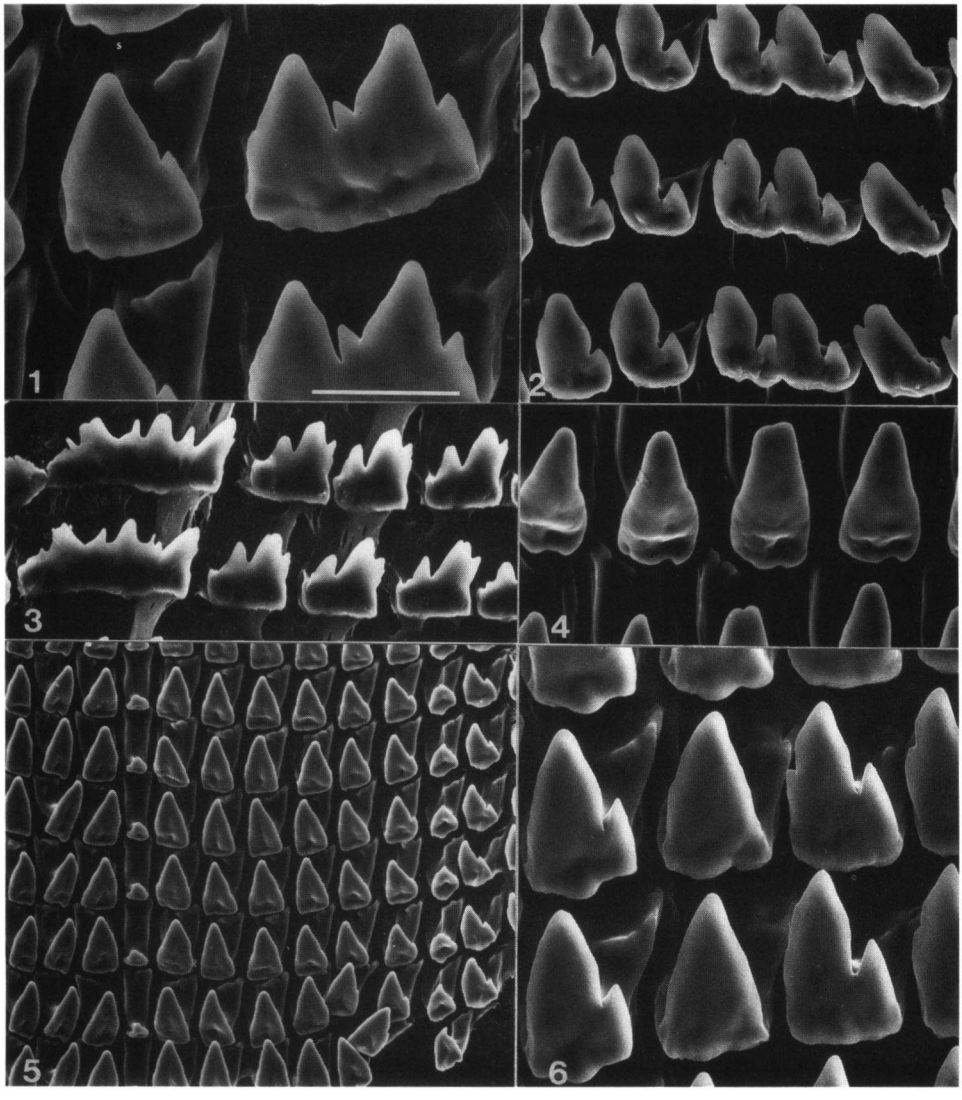
(2). Dwarfed mesocone. — We found teeth with a dwarfed mesocone in two specimens. One specimen of *A. a. adrianae* (544) has a relatively small mesocone of C. A specimen of *A. a. dubia* (060) has not only a small mesocone in C, but also in L7 (fig. 5).

(3). A missing ecto- or endocone. — In a specimen of *A. s. senilis* (539) we found a missing ectocone in L8 (fig. 6); this anomaly was also noticed in M5 of a specimen of *A. a. adrianae* (544) (fig. 2). An endocone was missing in M5 (left and right side of a single specimen) and M3 of *A. a. adrianae* (055).

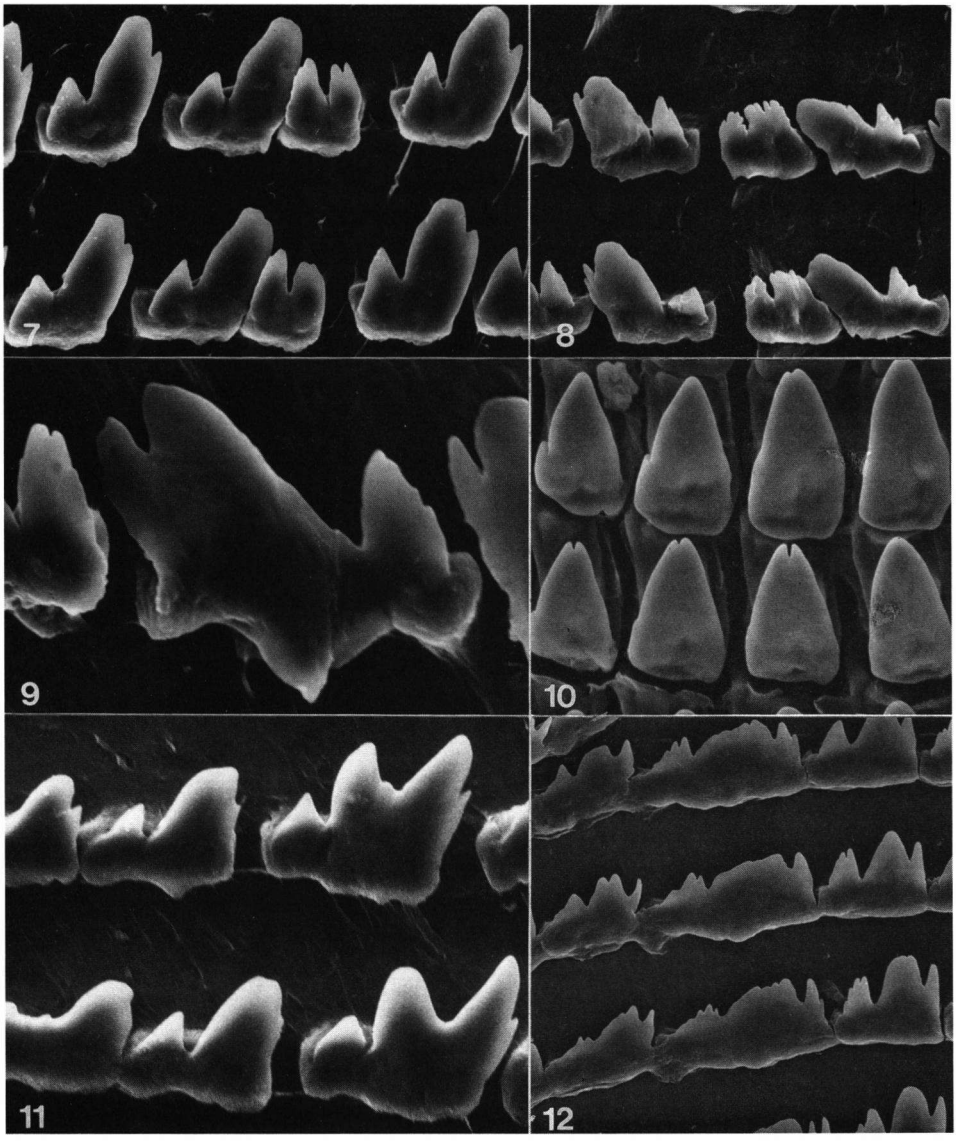
(4). A blunted or two-topped mesocone. — One specimen of the Ithakian subspecies *A. c. odysseus* (604) shows a L3 with a blunted and sometimes slightly two-topped mesocone (fig. 4). A specimen of *A. a. dubia* (579) had a very broad mesocone in M9. Several shortly but distinctly bifid mesocones were found in isolated teeth in a specimen of *A. a. adrianae* (055) (fig. 10).

(5). A missing mesocone in marginal teeth. — The mesocone is reduced to the height of the ectocone. This is found in four cases. Three specimens of *A. a. adrianae* (055 [1], 053 [2]) have an aberrant M4 (fig. 7), M7 and M10, respectively; a specimen of *A. c. muraria* (585) has an aberrant M11 (fig. 8).

(6). A broad marginal. — The marginal tooth is exceptionally broad and shows a protrusion at the base of the mesocone (fig. 9). This is found in five cases within two different species. Two specimens of *A. a. adrianae* (544) have this anomaly, in M7 and M9, respectively. In *A. contaminata* it was seen in specimens of three different subspecies, viz., in M8 of *A. c. contaminata* (294), M15 of *A. c. muraria* (585) and M8 of *A. c. odysseus* (614).



Figs. 1-6. Anomalies in radulae of *Albinaria* spec. 1, *A. a. adrianae* (loc. 507), fused L8-L9 (1750x); 2, *A. a. adrianae* (loc. 544), fused M3-M4 (1050x); 3, *A. a. dubia* (loc. 578), three marginal teeth fused (1050x); 4, *A. c. odysseus* (loc. 604), mesocone L3 with blunted apex (1050x); 5, *A. a. dubia* (loc. 060), reduced mesocone of C and L7 (700x); 6, *A. s. senilis* (loc. 539), L8 without ectocone (1400x).



Figs. 7-12. Anomalies in radulae of *Albinaria* spec. 7, *A. a. adrianae* (loc. 055), missing mesocone in M4 (2400x); 8, *A. c. muraria* (loc. 585), missing mesocone in M11 (1190x); 9, *A. c. odysseus* (loc. 614), a very broad M8 with a basal protrusion (2800x); 10, *A. a. adrianae* (loc. 055), L4-7 with some bifid mesocones, not longitudinally constant (1400x); 11, *A. s. senilis* (loc. 467), M12 with a doubled mesocone (1890x); 12, *A. a. dubia* (loc. 579), fused M9-M10 (1400x).

Subspecies	Nr	N1	N2	N3	N4	N5	N6	N7	Na	Pa
a. adrianae	18	2	1	4	1	3	2		10	55
a. dubia	13	2	2		1				4	31
c. contaminata	17	1					1		2	11
c. periporon	6								0	0
c. muraria	3					1	1		2	66
c. odysseus	8				1		1		2	25
c. samiensis	4								0	0
j. jonica	2								0	0
j. assicola	8								0	0
s. senilis	17			1				1	2	11
s. flavescens	8								0	0
s. kolpomyrtensis	4								0	0
Total	**108**	**5**	**3**	**5**	**3**	**4**	**5**	**1**	**22**	**20**

Table 1. Number and percentage of anomalies in *Albinaria*. Nr, number of specimens studied; N1-7, category number of the anomaly (see the text); Na, number of radulae with one or more anomalies; Pa, percentage of radulae with one or more anomalies. (Na does not always match the total of N1-7 because some radulae have more than one anomaly).

(7). A doubled mesocone. — A specimen of *A. s. senilis* (467) has a M12 which has a doubled mesocone (fig. 11). The two cusps are almost equal in size.

The number and percentages of radular anomalies in the various taxa are shown in table 1.

DISCUSSION

There is not much literature on anomalies in radular structures. A most interesting paper on this subject was mentioned by Runham (1975: 68), viz. an unpublished Ph.D. thesis of Isarankura (1966), in which radular abnormalities in various gastropod species are dealt with. This thesis contains many very interesting data. Isarankura divided the observed abnormalities in several types, the most important being 'longitudinal' (involving one or more longitudinal teeth-rows) and 'transversal' (involving generally two or

three transverse tooth-rows). In our research we found almost exclusively longitudinal anomalies.

It is unclear how the defect odontoblasts, which are responsible for the production of the particular tooth-row(s) originated during the life of the animal. Isarankura (1966: 69) concluded that: "longitudinal abnormalities were permanent and probably arose spontaneously while the other types were only temporary, forming during or after deep dormancy and they could be induced experimentally". He also stated (p. 129) that "there are indications that severe cold (winter), and heat (cautery) can produce this [longitudinal] abnormality".

It is unclear whether and, if so, in what way, the conditions under which *Albinaria* species live, might be related to the frequency and type of radular anomalies in these species. Our results, summarized in table 1, indicate that there might be (sub)species specific differences in the incidence of radular anomalies. The differences between *A. adrianae* and *A. senilis* are most conspicuous in this respect. It is still an open question, however, whether populations of a single subspecies, living under different conditions (various altitudes for example), show differences in percentage of radular anomalies.

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