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Discovery of the South African polyplacophoran *Stenosemus simplicissimus* (Thiele, 1906) (Mollusca, Polyplacophora, Ischnochitonidae) in the Southern Ocean

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Abstract: Recent expeditions to the Atlantic sector of the Southern Ocean have yielded valuable collections of shelf and deep water polyplacophorans. These included several specimens of *Stenosemus simplicissimus* (Thiele, 1906), a species previously known only by its holotype and type locality at the Cape of Good Hope. The new material enabled a thorough morphological redescription of the species by studying valve, perinotum, and radula characters with SEM. The new records from Shag Rocks and the eastern Weddell Sea enlarge the species' biogeographic distribution from the temperate South African region to the polar South Georgia and Weddell Sea regions. Its bathymetric range is extended from 318 m to 285-1064 m. The limited occurrence of deep-water Antarctic polyplacophorans may be caused by benthic predators that limit the expansion of non-herbivorous chitons in the Antarctic deep sea.

Key words: Atlantic Ocean, Antarctica, zoogeography, distribution, new records

Antarctic waters support a small number of Polyplacophora in contrast to the highly diverse fauna of other marine molluscs (Thiele 1912, Dell 1990, Numanami 1996, Sirenko and Schrödl 2001). The species discovered to date are: *Leptochiton kerguelensis* Haddon, 1886, *Callochiton bouveti* Thiele, 1906, *Callochiton gaussae* Thiele, 1908, *Leloupia belgicae* (Pelseneer, 1903), *Stenosemus exaratus* (G. O. Sars, 1878), *Stenosemus simplicissimus* (Thiele, 1906), *Tonicina zschaui* (Pfeffer *in* von Martens and Pfeffer, 1886), *Nuttallochiton mirandus* (E. A. Smith MS, Thiele, 1906), and *Hemiathrum setulosum* Carpenter in Dall, 1876. With the exception of *S. simplicissimus*, all species are more or less well described in earlier revisions (*e.g.*, Thiele 1906a, 1906b, 1908, Dell 1964, Kaas and Van Belle 1985a, 1985b, 1990, Götting 1993). The recent rediscoveries of this species, which was known only from the type material, enable a detailed morphological description using scanning electron microscopy (hereafter, SEM). The description will help non-chiton specialists to separate this species from similar representatives of the genus *Callochiton* Gray, 1847. In addition, deep water polyplacophorans from Antarctica are rare and our knowledge of their biology and habitat preference is limited. Analysis of abiotic parameters at a certain depth may help getting a better understanding of how chitons interact with their environment. The present paper deals with the unknown Antarctic deep-water chiton fauna.

MATERIALS AND METHODS

Specimens of *Stenosemus simplicissimus* were collected during recent expeditions with R/V *Polarstern* (ANT XIII/3, ANT XVII/3, ANT XXI/2, and ANT XXII/3) to the Scotia and eastern Weddell Seas. The material was obtained by using Agassiz trawls (AGT), bottom trawls (BT), epibenthic sledges (EBS), and Rauschert dredges (RD). When the catch reached the deck, the samples were sieved through 500 µm or 1000 µm mesh, the remainder was fixed in 4% buffered formaldehyde or 75-96% ethanol and then sorted under stereomicroscopes. Most of the polyplacophorans were found attached to hard substrates, such as cobbles. Specimens were stored in ethanol for further morphological examinations. To confirm the identification of *S. simplicissimus*, the holotype was examined.

The type material is deposited at the Natural History Museum Berlin, Germany (ZMB). The newly collected material is deposited at the British Antarctic Survey, United Kingdom (BAS), the Zoological Institute St. Petersburg, Russia (ZISP), and the Bavarian State Collection of Zoology, Germany (ZSM).

Preparation of the specimens followed Schwabe and Ruthensteiner (2001). Specimens used for SEM were partly disarticulated, enabling examination of valves, perinotum, and radula. Microsculpture and radular photographs were made on a LEO 1430VP SEM (at the ZSM). Abiotic factors were established using a conductivity-temperature-depth (CTD) data logger, or by visual inspection of the substratum on board of the research vessel.

SYSTEMATICS

Class Polyplacophora Gray, 1821
Subclass Neoloricata Bergenhayn, 1955
Order Chitonida Thiele, 1910
Family Ischnochitonidae Dall, 1889

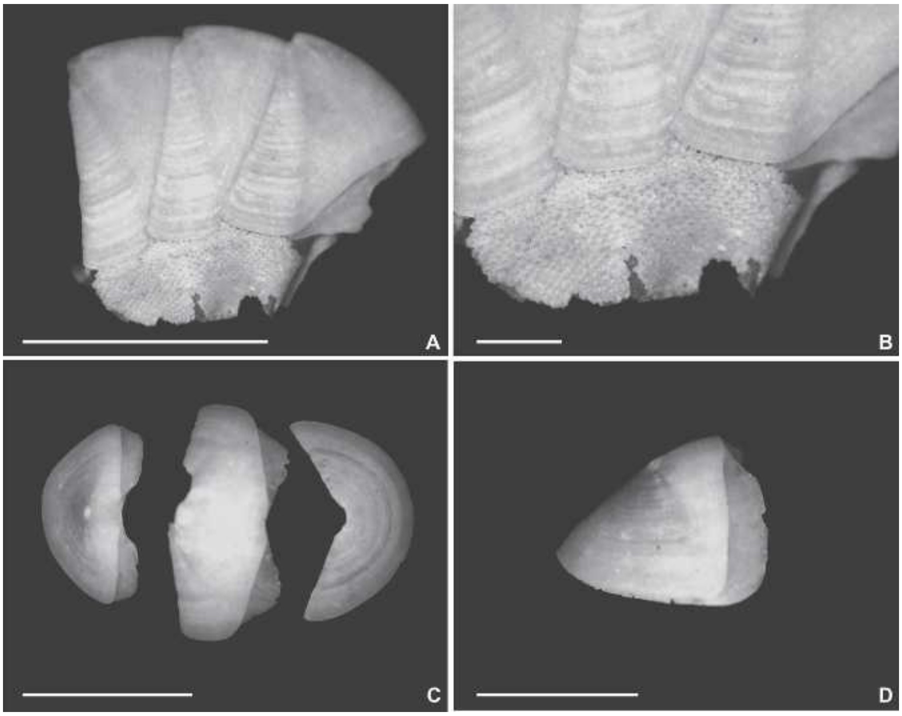

Figure 1. Light micrographs of the holotype of *Stenosemus simplicissimus*, ZMB Moll 59908. A, valves ii to iv *in situ*, anterior at right; B, detail of fig. 1A, showing the dorsal perinotum scales; C, valves (from left to right) viii, v, i in dorsal view, anterior at right; D, right lateral view of the tail valve, anterior at right. Scale bars: A, 5 mm; B, D, 1 mm; C, 500 µm.

Genus *Stenosemus* von Middendorff, 1847

Type species: *Chiton albus* Linnaeus, 1767, by subsequent designation, Winckworth (1926: 15)

Stenosemus simplicissimus (Thiele, 1906)
(Figs. 1-5)

Ischnochiton (Chondropleura) simplicissimus Thiele 1906b: 335, pl. 29, figs 21-25.

Additions to the bibliography in Kaas and Van Belle (1990: 67):

Ischnochiton simplicissimus; Barnard 1974: 740.

Ischnochiton (Stenosemus) simplicissimus; Kaas and Van Belle 1980: 120; 1990: 67, fig. 27; 1998: 171.

Ischnochiton (Chondropleura) simplicissimus; Kilias 1995: 169.

Stenosemus simplicissimus; Sirenko 1994: 164; 2005: 36; Gutt *et al.* 2000: 40; Linse *et al.* 2006: 155 (partim).

Type material: ZMB Moll 59908 (partly disarticulated holotype) (Figs. 1A-D).

Type locality: South Africa, Cape of Good Hope, Deutsche Tiefsee-Expedition St. 113: 34°33.3′S 18°21.2′E, 318 m.

Additional material examined

ZSM Mol 20050857 (1 specimen - 3.4 × 2.2 mm, partly disarticulated) (Figs. 2-3), Antarctica, Weddell Sea: ANT XXII-3 (ANDEEP III) St. PS 67/074-7: 71°18.60′S 13°59.11′W-71°18.38′S 13°58.17′W, 1047-1064 m, on rock (quartz-amphibolite gneiss), laying on a sandy sediment (only 5 cm thick) (salinity: 34.7 psu; water temperature: 0.5 °C; O_2 concentration: 5.8 ml/l; pressure: 1016.5 dBar; all data from 1004 m, measured by CTD), AGT, collected by J. M. Bohn and E. Schwabe, 20 February 2005, preserved in 96% ethanol.

ZSM Mol 20020914 (1 specimen - width 3.1 mm [curled]), Shag Rocks, South Georgia and South Sandwich Islands: ANT XIX-5 (LAMPOS) St. PS 61/169-1: 53°22.94′S 42°41.37′W-53°22.89′S 42°41.50′W, 284.3 m, RD, collected by Dr. M. Schrödl, 10 April 2002, preserved in 78% ethanol.

ZSM Mol 20008502 (1 specimen - 8.7 × 4.2 mm, partly disarticulated) (Fig. 4), Antarctica, Weddell Sea: ANT XVII-3 (EASIZ III) St. 97-1: 71°06.27′S 12°50.46′W-71°06.24′S 12°49.92′W, 728-743 m, EBS, collected by Dr. M. Schrödl, 3 April 2000, preserved in 78% ethanol.

BAS (Dr. Katrin Linse) 03-802 (1 specimen - width 3.8 mm [curled]), Antarctica, Weddell Sea: ANT XXI-2 (BENDEX) St. PS 65/324-1: 72°54.52′S 19°47.74′W-72°54.55′S 19°47.30′W, 647.2-693.6 m, RD, collected by Dr. K. Linse, 3 January 2004, preserved in 96% ethanol.

BAS (Dr. K. Linse) 03-769 (1 specimen - width 3.4 mm [curled]), Antarctica, Weddell Sea: ANT XXI-2 (BENDEX) St. PS 65/297-1: 72°48.50′S 19°31.66′W-72°48.65′S 19°31.85′W, 630.8-668 m, RD, collected by Dr. K. Linse, 1 January 2004, preserved in 96% ethanol.

Description

Species moderately large, up to 16 mm (the largest specimen is the holotype). It is elongate, oval, with a cari-

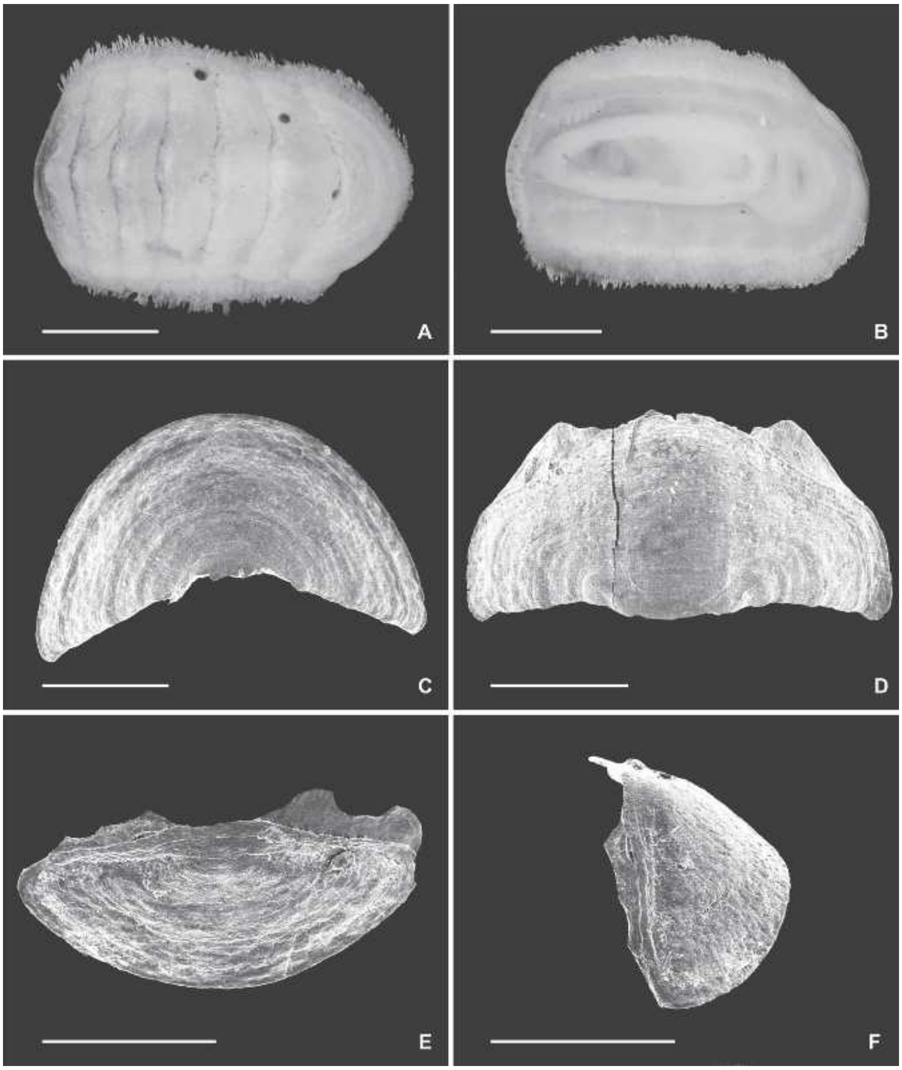

Figure 2. *Stenosemus simplicissimus* (ZSM Mol 20050857), 3.4 × 2.2 mm. A-B, light micrographs, C-F, scanning electron micrographs. A, dorsal view of the complete specimen, anterior at right; B, ventral view of the complete specimen, anterior at right; C, dorsal view of the head valve; D, dorsal view of valve ii; E, dorsal view of the tail valve; F, left lateral view of the tail valve, anterior at left. Scale bars A-B: 1 mm, C-F: 500 µm.

nated, moderately high-elevated dorsum. Dorsal elevation quotient (height/width) (of isolated valve v of the holotype): 0.51. Color of tegmentum and perinotum uniform dull white.

Tegmentum virtually smooth, except for commarginal growth marks, which occur on all valves (Figs. 1A-D, 2C-F, 4A-D) and a micro-perforation. In earlier growth stages, fine radial striation is visible in apical regions and the middle of the first valve. The head valve has a wide V-shaped posterior margin and is clearly notched in the middle (Figs. 1C, 2C, 4A). Intermediate valves (Figs. 1A, 1C, 2D, 4B) are trapezoid (valve ii) to rectangular, with short and rounded side margins, and straight to slightly concave posterior margins (on both sides of the slightly protruding apex). Anterior valve margin is convex. Lateral areas are clearly elevated. Tail valve (Figs. 1C-D, 2E-F, 4C-D) is semicircular with an anteriorly directed, weakly elevated mucro that is situated in the two anterior thirds of the valve length. Postmucronal slope is steep and straight.

Articulamentum is thin and white. Apophyses (Figs. 1A, 1C-D, 2D-E, 4B-D) are well developed, rather short, wide, and medially connected by a short smooth jugal lamina. Apophyses are triangular in intermediate valves, and rectangular in tail valve. Slit formula varies from 14/1/10 (holotype) to 16/1-2/13 (8.7 mm long specimen, ZSM Mol 20008502). Slits are wide and rather long, teeth edges are slightly thickened and faintly crenulated. Slit rays are present in all valves. Eaves are spongy.

Perinotum is rather narrow (Figs. 1A-B), dorsally covered with juxtaposed, bent, conical, round-topped, and inwardly directed calcareous scales, 160-176 µm long, 144-150 µm in diameter on mid-perinotum, rhomboidal at the base, and weakly longitudinally striated (Kaas and Van Belle 1990). Towards the outer margin, the scales are smaller and measure 80-90 × 50-57 µm (Fig. 3B). Marginal fringe (Fig. 3C) consists of straight, obtusely-pointed solid spicules, which are medially keeled and measure about 110 × 22 µm. Among them are smaller, straight, and sharp spicules, 50 µm in length and 10 µm in width. These spicules are situated distally either on long, very slender shafts (140 × 7 µm) or in shorter tubs that may attain a diameter of 15 µm (Fig. 4E). Ventrally there are radial rows of rectangular scales that measure 53 × 27 µm (Fig. 3D).

Radula (Fig. 3D) of a partially disarticulated specimen (ZSM Mol 20008502) measures 3.3 mm, of which 1.6 mm were taken up by the radula cartilage, with 44 teeth rows of which 31 are mineralized. Central tooth is rectangular, its distal end a little wider than the base. It measures 71 × 31 µm long and has a forward-directed simple, slightly bent cusp.

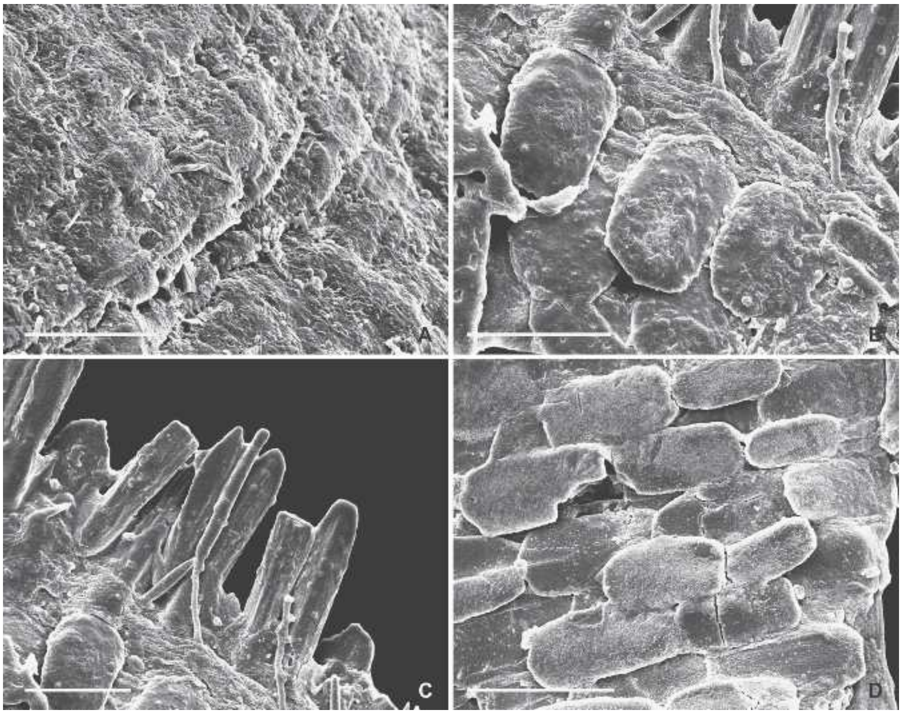

Figure 3. Scanning electron micrographs of *Stenosemus simplicissimus* (ZSM Mol 20050857), 3.4 × 2.2 mm. A, detail of Fig. 2F, showing the valve microsculpture; B, dorsal perinotum scales at the margin; C, marginal perinotum fringe; D, ventral perinotum scales. Scale bars: 50 μm.

First lateral tooth is wing-shaped and covers the lower two thirds of central tooth. It may attain a length of 60 μm and has a simple inward directed small cusp. Total length of second lateral tooth is 175 μm; one third of its length is taken up by the squarish head with the single, sharply pointed, and inwardly curved elongate denticle. Shaft of second lateral tooth is sharply keeled on its inner side and slightly curved in the upper half. Basally the tooth is wing-shaped. First uncinal tooth is triangular in outline with a straight inner edge and a steep slightly convex, outer edge. Second uncinal tooth is very broad and S-shaped. Third uncinal tooth is extremely slender, measuring 138 × 18 μm, with a spoon-shaped distal extension, which may attain the double width of the shaft. First marginal tooth is similar to, but slightly more slender than, the second uncinal. Second marginal tooth is arrowhead-shaped, measuring 71 × 31 μm. Third marginal tooth is rectangular in outline, 75 μm long, and 46 μm wide. Its inner edge is thickened.

Ctenidia are arranged merobranchially with the longest ctenidium on each side positioned the fourth from the posterior end. Size and number of ctenidia depend on animal size. The 8.7 mm long specimen has 16 ctenidia on the right and 17 on the left side; the juvenile (3.4 mm) has 7 ctenidia on each side of the foot (Fig. 2B).

Distribution

Known from the Cape of Good Hope (type locality), Shag Rocks near South Georgia Island and eastern Weddell Sea (this study) (Fig. 5). Bathymetrically the species lives between 284-1064 m depth (Thiele 1906b, Gutt *et al.* 2000, Sirenko and Schrödl 2001, Linse *et al.* 2006).

DISCUSSION

Since its description, *Stenosemus simplicissimus* was never recollected. Several expeditions to the Subantarctic Marion and Prince Edward Islands failed to locate this species, although the congeneric *Stenosemus exaratus* (G. O. Sars, 1878) [reported as *Stenosemus dorsuosus* (Haddon, 1886)] was found together with the following species: *Leptochiton kerguelensis* Haddon, 1886, *Hemiathrum setulosum* Carpenter in Dall, 1876, and *Placiphorella* sp. (Branch *et al.* 1991). *Leptochiton kerguelensis* and *H. setulosum* are typical faunistic elements of the Antarctica; the latter is *Placiphorella atlantica* (Verrill and S. I. Smith in Verrill, 1882) (pers. obs.).

Stenosemus simplicissimus was first rediscovered during the ANT XIII-3 (EASIZ I) – Antarctic expedition at St. 01: 71°03.10′S 11°25.50′W, at 462 m (Gutt *et al.* 2000). During subsequent expeditions, the species was found again but only in small numbers.

The Weddell Sea supports a high diversity of mollusc species and, not surprisingly, their numbers decrease with increasing depth, along with a significant decrease in total biomass (Brey and Gerdes 1997, 1998). During the ANDEEP III expedition (from the Cape Basin to Kapp Norvegia and across the Weddell Sea), 186 mollusc morphospecies (3801 specimens from 12 EBS and 19 AGT stations) were collected from depths ranging from 1000 to 4900 m (Linse *et al.* 2006).

In contrast to former expeditions in this area of comparable scope (Sirenko and Schrödl 2001), only two polyplacophoran specimens were found, the herein mentioned juvenile of *Stenosemus simplicissimus* and *Leptochiton kerguelensis* (ZSM Mol 20060001). The latter specimen was collected at station PS67/133-2 (62°46′44″S 53°02′34″W-62°46′20″S 53°04′08″W) at 1581-1582 m depth. This is the maximum depth reported for this species, which was for-

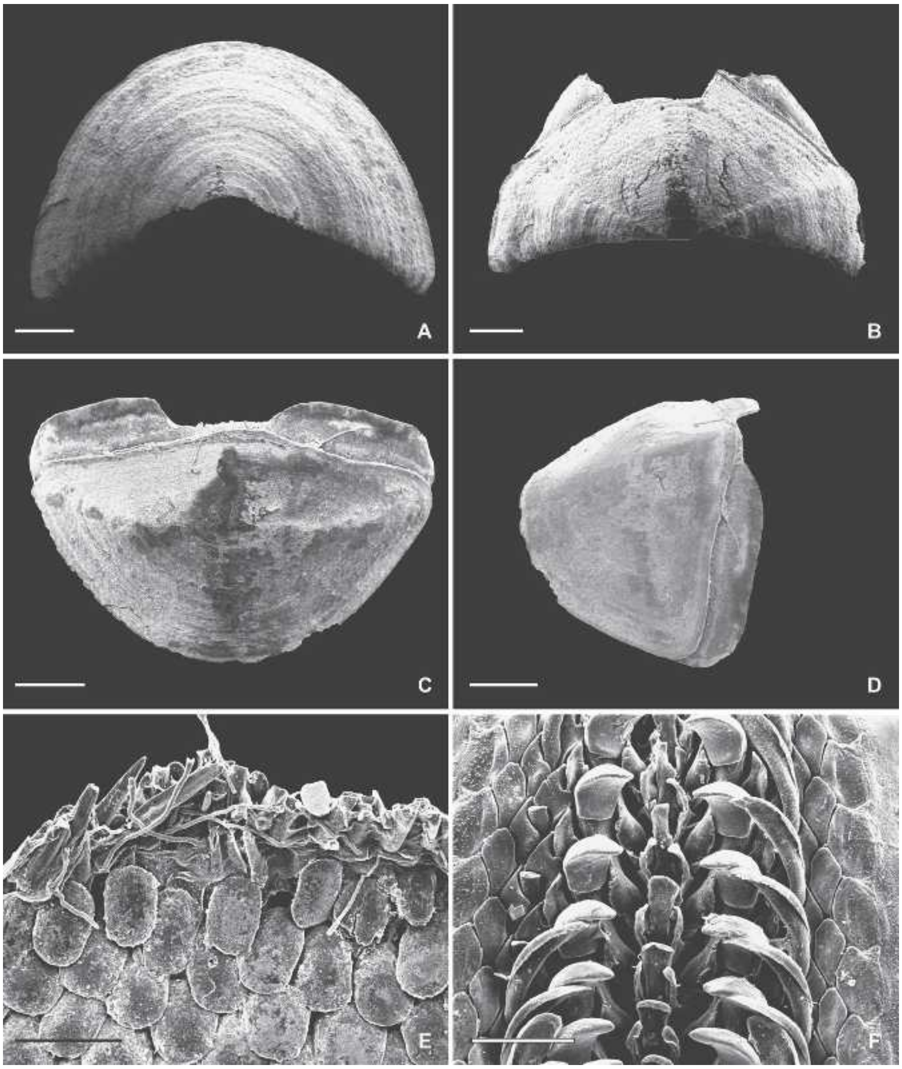

Figure 4. Scanning electron micrographs of *Stenosemus simplicissimus* (ZSM Mol 20008502), 8.7 × 4.2 mm. A, dorsal view of the head valve; B, dorsal view of valve ii; C, dorsal view of the tail valve; D, right lateral view of the tail valve, anterior at right; E, dorsal perinotum scales, close to the margin; F, rows 3-8 of the radula. Scale bars A-D: 500 μm, E-F: 100 μm.

merly only known from 1335 m in the Ross Sea (Dell 1990). A bulk of stones was found during the recent expedition, a substratum that allows settlement of chiton larvae. That they could be covered by sediment can be excluded because Paul (1976) has shown that chitons are able to remove sediment layers. Is the extremely low chiton diversity and density in the Antarctic merely a function of the great depth or related abiotic environmental conditions? Temperature is unlikely to be a problem as it does not change with depth (Brey and Gerdes 1998). The increase in water pressure can also be ruled out as diverse deep sea chiton faunas are known from other regions (Sirenko 2001). Most deep water chitons are dependent on plant remains (*e.g.*, sunken wood) that may not found in the Antarctic deep sea. The high organic food input (Brey and Gerdes 1997) in the Weddell Sea, together with abiotic conditions should favor colonization by non-herbivorous chitons. Several carnivorous taxa such as asteroids, ophiuroids, and polychaetes are highly adapted to the conditions of the Weddell Sea (Brey and Gerdes 1997, 1998). The chitons may lack the ability to co-occur with abundant predators such as the asteroids, which feed on chitons (Seiff 1975).

In summary, this report gives a detailed description of *Stenosemus simplicissimus*, contributes the first record of the species' juvenile stage, and extends its bathymetric range and that of *Leptochiton kerguelensis*, thus providing a further piece of the unfinished puzzle documenting Antarctic deep sea communities. The material obtained to date for *S. simplicissimus* suggests that it *could be* geographically restricted to the Southern Atlantic Ocean.

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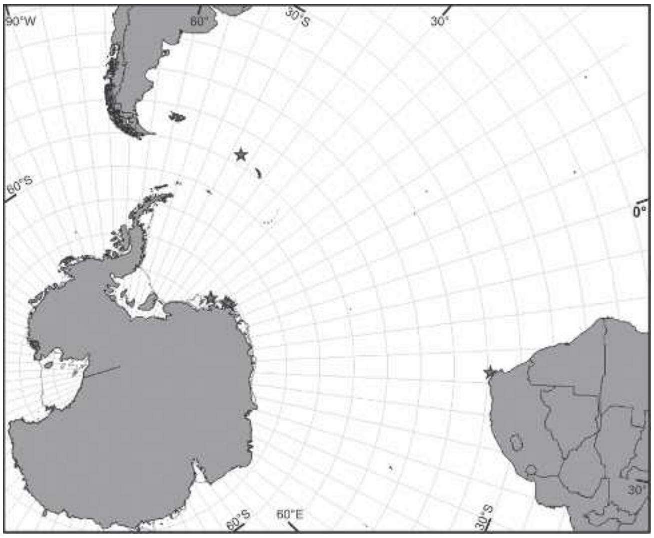

Figure 5. The geographical distribution of *Stenosemus simplicissimus.*

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