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Morphology and taxonomy of *Sinophysis* (Dinophyceae, Dinophysiales) including two new marine sand-dwelling species from the North German Wadden Sea

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Three sand-dwelling species of the marine dinoflagellate genus *Sinophysis* were examined from intertidal and subtidal North German Wadden Sea sand and are illustrated by light and scanning electron microscopy. Two are described as new: *S. stenosoma* sp. nov. and *S. grandis* sp. nov. *Sinophysis stenosoma* sp. nov. is compressed laterally with a cell size of 37–56 μm long and 21–33 μm wide, a length/width ratio of 1·43–1·89, an epitheca width (dorsoventrally) of 5·5–8·0 μm, and a sulcus length of about half the cell length. *Sinophysis grandis* sp. nov. is compressed laterally with a cell size of 50–59 μm long and 35·0–41·5 μm wide, a length/width ratio of 1·29–1·61, an epitheca width (dorsoventrally) of 12–17 μm, and a sulcus length of about three-quarters the cell length. The third species, *Sinophysis ebriolum* (Herdman) Balech, is the most common species in the Wadden Sea. All species occur throughout the year and are all sand-dwelling, non-photosynthetic, with a smooth theca. They can be distinguished by size, length/width ratio, epitheca size, relative sulcal length and thecal pore pattern. A key to the five known *Sinophysis* species is provided.

Key words: dinoflagellate, Dinophysales, marine sand, *Sinophysis*, taxonomy

Introduction

Since the pioneering work of Herdman (1922–4) there have been several studies on psammophilic dinoflagellates: Balech (1956), Dragesco (1965), Baillie (1971), Dodge (1982), Horiguchi & Chihara (1983), Saunders & Dodge (1984), Larsen (1985), Dodge & Lewis (1986), Horiguchi & Pienaar (1988, 1992), Horiguchi (1995) and Hoppenrath & Elbrächter (1998). The genus *Sinophysis* has been reported both in benthic and in planktonic habitats (Nie & Wang, 1944; Campbell, 1973; Hernandez-Becerril, 1988; Hansen & Larsen, 1992). *Sinophysis ebriolum* (Herdman) Balech was originally described by Herdman (1924) as *Phalacroma ebriola* Herdman but transferred to *Sinophysis* by Balech (1956). Baillie (1971), Dodge (1982) and Saunders & Dodge (1984) reported *Sinophysis ebriolum* from marine sand. To date, there are two other known *Sinophysis* species: *S. microcephalus* Nie & Wang (1944) and *S. canaliculata* Quod *et al.* (1999). *Sinophysis microcephalus* is the type species (Nie & Wang, 1944), described from the Hainan Region in the South China Sea. Its morphology was investigated in detail by Faust (1993) from mangrove habitats in Belize. *Sinophysis canaliculata* was isolated from coral and sediments in the southwestern Indian Ocean, and was described in detail by Quod *et al.* (1999).

During a study of the temporal and spatial distribution of marine sand-dwelling dinoflagellates in the North German Wadden Sea, *Sinophysis ebriolum* and two new *Sinophysis* species were recorded. In addition to light microscopic observations, I have examined these species using scanning electron microscopy (SEM).

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History of the genus Sinophysis

The genus *Sinophysis* was established by Nie & Wang (1944) as a member of the family Dinophysaceae and *S. microcephalus* was designated as the type species. The authors described two epithecal plates but assumed that they lost two further plates during manipulation. Also they detected four girdle plates, four hypothecal plates and four sulcal plates. Faust (1993) distinguished only two epithecal plates, but pointed out two further epithecal plates seen by Nie & Wang (1944). Moreover she identified four cingular and four hypothecal plates while the sulcus was not visible in her micrographs. She mentioned that 'The plate arrangement of *S. microcephalus* is similar to that described by Balech (1976) for *Dinophysis*' (Faust, 1993, p. 359). Herdman (1924) described a colourless, benthic dinoflagellate, *Phalacroma ebriola* Herdman. When Kofoid & Skogsberg (1928) erected the new genus *Thecadinium*, they transferred *Phalacroma ebriola* into it as *Thecadinium ebriolum* (Herdman) Kofoid *et* Skogsberg. Nie & Wang (1944) discussed whether *Thecadinium ebriolum* (Herdman, 1924: 38, p. 79, fig. 24) really belonged to *Thecadinium* and Balech (1956) trans-

ferred it to *Sinophysis* as *S. ebriolum* (Herdman) Balech. He identified four epithecal, four cingular, four hypothecal and three sulcal plates. Saunders & Dodge (1984) saw two epithecal, four cingular and two hypothecal plates, but only one sulcal plate was visible. In the present study two epithecal, four cingular and three hypothecal plates were distinguished, while the sulcal plates could not be identified. The plate formula of the genus *Sinophysis* thus remains uncertain (2 or 4 epithecal, 4 cingular, 2–4 hypothecal, 3 or 4 sulcal plates).

Species now regarded as belonging to *Sinophysis* Nie & Wang were previously assigned to the genera *Phalacroma* Stein and *Thecadinium* Kofoid & Skogsberg. In addition, Balech (1956), Baillie (1971) and Dodge (1982) regarded *Dinophysis ebriola* Herdman 1924 as a synonym of *Sinophysis ebriolum*. Therefore Dodge (1982) listed as synonyms of the genus *Sinophysis*: *Phalacroma* Stein partim, *Thecadinium* Kofoid & Skogsberg partim and *Dinophysis* Ehrenberg partim. Concerning *Dinophysis ebriola*, Herdman (1924, p. 82) listed this name in an additional note, without any comment or reference to a description or figure. Therefore the name *Dinophysis ebriola* is a *nomen nudum* and it is only speculation to relate it to *Phalacroma ebriola*. We delete *Dinophysis* from the list of synonyms of *Sinophysis*. Abé (1967), Sournia (1986) and Fensome *et al*. (1993) considered the genus *Sinophysis* to belong to the family Dinophysaceae.

Species of *Sinophysis* are regarded as benthic. The type species, *S. microcephalus*, may be associated with detritus, *S. canaliculata* may be associated with sediment or attached to macroalgal turf surfaces or coral rubble, and the third known species is sand-dwelling, but may be washed into the plankton.

Materials and methods

Study area

Sylt is the most northwestern island of Germany. It is situated in the North Friesian Wadden Sea, part of the eastern North Sea. Sampling sites were in bare, eulittoral regions, south of List Harbour (55°00·85′ N; 08°06·30′ E; tidal flat of 100 m) and at the '*Oddewatt*' northeast of List (55°01·80′ N; 08°26·00′ E; tidal flat of 500 m), both sites facing the mainland. In addition, the sublittoral region of the west coast of List (55°01·73′ N; 08°21·00′ E), facing seaward, was sampled. Both sand flats were rippled and populated by the lugworm *Arenicola marina*. Sediment temperature was between −1·6 °C and 22·5 °C over the year. There was a conspicuous blackish sulphide layer in the flat which, south of List harbour, commenced at 2·0 to 10·0 cm, and at 0·1 to 4·0 cm at the '*Oddewatt*'. Salinity in the overlying water was 30 to 32 PSU.

Sampling methods

At eulittoral stations, samples were collected with sample tubes during low tide in the morning. A box corer on the research-boat *Mya* was used to obtain sublittoral samples. The sand samples were transported directly to the laboratory and the dinoflagellates separated from the sand by extraction with melting seawater-ice (Uhlig, 1964), through a fine filter (mesh size 45 μm). They accumulated in a Petri dish beneath the filter and were then identified with a Leitz Fluovert FS invert-microscope at × 40 to × 250 magnification. Cells were also isolated by micropipetting and examined with a Leica DMRB microscope using differential-interference-contrast microscopy (*S. ebriolum* cells also after treatment with 2% sodium hypochlorite), epifluorescence microscopy (filter system I3, for detection of chlorophyll) and a Leitz Orthoplan microscope, using a seawater-immersion objective SW 50. Cell dimensions were determined either directly with the light microscope or from scanning electron micrographs of at least 10 cells.

SEM preparation

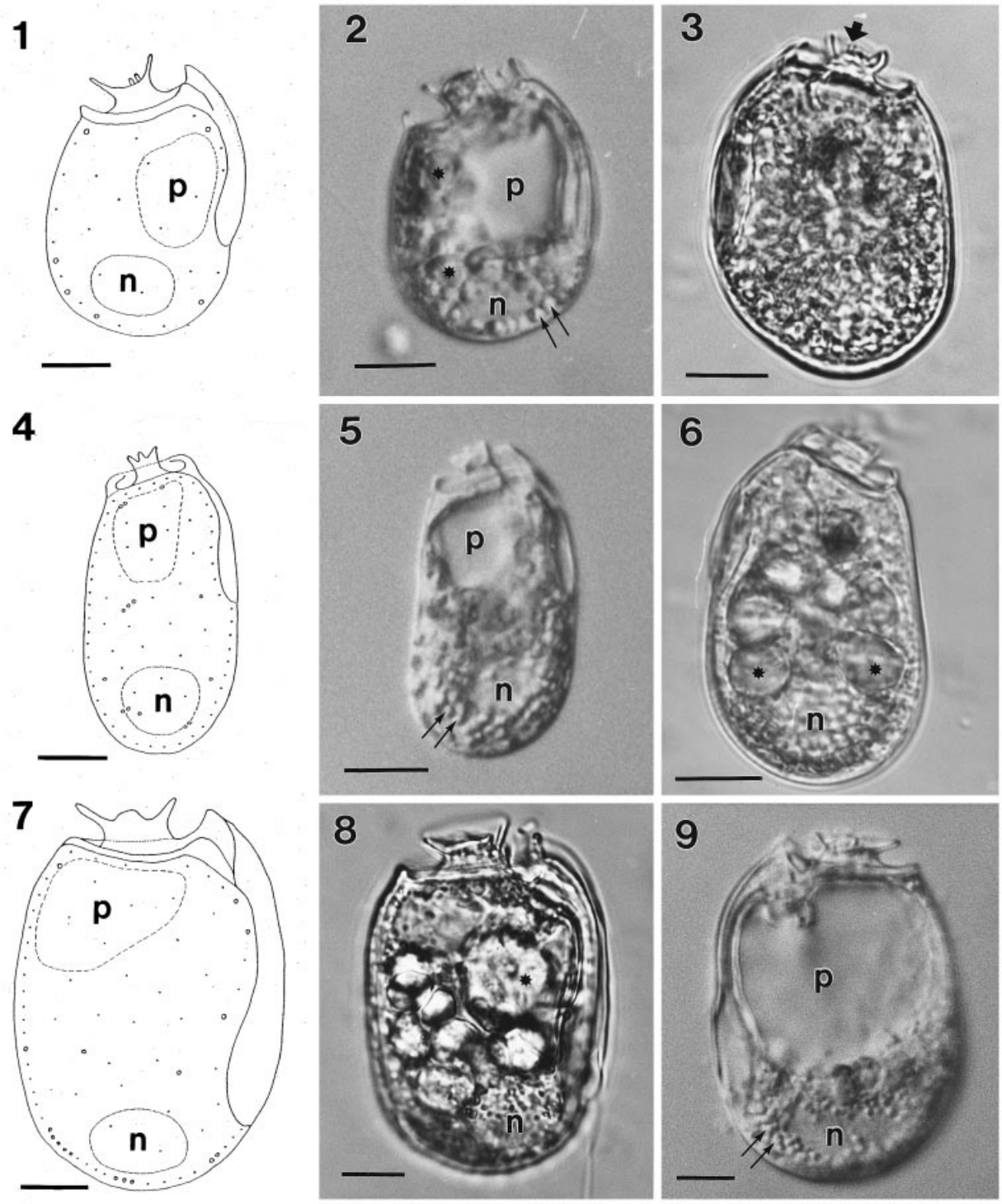
For SEM, specimens were fixed in Lugol's solution, filter-mounted, rinsed with distilled water and dehydrated with 30% ethanol followed by dimethoxypropane (Merck). The filter was air-dried and sputter-coated with gold-palladium for 3 min at 45 mA (Bal-Tec SCD 050) before examination in a Zeiss DSM 940A scanning electron microscope.

Results and discussion

Sinophysis ebriolum (Herdman) Balech (Figs 1–3, 10–23)

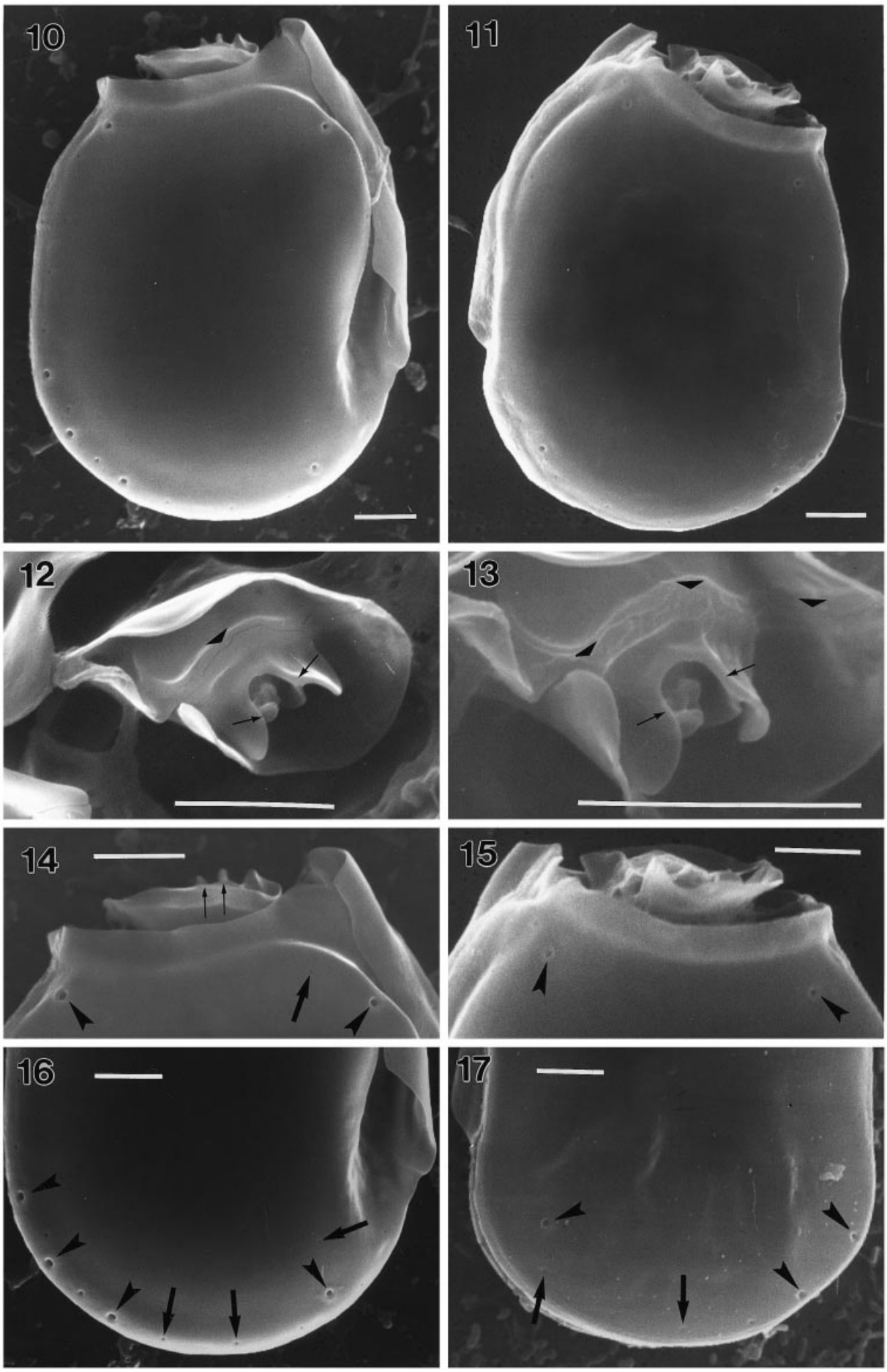
Synonyms: *Phalacroma ebriola* Herdman, 1924, p. 79, fig. 24; *Phalacroma ebriolum* Lebour, 1925, p. 77, fig. 20c; *Thecadinium ebriolum* Kofoid & Skogsberg, 1928, p. 32; *Thecadinium ebriolum* Schiller, 1933, p.51, fig. 50.

Cells are roughly oval, 35·0–45·0 μm long and 25·0–31·5 μm wide (dorsoventrally), with a length/width ratio of 1·2–1·5 (Figs 1–3). They are flattened laterally. The small epicone is of medium size, 9·0–12·0 μm wide (dorsoventrally), surrounded by a wide collar (Figs 2, 3, 10, 11) and slightly tilted back to the dorsal side (Figs 2, 11). The epitheca is divided into two asymmetrical plates (Figs 12, 13). The left plate possesses two parallel, upright, anterior projections (Figs 12, 13, 14, small arrows). The stocky hypocone is broadest in the posterior third (Figs 10, 11). The deep girdle is bounded by lists forming a collar. These lists are part of the large lateral hypothecal plates (Figs 10, 11). The sulcus lies on the right side and is about two thirds of the length of the cell (Figs 1, 2, 10). The sulcus is partly covered by a sulcal list, which is part of the narrow hypothecal plate bordering the left sulcal area (Fig. 10). The cell is colourless and usually contains numerous small colourless granules and large coloured food bodies (Fig. 2). Chloroplasts could not be detected with epifluorescence microscopy. One or two large



Figs 1–9. Line drawings and light micrographs of the three *Sinophysis* species. Fig. 1. *Sinophysis ebriolum*. Fig. 2. Light micrograph of *S. ebriolum*, right lateral view. Fig. 3. Light micrograph of *S. ebriolum*, left lateral view. Fig. 4. *Sinophysis stenosoma* sp. nov. Fig. 5. Light micrograph of *S. stenosoma*, right lateral view. Fig. 6. Light micrograph of *S. stenosoma*, left lateral view. Fig. 7. *Sinophysis grandis* sp. nov. Fig. 8. Light micrograph of *S. grandis*, right lateral view. Fig. 9. Light micrograph of *S. grandis*, left lateral view. n, nucleus; p, pusule; asterisk, large food body; small arrow, small colourless granules; large arrow, two parallel, upright, anterior projections. Scale bars represent 10 μm.

pusules are situated in the anterior half of the hypocone (Figs 1, 2). The ellipsoidal nucleus is located posteriorly in the hypocone (Figs 1, 2). The thecal surface is smooth with a distinct pore pattern. There are two pore types: small (0·2–0·3 μm) and large (0·5–0·6 μm). The small pores are randomly distributed over the thecal surface, and there is also a marginal row with wide intervals of nearly equal distance (Figs 1, 10). The large pores always have the same characteristic position at the plate margins (Figs 1, 10). There is one pore at each of the anterior ventral, anterior dorsal and posterior ventral edges (Figs 14–17). Furthermore there are three large pores situated in a cluster posterior dorsally (Figs 16, 17). The pore pattern is identical on both lateral hypothecal plates.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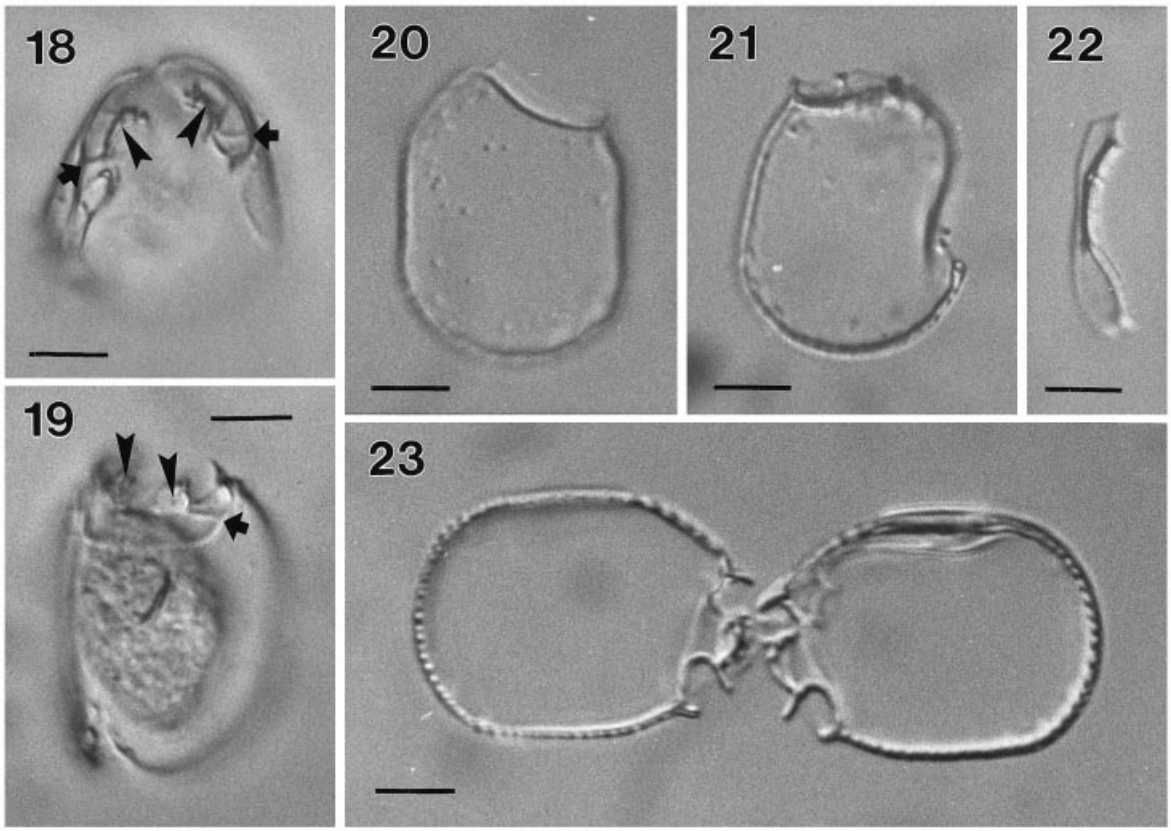


Figs 18–23. Light micrographs of *Sinophysis ebriolum* after treatment with sodium hypochlorite. Fig. 18. Apical view, showing two epithecal and four cingular plates. Fig. 19. Right lateral to dorsal view. Fig. 20. Large left lateral hypothecal plate. Fig. 21. Large right lateral hypothecal plate. Fig. 22. Small right lateral hypothecal plate. Fig. 23. Total theca split into the left and right half. Arrowheads, epithecal plates; arrows, sutures between the cingular plates. Scale bars represent 10 μm.

Treatment with sodium hypochlorite revealed two epithecal, four cingular and three hypothecal plates (Figs 18–23). Sulcal plate dissection was not successful.

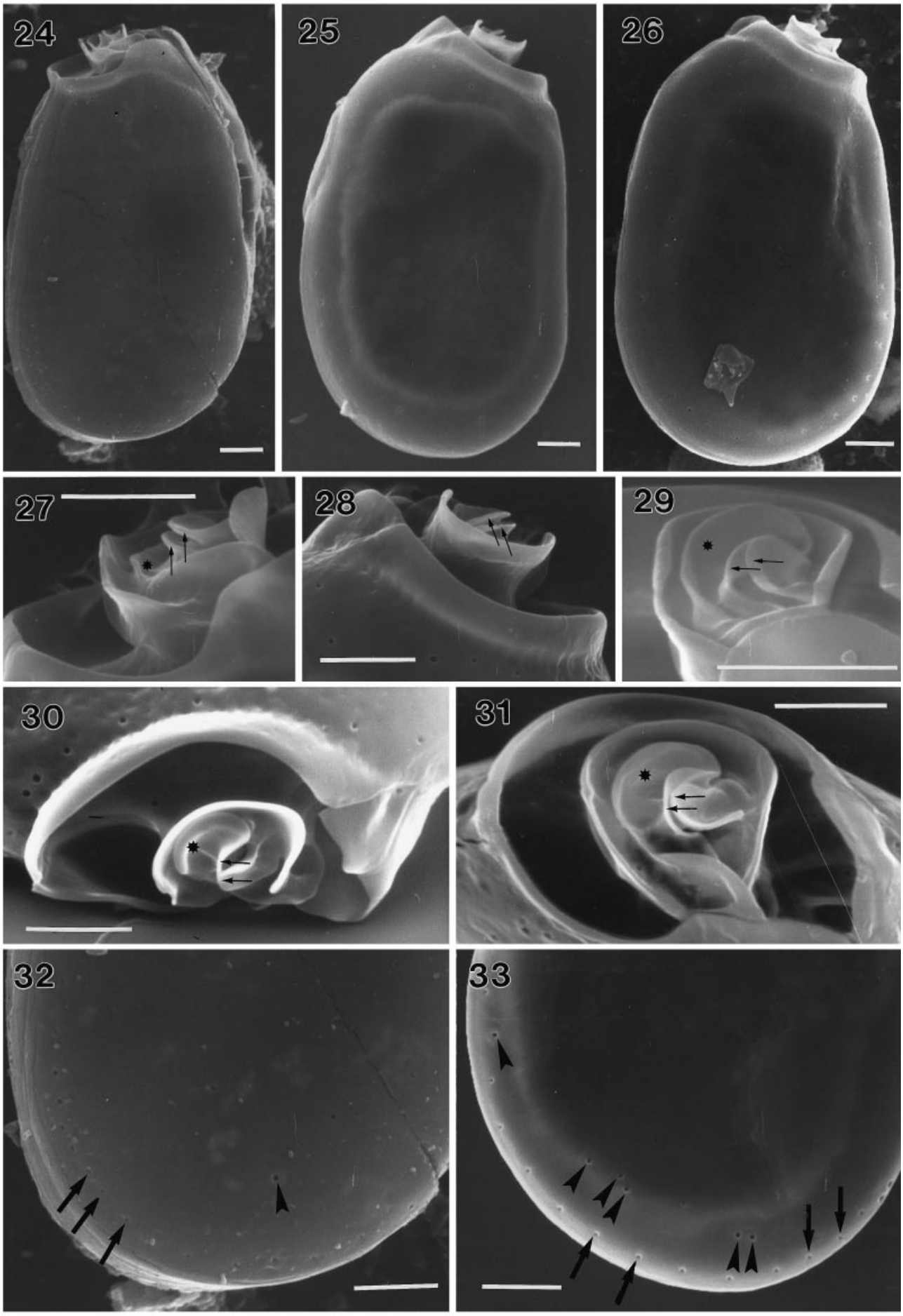
Sinophysis ebriolum showed no seasonality – it occurred throughout the year with highest abundance in summer and autumn (June to September). Most cells were detected in the oxic surface sediment, but cells were also recorded in grey to black 'sulphidic' sediment. *Sinophysis ebriolum* occurred in all eulittoral regions and also at sublittoral stations, with highest abundance around the low tide line. It was clearly more frequent than the other two *Sinophysis* species.

The observed specimens are in good agreement with the original description of *Phalacroma ebriola* (Herdman, 1924). Lebour (1925) adopted Herdman's data without additional notes. In 1928 Kofoid & Skogsberg transferred *Phalacroma ebriola* to *Thecadinium* because of theoretical considerations and this was accepted by Schiller (1933). *Phalacroma ebriola* is the basionym of *Sinophysis ebriolum* (Balech, 1956; Dodge, 1982). Balech (1956), Baillie (1971) and Dodge (1982) included *Dinophysis ebriola* (Herdman, 1924, p. 82) as a synonym. This name is listed in an additional note, without any comments (*nomen nudum*). All the early descriptions were based on light microscopic examinations and resulted in line drawings. The present observations of the cell surface structure are the first scanning electron micrographs of *S. ebriolum*. In my opinion the scanning electron micrographs of Saunders &

Table 1. Size range of the investigated species

	S. ebriolum	*S. stenosoma*	*S. grandis*
Length (μm)	39·2 ± 2·51 (35·0–45·0)	45·6 ± 4·20 (37·0–56·0)	55·4 ± 2·26 (50·0–59·0)
Width (μm)	29·4 ± 1·83 (25·0–31·5)	27·5 ± 3·12 (21·0–33·0)	37·6 ± 2·17 (35·0–41·5)
Length/width ratio	1·33 ± 0·07 (1·2–1·5)	1·67 ± 0·12 (1·43–1·89)	1·48 ± 0·09 (1·29–1·61)
Measured cells (LM and SEM)	$n = 30$	$n = 23$	$n = 30$
Epitheca width (μm) (dorsoventrally)	10·3 ± 0·78 (9·0–12·0)	6·3 ± 0·82 (5·5–8·0)	14·1 ± 1·29 (12·0–17·0)
Measured cells (SEM)	$n = 15$	$n = 10$	$n = 15$

Figs 10–17. Scanning electron micrographs of *Sinophysis ebriolum*. Fig. 10. Right lateral view. Fig. 11. Left lateral view. Figs 12, 13. Apical view of the epitheca. Fig. 14. Right lateral view of the epitheca and the apical part of the hypotheca. Fig. 15. Left lateral view of the epitheca and the anteriormost part of the hypotheca. Fig. 16. Right lateral view of the antapical hypotheca. Fig. 17. Left lateral view of the antapical hypotheca. Long arrowheads, large pores; wide arrowheads, suture; large arrows, small pores; small arrows, two parallel, upright, anterior projections. Scale bars represent 5 μm.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Dodge (1984) illustrate *Sinophysis grandis* sp. nov. (see below).

Distribution: Sand at Port Erin, Isle of Man, England (Herdman, 1924); sand at Roscoff, France (Balech, 1956); tidal sandflats, Southwest British Columbia, Canada (Baillie, 1971); tidal sandflats of the North German Wadden Sea (present study).

Sinophysis stenosoma Hoppenrath, sp. nov. (Figs 4–6, 24–33)

Descriptio: Cellulae oblongae ovales, 37·0–56·0 μm longae et 21·0–33·0 μm latae. Proportio longitudinis/latitudinis 1·43–1·89. Epitheca parva, latitudo (dorsoventralis) 5·5–8·0 μm. Longitudo sulci ca. semilonga cellula. Globi pororum magnorum non in marginale ordine pororum.

Locality: Tidal sand flat ('*Oddewatt*') on the island of Sylt, Germany.

Holotype: Figure 25.

Etymology: In the light microscope the cells appear slender, compared with the other *Sinophysis* species. From 'steno' = slender in Greek, and 'soma' = body in Greek.

Cells are oblong ellipsoidal, 37·0–56·0 μm long, and 21·0–33·0 μm wide (dorsoventrally), with a length/width ratio of 1·43–1·89 (Figs 4–6). They are flattened laterally. The small cylindrical, crown-like epicone is notably small compared with the other *Sinophysis* species, and 5·5–8·0 μm wide (dorsoventrally). It is surrounded by a well-developed smooth girdle list of the hypotheca (Figs 5, 6, 26) and slightly tilted back to the dorsal side (Figs 6, 25). The epitheca consists of an outer epithecal list encircling four-fifths of it (Figs 27, 29), with the 'open' area at the right lateral side. This area is closed by a smaller list (Fig. 27). In lateral view, two parallel, curved, upright projections are located in the ventral epithecal half (Figs 27–31). In front of this structure (dorsally) lies a third upright projection encircling one half of it, extending from mid-lateral position on one side to mid-lateral position on the other side (Figs 27, 29–31). The apical view of the epitheca shows that the third upright projection forms the outer margin of a curved tongue-like flap (Figs 30, 31). The inner margin of the flap is identical with the second upright projection (Figs 30, 31). That means the two dorsal projections are connected. I was not able to distinguish epithecal plates. The longish hypocone has nearly parallel sides or is slightly broader in the posterior third, with a rounded antapex (Figs 24–26). The deep girdle is surrounded by a collar, which is part of the hypothecal plates (Figs 24, 25). The sulcus is located on the right side, partly covered by a narrow list and about half the cell length (Figs 5, 24). The cell is colourless and usually contains numerous small colourless granules and large colourless or coloured food vacuoles (Figs 5, 6). Chloroplasts were not detected. One large pusule is situated in the anterior half of the hypocone (Figs 4, 5). The spherical nucleus is located posteriorly in the hypocone (Figs 4–6). The thecal surface is smooth with a distinct pore pattern. There are two pore types: small (0·2–0·3 μm) and large (0·3–0·4 μm). The small pores are randomly distributed over the thecal surface, more densely so than in *Sinophysis ebriolum*. In addition, small pores are arranged in a marginal row, with shorter intervals than in *S. ebriola* (Figs 4, 32, 33). Large pores, single or in small groups, are distributed randomly but never in the marginal row (Figs 4, 32, 33). The large pore pattern could differ from specimen to specimen.

Sinophysis stenosoma showed no seasonality but occurred sporadically, singly or as a few cells. Most cells were detected in the oxic surface sediment, but single cells were also recorded in grey 'sulphidic' sediment. *Sinophysis stenosoma* occurred in all eulittoral regions and also at sublittoral stations, with its highest abundance in the sublittoral.

This species has apparently been reported before. Campbell (1973, pl. 23, fig. 9) described in his studies on brackish-water phytoplankton *Sinophysis* aff. *ebriolum* which I regard as *Sinophysis stenosoma*. He recognized some differences between the observed *Sinophysis* and *Sinophysis ebriolum*, but had insufficient material. Moreover, Saunders & Dodge (1984, p. 273, fig. 2) showed a light micrograph of *Sinophysis ebriolum* which I regard as conspecific with *S. stenosoma*.

Distribution: Sandy beaches around the British Isles and in northern France (Saunders & Dodge, 1984); free water of Gales Creek, North Carolina (Campbell, 1973); tidal sandflats of the North German Wadden Sea (present study).

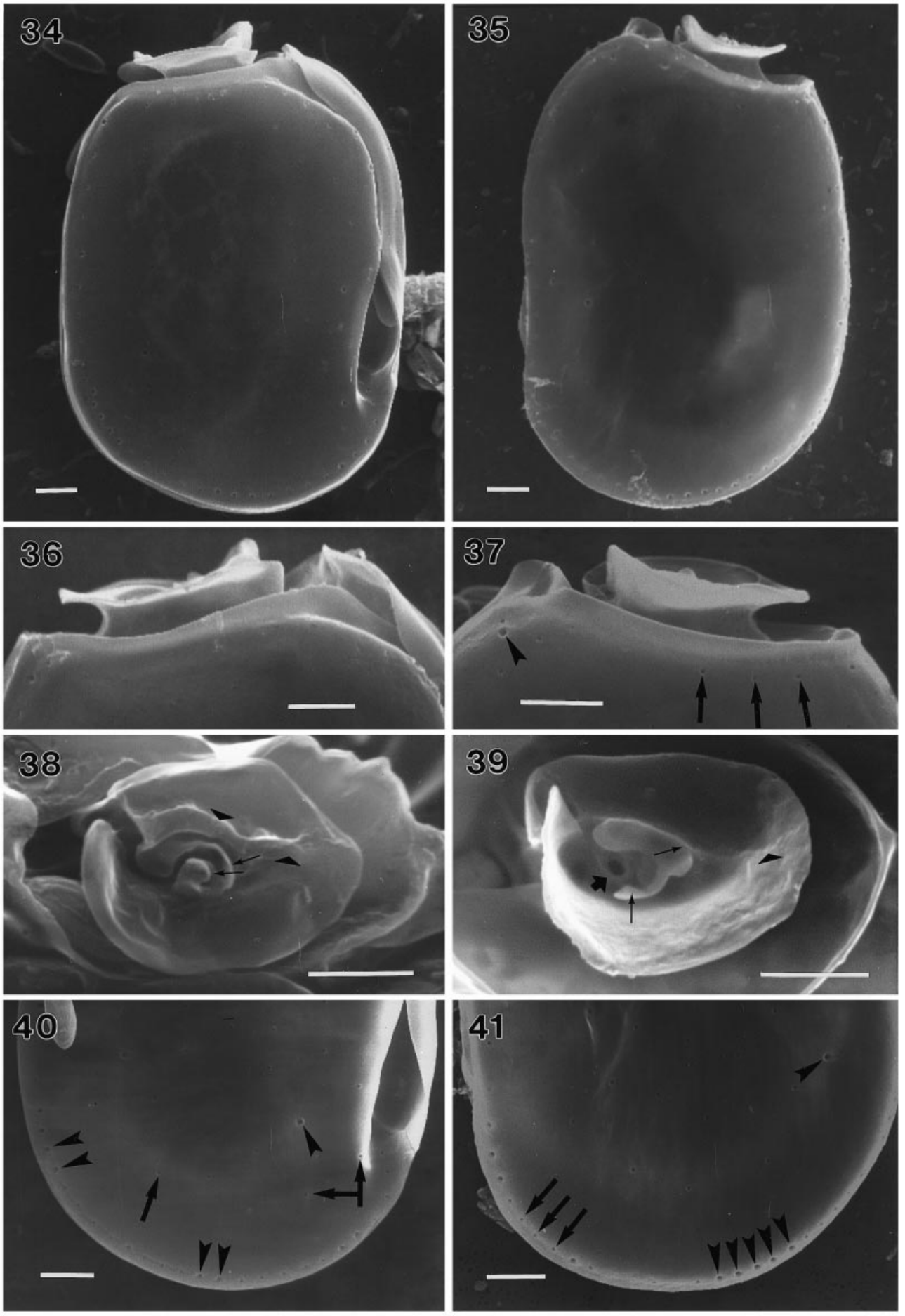
Sinophysis grandis Hoppenrath, sp. nov. (Figs 7–9, 34–41)

Descriptio: Cellulae paene rectangulares angulis rotundis, 50·0–59·0 μm longae et 35.0–41.5 μm latae. Proportio longitudinis/latitudinis 1·29–1·61. Epithecae latitudo (dorsoventralis) 12·0–17·0 μm. Longitudo sulci c. longitudo dodrans cellulae. Globi magnorum pororum in ordine positi in marginale ordine pororum (posteriores) et magni pori singuli temere distributi.

Locality: Tidal sand flat (south of List Harbour) on the island of Sylt, Germany.

Holotype: Figure 34.

Figs 24–33. Scanning electron micrographs of *Sinophysis stenosoma* sp. nov.
Fig. 24. Right lateral view. Figs 25, 26. Left lateral view. Fig. 27. Right lateral view of the epitheca. Fig. 28. Left lateral view of the epitheca. Fig. 29. Nearly apical view of the epitheca. Figs 30, 31. Apical view of the epitheca. Fig. 32. Right lateral, antapical hypotheca detail. Fig. 33. Left lateral, antapical hypotheca detail. Asterisk, the third upright projection; small arrows, two parallel, upright, anterior projections; large arrows, small pores; arrowheads, large pores. Scale bars represent 5 μm.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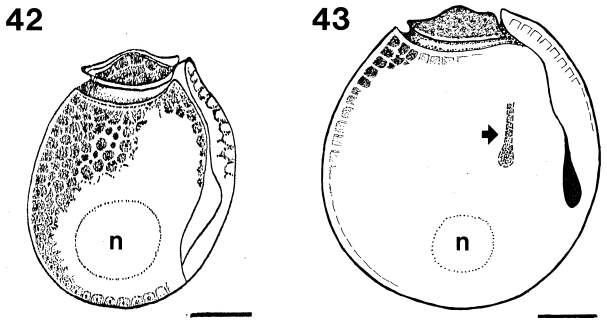
ETYMOLOGY: 'grandis' = large in Latin, being the largest known *Sinophysis* species.

Cells are roughly rectangular with roundish edges, 50·0–59·0 μm long, and 35·0–41·5 μm wide (dorso-ventrally), with a length/width ratio of 1·29–1·61 (Figs 7–9). They are flattened laterally. The epicone is the largest found in *Sinophysis*, 12·0–17·0 μm wide (dorso-ventrally), surrounded by a weakly developed smooth girdle list (Figs 34–37), and less tilted to the dorsal side (Figs 8, 9, 34). The epitheca is divided into two asymmetrical plates (Figs 38, 39). The left plate possesses two parallel, curved, upright projections (Fig. 38). There is a large apical pore below the inner projecton (Fig. 39). The corpulent hypocone has nearly parallel sides and is more or less rounded posteriorly (Figs 34, 35). The deep girdle is bounded by narrow lists (Figs 36, 37). The sulcus is located on the right side and has a length of about three-quarters the cell length (Figs 7–9, 34). It is partly covered by a sulcal list (Fig. 34). The cell is colourless and usually contains numerous colourless small granules, in addition to coloured and colourless large vacuoles (Figs 8, 9). Chloroplasts were not detected. One large pusule is situated anteriorly (Fig. 9). The oval nucleus is located posteriorly in the hypocone (Figs 7, 9). The thecal surface is smooth with a distinct pore pattern. There are two pore types: small (0·3–0·4 μm) and large (0·5–0·8 μm). The small pores are randomly distributed over the thecal surface, more densely than in *Sinophysis ebriolum*, and lie in a marginal row relatively close together (Figs 7, 34, 35). Single large pores are distributed irregularly and groups of large pores lie in the marginal row (Figs 7, 40, 41).

Sinophysis grandis showed no seasonality and only a few cells were seen. Most cells were detected in the oxic surface sediment, but individuals were also recorded in grey 'sulphidic' sediment. It occurred in all eulittoral regions, with highest abundance at the bend between the steep beach face and the gentle flat in summer (June and July). It was never recorded at sublittoral stations.

Sinophysis grandis has been reported previously. It was illustrated by SEM as *Sinophysis ebriolum* by Saunders & Dodge (1984, p. 274, figs 8–11). The two light micrographs by Hansen & Larsen (1992, p.109, figs. h,i) identified as *Sinophysis ebriolum* also look very much like *Sinophysis grandis*. Baillie's (1971) *Sinophysis* species is problematic. The sizes indicated in the text do not fit with the figures, but the light micrograph resembles *Sinophysis grandis*.

DISTRIBUTION: Sandy beaches around the British Isles and in northern France (Saunders & Dodge, 1984); open water of the Kattegat, Denmark (Hansen & Larsen, 1992); tidal sandflats of the North German Wadden Sea (present study).



Figs 42–43. Fig. 42. Line drawing of *Sinophysis microcephalus*. n, nucleus. Scale bar represents 10 μm. Fig. 43. Line drawing of *Sinophysis canaliculata*. n, nucleus; arrow, long, narrow, thecal cut, only visible on the left hypothecal plate. Scale bar represents 10 μm.

Sinophysis microcephalus Nie *et* Wang 1944

This species has a subcircular body in lateral view, 40–44 μm long, and is compressed laterally. The convex, small epitheca is nearly perpendicular to the longitudinal axis. The left epithecal plate bears two slightly curved, upright anterior projections. The girdle is slightly descending and the sulcus nearly reaches the antapex. Cingular lists and one sulcal list are present. The cell is covered with plates having a highly areolated surface. *Sinophysis microcephalus* is heterotrophic and contains numerous colourless bodies. The large nucleus is located posteriorly. The line drawing (Fig. 42) reproduces informations from the literature.

DISTRIBUTION: Surface water of the Shin-tsuen Kong, Hainan Region, South China Sea (Nie & Wang, 1944); open water of the Pacific Ocean of Mexico (Hernandez-Becerril, 1988); floating detritus of Twin Cays, Belize, Central America (Faust, 1993).

Sinophysis canaliculata Quod *et al*., 1999

This species resembles *Sinophysis microcephalus* because of its surface ornamentation and shape, but it is more round and larger (45–57 μm long) and the sulcus is shorter. There is a long, narrow, thecal cut in the middle of the left hypothecal plate. The nucleus is located posteriorly. The species is heterotrophic. The line drawing (Fig. 43) reproduces information from the original description of *S. canaliculata* (Quod *et al*., 1999).

DISTRIBUTION: Sediment or macroalgal turf surfaces, reef of St Leu, La Réunion Island (Quod *et al*., 1999) ; coral rubble, southwestern part of the Indian Ocean (Quod *et al*., 1999).

Conclusions

Three marine, sand-dwelling *Sinophysis* species are described in this study. The two new species, *Sinophysis*

Figs 34–41. Scanning electron micrographs of *Sinophysis grandis* sp. nov. Fig. 34. Right lateral view. Fig. 35. Left lateral view. Fig. 36. Right lateral view of the epitheca and the anterior part of the hypotheca. Fig. 37. Left lateral view of the epitheca and the anterior part of the hypotheca. Figs 38, 39. Apical view of the epitheca. Fig. 40. Right lateral view of the antapical hypotheca. Fig. 41. Left lateral view of the antapical hypotheca. Long arrows, small pores; short arrow, apical pore; small arrows, two parallel, upright projections; long arrowheads, large pores; wide arrowheads, suture. Scale bars represent 5 μm.

stenosoma and *Sinophysis grandis*, occurred together with *Sinophysis ebriolum* but in much lower numbers. The individual species can be distinguished by size, length/width ratio, epitheca size, epithecal microarchitecture, relative sulcal length and thecal pore pattern. Only two further *Sinophysis* species are known. *Sinophysis microcephalus* is the type species of the genus (Nie & Wang, 1944). This tropical species differs from the temperate species in its thecal surface ornamentation (Faust, 1993). *Sinophysis canaliculata*, isolated from the southwestern Indian Ocean, resembles *S. microcephalus* in its surface ornamentation but differs in possessing a long, narrow thecal cut (Quod *et al*., 1999). All known species are colourless (no chloroplasts), heterotrophic (phagotrophic), marine, benthic dinoflagellates. They clearly belong to the order Dinophysales (Sournia, 1986; Fensome *et al*., 1993).

Key to the species of Sinophysis

1a Thecal plates with ornamentation 4
b Thecal plates with a smooth surface 2
2a Cells elongate-ellipsoidal, epitheca cylindrical, crown-like, 5·5–8·0 μm wide *S. stenosoma*
b Cells roughly sack-shaped, epitheca 9–17 μm wide 3
3a Cells small (about 35–45 μm), roughly oval, epitheca 9–12 μm wide *S. ebriolum*
b Cells large (about 50–59 μm), roughly rectangular, epitheca 12–17 μm wide *S. grandis*
4a Cells 40–44 μm long and 33–35 μm wide *S. microcephalus*
b Cells 45–57 μm long and 37–51 μm wide, with a deep, long, narrow thecal cut in the middle of the left hypothecal plate *S. canaliculata*

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