

11-18-2015

# Tursiocola denysii sp. nov. (Bacillariophyta) from the neck skin of Loggerhead sea turtles (*Caretta caretta*)

Thomas A. Frankovich

*Department of Biological Sciences and Southeast Environmental Research Center, Florida International University,*  
tfrankov@fiu.edu

Michael J. Sullivan

Nicole I. Stacy

*University of Florida*

Follow this and additional works at: [https://digitalcommons.fiu.edu/merc\\_fac](https://digitalcommons.fiu.edu/merc_fac)



Part of the [Life Sciences Commons](#)

## Recommended Citation

Frankovich, Thomas A.; Sullivan, Michael J.; and Stacy, Nicole I., "Tursiocola denysii sp. nov. (Bacillariophyta) from the neck skin of Loggerhead sea turtles (*Caretta caretta*)" (2015). *Center for Coastal Oceans Research Faculty Publications*. 29.  
[https://digitalcommons.fiu.edu/merc\\_fac/29](https://digitalcommons.fiu.edu/merc_fac/29)

This work is brought to you for free and open access by the Institute of Water and Environment at FIU Digital Commons. It has been accepted for inclusion in Center for Coastal Oceans Research Faculty Publications by an authorized administrator of FIU Digital Commons. For more information, please contact [dcc@fiu.edu](mailto:dcc@fiu.edu).



## *Tursiocola denysii* sp. nov. (Bacillariophyta) from the neck skin of Loggerhead sea turtles (*Caretta caretta*)

THOMAS A. FRANKOVICH<sup>1,\*</sup>, MICHAEL J. SULLIVAN<sup>2</sup> & NICOLE I. STACY<sup>3</sup>

<sup>1</sup>Florida International University, Florida Bay Interagency Science Center, 98630 Overseas Highway, Key Largo, FL 33037, USA

<sup>2</sup>130 Martinique Drive, Madison, MS 39110, USA, E-mail: [sullivanmi@gosaints.org](mailto:sullivanmi@gosaints.org)

<sup>3</sup>University of Florida, College of Veterinary Medicine, Large Animal Clinical Sciences, Gainesville, FL 32641, USA,

E-mail: [stacyn@ufl.edu](mailto:stacyn@ufl.edu)

\* Corresponding author (E-mail: [frankovich@virginia.edu](mailto:frankovich@virginia.edu))

### Abstract

*Tursiocola denysii* sp. nov. is described from the dorsal neck skin of loggerhead sea turtles (*Caretta caretta*), bringing the total number of known species in the genus *Tursiocola* to eight. A gradient of striae density on the valve face, the low length: width ratio of the valves, radiate striae at mid-valve, and a second partial row of pores on the valvocopulae are characteristics that expand the range of morphological diversity within the genus. The different morphology of the pars interior and the pars exterior of the valvocopula is described for the first time in the genus. *T. denysii* accounted for up to ca. 40% of all diatom valves on the skin of loggerhead turtles. This is the first report of a new epizoic diatom species from the skin of loggerhead sea turtles.

**Keywords:** *Tursiocola*, biogeographical distribution, epidermal diatoms, Florida, new species, morphology, SEM

### Introduction

Aquatic animals provide suitable habitats on their skin, shells, and feathers for the development of diatom communities (see Tiffany 2011 for review). The existence of epizoic diatom floras dominated by a few unique taxa (Hart 1935, Nemoto 1956, Holmes 1985, Holmes *et al.* 1989, 1993a, b, Denys 1997, Majewska *et al.* 2015) suggests that the micro-environments on these biotic surfaces differ from that of other substrates, but the specific factors that favor these unique diatom assemblages remain unknown. Familiar, widely distributed benthic species are often observed only in very low abundance in epizoic communities, suggesting that they are incidental and originate from the animal's surrounding environment (Nemoto 1956, Denys 1997).

The degree of host specificity, endemism, and the biogeographical distribution of epizoic taxa are largely unknown due to the scarcity of epizoic diatom investigations. Diatom species of the epizoic genera *Epipellis* Holmes (1985: 53), *Bennettella* Holmes (1985: 48), *Tursiocola* Holmes, Nagasawa & Takano (1993a: 5) and *Epiphallina* Holmes, Nagasawa & Takano (1993a: 4), a group commonly referred to as the “ceticolous taxa”, have been observed on a few different whale and porpoise species (Holmes 1985, Holmes *et al.* 1989, 1993a, 1993b, Denys 1997), one of the best studied groups of host animals. Recently, new species of *Tursiocola* have been described from a freshwater turtle (Wetzel *et al.* 2012) and a euryhaline West Indian manatee (Frankovich *et al.* 2015), expanding the range of *Tursiocola* into freshwater environments and the variety of known host animals.

As part of an effort to increase the diversity of host animals examined for their epizoic diatom assemblages, we recently observed an unknown diatom taxon from the dorsal neck skin of loggerhead turtles *Caretta caretta*. Scanning electron microscopy (SEM) revealed this entity to be an undescribed species of the genus *Tursiocola*, as indicated by the presence of the unique “butterfly structure” on the interior of the valves. The present study describes this new species as *Tursiocola denysii*, and discusses affinities and differences with other described species within the genus. This is the first report of a new epizoic diatom species from the skin of loggerhead sea turtles.

## Materials and Methods

During an annual survey of sea turtle populations in Florida Bay, 24 June–1 July 2015, epizoic diatoms were opportunistically sampled from loggerhead sea turtles that were captured from the marine waters (salinity *ca.* 38 psu) of western Florida Bay (24° 55' 18" N, 80° 48' 28" W). Dorsal areas of the neck and lateral carapace of the turtles were cleaned for blood collection using cotton-tipped applicators (Fisherbrand, Fishersci.com). Epibiota collected on the cotton-tipped applicators applied to these two areas were sampled separately from individual turtles. Subsequent LM examination revealed an abundance of an undescribed *Tursiocola* species from the neck samples from the four individual turtles that have been analyzed so far. The description of the new *Tursiocola* species and the identification of co-occurring taxa are limited to these 4 neck samples from 4 individual turtles at the present time because of their higher relative abundances in the neck samples

In the laboratory, the cotton tips of the applicators were removed using a razor blade and then oxidized for diatom examination. The cotton fibers of the applicator tip and epizoic organic material were removed by oxidation in 100 ml of boiling 30% nitric acid followed by addition of potassium dichromate when 50 ml of acid remained. Cleaned diatoms were settled from the mixture for a minimum of 6 h and the remaining acid solution decanted. The settled diatoms were rinsed with deionized water. The rinsing/settling/decanting process was repeated six times until the solution reached a neutral pH.

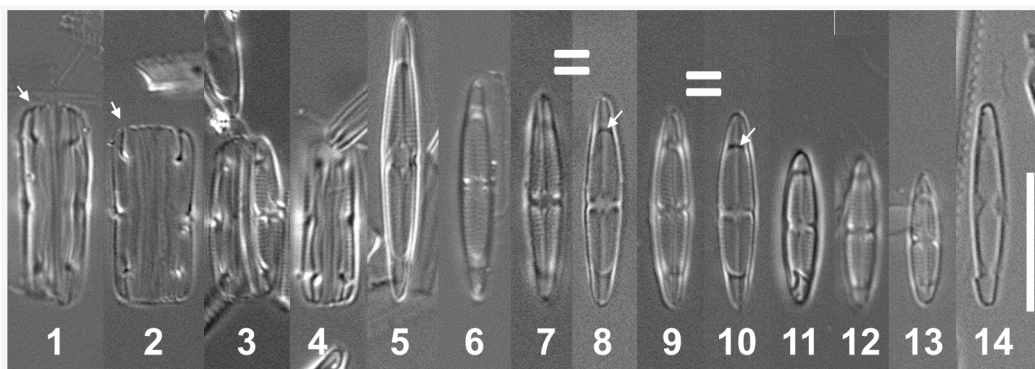
For light microscopy (LM), cleaned diatoms were air-dried on cleaned No. 1 coverslips which were then mounted onto glass slides using Naphrax® (The Biology Shop, New South Wales, Australia). LM analyses were made using differential interference contrast (DIC) and an oil immersion planapochromatic lens (NA = 1.40) on a Nikon E600 microscope (×600 and ×1200 magnification) equipped with a Leica DFC425 digital camera. Diatom morphometrics were determined using Leica Application Suite version 3.7 imaging software. The relative abundances of individual taxa were determined from the holotype and paratype slides of *Tursiocola denysii* by identifying and counting 255–508 diatom valves along arbitrary linear transects.

For comparative purposes, LM images produced from the holotype slide (BRM! NA1/77) of *Stauroneis olympica* Hustedt [= *Tursiocola olympica* Hustedt (1952: 287) Holmes, Nagasawa & Takano (1993a: 6)], containing specimens from a humpback whale caught in the Ross Sea, Antarctica (slide BRM! NA/77), and from the isotype slide (BRM! ZU4/76) of *Tursiocola staurolineata* Denys (1997: 8), containing specimens from a sperm whale stranded on the Belgium coast, were also examined.

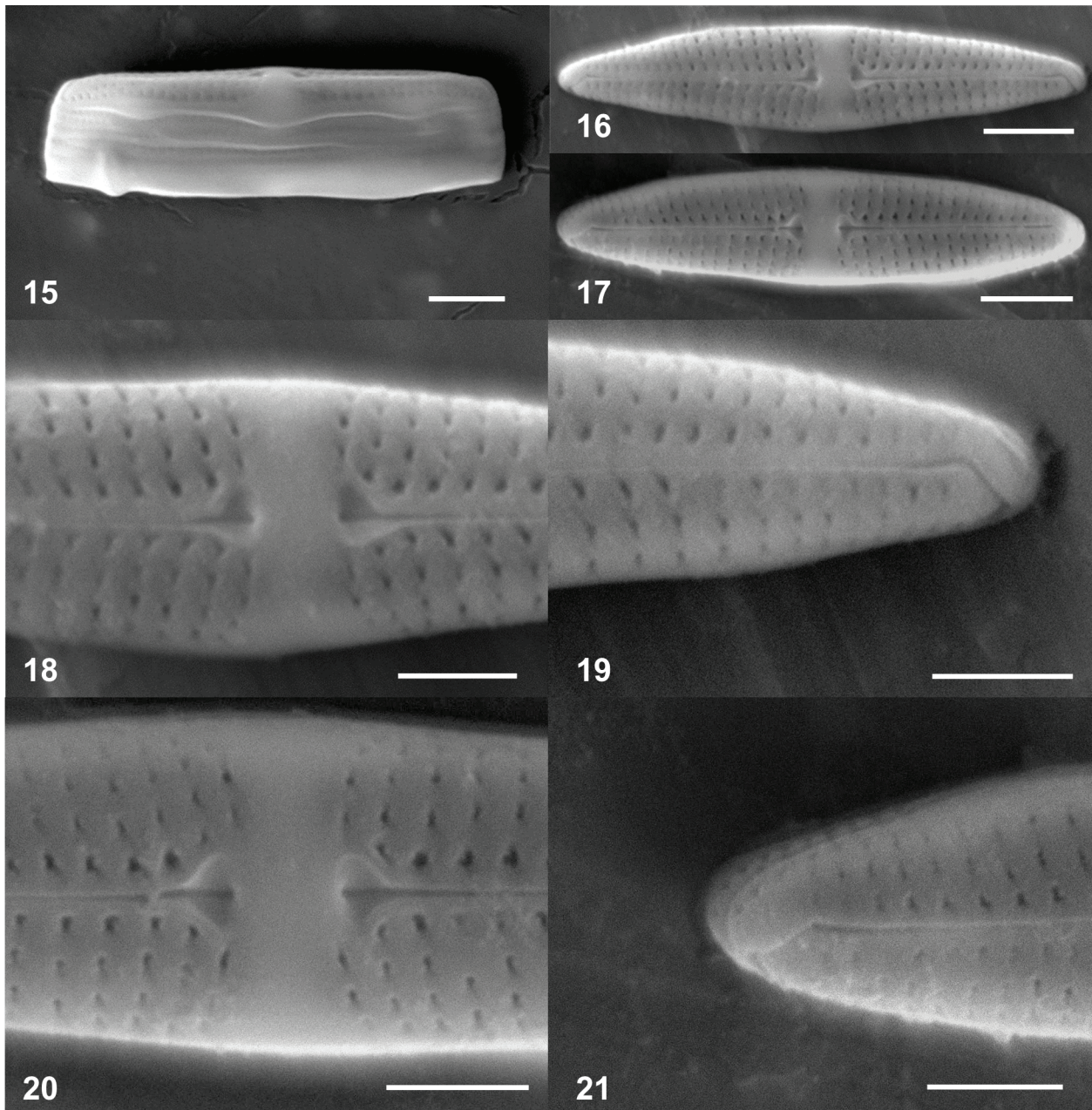
For scanning electron microscopy (SEM), subsamples of the cleaned material were dried onto aluminum stubs and sputter-coated with gold. SEM analyses were made with a JEOL-5900LV scanning electron microscope operated at 15–25 kV. Diatom terminology followed Round *et al.* (1990) and Denys (1997).

## Results

### *Tursiocola denysii* Frankovich & M.J. Sullivan, *sp. nov.* (Figs 1–30)



**FIGURES 1–14.** *Tursiocola denysii*. Type population, LM. 1–4. Frustules in girdle view showing size range and morphological variation. Arrows in Figs 1, 2, 8, 10 indicate pseudosepta. 5–13. Specimens in valve view showing size range. 14. Valvocopula. Scale bar: Figs 1–14 = 10  $\mu$ m. = indicates same specimen at different foci.

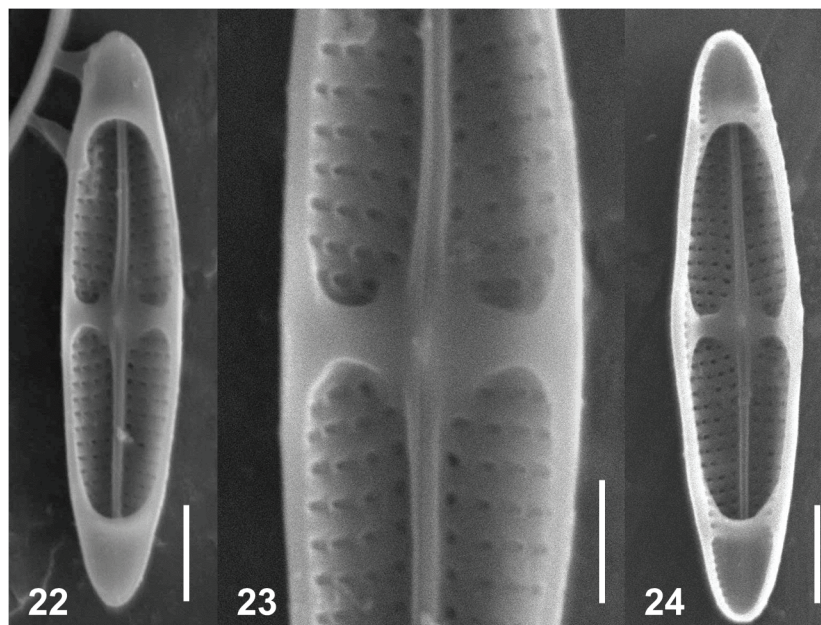


**FIGURES 15–21.** *Tursiocola denysii*. Type population, SEM. 15. Single valve with attached cingulum in girdle view. Note undulate mantle margin with three tabs. 16–17. External view of whole valves showing axial and central areas. 18. Detail of external central area of valve depicted in Fig. 16 showing bow tie-shaped stauros and proximal raphe ends within spathulate grooves. 19. Detail of external valve apex of valve depicted in Fig. 16 showing hooked distal raphe end obscured by overhanging siliceous flap. 20. Detail of external central area of valve depicted in Fig. 17 showing areolae structure. 21. Detail of external valve apex of valve depicted in Fig. 17. Scale bars: Figs 15–17 = 2  $\mu$ m, Figs 18–21 = 1  $\mu$ m.

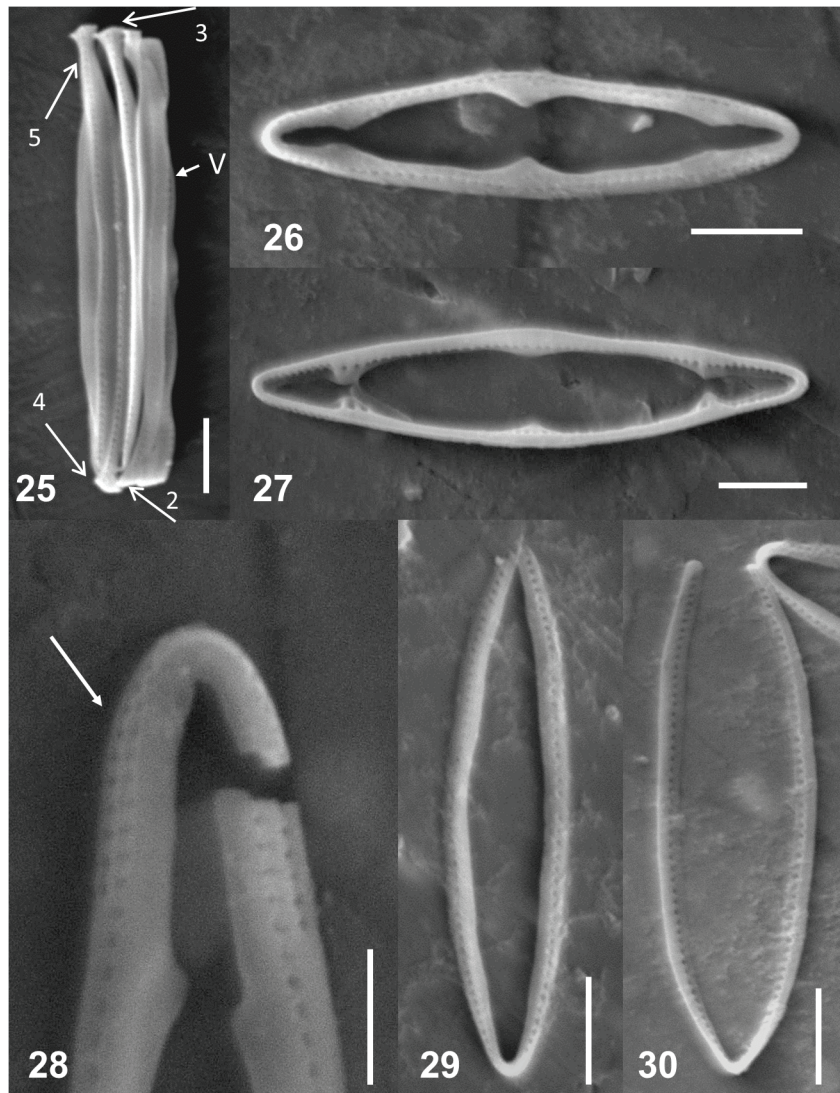
LM morphology: frustules are rectangular in girdle view with bluntly rounded ends and porose girdle copulae (Figs 1–4). Pseudosepta are evident in girdle view and are deflected towards the interior of the frustule at their termination (Figs 1–2, 4). Valves are isopolar to slightly heteropolar and narrowly lanceolate, tapering gradually from the middle of the valves to the juncture of the pseudosepta and the valve margin and then tapering more rapidly towards sub-acute apices (Figs 5–13). Valve morphometrics are as follows: length 10–20  $\mu$ m, width 2.0–2.9  $\mu$ m, length to width ratio 4.1–7.4,  $n = 30$ . Heteropolarity of the valve, when present, is evidenced by small differences in the lengths of the valve halves and differences in the shape of the apices (*i.e.*, one valve apex, usually the shorter valve half, may be more bluntly rounded than the opposing end). The valve face is slightly asymmetric around a narrow axial area with 1/2 of the valve face slightly wider than the other (Figs 5–7, 9, 11–13). The raphe is straight and the central area is formed by a wide stauros that extends to the valve margins (Figs 5, 7, 9, 11–13). The transapical striae are radiate around the central area becoming undiscernible in LM at the apices, 26–34 in 10  $\mu$ m,  $n = 30$  (Figs 5, 7, 9, 11–13). By focusing through the valve, each pseudoseptum

can be seen to extend over *ca.* 1/6 of the valve length from the apices and then continues as narrow strips along the valve margin. These strips then widen at the central area where they fuse with the stauros (Figs 8, 10). SEM morphology: Externally, the valve face has uniseriate transapical striae composed of transapically elongated areolae (Figs 16–21). The striae are radiate and more distantly spaced in the middle of the valve, 26–34 in 10  $\mu\text{m}$ ,  $n = 5$  (Figs 16–18, 20), becoming less radiate to parallel and more closely spaced towards the apices, 37–43 in 10  $\mu\text{m}$ ,  $n = 5$  (Figs 16–17, 19, 21). The striae extend partly onto the valve mantle terminating before a hyaline mantle margin (Fig. 15). The areolae are arranged in slightly undulate longitudinal rows along the transapical axis, 33–37 areolae in 10  $\mu\text{m}$ ,  $n = 5$  (Figs 16–21). The valve mantle slopes steeply without a sharp transition between the valve face and mantle (Fig. 15). The mantle margin is undulate (Fig. 15). A straight and narrow rib lies within the axial area (Figs 16–21). The raphe is slightly eccentric and straight (Figs 16–21). A large, non-punctate, rectangular to bow tie-shaped stauros that extends to the valve margins is located in the central area (Figs 16–18, 20). The external proximal raphe ends are straight, opening into asymmetric spatulate grooves, and terminate where the stauros extends towards the valve margin (Figs 16–18, 20). The distal raphe ends are hooked but are obscured by overhanging siliceous flaps that bend towards the same side of the valve at both apices (Figs 19, 21). Internal views of the valve reveal the butterfly-like structure that connects the pseudosepta to the central area and stauros (Figs 22–24). The pseudosepta extend from the apices as siliceous plates for *ca.* 1/6 of the valve length, and then continue as narrow strips that run along the valve margins before expanding into the “wings” of the butterfly-like structure in the central area (Figs 22–24). The wings fuse with the large oval central area close to the raphe sternum (Fig. 23). The wings of the butterfly widen at their junction with the central area forming narrow concave “wings” on each side of the raphe sternum (Figs 22–24). Internally, the raphe slits open along the middle of a strong siliceous rib that widens slightly in the central area (Figs 22–24). A single knob-like structure is present on the rib at the valve center (Figs 22–24). The bands of the cingulum are differentiated into two types: closed valvocopulae (Figs 25–27) and multiple copulae (up to 4 observed) that are open at one end (Figs 25, 29, 30). The valvocopula is flanged inward on the pars interior where it attaches to the valve (Fig. 26). The flange widens into 3 pairs of opposing tabs (Figs 26–27). One pair of tabs is located at the valve middle underneath the butterfly structure, whereas the other two pairs are located near the poles underneath the valve where the pseudosepta start to widen at the valve apices (Figs 24, 26–27). The valvocopula has a single row of ovoid pores around the perimeter, pore density = 37–45 in 10  $\mu\text{m}$  (Figs 26–28), and a second row of similarly spaced pores located abvalvar to the complete row only at the poles (Fig. 28). Views of the pars exterior side of the valvocopula show a thickening of the polar tabs and extension of the pores through the tabs (Figs 24, 27). The copulae have only a single row of ovoid pores, pore density = 39–54 in 10  $\mu\text{m}$ ,  $n = 2$  (Figs 29–30).

**Type:**—UNITED STATES. Florida: Florida Bay, samples removed from the skin in the dorsal neck area of loggerhead sea turtles *Caretta caretta*, 24° 55' 01" N, 80° 48' 28" W, *B.A. Stacy*, 24 June 2015 (holotype CAS! 223049, illustrated as Figs 1–4, 6, 12, 15–30, paratypes ANSP! GC59142, BM! 101 808, illustrated as Figs 7–10, 14, BRM! ZU10/31, Figs 5, 11, 13).



**FIGURES 22–24.** *Tursiocola denysii*. Type population, SEM. 22. Internal view of whole valve showing pseudosepta and butterfly structure. 23. Detail of butterfly structure and internal central area with one knob on the raphe rib. 24. Internal view of whole valve with attached valvocopula. Note one central and 2 polar tabs underlying undulate valve margin on each side of the valve. Scale bars: Figs 22, 24 = 2  $\mu\text{m}$ , Fig. 23 = 1  $\mu\text{m}$ .



**FIGURES 25–30.** *Tursiocola denysii*. Type population, SEM. 25. Cingulum showing valvocopula (V) with four attached abvalvar copulae (numbered arrows) in side view. 26. Pars interior of valvocopula showing flanged margin and three pairs of opposing tabs. 27. Pars exterior of valvocopula showing thickening of the two pairs of polar tabs. 28. Detail of apex of valvocopula showing second row of abvalvar pores (arrow) located only at the poles. 29–30. Copulae showing open ends and only a single row of pores. Scale bars: Figs 25–27, 29–30 = 2  $\mu$ m, Fig. 28 = 1  $\mu$ m.

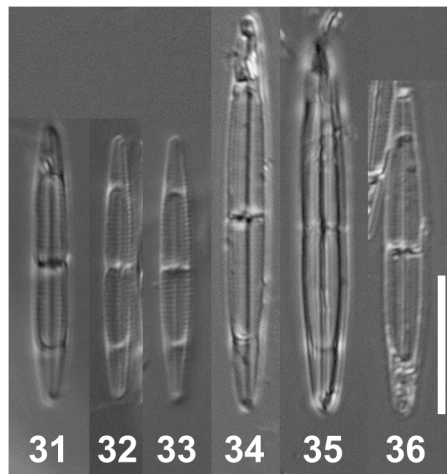
**Etymology:**—the epithet honours Dr. Luc Denys (Research Institute for Nature and Forest, Brussels, Belgium), in recognition of his important research on epizoic diatoms.

**Taxa relative abundances:**—46 taxa from 23 genera were observed from the neck skin of 4 loggerhead turtles. The relative abundances of the newly described *Tursiocola denysii* ranged from 5 to 43%. The most relatively abundant taxon was *Hyalosynedra* cf. *laevigata* (Grunow 1877: 166) D.M. Williams & F.E. Round (1986: 316), comprising 2–62% of the valve counts. The next most relatively abundant taxon was an undescribed species of *Poulinea* Majewska, De Stefano & Van de Vijver (in press), comprising 13–47% of the valve count. We were unable to identify ca. 7% of the valves to genus or species. Only four other taxa (i.e., *Mastogloia cuneata* (Meister 1937: 268) Simonsen (1990: 134), *Navicula* sp., *Achnanthes* cf. *pseudogroenlandica* Hendey (1964: 177), and *Brachysira aponina* Kützing (1836: 3)) exhibited mean relative abundances >1%. The remaining taxa observed are common benthic forms. Only a single valve of *Tursiocola ziemanii* Frankovich & M.J. Sullivan in Frankovich *et al.* (2015: 34) of the seven previously described *Tursiocola* species was observed in the material.

*Tursiocola olympica* (Hustedt) Holmes, Nagasawa & Takano (Figs 31–33)

LM morphology: valves are isopolar to slightly heteropolar and linear to narrowly lanceolate, tapering gradually from the middle of the valves towards sub-acute apices (Figs 31–33). Valve morphometrics are as follows: length 19–20  $\mu\text{m}$ , width 2.1–2.2  $\mu\text{m}$ , length to width ratio 8.7–9.3,  $n = 5$ . Heteropolarity of the valve, when present, is evidenced by differences in the shape of the apices (*i.e.*, one valve apex may be more bluntly rounded than the opposing end). The raphe is straight and the central area is formed by a stauros that extends to the valve margins (Figs 31–33). The transapical striae are parallel to slightly radiate, 29–30 in 10  $\mu\text{m}$ ,  $n = 5$  (Figs 31–33). By focusing through the valve, each pseudoseptum can be seen to extend over ca. 1/5 of the valve length from the apices (Figs 31–33).

**Type:**—ANTARCTICA. Ross Sea, specimens from the skin of a humpback whale, 75° S 160° W, February 1951 (holotype BRM! NA1/77).



**FIGURES 31–36.** *Tursiocola olympica* and *T. staurolineata* type populations, LM, specimens in valve view showing valve shape and size range. 31–33. *Tursiocola olympica* (holotype slide BRM! NA1/77). 34–36. *Tursiocola staurolineata* (isotype slide BRM! ZU4/76), Scale bar = 10  $\mu\text{m}$ .

*Tursiocola staurolineata* Denys (Figs 34–36)

LM morphology: valves are isopolar to slightly heteropolar and linear to narrowly lanceolate, tapering gradually from the middle of the valves towards sub-acute apices (Figs 34–36). Valve morphometrics are as follows: length 23–29  $\mu\text{m}$ , width 2.6–2.8  $\mu\text{m}$ , length to width ratio 8.3–10.5,  $n = 5$ . The raphe is straight and the central area is formed by a narrow stauros that extends to the valve margins (Figs 34–36). The transapical striae are parallel in the middle of the valve, 30–32 in 10  $\mu\text{m}$  but sometimes undiscernible,  $n = 4$  (Figs 34–36). By focusing through the valve, each pseudoseptum can be seen to extend over ca. 1/5 of the valve length from the apices (Figs 34–36).

**Type:**—BELGIUM. Lombardsijde, specimens from the skin of a sperm whale, 51° 9' N 2° 44' E, November 1994 (isotype BRM! ZU4/76).

## Discussion

The new species, *Tursiocola denysii*, is morphologically similar to other species in the genus with its narrow linear to lanceolate valves, well-developed pseudosepta, stauros, internal raphe slits along the center of strong siliceous ribs, and uniseriate striae (Holmes *et al.* 1993a). All *Tursiocola* species live either on the skin of aquatic mammals (Denys 1997, Frankovich *et al.* 2015) or the skin and carapaces of freshwater (Wetzel *et al.* 2012) and marine turtles (present study, Mariska Brady pers. comm.). The presence of the butterfly structure in the internal central area of the valves of *T. denysii* is a morphological feature distinct to the genus *Tursiocola* (Holmes *et al.* 1993a) that clearly places the new species within the genus.

*Tursiocola denysii* exhibits several morphological characteristics that distinguish it from other similar *Tursiocola* taxa (Table 1, see also table 2 in Frankovich *et al.* 2015 for detailed comparison of all previously described species). *Tursiocola denysii* is most similar to *T. olympica* (Figs 31–33, see also Hustedt 1952, Holmes *et al.* 1993a, Denys

1997) and *T. staurolineata* (Figs 34–36). *Tursiocola denysii* shares the following characteristics with *T. olympica* and *T. staurolineata*: overlapping size ranges and striae densities, straight external proximal raphe ends, and hooked external distal raphe ends (Table 1). The following morphological characteristics of *T. denysii* distinguish it from *T. olympica* and *T. staurolineata*: increasing striae density from the valve middle to apex, the radiate striae at mid-valve, lower length:width ratio of the valves (4.1–7.3), and a large cingulum comprised of a distinct valvocopulae that is differentiated from the copulae (Table 1). The shape of the stauros also differs between these three species. The stauros of *T. denysii* is wide and rectangular to bow tie-shaped, while that of *T. staurolineata* is narrow and decreases in width towards the mantle and that of *T. olympica* is wide but strictly rectangular (Table 1).

**TABLE 1.** Comparison of morphological characteristics and habitats of *Tursiocola denysii*, *T. staurolineata*, and *T. olympica*.

	<i>Tursiocola denysii</i>	<i>Tursiocola staurolineata</i>	<i>Tursiocola olympica</i>
Length (µm)	10–20	15–35	14–30
Width (µm)	2.0–2.9	1.5–4.0	1.5–2.4
Length: width ratio	4.1–7.4	6.5–12.2	7.1–11.7
Striae in 10 µm	26–34 in middle 37–43 towards apices	28–36	29–38
Striae pattern	Radial at mid-valve, becoming finally parallel at apices	Parallel in middle, becoming slightly radiate, finally convergent at apices	Parallel in middle, becoming slightly radiate, finally convergent at apices
Areolae	Fine, slit-like to oval	Circular	Circular
Valve outline	Narrowly lanceolate with sub-acute apices	Linear to narrowly lanceolate with sub-acute apices	Linear to narrowly lanceolate with sub-acute apices
Symmetry	Isopolar to slightly heteropolar	Isopolar to slightly heteropolar	Slightly heteropolar
External central area	Large, indistinguishable from stauros	Small, round	Large, rectangular
Stauros	Wide, rectangular to bow tie-shaped	Narrow and narrowing towards mantle	Very broad, rhombic
External proximal raphe ends	Straight, opening into spathulate grooves	Straight, slightly expanded	Straight, expanded
External distal raphe ends	Strongly hooked but obscured by overhanging siliceous flaps	Strongly hooked with angular bend toward secondary side	Strongly hooked toward secondary side
Butterfly structure	Narrow, concave wings, oval central area	Narrow concave wings, oval central area	Narrow concave wings, circular central area
Internal knobs	1	2	1
Cingulum	Closed valvocopulae with 1 complete row and 2 <sup>nd</sup> partial row of pores, Up to 4 abvalvar copulae with 1 row of pores	2 closed copulae with 2 rows of aligned pores	Copulae with 2 rows of pores
Habitat	Marine	Marine	Marine
Host animals	Loggerhead sea turtles	Sperm whale, Dall's porpoise	Humpback, blue, and sperm whales, Dall's porpoise
References	Present study	Denys (1997), present study	Hustedt (1952), Nemoto (1956), Holmes <i>et al.</i> (1993a), Denys (1997), present study



The five other *Tursiocola* species are unlikely to be confused with *T. denysii*. *Tursiocola costata* Frankovich & M.J. Sullivan in Frankovich *et al.* (2015: 40) is unique within the genus by exhibiting convergent striae with prominent raised interstriae costae on the external valve face (Frankovich *et al.* 2015). *Tursiocola omurai* (Nemoto 1956: 110) Denys (1997: 7) is also easily differentiated from all other species within the genus by the distinct median constrictions of the species' valves (Nemoto 1956). *Tursiocola podocnemicola* Wetzel, Van de Vijver & Ector (2012: 2) is another small-celled species, but can be differentiated from *T. denysii* by the almost parallel striae and deflected external central raphe ends of the former (Wetzel *et al.* 2012). *Tursiocola ziemanii* also exhibits deflected external central raphe ends and also has a larger observed size range (Frankovich *et al.* 2015) than that of *T. denysii*. *Tursiocola varicopulifera* Frankovich & M.J. Sullivan in Frankovich *et al.* (2015: 37) and *T. denysii* are the only species of the genus possessing large, complex cingula, but one is unlikely to confuse the two taxa because of the much larger size range of *T. varicopulifera* (31–57 µm) (Frankovich *et al.* 2015). The valvocopulae are also structured differently. *T. denysii* has a narrow, closed valvocopula with one complete row of ovoid pores and a second partial row located abvalvar of the complete row only at the poles. In contrast, *T. varicopulifera* has a wide valvocopula open at one end with 2 rows of transapically elongated pores (Frankovich *et al.* 2015).

*Tursiocola* species have now been found on cetaceans, a freshwater turtle, a sea turtle, and a manatee. To date the epizoic diatom assemblages on these four different groups of host animals differ greatly from each other suggesting some degree of host specificity within the genus. *T. olympica*, *T. omurai* and *T. staurolineata* have been observed on whales and porpoises (Hustedt 1952, Nemoto 1956, Holmes *et al.* 1993a, Denys 1997), and may represent true "ceticolous taxa". *Tursiocola ziemanii*, *T. varicopulifera* and *T. costata* were abundant on a West Indian manatee (Frankovich *et al.* 2015), while *T. podocnemicola* and *T. denysii* were observed on the freshwater turtle *Podocnemis erythrocephala* (Wetzel *et al.* 2012) and the marine turtle *Caretta caretta* (present study), respectively. None of the ceticolous *Tursiocola* taxa have been observed on the turtle or manatee hosts, and conversely, none of the *Tursiocola* species observed on the manatee and turtles have been observed in abundance on host animals different from which they were originally described. A single valve of *T. ziemanii* was observed in the present study from the skin samples of the loggerhead turtles. The ceticolous *Tursiocola* taxa and the other *Tursiocola* species observed on the skin of the West Indian manatee and the loggerhead sea turtle are generally abundant in their assemblages. A similar low species number and dominance by a few unique diatom taxa was recently observed on the carapaces of olive ridley sea turtles (*Lepidochelys olivacea*) (Majewska *et al.* 2015). These observations suggest unique environmental and preferred habitat conditions on the skin and carapace surface that promotes the development of exclusively epizoic taxa and prevents the development of diatom assemblages more characteristic of surrounding benthic environments. Interestingly, *Tursiocola* species were not observed on the carapaces of olive ridley sea turtles from the Pacific coast of Costa Rica (Majewska *et al.* 2015) suggesting the possibility of host-specificity of *Tursiocola* taxa among sea turtle species or that diatom species assemblages occurring on the skin differ from that occurring on the carapace. The limited number of host animal species studied, the few individuals of the animal species sampled, and the limited geographic range of epizoic investigations do not permit a definitive conclusion of host-specificity or endemism at this time. Increased study of epizoic diatom communities on a wider variety of possible host animals across larger geographical areas is needed.

The loggerhead sea turtle is one of seven sea turtle species world-wide and is found within temperate to tropical regions of the Atlantic, Pacific, and Indian Oceans, and the Mediterranean Sea, and is known to frequent brackish and lower salinity habitats of estuaries and rivers (Dodd 1988). The species is widely distributed throughout its range and nine distinct population segments are recognized for categorization of their conservation status (Conant *et al.* 2009). The largest nesting aggregations occur in Florida USA and Masirah Island, Oman, and less frequent in a number of other countries (Conant *et al.* 2009). Their range overlaps with that of all other sea turtle species. In the marine sampling area of the present study, loggerhead sea turtles are sympatric with green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), and Kemp's ridley turtles (*Lepidochelys kempii*). Bodily contact between host species is believed to be necessary for the exchange of epizoic taxa (Holmes *et al.* 1993a). Such interactions are possible among the sea turtle species given the overlap in geographic range and known hybridization between sea turtle species (Witherington & Witherington 2015).

In a recent study of epizoic diatoms observed on the carapaces of olive ridley sea turtles (*Lepidochelys olivacea*) (Majewska *et al.* in press), two new gomphonemoid genera and species in the Family Rhoicospheniaceae were described: *Chelonicola costaricensis* Majewska, De Stefano & Van de Vijver (in press) and *Poulinea lepidochelicola* Majewska, De Stefano & Van de Vijver (in press) were not observed on the skin of the loggerhead sea turtles of the present study, but an undescribed species of *Poulinea* was abundant. A comprehensive description of the *Poulinea* sp. is being prepared for future publication. A growing interest in the study of epizoic diatom communities should lead to a better understanding of epizoic diatom biogeography and host-specificity.

## An updated artificial key to *Tursiocola* species

1. Copulae differentiated, valvocopulae distinct from abvalvar copulae .....2
- Copulae undifferentiated .....3
2. Valves small, most valves shorter than 20  $\mu\text{m}$  length ..... *Tursiocola denysii*
- Valves large, most valves longer than 30  $\mu\text{m}$  length ..... *Tursiocola varicopulifera*
3. Transapical costae present on external valve face ..... *Tursiocola costata*
- Transapical costae absent .....4
4. Valve outline linear with a distinct median constriction and rostrate apices ..... *Tursiocola omurai*
- Valve outline otherwise .....5
5. External central area diamond-shaped ..... *Tursiocola ziemanii*
- External central area otherwise .....6
6. External proximal raphe ends deflected ..... *Tursiocola podocnemicola*
- External proximal raphe ends straight .....7
7. Stauros very broad ..... *Tursiocola olympica*
- Stauros narrow and narrowing towards mantle ..... *Tursiocola staurolineata*

## Acknowledgments

We thank Brian Stacy of the National Marine Fisheries Service for the collection of diatom samples and Allen Foley of the Florida Fish and Wildlife Conservation Commission and Jennifer Keene of the University of Florida College of Veterinary Medicine for allowing us to receive samples from captured loggerhead turtles during the annual Florida Bay sea turtle survey. We thank the University of Florida Aquatic Animal Health Program for the funding of SEM time at Florida International University, the George Barley Scholars Program of the University of Virginia for the funding of LM instruments, and Sven Holbik and Tom Beasley of the Florida Center for Analytical Electron Microscopy at Florida International University for assistance with SEM. We thank Friedel Hinz, Bánk Beszteri, and Sarah Olischläger for hosting a visit to the Hustedt Diatom Study Center at the Alfred Wegener Institute and for their generous assistance with the examination of type slides from the Hustedt Collection. We thank Dave Rudnick for use of Everglades National Park facilities, and Mariska Brady, Bart Van de Vijver, Luc Denys, and Andrzej Witkowski for sharing images and discussion of similar epizoic diatoms. We also thank two anonymous reviewers and Editor Saúl Blanca Lanza for their constructive comments and recommendations that greatly improved the manuscript. The samples were collected under NMFS permit 14622 and MTP 15-021. This is contribution number 763 from the Southeast Environmental Research Center.

## References

- Conant, T.A., Dutton, P.H., Eguchi, T., Epperly, S.P., Fahy, C.C., Godfrey, M.H., MacPherson, S.L., Possardt, E.E., Schroeder, B.A., Seminoff, J.A., Snover, M.L., Upton, C.M. & Witherington, B.E. (2009) *Loggerhead sea turtle (Caretta caretta) 2009 status review under the U.S. Endangered Species Act*. Report of the Loggerhead Biological Review Team to the National Marine Fisheries Service, August 2009, 222 pp.
- Denys, L. (1997) Morphology and taxonomy of epizoic diatoms (*Epiphallina* and *Tursiocola*) on a sperm whale (*Physeter macrocephalus*) stranded on the coast of Belgium. *Diatom Research* 12: 1–18.  
<http://dx.doi.org/10.1080/0269249X.1997.9705398>
- Dodd Jr., C.K. (1988) Synopsis of the biological data on the loggerhead sea turtle *Caretta caretta* (Linnaeus 1758). *U.S. Fish and Wildlife Service Biological Report* 88 (14): 1–110.
- Frankovich, T.A., Sullivan, M.J. & Stacy, N.I. (2015) Three new species of *Tursiocola* (Bacillariophyta) from the skin of the West Indian manatee. *Phytotaxa* 204 (1): 33–48.  
<http://dx.doi.org/10.11646/phytotaxa.204.1.3>
- Grunow, A. (1877) New diatoms from Honduras. *The Monthly Microscopical Journal* 18: 165–186.  
<http://dx.doi.org/10.1111/j.1365-2818.1877.tb00123.x>
- Hart, T.J. (1935) On the diatoms of the skin film of whales and their possible bearing on problems of whales movements. *Discovery Reports* 10: 247–282.
- Hendey, N.I. (1964) *An introductory account of the smaller algae of British coastal waters. Part V. Bacillariophyceae (Diatoms)*. Ministry

of Agriculture, Fisheries and Food, Fisheries Investigations, Series IV, London, 317 pp.

- Holmes, R.W. (1985) The morphology of diatoms epizoic on cetaceans and their transfer from *Cocconeis* to two new genera, *Benettella* and *Epipellis*. *British Phycological Journal* 20: 43–57.  
<http://dx.doi.org/10.1080/00071618500650061>
- Holmes, R.W., Nagasawa, S. & Nemoto, T. (1989) Epidermal diatoms on the Dall's porpoise landed at Otsuchi, Iwate, Japan. *Otsuchi Marine Research Center Reports* 15: 15–20.
- Holmes, R.W., Nagasawa, S. & Takano, H. (1993a) The morphology and geographic distribution of epidermal diatoms of the Dall's porpoise (*Phocoenoides dalli* True) in the Northern Pacific Ocean. *Bulletin of the National Science Museum, Tokyo Series B* 19: 1–18.
- Holmes, R.W., Nagasawa, S. & Takano, H. (1993b) A re-examination of diatom samples obtained from cetaceans collected off South Africa. *Bulletin of the National Science Museum, Tokyo Series B* 19: 127–135.
- Hustedt, F. (1952) Diatomeen aus der Lebengemeinschaft des Buckelwals (*Megaptera nodosa* Bonn.). *Archiv für Hydrobiologie* 46: 286–298.
- Kützing, F.T. (1836) *Algarum aquae dulcis germanicarum, Decas XVI*. Halis Saxonum: in commissis C.A. Schwetschkii et fil, 25 pp.
- Majewska, R., Santoro, M., Bolanos, F., Chaves, G. & De Stefano, M. (2015) Diatoms and other epibionts associated with olive ridley (*Lepidochelys olivacea*) sea turtles from the Pacific Coast of Costa Rica. *PLoS One* 10: e0130351.  
<http://dx.doi.org/10.1371/journal.pone.0130351>
- Majewska, R., De Stefano, M. & Van de Vijver, B. (in press) Two new gomphonemoid diatom genera (Bacillariophyta) living on marine turtles from Costa Rica. *Phytotaxa*.
- Meister, F. (1937) Seltene und neue Kieselalgen II. *Berichte der Schweizerischen Botanischen Gesellschaft* 48: 258–276.
- Nemoto, T. (1956) On the diatoms of the skin film of the whales in the Northern Pacific. *Scientific Reports of the Whales Research Institute, Tokyo* 11: 99–132.
- Round, F.E., Crawford, R.M. & Mann, D.G. (1990) *The diatoms. Biology and morphology of the genera*. Cambridge University Press, Cambridge, 747 pp.
- Simonsen, R. (1990) On some diatoms of the genus *Mastogloia*. *Beiheft zur Nova Hedwigia* 100: 121–142.
- Tiffany, M.A. (2011) Epizoic and epiphytic diatoms. In: Seckbach, J. & Kociolek, J.P. (Eds.) *The Diatom World*. Springer, New York, pp. 197–209.  
[http://dx.doi.org/10.1007/978-94-007-1327-7\\_8](http://dx.doi.org/10.1007/978-94-007-1327-7_8)
- Wetzel, C.E., Van De Vijver, B., Cox, E.J., Bicudo, D. de C. & Ector, L. (2012) *Tursiocola podocnemicola* sp. nov., a new epizoic freshwater diatom species from the Rio Negro in the Brazilian Amazon Basin. *Diatom Research* 27: 1–8.  
<http://dx.doi.org/10.1080/0269249X.2011.642498>
- Williams, D.M. & Round, F.E. (1986) Revision of the genus *Synedra* Ehrenb. *Diatom Research* 1: 313–339.  
<http://dx.doi.org/10.1080/0269249X.1986.9704976>
- Witherington, B. & Witherington, D. (2015) *Our sea turtles: a practical guide for the Atlantic and Gulf, from Canada to Mexico*. Pineapple Press, Inc., Sarasota, 282 pp.