

The diatom types of M. Giffen from Kidd's Beach, Eastern Cape, South Africa

F de Ridder



orcid.org/0000-0002-2467-6510

Dissertation submitted in fulfilment of the requirements for the degree
Master of Science in Environmental Sciences at the North-West
University

Supervisor: Prof JC Taylor

Graduation May 2022
25162152

Acknowledgements

This Master's dissertation would not have been possible if not for the support, aid and guidance of friends, family and colleagues and I will be forever grateful for their input in my life and this dissertation.

I would like to thank my supervisor, Prof. J.C. Taylor, for his mentorship, guidance and support throughout my studies, not only academically but as a friend as well. I like to thank him for the laboratory assistant position that assisted me to pay for this MSc. I also like to thank him for the knowledge about diatom taxonomy and diatoms overall that he passed on to me together with the bits and pieces of general knowledge. Lastly for the key contributions, he made to the spelling and grammar of this dissertation.

I would also like to thank my partner A. Curran for her emotional support, motivation, patience and input. I especially like to thank her for dropping me off and picking me up in the late evenings at the SEM, while I was unable to drive myself. I also like to thank her for the assistance she gave me in the final stretch of this dissertation, assisting me with the reference list lay out and format as well as with spelling and grammar.

I would like to thank my mother Dr. C. Reyneke and late stepfather P. Reyneke for their emotional and financial support throughout my studies. I would also like to thank them for the opportunity they have given me to study. I thank my mother for her emotional support especially during pre-grad and her understanding if I said I'm struggling with a subject.

I would also like to thank my brother G. de Ridder who wrote a small program to generate codes for species names that saved me a lot of time, as well as for all the assistance he provided regarding any computer-related queries.

I would like to thank R. C. J Koen for his assistance with the identification of some of the species, that form part of the ecological section of this study, improving the results of the section.

I would like to thank D. Esterhuizen and M. Erasmus for proofreading and editing this dissertation, improving the quality of this dissertation.

I would like to thank the following people for their support in general especially during the time I was unable to drive: Dr. A. Venter, W. Landman, A. Erasmus, and D. Lancaster.

Lastly, I would like to thank GOD for being by my side the entire time and for His help to obtain this degree, hopefully, I will be able to help to protect the earth He created.

Abstract

Marine littoral diatoms are rarely studied and are important in the littoral zone ecosystem. Diatoms contribute to numerous aquatic ecosystem functions including: primary productivity, sediment binding, and stability. There is relatively little taxonomic work related to marine littoral diatoms, especially in South Africa (SA).

Malcolm Giffen was one of the pioneers in this field of study and described many marine littoral diatoms taxa in South Africa. Giffen collected 10 marine littoral diatom samples from the Kidd's Beach area between 1946 and 1963. These were documented with line diagrams which could be potentially misinterpreted. Recently several of Giffen's taxa have been re-examined; however, this research is restricted mostly to the West Coast of South Africa. For this reason, this present project focus on taxa that he described from Kidd's Beach in the Eastern Cape. Of the 10 marine littoral diatom samples Giffen had collected from Kidd's Beach area, 8 were used to describe 27 new diatom species. Twenty-six of these taxa were documented with light microscopy and 23 with electron microscopy.

Taxa were evaluated, descriptions emended and some were re-described or transferred to more appropriate genera, based on morphological characteristics observed with LM and SEM. After examinations of the SEM micrographs, 8 of the 27 species were transferred to more appropriate genera (*Nitzschia erosa* to *Entomoneis erosa*; *Amphiprora galerita* to *Entomoneis galerita*; *Navicula pragmatica* to *Fallacia pragmatica*; *Stauroneis exilissima* to *Olifantiella exilissima*; *Navicula pseudogamma* to *Moreneis pseudogamma*; *Amphora tenellula* to *Seminavis tenellula*; *Opephora perlonga* to *Tabularia perlonga* and *Opephora perlonga* var. *clavata* to *Tabularia perlonga* var. *clavata*). One status change *Petroneis capensis* (synonym: *Navicula humerosa* f. *capensis*) was also made after the examination of the cell morphology under SEM.

Additionally, the 8 sites as described by Giffen were re-sampled in October of 2018 and October 2019, to determine if any temporal changes occurred during the past circa 57 years. DCA bi-plots were used to illustrate the temporal changes of the two re-sampled years also comparing these samples with those collected by Giffen. Physico-chemical data were also measured in 2019 to determine if there was any external driving factor influencing the diatom community at Kidd's Beach. A CCA bi-plot was used to present the influence of the physico-chemical variables on the diatom community. From the DCA bi-plots, it was apparent that the diatom community structure in 2018 was remarkably different from the diatom community structure sampled by Giffen. However, the diatom community structure in 2019 was in some respects more similar to the diatom community structure sampled by Giffen. It was found that there was no direct external factor influencing the diatom community and that the main internal driving factor determining community structure is salinity. The resampling of the 8 sites in question only yielded 6 of the 27 taxa described as new by Giffen. From these results, it was clear that the diatom community at Kidd's Beach is constantly in flux and that the resampling at original sites where type material was collected is not guaranteed to contain the species in question, therefore, the preservation, maintenance and documentation of extant types is of the utmost importance.

Keywords: diatom types, emended descriptions, Kidd's Beach, M. Giffen, temporal change

Contents

Chapter 1 - Introduction and literature review.....	1
1.1 The ocean.....	1
1.1.1 Global climate.....	1
1.1.2 Zones in the ocean.....	2
1.1.3 CO ₂ storage.....	3
1.2 Primary production.....	4
1.3 Marine algae and diatoms.....	6
1.4 Diatoms.....	7
1.4.1 Habitats.....	8
1.5 Diatoms in the littoral zone.....	8
1.5.1 Diatoms as primary producers in the littoral zone.....	8
1.5.2 Sediment stabilisation by diatoms.....	10
1.6 International research regarding littoral zone diatoms.....	12
1.7 South African research on littoral zone diatoms.....	20
1.7.1 M. H. Giffen.....	20
1.7.2 Further contributions to research on marine littoral diatoms in South Africa.....	23
1.8 Diatom taxonomy.....	28
1.9 Aims and objectives.....	29
Chapter 2 - Materials and methods.....	30
2.1 Study area.....	30
2.2 Giffen's material.....	30
2.3 Resampling from Giffen's study sites.....	32
2.3.1 Statistical analysis.....	37
Chapter 3 - Augmented and emended taxa descriptions of the 27 taxa described by Giffen from Kidd's Beach.....	39
Chapter 4 - Temporal changes in the littoral diatom assemblage at Kidd's Beach between the mid-20 th century and 2018 and 2019.....	92
Chapter 5 - Conclusions.....	103
References.....	105
Appendix A - List of new marine littoral zone diatom taxa described by M. H. Giffen.....	113
Appendix B - List of new marine littoral zone diatom taxa described by B. J. Cholnoky.....	120
Appendix C - Original pencil drawings by M. H. Giffen of the new diatom species at Kidd's Beach.....	126

Appendix D – Relative abundance of taxa in counted samples.....	153
---	-----

Chapter 1 - Introduction and literature review

1.1 The ocean

The world's ocean is a vast interconnected system, covering 70% of the Earth's surface. Globally there are five oceans namely the: Antarctic, Arctic, Atlantic, Indian and Pacific oceans. These oceans have their own physio-chemical composition depending on the geographical area of the ocean but are all connected by currents. Therefore, each ocean contributes to the world's ocean in their own way, either by adding salinity, oxygen (O₂), Carbon dioxide (CO₂), or warm or cold water to the global system (European Marine Board, 2019; Pendleton *et al.*, 2020). The ocean plays a major role in the earth's sustainability, contributing to global climate regulation, the storage of excess CO₂, oxygen production, cloud formation, and other resources (food, lipids, oil, pharmacological, cosmetic, etc.). Additionally, the ocean also represents 99% of habitable space on Earth, (Broderick, 2015; European Marine Board, 2019). However, the European Marine Board states in a 2019 report that marine organisms only contribute to 13% of the world's described species, with the remaining 87% of organisms described being terrestrial or freshwater organisms. The main reason for this is due to the fact that more focus is given to terrestrial and freshwater research (Richardson & Poloczanska, 2008; Broderick, 2015). According to Broderick (2015) the most concerning reasons for a lack in research in marine ecosystems come down to interest, funding, and access, of which funding is the major limiting factor that hinders both development and implementation of marine research (Richardson & Poloczanska, 2008). Pendleton *et al.* (2020) describe the lack in marine research as a considerable gap in scientific capacity, which includes funding, data acquisition, data sharing, and transdisciplinary ocean research. Additionally, technical and logistic constraints such as government policies or geopolitical disputes are also a major determining factor in data acquisition (Skelton, 2014). Regarding access as previously mentioned, the ocean, either coastal or deep sea, is an extremely difficult environment to explore.

1.1.1 Global climate

The world's oceans contribute to the earth's climate and weather patterns in two major ways. The first being the vast amount of absorption and redistribution of excess heat by the ocean. The main reason for this is that the ocean's capacity to store heat is much higher than that of the earth's atmosphere (European Marine Board, 2019). According to the IPCC's (Intergovernmental Panel on Climate Change) report in 2013, the increase in greenhouse gasses over the past 50 years led to the storage of 93% of the excess energy (in the form of heat) in the ocean.

The second major way in which the ocean contributes to the earth's climate and weather patterns is via ocean currents that circulate warm and cold water as well as salt, oxygen, carbon dioxide, and nutrients across the planet and connect all the earth's water, creating a "Meridional Overturning Circulation" or MOC. These ocean currents are formed by a process called deep-water formation, which occurs naturally as the density of the water increases (that causes the water to sink) due to an increase in salinity and a decrease in water temperature (European Marine Board, 2019).

Surface currents also play a major role in the global climate. The Gulf Stream is a good example of how surface currents affect the climate, as it circulates warm water from the equator up the east coast of North America and across the Atlantic to Europe. The result of this transport of warm water is that the temperature of the water in the North Sea rises, which in turn raises the air temperature over land between 3 and 6 °C. In the case of London, the air travels across the warm water in the Gulf Stream, picking up large amounts of water and it is precipitated over London (Pinet, 2009).

1.1.2 Zones in the ocean

To better explain the below concepts a brief description of the different zones in the ocean is first given. The ocean can be divided into different zones each with different parts. The first division divides the ocean bottom from the water column. These are known as the benthic zone (bottom of the ocean) and the pelagic zone (water column) and can both be divided further (Pinet, 2009).

A division that can be made with respect to the pelagic zone is by separating the water present over the continental shelf (neritic zone) and the deep water after the shelf break (oceanic zone). The neritic zone is characterized by shallow water and light penetrates to the bottom of this zone and thus no further division occurs in this zone (Pinet, 2009).

As for the oceanic zone or open ocean, beyond the edge of the continental shelf where the water column reaches depths of 11,000 m, further division results in five zones, each with physical characteristics that differ with depth. These include light penetration, temperature, oxygen, pressure, and mineral nutrients (Chase & Keener-Chavis, 2003). The first zone is the epipelagic zone, extending from 0 - 200 m with light highly available as a result of light penetrating relatively well up to 200 m, and thus promoting photosynthesis by primary producers. Low nutrient levels limiting primary production are present in the euphotic zone, due to the sinking of nutrients below 200 m. The euphotic zone also has the highest temperature of the five open ocean zones (Chase & Keener-Chavis, 2003; Pinet, 2009; Sayre *et al.*, 2017). The second zone is the mesopelagic zone extending from 200 – 1,000 m, in which the light availability is very limited due to little light penetrating this zone. Only 20% of the products of primary production from the euphotic zone reach this zone. In this zone, bioluminescent organisms also begin to occur (Chase & Keener-Chavis, 2003; Pinet, 2009; Sayre *et al.*, 2017). The third zone is the bathypelagic zone that extends from 1,000 – 4,000 m. At this depth, no light penetrates and the only light that occurs in this zone is from bioluminescent organisms; sperm whales frequently dive down to this zone in search of food. In this zone only 5% of products of primary production are available (Chase & Keener-Chavis, 2003; Pinet, 2009; Sayre *et al.*, 2017). Despite the extreme conditions (no-light, high-pressure (403,343 bar), low temperature, and O₂ levels) a large number of animals live in this zone, and it is also characterized as the largest ecosystem on earth. The second deepest and the fourth zone is the abyssopelagic zone. This zone stretches from 4,000 - 6,000 m deep and the small number of organisms that occur in this zone is limited to invertebrates (Chase & Keener-Chavis, 2003; Pinet, 2009; Sayre *et al.*, 2017). This zone also covers most (75%) of the ocean floor. The fifth zone is the hadalpelagic zone and extends from 6,000 - 11,000 m, occurring only in areas where deep water trenches are present in the otherwise relatively flat

seafloor. Still, life limited to invertebrates occurs at these depths (Chase & Keener-Chavis, 2003; Pinet, 2009; Sayre *et al.*, 2017).

The benthic province is another complex zone within the ocean which is divided into 5 zones: littoral, sublittoral, bathyal, abyssal, and hadal zones. The littoral zone can also be referred to as the intertidal zone and lies between the high and low tide of the shore line (Pinet, 2009). The sublittoral zone entails the whole floor of the continental shelf ranging from the beach at 0 m to the shelf break at a depth of 200 m (Pinet, 2009). The bathyal zone extends outwards from the depth of 200 – 2,000 m and thus represents the seafloor for the mesopelagic and bathypelagic zones. The abyssal zone is the second deepest zone of the ocean floor extending over depths of 2,000 – 6,000 m and is considered to be the seafloor of the corresponding abyssalpelagic zone (Pinet, 2009). The last and deepest benthic zone is the hadal zone, extending over the depth of 6,000 - 11,000 m, and is the seafloor for the hadalpelagic zone (Pinet, 2009).

All of these zones are considered habitats for organisms to live in and can also be distinguished from one another by the organisms that reside in them (Pinet, 2009). However, the main habitat that will be focused on in the present study will be the littoral zone.

1.1.3 CO₂ storage

With regards to CO₂ storage by the ocean, also known as the ocean carbon sink, the ocean has contributed greatly to the absorption of excess anthropogenic CO₂ during the past two decades, decreasing the total CO₂ load of the atmosphere and in doing so, decreasing the rate of anthropogenic climate change (De Vries *et al.*, 2019). According to McKinley *et al.* (2020), the ocean has absorbed 39% of the total anthropogenic CO₂ since the industrial age during the 1700s (1750). Bopp *et al.* (2017) state that the ocean is responsible for the sequestration of 30% of the anthropogenic CO₂ in only ten years (2004-2013), and also state that the ocean has absorbed 30% of anthropogenic CO₂ during the period 1870 till 2017. Furthermore, a major part of the earth's carbon is stored in the ocean, more than in the atmosphere (Marinov & Sarmiento, 2004). The process responsible for this and for sustaining the ocean carbon sink is the carbon pump (a process that transports CO₂ from the ocean surface towards the deep ocean or the sea bed where the CO₂ resides for thousands to millions of years depending on the depth gained by the CO₂) (Passow & Carlson, 2012).

The carbon pump consists of two separate pumps or processes (Bopp *et al.*, 2017; Basu and Mackey, 2018). The first is a physical pump, physico-chemical process or solubility pump, by which CO₂ is transferred to the deep ocean by circulation which is driven by the density of water that is mainly influenced by salinity and temperature (Marinov & Sarmiento, 2004). The process of this pump is as follows: CO₂ enters the ocean surface by diffusion between the atmosphere and the ocean surface, where the CO₂ dissolves, but also reacts with the water to form bicarbonate (HCO₃⁻) and carbonate (CO₃²⁻), thus the total dissolved inorganic carbon (DIC) consists of CO₂, HCO₃⁻ and CO₃²⁻ (Marinov & Sarmiento, 2004). The DIC is then transported downwards out of reach of the atmosphere, with denser water where the DIC will reside for a long period (Bopp *et al.*, 2017). At deep water formation sites, the physical pump is the most efficient, taking into account that CO₂ is more soluble in colder water and the fact that, as the temperature of water decreases the denser the water becomes, dragging the CO₂ down faster due to the increased density of the surface water (Bopp *et al.*, 2017).

The second pump, with the largest contribution to the ocean carbon pump, is the biological pump (Marinov & Sarmiento, 2004). This pump relies on the transport of DIC from the ocean surface to the deep ocean and ocean sediment via the very integrated marine food web (Bopp *et al.*, 2017). In brief the marine food web consists of phytoplankton cells (primary processors), the phytoplankton's consumers (primary consumers), the consumers' consumers (secondary consumers), and the bacteria that assimilate their waste or dead matter (Basu & Mackey, 2018). One of the key differences that makes the biological pump more effective when compared to the physical pump is that the biological pump does not only transport DIC to the deep ocean but organic carbon as well (Basu & Mackey, 2018). The process of the biological pump is complex and the atmospheric CO₂ undergoes some alterations before ending up in the deep ocean (Bopp *et al.*, 2017). Firstly, it is converted to organic CO₂ (lipids, oils, starch, etc.) (can also be referred to as particulate organic carbon (POC)) through photosynthetic phytoplankton (primary producers consisting primarily of diatoms), this process is also the primary driver of the biological pump (Basu & Mackey, 2018). Secondly, the phytoplankton can die and decompose or be directly consumed by primary consumers (heterotrophic bacteria, zooplankton, and some fish) or indirectly by their consumers (secondary consumers). Thirdly the CO₂ in the form of POC is transported through sinking or vertical migration by fish or zooplankton to the carbon sink (-1,000m deep), in various forms, it can be as faecal pellets, detrital matter (marine snow, organic aggregates), dead cells or other forms. Although only a fraction (0.1 – 1% or 10 billion tonnes of carbon per year) of the organic CO₂ from the surface, mostly POC ends up in the carbon sink with the rest being re-mineralized by respiration and returning to the atmosphere, it is important to take into account that the carbon that reaches the carbon sink (especially deep sediment) is stored for millennia (Bopp *et al.*, 2017) contributing greatly to the decrease in atmospheric CO₂. Basu & Mackey (2018) also state that without the biological pump the atmospheric CO₂ would be 400 ppm higher than it is presently.

However, the increase of DIC also decreases the ocean's pH contributing to acidification of the ocean, leading to stronger stratification (this process is when a water body, for instance, the ocean, forms different layers due to the different density of the layers) that is also intensified with the increase in temperature by the remaining CO₂ that is not absorbed by the ocean (Basu & Mackey, 2018). The stronger stratification is related to a decrease in mixing and deep-water formation that, in turn, could result in drastic climate change due to the halt of the oceanic global circulation and accumulation of atmospheric CO₂. Although the processes of the carbon sink are well studied there are many uncertainties regarding the variability of the ocean carbon sink and if this sink will be able to mediate the ongoing anthropogenic climate change (McKinley *et al.*, 2020).

1.2 Primary production

As briefly mentioned above primary producers in the ocean are primarily phytoplankton, which are photosynthetic (the ability to convert light energy, inorganic CO₂ and water into organic carbon and O₂) (Helbling & Villafañe, 2009)) microorganisms (0.4 - 200 µm in size) living in the euphotic zone (0 - 200m deep) of the ocean. However, phytobenthos (photosynthesizing microorganisms living in benthic environments) also play a relatively large role in primary production especially in the littoral zone (Christianen *et al.*, 2017; Wulff *et al.*, 2005). Phytoplankton is extremely important not only for the carbon pump as mentioned above but also for a large amount of O₂ production and maintaining oceanic food webs. Half of the world's O₂ production is produced by marine phytoplankton despite

phytoplankton only possessing 1 - 2% of the total global biomass (Helbling & Villafañe, 2009; Simon *et al.*, 2009; IPCC., 2014). The main reason for this occurrence is the high turnover rate of phytoplankton combined with the high rate of consumption by primary consumers (Simon *et al.*, 2009; Guillard & Kilham, 1977).

The presence and distribution of phytoplanktonic primary producers across the world's oceans can be observed by satellite from space. The observations made are based on the ocean's colour. Satellite images showed that phytoplankton is distributed heterogeneously throughout the world's oceans with low abundance at the five gyres and high abundance in the ocean west of continents (Helbling & Villafañe, 2009). The main reason for this is directly related to nutrient availability in these areas, taking into account that phytoplankton is nutrient-dependent. At the gyres, water accumulates in the centre of the gyres isolating these waters from a nutrient supply facilitated by surface currents. (Helbling & Villafañe, 2009). Vertical mixing which contributes to the nutrient supply to the euphotic zone is also limited, due to the strong thermal stratification at the gyres, resulting in a low abundance of phytoplankton (Helbling & Villafañe, 2009). The waters at the gyres are primarily dominated by small nano-picoplankton (cells smaller than 20 μm) (Helbling & Villafañe, 2009). This is due to the high surface-to-volume ratio of such small cells, which therefore allows them to dominate in nutrient poor waters (Helbling & Villafañe, 2009). The high abundance of phytoplankton in the ocean west of continents is mainly due to upwelling, which brings cold nutrient water to the surface (Helbling & Villafañe, 2009; Basu & Mackey, 2018). High phytoplankton abundance is also present in areas with extended continental shelves and depths not exceeding 200 m. The high abundance in these areas is related to ventral mixing, which resupplies the area with nutrients, as well as coastal runoffs (Helbling & Villafañe, 2009). Helbling & Villafañe (2009) further state that the characteristics of fronts also have the potential of contributing to a high abundance of phytoplankton in that area. Frontal systems as described by Helbling & Villafañe (2009), are characterised as two water masses with different physico-chemical characteristics and origins meeting. Generally, this results in the denser water mass sinking, while the lighter water mass rises. This in effect allows for stratification to occur due to a spike in the salinity and temperature gradient within the area. As a result of this frontal dynamic, there is an accumulation of phytoplankton and particles leading to high productivity within the front, (Helbling & Villafañe, 2009). In the polar areas of the Northern Hemisphere, a high abundance of phytoplankton occurs together with occasional booms related to the retreating of icepacks. In the southern polar region, low abundances of phytoplankton occur in the area south of the polar front (deep open parts of the Southern Ocean) regardless of the high nutrient presence in the area (Helbling & Villafañe, 2009). In this region iron (Fe) is the limiting factor which results in a low abundance of phytoplankton in these regions (Helbling & Villafañe, 2009). However, iron limitation is not restricted to the deep open parts of the Southern Ocean and is a limiting factor throughout the world's oceans, with 30% of the world ocean's primary producers being limited by iron (Basu & Mackey, 2018).

1.3 Marine algae and diatoms

Algae are photosynthesizing organisms that can vary in size from 0.2 - 2 μm (microalgae) and up to 60 m (macro algae) (Malcata *et al.*, 2018), and lifeforms that can be unicellular, colonial, constructed of filaments, or composed of simple tissue (Guiry, 2012).

In the case of unicellular forms, the cells can be motile utilising a flagellum (many Dinoflagellates) or by the secretion of mucilage (pennate raphid diatoms). The reproduction of algae may be asexual or sexual (Malcata *et al.*, 2018). Most microalgae reproduce asexually by vegetative reproduction that can occur by cell division or by fragmentation of a colony or filament (Malcata *et al.*, 2018). This form of reproduction produces no genetic variation thus decreasing the gene pool. Microalgae can also reproduce sexually with gametes resulting in genetic recombination that is needed to evolve and adapt to changing environments (Malcata *et al.*, 2018). Algae are considered to be predecessors of “modern” vascular plants. However, algae do not possess any definitive structures like roots, stems or leaves, or vascular tissue, and are therefore separated from “modern” plants (kingdom: Plantae) due to the lack of these structures (Krienitz, 2009).

Algae are thus classified under 2 other kingdoms. The first being Monera under which prokaryotic organisms (organisms that lack membranes around organelles) are classified. In the case of algae, this includes the Cyanobacteria commonly known as blue-green algae due to their photosynthetic pigments (Krienitz, 2009). Cyanobacteria are considered to be one of the most successful groups of algae on earth and are the most widely distributed and most dominant algae group in the marine environment (Malcata *et al.*, 2018). The second kingdom is the Protocista and includes the eukaryotic algae (organisms with a membrane around genetic material, also termed a true nucleus, as well as around other organelles (Krienitz, 2009)) (Malcata *et al.*, 2018; Taylor & Cocquyt, 2016). According to Guiry (2012) algae are a very diverse group of organisms distributed in 54 classes over 15 phyla, however, in this introduction only the dominant eukaryotic groups of planktonic and benthic microalgae will be briefly discussed.

There are 2 main groups of algae, classified as to where in the aquatic system they reside. The first being algae that are free-floating in the ocean or water column, termed planktonic. The second group are algae that reside in, or attach themselves to the substrate (benthos) of an aquatic system and are termed benthic (Malcata *et al.*, 2018). Three dominant groups of algae are present in the phytoplankton: Dinoflagellates, haptophytes, and diatoms (Simon *et al.*, 2009). Although these three groups are dominant in the oceanic and sub-littoral zones, the planktonic algae community structure in the littoral zone is dominated by dinoflagellates, chlorophyta, and diatoms (Semcheski, 2014). As for marine microphytobenthos, the littoral zone is primarily dominated by diatoms and chlorophyta.

Chlorophyta

Chlorophyta are commonly known as “green algae” due to the green colour as a result of their photosynthesizing pigments, mainly chlorophyll *a* and *b*, with β and γ carotene, and various xanthophylls (Malcata *et al.*, 2018) that do not mask chlorophyll *a* and *b* (Krienitz, 2009). Chlorophyta store starch as the main reserve polysaccharide (Malcata *et al.*, 2018;

Krienitz, 2009). Chlorophyta are also characterised by isokont flagella that lack mastigonemes. Although Chlorophyta are dominated by unicellular freshwater species, the marine species in this phylum are macro algae (Malcata *et al.*, 2018).

Haptophyta

In contrast to Chlorophyta, Haptophyta are dominated by marine species, with only a few freshwater species (Malcata *et al.*, 2018; Krienitz, 2009), with coccolithophores being one of the most abundant marine plankton groups, especially in the oceanic zone. Some haptophytes are also responsible for periodic toxic blooms (Malcata *et al.*, 2018). The majority of haptophytes are unicellular with two apical or lateral, naked uneven flagella, the cell wall is covered with cellulosic or calcified scales. The colour of Haptophyta is golden yellow-brown and is the result of chlorophyll *a* and *c*, β carotene, and various xanthophylls. The storage product of Haptophyta is the polysaccharide chrysolaminarine. Another characteristic of Haptophyta is the presence of a haptonema, which is an organelle similar to a flagellum but it has a distinct ultrastructure (Malcata *et al.*, 2018).

Dinoflagellata

Dinoflagellata is a supergroup of the phylum Miozoa (Malcata *et al.*, 2018) and is mostly marine with only 10% of the superclass living in freshwater (Krienitz, 2009). Most Dinoflagellata are unicellular organisms, characterized by two flagella situated in two grooves known as the cingulum groove and sulcus groove, as well as the presence of thecal plates covering the cell (also known as armour). The plate arrangement, size, and shape differ between species and are used in morphological classification. The theca plates can be empty or filled with cellulose. The cingulum groove runs transversally in the theca plates along the cell, dividing the cell into two halves known as the epicone (upper) and hipocone (lower). The cingulum groove contains the cingulum flagellum which is responsible for the rotation of the cell. The sulcus groove is present longitudinally at the ventral side of the cell and contains the sulcus flagellum which is responsible for navigation and forward movement of the cell (Malcata *et al.*, 2018; Krienitz, 2009). The chloroplast of Dinoflagellata contains chlorophyll *a* and *c*, which are masked by β carotene and peridinin giving the cells a brown colour (Krienitz, 2009). Some Dinoflagellata (termed zooxanthellae) are endosymbiotic with coral and play a major role in sustaining coral's life, as most of the coral's nutrients are produced by the zooxanthellae (Sheppard *et al.*, 2012).

1.4 Diatoms

Diatoms fall under the class Bacillariophyceae in the phylum Ochrophyta and are present in marine and freshwater systems (Malcata *et al.*, 2018). Diatoms also represent 40% of all described marine plankton species. As stated above in section 1.1.3, diatoms are extremely important in the biological carbon pump and in primary production. Diatoms are unicellular microalgae, often forming colonies. Diatoms are primarily characterized by their unique cell wall which consists of silica and is termed a frustule (Simon *et al.*, 2009; Barsanti & Gualtieri, 2014; Taylor & Cocquyt, 2016). The frustule is composed of two valves and girdle bands (copulae) connecting the two valves. The valves can be distinguished from one another, and are termed the epitheca and hypotheca. The epitheca being the older and larger valve and the hypotheca being the younger and smaller valve. Nutrient exchange, between the water and the cell is restricted to openings in the frustule in the form of pores or slits (areolae). The

frustule is also covered externally with a fine organic membrane (Simon *et al.*, 2009). The ornamentations (stria, apical porefield, raphe, granules, spines, axial area, and proximal and distal raphe endings) present on the frustule are used for morphological identification under light and scanning electron microscopes. Two main groups of diatoms can be distinguished based on the symmetry of the frustule (Taylor & Cocquyt, 2016). The first group is the centric diatoms, with radial symmetry. Centric diatoms are araphid (raphe is absent) and non-motile and usually planktonic. The second group is the pennate diatoms which has bilateral symmetry (Taylor & Cocquyt, 2016). Pennate diatoms can be araphid, monoraphid (only one valve bears a raphe), or biraphid (a raphe is present on both valves) depending on the genus and are primarily benthic (Taylor & Cocquyt, 2016). The chloroplast of diatoms contain chlorophyll *a* and *c* with the dominant accessory pigment being fucoxanthin (Krienitz, 2009; Taylor & Cocquyt, 2016). In addition to these pigments, diatoms also have the following pigments: antheraxanthin, β -carotene, diadinoxanthin, diatoxanthin, violaxanthin, and zeaxanthin with the main storage product of diatoms being oil droplets (Taylor & Cocquyt, 2016).

1.4.1 Habitats

With regards to habitat, diatoms are a very diverse group of organisms which can be planktonic, cryophytic (algae which occur in snow and ice), or benthic - which in turn can be divided into more subgroups depending on the substrate to which diatoms attach (Simon *et al.*, 2009; Taylor & Cocquyt, 2016; Malcata *et al.*, 2018). Benthic diatoms can be epizoic (algae which live non-parasitically on the surface of another animal), epiphytic (algae which live on another plant), epilithic (algae which grow on the surface of stones and rocks), epipelagic (algae which grow on the surface of sediment and mud), epixylic (algae which grow on wood) and epipsammic (algae which attach to sand grains) (Simon *et al.*, 2009; Taylor & Cocquyt, 2016; Malcata *et al.*, 2018).

Diatoms are present in all the zones of the ocean (littoral, sublittoral, neritic, and epipelagic) into which light penetrates. In the littoral zone diatoms can be planktonic, epiphytic, epipsammic or epilithic (Semcheski, 2014). In the sublittoral, Wulff *et al.* (2005) note that diatoms occur at depths from 7 m to 35 m at Gullmar Fjord. At shallower depths (7 - 20 m) the diatoms were epipelagic–epipsammic and at greater depths (25 - 35 m) the diatoms were pelagic. In the neritic zone, planktonic diatoms are usually present with centric diatoms being dominant as observed in the Urdaibai estuary in Northern Spain by Trigueros & Orive (2001). Diatom distribution in the epipelagic zone is related to the distribution of primary producers as discussed in section 1.2, with diatoms being one of the 3 dominant phytoplanktonic groups (Simon *et al.*, 2009) and found in very clear water up to a depth of 200 m (Simon *et al.*, 2009; Barsanti & Gualtieri, 2014).

1.5 Diatoms in the littoral zone

1.5.1 Diatoms as primary producers in the littoral zone

Studies focusing on primary production in estuaries or in nearshore marine systems generally use the collective term microphytobenthos or benthic microalgae to group these organisms for surveys and experiments. This approach groups all primary producers in one category

regardless of taxonomic rank (Christianen *et al.*, 2017). It is known that microphytobenthos contributes greatly to the dynamics of a coastal ecosystems not only as the primary source of organic carbon, but also as oxygen producers (Christianen *et al.*, 2017; Wulff *et al.*, 2005). According to Christianen *et al.* (2017) diatoms and cyanobacteria are the most abundant taxonomic groups in the microphytobenthos. Additionally, Underwood & Kromkamp (1999) state that the microphytobenthos contributes up to 50% of an estuary's primary production, yet there is a lack of taxonomic differentiation within the microphytobenthos in published studies.

The lack of taxonomic differentiation regarding microphytobenthos studies in estuaries or in nearshore marine systems was also noted by Semcheski (2014). Over the two-year period of his studies, Semcheski (2014) found a total of 95 taxa present in the microphytobenthic community at his study area (Lower Chesapeake Bay, USA). The observed community consisted of the following: 61% diatoms, 18% cyanobacteria, and 8% chlorophytes, comparable to the community structure described by Christianen *et al.* (2017) in the paragraph above. The primary productivity of diatoms as a separate group was not measured by Semcheski (2014).

The observations recorded by Semcheski (2014) which may give an indication of diatom productivity are as follows: The diatom biomass was the highest in winter and declines towards summer, with the cyanobacteria having a contrasting trend. The average primary production of the 2-year study period across all the sampling sites ranged from 2.75 mg/C/m³/hr- to 20 mg/C/m³/hr-. (Semcheski, 2014). From this, it can be said that diatoms contribute the most to primary production in the winter (between 2.75 mg/C/m³/hr- and 20 mg/C/m³/hr-) and less so in the summer. However, Semcheski (2014) states other algal groups (such as cyanobacteria and chlorophytes) have been overlooked as major contributors to the primary production in the benthos of the littoral zone.

In another study by Christianen *et al.* (2017), stable carbon isotopes were used to determine the value of benthic primary producers in the food web of the Wadden Sea. In this study benthic primary production was measured by using an algal consumer, the snail *Peringia ulvae* Pennant as a proxy. To validate the proxy, they analysed the $\delta^{13}\text{C}$ of diatoms at a selected site and found that the $\delta^{13}\text{C}$ value of the diatoms overlapped with the $\delta^{13}\text{C}$ value of *P. ulvae*. The final results of the study showed that the microphytobenthos on the intertidal mudflats supported most of the consumers in the Wadden Sea (Christianen *et al.*, 2017), demonstrating the value of diatoms as primary producers in the littoral zone. However, the contribution of diatoms alone was not measured as *P. ulvae* feeds on a variety of algal groups (Christianen *et al.*, 2017).

Wohlgemuth (1991) in his work "Primary Producers and Decomposers of Intertidal Flats" notes that diatoms have a reproduction rate of 0.5 to 6 new individuals per day, which results in a yearly turnover of 182-2190 times, while vascular marsh plants have a turnover of 1-2 per year (Wohlgemuth, 1991). Wohlgemuth (1991) further states that diatoms may occur in very high numbers up to 40 million per centimetre.

Taking all of the above mentioned into account, it can be concluded that diatoms contribute greatly to the primary production of the marine littoral zone, especially the tidal zones where other plants and algae cannot easily establish themselves. The contribution of diatoms may be exaggerated (Semcheski, 2014), nevertheless, there is still a lack of research regarding the contribution of diatoms as a single taxonomic group to the primary production of the marine littoral zone.

1.5.2 Sediment stabilisation by diatoms

According to Prasad & Felgenhauer (1988), numerous marine benthic diatoms are able to attach themselves to a substrate by different methods. These methods include attachment by stalks, pedicels, or interlinked chains (which consist of linking spines, as well as interposed gelatinous substance). These linked chains, are usually a result of incomplete or imperfect separation after cell division. The attachment of diatoms to substrates is mainly related to an extracellular secretion of mucilaginous substances (in short mucilage). Mucilage is often found in a few different forms. The mucilage may be in a simple layer in between the diatoms and the substrate or as morphological structures such as pads, envelopes, stalks, or tubes (these forms are the result of a continuous secretion of mucilage) (Prasad & Felgenhauer, 1988). In more recent articles, mucilage is referred to as extracellular polymeric substance (EPS) (Stal & de Brouwer, 2003).

Later studies by Stal & de Brouwer (2003) investigated the composition of mucilage and found that two types of mucilage are produced by diatoms, namely water-extractable and EDTA-extractable mucilage. The two types of mucilage differ mostly in the percentage of glucose present in the mucilage, EDTA- extractable mucilage contains 80% of glucose where water-extractable mucilage contains 11% glucose (Stal & de Brouwer, 2003).

Stal & de Brouwer (2003) show that mucilage mats or biofilms forming on the sediment surface in estuaries and especially in mudflats, play a major part in the stabilisation of these sediments. According to Paterson (1989), migratory diatoms in the littoral zone have a positive effect on sediment stabilisation in the short term. Paterson (1989) demonstrated a positive correlation between the density of the diatom assemblage and the cohesive strength of the sediment and also noted that there was an increase in sediment stabilisation in all experimental testbeds that had an active diatom community.

Diatoms in marine littoral zones migrate upward through the sand at low tide during the day and downwards a few minutes before high tide. As the diatoms migrate through the sediment, they secrete mucilage (Paterson, 1986). This migratory behaviour is mostly controlled by photo- as well as chemotactic responses (Stal & de Brouwer, 2003). The mucilage secreted by migratory diatoms binds sand grains together due to the cohesive properties of the mucilage (Paterson, 1986). According to Paterson (1986), the mucilage does not only create a firm network on the sediment surface but also creates a network of mucilage which extends at least 1.6 mm beneath the sediment surface in experimental conditions. However, diatoms and the mucilage network may extend a lot deeper in the sediment in nature, due to bioturbation or sediment remixing (Paterson, 1986).

Stal & de Brouwer (2003) state that stabilisation of sediment by mucilage is also dependent on where the diatoms occur in the nearshore, in other words, in more turbid parts (high energy environment) fewer diatoms will occur resulting in less mucilage, wherein low flow (low energy environment) parts more diatoms will be present resulting in more mucilage. A good example is runnels and ridges in an estuary. The runnels will get deeper where the ridges will hold their form and, in some cases, ridges will even grow as more silts and muds get deposited and bind to the mucilage biofilm. Taking the aforementioned into account, Stal & de Brouwer (2003) noted that water-extractable mucilage has a strong relationship with chlorophyll-*a* in low energy environments, and a very dynamic pattern between water-extractable mucilage and chlorophyll-*a* can be observed. This is because water-extractable mucilage excretion rate increases with chlorophyll-*a* and if more CO₂ is fixed than can be stored, the excess storage products are excreted as mucilage. However, the excess is not of the same carbohydrate chrysolaminarine as the intracellular storage, and thus has a different metabolic synthesis (Stal & de Brouwer, 2003). Furthermore, water-extractable mucilage is soluble in water and decreases in the sediment if immersion occurs and photosynthesis decreases. Another reason for the strong relationship between water-extractable mucilage and chlorophyll-*a* and the dynamic pattern between the two, is the fact that diatoms use the glucose in the water-extractable mucilage in the dark period for energy (Stal & de Brouwer, 2003).

EDTA-extractable mucilage does not show the same dynamic pattern as water-extractable mucilage regarding chlorophyll-*a*. There are two main reasons for this phenomenon. The first is that EDTA-extractable mucilage binds tightly to the sediment by their negatively charged groups and is therefore not washed-out during inundation. This is because of the cation bridges that form between the sediment and the mucilage. Stal & de Brouwer (2003) also found that the binding strength is relevant to the amount of binding sites on the mucilage molecule as well as the availability of Ca²⁺ and divalent ions like Ca²⁺ and Mg²⁺ in the sediment. Stal & de Brouwer (2003) also noted that some of the mucilage is irreversibly bound to the sediment and the amount of irreversibly bound ESP increases to 50% if Ca²⁺ ions are present in the environment. Thus, in the case of a high number of divalent ions being present in the sediment, a stronger bond will form between the mucilage and the sediment. Secondly, EDTA-extractable mucilage is not subject or only slightly subject to degradation by diatoms in the dark period. Thus EDTA-extractable mucilage does not degrade during the dark period (Stal & de Brouwer, 2003). For this reason, Stal & de Brouwer (2003) suggest that if diatoms have any effect on the stabilisation of sediments in the littoral zone by secreting mucilage, EDTA-extractable mucilage is mostly responsible for the stabilisation and not water-extractable mucilage.

Thus, it can be said that diatoms in the littoral zone stabilise sediments, even if only for a short period and contribute greatly to sediment stabilisation in low energy environments with sediments with small grain size.

1.6 International research regarding littoral zone diatoms

Littoral zone diatoms are included in several research fields globally including: taxonomy, ecology, paleolimnology, ecotoxicology, biomonitoring, and general biogeology. A selection of key international papers in the aforementioned fields of study published over the past 70 years are summarised below.

Date	Authors	Title	Region	Main Focus of paper
1950	A. A. Aleem	Distribution and ecology of British marine littoral diatoms	Swange Bay, UK	Ecology
In this study, Aleem (1950) took 500 diatoms samples from different regions of the littoral zone at Swange Bay. After conducting this study, Aleem (1950) found that eleven communities could be identified in the littoral zones of Swange, Saltdean, and Ovitigdean. Aleem (1950) demonstrated that each community is influenced by environmental factors, e.g. latitudinal position in the littoral zone, substrate, season, salinity and light availability.				
1951	F. Hustedt and A.A. Aleem	Littoral diatoms from the Salstone, near Plymouth		Taxonomy
Hustedt and Aleem (1951) investigated the littoral diatom community of Salstone and noted a total of 141 species across 45 genera. From the 141 taxa, Hustedt and Aleem (1951) described 4 novel species namely <i>Cocconeis guttata</i> , <i>Navicula aleemi</i> , <i>N. britannica</i> and <i>Pleuroisigma subhyalinum</i> .				
1980	S. R. Stidolph	A record of some coastal marine diatoms from Porirua Harbour, North Island, New Zealand	North island, New Zealand	Taxonomy
Stidolph (1980) investigated the diatom assemblage of Porirua Harbour and observed a total number of 150 taxa that included marine planktonic as well as benthic diatoms. Twenty-five of the taxa found by Stidolph (1980), were new occurrences in New Zealand at that time with one new variety <i>Gyrosigma balticum</i> var. <i>turgidum</i> described by Stidolph (1980).				
1981	M. J. Sullivan	A preliminary checklist of marine benthic diatoms of Mississippi	Mississippi, USA	Ecology
Sullivan (1981) studied the littoral diatoms of the Mississippi and composed a checklist of the taxa present in the study area. Sullivan (1981) found a total of 213 taxa across 43 genera present in the study area with the most dominant genera being <i>Navicula</i> and <i>Nitzschia</i> followed by <i>Amphora</i> .				
1982	R. Huang	The interactions of certain littoral diatoms with young plants of marine algae	Isle of Cumbrae, Scotland	Ecology
Huang (1982) investigated the interactions of diatoms on young growth of macroalgae and made several observations; the first being that diatom blooms in spring occur when temperature increases and the time of available light increases from the minimums of winter. Secondly, Huang (1982) observed that the similarity of diatom communities collected from different taxa of microalgae increases during maximum development and decreases during minimum development. Thirdly Huang (1982) noted that the distribution of common epiphytic diatoms is mostly limited to certain microalgae in the lower littoral				

zone. Fourthly Huang (1982) showed that the diatom assemblages occurring on non-biotic substrate were dominated by tube-dwelling diatoms species while the diatom assemblages associated with microalga or other biota are dominated by sessile diatoms species.

The final observation made by Huang (1982) is that the interaction between diatoms and young growth of microalgae is most apparent when observing the growth rate of the two algae groups. Huang (1982) states that diatom growth increase in the presence of macroalgae sporeling and germlings. Where the opposite is apparent in the case of macroalgae as diatoms decrease the growth of macroalgae (Huang, 1982). Huang (1982) claims that the change in growth rate in both algae groups is linked to the method of attachment of the diatoms to the young growth of macroalgae and the growth strategy of the macroalgae.

1988	L. Pyle <i>et al.</i>	Diatom paleoecology Pass Key core 37, Everglades National Park, Florida Bay	Florida Bay, USA	Ecology + paleoecology
During this study, Pyle <i>et al.</i> (1988) investigated the diatom assemblage in a core of the Pass Key mudflats of Florida bay estuary to determine a baseline for water quality for the estuary, so that the ecosystem could be returned to the "natural state" as mandated by the Everglades Forever Act. During this study, Pyle <i>et al.</i> (1988) found a total of 95 taxa in the core with an overall increase of salinity in the more recent layers. There was also a decrease in epiphytic and epipellic diatom species higher in the core that may have been a result of the decrease in populations of seagrasses, increased levels of nutrients or turbidity, increased water depth or a decrease in light penetration.				
2003	D. A. Siqueiros Beltrones and F. O. López Fuerte	Epiphytic diatoms associated with red mangrove (<i>Rhizophora mangle</i>) prop roots in Bahía Magdalena, Baja California Sur, Mexico	Baja California Sur, Mexico	Ecology
Beltrones and Fuerte (2003) conducted the first benthic diatom study in the Bahía Magdalena-Bahía Almejas lagoon system and observed 86 diatom taxa associated with mangrove prop roots and epiphytic macroalgae. Of the 86 taxa 59 were new observations for the Bahía Magdalena area, and 12 taxa were novel observations for the Baja California peninsula. Beltrones and Fuerte (2003) also noted that some taxa seem to be characteristic of mangrove systems.				
2005	C. M. Lane	The use of diatoms as biological indicators of water quality, and for environmental reconstruction, in south-east Tasmania, Australia.	Tasmania, Australia	Ecology
The study conducted by Lane (2005) used diatoms as bioindicators for water quality as well as for environmental reconstruction, of the littoral zone of Pittwater Lagoon and Derwent Estuary. Lane (2005) found that diatoms can be used as bioindicators in littoral zone systems, however, there is a vast variety of environmental factors associated with diatoms assemblages across the littoral zone, however nitrogen, phosphates and silica were found to be the most important contributors to the water quality of the marine littoral system. Furthermore, Lane (2005) stated that the environmental reconstruction of Pittwater Lagoon by using sediment cores indicates that the major factor contributing to the diatom community shift was the decrease of tidal exchange as a result of the construction of a causeway.				

2006	O. Ragueneau <i>et al.</i>	Role of diatoms in silicon cycling and coastal marine food webs		Ecology
Ragueneau <i>et al.</i> (2006) explain the importance of the necessity of knowing how diatoms acquire the silica needed to construct their frustules, especially in a silica (Si) poor environments such as the marine littoral zone, while taking into account that diatoms serve as the most nutritional food source for grazers. Ragueneau <i>et al.</i> (2006) argue that there is a major lack in research regarding Si circulation in the littoral zone. Ragueneau <i>et al.</i> (2006) noted that rivers are a major source of dissolved and undissolved Si for the marine littoral zone and that groundwater and the atmosphere contribute minimally, however, there is very little research conducted regarding groundwater and the atmosphere as sources for Si in the marine environment. Lastly, Ragueneau <i>et al.</i> (2006) state that upwelling contributes much of the Si which sustains diatom productivity. In the absence of external sources of Si, internal recycling in the ecosystem becomes extremely important to sustain diatom production.				
2009	A. Y. Al-Handal	Littoral diatoms from the Shatt Al-Arab estuary, north west Arabian Gulf	Iraq	Taxonomy
In this study, Al-Handal (2009) studied the littoral zone diatoms in the Shatt Al-Arab estuary and noted 170 taxa including over 70 genera under LM. Al-Handal (2009) stated that most of the diatoms found were cosmopolitan in their distribution with a few taxa related to tropical to sub-tropical waters. Al-Handal (2009) proposed a novel species entity for <i>Navicula lyra</i> var. <i>abnormi</i> , transferring the species to the genus <i>Lyrella</i> and removing the variety - <i>Lyrella abnormis</i> . <i>Navicula peculiaris</i> was also placed in synonymy with <i>Lyrella abnormis</i> due to the lack of characteristics differentiating <i>Navicula peculiaris</i> from <i>Lyrella abnormis</i> .				
2010	A. Witkowski <i>et al.</i>	New marine littoral diatom species (Bacillariophyta) from Kerguelen Islands. II. Heteropolar species of Fragilariaceae	Artic	Taxonomy
During this study, Witkowski <i>et al.</i> (2010) observed the diatoms from the Kerguelen Islands under LEM and SEM from which they described six novel diatom taxa in the class Fragilariaceae: <i>Nanofrustulum squammatum</i> , <i>Pseudostaurosira quasielliptica</i> , <i>Pseudostaurosira gersondei</i> , <i>Pseudostaurosira latesternum</i> , <i>Pseudostaurosira versiformae</i> , <i>Staurosirella poulinii</i> .				
2014	A. Witkowski <i>et al.</i>	A description of <i>Biremis panamae</i> sp. nov., a new diatom species from the marine littoral, with an account of the phylogenetic position of <i>Biremis</i> D.G. Mann et E.J. Cox (Bacillariophyceae)	Coast of Panama	Taxonomy
In this paper, Witkowski <i>et al.</i> (2014) describe a novel species <i>Biremis panamae</i> Witkowski & Weisenborn from the genus <i>Biremis</i> D.G.Mann & Cox which contains mostly marine littoral zone diatoms. Witkowski <i>et al.</i> (2014) documented this novel taxon with LM, SEM and transmission electron microscopy (TEM). Under LM Witkowski <i>et al.</i> (2014) documented frustule morphology as well as plastid structure. Witkowski <i>et al.</i> (2014) also documented the genetic characteristic of the chloroplast focusing on the following protein sequences: <i>rbcL</i> , <i>psbC</i> and SSU.				
2016	Y. Sawai <i>et al.</i>	Relationships between diatoms and tidal environments in Oregon and Washington, USA	Oregon and Washington	Ecology

			estuaries, USA	
During the study, Sawai <i>et al.</i> (2016) investigated the interaction of four environmental variables (tidal exposure, salinity, grain size distribution, and organic content) on littoral marine diatoms in estuaries along the coast of Oregon and Washington. Sawai <i>et al.</i> (2016) collected 175 samples from 11 sites and noted a total of 425 taxa across all the sites. Sawai <i>et al.</i> (2016) noted individual species abundances are firstly related to mud content present and then to the tidal exposure and salinity. Furthermore, Sawai <i>et al.</i> (2016) state that in order to properly characterize species-environment relationships, a large modern training set from a range of ecologically diverse sites needs to be compiled. This is mainly since diatom assemblages have site-specific diversity in the littoral zone.				
2016	M. Garcia	Taxonomy, morphology and distribution of Cymatosiraceae (Bacillariophyceae) in the littorals of Santa Catarina and Rio Grande do Sul	Santa Catarina and Rio Grande do Sul, Brazil	Taxonomy
Garcia (2016) documented the morphology, taxonomy and distribution of five species (<i>Campylosira cymbelliformis</i>, <i>Cymatosira belgica</i>, <i>Cymatosirella minutissima</i>, <i>Plagiogrammopsis minima</i> and <i>Plagiogrammopsis vanheurckii</i>) of the class Cymatosiraceae from the littoral zone of Santa Catarina and Rio Grande do Sul. Garcia (2016) collected 303 samples in total on the beaches of Santa Catarina and Rio Grande do Sul, from which the abundance and distribution of the five species across 30 beaches was documented. According to Garcia (2016), two of the studied diatom taxa were new records for Brazil. The five diatom taxa were documented using LM, SEM and TEM accompanied by morphological descriptions which allowed further elucidation of some morphological structures, this included descriptions of rimoportulae on <i>C. minutissima</i> and a single row of poroids on the copulae of <i>P. minima</i>.				
2016	M. C. Amspoker	<i>Eunotogramma litorale</i> sp. nov. a marine epipsammic diatom from Southern California USA	Scripps Beach, La Jolla, California, USA	Taxonomy
The genus <i>Eunotogramma</i> is taxonomically challenging, as although <i>Eunotogramma</i> is a valid recognized distinct genus, however, until 2016 no generitype was assigned to this genus, even though <i>Eunotogramma</i> is a widespread and common epipsammic marine genus. This genus can be elusive under LM due to the small size of the cells (Amspoker, 2016). Amspoker (2016) investigated 17 species of <i>Eunotogramma</i> from which 14 were described by Weisse in 1854 without binomials. A year later Ehrenberg proposed some binomials for the taxa noted by Weisse together with three novel taxa. Unfortunately, neither Ehrenberg nor Weisse provided illustrations or descriptions for these taxa and no designated type for the genus itself. Amspoker (2016) then investigated papers to find a generitype for the genus <i>Eunotogramma</i> and discovered that two generitypes were designated for the genus, one by Boyers (<i>E. triloculatum</i> Weisse) and one by Round (<i>E. laevis</i> Grunow), unfortunately, <i>E. triloculatum</i> had not been validly published and there was no evidence that <i>E. laevis</i> was conspecific with material considered in the original 1854 publication. Amspoker (2016) also re-examined two slides (257 and 320) from Cleve and Möller - Grunow first described <i>E. laevis</i> from slide 257 and identified <i>E. laevis</i> again on slide 320. However, Amspoker (2016) found that three different species are identified as				

E. laevis, and thus designated a lectotype for *E. laevis* based on the illustration and description by Grunow. Amspoker (2016) then designated the taxon that was the second most dominant taxa in his samples of Scripps Beach as new, describing the taxon as *Eunotogramma litorale* and documented the species with LM and SEM.

2017	K. M. Estrada-Gutiérrez	New records of benthic diatoms (Bacillariophyceae) for Mexico in the Nayarit littoral found in gut contents of <i>Crassostrea corteziensis</i> (Mollusca: Bivalvia)	Coast of Nayarit, Mexico	Ecology
Estrada-Gutiérrez (2017) conducted this study on diatoms from the gut of the Cortez oyster (<i>Crassostrea corteziensis</i> Hertlien) collected from the coast of Nayarit, in the north west region of Mexico. Estrada-Gutiérrez (2017). This study added nine novel taxa to the Mexican benthic diatom species checklist, and also stated that in order to construct biogeographical and ecological models, much more floristic work is needed, especially in countries such as Mexico where relatively few biodiversity studies of diatoms have been undertaken.				
2017	N. Desianti <i>et al.</i>	Sediment diatoms as environmental indicators in New Jersey coastal lagoons	New Jersey, USA	Ecology
Desianti <i>et al.</i> (2017) investigated diatoms of two lagoons Barnegat Bay and Great Bay in New Jersey together with the water quality in order to use diatoms as a bio-monitoring tool. During this study 100 diatom samples were collected and 603 diatom taxa were observed, with 271 taxa most probably novel taxa. The main findings of this study were that, in estuaries, there are a great number of factors; physio-chemical variables, tide fluctuations, anthropogenic activities and habitats determined by, substrate, grain size, and depth. All these factors contributed to the diatom composition at a given sample site. Desianti <i>et al.</i> (2017) noted a strong north-south salinity gradient that had a greater effect on the diatom community composition than that of water-column nutrients and sediment contaminants. Desianti <i>et al.</i> (2017) also observed that the organic matter content of the sediment had a major effect on the diatom assemblage. Taking the two major factors into account Desianti <i>et al.</i> (2017) developed diatom inference models for salinity and sediment nitrogen content and concluded that diatom species with a high optimum for sediment nitrogen may be used as bio-indicators of nutrient enrichment in the two lagoons in New Jersey.				
2019	E. L. Nevrova and A. N. Petrov	Benthic diatoms species richness at Dvuyakornaya Bay and other coastal sites of Crimea (the Black Sea) under various environments	Crimean coast (Black Sea), Russia	Ecology
Nevrova and Petrov (2019) studied the diatom assemblages of four bays (Dvuyakornaya Bay, Cape Fiolent, Sevastopol Bay and Balaklava Bay) of the Crimean coast observing 543 taxa in total. Nevrova and Petrov (2019) compared the diatom community of the four bays with one another using Bray-Curtis similarity coefficients and found that the two bays (Dvuyakornaya Bay and Cape Fiolent) with the lowest anthropogenic activity (less polluted) were more closely related with 58% similarity and the remaining bays (Sevastopol Bay and Balaklava Bay) characterised by high anthropogenic activity (highly polluted), were more closely related. When the less polluted bays were compared to the highly polluted bays only a 32 - 36 % similarity was observed. Nevrova and Petrov (2019) also noted that diatom diversity increased in waters isolated from anthropogenic activity, however, invasive species are present at Dvuyakornaya Bay that may have been introduced to this area via the hulls of ships that pass Balaklava Bay. In addition, Nevrova and Petrov				

(2019) stated that high diversity in a coastal bay is promoted by a variety of micro biotopes (variety in grain size). The main conclusion made by Nevrova and Petrov (2019) is that trace metals, PCBs, PAHs, and pesticides in the bottom sediments together with a variability of micro biotopes are the major factors influencing the benthic diatom community composition of the four studied bays of the Crimean coast.

2019	B. S. Kim <i>et al.</i>	Taxonomy and diversity of a little-known diatom genus <i>Simonsenia</i> (Bacillariaceae) in the marine littoral: Novel taxa from the Yellow Sea and the Gulf of Mexico	Yellow Sea coast and Shinan-County, Korea, Gulf of Mexico, Corpus Christi, Texas.	Taxonomy + ecology
In this study conducted by Kim <i>et al.</i> (2019) discuss the distribution of the genus <i>Simonsenia</i> and document two novel taxa belonging to this genus from the Yellow Sea coast, Korea and the Gulf of Mexico, Corpus Christi, Texas. Kim <i>et al.</i> (2019) state that the genus <i>Simonsenia</i> was previously considered to be a fresh-to-brackish water genus, however, recent descriptions of novel taxa from this genus expanded the distribution of the genus to brackish-to-marine waters. The two novel taxa (<i>Simonsenia eileencoxiae</i> B. Kim, J.-G. Park & Witkowski and <i>Simonsenia paucistriata</i> Chunlian Li, Ashworth & Witkowski.) described by Kim <i>et al.</i> (2019) were documented by LM, SEM, TEM and genetic analysis by using mono-cultured samples and sequencing the SSU, <i>rbcL</i> and <i>psbC</i> genes. A third taxon, which was observed with SEM only, within samples that were collected in fish aquaculture enclosures, was identified as <i>Simonsenia</i> cf. <i>paucistriata</i> .				
2020	A. Kryk <i>et al.</i>	Marine diatom assemblages of the Nosy Be Island coasts, NW Madagascar: species composition and biodiversity using molecular and morphological taxonomy	Nosy Be Island coasts, NW Madagascar	Ecology
Kryk <i>et al.</i> (2020) investigated the diatom assemblages of Nosy Be and Nosy Tanikely north west of the coast of Madagascar, collecting 65 samples from 14 sites from which a total 332 taxa were observed with LM and SEM. Kryk <i>et al.</i> (2020) also conducted molecular studies for identification purposes and successfully isolated and cultured 90 taxa. Of these 90 taxa, Kryk <i>et al.</i> (2020) successfully sequenced one chloroplast gene (<i>rbcL</i>) from 21 taxa. However, Kryk <i>et al.</i> (2020) were only able to identify 115 taxa (35%) to species level suggesting that the remaining taxa may be new to science. In addition, Kryk <i>et al.</i> (2020) calculated the Shannon and Simpson biodiversity indices and noted that Nosy Be was characterized by high biodiversity at the time of sampling with <i>Cocconeis scutellum</i> being the most abundant taxon. Furthermore, Kryk <i>et al.</i> (2020) state that the diatom-species composition, as well as diatom biodiversity, observed in Nosy Be is very similar those of the Galapagos Islands. This may be due to the similarity of the environmental conditions present at both islands.				
2020	O. P. Bilous <i>et al.</i>	Benthic diatom composition in coastal zone of Black Sea, Sasyk Reservoir (Ukraine)	Sasyk Reservoir, Ukraine,	Ecology

			Black Sea	
Bilous <i>et al.</i> (2020) investigated the diatom composition of Sasyk Reservoir, an artificial coastal lake that is mostly separated from the Black Sea by a dam wall and is filled with fresh water using an artificial channel that connects the Danube River with Sasyk Reservoir. However, Bilous <i>et al.</i> (2020) stated that from 1979 until the time of their study, nearly double the volume of the reservoir was pumped out and replaced with fresh water from the Danube River to decrease the salinity of this reservoir. Nevertheless, the salinity remained too high for irrigation. The diatom community was composed of 97 species (100 infraspecific taxa). Some rare marine and freshwater taxa were noted as well as three taxa (<i>Navicula vandamii</i> Schoeman et R.E.M. Archibald, <i>Sellaphora dicillima</i> (Hustedt) C.E.Wetzel, L. Ector & D.G. Mann, and <i>Mastogloia laterostrata</i> Hustedt) that was reported for the first time in Ukraine. Furthermore, seven mesohalobous taxa were found that indicate fluctuating salinity, however 61 taxa typical of freshwater environments were also noted. Lastly Bilous <i>et al.</i> (2020) used the index for European lakes to determine the water quality of Sasyk Reservoir and found that this system is characterized by moderate water quality with some exceptions.				
2020	S. Kim <i>et al.</i>	The taxonomy and diversity of <i>Proschkinia</i> (bacillariophyta), a common but enigmatic genus from marine coasts	Original material: Inland saline waters in SE Germany, Svety Petar, Croatia, Trieste, Sumba Island, Oregon, USA, Florida, USA Madeira. New sp. Material: North Atlantic in Scotland, Gulf of Mexico near Corpus Christi (Texas, USA), Korean Yellow	Taxonomy

			Sea coasts.	
During the study, Kim <i>et al.</i> (2020) thoroughly investigated the taxonomy of one common marine littoral diatom genus <i>Proschkinia</i>. This study can be summarised into three parts namely: re-documentation and emended description of five taxa from type material; description of six novel <i>Proschkinia</i> taxa, and determination of phylogenetic relationships within <i>Proschkinia</i>. For the re-documentation and emended description of five taxa from type material, Kim <i>et al.</i> (2020) obtained the type material of <i>P. bulnheimii</i>, <i>P. complanata</i>, <i>P. complanatula</i>, <i>P. complanatoides</i> and <i>P. hyalosirella</i> and produced permanent slides and SEM stubs. The five taxa were then documented with LM and SEM, with special attention to the fistula (a structure characteristic of the genus). Novel taxa included <i>P. luticola</i>, <i>P. staurospeciosa</i>, <i>P. impar</i>, <i>P. modesta</i>, <i>P. fistulispectabilis</i>, and <i>P. rosowskii</i> all of which were documented with SEM and LM. The chloroplast structure of <i>P. rosowskii</i> was also added to the description. To determine the phylogeny of the genus <i>Proschkinia</i> Kim <i>et al.</i> isolated and cultured seven taxa and successfully sequenced the SSU RNA and the <i>rcbL</i> chloroplast gene of five of the seven taxa. Kim <i>et al.</i> (2020) used the genetic data, obtained from sequencing, to construct a phylogenetic tree from which they concluded that <i>Proschkinia</i> is genetically related to the class Stauroneidaceae even though the morphological characteristics of <i>Proschkinia</i> lean towards the class Naviculaceae.				

The works cited above provide a brief overview of the international research that has been done on diatoms of the marine littoral zone over the past 70 years. The research originates from around the world and has several focus points, including taxonomy, bio-geology, ecology, paleontology, and bio-monitoring. Overall, from such research, it can be noted that most littoral zones are characterized by high diatom diversity, mostly due to the variety in site-specific diversity in the littoral zone (Sawai *et al.*, 2016). Consequently, this increases the difficulty of using diatoms as a bioindicator tool in the littoral zone environments, and a large data set is required to determine the water quality of a particular littoral zone (Sawai *et al.*, 2016). Even so, diatoms were successfully used to determine the historical ecological state of marine littoral zones by using cores (see above Pyle *et al.* (1988) and Lane (2005)). With regards to taxonomy only, only 21 novel taxa were described in the selected papers, which is quite a small proportion in relation to the number of species that were identified only to genus level in these same papers. This includes an estimated number of 488 taxa that could be novel. However, as many novel taxa are now described with molecular data the process of documenting novel taxa is now prolonged. As for the re-documentation of previously described taxa, as in the case of the study by Amspoker (2016), only four of the 22 papers discussed above included LM and SEM micrographs of previously described taxa. Two of these papers, - one by Kim *et al.* (2020), and the other one by Amspoker (2016), re-document taxa from type material or type slides. There is, therefore, still a great need for historical, and novel taxonomical studies in the marine littoral zone.

1.7 South African research on littoral zone diatoms

The research conducted on marine littoral diatoms in South Africa has also focused on taxonomical, ecological, palaeontological, biomonitoring and biogeographical work, with ecotoxicological studies being excluded. The present study is primarily focused on taxonomic and biogeographical work from the 1960's to the 1980's, which was primarily conducted by Giffen and Chohnoky, and later shifted towards ecological and biomonitoring by Bate *et al.* (2004), with some taxonomical work conducted by Witkowski *et al.* (2020). As for palaeontological work conducted on South African marine littoral diatoms, only one study was conducted by Chohnoky. Below is a summary briefly discussing some of the papers published on South African littoral zone diatoms over the past 58 years. This summary is divided in two sections, the first being the work of Malcolm Giffen and the second being other authors that contributed to research related to marine littoral diatoms of South Africa.

1.7.1 M. H. Giffen

Malcolm Giffen was the pioneer of the study of marine littoral diatoms in South Africa and described 88 marine littoral diatom taxa. Giffen was a professor in Botany at the University of Fort Hare in the Eastern Cape, South Africa (Taylor *et al.*, 2007) and lived in the town of Kidd's Beach. The list below is a summary of the papers published by Giffen during 21 years of actively working on the marine littoral diatoms of South Africa.

Date	Author	Title	Region	Main Focus of the paper
1963	M. H. Giffen	Contributions to the diatom flora of South Africa: I. Diatoms of estuaries of the Eastern Cape Province	Nahoon, Igodo, Gulu, Umkantzi, Umlele and Ncera rivers and streams, Eastern Cape, South Africa	Taxonomy, Biogeography
Giffen (1963) conducted a study on marine littoral diatoms across six blind rivers (a river with an estuary closed for parts of the year) and associated streams near East London in the Eastern Cape, South Africa. The salinity at the different localities varied from slightly to extremally brackish, with the salinity during dry periods exceeding the salinity of the ocean in some cases (Giffen, 1963). Giffen (1963) noted the total taxa observed at each site, as part of the site descriptions. Additionally, Giffen (1963) added a table showing the distribution of taxa across the twelve study sites. In total Giffen observed 190 taxa from 36 genera which included 11 new species (<i>Amphiprora corrugata</i> , <i>Amphiprora paralia</i> , <i>Amphipora perplexa</i> , <i>Amphora castellata</i> , <i>Amphora gamtoosae</i> , <i>Auricula chohnokyi</i> , <i>Cocconeis testudo</i> , <i>Gyrosigma caffra</i> , <i>Navicula guluensis</i> , <i>Navicula rogersii</i> , <i>Raphoneis mirabunda</i>) documented with line drawings.				
1970	M. H. Giffen	Contributions to the diatom flora of South Africa IV. The marine littoral diatoms of The Kowie River, Port	Kowie River, Port Alfred, Eastern Cape,	Taxonomy, Biogeography

		Alfred, Cape Province	South Africa	
This study centred around the Kowie River estuary, one of the larger rivers in the Eastern Cape Province, with tidal intrusion for about 19 km upstream from the mouth. Giffen collected 46 samples from seven sites, from which he chose 6 samples with the highest species richness. Giffen (1970) stated that before the time of sampling the estuary underwent anthropogenic changes to form a sea port that was first known as Port Frances and later as Port Alfred. From the six samples chosen, Giffen noted a total of 273 taxa from 52 genera, that also included 11 new species and one new variety (<i>Amphora francescae</i>, <i>Auricula machutchoniae</i>, <i>Diploneis interrupta</i> var. <i>caffra</i>, <i>Gyrosigma diversitatum</i>, <i>Licmophora pfannkuckae</i>, <i>Navicula ponticula</i>, <i>Navicula pseudoincerta</i>, <i>Navicula subirritans</i>, <i>Nitzschia bathurstensis</i>, <i>Nitzschia kowiensis</i>, <i>Pleurosigma kowiense</i>, <i>Stauroneis bathurstensis</i>) documented with line drawings.				
1970	M. H. Giffen	New and interesting marine littoral diatoms from Sea point, Near Cape Town, South Africa	Sea Point, Western Cape, South Africa	Taxonomy, Biogeography
Giffen collected three diatom samples from drift seaweed at Seapoint during the summer of 1967. Seapoint is a suburb of Cape Town and its shores are washed by the cold Benguela current from the South Atlantic Ocean on the western side of South Africa's coastline. From the three diatom samples, Giffen noted 92 taxa from 37 genera. Of these 92 taxa 13 taxa were newly described by Giffen (<i>Achnanthes promunturii</i>, <i>Amphora profusa</i>, <i>Berkeleya capensis</i>, <i>Cuneolus minutus</i>, <i>Dimerogramma inane</i>, <i>Gomphonema pseudoseptatum</i>, <i>Grammatophora carteri</i>, <i>Licmophora opephoroides</i>, <i>Navicula speibonae</i>, <i>Rhabdonema scabellum</i>, <i>Rhoicosphenia flexa</i>, <i>Surirella scopuli</i>, <i>Trachyneis speibonae</i>) as well as one generic transfer from <i>Cocconeis</i> to <i>Navicula</i> (<i>Navicula biflexa</i>) which were all documented by line drawings.				
1971	M. H. Giffen	Marine littoral diatoms from the Gordon's Bay, Region of False Bay Cape Province, South Africa	Gordons Bay region of False Bay, Western Cape, South Africa	Taxonomy, Biogeography
False Bay is a natural, relatively large rectangular bay situated west of Cape Town. The water temperature of False Bay is usually a few degrees higher than the water outside the bay. The reason for this phenomenon is primarily due to a small branch of the Mozambique current that enters the bay, bringing in warm water, and also that the cold Benguela current flows more southwards past the bay. However, after strong south-easterly gales, cold water and diatoms species associated with Atlantic shores, enter the bay with the Benguela current that gets diverted. This occurrence may account for the presence of mesohalobic, oligohalobic and euhalobic diatoms found in the bay (Giffen, 1971). Giffen (1971) states that there were studies conducted in the region of False Bay dating back to 1901-1903 during a German subpolar expedition under the leadership of Dr E. von Drygalski. The samples collected from Simon's bay during the expedition were examined 20 years (1928) later by Heiden and Kolbe, who observed 365 different taxa that included seven mesohalobic taxa, 15 oligohalobic taxa with the remaining being euhalobic taxa. Giffen (1971) stated that more recent work, at the				

time of this study, was that of Chohnoky (1963), who investigated diatoms from Cape Hangklip, Steenbras, and Gordon's Bay. The material used by Giffen for his study was however collected in 1945, before Chohnoky's investigation. A single sample was obtained from *Dictyota dichotoma* (Hudson) J.V. Lamouroux collected from a large tidal pool south of the village of Gordon's Bay. From this sample Giffen noted a total of 138 taxa across 40 genera, of which four (*Amphora exilitata*, *Campylosira africana*, *Navicula sponsalia*, *Nitzschia composita*) were new taxa described by Giffen and documented with line drawings.

1973	M. H. Giffen	Diatoms of the marine littoral of Steenberg's Cove in St. Helena Bay, Cape Province, South Africa	Steenberg's Cove in St. Helena Bay, Western Cape, South Africa	Taxonomy, Biogeography
------	-----------------	---	--	------------------------

In this paper Giffen investigated the marine littoral diatom flora of Steenberg's Cove in St. Helena Bay and noted a total of 148 species in 39 genera from seven samples. Giffen described 11 new taxa (*Amphora helenensis*, *Licmophora partita*, *Navicula assuloides*, *Navicula dehissa*, *Navicula nasuta*, *Nitzschia aestatis*, *Nitzschia cacumina*, *Nitzschia proceroides*, *Nitzschia sibula*, *Nitzschia steenbergensis*, *Nitzschia vulpeculoides*) which he documented with line diagrams.

1975	M. H. Giffen	An account of the littoral diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	Saldanha Bay Lagoon, Western Cape, South Africa	Taxonomy, Biogeography
------	-----------------	--	---	------------------------

For this study Giffen collected six samples from the eastern shore of Saldanha Bay near the holiday resort of Langebaan. The bay is sheltered from the stormy wave action by the surrounding land, and only opened with a 5 km wide gap on the north western end of the bay at the time of sampling. From the six samples, Giffen (1975) noted a total of 211 taxa in 40 genera, including sixteen new taxa and 2 new combinations (*Achnanthes danicoides*, *Amphora langebaanae*, *Campylosira inane*, *Cocconeis deperdita*, *Cymatosira capensis*, *Grammatophora lepida*, *Navicula infirmitata*, *Navicula lusoria*, *Navicula melanocephala*, *Navicula occasa*, *Navicula pseudoinflata*, *Navicula pseudosalinarum*, *Navicula viminoides*, *Nitzschia rorida*, *Plagiogramma appendiculatum*, *Plagiogramma occasum*, *Auliscus sculptus* var. *strigillatus*, *Auliscus sculptus* var. *rhipis*), all documented with line drawings.

1976	M. H. Giffen	A further account of the marine littoral diatoms of Saldanha Bay Lagoon, Cape Province, South Africa	Saldanha Bay lagoon, Western Cape, South Africa	Taxonomy, Biogeography
------	-----------------	--	---	------------------------

In this paper Giffen (1976) further investigated the marine littoral diatoms of Saldanha Bay, focusing more on the southern and northern parts of the bay, collecting ten samples from four stations. Giffen (1976) stated that he conducted this further study of Saldana Bay to document the diatom taxa that reside in the bay before the bay succumbed to impacts associated with the construction of an iron bulk loading harbour. From the ten samples, Giffen (1976) noted 275 taxa from 51 genera including 4 newly described species (*Achnanthes navalis*, *Amphora ridicula*, *Navicula osterosa*, *Striatella aberrans*) which Giffen

documented with line drawings.

1984	M. H. Giffen	A checklist of marine littoral diatoms from Namaqualand, South Africa	Namaqualand , Northern Cape, South Africa	Taxonomy, Biogeography
------	--------------	---	---	------------------------

In this paper, Giffen (1984) created a checklist for the diatoms species occurring in the marine littoral zone of Namaqualand. Giffen collected 25 samples from which he used eight to construct the checklist in this paper and described 15 new taxa (*Achnanthes corrupta*, *Achnanthes namae*, *Achnanthes schoemaniana*, *Amphora arcana*, *Amphora evanida*, *Amphora pannucea*, *Amphora incrassata*, *Auricula pulchra* var. *namaquensis*, *Cocconeis namaquensis*, *Gomphonitzschia capensis*, *Navicula dolosa*, *Nitzschia hybridaeformis* var. *pannucea*, *Nitzschia miranda*, *Nitzschia mytilicola*, *Nitzschia nollothae*). The 15 novel taxa were also documented with line drawings. The checklist Giffen (1984) constructed consists of a total of 233 taxa from 54 genera.

A complete list of the new taxa described by Giffen is provided in Appendix A. This appendix contains the species names, journal, publication date, page number, plate number, figure number, province, locality and nominated type slide number for each taxon. This list excludes the taxa from Kidd's Beach which are discussed in detail in the sections below.

1.7.2 Further contributions to research on marine littoral diatoms in South Africa.

1962	B. J. Chohnoky	Beiträge zur Kenntnis des marinen Litorals von Südafrika	Steenbras, Rooi Els and Knysna, South Africa	Taxonomy, Biogeography
------	----------------	--	--	------------------------

Chohnoky (1962) investigated three estuaries along the southern coast of the Western Cape province. Two of these estuaries were permanently open (Rooi-Els and Steenbras) and the third (Knysna) was a lagoon-like estuary at the time of sampling. Chohnoky (1962) noted a total of 177 taxa from the three localities and the distribution of the taxa between sampling sites. Among these 177 taxa were 42 which Chohnoky described as new (41 species and 1 new variety). (See Appendix B for full list)

1965	B. J. Chohnoky	Preliminary report on the deposits and recent diatom flora of the St. Lucia Lagoon (unpublished report).	St. Lucia Lagoon, Kwazulu-Natal, South Africa	Ecology, Palaeontology
------	----------------	--	---	------------------------

Chohnoky (1965) investigated fossil diatoms collected from cores, as well as living diatoms from Lake St. Lucia in order to determine the age of the sediments of the lagoon. In order to verify the results obtained during the study, C-14 carbon dating would have been very helpful, however, as this was not available Chohnoky made a number of observations which gave an estimate of the age of sediment of the lake together with other findings, such as ecology, and trends the lake might follow. Firstly, Chohnoky (1965) stated that the surface sediment down to 58 feet (17,7 m) could not be older than the end of the Wurm Ice Age, as the diatom composition is the same throughout, and no true fossil diatoms were found within the cores. Secondly, Chohnoky (1965) noted that in most samples no freshwater

diatoms were found, and the lake was predominantly dominated by marine littoral diatoms with some marine diatoms. Chohnoky (1965) also states that this was the case with the core samples as well, with both sample sets being rich in diatom diversity. Chohnoky (1965) noted that the sediment of the lake did not contain silt, but a lot of sand (blown in from the dunes) and organic material was present during the time of sampling. In the conclusion Chohnoky (1965) suggested that if the conditions present during the time of this study (closed lagoon and high productivity) persisted, it is would be inevitable that the lake would convert to a more terrestrial system due to the accumulation of sand and organic material, Chohnoky (1965) also predicted that the shallower parts of the lake would be affected first (and be silted up) with the northward end of the lake remaining as a slowly silting swamp / lake area. In order to prevent this from occurring Chohnoky suggested artificial breaching of the mouth.

1965	B. J. Chohnoky	Die Diatomeenassoziationen der Santa-Lucia-Lagune in Natal (Südafrika)	St. Lucia Lagoon, False Bay, Richard's Bay and Hulhulwe Kwazulu-Natal, South Africa	Taxonomy, biogeography
------	----------------	--	---	------------------------

In this paper, Chohnoky (1965) investigated the diatoms sampled at lake St. Lucia and surrounding areas as well as the core samples mentioned above. Lake St. Lucia (described by Chohnoky as a lagoon) is a protected area situated approximately 250 km north, north-east of Durban in the Kwazulu-Natal province (SA). The lagoon is linked to the Indian Ocean by a delta at the mouth and is 65 km in length from the mouth to the Mkuzi River mouth where it flows into the lagoon. The lagoon was (and remains) primarily closed due to prolonged periods of water scarcity. Most of the samples, excluding the core samples, were collected by Chohnoky himself from sediments. Additional material was collected from False Bay, Richards Bay, and Hulhulwe which are also investigated and discussed in this paper. Chohnoky (1965) collected and investigated a total of 54 samples, observing and noting the distribution of 385 taxa from 52 genera. Of these, Chohnoky described 36 novel taxa which he documented with line drawings. (See Appendix B for full list).

2004	G. C. Bate <i>et al.</i>	Benthic diatoms in the rivers and estuaries of South Africa	27 estuaries along the coast line of South Africa	Ecology
------	--------------------------	---	---	---------

In this report, Bate *et al.* (2004) investigated the diatoms of a large number of rivers and estuaries across South Africa (SA) in order to produce a manual of South African benthic diatoms containing images of all dominant and sub-dominant taxa from these habitats. The data was presented in three sections:

Section 1: South African benthic diatom taxa – collection sites.

Section 2: Dominant benthic diatoms from the rivers of South Africa and the water quality associated with them.

Section 3: Dominant benthic diatoms from the estuaries of South Africa and their habitat conditions.

However, in the present brief overview, the focus will only be on the benthic diatoms in estuaries. In their study, Bate *et al.* (2004) only focused on the diatom taxa with an abundance of >10% (dominant to sub-dominant) disregarding diatom taxa with an abundance <10%, a total of 168 dominant to sub-dominant taxa from 289 sites were noted.

Of these 160 taxa were documented with LM, with notes on salinity range, and in some cases taxonomy. In the case of diatom taxa, occurring as dominant on four or more occasions Bate *et al.* (2004) added a brief discussion on the habitat of the dominant taxa, that, focused on the salinity range to which the taxa are adapted, with reference to international research as well. Bate *et al.* (2004) noted that the most challenging aspect of an estuary is the fluctuation of salinity at any given site.

2013	G. C. Bate <i>et al.</i>	Epipellic diatoms in the estuaries of South Africa	Coast line of South Africa 27 estuaries along the coast	Ecology
------	-----------------------------	--	---	---------

Bate *et al.* (2013) conducted this study in order to determine if there were epipellic diatom taxa that could be used as bioindicators of salinity within South African estuaries. Epipellic diatoms were sampled from 27 estuaries along the South African, from the northern parts of KwaZulu-Natal (Nhlabane and Mhlathuze), southwards along the Cape east coast, south coast and continuing northwards up the west coast, as far north as the Olifants Estuary in the Western Cape. These samples were observed under LM and SEM and Bate *et al.* (2013) found that a large number of freshwater diatoms have a greater than expected tolerance range regarding salinity, from this it was concluded that in South African estuarine diatoms are not reliable indicators for salinity. The greatest similarity in species amongst the sample sites was between the Olifants, Great Berg and Breede estuaries, suggesting that the Breede Estuary, which is considered to be within the warm temperate region, is similar in species composition to the cool temperate type estuaries. In total 333 epipellic diatom taxa were observed by Bate *et al.* (2013) with 14 taxa being ubiquitous, 90 taxa could not be identified to species level.

2014	Dąbek <i>et al.</i>	<i>Minutocellus africana</i> Dąbek & Witkowski sp. nov.: a new marine benthic diatom (Bacillariophyta, Cymatosiraceae) from Lambert's Bay, Western Cape Province, South Africa	Lambert's Bay, Western Cape Province, South Africa	Taxonomy
------	---------------------	--	--	----------

Dabek *et al.* (2014) documented a new species (*Minutocellus africana*) found dominant in a sample collected from the sandy beaches of Lambert's Bay. Dabek *et al.* (2014) documented this novel taxon with LM and SEM together with a species description and comparison to the remaining taxa from the genus (*M. pseudopolymorphus* Hasle, von Stosch & Syvertsen, *M. scriptus* Hasle, von Stosch & Syvertsen and *M. polymorphus* (Hargraves & Guillard) Hasle, von Stosch & Syvertsen)).

2020	P. Cotiyane-Pondo <i>et al.</i>	Austral winter marine epilithic diatoms: Community composition and distribution on intertidal rocky substrate around the coast of South Africa	Coast line of South Africa (Port Nolloth to Richards Bay).	Biogeography
------	---------------------------------	--	--	--------------

Cotiyane-Pondo *et al.* (2020) focused on the epilithic diatoms occurring on natural rocky substrates in the intertidal zone of South Africa's shores in order to document the

community composition as well as the distribution of the diatom taxa found at the study sites. Cotiyane-Pondo *et al.* (2020) observed a total of 85 taxa from 31 genera at the 15 sites sampled, they also noted that three genera (*Nitzschia*, *Cocconeis*, and *Achnanthes*) were the most abundant. In their study Cotiyane-Pondo *et al.* (2020) further observed that the Shannon–Wiener diversity of the sites varied substantially, ranging from 0.44 (Kraaldraai) to 2.09 (Bird Island). Cotiyane-Pondo *et al.* (2020) also noted variability in the number of diatom taxa across the sites along the coastline, even though some similarities in the diatom assemblages between the sites sampled were present. With regards to the distribution of the epilithic diatom taxa on the South African coastline, Cotiyane-Pondo *et al.* (2020) observed both widespread and some site-specific taxa occurring along the South African coast. Cotiyane-Pondo *et al.* (2020) attributed the observed distribution and community structure to the measured physio-chemical data.

2020	A. Witkowski <i>et al.</i>	Exploring diversity, taxonomy, and phylogeny of diatoms (Bacillariophyta) from marine habitats. Novel taxa with internal costae.		Taxonomy and biogeography
------	----------------------------	--	--	---------------------------

This paper by Witkowski *et al.* (2020) investigated the morphological and well as phylogenetic diversity of two small marine littoral and sub-littoral diatom genera (*Anaulus* and *Eunotogramma*) that received little attention in the past and proved difficult to identify under LM. During the investigation of these two genera, it became apparent that there are taxa exhibiting morphological traits that are not congruent with the genus descriptions of either of the genera initially under investigation. Witkowski *et al.* (2020) hence proposed two new genera (*Ambo* and *Ceratanaulus*) to include these taxa. Witkowski *et al.* (2020) further proposed four novel combinations (*Ambo tenuissimus* (previously in the genus *Plagiogramma*), *Ambo balticus*, *Ambo simonsenii* (previously in the genus *Anaulus*) and *Ceratanaulus creticus* (previously in the genus *Anaulus*)) as well as two new taxa, *Ambo gallaeciae* and *Eunotogramma lunatum*. For all six of the taxa mentioned Witkowski *et al.* (2020) include the following in the taxonomy section of the paper: Description, morphology, distribution and comments. Witkowski *et al.* (2020) documented all the taxa with LM, SEM and used molecular analysis, where possible. In relation to specifically to South African littoral zones Witkowski *et al.* (2020) noted the distribution of three of the six taxa (*Ambo tenuissimus*, *Ambo balticus* and *Ambo simonsenii*) occurring in the littoral zone of South Africa. The last taxon discussed in the taxonomy section is identified as *Anaulus* cf. *australis*. The reason for the “cf” is that *Anaulus australis* was initially described from South Africa and the strains collected by Witkowski *et al.* (2020) were from Brazil. Witkowski *et al.* (2020) state that they are not entirely sure of the species identification. However, this is the taxon on which genus description of *Anaulus* is based, as Witkowski *et al.* (2020) failed to find the Typus Generis on the mica designated by Ehrenberg as the holotype of *Anaulus scalaris*, the generitype of *Anaulus*. The cultures of *Anaulus* cf. *australis* were also used to obtain the phylogenetic data for the genus *Anaulus*.

From the above it can be concluded that the research regarding marine littoral diatoms in SA is somewhat sparse, and completely halted for almost 22 years until Bate *et al.* (2004) conducted their study on fresh - and marine littoral diatoms. As mentioned above a large proportion of the work in SA was focused on taxonomy, however most of the work was

conducted during the time before LM micrographs were commonly used and all the new taxa described at this time were documented by line drawings only, which makes the task of accurate identification under LM difficult at a later time. In more recent works, Bate *et al.* (2012) state that they were unable to identify 90 taxa, which implies that, either the taxa are new to science, or it gives an indication of the difficulty of identifying taxa from published material illustrated with line drawings. Overall, relatively little research is available on marine littoral diatoms in SA compared to international research.

1.8 Diatom taxonomy

“Taxonomy is one of the oldest branches of biology and the Linnaean system of classification established in the 1750s is still in use today” - European Academies’ Science Advisory Council (2016). “However, taxonomy is today experiencing an unprecedented rate of change, driven particularly by advances in methodology due to the rapid development of molecular techniques, and by changes in the way taxonomy is disseminated, as a result of the revolution in information technology. At a time when taxonomic expertise is in great demand for documenting and monitoring changing patterns of species diversity, it is ironic, and potentially problematic, that the pool of expert taxonomists is shrinking (House of Lords Science and Technology Committee, 2008). In addition, it is difficult to attract younger scientists into the discipline because of poor career prospects. Successful monitoring of good environmental status under the marine strategy framework directive depends upon the availability of taxonomic expertise so the training of the next generation of taxonomists should be a high priority.” (European Academies’ Science Advisory Council (EASAC) and the Joint Research Centre (JRC) of the European Commission, 2016)

Even more pressing is the fact that, according to Guiry (2012) in 2012, the total amount of described algae (including diatoms) was close to 43 918 species distributed among 54 classes in 15 phyla, this number is a lot higher at present (Algaebase’s present number of published species is 163 576). Even so, Guiry (2012) estimated at that time, that up to 28 500 taxa remained undescribed. Of these undescribed species, the majority are cyanobacteria, diatoms, and freshwater green algae (Guiry, 2012). However, Mann & Vanormelingen (2013) estimate there are more than 30 000 extant diatom species - thus the exact number of validly published algae species is still debatable. Although many thousands of algae (including diatoms) have been validly described, these descriptions are often only accompanied by line drawings. Line drawings are often difficult to interpret, especially when trying to examine these species when differentiating them from suspected new taxa (Taylor *et al.* 2016).

Considering the above, the re-documentation of diatom types illustrated only with line drawings, is important to ensure that the study of diatoms can be further advanced, especially regarding the identification and description of marine littoral diatoms. Furthermore, it should be noted, as proposed by Taylor *et al.* (2016), several diatom species are subject to ‘species concept drift’, which can be defined as the misinterpretation of the original taxon concept as described by the author, which can lead to the change of the original species concept over time. The two possible reasons for this occurrence, as stated by Taylor *et al.* (2016), are the interpretation difficulties posed by line drawings and in some cases the unclear written descriptions, as in the case of the genus *Eunotogramma* (Amspoker, 2016) (see brief discussion in section 1.6). Therefore, in order to reduce the manifestation of ‘species concept drift,’ there has been an increase in authors referring directly to the type material, emphasizing the importance of type material and the proper documentation and description thereof (Wetzel *et al.*, 2015; Taylor *et al.*, 2016).

1.9 Aims and objectives

Given the general lack of research on the marine littoral zone, especially in relation to marine littoral diatom systematics in South Africa, the focus of the present work is to re-document the diatom types of Malcolm Giffen, and in addition, temporal changes of the marine littoral zone diatoms at Kidd's Beach, Eastern Cape province.

1.9.1 Aims

To re-document the 27 diatoms taxa described by Giffen from Kidd's Beach with LM and SEM micrographs together with emending and augmenting species descriptions where needed.

The present study also aims to provide an overview of the research conducted on the diatoms of the marine littoral zone in South Africa. Providing a complete species list of novel marine littoral diatoms from SA described by Giffen and Chohnoky.

Lastly, to document temporal changes in the diatom communities in the marine littoral zone at Kidd's Beach over the last five decades or more.

1.9.2 Objectives

To conduct a thorough literature study regarding the marine littoral diatoms of South Africa.

To locate the 27 novel diatom taxa in question on Giffen's type slides and micrograph the taxa under LM.

To prepare SEM stubs from the original material collected by Giffen as well as to locate and micrograph the 27 novel diatom taxa in question under SEM.

To emend and/or augment species descriptions based on new information available after SEM observations of the 27 taxa in question.

To resample diatom material from the sites described by Giffen, and to enumerate the taxa present in the samples.

To compare the results from the two time periods (resampling and Giffen's samples) in order to note temporal changes occurring in the diatom communities at Kidd's Beach.

Chapter 2 - Materials and methods

2.1 Study area

Kidd's Beach is a small coastal town, located in the Eastern Cape about 32 km south-west of East London on the Indian Ocean coast line. Kidd's Beach is in a summer rainfall region with dry mild winters (Giffen, 1967). The temperature of the littoral zone at Kidd's Beach may range from 15°C to 24°C and is affected by the warm Mozambican current and especially by the prevalent north-easterly and south-westerly winds that influence the movement of the sea water (Giffen, 1967). Giffen (1967) noted that, in the summer (rainy season), the salinity of the coast line may decrease from 35-36‰ to 30‰ as a result of the coastal rivers that have high flow or are in flood. Giffen also noted that the seeping of fresh or brackish water from coastal springs in the area may also affect the composition of diatoms in rock and sandy pools. The water level change between neap and spring tides also increases the salinity in the rock and sandy pools and affects the diatom composition (Giffen, 1967).



Fig. 1: Google Earth image of the location of Kidd's beach in South Africa with an enlarge image of Kidd's beach. (GPS: S 33°08'27" E 027°42'03") (Google Earth, 2020).

2.2 Giffen's material

Both the type slides and type material were obtained from the South Africa National Diatom Collection (SANDC) (ex CSIR/NIWR diatom collection) housed at the North-West University (NWU), Potchefstroom, South Africa. The collection is owned by the South African Institute for Aquatic Biodiversity and is on long loan to the NWU. The type slides were examined under the light microscope (LM) and the original material was used to make stubs for scanning electron microscopy. Giffen made a number of slides from a single sample and differentiated them with an underscore as follow: 165_1 (site number underscore slide number from the site.). Giffen created series of slides (up to ten or more) for each of the samples he examined, when examining the different slides in the series there was a marked difference in the cell size class found on each side, some in the series with many large cells present and some with almost none. This implies that the samples were allowed to settle at different rates for each slide, however, no evidence of such a procedure could be found in

Giffen's notes. In the case of rare species, one or two slides were nominated as the type of the species, and the cells were marked with a ring scratched into the back of the slide. For this reason, the following type slides were used in order to find the 27 taxa described by Giffen (Giffen's sample number followed by NIWR number): 165_3: 286/5719, 195_4: 287/5723, 197_3: 287/5725, 197_4: 454/9073, 197_5: 454/9074, 210_5: 287/5727, 210_8: 454/9078, 210_x: 454/9079, 211_1: 287/5729, 509_4: 287/5734, 509_5: 287/5733, 510_D: 287/5735, 510_1, 455/9081, 518_3: 287/5737, 518_6: 454/9085. Malcolm Giffen donated his slide collection to the then NIWR in the 1980s, the types (usually marked with a 'T' scratched into the glass – but not always) were then selected from his collection by a third party (possibly F.R. Schoeman), these slides were then given NIWR numbers and accessioned as the types. However, many of the slides designated in this way do not have cells of the taxa which Giffen described. For this reason, the original pencil drawings made by Giffen (also housed in the SANDC) were investigated (see Appendix C). Giffen usually only wrote the site number e.g., "165" adjacent to the illustration of the new taxon, however in some cases a specific slide e.g., "165_3" was noted next to the drawing of the type, and thus the exact slide that Giffen himself used for the description could be examined and in many cases the exact cells he drew could be micrographed. Giffen did not include these specific slide numbers in his paper: Giffen, M. H. 1967. Contributions to the Diatom Flora of South Africa, III Diatoms of the Marine Littoral Region at Kidd's Beach Near East London, Cape Province, South Africa. However, he did add these dedicated slide numbers in his later work - see Appendix A.

A Nikon ECLIPSE 80i Light microscope equipped with a Nikon digital sight DS-U2 camera system was used to obtain the LM micrographs of 26 of the 27 diatom taxa in question. The preserved original material collected by Giffen was used to make stubs for scanning electron microscopy (SEM) using the following method: A subsample of original material (dry at the time of this study, originally stored in formalin) was carefully removed from the original glass vial with a scalpel and placed into a new glass vial marked with the corresponding sample number. Distilled water was then added to the subsample to re-suspend the dried material. The subsamples of the original material were sonicated and re-cleaned using the same method described below for more recent samples. Aliquots of the subsamples were then filtered through a 1 µm Millipore® filter with distilled water. The filters were then air-dried and mounted on aluminium stubs using double-sided carbon tape. The stubs were then sputter-coated with carbon and gold-palladium and used to obtain electron micrographs of 23 of the 27 taxa in question, using a FEI Quanta 2000 F-SEM (10 KV, WD 10 mm). The SEM and LM images were edited with Photoshop CS and plates were composed with Corel Graphics Suite.

During the course of the study of the Giffen types it became apparent that a number of these should be transferred to more appropriate genera. The transfers and the reasons for these decisions are outlined in the following section but are not considered to be effectively published, effective publication will take place in a journal article at a later date. The relevant section from the International Code of Nomenclature for algae, fungi and plants is as follows: "30.9. Publication on or after 1 January 1953 of an independent non-serial work stated to be a thesis submitted to a university or other institute of education for the purpose of obtaining a degree does not constitute effective publication unless the work includes an explicit statement

(referring to the requirements of the code for effective publication) or other internal evidence that it is regarded as an effective publication by its author or publisher.” (Turland *et al.*, 2017).

2.3 Resampling from Giffen’s study sites

Additional material for the present study was collected on 20 October 2018 and 27 October 2019 from the sites as described by Giffen (165, 195, 197, 210, 211, 509, 510, and 518).

165: ‘Collected from washings of *Codium* sp. This station was exposed after the mouth of the river (lagoon) opened after high tide and the water level dropped about 1.5 m’. 01 January 1946 (Giffen, 1967). At the time of resampling, the river mouth was closed and the sample was taken at the lagoon itself. 20 October 2018 and 27 October 2019 (S 33°14’53.80” E 027°70’09.93”) (Fig. IV).

195: ‘Washings from *Ectocarpus* sp. in very brackish water’. 22 September 1963 (Giffen, 1967). The resampled material was collected from *Ectocarpus* sp. in a pool that formed next to the tide pool. 20 October 2018 and 27 October 2019 (S 33°08’51.16” E 027°42’09.80”) (Fig. II).

197: ‘From pools at the high tide mark along the beach north-east of the river mouth’. 30 January 1946 (Giffen, 1967). The resampled material was collected from the same pools. 20 October 2018 and 27 October 2019 (S 33°08’33.76” E 027°42’16.41”) (Fig. III).

210: ‘From algal masses (*Cladophora* sp.) floating in the children’s paddling pool. This enclosure up to 30 cm. deep had been recently constructed above normal tide level and only refills after spring tide. It is contaminated with fresh water flowing in during rainy periods from the Village Commonage’. 10 October 1963 (Giffen, 1967). At the time of resampling, the paddling pool Giffen refers to, did not exist and turned into a tidal pool that is refilled at high tide. 20 October 2018 and 27 October 2019 (S 33°08’51.16” E 027°42’09.80”) (Fig. II).

211: ‘From algal masses *Cladophora* sp. and *Ectocarpus* sp. floating near the mouth of the Umkantzi Lagoon. This is very brackish water, regularly fed by seawater during spring tides’. 10 October 1963 (Giffen, 1967). Resampled material was collected at the same location. 20 October 2018 and 27 October 2019 (S 33°14’53.80” E 027°70’09.93”) (Fig. IV).

509: ‘Scraping from rock surfaces in rock pool north-east of the river mouth above normal tide level. Fed by wave action at spring tides and by seepage of fresh or brackish water from the land above’. 23 January 1961 (Giffen, 1967). Resampled material was collected from rock pools at the high tide mark, no rock pools were found further inland or at Kidd’s Beach. 20 October 2018 and 27 October 2019 (S 33°08’33.76” E 027°42’16.41”) (Fig. III).

510 & 511: ‘From diatom covered sand in pools on the beach full only during spring tides’. 23 January 1961 (Giffen, 1967). Resampled material was collected from diatom covered sands from the pool that formed next to the tide pool. 20 October 2018 and 27 October 2019 (S 33°08’51.16” E 027°42’09.80”) (Fig. II).

518: ‘From diatom covered sands at the mouth of time Umkantzi Lagoon. The river mouth

was closed (“blind”) at the time and evaporation and seepage through the sandy bar had lowered the level at a few ends’ (Giffen, 1967). Resampled material was collected at the same location. 20 October 2018 and 27 October 2019 (S 33°14’53.80” E 027°70’09.93”) (Fig. IV).



Fig. II: Site 195, 210 & 510. Tidal pool at Kidd's beach with a new pool that formed next to the pool wall.



Fig. III: Site 197 & 509. Rock pool north east of the river mouth.



Fig. IV: Site 165, 211 & 518. River mouth of the Mcantsi river at Kidd's Beach

Sample information on Giffen's samples and the samples from the resampled sites in 2018 and 2019			
Sample no.	Sampling date	Coordinates	Sample description
165_G	01 January 1946		'Collected from washings of <i>Codium</i> sp. This station was exposed after the mouth of the river (lagoon) opened after high tide and the water level dropped about 1.5 m'.
195_G	22 September 1963		'Washings from <i>Ectocarpus</i> sp. in very brackish water'
197_G	30 January 1946		From pools at the high tide mark along the beach north-east of the river mouth
210_G	10 October 1963		From algal masses (<i>Cladophora</i> sp.) floating in the children's paddling pool. This enclosure up to 30 cm. deep had been recently constructed above normal tide level and only refills after spring tide. It is contaminated with fresh water flowing in during rainy periods from the Village Commonage
211_G	10 October 1963		From algal masses <i>Cladophora</i> sp. and <i>Ectocarpus</i> sp. floating near the mouth of the Umkantzi Lagoon. This is very brackish water, regularly fed by seawater during spring tides
509_G	23 January 1961		Scraping from rock surfaces in rock pool north-east of the river mouth above normal tide level. Fed by wave action at spring

			tides and by seepage of fresh or brackish water from the land above
510_G	23 January 1961		From diatom covered sand in pools on the beach full only during spring tides
511_G	23 January 1961		From diatom covered sand in pools on the beach full only during spring tides
518_G	Not available		From diatom covered sands at the mouth of time Umkantzi Lagoon. The river mouth was closed (“blind”) at the time and evaporation and seepage through the sandy bar had lowered the level at a few ends
165_18	20 October 2018	S 33°14’53.80” E 027°70’09.93”	At the time of resampling, the river mouth was closed and the sample was taken at the lagoon itself.
195_18	20 October 2018	S 33°08’51.16” E 027°42’09.80”	The resampled material was collected from <i>Ectocarpus</i> sp. in a pool that formed next to the tide pool.
197_18	20 October 2018	S 33°08’33.76” E 027°42’16.41”	From pools at the high tide mark along the beach north-east of the river mouth
210_18	20 October 2018	S 33°08’51.16” E 027°42’09.80”	From algal masses (<i>Cladophora</i> sp.) floating in the children’s tidal pool. At the time of resampling, the paddling pool Giffen refers to, did not exist and turned into a tidal pool that is refilled at high tide.
211_18	20 October 2018	S 33°14’53.80” E 027°70’09.93”	From algal masses <i>Cladophora</i> sp. and <i>Ectocarpus</i> sp. floating near the mouth of the Umkantzi Lagoon. This is very brackish water, regularly fed by seawater during spring tides
509_18	20 October 2018	S 33°08’33.76” E 027°42’16.41”	Resampled material was collected from rock pools at the high tide mark, no rock pools were found further inland or at Kidd’s Beach.
510_18	20 October 2018	S 33°08’51.16” E 027°42’09.80”	Resampled material was collected from diatom covered sands from the pool that formed next to the tide pool.
511_18	20 October 2018	S 33°08’51.16” E 027°42’09.80”	Resampled material was collected from diatom covered sands from the pool that formed next to the tide pool.
518_18	20 October 2018	S	From diatom covered sands at the mouth

		33°14'53.80" E 027°70'09.93"	of time Umkantzi Lagoon. The river mouth was closed ("blind") at the time and evaporation and seepage through the sandy bar had lowered the level at a few ends.
165_19	27 October 2019	S 33°14'53.80" E 027°70'09.93"	At the time of resampling, the river mouth was closed and the sample was taken at the lagoon itself.
195_19	27 October 2019	S 33°08'51.16" E 027°42'09.80"	The resampled material was collected from <i>Ectocarpus</i> sp. in a pool that formed next to the tide pool.
197_19	27 October 2019	S 33°08'33.76" E 027°42'16.41"	From pools at the high tide mark along the beach north-east of the river mouth
210_19	27 October 2019	S 33°08'51.16" E 027°42'09.80"	From algal masses (<i>Cladophora</i> sp.) floating in the children's tidal pool. At the time of resampling, the paddling pool Giffen refers to, did not exist and turned into a tidal pool that is refilled at high tide.
211_19	27 October 2019	S 33°14'53.80" E 027°70'09.93"	From algal masses <i>Cladophora</i> sp. and <i>Ectocarpus</i> sp. floating near the mouth of the Umkantzi Lagoon. This is very brackish water, regularly fed by seawater during spring tides
509_19	27 October 2019	S 33°08'33.76" E 027°42'16.41"	Resampled material was collected from rock pools at the high tide mark, no rock pools were found further inland or at Kidd's Beach.
510_19	27 October 2019	S 33°08'51.16" E 027°42'09.80"	Resampled material was collected from diatom covered sands from the pool that formed next to the tide pool.
511_19	27 October 2019	S 33°08'51.16" E 027°42'09.80"	Resampled material was collected from diatom covered sands from the pool that formed next to the tide pool.
518_19	27 October 2019	S 33°14'53.80" E 027°70'09.93"	From diatom covered sands at the mouth of time Umkantzi Lagoon. The river mouth was closed ("blind") at the time and evaporation and seepage through the sandy bar had lowered the level at a few ends.

The resampled material was brushed, with a toothbrush, from the walls of rock pools, or

gently removed from diatom covered sand with a spoon, or a sample of macroalgae was taken (where applicable as per site description). The samples were placed in a Whirl-Pak® bag and stored in a refrigerator. The samples obtained were cleaned by the following acid digestion method: The samples were left to settle for a day, after which the excess water was drained, leaving a highly concentrated sample and 2 ml of the sample was then added to a glass test tube, followed by 2 ml of potassium permanganate (Taylor *et al.*, 2007). The sample was vortexed and was left to settle for a day after which 2 ml of hydrochloric acid was then added to the sample in the test tube, vortexed and heated in a water bath to 240 °C until the sample turned straw-yellow (Taylor *et al.*, 2007). The test tube was taken out of the water bath and 1-3 drops of hydrogen peroxide were added to the test tube (Taylor *et al.*, 2007) to test for the presence of organic matter. The sample was then transferred to a centrifuge tube and topped up with distilled water to 10 ml. The sample was then centrifuged at 2500 rpm for 10 minutes, the supernatant was then decanted into a waste container and the precipitant was re-suspended with a jet of distilled water (Taylor *et al.*, 2007). The centrifuge tube was then refilled with distilled water to 10 ml. This process was repeated four times. After the supernatant of the fourth centrifugation was decanted, 2 ml of distilled water was added to the centrifuge tube and vortexed to re-suspend the precipitate (Taylor *et al.*, 2007). The now cleaned material was then transferred to a small glass vial and topped up with 90% ethanol to preserve the material (Taylor *et al.*, 2007). The glass vial was marked with a unique sample number and archived in the South Africa National Diatom Collection (SANDC) (Taylor *et al.*, 2007). The remaining uncleaned material was transferred to a plastic bottle, marked with the corresponding number of the glass vial and topped up with 90% ethanol for long term storage (Taylor *et al.*, 2007). The clean material was dried on to coverslips and mounted on glass slides with Pleurax. Additional slides from Giffen's original material were also made, where possible, in order to obtain the same size variety of diatom as the resampled sites. A Nikon ECLIPSE 80i Light microscope (LM) was used to observe and count specimens (~ 400 cells) on slides.

The field data concerning chemical physical variables were obtained at each site in 2019 with LAQUAtwin® compact water quality meters. The meters were calibrated before sampling. The meters for each variable were paced in the water at each site and the data were recorded and entered into Excel.

2.3.1 Statistical analysis

Count data (relative abundance of all species noted) was imported into Canoco 4.5 to generate a CCA (canonical correspondence analysis) and DCA (detrended correspondence analysis) from the three data sets. The DCA was used to determine the temporal changes at Kidd's beach between Giffen's samples and those collected in 2018 and 2019. The CCA was used to illustrate the influence of the physico-chemical variables on the diatom community composition at Kidd's Beach in 2019. Physico-chemical data was Log transformed prior to statistical analysis.

DCA was chosen to determine the temporal change in community composition, as DCA is a more accurate method of analysis for the obtained data, than a CA (Correspondence analysis) (Holland, 2008). The reason being that CA is restricted is due to the fact that it follows a one-

dimensional approach (Holland, 2008). This approach creates an arch on the plot area that makes it difficult to interpret the data (for instance: to observe similarities between sites) (Holland, 2008). Thus DCA gives a better species and site ordination to interpret the similarities between sites (Hill & Gauch, 1980).

A CCA was chosen to illustrate the influence of the physico-chemical variables on the diatom community composition as it is a multivariate method used to explain the relationship between biological assemblages and their environment, that can be easily presented in an ordination diagram (Ter Braak & Verdonschot, 1995). CCA is based on Shelford's law of tolerance (a species requires a minimum amount of resources to grow but, does not tolerate more than a certain maximum) together with the weighted average of a species (Ter Braak & Verdonschot, 1995). CCA also uses the ordination method of reciprocal averaging, adding statistical methodology or regression to a CCA. This makes a CCA accurate in presenting the relationship between species and the physico-chemical environment they live in (Ter Braak & Verdonschot, 1995).

The method of interpreting the DCA (excluding the environmental variables in the case of DCA) and CCA ordination diagram is as follows: The distance of the sites from one another indicates the degree of similarity in community composition. Thus the closer the sites are to each other in the ordination, the higher the similarity in community structure between the sites (Ter Braak & Verdonschot, 1995). The relationship or correlation of a site to the vectors representing environmental variables is based on the horizontal plane on which the site lies in relation to the vector and not the distance of the site from the vector (Ter Braak & Verdonschot, 1995). These CCA and DCA ordination diagrams were hence used to explain the temporal changes of the marine littoral community structure at Kidd's Beach over the past 57 years.

Chapter 3 - Augmented and emended taxa descriptions of the 27 taxa described by Giffen from Kidd's Beach

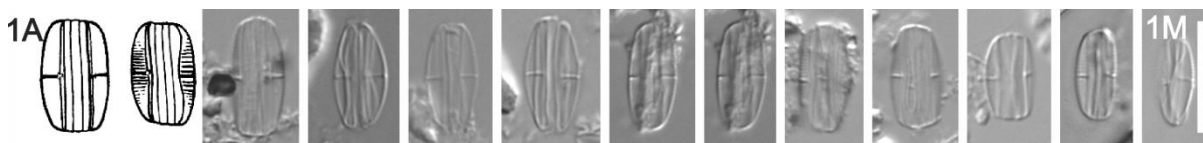
Amphora exilissima Giffen 1967 (Figs 1A–1M)

Type: SOUTH AFRICA. 'Kidd's Beach' (indicated in Giffen 1967: 251); Giffen 210, SANDC, Potchefstroom, (Giffen's "iconotype" can be interpreted as: "Giffen 1967: Figs 8, 9 are representing the type").

Lectotype: SOUTH AFRICA. 'Kidd's Beach' (Giffen 1967: 252); Slide number 210_5, NIWR 287/5727, SANDC, Potchefstroom, the lectotype is represented by Figs. 1C-1M.

Emended description: Cells elliptical with truncate ends. The valves have a convex dorsal margin and almost straight ventral margin, 7.8-10.6 μm long, 2.5-4.7 μm broad. Valve ends are slightly acute. The raphe is straight and close to the ventral margin. Striae are not visible under LM. Prominent, narrow stauros crosses the centre of the valve face. No cells were observed under SEM.

The samples were initially stored in un-buffered formalin, thus it may be the case that the silica of these rather delicate cells dissolved before the sample dried (Müller, 2005).



Figs 1A-1M. *Amphora exilissima* Giffen. **Figs 1A, 1B.** Original line drawings reproduced from Giffen (1967).

Figs 1C-1M. Scale bar = 10 μm (Figs 1A–1M).

Amphora incredulata Giffen 1967 (Figs 2A-2G)

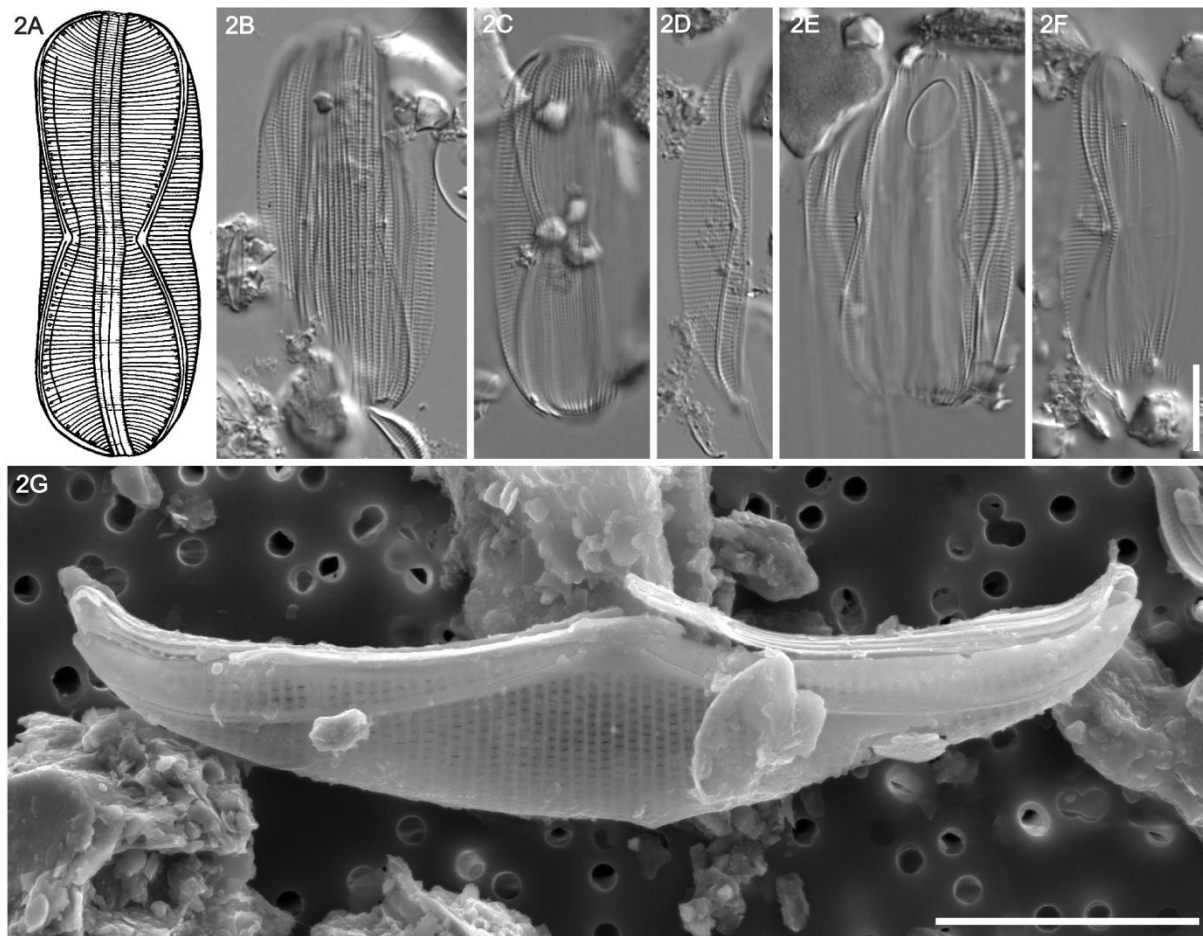
Type: SOUTH AFRICA. 'Kidd's Beach' (indicated in Giffen 1967: 252); Giffen 197, SANDC, Potchefstroom, (Giffen's "iconotype" can be interpreted as: "Giffen 1967: Fig. 13 is representing the type").

Lectotype: SOUTH AFRICA. 'Kidd's Beach' (Giffen 1967: 252); Giffen 197_3, NIWR 287/5725, SANDC, Potchefstroom, the lectotype is represented are Figs. 2B-2F.

Additional slide: SOUTH AFRICA. 'Kidd's Beach' (Giffen 1967: 252); Slide number 210_5, NIWR 287/5727, SANDC, Potchefstroom..

Emended description: Frustule linear with broad rounded ends. Valves linear with obliquely rounded ends 52 μm long, 18 μm broad. Axial area narrow. Raphe biarcuate more or less distant from the ventral margin. Striae 20 in 10 μm on both sides of the raphe composed of moderately large areolae 8-11 in 10 μm along the ventral edge of the raphe. A slight fold or limbus also appears on the ventral side. Copulae 8-10 in 10 μm , striae 25-26 in 10 μm . Under SEM the external proximal raphe endings are straight and simple (Fig. 2G). Externally the

central area is prominent and squared (Fig. 2G). The striae are parallel to radiate at the valve ends and consist of slit-like areolae (Fig. 2G).



Figs 2A-2G. *Amphora incredulata* Giffen. Fig. 2A. Original line drawings reproduced from Giffen (1967). **Figs 2B-2F. LM. Fig. 2G.** SEM External view of valve. Scale bars = 10 μ m (Figs 2B-2G).

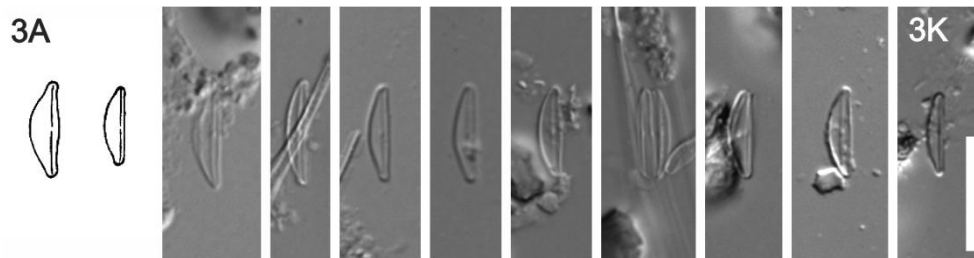
Giffen compared *A. lineolata* Ehrenberg with *A. incredulata* and concluded the size range of these two taxa was rather similar. However, Jahn & Kusber (2004) documented the lectotype of *A. lineolata* and the size range is greater than originally stated, Ehrenberg (1838) states that the length of the valves is 94-188 μ m, however, according to Jahn & Kusber (2004) the valve measured on the drawing sheet of the type specimen was 229 μ m long thus *A. incredulata* and *A. lineolata* have very different size ranges.

***Amphora micrometra* Giffen 1967 (Figs 3A-3K)**

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (indicated in Giffen 1967: 252); Slide number **210**, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 16, 17 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 252); Slide number **210_8**, NIWR 454/9078, SANDC, Potchefstroom, the lectotype is represented by Figs. 3C-3K.

Emended description: Frustules very small, 7-9.4 long, μm up to 3.4-5 μm wide, elliptical with truncate ends. The valves are 7-9.4 μm long, 1.7-2.7 μm wide, with convex dorsal margins, and slightly protracted rounded ends, ventral margin straight or slightly convex. The raphe is nearly straight and close to the ventral margin. Under LM, striae cannot be distinguished on either side of the raphe. No cells were observed under SEM.



Figs 3A-3K. *Amphora micrometra* Giffen. **Figs 3A, 3B.** Original line drawings reproduced from Giffen (1967). **Figs 3C-3K.** LM. Scale bar = 10 μm (Figs 3A-3K).

***Caloneis africana* (Giffen) Stidolph 1995 (Figs 4A–4T)**

Basionym: *Caloneis brevis* (Greg.) Cleve var. *distoma* Grunow f. *africana* M. H. Giffen 1967:256, pl 60 (2), fig. 23.

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (indicated in Giffen 1967: 256); Giffen **197**, SANDC, Potchefstroom (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Fig. 23 represents the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 256); Slide number **197_3**, NIWR 287/5725, SANDC, Potchefstroom, the lectotype is represented by Figs. 4C-4L.

Additional slides: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 256); Slide number **518_6**, NIWR 454/9085, SANDC, Potchefstroom, .

The taxonomy of *Caloneis brevis* (Greg.) Clave var. *distoma* Grunow f. *africana* Giffen 1967 was reviewed by Stidolph (1995) after observing a similar species in his samples from New Zealand. Stidolph noted several synonyms for the proposed entity *Caloneis africana*.

Caloneis brevis var. *elliptica* Van Heurck in Van Heurck 1896, p. 207, pl. 4, fig. 181.

Caloneis brevis (Gregory) Cleve, *sensu* Brocmann 1950, p.20, pl. 3, fig. 19; *non* Gregory.

Caloneis brevis var. *vexans* Grunow, *sensu* Clave-Euler 1955, p. 89, fig. 1123b; *non* Grunow.

Caloneis silicula var. *inflata* (Grunow) Clave, *sensu* Wood 1961, p. 707, pl. 58, fig. 35; *non* Grunow.

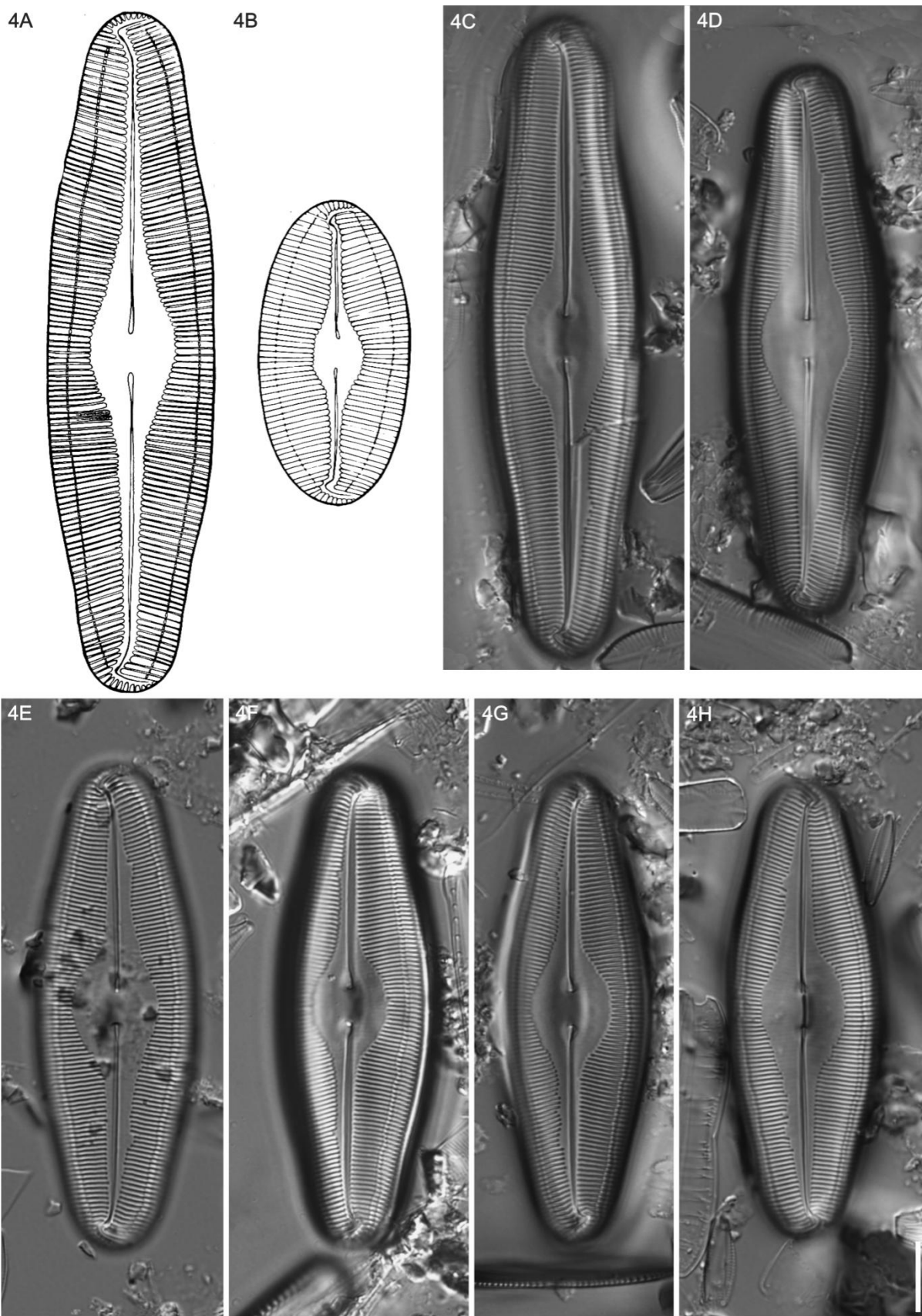
Caloneis brevis (Gregory) Clave, *sensu* Giffen 1967, p. 255, pl. 2, fig. 22; *non* Grunow.

Caloneis subsalina (Donkin) Hendey, *sensu* Foged 1979, p. 31, pl. 20, figs 1, 2; *non* Donkin.

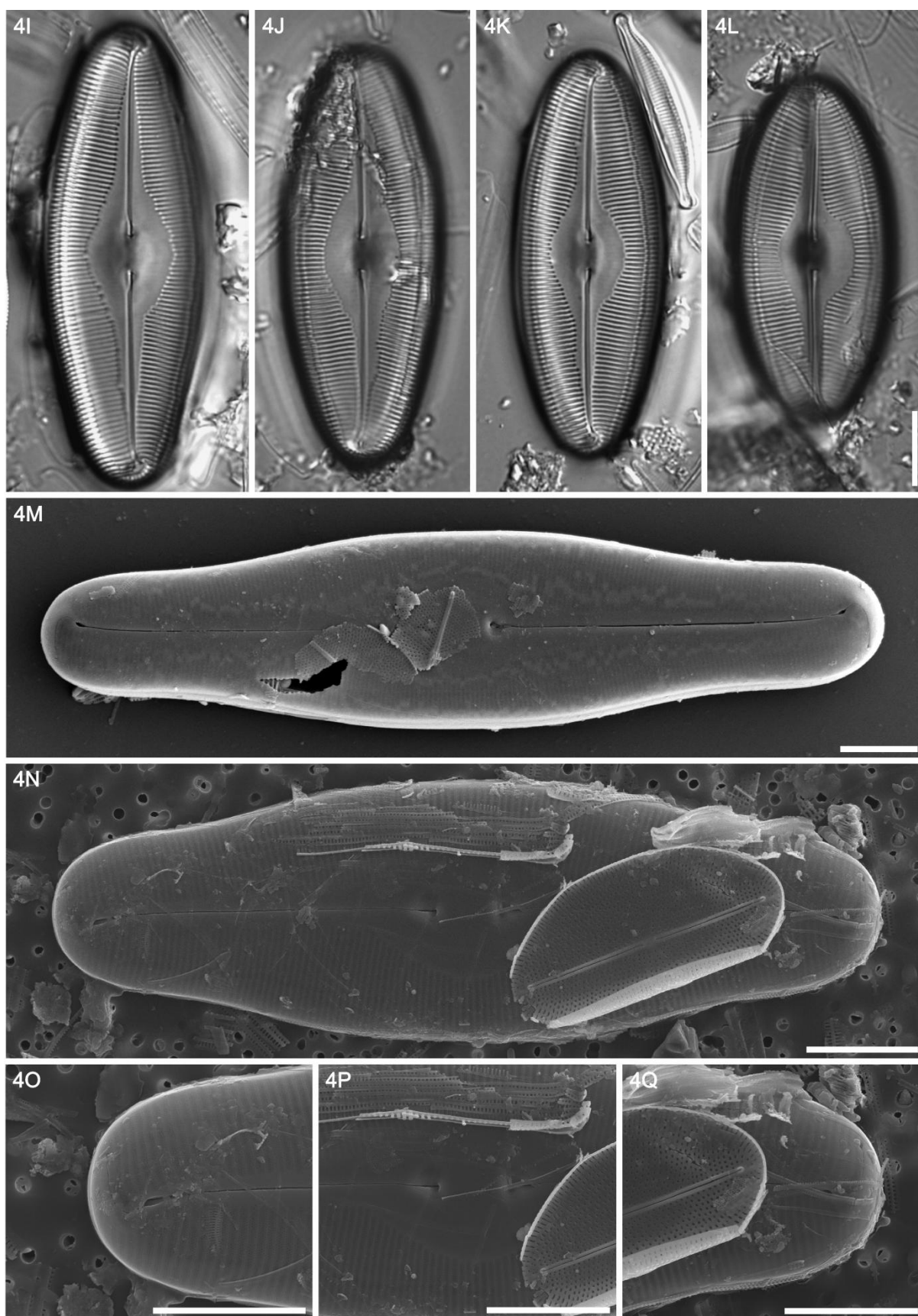
Stidolph (1995) regarded all of the above as synonyms of *Caloneis africana*, but Stidolph (1995) did not examine the type slide of the species in question.

Morphological observations: Valves are lanceolate to elliptical with rostrate ends (larger cells), 108-44 μm long, 22-24.5 μm broad, prominent axial area with broad oval central area, broader, more circular and slightly shorter at the primary side, than the secondary side. One

longitudinal line running parallel with the valve margin. Prominent voight discordance is present. The distal raphe endings are large and sickle-shaped and deflected to the same side. Proximal raphe endings are pore-like and deflected slightly to the primary side near the central area. Striae are radiate throughout, 15-16 in 10 μm . Under SEM the external distal raphe endings are sickle-shaped and deflected to the same side (Figs 4N, 4P, 4T). The external proximal raphe terminates in pore-like expansions (Fig. 4S). The striae consist of 4-5 rows of fine areolae (Fig. 4R, 4S).



Figs 4A–4H. *Caloneis africana* (Giffen) Stidolph. **Figs 4A, 4B.** Original line drawings reproduced from Giffen (1967). **Figs 4C–4H.** LM. Scale bar = 10 μm (Figs 4A–4H).



Figs 4I-4Q. *Caloneis africana* (Giffen) Stidolph. **Figs 4I-4L.** LM. **Figs 4M-4Q** SEM. **Figs 4M-4Q.** External view of valve. **Figs 4O, 4Q.** Distal raphe endings. **Fig. 4P.** Proximal raphe endings. Scale bar = 10 μm (Figs 4I-4Q).

***Cavinula kantsiensis* (Giffen) De Ridder & J.C. Taylor comb. nov. (Figs 5A–5L)**

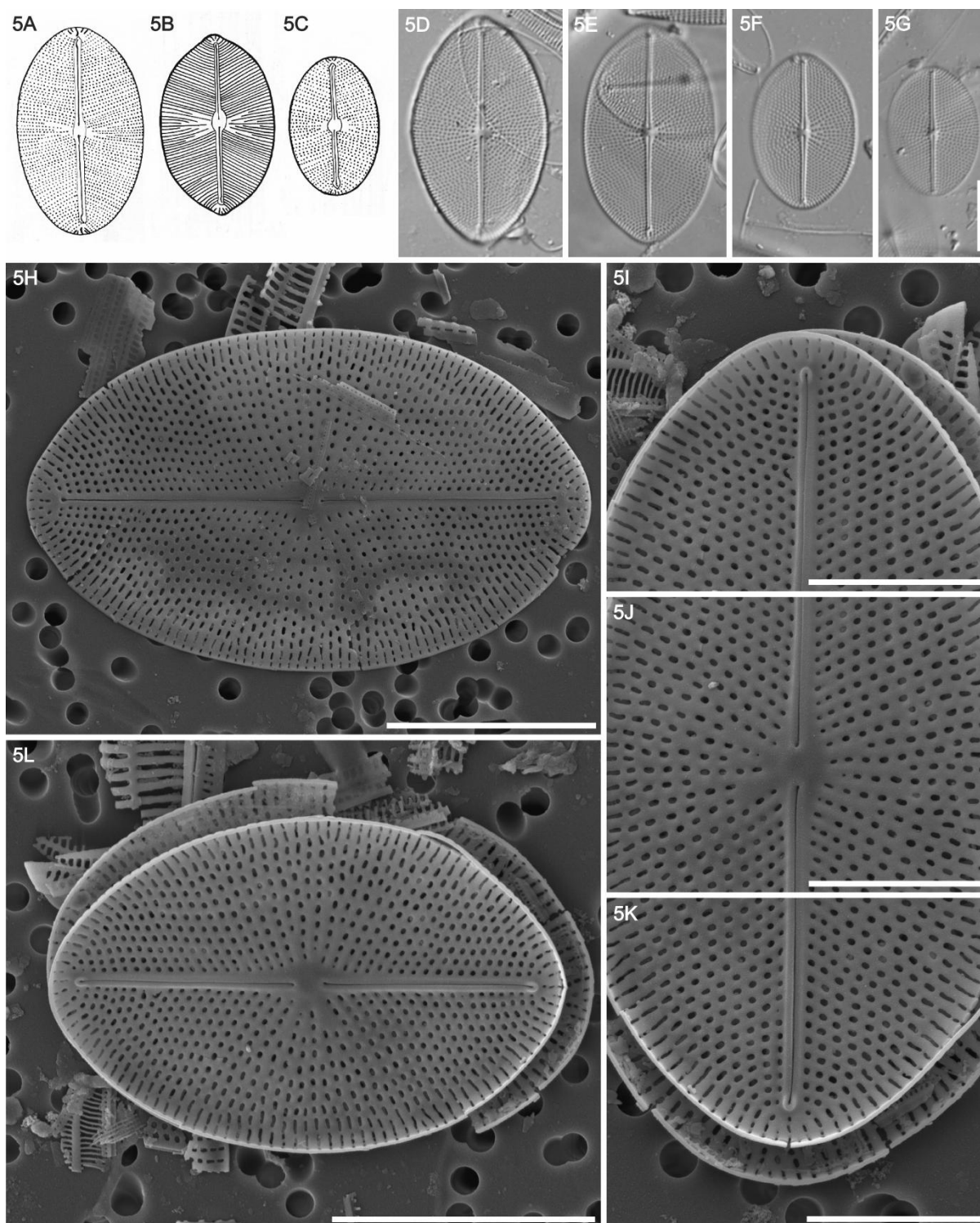
Basionym: *Navicula kantsiensis* Giffen 1967: 269, pl 61 (3), figs 65–67.

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 269); Giffen **197**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 65–67 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 269); Slide number **197_3**, NIWR 287/5725, SANDC, Potchefstroom, the lectotype is represented by Figs. 5D–5G.

Emended description: The valves are broadly elliptical with rounded or slightly subrostrate apices, 17–33 µm long 12–20 µm broad. The raphe is straight, simple, with the distal raphe endings being small, ending a short distance from the margin of the valve. Axial area is narrow linear with a small lanceolate central area. Transapical striae 20–22 in 10 µm, strongly radiate, alternately longer and shorter in the centre, distinctly punctate, the areolae forming undulate rows about 18–20 in 10 µm. Under SEM the external distal raphe endings are slightly expanded, pore-like and terminate on the valve face (Fig. 5H). The external proximal raphe endings are simple and pore-like (Fig. 5H). No clear junction is present between the valve face and mantle (Fig. 5H). Externally the striae are radiate throughout the valve. The areolae near the axial area are rounded to elongate, becoming slit-like near the valve margin (Fig. 5H). The internal distal raphe endings are simple and terminate in helictoglossae which are very slightly flexed in the same direction (Figs. 5I, 5K, 5L). The internal proximal raphe endings are simple and slightly bent to opposite sides (Figs. 5J, 5K). Internally the areolae are occluded by thin hymenes.

Navicula kantsiensis is transferred to *Cavinula* D.G. Mann & Sickle as the striae are uniseriate, radial and composed of round to elongate areolae (Fig. 5H) whereas in *Navicula* the areolae are slit like (lineolae). The valves are linear-lanceolate to elliptical in outline with a shallow mantle where in the case of *Navicula* there is a prominent mantle (Fig. 5H). The external, proximal raphe endings are expanded (Fig. 5H). The external distal raphe endings do not extend over the mantle (Fig. 5H) whereas in *Navicula* the external distal raphe endings extend over the mantle (Spaulding *et al.*, 2009) (Round *et al.*, 1990).



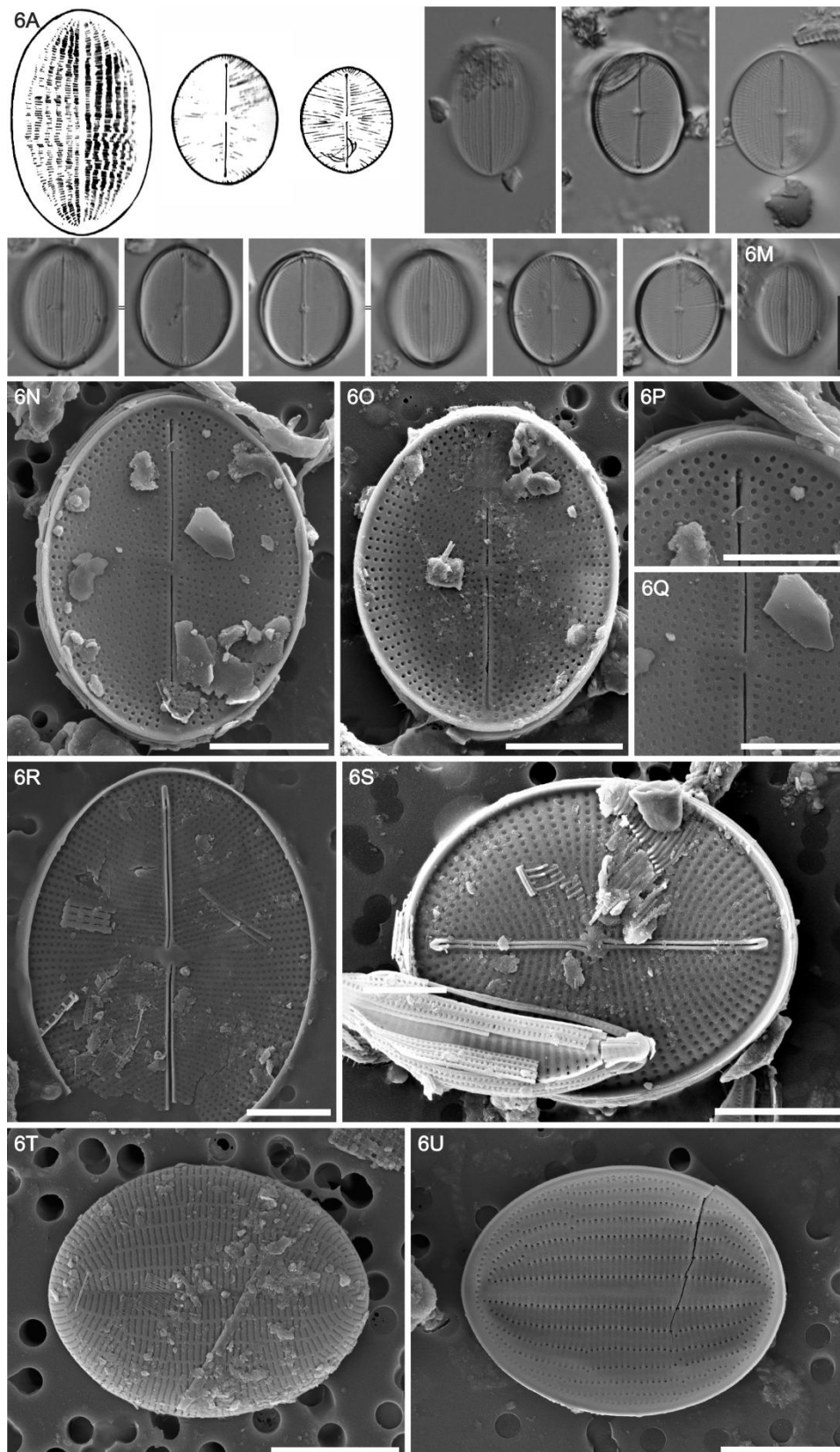
Figs 5A–5L. *Cavinula kantsiensis* (Giffen) De Ridder & J.C. Taylor comb. nov. **Figs 5A–5C.** Original line drawings reproduced from Giffen (1967). **Figs 5D–5G.** LM. **Figs 5H–5L.** SEM. **Fig. 5H.** External view of valve. **Figs 5I–5L.** Internal view of valve. **Figs 5I, 5K.** Distal raphe endings. **Fig. 5J.** Proximal raphe endings. Scale bar = 10 µm (Figs 5A–5H, 5L). Scale bar = 5 µm (Figs 5I–5K).

***Cocconeis convexa* Giffen 1967 (Figs 6A–6U)**

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 257); Giffen **210**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: Giffen 1967: Figs 26–28 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 257); Slide number **210_5**, NIWR 287/5727, SANDC, Potchefstroom, the lectotype is represented by Figs. 6D–6M.

Emended description: Frustules are flexed, RV concave and RLV strongly convex. Valves are broadly elliptical 12–22 µm long, 9–17 µm broad. The RV has a narrow straight axial area that is slightly widened around the central area and terminates a short distance from the valve margin. The raphe is straight and simple with moderately close proximal endings and enlarged elongate distal endings. Striae are radiate across the RV, 25–28 in 10 µm, centre striae alternately longer and shorter and finely punctate. Striae on the RLV 28–39 in 10 µm forming 6–9 undulate rows in the apical plane. Externally under SEM the distal raphe endings on the RV are marginally curved in the same direction and pore-like (Figs 6N, 6O). The external axial area is very narrow, with a small elliptical central area (Fig. 6N). The striae externally on the RV consist of small pore-like areolae and terminate before the valve margin (Figs 6N, 6O). Externally on the RV no striae are present directly above the distal raphe endings (Fig. 6P). Internally on the RV the distal raphe endings are deflected in opposite directions and terminate in prominent helictoglossae (Figs 6S). Internally on the RV the proximal raphe endings are deflected in opposite directions (Figs 6R, 6S). Internally the raphe is carried in a sternum, the central area is silicified and elliptical (Figs 6R, 6S). Externally on the RLV the striae are composed of slit-like areolae (Fig. 6T). Internal view of the RLV, areolae pore-like, rounded, forming undulating longitudinal lines (Fig. 6U).



Figs 6A–6U. *Cocconeis convexa* Giffen. **Figs 6A–6C.** Original line drawings reproduced from Giffen (1967). **Figs 6D–6M.** LM. **Figs 6N–6U.** SEM. **Figs 6N–6Q.** External view of RV. **Fig. 6P.** Distal raphe ending. **Fig. 6Q.** Proximal raphe endings. **Figs 6R, 6S.** Internal view of RV. **Fig. 6T.** External view of RLV. **Fig. 6U.** Internal view of RLV. Scale bar = 10 μm (Figs 6A–6M). Scale bar = 5 μm (Figs 6N, 6O, 6R–6U). Scale bar = 3 μm (Figs 6P, 6Q).

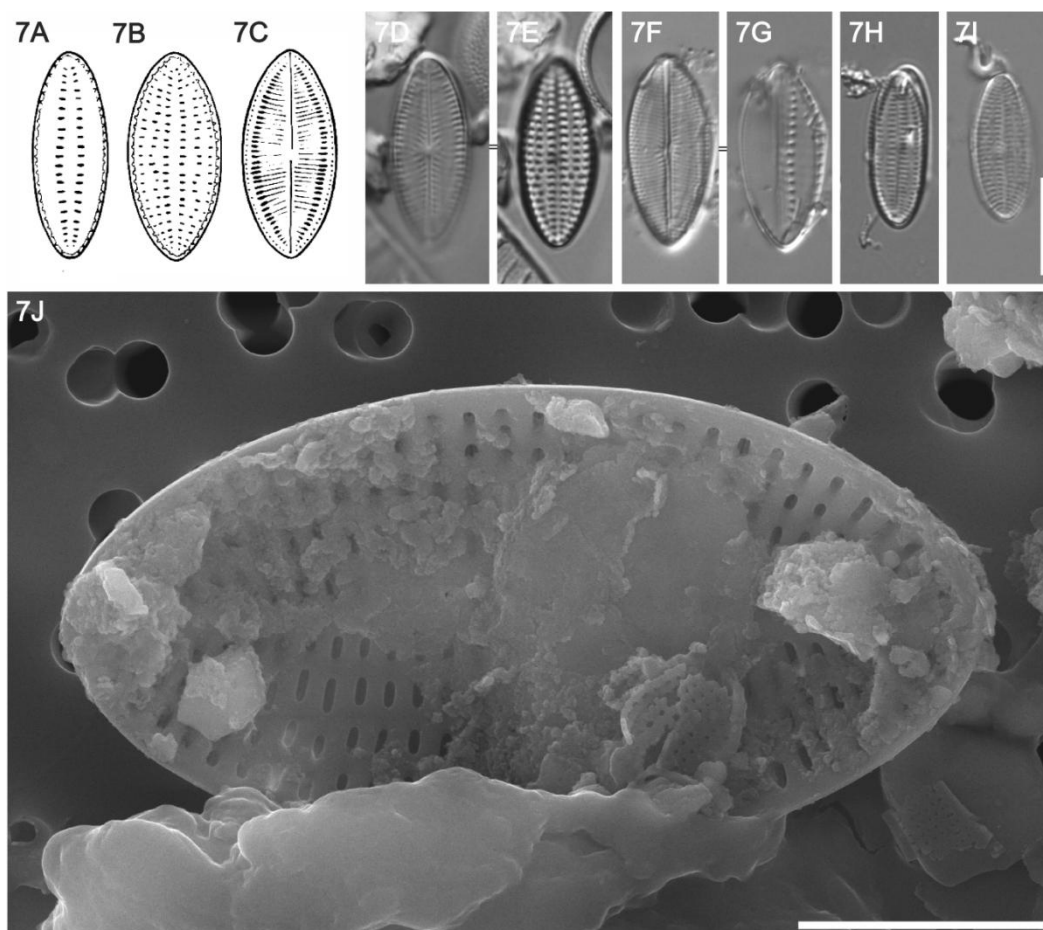
***Cocconeis distantula* Giffen 1967 (Figs 7A–7J)**

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (indicated in Giffen 1967: 258-259); Giffen **510**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 29, 30 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 258-259); Slide number **510_D**, NIWR 287/5735, SANDC, Potchefstroom, the lectotype is represented by Figs. 7D-7I.

Emended description: Valves are narrow elliptical to elliptical-lanceolate. 13-20 µm long, 6-9 µm broad. The rapheless valve (RLV) has prominent striae, 11-20 in 10 µm, crossed by several hyaline lines on each side of the axial area, forming 3-4 rows of transapically elongated areolae (occasionally 1-2 rows). On the raphe valve (RV) the striae continue onto the valve margin with distinct areolae. Raphe is straight and the axial area is narrow, widening slightly around the central area. Striae 17-24 in 10 µm are weakly punctate. Under SEM only one internal view of one RLV was found. The areolae are slit-like and striae terminate on the valve margin (Fig. 7J). The striae are radiate at the ends to parallel in the centre (Fig. 7J).

Cocconeis distantula should probably be placed in an Achnanthoid genus, as it does not belong within *Cocconeis*. However, *Cocconeis distantula* was not transferred to a more appropriate genus, as there were not enough cells observed under LM or SEM to provide the evidence needed to transfer *Cocconeis distantula* to a more appropriate genus.



Figs 7A–7J. *Cocconeis distantula* Giffen. **Figs 7A–7C.** Original line drawings reproduced from Giffen (1967). **Figs 7D–7I.** LM. **Fig. 7J.** SEM Internal view of RLV. Scale bar = 10 µm (Figs 7A–7I). Scale bar = 5 µm (Fig. 7J).

***Entomoneis erosa* (Giffen) De Ridder & J.C. Taylor comb. nov. (Figs 8A–8K)**

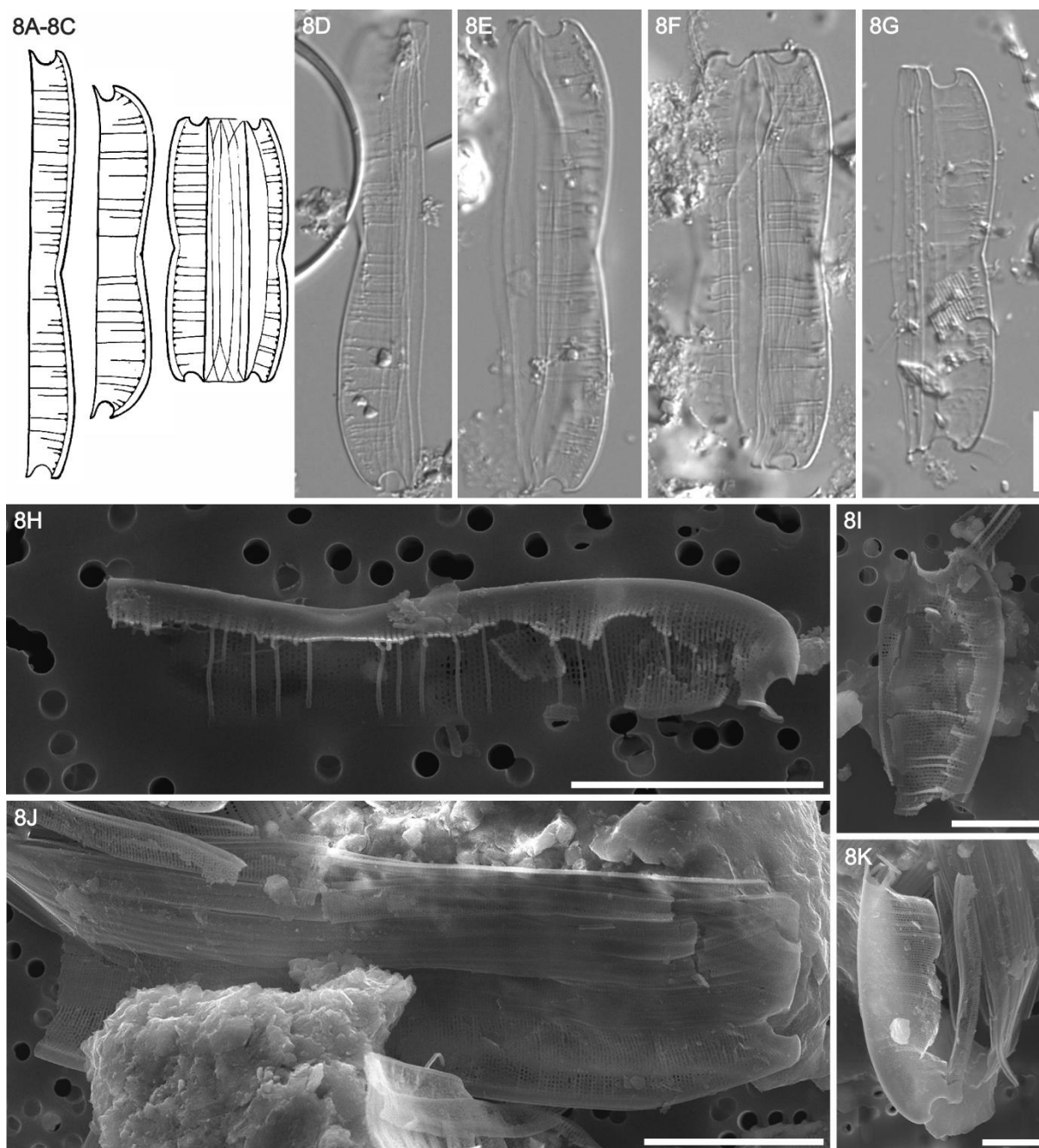
Basionym: *Nitzschia erosa* Giffen 1967:274-275, pl 62 (4), figs 85–87.

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (indicated in Giffen 1967: 274-275); Giffen **510**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 85–87 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 274-275); Slide number **510_D**, NIWR 287/5735, SANDC, Potchefstroom, the lectotype is represented by Figs. 8D-8G.

Emended description: Cells in girdle view are slightly constricted in the center, 36-58 µm long 14-18 µm broad. The valves are linear with oblique rounded ends, 5-8.7 µm broad, with a small rounded sinus at the end, close to the margin and producing a more or less S-shaped end (sickle-shaped). Keel somewhat eccentric, constricted in the centre, fibulae irregular 9-14 in 10 µm and irregularly elongated into ribs, some but not all, reaching the margin. Transapical striae very delicate and not visible under LM, 52 in 10 µm under SEM. Under SEM the valves expand outwards from the raphe keel towards the copulae. This swelling of the valve is symmetric giving a triangular shape to the valve in cross section. The axial area is narrow and broadens at the central area (Fig. 8H). Striae externally and internally are straight and parallel extending to the very narrow valve margin (Fig. 8H). The striae consist of round to slit-like areolae (Figs 8H-8K). Rib-like structures extending from some of the fibulae to the valve margin internally across the valve face (Fig. 8H). The girdle is composed of multiple copulae, perforated with fine slit-like pores (Figs 8J, 8K). The cells are very fine silicified and all the cells obtained under SEM were broken.

Nitzschia erosa is transferred to *Entomoneis* Ehrenberg as the valve face is laterally compressed with a thin bilobate keel (Fig. 8J), whereas in *Nitzschia* Hassall the keel is thick. The raphe of *Nitzschia erosa* is positioned on the outer edge of the keel as in the case of *Entomoneis* (Fig. 8J), whereas in the case of *Nitzschia* the raphe is within a keel. Multiple copulae, perforated with fine slit-like pores are present in *Nitzschia erosa*, (Fig. 8J) whereas *Nitzschia* has far less copulae. (Spaulding *et al.*, 2021)



Figs 8A–8K. *Entomoneis erosa* (Giffen) De Ridder & J.C. Taylor comb. nov. **Figs 8A–8C.** Original line drawings reproduced from Giffen (1967). **Figs 8D–8G.** LM. **Figs 8H–8K.** SEM. **Figs 8H, 8I.** Internal view of valve. **Figs 8J, 8K.** External view of valve. Scale bar = 10 μm (Figs 8A–8H, 8J). Scale bar = 5 μm (Figs 8I, 8K).

***Entomoneis galerita* (Giffen) De Ridder & J.C. Taylor comb. nov. (Figs 9A–9F)**

Basionym: *Amphiprora galerita* Giffen 1967:249-250, pl 59 (1), figs. 1-3.

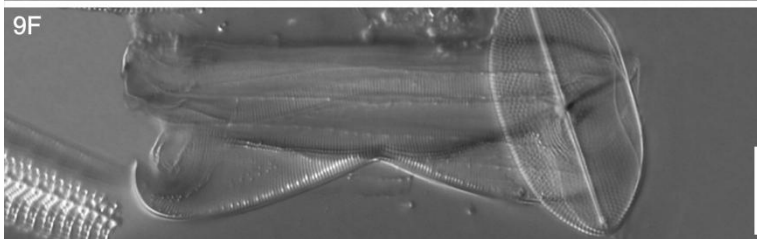
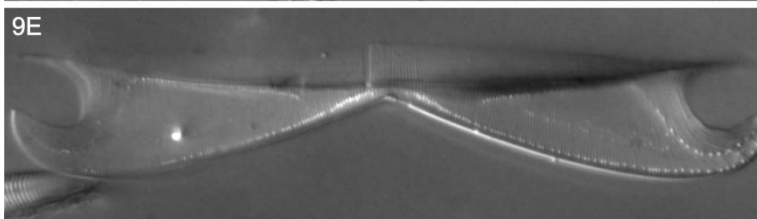
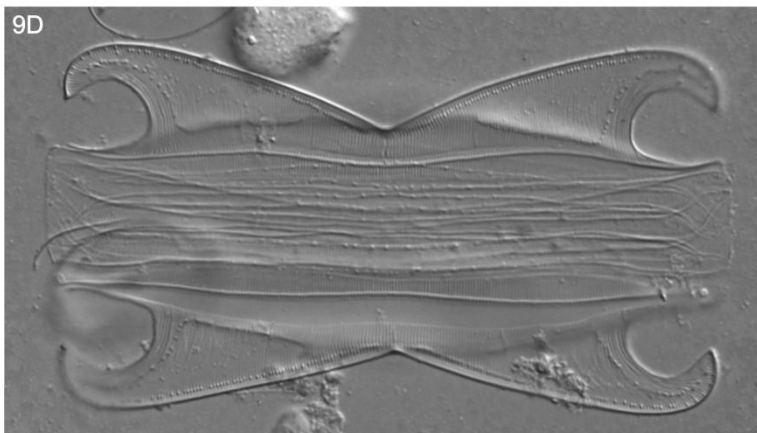
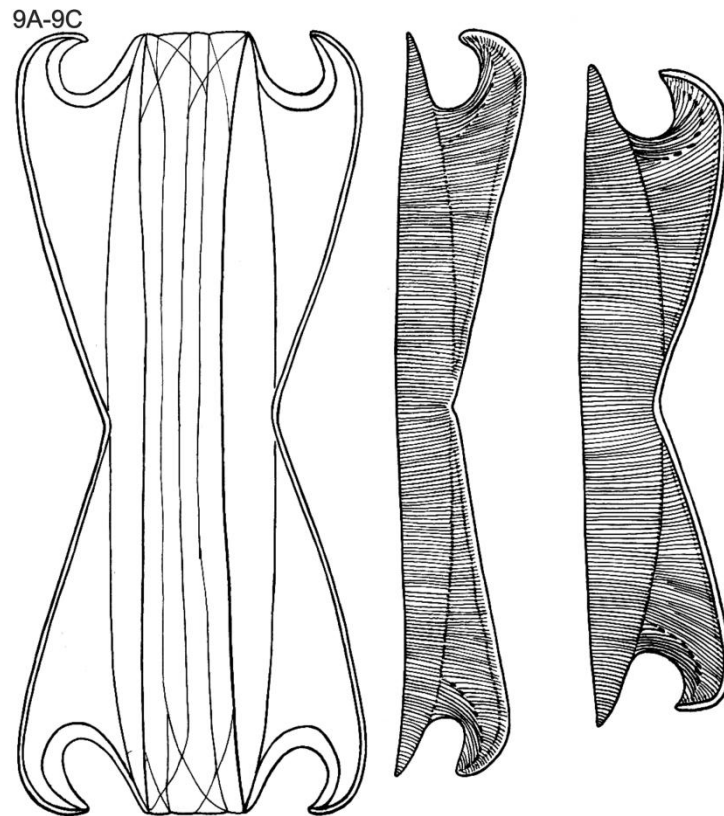
Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 249-250); Giffen **197**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 1-3 are representing the type”).

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 249-250); Slide number **197_4**, NIWR 454/9073, **197_5**, 454/9074 SANDC, Potchefstroom, the lectotype is represented by Figs. 9D-9F.

Emended description: Cells in girdle view are deeply constricted with truncate widely hooked ends, 58-90 (58-86?) μm long, 30-42 μm wide. Valves have prominent keels, about 15 μm wide at the ends, 6-10 μm in the centre, base line of the wings arcuate. The raphe canal within a raised keel is sharply defined. Valve with striae 27-31 in 10 μm on both keels and valve. Fibulae are very short bar-like structures, present below the raphe canal throughout the whole length of the keel. The striae are parallel in the centre becoming convergent at the ends, following the shape of the keel at the hooked end.

No cells were obtained under SEM. Only 3 cells were observed under LM on two designated type slides, cells were marked by Giffen with an engraved circle on the back of the slide.

Amphiprora Ehrenberg as stated by Al-Handal, *et al.* (2020) was found to be an invalid genus. Thus we transferred *Amphiprora galerita* to *Entomoneis* Ehrenberg also taking, into account that *Amphiprora galerita* shares the diagnostic characteristics of *Entomoneis* which includes the following: The valve face is laterally compressed with a thin bilobate keel (Figs 9D-9F). Multiple girdle bands are present (Figs 9D-9F). The raphe is positioned on the outer edge of the keel (Figs 9D-9F). (Al-Handal, *et al.*, 2020; Spaulding *et al.*, 2021).



Figs 9A–9F. *Entomoneis galerita* De Ridder & J.C. Taylor comb. nov. **Figs 9A–9C.** Original line drawings reproduced from Giffen (1967). **Figs 9D–9F.** LM. Scale bar = 10 μ m (Figs 9A–9F).

***Fallacia pragmatica* (Giffen) De Ridder & J.C. Taylor comb. nov. (Figs 10A–10D)**

Basionym: *Navicula pragmatica* Giffen 1967:271-272 (Figs 126, 127)

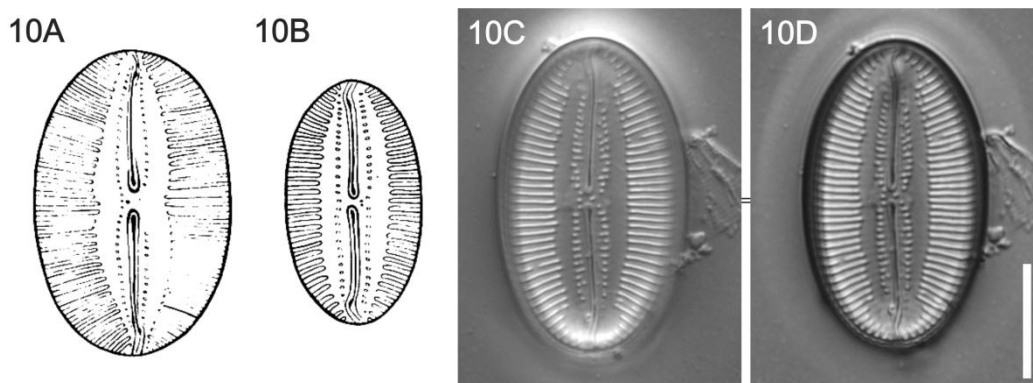
Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 271-272); Giffen **510**, SANDC, Potchefstroom, holotype (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 126, 127 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 271-272); Slide number **510_1**, NWIR 455/9081, SANDC, Potchefstroom, the lectotype is represented by Figs. 10C-10D.

Emended description: The valves are broadly elliptical with blunt rounded ends 22-28 µm long, 12-18 µm broad. The raphe is slightly curved with somewhat incrassate proximal endings and long-comma shaped endings. The axial area is linear-lanceolate, narrow on one side and wider on the arch of the raphe. The central area is small, quadrate. Lyre-shaped hyaline lines are narrow and terminate next to the distal raphe endings (lateral areas are narrow, lunate, narrowing from the centre to the ends, separated from the central and axial areas by rows of moderately strong puncta). Transapical striae parallel in the centre to radiate at the ends interrupted by lateral sterna 12 in 10 µm.

Only one cell was found under LM on the designated type slide, the cell was marked by an engraved circle on the back of the slide. No cells were observed under SEM.

Navicula pragmatica is transferred to *Fallacia* Stickle & Mann as lyre-shaped canals are present, and absent in *Navicula* (Figs 10C-10D). The striae of *Navicula pragmatica* are interrupted by lateral sterna (Figs 10C-10D), where the striae are uninterrupted in *Navicula*. The striae of *Navicula pragmatica* consist of round areolae (Figs 10C-10D) and not of lineolae as in *Navicula* (Round *et al.*, 1990).



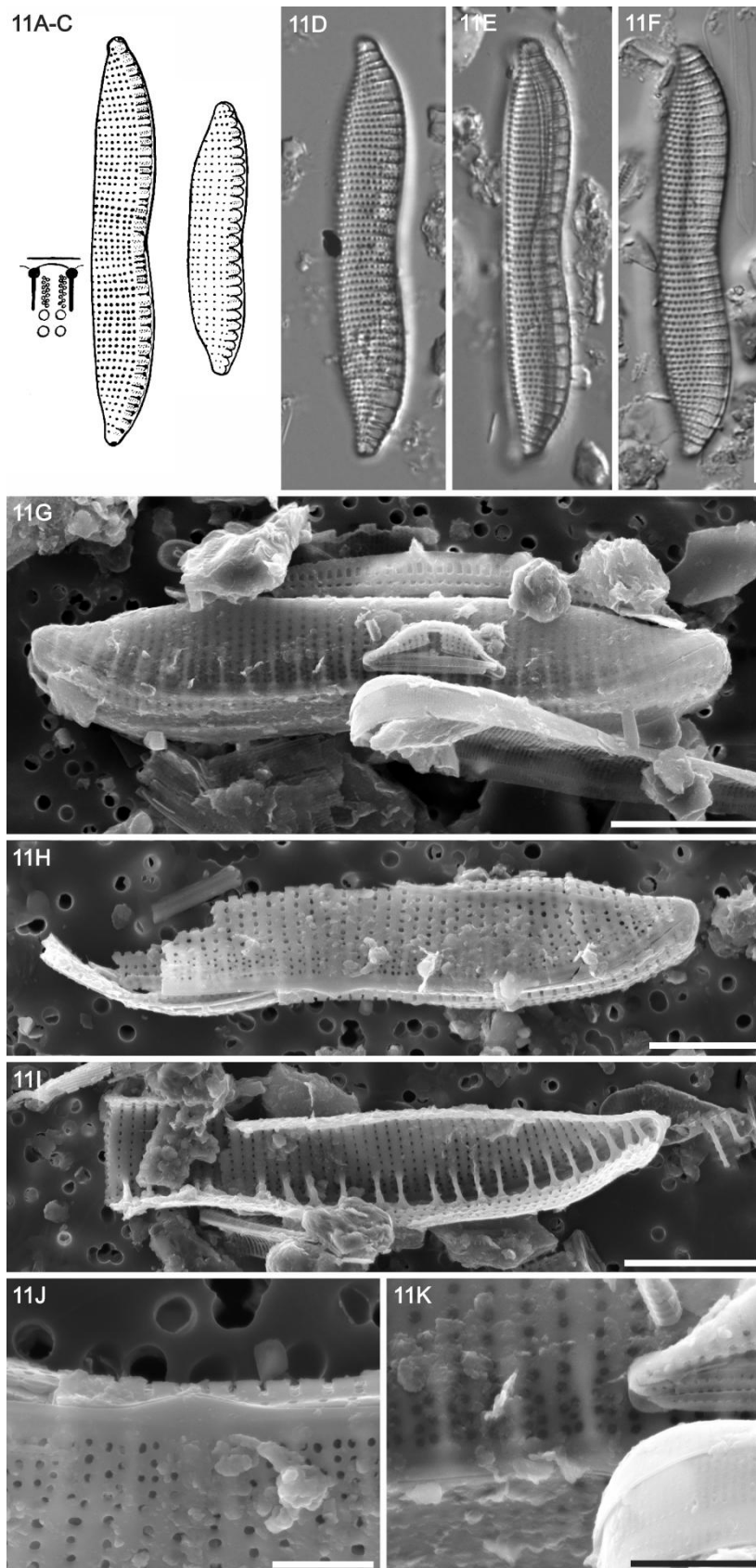
Figs 10A–10D. *Fallacia pragmatica* (Giffen) De Ridder & J.C. Taylor comb. nov. **Figs 10A, 10B.** Original line drawings reproduced from Giffen (1967). **Figs 10C, 10D.** LM. LM Scale bar = 10 µm (Figs 10A-10D).

***Hantzchia insolita* Giffen 1967 (Figs 11A–11K)**

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 263); Giffen **210**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 39–41 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 263); Slide number **210_5**, NIWR 287/5727, SANDC, Potchefstroom, the lectotype is represented by Figs. 11D–11F.

Emended description: Valves are linear-lanceolate, dorsi-ventral, slightly constricted in the centre, with slightly protracted broadly rounded apices, 35–52 µm long, 6–9 µm broad. Valves are slightly narrower at the constriction. The raphe is carried in a marginal keel, with elongated, narrow, evenly spaced fibulae, 5–6 in 10 µm. Striae 10–12 in 10 µm and clearly punctate, consisting of a single row of areolae (12 in 10 µm) terminating in short double rows of areolae on the keel between the fibulae (Fig. 11J). Under SEM the raphe is simple, running along the valve margin and continues on the valve near the apex (Figs 11G, 11H). The external distal raphe endings are straight and simple, not extending over the valve margin (Fig. 11G). Externally the proximal raphe endings are straight, simple and pore-like, terminating in a protrusion on the valve margin (Fig. 11J). The internal distal raphe endings are straight and simple, extending to the valve margin (Fig. 11I).



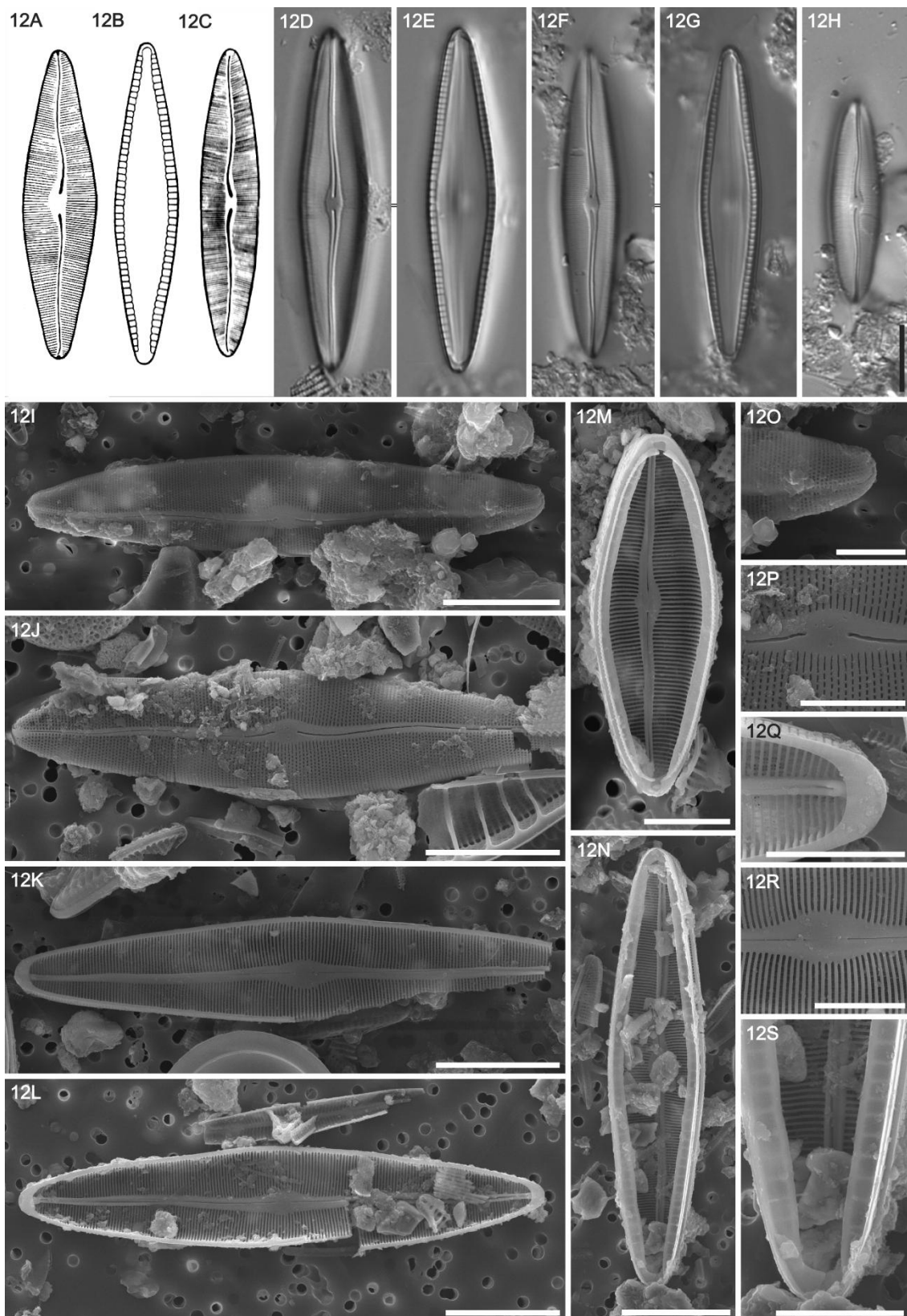
Figs 11A–11K. *Hantzchia insolita* Giffen. **Figs 11A–11C.** Original line drawings reproduced from Giffen (1967). **Figs 11D–11F.** LM. **Figs 11G–11K.** SEM. **Figs 11G, 11H, 11J, 11K.** External view of valve. **Fig. 11J.** proximal raphe endings. **Fig. 11I.** Internal view of valve. Scale bar = 10 μm (Figs 11A–11I). Scale bar = 3 μm (Figs 11J, 11K).

***Mastogloia ciskeiensis* Giffen 1967 (Figs 12A–12S)**

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 264); Giffen **211**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 43-45 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 264); Slide number **211_1**, NIWR 287/5729, SANDC, Potchefstroom, the lectotype is represented by Figs. 12D-12H.

Emended description: The valves are linear lanceolate with narrow, acutely rounded ends, 20-52 µm long 7-10 µm broad. The Raphe is sigmoidal and extends over the valve margin. The axial area is narrow, widening into a lanceolate central area. Transapical striae 38-44 in 10 µm, parallel to slightly radiate throughout. The partecta are narrow and close to the valve margin. Partecta 10-15 in 10 µm and are equal in size throughout. Under SEM the distal raphe endings are gradually hooked and extend over the valve margin (Figs 12I, 12O). The external proximal raphe endings are simple (Fig. 12P). Externally the striae extend over the valve margin and consist of slit-like areolae (Fig. 12J). The areolae directly adjacent to the central area are notably more elongate than the rest of the areolae (Fig. 12P). Internally the distal raphe endings are straight and simple and terminate distally in helictoglossae (Figs 12L, 12Q). The internal proximal raphe endings are straight and simple (Figs 12L, 12R). Internally the striae are separated by distinct virgae and consists of two parallel rows of areolae (Fig. 12R). The partectal ring is perforated (Fig. 12S) externally as well as internally, the central area is unilaterally expanded (Figs 12O, 12Q).



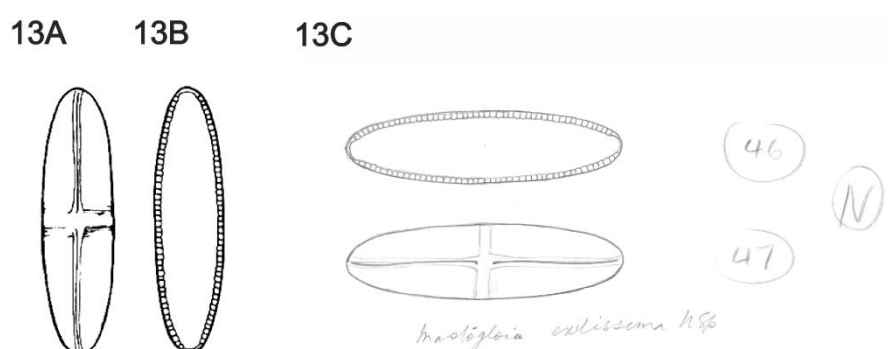
Figs 12A–12S. *Mastogloia ciskeiensis* Giffen. **Figs 12A–12C.** Original line drawings reproduced from Giffen (1967). **Figs 12D–12H.** LM. **Figs 12I–12S.** SEM. **Figs 12I, 12J, 12O, 12P.** External view of valve. **Fig. 12O.** Distal raphe endings. **Fig. 12P.** Proximal raphe endings. **Figs 12K–12N, 12Q–12S.** Internal view of valve. **Fig. 12Q.** Distal raphe endings. **Fig. 12R.** Proximal raphe endings. **Fig. 12S.** Partecta. Scale bar = 10 µm (Figs 12A–12L, 12N). Scale bar = 5 µm (Figs 12M, 12S). Scale bar = 4 µm (Figs 12O–12R).

***Mastogloia exilissima* Giffen 1967 (Figs 13A–13D)**

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 265); Giffen **509**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: Giffen 1967: Figs 46, 47 are representing the type”).

Note: No cells were found under LM or SEM.

Species description from Giffen 1967: Valve linear-lanceolate with somewhat broad, rounded ends. 24 μm long, 6 μm broad. Raphe slightly undulate, axial area narrow, central area a transverse fascia. Striae very faint and visible only near the centre of the valve. Locular rim (partectal ring) marginal with small loculi (partecta), 20 in 10 μm and about 0.5 μm deep.



Figs 13A–13C. *Mastogloia exilissima* Giffen. **Figs 13A, 13B.** Original line drawings reproduced from Giffen (1967). **Fig. 13C.** Original pencil line drawings by M. H. Giffen. Scale bar = 10 μm (Figs 13A–13C).

***Mastogloia pumila* Grunow f. *africana* Giffen 1967 (Figs 14A–14S)**

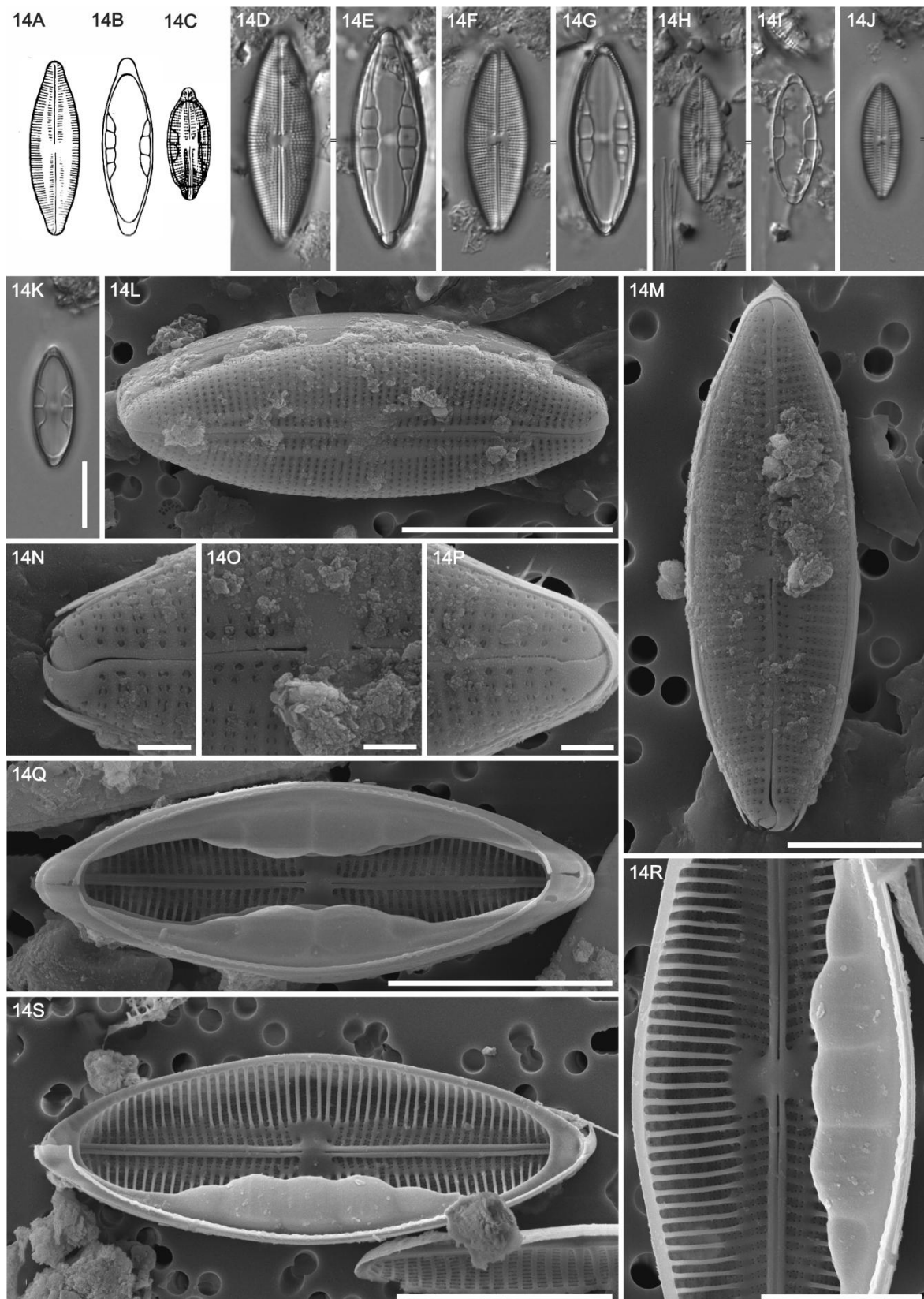
Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 265); Giffen **211**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 48–50 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 265); Slide number **211_1**, NIWR 287/5729, SANDC, Potchefstroom, the lectotype is represented by Figs. 14D–14J.

Emended description: Valves are lanceolate to elliptic with a fine H-shaped hyaline area (barely visible under LM). 18–31 μm long, 6–10 μm broad. The raphe is straight, extending over the mantle, terminating proximally in pore-like endings. 2–5 large partecta are present in the partectal ring, the last partectum ends with a gentle slope into the ring 5 μm long, 1 μm broad. In small cells, the striae are parallel to radial at the ends, and radial throughout in larger cells, 21–23 in 10 μm . Under SEM the external distal raphe endings are hooked and sickle-shaped, terminating on the valve mantle (Figs 14N, 14P). External proximal raphe endings are straight and pore-like (Fig. 14O). The external axial area is very narrow opening in a rectangular central area (Fig. 14L). The H-shaped hyaline area is narrow, and fine in most cells, interrupting the striae slightly (Figs 14L, 14M). Externally the striae consist of slit-like areolae (Fig. 14M). Internally the raphe runs in a sternum with simple proximal raphe

endings (Figs 14Q, 14R). Internally the partectum is perforated after the lacunae terminate (Fig. 14Q). The internal striae are separated by distinct virgae which terminate at the H-shaped hyaline area (Figs 14Q, 14S). Internally the areolae open in 4 small pores that are in squared orientation (Figs 14R, 14S).

The illustrations of *M. pumila* var. *capensis* Cholnoky 1959 Figs 178, 179 pl. 37 are very similar to *M. pumila* f. *africana*. The H-shape hyaline area in *M. pumila* var. *capensis* is similar to the H-shape hyaline area of *M. pumila* f. *africana*, being very fine and barely visible under LM. Giffen, however, described the H-shape hyaline area as prominent, which is not the case. However, the number and size of partecta differ between the two taxa. *M. pumila* f. *africana* has 2-5 large partecta where *M. pumila* var. *capensis* has 7 partecta, 3 large in the centre and 2 becoming gradually smaller near the apices. *M. pumila* f. *africana* is probably a new species, however, the type material of *M. pumila* (Grunow) Cleve 1985, would need to be examined in order to accurately determine the diagnostic characteristics to separate *M. pumila* f. *africana* from the nominate variety.



Figs 14A–14S. *Mastogloia pumila* f. *africana* Giffen. **Figs 14A–14B.** Original line drawings reproduced from Giffen (1967). **Figs 14D–14K.** LM. **Figs 14L–14S.** SEM. **Figs 14L–14P.** External view of valve. **Figs 14N, 14P.** Distal raphe endings. **Fig. 14O.** Proximal raphe endings. **Figs 14Q–14S.** Internal view of valve. **Fig. 14R.** Proximal raphe endings and partecta. Scale bar = 10 μm (Figs 14A–14L, 14Q, 14S). Scale bar = 5 μm (Figs 14M, 14R). Scale bar = 1 μm (Figs 14N–14P).

***Moreneis pseudogamma* (Giffen) De Ridder & J.C. Taylor comb. nov. (Figs 15A-15L)**

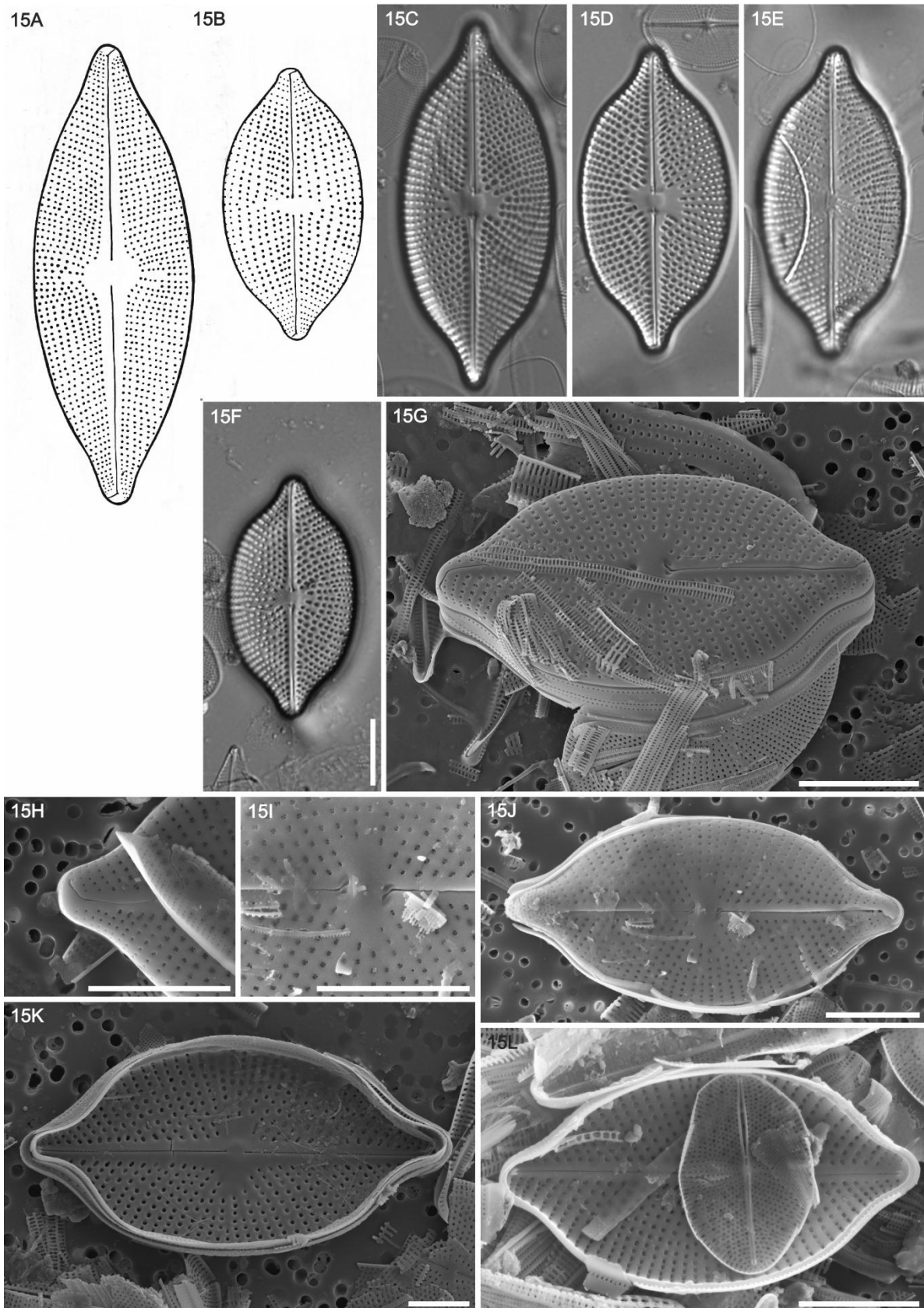
Basionym: *Navicula pseudogamma* Giffen 1967: 272-273, pl 61 (3) figs 76, 77.

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 272-273); Giffen **197**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 76, 77 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 272-273); Slide number **197_3**, NIWR 287/5725, SANDC, Potchefstroom, the lectotype is represented by Figs. 15C-15F.

Emended description: Valves elliptic-lanceolate with apiculate apices 30-70 µm long, 15-36 µm broad. The raphe is straight and simple, proximal endings are hooked in opposite directions, with the distal raphe endings being hooked in the same direction as their related proximal endings. Striae 8-11 in 10 µm, distinctly punctate, puncta forming curved or undulate longitudinal lines 6-12 in 10 µm. Under SEM the external distal raphe endings are deflected 45° in opposite directions and terminate on the valve face or extend onto the mantle in larger specimens (Fig. 15G). The external proximal raphe endings are apiculate in the same direction as the distal endings and situated in a crescent-shaped groove (Figs 15G, 15I). Externally the areolae adjacent to the axial area are transapically elongated (Figs 15G, 15J). The marginal areolae are smaller than those on the rest of the valve and are round openings (Fig. 15G). Copulae are perforate with one row of pores on the valvo-copula and two rows of pores on the copulae (Fig. 15G). Internally the distal raphe endings terminate in small helictoglossae (Figs 15K, 15L). The internal proximal raphe endings are simple (Fig. 15K).

Navicula pseudogamma is transferred to *Moreneis* J. Park, Koh & Witkowski. as *N. pseudogamma* shares more characteristics with *Moreneis* than with *Navicula* Bory. In *Moreneis* the valves are linear to lanceolate with the apices being rostrate to capitate, as is the case for *N. pseudogamma* (Figs 15J-15L), whereas in *Navicula* the valves tend to be more elliptic to broadly-lanceolate. The external distal raphe endings in *Moreneis* and *N. pseudogamma* are hooked in opposite directions (Fig. 15G), this is not the case in *Navicula* ss. The external proximal raphe endings are expanded and grooved, deflected in opposite directions to one another with a small dent-like depression present at the opposite side of each of the external proximal raphe endings - a diagnostic morphological characteristic of *Moreneis* which is clearly present in *N. pseudogamma* (Figs 15G, 15I). Externally the striae in both *Moreneis* and *N. pseudogamma* are uniseriate and not composed of lineolae as in the case of *Navicula* (Fig. 15I). Areolae on the valve face of *Moreneis* and *N. pseudogamma* have denticulate occlusions that are absent in *Navicula* (Figs 15I, 15J) (Park *et al.*, 2012).



Figs 15A-15L. *Moreneis pseudogamma* (Giffen) De Ridder & J.C. Taylor comb. nov. **Figs 15A, 15B.** Original line drawings reproduced from Giffen (1967). **Figs 15C-15F.** LM. **Figs 15G-15J.** SEM. **Figs 15G-15J.** External view of valve. **Fig. 15H.** Distal raphe endings. **Fig. 15I.** Proximal raphe endings. **Figs 15K, 15L.** Internal view of valve. Scale bar = 10 µm (Figs 15A-15L).

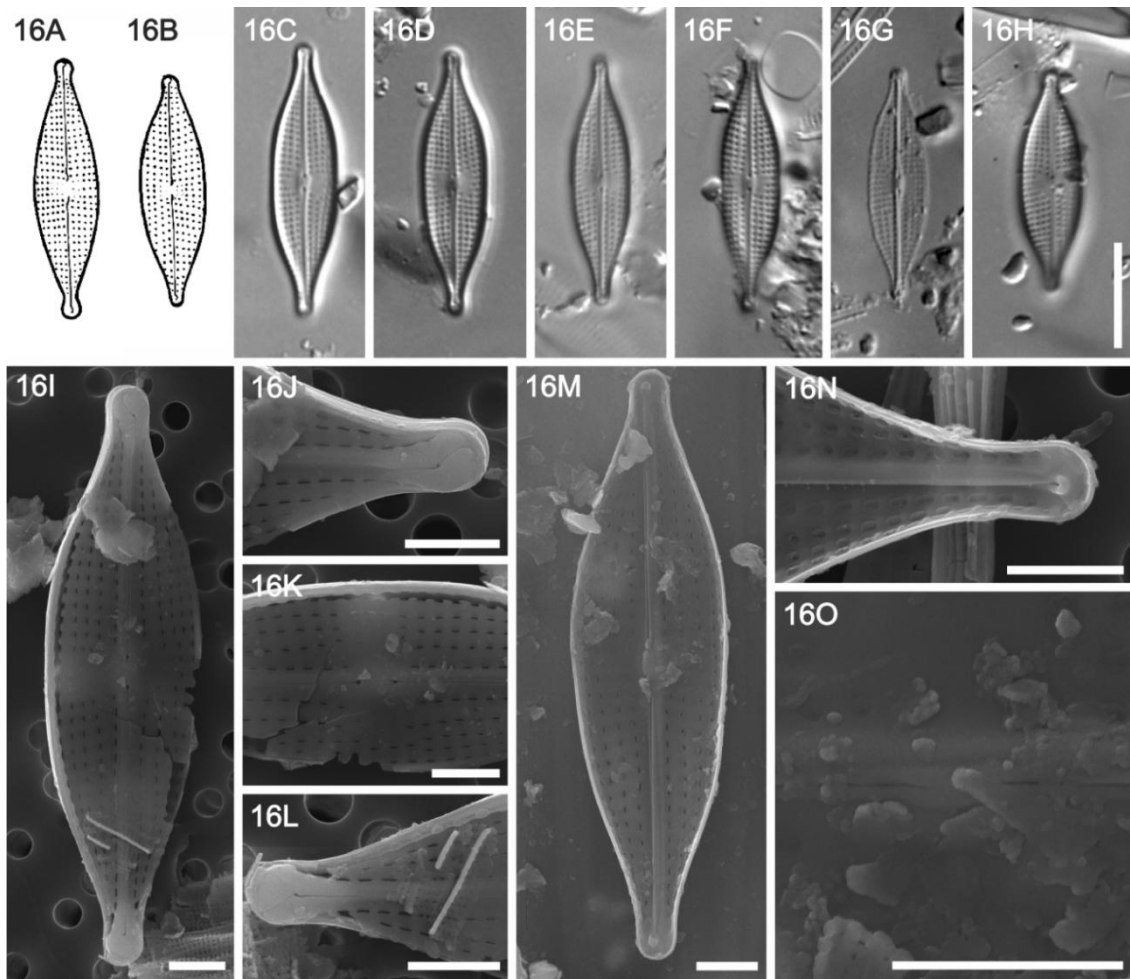
***Navicula evulsa* Giffen 1967 (Figs 16A–16O)**

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 266-267); Giffen **518**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 57-58 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 266-267); Slide number **518_3**, NIWR 287/5737, SANDC, Potchefstroom, the lectotype is represented by Figs. 16C-16H.

Emended description: Valves are lanceolate with slightly capitate ends, 20-25 µm long, 6 µm broad. The raphe is straight with a narrow axial area. The central area varies in size and shape from rectangular to elliptical, with 5-6 shortened striae present. Transapical striae are radiate in the centre to parallel to convergent at the ends, 15-18 in 10 µm, clearly punctate. Under SEM the external distal raphe endings are slightly hooked to sickle-shaped and deflected to the same side (Figs 16I, 16J, 16L). The external proximal raphe endings are straight, simple and pore like (Fig. 16K). The axial area is straight and narrow (Fig. 16I). Externally the striae consist of widely spaced, slit-like areolae. Internally the raphe is located in a prominent sternum and the distal raphe endings terminate in helictoglossae (Figs 16M, 16N). The internal proximal raphe endings are straight and simple and terminate in a slight silica thickening (Fig. 16O). Internally the areolae are slightly ovate and occluded by hymenes (Fig. 16N).

It was clear after close examination that *Navicula evulsa* does not belong to the genus *Navicula*, considering the lack of internal virgae separating the striae Figs. 16N, 16M. However *Navicula evulsa* was not transferred out of *Navicula* as a more appropriate genus was not found at this time.



Figs 16A–16O. *Navicula evulsa* Giffen. **Figs 16A, 16B.** Original line drawings reproduced from Giffen (1967).
Figs 16Cs-16H. LM. **Figs 16I-16O.** SEM. **16I-16L.** External view of valve. **Figs 16J, 16L.** Distal raphe endings. **Fig. 16K.** Proximal raphe endings. **Figs 16M-16O.** Internal view of valve. **Fig. 16N.** Distal raphe ending. **Fig. 16O.** Proximal raphe endings. Scale bar = 10 µm (Figs 16A-16H). Scale bar = 2 µm (Figs 16I-16O).

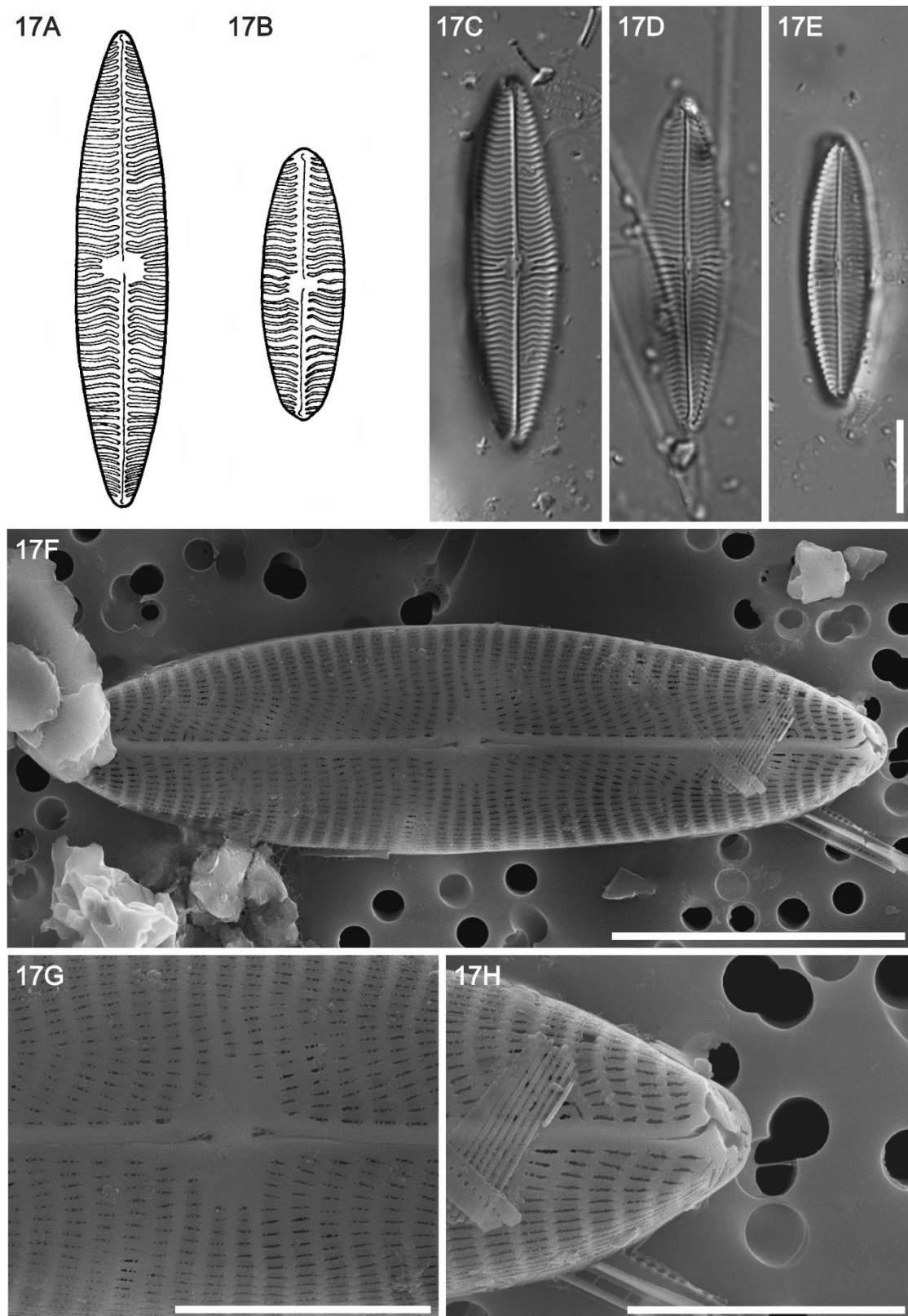
***Navicula johanrossii* Giffen 1967 (Figs 17A–17H)**

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 268-269); Giffen **165**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 63, 64 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 268-269); Slide number **165_3**, NIWR 286/5719, SANDC, Potchefstroom, the lectotype is represented by Figs. 17C-17E.

Additional material: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 268-269); Slide number **509_4**, 287/5734, SANDC, Potchefstroom

Emended description: Valves lanceolate and slightly convex with bluntly rounded ends, 27.4-52 µm long, 7-10 µm broad. The raphe is straight and simple and distal ends are sickle-shaped. The proximal raphe endings are simple and slightly deflected towards the primary side. The axial area is straight and narrow, with an oval central area being rounded through shortening of the central striae. Transapical striae 15-18 in 10 µm in the mid valve to 15 in 10 µm at the ends, radiate in the centre, convergent at the ends. Under SEM the external distal raphe endings are sickle-shaped and extend onto the mantle (Fig. 17H). Externally the proximal raphe endings are spatulate-shaped and are slightly deflected towards the primary side (Fig. 17G). The central area is oval and formed by 3-4 shorter striae (Fig. 17G). Striae are sigmoidal in the centre of the cell, becoming curved at the ends and consist of slit-like areolae (Fig. 17F). Cells were very scarce and only one external valve view was found under SEM.



Figs 17A–17H. *Navicula johanrossii* Giffen. **Figs 17A, 17B:** Original line drawings reproduced from Giffen (1967). **Figs 17C–17E.** LM **Figs 17F–17H** SEM. **Figs 17F–17H.** External view of valve. **Fig. 17G.** Proximal raphe endings. **Fig. 17H.** Distal raphe ending. Scale bar = 10 μm (Figs 17A–17F). Scale bar = 5 μm (Figs 17G, 17H).

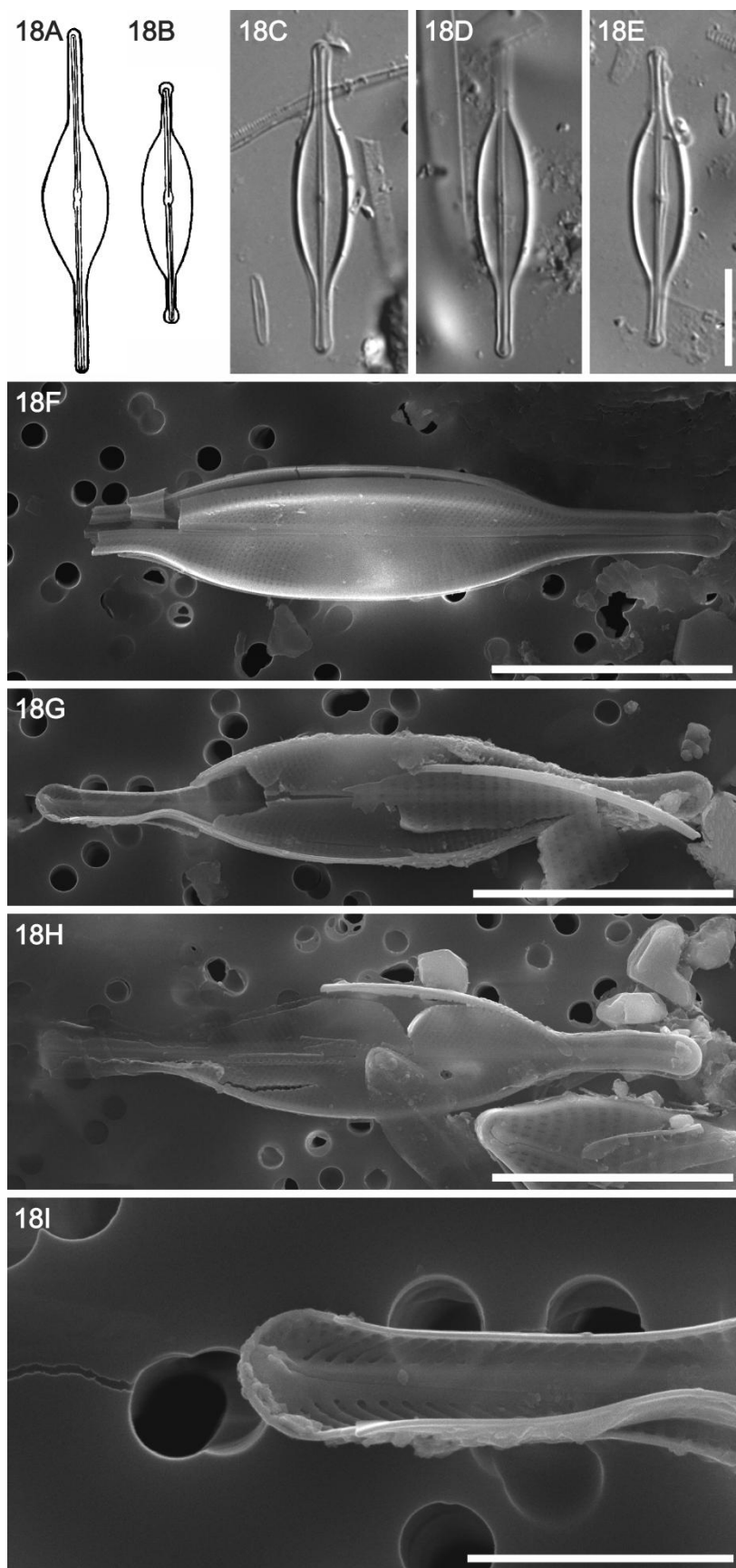
***Navicula pertensa* Giffen 1967 (Figs 18A–18I)**

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 271); Giffen **518**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 74, 75 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 271); Slide number **518_3**, NIWR 287/5737, SANDC, Potchefstroom, the lectotype is represented by Figs. 18C-18E.

Emended description: Valve lanceolate with very long protracted ends and sub-rostrate to sub-capitate apices 25-36 µm long, 5-6 µm wide, the raphe is straight and simple. The axial area is straight and very narrow. Striae under LM are indistinguishable. Under SEM, the external distal raphe ending is strongly deflected to one side (Fig. 18F). The proximal raphe endings are straight and pore-like (Fig. 18F). The valves are densely striated (39 in 10 µm), striae are curved and radiate at the centre and convergent at the ends (Fig. 18F). Externally the striae consist of pore-like areolae and extend onto the mantle (Fig. 18F). Externally the central area is broad and appears to reach both margins (Fig. 18F). The internal distal raphe endings terminate in helictoglossae (Fig. 18I). Internally the striae are separated by distinct virgae (Fig. 18I).

Navicula pertensa probably does not belong to the genus *Navicula* as the stria of *Navicula pertensa* consist of pore-like areolae (Fig. 18F) and not of slit-like areolae, a diagnostic characteristic of *Navicula sensu stricto*. However, *Navicula pertensa* is not transferred to a more appropriate genus, as there is not enough evidence available from the type material to support a transfer.



Figs 18A–18I. *Navicula pertensa* Giffen. **Figs 18A, 18B.** Original line drawings reproduced from Giffen (1967). **Figs 18C–18E.** LM. **Figs 18F–18I.** SEM. **Figs 18F–18H.** External view of valve. **Fig. 18I.** Internal view of valve. **Fig. 18I.** Distal raphe ending. Scale bar = 10 µm (Figs 18A–18H). Scale bar = 3 µm (Fig. 18I).

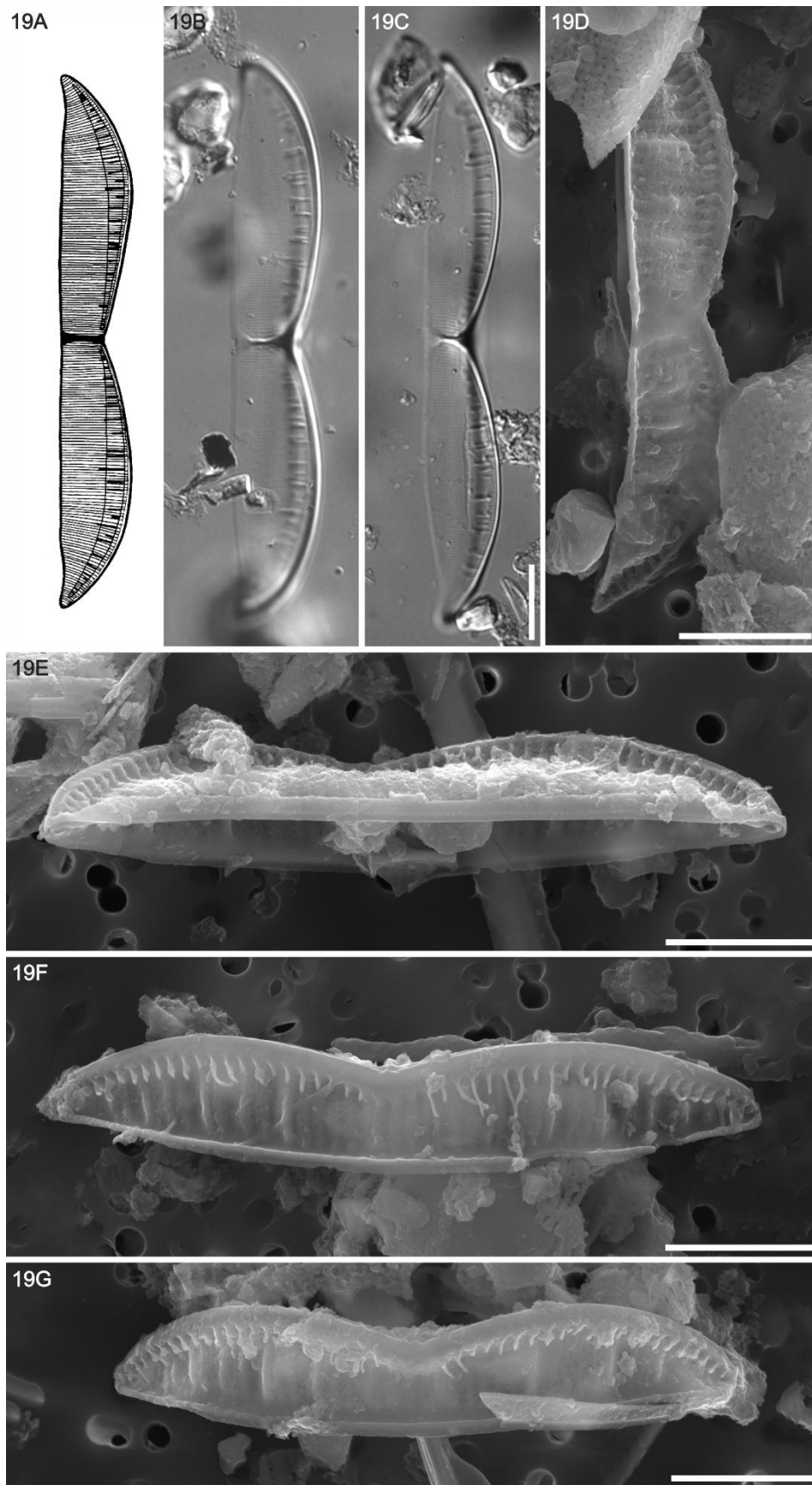
***Nitzschia staurophora* Giffen 1967 (Figs 19A–19G)**

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 278); Giffen **210**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Fig. 96 is representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 278); Slide number **210_X**, NIWR 454/9079, SANDC, Potchefstroom, the lectotype is represented by Figs. 19B-19C.

Emended description: Valve broadly linear, dorsi-ventral and constricted in the centre with oblique acute ends, 56-75 μm long, 8-9 μm broad in the widest part and 6 μm wide at the constriction. Keel moderately eccentric, lunate, very wide in the widest part of the valve tapering towards the centre and the ends. Fibulae are difficult to discern and may be confused with irregularly spaced fimbriate silica protrusions which extend from the keel externally, 6-10 in 10 μm . From the central area a strong stauros crosses the valve to the margin. Transapical striae 25-28 in 10 μm . Under SEM the valves expand outwards from the raphe keel towards the copulae. This swelling of the valve is symmetric giving a triangular shape to the valve in cross section (Fig. 19E). The external proximal raphe endings are straight and simple and terminate in a small silica protrusion (Fig. 19F). Externally the keel is bowed upwards from the valve face (Fig. 19D & 19E). Externally the fibulae extend a quarter to half the length of the valve from the keel (Fig. 19F). The fibulae are attached to the keel terminating in bifurcate ends (Fig. 19F). Externally prominent ridges are present which extend from the keel to the margin, terminating before the prominent marginal silica ridge (Fig. 19F). Externally the striae are not interrupted by the ridges and consist of pore-like areolae (Fig. 19F & 19E). The striae are interrupted by a thick silica protrusion in the centre of the valve, extending from the central area to the mantle (Fig. 19D). Due to the shape of the valves, it was not possible to obtain internal views under SEM.

The generic placement of the species is uncertain at this time; however, it likely does not belong to the genus *Nitzschia* Hassall.■



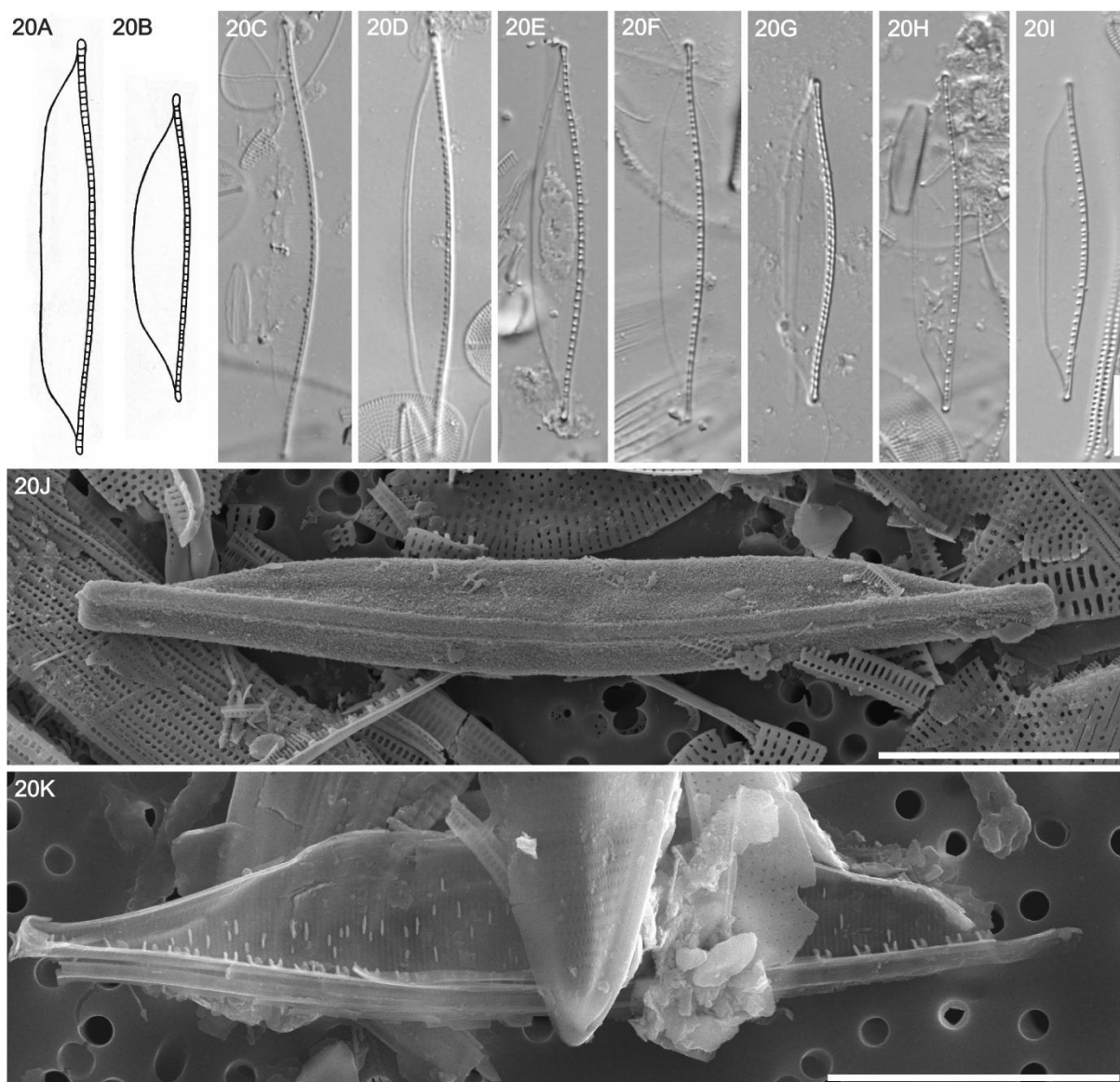
Figs 19A–19G. *Nitzschia staurophora* Giffen. **Fig. 19A.** Original line drawings reproduced from Giffen (1967).
Figs 19B, 19C. LM. **Figs 19D–19G.** SEM. **Figs 19D–19G.** External view of valve. Scale bar = 10 μm (Figs 19A–19C). Scale bar = 5 μm (Figs 19D–19G).

***Nitzschia vacillata* Giffen 1967 (Figs 20A–20K)**

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 279); Giffen 197, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 98–99 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 279); Slide number **197_3**, NIWR 287/5725, SANDC, Potchefstroom, the lectotype is represented by Figs. 20C–20I.

Emended description: Valves linear-lanceolate, dorsi-ventral, with straight or slightly convex keel, opposite margin straight to curved. The apices are moderately protracted, rostrate, 39–55 µm long, 5–7 µm broad. Fibulae are small, similar in shape and size, irregularly spaced, 10–15 in 10 µm. The striae are not visible under LM, however striae are visible under SEM, finely punctate 40 in 10 µm. Cells under SEM were rare and only 2 were obtained. The external valve view provides no additional morphological information (Fig. 20J). Internally the valve is very finely striated (50 in 10 µm) with irregularly spaced rod-shaped granules throughout the valve face (Fig. 20K).



Figs 20A–20K. *Nitzschia vacillata* Giffen 1967. **Figs 20A, 20B.** Original line drawings reproduced from Giffen (1967). **Figs 20C–20I.** LM **Figs 20J–20K.** SEM. **Fig. 20J.** External view of valve. **Fig. 20K.** Internal view of valve. Scale bar = 10 μ m (Figs 20A–20K).

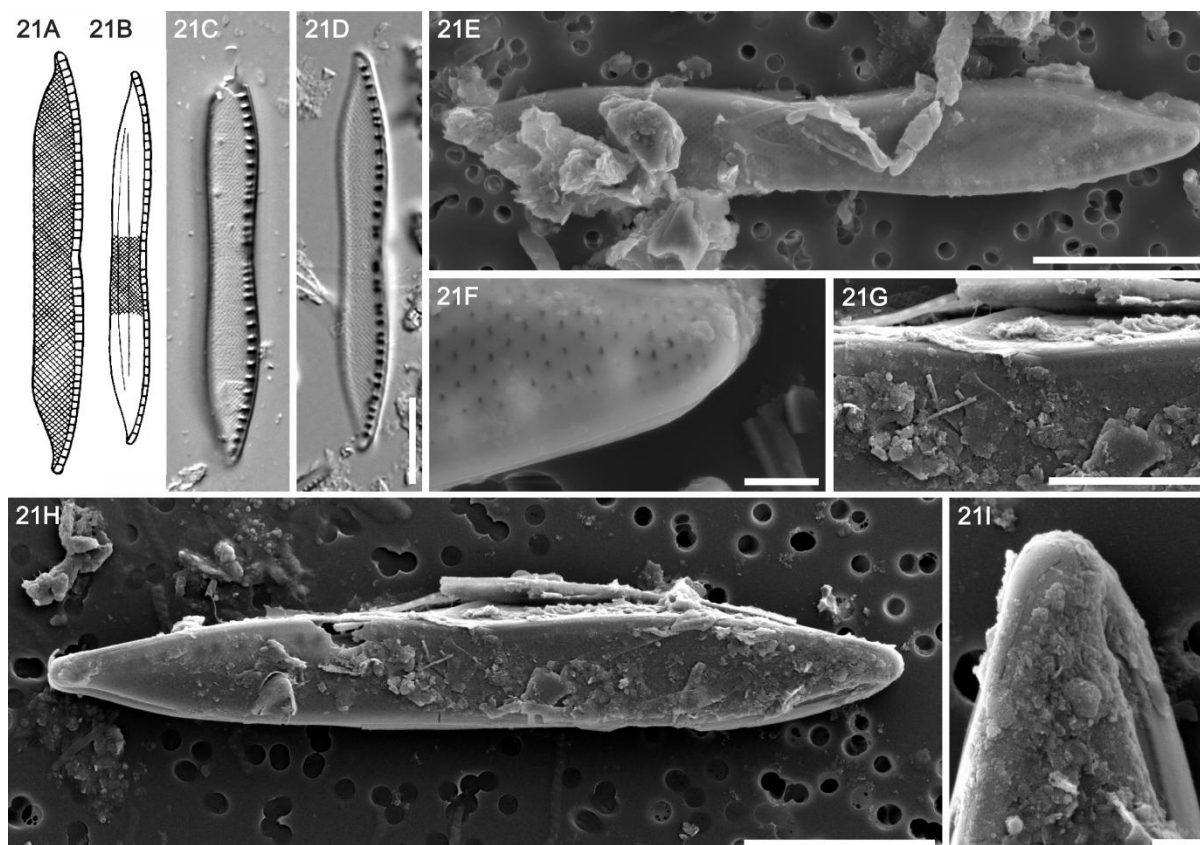
***Nitzschia vulpecula* Giffen 1967 (Figs 21A–21I)**

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 280); Giffen **210**, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: Giffen 1967: Figs 100, 101 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 280); Slide number **210_5**, NIWR 287/5727, SANDC, Potchefstroom, the lectotype is represented by Figs. 1C-1M

Emended description: The valves are linear and slightly constricted in the centre, with obliquely rounded, slightly protracted ends 44-55 µm long, 4.5-6 µm broad. The keel is moderately eccentric. The fibulae are elongate 8-10 in 10 µm, central area prominent with a prominent space between the 2 fibulae in the centre of the valve. The striae are composed of evenly spaced decussate rows 24-27 in 10 µm in the centre, 42-45 µm at the apices. Under SEM the external distal raphe endings are gradually hooked, sickle-like and extend over the mantle (Fig. 21I). The external proximal raphe endings are straight and simple, terminating on a small silica thickening (Fig. 21G). Externally the striae run from the keel to the opposite valve face and do not extend over the mantle (Fig. 21E).

Giffen initially drew this taxon as a pencil sketch (see Appendix C) and made striae counts based on these drawings, these counts are in fact incorrect, as Giffen stated on his sketch that the striae should be more closely spaced (See Appendix C). Although Giffen made these corrections in his notes, the published illustration was not corrected and shows more sparsely spaced striae.



Figs 21A–21I. *Nitzschia vulpecula* Giffen. **Figs 21A, 21B.** Original line drawings reproduced from Giffen (1967). **Figs 21C, 21D.** LM. **Figs 21E–21I.** SEM. **Figs 21E–21I.** External view of valve. **Fig. 21F.** Fine decussate densely spaced areolae. **Fig. 21G.** Proximal raphe endings. **Fig. 21I.** Distal raphe ending. Scale bar = 10 μ m (Figs 21A–21E, 21H). Scale bar = 5 μ m (Fig. 21G). Scale bar = 1 μ m (Figs 21F, 21I).

***Olifantiella exilissima* (Giffen) De Ridder & J. C. Taylor comb. nov. (Figs 22A–22P)**

Basionym: *Stauroneis exilissima* Giffen 1967:285, pl 63 (5), figs 119, 120.

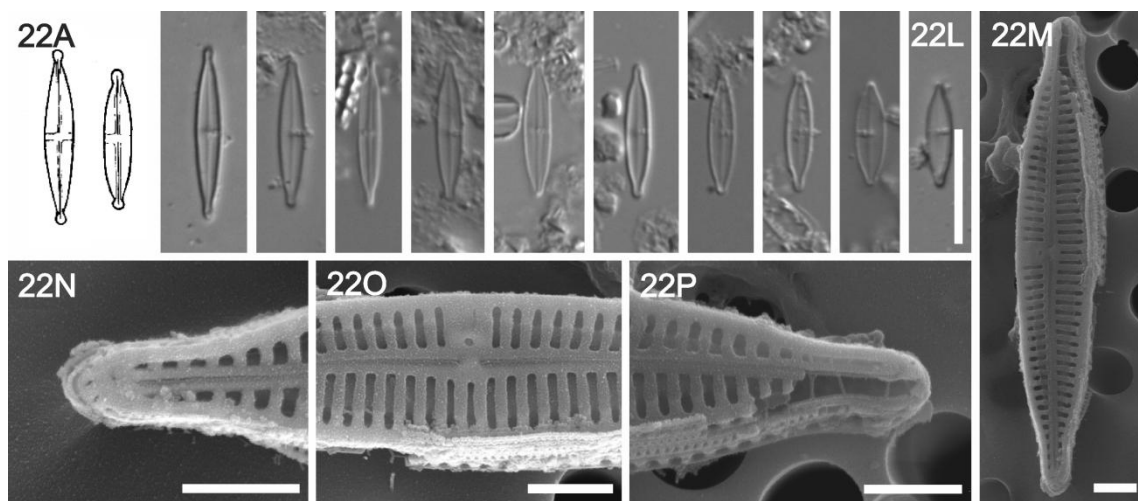
Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 285); Giffen **211**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 119–120 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 285); Slide number **211_1**, NIWR 287/5729, SANDC, Potchefstroom, the lectotype is represented by Figs. 22C–22L

Emended description: Valves narrow lanceolate with capitate ends 9–16 μ m long, 2–3 μ m broad. The raphe is straight and simple. Striae are fine, not visible under LM, visible under SEM, 45 in 10 μ m. Under SEM the external distal raphe endings are straight, sickle-like and terminate on the valve face (Fig. 22N). The external proximal raphe endings are deflected slightly to one side, terminating in a slight indentation (small groove) (Fig. 22O). The external axial area is straight and narrow (Fig. 22M). Externally in centre of the valve next to the axial area a buciniporula is present (Fig. 22O). Externally the striae are uniseriate, radiate to parallel (Fig. 22M). Externally, on the apices, apical slits are present with a punctum

between the valve margin and the distal raphe endings (Fig. 22N). Only one cell was observed under SEM and no internal view was found.

Stauroneis exilissima is transferred to *Olifantiella* Riaux-Gobin & Compère as the striae are uniseriate, radiate to parallel (Fig. 22M), where in *Stauroneis* Ehrenberg the striae are distinctly punctate. A stauros is absent in *Stauroneis exilissima* (Fig. 22M). At the junction of the valve face and the mantle lies a prominent, large void crest, running over the striae, and opening in large round to sub-quadrangular apertures. Externally at the apices several apical slits are visible (Fig. 22N) which do not occur in *Stauroneis*. Externally a crater or funnel-like, large, transapically oblong foramen (buciniportula) is present (Fig. 22O), whereas in the case of *Stauroneis* no such structure exists (Riaux-Gobin & Compère. 2009).



Figs 22A–22P. *Olifantiella exilissima* (Giffen) De Ridder & J.C. Taylor comb. nov. **Figs 22A, 22B.** Original line drawings reproduced from Giffen (1967). **Figs 22C, 22L.** LM. **Figs 22M–22P.** SEM. **Figs 22M–22P.** External view of valve. **Fig. 22N.** Distal raphe endings. **Fig. 22O.** Proximal raphe endings and buciniportula. Scale bar = 10 µm (Figs 22A–22L). Scale bar = 1 µm (Figs 22M–22P).

***Petroneis capensis* De Ridder & J. C. Taylor stat. nov. (Figs 23–23L)**

Synonym: *Navicula humerosa* f. *capensis* Giffen 1967:252, pl 61 (3), fig. 60.

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 252); Giffen 197, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Fig. 60 is representing the type”).

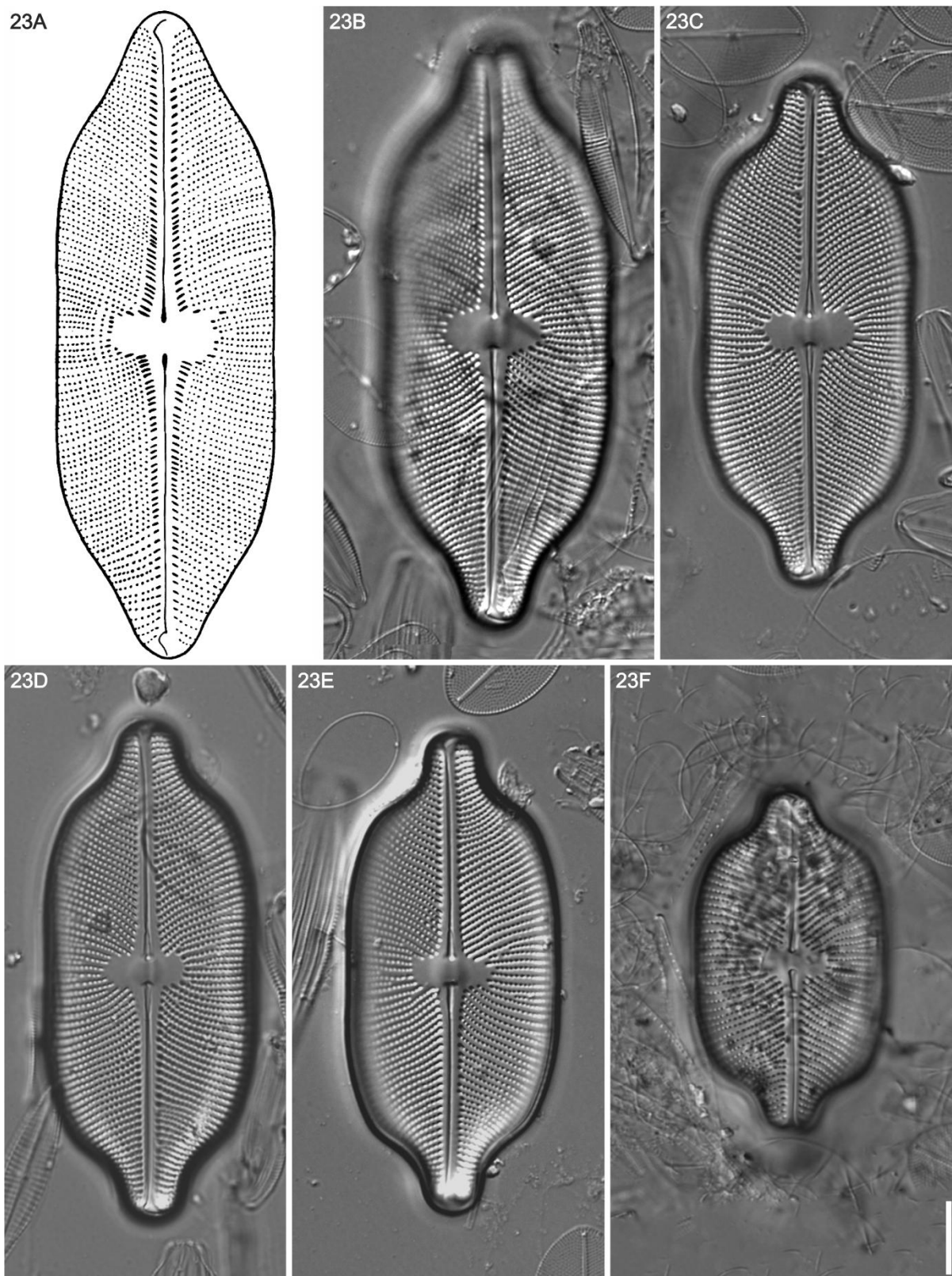
Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 252); Slide number 197_3, NIWR 287/5725, SANDC, Potchefstroom, the lectotype is represented by Figs. 23B–23F.

Description: Valves lanceolate to elliptical with rostrate ends, 55–93 µm long, 25–31 µm wide. The raphe is straight and terminal ends are distally long and abruptly bent to the same side, proximally the raphe terminates in prominent pore-like endings. The striae are curved and radiate becoming slightly parallel at the ends, 10–11 in 10 µm. Striae consist of coarse pore-

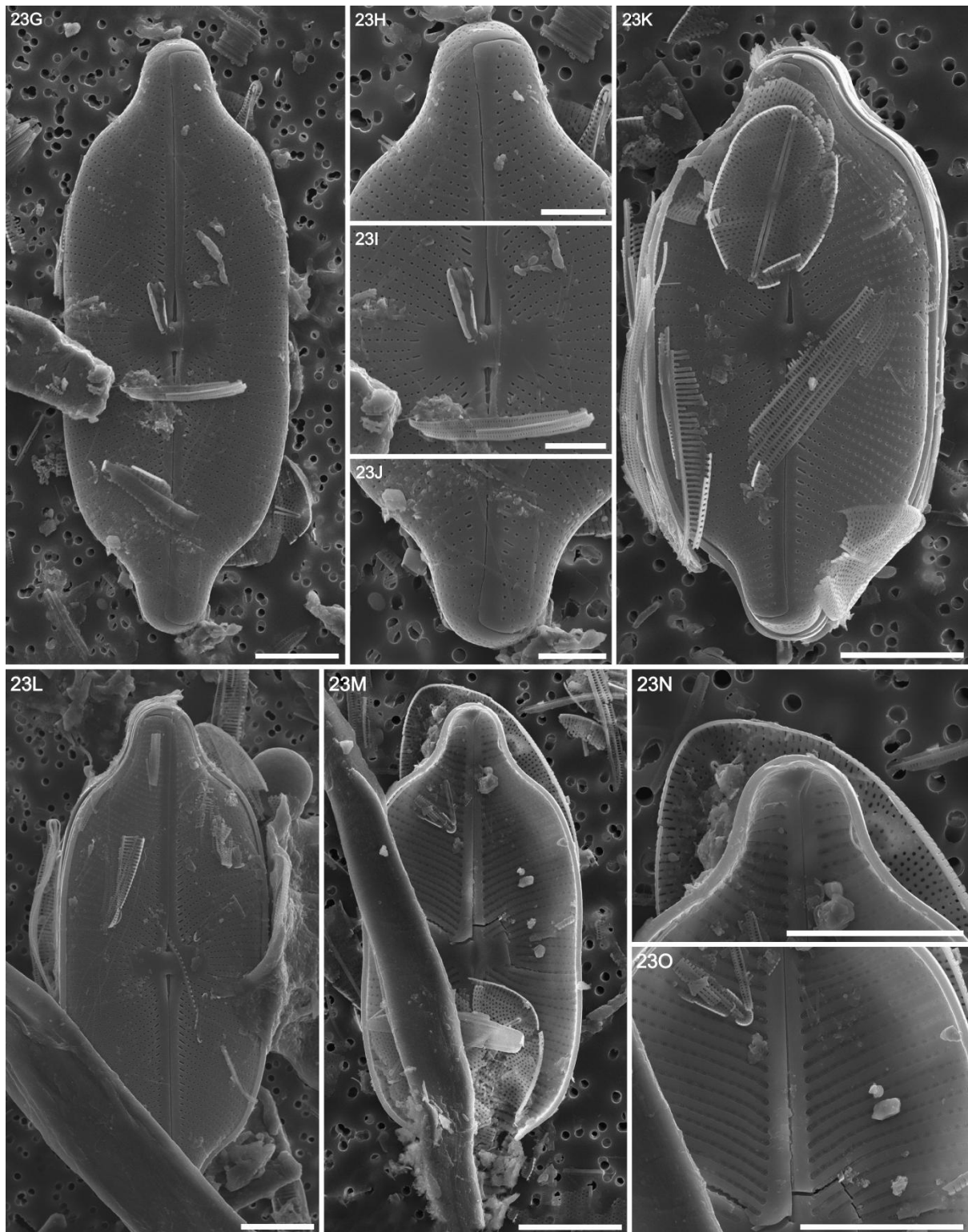
like areolae with elongate areolae next to the axial area, 14 in 10 μm . The central area is large and rectangularly-oval. Under SEM the external distal raphe endings are long and abruptly bent terminating in broad pore-like structures (Figs 23H, 23J). The external proximal raphe endings are straight and pore-like, opening in narrow spatulate grooves (Fig. 23I). Internally the distal raphe endings terminate in prominent helictoglossae (Fig. 23N). The internal proximal raphe endings are hooked (Fig. 23M). According to Jones *et al.* (2005), the proximal raphe endings in the genus *Petroneis* are straight at first becoming hooked at a later stage of silicification, however, this was not observed in the type material of *P. capensis*. Internally the striae consist of large continuous areolae near the axial area, becoming pore-like near the margin (Fig. 23O). Internally the striae are occluded by hymenes (Fig. 23O).

Giffen (1967) described this taxon as a novel form, considering it different from the type of *Petroneis humerosa* (Brébisson ex W.Smith) Stickle & D.G. Mann as the areolae next to the axial area are elongate. These forms are similar to those figured by Heiden in Atlas der Diatomaceen-Kunde (A. S. At-I), T. 243, f. 1—3, for *P. monilifera* (Cleve) Stickle & D. G. Mann however, *P. monilifera* differs from *N. humerosa* f. *capensis* by having coarser punctate striae 7-8 in 10 μm and 9-10 areolae in 10 μm . The elongated areolae next to the axial area links it to *N. humerosa* var. *fuchsii* (Pantocsek) Cleve (Giffen, 1967). Although not illustrated in A. S. A., these elongate areolae are present in *P. humerosa* (Jones *et al.*, 2005) and is not diagnostic of a novel form. However, *N. humerosa* f. *capensis* differs from the illustrations of *P. humerosa* in Jones *et al.* (2005) in a number of respects and therefore we elevate this taxon to the rank of species.

Differential diagnosis: The central area of *P. capensis* is notably more transapically elongate than in *P. humerosa*. The external proximal raphe endings in *P. capensis* terminate in narrow spatulate grooves while in *P. humerosa* the proximal raphe endings terminate in broadly spatulate grooves (Fig. 24I). The internal proximal raphe endings in *P. capensis* are hooked as in *P. humerosa* but apically longer than those of *P. humerosa* (Fig. 23M). The valve margin in *P. capensis* is more abruptly angled compared to the valve face than in *P. humerosa* (Fig. 23K). The apices of *P. capensis* are more constricted and elongated than those of *P. humerosa* (Figs 23B-23F). There are also more rows of areolae present on the apices (5-6 rows) in *P. capensis* than in *P. humerosa* (1-2 rows) in similarly sized specimens (Figs 23H, 23J & 23K).



Figs 23A-23F. *Petroneis capensis* De Ridder & J.C. Taylor nov. spec. **Fig. 23A.** Original line drawings reproduced from Giffen (1967). **Figs 23B-23F.** LM. Scale bar = 10 μ m (Figs 23A-23F).



Figs 23G-23O. *Petroneis capensis* (Giffen) De Ridder & J.C. Taylor. **Figs 23G-23O.** External view of valve. **Figs 23H, 23J.** Distal raphe endings. **Fig. 23I.** Proximal raphe endings. **Figs 23M-23O.** Internal view of valve. **Fig. 23N.** Distal raphe ending. **Fig. 23O.** Striae with areolae occluded by hymenes. Scale bar = 10 μm (Figs 23G, 23K-23O). Scale bar = 5 μm (Figs 23H-23J).

***Seminavis tenellula* (Giffen) De Ridder & J.C. Taylor comb. nov. (Figs 24A–24W)**

Basionym: *Amphora tenellula* Giffen 1970: 286, pl 1, fig. 21

Synonym: *Amphora tenuissima* Giffen 1967: 254, pl 59 (1), figs 19-21

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 254); Giffen **165**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 19–21 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 254); Slide number **165_3**, NIWR 286/5719, SANDC, Potchefstroom, the lectotype are represented by Figs. 24D–24O.

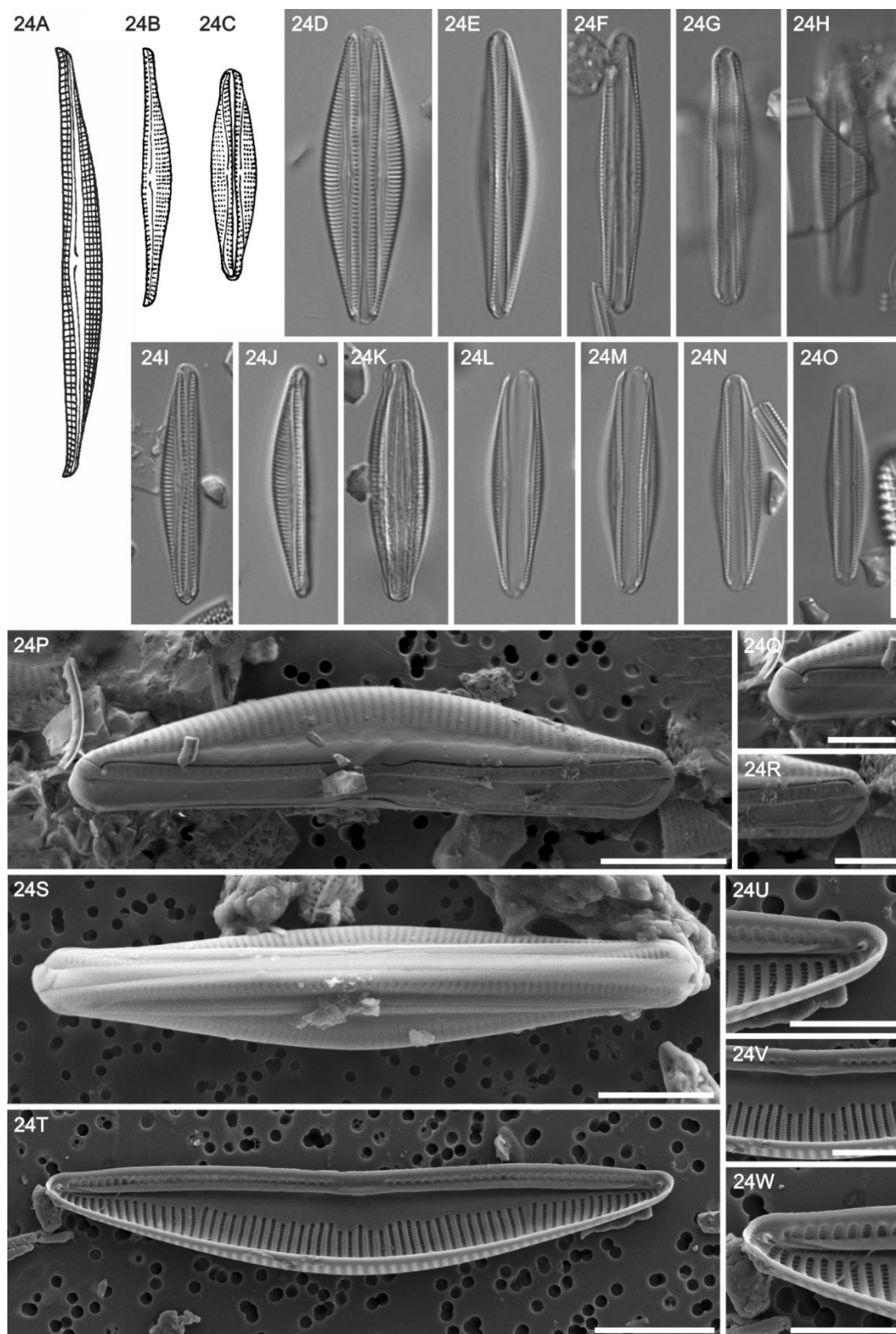
Note: The name given to this species in the paper “Contributions to the Diatom Flora of South Africa III. Diatoms of the Marine Littoral Region at Kidd’s Beach Near East London, Cape Province, South Africa. M. H. Giffen. 1967” was *A. tenuissima*. However, this name was already in use at that time, thus Giffen renamed the species in “Contributions to the diatom flora of South Africa IV. The Marine Littoral Diatoms of the Estuary of the Kowie River, Port Alfred, Cape Province. M. H. Giffen. 1970” as *Amphora tenellula*.

Emended description: Valves semi-lanceolate with narrow rounded ends, 26–66 µm long, and 5–7.6 µm broad. The raphe is simple and slightly convex towards the apex. The distal raphe endings are biarcuate and coma-shaped and extend over the mantle. The proximal raphe endings are slightly flexed towards the dorsal margin. The axial area is narrow and lanceolate and broadens at the central area. Striae, 12–18 in 10 µm. Under SEM the external distal raphe endings are fissures, hooked and reflexed towards the dorsal margin of the cell and extending over the mantle (Figs 24R, 24Q). The external proximal raphe endings are gradually hooked, deflected towards the ventral margin and ends straight and simple (Fig. 24P). The striae are composed of fine slit-like areolae. Striae are radiate at the valve centre, becoming convergent after the voight discordance, typical of Naviculoid taxa (Fig. 24P). Internally the axial area is broad, covering half the width of the dorsal part of the cell (Fig. 24T). Internally the distal raphe endings are straight and simple. The raphe terminates distally in prominent helictoglossae (Figs 24U, 24W). Internally the raphe is located in a prominent sternum (Fig. 24T). Internal view shows that the striae are separated by distinct virgae (Fig. 24T).

Giffen describes the valves as very finely areolate, however, after observation of cells in a series of slides designated by Giffen as containing this taxon, it was clear that all the specimens observed do not have clearly areolate striae under LM (Figs 24B–24O) and that these areolae are in fact artefacts as at certain focal depth the punctae of the copulae give the impression that the striae are areolate.

Amphora tenellula is transferred to *Seminavis* D.G. Mann as the valves are semi-lanceolate together with a straight or slightly curved ventral margin and a curved dorsal margin (Figs 24P, 24T). The valve face curves deeply into the dorsal mantle and the ventral mantle is absent (Fig. 24T). The striae are uniseriate, opening internally between prominent transapical virgae (which are absent in *Amphora*), containing apically elongate areolae (Fig. 24T). The areolae open externally in narrow slits (Fig. 24P). The axial area is wider dorsally than

ventrally (Fig. 24P). External proximal raphe endings are slightly expanded and deflected towards the ventral side (Fig. 24P). Internal proximal raphe endings are simple (Fig. 24V). External distal raphe fissures are hooked towards the dorsal side (Figs 24Q, 24R). The girdle is wider dorsally than ventrally, but less so than in *Amphora* (Fig. 24S) (Round *et al.*, 1990).



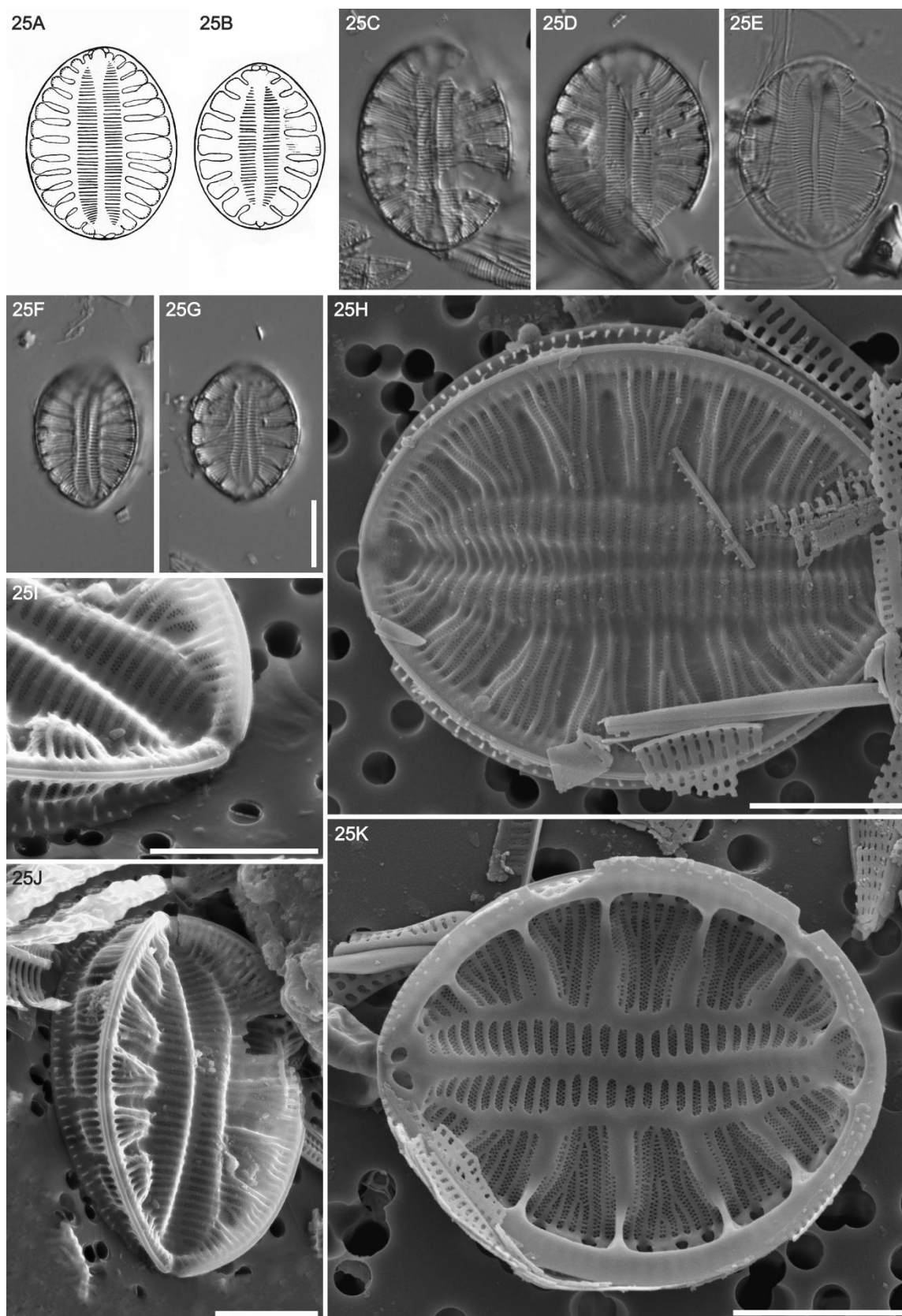
Figs 24A–24W. *Seminavis tenellula* (Giffen) De Ridder & J.C. Taylor comb. nov. **Figs 24A–24C.** Original line drawings reproduced from Giffen (1967). **Figs 24D–24O.** LM. **Figs 24P–24W.** SEM. **Figs 24P–24S.** External view of valve. **Figs 24Q, 24R.** Distal raphe endings. **Figs 24T–24W.** Internal view of valve. **Figs 24U, 24W.** Distal raphe endings. **Fig. 24V.** Proximal raphe endings. Scale bar = 10 µm (Figs 24A–24O, 24P, 24S, 24T). Scale bar = 5 µm (Figs 24Q, 24R, 24U–24W).

***Surirella scalaris* Giffen 1967 (Figs 25A–25K)**

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 286); Giffen **197**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 121, 122 are representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 286); Slide number **197_3**, NIWR 287/5725, SANDC, Potchefstroom, the lectotype is represented by Figs. 25C-25G.

Emended description: Valves heteropolar, elliptical to ovate with broadly rounded ends 18-32 µm long, 13-24 µm broad. Transapical porcae, 2 apical porcae $\frac{1}{4}$ of the width of the valve, leaving a wide, more or less linear axial area, which is perforated with a row of striae 15-18 in 10 µm on either side of the axial area. The surface of the valves is striate, 20-23 in 10 µm. Under SEM the vertical wings are well developed from the valve face, highest in the centre of the valve and lowest at the apices (Fig. 25J). Externally the raphe endings are straight and simple (Figs 25I, 25J). External striae consist of 2 to 3 rows of alternately spaced punctae, extending across the valve face on to the mantle, interrupted at the foot of each of the 2 apical porcae in the centre of the valve as well as by the raphe (Figs 25H, 25I). Striae are absent between the porcae (Fig. 25H). The striae are divided by costae that extend across the valve face onto the mantle, interrupted only by the raphe (Figs 25H, 25I). Internally 2-3 fenestrae are present at the margin of each porca, and 2 distinct fenestrae are present at the foot pole (Fig. 25K), which can also be observed in LM (Fig. 25C). The costae internally are flat, extending across the valve, interrupted by the margins of the porcae (Fig. 25K).



Figs 25A–25K. *Surirella scalaris* Giffen. **Figs 25A–25B.** Original line drawings reproduced from Giffen (1967). **Figs 25C–25G.** LM. **Figs 25H–25K.** SEM. **Figs 25H–25J.** External view of valve. **Fig. 25I.** Raphe endings. **Fig. 25K.** Internal view of valve. Scale bar = 10 μm (Figs 25A–25G). Scale bar = 5 μm (Figs 25H–25K).
***Tabularia perlonga* (Giffen) De Ridder & J.C. Taylor comb. nov. (Figs 26A–26I)**

Basionym: *Opephora perlonga* Giffen 1967:281, pl 63 (5), fig. 105.

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 281); Giffen **195**, SANDC, Potchefstroom, (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Fig. 105 is representing the type”).

Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 281); Slide number **195_4**, NIWR 287/5723, SANDC, Potchefstroom, the lectotype is represented by Figs. 26B-26E.

Emended description: Valves are lanceolate, 92-232 μm long and 4.1-7 μm broad, narrowing gradually from the centre towards the rounded apices. Cells are weakly heteropolar, one apex being bluntly rounded and the other being weakly rounded and protracted, sometimes being weakly sub-capitate. Axial area is lanceolate with no clearly defined central area. Striae are transversely elongate composed of macro areolae, 10-17 in 10 μm . The transapical ribs are parallel in the centre of the valve and slightly radiate at the apices. At the apices there is a row of small puncta around the apical pore field which are clearly defined. Under SEM the external striae are occluded with perforate hymenes (Figs 26H, 26I), and carried in slight depressions (Fig. 26I). Externally the apical pore field is partially covered by finger-like projections that extend from the mantle (Fig. 26I), the pores are parallel throughout the apical pore field (Fig. 26G). Externally at both apices, a single off-centre rimoportula occurs which opens in a simple oval pore (Figs 26G, 26I). The rimoportulae are circular and occluded internally (Fig. 3I). The last row of striae are not occluded and consists of 3-4 puncta (Figs 3G, 3I).

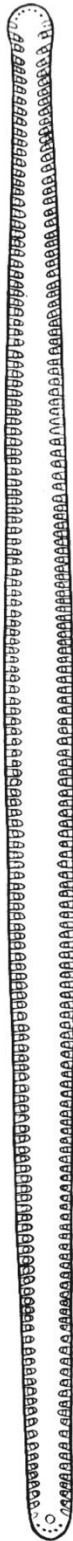
Note: *Opephora perlonga* and *Opephora perlonga* var. *clavata* may be conspecific with *Tabularia fasciculata* Williams and Round, however as stated by Archibald (1983) as well as by Williams & Round (1986) *Tabularia fasciculata* is a difficult species to identify correctly. “The taxonomy of this species is somewhat confusing and is in need of careful revision” (Archibald, 1983). Archibald (1983) states that there is great variability with regards to: dimensions, shape of poles, length and density of striae and the width of the axial area. The SEM images (figs 49-52) published by Williams & Round (1986) shows two different striae structures that supports Archibald’s statement. However, due to a lack of evidence *Opephora perlonga* and the variety *Opephora perlonga* var. *clavata* are not yet synonymized with *Tabularia fasciculata*.

Opephora perlonga is transferred to *Tabularia* (Kützinger) Williams & Round as the valves are elongate, linear to slightly lanceolate and sometimes with capitate ends, with a broad sternum (Fig. 26F). This is not the case in *Opephora* P. Petit where the valves are clavate to rhombic with a broad sternum. The striae of *Opephora perlonga* are broad and shortened as in the case of *Tabularia* (Fig. 26H). Another characteristic present in both *Tabularia* and *Opephora perlonga* is the presence of an apical pore fields at both apices (Figs 26G, 26I).

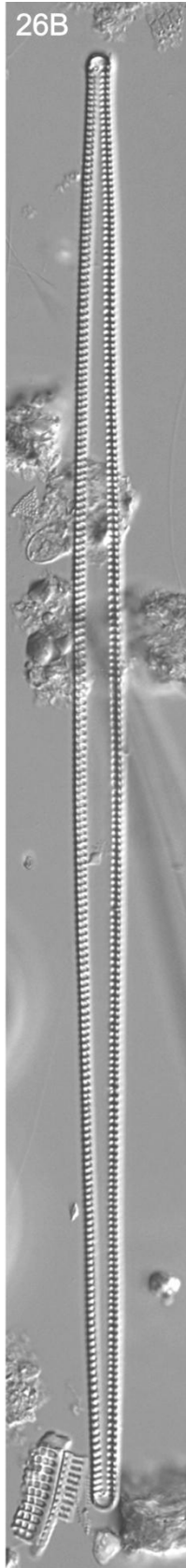
One notable difference between *Tabularia* and *Opephora perlonga* is the number of rimoportulae. In the case of *Tabularia* there is a single rimoportula present at one apex,

however, in the case of *Opephora perlonga* there is a single rimoportula present at both apices (Figs 26G, 26I) (Round *et al.* 1990).

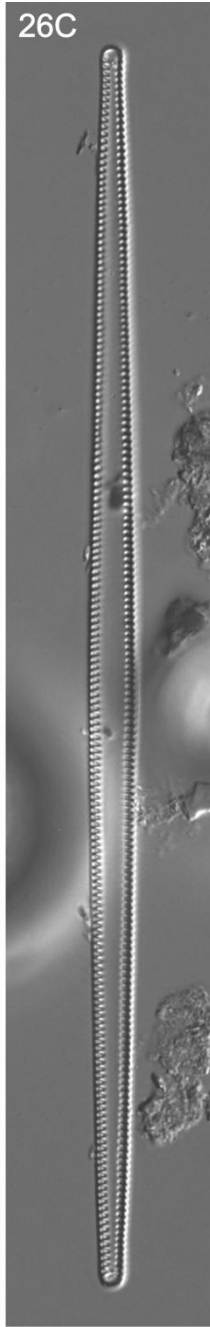
26A



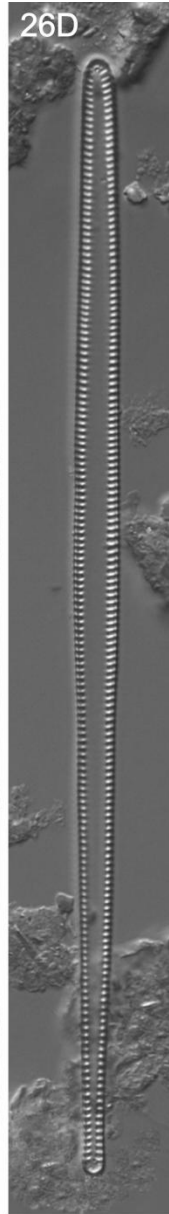
26B



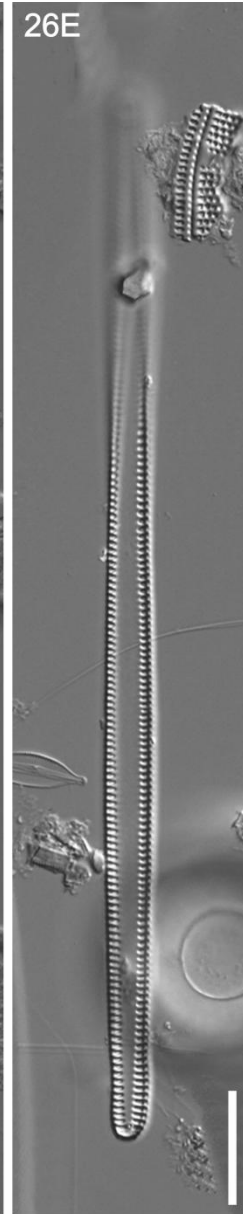
26C



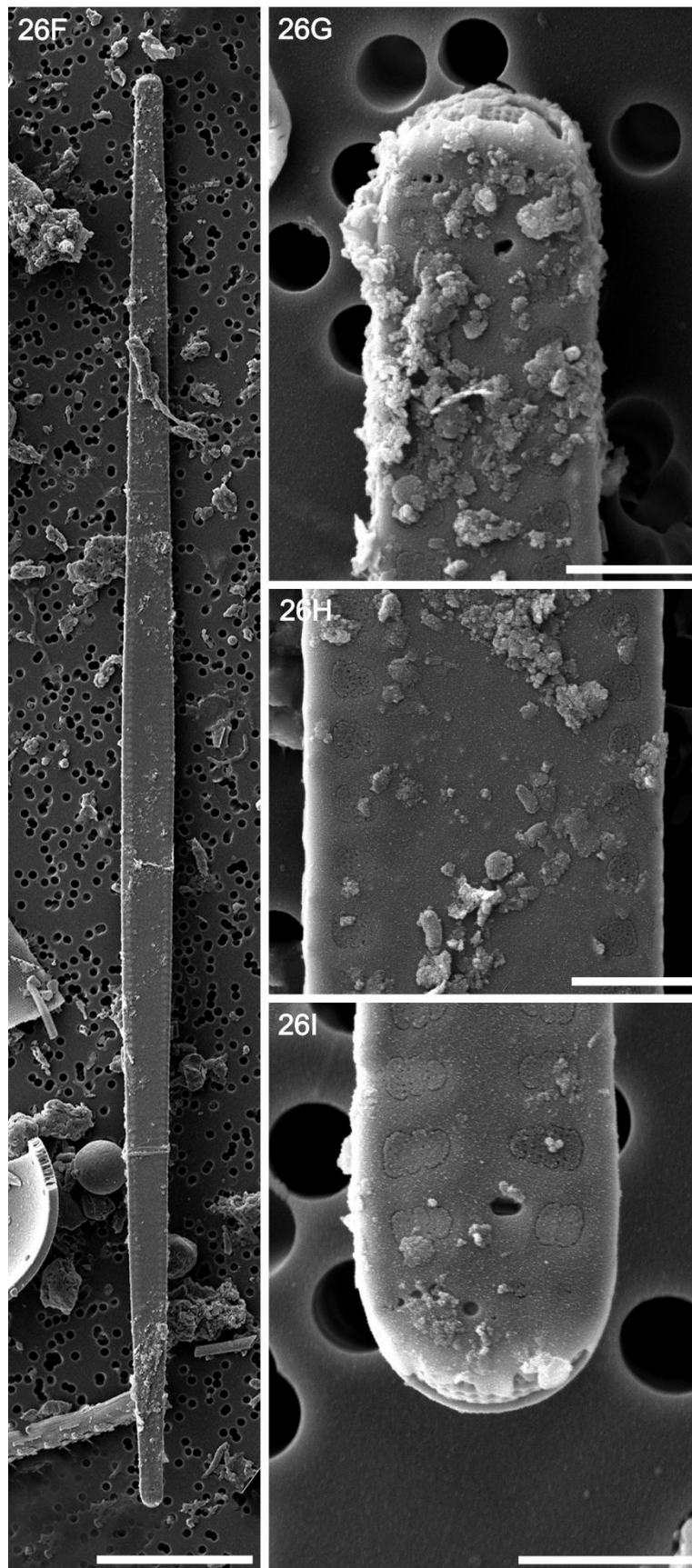
26D



26E



Figs 26A–26E. *Tabularia perlonga* (Giffen) De Ridder & J.C. Taylor comb. nov. **Fig. 26A.** Original line drawings reproduced from Giffen (1967). **Figs 26B–26E.** LM. Scale bar = 10 μ m (Figs 26A–26E).



Figs 26F–26I. *Tabularia perlonga* (Giffen) De Ridder & J.C. Taylor comb. nov. **Figs 25F–25I.** SEM. **Figs 25F–25I.** External view of valve. **Figs 26G, 26I.** Apices, porefields and rimoportula. **Fig. 26H.** Striae occluded with perforate hymenes. Scale bar = 20 μm (Fig. 26F). Scale bar = 2 μm (Fig. 26G–26I).

***Tabularia perlonga* var. *clavata* (Giffen) De Ridder & J.C. Taylor comb. nov. (Figs 27A–27C)**

Basionym: *Opephora perlonga* var. *clavata* Giffen 1967:281, pl 63 (5) figs 106, 107.

Type: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 281); Giffen **195**, SANDC, Potchefstroom, holotype (Giffen’s “iconotype” can be interpreted as: “Giffen 1967: Figs 106, 107 are representing the type”).

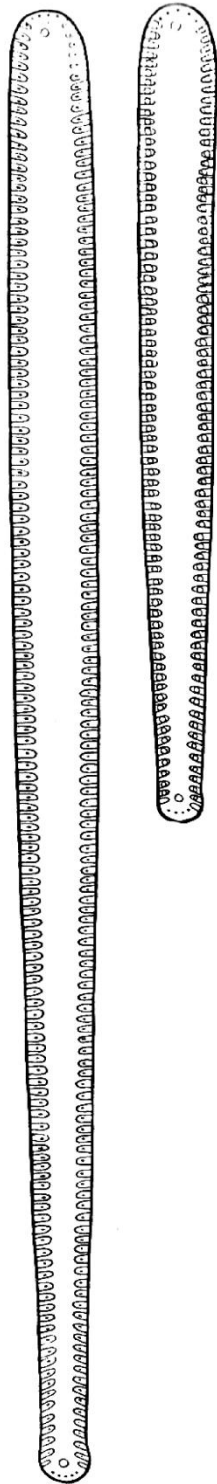
Lectotype: SOUTH AFRICA. ‘Kidd’s Beach’ (Giffen 1967: 281); Slide number **195_4**, NIWR 287/5723, SANDC, Potchefstroom, the lectotype is represented by Fig. 27C.

Emended description: Valves clavate and moderately heteropolar, with one end being broadly rounded and the other end narrowly rounded, 75-135 µm long, 7 µm broad at the widest point. The striae are parallel through the centre becoming slightly radiate at the ends, 10 in 10 µm. At the apices there is a row of small puncta around the apical pore fields as well as a rimoportulae present at either apex. No cells were observed under SEM.

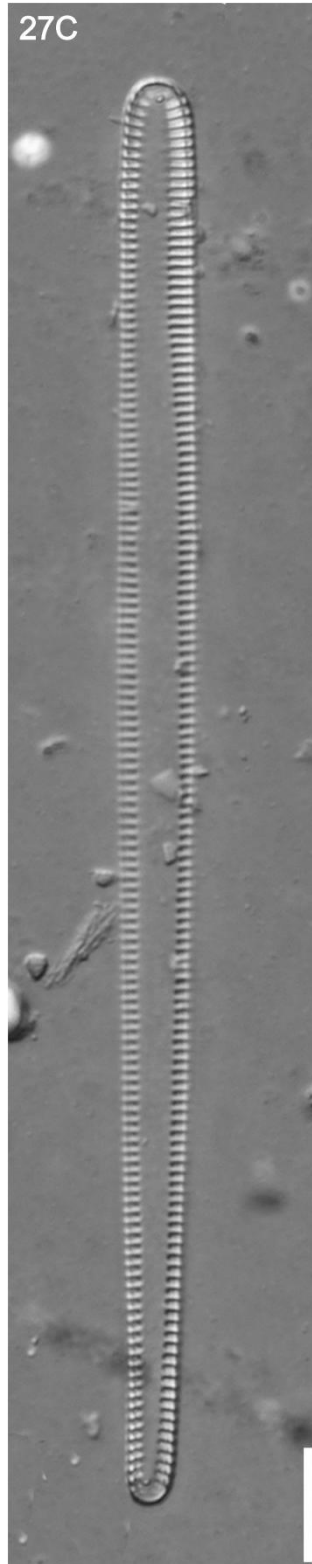
Opephora perlonga var. *clavata* is transferred to *Tabularia* as the valves are elongate, linear to clavate, sometimes with capitate ends and with a broad sternum. This is not the case in *Opephora* P. Petit where the valves are clavate to rhombic with a broad sternum. The striae of *Opephora perlonga* var. *clavata* are broad and shortened as in the case of *Tabularia*. Another characteristic of *Tabularia* present in *Opephora perlonga* var. *clavata* is the apical pore fields present at both apices, also present in *Tabularia*. One difference between *Tabularia* and *Opephora perlonga* var. *clavata* is the number of rimoportulae. In the case of *Tabularia* there is a single rimoportula present at one apex, however, in the case of *Opephora perlonga* var. *clavata* there is a single rimoportulae present at both apices (Round *et al.* 1990).

27A

27B



27C



Figs 27A–27C. *Tabularia perlonga* var. *clavata* (Giffen) De Ridder & J.C. Taylor comb. nov. **Figs 27A, 27B.** Original line drawings reproduced from Giffen (1967). **Fig. 27C.** LM. Scale bar = 10 μ m. (Figs 27A–27C).

Chapter 4 - Temporal changes in the littoral diatom assemblage at Kidd's Beach between the mid-20th century and 2018 and 2019

In 2018 and 2019, samples were taken at the sites from which Giffen originally collected his material. These samples were cleaned using acid digestion and subsamples were permanently mounted on glass slides with Pleurax. The slides from the newly sampled material together with additional slides made from Giffen's original material were counted (400 cells). The results from collections from 2018 and 2019 were compared to those samples collected by Giffen in order to try to detect temporal changes in diatom communities over the past half century or more. Unfortunately, the sample (509_19) collected in 2019 at site 509 healed little to no diatoms and the slide of 509_19 was unable to be counted accurately.

From the 23 samples analysed, a total of 560 diatom taxa were noted from 49 genera, with *Amphora* being the most dominant genus followed by *Nitzschia*, *Cocconeis*, and *Navicula*. During the counts, 421 taxa were recorded as unidentified or identified to genus level only. For the sake of brevity Table 1, that follows, contains only the taxa with an abundance of 10% or higher at one or more sites.

From Table 1 it can be observed that most species are site-specific regardless of the time the sample was taken, with only four species (*Achnanthes brevipes*, *Cocconeis convexa*, *Fragilaria sopotensis* and *Nitzschia frustulum*) showing a distribution with a "high abundance" (>3%) over more than two sites. Detrended Correspondence Analysis (DCA) (Holland, 2008) was used to illustrate the relationship between sampling sites in terms of diatom species composition. There were noticeable differences between the sites in both DCA bi-plots. However, three groups can still be distinguished with one outlier site in both of the DCA bi-plots.

Table 1: Relative abundance and distribution of species with 10% or higher abundance across all the samples from the 8 sites in question.

Species	Relative abundance and distribution of species with 10% or higher abundance across all the samples.																						
	Samples																						
	165_G	195_G	197_G	210_G	211_G	509_G	510_G	518_G	165_18	195_18	197_18	210_18	211_18	509_18	510_18	518_18	165_19	195_19	197_19	210_19	211_19	510_19	518_19
Achnanthes brevipes	1,0			7,2		0,7								21,3			0,5		0,5	22,6	1,5	0,2	0,2
Amphora castellata			13,8				1,7							2,7			0,3						
Amphora decussata													17,7		1,5								
Amphora exilissima		1,2		18,0	0,2	0,7		1,0					0,2	0,2	0,2	2,5							
Amphora pediculus				23,3					0,7			0,7											
Amphora sp13																21,8							1,0
Amphora sp39			5,0				14,5										0,5						
Amphora sp40						2,5										1,5	1,3					0,5	4,6
Amphora sp59								16,0															
Anorthoneis sp1																0,5					0,2		30,6
Berkeleya rutilans		0,7												15,1							8,4		
Cocconeis convexa				0,5		0,7				41,5	8,0	24,1	16,9		7,7			1,0	4,0	1,0			
Cocconeis placentula var. klinoraphis	21,2																						
Cocconeis scutellum						7,4	0,7					0,2					0,3	6,5	0,5				
Cocconeis sp26																			15,0				
Fragilaria sopotensis										0,7	6,5	5,0	8,0		12,2								
Mastogloia pumila																					10,7		
Melosira moniliformis var. octogoma		21,6																					
Navicula kantsiensis			69,7				0,5							2,0			0,3						
Navicula normaloides		1,0							20,0		0,5						0,8	5,0		0,2			
Navicula paeninsulae	4,6																				15,1		
Navicula perminuta		1,5		0,2	1,0			0,5	0,5			0,5		0,2	1,2	7,9	0,5			0,2	4,2		0,5
Navicula perthombus						1,0	0,5					0,2					32,8	6,0	2,0	0,7			
Navicula sp1													2,0			10,1	0,5	0,5	0,5	0,7		2,7	8,0
Navicula sp11	0,5		8,4				1,2	1,8								0,2						0,5	
Nitzschia distantoides				1,0					15,3	0,2					0,2			2,5				0,2	
Nitzschia frustulum	1,0	9,4	0,5	15,1	4,4	4,0	4,2		10,6		5,0	6,2		3,2	7,9		6,0				6,5		
Nitzschia inconspicua		0,5		1,0	1,2	2,7				3,7	10,5			3,0		1,2	3,3						
Nitzschia ovalis							1,2								10,2								
Nitzschia perindistincta												11,9											
Nitzschia sp12											13,0												
Nitzschia sp14							5,7				8,0												
Nitzschia sp17												14,2										0,5	
Nitzschia sp19						25,7																	
Nitzschia sp36																				36,7			
Nitzschia sp4					4,4	3,7	1,7										11,0			1,2	2,0	1,5	2,7
Nitzschia sp9						19,5	0,5			28,9										0,5			
Nitzschia vacillata		0,5					11,2																
Nitzschia zuluandica				0,5					11,8	1,2			8,0				0,5						
Opephora horstiana		1,5		9,6	0,5							0,2						2,0					
Opephora sp1										5,4	2,0	2,7			1,0			1,5		5,0		2,0	
Pseudostaurosira sp1	40,2	0,5																0,5			1,2		
Pseudostaurosira sp3	1,0	20,1																					
Pseudostaurosira sp5				7,0	0,5									16,6			0,5	1,0			1,2		
Rhopalodia sp1	7,5				29,8																22,3		
sp102														1,0		0,7						6,4	5,6
sp108																11,6							
sp14		1,0			0,2		7,7	27,5		0,2			1,5					0,5	1,0			4,6	3,9
sp210																		0,5	13,0				
sp44											1,5	0,5			8,2							1,5	
sp46							1,2				2,0				0,2					0,5		14,2	
sp58													0,2		13,2								
sp84													3,2		2,0					0,2		17,6	
sp89													0,2			5,4					0,2	1,7	2,4
Stephanopyxis sp1	8,7				14,0													0,5			7,7		10,3

Table 2: Species with codes and distribution in the samples in Group 1 from Figure VII

Group 1								
Species	Codes	Samples						
		509_G	165_18	195_18	197_18	210_18	211_18	510_18
<i>Amphora decussata</i>	Amde						17.7	1.5
<i>Amphora exilissima</i>	Amex	0.7					0.2	0.2
<i>Cocconeis convexa</i>	Coco	0.7		41.5	8.0	24.1	16.9	7.7
<i>Fragilaria sopotensis</i>	Frso			0.7	6.5	5.0	8.0	12.2
<i>Navicula normaloides</i>	Nano		20.0		0.5			
<i>Nitzschia distantoides</i>	Nitzdist		15.3	0.2				0.2
<i>Nitzschia inconspicua</i>	Nitzinco	2.7		3.7	10.5			
<i>Nitzschia ovalis</i>	Niov							10.2
<i>Nitzschia perindistincta</i>	Nitzperi					11.9		
<i>Nitzschia</i> sp12	Nitzsp12				13.0			
<i>Nitzschia</i> sp17	Nitzsp17					14.2		
<i>Nitzschia</i> sp19	Nitzsp19	25.7						
<i>Nitzschia</i> sp9	Nitsp9	19.5		28.9				
<i>Nitzschia zululandica</i>	Nizu		11.8	1.2			8.0	
<i>Opephora</i> sp1	Opesp1			5.4	2.0	2.7		1.0
sp44	sp44				1.5	0.5		8.2
sp58	sp58						0.2	13.2

Table 3: Species with codes and distribution in the samples in Group 2 from Figure VII

Group 2							
Species	Codes	Samples					
		195_G	197_G	210_G	510_G	518_G	509_18
<i>Achnanthes brevipes</i>	Acbr			7.2			21.3
<i>Amphora castellata</i>	Amca		13.8		1.7		2.7
<i>Amphora pediculus</i>	Amped			23.3			
<i>Amphora</i> sp39	Amphsp39		5.0		14.5		
<i>Amphora</i> sp59	Amphsp59					16.0	
<i>Amphora</i> sp64	Amphsp64				1.7	9.0	
<i>Berkeleya rutilans</i>	Beru	0.7					15.1
<i>Melosira moniliformis</i> var. <i>octogoma</i>	Memooc	21.6					
<i>Navicula kantsiensis</i>	Naka		69.7		0.5		2.0
<i>Navicula</i> sp11	Navisp11		8.4		1.2	1.8	
<i>Nitzschia frustulum</i>	Nifr	9.4	0.5	15.1	4.2		3.2
<i>Nitzschia</i> sp14	Nitzsp14				5.7		
<i>Nitzschia vacillata</i>	Nitvac	0.5			11.2		
<i>Opephora horstiana</i>	Opho	1.5		9.6			
<i>Pseudostaurosira</i> sp3	Psesp3	20.1					
<i>Pseudostaurosira</i> sp5	Pseudosp5			7.0			16.6
sp14	sp14	1.0			7.7	27.5	

Table 4: Species with codes and distribution in the samples in Group 3 from Figure VII

Group 3			
Species	Codes	Samples	
		165_G	211_G
<i>Cocconeis placentula</i> var. <i>klinoraphis</i>	Coplkl	21.2	
<i>Pseudostaurosira</i> sp1	Pseudosp1	40.2	
<i>Rhopalodia</i> sp1	Rhosp1	7.5	29.8
<i>Stephanopyxis</i> sp1	Stesp1	8.7	14.0

Table 5: Species with codes found in sample 518_18 in Figure VII

Sample 518_18		
Species	Codes	Sample
		518_18
<i>Amphora</i> sp13	Amphsp13	21.8
<i>Navicula perminuta</i>	Naviperm	7.9
<i>Navicula</i> sp1	Navisp1	10.1
sp108	sp108	11.6

The DCA bi-plot (Figure VII) shows the correlation between the community structure in the material collected by Giffen and the re-sampled material collected in 2018. Three main groups of correlation are found between the diatom community structure across the eight re-sampled sites in 2018 and the original eight sites sampled by Giffen, with one outlier sample (518_18).

Group 1 consists of six samples from 2018 (165_18, 195_18, 197_18, 210_18, 211_18, and 510_18) and one of the original samples (509_G) (Figure VII). In group 1 there is a very strong correlation between the samples (195_18, 210_18, 211_18 and 510_18), with *Cocconeis convexa* being present and dominant in all the samples and *Fragilaria sopotensis* being present in all the samples collected in 2018 (Table 2). A very strong correlation was observed between samples 509_G and 165_18 because of the presence of *Nitzschia scalpelliformis* which only occurs in these two samples (see full species list in Appendix D). This indicates that diatom community composition at the site 165 in 2018 had changed more towards the diatom community composition found at site 509 at the time Giffen collected his samples.

Group 2 contains five of the original samples collected by Giffen, (195_G, 197_G, 210_G, 510_G, and 518_G), with one sample collected in 2018 (509_18) (Figure VII). Within Group 2 there is a weak correlation between all the samples. This is due to the presence and relative dominance of *Nitzschia frustulum* in all of the samples (Table 3). *Amphora exilissima* also plays a role in this grouping, and is present in all the samples, except for 197_G and 510_G (Table 1). Sample 197_G has a very weak correlation with the rest of the samples due to the very low abundance of *Nitzschia frustulum*. However, *Nitzschia frustulum* is one of the species that contributes to the position of sample 197_G in this group together with *Amphora* sp39 (shared with sample 510_G), *Navicula* sp11 (shared with sample 510_G and 518_G), *Amphora castellata* (shared with sample 509_18 and 510_G) and *Navicula kantsiensis* (shared with sample 509_18 and 510_G) which is the dominant species in sample 197_G (Table 3). Samples 509_18 and 195_G have the strongest correlation in Group 2 sharing five species (*Amphora exilissima*, *Berkeleya rutilans*, *Navicula perminuta*, *Nitzschia frustulum*

and *Nitzschia inconspicua*) with a similar abundance across the 2 samples (Table 3). This strong correlation between these two samples (509_18 and 195_G) shows that the community structure of site 509 has shifted closer to the original community structure of site 195 over the past over the past half century or more.

Group 3 consists of the remaining two sites of Giffen (samples 165_G and 211_G) (Figure VII). Within Group 3 a strong correlation is observed between the two samples. This can be attributed to the dominance of *Rhopalodia* sp1 and *Stephanopyxis* sp1 in both samples that only occur in these two samples (Table 4).

The remaining sample from 2018 (518_18) shows a very weak correlation with the rest of the samples (Figure VII). The reason being the presence and dominance of sp108 and *Amphora* sp13 occurring only in this sample (Table 5).

Overall, the community structure of all the eight sites in question, changed noticeably between the time Giffen sampled (1946- 1964) and 2018, as illustrated by the weak correlation between the majority of the samples from 2018 and those collected by Giffen.

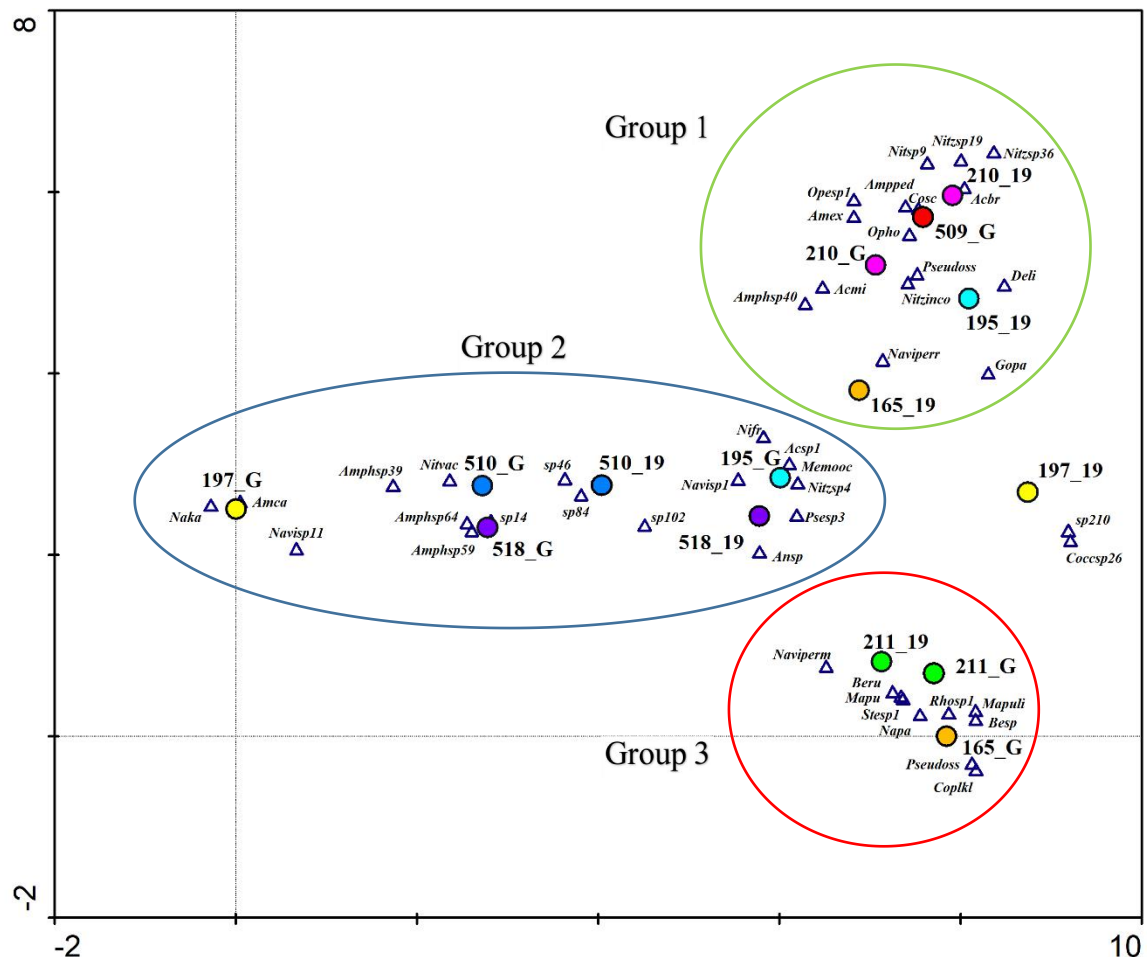


Figure VIII: DCA: Comparison between species distribution in samples collected by Giffen and samples from the same sites collected in 2019

Key: Giffen's samples: 165_G, 195_G, 197_G, 210_G, 211_G, 509_G, 510_G, 518_G
2019 samples: 165_19, 195_19, 197_19, 210_19, 211_19, 510_19, 518_19

Table 6: Species with codes and distribution in the samples in Group 1 of Figure VIII

Group 1						
Species	Codes	Samples				
		210_G	509_G	165_19	195_19	210_19
<i>Achnanthes brevipes</i>	Acbr	7.2	0.7	0.5		22.6
<i>Achnanthidium minutissimum</i>	Acmi					2.7
<i>Amphora exilissima</i>	Amex	18.0	0.7			
<i>Amphora pediculus</i>	Amped	23.3				
<i>Amphora</i> sp40	Amphsp40		2.5	1.3		
<i>Cocconeis scutellum</i>	Cosc		7.4	0.3	6.5	
<i>Delphineis livingstonii</i>	Deli			0.5	8.0	
<i>Gomphonema parvulum</i>	Gopa			2.5	1.5	0.7
<i>Navicula perrhombus</i>	Naviperr		1.0	32.8	6.0	0.7
<i>Nitzschia inconspicua</i>	Nitzinco	1.0	2.7	3.3		
<i>Nitzschia</i> sp19	Nitzsp19		25.7			
<i>Nitzschia</i> sp36	Nitzsp36					36.7
<i>Nitzschia</i> sp9	Nitsp9		19.5			0.5
<i>Opephora horstiana</i>	Opho	9.6			2.0	
<i>Opephora</i> sp1	Opes1				1.5	5.0
<i>Pseudostaurosira</i> sp5	Pseudosp5		16.6	0.5	1.0	

Table 7: Species with codes and distribution in the samples in Group 2 of Figure VIII

Group 2							
Species	Codes	Samples					
		195_G	197_G	510_G	518_G	510_19	518_19
<i>Achnanthes</i> sp. 1	Acsp1	7.9					
<i>Amphora castellata</i>	Amca		13.8	1.7			
<i>Amphora</i> sp39	Amphsp39		5.0	14.5			
<i>Amphora</i> sp59	Amphsp59				16.0		
<i>Amphora</i> sp64	Amphsp64			1.7	9.0		
<i>Anorthoneis</i> sp1	Ansp						30.6
<i>Melosira moniliformis</i> var. <i>octogoma</i>	Memooc	21.6					
<i>Navicula kantsiensis</i>	Naka		69.7	0.5			
<i>Navicula</i> sp1	Navisp1					2.7	9.0
<i>Navicula</i> sp11	Navisp11		8.4	1.2	1.8	0.5	
<i>Nitzschia frustulum</i>	Nifr	9.4	0.5	4.2			
<i>Nitzschia</i> sp4	Nitzsp4			1.7		1.5	2.7
<i>Nitzschia vacillata</i>	Nitvac	0.5		11.2			
<i>Pseudostaurosira</i> sp3	Psesp3	20.1					
sp102	sp102					6.4	5.6
sp14	sp14	1.0		7.7	27.5	4.6	3.9
sp46	sp46			1.2		14.2	
sp84	sp84					17.6	

Table 8: Species with codes and distribution in the samples in Group 3 of Figure VIII

Group 3				
Species	Codes	Samples		
		165_G	211_G	211_19
<i>Berkeleya rutilans</i>	Beru			8.4
<i>Berkeleya</i> sp1	Besp	1.2	6.7	
<i>Cocconeis placentula</i> var. <i>klinoraphis</i>	Coplkl	21.2		
<i>Mastogloia pumila</i>	Mapu			10.7
<i>Mastogloia pusilla</i> var. <i>linearis</i>	Mapuli		9.1	
<i>Navicula paeninsulae</i>	Napa	4.6		15.1
<i>Navicula perminuta</i>	Naviperm		1.0	4.2
<i>Pseudostaurosira</i> sp1	Pseudosp1	40.2		1.2
<i>Rhopalodia</i> sp1	Rhosp1	7.5	29.8	22.3
<i>Stephanopyxis</i> sp1	Stesp1	8.7	14.0	7.7

Table 9: Species with codes from sample 197_19 in Figure VIII

Sample 197_19		
Species	Codes	Sample
		197_19
<i>Cocconeis</i> sp26	Coccsp26	15
sp210	sp210	13

A comparison between the species composition from material collected by Giffen and re-sampled material collected in 2019 is presented in the second DCA bi-plot (Figure VIII). Three groups can be identified in which correlations are observed between the samples collected in 2019 and those collected by Giffen, with one outlier sample (197_19). The species composition in samples collected in 2019 is more closely related to the corresponding material collected by Giffen, in comparison to the re-sampling of 2018. This observation is illustrated in Figure VIII with all three groups containing one or more samples collected by Giffen with the corresponding samples collected at the same sites in 2019. It can be noted from Figure VII that no samples collected by Giffen grouped with a corresponding sample collected more recently from the same sites, despite the 2018 and 2019 collections being in the same season.

In Figure VIII group 1 consists of two samples collected by Giffen (210_G and 509_G) and three samples from 2019 (165_19, 195_19, and 210_19). A relatively strong correlation can be observed between all the samples excluding sample 165_19 that shows a weak correlation with the rest of the samples in Group 1. This is mainly due to the presence of *Achnanthes brevipes* (absent in sample 195_19) and *Navicula perrhombus* (absent in sample 210_G) in most of the samples (Table 6). The weak correlation observed between sample 165_19 and the rest of the samples in the group is due to the high abundance of *Navicula perrhombus* (32.76%), which has a low abundance in the rest of the samples in this group (Table 6). Sample 195_19 also has a slightly weaker correlation with other samples in this group, mainly due to the presence and high abundance of *Delphineis livingstonii* (8%). *Delphineis livingstonii* that only occurs in one other sample (165_19) with a low abundance (0.5%) (Table 6).

In Group 1 (Figure VIII), one site sampled by Giffen (210_G) with the corresponding site sampled in 2019 (210_19) is present. The correlation between these two samples is mainly due to the high abundance of *Achnanthes brevipes* in both samples (7.1% in sample 210_G and 22.5% in sample 210_19) (Table 6). Even though there is a stronger correlation between samples 509_G and 210_19, due to these sites sharing four species (*Achnanthes brevipes*, *Navicula perrhombus*, *Nitzschia* sp9, and *Nitzschia* sp4) (Table 6), the community structure of site 210 (sample 210_19) sampled in 2019 shifted more towards the community structure of the corresponding samples collected by Giffen between 1946-1963, compared to the samples collected in 2018.

Group 2 consists of four original samples collected by Giffen (no. 195_G, 197_G, 510_G, and 518_G) and two samples collected in 2019 (no. 510_19 and 518_19) (Figure VIII). An overall weak correlation between all the samples can be observed, with a strong correlation between samples 510_G and 518_G as well as between samples 195_G and 518_G (Figure VIII). The reason for the correlations across all the samples in this group is related to the presence of sp14 (absent in sample 195_G) and *Navicula* sp11 (absent in sample 197_G) across the majority of the sites (Table 7). The strong correlation between samples 510_G and 518_G is due to *Amphora* sp64 being present in these two samples only (Table 7). The strong correlation between samples 195_G and 518_19 is mainly because sp16 only occurs in these two samples (see full species list in Appendix D).

Group 2 (Figure VIII), contains two samples collected by Giffen (510_G) and (518_G) with their corresponding samples collected in 2019 (510_19) and (518_19). Samples 510_G and 510_19 are strongly correlated, with the two samples sharing four taxa; sp46 that occurs only in sample 510_G and 510_19, sp14, *Nitzschia* sp4 and *Navicula* sp11 (Table 7). A weaker correlation can be observed between samples 518_G and 518_19, only sharing two taxa *Navicula perminuta* and sp14 (Table 7). This would imply that the community structure at the sites 510 and 518 in 2019 has shifted back towards the community structure sampled by Giffen between 1946-1963 at sites 510 and 518, compared to the sites resampled in 2018.

Group 3, consists of two samples collected by Giffen (211_G and 165_G) and one sample collected in 2019 (211_19) (Figure VIII). A strong correlation can be observed between all the sites in the group due to the presence of *Stephanopyxis* sp1 and *Rhopalodia* sp1 at all three samples (Table 8). A slightly stronger correlation is observed between the sample collected by Giffen (211_G) and the corresponding re-sampled in 2019 (211_19) compared to sample 165_G. This is due to the presence of *Navicula perminuta* (absent in sample 165_G) in both samples and the relatively high abundance of *Rhopalodia* sp1 (29.0% in sample 211_G and 22.3% in sample 211_19) (Table 8). The sample collected in 2019 (211_19) from site 211 has the strongest correlation with the corresponding sample originally collected by Giffen (211_G), in comparison to the rest of the closely related corresponding samples from 2019 and samples collected by Giffen (Figure VIII). This would imply that the community structure of site 211 in 2019 is very close to that at the time Giffen collected his sample.

Sample 197_19 is not within a group, although this sample shares several species with the rest of the samples (Figure VIII). The main reason for this is that *Cocconeis* sp26 is present in this sample only and with a high relative abundance of 15%. Additionally, sp210 has a

relatively high abundance of 13% in sample 197_19, sp210 also occurs in sample 195_10, but with a very low abundance - 0.5% (Table 9).

Overall, it can be observed that the community structure found in the samples collected in 2019 is relatively similar to the community structure of the samples collected by Giffen between 1946-1963, despite the fact that the diatom community structure documented in 2018 was very different. This has important implications for determining temporal changes, as if only the 2018 samples had been taken into account it may have been concluded that there was a very high degree of change between when Giffen sampled and more recently.

Physico-chemical data was collected in 2019, to determine if there were any apparent external driving factors influencing the littoral diatom community structure at Kidd's Beach. No direct sources of pollution (e.g. intensive agricultural activities or wastewater treatment works) were observed. Canonical Correspondence Analysis (CCA) (Ter Braak & Verdonschot, 1995) was used to illustrate the relationship between the diatom community composition and the measured environmental variables. The data as illustrated in the CCA-tri plot (Figure IX) indicates that no single variable, with the exception of salinity, had an overwhelming influence in terms of shaping community structure.

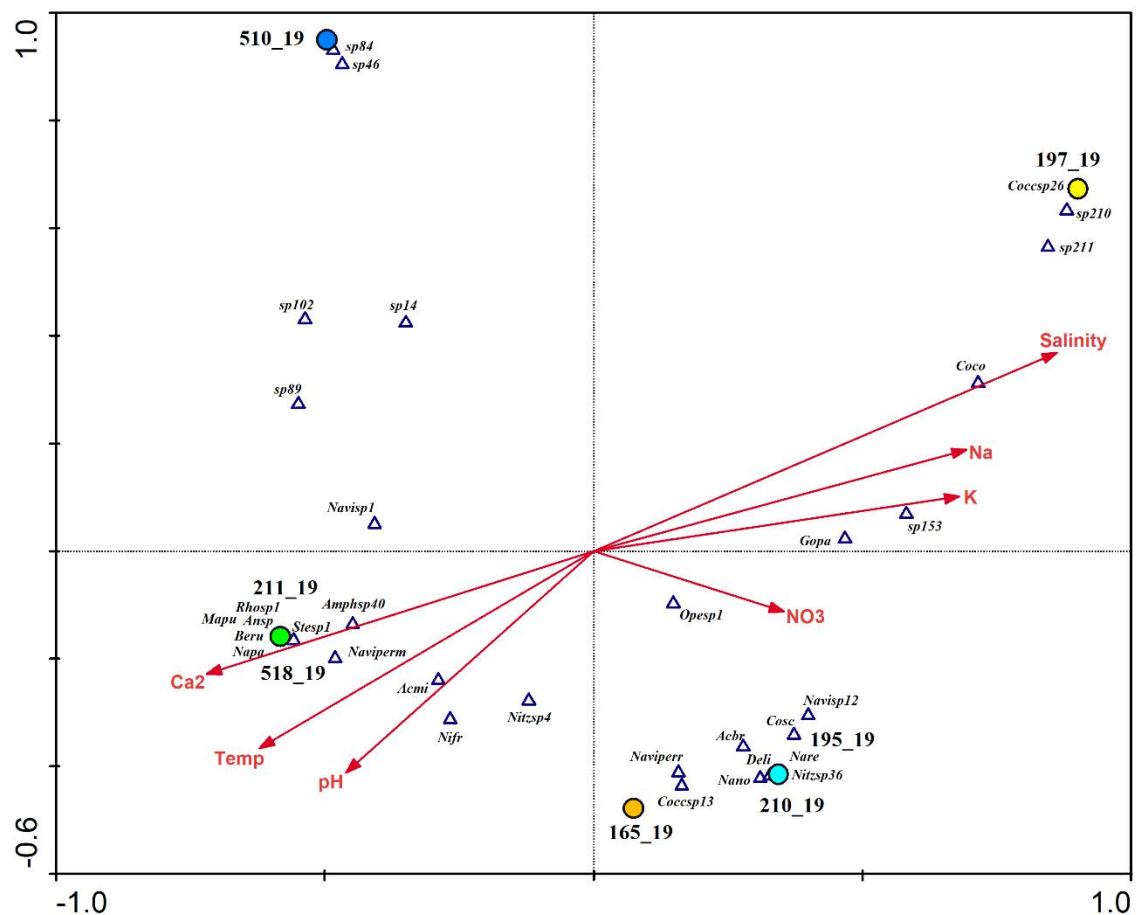


Figure IX: CCA: Comparison between environmental data and the diatom community composition in samples collected in 2019 from Giffen's sites at Kidd's Beach.

2019 sites: 165_19, 195_19, 197_19, 210_19, 211_19, 510_19, 518_19

Table 10: Physico-chemical variables for the resample sites collected in 2019

Physico-chemical variables for the resample sites collected in 2019							
Chemical variables	Sites						
	165_19	195_19	197_19	210_19	211_19	510_19	518_19
Na ppm	9900	9900	9900	9900	5600	9900	5600
NO ₃ ⁻ ppm	490	450	340	450	270	450	270
Salinity %	1.9	1.7	2.5	1.7	0.99	1.7	0.99
Ca ²⁺ ppm	250	240	180	240	980	230	980
K ppm	610	640	580	640	230	600	230
pH	8.31	8.19	7.61	8.19	8.04	8.26	8.04
Temp °C	28.8	24.5	25	24.5	30.7	24.4	30.7

Nitrate (NO₃⁻) seems to have a relatively small influence on diatom community composition, compared to that of the other measured variables. The CCA tri-plot (Figure IX) does however show that, as would be expected, salinity is the primary internal driving variable in this system, with site 3 having a community with the highest tolerance to salinity. *Cocconeis* sp26 and sp210 are the two taxa with the highest tolerance of salinity. Also observed in the plot is that *Cocconeis* sp26 is selective for high salinity, as *Cocconeis* sp26 does not occur in any of the other sites. Bate *et al.* (2013) stated that marine littoral diatoms in South Africa cannot be used as reliable indicators for salinity. The main reason for this statement is that a large number of freshwater diatom species have a broad tolerance range for salinity, as can be seen in Figure IX with the presence of *Gomphonema parvulum* (relative high tolerance) and *Nitzschia frustulum* (lower tolerance). It should also be taken into account that conditions within the marine littoral zone are constantly in flux, especially in terms of salinity (influenced by rainfall, swell size, and the mouth condition of the estuary). Thus, with salinity as the primary driving variable, the diatom community structure is constantly changing, as observed in Figures VII and VIII.

Chapter 5 - Conclusions

From the brief overview of previous research concerning South African marine littoral diatoms, it is apparent that there is a great need across all disciplines, not only taxonomy, for more study in this field in South Africa. The two species lists presented in Appendices A and B show a considerable number of species described by Giffen and Cholnoky from the S.A. marine littoral that still need to be re-documented which could, in turn, assist in the identification of diatom taxa in future studies of S.A.'s marine littoral zones. The number of unidentified taxa observed in the present study also clearly highlight the need for further studies.

Of the 27 taxa described as new by Giffen from Kidd's Beach, 26 were found on the type slides and documented under LM. However, only 23 of the 27 taxa in question were found and documented under SEM, mainly due to the degradation of the material in sample 510. Unfortunately, no additional material was found for this site. Emended and augmented descriptions were given for 26 of the 27 taxa in question, resulting in the transfer of 9 taxa to more appropriate genera based on new information gathered under SEM (*Nitzschia erosa* to *Entomoneis erosa*; *Amphiprora galerita* to *Entomoneis galerita*; *Navicula pragmatica* to *Fallacia pragmatica*; *Stauroneis exilissima* to *Olifantiella exilissima*; *Navicula pseudogamma* to *Moreneis pseudogamma*; *Amphora tenellula* to *Seminavis tenellula*; *Opephora perlonga* to *Tabularia perlonga* and *Opephora perlonga* var. *clavata* to *Tabularia perlonga* var. *clavata*). One status change *Petroneis capensis* (synonym: *Navicula humerosa* f. *capensis*) was also described after the examination of the cell morphology under SEM. These names will be published in a peer-reviewed journal article.

The present study found that the littoral zone of Kidd's Beach has a very diverse diatom community. A total of 560 diatom taxa were observed, with many of these being specific to one site only. Of the 560 diatom taxa observed during counts, only 139 taxa were identified to species level. Counts were made of 400 cells, and the diversity could well be higher if more cells were enumerated per site. There were a number of differences in the diatom community composition between the samples collected by Giffen and those from 2018 and 2019. The samples collected in 2018 had very few species in common with those collected by Giffen, however, in 2019 there were far more species in common between the two sets of samples (Giffen's and 2019).

Giffen described 27 new taxa from Kidd's beach, only 6 taxa were present in the re-sampled material from 2018 and 2019. From this it can be concluded that re-sampling sites from which diatom material was originally collected is not guaranteed to contain the species of interest, therefore, the preservation, maintenance and documentation of extant types is of the utmost importance.

The present study has clearly illustrated that more research is needed to fully understand diatom community structure in the highly dynamic littoral environment, not just in South Africa, but around the world. In order to achieve this understanding, it is necessary to firstly to have a solid taxonomic base upon which to build ecological and other studies. In addition to documenting species with light and electron microscopy, there is a growing need to

document diatom taxa using molecular techniques in order to determine the identities of individual taxa as well as phylogenetic relationships.

References

- Aleem, A. A., 1950. Distribution and ecology of British marine littoral diatoms. *The Journal of Ecology*, 38(1): 75-104.
- Al-Handal, A., 2009. Littoral diatoms from the Shatt Al-Arab estuary, North West Arabian Gulf. *Cryptogamie Algologie*, 30: 153-183.
- Al-Handal, A. Y., Mucko, M. and Wulff, A., 2020. *Entomoneis annagodhei* sp. nov., a new marine diatom (Entomoneidaceae, Bacillariophyta) from the west coast of Sweden. *Diatom Research*, 35(3): 269-279.
- Amspoker, M. C., 2016. *Eunotogramma litorale* sp. nov., a marine epipsammic diatom from Southern California, USA. *Diatom Research*, 31(4): 389-395.
- Archibald, R. E. M., 1983. *The diatoms of the Sundays and Great Fish rivers in the Eastern Cape Province of South Africa*. 1st ed. Bibliotheca Diatomologica, 1. Hirschberg: Strauss & Cramer GmbH. pp.316-320.
- Barsanti, L. and Gualtieri, P., 2014. *Algae: Anatomy, Biochemistry and Biotechnology*. 2nd ed. Broken Sound Parkway, Boca Raton: CRC Press, pp.36-90.
- Basu, S. and Mackey, K., 2018. Phytoplankton as key mediators of the biological carbon pump: Their responses to a changing climate. *Sustainability*, 10(3): 869.
- Bate, G. C., Smailes, P. A. and Adams, J. B., 2004. *Benthic Diatoms in the Rivers and Estuaries of South Africa*. WRC Report No. TT 234/04. Water Research Commission, Pretoria, pp.1-45.
- Bate, G. C., Smailes, P. S. and Adams, J. B., 2013. Epipelagic diatoms in the estuaries of South Africa. *Water SA*, 39(1): 105-118.
- Bilous, O. B., Wojtal, A. Z., Ivanova, N. O., Tsarenko, P. M., Burova, O. V. and Barinova, S., 2020. Benthic Diatom composition in coastal zone of Black Sea, Sasyk Reservoir (Ukraine). *Diversity*, 12(12): 458.
- Bopp, L., Bowler, C., Guidi, L., Karsenti, É. and de Vargas, C., 2017. The Ocean: a Carbon Pump. https://www.ocean-climate.org/wp-content/uploads/2017/03/ocean-carbon-pump_07-2.pdf Date of access: 9 March 2021.
- Broderick, A. C., 2015. Grand challenges in marine conservation and sustainable use. *Frontiers in Marine Science*, 2: 1-3.
- Chase, V. C. and Keener-Chavis, P. 2003. *Learning ocean science through ocean exploration*. 3rd ed. Charleston, S.C.: U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, Office of Ocean Exploration, pp.93-96.

Cholnoky, B. J., 1963. Beiträge zur Kenntnis des marinen Litorals von Südafrika. *Botanica Marina*, 5(2-3): 38-83.

Cholnoky, B. J., 1965. *Preliminary report on the deposits and recent diatom flora of the St. Lucia Lagoon*. National Institute for Water Research, Report No. 107 Pretoria, pp.1-12.

Cholnoky, B. J., 1965. Die Diatomeenassoziationen der Santa-Lucia-Lagune in Natal - (Südafrika). *Botanica Marina*, 11: 7-116

Christianen, J. A., Middelburg, J. J., Holthuijsen, S. J., Jouta, J., Compton T. J., Van Der Heide, T., Piersma, T., Sinninghe Damst J. S., Van Der Veer, H. W., Schouten, S. and Olff, H., 2017. Benthic primary producers are key to sustain the Wadden Sea food web: stable carbon isotope analysis at landscape scale. *Ecology*, 98(6): 1498–1512.

Cotiyane-Pondo, P., Bornman, T. G., Dąbek, P., Witkowski, A. and Smit, A., 2020. Austral winter marine epilithic diatoms: Community composition and distribution on intertidal rocky substrate around the coast of South Africa. *Estuarine, Coastal and Shelf Science*, 242: 1-11.

Dąbek, P., Witkowski, A. and Archibald, C. G. M., 2014. *Minutocellus africana* Dąbek & Witkowski sp. nov.: a new marine benthic diatom (Bacillariophyta, Cymatosiraceae) from Lamberts Bay, Western Cape Province, South Africa. *Nova Hedwigia*, 99(1-2): 223-232.

Desianti, N., Potapova, M., Enache, M., Belton, T. J., Velinsky, D. J., Thomas, R. and Mead, J., 2017. Sediment Diatoms as Environmental Indicators in New Jersey Coastal Lagoons. *Journal of Coastal Research*, 78(1): 127-140.

DeVries, T., Le Quéré, C., Andrews, O., Berthet, S., Hauck, J., Ilyina, T., Landschützer, P., Lenton, A., Lima, I., Nowicki, M., Schwinger, J. and Séférian, R., 2019. Decadal trends in the ocean carbon sink. *Proceedings of the National Academy of Sciences*, 116(24): 11646-11651.

Estrada-Gutiérrez, K. M., Siqueiros-Beltrones, D. A. and Hernández-Almeida, O. U., 2017. New records of benthic diatoms (Bacillariophyceae) for Mexico in the Nayarit littoral found in gut contents of *Crassostrea corteziensis* (Mollusca: Bivalvia). *Revista Mexicana de Biodiversidad*, 88(4): 985-987.

European Academies' Science Advisory Council (EASAC) and the Joint Research Centre (JRC) of the European Commission, 2016. *Marine sustainability in an age of changing oceans and seas*. Luxembourg: Publications Office of the European Union, p.46.

European Marine Board, 2019. *Navigating the future V: Marine Science for a Sustainable Future*. Position Paper 24 of the European Marine Board, Ostend, Belgium. ISBN: 9789492043757. ISSN: 0167-9309. pp 1-88

Garcia, M., 2016. Taxonomy, morphology and distribution of Cymatosiraceae (Bacillariophyceae) in the littorals of Santa Catarina and Rio Grande do Sul. *Biota Neotropica*, 16(2): 1-9.

Giffen, M. H., 1963. Contributions to the diatom flora of South Africa I. Diatoms of the estuaries of the Eastern Cape Province. *Hydrobiologia*, 21(3-4): 201-265.

Giffen, M. H., 1967. Contributions to the diatom flora of South Africa, III Diatoms of the marine littoral regions at Kidd's Beach near East London, Cape Province, South Africa. *Nova Hedwigia*, 13: 245-292.

Giffen, M. H., 1970. New and interesting marine and littoral diatoms from Sea Point, near Cape Town, South Africa. *Botanica Marina*, 13(2): 87-99.

Giffen, M. H., 1970. Contributions to the diatom flora of South Africa IV. The marine littoral diatoms of the estuary of the Kowie River, Port Alfred, Cape Province. *Nova Hedwigia*, 31: 256-312.

Giffen, M. H., 1971. Marine littoral diatoms from the Gordon's Bay region of False Bay Cape Province, South Africa. *Botanica Marina*, 14(1): 1-16.

Giffen, M. H., 1973. Diatoms of the marine littoral of Steenberg's Cove in St. Helena Bay, Cape Province, South Africa. *Botanica Marina*, 16(1): 32-48.

Giffen, M. H., 1975. An account of the littoral diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa. *Botanica Marina*, 18(2): 71-95.

Giffen, M. H., 1976. A further account of the marine littoral diatoms of the Saldanha Bay Lagoon, Cape Province, South Africa. *Botanica Marina*, 19(6): 379-394.

Giffen, M. H., 1984. A checklist of marine littoral diatoms from Namaqualand, South Africa. *Bacillaria*, 7: 179-200.

Google Earth Version 9.140.0.4 (2020) Kidd's Beach 33°08'27" S, 027°42'03" E, elevation 3M. <https://earth.google.com/web/@-33.13850301,27.70688372,41.51572441a,7338.52562672d,30.00005528y,0h,0t,0r> Date of access 3 January 2020.

Guillard, R. R. L. & P. Kilham, 1977. The ecology of marine planktonic diatoms. In D. Werner (ed.), *The biology of diatoms*. Oxford : Blackwell Scientific Publications, pp. 372–469.

Guiry, M. D., 2012. How many species of algae are there? *Journal of Phycology*, 48(5): 1057-1063.

Helbling, E. W. and Villafañe, V. E., 2009. *Fisheries and aquaculture* vol. V. Oxford, United Kingdom: Eolss Publishers Co. Ltd, pp.206-215.

Hill, M. O. and Gauch, H. G. Jr., 1980. Detrended correspondence analysis: An improved ordination technique. *Vegetatio*, 42: 47-58.

Holland, S, M., 2008. Tutorial: *Detrended correspondence analysis (DCA)*. University of Georgia, Athens, GA 30602-2501, pp.1-9.

Huang, R., 1982. The interactions of certain littoral diatoms with young plants of marine algae Scotland: University of Glasgow. (Thesis – PhD).

Hustedt, F. and Aleem, A. A., 1951. Littoral diatoms from the Salstone, near Plymouth. *Journal of the Marine Biological Association of the United Kingdom*, 30(1): 177-196.

Intergovernmental Panel on Climate Change (2014) “Cross-Chapter Boxes,” in *Climate Change 2014 – Impacts, adaptation and vulnerability: part A: global and sectoral aspects: working group II contribution to the IPCC fifth assessment report*. Cambridge: Cambridge University Press, pp. 95–96.

Jahn, R. and Kusber, W., 2004. Algae of the Ehrenberg collection – 1. Typification of 32 names of diatom taxa described by C. G. Ehrenberg. *Willdenowia*, 34: 577.

Jones, H., Simpson, G., Stickle, A. and Mann, D. G., 2005. Life history and systematics of *Petroneis* (Bacillariophyta), with special reference to British waters. *European Journal of Phycology*, 40(1): 61-87.

Kim, S., Witkowski, A., Park, J., Li, C., Trobajo, R., Mann, D. G., Kim, S., Ashworth, M., Bąk, M. and Gastineau, R., 2019. Taxonomy and diversity of a little-known diatom genus *Simonsenia* (Bacillariaceae) in the marine littoral: novel taxa from the Yellow Sea and the Gulf of Mexico. *Plant Ecology and Evolution*, 152(2): 248-261.

Kim, S., Witkowski, A., Park, J., Gastineau, R., Ashworth, M. P., Kim, B., Mann, D. G., Li, C., Igersheim, A., Płociński, T., Yoo, Y., Chung, S. and Theriot, E. C., 2020. The Taxonomy and Diversity of *Proschkinia* (Bacillariophyta), A Common but enigmatic genus from marine coasts. *Journal of Phycology*, 56(4): 953-978.

Krienitz, L., 2009. Algae (incl. Cyanobacteria): Types, Phytoplankton, and eutrophication/ Remediation. (In Likens, G. E., ed. *Encyclopedia of inland waters*. Amsterdam, Boston: Elsevier, pp.103-112).

Kryk, A., Bąk, M., Górecka, E., Riaux-Gobin, C., Bemiasa, J., Bemanaja, E., Li, C., Dąbek, P. and Witkowski, A., 2020. Marine diatom assemblages of the Nosy Be Island coasts, NW Madagascar: species composition and biodiversity using molecular and morphological taxonomy. *Systematics and Biodiversity*, 18(2): 161-180.

- Lane, M. L., 2005. The use of diatoms as biological indicators of water quality, and for environmental reconstruction, in south-east Tasmania, Australia. Tasmania: University of Tasmania. (Thesis – PhD)
- Malcata, F. X., Pinto, I. S. and Guedes, A. C., 2018. *Marine macro- and microalgae: An overview*. Broken Sound Parkway, Boca Raton: CRC Press, pp.1-16.
- Mann, D. G. and Vanormelingen, P., 2013. An inordinate fondness? The number, distributions, and origins of diatom species. *Journal of Eukaryotic Microbiology*, 60(4): 414-420.
- Marinov, I. and Sarmiento, J., 2004. The role of the oceans in the global carbon cycle: an overview. *The ocean carbon cycle and climate*, 251-295.
- McKinley, G., Fay, A., Eddebbar, Y., Gloege, L. and Lovenduski, N., 2020. External forcing explains recent decadal variability of the ocean carbon sink. *AGU Advances*, 1(2): .1-10.
- Müller, R., 2005. Schäden bei Plankton aus der Konserve? *Mikrokosmos*: 45–47.
- Nevrova, E. and Petrov, A., 2019. Benthic diatoms species richness at Dvuyakornaya Bay and other coastal sites of Crimea (the Black Sea) under various environments. *Mediterranean Marine Science*, 20(3): 506.
- Park, J., Koh, C., Khim, J. S., Ohtsuka, T. and Witkowski, A., 2012. Description of a new Naviculoid Diatom Genus *Moreneis* gen. nov. (Bacillariophyceae) from sand flats in Korea. *Journal of Phycology*, 48(1): 186-195.
- Passow, U. and Carlson, C. A., 2012. The biological pump in a high CO₂ world. *Marine Ecology Progress Series*, 470: 249-271.
- Paterson, D. M., 1986. The migratory behaviour of diatom assemblages in a laboratory tidal micro ecosystem examined by low temperature scanning electron microscopy. *Diatom Research*. 1: 227-239.
- Pendleton, L., Evans, K. and Visbeck, M., 2020. Opinion: We need a global movement to transform ocean science for a better world. *Proceedings of the National Academy of Sciences*, 117(18): 9652-9655.
- Paterson, D. M., 1989. Short-term changes in the erodibility of intertidal cohesive sediments related to the migratory behavior of epipellic diatoms. *Limnol. Oceanogr.*, 34: 223-234.
- Pinet, P. R., 2009. *Invitation to oceanography*. 5th ed. Sudbury, Mass.: Jones and Bartlett Publishers, pp.293-295.
- Prasad, A. K. S. K. and Felgenhauer, B. E., 1988. Colony formation and valve morphology in the marine benthic diatom. *Dimeregramma fulvum*. *Br. phycol. J.* 23: 365-378.

Pyle, L., Cooper, S. R. and Huvane, J. K., 1998. Diatom paleoecology pass key core 37, Everglades National Park, Florida Bay. *USGS*, 1-8.

Ragueneau, O., Conley, D. J., Leynaert, A., Longphuirt, S. N. and Slomp, C. P., 2006. Role of diatoms in silica cycling and coastal marine food webs, 163-195. In: Ittekkot, V., Unger, D.,

Humborg, C. and An, N., eds. 2006 *The silicon cycle: human perturbations and impacts on aquatic systems*. Island Press, Washington, D.C., pp.163-195.

Riaux-Gobin. C., and Compère. P., 2009. *Olifantiella mascarenica* gen. & sp. nov., a new genus of pennate diatom from Réunion Island, exhibiting a remarkable internal process. *Phycological Research*, (57): 178–185.

Richardson, A. J. and Poloczanska, E. S., 2008., Ocean science: Under-resourced, under threat. *Science*, 320(5881): 1294-1295.

Round, F. E., Crawford, R. M. & Mann, D. G., 1990. *The diatoms: biology and morphology of the genera*. Cambridge: Cambridge University Press. pp. [i-ix], pp. 1-747.

Sayre, R. G., Wright, D. J., Breyer, S. P., Butler, K. A., Van Graafeiland, K., Costello, M. J., Harris, P. T., Goodin, K. L., Guinotte, J. M., Basher, Z., Kavanaugh, M. T., Halpin, P. N., Monaco, M. E., Cressie, N., Aniello, P., Frye, C. E. and Stephens, D., 2017. A three-dimensional mapping of the ocean based on environmental data. *Oceanography*, 30(1): 90-103.

Sawai, Y., Horton, B. P., Kemp, A. C., Hawkes, A. D., Nagumo, T. and Nelson, A. R., 2016. Relationships between diatoms and tidal environments in Oregon and Washington, USA. *Diatom Research*, 31(1): 17-38.

Schmidt, A., 1874-1959. *Atlas der Diatomaceen-Kunde. Fortgesetzt durch Martin Schmidt, F. Fricke, H. Heiden, O. Müller und F. Hustedt*. Aschersleben und Leipzig. 400 plates.

Semcheski, M., R., 2014. Benthic and planktonic microalgal community structure and primary productivity in Lower Chesapeake Bay. Norfolk: Old Dominion University. (Theise - PhD).

Sheppard, C. R. C., Davy, S. K. and Pilling, G. M., 2012. *The biology of coral reefs*. Oxford: Oxford University Press. p.100

Simon, N., Cras, A., Foulon, E. and Lemée, R., 2009. Diversity and evolution of marine phytoplankton. *Comptes Rendus Biologies*, 332(2-3): 159-170.

Siqueiros Beltrones, D. A. and López Fuerte, F., 2006. Epiphytic diatoms associated with red mangrove (*Rhizophora mangle*) prop roots in Bahía Magdalena, Baja California Sur, Mexico. *Revista de Biología Tropical*, 54(2): 287-297.

Spaulding, S. A., Bishop, I. W., Edlund, M. B., Lee, S., Furey, P., Jovanovska, E. and Potapova, M. Diatoms of North America. <https://diatoms.org/genera/entomoneis/guide> Date of access: 16 November 2020.

Spaulding S. A., Edlund M., Morales E. and Metzeltin D., 2009. *Cavinula*. Diatoms of North America. <http://westerndiatoms.colorado.edu/taxa/genus/Cavinula> Date access: 09 November 2020.

Stal, L. J. and de Brouwer, J. F. C., 2003. Biofilm formation by benthic diatoms and their influence on the stabilization of intertidal mudflats. *Berichte – Forschungszentrum Terramare*, 12: 109-111.

Stidolph, S. R., 1980. A record of some coastal marine diatoms from Porirua Harbour, North Island, New Zealand. *New Zealand Journal of Botany*, 18(3): 379-403.

Stidolph, S. R., 1995. A morphological and taxonomic study of the complex of diatoms assigned to *Caloneis brevis* (Gregory) Cleve. *Diatom Research*, 10(1): 165-177.

Sullivan, M. J., 1981. A Preliminary checklist of marine benthic diatoms of Mississippi. *Gulf Research Reports*, 7(1): 13-18.

Taylor, J. C. and Cocquyt, C., 2016. *Diatoms from the Congo and Zambezi basins: methodologies and identification of the genera*. *Abc Taxa*, 16, pp.1-355.

Taylor, J. C., Cocquyt, C. and Mayama, S., 2016. *Navicula nielsfogedii* J.C. Taylor & Cocquyt sp. nov., a new diatom (Bacillariophyta) from tropical and sub-tropical Africa. *Fottea*, 16(2): 201-208.

Taylor, J. C., Harding, W. R., and Archibald, C. G. M., 2007. *A methods manual for the collection, preparation and analysis of diatom samples*. WRC Report TT 281/07. Water Research Commission, Pretoria, pp 1-48.

Ter Braak, C. J. F. and Verdonschot, P. F. M., 1995. Canonical correspondence analysis and related multivariate methods in aquatic ecology. *Aquatic Sciences*, 57(3): 255-289.

Trigueros, J. M. and Orive, E., 2001. Seasonal variations of diatoms and dinoflagellates in a shallow, temperate estuary, with emphasis on neritic assemblages. *Hydrobiologia*, 444(1/3): 119-133.

Turland, N. J., Wiersema, J. H., Barrie, F. R., Greuter, W., Hawksworth, D. L., Herendeen, P. S., Knapp, S., Kusber, W.-H., Li, D.-Z., Marhold, K., May, T. W., McNeill, J., Monro, A. M., Prado, J., Price, M. J. & Smith, G. F. (eds.) 2018: *International Code of Nomenclature for algae, fungi, and plants (Shenzhen Code) adopted by the Nineteenth International Botanical Congress Shenzhen, China, July 2017*. Regnum Vegetabile 159. Glashütten: Koeltz Botanical Books. DOI <https://doi.org/10.12705/Code.2018>.

Underwood, G. J. C. and Kromkamp J., 1999. Primary production by phytoplankton and microphytobenthos in estuaries. *Advanced Ecological Research*, 29: .93–153.

Wetzel, C. E., Ector, L., Van de Vijver, B., Compère, P. and Mann, D. G., 2015. Morphology, typification and critical analysis of some ecologically important small naviculoid species (Bacillariophyta). *Fottea*, 15(2): 203-234.

Williams, D. M. and Round, F. E., 1986. Revision of the genus *Synedra* Ehrenb. *Diatom Research*, 1(2): 313-339.

Witkowski, A., Ashworth, M., Li, C., Sagna, I., Yatte, D., Górecka, E., Franco, A., Kusber, W., Klein, G., Lange-Bertalot, H., Dąbek, P., Theriot, E. C. and Manning, S. R., 2020. Exploring diversity, taxonomy and phylogeny of diatoms (Bacillariophyta) from marine habitats. Novel taxa with internal costae. *Protist*, 171(2): 1-25.

Witkowski, A., Barka, F., Mann, D. G., Li, C., Weisenborn, J. F. L., Ashworth, M. P., Kurzydłowski, K. J., Zglobicka, I. and Dobosz, S., 2014. A description of *Biremis panamae* sp. nov., a new diatom species from the marine littoral, with an account of the phylogenetic position of *Biremis* D.G. Mann et E.J. Cox (Bacillariophyceae). *PLoS ONE*, 9(12): 1-24.

Witkowski, A., Riaux-Gobin, C. and Daniszewska-Kowalczyk, G., 2010. New marine littoral diatom species (Bacillariophyta) from Kerguelen Islands. II. Heteropolar species of Fragilariaceae. *Vie et Milieu*, 60(3): 265-281.

Wohlgemuth, M., 1991. *Primary producers and decomposers of intertidal flats*. Wetlands program. Gloucester Point, Virginia U.S.A. No. 91-94.

Working Group I of the IPCC, 2013. *Climate change 2013 The physical science basis. summary for policymakers, technical summary and frequently asked questions*. Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, p.8.

Wulff, A., Vilbaste, S. and Truu, J., 2005. Depth distribution of photosynthetic pigments and diatoms in the sediments of a microtidal fjord. *Hydrobiologia*, 534(1-3): 117-130.

Appendix A - List of new marine littoral zone diatom taxa described by M. H. Giffen

Species	Publication	Year	Page	Plate	Figure	Province	Location	Type slide	SANDC (NIWR) no.
<i>Amphiprora corrugata</i>	Contribution of Diatom Flora of South Africa I. Diatoms of Estuaries of the Eastern Cape Province	1963	213	1	6, 7	Eastern Cape	464	464	293/5855
<i>Amphiprora paralia</i>	Contribution of Diatom Flora of South Africa I. Diatoms of Estuaries of the Eastern Cape Province	1963	215	1	11	Eastern Cape	482	482	293/5856
<i>Amphipora perplexa</i>	Contribution of Diatom Flora of South Africa I. Diatoms of Estuaries of the Eastern Cape Province	1963	215-216	1	12	Eastern Cape	203	203	293/5841
<i>Amphora castellata</i>	Contribution of Diatom Flora of South Africa I. Diatoms of Estuaries of the Eastern Cape Province	1963	216-217	1	13, 14	Eastern Cape	203	203	293/5841
<i>Amphora gamtoosae</i>	Contribution of Diatom Flora of South Africa I. Diatoms of Estuaries of the Eastern Cape Province	1963	218	2	21	Eastern Cape	484	484	293/5859
<i>Auricula chalnokyi</i>	Contribution of Diatom Flora of South Africa I. Diatoms of Estuaries of the Eastern Cape Province	1963	220	2	27-29	Eastern Cape	482	482	293/5856
<i>Cocconeis testudo</i>	Contribution of Diatom Flora of South Africa I. Diatoms of Estuaries of the Eastern Cape Province	1963	225	3	37-39	Eastern Cape	M 12/1	M 12/1	457/9132
<i>Gyrosigma caffra</i>	Contribution of Diatom Flora of South Africa I. Diatoms of Estuaries of the Eastern Cape Province	1963	230	3	50	Eastern Cape	464	464	293/5855
<i>Navicula guluensis</i>	Contribution of Diatom Flora of South Africa I. Diatoms of Estuaries of the Eastern Cape Province	1963	238	4	70	Eastern Cape	464	464	293/5855
<i>Navicula rogersii</i>	Contribution of Diatom Flora of South Africa I. Diatoms of Estuaries of the Eastern Cape Province	1963	241	4	78	Eastern Cape	485	485	294/5861
<i>Raphoneis mirabunda</i>	Contribution of Diatom Flora of South Africa I. Diatoms of Estuaries of the Eastern Cape Province	1963	251-252	6	100, 101	Eastern Cape	197	197/8	Lectotype available: 457/9125
<i>Achnanthes promunturii</i>	New and Interesting Marine Littoral Diatoms From Sea point, Near Cape Town, South Africa	1970	88	1	1-4	Western Cape	602	602	456/9110
<i>Amphora profusa</i>	New and Interesting Marine Littoral Diatoms From Sea point, Near Cape Town, South Africa	1970	88-89	1	8	Western Cape	591	591	Lectotype available: 456/9104

<i>Berkeleya capensis</i>	New and Interesting Marine Littoral Diatoms From Sea point,Near Cape Town, South Africa	1970	89	1	5-7	Western Cape	591	591	456/9104
<i>Cuneolus minutus</i>	New and Interesting Marine Littoral Diatoms From Sea point,Near Cape Town, South Africa	1970	90-91	1	14-18	Western Cape	591	591	456/9107
<i>Dimerogramma inane</i>	New and Interesting Marine Littoral Diatoms From Sea point,Near Cape Town, South Africa	1970	91	1	20-21	Western Cape	602	602	457/9136
<i>Gomphonema pseudoseptatum</i>	New and Interesting Marine Littoral Diatoms From Sea point,Near Cape Town, South Africa	1970	92	1	29-32	Western Cape	591	591	456/9108
<i>Grammatophora carteri</i>	New and Interesting Marine Littoral Diatoms From Sea point,Near Cape Town, South Africa	1970	92-93	1	33, 34	Western Cape	602	602	456/9109
<i>Licmophora opephoroides</i>	New and Interesting Marine Littoral Diatoms From Sea point,Near Cape Town, South Africa	1970	93	1, 2	35-37	Western Cape	602	602	456/9109
<i>Navicula speibonae</i>	New and Interesting Marine Littoral Diatoms From Sea point,Near Cape Town, South Africa	1970	94	2	44, 45	Western Cape	591	591	456/9105
<i>Rhabdonema scabellum</i>	New and Interesting Marine Littoral Diatoms From Sea point,Near Cape Town, South Africa	1970	95-96	2	48-50	Western Cape	591	591	456/9104
<i>Rhoicosphenia flexa</i>	New and Interesting Marine Littoral Diatoms From Sea point,Near Cape Town, South Africa	1970	96	2	55-58	Western Cape	591	591	456/9104
<i>Surirella scopuli</i>	New and Interesting Marine Littoral Diatoms From Sea point,Near Cape Town, South Africa	1970	96	2	61	Western Cape	591	591	Lectotype available: 456/9104
<i>Trachyneis speibonae</i>	New and Interesting Marine Littoral Diatoms From Sea point,Near Cape Town, South Africa	1970	97-98	2	62, 63	Western Cape	591	591	456/9104
Transfer <i>Cocconeis</i> to <i>Navicula biflexa</i>	New and Interesting Marine Littoral Diatoms From Sea point,Near Cape Town, South Africa	1970	94	2	64	Western Cape	591, 592, 602		
<i>Amphora francescae</i>	Contributions to the Diatom Flora of South Africa IV. The Marine Littoral Diatom of The Kowie River,Port Alfred,Cape Province	1970	266	1	16, 17	Eastern Cape	564	564	Lectotype available: 456/9120
<i>Auricula machutchoniae</i>	Contributions to the Diatom Flora of South Africa IV. The Marine Littoral Diatom of The Kowie River,Port Alfred,Cape Province	1970	269	2	24	Eastern Cape	570	570	457/9121
<i>Diploneis interrupta</i> var. <i>caffra</i>	Contributions to the Diatom Flora of South Africa IV. The Marine Littoral Diatom of The Kowie River,Port Alfred,Cape Province	1970	273-274	2	29, 30	Eastern Cape	523	523	456/9113
<i>Gyrosigma diversitatum</i>	Contributions to the Diatom Flora of South Africa IV. The Marine Littoral Diatom of The Kowie River,Port Alfred,Cape Province	1970	276-277	2	35, 36	Eastern Cape	564	564	456/9120

<i>Licmophora pfannkuckae</i>	Contributions to the Diatom Flora of South Africa IV. The Marine Littoral Diatom of The Kowie River,Port Alfred,Cape Province	1970	278-279	2	41, 42	Eastern Cape	563	563	456/9118
<i>Navicula ponticula</i>	Contributions to the Diatom Flora of South Africa IV. The Marine Littoral Diatom of The Kowie River,Port Alfred,Cape Province	1970	284-285	5	100, 101	Eastern Cape	551	551/1	Lectotype available: 291/5806
<i>Navicula pseudoincerta</i>	Contributions to the Diatom Flora of South Africa IV. The Marine Littoral Diatom of The Kowie River,Port Alfred,Cape Province	1970	285-286	4	60-62	Eastern Cape	570	570	Lectotype available: 457/9121
<i>Navicula subirritans</i>	Contributions to the Diatom Flora of South Africa IV. The Marine Littoral Diatom of The Kowie River,Port Alfred,Cape Province	1970	286-287	4	65, 66	Eastern Cape	523	523	456/9115
<i>Nitzschia bathurstensis</i>	Contributions to the Diatom Flora of South Africa IV. The Marine Littoral Diatom of The Kowie River,Port Alfred,Cape Province	1970	287-288	4	67-69	Eastern Cape	564	564	Lectotype available: 456/9120
<i>Nitzschia kowiensis</i>	Contributions to the Diatom Flora of South Africa IV. The Marine Littoral Diatom of The Kowie River,Port Alfred,Cape Province	1970	289-290	4	71-74	Eastern Cape	523	523	Lectotype available: 456/9115
<i>Pleurosigma kowiense</i>	Contributions to the Diatom Flora of South Africa IV. The Marine Littoral Diatom of The Kowie River,Port Alfred,Cape Province	1970	296-297	5	90	Eastern Cape	551	551	Lectotype available: 291/5806
<i>Stauroneis bathurstensis</i>	Contributions to the Diatom Flora of South Africa IV. The Marine Littoral Diatom of The Kowie River,Port Alfred,Cape Province	1970	299	5	94-96	Eastern Cape	566	566	Lectotype available: 291/5817-8
<i>Amphora exilitata</i>	Marine Littoral Diatoms from the Gordons Bay, Region of False Bay Cape Province, South Africa	1971	2, 3	1	5-7	Western Cape	594	594/1	457/9128
<i>Campylosira africana</i>	Marine Littoral Diatoms from the Gordons Bay, Region of False Bay Cape Province, South Africa	1971	4	1	15-18	Western Cape	294	594/1	457/9128
<i>Navicula sponsalia</i>	Marine Littoral Diatoms from the Gordons Bay, Region of False Bay Cape Province, South Africa	1971	8	2	37-39	Western Cape	594	594	Lectotype available: 454/9062
<i>Nitzschia composita</i>	Marine Littoral Diatoms from the Gordons Bay, Region of False Bay Cape Province, South Africa	1971	8, 9	2	42, 43	Western Cape	594	594	Lectotype available: 454/9062
<i>Amphora helenensis</i>	Diatoms of The Marine Littoral of Steenbergs Cove in St. Helena Bay, Cape Province, South Africa	1973	33-34	1	7-9	Western Cape	619, 621	621/2	455/9098
<i>Licmophora partita</i>	Diatoms of The Marine Littoral of Steenbergs Cove in St. Helena Bay, Cape Province, South Africa	1973	38	2	28-30	Western Cape	627	627	456/9103
<i>Navicula assuloides</i>	Diatoms of The Marine Littoral of Steenbergs Cove in St. Helena Bay, Cape Province, South Africa	1973	38-39	2	32-34	Western Cape	623	623/3	Lectotype available: 455/9099
<i>Navicula dehissa</i>	Diatoms of The Marine Littoral of Steenbergs Cove in St. Helena Bay, Cape Province, South Africa	1973	39	2	35, 36	Western Cape	621	621/2	455/9098

<i>Navicula nasuta</i>	Diatoms of The Marine Littoral of Steenbergs Cove in St. Helena Bay, Cape Province, South Africa	1973	39	2	38, 39	Western Cape	621	621/2	455/9098
<i>Nitzschia aestatis</i>	Diatoms of The Marine Littoral of Steenbergs Cove in St. Helena Bay, Cape Province, South Africa	1973	40	2	48, 49	Western Cape	621	621/2	455/9098
<i>Nitzschia cacumina</i>	Diatoms of The Marine Littoral of Steenbergs Cove in St. Helena Bay, Cape Province, South Africa	1973	40-41	2	54, 25	Western Cape	625	625/1	455/9100
<i>Nitzschia proceroides</i>	Diatoms of The Marine Littoral of Steenbergs Cove in St. Helena Bay, Cape Province, South Africa	1973	41-42	2, 3	56-58	Western Cape	619	619/5	455/9096
<i>Nitzschia sibula</i>	Diatoms of The Marine Littoral of Steenbergs Cove in St. Helena Bay, Cape Province, South Africa	1973	42	3	59, 60	Western Cape	621	621/1	455/9097
<i>Nitzschia steenbergensis</i>	Diatoms of The Marine Littoral of Steenbergs Cove in St. Helena Bay, Cape Province, South Africa	1973	42	3	61, 62	Western Cape	621	621/2	455/9098
<i>Nitzschia vulpeculoides</i>	Diatoms of The Marine Littoral of Steenbergs Cove in St. Helena Bay, Cape Province, South Africa	1973	42-43	3	63-65	Western Cape	625	625/1	455/9100
<i>Achnanthes danicoides</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	72	1	3-6	Western Cape	629	629	455/9088
<i>Amphora langebaanae</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	74	1	13-15	Western Cape	632	632/7	455/9093
<i>Campylosira inane</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	76	2	33-35	Western Cape	628	628/6	455/9098
<i>Cocconeis deperdita</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	78	1	26-28	Western Cape	632	632	455/9093
<i>Cymatosira capensis</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	79	2	36-39	Western Cape	630	630/7	455/9089
<i>Grammatophora lepida</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	81	2	51-54	Western Cape	631	1 631/8	455/9090
<i>Navicula infirmitata</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	83-84	2	69-73	Western Cape	629	629	455/9088
<i>Navicula lusoria</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	84	2	75-77	Western Cape	623	623/7	Lectotype available: 455/9091
<i>Navicula melanocephala</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	84, 86	2	78-80	Western Cape	632	632/1	455/9091

<i>Navicula occasa</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	86	3	83, 84	Western Cape	629	629/7	Lectotype available: 455/9088
<i>Navicula pseudoinflata</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	87	3	90-93	Western Cape	633	633	455/9095
<i>Navicula pseudosalinarum</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	87	3	94-96	Western Cape	630	630	455/9089
<i>Navicula viminoides</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	88	3	99-101	Western Cape	632	632/1	455/9091
<i>Nitzschia rorida</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	90	3	103, 104	Western Cape	633	633/1	Lectotype available: 455/9094
<i>Plagiogramma appendiculatum</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	91	3	109-112	Western Cape	632	632/7	455/9092 and 455/9093
<i>Plagiogramma occasum</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	91-92	3	113-116	Western Cape	629	629/7	Lectotype available: 455/9088
<i>Auliscus sculptus</i> var. <i>strigillatus</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	75	1	23	Western Cape	630, 631, 633	630, 631, 634	Lectotype available: 455/9089
<i>Auliscus sculptus</i> var. <i>hipis</i>	An Account of the Littoral Diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa	1975	75	??	??	Western Cape	628, 632	628, 633	Lectotype available: 455/9094
<i>Achnanthes navalis</i>	A Further Account of the Marine Littorale Diatoms of Saldanaha Bay Lagoon, Cape Province, South Africa	1976	381	1	1, 2	Western Cape	617	617/5	Lectotype available: 288/5745
<i>Amphora ridicula</i>	A Further Account of the Marine Littorale Diatoms of Saldanaha Bay Lagoon, Cape Province, South Africa	1976	382	1	10-13	Western Cape	636	636	Lectotype available: 456/9111
<i>Navicula osterosa</i>	A Further Account of the Marine Littorale Diatoms of Saldanaha Bay Lagoon, Cape Province, South Africa	1976	388	2	42	Western Cape	636	636/16	Lectotype available: 456/9111
<i>Striatella aberrans</i>	A Further Account of the Marine Littorale Diatoms of Saldanaha Bay Lagoon, Cape Province, South Africa	1976	392	2	61, 62	Western Cape	636	636/12	456/9111
<i>Achnanthes corrupta</i>	A Checklist of Marine Littoral Diatoms from Namaqualand, South Africa	1984	184-185	1	1-6	Northern Cape	657	657/6	458/9144
<i>Achnanthes namae</i>	A Checklist of Marine Littoral Diatoms from Namaqualand, South Africa	1984	185-186	1	11,12	Northern Cape	662	662/7	458/9148
<i>Achnanthes schoemania</i>	A Checklist of Marine Littoral Diatoms from Namaqualand, South Africa	1984	186-187	1	9, 10	Northern Cape	660	660/4	Slide missing from SANDC, Lectotype

									available from Hustedt Diatom Collection: 426-38
<i>Amphora arcana</i>	A Checklist of Marine Littoral Diatoms from Namaqualand, South Africa	1984	187	1	13	Northern Cape	660	660/5	Slide missing from SANDC , Lectotype available from Hustedt Diatom Collection: 426-33
<i>Amphora evanida</i>	A Checklist of Marine Littoral Diatoms from Namaqualand, South Africa	1984	187-188	1	15-17	Northern Cape	660	660/4	Slide missing from SANDC , Lectotype available from Hustedt Diatom Collection: 426-39
<i>Amphora pannucea</i>	A Checklist of Marine Littoral Diatoms from Namaqualand, South Africa	1984	188-189	1	18, 19	Northern Cape	660	660/6	Slide missing from SANDC , Lectotype available from Hustedt Diatom Collection: 426-39
<i>Amphora incrassata</i>	A Checklist of Marine Littoral Diatoms from Namaqualand, South Africa	1984	189	1	20-22	Northern Cape	732	732/8 in text as 732/VIII	Lectotype available: 459/9167
<i>Auricula pulchra</i> var. <i>namaquensis</i>	A Checklist of Marine Littoral Diatoms from Namaqualand, South Africa	1984	189-190	1	23, 24	Northern Cape	662	662/7	458/9148
<i>Cocconeis namaquensis</i>	A Checklist of Marine Littoral Diatoms from Namaqualand, South Africa	1984	190	1	25-28	Northern Cape	651	651/6	458/9142
<i>Gomphonitzschia capensis</i>	A Checklist of Marine Littoral Diatoms from Namaqualand, South Africa	1984	191	1	29-32	Northern Cape	647	647/7	21-215
<i>Navicula dolosa</i>	A Checklist of Marine Littoral Diatoms from Namaqualand, South Africa	1984	191-192	2	33	Northern Cape	662	662/7	458/9148
<i>Nitzschia hybridaeformis</i> var. <i>pannucea</i>	A Checklist of Marine Littoral Diatoms from Namaqualand, South Africa	1984	192	2	36, 37	Northern Cape	662	662/5	458/9147
<i>Nitzschia miranda</i>	A Checklist of Marine Littoral Diatoms from Namaqualand, South Africa	1984	192-193	2	38-41	Northern Cape	648	648/1	Lectotype available: 458/9141

<i>Nitzschia mytilicola</i>	A Checklist of Marine Littoral Diatoms from Namaqualand, South Africa	1984	193-194	2	34, 35	Northern Cape	648	648/6	458/9141
<i>Nitzschia nollothae</i>	A Checklist of Marine Littoral Diatoms from Namaqualand, South Africa	1984	194	2	42-44	Northern Cape	652	652/7	Lectotype available: 21-216

Appendix B - List of new marine littoral zone diatom taxa described by B. J. Chohnoky

Species	Publication	Year	Page	Plate	Figure	Province	Location	Type slide	SANDC (NIWR) no.
<i>Achnanthes exiloides</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	39	1	1, 2	Western Cape	Steenbras	K. 263	220/4385-6
<i>Cocconeis clandestina var capensis</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	42, 43	1	6, 7	Western Cape	Steenbras	K. 263	220/4385-6
<i>Cocconeis cunoniae</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	43	1	8, 9	Western Cape	Rooi Els	K. 265	220/4389-90
<i>Cocconeis hirsuta</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	45, 56	1	12, 13	Western Cape	Steenbras	K. 263	220/4385-6
<i>Cocconeis stompsii</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	46, 47	1	18, 19	Western Cape	Knysna	K. 179	214/4261-2
<i>Diploneis modicella</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	48	1	21	Western Cape	Knysna	K. 179	214/4261-2
<i>Diploneis pseudopetersenii</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	49	1	24, 25	Western Cape	Steenbras	K. 263	220/4385-6
<i>Fragilaria litoralis</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	50	1	28	Western Cape	Knysna	K. 179	214/4261-2
<i>Gyrosigma stompsii</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	51	1	31	Western Cape	Steenbras	K. 263	220/4385-6
<i>Navicula adnatoides</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	52, 53	1	33	Western Cape	Steenbras	K. 263	220/4385-6
<i>Navicula assula</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	53	1	35	Western Cape	Steenbras	K. 263	220/4385-6
<i>Navicula cingulatooides</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	54	1	38	Western Cape	Rooi Els	K. 265	220/4389-90
<i>Navicula confidens</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	54, 55	1	40	Western Cape	Knysna	K. 179	214/4261-2
<i>Navicula conscensa</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	55	1	41	Western	Rooi Els	K. 265	220/4389-90

						Cape			
<i>Navicula cryptorrhyncus</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	55, 56	1	44a, 44d	Western Cape	Knysna	K. 179	214/4261-2
<i>Navicula cunoniae</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	56, 57	1	46, 47	Western Cape	Rooi Els	K. 265	220/4389-90
<i>Navicula flebilis</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	57	1	49	Western Cape	Steenbras	K. 263	220/4385-6
<i>Navicula gregalis</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	57, 58	1	50	Western Cape	Knysna	K. 179	214/4261-2
<i>Navicula grimmiioides</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	58, 59	1	53	Western Cape	Steenbras	K. 263	220/4385-6
<i>Navicula insolubilis</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	59, 60	2	55	Western Cape	Steenbras	K. 263	220/4385-6
<i>Navicula knysnensis</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	60	2	56, 57	Western Cape	Knysna	K. 179	214/4261-2
<i>Navicula lithognatha</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	60, 61	2	58, 59	Western Cape	Steenbras	K. 263	220/4385-6
<i>Navicula lithognathoides</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	61	2	60	Western Cape	Steenbras	K. 263	220/4385-6
<i>Navicula nautica</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	62	2	64	Western Cape	Steenbras	K. 263	220/4385-6
<i>Navicula ostii</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	62, 63	2	66	Western Cape	Knysna	K. 179	214/4261-2
<i>Navicula paeninsulae</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	63, 64	2	67	Western Cape	Steenbras	K. 263	220/4385-6
<i>Navicula salebrosa</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	64	2	71	Western Cape	Steenbras	K. 263	220/4385-6
<i>Navicula salinaroides</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	64, 65	2	72, 73	Western Cape	Steenbras, Rooi Els	K. 263	220/4385-6
<i>Navicula sobria</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	65, 66	2	76	Western Cape	Rooi Els	K. 265	220/4389-90

<i>Navicula stompsii</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	66, 67	2	77, 78	Western Cape	Knysna	K. 179	214/4261-2
<i>Navicula struggeri</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	67	2	79, 80	Western Cape	Knysna	K. 179	214/4261-2
<i>Navicula subcingulata</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	67,68	2	81	Western Cape	Rooi Els	K. 265	220/4389-90
<i>Navicula subtilyra</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	68	2	82	Western Cape	Steenbras	K. 263	220/4385-6
<i>Navicula superciliaris</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	68, 69	2	83	Western Cape	Steenbras	K. 263	220/4385-6
<i>Navicula valens</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	69, 71	2	84	Western Cape	Steenbras	K. 263	220/4385-6
<i>Nitzschia knysnensis</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	73	2	92	Western Cape	Knysna	K. 179	214/4261-2
<i>Nitzschia lesbia</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	73, 74	2	93	Western Cape	Knysna	K. 179	214/4261-2
<i>Nitzschia miserabilis</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	74	2	95	Western Cape	Steenbras	K. 263	220/4385-6
<i>Nitzschia morosa</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	74, 75	2	96	Western Cape	Knysna	K. 179	214/4261-2
<i>Nitzschia stompsii</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	75, 76	2	100-102	Western Cape	Knysna, steenbras	K. 179	214/4261-2
<i>Stauroneis indistincta</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	77, 78	3	109, 110	Western Cape	Knysna	K. 179	214/4261-2
<i>Stauroneis pseudothermicola</i>	Beitrage zur Kenntnis des marinen Litorals von Sudafrica	1962	78	3	111	Western Cape	Steenbras	K. 263	220/4385-6
<i>Amphora catharinaria</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrica)	1968	17, 18	1	16	Kwazulu-Natal	SL 39	SL 39	174/3475
<i>Amphora piper</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrica)	1968	20	1	19	Kwazulu-Natal	SL 38	SL 38	174/3474
<i>Amphora richardiana</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrica)	1968	21, 22	1	21	Kwazulu-Natal	SL 21	SL 21	173/3457

<i>Cocconeis carminata</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	25, 26	1	23-25	Kwazulu-Natal	SL 60	SL 60	175/3496
<i>Dimerogramma luciae</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	30, 31	1	28, 29	Kwazulu-Natal	SL 48	SL 48	175/3484
<i>Fragilaria luciae</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	34, 35	1	31	Kwazulu-Natal	SL 38	SL 38	174/3474
<i>Gomphonema oceanicum</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	36, 37	1	35, 36	Kwazulu-Natal	SL 38	SL 38	174/3474
<i>Gyrosigma lucianum</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	39	2	37	Kwazulu-Natal	SL 55	SL 55	175/3491
<i>Mastogloia manguinii</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	41, 42	2	43, 44	Kwazulu-Natal	SL 34	SL 34	174/3470
<i>Navicula chloridorum</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	46	2	56, 57	Kwazulu-Natal	SL 21	SL 21	173/3457
<i>Navicula disertoides</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	49, 50	2	64, 65	Kwazulu-Natal	SL 38	SL 38	174/3474
<i>Navicula impangenica</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	52, 53	2	72	Kwazulu-Natal	SL 22	SL 22	173/3458
<i>Navicula inquisitor</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	53, 54	2	73	Kwazulu-Natal	SL 50	SL 50	175/3486
<i>Navicula normaloides</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	55, 56	2, 3	76-86	Kwazulu-Natal	SL 58	SL 58	175/3494
<i>Navicula persignata</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	57	3	87	Kwazulu-Natal	SL 56	SL 56	175/3492
<i>Navicula poseidon</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	57, 58	3	88	Kwazulu-Natal	SL 38	SL 38	174/3474
<i>Navicula reservata</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	59, 60	3	93	Kwazulu-Natal	SL 24	SL 24	173/3460
<i>Navicula soluta</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	61, 62	3	94	Kwazulu-Natal	SL 22	SL 22	173/3458
<i>Navicula staminea</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	62	3	95	Kwazulu-Natal	SL 38	SL 38	174/3474

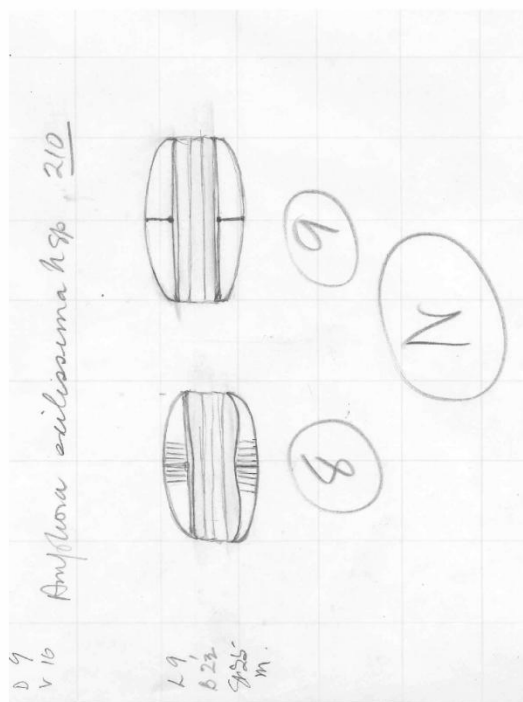
<i>Navicula taedens</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	63, 64	3	99	Kwazulu-Natal	SL 23	SL 23	173/3459
<i>Navicula umpatica</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	65	3	102	Kwazulu-Natal	SL 36	SL 36	174/3472
<i>Nitzschia admissoides</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	66	3	103-106	Kwazulu-Natal	SL 31	SL 31	174/3467
<i>Nitzschia buceros</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	68, 69	3	116	Kwazulu-Natal	SL 48	SL 48	175/3484
<i>Nitzschia condemnata</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	69, 70	3	117	Kwazulu-Natal	SL 23	SL 23	173/3459
<i>Nitzschia forfica</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	71	4	124, 125	Kwazulu-Natal	SL 53	SL 53	175/3489
<i>Nitzschia fundi</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	72	4	127-130	Kwazulu-Natal	SL 21	SL 21	173/3457
<i>Nitzschia lacessens</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	74	4	140	Kwazulu-Natal	SL 34	SL 34	174/3470
<i>Nitzschia manguinii</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	76	4	142	Kwazulu-Natal	SL 20	SL 20	173/3456
<i>Nitzschia ruda</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	79	4	144-146	Kwazulu-Natal	SL 21	SL 21	173/3457
<i>Nitzschia serpenticula</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	79, 80	4	148	Kwazulu-Natal	SL36	SL 36	174/3472
<i>Nitzschia subsalsa</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	80, 81	4	150	Kwazulu-Natal	SL39	SL 39	174/3475
<i>Nitzschia valga</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	81, 82	4	151-153	Kwazulu-Natal	SL 57	SL 57	175/3493
<i>Nitzschia zuzulandica</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	82	4	154	Kwazulu-Natal	SL 34	SL 34	174/3470
<i>Rhaphoneis luciana</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	85, 86	4	156-158	Kwazulu-Natal	SL 38	SL 38	174/3474
<i>Stauroneis concapta</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	87	4	159, 160	Kwazulu-Natal	SL 21	SL 21	173/3457

<i>Stauroneis lacunae</i>	Die diatomeenassoziationen der Santa-Lucia-lagune in Natal (Sudafrika)	1968	88	4	162	Kwazulu- Natal	SL 38	SL 38	174/3474
---------------------------	---	------	----	---	-----	-------------------	-------	-------	----------

Appendix C - Original pencil drawings by M. H. Giffen of the new diatom species at Kidd's Beach

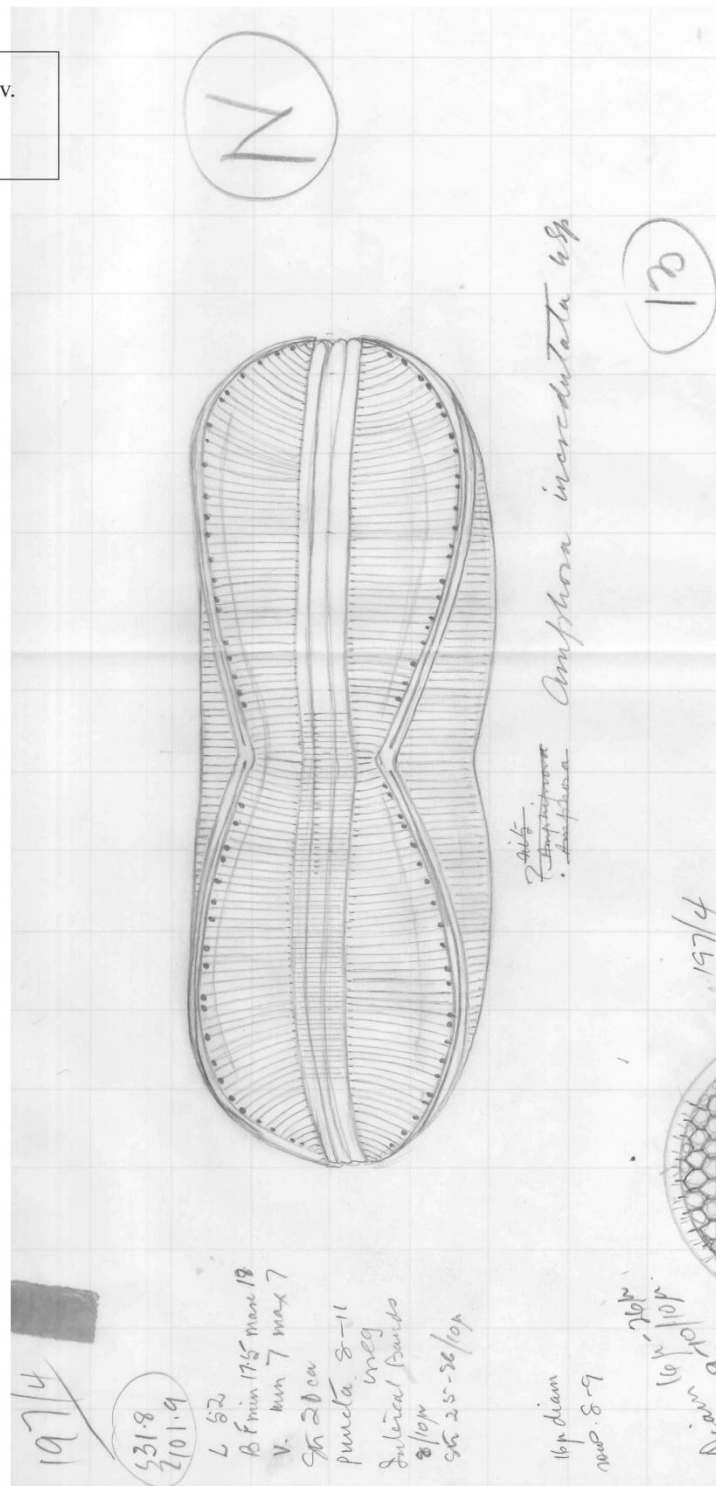
Amphora exilissima sp. nov.

Slide: 210



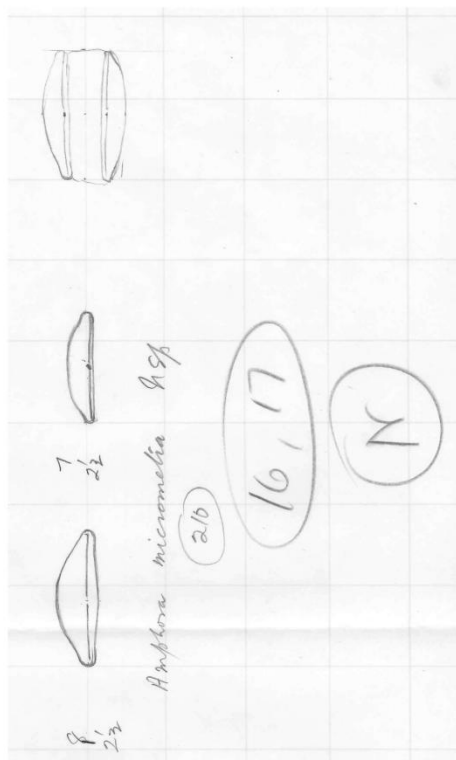
Amphora incredulata sp. nov.

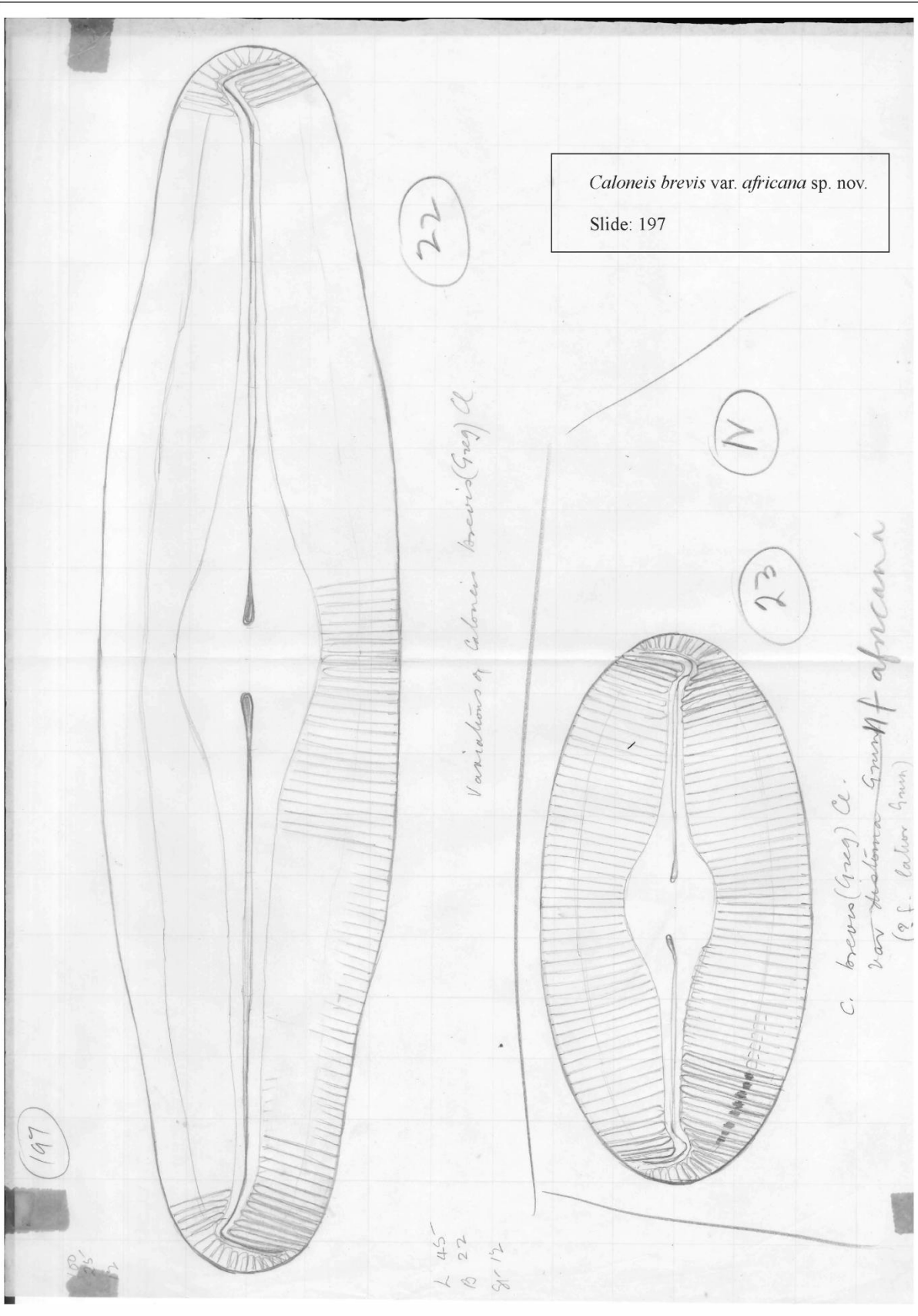
Slide: 197/4

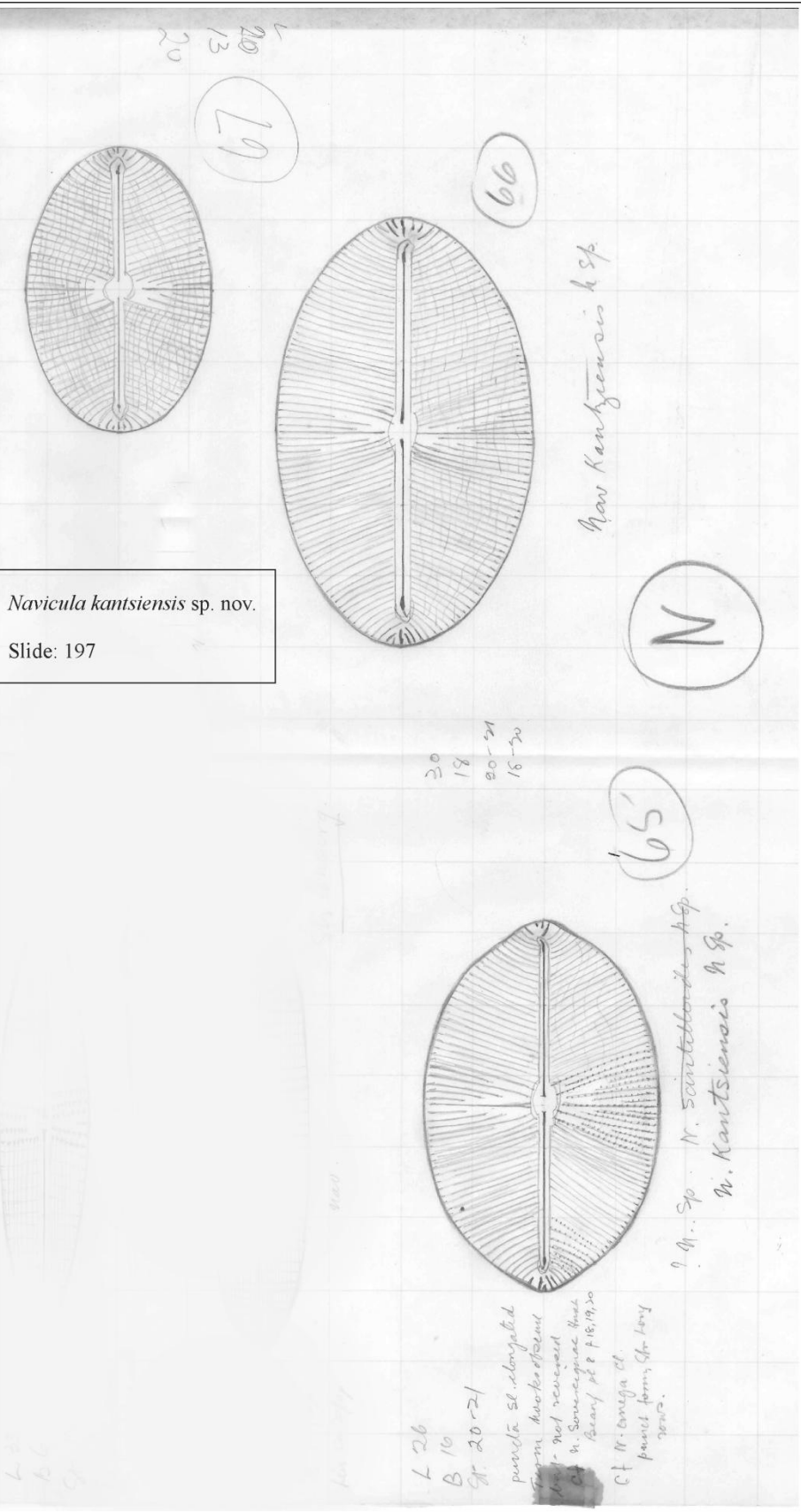


Amphora micrometra sp. nov.

Slide: 210







Navicula kantsiensis sp. nov.
Slide: 197

Slide: 510



Slide: 510

L 30
B 8
Cp 12-13

56 5 Q12

36
16
CP 17-18

Keel eccentric

Anth. crocea Ksp

hibiscus erosa 9/5

related to *N. phidmoides* Guen. & *N. phidmoides* Guen.
Hutch Bee p 407 f 779 / beam #5 p 15 f 16
diff. in number of abdominal & No. of setae on abdominal

2

87

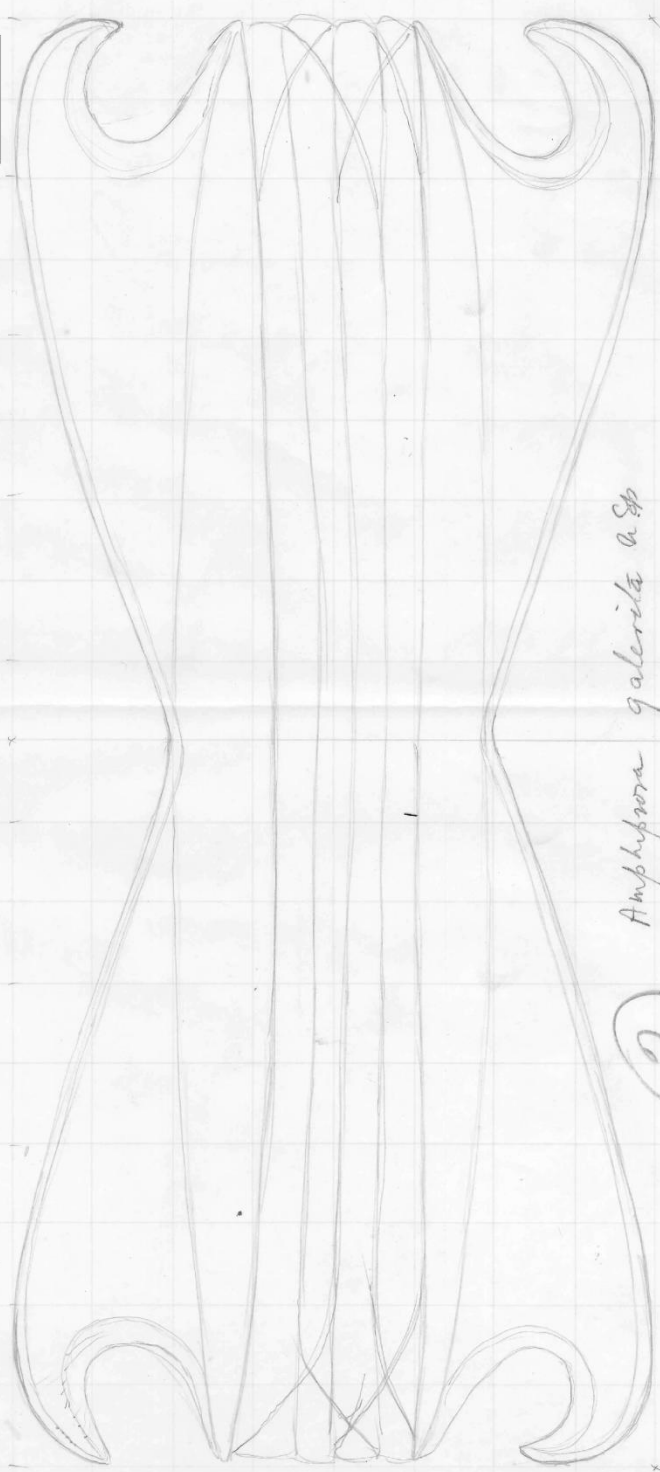
85

197

LSB
 B 14.5 max 6 min
 35 25-29/10p. ✓ V.1 wing
 40 B max Sinus 8p
 22 B min
 intercal bands 4/10p.

L	B	W.	V.
88	14, 6, 6	25	25
74	16, 8, 8	25	25
75	15, 9	25	25
53	14, 6, 8	25	25

Amphiprora galerita sp. nov.
 Slide: 197

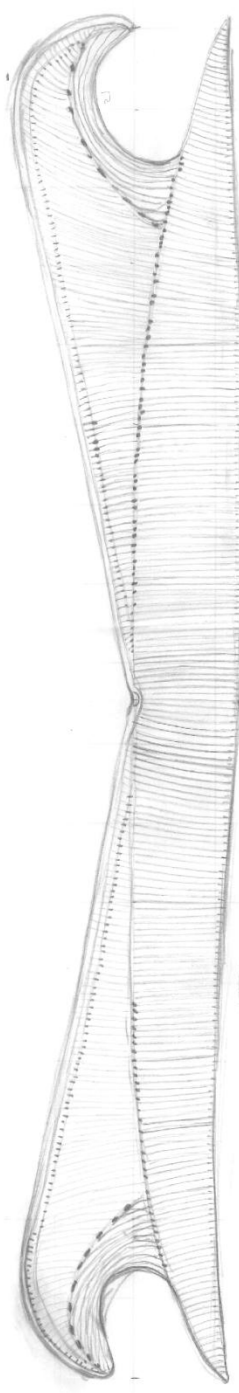


Amphiprora galerita a. sp.

(2)

197

197/4
 321.4
 194.5
 L 83/4
 B 14 1/2
 6.5 1/4
 ST 25-
 W 40



Amphiprora galerita n. sp.

510/5-
~~501/5~~
 599.5
 244.9

L 75 1/2
 B wings 15 1/2
 min 9 1/2
 Pocket 9 1/2
 ST 15/6
 25 in 10 1/2

See also
 210

210/5- { 39.3
 102.7

fragm of end.

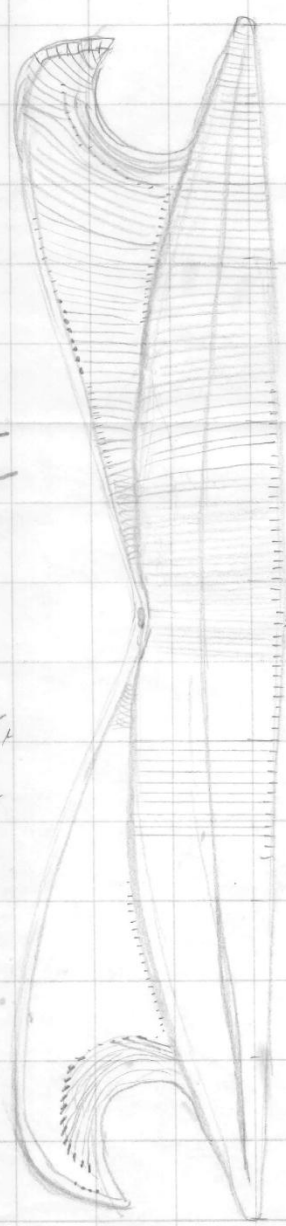
210/6 { 33.5
 105.0

fragm of end.

197

Amphiprora galerita sp. nov.

Slide: 197



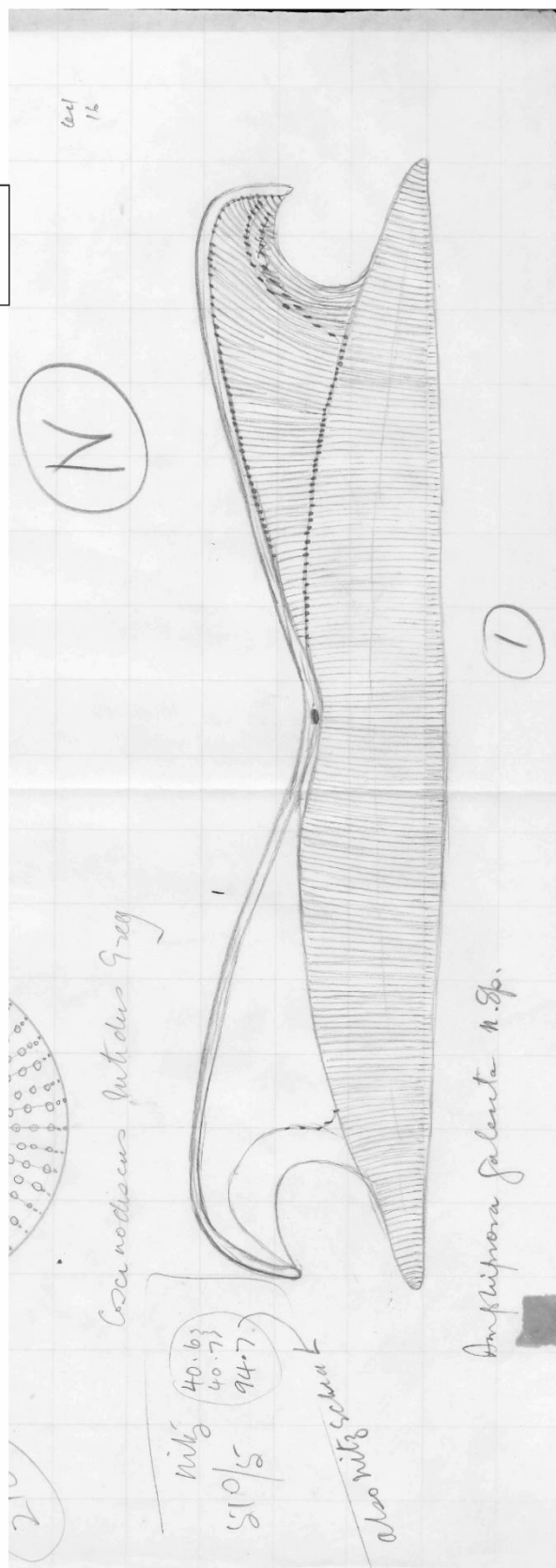
Amphiprora galerita n. sp.

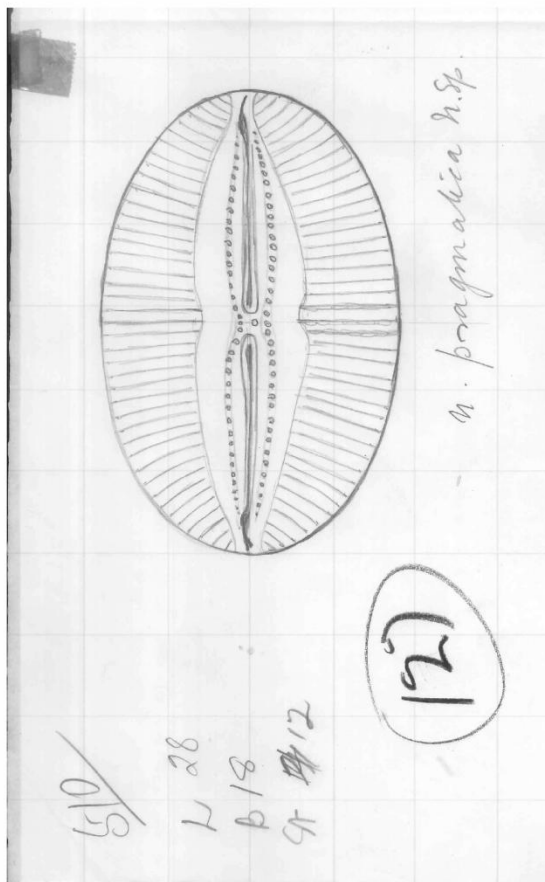
Slide 197
 151
 152
 153

another spec. L 83
 B 14 more 6.5 mm
 ST wings 20 valve 25-

Amphiprora galerita sp. nov.

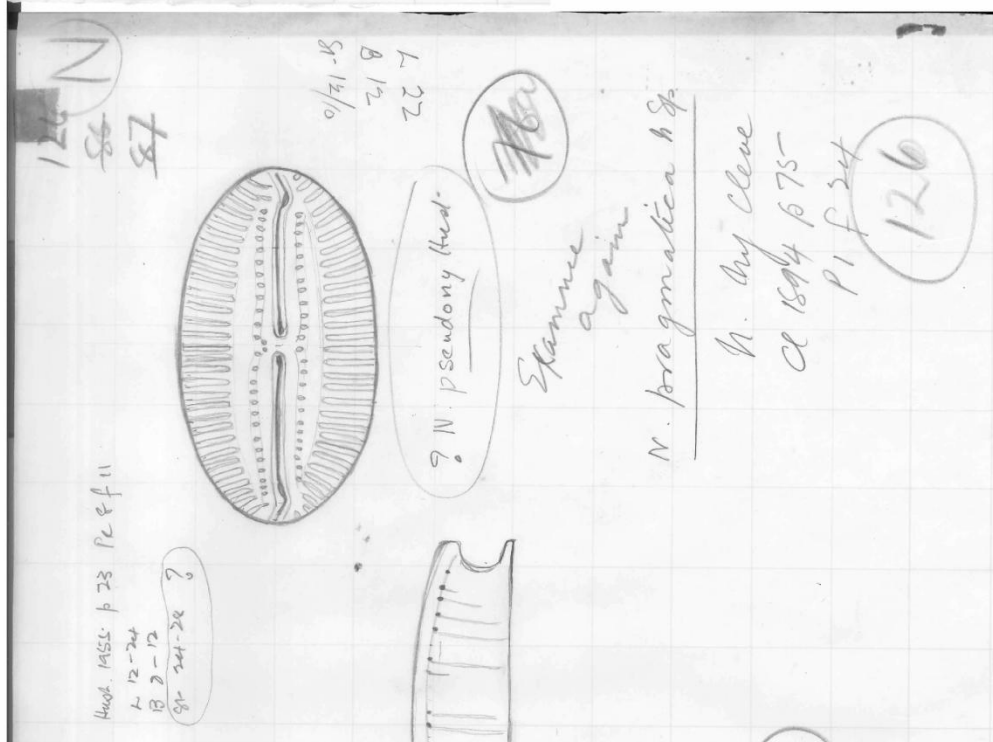
Slide: 210/5





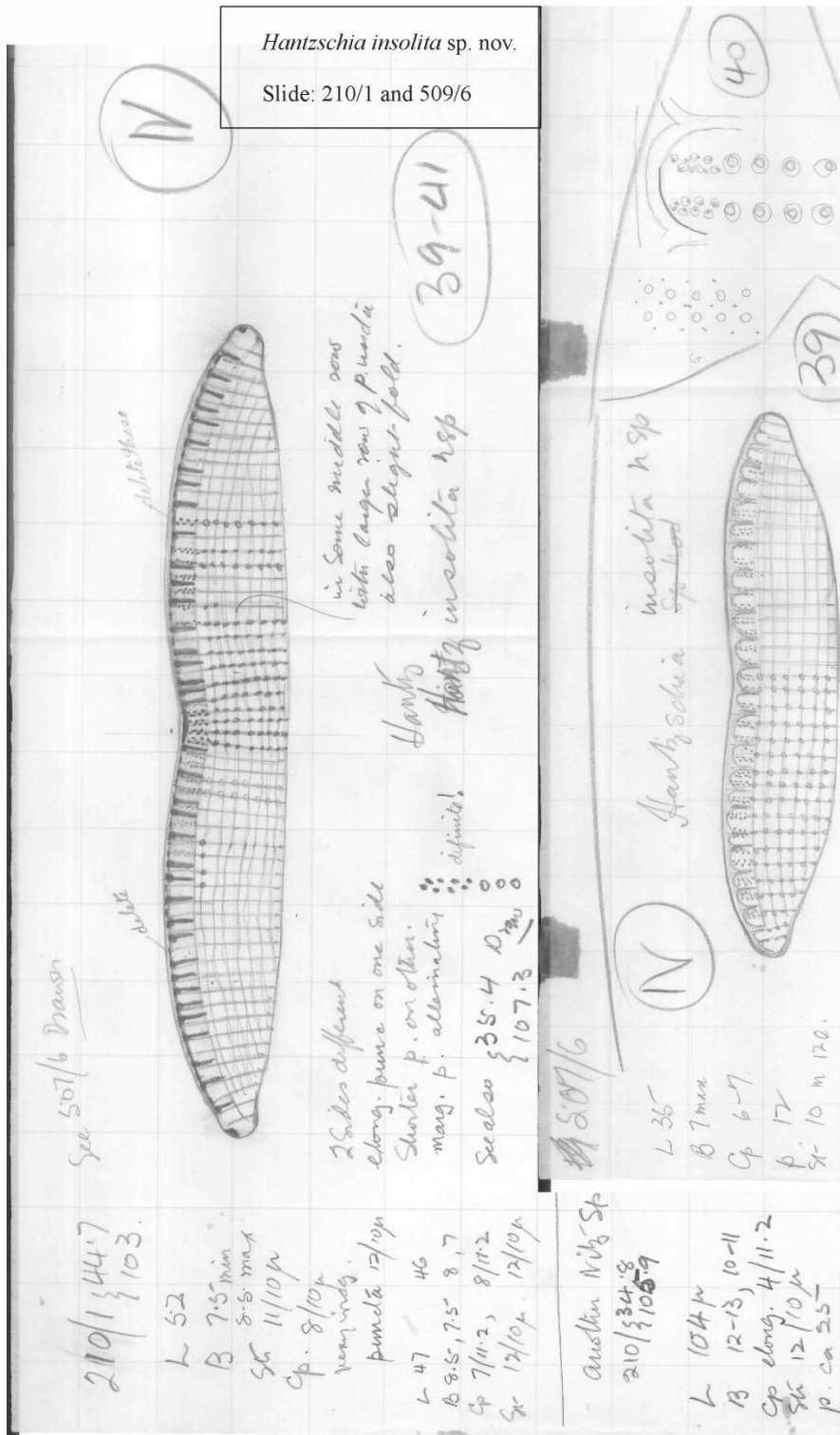
Navicula pragmatica sp. nov.

Slide: 510



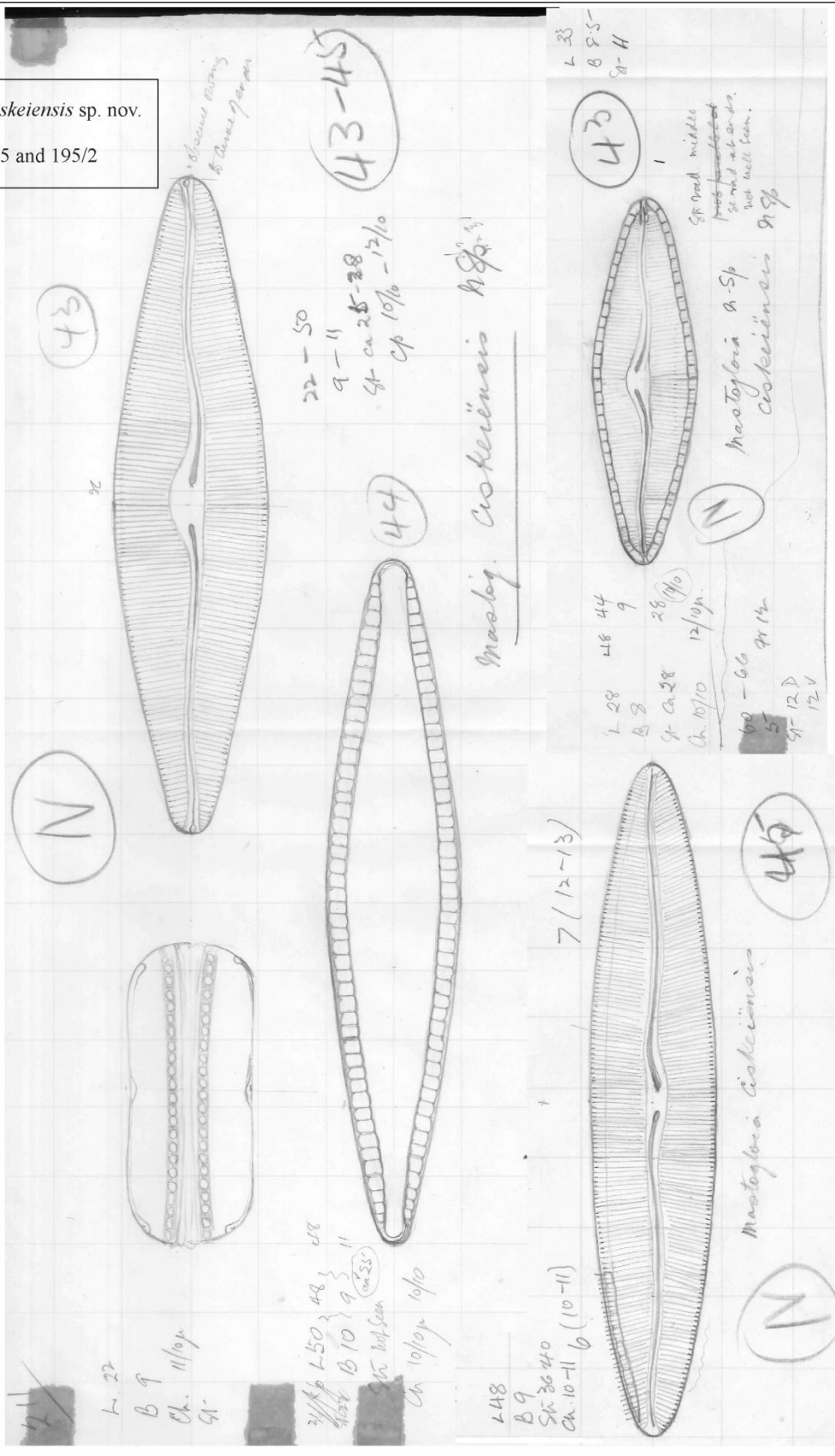
Hantzschia insolita sp. nov.

Slide: 210/1 and 509/6



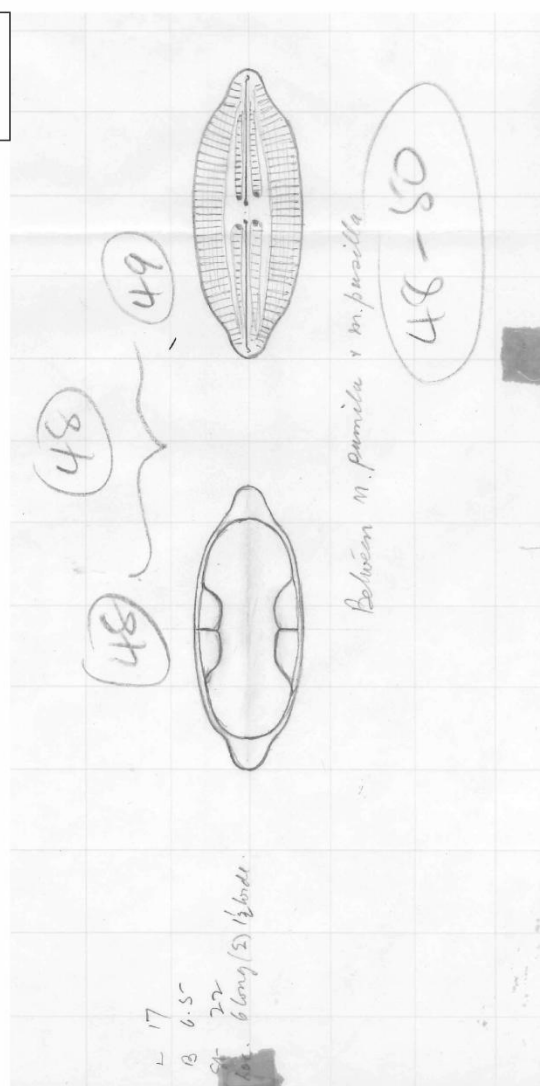
Mastogloia ciskeiensis sp. nov.

Slide: 211, 165 and 195/2



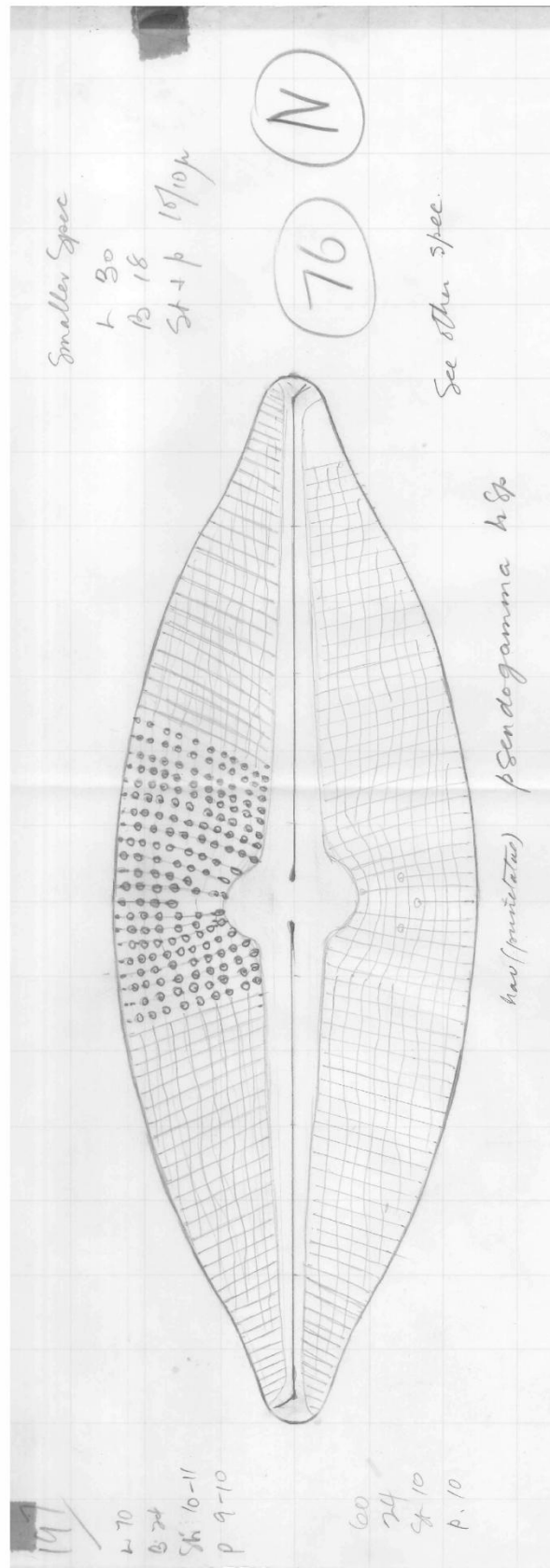
Mastogloia pumila f. nov. *africana*

Slide: 211



Navicula pseudogamma sp. nov.

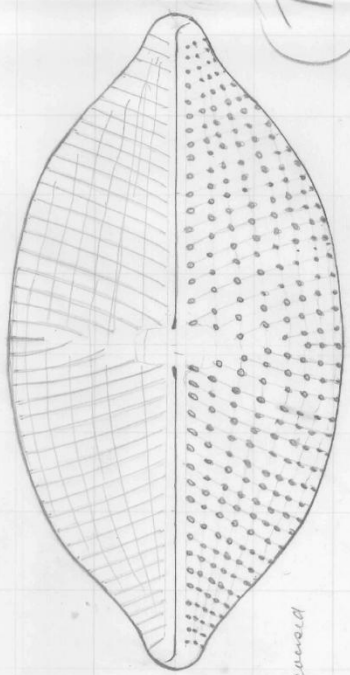
Slide: 197



97

L 41
B 21
St 8-9
p 6-7

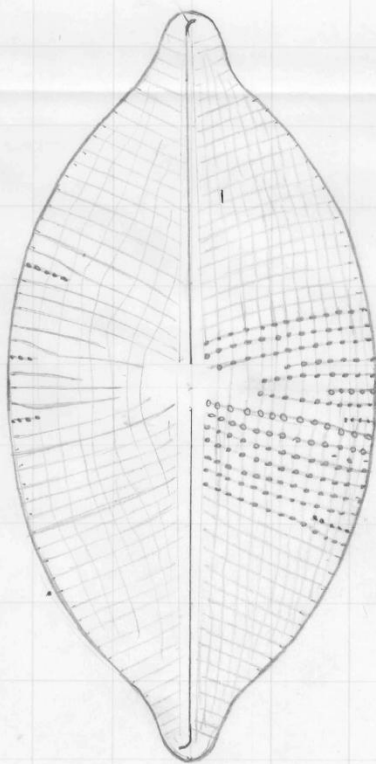
Term bio. & rearsid



77

Nav. pseudogamma sp. nov.

L 47
B 23
St 10
p. 12



Nav. gamma cl.

N. pseudogamma sp. nov.

N

cl.
36
14
13-13
14

R 41-47
B 21-23
St 8-10
p. 6-12

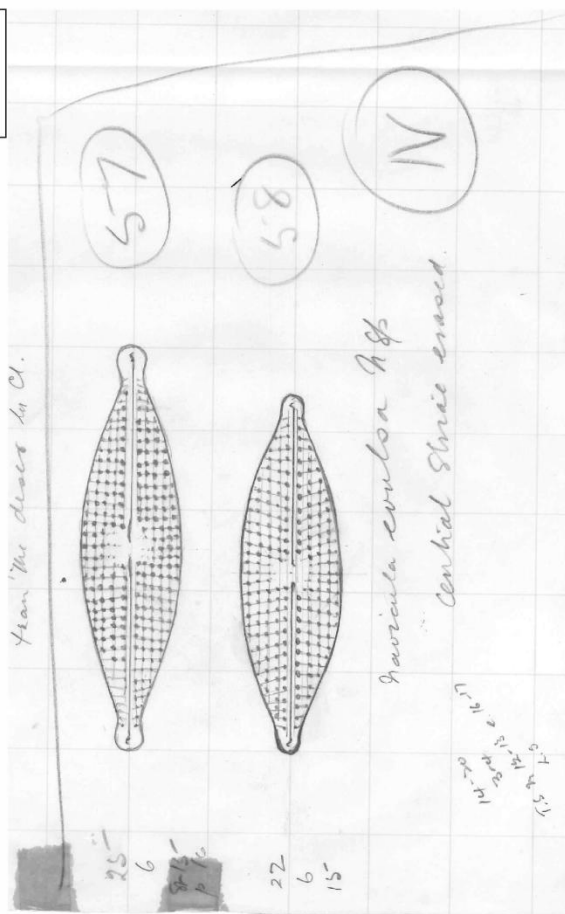
rearsid term
hooks.

Variations of N. gamma
cl. 1896 p 44
Giffen

Navicula pseudogamma sp. nov.
Slide: 197

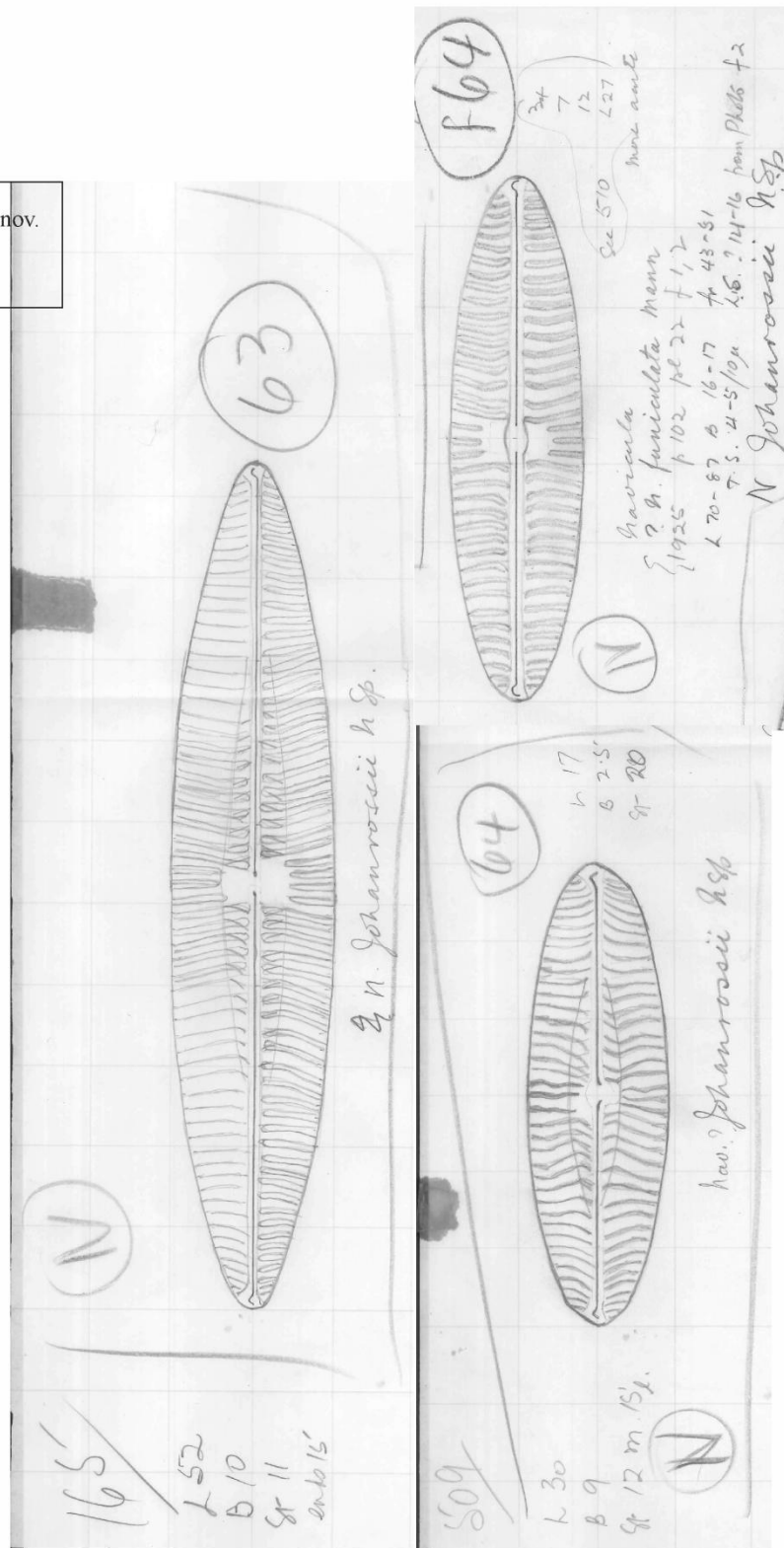
Navicula evulsa sp. nov.

Slide: 518



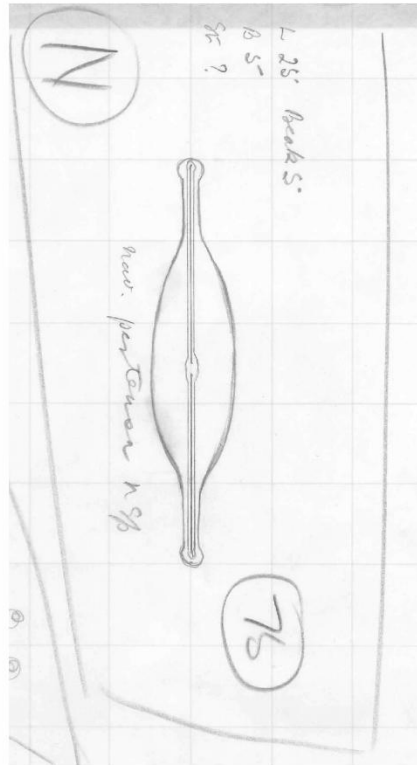
Navicula johanrossii sp. nov.

Slide: 165 and 509



Navicula pertensa sp. nov.

Slide: 509/6

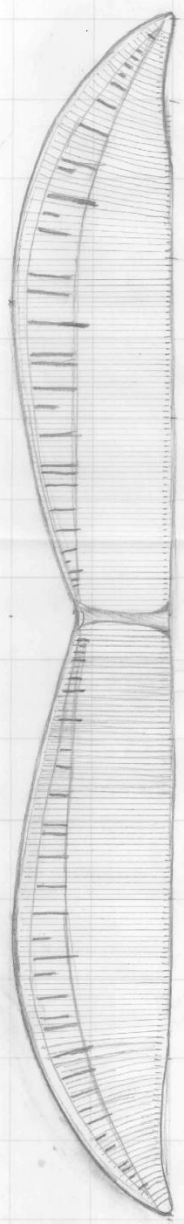


44

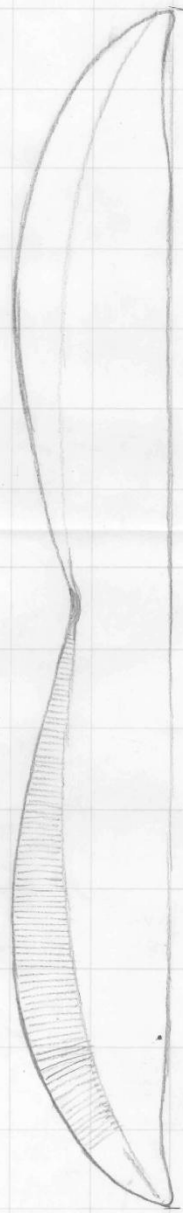
Nitzschia staurophora sp. nov.
Slide: 210/4

N

96



Nitzschia ? sp. (*N. staurophora* h.s.)



staurophora

Type
210/x (R 31), (L 34)

210/4
L 75
B 100
max 9
sp 27-28
cp. 6-7

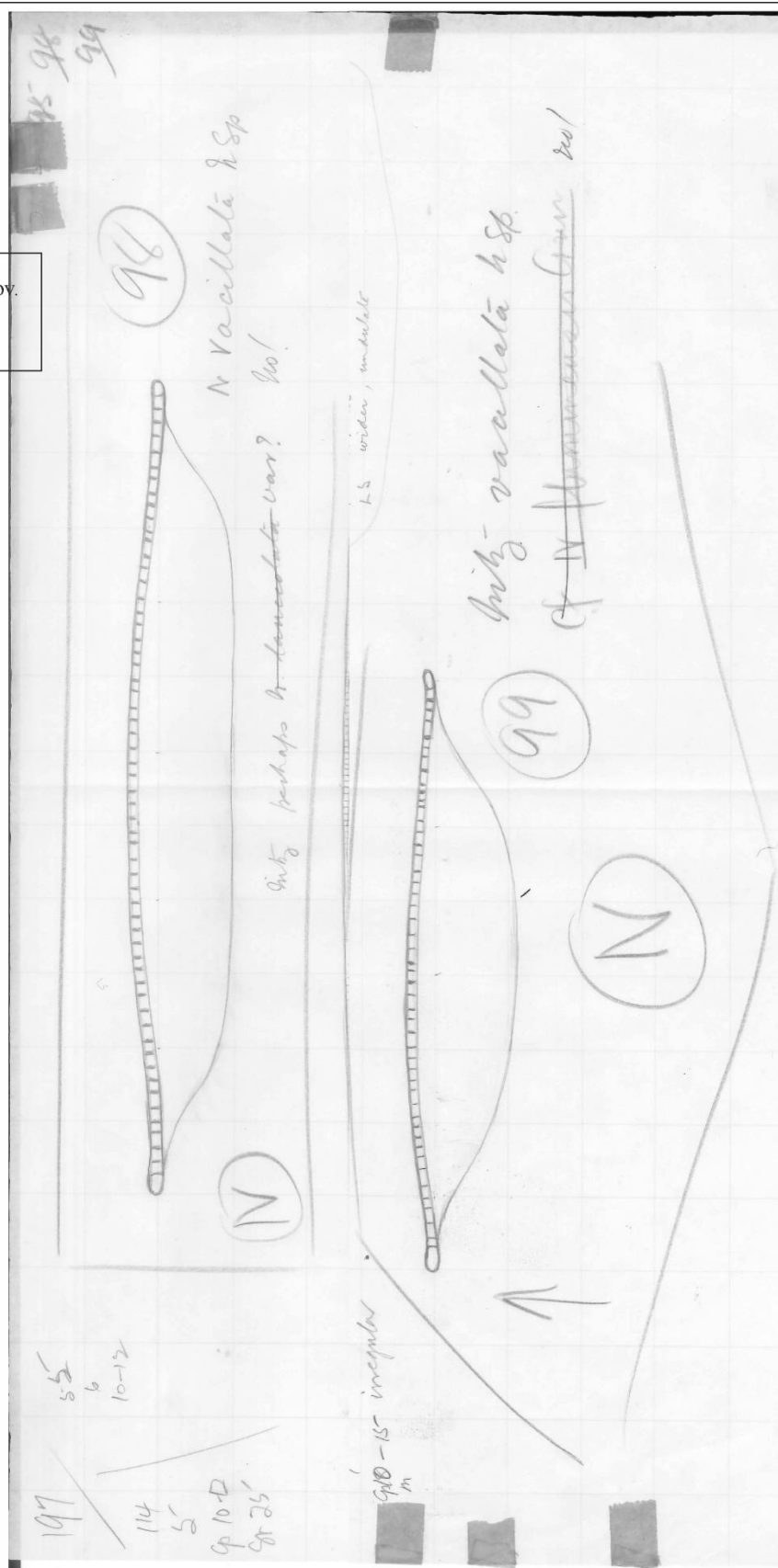
L 24

as above
210/5
36
1103.2

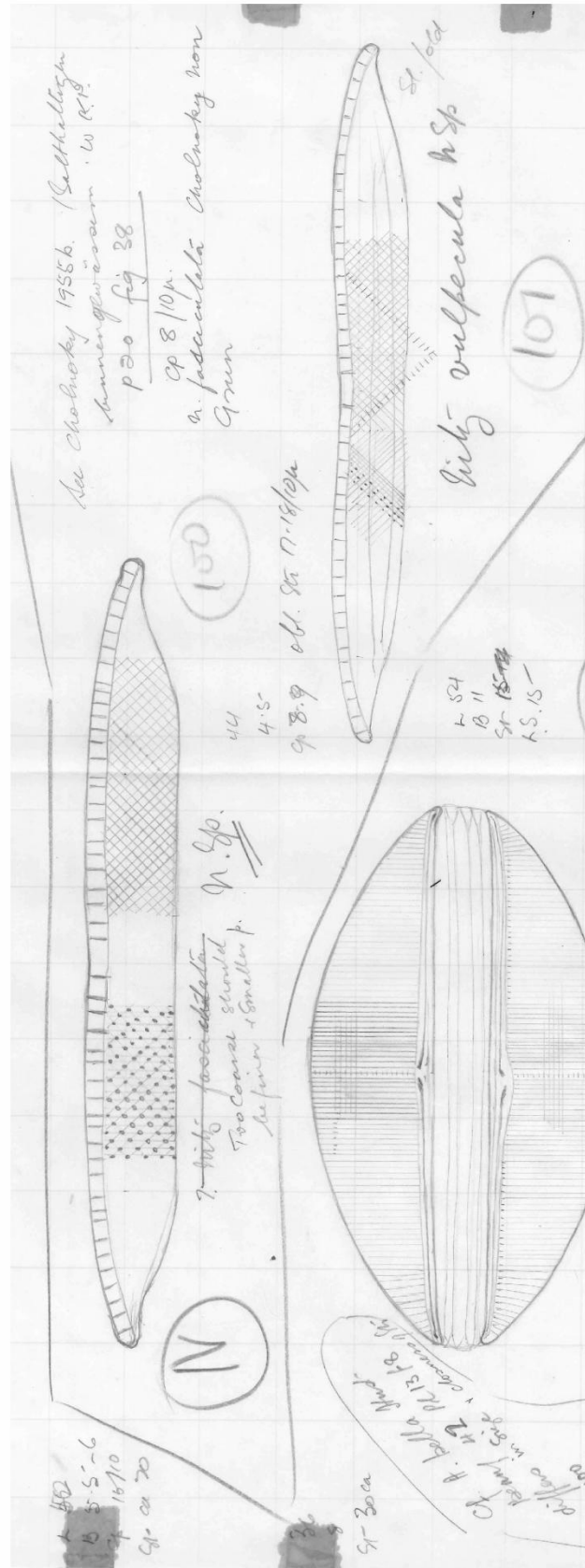
also
510/5 L sb
B 8-9
cp 10 ~~very~~ varying
94.7
94.7
94.25

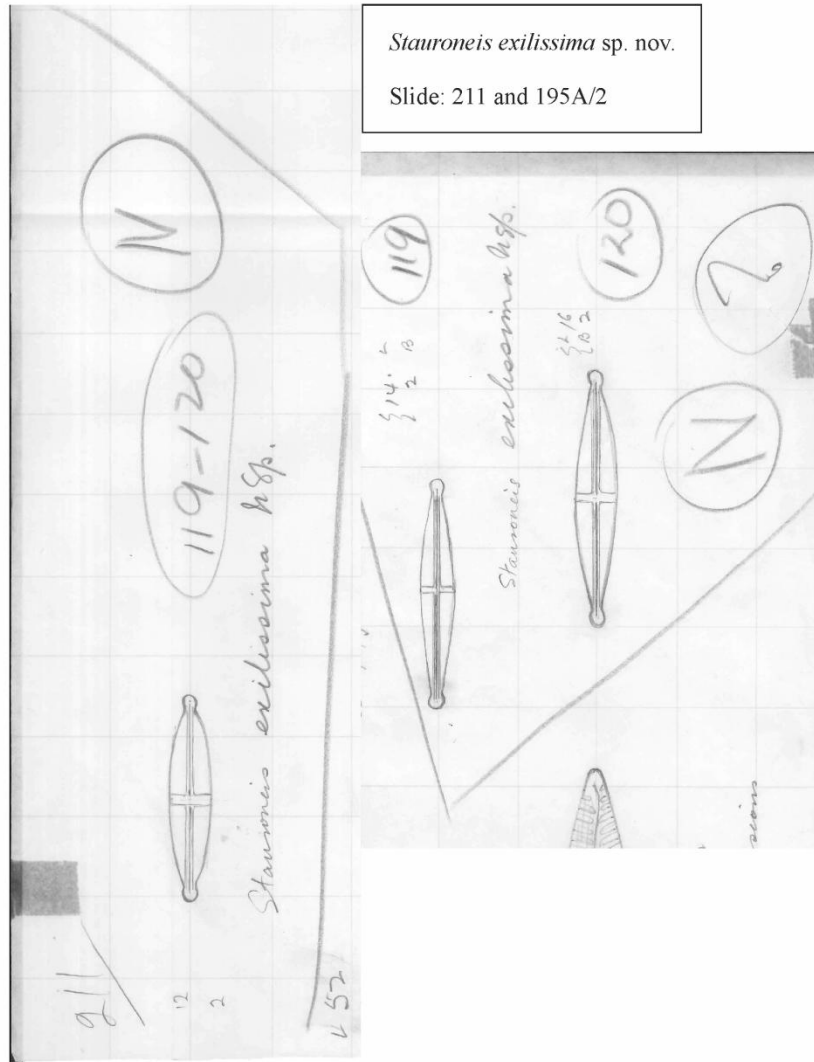
Nitzschia vacillata sp. nov.

Slide: 197



Slide: 210



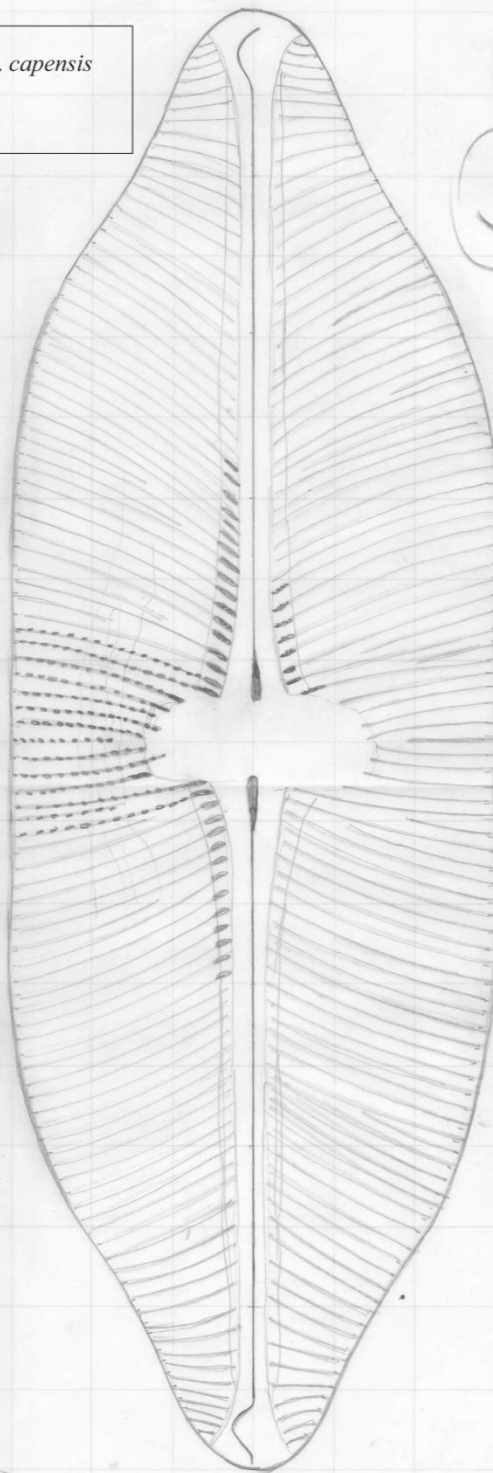


Stauroneis exilissima sp. nov.

Slide: 211 and 195A/2

Navicula humerosa f. nov. *capensis*

Slide: 197



60

IV

Nav. humerosa Det. ? v. fuchsi
nf *capensis*

107

L93

B31

8.10-11/10/10

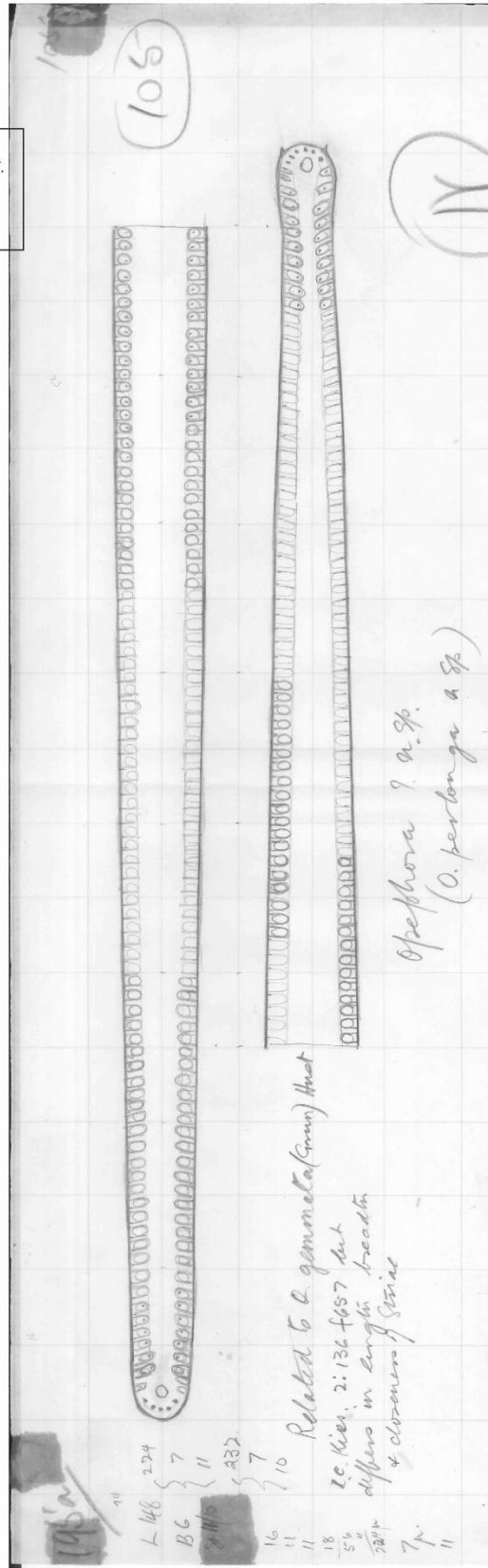
p. 14/10/10

[illegible]

Slide: 165, 165/4 and 197

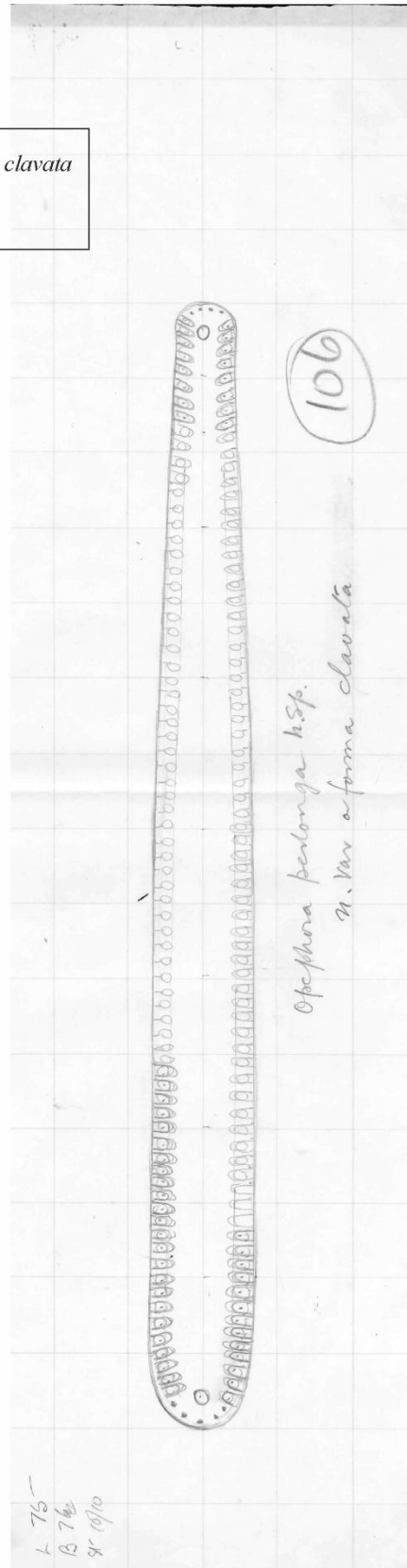
Opephora perlonga sp. nov.

Slide: 195 'a



Opephora perlonga sp. nov. var. nov. *clavata*

Slide: 195 'a



Appendix D – Relative abundance of taxa in counted samples

Species	Codes	Samples																							
		165_G	195_G	197_G	210_G	211_G	509_G	510_G	518_G	165_18	195_18	197_18	210_18	211_18	509r_18	510_18	518_18	165_19	195_19	197_19	210_19	211_19	510_19	518_19	
<i>Achnanthes brevipes</i>	Acbr	0.96			7.19		0.74								21.29			0.50		0.50	22.58	1.49	0.24	0.24	
<i>Achnanthes cuneata</i>	Accu																				1.99				
<i>Achnanthes grana</i>	Acgr					0.25																			
<i>Achnanthes linearis</i>	Acli										0.50														
<i>Achnanthes lutheri</i>	Aclu		0.25																						
<i>Achnanthes pinnata</i>	Acpi																		1.00						
<i>Achnanthes</i> sp. 1	Acsp1		7.94																						
<i>Achnanthes</i> sp. 3	Acsp3						3.21																		
<i>Achnanthes</i> sp. 5	Acsp5																0.74								
<i>Achnanthes</i> sp3	Achsp3																				0.25				
<i>Achnanthes</i> sp4	Achsp4																				0.74				
<i>Achnanthes</i> sp6	Achsp6						0.49																		
<i>Achnanthes suchlandtii</i>	Acsu																			0.50					
<i>Achnanthidium biasolettianum</i>	Acbi										0.50														
<i>Achnanthidium crassum</i>	Accr																				0.99				
<i>Achnanthidium minutissimum</i>	Acmi											0.50									2.73			5.87	
<i>Actinoptychus</i> sp1	Actsp1																		0.50						
<i>Amphiprora gigantea</i> var. <i>tahitiensis</i>	Amgita										0.50														
<i>Amphiprora perplexa</i>	Ampper																3.22								
<i>Amphora</i> sp18	Amphsp18				0.24															0.50			2.69		
<i>Amphora castellata</i>	Amca			13.84				1.75							2.72			0.25							
<i>Amphora decussata</i>	Amde													17.66		1.49									
<i>Amphora exilissima</i>	Amex		1.24		17.99	0.25	0.74		1.00					0.25		0.25	2.48								
<i>Amphora helenensis</i>	Amhe	1.45				0.25			0.50														0.24		
<i>Amphora incredulata</i>	Amin																								
<i>Amphora kolbei</i>	Amko																		0.50						
<i>Amphora lineolata</i>	Amlt												0.25												
<i>Amphora micrometra</i>	Ammi							1.00																	
<i>Amphora pediculus</i>	Amped				23.26					0.74			0.75												
<i>Amphora</i> sp1	Amphsp1		0.25																			0.50	0.49		
<i>Amphora</i> sp10	Amphsp10										0.74														
<i>Amphora</i> sp11	Amphsp11					0.99						2.50					0.99	0.25							
<i>Amphora</i> sp12	Amphsp12								0.50																
<i>Amphora</i> sp13	Amphsp13																21.78							0.98	
<i>Amphora</i> sp14	Amphsp14											0.50				0.50								0.49	
<i>Amphora</i> sp15	Amphsp15											0.50													
<i>Amphora</i> sp16	Amphsp16											0.50													
<i>Amphora</i> sp17	Amphsp17							1.00	2.25							6.20									
<i>Amphora</i> sp19	Amphsp19													0.25											
<i>Amphora</i> sp2	Amphsp2									1.48					2.97									1.47	
<i>Amphora</i> sp20	Amphsp20														1.24										
<i>Amphora</i> sp21	Amphsp21															0.50									
<i>Amphora</i> sp22	Amphsp22																2.97						0.49		
<i>Amphora</i> sp24	Amphsp24											2.49						0.25					0.24		
<i>Amphora</i> sp25	Amphsp25			0.24											0.25			0.25					0.24		
<i>Amphora</i> sp26	Amphsp26							2.74															0.24		
<i>Amphora</i> sp27	Amphsp27					0.25																			
<i>Amphora</i> sp28	Amphsp28					0.25																			
<i>Amphora</i> sp29	Amphsp29						0.99	1.00					1.24										0.24		
<i>Amphora</i> sp3	Amphsp3	0.48													4.95										
<i>Amphora</i> sp31	Amphsp31													1.49						1.00			0.49		
<i>Amphora</i> sp32	Amphsp32													0.25											
<i>Amphora</i> sp33	Amphsp33						0.25	1.25						1.00			0.99		0.50				0.49		

<i>Caloneis africana</i>	Caaf								4.00														
<i>Campylodiscus</i> sp1	Campylodsp1																	0.50					
<i>Campyloneis</i> sp1	Campylonsp1					0.25				0.25	0.25							0.25	1.50		0.25		
<i>Campyloneis</i> sp2	Campsp2																	0.25					
<i>Campyloneis</i> sp3	Campsp3																		1.00				
<i>Cocconeis borbonica</i>	Cobo												1.49										
<i>Cocconeis convexa</i>	Coco				0.48		0.74				41.48	8.00	24.13	16.92		7.69			1.00	4.00	0.99		
<i>Cocconeis dirupta</i>	Coedir						0.99																
<i>Cocconeis discrepans</i>	Cocedisc											1.00											
<i>Cocconeis distantula</i>	Cocedist	0.48																					
<i>Cocconeis guttata</i>	Cogu				1.20					0.25	2.96	2.50											
<i>Cocconeis neothumensis</i>	Cone					0.74										0.74							
<i>Cocconeis pediculus</i>	Cope					0.99																	
<i>Cocconeis placentula</i>	Copl	1.69				0.25	0.74			1.97			1.49				2.72	0.75	0.50				
<i>Cocconeis placentula</i> var. <i>klinorahis</i>	Coplkl	21.20																					
<i>Cocconeis placentula</i> var. <i>lineata</i>	Coplli																0.25			0.50	0.25		
<i>Cocconeis pseudomarginata</i>	Cops									9.11								0.75					
<i>Cocconeis scutellum</i>	Cosc					7.41	0.75						0.25					0.25	6.50	0.50			
<i>Cocconeis scutellum</i> var. <i>coronatoides</i>	Coscco											1.98											
<i>Cocconeis scutellum</i> var. <i>sutellum</i>	Coscsu											0.25											
<i>Cocconeis</i> sp1	Coccspl	0.48							0.25												0.25		
<i>Cocconeis</i> sp10	Coccspl10					2.16	0.49									2.48							
<i>Cocconeis</i> sp11	Coccspl11				3.12																0.99		0.24
<i>Cocconeis</i> sp12	Coccspl12																0.50	0.25					
<i>Cocconeis</i> sp13	Coccspl13						0.49												3.00	2.50			0.24
<i>Cocconeis</i> sp14	Coccspl14						0.74																
<i>Cocconeis</i> sp15	Coccspl15						0.49																
<i>Cocconeis</i> sp16	Coccspl16						0.25																
<i>Cocconeis</i> sp17	Coccspl17						0.99							0.75					0.50	0.50	0.50		0.24
<i>Cocconeis</i> sp18	Coccspl18						0.99																
<i>Cocconeis</i> sp19	Coccspl19							0.25															
<i>Cocconeis</i> sp2	Coccspl2	0.96																					
<i>Cocconeis</i> sp22	Coccspl22																					0.25	
<i>Cocconeis</i> sp23	Coccspl23																	1.25	0.50	0.50			
<i>Cocconeis</i> sp25	Coccspl25																		0.50	1.00			
<i>Cocconeis</i> sp26	Coccspl26																			15.00			
<i>Cocconeis</i> sp27	Coccspl27																			0.50			
<i>Cocconeis</i> sp28	Coccspl28																	0.25					
<i>Cocconeis</i> sp29	Coccspl29																	0.75					
<i>Cocconeis</i> sp3	Coccspl3									9.36													
<i>Cocconeis</i> sp31	Coccspl31																			1.50			
<i>Cocconeis</i> sp4	Cocsp4			0.99						2.71													
<i>Cocconeis</i> sp5	Cocsp5			0.50		0.24							4.48							0.50	0.25		0.24
<i>Cocconeis</i> sp6	Cocsp6											0.25									0.25		
<i>Cocconeis</i> sp7	Cocsp7											0.49											
<i>Cocconeis</i> sp8	Cocsp8											0.25											
<i>Cocconeis</i> sp9	Cocsp9												0.50										
<i>Cocconeis subtilissima</i>	Cosu																		3.50				
<i>Craticula molestiformis</i>	Crmo				0.48																		
<i>Cyclotella meneghiniana</i>	Cyme																				0.25		
<i>Cymbella aspera</i>	Cyas																		0.50				
<i>Cymbella turgidula</i>	Cytu																				0.74	0.25	
<i>Delphineis livingstonii</i>	Deli											0.50						0.50	8.00				
<i>Delphineis</i> sp2	Delspl2																		0.50				
<i>Delphineis</i> sp3	Delspl3															0.25				1.00			
<i>Diploneis crabro</i>	Dier												0.75										
<i>Diploneis littoralis</i>	Dili							1.00															0.24
<i>Diploneis parca</i>	Dipa																	0.25					
<i>Diploneis</i> sp1	Dipspl1																						0.73

<i>Diploneis</i> sp2	Dipsp2															1.49								
<i>Diploneis</i> sp3	Dipsp3			0.24													0.50							
<i>Diploneis</i> sp4	Dipsp4							0.75												0.50			1.47	
<i>Diploneis</i> sp5	Diplonesp5			0.96														1.50						
<i>Diploneis</i> sp6	Dipsp6																	0.50				0.24	0.24	
<i>Diploneis splendida</i>	Dipsp1										1.00													
<i>Diploneis subovalis</i>	Disu	0.48	2.48					2.25											1.50				0.49	
<i>Diplonies</i> sp5	Diplonisp5																						0.24	
<i>Fallacia</i> sp1	Fasp																		3.00					
<i>Fragilaria capucina</i>	Frca																0.50							
<i>Fragilaria sopotensis</i>	Frso									0.74	6.50	4.98	7.96		12.16									
<i>Fragilaria</i> sp1	Frasp1																0.25							
<i>Fragilaria</i> sp2	Frasp2																	0.50						
<i>Gomphonema parvulum</i>	Gopa										0.50						2.50	1.50	3.50	0.74			0.24	
<i>Gomphonema</i> sp1	Gosp																				0.25			
<i>Gomphonemopsis exigua</i> var. <i>exigua</i>	Goexvaex																				0.74			
<i>Gramatophora</i> sp1	Grsp																0.50	1.50						
<i>Grammatophora angulosa</i> var. <i>islandica</i>	Granis																	0.50	0.50					
<i>Grammatophora hamulifera</i>	Grha				0.25													2.00		1.24		0.49		
<i>Grammatophora oceanica</i>	Groc																	1.50						
<i>Hantzschia</i> sp1	Hasp							0.25																
<i>Hantzschia insolita</i>	Hain					0.50																		
<i>Haslea nautica</i>	Hana														0.25			0.50						
<i>Hippodonta ruthnielseniae</i>	Hiru												1.74											
<i>Lichmorpha</i> sp1	Licsp1							0.25									0.25							
<i>Lichmorpha</i> sp2	Licsp2												0.25											
<i>Lichmorpha</i> sp3	Licsp3			0.48																				
<i>Lichmorpha</i> sp4	Licsp4	1.20																						
<i>Mastogloia harrisonii</i>	Maha												0.25											
<i>Mastogloia pumila</i>	Mapu																				10.67			
<i>Mastogloia pumila</i> f. <i>africana</i>	Mapuaf	0.96				1.75							0.74								1.74			
<i>Mastogloia pusilla</i> var. <i>linearis</i>	Mapuli				9.11																			
<i>Mastogloia</i> sp1	Massp1								0.25															
<i>Mastogloia</i> sp2	Massp2													1.73										
<i>Mastogloia</i> sp3	Massp3													0.25										
<i>Melosira moniliformis</i> var. <i>octogoma</i>	Memooc		21.59																					
<i>Melosira</i> sp1	Mesp																0.25							
<i>Moreis pseudogamma</i>	Mops																		4.00					
<i>Navicula duerrenbergiana</i>	Nadu	1.69			0.25						0.25													
<i>Navicula evulsa</i>	Naev							3.75																
<i>Navicula gieskesii</i>	Nagi																2.50	1.00						
<i>Navicula gregaria</i>	Nagr							1.75																
<i>Navicula humerosa</i>	Nahu							0.50																
<i>Navicula humerosa</i> var. <i>capensis</i>	Nahuca		0.50	0.24																			0.49	
<i>Navicula incertata</i>	Nain				0.25																			
<i>Navicula johanrossii</i>	Najo												0.25											
<i>Navicula kantsiensis</i>	Naka			69.69			0.50							1.98			0.25							
<i>Navicula lucens</i>	Nalu		0.25																					
<i>Navicula minima</i>	Nami										0.25													
<i>Navicula muraliformis</i>	Namu										0.25													
<i>Navicula normaloides</i>	Nano		0.99						19.95		0.50						0.75	5.00		0.25				
<i>Navicula paeninsulae</i>	Napa	4.58																			15.14			
<i>Navicula perlensa</i>	Naviperl						0.25																	
<i>Navicula perminuta</i>	Naviperm		1.49		0.24	0.99			0.50	0.49			0.50	0.25	1.24	7.92	0.50			0.25	4.22		0.49	
<i>Navicula perrhombus</i>	Naviperr					0.99	0.50						0.25				32.75	6.00	2.00	0.74				
<i>Navicula pragmatica</i>	Napr		0.50				0.50	2.50						0.25										
<i>Navicula pseudogamma</i>	Naps			0.48																				
<i>Navicula radiosa</i>	Nara														1.99									
<i>Navicula recens</i>	Nare																	4.50						

Navicula sp1	Navisp1														1.99				10.15	0.50	0.50	0.50	0.74			2.69	9.05
Navicula sp10	Navisp10																		1.73							0.49	
Navicula sp11	Navisp11	0.48			8.35				1.25	1.75									0.25							0.49	
Navicula sp12	Navisp12							0.49													4.50	0.50					
Navicula sp13	Navisp13																							3.72			
Navicula sp14	Navisp14																		0.25							3.67	
Navicula sp15	Navisp15																				0.50						
Navicula sp16	Navisp16																				0.50						
Navicula sp18	Navisp18																				0.50						
Navicula sp19	Navisp19																								3.67		
Navicula sp20	Navsp2																					2.00					
Navicula sp3	Navsp3				0.24																						
Navicula sp4	Navsp4					2.40																			1.49		
Navicula sp5	Navsp5								1.00																		
Navicula sp6	Navsp6																		0.25							1.22	1.22
Navicula sp7	Navsp7																		0.25			0.50					
Navicula sp8	Navsp8																		0.25								
Navicula stachurea	Navsta																						1.00				
Navicula stroemii	Navstr												0.25														
Nitzschia persuadens	Niuper																					0.50					
Nitzschia aequorea	Niae														8.71												
Nitzschia aurariae	Niau													3.98													
Nitzschia bicipitata	Nibi									0.25																	
Nitzschia buceros	Nibu														8.71												
Nitzschia closterium	Niel			1.99																							
Nitzschia confinis	Niteon																										
Nitzschia corpulenta	Nitecor						0.74																				
Nitzschia dissipata	Nitzdiss	0.96														0.50											
Nitzschia distantoides	Nitzdist					0.96					15.27	0.25						0.25			2.50					0.24	
Nitzschia erosa	Nier				0.24				2.00	3.75																	
Nitzschia fonticola	Nitfon								2.00							6.22											
Nitzschia fossilis	Nitfos									1.25																	
Nitzschia frustulum	Nifr	0.96	9.43	0.48	15.11	4.43	3.95	4.24			10.59		5.00	6.22			3.22	7.94		6.00				6.45			
Nitzschia hustediana	Nihu					0.74																					
Nitzschia inconspicua	Nitzinco		0.50		0.96	1.23	2.72					3.70	10.50				2.97		1.24	3.25							
Nitzschia incrustans	Nitziner							0.75						0.25									0.25				0.24
Nitzschia liebetruthii	Nili						5.68										3.22										
Nitzschia ovalis	Niov							1.25										10.17									
Nitzschia perindistincta	Nitzperi													11.94													
Nitzschia persuadens	Nitzpers												2.00					1.24									
Nitzschia pseudohybrida	Nips	0.48																									
Nitzschia ruba	Niru									0.49					1.24	0.25					1.00						
Nitzschia scalpelliformis	Nisc					0.74				0.99												0.50					
Nitzschia sp	Nitsp																									2.20	
Nitzschia sp1	Nitzsp1	0.24									2.71															0.24	
Nitzschia sp10	Nitzsp10												4.00														0.49
Nitzschia sp11	Nitzsp11				1.44										1.24					0.75			0.50				
Nitzschia sp12	Nitzsp12												13.00														
Nitzschia sp13	Nitzsp13												0.50														
Nitzschia sp14	Nitzsp14							5.74					8.00														
Nitzschia sp15	Nitzsp15			0.96																		0.50				0.49	
Nitzschia sp16	Nitzsp16			0.96												0.25											
Nitzschia sp17	Nitzsp17												14.18													0.49	
Nitzschia sp18	Nitzsp18					2.46	1.98													0.25							
Nitzschia sp19	Nitzsp19						25.68																				
Nitzschia sp20	Nitzsp20							1.00																			
Nitzschia sp21	Nitzsp21					4.19																					
Nitzschia sp22	Nitzsp22				0.25					1.00																	
Nitzschia sp23	Nitzsp23						1.73																				1.47

Nitzschia sp25	Nitzsp25						2.96																
Nitzschia sp26	Nitzsp26							1.25															
Nitzschia sp27	Nitzsp27													6.68									
Nitzschia sp28	Nitzsp28													0.74									
Nitzschia sp3	Nitzsp3								0.25														
Nitzschia sp30	Nitzsp30													3.72								1.22	
Nitzschia sp31	Nitzsp31														0.74								
Nitzschia sp32	Nitzsp32							3.49															
Nitzschia sp33	Nitzsp33							0.50															
Nitzschia sp34	Nitzsp34							1.00															
Nitzschia sp35	Nitzsp35																			0.50			
Nitzschia sp36	Nitzsp36																			36.72			
Nitzschia sp37	Nitzsp37																			0.74			
Nitzschia sp38	Nitzsp38																			0.25			
Nitzschia sp39	Nitzsp39																			0.74			
Nitzschia sp4	Nitzsp4				4.43	3.70	1.75									11.00				1.24	1.99	1.47	2.69
Nitzschia sp40	Nitzsp40															0.50					1.99		
Nitzschia sp43	Nitzsp43																					0.24	
Nitzschia sp44	Nitzsp44																					0.49	
Nitzschia sp45	Nitzsp45															0.25		0.50					
Nitzschia sp46	Nitzsp46															1.25							
Nitzschia sp47	Nitzsp47															0.25							
Nitzschia sp48	Nitzsp48																2.00						
Nitzschia sp5	Nitsp5		0.25					3.99													2.73		
Nitzschia sp6	Nitsp6		0.50																				
Nitzschia sp7	Nitsp7		2.98																				
Nitzschia sp8	Nitsp8		1.49																				
Nitzschia sp9	Nitsp9						19.51	0.50			28.89									0.50			
Nitzschia stompisii	Nist									0.74													
Nitzschia umbonata	Nium								1.25													0.49	
Nitzschia vacillata	Nitvac		0.50					11.22															
Nitzschia valdecostata	Nitzsevaldec									0.99							0.50						
Nitzschia valdestriata	Nitzsevaldes											8.21											
Nitzschia vildaryana	Nivi								0.25														
Nitzschia zululandica	Nizu			0.48						11.82	1.23			7.96			0.50						
Opephora horstiana	Opho		1.49		9.59	0.49						0.25					2.00						
Opephora minuta	Opmi												1.24										
Opephora perlonga	Oppe		0.50																				
Opephora sp1	Opesp1										5.43	2.00	2.74			0.99		1.50		4.96		1.96	
Opephora sp2	Opesp2									2.71										0.25			
Opephora sp3	Opesp3										0.49												
Parlibellus sp1	Pasp																				0.25		
Pinnularia cruciformis	Picr													0.50									
Planothidium frequentissimum	Plifr										0.50					0.50			0.50			0.24	
Planothidium sp101	Plasp1																0.74						
Planothidium sp99	Plasp9																0.25						
Pleurosigma carinatum	Plca									0.25									1.00				
Pleurosigma marinum	Plma															0.25							
Pleurosigma sp1	Pleurosigsp1																	0.50				0.49	
Pleurosira sp1	Pleurosirsp1						0.25																
Pseudofallacia sp1	Pseudofsp1															0.50				0.50			
Pseudofallacia sp2	Pseudofsp2																					0.73	
Pseudofallacia sp4	Pseudofsp4																	0.50	3.00				
Pseudofallacia sp5	Pseudofsp5																					0.73	
Pseudofallacia sp6	Pseudofsp6																		0.50				
Pseudostaurosira sp1	Pseudossp1	40.24	0.50														0.50				1.24		
Pseudostaurosira sp2	Pseudossp2									0.25													
Pseudostaurosira sp3	Psesp3	0.96	20.10																				
Pseudostaurosira sp4	Pseudossp4		1.99														0.50				0.99		

<i>Pseudostaurosira</i> sp5	Pseudosp5				6.95	0.49								16.58			0.50	1.00			1.24		
<i>Pseudostaurosira</i> sp6	Pseudosp6						0.25																
<i>Pseudostaurosira</i> sp7	Psep7														0.25								
<i>Rhaphoneis capensis</i>	Rhca									0.25													
<i>Rhopalodia gibberula</i>	Rhgi					2.22																	
<i>Rhopalodia musculus</i> var. <i>suprasemicirculata</i>	Rhmu	0.24				1.48																	
<i>Rhopalodia</i> sp1	Rhosp1	7.47				29.80															22.33		
<i>Rhopalodia</i> sp2	Rhosp2	0.24				1.48																	
<i>Rhopalodia</i> sp3	Rhosp3																				1.49		
<i>Rhopalodia</i> sp4	Rhosp4					5.67				1.50													
<i>Rhopalodia</i> sp5	Rhosp5					0.74																	
<i>Rhopalodia</i> sp6	Rhosp6					0.25																	
<i>Sellaphora parapupula</i>	Sepa																0.25						
<i>Sellaphora seminulum</i>	Sese									0.50									3.00				
<i>Sellaphora</i> sp1	Selsp1									0.50	1.00				0.25		0.25						
<i>Seminavis</i> sp1	Semsp1		1.74															1.00					
<i>Seminavis</i> sp2	Semsp2																	1.00					
<i>Seminavis</i> sp3	Semsp3				0.24					0.25		0.25											
<i>Seminavis</i> sp4	Semsp4							0.50															
<i>Seminavis</i> sp5	Semsp5		0.50																				
<i>Seminavis robusta</i>	Sero									0.25													
sp1	sp1									0.25													
sp10	sp10									1.23													
sp102	sp102													0.99		0.74					6.36	5.62	
sp103	sp103													0.25									
sp104	sp104						0.25																
sp105	sp105						1.00																
sp106	sp106						2.24														1.47		
sp107	sp107							1.50															
sp108	sp108															11.63							
sp109	sp109						0.50																
sp11	sp11		0.25							1.72													
sp11.1	sp11.1										1.00												
sp110	sp110						1.00														0.49		
sp111	sp111						0.25																
sp112	sp112						0.25														0.24	1.71	
sp113	sp113														0.25						1.96		
sp114	sp114														0.25			0.50					
sp115	sp115														0.25								
sp116	sp116															0.50						1.22	
sp117	sp117														0.74								
sp118	sp118														0.25								
sp12	sp12		1.49																				
sp120	sp120														0.25								
sp121	sp121														0.25						0.73		
sp122	sp122							0.25															
sp123	sp123							0.50															
sp124	sp124							0.25															
sp125	sp125															0.50						1.96	
sp126	sp126															0.74		0.50					
sp127	sp127															0.74		0.50					
sp128	sp128															0.50							
sp129	sp129															0.25		0.50					
sp13	sp13		5.21				1.00																
sp130	sp130																					0.49	
sp131	sp131															0.25		0.50					
sp133	sp133															0.25							
sp14	sp14		0.99			0.25		7.73	27.50		0.25			1.49				0.50	1.00			4.65	3.91
sp141	sp141					0.74																	

sp142	sp142																			1.99			
sp143	sp143																0.50						
sp144	sp144																			0.25			
sp145	sp145																	1.00	0.50				
sp146	sp146																			0.25			
sp147	sp147																			0.50			
sp148	sp148																1.25		0.50	1.74			
sp149	sp149																			0.50			
sp15	sp15								3.00														
sp150	sp150																	1.00	0.50	0.25			
sp153	sp153																0.25	0.50	3.00	2.98			
Sp154	Sp																					0.49	
sp155	sp155																					1.22	
sp156	sp156																					1.47	
sp157	sp157																					0.49	
sp158	sp158																	1.00					
sp159	sp159																					1.22	
sp16	sp16		0.50																				3.42
sp160	sp160																					0.24	
sp161	sp161																					0.49	
sp162	sp162																					0.98	
sp163	sp163																					0.24	
sp164	sp164																					0.49	
sp165	sp165																0.50					1.47	0.49
sp166	sp166																						0.49
sp167	sp167																						0.24
sp168	sp168																2.00						
sp169	sp169																0.50						
sp17	sp17										0.50								0.50				
sp170	sp170																0.75						
sp171	sp171																0.50						
sp172	sp172																0.75						
sp173	sp173																1.00						
sp174	sp174																0.25						
sp175	sp175																0.25						
sp178	sp178																0.50						
sp179	sp179																1.00						
sp18	sp18		0.50																				
sp180	sp180																0.25						
sp183	sp183																0.25						
sp184	sp184																0.50						
sp187	sp187																0.50						
sp189	sp189																0.75						
sp19	sp19		2.98																				
sp190	sp190																0.50						
sp191	sp191																0.25						
sp192	sp192																0.25						
sp193	sp193																0.25						
sp195	sp195																	1.00					
sp196	sp196																	0.50					
sp197	sp197																	0.50					
sp198	sp198																	1.50					
sp20	sp20		0.50																				
sp201	sp201																	1.00					
sp207	sp207																	1.00	0.50				
sp208	sp208																		0.50				
sp209	sp209																	0.50					
sp21	sp21		0.74																				
sp210	sp210																	0.50	13.00				

sp211	sp211																		0.50	4.50				
sp213	sp213																			1.00				
sp215	sp215																			1.00				
sp216	sp216																			1.00				
sp218	sp218																			0.50				
sp219	sp219																			0.50				
sp22	sp22		0.50																					
sp220	sp220																			0.50				
sp221	sp221																			0.50				
sp223	sp223																			1.00				
sp225	sp225																			0.50				
sp226	sp226																			1.00				
sp227	sp227																			1.00				
sp229	sp229																		0.50	0.50				
sp23	sp23		1.24																					
sp231	sp231																			0.50				
sp24	sp24		0.50																					
sp25	sp25		0.25																					
sp26	sp26										1.48		0.25											
sp27	sp27														0.50									
sp28	sp28						0.50																	
sp3	sp3															1.49	0.50	0.50						
sp30	sp30						0.25																	
sp31	sp31										6.00													
sp32	sp32									0.25														
sp33	sp33									0.49														
sp34	sp34									0.25											0.25			
sp35	sp35									0.49														
sp36	sp36									0.25														
sp37	sp37									0.25	3.00	1.49						1.25			0.25			0.49
sp39	sp39						0.25																	
sp4	sp4						1.25													0.50				
sp40	sp40																		0.50					
sp41	sp41						0.25																	
sp42	sp42														0.25									
sp43	sp43															0.25								
sp44	sp44										1.50	0.50				8.19								1.47
sp45	sp45																0.50							
sp46	sp46					1.25					2.00					0.25					0.50			14.18
sp5	sp5							2.71																
sp50	sp50									0.50	0.25													
sp51	sp51									1.00		0.50												
sp52	sp52											0.25												
sp53	sp53			0.25																				
sp55	sp55													0.25										
sp56	sp56													0.25							0.25			
sp58	sp58													0.25		13.15								
sp60	sp60									0.50											0.25			
sp61	sp61												0.25											
sp63	sp63														0.25									
sp64	sp64										5.00													1.47
sp66	sp66													0.25										
sp67	sp67													4.48										
sp68	sp68													0.25										0.24
sp69	sp69										1.00		3.23											
sp7	sp7						0.25																	
sp70	sp70										1.00									0.50				
sp71	sp71															0.25								
sp73	sp73						0.50																	

sp74	sp74					0.25																	
sp75	sp75						0.25										1.50						
sp76	sp76													0.74									
sp78	sp78										0.25												
sp79	sp79														0.25								
sp82	sp82										0.25	0.50		0.74	2.72		0.50		0.50		0.24	0.73	
sp84	sp84											3.23		1.99					0.25		17.60		
sp86	sp86					1.23																	
sp87	sp87											0.25					0.50						
sp88	sp88											0.25				0.25							
sp89	sp89											0.25			5.45					0.25	1.71	2.44	
sp9	sp9								0.74												0.24		
sp90	sp90											0.25				0.25							
sp91	sp91											0.25											
sp92	sp92							0.25												0.50			
sp93	sp93				0.25	1.50															0.49		
sp94	sp94												1.49								0.24		
sp95	sp95												5.45										
sp96	sp96												0.25				0.50					0.49	
sp97	sp97							1.00															
sp98	sp98												0.25										
sp99	sp99																						
Stauroneis exilissima	Stex					0.49																	
Stauroneis sp1	Stasp1		0.48						0.50												0.98		
Stephanopyxis sp1	Stesp1	8.67			14.04											0.50				7.69		10.27	
Stiatella sp1	Stisp1											0.25											
Surirella gemma	Suge				0.99																		
Tabularia sp1	Tasp																			0.50			
Thalassionema sp	Thasp																1.00						
Thalassionema sp1	Thasp1								0.50								4.00						
Thalassiosira simplex	Thsi																1.50		0.50				
Tropidoneis semistriata	Trse			0.24				4.00													0.73		
Tryblionella coarctata	Trco															1.25						0.49	
Tryblionella sp1	Trsp																					0.24	