Otari and Taputeranga bioblitzes: diatoms – microscopic algae

Margaret A. Harper[1] and John F. Harper[1,2]

INTRODUCTION

Rodney Lewington and Carol West have previously written about the bioblitz at Otari-Wilton's Bush (Lewington & West 2008). They covered the plant groups visible to the naked eye that were identified during a 24 hour period ending at 3 p.m. on 24 March 2007. We were also involved in the Otari bioblitz, looking for microscopic algae in the Kaiwharawhara Stream. We collected samples of diatoms in three ways: by scrubbing material off rocks into a bowl; by picking pieces of water weed; and by suction of surface sediment. Later in the year we joined in the world's first marine bioblitz at what is now the Taputeranga Marine Reserve on Wellington's South Coast. The marine bioblitz ran over three Sundays in October to allow for tides and bad weather. Divers collected seaweeds in the morning and specialists identified them in the afternoon. We took samples from these seaweeds and also from the shore.

Diatoms are microscopic algae that are golden brown in colour. They live in both marine and fresh waters, and in damp places. Sometimes you see them en masse as golden patches on the surface of mud, or brownish red patches on rocks, or brown fluff on water weeds and seaweeds. The notorious "Didymo" (*Didymosphenia geminata*) is the diatom equivalent of old man's beard (*Clematis vitalba*). Most plant allies have permeable cellulose cell walls, but diatoms live in glass (silica) boxes with lids and bases referred to as valves (like shellfish) with pores through which they absorb and exchange dissolved substances (e.g., gases, nutrients).

Diatoms are identified by their shapes and the patterns of pores in them. In 1905 Albert Mann of the Carnegie Institute first called them "jewels of the plant-world" for their attractive appearance under the microscope, and "grass of the sea" for their place in ocean food chains (see Mann 1907). Free-floating (planktonic) diatoms account for about 40% of ocean primary productivity; they are also important in sequestering carbon dioxide, as over 50% of the organic carbon buried in ocean sediments comes from

1. School of Geography, Environment and Earth Sciences, Victoria University of Wellington, P.O. Box 600, Wellington 6140. E-mail: Margaret.Harper@vuw.ac.nz

2. School of Mathematics, Statistics and Operations Research, Victoria University of Wellington, P.O. Box 600, Wellington 6140.

them (Falkowski et al. 2004). As well as planktonic diatoms there are benthic ones that live on surfaces of rocks, mud, plants, animals and other algae where there is at least some sunlight to support their photosynthesis. Given this wide range of habitats it is not surprising that there are more species of benthic diatoms than planktonic ones. Therefore we concentrated on collecting benthic diatoms as bioblitzes are held to impress the general public with the amount of biodiversity. Diatoms are a useful group at bioblitzes: first, because there are a very large number of species of diatoms (perhaps as many as 100,000); and second, since most species are cosmopolitan, Floras developed for Europe and North America can be used in New Zealand.

There are no earlier lists of freshwater diatoms from the Kaiwharawhara Stream and few records for the Wellington area (Cassie 1984). As preparation for the Otari bioblitz, we compiled a preliminary list by identifying diatoms in samples collected (with a permit) a month earlier in various parts of the stream in Otari. It takes about half an hour to identify each species initially, but checking that it fits the specifications of those on a pre-existing list only takes a few minutes. The marine bioblitz had a less clearly defined period for identification, so our diatomist (M.A.H.) identified them over about three working weeks in October. Ursula Cochran's PhD thesis (Cochran 2002) contained a list of 74 diatom taxa in sub-surface sand from Island Bay.

A research microscope and specially prepared microscope slides are needed to identify most species. Examination of live diatoms in water only allows them to be placed in major taxonomic groups such as families and genera, as their golden-brown plastids obscure the pore patterns of their glass walls. Live diatoms cannot readily be observed at high magnifications (×1000) as normal light microscopes require immersion oil on top of the coverslip. Oil is more adhesive than water so when the slide is moved on the microscope stage, the coverslip does not move with it. This randomly stirs the water, and diatoms formerly in view are lost. Therefore, the samples were bleached with hydrogen peroxide, disaggregated with hydrochloric acid, rinsed with water, and dried on microscope coverslips (thin glass discs). Thin diatoms appear "ghostlike" in water mounts as their silica walls have a refractive index (R.I. 1.43) close to that of water (R.I. 1.33) and this does not provide enough contrast for small features to be clearly visible. Therefore the slips are mounted (stuck) on microscope slides with a high refractive index resin (Naphrax, R.I. 1.7) which bends the light rays more than the diatom walls (R.I. 1.43), making the walls appear like tiny air bubbles (R.I. 1.0) in water rather than submerged thin ice. The National Institute for Water and Atmospheric sciences (NIWA) has a key to freshwater genera (www.niwa.co.nz/rc/prog/freshbiodiversity/diatom/help). For the bioblitzes

we depended on specialist Floras; for freshwater diatoms mainly Krammer & Lange-Bertalot (1986–1991), and for marine diatoms mainly Witkowski et al. (2000).

OTARI WILTON'S BUSH

We found 101 different species of diatoms in the Otari part of the Kaiwharawhara Stream. Seventy-six were seen during the bioblitz itself (Appendix 1). Six species were new records for New Zealand (absent from Gordon in press). Most of these were small diatoms that could easily have been overlooked. The most interesting find was a new species, *Tabularia variostriata* (Harper et al. 2009a; Fig. 1). Mark Harvey (1996) took a photograph of it (as *Synedra* sp.) from sediment collected in the basin of Lake Ellesmere and Ursula Cochran (2002) found it at several brackish water sites, but neither author erected a new species for it. Unlike other recently described species endemic to New Zealand or Australasia, it is not restricted to peaty alpine tarns, but favours slightly brackish waters. Twelve other diatoms that tolerate slightly salty water were also found, which could indicate some run-off of heavy metals from the suburban catchment. In the stream the new diatom formed a dark brownish-red coating on the rocks. It comprised a sort of miniature grass, which would be grazed by insect larvae that were in turn eaten by freshwater crayfish. The main distinguishing feature of the new diatom species is the variation in length of its "striae", the lines of pores on its valve.

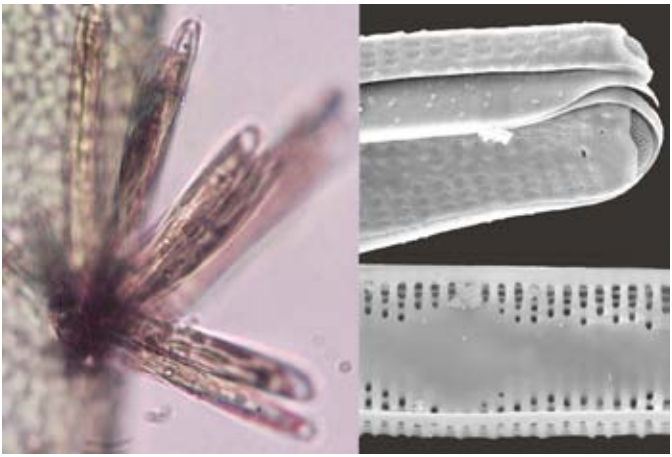

Figure 1. *Tabularia variostriata*, a newly named diatom species, collected at Otari-Wilton's Bush. Left: living cells (0.1 mm long), with light microscope. Top right: cell end, with electron microscope. Below right: interior of valve, with electron microscope. Scanning electron micrographs by David Flynn.

TAPUTERANGA MARINE RESERVE

During the marine bioblitz we recorded more species (158 species and 7 varieties; Appendix 2) than during the freshwater one. The main reasons for this were the wider range of habitats involved, from sub-tidal water to high tidal pools and freshwater seeps, and because more time was spent on diatom identification. Records include 17 diatom taxa which prefer freshwater, and 20 that tolerate brackish water. There were also 59 new records for New Zealand (including 6 informal taxa), far more than from the Kaiwharawhara Stream. This is because few diatomists have studied our benthic marine diatoms. Most new records of diatoms came from sub-tidal seaweeds, especially feathery ones, that were collected by divers; later we saw a grazing snail which could not get its rasping tongue (radula) deep into the forks of these weeds. We found only 18 taxa in common with the previous list of 74 taxa from Island Bay (Cochran 2002), from sub-surface sand, because of sampling very different situations.

We thought we had found a new species (Fig. 2) of *Mastogloia*, but then discovered it had been named *Cocconeis coelata* about 150 years ago. It was clearly not a *Cocconeis* as they have an upper domed-valve without slits and a lower flat one with slits. Slime exuded through these slits attaches them to surfaces like mini-limpets. *Mastogloia* species have two flattish valves and their slime forms stalk-like structures. We had expected further examination would prove it was a *Mastogloia*. However, when we studied it at a much higher magnification using a scanning electron microscope (SEM) we saw it had a solid shelf-like rim around its inside edge, unlike the hollow chambers characteristic of all *Mastogloia* species. Our find did not fit into any other existing genus so we have placed it in a new genus, *Skeletomastus* (Harper et al. 2008, Harper et al. 2009b). The first part of the name (*Skeleto-*) comes from Professor Walker Arnott's description in which he commented on its having thick ribs like a skeleton (Greville 1862). The second part (*-mastus*, meaning nipple-like) refers to its similarity to *Aneumastus*. *Aneumastus* is another member of the family *Mastogloiaceae*, but all its species have some pores covered by flaps.

We had already told the press we had a new diatom species when we found out that it had already been described, and thought we then merely had a new combination. In the hope of finding something genuinely new, we re-checked those diatoms that had been identified only to genus level. Photographs of an unidentified *Pleurosigma* (Fig. 3) were e-mailed to the New Zealand and world experts on this genus (Stuart Stidolph and Frithof Sterrenburg). They agreed it was a new species, and we have named it *Pleurosigma inscriptura* (Harper et al. 2009b). Its name is based on its appearance like an oval lozenge inscribed with an integral sign (∫).

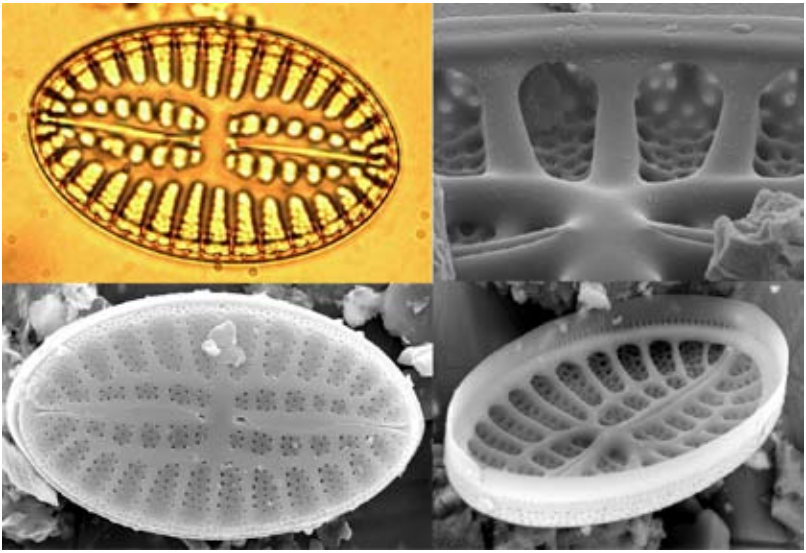

Figure 2. *Skeletomastus coelata*, a new diatom genus from Wellington's south coast. Valve exterior with, top left, light microscope and, bottom left, electron microscope. Right top and bottom: valve interior, with electron microscope. Scanning electron micrographs by David Flynn.

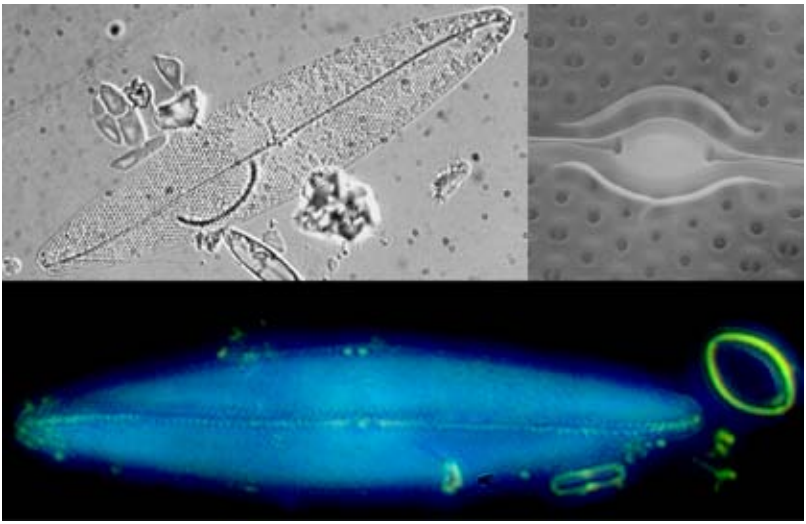

Figure 3. *Pleurosigma inscriptura*, a new diatom species from Wellington's south coast. Valve with, top left, light microscope light field and, below, dark field. Top right: central area, with electron microscope. Dark field by John Patterson. Scannng electron micrographs by David Flynn.

DISCUSSION

The interest of the various sponsors of the two Wellington bioblitzes encouraged us to make a determined effort to identify not only the diatoms that were common in the samples, but also the infrequent ones. They also stimulated us into describing fully one new genus and two new species in two published papers (Harper et al. 2009a, b). From these two Wellington biobiltzes, a total of 233 diatom species (254 formal taxa) were recorded, with 58 (excluding informal taxa) being newly recorded for New Zealand.

ACKNOWLEDGEMENTS

We thank Otari Wilton's Bush Trust, Rodney Lewington of the Wellington Botanical Society, Kirstie Knowles and Helen Anderson of Forest and Bird, Wendy Nelson and Dennis Gordon of the National Institute of Water and Atmosphere, and also Phil Garnock-Jones, John Patterson and David Flynn of Victoria University of Wellington for help and encouragement.

REFERENCES

Cassie, V. 1984: Checklist of the freshwater diatoms of New Zealand. *Bibliotheca Diatomologica 4 (pt 3)*: 5–129.

Cochran, U. 2002: Detection of large Holocene earthquakes in the sedimentary record of Wellington, New Zealand, using diatom analysis. Unpublished PhD thesis. 303 pp. plus CD. Victoria University of Wellington.

Falkowski, P.G.; Katz, M.E.; Knoll, A.H.; Quigg, A.; Raven, J.A.; Scholofield, O.; Taylor, F.J.R. 2004: The evolution of modern eukaryotic phytoplankton. *Science 305*: 354–360

Gordon, D.P. (ed.) In press: New Zealand Inventory of Biodiversity, Vol. 3. Canterbury University Press.

Greville, R.K.1862: Descriptions of new and rare diatoms Series VII: *Quarterly Journal of Microscopical Science new series 2*, 234–236, & pl X.

Harper, M.A.; Mann, D.G.; Patterson, J.E. 2009a: Two unusual diatoms from New Zealand: *Tabularia variostriata* a new species and notes on *Eunophora berggrenii*. *Diatom Research 24 (2)*: 291–306.

Harper, M.A.; Patterson, J.E.; Harper, J.F. 2009b: New diatom taxa from the world's first marine bioblitz held in New Zealand: *Skeletomastus* a new genus, *Skeletomastus coelatus* nov. comb. and *Pleurosigma inscriptura* a new species. Proceedings of the 20th International Diatom Symposium, Dubrovnik 2008. *Acta Botanica Croatica 68: 339–349.*

Harper, M.A.; Patterson, J.E; Harper, J.F. 2008: New diatom taxa from the world's first marine bioblitz held in New Zealand: proposed *Skeletomastus* a new genus, *Skeletomastus coelatus* nov. comb. and *Pleurosigma inscriptura* a new species. Abstracts of the 20th International Diatom Symposium, Dubrovnik 2008.

Harvey, M.C. 1996: *A paleolimnological study of Lake Ellesmere (Te Waihora), South Island, New Zealand*. Unpublished MSc thesis. 277 pp. University of Canterbury, Christchurch.

Krammer, K.; Lange-Bertalot, H. 1986–1991: Bacillariophyceae Vol 1–4. Süsswasserflora von Mitteleuropa. Gustav Fischer Verlag, Jena.

Lewington, R.J.; West, C.J. 2008: Otari BioBlitz: detailing plants, mosses and liverworts. *Wellington Botanical Society Bulletin 51*: 5–23.

Mann, A. 1907: Diatoms: the jewels of the plant world. *Smithsonian Miscellaneous collection 48* (*3*) *Quarterly Issue* (*1*) *1578*: 50–58 pls 22–25 (lecture given 18 March 1905 at the Smithsonian Institute).

Witkowski, A.; Lange-Bertalot, H.; Metzeltin, D. 2000: Diatom flora of marine coasts. *Iconographia Diatomologica* volume 7: A.R.G.Gantner Verlag. 925pp

APPENDIX 1: LIST OF DIATOMS FROM KAIWHARAWHARA STREAM IN OTARI-WILTON'S BUSH

(# new species record for New Zealand, † only in preliminary samples, * tolerate some salt).

Achnanthes elata (Leud.-Fortm.) Ghandhi.

Achnanthidium biasolettianum (Grun.) Lange-Bert.

#*Achnanthidium kranzii* (Lange-Bert.) Rnd. & Bukh.

Achnanthidium minutissima (Kütz.) Czar.

A. minutissum var. *jackii* (Rab.) Lange-Bert.

†*Actinocyclus normanii* (Greg.) Hust.

Amphora libyca Ehr.

Amphora pediculus (Kütz.) Grun.

Asterionella formosa Hassall

Aulacoseira crassipunctata Kram.

Aulacoseira distans (Ehr.) Simon.

Aulacoseira granulata (Ehr.) Simon.

A. granulata var.*angustissima* (O.M.) Simon.

†*Aulacoseira valida* (Grun.) Kram.

Caloneis bacillum (Grun.) Cl.

†*Calvinula lapidosa* (Krass.) Lange-Bert.

**Cocconeis placentula* Ehr.

**C. placentula* var. *euglypta* (Ehr.) Grun.

**C. placentula* var. *klinoraphis* Geit.

**C. pseudolineata* (Geitler) Lange-Bert.

†**Cyclotella meneghiniana* Kütz.

Cymbella kappi (Chol.) Chol.

Diadesmis contenta (Grun.) D.Mann

Discotella stelligera (Cl. & Grun.) Houk. & Klee

†*Encyonema elginense* (Kram.) D.Mann

Encyonema minutum (Hilse) D.Mann

Encyonema turgidum (Greg.) D.Mann

Epithemia adnata (Kütz.) Bréb.

†*Epithemia sorex* Kütz.

†*Eunotia bilunaris* (Ehr.) Mills

†*Eunotia minor* (Kütz.) Grun.

Eunotia pectinalis (Kütz.) Rab.

#†*Fallacia muraloides* (Hust.) D.Mann

†*Fragilaria capucina* Desm.

F. capucina var. *rumpens* (Kütz.) Lange-Bert.

**F. capucina* var. *vaucheriae* (Kütz.) Lange-Bert.

Fragilaria danica [*Ulnaria*] (Kütz.) Lange-Bert.

†*Fragilaria gracilis* Øst.

Frustulia saxonica Rab.

Frustulia vulgaris (Thw.) De Toni

†*Gomphonema angustatum* (Kütz.) Rab.

Gomphonema clavatum Ehr.

†*Gomphonema gracile* Ehr.

Gomphonema minutum Ag.

Gomphonema olivaceum (Horn.) Bréb.

Gomphonema parvulum (Kütz.) Kütz.

G. productum (Grun.) Lange-Bert. & Reich.

G. pumilum (Grun.) Reich. & Lange-Bert.

†*Gomphonema truncatum* Ehr.

Gyrosigma acuminatum (Kütz) Rab.

Hantzschia amphioxys (Ehr.) Grun.

Karayevia clevei (Grun.) Rnd. & Bukh.

†*Kolbesia ploenensis* (Hust.) Kingston

**Luticola cohnii* (Hilse) D. Mann

Melosira varians Ag.

#†*Microcostatus kuelbsii* (Lange-Bert.) Lange-Bert.

†*Navicula cari* Ehr.

Navicula cryptocephala Kütz.

†*Navicula erifuga* Lange-Bert.

**Navicula gregaria* Donk.

**Navicula lanceolata* (Ag.) Ehr.

Navicula oblonga Kütz.

Navicula peregrina (Ehr.) Kütz.

Navicula rhyncocephala Kütz.

Navicula viridula (Kütz.) Ehr.

#†*Naviculadicta cosmopolitana* Lange-Bert.

#†**Nitzschia aequorea* Hust.

Nitzschia amphibia Grun.

Nitzschia dissipata (Kütz.) Grun.

**Nitzschia frustulum* (Kütz.) Grun.

Nitzschia gracilis Hantz.

Nitzschia hantzschiana Rab.

**Nitzschia inconspicua* Grun.

#**Nitzschia lacunarum* Hust

Nitzschia linearis (Ag.) W.Sm.

†*Nitzschia microcephala* Grun.

Nitzschia palea (Kütz.) W.Sm.

Nitzschia palacea (Grun.) Grun.

#**Nitzschia cf. pellucida* Grun.

Nitzschia umbonata (Ehr.) Lange-Bert.

†*Pinnularia borealis* Ehr.

Pinnularia gibba Ehr.

Pinnularia viridis (Nitz.) Ehr.

Placoneis exigua (Greg.) Meresch.

†**Planothidium delicatulum* (Kütz.) Rnd. & Bukh.

Planothidium ellipticum (Cl.) Rnd. & Bukh.

**P. frequentissimum* (Lange-Bert.) Lange-Bert.

Planothidium lanceolatum (Bréb.) Lange-Bert.

Planothidium robustius (Hust.) Lange-Bert.

Planothidium rostratum (Øst.) Lange-Bert.

Psammothidium oblongellum (Øst.) de Vij.

Reimeria sinuata (Greg.) Kocio. & Stoer.

**Rhoicosphenia abbreviata* (Ag.) Lange-Bert.

Rossithidium linearis (W.Sm.) Rnd. & Bukht.

Rossithidium pusillum (Grun.) Rnd. & Bukht.

Sellaphora seminulum (Grun.) D. Mann

Stauroneis anceps Ehr.

Staurosira construens (Ehr.) Williams & Rnd.

†*Staurosira elliptica* (Schum.) Williams & Rnd.

Staurosira venter (Ehr.) Cl. & Möll.

†*Staurosirella pinnata* (Ehr.) Williams & Rnd.

†*Stephanodiscus atmosphaerica* (Ehr.) Håk. & Rnd.

Surirella angusta Kütz.

**Tabularia variostriata* M.Harper

Ulnaria biceps (Kütz.) Compère

Ulnaria ulna (Nitz.) Compère

APPENDIX 2: LIST OF DIATOMS FROM WELLINGTON'S SOUTH COAST

(# new species record for New Zealand, * brackish water species, † freshwater species).

Achnanthes brevipes var. intermedia (Kütz.) Cl.

**Achnanthidium subatomus* (Hust.) Lange-Bert.

Amphora bigibba var. interrupta Grun.

#*Amphora borealis* Kütz.

**Amphora coffeaeformis* (Ag.) Kütz.

#*Amphora cymbaphora* Chol.

#*Amphora exigua* Greg.

†*Amphora fogediana* Kram.

#*Amphora helensis* Giff.

#*Amphora aff. kolbei* Aleem

#*Amphora laevissima* Greg.

Amphora marina W.Sm.

#*Amphora ocellata* Donkin

#*Amphora pannucea* Giff.

Amphora profusa Giff.

#*Amphora pseudohyalina* Simon.

#*Amphora pseudoproteus* Wach. & Gais.

†*Aulacoseira italica* (Ehr.) Simon.

Bacillaria paxillifer (O. Müll.) Hend.

Biddulphia alternans (Bail.) van H.

#*Biddulphia antediluviania* (Ehr.) van H.

Biddulphia reticulum (Ehr.) Boyer

Campyloneis grevillei (W.Sm.) Grun.

#*Chaetoceros holosaticum* Schuett

Chaetoceros aff. *simplex* Osten.

Cocconeiopsis fraudulenta (A.S.) Witk. et al.

#*Cocconeiopsis regularis* (Hust.) Witk. et al.

Cocconeiopsis wrightii (O'Meara) Witk. et al.

#*Cocconeis britannica* Naegeli

#**Cocconeis capensis* (Chol.) Witk. et al.

Cocconeis costata Greg.

Cocconeis costata var. hexagona Grun.

Cocconeis discrepans A.S.

#*Cocconeis finnmarchica* Grun.

#*Cocconeis convexa* Giffen

†*Cocconeis neodiminuta* Krammer

**Cocconeis placentula* Ehr.

**C. placentula* var. *euglypta* (Ehr.) Grun.

**C. placentula.* var. *lineata* (Ehr.) van H.

**C. placentula* var. *tenuistriata* Geitler

#*Cocconeis pseudodiruptoides* Foged

**Cocconeis pseudolineata* (Geit.) Lange-Bert.

Cocconeis pseudomarginata Greg.

Cocconeis stauroneiformis (W.Sm.) Okuno

**Cocconeis scutellum* Ehr.

C. scutellum var. parva (Grun.) Cl.

Cocconeis sublittoralis Hendey

†*Cyclostephanos novaezeelandiae* (Cl.) Rnd.

Cymatosira belgica Grun.

†*Cymbella cymbiformis* Ag.

#*Delphineis karstenii* (Bod.) Fryx.

Delphineis minutissima (Hust.) Simon.

Delphineis surirelloides (Simon.) Andr.

Denticula neritica Holmes & Croll

#†*Diadesmis gallica* W. Sm.

#*Diploneis aestuarii* Hust.

#**Diploneis aff. boldtiana* (A.S.) Cl.

Diploneis smithii (Bréb.) Cl.

Diploneis vacillans (A.S.) Cl.

D. vacillans var. *renitens* (A.S.) Cl.

Diploneis weissflogii (A.S.) Cl.

Entomoneis paludosa (W.Sm.) Reim.

Eunotogramma aff. marinum (W.Sm.) Perag.

Fallacia forcipata (Grev.) Stickle & Mann

#*Fallacia inscriptura* (Hend.) Witk. et al.

#*Fallacia litoricola* (Hust.) D.Mann

#*Fallacia oculiformis* (Hust.) D.Mann

#*Fallacia scaldensis* Sabbe & Muyl.

†*Fragilaria capucina* Desm.

**F. capucina* var. *vaucheriae* (Kütz.) Lange-Bert.

†*Frustulia vulgaris* (Thw.) De Toni

†*Gomphonema minutum* Ag.

†*Gomphonema parvulum* (Kütz.) Kütz.

#*Gomphosphenia tackei* (Hust.) Lange-Bert.

Grammatophora angulosa Ehr.

G. angulosa var. islandica (Ehr.) Grun.

Grammatophora arcuata Ehr.

Grammatophora hamulifera Kütz.

Grammatophora longissima Petit

Grammatophora marina (Lyng.) Kütz.

Grammatophora oceanica Ehr.

G. oceanica fo. *intermedia* (Grun.) Hust.

Grammatophora undulata Ehr.

Gyrosigma mediterraneum (Cl.) Cl.

Haslea britannica (Hust.) Witk. et al.

#*Hyalinella lateripunctata* Witk. et al.

Hyalodiscus scoticus (Kütz.) Grun.

†*Karayevia clevei* (Grun.) Rnd. & Bukht.

Licmophora juergensii Ag.

Licmophora paradoxa (Lyng.) Ag.

#*Licmophora* aff. *pfannkucheae* Giff.

#*Lunella* aff. *bisecta* Snoeijs

#*Navicula abscondita* Hust.

Navicula cancellata Donk.

*Navicula directa var. remota (*Cl.) Grun.

#*Navicula duerrenbergiana* Hust.

#*Navicula hamiltonii* Witk. et al.

**Navicula lanceolata* (Ag.) Ehr.

#*Navicula* [*Cocconeiopsis*] *lubetii* König

Navicula lusoria Giff.

Navicula pavillardii Hust.

**Navicula perminuta* Grun.

#*Navicula rusticensis* Lobban

Navicula salinicola Hust.

#*Navicula* aff. *taedens* Chol.

#*Navicula wunsamiae* Witk. et al.

†*Nitzschia* aff. *dissipata* (Kütz.) Grun.

#*Nitzschia fusiformis* Grun.

Nitzschia harderi Hust.

**Nitzschia* aff. *lorenziana* Grun.

Nitzschia parvula W. Sm.

#**Nitzschia pellucida* Grun.

Odontella mobilensis (Bailey) Grun.

#*Orthoseira dendroteres* (Ehr.) Craw.

Opephora marina (Greg.) Petit

Paralia marina (W. Sm) Heib.

#*Parlibellus* aff. *perytii* Witk. et al.

#*Parlibellus plicatus* (Donk.) Cox

**Parlibellus protracta* (Grun.) Witk. et al.

#*Parlibellus rhombicula* (Hust.) Witk. et al.

**Pinnularia borealis* var. *rectangularis* Carl.

**Planothidium frequentissimum* (Lange-Bert.) Rnd. & Bukht.

†*P. hauckianum* (Grun.) Rnd. & Bukht.

Pleurosigma acus A.Mann

#*Pleurosigma inscriptura* M.Harper

Pleurosigma strigosum W.Sm.

Pleurosigma stidolphii Sterrenberg

Podosira maxima (Kütz.) Grun.

Podosira montagnei Kütz.

Proschkinia complanata (Grun.) D.Mann

Psammodictyon panduriforme (Greg.) D.Mann

Psammodiscus nitidus (Greg.) Rnd. & Mann

†*Psammothidium oblongellum* (Øst.) de Vij.

#*Pseudogomphonema kamtschaticum* (Grun.) Medl.

Pseudopodosira westii (W.Sm.) Shesh.-Poret.

†*Reimeria sinuata* (Greg.) Kocio. & Stoer.

Rhabdonema adriaticum Kütz

#*Rhabdonema torelli* Cl.

Rhaphoneis amphiceros Ehr.

#*Rhoiconeis sponsalia* (Giff.) Medl.

**Rhoicosphenia abbreviata* (Ag.) Lange-Bert.

Rhoicosphenia genuflexa (Kütz.) Medl.

#*Rhoicosphenia marina* (Kütz.) (W.Sm.) M.Schmidt

†*Rhopalodia operculata* (Ag.) Håkansson

†*Rossithidium linearis* (W.Sm.) Bukht. & Rnd.

#*Semiavis delicatula* Wach. & Gais.

#*Semiavis witkowskii* Wach. & Gais.

Shionodiscus oestrupia (Osten.) Alvers.

Skeletomastus coelata (Arn.) M.Harper

Tabularia investiens (W.Sm.) Williams & Rnd.

Thalassionema nitzschioides var. *lanceolata* Grun.

#*Thalassiosira lineata* Jousé

#*Thalassiosira pacifica* Gran & Angst

#*Trachyneis velata* A.S.

#**Tryblionella aerophila* (Hust.) D. Mann

Tryblionella coarctata (Grun.) D.Mann

**Tryblionella debilis* Arnott

**Tryblionella hungarica* (Grun.) D.Mann

Four informal species in Witkowski et al. (2000):

#*Amphora* spec 164/1, pl.164, fig.7

#*Amphora immarginata* pl. 162, figs.20-21

#*Diploneis* sp. pl 88, figs. 6-8

#*Navicula* aff. "Elbe estuary" pl. 125 figs 20-28

#*Rhoicosphenia* 59/2, pl. 59, figs. 10-16

#*Seminavis* 164/5, pl. 164, figs 21-25..

One informal species in Cochran (2002) *Pseudopodosira* sp.2, pl. 4, fig . 8