The Mana Land and Sea Bioblitz from a diatomist's view-point

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INTRODUCTION

Diatoms are microscopic algae with two valves (like shells of bivalve shellfish; see Fig. 2f) enclosing each single-celled organism. We measure them under the microscope in microns (μm) which are thousandths of a millimetre; most are ten to fifty microns in size. They become visible to the naked eye when millions of them form dark or golden-brown fluffy or slimy blooms in water, on mud, on seaweeds or on water-weeds or rocks. Like their nearest multicellular relatives, the brown seaweeds, they have brown and orange pigments that mask the green chlorophyll they use for photosynthesis. Their valves are made of silica (glass) which is impermeable, so diatoms have pores (holes) in them so the chemical nutrients and dissolved gases they need can reach them from the surrounding water. Diatom specialists identify them by the patterns of these pores and the shapes of their valves. The main Floras we used were Krammer & Lange-Bertalot (1986–1991) for freshwater species and Witkowski et al. (2000) for coastal species. These are the best Floras available and used globally, but they are based on European material. While most diatoms appear to have world-wide distributions, recent careful study of diatoms from some Southern Hemisphere localities indicates there are some genera and species endemic to Australasia that have been incorrectly identified or overlooked (Kilroy et al. 2007).

Diatoms are unusual organisms in having a wide range of species living in all three of fresh, brackish and marine waters. Most groups of organisms are either predominantly marine or terrestrial (including freshwater) with only a few families living permanently in the other habitat (e.g., sea grasses among vascular plants, whales among mammals). It seems that diatoms evolved in coastal waters somewhat before 200 million years ago during the Triassic period and then spread to inland and oceanic waters (Sims et al. 2006). This means that those living in coastal waters should be of especial interest as species resembling ancestral forms could have survived in some

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of these waters. Shoreline species which grow in tidal estuaries like Porirua harbour have to cope with frequent changes in salinity and may also tolerate drying out.

There were several earlier listings of vascular plants for both Mana Island and the Titahi Bay area. However, only one diatomist has previously listed diatoms from the actual Bioblitz area. Ursula Cochran as part of her PhD thesis on geologically recent earthquakes in the Wellington area (Cochran 2002) produced lists of diatom remains found in sediment samples from Titahi Bay (27 taxa) and the west side of Porirua Harbour near the end of Te Pene Avenue (35 taxa). An earlier collection (Stidolph 1980) from Porirua Harbour (Mana Marina by the Ngatitoa domain) was just outside the Bioblitz area. Stidolph collected and published details of 150 species. The richest flora came from sample RM-62, scrapings of a dredge and flotation drums (Stidolph 1980).

The organisers of bioblitzes aim to educate the general public in local biology by letting them interact with a wide range of scientists and naturalists listing as many species of all sorts of organisms as they can from a limited area in a limited time. The Mana Bioblitz included both marine and freshwater organisms from the Titahi Bay peninsula, Mana Island and surrounding seas (Fig. 1). To access several low tide periods and allow for possible bad weather it was organised for the period of a month (5/2/2011 to 6/3/2011) like the Taputeranga Bioblitz (Harper & Harper 2010). Our marine samples were mainly from seaweed drift collected at weekends. Our study of Mana Island was more like a typical terrestrial Bioblitz as we visited it on a single day (12/2/2011).

Samples of water and seaweeds were first treated with mild sonication to remove adhering diatoms, while sediment samples were sieved to remove large particles (> 1mm). Both were then oxidised with hydrogen peroxide and disaggregated with hydrochloric acid. Microscope slides were made of strewn samples using a high refractive index mountant (glue) to improve the visibility of the pores (see Harper & Harper 2010). The slides were examined under magnification of 400 and 1000 times, with a Leitz Diaplan DIC microscope, and diatoms were listed and photographed with a Leica DFC280 camera. As the aim of a bioblitz is only to list the presence of species in a given area, further valves of species already listed in earlier samples were only noted if easily identified, or photographed if they looked unlike listed species.

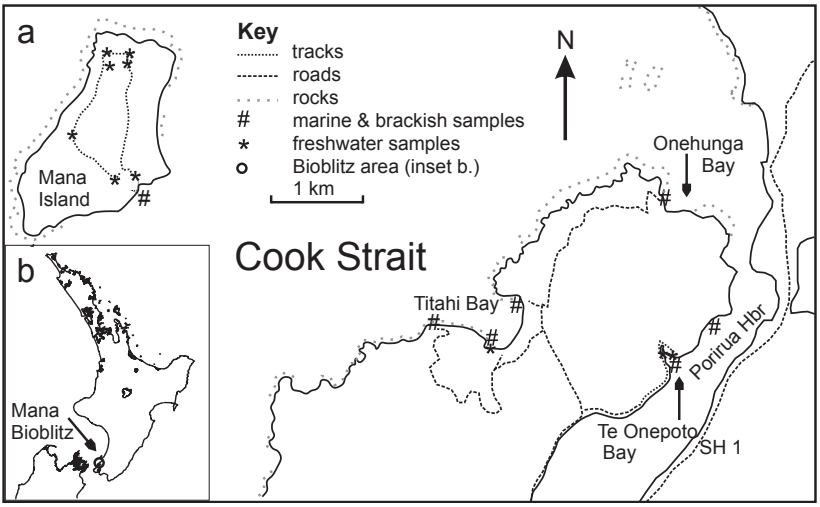

Figure 1. a) map of Bioblitz sampling sites. b) map of New Zealand indicating location of Mana Island and Porirua inlet.

FRESHWATER SITES

Titahi Bay (sampled 5/2/2011)

Our first freshwater samples were collected from a turbid stream towards the south end of the beach. There were only five sorts of diatoms present, and we could identify only three of these. Muddy sediment from an eroding path could have killed other diatoms by blocking their sunlight and coating their pores. Freshwater diatoms are washed out to sea and some were found in marine samples from Titahi Bay.

Mana Island (sampled 12/2/2011)

We identified 59 different freshwater diatom species in 18 samples from seven ponds and three streamlets. 42 of these we did not find in our other samples, but we were more thorough in our sampling and analysis of freshwater on Mana Island than elsewhere. We collected ten samples of silt, five of pondweeds, two of algae and one of scrapings from a submerged stick. The richest samples were two silt samples. The first (MI F2) from a pond near the track junction at the top of the hill contained 27 species all of which lived attached to waterweeds or algae. There was algal and plant material round this natural pool. The second sample (MI F3) from an artificial pond at the bottom of the hill contained 25 species which included both forms that live attached to waterweeds and forms that live on the surface of silt. Four marine species were present, brought in by either sea birds or wind.

Coast at Te Onepoto Bay *(Porirua Harbour, sampled on 19/2/2011)*
The richest sample (PH F6, with 20 freshwater species) came from a puddle in a rut left by a motorbike! The treads could have picked up superficial sediment from upstream and discarded it with water as the bike topped the estuary bank.

MARINE SITES

Titahi Bay (sampled on 5/2/2011, and 26/2/2011)
This was the site of the first marine sample studied. Small algal epiphytes from 12 freshly stranded seaweed species (sample TB S3) yielded 34 diatom species, which was nearly as many as the richest sample from the Taputeranga Bioblitz (Harper & Harper 2010). That diver's collection of just two entwined epiphytic seaweeds yielded 38 diatom species. However, common diatoms which were recorded in this sample were ignored in later samples as the aim of the Bioblitz was to list the diversity of the whole area. Some seaweeds collected from drift in Titahi Bay and elsewhere yielded relatively few diatoms. Diatoms could well be stripped from seaweeds as they pass through turbulent surface waters before reaching beaches. Seaweeds from the west end of the bay below Stuart Park yielded 10 marine species.

Onehunga Bay (Whitireia Park, sampled on 19/2/2011)
This was the richest source of marine diatoms although we only collected samples from one small area near and on the rocks at one low tide. We identified 83 species, 50 of which were not found in our other samples. Most variety was found in the first sample of sand near a small bed of seagrass from the west end of the beach at Onehunga Bay (WP S1, 60 species). The second sample (WP S2) contained eight species of seaweed and a seagrass and yielded 23 diatom species.

Te Onepoto Bay (Porirua Harbour, sampled on 19/2/2011)
Seaweeds collected from the outer side of the spit yielded 6 diatom species, two of which had not previously been recorded from New Zealand.

Mana Island (sampled on 12/2/2011)
11 marine species were collected from the shore and a few separated from seaweed growing on a buoy.

DIATOMS OF SPECIAL INTEREST

Diatoms in Fig. 2 include species that float in the sea (circular, Fig. 2b, c, k), live attached to seaweeds (Fig. 2d, e), move around on seaweeds (Fig. 2a, g, h), and one that can move but usually stays put like a limpet on dry rocks (Fig. 2f). The other two diatoms (Fig. 2i, j) live in freshwater and move

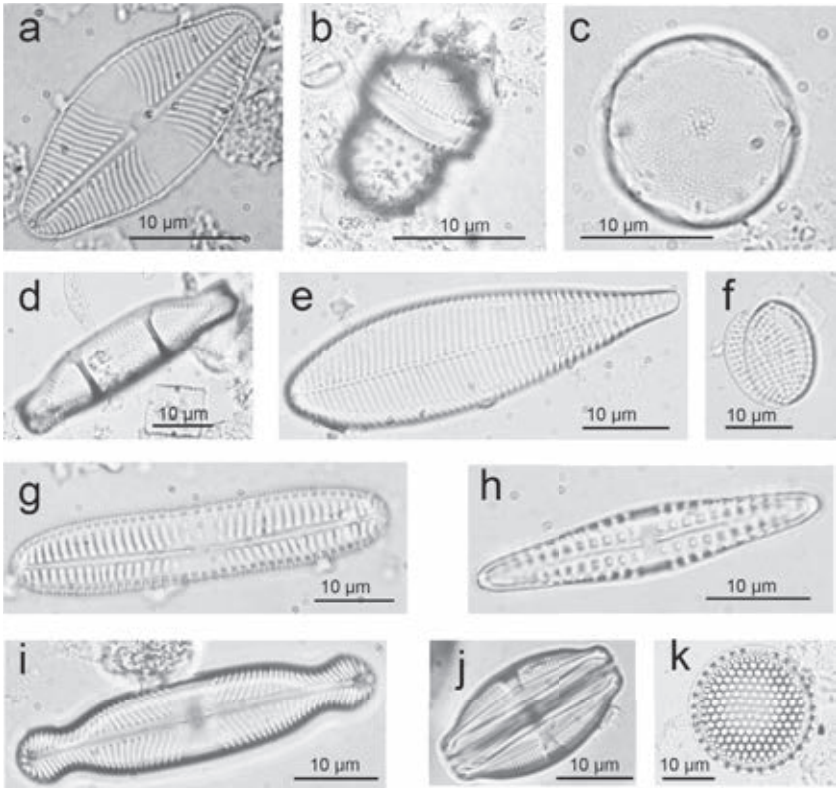

Figure 2. Light microscope photographs of some of the diatoms (*new record for New Zealand). a) *Pinnularia woodiana* Foged (*Lecohuia*?). b) Spore of **Chaetoceros* cf. *lauderi* Ralfs. c) *Thalassiosira* cf. *gracilis* (Karsten) Hustedt. d) *Neohuttonia* cf. *reichardtii* (Grunow) Kuntze. e) **Licmophora* cf. *abbreviata* Agardh. f) *Cocconeis stauroneiformis* (W. Smith) Okuno. g) **Oestrupia* cf. *ergadensis* (Gregory) Witkowski. h) **Achnanthes* cf. *groenlandica* (Cleve) Grunow. i) **Pinnularia* cf. *lundii* Hustedt. j) *Amphora normannii* Rabenhorst. k) *Stephanopyxis turris* (Greville & Arnott) Ralfs.

around on silt surfaces and waterweeds. *Amphora normanii* (Fig. 2j) is a species that can grow in damp places and is tolerant of being dried.

An unusual, probably endemic, diatom species (Fig. 2a) was found in the first sample (WP S1) from Onehunga Bay (Whitireia Park). It has some of the characteristics of *Pinnularia*, so during the Mana Bioblitz we referred to this diatom as "*Pinnularia* cf. *lundii* var. *rhombica*". We then found it had been formally described and named as *Pinnularia woodiana* by Foged (1979) who collected it from stagnant water from the coast south of Waiwera. It was also found in Porirua Harbour by Stidolph (1980) who referred to it as "*Pinnularia rhombica* Hustedt". However, it does not have the hooked

terminal fissures of *Pinnularia* species or the depth of valve formed by the chambers that are characteristic of the genus. When submitted to the Diatom-l special interest group, an expert (A. Witkowski, pers. comm. 2011) considered it could belong to the genus *Lecohuia*, recently separated from *Navicula* sensu lato. The appearance of faint zig-zag edges to its ribs could well indicate it has biseriate striae like those of *Lecohuia*. The polar ends of its raphe slits are also similar to those of *Lecohuia*, some species of which have enlarged hyaline central areas. The genus *Lecohuia* appears to have a southern hemisphere distribution and consists mainly of terrestrial species, but *L. geniculata* grows abundantly on salt-sprayed subantarctic mosses (Van de Vijver et al. 2008). However specimens need to be examined at higher magnification under a scanning electron microscope to resolve the question as to whether it is indeed a species of *Lecohuia*. Unfortunately it is both small and uncommon in the sample, so it is hard to locate specimens for further examination.

Neohuttonia cf. *reichardtii* (Fig. 2d) is an infrequently-encountered diatom; our form has sub-captitate ends which is unlike that in Witkowski et al. (2000). Like other attached diatoms, it has mucilage-secreting pads with fine pores. Although it appears at first to be bilaterally symmetrical, it is in fact curiously twisted with its pads placed on opposite sides of its ends. It grows on sand grains and links us to the coastal sands of Zealandia about 34 million years ago. It belongs to *Neohuttonia* (originally named *Huttonia*), a small genus of only seven recognised species. The type of this genus, *Huttonia alternans*, was first described from New Zealand's internationally famous Oamaru diatomite (Grove & Sturt 1886, 1887). This diatomite dates from the Latest Eocene period and the curious diatoms in it have intrigued many workers including two New Zealand amateur diatomists: A. Doig and F. Reed (see Edwards 1991). Enter "Oamaru diatoms" in an internet search engine and you will find several sites with photographs of these diatoms including the site of Nigel Charles—www.oamarudiatoms.co.uk.

Recently we were asked whether *Haslea ostrearia* (Gaillon) Simonsen really occurs in New Zealand. There is a previous record (Cassie 1984) based on *Navicula tripunctata* (O. Müller) Bory identified by Barber and Carter (1971) from Auckland, being considered the same as *Navicula ostrearia* (Gaillon) Bory. However, the best modern microscopy shows that only the latter has longitudinal striae, so Simonsen (1971) set up a new genus for it, *Haslea*. Krammer and Lange-Bertalot (1986) accepted the new genus and rejected the earlier synonymy. *Haslea ostrearia* is of interest as French oyster farmers find that its presence on gills promotes the growth of oysters. The live diatom exudes a unique blue pigment with antioxidant properties (Pouveau et al. 2008). Now, with our find, it appears

that it could well be living in New Zealand, but its identification would be more certain if it had been found "greening" oyster gills, as its striae are not readily visible. It is best known as living in the North Atlantic, but it has also been recognised in samples from the Indian Ocean and the east coast of Tasmania (Saunders et al. 2010).

COMPARISON WITH EARLIER RECORDS.

We tentatively identified 16 taxa not previously noted in New Zealand based on lists in the New Zealand Inventory of Biodiversity (diatoms based on pre-2011 publications, Harper et al. 2012). Our Mana Bioblitz totals were 87 freshwater species (88 taxa, Appendix 1) and 130 marine species (133 taxa, Appendix 2); these are about one-tenth and one-fifth of the number of species listed in the Inventory which has 678 marine species (including 117 brackish-marine) and 933 freshwater species (including 80 fresh-brackish, Harper et al. 2012). Our Mana samples undoubtedly contained other diatoms we could have found and eventually identified if we had more time.

Only eleven marine taxa (plus other varieties of two species) and five freshwater species were found in the area by both Ursula Cochran (Cochran 2002) and us. We found 39 taxa out of the 150 taxa collected from near the Mana Boat club by Stidolph (1980) who concentrated on larger diatoms (> 38 µm). The limited amount of correspondence between lists indicates our lack of knowledge of coastal diatom floras of this area and their seasonal changes.

NEW RECORDS FOR NEW ZEALAND

(Diatoms not in current checklists of Harper et al. 2012.)

"cf." before a name means that the diatom appeared most like the taxon mentioned; the comments that follow mention some differences and occurrences in Australia. Ranges of dimensions of valves and frequency of striae are used to distinguish species. Striae are microscopic lines formed by ribs and the pores between them. * shown in Fig. 2.

**Achnanthes* cf. *groenlandica* (Cleve) Grunow. Size of our valve 36 × 6 µm, with 7 striae / 10 µm. Ours have unusual pointed apices (see Cox 2006, p. 72, fig. 17–18).

**Chaetoceros* cf. *lauderi* Ralfs; spore. Ours 21 × 15 µm (see Hustedt 1930, p. 683, fig. 387). Rare on Australia's east coast (Crosby & Wood 1959)

Fragilaria cf. *hyalina* (Kützing) Grunow. Ours 11 × 2.5 µm, appears hyaline (see Witkowski et al. 2000, pl. 26, 20–22).

Gomphonemopsis cf. *obscurum* (Krasske) Lange-Bertalot. Ours 7.5 × 2 µm, 20 striae / 10 µm (see Witkowski et al. 2000, pl. 61, fig. 4–9).

Haslea cf. *ostrearia* (Gaillon) Simonsen. Ours 57 × 7.5 µm, appears hyaline (see Witkowski et al. 2000, pl. 148, fig. 3–5). Found in Tasmania (Saunders et al. 2010).

**Licmophora* cf. *abbreviata* Agardh. Ours 47 µm, depth 27 µm (see Honeywill 1998 and Hartley et al. 1996, pl. 122, fig. 2).

Navicula cf. *kuripanensis* Hustedt sensu Witkowski. Ours 18 × 5 µm (see Witkowski et al. 2000, pl. 138, fig. 13); shaded appearance differs from Simonsen (1987, pl. 307, 1–7).

Navicula cf. *syvertsenii* Witkowski et al. Ours 7.5 × 2.5 µm, 20 striae / 10 µm (see Witkowski et al. 2000, pl. 141, fig.7–12); ours smaller with slightly finer striae.

Nitzschia cf. *littorea* Grunow. Ours 68 × 11 µm, 30 striae / 10 µm, 10 irregular fibulae / 10 µm (see Witkowski et al. 2000, pl 197, fig. 14–16).

**Oestrupia* cf. *ergadensis* (Gregory) Witkowski. Ours 48 × 9 µm, 8.5 striae / 10 µm (see Witkowski et al. 2000, pl. 153, fig. 4). Also found in Western Australia (John 1983).

Opephora cf. *olsenii* Möller. Ours 30 × 6 µm, 6 striae / 10 µm (see Krammer and Lange-Bertalot 1986–1991, Vol. 3, p. 166, fig. 134).

Plagiotropis cf. *gibberula* Grunow in van Heurck. Ours 78 × 5 µm, 17 striae / 10 µm & 40 × 4 µm, 20 striae/10 µm; latter specimen with unusual finer striae (see Witkowski et al. 2000, pl. 174, fig. 6–7, and Hartley et al. 1996, pl. 243, fig. 11).

Pinnularia cf. *lundii* Hustedt. Ours 43 × 12 µm, 12 costae / 10 µm & 40 × 9.5 µm, 13 striae / 10 µm (see Krammer Lange-Bertalot 1986-1991, Vol. 1, pl. 187, fig. 16); freshwater species.

Seminavis cf. *cymbelloides* (Grunow) D.G. Mann. Our valve 51 × 9 µm, 25 striae / 10 µm (see Witkowski et al. 2000, pl. 164, fig. 29).

Stauronella cf. *arctica* (Hustedt) Lange-Bertalot. Ours 31 × 6 µm & 29 × 5 µm, > 35 striae / 10 µm (see Witkowski et al. 2000, pl. 149, fig. 6–7); ours has a fainter stauros.

Tryblionella cf. *littoralis* (Grunow) D.G. Mann. Ours 39 × 10 µm, 10 irregular fibulae / 10 µm (see Witkowski et al. 2000, pl. 182, fig. 7–11).

ACKNOWLEDGEMENTS

Allie Burnett and Kirstie Knowles of Forest and Bird for organising the BioBlitz; Frank & Sue Caldwell of the Department of Conservation for making our trip to Mana Island a success; Paula Warren and Mike Joy for collecting seaweed samples; Aline Homes of the School of Geography, Environment and Earth Sciences, Victoria University of Wellington for identifying seaweeds; and Dennis Gordon of the National Institute of Water and Atmosphere for his interest and encouragement.

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APPENDIX 1: FRESHWATER DIATOMS

* new record for New Zealand, *M* = Mana Is, *P* = Porirua Harbour (Te Onepoto Bay), *S* = west end Titahi Bay (Stuart Park), *T* = main Titahi Bay, *W* = Whitireia Park (Onehunga Bay), underlined from a marine sample, *bw* = prefers or tolerates brackish water, (p) (t) = *P*, *T* from Cochran (2002) and (*p*) = *P* from Stidolph (1980); † identification made since Bioblitz.

Achnanthidium cf. *biasolettianum* (Grunow) Lange-Bertalot *M*

Achnanthidium cf. *minutissimum* (Kützing) Czarnecki S

Achnanthes crosbyana Foged *(p)* (p) *W*

Amphicampa cf. *mirabilis* Ehrenberg *M*

Amphora cf. *normannii* Rabenhorst *P*

Aulacoseira cf. *crenulata* (Ehrenberg) Thwaites *M*

Caloneis cf. *bacillum* (Grunow) Cleve *M P*

Cocconeis cf. *neodiminuta* Krammer *T*

Cocconeis placentula Ehrenberg *(p)* (p) *W*

C. placentula var *pseudolineata* Geitler *T*

Craticula cf. *ambigua* (Ehrenberg) Mann *M bw*

Cyclotella meneghiniana Kützing *M*

Cymbopleura cf. *naviculiformis* (Auerswald) Krammer *P*

Diadesmis contenta (Grunow ex V. Heurck) Mann *M*

Diploneis cf. *parma* Cleve *T*

Diploneis subovalis Cleve *(p) P*

Discostella cf. *stelligera* (Cleve & Grunow) Houk & Klee *M*

Encyonema cf. *neogracile* Krammer *T*

Encyonopsis falaisensis (Grunow) Krammer *T*

Eunotia cf. *bilunaris* (Ehrenberg) Schaarschmidt *M*

Eunotia cf. *crista-galli* Cleve *M*

Eunotia pectinalis var. *undulata* (Ralfs) Rabenhorst *M*

Eunotia cf. *soleirolii* (Kützing) Rabenhorst *M*

Eunotia cf. *minor* (Kützing) Grunow *M*

†Fragilaria cf cassubica Witkowski & Lange-Bertalot *M*

Fragilaria capucina var. *mesolepta* (Rabenhorst) Rabenhorst *P*

F. capucina var. *vaucheriae* (Kützing) Lange-Bertalot *M*

Frustulia vulgaris (Thwaites) De Toni *M*

Geissleria cf. *decussis* (Östrup) Lange-Bertalot & Metzeltin *M*

Gomphonema cf. *angustatum* (Kützing) Rabenhorst *M*

Gomphonema gracile Ehrenberg *M*

Gomphonema cf. *lagenula* Kützing *M*

Gomphonema cf. *parvulum* (Kützing) Kützing *M*

Gomphonema cf. *truncatum* Ehrenberg *P*

Gyrosigma cf. *attenuatum* (Kützing) Rabenhorst *M P*

Hantzschia amphilepta (Grunow) Lange-Bertalot *T*

Hantzschia cf. *amphioxys* (Ehrenberg) Grunow *M P*

Hippodonta capitata (Ehr.) Lange-Bert. Metzeltin & Witkowski *M*

Hyalodiscus cf. *lentiginosus* John *P*

Lemnicola hungarica (Grunow) Round & Basson *M*

Luticola cf. *mutica* (Kützing) D.Mann *M P*

†Melosira cf. *dickiei* (Thwaites) Kützing

Melosira varians Agardh *M*

Meridion circulare (Greville) Brun *M*

Navicula cincta (Ehrenberg) Ralfs *M P*

Navicula cf. *cryptocephala* Kützing *M*

Navicula cf. *lanceolata* (Agardh) Ehrenberg *P T*

Navicula rhynchocephala Kützing *M P*

Navicula cf. *salinarum* Grunow *M bw*

Navicula cf. *tenelloides* Hustedt *M*

Neidium cf. *iridis* (Ehrenberg) Cleve *P*

Neidium productum (W. Smith) Cleve *M P*

Nitzschia dissipata (Kützing) Grunow *M* (p)

Nitzschia cf. *dubia* W. Smith *M*

Nitzschia nana Grunow in Van Heurck *P*

Nitzschia cf umbonata (Ehrenberg) Lange-Bertalot

Nitzschia cf. *palea* (Kützing) W. Smith *M P*

Nitzschia cf. *paleaeformis* Hustedt *M*

Nitzschia cf. *prolongata* Hustedt *M*

Nitzschia sigma (Kützing) W. Smith *M (p)* (p) *P bw*

Nitzschia sociabilis Hustedt *M (p) T*

Pinnularia appendiculata (Agardh) Cleve *M*

Pinnularia borealis fo. *rectangularis* Carlson *M*

Pinnularia divergentissima (Grunow) Cleve *M*

Pinnularia cf. *gibba* Ehrenberg *M P*

**Pinnularia* cf. *lundii* Hustedt *P*

Pinnularia cf. *maior* (Kützing) Rabenhorst *(p) M*

Pinnularia cf. *microstauron* (Ehrenberg) Cleve *M*

Pinnularia cf. *subcapitata* Gregory *M P*

Pinnularia cf. *viridis* (Nitzsch) Ehrenberg *M*

Placoneis exigua (Gregory) Mereschkowsky *M P*

Planothidium delicatulum (Grunow) Round & Bukhtiyarova *M P* (p) *bw*

Planothidium cf. *frequentissimum* (Lange-Bertalot) Lange-Bertalot *M*

Planothidium pericavum (Carter) Lange-Bertalot *P*

Psammothidium cf. *oblongellum* (Östrup) Van de Vijver *M*

Rhopalodia cf. *gibberula* (Ehrenberg) O. Müller *P*

Sellaphora pupula (Kützing) Mereschkowsky *M*

Stauroneis cf. *anceps* Ehrenberg *M*

Stauroneis frauenfeldiana (Grunow) Heiden *M*

Stauroneis cf. *kriegerii* Patrick *M P*

Staurosirella cf. *martyi* (Héribaud) Morales *T*

Surirella cf. *brebissonii* Krammer & Lange-Bertalot *M*

Surirella cf. *angusta* Kützing *M P*

Surirella cf. *minuta* Brebisson *P*

Tryblionella cf. *aerophila* (Hustedt) D.G. Mann *T*

Tryblionella cf. *debilis* Arnott ex O'Meara *M*

Tryblionella hungarica (Grunow) Frenguelli *P*

Ulnaria ulna cf. *var amphirhynchus* (Ehrenberg) Aboal *M*

APPENDIX 2: MARINE DIATOMS

* new record for New Zealand, *M* = Mana Is, *P* = Porirua Harbour (Te Onepoto Bay), *S* = west end Titahi Bay (Stuart Park), *T* = main Titahi Bay, *W* = Whitireia Park (Onehunga Bay), underlined from a marine sample, *bw* = prefers or tolerates brackish water, (p) (t) = *P*, *T* from Cochran (2002) and (*p*) = *P* from Stidolph (1980); † identification made since Bioblitz.

Achnanthes brevipes var. *intermedia* (Kützing) Cleve *(p) S T W bw*

**Achnanthes* cf. *groenlandica* (Cleve) Grunow

Achnanthes longipes Agardh *(p) S*

Achnanthes parvula Kützing *M bw*

Actinocyclus octonarius Ehrenberg *T*

A. octonarius var. *ralfsii* (W. Smith) Hendey *(p) T*

A. octonarius var. *sparsus* (Gregory) Hendey *T*

Actinoptychus splendens (Shadbolt) Ralfs *(p) T*

Amphora coffeaeformis (Agardh) Kützing (p) *W bw*

Amphora cf. *exigua* Gregory *T bw*

Amphora cf. *graeffana* Hendey *W*

Amphora hyalina Kützing *W*

Amphora cf. *laevissima* Gregory *W*

Amphora cf. *marina* W. Smith *W*

Amphora pseudohyalina Simonsen *W*

Anaulus cf. *balticus* Simonsen *T* (t) *W*

Ardissonea crystallina (Agardh) Grunow *(p) W*

Ardissonea fulgens Grunow *(p) T*

†*Auliscus sculptus* (W. Smith) Ralfs in Pritchard *(p) P*

Biddulphia alternans (Bailey) van Heurck *(p) T*

Biddulphia antediluviana (Ehrenberg) van Heurck *W*

Biremis ambigua (Cleve) D Mann *(p) W bw*

Campylodiscus fastuosus Ehrenberg *M (p) T*

Campyloneis grevillei (W. Smith) Grunow *(p) W*

Catenula adhaerens Mereschkowsky (p) (t) *W bw*

Chaetoceros cf. *diadema* (Ehrenberg) Gran *W*

Chaetoceros cf. *didymus* Ehrenberg *W*

Chaetoceros cf. *eibenii* (Grunow) Meunier *W*

**Chaetoceros* cf. *lauderi* Ralfs *W*

Climacosphenia moniligera Ehrenberg *(p) T W*

Cocconeiopsis regularis (Hustedt) Witkowski et al. *T*

Cocconeis pellucida Grunow *W*

Cocconeis peltoides Hustedt (p) *T S bw*

Cocconeis cf. *molesta* var. *crucifera* Grunow *T*

Cocconeis scutellum Ehrenberg *(p)* (p) *T W bw*

C. scutellum var. *parva* (Grunow) Cleve *M* (p) *T* (t) *W*

Cocconeis speciosa Gregory *W*

Cocconeis stauroneiformis (W. Smith) Okuno *M M S T W*

Craticula cf. *halophila* (Grunow) Mann *S W*

Delphineis surirella (Ehrenberg) Andrews *(p) S* (t) *T W*

Dimeregramma minor (Gregory) Ralfs (p) *P W*

Diploneis cf. *bombus* (Ehrenberg) Ehrenberg *P bw*

Diploneis litoralis (Donkin) Cleve *W*

Diploneis smithii (Brébisson) Cleve *(p) W bw*

D. smithii var. *rhombica* Mereschkowsky *P*

Diploneis vacillans cf. var. *renitens* (Schmidt) Cleve *T W*

Ehrenbergiulva granulosa (Grunow) Witkowski et al. (t) *W bw*

Entopyla cf. *ocellata* var. *pulchella* (Arnott) Fricke *T*

Eunotogramma laevis Grunow *W bw*

Eunotogramma cf. *marinum* (W. Smith) Peragallo *T W*

Fallacia cf. *forcipata* (Greville) Stickle & D. Mann *W bw*

Fallacia vittata (Cleve) D. Mann *(p pers comm Stidolph) W*

**Fragilaria* cf. *hyalina* (Kützing) Grunow *W*

**Gomphonemopsis obscurum* (Krasske) Lange-Bertalot *T*

Grammatophora angulosa Ehrenberg *(p) M*

Grammatophora hamulifera Kützing *M T W*

Grammatophora marina (Lyngbye) Kützing *(p) T W*

Grammatophora cf. *oceanica* Ehrenberg *T*

Gyrosigma rectum (Donkin) Cleve *P T*

Gyrosigma tenuissimum (W.M.Smith) Griffith et Henfrey *(p) T bw*

**†Haslea* cf. *ostrearia* (Gaillon) Simonsen *W*

Hyalinella lateripunctata Witkowski et al. *T*

Hyalosynedra laevigata (Grunow) Williams & Round *P T*

**Licmophora* cf. *abbreviata* Agardh *S T*

Licmophora cf. *communis* (Heiberg) Grunow *T*

Licmophora flabellata (Carmichael) Agardh *(p) T*

Licmophora gracilis var. *anglica* (Kützing) Peragallo *T*

Licmophora cf. *paradoxa* (Lyngbye) Agardh *T*

Lyrella atlantica (A. Schmidt) D.Mann *W*

Martyana schulzii (Brockman) Snoejis *S bw*

Melosira moniliformis (O. Müller) Agardh *M bw*

Melosira nummuloides (Dilwyn) Agardh *(p) P bw*

Navicula cancellata Donkin *P W*

Navicula cf. *digitoradiata* (Gregory) Ralfs *T bw*

Navicula directa (W. Smith) Ralfs *M W*

Navicula duerrenbergiana Hustedt in Schmidt et al *T W*

Navicula gregaria Donkin *W bw*

**Navicula* cf. *kuripanensis* Hustedt *T*

Navicula pavillardii Hustedt *T*

Navicula phyllepta Kützing *T bw*

Navicula ramosissima (Agardh) Cleve *(p) M*

**Navicula* cf. *syvertsenii* Witkowski et al. *T*

Neohuttonia cf. *reichardtii* (Grunow) Kuntze *W*

Nitzschia cf. *distans* Gregory *W*

**†Nitzschia* cf. *littorea* Grunow *W*

Nitzschia longissima (Brébisson) Ralfs *M (p) P*

Nitzschia cf. *pellucida* Grunow *M bw*

Odontella aurita (Lyngbye) C. Agardh *(p) S T W*

**Oestrupia* cf. *ergadensis* (Gregory) Witkowski *W*

Opephora cf. *olsenii* Möller *W*

Parlibellus cf. *rhombicula* (Hustedt) Witkowski et al. *P*

Paralia sulcata (Ehrenberg) Cleve *M (p) P* (t) *W*

†*Pinnularia woodiana* Foged *(p) W bw*

Plagiogramma appendiculatum Giffen *P W*

Plagiogrammopsis vanheurckii (Grunow) Hasle et al. *P*

**Plagiotropis* cf. *gibberula* Grunow *T*

Pleurosigma decorum W. Smith *(p) W*

Pleurosigma inscriptura M. Harper *P W*

Pleurosigma intermedium W. Smith *(p) W*

Pleurosigma perthense John *(p) T*

Pleurosigma cf. *strigosum* W. Smith *W bw*

Podocystis americana Bailey *(p) W*

Podosira montagnei Kützing *(p) T W*

Psammodictyon panduriforme (Gregory) Mann *W*

Rhabdonema adriaticum Kützing *(p) M*

Rhabdonema minutum Kützing *T bw*

Rhaphoneis amphiceros (Ehrenberg) Ehrenberg *(p)* (t) *W*

Rhizosolenia setigera Brightwell *T*

Rhoicosphenia genuflexa (Kützing) Medlin *S T*

Rhoicosphenia marina (Kützing) M.Schmidt *T*

**Seminavis* cf. *cymbelloides* (Grunow) D Mann *W*

Seminavis strigosa (Hustedt) Danielidis & Economou-Amilli *W*

**Stauronella* cf. *arctica* (Hustedt) Lange-Bertalot *W*

Stauroneis phoenicenteron (Nitzsch) Ehrenberg *P*

Stephanopyxis turris (Greville & Arnott) Ralfs *M (p) W*

Striatella unipunctata (Lyngbye) Agardh *(p) W*

**Synedra* cf. *commutata* Grunow *T*

Shionodiscus cf. *oestrupii* (Ostenfeld) Alverson, Kang & Theriot 2006 *M T*

Tabularia cf. *fasciculata* (Agardh) Williams & Round *M P T W bw*

Tabularia investiens (W.Smith) Williams & Round *(p) T*

Tabularia tabulata (C.A.Agardh) Snoeijs *(p) M*

Thalassiosira eccentrica (Ehrenberg) Cleve *(p) W*

Thalassiosira cf. *gracilis* (Karsten) Hustedt *T W*

Trachyneis cf. *aspera* (Ehrenberg) Cleve *M W*

Trachysphenia australis Petit *T W*

Trachysphenia australis var rostellata Hustedt *W*

Triceratium dubium Brightwell *(p) T*

Trichotoxon cf. *reinboldii* (van Heurck) Williams & Round *T*

Trigonium reticulum (Ehrenberg) Simonsen *T W*

Tryblionella cf. *apiculata* Gregory *P bw*

Tryblionella cf. *coarctata* (Grunow in Cl. & Grun.) D.G. Mann *W*

Tryblionella cf. *levidensis* Wm. Smith var *salinarum M*

**Tryblionella* cf. *littoralis* (Grunow) D G Mann *W*