Duplicate

Sensitivity of freshwater algal communities to environmental variables in wetlands in Betty's Bay and Onrust in the Western Cape, South Africa

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Abstract

This study was a first attempt at investigating whether algal groups respond to environmental differences including human impacts in wetlands in the Western Cape of South Africa. Samples were collected from three permanent and three temporary wetlands in Betty's Bay and a temporary wetland in Onrust, near the town of Hermanus. The environmental variables which were measured were pH, conductivity, water depth, whether wetlands were temporary or permanent and whether the samples were from the wetland or from waterlogged soils next to the wetlands. The wetlands sampled were found to be very similar and overall there was not a strong species response to the environmental variables. When only the diatom species data were analysed, however, it was possible to differentiate between samples from Bass Lake and Vermont Vlei. These wetlands had contrasting pH and conductivity values, with Bass Lake having an average pH of 6.8 and a mean conductivity of 262.5 µS/cm and Vermont Vlei having an average pH of 8.4 and 152.1 µS/cm for the average conductivity value. This suggests that diatom species are sensitive to small differences in pH and conductivity. Diatoms were found on average to make up 91% of the taxa sampled in the different wetlands and were ubiquitous in their distribution among the different wetlands. The algal taxa that occurred in the greatest number of samples included *Amphora sp., Cymbella sp., Navicula sp., Nitzschia sp., Pinnularia sudetica, Rhizoclonium hieroglyphicum, Surirella sp.* and *Synedra sp.*. The average Shannon-Wiener biodiversity index was 3.53 for the seven wetlands. It is recommended that in future studies there should be greater standardisation in sampling with specific micro-habitats sampled to make algal groups comparable. It is also possible that a greater number of wetlands with a wider range in water chemistry properties are needed to be able to detect clear algal species responses to environmental gradients.

Introduction

Wetlands are often difficult to define as they encompass a wide range of biotopes. In general, a common definition of a wetland is an area where the soil is more or less permanently waterlogged (Stevenson *et al.* 1996; Davies and Day 1998). The soils tend to be dark in colour due to anaerobic conditions and release hydrogen sulphide. These

habitats are threatened due to urban encroachment and human activities (Gibbs 2000). It is therefore becoming increasingly important to successfully manage and protect these delicate aquatic ecosystems. Analytical studies measuring the toxicity levels of chemical pollutants are expensive and on their own are insufficient to account for the frequent fluctuations which can occur in aquatic environments (Harding *et al.* 2005). The disadvantage of measuring pollution directly is that an observation in one habitat may not necessarily be comparable to those made in other habitats and cannot be used predictively (Cairns 1981). Often pollutants may have synergistic effects with others and measuring individual toxic substances in isolation may not reveal their full effect on the ecosystem (Adamus and Brandt 1990; Karr and Chu 1997).

Bioassessment in wetlands enables researchers and managers to assess the "health" of these habitats and their ability to support life as opposed to just measuring their chemical properties (Harding *et al.* 2005). It has been noted in other studies which have used biological assemblages as indicators, that they are good at showing the integrated effects of environmental factors (Adamus and Brandt 1990). One of the main forms of bioassessment that has been used in South Africa is the South African Scoring System (SASS), which uses aquatic invertebrates to assess water quality (Davies and Day 1998). Whilst this has been effective in assessing water quality in riverine habitats it is not suited for testing wetland water conditions (Harding *et al.* 2005). Benthic algae in general have been recognised as good indicators of the health of aquatic ecosystems (Stevenson *et al.* 1996). Algae are found in most water bodies capable of supporting photosynthesis and provided that there is enough moisture present, even if only intermittently, algae can develop in a range of terrestrial habitats (John *et al.* 2002). They form the base of food chains and their absence may have long term effects on the environments in which they no longer occur (Truter 1987; Joska and Bolton 1994; Harding *et al.* 2006). They also have rapid reproductive rates and life cycles and so are quick to respond to changes in water conditions (Adamus and Brandt 1990). There are a variety of freshwater algae ranging from single celled and microscopic forms which may occur individually or in colonies, through filamentous groups which consist of continuous rows or networks of cells to large, multi-celled macro-algae (Truter 1987; Joska and Bolton 1994). The

majority of algal species are microscopic and are only visible to the naked eye when they are present in large numbers and discolour the water or form surface growths (John *et al.* 2002).

Diatoms have already been used in riverine and some wetland water quality assessment in other parts of South Africa and the world (Harding *et al.* 2006). Their community structure has been found to show a strong response to environmental factors such as: water chemistry; disturbances such as desiccation or flooding; nutrient and other resource availability; grazing by other aquatic organisms and the amount of light that penetrates their different microhabitats (Harding *et al.* 2005). It is possible that other algal groups could also be useful and prove to be a relatively inexpensive monitoring method. Benthic or bottom-dwelling algae (periphyton) and phytoplankton communities have often been used in integrated assessments of physical, chemical and biological aspects of water quality (Porter *et al.* 1993). Qualitative algal samples give an idea of the occurrence of algal species in as many of the available periphyton microhabitats as possible (Porter *et al.* 1993). Typical periphyton microhabitats include submerged surfaces to which algae can attach and areas such as vegetation stems, where algal biomass can accumulate.

The main objective of this project was to see if freshwater algal communities are reflective of varying water quality conditions in wetlands in the Cape Peninsula of South Africa. By assessing the algal flora present in several temporary and permanent wetlands in the Betty's Bay area and a temporary wetland in Onrust, near Hermanus, this study will assess whether or not distinct suites of algal communities are found in these differing habitats and can perhaps be used to assess human impact in these wetlands. This study aims to see if freshwater algae in areas in the Western Cape show clear distribution patterns in response to physical-chemical gradients. Due to the fact that benthic algae are often attached to solid substrates they are directly affected by physical, biological and chemical disturbances (Stevenson and Bahls 1990). Diatoms and other algae have been found to respond rapidly to environmental variables such as nutrients, heavy metals, salinity, dissolved organic carbon and pH (Pan and Stevenson 1996). In this study the two environmental variables that were measured were water pH and conductivity.

Conductivity is a good indicator of overall salinity and dissolved material as it is a function of the number of ions in solution (Dallas and Day 2004). Permanent and temporary wetlands were also compared. The algae were mainly collected from the littoral zone and the epiflora on aquatic macrophyte vegetation (flowering plants) was noted. Soil samples were also collected and the algae present in these were recorded.

Besides the possibility of using algae in bioassessment of wetlands in the Cape Peninsula in the future, this project will also provide valuable information on the algal species present in these wetlands. As noted by Pocock (1966), the algal flora of the Cape has been relatively under-studied. Although extensive sampling of diatom communities in South African aquatic systems was carried out in the early to mid 20th century, these algal groups have been neglected until recently (Harding *et al.* 2005). It is only in the last decade that a renewed interest in these assemblages has been developed and the Water Research Commission of South Africa is currently funding research on this flora and how it relates to water quality.

Methods

Study sites

Locations were chosen to represent a range in natural and anthropogenic factors that might influence water quality and therefore be reflected in algal communities. The first wetland sampled from was a temporary wetland called Vermont Vlei in Onrust, near the town of Hermanus in the Western Cape (Fig. 1). This wetland was located in the foothills zone and was impacted by urban encroachment. Many of the houses around the wetland were less than 20 m from the water's edge and there was sewage effluent entering the wetland from septic tanks in the area. There was also a large stand of alien vegetation on the one side of the wetland and thick beds of *Typha* around it. The other six wetlands were all located in Betty's Bay (Fig. 1). Three of them were permanent (Bass Lake, Grootvlei and Rondevlei) and three were temporary (wetlands on Lachenalia, Hibiscus and White Roads). Bass Lake had a sign next to it indicating that at times there are toxic algal blooms and there were septic tanks in the area which possibly seep into this

wetland. The other two permanent wetlands had tannin rich waters and appeared to be slightly less impacted, although they all face the threat of urban encroachment.

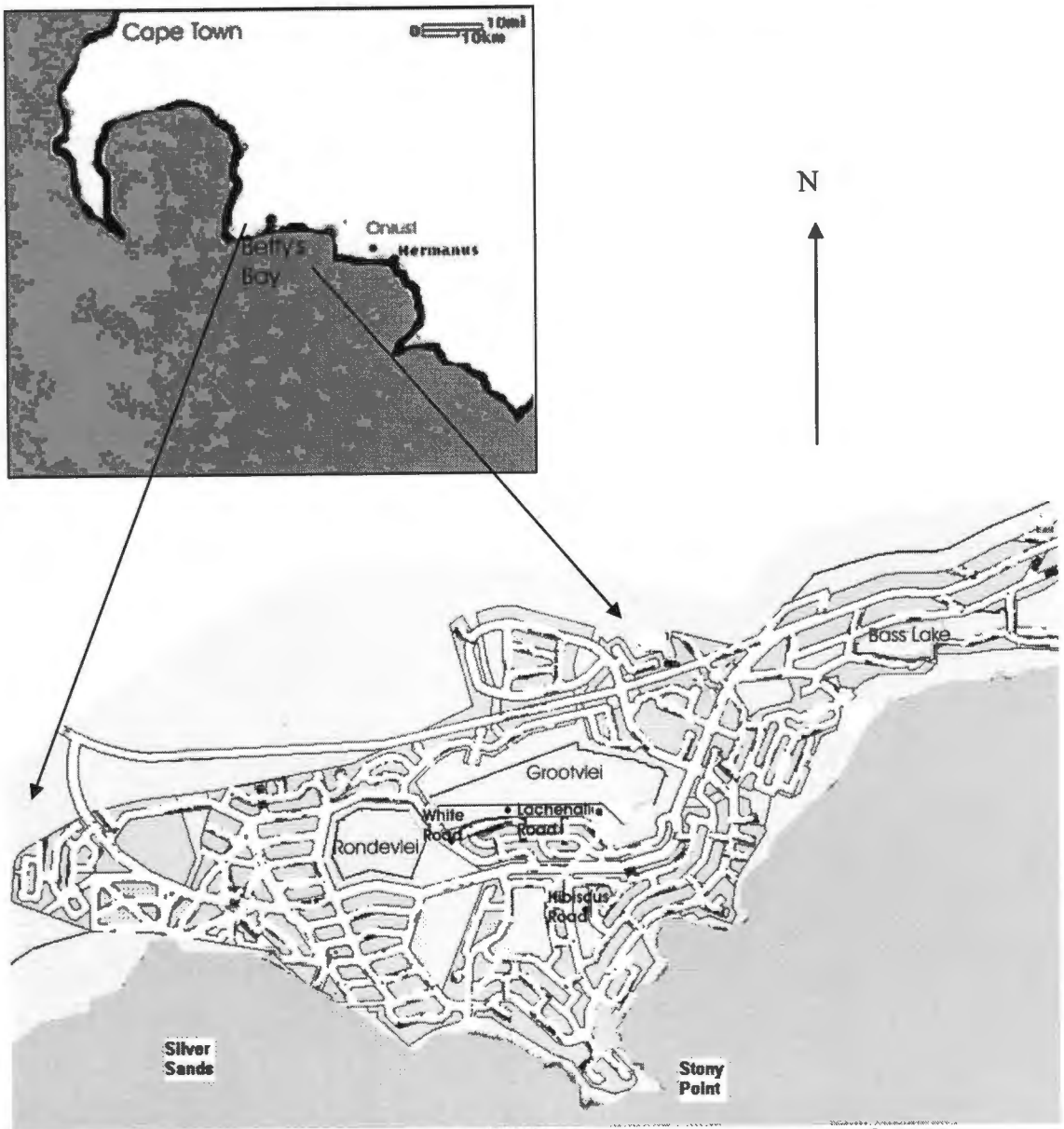


Fig. 1. Map showing the locality of Betty's Bay (34°21`47S, 18°53`24E) and Onrust (34°40`89S, 19°15`05E) and where the study sites were situated within Betty's Bay.

Field work

This study was conducted over three days in July 2006. Samples were collected from a number of different microhabitats. Microhabitats include: rock surfaces; submerged vegetation roots; surfaces of aquatic vegetation and wetland soils (Porter *et al.* 1993). In general aquatic plants provide an important niche for plankton and tend to increase the

diversity of algae and other micro-organisms found in an aquatic habitat. Samples were therefore taken from around aquatic vegetation in the wetlands sampled. Standard 500 ml jars were used to collect algae from the various substrates and water surfaces. In wetlands the littoral zone, which is the region forming an interface between the land and the main water body, often has macrophytes established in it (Harding *et al.* 2006). The number of samples taken from each wetland varied depending on the amount of algae that was visibly present as algal mats and films and also on how different the littoral vegetation was (see Table 1 in the Appendix for details on where each sample was collected from). The water pH and conductivity were measured using a calibrated YSI pH100 pH meter and a YSI EC300 conductivity meter in the field. Soil samples were brought back to the laboratory where the pH and conductivity were measured using the procedure outlined by Pearcy *et al.* (1991). 50 ml of distilled water was added to 20 g of soil from each sample. The mixture was then stirred for ten minutes and left to stand for half an hour. The soil was subsequently stirred again and passed through a filter and the pH and conductivity of the filtrate was measured.

Laboratory work

Samples were left standing so that the algae would settle out (Harding *et al.* 2006). The algae were kept alive and slides were prepared and examined using 100x to 1000x magnification. The algae present were identified using taxonomic keys by Prescott (1981), Joska and Bolton (1994) and Cox (1996). This study was looking at all the algal groups present in the samples and diatom frustules were therefore not prepared separately. Diatoms were identified as far as possible using Cox (1996). Due to the large variation in size in the different algal groups sampled it was not possible to measure relative abundance and density. This is because the differences in the scales of size of the different algal taxa make comparisons difficult. A photographic record was made of the algal species found within the samples using a light microscope with a digital camera setup.

Statistical analysis

For the data analysis clustering and multivariate methods were carried out in the program Community Analysis Package (version 2.0) to see if the species assemblages of the different samples clustered into their respective wetland groupings. A Detrended Correspondence Analysis (DECORANA) of the samples was performed on all of the species data and then on just the diatom data using the default settings. Overall similarity between each of the wetlands was assessed using Euclidean distance measures, first using all of the species, and then with just the diatom species. Distribution patterns of the species and the different samples were related to the environmental variables of pH, conductivity, whether the wetland was permanent or not, whether the sample was from soil or water and water depth by Canonical Correspondence Analysis (CCA) in the programme Environmental Community Analysis (version 1.37). The data on whether wetlands were permanent or not were given binary scores of one if they were permanent and zero if they were temporary. Samples were also scored as one if they were soil samples and zero if they were water samples. A Monte Carlo test was used to test the significance of the canonical axes using 100 trials. Shannon Wiener biodiversity indices were calculated for each sample and for each wetland overall using the programme Species Diversity and Richness III (Pisces Conservation Ltd, version 3.0). The default settings of the programme were used when producing the Shannon Wiener biodiversity indices.

Results

The samples taken from the seven different wetlands do not show distinct clustering patterns when a DECORANA plot is generated using all of the species data (Fig. 2). Looking at the overall species list for the samples (Table 2), it can be seen that the dominant algal group present in all the samples was the diatoms. When only the diatom species are used the samples taken from the Vermont Vlei in Onrust and from Bass Lake in Betty's Bay form two rather distinct groupings at opposite ends of Axis 1 (Fig. 3). The samples from the other wetlands are scattered amongst them however. There is a slight differentiation between permanent and temporary wetlands in this DECORANA plot, however, this pattern is not strong. In both of the DECORANA plots samples On2, On11,

LR3, M5, BL1, BL2 and HR1 do not cluster together despite the fact that they were all soil samples and therefore collected from the same substrate (Fig. 2 and 3).

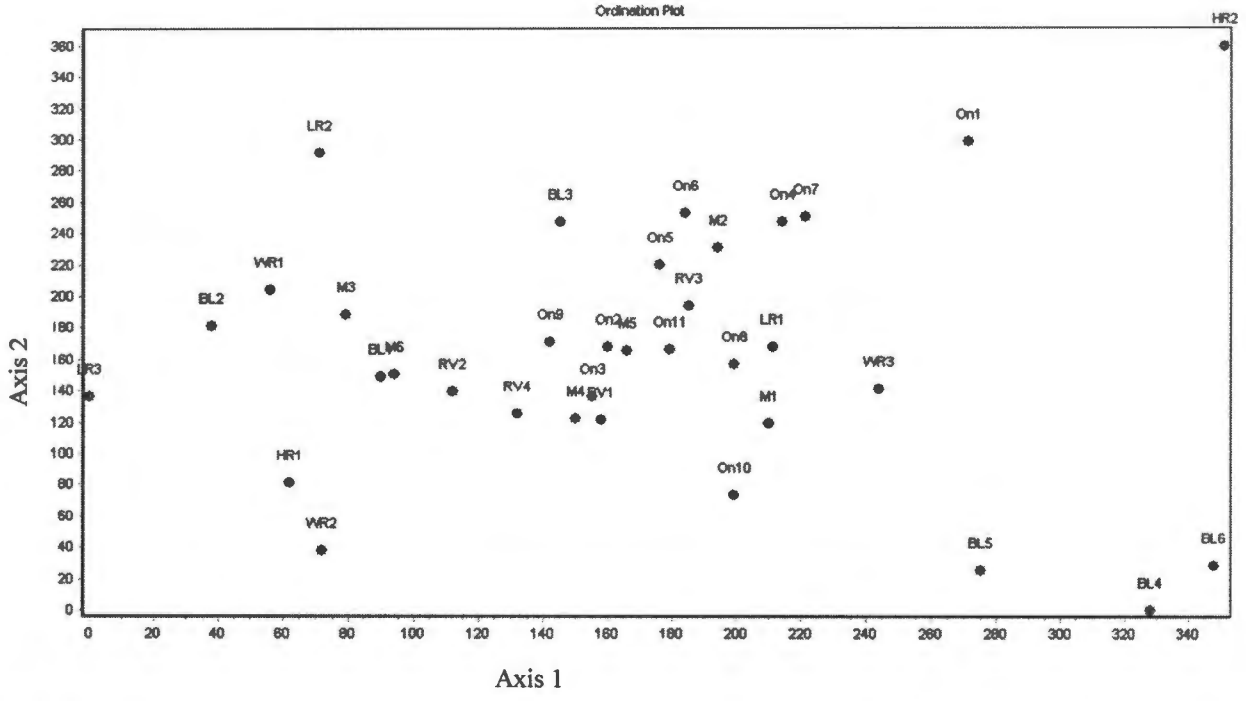


Fig. 2. Detrended Correspondence Analysis of the algal samples taken from wetlands in Betty's Bay and Onrust based on the general algal species found in the wetlands (eigenvalues Axis 1 = 0.49 and Axis 2 = 0.42). (On = Onrust, LR = Lachenalia Road, M = Grootvlei, BL = Bass Lake, HR = Hibiscus Road, RV = Rondevlei and WR = White Road.)

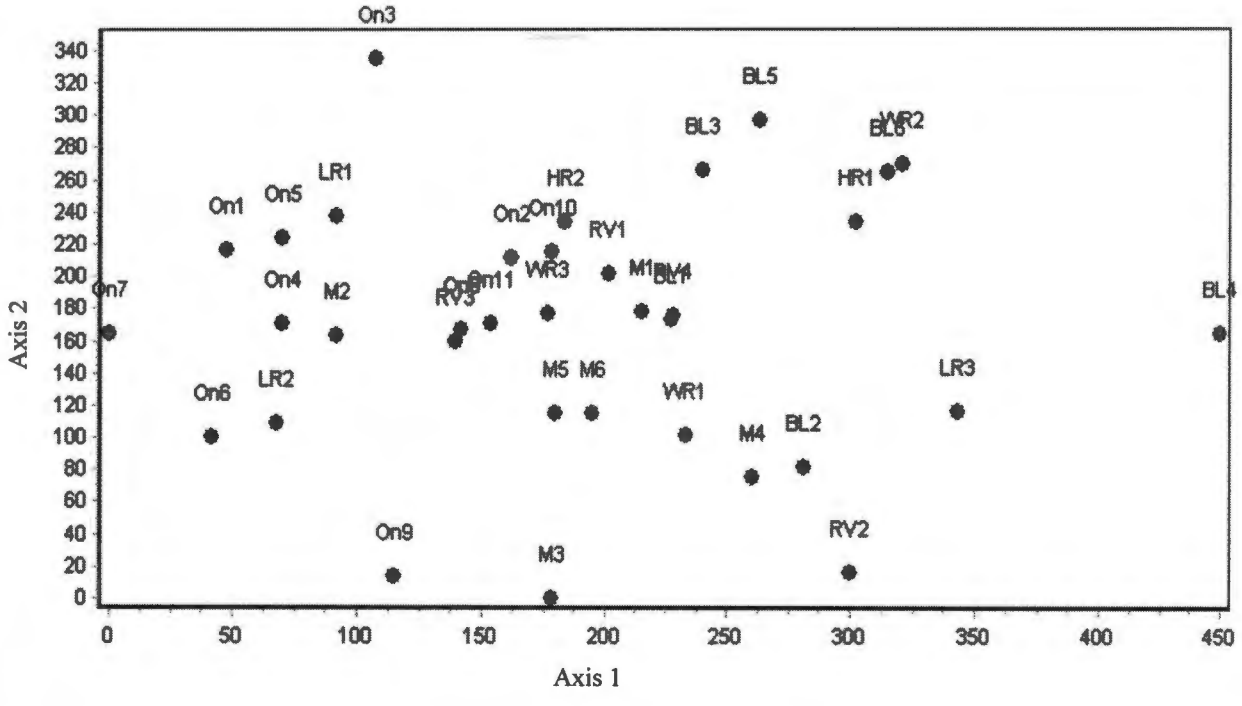


Fig. 3. Detrended Correspondence Analysis of the algal samples taken from wetlands in Betty's Bay and Onrust based on the diatom species found in the wetlands (eigenvalues Axis 1 = 0.51 and Axis 2 = 0.40) (On = Onrust, LR = Lachenalia Road, M = Grootvlei, BL = Bass Lake, HR = Hibiscus Road, RV = Rondevlei and WR = White Road.)

When the overall similarity between the species found in each of the wetlands is plotted in a dendrogram it can be seen that the wetland in Onrust forms a side branch to the grouping of wetlands found in Betty's Bay (Fig. 4). On the whole, the similarity between wetlands based on all the samples combined is low and temporary and permanent wetlands in Betty's Bay do not form distinct groups. When the similarity between wetlands is analysed using just the diatom species a similar pattern is observed (Fig. 5). Grootvlei shows a lower similarity than the wetland on Lachnalia Road to the grouping of the Hibiscus Road and White Road wetlands and Rondevlei.

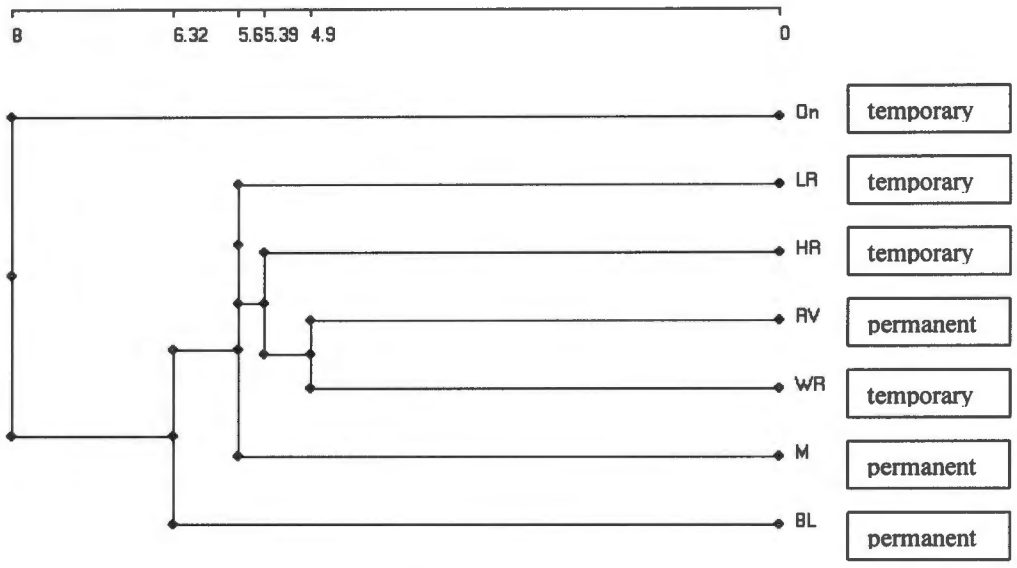


Fig. 4. Similarity plot based on Euclidean distance measures when samples for each wetland were combined to see the overall similarity of wetlands sampled from Onrust and Betty's Bay. (On = Onrust, LR = Lachenalia Road, M = Grootvlei, BL = Bass Lake, HR = Hibiscus Road, RV = Rondevlei and WR = White Road.)

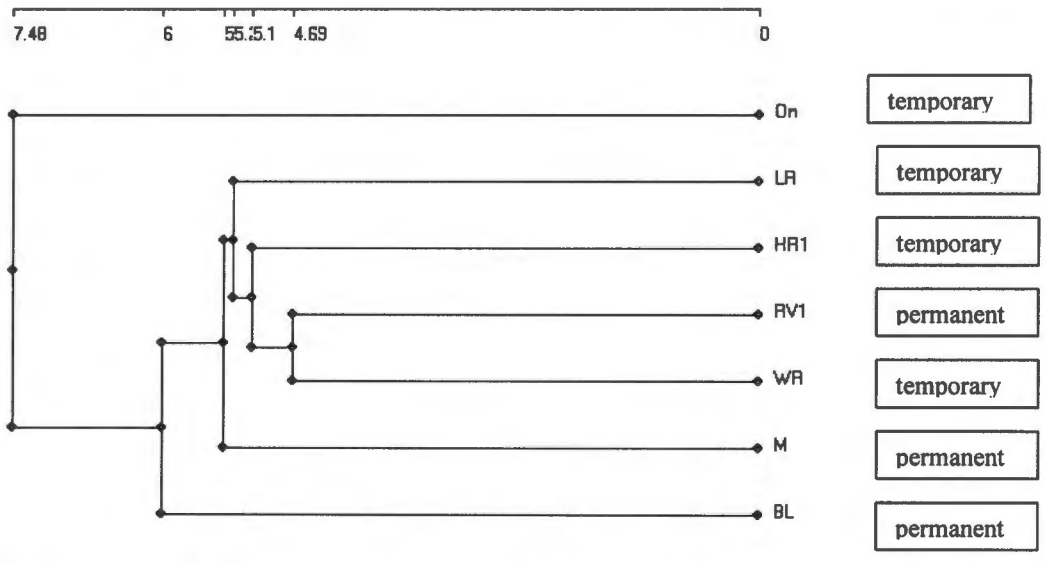


Fig. 5. Similarity plot using Euclidean distance measures where the samples for the wetlands studied in Onrust and Betty's Bay were combined to see the overall similarity of the wetlands based on the diatom species found in each of them. (On = Onrust, LR = Lachenalia Road, M = Grootvlei, BL = Bass Lake, HR1 = Hibiscus Road, RV1 = Rondevlei and WR = White Road.)

The CCA eigenvalues for all the species found in the different samples were 0.49 and 0.43 for Axes 1 and 2 (Fig. 6 and 7). The axes only accounted for 4.14% and 4.03% of the variance in the species-environment relationship. Monte Carlo permutations show that the first axis is not significant ($p > 0.05$, Fig. 6 and 7), whereas the second axis is ($p < 0.05$, Fig. 6 and 7). Based on the length of the vectors, pH and conductivity appear to

be the most important variables relating to species distribution in the different samples. Whether the wetland is permanent or temporary (denoted by the variable wetland) also seems to be an important factor. Species which are found in wetlands with higher pH values show a corresponding trend of being located in temporary wetlands with lower conductivity.

The CCA ordination for just the diatom species also showed that the principle axes did not capture a high proportion of the variance in the data (Fig. 8 and 9). The CCA eigenvalues for Axes 1 and 2 were 0.35 and 0.32 (Fig. 8 and 9) and they captured 4.18% and 3.91% of the variance in the species-environment relationship. Monte Carlo permutations indicated that the first axis is not significant ($p > 0.05$, Fig. 8 and 9), whilst the second axis is ($p < 0.05$, Fig. 8 and 9). Whether the wetland was temporary or permanent was strongly associated with the first axis and pH and conductivity were again seen to be important variables influencing the distribution of the diatom species. Species found in wetlands with a higher pH were again seen to also be in temporary wetlands with lower conductivity. It can be seen that the samples from Bass Lake follow the gradient of higher conductivity and are in a permanent wetland with lower pH. The species in the samples from Onrust show a response to higher pH and being in a temporary wetland (Fig. 6 and 8). Based on the intraset correlations of the different environmental variables (Table 3) it is evident that Axis 1 represents gradients in whether the wetland is permanent or temporary and conductivity while Axis 2 is linked with pH in both CCA ordinations.

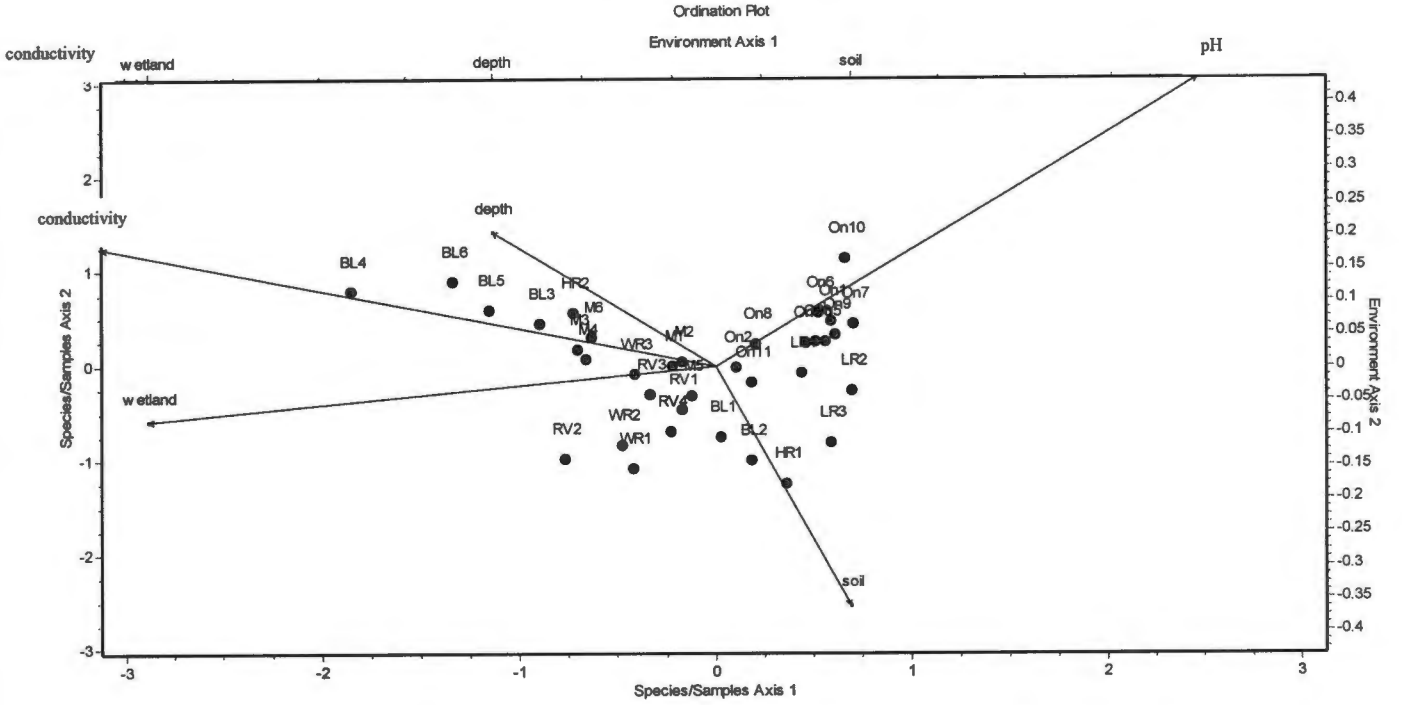


Fig. 6. Canonical Correspondence Analysis ordination diagram of the site-environmental biplot for all the algal species found in wetlands in Onrust and Betty's Bay. (The Canonical eigenvalues for Axis 1 = 0.49 and Axis 2 = 0.43, the mean Monte Carlo eigenvalues for Axis 1 = 0.33 (p = 0.22) and Axis 2 = 0.29 (p = 0.02))

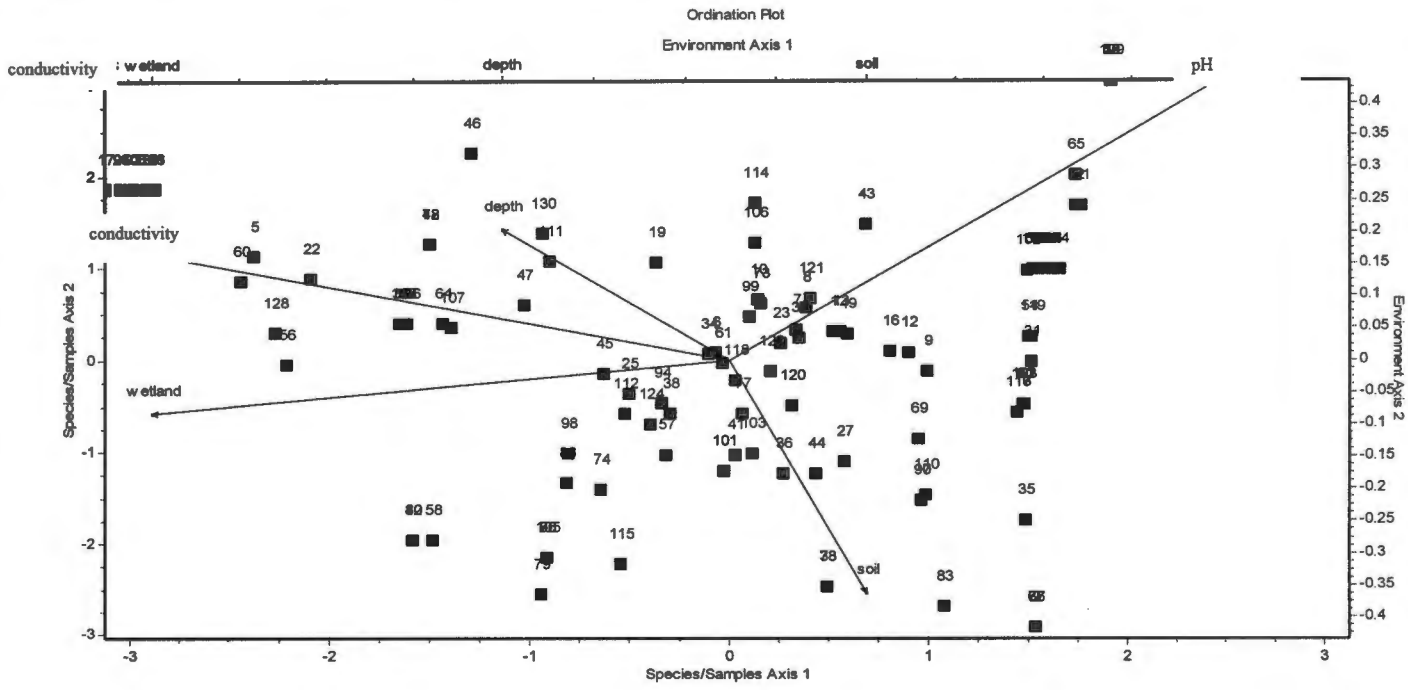


Fig. 7. Canonical Correspondence Analysis ordination diagram of the species-environmental biplot for all the algae species found in wetlands in Onrust and Betty's Bay. (The Canonical eigenvalues for Axis 1 = 0.49 and Axis 2 = 0.43, the mean Monte Carlo eigenvalues for Axis 1 = 0.33 (p = 0.22) and Axis 2 = 0.29 (p = 0.02))

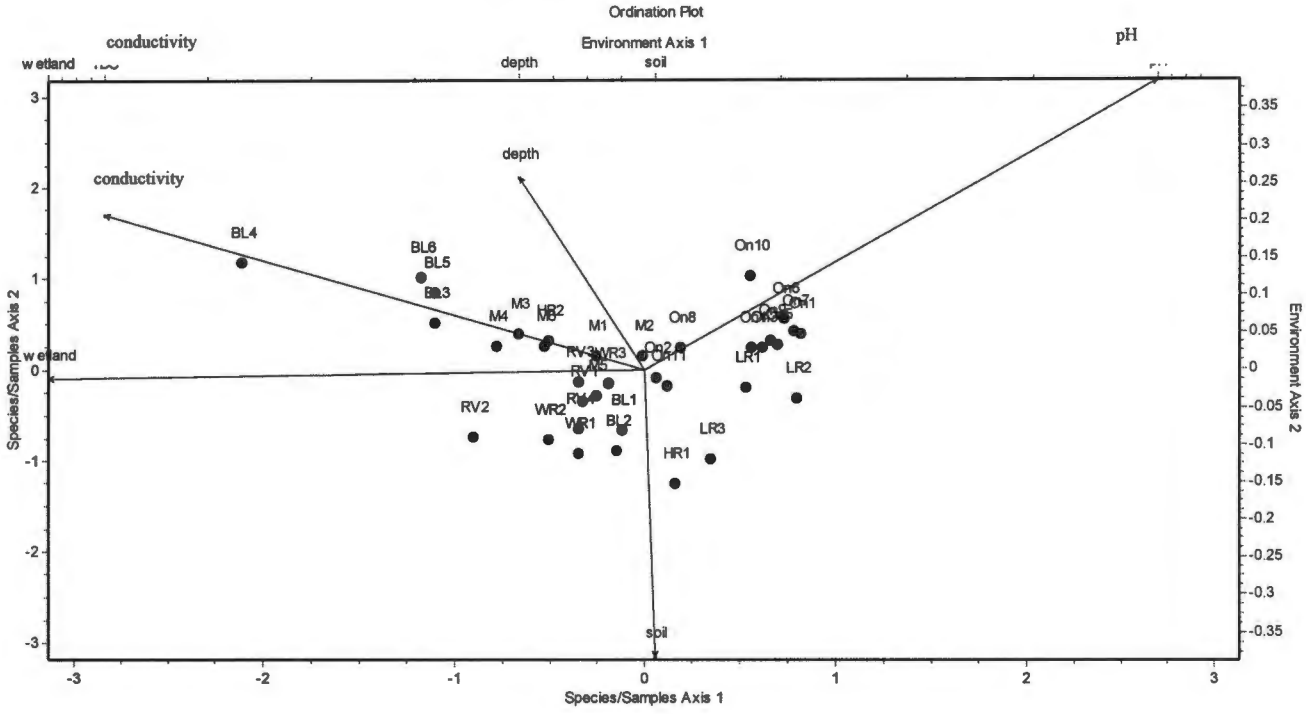


Fig. 8. Canonical Correspondence Analysis ordination diagram of the site-environmental biplot for diatom species found in wetlands in Onrust and Betty's Bay. (The Canonical eigenvalues for Axis 1 = 0.35 and Axis 2 = 0.32, the mean Monte Carlo eigenvalues for Axis 1 = 0.33 (p = 0.16) and Axis 2 = 0.28 (p = 0.02)).

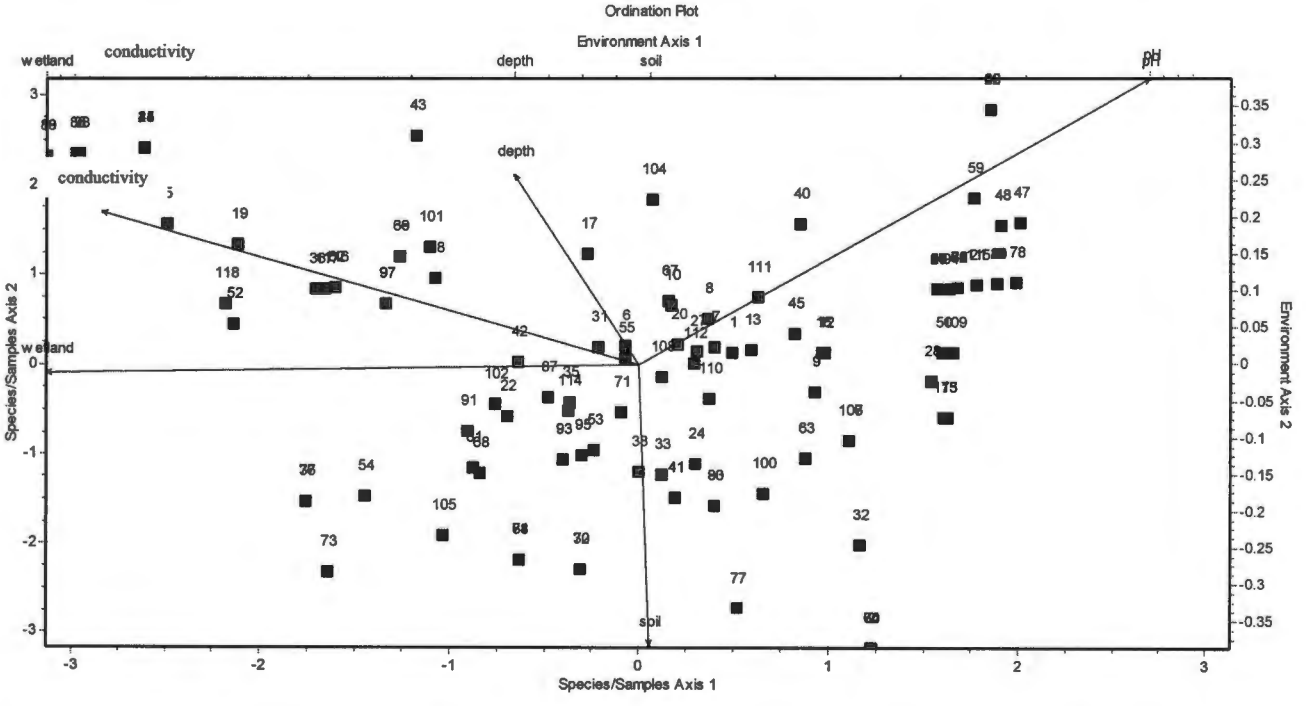


Fig. 9. Canonical Correspondence Analysis ordination diagram of the species-environmental biplot for diatom species found in wetlands in Onrust and Betty's Bay. (The Canonical eigenvalues for Axis 1 = 0.35 and Axis 2 = 0.32, the mean Monte Carlo eigenvalues for Axis 1 = 0.33 (p = 0.16) and Axis 2 = 0.28 (p = 0.02)).

Table 3. Intraset correlations of environmental variables for the canonical correspondence analysis of all the species data and the diatom data.

	All species		Diatoms	
Intraset correlations	Axis 1	Axis 2	Axis 1	Axis 2
pH	0.38	0.43	0.41	0.38
Conductivity	-0.48	0.17	-0.43	0.20
Depth	-0.17	0.20	-0.10	0.25
Wetland (temporary or permanent)	-0.45	-0.08	-0.48	-0.01
Soil	0.10	-0.36	0.008	-0.38

Comparing the pH and conductivity values across the different wetlands, it can be seen that the wetlands in Onrust and Lachenalia Road had lower conductivity values, but higher pH values than the other wetlands (Fig. 10). Overall it can be seen that the greatest biodiversity was present in Vermont Vlei in Onrust (Table 4). Within the samples taken from this wetland however there was considerable variation in species diversity (Fig. 11) and when all the samples are compared there is no distinctive pattern in species diversity in the different samples. It is evident that the dominant algal group in all of the wetlands sampled was the diatoms or Bacillariophyta (Table 4). Chlorophyta were also present in all of the sites, however, there were fewer taxa present. Besides diatoms, one other Chrysophyte species, *Tribonema sp.*, is present in Vermont Vlei in Onrust.

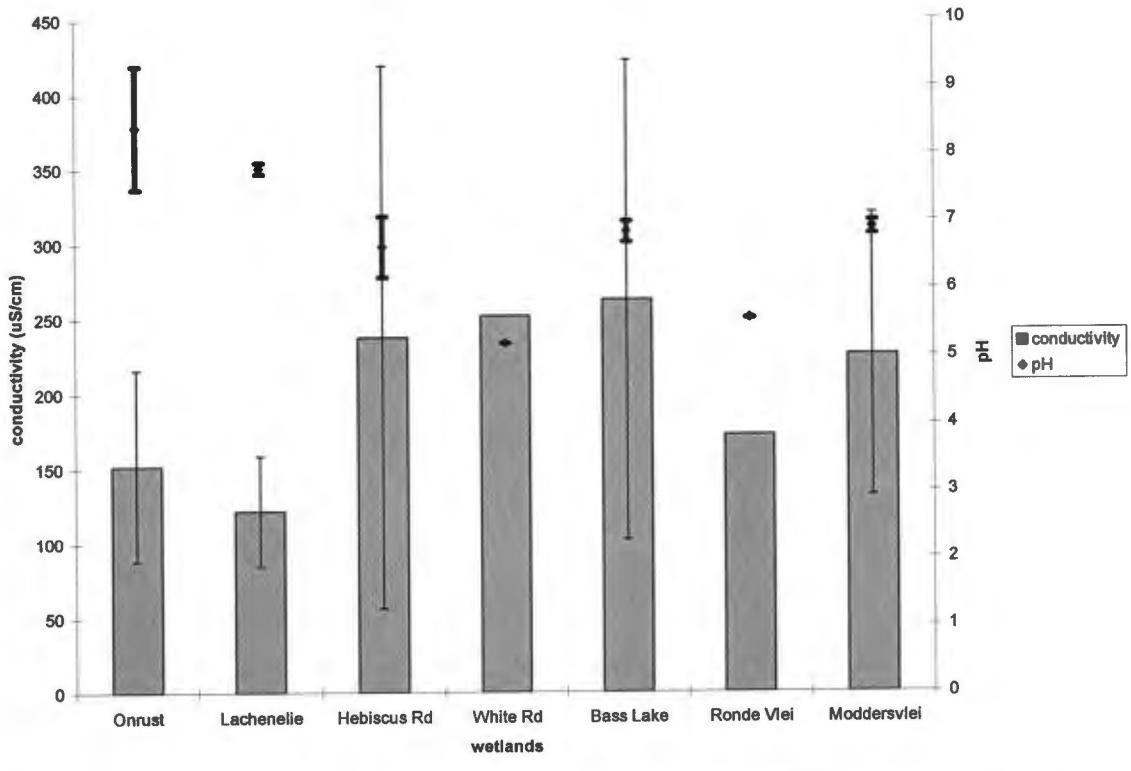


Fig. 10. Relationship between average pH and conductivity at each of the wetlands sampled from in Onrust and Betty's Bay with standard error bars (n = 2).

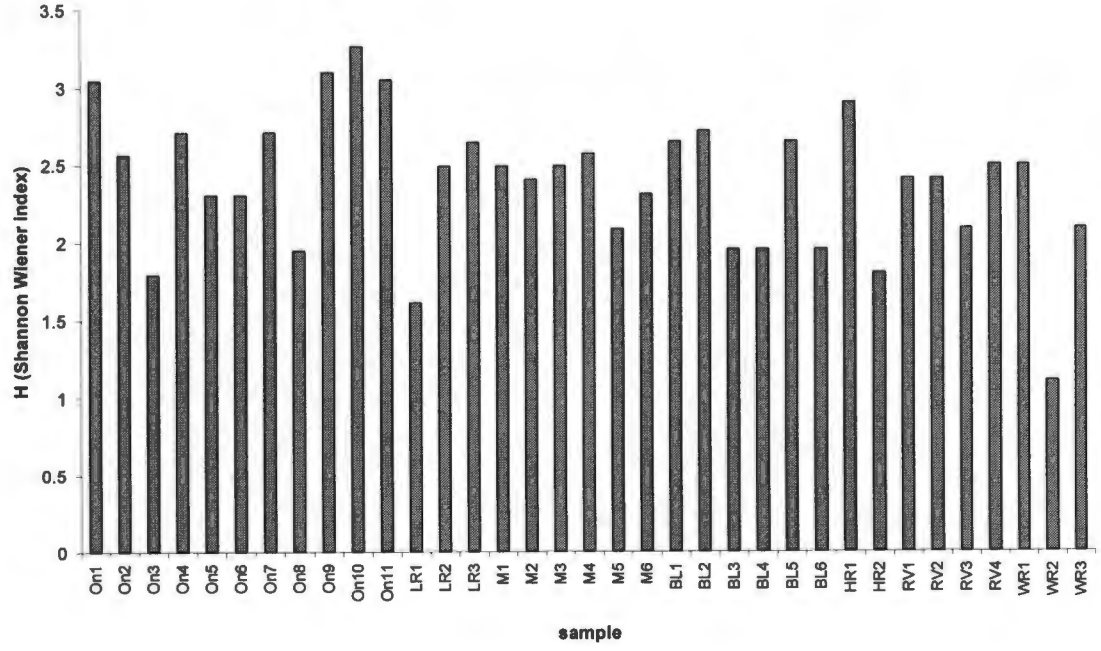
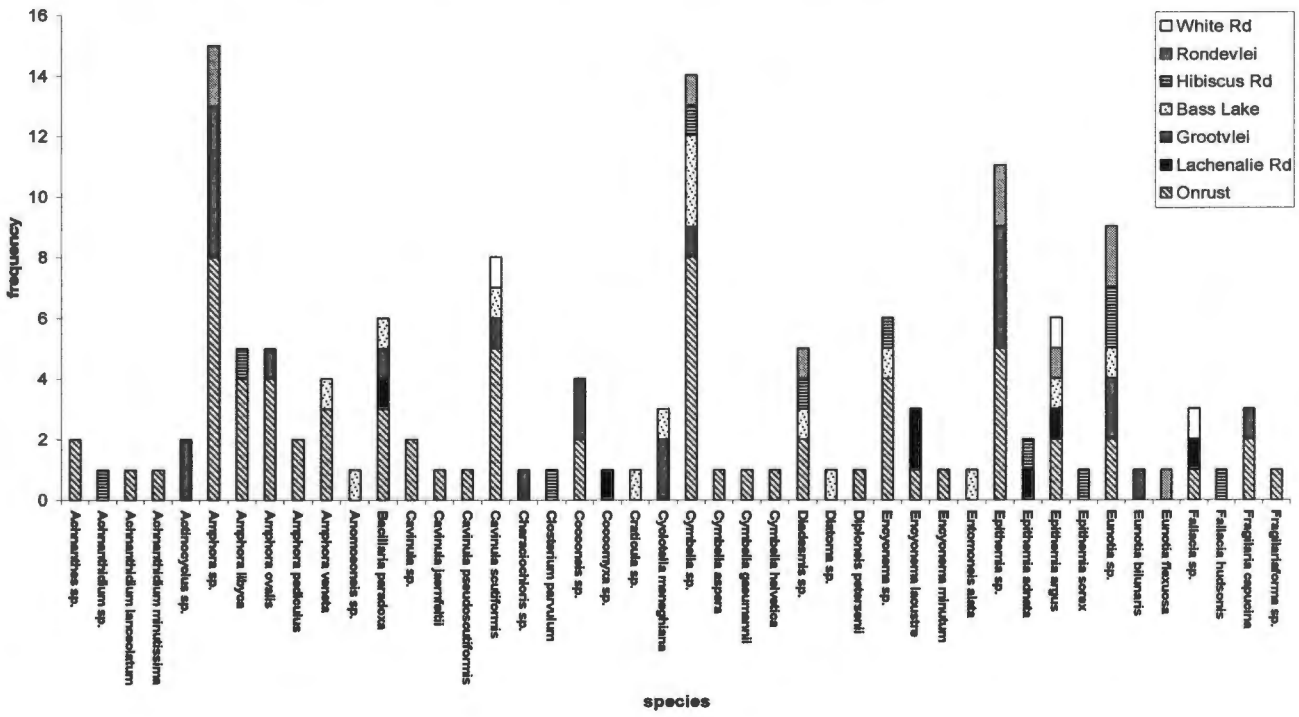


Fig. 11. The Shannon Wiener biodiversity indices for each of the samples taken from wetlands in Onrust and Betty's Bay.

Table 4. Overall Shannon-Wiener Biodiversity indices for each of the wetlands sampled from in Betty's Bay and Onrust and the representation of the major taxa within these wetlands from all of the samples collected.

	Onrust	Lachenalia Road	Grootvlei	Bass Lake	Hibiscus Road	Ronde Vlei	White Road	Average
Shannon-Wiener Biodiversity index	4.34	3.37	3.66	3.85	3.09	3.29	3.13	3.53
Bacillariophyta (Diatoms)	72	26	36	41	21	26	18	34.2
Chlorophyta (green algae)	4	3	4	5	2	1	3	3.1
Chrysophyta (yellow-brown algae)	1	0	0	0	0	0	0	0.1

Looking at the frequency of occurrence of each of the algal species in all of the samples, it can be seen that *Amphora sp., Cymbella sp., Navicula sp., Nitzschia sp., Pinnularia sudetica, Rhizoclonium hieroglyphicum, Surirella sp.* and *Synedra sp.* were found in the highest number of samples (Fig. 12). *Navicula sp., Nitzschia sp., Pinnularia sudetica* and *Surirella sp.* were found in all of the wetlands whilst the remaining species were less ubiquitously distributed, with 49% of the species found in only one sample.



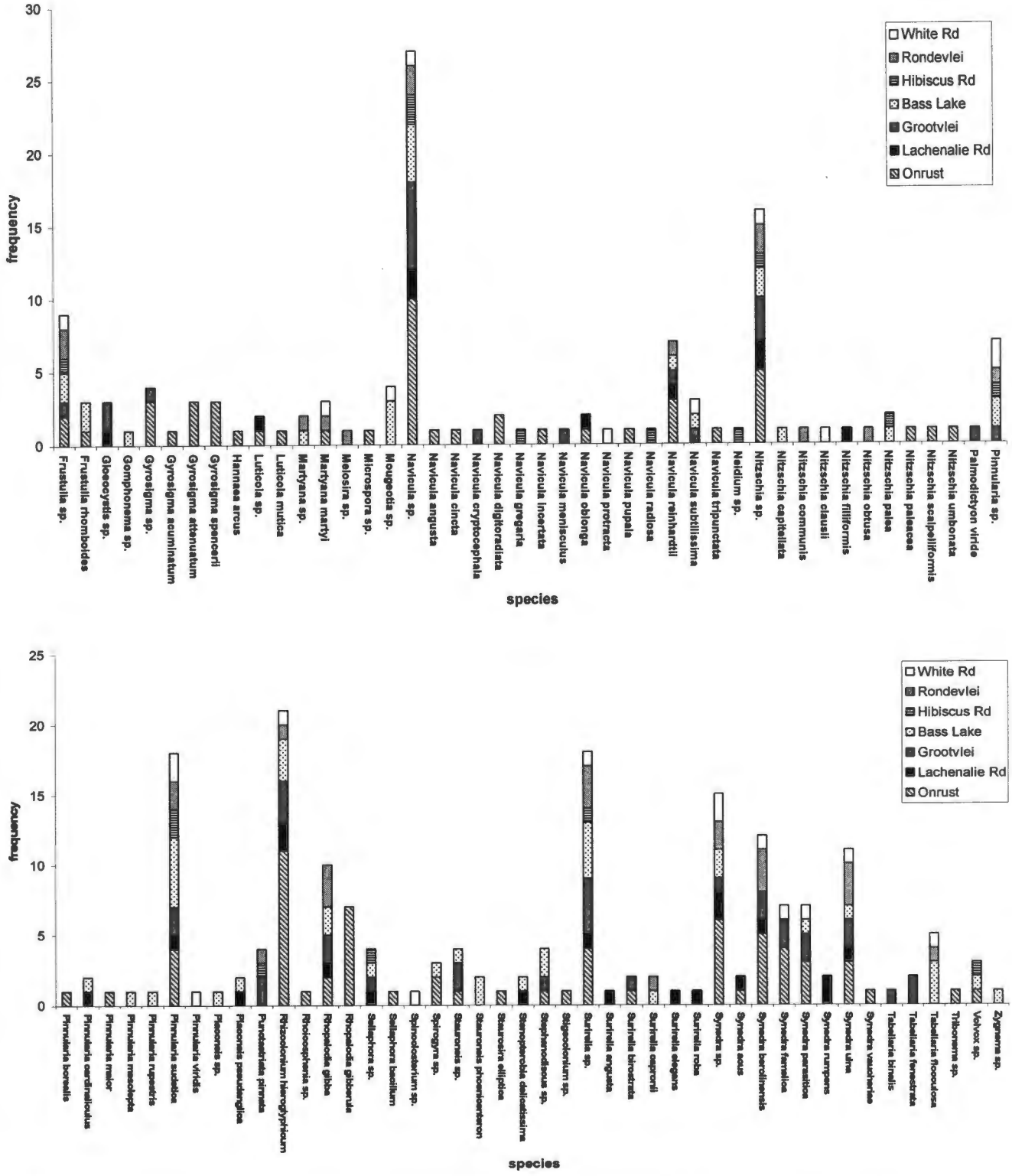


Fig. 12. Frequency of occurrence of algal taxa out of the 35 samples taken in wetlands in Betty's Bay and Onrust.

Discussion

The wetlands sampled in this study represent sites varying in their degree of human impact and corresponding environmental variables. However, the environmental variables measured and the species compositions of these sites did not differ considerably. The waters of the south-western Cape are usually slightly acidic due to low-nutrient soils and large quantities of secondary polyphenolic plant compounds from the fynbos vegetation (Dallas and Day 2004). The pH values recorded in this study were relatively neutral however. Although there was only a small range in pH and conductivity there was some differentiation between diatom species present in Vermont Vlei and Bass Lake. Vermont Vlei had a lower conductivity and slightly more alkaline conditions whereas Bass Lake was more acidic and had higher conductivity. Bass Lake possibly has a higher conductivity than Vermont Vlei as it is closer to the sea and it has been documented that coastal wetlands often have greater salt content due to high quantities of sea salt being present in the air (Dallas and Day 2004). The diatom assemblages in Bass Lake and Vermont Vlei showed a degree of clustering and this related to the differences in their pH and conductivities. The differential grouping of these two wetlands was not as clearly defined when all the algal species found in the samples were considered and this suggests that diatom species may be more sensitive than the other algal groups. It is acknowledged by Adamus *et al.* (2001) that diatoms are noted for being particularly sensitive to pH, and a study by Pan and Stevenson (1996) found that conductivity influences diatom species distributions.

Wetlands have been described as mosaics of diverse habitats and may show significant variation in the amount of habitat heterogeneity found within them (Pan and Stevenson 1996). The results from this study suggest that the diatom species were to a certain extent reflective of overall environmental conditions with their occurrence being influenced by pH and conductivity. This was despite the fact that the species compositions of samples taken from the various microhabitats within each wetland were different to each other. Even though diatoms occurring in the water column have been found to respond to environmental variables in a different manner to those found on macrophytes, it has been shown that planktonic and epiphytic diatoms provide complementary information on

wetland conditions (Pan and Stevenson 1996). The open-water biotope was not really sampled in this study and this should be examined in future studies. When samples collected from specific microhabitats were compared across the wetlands in Onrust and Betty's Bay they had dissimilar species compositions across the wetland samples. From the cluster analysis it can be seen that the soil samples from the different wetlands did not cluster together. This showed that different algal species were found within this particular biotope across the wetlands sampled even though the substrate was relatively uniform. This suggests that the overall soil chemistry and other factors are more influential than biotope type in determining where species occur.

In terms of the biodiversity of the different wetlands, the Shannon-Wiener diversity indices were high for all of the samples and there was not a marked difference between them. Harding *et al.* (2005) comment on the fact that diatom assemblages tend to be species rich however and so these results are not that surprising. In a study looking at the composition of epipelic and planktonic algal species composition in Ontario, Canada it was found that 93-99% of the taxa were diatoms (Moore 1972). Out of the 388 taxa recorded in Ontario, 321 were Bacillariophyceae, 32 were Chlorophyta, 14 were Cyanobacteria, 20 were Euglenophyta and there was one Chrysophyceae. These are similar results to what was found in this study, with diatoms making up on average 91% of the taxa found in the samples. Chlorophyta were also found in all of the samples and *Tribonema sp.*, a yellow-brown alga, was found in Vermont Vlei. Cyanobacteria and Euglenophyta were not studied however. Previous work has found that desmids which are members of the Chlorophyta can be sensitive to water quality conditions (Coesel 1982). In this study, however, there were only two species, *Closterium parvulum* and *Spinoclosterium sp.*, and it is not possible to assess water chemistry using this group in these wetlands.

Nutrient levels were not assessed in this study and so it is difficult to ascertain how eutrophic the different wetlands were. It has been found that nutrient enrichment can reduce diatom species diversity (Adamus *et al.* 2001) and so the relatively high diatom species diversity indices in this study may suggest that the wetlands had relatively low

nutrient levels. Other studies, however, have shown that diversity indices are not necessarily consistent with water quality and can at times be misleading (Archibald 1972). It has been suggested that the species composition of algal communities may be a better indicator of water quality and knowledge of each species' autecology is beneficial. The genera *Navicula* and *Nitzschia* were present in all of the samples and previous studies have shown that many of the species in these genera tend to be found in water with high organic pollution (Palmer 1969; Cox 1996). It would be worthwhile exploring the sensitivity of individual species in more detail.

Overall the dominant algal species found in a wetland can be determined by where the algal sample is collected from, the geographic location of the wetland, the season, water depth, the other vegetation present and nutrient and mineral concentrations (Stevenson *et al.* 1996). As already stated the wetlands in this study were very similar and a future study comparing the algal composition of these wetlands to those with greater variability in their water chemistry would be beneficial. This would possibly enable the comparison of algal species response over a wider range of pH and conductivity values. In future it may also be advisable to do a comparison across a greater number of wetlands as this may generate a greater gradient. It has been found that the importance of geographical factors in influencing patterns in diatom communities are at times underestimated (Potapova and Charles 2002). These wetlands were from a relatively limited geographical area and in future a comparison across a greater spatial scale should be done. All of the wetlands in this study were located in the foothill zone and it would be informative to sample from other parts of the landscape.

Stevenson and Bahls (1990) comment that whilst sampling from multiple habitats gives a good idea of the overall species composition of a wetland, it may not be sensitive to subtle overall water quality changes because of microhabitat variability. They suggest that comparing the species composition from a single microhabitat type would reflect water quality differences between sites more precisely than comparing numerous microhabitats. This however means that impacts on smaller scales are overlooked. Multiple microhabitats used in this study still reflected basic trends in diatom distribution

in response to environmental variables. Sampling could have been standardised to a greater extent however. This is difficult though, as unlike in riverine habitats it is hard to define set microhabitats within wetlands and to standardise which to sample from. As wetlands usually have soft sediments making up their substratum they tend to have fewer different biotopes than rivers (Dallas and Day 2004). In a study by Pan and Stevenson (1996) sampling was standardised by collecting algae only from the dominant macrophyte species found in wetlands. It is possible that in this study in Betty's Bay and Onrust, the wide variety of vegetation types may have incorporated too many additional variables and have contributed to the general lack of discernible pattern in the data. Lowe and Pan (1996) also note that the type of substratum may strongly influence the algal community structure. They advocate using artificial substrata to standardise sampling and this could be done in a future study.

Standardising sampling may help to reduce variance and consequently help to highlight algal species' sensitivity to major environmental factors (Kelly *et al.* 1998). One of the main objectives of using algae as biological indicators is to be able to decipher the integrated environmental information represented by species-rich communities (Pan *et al.* 1996). Although pH and conductivity were found to influence the occurrence of diatom species, overall they accounted for a relatively small amount of the variance expressed in the data. Other environmental variables such as dissolved oxygen, nutrient loads, metal and micronutrient availability and wetland size may be equally important in determining diatom community compositions (Adamus *et al.* 2001). In future it would be advantageous to measure some of these other variables.

Variation in the composition of diatom communities in wetlands can be attributed to how stable the wetlands are in terms of their water levels (Gaiser and Johansen 2000). Different assemblages of diatoms were found in permanent wetlands compared to temporary wetlands in a study in South Carolina in the United States. Interestingly in this study in Betty's Bay the temporary and permanent wetlands did not show distinct algal communities. The overall similarity between the temporary wetlands in White Road, Lachenalia Road and Hibiscus Road to the permanent wetlands of Grootvlei and

Rondevlei may be partly due to their close proximities to each other. The wetlands were sampled during the middle of the rainy season when the temporary wetlands would be at their maximum volume. In future it would be more helpful to sample the wetlands at several different times during a year. As mentioned by Ashton (1985) algae found at all latitudes display fluctuations in abundance, productivity and composition in response to seasonal changes in their abiotic environment. Sampling at different times of the year would facilitate assessing these differences.

The diatom species in this study were identified from live material using a classification guide that was devised for the northern hemisphere. It is noted by Kelly *et al.* (1998), however, that the majority of diatoms are cosmopolitan in their distribution and occur anywhere where their specific environmental requirements are met. In South Africa most of the classification of diatoms is performed by analysing the frustule morphology of prepared specimens under an electron microscope. It would be interesting in a future study to assess how classifications from the northern hemisphere taxonomic guides compare to those compiled in southern Africa. Diatoms in this study displayed a better response to environmental variability than the other algal species. This suggests that they may be a better taxonomic group to use in future as they tend to be more sensitive to subtle differences in environmental conditions. They were also present in high species numbers in all of the wetlands sampled from and this would make them a useful indicator group. From the results of this pilot study it appears that diatoms could be a useful group for bioassessment and this should be explored and developed further.

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Appendix

Table 1. Description of sites in Betty's Bay and Onrust where samples were collected from.

Date	Name	Sample no.	Description	Depth
26 July 2006	Vermont Vlei Onrust 34°40`89.7S 19°15`05.7E Large, temporary.	On1	Saturated sediment and water amongst dead *Eucalyptus* tree stems at water's edge.	~ 40 cm
		On2	Water saturated sand/clay amongst restio stems in alien vegetation dominated area.	<2 cm
		On3	Water around *Typha*/alien vegetation and scraping from vegetation stems.	<30 cm
		On4	Water around *Typha*/alien vegetation, oil layer on water surface, submerged tree stems.	~ 40 cm
		On5	Water samples from *Typha* reed bed.	~ 50 cm
		On6	Disturbed sediment +	~ 80 cm

			water above benthic vegetation near *Typha.*	
		On7	Water around grass/sedge, dead branches, wattles+ *Eucalyptus.*	~10 cm
		On8	Water from around dead plant stems in water.	~50 cm
		On9	Water around *Typha* (small plants), less dense than other area.	~20 cm
		On10	Algal film from rocky outcrop, 20m from houses. Restio and grasses. Opposite side of wetland from other sites.	~2 cm
		On11	Soil (sandy/clay), next to houses (15m away), restio and lawn grass.	0 cm
27 July 2006	Lachenalia Rd Betty's Bay 34°21`47S 18°53`24E Small, temporary.	LR1	Algae floating above pond weed/grass. Rocky substrate.	~15 cm
		LR2	Algae floating in open water which is relatively clear, few tannins. Sparse clumps of grass + restio.	~20 cm
		LR3	Soil, semi-damp.	0 cm
27 July 2006	Grootvlei Betty's Bay 34°21`47S 18°53`29E Large, permanent.	M1	Amongst restio stems, 6m from dirt road and before *Typha* beds.	~60 cm
		M2	Water from edge of *Typha* in centre of wetland, close to Ibis colony and scrapings from *Typha* stems.	~1 m
		M3	Floating vegetation and submerged vegetation.	~50 cm
		M4	Water next to rocky outcrop, floating vegetation mass and restio stems.	~40 cm
		M5	Soil (alien vegetation and *Euclea,* sedges, kikuyu grass).	0 cm
		M6	Water in crevices of rocky outcrop. Bird faeces present on rock face.	Surrounding water ~40cm
28 July 2006	Bass Lake Betty's Bay 34°21`47S 18°53`29E Large, permanent.	BL1	Soil from amongst lawn grass. Soil water saturated, ~25 m from main water body.	0 cm
		BL2	Saturated soil, boggy with rotting vegetation, grasses. ~10 m from water, grass less dense.	0 cm
		BL3	Deep standing water, mats of *Spirogyra* above grass	~40 cm

			and amongst grass stems.	
		BL4	Stems and roots of bank vegetation (Arums, succulents + fynbos), steep drop to water.	~25 cm
		BL5	*Typha* stems floating on water surface.	~75 cm
		BL6	Restio +*Typha* stems+scraping off bank.	~60cm
28 July 2006	Hibiscus Road Betty's Bay 34°21`97S 18°53`52E Small, temporary.	HR1	Soil with algal mats, amongst restio stems on rocky/sandy substrate. Dry ground.	0 cm
		HR2	Restio stems in standing water, water relatively clear. Small channel from main water body.	~5 cm
28 July 2006	Rondevlei Betty's Bay 34°21`49S 18°52`45E Large, permanent	RV1	Soil on cleared path leading to water's edge. Restio stems present.	0 cm
		RV2	Water around decomposing bracken and Arum lilies.	~20 cm
		RV3	Water around restio and Arums.	~30 cm
		RV4	Relatively open water with submerged vegetation. On adjacent bank shift to *Erica sp.*	~50 cm
28 July 2006	White Road Betty's Bay 34°21`43S 18°52`58E	WR1	Water around restio and bracken.	~10 cm
		WR2	Open water with restio and restio detritus.	~30 cm
		WR3	Small pool isolated from main temporary wetland and possibly excavated.	~10 cm

Table 2. Species present in each of the samples from wetlands in Betty's Bay and Onrust, the taxonomic group they belong to and the total number of samples they occur in.

Species	Taxon	Species Number	On1	On2	On3	On4	On5	On6	On7	On8	On9	On10	On11	LR1	LR2	LR3	M1	M2	M3	M4	M5	M6	BL1	BL2	BL3	BL4	BL5	BL6	HR1	HR2	RV1	RV2	RV3	RV4	WR1	WR2	WR3	Total
Achnanthes sp.	Bacillariophyta	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Achnanthidium sp.	Bacillariophyta	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Achnanthidium lanceolatum	Bacillariophyta	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Achnanthidium minutissima	Bacillariophyta	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Actinocyclus sp.	Bacillariophyta	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Amphora sp.	Bacillariophyta	6	1	1	0	1	0	1	1	1	1	0	1	0	0	0	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	15
Amphora libyca	Bacillariophyta	7	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	5
Amphora ovalis	Bacillariophyta	8	0	1	0	0	0	0	0	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Amphora pediculus	Bacillariophyta	9	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Amphora veneta	Bacillariophyta	10	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4
Anomoeoneis sp.	Bacillariophyta	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Bacillaria paradoxa	Bacillariophyta	12	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Cavinula sp.	Bacillariophyta	13	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Cavinula jaernfeltii	Bacillariophyta	14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cavinula pseudoscutiformis	Bacillariophyta	15	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cavinula scutiformis	Bacillariophyta	16	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	8
Characiochloris sp.	Chlorophyta	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Closterium parvulum	Chlorophyta	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Cocconeis sp.	Bacillariophyta	19	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Coccomyxa sp.	Chlorophyta	20	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Craticula sp.	Bacillariophyta	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Cyclotella meneghiana	Bacillariophyta	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3
Cymbella sp.	Bacillariophyta	23	1	1	1	0	1	0	1	1	0	1	1	0	0	0	1	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	0	0	0	0	0	14
Cymbella aspera	Bacillariophyta	24	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cymbella gaeumannii	Bacillariophyta	25	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Cymbella Helvetica	Bacillariophyta	26	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Diadesmis sp.	Bacillariophyta	27	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	5
Diatoma sp.	Bacillariophyta	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Diploneis petersenii	Bacillariophyta	29	0	0	0	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Encyonema sp.	Bacillariophyta	30	0	1	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	6
Encyonema lacustre	Bacillariophyta	31	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Encyonema minutum	Bacillariophyta	32	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Entomoneis alata	Bacillariophyta	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Epithemia sp.	Bacillariophyta	34	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	11
Epithemia adnata	Bacillariophyta	35	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
Epithemia argus	Bacillariophyta	36	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	6
Epithemia sorex	Bacillariophyta	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Eunotia sp.	Bacillariophyta	38	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	1	1	0	1	1	0	0	0	0	9
Eunotia bilunaris	Bacillariophyta	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Eunotia flexuosa	Bacillariophyta	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Fallacia sp.	Bacillariophyta	41	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3
Fallacia hudsonis	Bacillariophyta	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Fragilaria capucina	Bacillariophyta	43	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Fragilariaforma sp.	Bacillariophyta	44	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Frustulia sp.	Bacillariophyta	45	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	1	0	1	0	9
Frustulia rhomboids	Bacillariophyta	46	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	3
Gloeocystis sp.	Chlorophyta	47	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Gomphonema sp.	Bacillariophyta	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Gyrosigma sp.	Bacillariophyta	49	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Gyrosigma acuminatum	Bacillariophyta	50	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Gyrosigma attenuatum	Bacillariophyta	51	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Gyrosigma spencerii	Bacillariophyta	52	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Hannaea arcus	Bacillariophyta	53	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Luticola sp.	Bacillariophyta	54	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

Luticola mutica	Bacillariophyta	55	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Martyana sp.	Bacillariophyta	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	2
Martyana martyi	Bacillariophyta	57	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	3
Melosira sp.	Bacillariophyta	58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Microspora sp.	Chlorophyta	59	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Mougeotia sp.	Chlorophyta	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	4
Navicula sp.	Bacillariophyta	61	1	1	1	1	1	0	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	0	1	1	0	0	27
Navicula angusta	Bacillariophyta	62	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Navicula cincta	Bacillariophyta	63	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Navicula cryptocephala	Bacillariophyta	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Navicula digitoradiata	Bacillariphyta	65	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Navicula gregaria	Bacillariophyta	66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Navicula incertata	Bacillariophyta	67	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Navicula menisculus	Bacillariophyta	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Navicula oblonga	Bacillariophyta	69	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Navicula protracta	Bacillariophyta	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Navicula pupala	Bacillariophyta	71	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Navicula radiosa	Bacillariophyta	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Navicula reinhardtii	Bacillariophyta	73	1	0	0	0	0	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	7
Navicula subtilissima	Bacillariophyta	74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3
Navicula tripunctata	Bacillariophyta	75	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Neidium sp.	Bacillariophyta	76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Nitzschia sp.	Bacillariophyta	77	0	1	1	0	1	0	0	0	0	1	1	0	1	1	0	1	0	1	0	1	1	1	0	0	0	0	1	0	1	0	1	0	1	0	0	16
Nitzschia capitellata	Bacillariophyta	78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Nitzschia communis	Bacillariophyta	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Nitzschia clausii	Bacillariophyta	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Nitzschia filliformis	Bacillariophyta	81	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Nitzschia obtusa	Bacillariophyta	82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Nitzschia palea	Bacillariophyta	83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
Nitzschia	Bacillariophyta	84	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

paleacea																																								
Nitzschia scalpelliformis	Bacillariophyta	85	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Nitzschia umbonata	Bacillariophyta	86	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Palmodictyon viride	Chlorophyta	87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pinnularia sp.	Bacillariophyta	88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	0	0	0	0	1	1	1	0	7
Pinnularia borealis	Bacillariophyta	89	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pinnularia cardinaliculus	Bacillariophyta	90	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Pinnularia maior	Bacillariophyta	91	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pinnularia mesolepta	Bacillariophyta	92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Pinnularia rupestris	Bacillariophyta	93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Pinnularia sudetica	Bacillariophyta	94	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	0	0	0	1		1	1	1	1	1	0	1	1	1	0	0	1	1	0	1	18
Pinnularia viridis	Bacillariophyta	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	
Placoneis sp.	Bacillariophyta	96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	
Placoneis pseudanglica	Bacillariophyta	97	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	
Punctastriata pinnata	Bacillariophyta	98	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	4
Rhizoclonium hieroglyphicum	Chlorophyta	99	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	1	0	0	1	21	
Rhoicosphenia sp.	Bacillariophyta	100	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Rhopalodia gibba	Bacillariophyta	101	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	1	0	1	1	0	0	0	0	0	0	1	1	0	1	0	0	0	10	
Rhopalodia gibberula	Bacillariophyta	102	0	0	0	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	
Sellaphora sp.	Bacillariophyta	103	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	4
Sellaphora bacillum	Bacillariophyta	104	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Spinoclosterium sp.	Chlorophyta	105	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	
Spirogyra sp.	Chlorophyta	106	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	
Stauroneis sp.	Bacillariophyta	107	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	4	
Stauroneis phoenicenteron	Bacillariophyta	108	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	2	
Staurosira elliptica	Bacillariophyta	109	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	

Stenopterobia delicatissima	Bacillariophyta	110	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Stephanodiscus sp.	Bacillariophyta	111	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4
Stigeoclonium sp.	Chlorophyta	112	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Surirella sp.	Bacillariophyta	113	0	1	0	0	0	0	0	0	1	1	1	0	0	1	0	0	1	1	1	1	1	1	1	1	0	0	1	0	1	1	0	1	1	0	0	18
Surirella angusta	Bacillariophyta	114	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Surirella birostrata	Bacillariophyta	115	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Surirella capronii	Bacillariophyta	116	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	2
Surirella elegans	Bacillariophyta	117	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Surirella roba	Bacillariophyta	118	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Synedra sp.	Bacillariophyta	119	1	1	1	1	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	1	1	1	0	1	15
Synedra acus	Bacillariophyta	120	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Synedra berolinensis	Bacillariophyta	121	1	0	0	1	1	1	1	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	1	12
Synedra famelica	Bacillariophyta	122	1	0	0	1	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7
Synedra parasitica	Bacillariophyta	123	1	0	0	1	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7
Synedra rumpens	Bacillariophyta	124	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Synedra ulna	Bacillariophyta	125	1	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	1	1	1	0	0	1	11
Synedra vaucheriae	Bacillariophyta	126	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Tabellaria binalis	Bacillariophyta	127	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Tabellaria fenestrate	Bacillariophyta	128	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Tabellaria flocculosa	Bacillariophyta	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0	0	0	0	1	5
Tribonema sp.	Chrysophyta	130	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Volvox sp.	Chlorophyta	131	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	3
Zygnema sp.	Chloropyta	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1