4.1.1 Description of Morphological Characters of Phytoplankton Species

4.1.1.1 *Chaetoceros constrictum* (Plate 4.1)

Cells are aligned in straight chain and viewed as rectangular in girdle view. Part in between the valve and girdle is narrow. From girdle, the valve usually defined by small and sharp constriction. The aperture is lanceolate shaped and a bit narrow in the middle. Setae emerge from the valve margin while the terminal setae are distinguished by its character to protrude out at both end with acutely divergent. Chromatophores have round or plat-like shaped. The width of the cell is sized between 20-30µm.

4.1.1.2 *Chaetoceros constrictus* (Plate 4.2)

Cells are aligned in straight chain with broad valves. The valves equipped with quite sharp end corners and concave. The species has an acutely divergent terminal setae with two chromatophores found per cell. The aperture has a long almost elliptical shape with setae emerging from the structure and fused at point of exit from margin.

4.1.1.3 *Chaetoceros curvisetus* (Plate 4.3)

Chain usually formed elliptical or spiraling shaped. Setae have slightly different length and shape, emerge from the valves' margin. The longer setae protrude to the outside of the chain while the shorter toward inner side of the spiral chain. One cell of the chain measured between 10µm to 17µm. Chromatophores settled at the bottom of the cells that point to the inner side of the spiral chain.

4.1.1.4 *Chaetoceros debilis* (Plate 4.4)

Cells arrangement made up a straight chain. The cells have square shape and there are dent formed at the middle part of the cells' margin at both sides. The aperture is wide while the terminal setae are usually shorter than the other setae. Terminal setae are

protruding out at wide angle more than 90°. Chromatophores have irregular shape and usually more than one are occupying the cells.

4.1.1.5 *Chaetoceros decipiens* (Plate 4.5)

Arrangement of its cells formed a straight perfect chain. It has wide and almost rectangular shaped aperture. Usually, the valves surface measured twice or triple the length of its girdle. It is quite a rare species to be found in any locality with cells width in the range of 10 - 80µm. The chromatophore observed to have round shape. The setae of the species emerged from the margin of the valves and beautifully arranged side by side along the straight chain.

4.1.1.6 *Chaetoceros distans*

Cells are united in straight chain and rectangular in girdle view. Intercalary setae emerge from the valve at the margin and directed at different direction. Both terminal and intercalary setae have similar shape. Chromatophores are normally located at the centre of the valve. The arrangement of the cells in a chain resulted in a narrow aperture.

4.1.1.7 *Chaetoceros laciniosum*

Cells form straight chain. Its aperture shows a wide shape with round corner and slight central inflation (small knob). Intercalary setae are long, thin and all directed toward one end of chain. Just like the intercalary setae, terminal setae directed toward end of chain. The width of the cell ranged between 12-20 µm while the length is between 20-30 µm.

4.1.1.8 *Chaetoceros lauderii*

Arrangement of the cells forms a curved and sometimes spiraling chain. It has narrow and elliptical aperture. Intercalary setae emerge from the apices of the valve and have a short and thin structure.

4.1.1.9 Chaetoceros lorenzianus (Figure 4.6)

Chains are observed straight and stiff. Intercalary setae fused at the end of exit point with distinct transverse rows of pores. The aperture is wide and elliptic. There is numerous numbers of chromatophores occupying each cell. Terminal setae are distinct which is thicker than intercalary setae and parallel to the chain axis.

4.1.1.10 *Chaetoceros* sp. 1 (Figure 4.10)

Chain forms slightly curved non- spiraling chain. Poles of adjacent valves do not touch. Valves have almost oval shape, however with straight margin, which is conspicuous among its genus. Intercalary setae emerge at valve edge with thin and straight structure perpendicular to chain axis. Chromatophores settled at base of the cells. Terminal setae are unknown.

4.1.1.11 *Chaetoceros* sp. 2 (Figure 4.11)

Arrangement of cells is straight and stiff. Setae are thin, arising slightly from inside valve, to be specific the aperture. Intercalary setae are perpendicular to chain axis and short. Terminal setae are unknown. Apertures are rectangular while the valves are square in shape. 2 chromatophores accommodate each cells and located at each valves' poles.

4.1.1.12 *Chaetoceros* sp. 3 (Figure 4.12)

Chain straight or slightly bent. Apertures narrowly elliptical. Setae are thin and perpendicular to chain axis and some ended toward one end of chain while upward the chain. Resting spores are unknown. Terminal setae are unknown.

4.1.1.13 Bacteriastrum comosum (Figure 4.13)

Setae are long and bent toward terminal valve with coarse setae. Terminal setae are on either end of chain which is different in form and direction. Valves view showed circular shape with 16-32 bristles.

4.1.1.14 Bacteriastrum delicatulum (Figure 4.14)

Valves view showed circular shape. Equipped with 6-11 intercalary setae in each valves, which are bent backward toward the perpendicular to the end of valve surface. Intercalary setae branched at the end and formed Y shape (from valve view). Terminal setae of both ends directed toward the chain.

4.1.1.15 *Bacteriastrum varians* (Figure 4.15)

Valve view showed circular shape. Distinct terminal setae transverse to chain axis and finally curved toward the chain in their outerpart. Intercalary setae have similar shape like a common genus *Chaetoceros*. Poorly known as *B. furcatum*.

4.1.1.16 *Rhizosolenia alata* (Plate 4.16)

Cell is always solitary. Resting spores are really fine and abundant. Spiraling band (segment) from lateral view. Process tip is conspicuous, which is the main morphological structure to differ the species with other *Rhizosolenia* species.

4.1.1.17 *Rhizosolenia hebetata* (Plate 4.17)

Process tip is long and sharp, hair-like spine. Resting spores are fine and numerous and clumping at one part of the cell. Often found as solitary cell. The cell is long and cylindrical.

4.1.1.18 *Rhizosolenia imbricata* (Figure 4.18)

Cell has cylindrical shape. Scale-like intercalary ring. Process tip is short, oblique, sharp and pointed. Chromatophores or resting spores are numerous and small.

4.1.1.19 *Rhizosolenia setigera* (Figure 4.19)

A centric diatoms that are conical. Process tip are thick, long, pointed and not always straight. Resting spores are numerous and normally accumulated at the nucleus.

4.1.1.20 *Rhizosolenia striata* (Figure 4.20)

Valve is shallow. Process tip is triangular in outline with lateral edges that usually concave. Band striation is in layer from lateral view.

4.1.1.21 *Guinardia flaccida* (Figure 4.21)

Cells are in cylindrical shape and in close set chain. Cells are straight or slightly curved. Bands are distinct and has collar-like shape. Valves are normally flat or slightly concave.

4.1.1.22 *Pleurosigma elongatum* (Figure 4.22)

Valve has linear-lanceolate and sigmoid shape with sharp end. Resting spores are numerous and distributed scatterly in the cell. Raphe is straight and located at central of the valve.

4.1.1.23 *Pleurosigma directum* (Plate 4.23)

Valves are elongated, lightly sigmoid and have rhombo-labceolate to elliptical-lanceolate shape. Raphe is almost straight. Two irregular shaped chromatophores, one at each valve.

4.1.1.24 *Pleurosigma angulatum* (Plate 4.24)

Valve has slightly distinct angular shape in the middle. Valve is gently sigmoid with rhombo-lanceolate shape with rounded ends. Raphe is sigmoid. Chromatophores located at each halves equally.

4.1.1.25 *Pleurosigma* sp. 1 (Plate 4.25)

Valve is slightly sigmoid and slender. Raphe is straight and central with striae parallel to each other. Chromatophore is unknown.

4.1.1.26 *Gyrosigma scalproides* (Plate 4.26)

Valves are a combination of sigmoid and linear shape which gradually attenuated to blunt end. Raphe is eccentric and slightly sigmoid.

4.1.1.27 *Gyrosigma spencerii* (Plate 4.27)

Valve is sigmoid and moderately lanceolate and attenuated to rounded ends. The valve is normally longer and wider than *G. scalproides*.

4.1.1.28 *Navicula peticolasii* (Plate 4.28)

Valve is lanceolate, long and slender with length ranged, 150-200 µm. Raphe is generally straight and not raised on a ridge. 2 chloroplasts accommodate each half of the valve.

4.1.1.29 *Navicula radiosa* (Plate 4.29)

Valve is linearly lanceolate with acute, rounded ends. The length is between 20-40 µm. Has 2 chloroplasts each covering less than half of each side of the girdle.

4.1.1.30 *Pinnularia acuminata* (Plate 4.30)

Valve is linear with slightly rounded ends. 2 chloroplasts covered the girdle from end to end.

4.1.1.31 *Pinnularia tabellaria* (Plate 4.31)

Valve is straight with rounded poles. 2 chloroplasts settled at the centre of the valve. The valve is constricted towards the ends forming rounded ends (rounded poles).

4.1.1.32 *Pinnularia* sp. (Plate 4.32)

Straight valve with rounded ends. 2 chloroplasts covering girdle from end to end.

4.1.1.33 *Coscinodiscus asteromphalus* (Plate 4.33)

Valve view, the species is disc-shaped. Valves contained numerous chloroplasts. central rosette with large areolae. Ring of processes close to valve margin and visible using light microscope.

4.1.1.34 *Coscinodiscus centralis* (Plate 4.34)

Numerous plate-like chloroplasts (girdle view). Distinct rosette with large areolae which formed decussating arcs in the central part of valves. Distinct areolae shape which is hexagonal and 3-4 areolae found in 10 µm. Valve diameter is between 100-250 µm.

4.1.1.35 *Coscinodiscus concinnus* (Plate 4.35)

Girdle view, valves convex. Numerous small chloroplasts. Central rosette. Areolae rows in bundle running from marginal labiate processes to valve center. Diameter of valve is between 70-150µm.

4.1.1.36 *Coscinodiscus gigas* (Plate 4.36)

Solitary cell. Distinct because of its size, valve diameter is between 300-500 µm. Central rosette is absent. 3-4 areolae in 10 µm. Areolae decreased their size towards valves margin.

4.1.1.37 *Coscinodiscus lineatus* (Plate 4.37)

Areolae has polygonal shape and slightly smaller at the margin compared at the central of the valve. Often solitary cell. Is relatively small compared to other *Coscinodiscus* species. Valve diameter is between 40 – 100 µm. Numerous plate-like chromatophores.

4.1.1.38 *Coscinodiscus rothii* (Plate 4.38)

Areolae is radial with hexagonal shape and the size is smaller at central part than the margin. Valve diameter is between 150-200 µm.

4.1.1.39 *Coscinodiscus* sp. 1 (Plate 4.39)

Girdle view, cell is concave with numerous plate-like chloroplasts which is clumping at one location. Girdle view length is relatively small, less than 50 µm.

4.1.1.40 *Coscinodiscus subtilis* (Plate 4.40)

Often solitary cell. valves are usually flat. Valves with polygonal (hexagon) areolation arranged in a wheel-like shape. 7-8 areolae in 10 µm. The size of areolae are smaller towards valve's margin. Valve diameter is between 100 – 250 µm.

4.1.1.41 *Frustulia vulgaris* (Plate 4.41)

Valve is straight, broad and has rhomboid-lanceolate shape with rostrate apices. Often solitary cell. Longitudinal rib incomplete at valve center. The length of the valve is between 70- 100 µm.

4.1.1.42 *Stauroneis obtusa* (Plate 4.42)

Valve is straight with linear-elliptical shape with blunt ends. Incomplete lingotudinal rib (raphe) at the middle of the valve. Striae is slightly curved, however become straight towards the ends of the valve. Length is between 50-90 µm.

4.1.1.43 *Biddulphia mobiliensis* (Plate 4.43a)

Cells are normally solitary or united forming a short chain. Valve is elliptical and equipped with 2 spines at each of valve's poles. There are special horns-like structure (processes) emerged from the edge of the valve. The surface of the valve is normally concave. Chromatophores are numerous and clumping.

4.1.1.44 *Biddulphia longicuris* (Plate 4.43b)

Cells is often solitary or fused to form short chain. Valve is elliptical. Equipped with horns-like structure just like *B. mobiliensis*. Spines emerged from the slightly curved valve's ends. Normally, longer than *B. mobiliensis*.

4.1.1.45 *Triceratium favus* f. *quadrata* (Plate 4.44)

Valve is almost square with straight or concaved edge. Areolae has hexagonal shape. Chromatophores are numerous and clumping at one location of the valve. Corners edge has blunt structure.

4.1.1.46 *Triceratium* sp. (Plate 4.45)

Valve is triangular with concave edges. Areolae has hexagonal shape and the size is smaller towards the margin of the valve. Valve's length is between 40- 120 µm.

4.1.1.47 *Planktoniella sol* (Plate 4.46)

Cell has discoid shape and often solitary. Diameter is between 10-80 µm with 5-9 areolae found in 10 µm. The areolae structure has polygonal shape.

4.1.1.48 *Cyclotella meneghiniana* (Plate 4.47)

Cells usually solitary. Valves are tangentially undulated. Center area of the valve is covered with fine radial striae. Distinct marginal striae. Valve's diameter is between 10-30 µm. Chromatophores are numerous, often observed at the center of the valve.

4.1.1.49 *Thalassionema nitzschoides* (Plate 4.48)

Cells are linear and narrow in girdle view with bluntly rounded ends. Cells united by gelatinous liquid at one end into zig-zag or star shaped colonies. Numerous granular chromatophores.

4.1.1.50 *Thalassiothrix frauenfeldii* (Plate 4.49)

Cells are linear or slightly linear-concaved. Cells are united at the end of the tips and fromed star-shaped colonies. A colony normally consists of 10 cells. Length is between 130-250 µm.

4.1.1.51 *Melosira moniliformis* (Plate 4.50)

Cells connected to form long chain. Equipped with membranous costa on the outer side of valve. Numerous plate-like chromatophores distributed throughout the cell.

4.1.1.52 *Melosira nummuloides* (Plate 4.51)

Unclear resting spores. Equipped with membranous costa (collar) which is away from valve apex. Relatively small compared to *M. moniliformis*. Cells connected to form curved chain. Often found as colonies.

4.1.1.53 *Amphora quadrata* (Plate 4.52)

Cells are thin with elliptical shape. Expansion of central nodule which formed stauros that almost reaches the margin of the valve. Raphe often eccentric. Length is between 60-70 µm.

4.1.1.54 *Campylodiscus daemilianus* (Plate 4.53)

Cells are circular and often solitary. Lateral striation alternated with ribs. Areolae covered most of its valve. Areolae are bigger at margin compared to other part of the valve. Length is between 80-100 µm.

4.1.1.55 *Corethron criophilum* (Plate 4.54)

Cells are cylindrical with dome-shaped valves. Valves with long spines emerged from margin area.

4.1.1.56 *Bellerochea horogicalis* (Plate 4.55)

Ribbons or chains curved in transapical plane. Cells are often tubular and united from one end to another end. Valves are slightly convex. Numerous clumping resting spores. Valve's length, 60-90 µm.

4.1.1.57 *Fragilaria pinnata* var *trigona* (Plate 4.56)

Cell is star-shaped. Chromatophores is numerous and clumping at the center of the valve. Conspicuous species and easily identified due to its unique valve structure.

4.1.1.58 *Fragilaria* sp. (Plate 4.57)

In gridle view, cells are rectangular, with bluntly flat ends. Raphe is strongly eccentric and straight. Parallel striation along the margin of the valve. Resting spores are unknown. Cell is extremely long with length between 300-500 µm.

4.1.1.59 *Diatoma elongatum* (Plate 4.58)

Cells are linear with blunt, knob ends. Length is between 80-150 µm, while width is between 5-10 µm.

4.1.1.60 *Asterionellopsis glacialis* (Plate 4.59)

Cells are rod-like with distinctly dissimilar ends, one end enlarged. Larger end united to form star-like colonies. Chromatophore normally observed at larger end area.

4.1.1.61 *Lauderia borealis* (Plate 4.60)

Cells in chains are slightly close which only separated by processes on margin of the valve. Chromatophores are numerous which covered most of the valve. Prevalvar axis is longer than the valve's diameter. Diameter of the valve is between 30-50 µm.

4.1.1.62 *Amphiprora alata* (Plate 4.61)

Pennate diatom with ribbon-shaped valve. Expansion of central nodule formed stauron. Raphe present at the valve. Length between 60-120 µm and width, 40-55 µm.

4.1.1.63 *Leptocylindricus danicus* (Plate 4.62)

Cells are cylindrical and slender and united to form long straight chain. Clear cell wall structure between cells using light microscopy. One end has concave structure while the other is convex. Numerous small and rounded chromatophores.

4.1.1.64 *Ditylum brightwelli* (Plate 4.63)

Weakly siliceous cell wall. Often solitary cell and is rectangular from girdle view. End of valve is triangular shape with sharp spine emerging from the valve's surface. Resting spores are numerous and look like small granules. Prevalvar axis length is between 80-130 µm, while diameter is 25-100 µm.

4.1.1.65 *Cymbella tumida* (Plate 4.64)

Cells are broadly-lanceolate. Dorsal margin is convex and rounded while ventral margin is slightly linear. Raphe in the middle of the valve bent towards the margin. Valve has blunt end with mild constriction that formed pin-like ends.

4.1.1.66 *Skeletonema costatum* (Plate 4.65)

Cells are cylindrical with rounded ends and formed straight chain which is held by fine marginal processus. 2 chromatophores per cell that located at the margin of the valve.

4.1.1.67 *Bacillaria paradoxa* (Plate 4.66)

Cells are straight and rectangular from girdle view. Length of valve is between 70-100 µm. Valve has surface striation with tranverse arrangement along the valve's margin. Rpahe is straight.

4.1.1.68 *Nitzschia acicularis* **(Plate 4.67)**

Cells often solitary and straight. Middle of the valve is narrowly-lanceolate with long drawn out rostrate poles which is conspicuous. Striation is invisible using light microscopy. The valve is sometimes very slightly constricted at the central region.

4.1.1.69 *Nitzschia longissima* **(Plate 4.68)**

Girdle view, cells is slight sigmoid, linear to lanceolate shape with thin ends, tapering to very long projections. 2 rounded resting spores often located at the center of the valve.

4.1.1.70 *Pseudo-nitzschia pungens* **(Plate 4.69)**

Cells normally joined at tips (with overlaps of ¼ of the cell) to form straight chain. Cells is linear and narrowly lanceolate. Poles are slightly rostrate. Fine striation which hardly visible using light microcopy. Length is between 60-150 µm. 2 plate-like chromatophores at each halves of the valve.

4.1.1.71 *Pseudo-nitzscia cuspidata* **(Plate 4.70)**

Cells are long and thin. Poles are pointed. Raphe is eccentric. Length is between 30-100 µm. Valve is comparatively wide, 3-8 µm and has tapering ends. Overlap of cells in chains is 1/5 or 1/6 of cell length**.**

4.1.1.72 *Stauroneis pusilla* **(Plate 4.71)**

Valve has lanceolate shape with capitates apices. Broad valve with constricted ends. Raphe often straight with narrow ends. Length is between 30-45 µm with width of 8-12 µm.

4.1.1.73 *Mastogloia smithii* (Plate 4.72)

Valve is elliptical with subrostrate ends. Raphe is straight and filiform. Striae parallel or sluightly radiate. Valve's length is between 15-30 µm.

4.1.1.74 *Cosmarium humile* (Plate 4.73)

Often a single celled desmid. Cells are divided in the middle by short isthmus. 2-4 Chloroplasts found at each of semicells. Length is between 30-40 µm. Cells wall is normally smooth.

4.1.1.75 *Mougeotia* sp. (Plate 4.74)

A filamentous green algae. Cells contained plate-like or sometimes ribbon-like chloroplast which covers most of the cell. Cells are straight and slender and fused at its end to form straight or slightly curved colony.

4.1.1.76 *Rhizoclonium* sp. (Plate 4.75)

Filaments are slender. Often has one to few-celled rhizoidal lateral. Filaments are covered by sticky-like structure. Chloroplasts often densely packed with starch.

4.1.1.77 *Peridinium anglicum* (Plate 4.76)

Cell is often round to polygonal. Cingulum is median. Cells body is fully covered by theca. Epitheca and hypotheca are at same sizes. Length is between 40-50 µm. Sutures have polygonal shape.

4.1.1.78 *Oscillatoria tenuis* (Plate 4.77)

Filaments are long and slender and often non straight. Filaments have conspicuous septum between adjacent cells if observed using light microscope. Cells' length is between 2-5 µm. Rounded or tapered ends.