CHAPTER 5

DISCUSSION

5. DISCUSSION

5.1 Environmental quality of Tasek Bera

5.1.1 Water depth and transparency

Reported water depth for Tasek Bera ranged from 0.66 to 5.72 m (Furtado and Mori, 1982). Water depth ranged between 0.40 to 1.50 m (Phang and Murugadas, 1997) compared to present survey which recorded a range between 0.15 to 5.40 m. The narrower range of depth measured by Phang and Murugadas (1997) could be due to lower number of sampling stations. The maximum depth observed for all the stations in August 1998 coincided with the rainy season.

Furtado and Mori (1982) reported that transparency at one of the stations at Tasek Bera ranged from 1.50 to 2.50 m when measured for a period of three years (1970 to 1973). According to Phang and Murugadas (1997), transparency measured in September 1997 ranged between 0.32 m to 2.18 m. The range is quite close to the present study which was between 0.14 m to 2.19 m. In the present study, Station 11 (Paya Kelantong) and Station 12 (Sungai Tembangan) have low transparency because they are located in the oil palm plantation with disturbed ecosystem. Both Station 9 (Sungai Bera 1) and Station 10 (Sungai Bera 2) are exposed to anthropogenic disturbances such as washing, bathing and boating. Therefore, relatively turbid conditions were recorded.

In April and May 1998, turbid conditions coincided with low rainfall. However, high transparency was noted in July and August 1998 when there was an increase in rainfall. This is due to dilution effect from high rainfall. However, turbidity in rivers sometimes increases during rainfall or flow events. This is because sediment is transported into waterways and streambed sediments are resuspended. Diffuse sources of most suspended matter include soil and riverbank erosion while sewage effluent is an important point source. Riparian vegetation maintains stream bank stability, physically filters run-off and removes coarse sediment. Riverbank erosion and collapse are often brought about by removal of riparian vegetation. Therefore, turbidity is a good indicator of sedimentation and erosion in a catchment. In comparison to the studies done by Furtado and Mori (1982), it is obvious that much lower transparency measurements have been recorded in recent times. This indicates that development in the catchment area had in turn caused an increase in erosion and sedimentation.

High turbidity has detrimental effect on riverine ecosystem as it reduces light penetration and visibility. This in turn limits plant growth, fish movements and the ability of predatory fish and birds to see their prey. Moreover, when sediments from turbid water settle, they may alter aquatic habitats and stifle benthic organisms on the bottom of waterways. High levels of suspended solids also render water unsuitable for a range of environmental and human uses. Nevertheless, high turbidity levels enable higher phosphorus and nitrogen levels to be tolerated without triggering eutrophication as the availability of light to the algae is reduced.

5.1.2 Conductivity

Conductivity gives an indication of the mineral content of the water. The conductivity of water at Tasek Bera recorded during the period of 1970 to 1972 ranged from 10.5 μmhos.cm^{-1} to 23.0 μmhos.cm^{-1}. Conductivity measurement in 1997 ranged from 30.3 to 64.6 mS^{-1} (Phang and Murugadas, 1997). In the present study, a wider range, between 21 to 129.60 mS^{-1} was recorded. According to Allan (1995), conductivity is a measure of electrical conductance of water, and an approximate predictor of total dissolved ions. Both Station 11 (Paya Kelantong) and

Station 12 (Sungai Tembangan) which recorded high conductivity values are located in the middle of oil palm plantations. Therefore, a combination of fertiliser application and increased leaching due to exposed soil areas may have contributed to the observation.

5.1.3 pH

Furtado and Mori (1982) reported that pH at Tasek Bera ranged from 4.57 to 6.83. Phang and Murugadas (1997) reported the range for pH as between 5.9 to 6.7 as compared to the range of 4.45 to 6.73 in the recent study. Allan (1995) noted that freshwaters can vary in acidity and alkalinity due to natural causes as well as anthropogenic inputs. The pH of water in Tasek Bera is slightly acidic. In swamps and peaty areas, the abundant decaying plant matter releases humic acid into the waters that result in 'black' waters and causes the water to have a pH range that is slightly acidic.

5.1.4 Temperature

Furtado and Mori (1982) reported that the mean water temperature in Tasek Bera was 26.3 °C. The range for temperature in 1997 and 1998 is almost similar. Survey by Phang and Murugadas in 1997 recorded a pH from 26.0 to 30.0°C as compared to 25.3 to 33.3°C in the present study. The high temperature in May/June 1998 coincides with the dry season while the lowest temperature with the wet season in August 1998. The temperature of running waters usually varies on seasonal and daily time scales, and among locations due to climate, elevation, extent of streamside vegetation and the relative importance of groundwater inputs (Allan, 1995). Reynolds (1984) maintained that temperature is an important factor in determining growth of phytoplankton. This is because many cellular processes are temperature dependant. Hence, their rates accelerate with increasing temperature, doubling per 10°C rise in temperature.

5.1.5 Dissolved oxygen

Furtado and Mori (1982) noted that dissolved oxygen measured at Tasek Bera between 1970 to 1972 ranged from 0.84 to 4.43 mgL^{-1}. Dissolved oxygen measured by Phang and Murugadas in 1997 had a narrower range between 4.0 to 6.5 mgL^{-1} as compared to the present study in 1998 that is between 0.40 to 5.80 mgL^{-1}. Furtado and Mori (1982) also reported that low oxygen levels are usually associated with low primary production, oxygen uptake by humic colouring matter undergoing oxidation, bleaching reactions, presumably by ultraviolet radiation that causes photoxidation or a high chemical oxygen demand by suspended organic matter which was abundant.

5.1.6 Dissolved orthophosphate

Furtado and Mori (1982) reported that dissolved orthophosphate in Tasek Bera ranged from 0.000 to 0.1050 mgL^{-1}. In 1997, dissolved orthophosphate measured between ND (non-detectable) to 2.80 mgL^{-1}. However, the concentration recorded in 1998 is very low, ranging between 0.000 to 0.009 mgL^{-1} and is maximum in the dry month (April 98). Furtado and Mori (1982) noted that the high value is due to mineralisation of decomposing organic matter in the dry seasons.

Biggar and Corey (1969) stated that phosphorus occurs in both organic and inorganic forms. In acid soils, organic forms of phosphorus are mainly iron and aluminium phosphates while calcium phosphates are found in alkaline soils.

However, all inorganic forms of phosphates in soils are extremely insoluble. Therefore, any phosphorus added as fertiliser or released by decomposition of the organic matter will be instantaneously converted to one of its insoluble form. Due to this, Pierre and Parker (1927) reported that the overall concentration of soluble phosphorus in the soil surface hardly exceeds 0.2 mgL^{-1} while concentrations in the range of 0.01 to 0.1 mgL^{-1} are common. In addition, it was stated that displaced soil solutions contained 0.03 mgL^{-1} of phosphorus as inorganic orthophosphates and phosphorus concentrations in the soil solution of subsoil layers are usually less than 0.01 mgL^{-1}.

Biggar and Corey (1969) also emphasised that phosphorus applied to the soil tends to be fixed at the surface and locally raise the concentration of phosphorus in the soil solution, forming a near equilibrium system. If infiltrating waters carry the soluble phosphorus downward, more will quickly dissolve to maintain the concentration in solution. If runoff water comes in contact with this surface soil, the phosphorus concentration in the runoff would likely approach the equilibrium concentration. When phosphorus fertilisers are applied to the soil surface, the equilibrium concentration of phosphorus in a thin surface layer could reach one mgL^{-1} or more. In fact, the concentration of phosphorus in the run-off ranges up to a few tenths of a mgL^{-1}. The concentration of soluble phosphorus concentration in the water that percolates through the soil is usually very low due to precipitation of phosphorus in the subsoil. As such, most of the soluble phosphorus reaches the waterways through surface runoff.

Therefore, the maximal orthophosphate concentration recorded in the dry months may have originated through decomposition of organic matter that reach the waterways through surface run-off.

Moss (1980) noted that phosphorus is generally the most scarce element in the lithosphere of those required absolutely for algal and higher plant growth. In addition, its compounds are also relatively insoluble and there is no reservoir of gaseous phosphorus compounds available in the atmosphere compared to carbon and nitrogen. Therefore, a general belief is that the potential productivity of open water phytoplankton in a water body is determined by the supply of available phosphorus compounds.

5.1.7 Ammoniacal-N

Furtado and Mori (1982) noted that ammoniacal-N at Tasek Bera ranged between 0.000 to 0.767 mgL^{-1}. Ammoniacal-N recorded by Phang and Murugadas in 1997 was between 0.057 to 0.080 mgL^{-1}. In the present study (1998), the range is between 0.000 to 2.913 mgL^{-1}. The concentration peaked during the dry season (May/June 1998) as well as the wet season (August 1998). This observation is supported by the explanation of Furtado and Mori (1982) stating that the oxidation of nitrogen from the nitrate to ammonium was enhanced by the reduction processes predominating during the dry seasons, and enrichment from the watershed during the wet season.

According to Biggar and Corey (1969), 95% or more of N in soil occurs in organic forms and microbial decomposition of the organic matter results in the release of nitrogen in the ammonium form (NH_4^+) through the process called ammonification. The ammonium will be oxidised by microorganisms to nitrite (NO_2^-) and then to nitrate (NO_3^-) through a process known as nitrification under conditions of good aeration and favourable temperatures. Nitrite, which is toxic to many organisms, rarely accumulates in the soil except when the content of ammonia

(NH_3) in the system is high because the process of oxidation from nitrite to nitrate is faster than ammonium to nitrate. However, nitrate will be reduced to gaseous nitrogen forms and lost to the atmosphere through denitrification when conditions of poor aeration prevail. The concentration of ammonium in soil solution is not very high as ammonium ions are held on the cation-exchange sites in soils. However, the nitrate anion is completely soluble in the soil solution and is the form of nitrogen most subject to leaching.

5.1.8 Nitrate

Furtado and Mori (1982) reported that nitrate levels at Tasek Bera ranged from 0.010 to 0.290 mgL^{-1}. Nitrate levels in 1997 range between 0.08 to 0.41 mgL^{-1}. In 1998, the range is between 0.000 to 5.600 mgL^{-1}. In general, the concentration peaked during the wet season (August 1998).

Biggar and Corey (1969) noted that there are considerable difference in the concentration of nitrogen and phosphorus in surface run-off as compared to those in soil percolates. This is due to the fact that ammonium and nitrate forms of nitrogen are very soluble. If these materials exist in the surface of the soil at the beginning of a rain, it will be dissolved by the first rain that fall and carried into the soil. If the surface runoff occurs later, there will be little soluble nitrogen left at the surface to be carried away with the runoff. This explains why runoff waters usually contain very little soluble inorganic nitrogen. However, water that percolates through the soil may contain considerable amount of nitrate because nitrate is completely soluble in the soil solution and moves with it. Nitrate ions that manage to evade absorption by plant roots as they move downwards will be present in the drainage waters that move to the lake and streams by base flow.

5.1.9 Rainfall in the catchment area

Furtado and Mori (1982) reported that total annual rainfall at Tasek Bera in 1971 is 2505.0 mm. Rainfall patterns in the catchment area surrounding Tasek Bera are very localized and erratic. In addition, precipitation also varies from year to year.

According to Furtado (1987), the climate of Tasek Bera had to be extrapolated on the basis of climatic records for Temerloh and Sungai Charmai during the period August 1979 to February 1980. This is due to the absence of meteorological stations at Tasek Bera. The total annual rainfall is 1936.51 mm at Temerloh (monthly mean of 153.0 mm) and 1751.60 mm at Sungai Charmai (monthly mean of 134.7 mm). These figures are relatively lower than the average quoted for Peninsular Malaysia of 2032 mm per annum. However, it compared favourably with average figures for adjacent districts in Negeri Sembilan and Pahang of 1800 mm annually. In the present study (1998), mean total rainfall in 1997 was 1596.50 mm while rainfall in the following year was 1558.07 mm.

5.2 Primary productivity in Tasek Bera

5.2.1 Chlorophyll-a measurements

According to Furtado and Mori (1982), chlorophyll-a content ranged from 0.70 to 1.94 $mg.m^{-3}$ in the modified limnetic and forested limnetic regions while in the littoral Lepironia region, it ranged from 1.25 to 3.74 mgm^{-3}. Okina *et al.* (1982) reported that chlorophyll-a concentration of the lakes at Pos Iskandar, an *orang asli* settlement to the south of Station 8 (Kampung Baapa), ranged from 0.7 to 1.9 mgm^{-3} with an average of 1.3 mgm^{-3}. Phang and Murugadas (1997) noted that chlorophyll-a measured between 0.11 and 2.02 mgm^{-3} in 1997. The highest concentration was recorded at Station 7 (Lubuk Kuang). In 1998, a wider concentration is recorded, ranging from not detectable to 7.3437 mgm^{-3} with the highest concentration at Station 3 (Lubuk Pathir).

5.2.2. Photosynthethic production

Gross photosynthetic production was reported to range between 0.07 to 0.25 mg $CL^{-1}day^{-1}$ in the limnetic region and 0.19 mg $CL^{-1}day^{-1}$ in the stream channels. Net production was greatly reduced. It ranged between 0.02 to 0.07 mg $CL^{-1}day^{-1}$ in the limnetic and 0.01 mg $CL^{-1}day^{-1}$ in the stream channel (Furtado and Mori, 1982). This was noted to fall between 5% and 35% of the daily gross production. Photosynthetic production was determined *in situ* and in tanks using the ^{14}C method. In the present study (1998), gross primary productivity measurement ranged from –0.1292 to 0.8573 $mgO_2^{-1}L^{-1}hour^{-1}$. The light and dark bottle technique was used. The light and dark bottle technique is based on the fact that the respiration of organisms, including plants, animals and microorganism, removes oxygen from water, while photosynthesis releases oxygen into the water. The net effect of these two processes is reflected in the changes in oxygen concentration in the water.

In the dark bottle, only respiration occurs. Thus, the decrease in oxygen concentration is a measure of respiration by all organisms. However, in the light bottle, both respiration and photosynthesis occur, and the oxygen concentration increases, or at least decreases less than in the dark bottle, depending upon the rate of photosynthesis. Therefore, the difference between the final oxygen concentrations in the light and dark bottles is a measure of the total photosynthesis, or gross primary production, over the period.

This technique makes the assumption that respiration is occurring at the same rate in both the light and dark bottles although this does not seem to be the case in actuality. Phytoplankton productivity recorded in Appendix 17 clearly supports this variation. In addition, the technique is also influenced by the fact that samples of water, including organisms, are enclosed in containers. Glass containers modify the light transmitted to the inside, bringing about some distortion of normal temperature relations. Another bias is due to the enclosed organism not representing a perfect cross section of those in the natural system.

Moreover, the period of exposure of the bottles needs to be such that the changes of oxygen concentration are small, preferably only a few parts per million. If left too long, the oxygen in the dark bottle may be exhausted, causing respiration to stop. This will give an underestimate of respiration in the natural system. In the light bottle, however, exceptionally high levels of oxygen may cause some oxygen to escape from the solution, leading to an underestimate of photosynthesis.

5.3 Phytoplankton Diversity

5.3.1 Checklist of phytoplankton and abundance

According to Ratnasabapathy *et al.* (1982), the algae of Tasek Bera is dominated by desmids (Chlorophyta). 328 species of algae have been recorded, with 293 species of Chlorophyta, 61 species of Bacillariophyta, 24 species of Euglenophyta, 23 species of Cyanophyta, seven species of Chrysophyta, five species species of Pyrrophyta, three species of Rhodophyta and two species of Charophyta. Okina *et al.* (1982) reported that the phytoplankton density at Pos Iskandar, ranged from 12 to 6904 cells.L^{-1} with an average of 343 cells.L^{-1}. In Tasek Bera, the genera represented by the most number of species are *Staurastrum, Cosmarium* and *Euastrum*. Wetzel (1983) studied the characteristics of common major algal associations of the phytoplankton in relation to increasing lake fertility. He noted that general lake trophy where dominant algae consists of desmid *Stauraodesmus* amd *Staurastrum* is oligotrophic. The water characteristics of such a lake are reported to be slightly acidic with very low salinity. This is found to be true in the case of Tasek Bera where the pH ranged between 4.57 to 6.83 (Furtado and Mori, 1982).

Amongst the phytoplankton, diatoms such *as Tabellaria fenestrata, Eunotia gracilis, Eunotia lunaris, Eunotia robusta, Frustularia rhomboides* and *Pinnularia major* are common. Desmids such as *Cosmarium moniliforme, Closterium dianae, Closterium gracile, Closterium libellula, Hyalotheca disssiliens, Hyalotheca undulata, Micrasterias foliacea* were most common. Several species of desmids that are unique to Tasek Bera include *Triploceras splendens* Prowse, *Micrasterias foliaceae* Bail. var. *spinosa* Prowse, *Micrasterias alata* Wall. f. *tumida* Prowse and *Xanthidium superbum* Elfv var. *centricornis* Prowse (Furtado and Mori, 1982).

Phang and Murugadas (1997) reported a total of 66 species with 27 species of Bacillariophyta, 26 species of Chlorophyta, two species of Chrysophyta, four species of Cyanophyta, six species of Euglenophyta and one species of Pyrrophyta. The Chlorophyta, followed by the Bacillariophyta, dominated three out of five of the stations. Cell density ranged between 2233 and 77178 cells.L^{-1} while the most commonly found species were *Dinobryon sertularia, Trachelomonas volvocina, Tabellaria fenestrata, Frustulia rhomboides* and *Staurastrum arachne.*

In the present study, a total of 326 species were recorded including 42 unidentified species. Cell density ranged between 192 to 380916 cells.L^{-1}.The most commonly found species include *Arthrodesmus octocornis*, *Rhizosolenia* sp., *Dinobryon sertularia*, *Staurastrum tetracerum* and *Cosmarium asphaerosporum*. Species unique to Tasek Bera were not recorded although genus of *Micrasteria*s, *Triploceras* and *Xanthidium* were found. Among the most common species recorded in 1997, only *Dinobryon sertularia* was observed to be one of the most abundant. However, of the most common species mentioned in the 1970 to 1974 survey, none was found to be dominant in the present survey. Therefore a shift in species composition was observed and this could be due to anthropogenic activities in the catchment that brought about changes in the water bodies around Tasek Bera.

Based on frequency of phytoplankton (Table 12) at the sampling stations, Euglenophyta and Pyrrhophyta were found to dominate in stations that are relatively disturbed while Chlorophyta dominate stations that have minimal disturbance.

5.3.2 Sorensen's Similarity Coefficient.

In the present study, the results in Appendix 15 showed that the 3 sampling stations, namely Station 1 (Tanjung Kuin), Station 2 (Sungai Tasek) and Station 3 (Lubuk Pathir), are most similar (51.28% to 55.78%) amongst the other stations. The habitat description in Appendix 1 supports this observation because the 3 sampling stations are located quite near to each other, with a continuous flow of water from Station 3 (Lubuk Pathir) to Station 2 (Sungai Tasik) and finally into the open water areas of Station 1 (Tanjung Kuin). In addition, the habitats of the 3 sampling stations consist of undisturbed riverine banks covered with *Pandanus* and swamp vegetation. However, both Station 8 (Kampung Baapa) and Station 12 (Sungai Tembangan) were highly dissimilar to Station 1 (Tanjung Kuin) and Station 3 (Lubuk Pahtir) with the similarity coefficient between 17.11% to 19.42%. Based on Appendix 1, Station 8 (Kampung Baapa) is exposed to anthropogenic effects as it is located in the vicinity of a village where local residents utilise the water in the lake for washing and bathing. Station 12 (Sungai Tembangan) is located in the middle of oil palm plantations. The altered landscape showed effects of disturbance through high sedimentation in the water body. Therefore, the analysis showed that effects of settlement and agricultural activities as compared to the less disturbed sites were reflected by the difference in species composition of the phytoplankton.

In Table 13, the phytoplankton diversity during the present study showed the closest similarity to that by Furtado and Mori (1982) with a percentage of 12.18%. Comparison between the present study with that of Phang and Murugadas (1997) has 9.94% of similarity. The percentage of similarity between that of Phang and Murugadas (1997) when compared to Furtado and Mori's (1982) is 7.89%.

In general, studies conducted in the late 90's showed that a considerable change in phytoplankton diversity was noted as compared to results reported by Furtado and Mori (1982). Relatively low similarity (7.88% to 12.18%) was observed. The analysis has reinforced the likelihood that significant changes had occurred in the aquatic environment due to land-based impacts such as increase in oil palm plantation areas, utilization of fertilizers and burning of 'rassau' on the riverine banks.

5.3.3 Diversity Indices

Diversity index is a mathematical measure of species diversity in a community. Diversity indices provide more information about community composition than simply species richness (i.e., the number of species present) because they also take the relative abundance of different species into account. Diversity indices also provide important information about rarity and commonness of species in a community. Therefore, it is an important tool for biologists trying to understand community structure.

Wilhm (1970) stated that diversity indices are utilised as measures of environmental stress following the observation by investigators that mature communities of stable environments usually show high species diversity while those of disturbed or stressed situations less diversity. Diversity is high where many kinds of organisms live and where no species far outnumber the others. This is usually true of clean streams. When there is low diversity, only a few kinds of organisms are found although there may be thousands of them. This is because the streams are so polluted that only very tolerant forms survive. Due to concern for the environmental impacts of pollution, diversity indices were rapidly introduced into the analysis of environmental quality.

The Shannon-Weiner index varies from a value of zero for communities with only a single species to high values for communities having many species, each with a few individuals. The Shannon diversity index (H) is another index that is commonly used to characterise species diversity in a community and accounts for both abundance and evenness of the species present.

There are two sampling stations in the study by Phang and Murugadas (1997) which coincides with that of the present study (1998). The Shannon-Weiner index for Station 1 (Tanjung Kuin) in September 97 is 0.7400 as compared to the present data calculated for September 1998 which is 1.3285. Similarly, Shannon-Weiner index for Station 7 (Lubuk Kuang) is 1.1000 in September 1997 as compared to 2.7616 in September 1998. The diversity indices for both stations are higher in 1998, suggesting that the population of phytoplankton in the stations are less disturbed as compared to the previous year.

In 1997, the diversity index ranged from 0.73 to 1.10. Station 7 (Lubuk Kuang) had the highest species diversity while Pos Iskandar had the lowest species diversity. In the present study, the diversity index ranged from 0.47 to 3.17. Station 8 (Kampung Baapa) recorded the highest diversity in April 1998 while Station 3 (Lubuk Pathir) recorded the lowest diversity in September 1998. In general, Station 7 (Lubuk Kuang) and Station 8 (Kampung Baapa) had relatively high H' value. This could be due to periphytic plankton found on *Pandanus* stands and *Lepironia* reeds that are abundant in the littoral zone at both stations. The H' value for Station 9 (Sungai Bera 1) is relatively low. This could be due to disturbances in the surrounding habitat as the Felda Bera 2 settlement is situated next to the river. Moreover, the locals use the river at this station for washing and bathing.

Species richness refers to the number of species in a given area of habitat or in a sample of given size. When number of species is related to area of habitat, the value is considered to be species density. However, numerical species richness is the number of species present in samples of a certain number of individuals. It is noted that communities very different in species density might be similar in numerical species richness. One way of quantifying species richness is Margalef's index (d). The lowest d value was recorded at Station 3 (Lubuk Pathir) in April 1998. The highest d value was recorded at Station 6 (Kuala Sungai Tembangan) in September 1998.

Equitability (Species Evenness Index) assumes a value between 0 and 1 with 1 being complete evenness. It is a measure of how similar the abundances of different species are. When there are similar proportions of all species then evenness is one, but when the abundances are very dissimilar (some rare and some common species) then the value decreases. The lowest J value was recorded at Station 7 (Lubuk Kuang) in September 1998. The highest J value was recorded at Station 6 (Kuala Sungai Tembangan) in September 1998.

5.3.4 Dominance

Based on Table 15, all stations were dominated by Chlorophyta followed by Chrysophyta, with the exception of Station 11, which was dominated by Euglenophyta, thus suggesting presence of organic pollution at this particular station. Station 7 (Lubuk Kuang) had the highest number of species, totaling at 84, followed by Station 3 (Lubuk Pathir) with 76 species, Station 1 (Tanjung Kuin) and Station 8 (Kampung Baapa) with 74 species and Station 2 (Sungai Tasik) with 73 species. Station 9 (Sungai Bera 1) had the lowest number of species (24). Table 16 shows the taxonomic composition of phytoplankton from April to September 1998. Throughout the five months, Chlorophyta has the highest number of species, followed by Chrysophyta and Euglenophyta.

5.3.5 Trophic Classes

Patrick (1973) noted that care should be taken to count sufficient diatoms in order to indicate the true structure of the community under study. Since counting is a laborious task, other approaches, such as measurement of chlorophyll-a, have been used to estimate the number of specimens present.

Table 17 illustrates trophic classes by chlorophyll-a and algal numbers according to Felfödy (1987). Table 18 shows the trophic states of the corresponding sampling stations in their respective months that are classified based on chlorophyll-a (Felfödy, 1987). The water body at the sampling stations ranged from oligo-mesotrophic to atrophic. Table 19 shows the trophic classes for those sampling stations based on algal numbers (Felfödy, 1987). The water body at the sampling stations ranged from mesotrophic to ultra-oligotrophic. In general, classification of water body based on chlorophyll-a resulted in a trophic class at one level lower than that based on algal numbers. This is because measurement based on chlorophyll-a

Table 15. Distribution (number of species) of phytoplankton by division for Stations 1 to 12.

Division	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9	Station 10	Station 11	Station 12
	Tanjung Kuin	Sungai Tasik	Lubuk Pathir	Tanjung Papan	Kampung Benal	K. Sg. Tembangan	Lubuk Kuang	Kampung Baapa	Sg. Bera 1	Sg. Bera 2	Paya Kelantong	Sg. Tembangan
Chlorophyta	51	51	55	34	27	27	39	29	10	37	13	14
Chrysophyta	17	12	14	24	15	16	33	33	7	13	14	10
Cyanophyta	-	-	-	1	-	-	-	-	-	1	-	1
Euglenophyta	5	9	5	8	7	4	10	10	7	4	15	9
Pyrrhophyta	1	1	2	2	2	1	2	2	-	1	1	2
Total number of species	74	73	76	69	51	48	84	74	24	56	43	36

le 16. Taxonomic composition (number of species) of phytoplankton from April - September 1998

Division	Apr-98	May/Jun 98	Jul-98	Aug-98	Sep-98
ophyta	87	65	57	64	46
sophyta	29	31	42	50	42
ophyta	-	1	1	1	-
enophyta	23	21	19	26	17
phyta	1	3	2	8	2
l number of species	**140**	**121**	**121**	**149**	**107**

Table 17. Trophic classes by chlorophyll-a and algal numbers according to Felfödy (1987).

Trophic Class	Chlorophyll-a (mgm^{-3})	Algal numbers (10^6 cells.L^{-1})
atrophic	0	0
ultra-oligotrophic	<1	<0.01
oligotrophic	1-3	0.01-0.05
oligo-mesotrophic	3-10	0.05-0.1
mesotrophic	10-20	0.1-0.5
meso-eutrophic	20-50	0.5-1
eutrophic	50-100	1-10
eu-polytrophic	100-200	10-100
polytrophic	200-800	100-500
hypertrophic	>800	>500

Table 18. Trophic classes for all stations by chlorophyll-a (Felfody, 1987).

No	Stations	Trophic class by chlorophyll-a				
		Apr-98	May/Jun 98	Jul-98	Aug-98	Sep-98
1	Tanjung Kuin	oligo-mesotrophic	ultra-oligotrophic	oligotrophic	ultra-oligotrophic	oligotrophic
2	Sungai Tasik	oligo-mesotrophic	oligotrophic	ultra-oligotrophic	ultra-oligotrophic	oligotrophic
3	Lubuk Pathir	oligo-mesotrophic	ultra-oligotrophic	ultra-oligotrophic	ultra-oligotrophic	oligo-mesotrophic
4	Tanjung Papan	oligo-mesotrophic	ultra-oligotrophic	ultra-oligotrophic	ultra-oligotrophic	ultra-oligotrophic
5	Kampung Benal	-	ultra-oligotrophic	ultra-oligotrophic	ultra-oligotrophic	ultra-oligotrophic
6	Kuala Sungai Tembangan	-	ultra-oligotrophic	ultra-oligotrophic	ultra-oligotrophic	ultra-oligotrophic
7	Lubuk Kuang	oligo-mesotrophic	oligotrophic	ultra-oligotrophic	ultra-oligotrophic	ultra-oligotrophic
8	Kampung Baapa	oligotrophic	oligotrophic	oligotrophic	ultra-oligotrophic	ultra-oligotrophic
9	Sungai Bera 1	oligo-mesotrophic	ultra-oligotrophic	ultra-oligotrophic	atrophic	ultra-oligotrophic
10	Sungai Bera 2	oligo-mesotrophic	ultra-oligotrophic	ultra-oligotrophic	atrophic	oligotrophic
11	Paya Kelantong	oligotrophic	ultra-oligotrophic	oligotrophic	atrophic	oligotrophic
12	Sungai Tembangan	oligo-mesotrophic	oligotrophic	ultra-oligotrophic	atrophic	ultra-oligotrophic

Table 19. Trophic classes for all stations by algal numbers (Felfody, 1987).

No	Stations	Trophic class by algal numbers				
		Apr-98	May/Jun 98	Jul-98	Aug-98	Sep-98
1	Tanjung Kuin	mesotrophic	oligo-mesotrophic	oligo-mesotrophic	oligotrophic	ultra-oligotrophic
2	Sungai Tasik	mesotrophic	oligo-mesotrophic	oligotrophic	oligotrophic	ultra-oligotrophic
3	Lubuk Pathir	mesotrophic	mesotrophic	oligo-mesotrophic	oligotrophic	oligotrophic
4	Tanjung Papan	oligotrophic	oligotrophic	oligotrophic	oligotrophic	ultra-oligotrophic
5	Kampung Benal	-	oligotrophic	ultra-oligotrophic	ultra-oligotrophic	ultra-oligotrophic
6	Kuala Sungai Tembangan	-	oligotrophic	oligotrophic	oligotrophic	ultra-oligotrophic
7	Lubuk Kuang	oligo-mesotrophic	oligotrophic	oligotrophic	oligotrophic	ultra-oligotrophic
8	Kampung Baapa	oligo-mesotrophic	oligotrophic	oligotrophic	ultra-oligotrophic	ultra-oligotrophic
9	Sungai Bera 1	oligotrophic	ultra-oligotrophic	oligotrophic	ultra-oligotrophic	ultra-oligotrophic
10	Sungai Bera 2	mesotrophic	ultra-oligotrophic	oligotrophic	ultra-oligotrophic	ultra-oligotrophic
11	Paya Kelantong	oligotrophic	oligotrophic	oligotrophic	ultra-oligotrophic	ultra-oligotrophic
12	Sungai Tembangan	oligotrophic	ultra-oligotrophic	ultra-oligotrophic	ultra-oligotrophic	ultra-oligotrophic

accounts only for the chlorophytes while algal numbers encompassed all the other divisions of phytoplankton in the sample. Trophic level refers a step in the transfer of food or energy within a chain. There may be several trophic levels within a system, for example, producers (autotrophs), primary consumers (herbivores) and secondary consumers (carnivores). Therefore, trophic level based on algal number is more accurate.

5.4 Effect of the environmental parameters on phytoplankton

Patrick (1973) discussed about the approach used to determine if algae could reliably indicate water quality by observing and analysing natural communities. This is because effect of a pollutant can be estimated by shifts in species composition and structure of the community. The basis stems from the fact that algae derive most of the nutrition they require from dissolved chemicals in water and therefore should reflect the chemical environment. However, it was also recognised that other physical factors and susceptibility to predation influence the ability of a given species to compete with other species. Therefore, the interaction of favourable and unfavourable stresses determines the degree of success of a species in an algal communitiy.

APHA (1989) noted that water quality is reflected in the species composition and diversity, population density and physiological condition of indigenous communities of aquatic organisms. Cairns *et al.* (1973) rationalised the importance for conducting biological monitoring is that aquatic organisms act as natural monitors. Organisms that cannot tolerate the stress of short-term exposure to poor water quality will not survive, hence the community structure changes. They also emphasized that since aquatic organisms respond to their total environment, they are able to provide a better assessment of environmental damage as compared to chemical and physical parameters. However, it was also recognised that biological monitoring should not replace chemical and physical monitoring because the information given actually supplement each other and are not mutually exclusive.

5.4.1 Statistical analysis

Two-way ANOVA analysis showed that primary productivity and transparency were significantly different among the sampling stations. In addition, chlorophyll-a level, H' value, phytoplankton cell count and pH were found to be significantly different among sampling occasions.

In multiple regression analysis, pH and nitrate levels contributed significantly to chlorophyll-a levels. Chlorophyll-a level was measured to indicate standing crop or primary productivity at the sampling stations.

Swale (1968) and Reynolds and Allen (1968) noted that species composition of plankton changes with the influence of pH. Various Chlorophytes (*Ankistrodesmus*, *Closterium* and *Chlorella* sp.) were reported to dominate water bodies with pH 4.5 while *Asterionella*, *Pediastrum*, *Anabaena* and *Microcystis* were found in pH 6.5.

Brönmark and Hansson (1998) noted that in lentic environments, the dependence on nutrients, particularly phosphorus and nitrogen is strong and usually limits primary productivity. Hutchinson (1967) reported that phosphate, nitrate and silica are the most critical nutrients for autotrophic production. Although inorganic phosphate is often the principal factor limiting the growth of plants, algae and other primary producers, nitrate-nitrogen has the tendency to become limiting when phosphate is plentiful and when the atomic ratio of N:P falls below some level. In theory, it was believed that a ratio of N:P below 16:1 caused nitrogen limitation (Redfield,1958) but in practice, the shift from phosphorus to nitrogen limitation had been reported to occur over a wider range of 10-30:1. Redfield *et al.* (1963) noted that the ratio of N:P indicates which nutrient is likely to limit algal growth in lakes. They explained that carbon, nitrogen and phosphorus occur in algal tissue in a consistent ratio of atomic weights of 106:16:1, referred to as the Redfield ratio. Following numerous bioassay experiments with lake algae and based on the Redfield ratio, it was concluded that when N:P ratios fall below 16:1, algae will have less nitrogen available per unit of phophorus and hence experience nitrogen limitation. Ratios above 16:1 indicate phosphorus limitation. It was also reported that joint limitation by both nutrients is likely at N:P ratios between 10:1 and 20:1.

Allan (1995) stated that algal growth in lakes is usually limited by the supply of inorganic phosphorus and therefore the productivity of a lake is taken as a function of phosphorus availability. Elser *et al.* (1990) pointed out that nitrogen is considered to be secondary. Nevertheless, nitrogen acts as the primary nutrient in some regions and both nitrogen and phosphorus sometimes influence algal growth.

Based on Table 14, conductivity contributed significantly to the Shannon-Weiner Index of Diversity (H'), Margalef's Species Index (d) and Equitability (Species Evenness) Index (J). Allan (1995) supported this observation by stating that stream-dwelling organisms undoubtedly require water of some minimal ionic concentration. It was also mentioned that studies linking the ionic contents of water to the stream biota established that streamwater of low ionic concentration has a restricted flora and fauna, in both abundance and species richness. In the present study, cell counts or density also showed significant correlation to conductivity.

Water depth, transparency and temperature contributed significantly to primary productivity that was measured using the light and dark bottle *in situ*. Lewis (1988) pointed out that decreased light penetration suppressed phytoplankton productivity. As the depth below water surface increases, availability of light decreases. Light penetration is also dependent on transparency of water. According to Horne and Goldman (1994), heat transmitted with light is responsible for establishing thermal stratification in water bodies in addition to regulating the rates of chemical reactions and biological processes.

In cluster analysis, groups of clustering obtained using Sorensen's Similarity Coefficient (Figure 47) are similar to the ones based on biotic parameters (Figure 48). Sampling stations are grouped into less disturbed sites, moderately disturbed sites and more polluted sites which coincides with development occurring at those sites as described in Appendix 1.

5.4.2 Biological indicators

Patrick (1948) proposed that algal flora in natural or healthy streams are represented by a high number of species, with relatively small populations. In addition, the species are dominated by diatoms with the presence of a few greens and blue-greens. It was suggested that the effect of pollution would reduce species numbers, bringing about a greater unevenness in sizes of population, with some becoming extremely common. Species composition of the algal community would shift from one dominated by diatoms to one being dominated by filamentous greens, or unicellular greens in some cases or by blue-green algae.

According to Patrick (1973), certain species of algae have wide ranges of tolerances while others have very narrow ranges of tolerances. More tolerant algae including *Nitzschia palea*, *Cyclotella meneghiniana*, *Gomphonema parvulum*, *Anacystic cyanae* and *Stigeoclonium lubricum* were noted to thrive in the presence of certain kinds of pollution, hence their abundance are indicative of the presence of such a pollution. Caution should be taken, however, in predicting the amount of pollution present solely based on the size of the population of the designated indicator species. The argument for this is because the growth of an algal population is influenced by other factors in the aquatic environment, which may cause stress or bring about unfavourable conditions to such an extent that a particular species is eliminated regardless of the concentration of the pollutant chemical. Turbidity in a stream was cited as an example as it prevents light from penetrating the water and will eliminate the algal population regardless of whether a pollutant is present. Similarly, low temperatures will inhibit reproduction of diatoms as well as limiting the effect of a pollutant that has capability to increase growth. However, it was agreed that associations of algae are very useful towards indicating water quality. Therefore, Patrick (1973) suggested that a variety of parameters be used in diagnosing water quality by the use of algae. Community structure such as the numbers of species, the relative abundance of species, the kinds of species and the total biomass present should be considered.

According to Levins (1966), it is of common practice to use a single diversity index to measure the effect of a pollutant upon an algae community. However, it was noted that many indices are biased in their evaluation of various characteristics of a community. Therefore, it was recommended that a variety of indices be used to determine whether they all, or at least a majority, indicate similar conditions.

Brinley (1942) reported a comparison that was made between the population of certain species of phytoplankton algae and the chemical and bacteriological indices of the degree of organic pollution in a flowing stream. The presence of large numbers of *Euglena, Trachelomonas* and *Phacotus* indicate that organic matter farther upstream has heavily polluted the water body. In addition, bacterial action has decomposed the organic matter to available plant nutrients, producing a rich medium. On the other hand, large numbers of *Chrysococcus* and *Crytomonas* indicate that the natural process has completed decomposition of organic matters in the stream and the stream is considered clean.

Anton (1991) proposed that algal species is utilised as an indicator for the initial occurrence for eutrophication before water quality deteriorates. Algae have relatively short generation time and simple cell organisation. Therefore, they are very sensitive to changes to their environment. However, specific indicator species need to be identified in order for it to be incorporated as one of the criteria to evaluate biotic life in a water body under the Water Quality Standards. Further investigation of the distribution of algae in each watershed and their ecological tolerance is required to accurately assign the appearance or absence to water quality instead of other environmental factors. This will enable the exploitation of algae as a potential biological early warning system for water quality management in Malaysia.

5.5 Sources of degradation and management recommendations

Many processes including altered hydrology such as drainage and irrigation, sedimentation, nutrient run-off, vegetation removal and fire threaten the wetland ecosystem in Tasek Bera, The vital physical, chemical and biological functions, which give Tasek Bera its unique character, are driven by water availability.

Although wetlands naturally alter in character over time, human disturbance of hydrological processes, directly by drainage or indirectly by catchment deforestation and rising water tables from irrigation, have very rapidly resulted in the degradation of wetlands, or the loss of it.

In the Malaysian Wetland Directory (DWNP,1987), Tasek Bera and Tasek Chini in Pahang, Sedili Kecil in Johore, Sabah's east coast and the lower reaches of certain rivers in Sarawak were identified as the main remaining freshwater swamp forests in Malaysia. Principal threats were noted to include agricultural use and non-sustainable exploitation for timber. Therefore, freshwater swamp are recognised as the most severely threatened wetland habitat and remains a serious gap in the country's protected area system.

Anton (1991) recognised the need to restore and conserve freshwater bodies in Malaysia which included reservoirs, fish and farm ponds, recreation and urban lakes and disused mining pools. Due to improper land use and poor water management, many of these water bodies have become eutrophic with algal scums and choked with prolific growths of vegetation. This brings about development of large shallow areas which encourages growth of macrophytes. Cooke *et al.* (1986) noted that eutrophication is caused by excessive additions of inorganic nutrients, organic matter and/or silt to water bodies, bringing about an increase in biotic production and decrease in water volume.

Prior to any management project for the sustainable use of wetlands, managers need to identify the aims and establish the behavior and effects of degrading agents. One of the challenges in undertaking the restoration and management of natural system is the lack of knowledge of the processes that drive the system as well as the latitude the manager has in determining the appropriate management strategies in reviving the system and re-establish its natural functions.

5.5.1 Human Induced Factors Influencing Water Quality

5.5.1.1 Modification of catchment area

The catchment area of Tasek Bera has been immensely modified and developed into oil palm and rubber plantations (Wetlands International – Asia Pacific, 1999b). Among the potential impacts in the Ramsar that had been identified were eutrophication problems due to fertiliser application and influx of other agrochemicals such as pesticides, herbicides and fungicides. In addition, alteration to seasonal flooding pattern have caused long periods of very low water levels and significant water level fluctuations over short time periods. Moreover, severe soil erosion due to exposed soil in areas of intensive agricultural practices in the catchment have significantly increased sedimentation on the lake bed, hence accelerating colonisation of water body by *Pandanus* and *Lepironia*. It was noted that soil erosion and eutrophication affect vegetation in the river channels by stifling with silt or by encouraging growth of diatoms and algae that compete with submerged vegetation such as the endemic *Crytocoryne purpure*.

The effects of nutrient inputs from human source are of particular concern as degrading processes in wetlands. Therefore, acceptable water quality limits needs to be established as a basis for managing non-point and point source discharges to minimize nutrient inputs.

Bowmer (1981) reported that eutrophication or nutrient enrichment resulted primarily from inputs of nutrient rich wastewaters such as sewage effluent and run-off from agricultural land. The eutrophication of wetlands promotes the growth of aquatic plants and an increase in organisms and processes responsible for decay. This increase in plant growth and biological processes can cause a number of problems. It leads to algal blooms that can pose threats to wildlife and humans, macrophyte blooms that can modify indigenous habitats and block water management structures, it can deplete oxygen supplies, kill fish and cause physio-chemical changes in water quality.

Phosphorus and to a lesser extent nitrogen appear to be the most important nutrient involved in eutrophication. Phosphorus is frequently a limiting element in natural systems. Its supplies are dominated by discrete concentrated sources associated with human activity. In general, increased productivity requires an increase in both nitrogen and phosphorus although one of these needs to be limited to reduce productivity. Nitrogen, which is generally available from diffuse sources throughout the catchment, is frequently less limiting. However, nitrogen is also readily lost to the atmosphere under certain chemical conditions. Due to the ready exchange of nitrogen between air and water, the impacts of nitrogen inputs are difficult to assess. According to the Ecological Horticulture (1989), eutrophication is more likely where accumulation of nutrients can occur, during low periods and where N : P ratios occur. It is generally accepted that the most efficient way of reducing nutrient input into aquatic systems is to control point source discharges. The relative and cumulative significance of non-point sources such as agricultural run-off also necessitates some control. Such control can be achieved by diverting nutrient-laden effluents away from wetlands, removing nutrient from effluent before it enters wetlands, improving agricultural practices including methods and rates of applying fertilizer, establishing appropriate vegetative buffers around the wetlands. In the instance of the State Pollution Control Commission (New South Wales), it is recommended that a minimum 20 metre indigenous vegetation buffer around wetlands be established to act as an infiltration area for surface run-off.

Irving (1993) reported that diffuse sources, largely from agriculture, contributed for most of the nutrient loading in water bodies although it is more difficult to quantify. Nutrients especially nitrate can be lost from the soils through leaching while phosphate may be lost through run-off. These inputs can be reduced through restriction of agricultural practices such as the excessive use of fertilisers. It was recommended that techniques such as the use of cultivated strips of land alongside water bodies as buffer strips or the presence of undrained wetlands adjacent to open water areas can also help restore habitats by significantly reducing nutrient loading.

5.5.1.2 Pollution (point source)

Point source pollution included sewage from the Semelai settlements and litters from residents and visitors especially around the existing resort area. Oil pollution from outboard engines and use of synthetic chemicals in fish poisoning by outsiders also made up for other point source of pollution.

5.5.1.3 Fires

Pandanus stands that grow profusely along the banks and choke the navigation channels in the swamp area need to be cleared from time to time by cutting or burning. However, unmonitored fires can become uncontrollable due to strong winds and spread to a vast area, sometimes towards the fringe of the jungle. These fires were considered to cause progressive replacement of swamp forest with open water and *Pandanus-Lepironia* swamps. Burning of *Pandanus* stands are usually done during dry season when most of the vegetative parts are exposed due to low water levels. Other than that, fire was set by the Semelai to facilitate turtle hunting and also clearing lowland forests for shifting cultivation.

According to Gore (1983), the effects of fire in wetlands include the destruction of peat beds, changes in vegetation composition, reduction of the organic surface layer, exposure of roots and rhizomes, increased sedimentation and short term increases in water temperature. It was also suggested that the severity or intensity of a fire event is a significant factor in wetland ecosystem. The recovery from fire depends on the fire frequency, vegetation composition, community age and condition and the post-fire weather conditions. A fire's severity, rate and extent of spread is determined by the presence or absence of free standing water as well as the seasonal and spatial variations in the wetness of the surface organic layer.

Fire influences the physico-chemical properties of soil by oxidizing the standing vegetation cover and soil organic matter. This leads to modification of microclimate in the soil and litter environment. In the short term, fire mobilizes nutrients by incinerating organic material, leading to deposition of ash and by heating the soil. However, not all elements are mobilized equally. Nutrient loss by leaching, run-off, the erosive action of the wind and losses to the atmosphere in smoke offsets these nutrient inputs and improved availability to plants. Raison (1980) reported that where rates of litter decay and mineralization are slow, a relative sudden redistribution and short-term mobilization of nutrients may follow burning. The general effects include increased stream flows, increases in suspended sediment loads, soil erosion and reduced infiltration. Nevertheless, information on changes in water chemistry and the effects on the aquatic biota are lacking.

The modification of natural water regime is a frequent degrading process in wetlands. Among the modifications are drainage, the diversion of water away from the wetlands and the stabilization of natural fluctuation levels. Removal or damage to aquatic, emergent and terrestrial fringing vegetation by cutting or burning to clear waterways for navigation purpose is also a source of disturbance. Deterioration in water quality can result from agricultural run-off, sewage discharge from settlement areas. Therefore the lowering diversity of plant and animal species, or a change in water quality and nutrient balance manifests degradation in the wetlands. In wetlands receiving high nutrient inputs, greater than normal flows or which are subjected to a stabilized water regime, certain species of plants frequently dominate at the expense of other species.

5.5.2 Legislation, Administration and Management of Tasek Bera

Furtado and Mori (1982), recognising the unique structure and dynamics of the Tasek Bera, had raised several conservation and management issues due to the fact that this lowland riparian swamp held potential for rural settlement and agro-industrial development. Being rich in flora and fauna, it was necessary to protect Tasek Bera and its catchment area to enhance research opportunities while facilitating a low level of tourism. It was proposed that an area of at least 200 km^2, which include the swamp and adjacent terrestrial system, be protected for biological purposes. A zone at least 1,000 m wide was recommended to be protected around the swamp because the swamp's intimate association with the catchment area.

It was also suggested that Tasek Bera and its catchment be conserved as an aboriginal area, national monument and nature reserve, with controlled exploitation and development of natural resources. The swamp ecosystem and its catchment area were emphasised to be vulnerable at two points. This was located at its northern boundary near the confluence of Sungai Bera, where reverse flow occurred during flood conditions especially the northeast monsoon and also at its south boundary where Sungai Palong meets Tasek Dampar, where it receives water from the Sungai Muar system during the floods. A buffer zone was proposed at these two points to protect the Tasek Bera from potential pollution originating from the Pahang-Bera and the Muar-Palong river systems.

There are a number of different laws in Malaysia where an area may be set aside for protection. The differences in the level of protection achieved, the agency responsible for management, and whether the protected area is under State or Federal jurisdiction is very much governed by the legislation used. States in Peninsular Malaysia have total right over all land matters under the Malaysian Constitution. Therefore, land use decisions are made primarily by the State and its administrative bodies. A variety of legislation at State level pertaining to wetlands are in existence although the establishment of protected areas vary from one State to another (DWNP,1987).

Government agencies have varying approaches to wetland utilization and management where each of these departments or agencies deals with one particular aspect of function of wetlands. For instance, the Fisheries Department is only concerned with fisheries, the Forestry Department is accountable for forestry issues while Drainage and Irrigation Department is responsible for agricultural drainage and flood control. As there are many agencies involved in wetland management, there are bound to be conflicting policies among these agencies that arise because of the different objectives and role of each agency. Therefore, a more concerted and multidisciplinary approach among these agencies is essential to avoid the beneficial functions of wetlands from being lost due to degradation.

Tasek Bera was designated as Malaysia's first Ramsar site when Malaysia joined the Convention on Wetlands of International Importance (Ramsar Convention) in November 1994 (Wetlands International – Asia Pacific, 1999a). The main aim for Ramsar sites is to maintain the ecological character of the wetland while allowing "wise use" of its wetland resources. This requires attaining a balance between nature conservation and human exploitation that will ensure that the wetland's values and functions are preserved in the long term. The term "wise use" includes full consultation and involvement of local communities in the management of the site.

The policy framework for wetland conservation in Malaysia is complex because it involves policies at national, state and district levels. Moreover, varied and sectoral interests included in wetland resources, such as flood control, fisheries and wildlife conservation also require application of a wide range of sectoral policies.

Although Tasek Bera is listed under the Ramsar Convention, implementation of the Convention on Biological Diversity, which Malaysia signed in June 1994, is also relevant to its conservation. In fact, a National Policy on Biological Diversity that was launched in 1998 had identified freshwater wetlands like Tasek Bera as a priority for conservation action. Other international treaties such as ASEAN Agreement on Conservation of Nature and Natural Resources and the Convention on International Trade in Endangered Species (CITES) are also found to be relevant to conservation of Tasek Bera.

The Pahang State Government implemented the "Integrated Management of Tasek Bera" in 1996 with technical assistance from Wetlands International – Asia Pacific, and financial assistance from Danish Cooperation for the Environment and Development (DANCED). This project was established to assist the Malaysian Government in meeting its obligation under the Ramsar Convention with regards to conservation of Tasek Bera. Therefore, appropriate planning and management measures were required for maintenance of the ecological integrity of the wetland system and the species it supports. In addition, it needs to ensure wise or sustainable use of the wetland and forest resources so that the area can continue to be used by the indigenous Semelai people, local visitors and tourists without damaging the area. The project also undertook activities such as boundary identification and gazettement, community development programme, training programme, education and public awareness programme, tourism planning, development of guidelines for the buffer zone, and establishment of nature trails and a visitor centre as a sound basis for the establishment of this protected area.

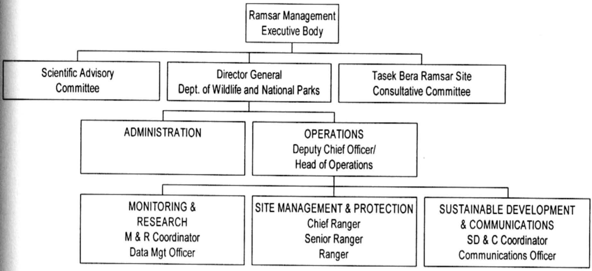
Challenges faced in maintaining the ecological and socio-economic values of Tasek Bera as a Wetland of International Importance include pollution from agricultural land use in the catchment area, conversion of forest habitats, burning of swamp vegetation to clear navigational routes, fish poisoning, overexploitation of fish stocks and trade in wildlife species. Availability of manpower and resources also dictates commitment in site management activities including enforcement of legal protection. In addition, logistical constraints in site management include difficulty of access to many parts of the site, navigational difficulty on the wetland and lacking of communication infrastructure.

Tasek Bera area is predominantly under State ownership. The Ramsar Site consisting of 31,120 ha was gazetted under the National Forestry Act as a Forest Reserve while an area of 77,380 ha, which consisted mostly of agricultural plantations on government owned land under the management of FELDA Plantations Sdn. Bhd., constituted for the buffer zone (Wetlands International – Asia Pacific, 1999a). The buffer zone also comprised the upper Bera River catchment within the Chini Forest Reserve and Bukit Ibam Proposed Forest Reserve and also three Orang Asli Areas totaling at 5,150 ha. The Ramsar Site had been recognised under the Bera District Structure Plan as an area for conservation and recreation while the buffer zone was identified for restricted development (agricultural land), environmental protection and water catchment (forested land). The authority responsible for the administration of the site is the Pahang State Director of Forest. Nevertheless, the Department of Wildlife and National Parks hold responsibility as the lead management agency while the Ministry of Science, Technology and the Environment is the national administrative authority for the Ramsar Convention. The Tasek Bera Ramsar Site Management Authority Organizational Chart is listed in Table 20.

Despite clear management guidelines, certain legal constraints that exist contributed to lack of species protection in Orang Asli areas and the inability to impose wildlife conservation laws in such areas.

For instance, the Aboriginal Peoples Act, 1954 contains certain clauses with potential significance to the future management and conservation of Tasek Bera. This is especially true of those pertaining to aboriginal areas and aboriginal reserves which once gazetted, cannot be declared under any other notification, whether as a Malay Reservation, a sanctuary or reserve relating to the protection of wildlife or a

Table 20. Tasek Bera Ramsar Site Management Authority Organizational Chart (Wetlands International – Asia Pacific, 1999a).



Note : The management authority staff are under the supervision of the Chief Officer, who reports to the Executive Body. This is the main decision-making body of the management authority, chaired by the Secretary General of the Ministry of Science, Technology and Environment. A Scientific Advisory Committee provides technical review of site management and research activities. A Consultative Committee chaired by the Director of the Pahang State Economic Planning Unit provides a formalized mechanisms for consultation with stakeholders and to coordinate site management with government planning processes.

Staff of the Operations Division will be seconded from relevant government agencies, including Department of Wildlife and National Parks, Forestry Department, Fisheries Department, Department of Environment, Pahang State Tourism Agency and Department for Orang Asli Affairs. The total staff number is under review.

forest reserve. In other words, these areas cannot be gazetted twice. In addition, the Act also imposes controls on access to these areas and would affect tourism, research and educational activities because permission had to be attained from the Department of Orang Asli Affairs. The current legal status as Orang Asli Area implied that the Semelai are still permitted to exploit the areas' natural resources irrespective of other legal implications. Therefore, the protection of species under the Protection of Wildlife Act, 1972 does not apply in the example of exploitation by Semelai in the Orang Asli Areas located at Tasek Bera. In Section 38 of the Fisheries Act, 1985, provision is made for control of fisheries and the conservation of fish and turtles at Tasek Bera. In addition, Section 27 of the act covers aquatic mammals and turtles and provide protection from disturbance or taking animals unless permitted under state legislation. The Asian Arowana (Kelisa) *Scleropages formosus* is the only prohibited species under State Fisheries Enactment – Fisheries (Riverine Waters) Rules 1991 while turtles were not mentioned, making the provision of Section 27 of the Fisheries Act applicable. Under the National Forestry Act where the Tasek Bera Ramsar Site had been gazetted, wide powers were provided for control of entry to designated areas, removal of timber and other forest products including wildlife under license, zoning for specific purposes, and enforcement.

5.5.3 Zonation for Site Management

Management of protected areas or areas designated for conservation requires that sensitive elements of the ecosystem be protected from disturbance, incompatible uses separated and prioritisation be made for various or purposes by adopting a management zoning approach (Wetlands International – Asia Pacific, 1999a).

Recommendation C.5.3 adopted at the Fifth Meeting of the Conference of the Contracting Parties to the Ramsar Convention, Kushiro, Japan, June 1993, states :

"the need to develop zoning measures related to larger Ramsar sites and wetland reserves, involving strict protection in key zones and various forms of wise use for the benefit of human populations in other zones; and the need to develop ecological corridors linking Ramsar sites"

Therefore, factors that are taken into consideration in the designation of management zones in the Ramsar site include Ramsar values, ecological sensitivities, on- and off-site factors influencing management, the wise use concept, physical attributes useful to management and requirements of management support activities. Management zones identified and assigned in the Tasek Bera Ramsar Site Management Plan were based on zone description according to permitted activities, incompatible activities and activities requiring management approval. It is brought to attention that the management zoning plan requires to be incorporated into law such as the National Forestry Act and other related legislation. Although the Bera District Structure Plan allows for planning controls in the Ramsar Site and its Buffer Zones, the zones at present are without legal status. Importance of active community participation in the identification of zones and field demarcation was emphasised as the basis for all co-management and land-use activities.

Although the Ramsar Site has a Buffer Zone, it is situated outside of the current Ramsar site boundary. As such, most of its management is beyond the scope of this plan. Incremental improvement in the environmental quality of the buffer zone can be achieved thought maintenance and rehabilitation of existing areas of natural habitats, improved soil protection measures, improved water quality and reduced input of chemicals. In addition, it was recommended for the Buffer Zone to cater to any significant increase in tourism facilities rather than within the Ramsar Site itself.

Three management goals had been identified in the Tasek Bera Integrated Management Plan. The first goal is to meet the Ramsar Convention obligations through i) promoting the wise use of the Ramsar Site, ii) reporting to the Ramsar Convention Bureau of any significant changes to the ecological character to the Ramsar Site, iii) promoting training in the field of wetland research, management and wardening and iv) exchanging data and publications concerning the Ramsar Site. The second goal is to maintain or increase the biodiversity values of the Ramsar Site at all scales (genetic, species and habitat diversity) and with emphasis on fostering natural ecological processes. The third goal is to realise the full potential of the Ramsar Site for education and raise public awareness with regards to wetland functions and values. There are a total of twenty-seven individual but related management objectives that were identified according to various management issues to attain the goals, with upper and lower "Limits of Acceptable Change" (LACs), where applicable, as a reference framework for evaluating management activities. In terms of water quality, the management objective is to maintain the natural water quality, such that the selected water quality parameters fall within the specified limits. Lower "Limits of Acceptable Change" stated that there should be no deterioration in water quality parameters from 1998 levels as a result of human activities while upper limits are not applicable. Management Prescriptions, with accompanying individual projects, must be addressed in order to achieve the Management Objectives. In the context of water quality, three Management

Prescriptions were listed, namely to i) monitor water quality parameters and analyse for any significant long-term trends especially those leading to lower water quality. The main parameters to be measured are nutrient levels, sediment load, agrochemical concentration, metal ions, acidity and dissolved oxygen levels, ii) identify and control and eliminate any on-site human activities, such as oil spills from boats and dumping garbage, or ecological processes that adversely affect water quality and iii) identify, monitor and mitigate any activities in the Tasek Bera catchment, such as pesticide use, that may adversely affect water quality.