CHAPTER THREE

RESULTS

3.1 WATER PARAMETERS

Results are interpreted in three parts; 4-month study, 12-hour study and 1-day "grid" sampling study. Case indication for figures are shown in Table 3. The mean reading and standard deviation (S.D.) for the water parameters recorded at each station for the above studies were shown in Figures 6 – 11 for 4-month study, Figures 12 – 23 for 12-hour study and Figures 24 – 28 for 1-day "grid" sampling study.

3.1.1 Water Parameters (4-Month Study)

3.1.1.1 pH

During the study period from December 1999 to March 2000, the range of pH was found to fluctuate between 6.99, as recorded at inside station (sample 32-4I) in Transect 4, in late March 2000, to 7.51 as recorded at middle station (1-2M) in Transect 2, in January 2000 (Appendix 1). In SSK, the range of pH was found to fluctuate between 7.3, as recorded at middle station (32-7M) in Transect 7, to 7.82 as recorded at right bank station (32-7R) in Transect 7, both sampled in late March 2000 (Appendix 1). Furthermore, all pH readings were quite close to each other, being in the range of 6.99 – 7.79, as indicated in Figure 6.

Table 3: Case Indication for Figures

Case Indication for Figures during 4-Month Study

Date	River	Month	Transcect	Sample Code		
				Inside St.	**Middle St.**	**Away St.**
20/12/99	SSB	12	1	**12-1I**	**12-1M**	**12-1A**
20/12/99	SSB	12	2	**12-2I**	**12-2M**	**12-2A**
23/1/00	SSB	1	1	**1-1I**	**1-1M**	**1-1A**
23/1/00	SSB	1	2	**1-2I**	**1-2M**	**1-2A**
7/3/00	SSB	3	1	**31-1I**	**31-1M**	**31-1A**
7/3/00	SSB	3	2	**31-2I**	**31-2M**	**31-2A**
8/3/00	SSB	3	3	**31-3I**	**31-3M**	**31-3A**
8/3/00	SSB	3	4	**31-4I**	**31-4M**	**31-4A**
28/3/00	SSB	3	3	**32-3I**	**32-3M**	**32-3A**
28/3/00	SSB	3	4	**32-4I**	**32-4M**	**32-4A**
29/3/00	SSK	3	5	**32-5I**	**32-5M**	**32-5A**
29/3/00	SSK	3	6	**32-6I**	**32-6M**	**32-6A**
29/3/00	SSK	3	7	**32-7I**	**32-7M**	**32-7A**

Case Indication for Figures during 12-Hour Study

Date	River	Month	Transect	Station	Sample Code	
					In/Right St.	**Aw/Left St.**
20/4/00	SSB	4	1	IN/AW	**1a-I**	**1a-A**
20/4/00	SSB	4	1	IN/AW	**1b-I**	**1b-A**
20/4/00	SSB	4	1	IN/AW	**1c-I**	**1c-A**
20/4/00	SSB	4	1	IN/AW	**1d-I**	**1d-A**
20/4/00	SSB	4	1	IN/AW	**1e-I**	**1d-A**
21/4/00	SSK	4	6	R/L	**6a-R**	**6a-L**
21/4/00	SSK	4	6	R/L	**6b-R**	**6b-L**
21/4/00	SSK	4	6	R/L	**6c-R**	**6c-L**
21/4/00	SSK	4	6	R/L	**6d-R**	**6d-L**
21/4/00	SSK	4	6	R/L	**6e-R**	**6e-L**

Case Indication for Figures during 1-day "Grid" Sampling Study

Date	River	Month	Transect	**Station**
14/5/00	SSB	5	2	**A1**
14/5/00	SSB	5	2	**A2**
14/5/00	SSB	5	2	**A3**
14/5/00	SSB	5	2	**A4**
14/5/00	SSB	5	2	**A5**
14/5/00	SSB	5	2	**B1**
14/5/00	SSB	5	2	**B2**
14/5/00	SSB	5	2	**B3**
14/5/00	SSB	5	2	**B4**
14/5/00	SSB	5	2	**B5**
14/5/00	SSB	5	2	**C1**
14/5/00	SSB	5	2	**C2**
14/5/00	SSB	5	2	**C3**
14/5/00	SSB	5	2	**C4**
14/5/00	SSB	5	2	**C5**
14/5/00	SSB	5	2	**D1**
14/5/00	SSB	5	2	**D2**
14/5/00	SSB	5	2	**D3**
14/5/00	SSB	5	2	**D4**
14/5/00	SSB	5	2	**D5**

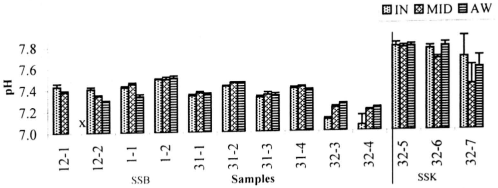


Fig.6. The Mean and Standard Deviation of pH during 4-Month Study

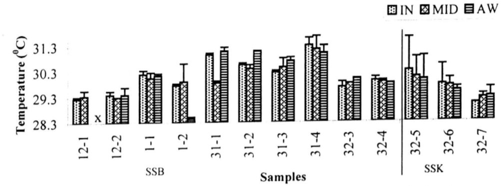


Fig.7. The Mean and Standard Deviation of Temperature during 4-Month Study

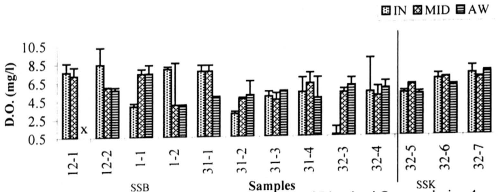


Fig.8. The Mean and Standard Deviation of Dissolved Oxygen during 4 Month Study

3.1.1.2 Temperature

Temperature of water recorded in SSB ranged from a minimum of 28.50 ^{0}C, as recorded at away station (sample 1-2A) in Transect 2, in January 2000, to 31.50 ^{0}C, as recorded at both inside (31-4I) and middle (31-4M) stations in Transect 4, in early March 2000 (Appendix 1). Temperature of water recorded in SSK, ranged from a minimum of 29.0^{0}C, as recorded at both right (32-7R) and left (32-7L) bank stations in Transect 7 in late March 2000, to 31.2^{0}C, as recorded ar right bank station (32-5R) in Transect 5, also in late March 2000. Mean temperature and standard deviation (S.D.) readings at each station are shown in Figure 7.

3.1.1.3 Dissolved Oxygen

In SSB, the maximum value of 9.72 mg/l for dissolved oxygen was recorded at inside station (sample 12-2I) in Transect 2, in January 2000 and the minimum of 0.03 mg/l was recorded at inside station (32-3I) in Transect 3, in late March 2000 (Appendix 1). In SSK, the maximum value of 7.78 mg/l for dissolved oxygen was recorded at right bank station (32-7R) in Transect 7 and the minimum of 5.00 mg/l was also recorded at right bank station (32-5R) in Transect 7, both sampled in late March 2000 (Appendix 1). The mean dissolved oxygen readings at all transects during the study period are shown in Figure 8.

3.1.1.4 Salinity

During the study period, salinity in SSB was found to range from a minimum of 23.0 ppt, recorded at away station (sample 31-2A) in Transect 2, in early March 2000, to a maximum of 27.7 ppt recorded at inside station (12-1I) in Transect 1, in December 1999 (Appendix 1). Salinity in SSK was found to range from a minimum of 25.2 ppt, recorded at left bank station (32-7L) in Transect 7, to a maximum of 26.1 ppt, recorded at right bank station (32-5R) in Transect 5, both sampled in late March 2000 (Appendix 1). The mean values at each transect during the study period are as indicated in Figure 9.

3.1.1.5 Conductivity

Conductivity of water recorded in SSB ranged from a minimum of 0.52 mS/cm^2, at middle station (sample 32-3M) in Transect 3, in late March 2000, to a maximum of 45.68 mS/cm^2, at away station (31-4A) in Transect 4, in early March 2000 (see Appendix 1). Conductivity of water recorded in SSK ranged from a minimum of 33.40 mS/cm^2, at left bank station (32-5L), in Transect 5, to a maximum of 46.35 mS/cm^2, at middle station (32-6M), in Transect 6, both sampled in late March 2000 (Appendix 1). These fluctuations in conductivity at all transects are summarised in Figure 10.

3.1.1.6 Depth

During the study period, the depth range at all transects was 0.2 – 8.8 meters (see Appendix 1). Differences in depth at each transect are shown in Figure 11.

3.1.2 Water Parameters (12- Hour Study)

The 12-hour study was done in April 2000. This study was conducted at Transect 1 and Transect 6 in SSB and SSK, respectively. For both rivers, only inside station and away

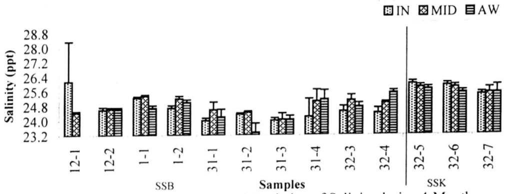


Fig.9. The Mean and Standard Deviation of Salinity during 4-Month Study

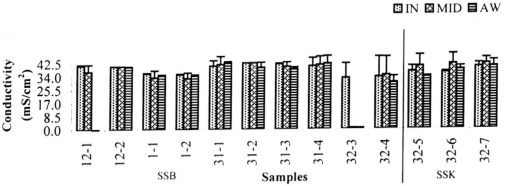


Fig.10. The Mean and Standard Deviation of Conductivity during 4-Month Study

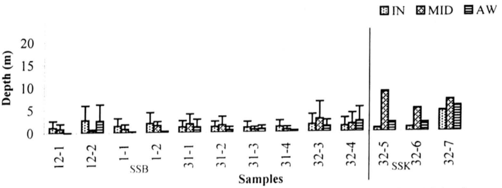


Fig. 11. The Mean and Standard Deviation of Depth during 4-Month Study

station were reported. Overall, five sampling occasions at each of 3 hour intervals were done at each transect during the study period.

3.1.2.1. pH

In SSB, results of pH for inside station showed the minimum of 7.15, recorded at 2100 hr (sample 1e-I) and the maximum of 7.45, recorded at 1330 hr (1b-I) (see Appendix 2). Results of pH for away station showed minimum and maximum of 7.19 and 7.46 recorded at 2145 hr (1e-A) and 1800 hr (1d-A), respectively (see Appendix 2). Both sites indicated that pH decreased towards night time. The mean values at each station are as indicated in Figure 12.

In SSK, results of pH for left bank station showed the minimum of 6.90, recorded at 2250 hr (sample 6e-L) and the maximum of 7.67, recorded at 1705 hr (6c-L) (Appendix 2). Results of pH for right bank station showed minimum and maximum of 7.02 and 7.70 recorded at 2225 hr (6e-R) and 1630 hr (6c-R), respectively (Appendix 2). Both cages also indicated that pH decreased towards night time. The mean values at each station are as indicated in Figure 13.

3.1.2.2 Temperature

In SSB, temperature for inside station ranged from a minimum of 30.7^{0}C, recorded at 1200 hr (sample 1a-I), to a maximum of 31.7^{0}C, recorded at 1620 hr (1c-I) (Appendix 2). Results on temperature for away station showed minimum of 30.3^{0}C, recorded at 0855 hr (1a-A), to a maximum of 31.8^{0}C, recorded at 1530 hr (1c-A) (Appendix 2).

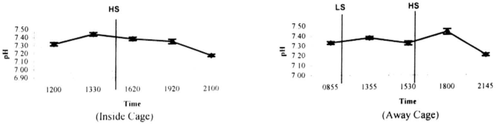


Fig.12. The Mean Bottom pH for SSB (Inside and Away Stations) in Relation to Time and Tide

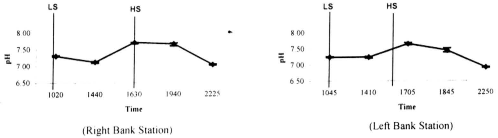


Fig.13. The Mean Bottom pH for SSK (Left Bank and Right Bank Stations) in Relation to Time and Tide

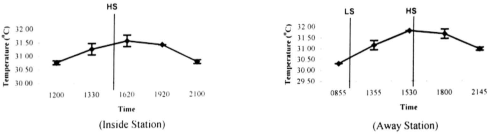


Fig.14. The Mean Bottom Temperature for SSB (Inside and Away Stations) in Relation to Time and Tide

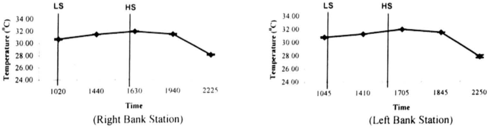


Fig.15. The Mean Bottom Temperature for SSK (Left Bank and Right Bank Stations) in Relation to Time and Tide (HS = High Slack; LS = Low Slack)

Mean temperature and standard deviation (S.D.) readings at each station are shown in Figure 14.

In SSK, temperature for left bank station ranged from a minimum of 27.6^{0}C, recorded at 2250 hr (sample 6e-L), to a maximum of 31.9^{0}C, recorded at 1705 hr (6c-L) (Appendix 2). Results on temperature for right bank station ranged from a minimum of 27.9^{0}C, recorded at 2225 hr (6e-R), to a maximum of 31.9^{0}C, recorded at 1630 hr (6c-R) (Appendix 2). Mean temperature and standard deviation (S.D.) readings at each station are shown in Figure 15.

3.1.2.3 Dissolved Oxygen

In SSB, the minimum value of 3.66 mg/l (Appendix 2) for dissolved oxygen in inside station was recorded at 1330 hr (sample 1b-I) and the maximum of 9.26 mg/l (Appendix 2) was recorded at 1620 hr (1c-A). For away station, the minimum and maximum values were 4.1 mg/l and 10.66 mg/l (Appendix 2), recorded at 2145 hr (1e-A) and 1530 hr (1c-A), respectively. The mean dissolved oxygen reading at all stations are shown in Figure 16.

In SSK, the minimum value of 1.53 mg/l for dissolved oxygen in left bank station was recorded at 1045 hr (sample 6a-L) and the maximum of 5.52 mg/l was recorded at 1705 hr (6c-L) (Appendix 2). For right bank station, the minimum and maximum values were 0.32 mg/l and 5.31 mg/l, recorded at 1020 hr (6a-R) and 1940 hr (6d-R), respectively (Appendix 2). The mean dissolved oxygen reading at all stations are shown in Figure 17.

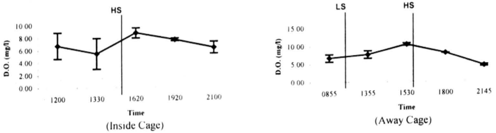


Fig.16. The Mean Bottom Dissolved Oxygen for SSB (Inside and Away Stations) in Relation to Time and Tide

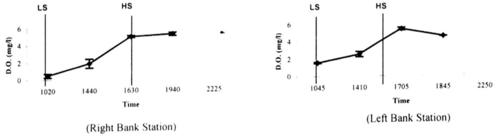


Fig.17. The Mean Bottom Dissolved Oxygen for SSK (Left Bank and Right Bank Stations) in Relation to Time and Tide

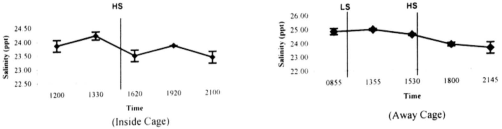


Fig.18. The Mean Bottom Salinity for SSB (Inside and Away Stations) in Relation to Time and Tide

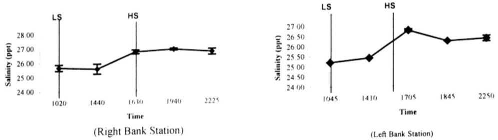


Fig.19. The Mean Bottom Salinity for SSK (Left Bank and Right Bank Stations) in Relation to Time and Tide (HS = High Slack; LS = Low Slack)

3.1.2.4 Salinity

In SSB, salinity of inside station was found to range from a minimum of 23.2 ppt, recorded at 2100 hr (sample 1e-A), to a maximum of 24.3 ppt, recorded at 1330 hr (1b-I). For away station, the minimum of 23.2 ppt was recorded at 2145 hr (1e-A) and the maximum of 25.0 ppt was recorded at 0855 and 1355 hr (1a-A and 1b-A) (Appendix 2). The mean salinities at all stations are summarised in Figure 18.

In SSK, salinity in left bank station was found to range from a minimum of 25.2 ppt, recorded at 1045 hr (sample 6a-L), to a maximum of 26.8 ppt, recorded at 1705 hr (6c-L). For right bank station, the minimum of 25.3 ppt was recorded at 1440 hr (6b-R) and the maximum of 26.9 ppt was recorded at 1940 hr (6d-R) (Appendix 2). The fluctuations at all stations are summarised in Figure 19.

3.1.2.5 Conductivity

In SSB, conductivity in inside station, was found to range from a minimum of 35.45 mS/cm^2, recorded at 1330 hr (sample 1b-I), to a maximum of 41.35 mS/cm^2, recorded at 2100 hr (1e-I). For away station, conductivity was found to range from a minimum of 33.2 mS/cm^2, recorded at 0855 hr (1a-A), to a maximum of 42.65 mS/cm^2, recorded at 1530 hr (1c-A) (Appendix 2). The mean values at each station are shown in Figure 20.

In SSK, conductivity in left bank station, was found to range from a minimum of 39.33 mS/cm^2, recorded at 1045 hr (sample 6a-L), to a maximum of 49.05 mS/cm^2, recorded at 1705 hr (6c-L). For right bank station, conductivity was found to range from a minimum of 39.88 mS/cm^2 recorded at 1020 hr (6a-R), to a maximum of 49.20 mS/cm^2, recorded at 1630 hr (6c-R) (Appendix 2). The mean values at each station are shown in Figure 21.

3.1.2.6 Depth

In SSB, the range in depth of transect in SSB and SSK was 0.05 – 5.12 meters and 0.05 – 5.00 meters (Appendix 2), respectively. Both showed some differences in transect depth as shown in Figures 22 and 23.

3.1.3 Water Parameters (1-Day "Grid" Sampling)

The study was conducted in Transect 1 (SSB) in May 2000. (Please refer to Figures 4 and 5 for location of sampling stations and their designated site numbers). B2, B3, B4, C2 and C3 were inside cage stations.

3.1.3.1 pH

Results of pH measurements showed the maximum of 8.11, recorded at Station D2 and minimum of 7.66 recorded at Station A2 (Appendix 3). pH values in inside cage stations were generally lower than in non-cage stations. The mean pH readings at all stations are shown in Figure 24.

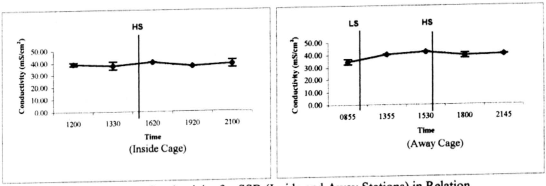


Fig.20. The Mean Bottom Conductivity for SSB (Inside and Away Stations) in Relation to Time and Tide

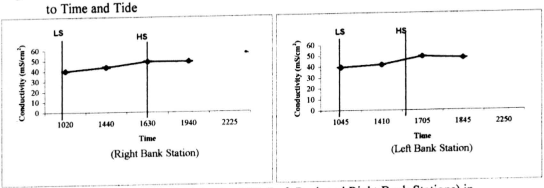


Fig.21. The Mean Bottom Conductivity for SSK (Left Bank and Right Bank Stations) in Relation to Time and Tide

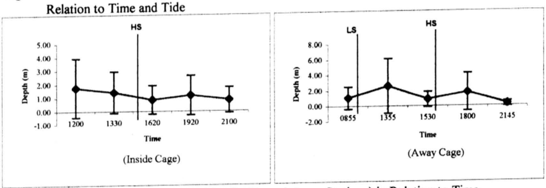


Fig.22. The Mean Bottom Depth for SSB (Inside and Away Stations) in Relation to Time and Tide

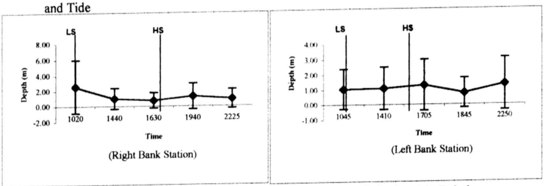


Fig.23. The Mean Bottom Depth for SSK (Left Bank and Right Bank Stations) in Relation to Time and Tide (HS = High Slack; LS = Low Slack)

3.1.3.2 Temperature

Bottom water temperatures were found to fluctuate between 30.3 ^{0}C, as recorded at Station A2, to 31.4 ^{0}C, as recorded at Station D1 (see Appendix 3). Fluctuations are shown in Figure 25.

3.1.3.3 Dissolved Oxygen

The maximum value of 5.32 mg/l for dissolved oxygen was recorded at Station D2 and the minimum of 0.41 mg/l was recorded at Station B5 (Appendix 3). Dissolved oxygen values were generally lower in cage stations than in non-cage stations. The mean dissolved oxygen and standard deviation (S.D.) readings at each station are shown in Figure 26.

3.1.3.4 Salinity

Salinity was found to range from a minimum of 23.9 ppt, recorded at Station A1, to a maximum of 26.7 ppt, recorded at Station D5 (Appendix 3). Salinity values were generally higher in cage stations than in non-cage stations. The mean values at each station are shown in Figure 27.

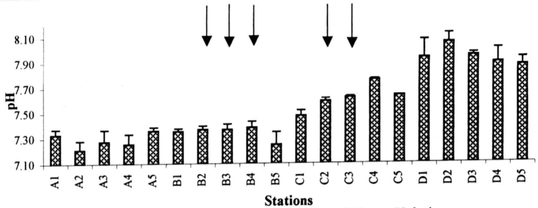


Fig.24. The Mean and Standard Deviation of Water pH during 1-Day "Grid" Sampling (Arrows Indicate Cage Sites)

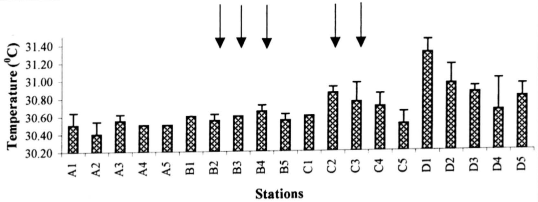


Fig.25. The Mean and Standard Deviation of Water Temperature during 1-Day "Grid" Sampling (Arrows Indicate Cage Sites)

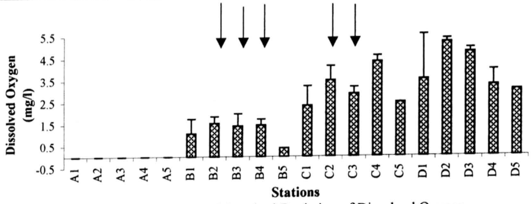


Fig.26. The Mean and Standard Deviation of Dissolved Oxygen during 1-Day "Grid" Sampling (Arrows Indicate Cage Sites)

3.1.3.5 Conductivity

Conductivity of water recorded during the study, ranged from a minimum of 43.18 mS/cm^2 at Station A2, to a maximum of 46.3 mS/cm^2 at Station D5 (Appendix 3). For cage stations mainly station B2 and B4, conductivity was higher. The mean conductivity and standard deviation (S.D.) readings at each station are as indicated in Figure 28.

3.1.3.6 Depth

Due to malfunction of the YSI depth sensor, the depth at station was not complete. However, based on available measurements, the depth from A (at right bank) to D (centre of river) increased gradually from approximately 1.5 m to 5.0 m.

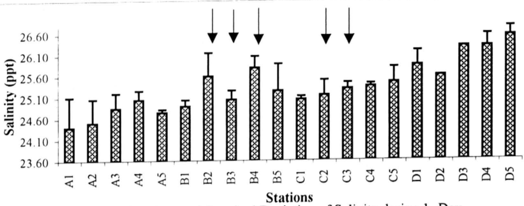


Fig.27. The Mean and Standard Deviation of Salinity during 1- Day "Grid" Sampling (Arrows Indicate Cage Sites)

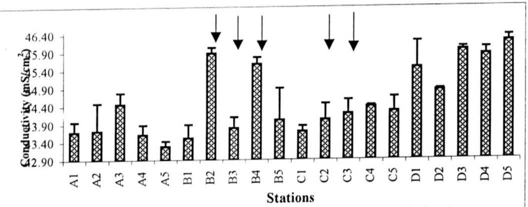


Fig.28. The Mean and Standard Deviation of Conductivity during 1- Day "Grid" Sampling (Arrows Indicate Cage Sites)

3.2 BOTTOM AND SEDIMENT CHARACTERISTICS

3.2.1 Sediment Parameters

3.2.1.1 Sediment Parameters (4-Month Study)

During the study period sediment pH, temperature, redox potential (Eh) and organic matter content were measured.

3.2.1.1.1 pH

During the study period from December 1999 to March 2000 in SSB, the minimum sediment pH of 6.52 was recorded at away station (sample 31-1A) in Transect 1 and the maximum of 7.19 was recorded at middle station (31-4M) in Transect 4, both sampled in early March 2000 (Appendix 4). In SSK, the minimum sediment pH of 6.00 was recorded at middle station (32-7M) in Transect 7 and the maximum of 6.58 was recorded at right bank station (32-6R) in Transect 6, both sampled in late March 2000 (Appendix 4). However, pH values in SSB and SSK mostly laid between 6.01 – 7.12 as shown in Figure 29. pH values in SSK were generally lower than in SSB.

3.2.1.1.2 Redox Potential (Eh)

The sediment redox potential in SSB ranged from a minimum of 28 mv, as recorded at middle station (sample 31-4M) in Transect 4, in early March 2000, to a maximum of 181 mv, as recorded at inside station (12-1I) in Transect 1, in December 1999 (see Appendix 4). The sediment redox potential in SSK ranged from a minimum of 71 mv,

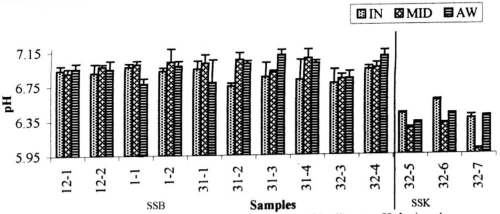
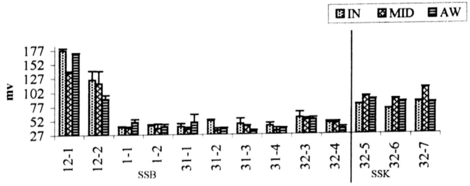


Fig.29. The Mean and Standard Deviation of Sediment pH during 4-Month Study



Samples

Fig.30. The Mean and Standard Deviation of Sediment Redox Potential during 4-Month Study

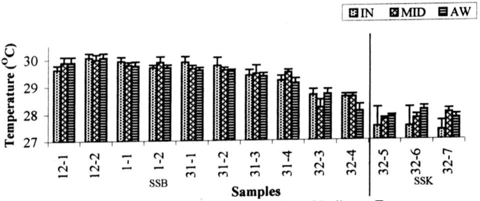


Fig.31. The Mean and Standard Deviation of Sediment Temperature during 4-Month Study

as recorded at right bank station (32-6R) in Transect 6, to a maximum of 107 mv, as recorded at middle station (32-7M) in Transect 7, both sampled in late March 2000 (Appendix 4). The mean values and standard deviation (S.D.) are shown in Figure 30.

3.2.1.1.3 Temperature

In-situ temperature of sediment in SSB ranged from a minimum of 27.8 ^{0}C, as recorded at away station (sample 32-4A) in Transect 4, in late March 2000, to a maximum of 30.2 ^{0}C, as recorded at inside (12-2I) and away (12-2A) stations in Transect 2, in December 1999 (Appendix 4). *In-situ* temperature of sediment in SSK ranged from a minimum of 27.0^{0}C, as recorded at right bank stations; 32-5R (Transect 5) and 32-6R (Transect 6), to a maximum of 28.2^{0}C, as recorded at left bank station (32-6L) in Transect 6, both sampled in late March 2000 (Appendix 4). The mean values at each transect are shown in Figure 31. Temperature values in SSK were generally lower than in SSB.

3.2.1.1.4 Organic Matter

In SSB, the percentages of organic matter (by weight) were found to range from a minimum of 3.36 %, as recorded at middle station (sample 31-1M) in Transect 1, to a maximum of 5.96 %, as recorded at away station (31-4A) in Transect 4, both sampled in early March 2000 (Appendix 4). In SSK, the percentages of organic matter (by weight) were found to range from a minimum of 3.55 %, as recorded at right bank station (32-5R) in Transect 5, to a maximum of 6.43 %, as recorded at left bank station (32-7L) in Transect 7, both sampled in late March 2000 (Appendix 4). The mean values at each transect during the study period are shown in Figure 32.

3.2.1.2 Sediment Parameters (12-Hour Study)

3.2.1.2.1 PH

In SSB, pH measurement for inside station ranged from a minimum of 6.38, recorded at 1200 (sample 1a-I) to a maximum of 6.86, recorded at 1620 (1d-I) (Appendix 5). Therefore, pH measurement for away station showed minimum of 6.26, recorded at 0855 hr (1a-A) and maximum of 6.95, recorded at 1530 hr (1c-A). The mean values at each station are as indicated in Figure 33.

In SSK, pH measurement for left bank station ranged from a minimum of 6.80. recorded at 1845 hr (sample 6d-L) to a maximum of 7.31, recorded at 1045 hr (6a-L). pH measurement for right bank station showed minimum of 6.75, recorded at 1630 hr (6c-R) and maximum of 7.22, recorded at 1020 hr (6a-R). The mean values at each station are as indicated in Figure 34.

3.2.1.2.2 Redox Potential (Eh)

In SSB, results of sediment redox potential for inside station showed the minimum of 90 mv, recorded at 1620 hr (sample 1c-I) and the maximum of 113 mv, recorded at 1200 hr (1a-A) (Appendix 5). Results for outside station showed minimum of 91 mv, recorded at 1530 hr (1c-A) and maximum of 121 mv, recorded at 0855 hr (1a-A). The mean values at each station are as indicated in Figure 35.

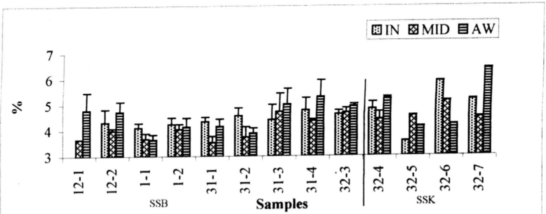


Fig.32. The Mean and Standard Deviation of Organic Matter during 4-Month Study

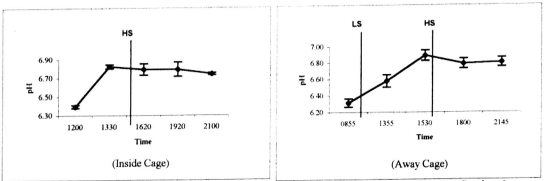


Fig.33. The Mean and Standard Deviation of Sediment pH for SSB (Inside and Away Stations) in Relation to Time and Tide

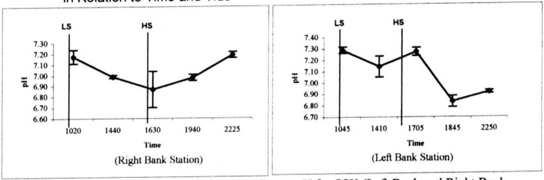


Fig.34. The Mean and Standard Deviation of Sediment pH for SSK (Left Bank and Right Bank Stations) in Relation to Time and Tide (HS = High Slack, LS = Low Slack)

In SSK, results of sediment redox potential for left bank station showed the minimum of 97 mv, recorded at 1410 hr (sample 6b-L) and the maximum of 119, recorded at 2250 hr (6e-L). Results for right bank station showed minimum of 98 mv, recorded at 1440 (6b-R) and maximum of 111 mv, recorded at 2225 hr (6e-R). The mean values at each station are as indicated in Figure 36.

3.2.1.2.3 Temperature

In SSB, the minimum value of 27.1 ^{0}C for *in-situ* sediment temperature in inside station was recorded at 1620 hr (sample 1c-I) and the maximum of 27.7 ^{0}C was recorded at 1200 hr (1a-I) (Appendix 5). For away station, the minimum value of 27.2 ^{0}C was recorded at 1530 hr and 1800 hr in samples 1c-A and 1d-A, respectively and the maximum value of 27.7^{0}C, was recorded at 0855 hr, 1355 hr and 2145 hr in samples 1a-A, 1b-A and 1e-A, respectively. The mean sediment temperature reading at all stations are shown in Figure 37.

In SSK, the minimum value of 27.2^{0}C for *in-situ* sediment temperature in left bank station was recorded at 1845 hr (sample 6d-L) and the maximum of 27.9^{0}C was recorded at 1410 hr at Station 6b-L (Appendix 5). For right bank station, the minimum value of 27.2^{0}C was recorded at 2225 hr in sample 6e-R and the maximum value of 28.2^{0}C was recorded at 1020 hr in sample 6a-R. The mean sediment temperature reading at all stations are shown in Figure 38.

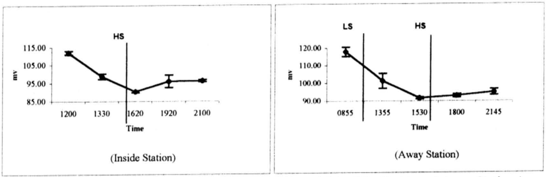


Fig.35. The Mean and Standard Deviation of Redox Potential for SSB (Inside and Away Stations) in Relation to Time and Tide

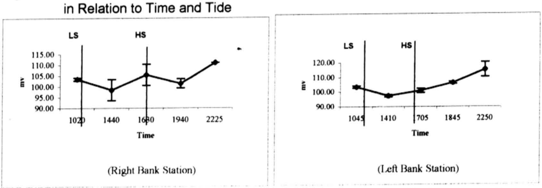


Fig.36. The Mean and Standard Deviation of Redox Potential for SSK (Left Bank and Right Bank Stations) in Relation to Time and Tide

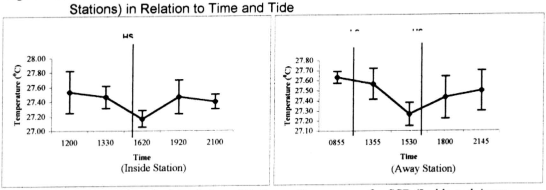


Fig.37. The Mean and Standard Deviation of Sediment Temperature for SSB (Inside and Away Stations) in Relation to Time and Tide

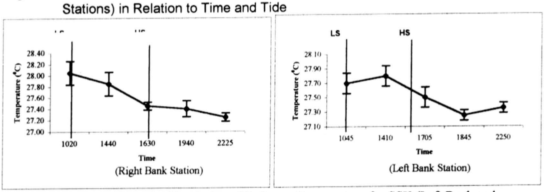


Fig.38. The Mean and Standard Deviation of Sediment Temperature for SSK (Left Bank and Right BankStations) in Relation to Time and Tide (HS = High Slack, LS = Low Slac

3.2.1.2.4 Organic Matter

In SSB, the percentages of organic matter in the sediment samples ranged from 4.22 % to 6.77 %, which were recorded in samples 1e-A and 1b-I, respectively (Appendix 5). The percentages of organic matter in inside stations were generally higher than in away stations. In SSK, the percentages of organic matter ranged from 2.95 % to 5.25 %, which were recorded at right bank station (6e-R) and left bank station (6b-L), respectively. Variations in the percentage values for both rivers are shown in Figure 39.

3.2.1.3 Sediment Parameters (1-Day Grid Sampling)

3.2.1.3.1 pH

The minimum sediment pH of 6.30 was recorded at Station A1 and the maximum of 7.12 was recorded at Station C3 (Appendix 6). Differences in pH at each station are shown in Figure 40.

3.2.1.3.2 Redox Potential (Eh)

The minimum sediment redox potential of –23 mv was recorded at Station C4 and the maximum reading of 9 mv was recorded at Station A1 (Appendix 6). The mean values for every station are shown in Figure 41.

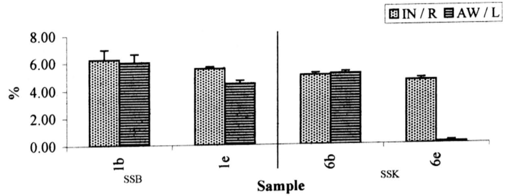


Fig.39. The Mean & Standard Deviation of Sediment Organic Matter Sampled Over 12 Hours

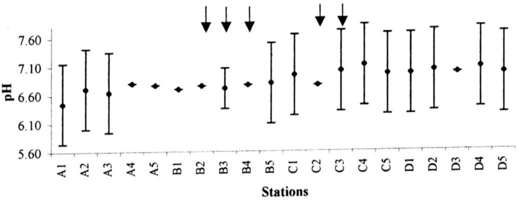


Fig.40. The Mean and Standard Deviation of Sediment pH during 1-Day "Grid" Sampling (Arrows Indicate Cage Sites)

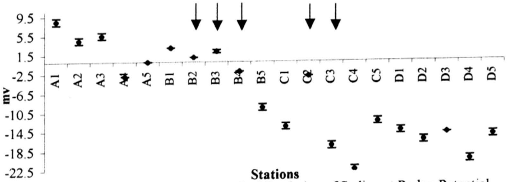


Fig.41. The Mean and Standard Deviation of Sediment Redox Potential during 1-Day "Grid" Sampling (Arrows Indicate Cage Sites)

3.2.1.3.3 Temperature

The minimum and maximum *in-situ* temperatures of the sediment ranged from 30.0 ^{0}C, recorded at Station D1 to 30.9 ^{0}C recorded at Stations A3, A5, C1 and C2 (Appendix 6). Variations in the temperature values at each station are as indicated in Figure 42.

3.2.1.3.4 Organic Matter

The minimum percentage of organic matter of 4.43 % was recorded at Station A2 and the maximum percentage of 7.75 % was recorded at Station D1 (Appendix 6). The mean values at each station are shown in Figure 43.

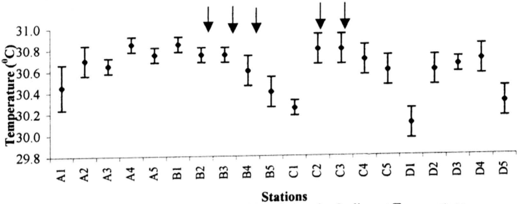


Fig.42. The Mean and Standard Deviation for Sediment Temperature during 1-Day "Grid" Sampling (Arrows Indicate Cage Sites)

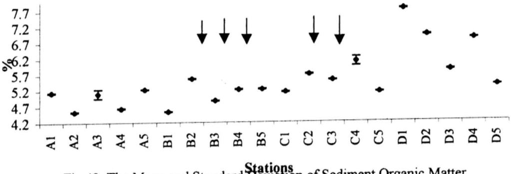


Fig.43. The Mean and Standard Deviation of Sediment Organic Matter during 1-Day "Grid" Sampling (Arrows Indicate Cage Sites)

3.2.2 Sediment Texture and Characteristics

3.2.2.1 Sediment Texture and Characteristics (4-Month Study)

During the 4-month study, the bottom sediment mostly comprised of silt and fine sand.

3.2.2.1.1 Clay

In SSB, the percentages of clay in inside station, ranged from 6.96–12.50 % (Appendix 7). For middle and away stations, the range of percentages was 7.04–15.36 % and 6.72–16.09 %, respectively (Appendix 7). In SSK, the percentages of clay in right bank station, ranged from 8.15-13.16 % (Appendix 7). For middle and left bank stations, the range of percentages was 8.71-11.18 % and 10.69-17.85 %, respectively (Appendix 7). Comparatively, higher percentages of clay were generally found in away stations. The mean values at each station during the study period are shown in Figure 44 (Inside Station), Figure 45 (Middle Station) and Figure 46 (Away Station).

3.2.2.1.2 Silt

In SSB, the percentages of silt in inside station, ranged from 23.96–38.29 % (Appendix 7). For middle and away stations, the range of percentages was 24.41–50.17 % and 23.94–49.40 %, respectively (Appendix 7). In SSK, the percentages of silt in right bank station, ranged from 27.09-47.52 % (Appendix 7). For middle and left bank stations, the range of percentages was 29.88-36.36 % and 34.45-62.97 % (Appendix 7).

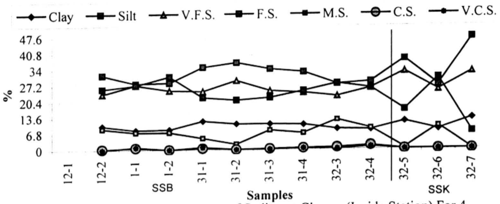


Fig.44. The Mean Percentage of Sediment Classes (Inside Station) For 4-Month Study

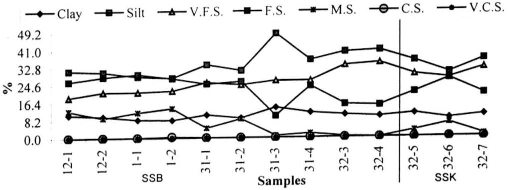


Fig.45. The Mean Percentage of Sediment Classes (Middle Station) for 4-Month Study

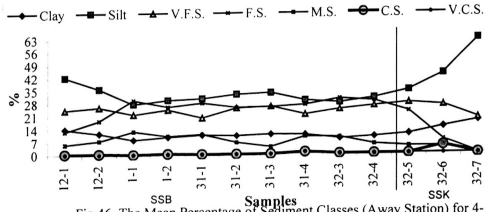


Fig.46. The Mean Percentage of Sediment Classes (Away Station) for 4-Month Study

Comparatively, higher percentages of silt were generally found in away stations. Station 32-7L showed the highest percentage (62.87 %), as it was located at the river mouth (downstream) (refer Figure 2). Muhammad Ali *et al.* (1999b) reported that higher clay and silt sediments were found in the river mouth area. The mean values at each station are shown in Figure 44 (Inside Station), Figure 45 (Middle Station) and Figure 46 (Away Station).

3.2.2.1.3 Sand

The percentages of sands [(very fine sand (vfs), fine sand (fs), medium sand (ms), coarse sand (cs) and very coarse sand (vcs)] were listed in Appendix 7 and the mean values are shown in Figure 44 (Inside Station), Figure 45 (Middle Station) and Figure 46 (Away Station). The sand component among the SSB stations did not show much difference but in SSK stations, the percentages were much higher except for left bank station; 32-7L (approximately 19.2 %) (Appendix 7).

3.2.2.2 Sediment Texture and Characteristics (12-Hour Study)

For this study, analysis was based on samples 1b and 1e (SSB) and also 6b and 6e (SSK). These samples were chosen to determine if there is any difference in sediment texture during flood and ebb tide. The sediment texture of sample collected during the 12-Hour study mainly reflected that of silt and fine sand.

3.2.2.2.1 Clay

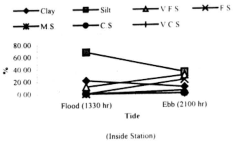
In SSB, the percentage of clay in inside station showed higher reading at flood tide (1330 hr) (sample 1b-I) compared to ebb tide (2100 hr) (1e-I). This pattern also occurred in away station where the percentage of clay was higher at flood tide (1355 hr) (1b-A) compared to ebb tide (2145 hr) (1e-A) (Appendix 8). The mean values of each station are shown in Figure 47.

In SSK, the percentage of clay in right bank station was higher during flood tide (1440 hr) (sample 6b-R) compared to ebb tide (2225 hr) (6e-R) (Appendix 8). The percentage of clay in left bank station was higher during flood tide (1410 hr) (6b-L) compared to ebb tide (2250 hr) (6e-L). The mean values of each station are shown in Figure 48.

3.2.2.2.2 Silt

In SSB, the percentage of silt in inside station showed higher reading at flood tide (1330 hr) (sample 1b-I) compared to ebb tide (2100 hr) (1e-I). Basically, this pattern also occurred in away station where percentage of silt was higher at flood tide (1355 hr) (1b-A) compared to ebb tide (2145 hr) (1e-A) (Appendix 8). The mean values of each station are shown in Figure 47.

In SSK, the percentage of silt in right bank station was higher at flood tide (1440 hr) (sample 6b-R) compared to ebb tide (2225 hr) (6e-R) (Appendix 8). The percentage of silt in left bank station, was also higher at flood tide (1410 hr) (6b-L) compared to ebb



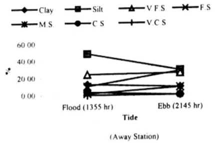
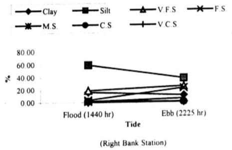


Fig.47. The Mean Percentage of Sediment Classes for SSB (Inside and Away Stations) in Relation to Time and Tide



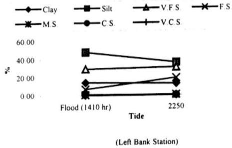


Fig.48. The Mean Percentage of Sediment Classes for SSK (Right and Left Bank Stations) in Relation to Time and Tide

tide (2250 hr) (6e-L). The mean values of each station are shown in Figure 48.

3.2.2.2.3 Sand

The percentage composition of the different size-classes of sands are listed in Appendix 8. In SSB, the percentage of very fine sand (vfs), fine sand (fs) and medium sand (ms) showed higher readings in inside station during ebb tide (2100 hr) (sample 1e-I) and also for away stations during ebb tide (2145 hr) (1e-A) (Appendix 8). The mean values of each station are shown in Figure 47.

In SSK, the percentages of fine sand and medium sand showed higher readings in right bank station during ebb tide (2225 hr) (sample 6e-R) and also for left bank station during ebb tide (2250 hr) (6e-L) (Appendix 8). The mean values of each station are shown in Figure 48. In contrast, coarse sand (c.s.) and very coarse sand (v.c.s.) showed the opposite trend, i.e. more during flood tide than ebb tide.

3.2.2.3 Sediment Texture and Characteristics (1-Day Grid Sampling Study)

The sediment samples collected during this study period were comprised mostly of silt and very fine sand. The sediment contour maps of the distribution of clay, silt and sand over the fish farm and surrounding area in Transect 1 (A-D) are illustrated in Figures 49, 50 and 51, respectively. All figures were based on the mean values of each station.

3.2.2.3.1 Clay

The percentage of clay showed minimum (7.15%) and maximum (22.04%) readings at stations D2 and B1, respectively (Appendix 9). Under the floating cage farm, the clay component of the sediment varied from 10.91 – 17.46 % (Figure 49). The B stations showed higher readings compared to the rest of the stations. Stations B2 and B3 (cage area) showed the two highest percentages of clay. The contour map (Figure 49) indicates that the percentage of clay gradually decreased towards the middle of the river.

3.2.2.3.2 Silt

The minimum percentage of silt of 25.97% was recorded at station D3 and the maximum of 71.68% was recorded at station B1 (Appendix 9). Under the floating cage farm, the silt component of the sediment varied from 35.46 – 60.91 % (Figure 50). The percentages of silt were mostly high in cage area particularly at stations B2 and B3. The contour map (Figure 50) shows that the percentage of silt decreased towards the middle of the river.

3.2.2.3.3 Sand

The percentage of very fine sand (vfs) showed minimum (6.12%) and maximum (34.86%) readings at Stations B1 and D1, respectively (Appendix 9). Under the floating cage farm, the sand component of the sediments varied from 32.71 – 57.27 %, from inside (river bank) to outside (Figure 51). The inner 'B' Stations (B1–B3) generally

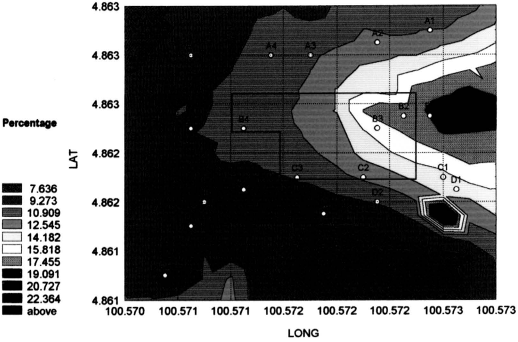


Fig. 49. Contour Map of Sediment Clay (%) Distribution over Fish Cage Area and Vicinity (Transect 2, SSB) (Drawn Box Refers to Perimeter of Fish Farm)

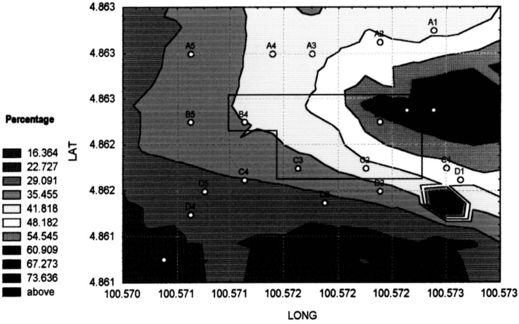


Fig. 50. Contour Map of Sediment Silt (%) Distribution over Fish Cage Area and Vicinity (Transect 2, SSB) (Drawn Box Refers to Perimeter of Fish Farm)

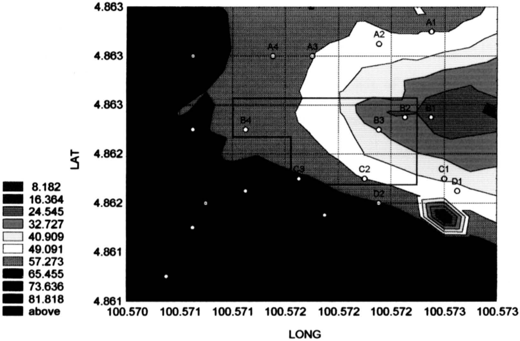


Fig. 51. Contour Map of Sediment Sand (%) Distribution over Fish Cage Area and Vicinity (Transect 2, SSB) (Drawn Box Refers to Perimeter of Fish Farm)

showed lower sand readings in the cage area compared to the rest of the stations (Figure 51). However, stations located towards the middle of the river (A5, B5, C4, C5, D2-D5) generally had higher sand content. Very fine sand (vfs) sediment generally occurred closer to the river bank, whereas medium sand (ms) occurred towards the middle of the river. Outside the cage area, on the downstream side of the farm, the distribution of sandy component followed the same pattern, but on its upstream side, the percentage of sand exceeded 65.46 %.

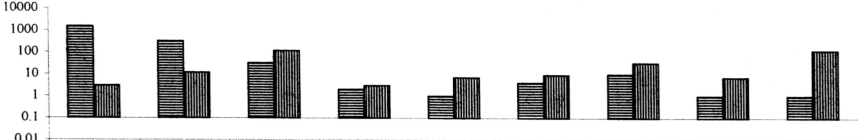
3.3 Macrobenthos Diversity and Abundance

The macrobenthic animals found during the study period were grouped into the following groupings i.e. Nemertea, Polychaeta, Bivalvia, Gastropoda, Decapoda, Isopoda, Amphipoda, Echinoidea and Pisces. A total of 2,181 macrobenthic specimens (1,867 from Sungai Sangga Besar (SSB) and 314 from Sungai Sangga Kecil (SSK)) were recorded (Figure 52). The mean abundance of macrobenthic animals was 106.69 ind/m^2 in SSB (aquaculture river) and 82.63 ind/m^2 in SSK (non-aquaculture river) (Figure 53).

A total of 53 species (including 7 unidentified species) belonging to 44 families (including 5 unidentified families) were recorded. Total family comprised of 1 nemertean, 12 polychaete, 5 bivalve, 11 gastropod, 7 decapod, 2 isopod, 2 amphipod, 1 ophiuroid and 3 fish (Table 4). The bivalves and polychaetes dominated the population of macrobenthos in SSB and SSK, respectively.

3.3.1 Macrobenthos Diversity and Abundance (4-Month Study)

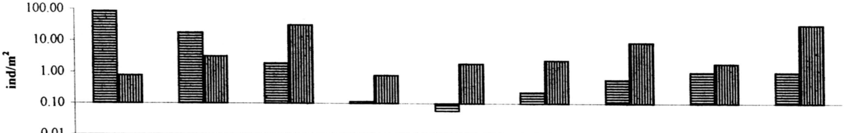
A total of 1,149 macrobenthos were recorded; 1,011 and 138 number of individuals from SSB and SSK, respectively (Table 5). The mean abundance of macrobenthic animals was 112.33 ind/m^2 in SSB and 76.67 ind/m^2 in SSK (Figure 54). A total of 39 species were recorded. The presence or absence of macrobenthic animals at each station during the study period is shown in Appendix 10.



	Bivalve	Gastropod	Polychaeta	Nemertea	Echinoidea	Pisces	Decapoda	Isopoda	Amphipoda
SSB	1504	313	33	2	1	4	10	0	0
SSK	3	12	119	3	7	9	33	7	121

Class

Fig.52. Total Number of Macrobenthos Sampled in SSB & SSK during the Study Period



	Bivalve	Gastropod	Polychaeta	Nemertea	Echinoidea	Pisces	Decapoda	Isopoda	Amphipoda
SSB	85.94	17.89	1.89	0.11	0.06	0.23	0.57	0.00	0.00
SSK	0.79	3.16	31.32	0.79	1.84	2.37	8.68	1.84	31.84

Famili

Fig.53 Mean Abundance of Macrobenthos (ind/m2) in SSB & SSK during the Study Period

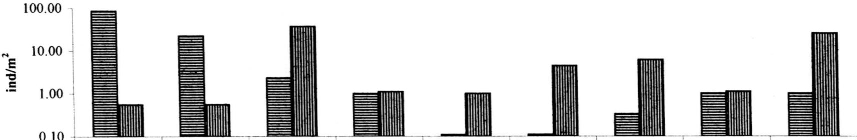
Table 4. List of Macrobenthos Found in Sungai Sangga Besar (SSB) and Sungai Sangga Kecil (SSK
Matang Mangrove Forest Reserve, Perak, Malaysia (Dec 1999 - April 2000)

PHYLUM	CLASS / ORDER	FAMILY	GENUS / SPECIES
NEMERTEA		Geonemertidae	*Pantinonemertes* sp.
ANNELIDA	Polychaeta	Capitellidae	*Capitella* sp.
	Polychaeta	Capitellidae	*Leiochrides australis*
	Polychaeta	Amphinomidae	*Aphrodita flava*
	Polychaeta	Glyceridae	*Ophioglycera* sp.
	Polychaeta	Spionidae	*Paraprionospio* sp.
	Polychaeta	Ctenodrilidae	*Ctenodrilus sp.*
	Polychaeta	Nereidae	*Nereis* sp.
	Polychaeta	Chaetopteridae	*Phyllochaetopterus* sp.
	Polychaeta	Hesionidae	*Hesiosyllis* sp.
	Polychaeta	Onuphidae	*Diopatra* sp.
	Polychaeta	Poebiidae	Unidentified sp. A
	Polychaeta	Arabellidae	Unidentified sp. B
	Polychaeta		Unidentified sp. C
MOLLUSCA	Bivalvia	Arcidae	*Anadara granosa*
	Bivalvia	Arcidae	*Plecyora trigona*
	Bivalvia	Mytilidae	*Xenostrobus* sp.
	Bivalvia	Nuculidae	*Nuculana* sp.
	Bivalvia	Solenidae	*Pharella acuminata*
	Bivalvia	Tellinidae	*Tellina* sp. A
	Bivalvia	Tellinidae	*Tellina* sp. B
	Bivalvia	Tellinidae	*Tellina* sp. C
	Bivalvia	Tellinidae	*Orbicularia orbicularia*
	Gastropoda	Potamididae	*Cerithidea cingulata*
	Gastropoda	Nassariidae	*Nassarius* sp. B
	Gastropoda	Nassariidae	*Nassarius jacksonianus*
	Gastropoda	Nassariidae	*Nassarius olivaceus*
	Gastropoda	Nassariidae	*Nassarius* sp. A
	Gastropoda	Marginellidae	*Marginella ventricosa*
	Gastropoda	Melongenidae	*Pugilina cochlidium*
	Gastropoda	Stenothyridae	*Stenothyra glabrata*
	Gastropoda	Naticidae	*Polinices* sp.
	Gastropoda	Acmaeidae	Unidentified sp. D
	Gastropoda	Assiminaeidae	*Assiminea* sp.
	Gastropoda	Cypraidae	*Cypraea* sp.
	Gastropoda	Mitridae	*Mitra* sp.
	Gastropoda		Unidentified sp. E
ARTHROPODA	Decapoda	Penaeidae	*Metapenaeus brevicornis*
	Decapoda	Alpheidae	*Alpheus* sp.
	Decapoda	Diogenidae	*Diogenes* sp.
	Decapoda	Camptandriidae	*Camptandrium sexdentatum*
	Decapoda	Pilumnidae	*Benthopanope* sp.
	Decapoda	Pinnotheridae	*Xenophthalmus pinnotheroides*
	Decapoda	Sergestidae	*Acetes* sp.
	Decapoda	Mysidae	*Mysis* sp.

	Isopoda	Sphaeromatidae	*Sphaeroma terebrans*
PHYLUM	**CLASS / ORDER**	**FAMILY**	**GENUS / SPECIES**
	Isopoda Isopoda Amphipoda Amphipoda	 Melitidae 	*Synopia ultramania* *Sphaeroma terebrans* *Ceradocus* sp. Unidentified sp. F
ECHINODERMATA	Ophiuroidea	Ophiactidae	*Ophiactis* sp.
PISCES		Gobiidae Synbranchidae 	*Hemigobius* sp. *Macrotrema caligans* Unidentified sp. G

Table 5. Total Number of Macrobenthos Collected during 4-Month Study in SSB and SSK

Sample	Bivalve	Gastropoda	Polychaeta	Nemertea	Echinoidea	Pisces	Decapoda	Isopoda	Amphipod	Total
12-1I	0	5	0	0	0	0	0	0	0	5
12-1M	8	3	0	0	0	0	0	0	0	11
12-1A	2	0	0	0	1	0	0	0	0	3
12-2I	0	1	0	0	0	0	0	0	0	1
12-2M	0	0	0	0	0	0	0	0	0	0
12-2A	2	1	0	0	0	0	0	0	0	3
1-1I	2	20	1	0	0	0	0	0	0	23
1-1M	0	1	2	0	0	0	1	0	0	4
1-1A	27	1	2	0	0	0	0	0	0	30
1-2I	0	1	0	0	0	0	0	0	0	1
1-2M	1	0	0	0	0	0	0	0	0	1
1-2A	1	0	0	0	0	0	0	0	0	1
31-1I	0	3	0	0	0	0	0	0	0	3
31-1M	7	0	1	0	0	0	0	0	0	8
31-1A	0	0	0	0	0	0	0	0	0	0
31-2I	0	0	0	0	0	0	0	0	0	0
31-2M	2	1	1	0	0	0	1	0	0	5
31-2A	1	0	1	0	0	0	0	0	0	2
31-3I	0	24	0	0	0	0	0	0	0	24
31-3M	1	1	1	0	0	0	0	0	0	3
31-3A	651	8	0	0	0	0	0	0	0	659
31-4I	0	2	1	0	0	0	1	0	0	4
31-4M	61	0	1	0	0	0	0	0	0	62
31-4A	3	2	1	0	0	1	0	0	0	7
32-3I	1	58	1	0	0	0	0	0	0	60
32-3M	1	1	2	0	0	0	0	0	0	4
32-3A	0	0	0	0	0	0	0	0	0	0
32-4I	0	67	1	0	0	0	0	0	0	68
32-4M	6	0	2	0	0	0	0	0	0	8
32-4A	4	4	3	0	0	0	0	0	0	11
32-5R	0	0	2	0	0	0	0	0	0	2
32-5M	0	0	0	0	0	0	0	0	0	0
32-5L	0	0	4	0	0	0	2	0	3	9
32-6R	0	0	15	0	0	0	2	0	2	19
32-6M	0	0	0	0	0	0	0	0	0	0
32-6L	0	0	5	0	0	0	0	0	0	5
32-7R	0	1	12	2	0	0	0	0	20	35
32-7M	1	0	6	0	0	3	7	2	0	19
32-7L	0	0	23	0	0	5	0	0	21	49
TOTAL	782	205	88	2	1	9	14	2	46	1149



	Bivalve	Gastropod	Polychaeta	Nemertea	Echinoidea	Pisces	Decapoda	Isopoda	Amphipoda
SSB	86.78	22.67	2.33	0.00	0.11	0.11	0.33	0.00	0.00
SSK	0.56	0.56	37.22	1.11	0.00	4.44	6.11	1.11	25.56

Class

Fig.54. Mean Abundance of Macrobenthos (ind/m^2) in SSB and SSK during 4-Month Study

3.3.1.1 Sungai Sangga Besar (SSB)

In SSB, bivalves became increasingly more abundant away from the cage culture area, increasing from a mean of 1.00 to 29.00 to 230.33 ind/m^2, at the inside, middle and away station, respectively (Figure 55). The bivalves which were abundant at the opposite bank (away station) were *Anadara granosa, Plecyora trigona, Xenostrobus* sp., *Nuculana* sp., *Tellina* sp. A, *Tellina* sp. B and *Orbicularia orbicularia* while the species found in the cage area were *Plecyora trigona* and *Xenostrobus* sp. (Appendix 10). Blood cockles (*Anadara* granosa) were more abundant in away stations as they were artificially seeded, away from the cage area, for aquaculture.

On the other hand, the gastropod population showed higher numbers of 60.3 ind/m^2 in the cage area as compared to its population at the opposite bank (away station). These gastropods were *Nassarius jacksonianus*, *N. olivaceus*, *N.* sp. B, *N.* sp. A, *Stenothyra glabrata*, *Polinices* sp., *Assiminea* sp., *Cypraea* sp. and an unidentified sp. E (Appendix 10). Gastropods were more abundant in the cage area probably because most of them were scavenging gastropods, where they probably consumed the food pellets and thrash fish leftovers from the surface or those buried in the sediment. The burying of these particles could be due to sedimentation process or current effect.

The polychaetes were more abundant in the middle (3.33 ind/m^2) as compared to away (2.33 ind/m^2) and inside (1.33 ind/m^2) stations. Only one species of echinoderm and fish, with very low abundance of 0.33 ind/m^2 were sampled. There were no nemertean, isopod and amphipod found in this river.

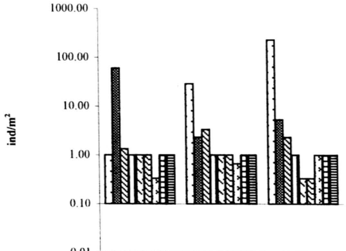
3.3.1.1 Sungai Sangga Kecil (SSK)

In SSK, polychaetes dominated the population of macrobenthos at both banks of the river with 48.33 and 53.33 ind/m^2 on the left and right bank, respectively (Figure 56). These polychaetes were *Capitella* sp., *Leiochrides australis*, *Ophioglycera* sp., *Paraprionospio* sp., *Ctenodrilus* sp., *Nereis* sp., *Diopatra* sp. and an unidentified sp. B (Appendix 10). Decapoda became increasingly more abundant in the middle (mean of 11.66 ind/m^2) as compared to both banks of the river where both banks have the same mean abundance of 3.33 ind/m^2. The decapoda which were abundant at the middle of the river were *Camptandrium sexdentatum* and *Xenophthalmus pinnotheroides* (Figure 56 and Appendix 10).

Amphipod showed higher population at both banks of the river, with a mean abundance of 36.67 ind/m^2 and 40.0 ind/m^2 for both right and left banks, respectively. The only species that dominated the amphipod population was *Ceradocus* sp. (Figure 56 and Appendix 10). For the other groupings, i.e. bivalve, gastropod, nemertean, fish and isopod, only one species each was present. There was no echinoderm sampled in SSK.

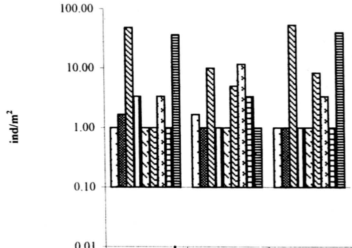
3.3.2 Macrobenthos Diversity and Abundance (12-Hour Study)

A total of 266 macrobenthos, which comprised of 90 animals from SSB (Transect 1), and 176 animals from SSK (Transect 6) were recorded (Table 6). A total of 36 species were recorded. The presence or absence of macrobenthos animals at each station during the study period is shown in Appendix 11. Figure 57 give the mean faunal abundance based on only inside and away stations in SSB or right and left bank stations in SSK.



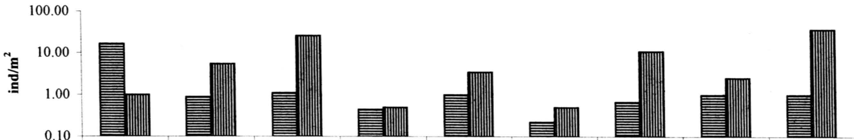
Stations	In	Mid	Aw
Bivalve	1.00	29.00	230.33
Gastropod	60.33	2.33	5.33
Polychaete	1.33	3.33	2.33
Nemertean	0.00	0.00	0.00
Echinoderm	0.00	0.00	0.33
Pisces	0.00	0.00	0.33
Decapoda	0.33	0.67	0.00
Isopoda	0.00	0.00	0.00
Amphipoda	0.00	0.00	0.00

Fig.55. Mean Abundance of Macrobenthos (ind/m^2) in SSB Sampling Stations during 4-Month Study



Stations	Right	Mid	Left
Bivalve	0.00	1.67	0.00
Gastropod	1.67	0.00	0.00
Polychaete	48.33	10.00	53.33
Nemertean	3.33	0.00	0.00
Echinoderm	0.00	0.00	0.00
Pisces	0.00	5.00	8.33
Decapoda	3.33	11.67	3.33
Isopoda	0.00	3.33	0.00
Amphipoda	36.67	0.00	40.00

Fig.56. Mean Abundance of Macrobenthos (ind/m^2) in SSK Sampling Stations during 4-Month Study



	Bivalve	Gastropod	Polychaeta	Nemertea	Echinoidea	Pisces	Decapoda	Isopoda	Amphipoda
SSB	16.67	0.89	1.11	0.44	0.00	0.22	0.67	0.00	0.00
SSK	1.00	5.50	26.00	0.50	3.50	0.50	11.00	2.50	37.50

Class

Fig.57. Overall Mean Abundance of Macrobenthos (ind/m^2) in SSB and SSK during 12-Hour Study

Table 6. Total Number of Macrobenthos Collected during 12-Hour Study in SSB and SSK

Sample	Bivalve	Gastropoda	Polychaeta	Nemertea	Echinoidea	Pisces	Decapoda	Isopoda	Amphipod	Total
1a-I	0	0	1	0	0	0	0	0	0	1
1a-M	6	1	0	0	0	1	1	0	0	9
1a-A	7	1	1	0	0	0	0	0	0	9
1b-I	1	1	0	0	0	0	0	0	0	2
1b-M	6	1	0	0	0	0	0	0	0	7
1b-A	4	0	0	0	0	0	0	0	0	4
1c-I	0	0	1	0	0	0	0	0	0	1
1c-M	14	0	0	1	0	0	0	0	0	15
1c-A	2	0	0	0	0	0	0	0	0	2
1d-I	1	0	1	0	0	0	0	0	0	2
1d-M	2	0	0	0	0	0	1	0	0	3
1d-A	0	0	0	0	0	0	0	0	0	0
1e-I	0	0	0	0	0	0	0	0	0	0
1e-M	3	0	0	0	0	0	0	0	0	3
1e-A	29	0	1	1	0	0	1	0	0	32
6a-R	0	0	5	0	1	0	2	0	0	8
6a-L	0	0	7	0	0	0	1	0	8	16
6b-R	0	1	6	0	0	0	2	0	3	12
6b-L	1	2	3	1	0	0	4	2	8	21
6c-R	1	0	1	0	1	0	1	0	0	4
6c-L	0	3	7	0	0	0	2	1	26	39
6d-R	0	2	11	0	1	0	2	2	6	24
6d-L	0	0	0	0	1	0	1	0	0	2
6e-R	0	1	3	0	0	1	2	0	6	13
6e-L	0	2	9	0	3	0	5	0	18	37
TOTAL	77	15	57	3	7	2	25	5	75	266

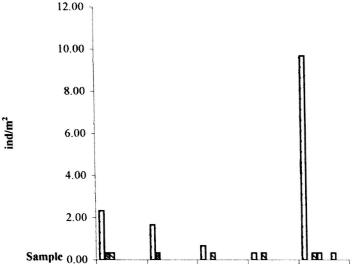
The mean abundance of macrobenthos based on animal groupings and tide are shown in Figures 58 and 59 for SSB and SSK, respectively. The animals found in SSK were more diverse compared to SSB.

3.3.2.1 Sungai Sangga Besar (SSB)

In SSB, the mean abundance according to macrobenthos groupings in inside station did not vary much with tide with low abundance of 0.67 ind/m^2 (Figure 60). Over the study period, only bivalves, gastropods and polychaetes were present. Bivalves were sampled during 1330 hr (Flood) and 1920 hr (Flood) (samples 1b-I and 1e-I, respectively). These bivalves were *Anadara granosa* (1b-I) and *Plecyora trigona* (1e-I) (Appendix 12). The polychaetes were sampled at 1200 hr (Ebb) (1a-I), 1620 hr (Flood) (1c-I) and 1920 hr (Flood) (1d-I) (Figure 59). These polychaetes were *Capitella* sp. (1a-I) and *Paraprionospio* sp. (1c-I and 1d-I). On the other hand, the only species of gastropod (*Nassarius* sp. B) was sampled at 1330 hr (Flood) (1b-I) (Figure 60). Hence, the results generally indicate more but few fauna during flood tide.

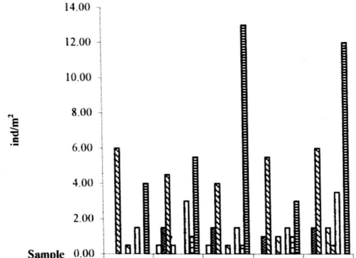
The diversity of macrobenthos for away stations were more diverse compared to inside station. Bivalves, gastropods, polychaetes, nemerteans and decapods were present. Bivalves became increasingly more abundant during night time, especially at 2145 hr (Ebb) (sample 1e-A). The bivalves species were *Anadara granosa* (1a-A, 1b-A, 1c-A, 1e-A); *Plecyora trigona* (1a-A, 1e-A) and *Pharella acuminata* (1e-A) (Appendix 11).

The only species of gastropod (unidentified sp. D), was sampled at 0855 hr (Flood) and 2145 hr (Ebb) (sample 1a-A). Polychates were sampled at 0855 hr (Flood) and 2145 hr (Ebb) (1a-A and 1e-A), respectively. These polychaetes were *Aphrodita flava* (1a-A)



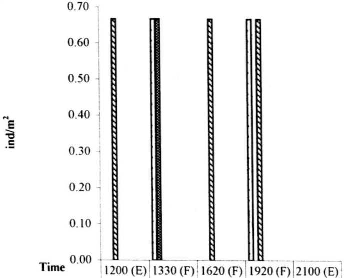
Sample	1a	1b	1c	1d	1e
Bivalve	2.33	1.67	0.67	0.33	9.67
Gastropod	0.33	0.33	0.00	0.00	0.00
Polychaete	0.33	0.00	0.33	0.33	0.33
Nemertean	0.00	0.00	0.00	0.00	0.33
Echinoderm	0.00	0.00	0.00	0.00	0.00
Pisces	0.00	0.00	0.00	0.00	0.00
Decapoda	0.00	0.00	0.00	0.00	0.33
Isopoda	0.00	0.00	0.00	0.00	0.00
Amphipoda	0.00	0.00	0.00	0.00	0.00

Fig.58. Mean Abundance of Macrobenthos (ind/m^2) in SSB (Transect 1), during 12-Hour Study



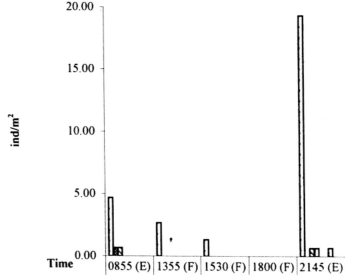
Sample	6a	6b	6c	6d	6e
Bivalve	0.00	0.50	0.50	0.00	0.00
Gastropod	0.00	1.50	1.50	1.00	1.50
Polychaete	6.00	4.50	4.00	5.50	6.00
Nemertean	0.00	0.50	0.00	0.00	0.00
Echinoderm	0.50	0.00	0.50	1.00	1.50
Pisces	0.00	0.00	0.00	0.00	0.50
Decapoda	1.50	3.00	1.50	1.50	3.50
Isopoda	0.00	1.00	0.50	1.00	0.00
Amphipoda	4.00	5.50	13.00	3.00	12.00

Fig.59. Mean Abundance of Macrobenthos (ind/m^2) in SSK (Transect 6), during 12-Hour Study



Time	1200 (E)	1330 (F)	1620 (F)	1920 (F)	2100 (E)
Bivalve	0.00	0.67	0.00	0.67	0.00
Gastropod	0.00	0.67	0.00	0.00	0.00
Polychaete	0.67	0.00	0.67	0.67	0.00
Nemertean	0.00	0.00	0.00	0.00	0.00
Echinoderm	0.00	0.00	0.00	0.00	0.00
Pisces	0.00	0.00	0.00	0.00	0.00
Decapoda	0.00	0.00	0.00	0.00	0.00
Isopoda	0.00	0.00	0.00	0.00	0.00
Amphipoda	0.00	0.00	0.00	0.00	0.00

(Inside Station)



Time	0855 (E)	1355 (F)	1530 (F)	1800 (F)	2145 (E)
Bivalve	4.67	2.67	1.33	0.00	19.33
Gastropod	0.67	0.00	0.00	0.00	0.00
Polychaete	0.67	0.00	0.00	0.00	0.67
Nemertean	0.00	0.00	0.00	0.00	0.67
Echinoderm	0.00	0.00	0.00	0.00	0.00
Pisces	0.00	0.00	0.00	0.00	0.00
Decapoda	0.00	0.00	0.00	0.00	0.67
Isopoda	0.00	0.00	0.00	0.00	0.00
Amphipoda	0.00	0.00	0.00	0.00	0.00

(Away Station)

Fig.60. Mean Abundance of Macrobenthos (ind/m^2) for SSB (Inside and Away Stations) in Relation to Time and Tide

and *Ophioglycera* sp. (1e). For nemertean and decapod, only 1 species sampled at 2145 hr (Ebb) (1e-A). The species were *Pantinonemertes* sp. (Nemertea) and *Mysis* sp. (Decapoda) (Appendix 11).

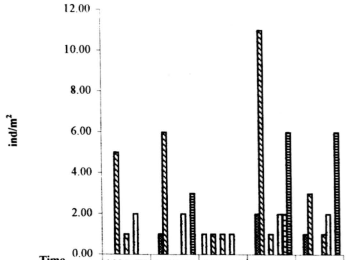
3.3.2.2 Sungai Sangga Kecil (SSK)

In SSK, various macrobenthos groupings in right bank station were generally present during day and night, irrespective of the tidal phase (Figure 61). Only 1 species of bivalve (*Xenostrobus* sp.) was sampled at 1630 hr (Flood) (sample 6c-R) with a low abundance of 1.00 ind/m^2. Gastropods were sampled at 1440 hr (Ebb), 1940 hr (Flood) and 2225 hr (Ebb). These gastropods were *Pugilina cochlidium* (1.00 ind/m^2, 6b-R) and an unidentified sp. E (2.00 ind/m^2; 6d-R and 1.00 ind/m^2; 6e-R) (Figure 61 and Appendix 11).

Polychaete species present were *Capitella* sp. (samples 6a-R, 6d-R), *Aphrodita flava* (6a-R), *Ophioglycera* sp. (6a-R, 6b-R), *Paraprionospio* sp. (6a-R, 6d-R, 6e-R), *Ctenodrilus* sp. (6d-R, 6e-R), *Diopatra* sp. (6b-R, 6d-R, 6e-R), unidentified sp. A (6c-R), unidentified sp. B (6b-R) and unidentified sp. C (6c-R) (Figure 61 and Appendix 11).

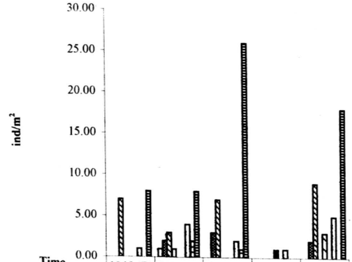
Only one species of echinoderm (*Ophiactis* sp.) was sampled at 1020 hr (Ebb) (6a-R), 1630 hr (Flood) (6c-R) and 2225 hr (Ebb) (6e-R) (Figure 61 and Appendix 11).

The decapods occurred throughout the sampling period, with a mean abundance of 2.00 ind/m^2 (samples 6a-R, 6b-R, 6d-R, 6e-R) except for sample 6d-R (1.00 ind/m^2). The decapod species found in all samples was *Xenophthalmus pinnotheroides* (Figure 61



Time	1020 (E)	1440 (F)	1630 (F)	1940 (F)	2225 (E)
Bivalve	0.00	0.00	1.00	0.00	0.00
Gastropod	0.00	1.00	0.00	2.00	1.00
Polychaete	5.00	6.00	1.00	11.00	3.00
Nemertean	0.00	0.00	0.00	0.00	0.00
Echinoderm	1.00	0.00	1.00	1.00	0.00
Pisces	0.00	0.00	0.00	0.00	1.00
Decapoda	2.00	2.00	1.00	2.00	2.00
Isopoda	0.00	0.00	0.00	2.00	0.00
Amphipoda	0.00	3.00	0.00	6.00	6.00

(Right Bank Station)



Time	1045 (E)	1410 (F)	1705 (F)	1845 (F)	2250 (E)
Bivalve	0.00	1.00	0.00	0.00	0.00
Gastropod	0.00	2.00	3.00	0.00	2.00
Polychaete	7.00	3.00	7.00	0.00	9.00
Nemertean	0.00	1.00	0.00	0.00	0.00
Echinoderm	0.00	0.00	0.00	1.00	3.00
Pisces	0.00	0.00	0.00	0.00	0.00
Decapoda	1.00	4.00	2.00	1.00	5.00
Isopoda	0.00	2.00	1.00	0.00	0.00
Amphipoda	8.00	8.00	26.00	0.00	18.00

(Left Bank Station)

Fig.61. Mean Abundance of Macrobenthos (ind/m^2) for SSK (Right and Left Bank Stations) in Relation to Time and Tide

and Appendix 11). For isopod, only one species of *Synopia ultramania* was collected at 1940 hr (Flood) (6d-R) with an abundance of 2.00 ind/m^2 (Figure 61 and Appendix 11). The mean abundance of amphipods estimated were 3.00 ind/m^2 at 1440 hr (Ebb) (6b-R), 6.00 ind/m^2 at 1940 hr (Flood) (6d-R) and 6.00 ind/m^2 at 2225 hr (Ebb) (6e-R). These amphipods were *Ceradocus* sp. (6b-R, 6d-R, 6e-R) and an unidentified sp. F (6d-R, 6e-R) (Figure 61 and Appendix 11).

For left bank station in SSK, the mean abundance of each macrobenthos groupings were generally present during day and night, irrespective of the tidal phase (Figure 61). Only 1 species of bivalve (*Tellina* sp. B) was sampled at 1410 hr (Flood) (sample 6b-L) with low abundance of 1.00 ind/m^2 (Figure 60 and Appendix 11). The gastropods were present at 1410 hr (Flood), 1705 hr (Flood) and 2250 hr (Ebb). The mean abundance of gastropod according to stations were *Nassarius* sp. B and *Nassarius* sp. A (2.00 ind/m^2 at 6b-L), unidentified sp. E (3.00 ind/m^2; 6c-L), *Nassarius olivaceus* and unidentified sp. E (2.00 ind/m^2; 6e-L) (Figure 61 and Appendix 11).

The polychaetes occurred throughout the study period except for sample 6d-L. Samples 6a-L and 6c-L showed the same abundance of 7.00 ind/m^2 while samples 6b-L and 6e-L showed the abundance of 3.00 and 9.00 ind/m^2, respectively. The occurrence of polychaetes according to samples were; *Capitella* sp., *Ophioglycera* sp., *Nereis* sp., and *Hesiosyllis* sp. (sample 6a-L), *Capitella* sp., *Paraprionospio* sp., *Ctenodrilus* sp. (6b-L), *Leiochrides australis*, *Ctenodrilus* sp., *Diopatra* sp. (6c-L) and *Paraprionospio* sp., *Ctenodrilus* sp. and *Diopatra* sp. (6e-L) (Figure 61 and Appendix 11).

For nemertean, only 1 species (*Pantinomertes* sp.) was sampled at 1410 hr (Flood) (6b-L) with low abundance of 1.00 ind/m^2. The echinoderm *Ophiactis* sp. was sampled at

1845 hr (Flood) and 2250 hr (Ebb) (6d-L and 6e-L, respectively), with abundance of 1.00 and 3.00 ind/m^2, respectively (Figure 61 and Appendix 11).

Decapods occurred throughout the sampling period. The mean abundance of decapods according to samples were 1.00 ind/m^2 (6a-L), 4.00 ind/m^2 (6b-L), 2.00 ind/m^2 (6c-L), 1.00 ind/m^2 (6d-L) and 5.00 ind/m^2 (6e-L). The species *Xenophthalmus pinnotheroides* was present in day and night samples, whereas the species *Alpheus* sp. and *Camptandrium sexdentatum* were present in night samples (6e-L) (Figure 61 and Appendix 11).

Isopods (*S. terebrans*) occurred at 1410 hr (Flood) and 1705 hr (Flood) with mean abundance of 2.00 and 1.00 ind/m^2, respectively (Figure 61 and Appendix 11).

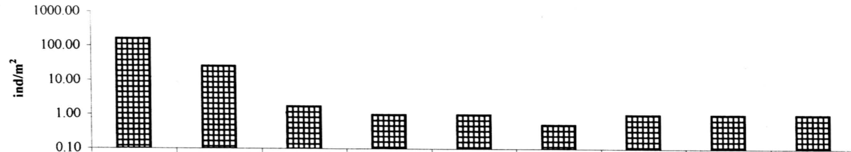
Amphipods occurred at all times except at 1845 hr during flood with interestingly higher abundance of 26.00 and 18.00 ind/m^2 in samples 6c-L and 6e-L, respectively. Therefore, 2 stations showed the same mean abundance of 8.00 ind/m^2 in samples 6a-L and 6b-L, respectively. Only the amphipod species (*Ceradocus* sp.) occurred at 1045 hr (Ebb), 1410 hr (Flood), 1705 hr (Flood) and 2250 hr (Ebb) (Figure 61 and Appendix 11), with higher abundance in samples 6a-L, 6b-L, 6c-L and 6d-L.

3.3.3 Macrobenthos Diversity and Abundance in SSB (1-Day "Grid" Sampling)

A total of 766 macrobenthic animals were recorded of which 77 individuals were obtained from the cage area at stations B2, B3, B4, C2 and C3 (Table 7). The mean abundance of macrobenthic animals was 199.5 ind/m^2 (Figure 62). The mean abundance of macrobenthic animals under the cage farm was 77.00 ind/m^2, but 230

Table 7. Total Number of Macrobenthos Collected in SSB during 1-Day "Grid" Sampling

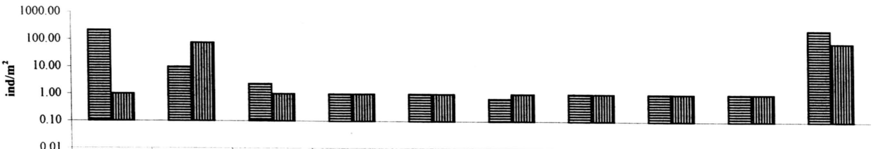
Station	Area	Bivalve	Gastropoda	Polychaeta	Nemertea	Echinoidea	Pisces	Decapoda	Isopoda	Amphipoda	Total
A1	Non-cage	324	7	0	0	0	2	0	0	0	333
A2	Non-cage	4	0	0	0	0	0	2	0	0	6
A3	Non-cage	270	15	0	0	0	0	0	0	0	285
A4	Non-cage	13	0	0	0	0	0	0	0	0	13
A5	Non-cage	37	0	0	0	0	0	0	0	0	37
B1	Non-cage	0	3	5	0	0	0	0	0	0	8
B2	Cage	0	4	0	0	0	0	0	0	0	4
B3	Cage	0	14	0	0	0	0	0	0	0	14
B4	Cage	0	32	0	0	0	0	1	0	0	33
B5	Non-cage	0	2	0	0	0	0	1	0	0	3
C1	Non-cage	0	2	0	0	0	0	0	0	0	2
C2	Cage	0	0	0	0	0	0	0	0	0	0
C3	Cage	0	26	0	0	0	0	0	0	0	26
C4	Non-cage	0	0	0	0	0	0	0	0	0	0
C5	Non-cage	0	0	2	0	0	0	0	0	0	2
D1	Non-cage	0	0	0	0	0	0	0	0	0	0
D2	Non-cage	0	0	0	0	0	0	0	0	0	0
D3	Non-cage	0	0	0	0	0	0	0	0	0	0
D4	Non-cage	0	0	0	0	0	0	0	0	0	0
D5	Non-cage	0	0	0	0	0	0	0	0	0	0
TOTAL		648	105	7	0	0	2	4	0	0	766



	Bivalve	Gastropod	Polychaeta	Nemertea	Echinoidea	Pisces	Decapoda	Isopoda	Amphipoda
Series1	162.00	26.25	1.75	0.00	0.00	0.50	1.00	0.00	0.00

Famili

Fig.62. Total Abundance of Macobenthos (ind/m^2) during 1-Day "Grid", Sampling



	Bivalve	Gastropoda	Polychaeta	Nemertea	Echinoidea	Pisces	Decapoda	Isopoda	Amphipoda	Total
Non-cage	216.00	9.67	2.33	0.00	0.00	0.67	1.00	0.00	0.00	229.67
Cage	0.00	76.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	77.00

Groupings

Fig.63. Mean Abundance of Macrobenthos (ind/m^2) during 1-Day "Grid" Sampling in Cage and Non-cage Area

ind/m^2 outside the cage area (Figure 63). A total of 11 species was recorded. The presence or absence of macrobenthic animals at each station during the study period is shown in Appendix 12.

Bivalves dominated the population of macrobenthic animals outside the cage area, with high abundance of 216.00 ind/m^2. These bivalves were *Anadara granosa*, *Plecyora trigona* and *Orbicularia orbicularia* (Figure 63 and Appendix 12). The gastropod population showed higher mean abundance of 76.00 ind/m^2 in the cage area as compared to its' population in non-cage area (9.67 ind/m^2). The gastropods which were abundant in the cage area were *Nassarius olivaceus* but this species together with another *Nassarius* sp. B were also present outside the cage area (Figure 63 and Appendix 12).

Polychaetes (*Ophioglycera* sp. and *Paraprionospio* sp.) and an unidentified fish sp. G, not found in the cage area but were found outside with an abundance of 2.33 and 1.00 ind/m^2, respectively. Decapods occurred at both cage and non-cage area with low abundance of 1.00 ind/m^2. These were *Benthopanope* sp. and *Diogenes* sp., respectively (Figure 63 and Appendix 12).

3.4 STATISTICAL ANALYSIS

3.4.1 4-Month Study

3.4.1.1 Univariate Analysis

Macrobenthos Abundance in Relation to Month, Transect and Station in SSB for December, January, early March (March 1) and late March (March 2) Data

A three-way ANOVA was applied to logarithmically-transformed abundance data with months (December*January*March1*March2), transects (1*2) and stations (IN*MID*AW) (Figure 64), as influencing factors. Results from the ANOVA showed that the total abundance of macrobenthos were not significantly influenced by month or station ($p > 0.05$) but significantly influenced by transect ($F=8.98$, $P=0.0049$) (Table 8). Total abundance of macrobenthos were significantly higher in transect 1 as compared to transect 2 (Figure 64).

Macrobenthos Abundance in Relation to Transect and Station in SSB for early March Data

A two-way ANOVA was applied to logarithmically-transformed abundance data with transects (1*2*3*4) and stations (IN*MID*AW), as influencing factors. Results from the ANOVA showed that the total abundance of macrobenthos were significantly influenced by transect ($P < 0.0001$) and station ($P=0.0004$) with significant interaction effects between transect and station ($P < 0.0001$) (Table 9).

Table 8. Analysis of Variance (ANOVA) of Macrobenthos Abundance in Relation to Month, Transect and Station in SSB for December, January, March 1 and March 2 Data

STAT GENERAL MANOVA	Summary of all Effects; design: (sdrawsta.sta) 1-MONTH, 2-TRANSECT, 3-STATION					
Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
1	2	0.5784	36	1.6035	0.3607	0.6997
2	1	14.3948	36	1.6035	8.9770	0.0049
3	2	0.4344	36	1.6035	0.2709	0.7642
12	2	2.9618	36	1.6035	1.8471	0.1723
13	4	2.2185	36	1.6035	1.3835	0.2591
23	2	1.5880	36	1.6035	0.9903	0.3814
123	4	0.8497	36	1.6035	0.5299	0.7145

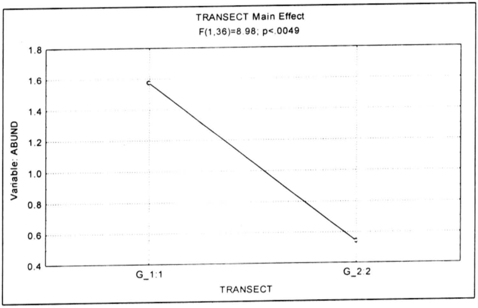


Figure 64. Mean Total Abundance of Macrobenthos in Transect 1 and 2 in SSB for December, January, March 1 and March 2

Total abundance of macrobenthos were highest on transect 3, followed by transects 4, 1 and 2 (Figure 65). Based on Newman-Keuls Test, the total abundance of macrobenthos between transect 1 and 2 were not significantly different ($p=0.71$). However, there was significant difference between transect 1 and transect 3 ($p=0.0001$) or transect 4 ($p=0.0023$). Transect 2 showed significant difference when compared to transect 3 ($p=0.0002$) and transect 4 ($p=0.0024$). Transect 3 was also significantly different from transect 4 ($p=0.0025$) (Appendix 13).

Total abundance of macrobenthos was highest in AW station, followed by MID and IN stations (Figure 66). Based on Newman-Keuls Test, generally all stations had macrobenthos abundance, which were significantly different ($p<0.05$) when compared to each other. IN station abundance was significantly different when compared to abundance of MID ($p=0.0222$) and AW ($p=0.0004$) stations. Abundance of MID station was also significantly different from that of AW station ($p=0.0372$) (Appendix 14).

The interaction effects between transect and station were however significant ($p<0.05$) contributing 57% of the total observed variability (Table 9). The significant interaction effects indicate that the influence of the main factor, transect or station, modified each other.

For instance, only in transect 3, was the abundance at the AW station significantly higher ($p<0.05$) than in other stations, as well as that of all other stations in the other transects (Figure 67). Similarly, the MID and AW stations at transect 4, showed significantly higher macrobenthos abundance than the IN station, but only the MID station had significantly higher abundance when compared to all stations of other transects (Figure 67; Appendix 15).

Table 9. Analysis of Variance (ANOVA) of Macrobenthos Abundance in Relation to Transect and Station in SSB for Early March

STAT GENERAL MANOVA	Summary of all Effects; design: (sdrawstb.sta) 1-TRANSECT, 2-STATION					
Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
1	3	27.2007	24	1.1891	22.8753	0.0000
2	2	12.8948	24	1.1891	10.8443	0.0004
12	6	23.4819	24	1.1891	19.7479	0.0000

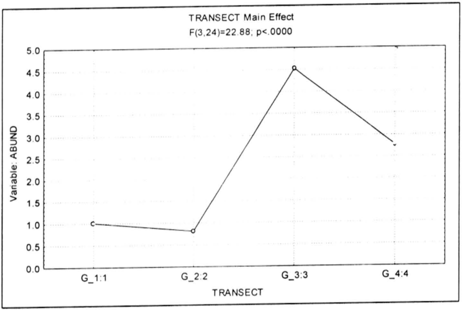


Figure 65. Mean Total Abundance of Macrobenthos in Transect 1, 2, 3 and 4 in SSB for Early March

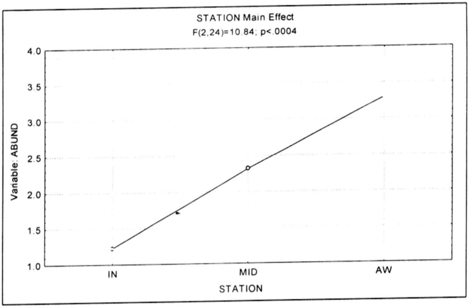


Figure 66. Mean Total Abundance of Macrobenthos in Inside, Middle and Away Stations in SSB for Early March

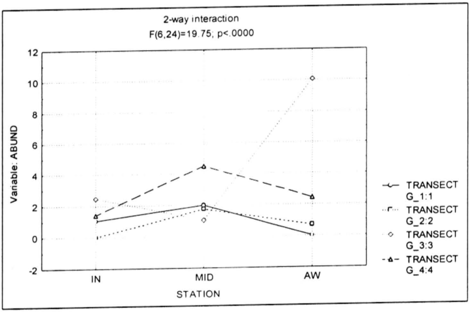


Figure 67. Mean Total Abundance of Macrobenthos in Every Station between All Transect in SSB for Early March

Macrobenthos Abundance in Relation to Transect and Station in SSB and SSK for Late March Data

A two-way ANOVA was applied to logarithmically-transformed abundance data with transects (3*4*5*6*7) and stations (IN/R*MID*AW/L), as influencing factors. Results from the ANOVA showed that the total abundance of macrobenthos was again significantly influenced ($F=12.64$, $P < 0.0001$) by transect (Table 10). 'Station' was not a significant influencing factor.

For transect, total abundance of macrobenthos was highest at transect 7 (SSK), followed by transects 5,6, (SSK) and 3,4 (SSB) (Figure 68). Based on the Newman-Keuls Test, the total abundance of macrobenthos in transect 7 was significantly different when compared to other transects; transect 3 ($p=0.0001$), transect 4 ($p=0.0002$), transect 5 ($p=0.0002$) and transect 6 ($p=0.0004$) (Appendix 16). Comparisons of abundance among transects 3,4,5 and 6 however indicate no significant difference ($p>0.05$).

Table 10. Analysis of Variance (ANOVA) of Macrobenthos Abundance in Relation to Transect and Station in SSB and SSK for Late March Dat

STAT GENERAL MANOVA	Summary of all Effects; design: (sdrawstc.sta) 1-TRANSECT, 2-STATION					
Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
1	4.0000	48.1370	21.0000	3.8085	12.6394	0.0000
2	2.0000	2.4991	21.0000	3.8085	0.6562	0.5291
12	8.0000	4.4552	21.0000	3.8085	1.1698	0.3618

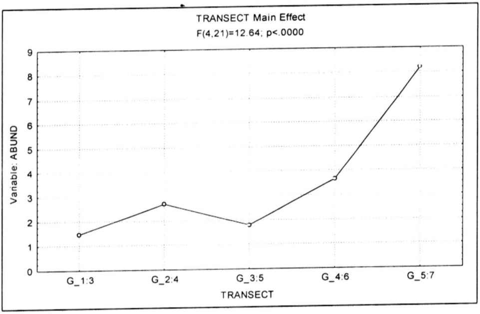


Figure 68. Mean Total Abundance of Macrobenthos in SSB (Transect 3 and 4) and SSK (Transect 5, 6 and 7) for Late March

3.4.1.2.1 Multivariate Analysis

Macrobenthos Species Abundance in Relation to Abiotic Variables

To assess the relationships between species abundance and environmental factors during the 4-month study, redundancy analysis (RDA) was performed only on the common species of each taxon. The total numbers of macrobenthos species were 22 (see Table 11), while 16 abiotic variables were used in the RDA.

Table 11: Common Macrobenthos Species from 4-Month Study for RDA analysis

PHYLUM	GENUS / SPECIES	Abbreviation
ANNELIDA	*Capitella* sp.	Capit
	Ophioglycera sp.	Opgly
	Paraprionospio sp.	Parap
	Ctenodrilus sp.	Cteno
	Nereis sp.	Nerei
	Unidentified sp. C	Poly3
MOLLUSCA	*Anadara granosa*	Angra
	Plecyora trigona	Pletri
	Xenostrobus sp.	Xynos
	Nuculana sp.	Nucul
	Tellina sp. A	TellA
	Tellina sp. B	TellB
	Nassarius sp. B	Nasa
	Nassarius jacksonianus	Najac
	Nassarius olivaceus	Naoli
	Stenothyra glabrata	Stegl
	Unidentified sp. D	Nas1
	Assiminea sp.	Asisp
	Ceradocus sp.	Cerad
ARTHROPODA	*Diogenes* sp.	Dioge
	Xenophthalmus pinnotheroides	Xepin
PISCES	*Hemigobius* sp.	Hemig

Results of RDA of the relationships between the environmental factors and the abundance of selected common macrobenthos species is shown in Table 12. The eigenvalues for RDA axis 1, (0.165), axis 2 (0.077) and axis 3 (0.053) accounted for 33.2%, 48.9% and 59.5% of the cumulative percentage variance in the data respectively (Table 12).

The environmental factors that showed statistically significant ($p<0.05$) relationships with the abundance of the common macrobenthos species were sediment pH (Sph), sediment temperature (Stemp), salinity (sal), silt, very fine sand (vfs), fine sand (fs), medium sand (ms) and very coarse sand (vcs). The species-environmental correlations were 0.903 (axis 1), 0.777 (axis 2) and 0.817 (axis 3) (Table 12).

The distribution of macrobenthos species along the axis suggests that species differed in their response to the abiotic factors. The abbreviation used in Figures 69, 70 and 71 are shown in Table 13.

Distribution of Site in Relation to Abiotic Factors

Based on Figure 69, it was shown that SSK sites were characterized by higher dissolved oxygen, water depth, salinity, pH, sediment redox potential and percentage of silt, which were higher as compared to the stations in SSB. Sites K5r, K5l and K7r which were located near the riverbanks were most highly correlated to dissolved oxygen, while the middle sites (samples K5m, K6m and K7m) were higher in pH and salinity.

Table 12: Results of Redundancy Analysis (RDA) for Macrobenthos Abundance in Relation to Abiotic Factors during 4-Month Study

Variable	Axis 1	Axis 2	Axis 3
Canonical Coefficients for Standardized Variables			
Sph	-0.5695	0.2832	0.0704
Srd	-0.1557	-0.3334	0.3092
Stemp	-0.1221	-0.1972	-1.042
pH	0.5675	0.7786	3.1593
temp	-1.044	-1.1101	-0.5769
do	0.2371	0.0801	-0.1723
sal	0.3997	-0.2123	-2.8054
dep	-0.1949	-0.103	-0.1833
org	-0.0062	0.4841	-1.5477
clay	-1.3359	0.6321	-2.5374
silt	2.0783	0.5246	3.9348
vfs	-0.5931	-2.3608	-1.3757
fs	-0.1474	2.5879	2.9923
ms	0.4344	-2.3302	-0.964
cs	-0.2659	0.5976	0.5332
vcs	0.2079	-0.8202	0.0421
Inter set Correlation of Environmental Variables with Ordination Axes			
Sph	-0.6862*	0.1164	-0.158
Srd	0.2284	-0.1208	-0.0626
Stemp	-0.5767	-0.0595	-0.1895*
pH	0.141	-0.089	0.0758
temp	0.0009	-0.0763	0.0685
do	0.3655	0.1141	-0.1015
sal	0.1433	-0.1214	0.0556*
dep	0.1768	-0.1008	-0.0874
org	0.1345	0.1706	-0.0678
clay	0.2388	0.2528	-0.1243
silt	0.3582*	0.2574	-0.1359*
vfs	0.0683	0.1601*	0.1005
fs	-0.4347	-0.0131*	0.3746*
ms	-0.3659	-0.2363*	0.2125
cs	-0.211	-0.3631	-0.1643
vcs	-0.2723	-0.4057*	-0.0711
Intra set Correlation of Environmental Variables with Ordination Axes			
Sph	-0.76	0.1497	-0.1934
Srd	0.253	-0.1554	-0.0766
Stemp	-0.6387	-0.0765	-0.232
pH	0.1561	-0.1145	0.0927
temp	0.001	-0.0981	0.0838
do	0.4048	0.1467	-0.1242
sal	0.1587	-0.1561	0.0681
dep	0.1958	-0.1296	-0.1069
org	0.1489	0.2194	-0.083
clay	0.2645	0.3251	-0.1521
silt	0.3967	0.3311	-0.1663
vfs	0.0757	0.2059	0.123
fs	-0.4815	-0.0169	0.4584
ms	-0.4052	-0.3039	0.26
cs	-0.2337	-0.467	-0.2011
vcs	-0.3016	-0.5219	-0.087
Summary Statistics for Ordination Axes			
Eigenvalue	0.165	0.077	0.053
Species-environment Correlation	0.903	0.777	0.817
Cumulative Percentage Variance			
of Species Data	16.5	24.2	29.5
of Species-environment Relation	33.2	48.9	59.5
Monte Carlo Significance Values (199 permutations under reduced model)			
p(sum of all eigenvalues) = 0.165			
p (axis 1) = 0.0100			
p (axis 2) = 0.0500			

***Significant at $p < 0.05$**

Table 13: Site Sample Abbreviation (in bold) as Used in Figures 69, 70 and 71 for 4-Month Study

				Inside Station		Middle Station		Away Station	
Date	River	Month	Transect	Sample Code	**Abb.**	Sample Cod	**Abb.**	Sample Code	**Abb.**
20/12/99	SSB	12	1	12-1I	**D1i**	12-1M	**D1m**	12-1A	**D1a**
20/12/99	SSB	12	2	12-2I	**D2i**	12-2M	**D2m**	12-2A	**D2a**
23/1/00	SSB	1	1	1-1I	**J1i**	1-1M	**J1m**	1-1A	**J1a**
23/1/00	SSB	1	2	1-2I	**J2i**	1-2M	**J2m**	1-2A	**J2a**
7/3/00	SSB	3	1	31-1I	**M1i**	31-1M	**M1m**	31-1A	**M1a**
7/3/00	SSB	3	2	31-2I	**M2i**	31-2M	**M2m**	31-2A	**M2a**
8/3/00	SSB	3	3	31-3I	**M3i**	31-3M	**M3m**	31-3A	**M3a**
8/3/00	SSB	3	4	31-4I	**M4i**	31-4M	**M4m**	31-4A	**M4a**
28/3/00	SSB	3	3	32-3I	**R3i**	32-3M	**R3m**	32-3A	**R3a**
28/3/00	SSB	3	4	32-4I	**R4i**	32-4M	**R4m**	32-4A	**R4a**
29/3/00	SSK	3	5	32-5I	**K5I**	32-5M	**K5m**	32-5A	**K5r**
29/3/00	SSK	3	6	32-6I	**K6I**	32-6M	**K6m**	32-6A	**K6r**
29/3/00	SSK	3	7	32-7I	**K7I**	32-7M	**K7m**	32-7A	**K7r**

The SSB stations were characterized by two different groups, the cage sites and non-cage sites. Cage sites were found to be higher in coarser sediment particles such as medium sand (ms), very coarse sand (vcs) and coarse sand (cs), as compared to the middle and away stations in SSB and SSK stations (Figure 69). The sites away from the cages were found to be higher in sediment pH.

Based on Figure 69, the middle and away sites in SSB and SSK stations had higher percentage of clay, silt, very fine sand (vfs) and organic matter.

Distribution of Macrobenthos Species in Relation to Abiotic Factors

The polychaetes (*Ctenodrilus* sp., *Capitella* sp., *Ophioglycera* sp., *Paraprionospio* sp.), *Ceradocus* sp and *Hemigobius* sp. were more abundant in relatively high dissolved oxygen, lower fine sand and lower sediment temperature. Three species, *Nereis* sp., *Diogenes* sp. and *Xenophthalmus pinnotheroides* were more abundant in higher water pH, sediment redox potential and salinity but *Xenophthalmus pinnotheroides* abundance was low in lower sediment pH (see Figure 70).

The abundance of nassarids (*Nassarius* sp. B, *Nassarius olivaceus*, *Nassarius* sp. A) and *Assiminea* sp. were higher in sediment relatively higher in very coarse sand (vcs) and coarse sand (cs) but lower in sediment richer in very fine sand (vfs), organic matter and clay. However, the other two species, *Xenostrobus* sp and *Stenothyra glabrata* were more abundant in higher medium sand (ms) and low silt. The abundance of polychaete C increased with higher sediment pH (Figure 70).

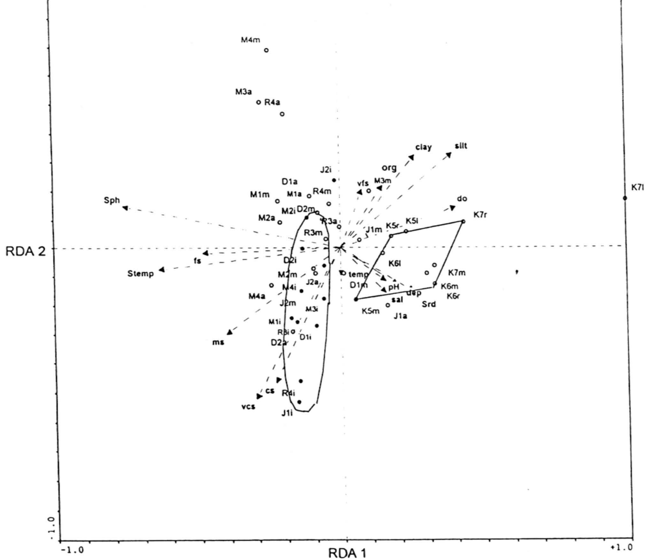


Fig.69: RDA Ordination Showing the Distribution of Site Samples in Relation to Abiotic Factors (Broken Arrows) [Ellipse Shows CLuster of Mainly Samples Inside Cage Area (SSB); Rhomboid Polygon Links all SSK Samples; see Tables 19 and 22 for Full Explanation of Siteand Abiotic Factors Abbreviation]

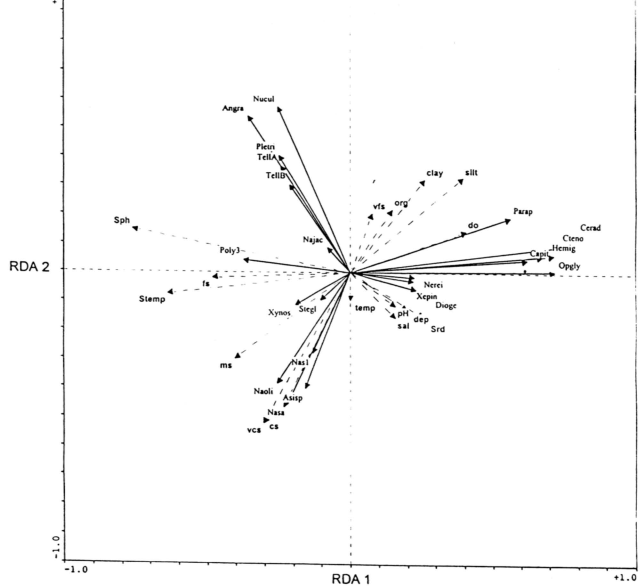


Fig.70: RDA Ordination Showing the Relationships BetweenAbiotic Variables (Broken Arrows) and Macrobenthos Species Species (Solid Arrows) (Refer to Table 22 and Table 19 for Environment and Species Abbreviations)

The bivalves (*Anadara granosa, Nuculana* sp., *Plecyora trigona, Tellina* sp. A and *Tellina* sp. B) and *Nassarius jacksonianus* were mainly found in lower salinity.

Distribution of Macrobenthos Species in Relation to Site

The polychaete, *Paraprionospio* sp occurred mainly in SSK stations (samples K5r, K5i, K7r). The abundance of *Nereis* sp., *Diogenes* sp. and *Xenophthalmus pinnotheroides* found mainly in SSK stations (K6i, K6m, K6r, K7m) were low. The abundance of nassarids (*Nassarius* sp. B, *Nassarius olivaceus, Nassarius* sp. A) and *Assiminea* sp. were high and found mostly in SSB in inside stations (samples M1i, M3i, R3i, D2a, D1i, R4i, and J4i) (Figure 71).

The abundance of *Xynostrobus* sp and *Stenothyra glabrata* were high in samples M2m, M4a, M4i, J2m and J2a. The bivalves (*Anadara granosa, Nuculana* sp., *Plecyora trigona, Tellina* sp. A and *Tellina* sp. B) and gastropod *Nassarius jacksonianus* were found in mostly middle and away stations in SSB (Figure 71).

The polychaetes (*Ctenodrilus* sp., *Capitella* sp. and *Ophioglycera* sp.), *Ceradocus* sp and *Hemigobius* sp. were mainly found in SSK stations. The present study showed that polychaete abundance was highest in SSK stations (Figure 71).

Cluster Analysis of Station Similarity Based on Species-Abundance

Cluster analysis based on similarity in macrobenthos species abundance showed three major clusters of the site samples (Figure 72). Two clusters which linked first were more similar to one another, where one comprised of mostly samples from middle (M)

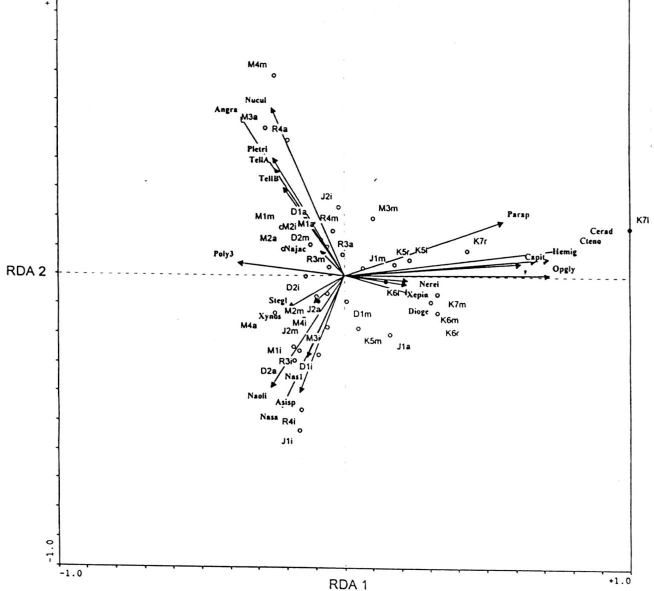


Fig.71: RDA Ordination Showing the Distribution of Site Samples Relation to Macrobenthos Species (Arrowed)

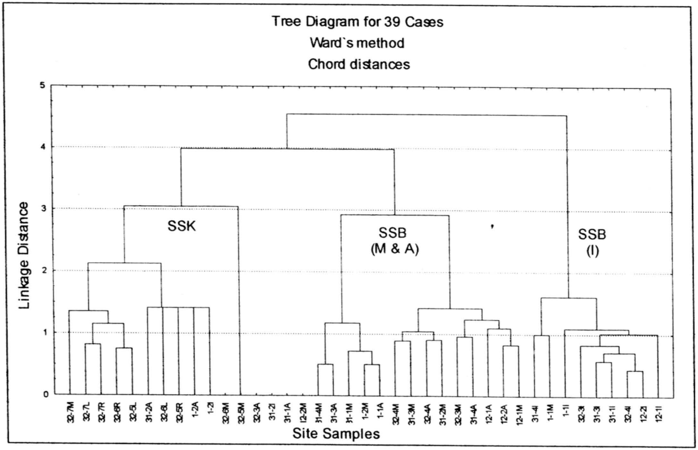


Figure 72: Cluster Analysis of Site Samples Grouped According to Similarity of Species Abundance for 4-Month Study

and away (A) stations, whereas the other one comprised of mostly samples from SSK stations. The third cluster which linked last with the 2 clusters, comprised of all samples from inside (I) stations except for one middle sample (sample 1-1M). The result obtained from cluster analysis essentially reflect those obtained from the RDA study.

3.4.2 12-Hour Study

3.4.2.1 Univariate Analysis

Macrobenthos Abundance in SSB and SSK in Relation to River, Station, Phase and Diel (April 2000) for Transects 1 and 6

A four-way ANOVA was applied to logarithmically-transformed abundance data with river (SSB*SSK), station (1 (IN/R)*3(AW/L)), tidal phase (1 (ebb)* 2(flood)) and diel (1(day)*2(night)) as influencing factors. Results from the ANOVA showed that the total abundance of macrobenthos was significantly influenced by (1) river ($P < 0.0001$), (2) interaction between station and tidal phase ($P=0.0015$), (3) interaction between station, tidal phase and diel ($P=0.0011$) and (4) interaction between river, station, tidal phase and diel ($P=0.0144$) (refer to Table 14).

For main 'river' effect, total abundance of macrobenthos was significantly higher in SSK compared to SSB ($p < 0.0001$) (Table 14; Figure 73).

Interaction effects between station and phase were significant ($p = 0.0015$). In IN/R station, total abundance of macrobenthos was higher but not significant ($p = 0.25$), during flood tide compared to ebb tide. In contrast, in AW/L station, macrobenthos abundance was significantly higher during ebb tide as compared to flood tide ($p = 0.0035$) (Figure 74; Appendix 17). The Newman-Keuls Test indicates that there were also significant differences between AW/L station with IN/R station, during ebb tide ($p=0.0037$) and during flood tide ($p=0.0421$).

Table 14. Analysis of Variance (ANOVA) of Macrobenthos Abundance in Relation to River, Station, Phase and Diel in SSB and SSK for April

STAT GENERAL MANOVA	Summary of all Effects; design: (sdrawste.sta) 1-RIVER, 2-STATION, 3-PHASE, 4-DIEL					
Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
1	1.0000	244.2452	34.0000	3.7013	65.9896	0.0000
2	1.0000	8.9875	34.0000	3.7013	2.4282	0.1284
3	1.0000	5.9899	34.0000	3.7013	1.6183	0.2120
4	1.0000	1.3978	34.0000	3.7013	0.3776	0.5430
12	1.0000	0.2626	34.0000	3.7013	0.0710	0.7916
13	1.0000	0.2948	34.0000	3.7013	0.0797	0.7795
23	1.0000	44.2006	34.0000	3.7013	11.9420	0.0015
14	1.0000	0.9253	34.0000	3.7013	0.2500	0.6203
24	1.0000	10.5977	34.0000	3.7013	2.8633	0.0998
34	1.0000	10.5847	34.0000	3.7013	2.8597	0.1000
123	1.0000	4.9314	34.0000	3.7013	1.3324	0.2564
124	1.0000	14.1616	34.0000	3.7013	3.8261	0.0587
134	1.0000	4.9535	34.0000	3.7013	1.3383	0.2554
234	1.0000	46.9498	34.0000	3.7013	12.6848	0.0011
1234	1.0000	24.6200	34.0000	3.7013	6.6518	0.0144

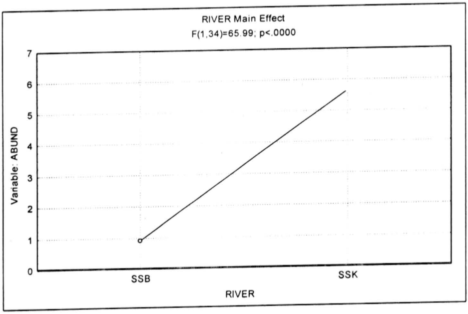


Figure 73. Mean Total Abundance of Macrobenthos between Rivers (SSB and SSK) for April

Interaction effects between station, phase and diel were also significant ($p = 0.001$) for macrobenthos abundance. During day time, macrobenthos abundance was higher in AW/L station than in IN/R station, but this difference was not significant ($p > 0.05$). Also during day time, total abundance of macrobenthos were slightly but not significantly higher ($p > 0.05$) at flood tide than ebb tide for both IN/R and AW/L stations. During night time, total abundance of macrobenthos in IN/R station were not significantly higher during flood tide than ebb tide ($p = 0.18$), but in AW/L station, abundance was significantly higher during ebb than during flood tide ($p = 0.0004$) (Figure 75; Appendix 18). Also, during night time, macrobenthos abundance at AW/L station was significantly higher ($p = 0.01$) than IN/R station during ebb tide, but vice versa during flood tide ($p = 0.012$). Essentially, these results reflect those obtained from the analysis of 'station x tidal phase' effect, but give the additional information that it is during the day that macrobenthos abundance was not significantly different between flood and ebb or between AW/L and IN/R stations ($p = 0.05$) (see Fig. 75, left diagram). The differences observed in the 2-way interaction are probably due to the 'night' effect.

Interaction effects between river, station, phase and diel were also significant ($p = 0.01$). During day, although macrobenthos abundance appeared higher in SSK than in SSB and in AW/L stations as compared to IN/R stations, these differences were not significant ($p < 0.05$), except during flood tide when abundance was higher in SSK than in SSB but only with respect to the left bank (i.e. AW or L) of the rivers ($p = 0.005$) (Fig. 76; Appendix 19). During night ebb tide, it is found that: (1) macrobenthos abundance was generally higher in SSK than in SSB, but the difference was only significant between the left banks ($p=0.009$), and (2) the macrobenthos abundance between IN and AW stations was not significantly different in SSB ($p > 0.05$), but was

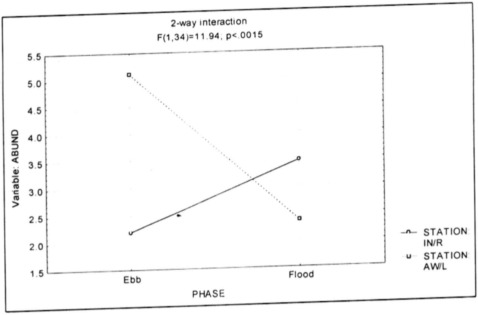


Figure 74. Mean Total Abundance of Macrobenthos in SSB and SSK in Relatio to Station and Tidal Phase for April 2000

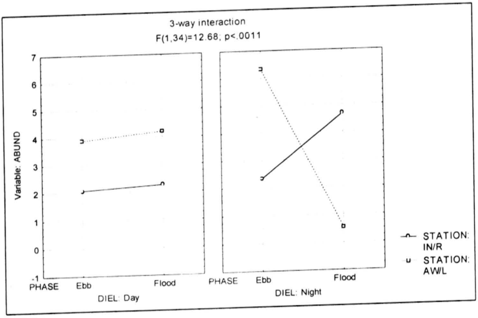


Figure 75. Mean Total Abundance of Macrobenthos in SSB and SSK in Relatio to Station, Tidal Phase and Diel for April 2000

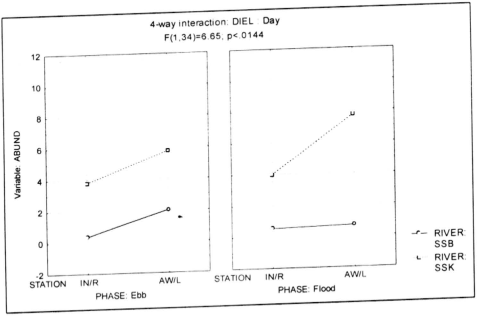


Figure 76. Mean Total Abundance of Macrobenthos in SSB and SSK in Relatio to River, Station, Phase and Diel (Day Time) for April

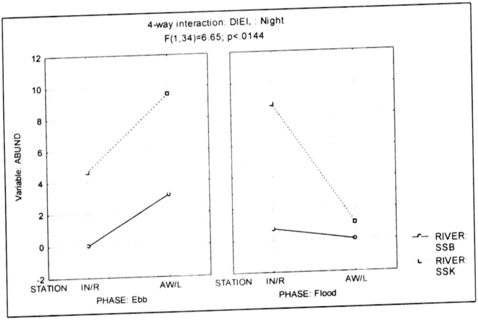


Figure 77. Mean Total Abundance of Macrobenthos in SSB and SSK in Relatio to River, Station, Phase and Diel (Night Time) for April

significantly different in SSK, being higher in the left bank ($p = 0.04$) (Figure 77). On the other hand, during night flood tide, it is observed that: (1) while macrobenthos abundance was generally also higher in SSK than in SSB, this was only significant between their right banks ($p = 0.001$), and (2) although IN or right bank stations had higher abundance than AW or left stations, it was only in SSK that this difference was significant ($p = 0.002$).