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THE HYDROBIOLOGICAL CONDITIONS OF KALLANG BASIN

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ABSTRACT

Kallang Basin was an extremely polluted body of water in the mid-1970s. In 1977, a ten-year urban clean-up and re-development project of Kallang Basin and its catchment area was started. In February 1987, near the completion of the project, a preliminary hydro-biological survey was conducted. This was followed by a second survey in February of 1988 which showed a marked increase in the number of families of marine organisms from 27 to 51. This re-emergence of life in the Basin could be attributed mainly to the efforts of the clean-up project.

INTRODUCTION

Located on the south-eastern sector of the Singapore mainland, the Kallang Basin catchment area, together with the Singapore River catchment area, make up about one sixth of the total land area of Singapore (Fig. 1). The Basin itself, is enclosed by the

Fig. 1 Map of Singapore showing Singapore River/Kallang Basin catchment area (shaded)

reclaimed land that is now Marina Center to the west, Kallang Park to the east, and what was once Kampong Bugis to the north. The catchment area however, ranges from Ang Mo Kio Industrial Park in the north to Tanjong Rhu in the south. Five main rivers are located within the catchment area, though only three rivers actually open into the Basin. This is because the Pelton and the Whampoa rivers open into the Kallang River, which then flows into the basin proper. The other two rivers are the Geylang and Bukit Timah/ Rochor Rivers (Fig. 2). The basin itself has a water surface area of approximately sixty hectares (Chiang, 1986).

The clean-up programme had to be implemented because in the preceeding years, pollutants of various forms from all over the catchment area had adversely affected the waters of the basin. From the outlying areas of the basin's catchment area, wastes from the thriving pig and duck farms emptied into the basin via the main rivers as the farms were set up mainly along the Whampoa and Kallang Rivers (Fig. 2). At its peak in 1977, there were 610 pig farms and 500 duck farms rearing a total of 75,600 pigs and 125,000 ducks (Chiang, 1986). From the central part of the catchment area, rampant and unchecked street hawking, backyard industries and wholesale markets emptied large amounts of filth and pollutants into the basin via the drains and canals. Sanitary facilities

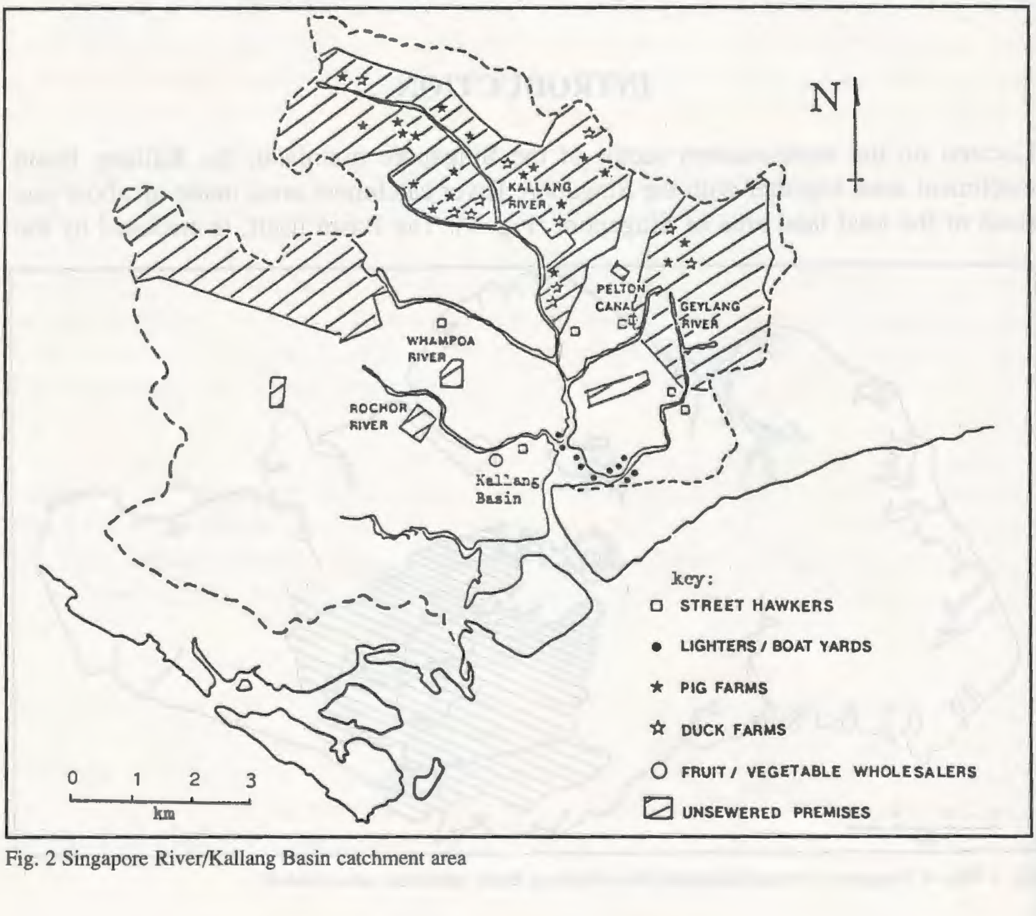

Fig. 2 Singapore River/Kallang Basin catchment area

were also of a poor standard and state, or even non-existent. Many of the residential areas within the catchment area were not properly sewered, and sanitation facilities were not only very primitive, but also in dilapidated conditions. Due to the large variety of activities in the area, many squatter colonies soon emerged and populated a large part of the catchment area. A significantly large portion of the activities was situated in areas near the main rivers that formed the catchment area, resulting in the direct emptying and dumping of rubbish, excreta and toxic substances into the basin (Chiang, 1986). The banks of the basin soon became heavily littered and congested with debris, flotsam, dead and decaying carcasses of animals. The waters of the basin darkened, and an oily layer could be clearly seen. A strong stench of hydrogen sulphide also became an ever present feature of the area. Marine life in the area declined, and the basin soon became a badly polluted body of water.

After careful consideration and planning, a ten-year clean-up and re-development programme of the basin and its catchment area commenced in 1977. This programme involved the removal of the root causes to the pollution by relocation of farms, hawkers, lighters and boatyards, resettlement of squatters and upgrading of sewerage and drainage systems, the actual cleaning up of the basin and its rivers, re-development of the cleaned up areas, and proper education and enforcement as to the laws regarding littering and pollution and to the use of catchment area.

The project was completed in mid-1987 (Ministry of Communication and Information, 1987). However prior to its final completion, a two-day hydrobiological survey was conducted of the basin, followed a year later by another similar survey. The surveys were conducted in February of 1987 and 1988.

MATERIALS AND METHODS

Two field surveys of the Basin were carried out, each survey being of two days duration. The first survey was carried out on 5 and 6 February 1987, and the second on 4 and 5 February 1988. Six sampling stations covering the whole Basin were selected (Fig. 3).

The following physico-chemical parameters were taken at the six sampling stations: salinity, conductivity, dissolved oxygen content, temperature, pH and light penetration. Light intensity readings were taken only during the second survey. All the parameters, with the exception of light penetration, were recorded at half-metre intervals along the water column. All physico-chemical parameters were recorded *in situ*.

Salinity and temperature were recorded using a portable YSI model 33 Salinity-Conductivity-Temperature meter. Dissolved Oxygen values were recorded using the portable YSI model 57 Oxygen meter. A portable pHOX 52E Conductivity meter was used to measure water conductivity. pH values at the various depths were measured using a hand-held electronic pH meter, with water samples from the various depths collected by a water sampler. Light penetration was measured with the use of a Secchi disc. A LI-COR underwater light sensor was used to measure the variation of light intensity with increasing depth.

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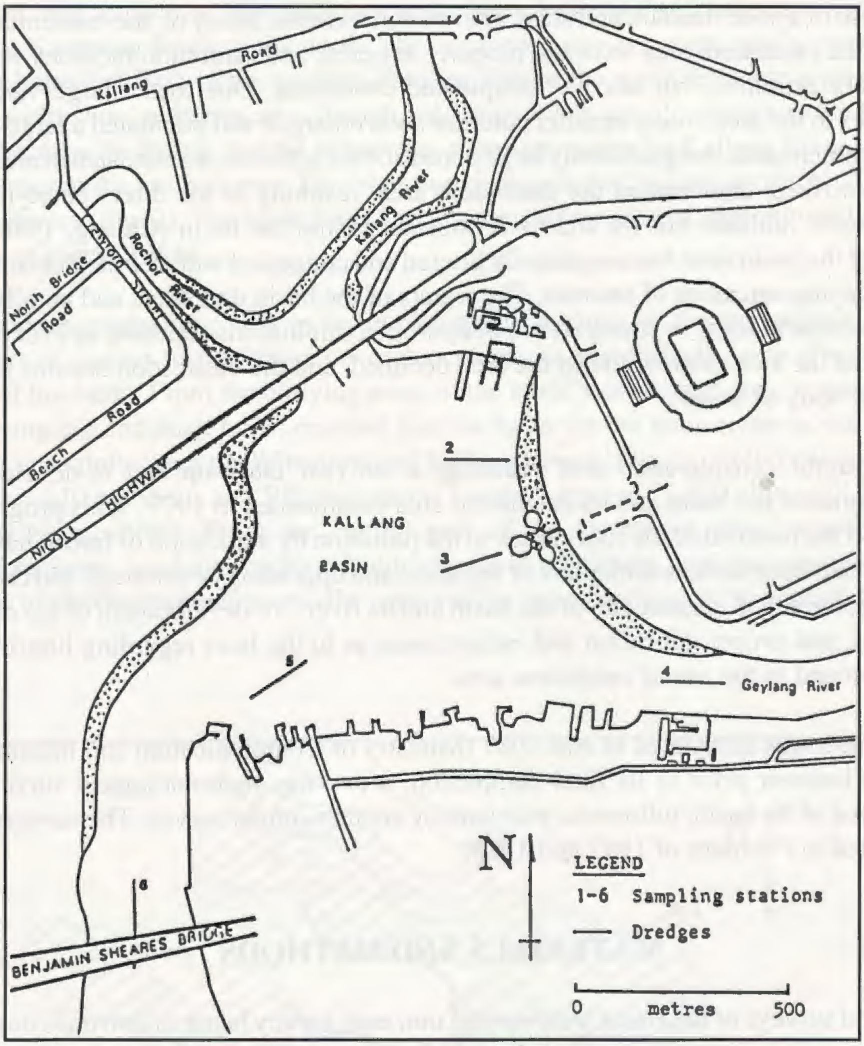

Fig. 3 Kallang Basin showing locations of sampling stations 1 to 6 (map adapted from Loo *et al.*, 1987)

Lifeform sampling was carried out with a ten-minute dredge at each station (Fig. 3) using a naturalist's rectangular dredge (with 75cm x 20cm opening and an attached 50cm long polypropylene net-bag, with stretched mesh-size of 2.5cm), and three grab samples using an Ekman grab (with gap size 15cm x 15cm) from each sampling station. Two trammel nets (30m x 1.5m with stretched mesh size of 4cm), were set one each at sampling stations 1 and 3 for a period of 24 hours. Dredge specimens were sorted at the stations while grab samples were preserved in 10% buffered formalin mixed with Bengal red dye, and brought back to the laboratory for sorting. Net specimens were kept in sea water, and brought back to the laboratory for identification and size measurement. All the specimens collected were first preserved in 10% buffered formalin and then transferred to 70% alcohol on the following day and subsequently identified and labelled.

RESULTS

Results obtained from the two surveys are presented in Tables 1, 2 and 3. From initial visual observations made during both surveys, a marked decrease in the stench coming from the Basin was noted. The waters also appeared cleaner and clearer. Water colour was greenish as compared to the previous year's brownish colour. There was also a marked absence of floating debris and patches of water covered with oil layers. Sand banks also replaced a number of concrete banks along the Basin and also along the Rochor and Kallang Rivers. These sand banks were constructed by the Public Works Department as part of the clean-up programme (Yap, 1986).

A comparison of the physico-chemical parameters recorded over the two surveys showed a general decrease in mean values from the first survey to the second survey, with salinity showing the greatest difference (Table 1). The mean conductivity levels between the two surveys showed a decrease of about 0.14 x 10^4 μS (Table 1). At station 4, the mean conductivity value increased by 0.17 x 10^4 μS. Mean salinity values revealed a general decrease at all the stations over the 1-year period. Station 4 showed the least decrease (0.83 ^{o}/oo) and station 3 the greatest difference (4.11^{o}/oo). The difference between the mean values was 2.67 ^{o}/oo. A comparison of the actual values showed a difference in the surface and sub-surface values between the surveys.

Likewise, values at the basin floor decreased over time at all stations (Table 1). A drop of 1.1 ppm in the mean dissolved oxygen level occurred. The greatest difference of the mean values between the two surveys was 1.43 ppm recorded at station 3. Dissolved oxygen values recorded at the bottom of the stations revealed low values in the second survey, compared to the first (Table 2). Mean pH values recorded in the first survey were constant with minor fluctuations, with the exception at station 6. During the second survey, however, not only were the mean pH values lower, but also the fluctuations across the stations were more pronounced. However, it should be noted that station 6 appeared to favour a region of higher pH values than the other stations. Mean temperature values were the only values that were consistently higher in the second survey than in the first survey. However this was due to weather conditions, as it was cloudy during the first survey and sunny during the second survey. Water visibility readings obtained with a Secchi disc ranged between 0.6m and 1.25m in the first survey and between 0.5m and 2.5m in the second survey.

The lifeform sampling methods used in both surveys resulted in the combined collection of eight groups of animals (Bivalvia, Cnidaria, Crustacea, Gastropoda, Isopoda, Osteichthyes, Polychaeta and Scaphopoda). The first survey recorded 27 families of organisms from the above eight classes, while the second survey recorded 54 families from the eight classes, thus indicating that there is an increase in marine life diversity of the area. Only the class Bivalvia showed a decrease in the number of families present between the first and second surveys. In the first survey, five families from the class Bivalvia were sampled, while in the second survey, only three of the five families were re-sampled, and no other new families were found. The three common bivalve families sampled were Tellinidae, Veneridae and Solenidae. In both surveys, the most abundant bivalve family was Solenidae (Table 3).

Table 1. Mean values of physico-chemical parameters recorded at Kallang Basin (Standard deviation values in parenthesis)

	SURVEY I - FEB 1987						SURVEY II - FEB 1988					
PARAMETERS/STATION	1	2	3	4	5	6	1	2	3	4	5	6
Max Depth* (m)	3.50	4.00	5.50	4.00	4.00	5.00	6.00	4.50	6.50	5.50	6.50	7.50
Conductivity (x 10^4 µS)	3.55 (0.38)	3.86 (0.14)	4.00 (0.09)	3.97 (0.22)	4.16 (0.17)	4.37 (0.06)	3.34 (1.04)	3.61 (0.71)	3.83 (0.72)	4.14 (0.73)	3.95 (0.88)	4.20 (0.51)
Salinity (‰)	19.40 (2.43)	20.50 (0.75)	21.30 (0.62)	19.30 (1.22)	19.90 (0.74)	21.00 (0.28)	16.40 (5.30)	17.90 (4.51)	17.20 (4.01)	18.50 (4.05)	16.90 (4.62)	18.50 (2.49)
Dissolved Oxygen (ppm)	4.08 (0.88)	5.01 (0.73)	5.59 (0.21)	4.70 (0.40)	5.04 (0.13)	5.60 (0.14)	3.41 (1.59)	4.59 (1.37)	4.16 (0.88)	3.89 (1.21)	3.91 (1.45)	4.45 (0.83)
Temperature (°C)	26.90 (0.35)	27.00 (0.00)	27.00 (0.00)	27.00 (0.00)	27.00 (0.00)	26.90 (0.20)	27.60 (0.35)	27.40 (0.44)	27.40 (0.18)	27.70 (0.33)	27.80 (0.31)	27.60 (0.37)
pH	8.18 (0.05)	8.20 (0.00)	8.20 (0.00)	8.11 (0.03)	8.11 (0.08)	8.21 (0.03)	7.85 (0.11)	7.86 (0.05)	7.92 (0.08)	7.83 (0.09)	7.86 (0.11)	7.94 (0.07)

Table 2. Minimum and maximum values of physico-chemical parameters recorded at Kallang Basin
(Survey I - Feb 1987; Survey II - Feb 1988)
(Survey II results in parenthesis)

	MINIMUM - MAXIMUM VALUES					
PARAMETERS/STATION	1	2	3	4	5	6
Conductivity (x 10^4 µS)	2.85 - 3.85 (1.40 - 4.20)	3.55 - 4.00 (1.60 - 4.15)	3.85 - 4.15 (1.50 - 4.20)	3.60 - 4.20 (1.80 - 4.30)	3.95 - 4.35 (1.40 - 4.50)	4.30 - 4.45 (2.30 - 4.45)
Salinity (‰)	15.00 - 21.50 (3.00 - 21.00)	19.00 - 21.50 (7.00 - 20.50)	20.50 - 22.00 (6.00 - 21.00)	17.50 - 21.00 (8.00 - 21.00)	19.00 - 21.00 (6.00)- 21.00)	20.50 (10.00 - 20.50)
Dissolved Oxygen (ppm)	3.00 - 5.20 (0.15 - 6.00)	3.10 - 5.40 (3.00 - 7.30)	5.10 - 5.80 (2.00 - 5.00)	4.25 - 5.50 (0.25 - 4.70)	4.80 - 5.20 (0.25 - 4.80)	5.40 - 5.90 (2.70 - 5.40)
Temperature (°C)	26.00 - 27.00 (27.00 - 28.00)	27.00 (26.50 - 28.00)	27.00 - 27.00 (27.00 - 27.50)	27.00 (27.00 - 28.00)	27.00 (27.00 - 28.00)	26.50 - 27.00 (27.00 - 28.50)
pH	8.10 - 8.20 (7.60 - 8.00)	8.20 - 8.20 (7.80 - 7.90)	8.20 - 8.20 (7.80 - 8.00)	8.10 - 8.20 (7.70 - 7.90)	8.00 - 8.20 (7.70 - 8.00)	8.20 - 8.30 (7.80 - 8.00)

Table 3. Lifeform distributions recorded from Kallang Basin (Survey I - Feb 1987; Survey II - Feb 1988)

Class	Family	Survey	Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Total
Cnidaria	Cnidaria fam #1	I						4	4
	Catostylidae	II				1			1
Polychaeta	Ophelidae	I				1			1
	Glyceridae	I		1	2		2		5
	Paraonidae	I		5					5
	Pisionidae	I		1					1
	Spionidae	I		1	3		7		11
	Amphinomidae	II			2				2
	Cirratulidae	II					3		3
	Eunicidae	II	1					1	2
	Glyceridae	II		1	1	1			3
	Lacydonidae	II		1					1
	Nephtyidae	II					1	3	4
	Spionidae	II		5	11		4	2	22
	Syllidae	II						1	1
	Terebellidae	II	1	1					2
	Ampharetidae	II		4					4
	Aphroditidae	II						1	1
	Capitellidae	II			1				1
	Cossuridae	II		1				1	2
	Paraonidae	II					1		1
	Pisionidae	II					1		1
	Sternapsidae	II					1		1
Crustacea	Dorippidae	I					2		2
	Grapsidae	I					1		1
	Porcellanidae	I					3	6	9
	Portunidae	I	3		5		2		10
	Penaeidae	I	2	3	1		3	1	10
	Cymathoidae	I	1						1
	Isopoda fam #1	I		1					1
	Cirolanidae	II			1				1
	Dorippidae	II		2		2			4
	Goneplacinae	II		0		4			4
	Grapsidae	II		1					1
	Leucosiidae	II	1	0			1		2
	Majidae	II	0	0				1	1
	Penaeidae	II	1	0		2		2	5
	Pinnotheridae	II	1	0		0			1
	Portunidae	II	17	0	22	1	1		41
	Squillidae	II		1		2			3
	Harpiosquillidae	II	1		1				2
Scaphopoda	Dentallidae	II		1		3			4

(cont.)

Table 3. (cont.)

Class	Family	Survey	Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Total
Gastropoda	Nassariidae	I					2	2	4
	Cerithiidae	II				5			5
	Crepidulidae	II						1	1
	Nassariidae	II		2	1	3	1	1	8
	Atlantacea	II		1					1
	Buccinidae	II		1					1
	Fasciolariidae	II		1					1
	Olividae	II		1		1			2
	Pyramidellidae	II		1					1
	Terebridae	II		1					1
Bivalvia	Arcidae	I	1	1					2
	Tellinidae	I			2		1		3
	Veneridae	I	1					1	2
	Crassatellidae	I			1				1
	Solenidae	I			1		7		8
	Solenidae	II	5	1		11	1	1	19
	Tellinidae	II		1				1	2
	Veneridae	II					1	1	2
Oesteicthtyes	Gobidae	I			1				1
	Platycephalidae	I						1	1
	Synanceiidae	I						1	1
	Carangidae	I			2				2
	Clupeidae	I	5		6				11
	Leiognathidae	I			1				1
	Plotosidae	I			1				1
	Serranidae	I			1				1
	Carangidae	II	4						4
	Clupeidae	II	1		10				11
	Leiognathidae	II	8		10				18
	Lutjanidae	II	1						1
	Plotosidae	II	1						1
	Serranidae	II	1						1
	Sphyraenidae	II	1		2				3
	Triacanthidae	II	1						1
	Trichiuridae	II			2				2
	Tetraodontidae	II	1						1

There was a two-fold increase in the number of families of crustacea found in the second survey as compared to the first (five families in the first survey, and 11 in the second survey). The dominant families in both surveys were Penaeidae and Portunidae (Table 3). The catches from the trammel nets in the second survey were varied, with the dominant species being the edible flower crab, *Portunus pelagicus*, individuals of which were of marketable size, with carapace length ranging from 10.0 to 14.0cm, and weight between 40.0 to 209.0g. A mantis shrimp, *Harpiosquilla*, (family Harpiosquillidae) weighing 79.20g, and of length 20.8cm was also from the second survey. In the first survey, only one family from the class Gastropoda (Nassariidae) was present. However in the second survey, eight other families besides the Nassariidae were obtained, with the most abundant being from the family Cerithiidae (Table 3).

Ten families of Osteichthyes (fish) were captured in the second survey compared to eight in the first survey. The total fish abundance doubled in the second survey, increasing from 19 to 43, with the Clupeidae and Leiognathidae being the dominant families. (Table 3). The predatory fish, *Sphyraena jello* (family Sphyraenidae), commonly known as the pike, was also captured in the trammel nets set during the second survey. The number of families of polychaete worms also showed a four-fold increase between the two surveys, from 5 in the first to 19 in the second. Abundance has also increased from 23 to 49. In both surveys, however, the most abundant family was still that of Spionidae (Table 3). Two different members of the family Cnidaria were collected in the two surveys, one in each survey. Two families of the class Isopoda recorded in the first survey were absent from the second survey.

DISCUSSION

The reduction in smell, and the greener colour of the water gave an indication of the positive effects of the clean-up programme. The increase in light penetration also indicated the reduction in sediment and other microscopic debris.

It should be noted that the decreased values observed in the physico-parameters recorded over the two surveys are actually the mean and not exact values. Table 1 shows that the lowered mean values of the second survey were due to a wider range of values and not a direct decrease of the values. For conductivity, the range of values obtained in the second survey was from a low of $1.40 \times 10^4 \mu S$ to a high of $4.50 \times 10^4 \mu S$, as compared to $2.85 \times 10^4 \mu S$ to $4.45 \times 10^4 \mu S$ in survey 1. Likewise for salinity levels, the range of values in the second survey was from 3.0 ^{o}/oo to 21.0 ^{o}/oo as compared with 15.0 ^{o}/oo to 21.5 ^{o}/oo in the first survey. This trend was also noted for the dissolved oxygen content of the 2 surveys. Specifically, dissolved oxygen values showed an extreme low of 0.15 ppm at the bottom of station 1, and an extreme high of 7.30ppm at the 1-metre level at station 2. It should be noted then that for conductivity, salinity and dissolved oxygen values, there is an improvement in some locations of the basin. However, the second survey also showed locations with low values, which could be attributed to poor water circulation. This could have been compounded by the renovation works done to the basin and its surrounding areas resulting in the basin being more enclosed from the open sea.

Day *et al.* (1989) noted that the response of individual species to varying factors that they may be exposed to, such as sediment characteristics, salinity, oxygen levels and their position in the intertidal zone, affects the composition and distribution of the macroinfaunal community of an area. As such, the marked increase in the return of marine life as seen from the data collected for the 2 surveys may be attributed to improved conditions as a result of the clean-up programme. Predators generally are present when food sources are available, and conditions favourable, and the presence of the small group of pikes *(Sphyraena jello)* could indicate that the Basin may be such a place. The large size of the crabs and the mantis shrimp *(Harpiosequilla)* captured in the second survey may be due to improved conditions. This also indicated by the large increase in the number of gastropod families, as well as the increased density of polychaete worms, both of which are detritus feeders. The layer of silt at the bottom of the basin traps nutrients, especially from the decomposition and breakdown of organic matter, thereby providing some hardier bivalves, gastropods and polychaete worms with a rich source of food. However, the present data cannot determine whether the worms are indicative of polluted conditions or not.

Although only two surveys have been carried out over a one-year span, the data is indicative of marine life returning with the improved conditions of the basin. The physico-chemical results also seem to indicate the same. In particular it should be noted that the previously high pH levels caused by industrial pollutants is on a decline. Increasing conductivity values could also mean that the Basin's waters are getting richer in minerals and ions.

It should be remembered however, that due to various factors, such as the inability to carry out the surveys at exactly the same place at each station, different weather and tidal conditions at the time of the surveys, together with the limitations of the equipment and techniques used, the results can only portray, at best, a qualitative and a semi-quantitative measure of the effects of urban clean-up of pollution on marine life in Kallang Basin. However, the results show that the waters of the basin are improving, and major marine groups are returning to inhabit the basin. Hence, it can be seen that with future monitoring, coupled with active education and enforcement, not only can the existing conditions be maintained, but also further improved. Kallang Basin has shown that through properly planned and executed urban clean-up programmes, marine life can be encouraged to rehabilitate once polluted bodies of water.

REFERENCES

Chiang, K. M., 1986. The cleaning up of Singapore River and Kallang Basin catchments. Paper presented at the Co-ordinating Body for the Seas of East Asia (COBSEA) Workshop on Cleaning Up of Urban Rivers held in Singapore. 14-16 January 1986. 10pp.

Day, J. W. Jr., C. A. S. Hall, W. M. Kemp and A. Yanez-Arancibia, 1989. Estuarine Ecology. John Wiley & Sons. 542pp.

Ministry of Communication and Information (Information Division), Ministry of the Environment, 1987. Clean Rivers : The Cleaning Up of Singapore River and Kallang Basin. A Commemorative Publication Booklet to Commemorate the Completion of the Singapore River and Kallang Basin Clean-Up Programme. 40pp.

Yap K.G., 1986. Physical improvement works to the Singapore River and Kallang Basin. Paper presented at the Co-ordinating Body for the Seas of East Asia (COBSEA) Workshop on Cleaning Up of Urban Rivers held in Singapore. 14-16 January 1986. 10pp.