A Preliminary Assessment of Water Quality in Fish Cages on Lake Kariba, Zimbabwe

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Abstract

The water quality in fish cages on Lake Kariba was studied. The Kruskal-Wallis test was used to determine whether the water quality parameters differed significantly among the cage-types (cage-type effect). Secchi disc readings ranged from 2 to 4 metres, while temperature ranged from 23°C to 29.5°C. The observed conductivity was between 98.7μS cm^{-1} and 102.3μS cm^{-1}. The pH was between 6.31 and 7.82. Concentrations of dissolved oxygen (DO) varied from 1.55 to 6.47mg l^{-1}, while dissolved oxygen saturation ranged from 22.3% to 83.1%.

Within the same month, temperature did not differ significantly among cages ($p<0.05$). Conductivity, pH, dissolved oxygen concentration and dissolved oxygen saturation differed significantly among the 3 cage-types.

Temperature and pH levels in the cages were close to the optimum levels for the culture of cichlids. Sub-optimal levels of dissolved oxygen occurred occasionally in the octagonal cages.

Introduction

Culture of fish in cages has increased rapidly in the last two decades. Several studies have shown that the culture of fish in cages results in increased levels of nutrients and suspended solids, while the dissolved oxygen levels decrease (Ackefors and Enell, 1990).

The economic viability of a cage culture enterprise is heavily dependent on choosing an optimum site. Several criteria are used in the selection of suitable cage culture sites. Environmental factors that affect the growth and production of the fish are an important component of the site selection criteria.

When selecting a site for cage culture, the ambient pH, temperature, dissolved oxygen and salinity must be as close as possible to the optimum requirements of the fish species to be cultured.

The objectives of this study were; i) to determine the water quality in the fish cages to provide preliminary baseline data. This baseline data can then be used in formulating more comprehensive monitoring programs, ii) to determine whether the water quality in the cages was optimal for fish growth.

Study Area

Lake Kariba is a manmade reservoir created in 1958 by the damming of the Zambezi River at the Kariba Gorge. The lake is situated on the border between Zambia and Zimbabwe. There are five distinct basins (Figure 1). The lake is 280 kilometres long, with a maximum width of 40 kilometres, and a surface area of 5 250 km^2 at full supply level. Although the maximum depth is 120 metres, 30% of the lake surface area is shallower than 17 metres (Begg, 1970). The lake is oligotrophic and monomictic. Mtada (1987) observed that thermal stratification occurred from December to May, while complete mixing occurred in June and July.

The study was carried out at a commercial cage farm established as a pilot project. The cage farm is located in an area near Antelope Island, which is in Basin 5 (Figure 1). The farm consists of ten 36 m^3 square cages and two 8 m^3 octagonal cages. The production system involves the use of mixed species of Tilapia (Family: Cichlidae) of mixed sex. There are three species used; the Red-breasted bream (*Tilapia rendalli*, Boulenger), Kariba Bream (*Oreochromis mortimeri*, Trewavas) and Nile Tilapia (*Oreochromis niloticus*, Linnaeus).

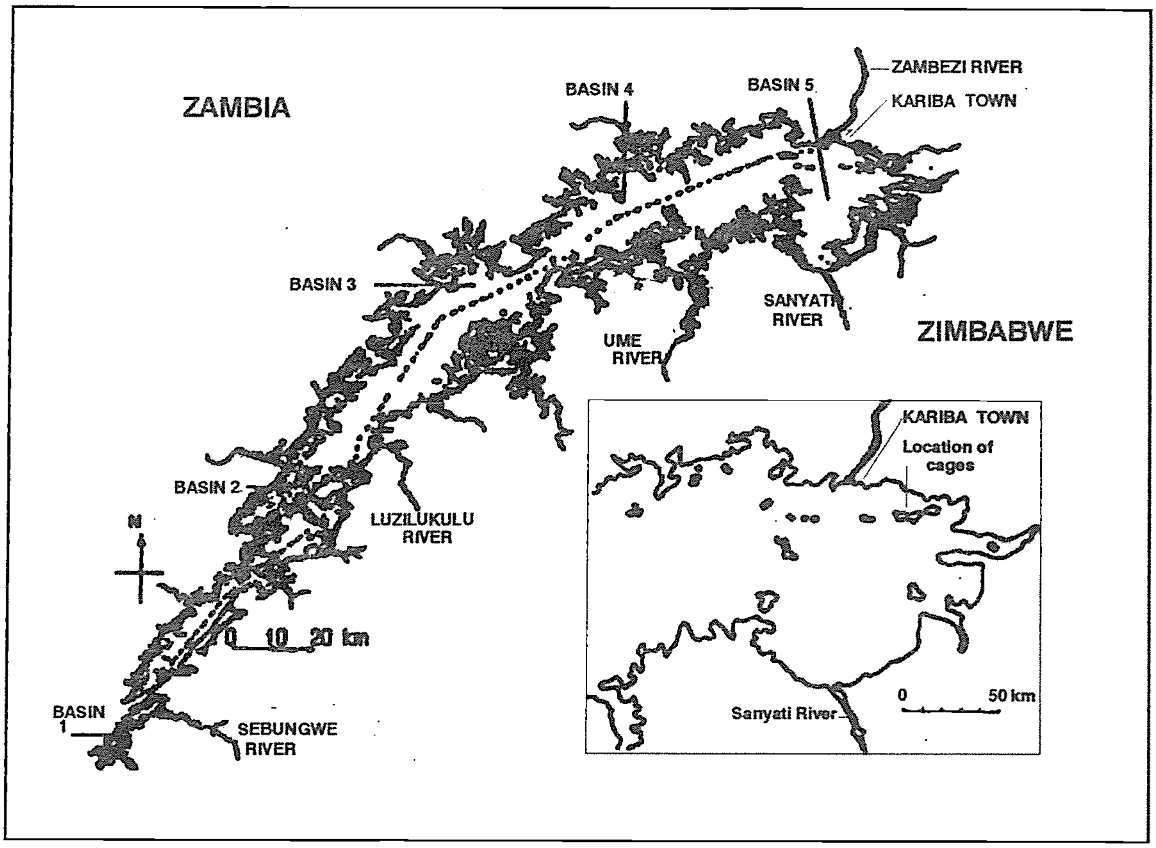

Figure 1: Map of Lake Kariba. Inset: Location of Study Area.

Materials and Methods

Field Sampling

Sampling was carried out monthly from August to December 1993. The following parameters were recorded for each cage; pH (WTW pH 96™), Conductivity (WTW LF 91™), Dissolved Oxygen and Temperature (WTW Oxi 96™). Water Transparency was recorded 1 metre from the cages. Water transparency was determined by means of a Secchi Disc (Wildco™ Instruments). Sampling was carried out between 1000 hours and 1200 hours. Apart from water transparency, all other parameters were determined in the surface layer (less than 40 centimetres deep).

Statistical Analyses

Nonparametric statistical methods were used as the data did not fulfil the assumptions of the Analysis of Variance. The Kruskal-Wallis test was used to determine whether, the parameters under investigation, were significantly different between the different cage types (cage-type effect).

The cages were grouped into three categories, based on their size. Cage Type 1 represented all the square cages that had a volume of 36 m^3; Cage Type 2 comprising all cages similar to Cage Type 2, which had been partitioned into two sections of equal size, and they had a volume of approximately 16 m^3. Cage Type 3 consisted of octagonal cages with a volume of 8 m^3.

Results

The observed values of water transparency in the area adjacent to the cages are shown in Figure 2. Transparency increased from August to September, and then decreased in October and November. There was no difference in transparency between November and December.

Figure 3 shows the mean temperatures with the standard deviations. The lowest mean temperature during the study was recorded in August (23°C) while the highest temperature was recorded in December (29.5°C). The Kruskal-Wallis test showed that temperature did not differ significantly between the cage types ($p<0.05$).

Conductivity results are shown graphically in Figure 4. The mean conductivity values ranged from 98.7 to 102.3μS cm^{-1}. There were significant differences in conductivity between the cage-types ($p<0.05$).

Figure 5 shows the pH levels in each cage-type. The pH values ranged from 6.31 to 7.82. Significant differences were observed in the pH levels of the 3 cage-types ($p<0.05$).

Dissolved Oxygen (DO) concentrations are shown in Figure 6. The mean DO concentrations for all the cages combined, ranged from 1.55 to 6.4 mg l^{-1}. The lowest value occurred in the smallest cages, (i.e. Cage Type 3). Dissolved Oxygen (DO) concentrations were significantly different among the 3 cage-types ($p<0.05$).

Figure 7 shows the percentage Saturation of Dissolved Oxygen in the different cages. The mean Dissolved Oxygen Saturation for all the cages combined varied from 22.3% to 83.1%. Percentage Saturation levels were significantly different among the 3 cage-types ($p<0.05$).

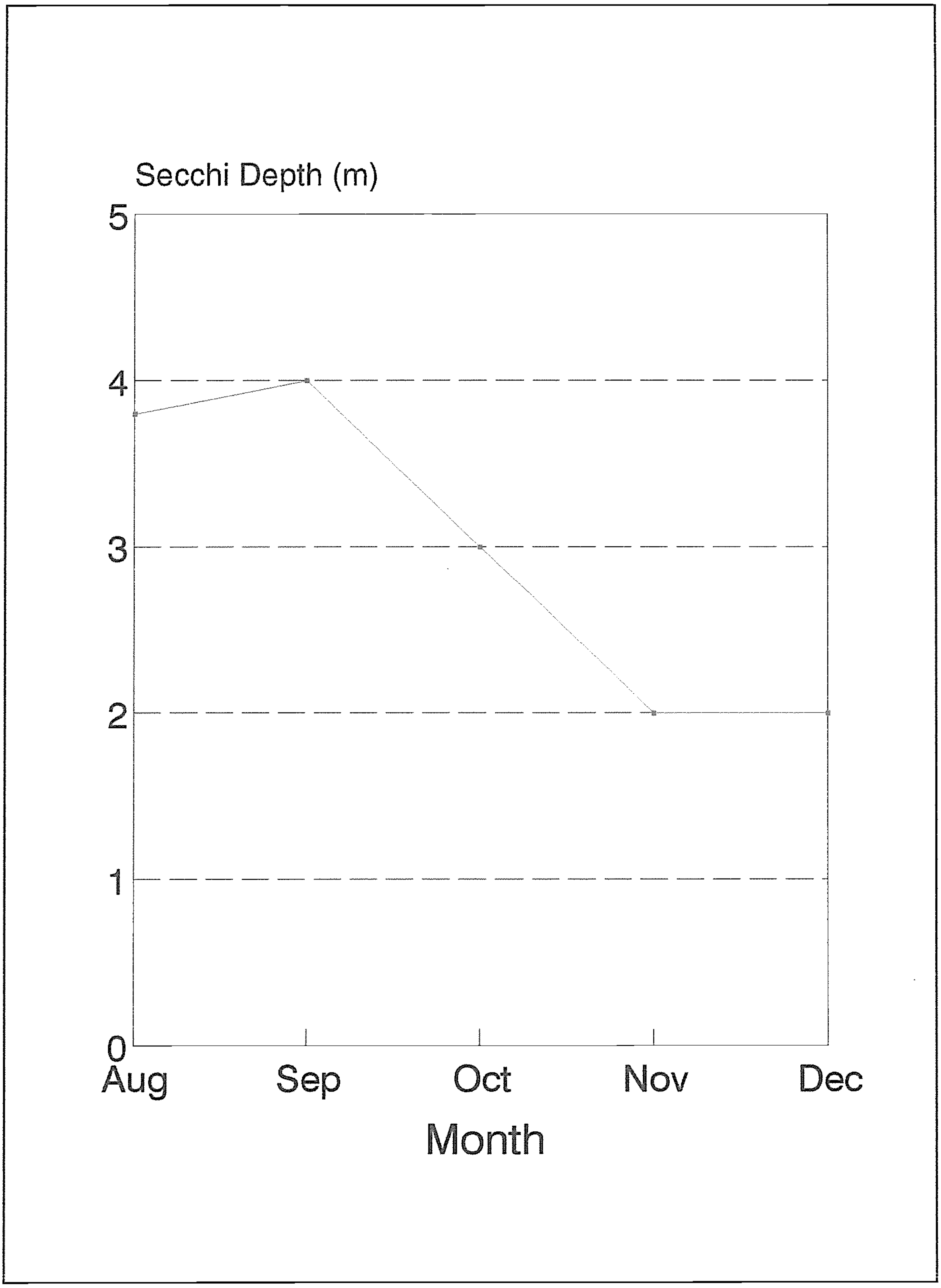

Figure 2: Water transparency in the area adjacent to the cages

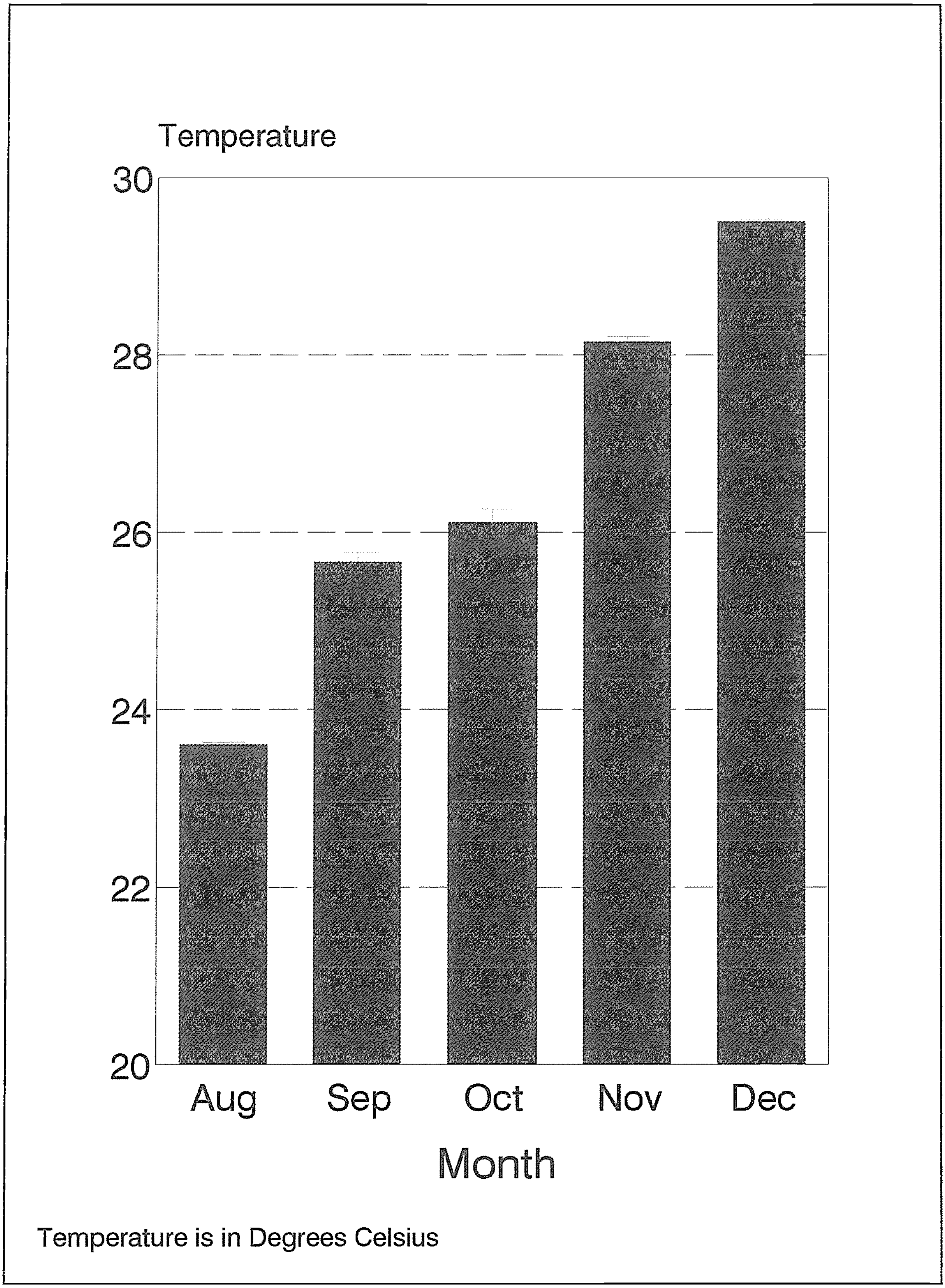

Figure 3: Mean temperatures recorded in the cages

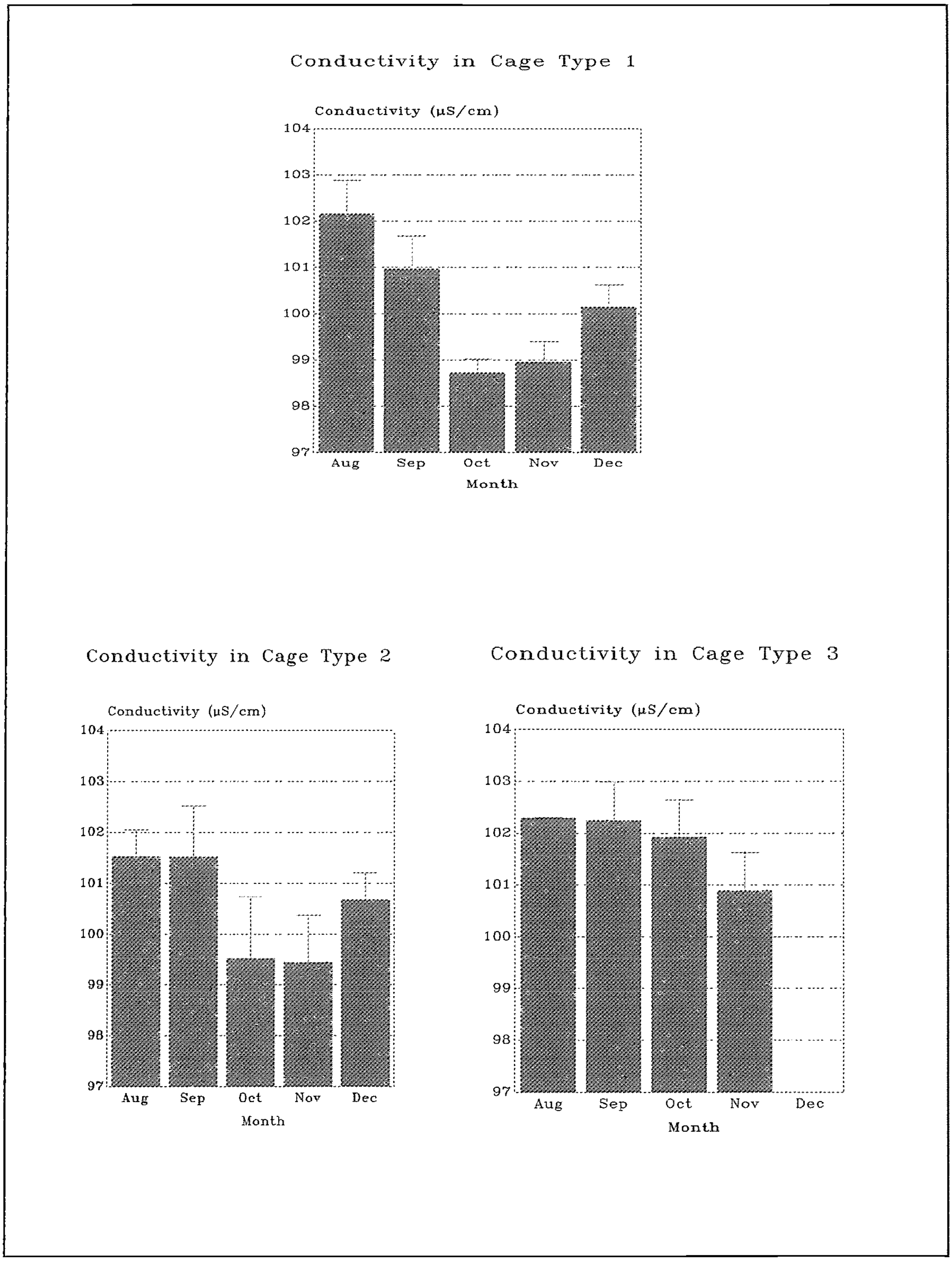

Figure 4: Mean conductivity values in each cage-type

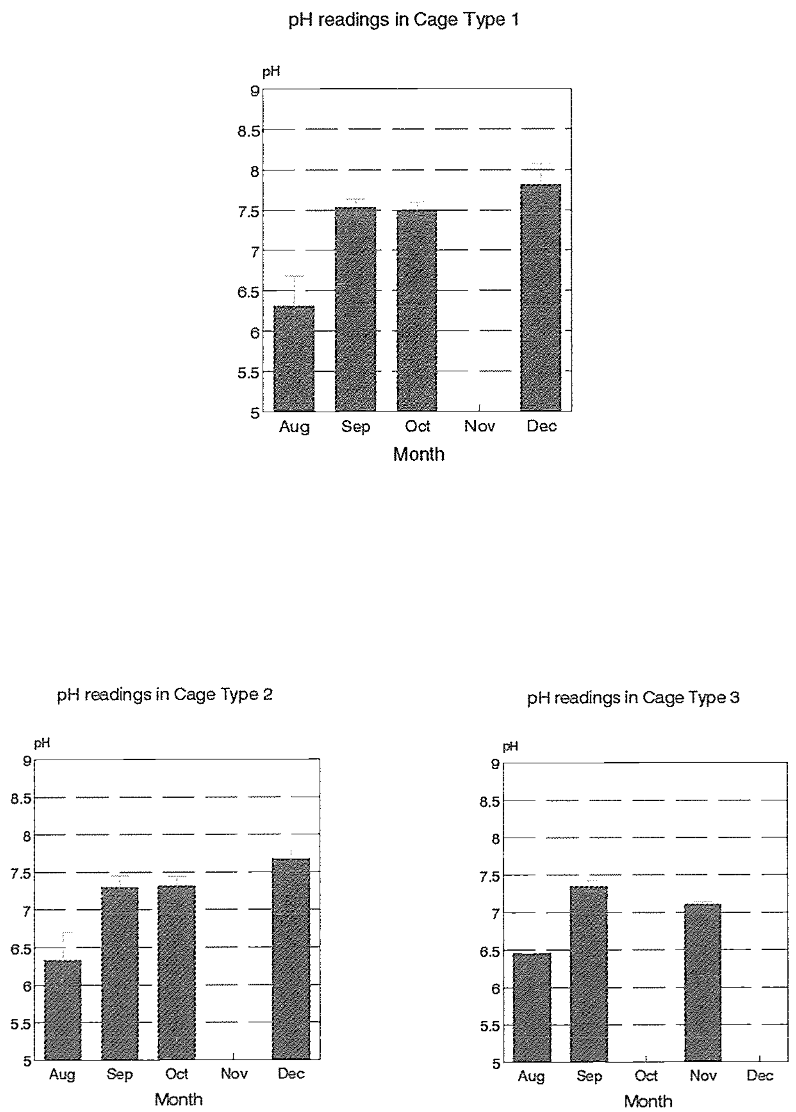

Figure 5: Mean pH levels in the 3 cage-types

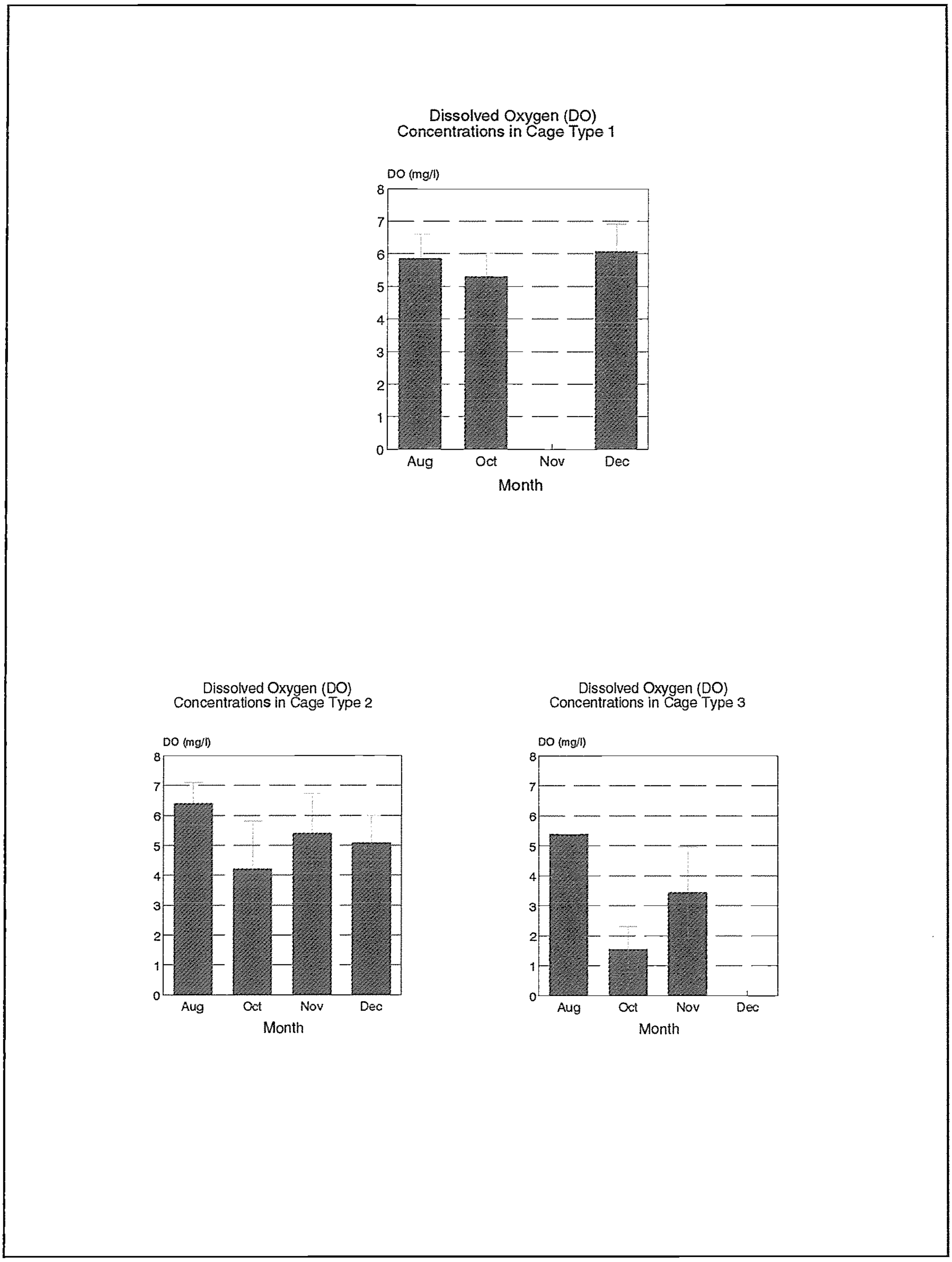

Figure 6: Mean dissolved oxygen (DO) concentrations in the 3 cage-types

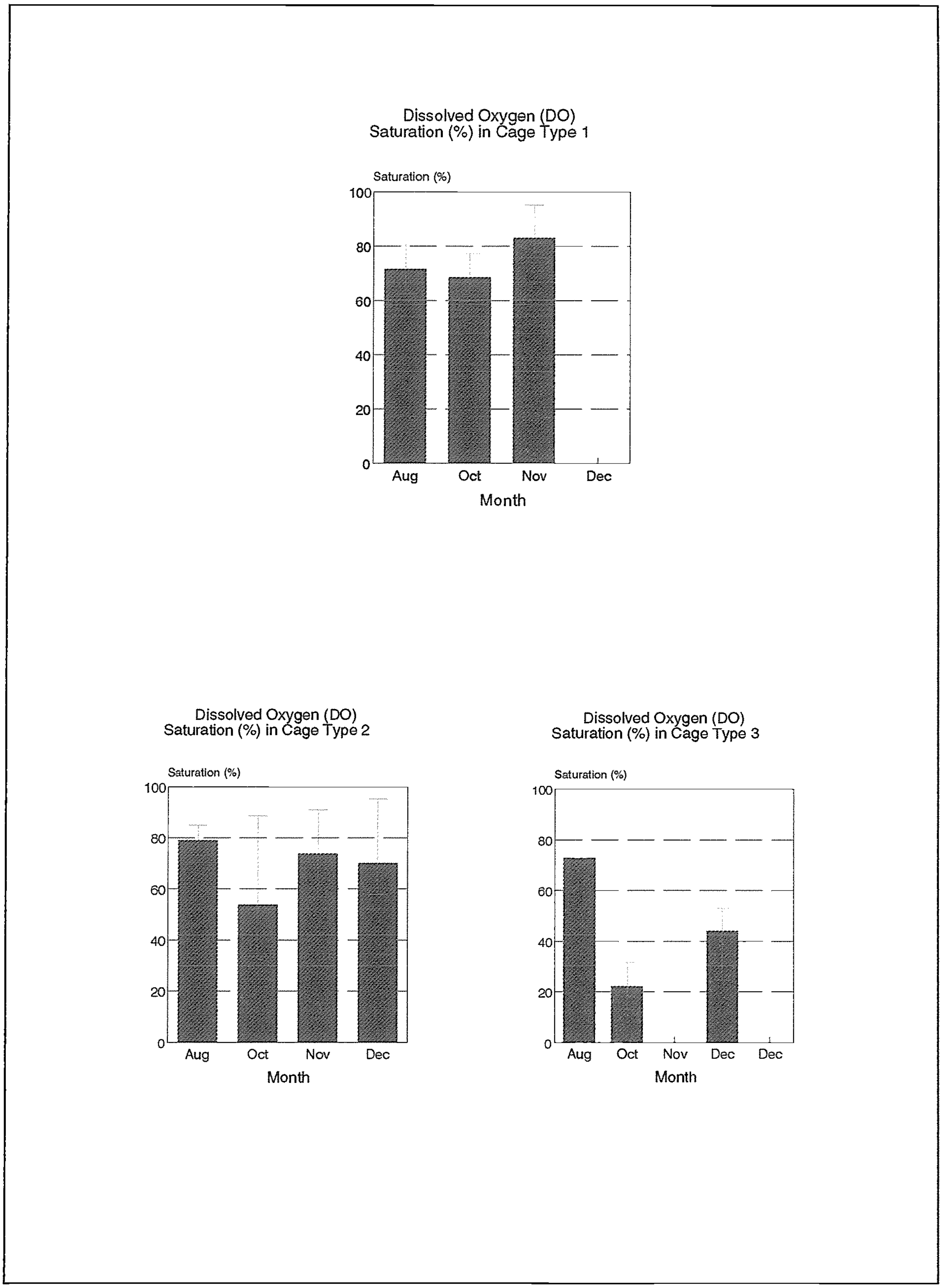

Figure 7: Mean dissolved oxygen saturation (%) in the 3 cage-types

Discussion

The major objective of this study was to make an inter-cage comparison of water quality parameters. As there was no reference site in the study, no direct comparison could be made between an area with cages and that without. However, a general comparison was made using literature data. The aim of this latter comparison, was to highlight the parameters that should receive priority attention in future detailed studies.

Water transparency in the area outside the cages (Figure 2) was lower than that observed by other workers. Begg (1970) reported that transparency in the Sanyati Basin ranged from 3.25 in March to 4.55 metres in November, while Ramberg (1987) reported a range of 3.0 to 6.5 metres.

The temperature values observed in this study are similar to those reported by Ramberg (1987); who noted that surface temperatures in the Sanyati Basin were 23°C and 29°C in August and December, respectively.

The temperatures observed in this study are within the range preferred by cichlids. Beamish (1970), noted that *O. niloticus* that had acclimated to temperatures between 15 and 30°C, showed preference for temperatures of 30°C. Those acclimated to 35°C preferred temperatures of 28°C. Denzer, 1968 (cited in Chervinski, 1982) reported that the upper lethal limit for *O. niloticus* was 42°C.

Conductivity values (Figure 4) were within the range of 87.7 $\mu S\ cm^{-1}$ to 103.6 $\mu S\ cm^{-1}$ observed in the surface waters near Redcliff Island (Magadza *et al.* 1988).

The pH values in the cages were lower than those observed in this Basin by earlier workers. Begg (1987) noted that the pH in the epilimnion usually ranged between 7.8 and 8.5. Magadza *et al.* (1987) also reported that the pH in the area near Redcliff Island was alkaline with the observed levels being within a range of about 7.1 to 8.7. The lower pH values that occurred in the cages are likely to have been due to the presence of metabolic wastes that contain acidic compounds. The pH ranges recorded in this study are close to the optimum levels for the culture of cichlids. Swingle, 1961 (cited in Chervinski, 1982) noted that although Tilapia could tolerate a pH range of 4 to 11, the recommended pH levels should be between 7 and 8.

The concentrations of dissolved oxygen observed in this study were much lower than those reported by other workers (*Ibid.*). The range reported in literature was between 6.4 and 8.8 mg l^{-1}. This difference is probably related to the fact that the area with the cages has a higher fish density than the rest of the surrounding areas. The higher fish densities result in a higher oxygen demand, mainly due to oxygen being taken up by the fish during respiration.

The concentrations of dissolved oxygen observed in this study were higher than the lethal lower limit. Chervinski (1982) noted that for *O. mossambicus* and *O. niloticus*, the lowest short-term dissolved oxygen limit was 0.1 ppm.

From Figure 7, it can be observed that, in Cage-types 1 and 2, the dissolved oxygen saturation levels were greater than 50% in all the months. In Cage-type 3, the mean dissolved oxygen saturation levels ranged from as low as 22.3% in October, to as high as 73% in August. The low levels of oxygen saturation observed in Cage Type 3 were partly because these cages had a comparatively lower surface area that was in contact with the surrounding water. Consequently, the deoxygenated water in the cages would be flushed out at a slower rate since water exchange between the cages and the surrounding area (with more oxygenated water) would be low.

The dissolved oxygen saturation levels in some cages may have had a negative effect on the caged fish. Chervinski (1982) reported that Dissolved Oxygen Saturation levels of less than 25%, resulted in reduced growth, and fish will die when exposed to Saturation levels of less than 20% for a period of 2 to 3 days.

Conclusions and recommendations

Conductivity, pH and dissolved oxygen (concentration and percentage saturation) differed significantly between the cages. Temperature did not differ significantly between the cages ($p<0.05$).
When designing future sampling programmes, the different cage-types have to be taken into consideration.

The water temperature and pH observed in this study were close to the levels that are optimum for the culture of cichlids. In some months, dissolved oxygen levels in the cages, were at sub-optimal levels, especially in the octagonal cages, and these may have had a negative effect on the fish.

The results of this study showed that apart from water transparency, dissolved oxygen and pH, the other parameters that were monitored did not differ significantly from the data reported in literature. The drop in water transparency, pH and dissolved oxygen was most probably due to the introduction of the cages. Detailed studies will be required to verify this observation. Future studies should include a reference site in order to validate these observations.

Other parameters such as nutrient levels (especially Phosphorus and Nitrogen), Ammonia, Chemical and Biological Oxygen Demand (COD and BOD), and suspended solids were not monitored due to time constraints. However, future work should include the measurement of these parameters.

As production is likely to increase, it is imperative that a long-term monitoring programme be instituted in order to detect the changes in water quality that are likely to occur.

Acknowledgements

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