

Malilangwe Reservoir

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Abstract

The study provides a 9-month record of Malilangwe Reservoir water chemistry periodicity, for the period between February and October 2011. Malilangwe Reservoir is a small (211 ha), shallow (mean depth 4.54 m) reservoir situated in the south-eastern lowveld of Zimbabwe. The reservoir has not spilled in nearly 11 years, which makes it a unique system as most of the water is retained in the bottom layers (<6 m depth). The water level, which decreased by over 149 cm between February and October. The N:P ratio rose to as high as 10.9 and generally poor water quality conditions being experienced during the hot-dry season and the cool-dry season when water levels were low. The reservoir currently merely a sink for nutrients.

Keywords: Malilangwe Reservoir, water chemistry, periodicity, water level, N:P ratio

Introduction

Limnology in the tropics has only recently developed past the stage of exploration (Lewis, 2000). Despite the large number of small storage reservoirs and lakes, baseline limnological information is available for relatively few of these (Hart, 1999; Nhiwatiwa and Marshall, 2007; Quarcoopome et al., 2008). The baseline limnological information that exists on small reservoirs is often based on once-off or short term studies, while the limnology of large and medium-sized African reservoirs has been extensively studied (Moss and Moss, 1969; McLachlan, 1974; UJHRORKHWD 1993; Mustapha, 2008). Seasonally comprehensive data are seldom available to encompass the inherent hydrological variability of the region (Hart, 1999). There is a large density of small reservoirs in most parts of the continent, with Zimbabwe having about

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Received 21 March 2012; accepted in revised form 11 December 2012.

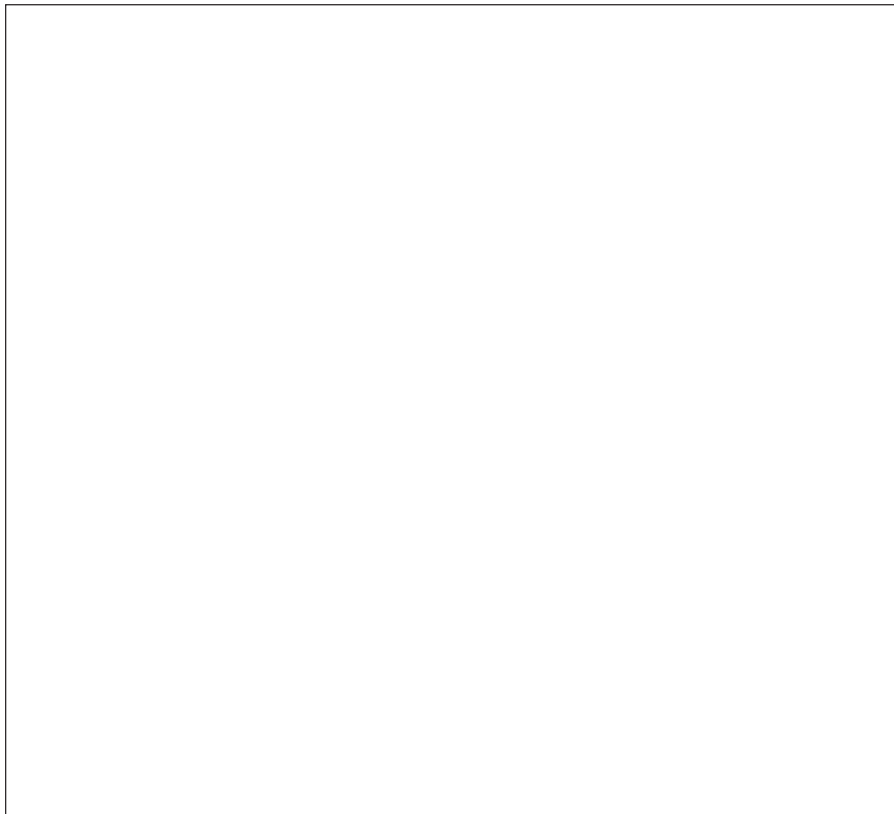


Figure 1
Map of Malilangwe Reservoir showing the location of sampling sites

is absorbed at the top of the water body, along with a large part of the incoming short-wave radiation. During the day this leads to more-or-less isothermal water temperatures, which can cause water bodies to become polymictic. During night-time, the most important forcing function is long-wave radiative cooling which triggers the formation of a mixing layer, starting from the water-atmosphere interface. Depending on the weather regime, the water temperature behaviour in shallow waters is very dynamic and complex (Jacobs et al., 1997). Given the advances in understanding of the structure and energetics of mixed layers, it is surprising that in tropical lakes even the most fundamental information, such as persistent inadequate (Nhiwatiwa and Marshall, 2006).

Water quality is the sum total of the physicochemical properties of a water body and generally gives information on the nutrient status, productivity and sustainability of a water body. Large-scale blooms of cyanobacteria in Malilangwe Reservoir have raised concerns about water quality. The aim of this study was to investigate the physical and chemical characteristics of the Malilangwe Reservoir, in order to assess water quality and

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Malilangwe Wildlife Reserve is located in the Chiredzi District (20°58' S, 31°47' E; 21°02' S, 32°01' E) of the south-eastern lowveld of Zimbabwe (Fig. 1). Malilangwe Reservoir was impounded in 1964 and is used for water supply in the reserve. The reservoir is situated on the Nyamasikana River, a tributary

It is a gravity section masonry dam with a surface area of 211 hectares and maximum volume of $1.2 \times 10^7 \text{ m}^3$ at full capacity. The characteristics of the reservoir are listed in Table 1. Flanked by rocky hills on most sides, the impoundment has a rocky substrate with a few sandy bays. It is poorly vegetated with few marginal plants, including *Azolla filiculoides* (Lam), *Ludwigia stolonifera* (Guill and Perr) Raven, *Panicum repens* (Lam), *Schoenoplectus corymbosus* (Roth ex Roem and Schult) Raynal, *Potamogeton* spp., *Phragmites mauritianus* (Kunth) and *Cyperus* sp. - nities include predators, omnivores, detritivores, micro- and macrophages (Barson et al., 2008; Dalu et al., 2012b,c).

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SHUFRGPHWELK

Sampling was carried out in the reservoir, throughout 3 seasons (hot-wet, cool-dry and hot-dry) between February and October 2011. All water samples were collected around midday so as to standardise sampling and reduce diurnal biases (Nhiwatiwa, 2004). Five sites were selected along the reservoir length and

Volume ($\times 10^7 \text{ m}^3$)	1.2
Surface area (ha)	211
Maximum depth (Z)	14.30
Mean depth (Z_m)	4.54
Volume development (D_v)	0.95
Maximum length (m)	3 187
Shoreline length (m)	9 415
Shoreline development (D_s)	1.83

Ruttner water sampler was used to collect water samples from the water column, at 1 m intervals from the bottom of the lake to the water surface. The collected water samples were placed in airtight containers and analysed within 24 h in the laboratory.

2.1.2. Bathymetric Survey

The Malilangwe Trust's *Harrier* bass boat was utilised to undertake the bathymetric survey. The vessel was equipped with a CEESTAR dual-frequency digital survey echo-sounder, 30 kHz and 200 kHz, capable of 0.01% of depth accuracy. The survey was conducted using a Trimble R5000 GPS with DGPS capability, which yields real-time horizontal accuracy of 1 m. The survey was conducted using a real-time correction system (RTK) due to real-time correction information being transmitted via satellite and from various terrestrial base stations. Six soundings were collected per second along predetermined survey lines. These were 25 m apart in the east-west direction and 50 m apart in the north-south orientation. Special manoeuvring had to be undertaken around zones with high tree densities and a few areas close to the dam edge could not be surveyed as they were too shallow for the boat to navigate. A land survey of the lake edge allowed for accurate extrapolation of elevation data across these problematic zones.

2.1.3. Sonar Mosaic

Side-scan sonar was used to generate a mosaic of the dam bottom. The survey was conducted using a Simrad EK60 echosounder. The survey lines were run parallel to the long axis of the dam and were positioned 35 m apart to produce 100% overlap between successive scan runs, whilst utilising a scan range of 40 m (80 m total swath). This allowed for a comprehensive side-scan sonar mosaic of the dam bottom to be produced. Extremely shallow areas (<1.5 m water depth) and zones with dense submerged trees proved problematic for surveying. Complete coverage of the dam was thus not possible.

2.1.4. Water Quality

Water quality was monitored at Site 1, the deepest point of the reservoir. Measurements were taken at 1 m intervals using an oxygen meter (LDO HQ20, HACH). Measurements were done once a month throughout the three seasons (hot-wet, cool-dry and hot-dry; February to October), at the deepest point of the reservoir (Site 1). It should be noted that the sampling strategy did not consider spatial variations due to time limitations, hence one site only was selected. The diurnal variations in temperature and dissolved oxygen concentration were determined by taking readings at 2 h intervals over a 24 h period for each of 3 different seasons, February (hot-wet), June (cool-dry) and October (hot-dry).

2.1.5. Statistical Analysis

Water samples were collected at each site and analysed for pH, conductivity, total dissolved solutes, temperature and dissolved oxygen (DO), using a pH, conductivity and DO meter (HACH, LDO, Germany). Water transparency was measured using a Secchi disk. Chemical oxygen demand (COD), nitrogen, nitrates and total and reactive phosphorus were determined using standard methods from HACH (2007) and Eaton et al. (2005). A Kruskal Wallis test ($p < 0.05$) was carried out to

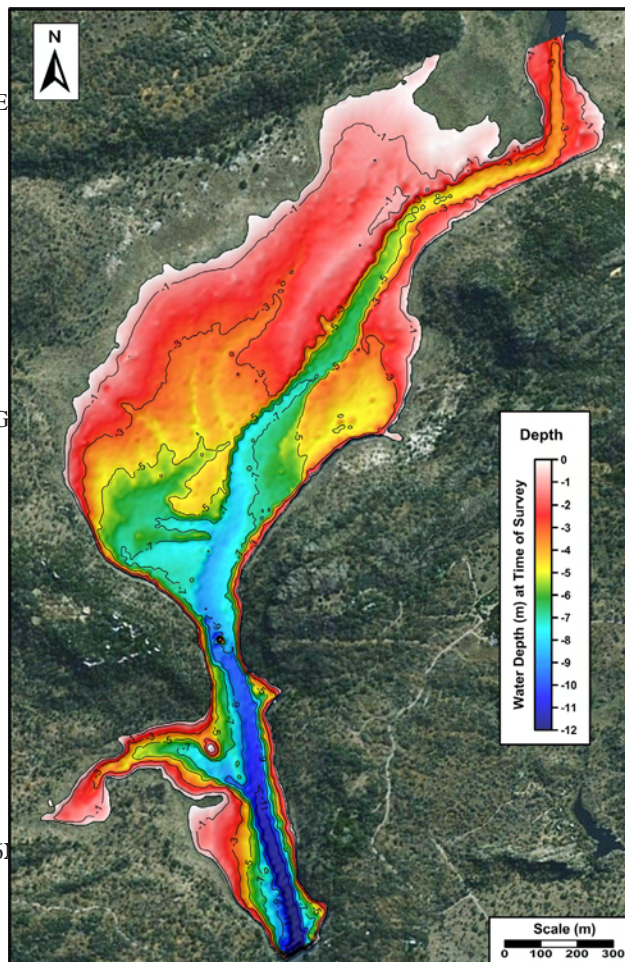


Figure 2
Contour map of Malilangwe Reservoir with depths corrected to water level height at time of survey (zero datum = water level)

compare characteristics between sampling stations (H_0 : no difference between sampling points). The analysis was done for the whole study period, February to October 2011, using SysStat ver. 12 (SYSTAT, 2007).

Results

Bathymetry

The results of the bathymetric survey are presented in Fig. 2. The zero-datum level used in Fig. 2 was the water level at the time of survey (3.76 m below dam spill level). Depth of the reservoir is represented as negative values and in metres. The bathymetric data, by the simultaneous interpretation of the side-scan sonar mosaic and bathymetric data. Ten major bottom types, as well as numerous submerged trees and high-relief boulders, were identified. The bottom is dominated by a submerged main channel that extends along the entire main axis of the dam, a central shallow alluvial basin with minor channels and a constricted steep-sided neck area with a secondary tributary channel (entering from the west) near the dam wall.

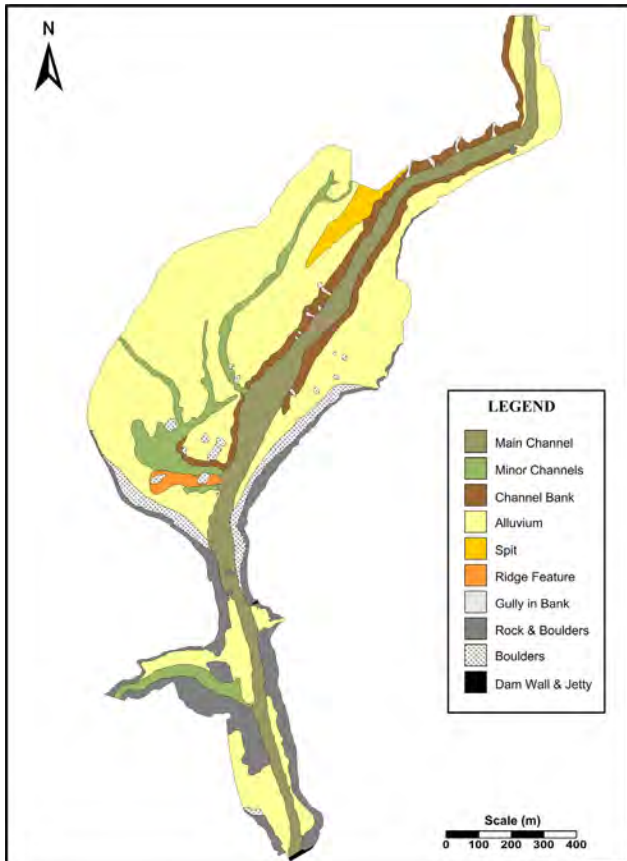


Figure 3
Geological classification map of the Malilangwe Reservoir

The base of the main channel occurs at a depth of 3 m at the northern limit of the survey area (main tributary input) and extends to a maximum depth of 12 m near the dam wall. This equates to a total elevation drop of 9 m over a horizontal distance of 2 990 m. The main channel incises the central basin and exits the southern part of the basin at a depth of 8 m. The sides of this main channel (banks) are relatively steeply sloped throughout this length, except in the northern and the southern part of the central basin. The shallow central basin is divided by the main channel into an extensive western region, with minor incised channels, and a smaller eastern portion. A split occurs in the northern part of the central basin and is clearly evident at depth of 2 m. During periods of lower water level this split would be emergent. The south-western part of the central basin is punctuated by a minor ridge feature that extends east-west at a depth of 6.0–7.5 m. Its orientation (at a depth of 6.0–7.5 m) appears odd relative to the more sinuous nature of the dam channel and it is suggested that the ridge may represent an igneous dyke intrusion. Both the south-western and south-eastern margins of the central basin are steep sided, to a depth of 5.5–6.5 m, as a result of being formed by rock exposures. The rock margins extend further north on the eastern side of the central basin (Figs. 2 and 3).

The constricted neck approaching the dam wall forms the deepest part of the impoundment (9–12 m). A secondary, well-developed channel meets the main central channel from

the west at a depth of 10.5 m. This channel descends 9 m (with a water depth of 1.5 m at the western limit) over a horizontal distance of 550 m. This area is characterised by steep rocky sides, with the exception of shallow regions at the western extremity of the secondary channel and the south-western edge between the secondary channel and the main channel within this neck. This rock exposure is clearly evident to a depth of 6 m. A second constriction with steep rocky sides and a deep channel occurs at the southern limit of the neck, and this is where the dam wall is situated (Figs. 2 and 3). The reservoir's morphology and bottom composition prior to the impoundment of this waterway.

6WUDWLFDWLRQ

Seasonal patterns of temperature and dissolved oxygen stratification

er a stratification as esta is e ring t e ot and hot-dry seasons and part of the cool-dry season (June–August) (Fig. 4c). During the hot-wet season (February), the mean water temperature at the water surface was 31.2°C, but in the cool-dry season (July) the mean water temperature was 20°C, with a mean bottom water temperature of 26.9°C and 18.6°C in February and July, respectively. Dissolved oxygen during the February to March and August to October periods (Fig. 4b). As the air temperature got cooler and the solar radiation input decreased during the cool-dry season, the surface water began to cool, which resulted in surface water and the thermocline cooling down to the temperature of the surface water. In this state the reservoir could be easily mixed, even by light wind, resulting in complete mixing or turnover at the beginning of the cool-dry season. This gave the bottom water an opportunity to become aerated. As the surface water heated again, towards the end of the cool-dry season, the reservoir state (Fig. 4c). The changes which occurred were related to air temperature and wind speed. Air temperature increased from 25.2°C in February to 27.3°C in March, before decreasing to a low of 16.8°C in July. Air temperature then increased from July to October, reaching 26.5°C. Wind speed followed a similar trend as temperature with a value of 1.1 km·h⁻¹ being recorded in February, and decreasing to a low of 0.5 km·h⁻¹ in May and June. Wind speed then increased to a value of 2.3 km·h⁻¹ during October (Fig. 4a).

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Hot-wet season

February 2011 (during the hot-wet season) when the water

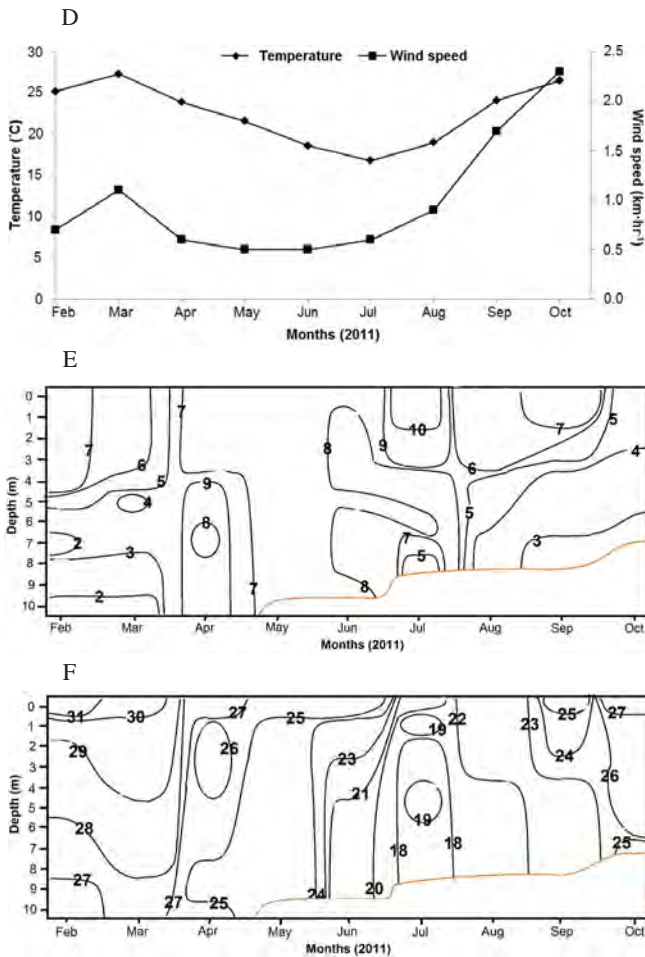


Figure 4

Seasonal variation in (a) water temperature (°C) and wind speed (km·h⁻¹), (b) dissolved oxygen (mg·l⁻¹) and (F) temperature (°C) in the Malilangwe Reservoir (February–October 2011)

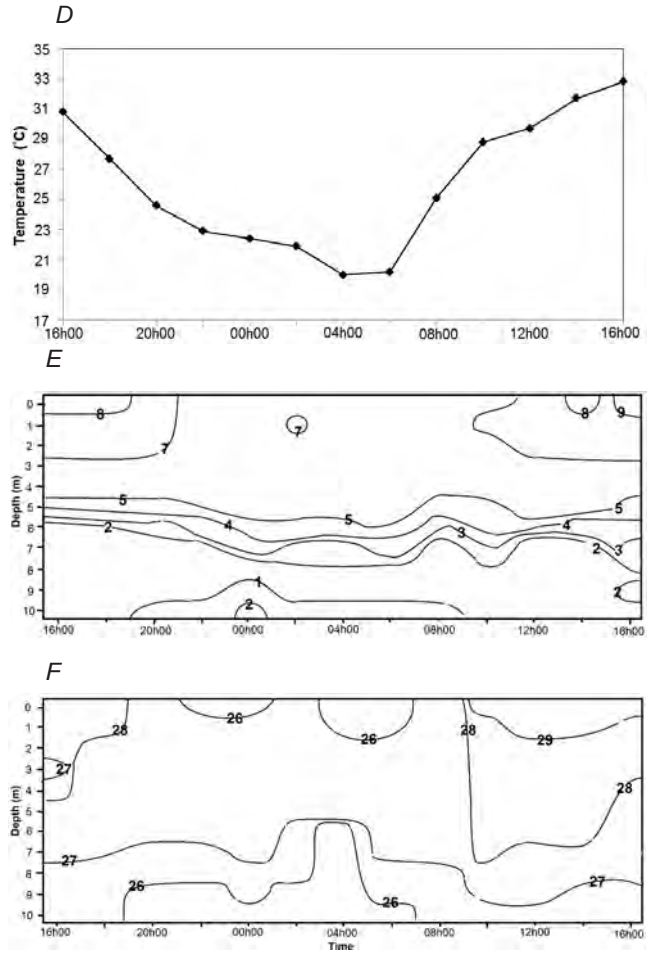


Figure 5

Diurnal variation in (a) air temperature (°C), (b) dissolved oxygen (mg·l⁻¹) and (F) water temperature (°C) in the Malilangwe Reservoir (24 February 2011)

the cool-dry season (10–24°C) compared to air temperatures of about 10°C were recorded during the early morning hours (04:00–06:00) (Fig. 6a). During the hot-dry season, the water was very warm during the day with surface water temperatures in the range of 34–35°C, and cooler during the night with surface water temperatures ranging from 25–26°C (Fig. 7c). This pattern was related to air temperatures, which reached 30.4°C around midday, with lower air temperatures observed in the early morning (22–24°C), between 10:00–16:00. Surface water temperatures decreased from a peak of 28°C during the day (10:00–16:00) to a low of 19°C during the night (Fig. 6b). Lower air temperatures were

Cool-dry season

The next 24-h sampling exercise was carried out on 15 June 2011 (cool-dry season). The reservoir water level was low as a result of evaporation and drawdown. There was weak thermal stratification during the day (10:00–16:00). Surface water temperatures decreased from a peak of 28°C during the day (10:00–16:00) to a low of 19°C during the night (Fig. 6b). Lower air temperatures were

more pronounced and the concentration of oxygen fell to 1 mg·l⁻¹ (at depth = 8 m) from approx. 10 mg·l⁻¹ (at depth = 0 m). Oxygen concentrations in the entire water column fell during the day (Fig. 5b). Below 5 m depth, the reservoir was anoxic (0 mg·l⁻¹) during the day.

Hot-dry season

The last 24-h sampling exercise was carried out on 27 October 2011 (during the hot-dry season) when the water was very warm during the day with surface water temperatures in the range of 34–35°C, and cooler during the night with surface water temperatures ranging from 25–26°C (Fig. 7c). This pattern was related to air temperatures, which reached 30.4°C around midday, with lower air temperatures observed in the early morning (22–24°C), between 10:00–16:00. Surface water temperatures decreased from a peak of 28°C during the day (10:00–16:00) to a low of 19°C during the night (Fig. 6b). Lower air temperatures were recorded during the hot-dry season.

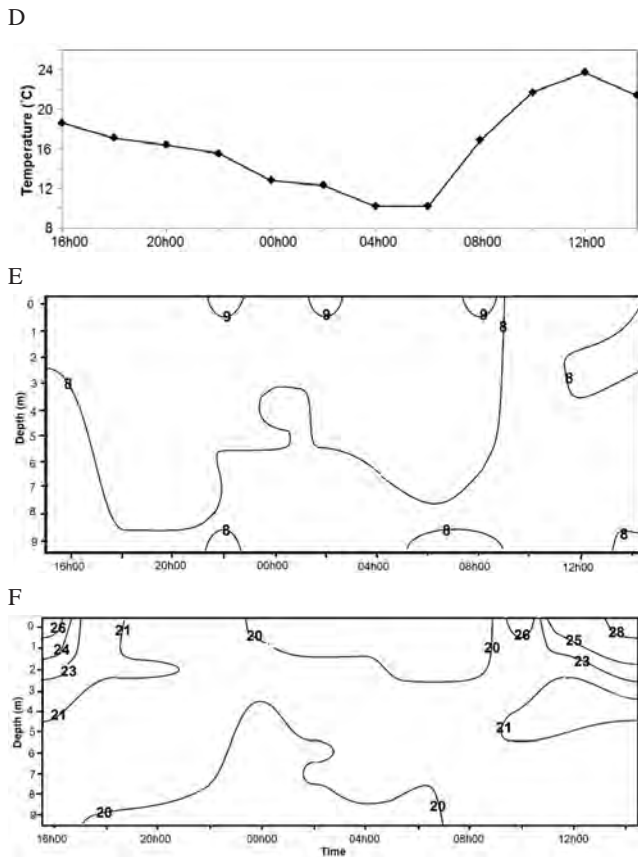


Figure 6
Diurnal variation in (a) air temperature (°C), (b) dissolved oxygen ($\text{mg}\cdot\text{l}^{-1}$) and (F) water temperature (°C) in the Malilangwe Reservoir (15 June 2011)

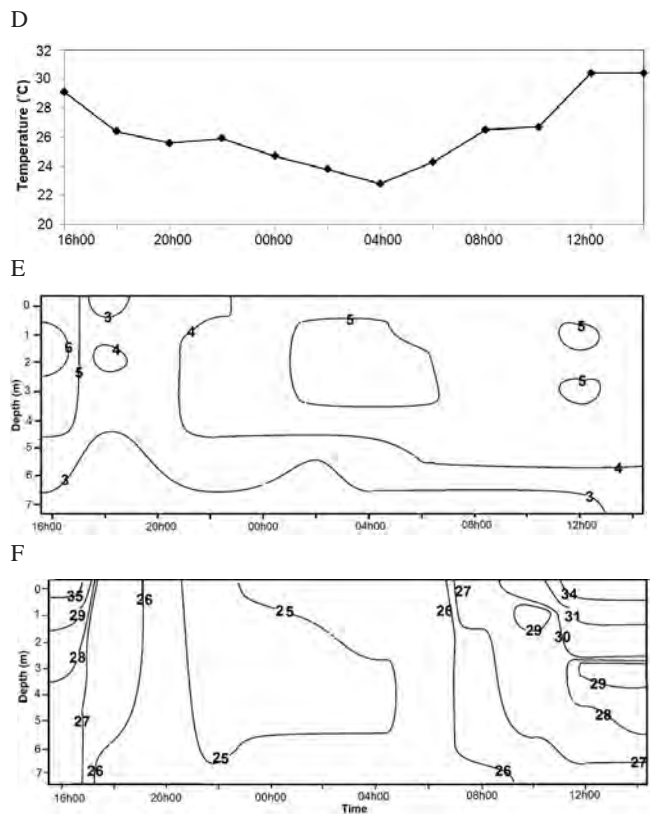


Figure 7
Diurnal variation in (a) air temperature (°C), (b) dissolved oxygen ($\text{mg}\cdot\text{l}^{-1}$) and (F) water temperature (°C) in the Malilangwe Reservoir (27 October 2011)

Variable	Site 1	Site 2	Site 3	Site 4	Mean	p-value
Water level (m)	0.4 ± 0.4	0.3 ± 0.3	0.3 ± 0.3	0.3 ± 0.3	0.4 ± 0.4	0.91
Water level change (m)	0.1 ± 0.2	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.2 ± 0.2	0.92
Water level change rate (cm·month ⁻¹)	0.9 ± 0.9	0.7 ± 0.7	0.8 ± 0.7	1.1 ± 1.6	1.1 ± 1.6	0.88
Water level change rate (cm·month ⁻¹)	0.9 ± 0.8	0.7 ± 0.3	0.6 ± 0.4	0.8 ± 0.8	1.7 ± 1.3	0.65
Water level change rate (cm·month ⁻¹)	0.07 ± 0.2	0.02 ± 0.02	0.03 ± 0.03	0.02 ± 0.02	0.02 ± 0.02	0.98
pH	7.9 ± 0.6	8.1 ± 0.5	8.1 ± 0.5	8.0 ± 0.5	8.2 ± 0.5	0.92
Water level change rate (cm·month ⁻¹)	271.6 ± 37.8	273.5 ± 38.5	273.2 ± 36.7	274.2 ± 37.5	275.7 ± 40.6	0.99
Water level change rate (cm·month ⁻¹)	347.5 ± 60.8	350.2 ± 63.5	349.6 ± 68.1	351.8 ± 66.8	352.5 ± 75.2	0.85
Water level change rate (cm·month ⁻¹)	33.6 ± 27.2	36.5 ± 29.1	36.7 ± 27.5	36.8 ± 26.2	49.4 ± 30.0	0.50
Secchi disk depth (m)	1.4 ± 0.4	1.3 ± 0.3	1.1 ± 0.2	1.1 ± 0.2	0.7 ± 0.4	0.01*
Water level change rate (cm·month ⁻¹)	6.1 ± 1.9	6.6 ± 1.1	7.2 ± 1.2	6.6 ± 1.3	6.7 ± 1.4	0.69
Temperature (°C)	24.5 ± 3.3	24.87 ± 3.6	25.2 ± 3.8	25.3 ± 3.7	25.6 ± 4.5	0.98
Water level change rate (cm·month ⁻¹)	16.4 ± 1.4	16.4 ± 1.5	16.9 ± 2.0	16.2 ± 1.5	17.6 ± 1.1	0.43

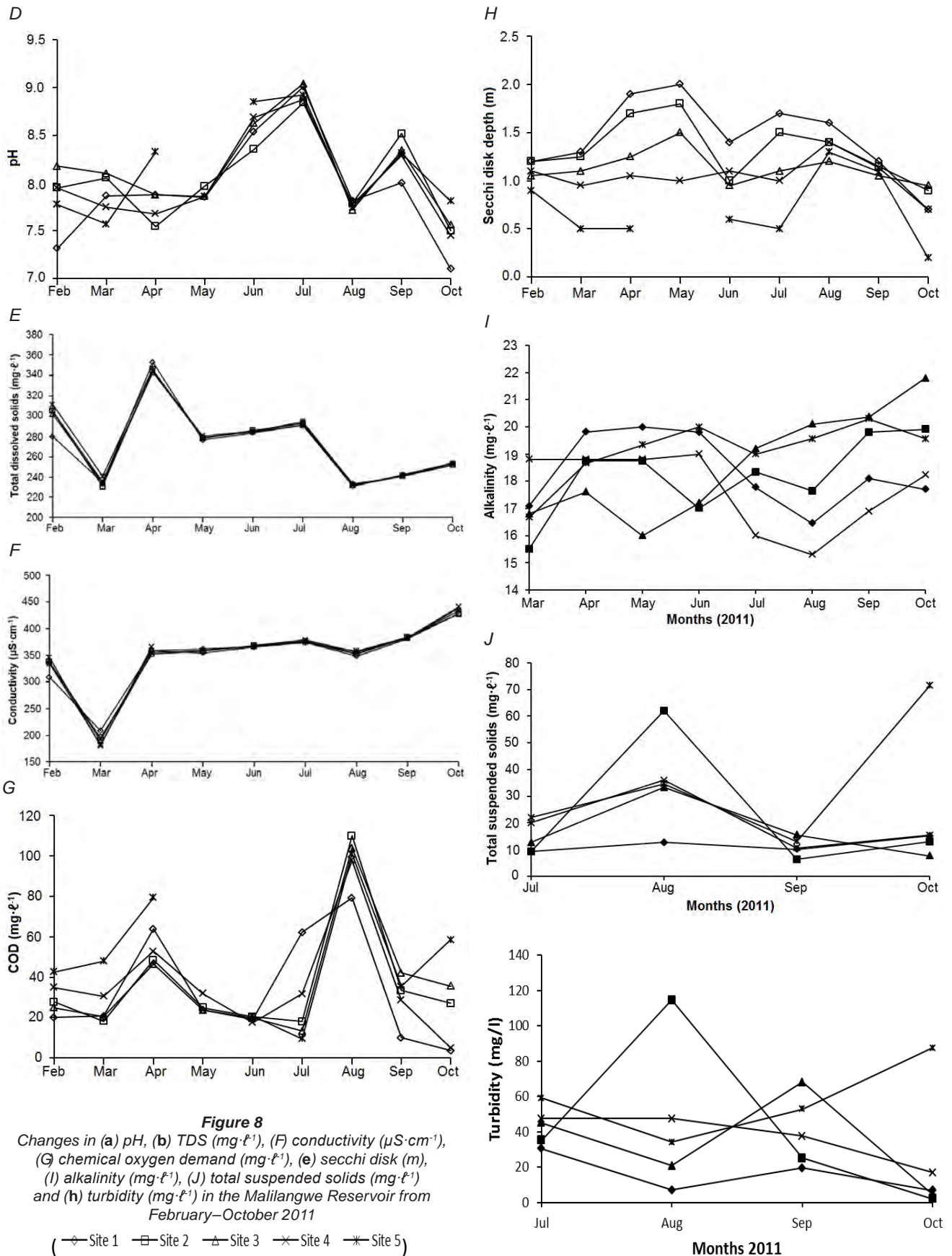
Between 16:00 and 18:00 at the water surface, whilst at 5 m depth the oxygen for the rest of the study period (Fig. 7b).

:DWHUFKHLVWU\

Table 2 summarises the mean values of the environmental variables measured in the Malilangwe Reservoir for the

study period. Water levels decreased at an average rate of 18.63 cm per month at all sites, with the greatest decrease being recorded at all sites during March (25 cm) and the smallest decrease being recorded during June (9 cm). From February to October a total of 149 cm of water had been lost from the reservoir due to drawdown and evaporation.

7KHS+KWBWHGGKLLQJWKHPQWKVRIVDPSOLQJWVKH start of the sampling campaign in February (during the hot-wet season), pH at all 5 sites ranged from 7.32 to 8.18. There was not



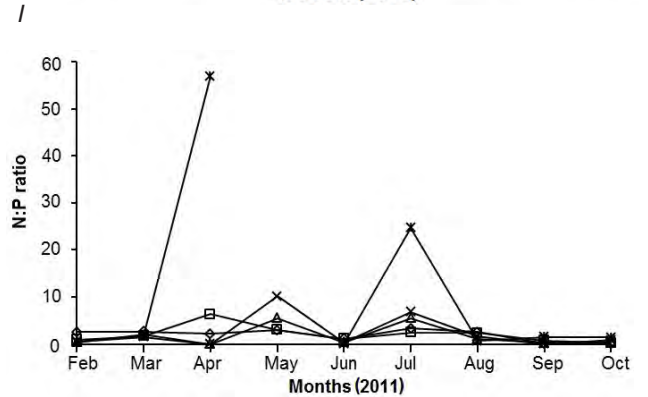
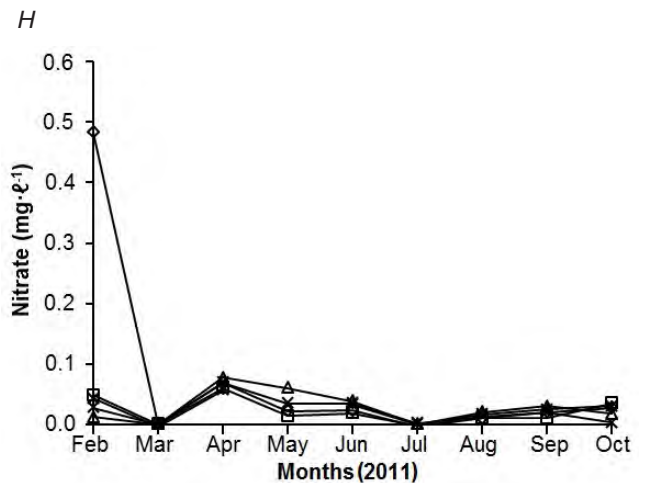
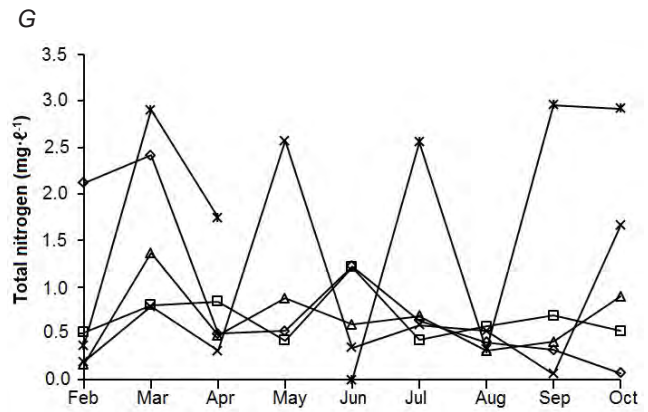
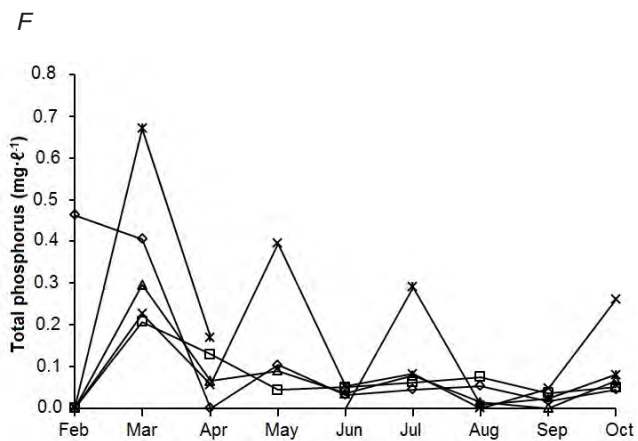
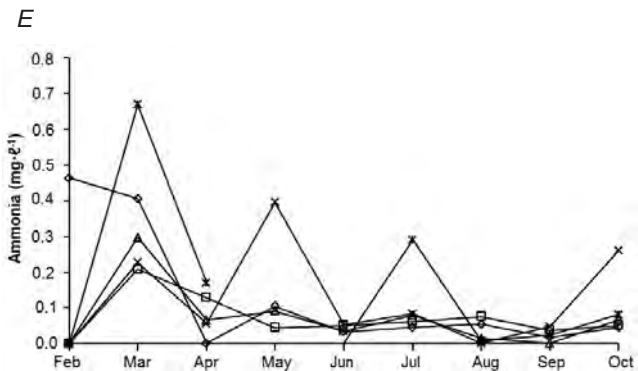
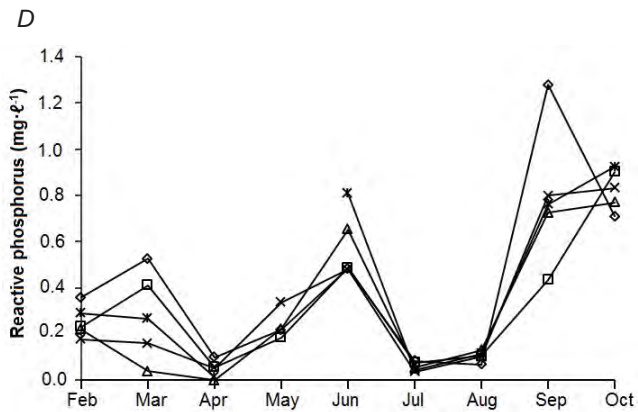


Figure 9

Changes in (a) reactive phosphorus ($\text{mg}\cdot\ell^{-1}$), (b) ammonia ($\text{mg}\cdot\ell^{-1}$), (F) total phosphorus ($\text{mg}\cdot\ell^{-1}$), (G) nitrogen ($\text{mg}\cdot\ell^{-1}$), (e) nitrogen ($\text{mg}\cdot\ell^{-1}$) and (I) N: P ratio in the Malilangwe Reservoir from February–October 2011

(—○— Site 1 —□— Site 2 —△— Site 3 —×— Site 4 —*— Site 5)

much difference in March and April but there was an increase in July at all of the study sites ($\text{pH} = 8.84\text{--}9.04$). The pH values dropped again in August as the cold season ended, being in the range of $7.72\text{--}7.82$, before increasing again in September to around $8.00\text{--}8.52$. The pH dropped once again in October, to its lowest values for the entire study period at 4 of the 5 sites. At this time, the pH was in the range $7.10\text{--}7.56$ (Fig. 8a).

In February, the conductivity ranged from $308.91\text{--}661.1\text{ }\mu\text{S}\cdot\text{cm}^{-1}$ (at Site 5). There was a decrease in conductivity at all sites in March and April, with the lowest values recorded at Site 1 ($101.5\text{--}108.5\text{ }\mu\text{S}\cdot\text{cm}^{-1}$) as a result of rainfall that occurred

From that time onwards, conductivity levels continued to rise, reaching the highest values in October, when all sites were above $400.00\text{--}661.1\text{ }\mu\text{S}\cdot\text{cm}^{-1}$. Site 1 recorded the lowest and Site 5 the highest concentration of total dissolved solutes during the study (Fig. 8b).

YDULDELOLWRIRJHQGHSOHWLROGHQHGDMPHs-
solved oxygen) that the reservoir exhibited could be partly
due to respiration as a result of decomposing organic matter
and the nature of the soils (Chapman et al., 1998). Seasonal
importation of allochthonous organic material during the rainy
season is a characteristic feature of most tropical reservoirs,
and Malilangwe Reservoir is no exception. The reduced rate of
oxygen depletion during the cool-dry season is mainly due to
complete mixing of the water column. Temperature is a major
determinant of the rates of biological and biochemical pro-
cesses such as decomposition (Nhiwatiwa and Marshall, 2006).

Dissolved oxygen (DO) depletion during the hot-wet
and hot-dry seasons is a result of demand exceeding supply.
Greater oxygen demand is due to the increase in activity of
aquatic animals, and a greater abundance of aquatic plants
DQGGHFDLQJRUDQLFPDWWHUZKLFKFRQVXH2/DUJHJH
populations in the reservoir have a faster metabolic rate as
water temperatures increase with the change of season (from
the cool-dry to hot-dry season), which increases their oxygen
requirements during the warm weather periods. As a result,
PRUHRJHQLVQHGHGGEWKHYKGLQJWKHKRWZHWDDQ
hot-dry seasons. Another factor leading to low DO levels dur-
ing the hot-dry season could be decomposition by bacteria,
a process that further reduces DO in the water column. The
development of hypolimnetic anoxia also reduces the biologi-
cally-available habitat, reducing the volume of the water body
in which the majority of aquatic organisms exist and severely
impacting less mobile benthic organisms. Fish usually avoid
ZDWHUODHUVFRQWDLQLQJH₂O₂ concentration
(Abd El-Monem, 2008) and the same is true for other aquatic
organisms. About 40% of the Malilangwe Reservoir volume
FDQEHRIHQGHFLHQWZLWKWKHDQRLFODHUHWHQG
4 m below the water surface), creating conditions of oxygen
stress during the hot-wet and hot-dry seasons and greatly
reducing available habitat.

7KHUPDODQGRJHQVWUDWLFDWLRQUHJLPHVKDYHLP
for nutrient exchange between sediments and water. Cowan and
Boynton (1996) observed that sediment oxygen consumption
rates increase with increasing temperature until bottom-water
GLVVROYHGRJHQFRQFHQWUDWLRQVIHOEHWZPH
point sediment oxygen consumption rates become limited.
This partly explains the depletion of oxygen that occurred in
Malilangwe Reservoir. With regards to nutrient cycling, high
DO concentrations in the hypolimnion inhibit sediment release
RIDPPRQLDEHQKQDLQJLWULFDWLRQRIDPPRQLDWRQIBYUDWH
(and thus nitrogen assimilation into bacterial biomass). However,
NVRIDPPRQLDZHUHHOHYDWHGDWKLJKWHPSHUDWKHVDQ
when coupled with increasing hypolimnetic anoxic conditions
PJ⁻¹ very large releases of ammonia occur (Beutel et al.,
3KRVSKDWHIVZHUHVPDOOHFHSWLQDUHDVRIKSRLF
and anoxic bottom waters. It is likely that nutrient exchange
is rapid and frequent in small reservoirs even though they are
characterised by vertical gradients associated with thermal
DQGRJHQVWUDWLFDWLRQ
Nhiwatiwa and Marshall, 2006). In
Malilangwe Reservoir, there were sKRUWWHUPANEWLRQVLO
some isopleths of temperature and dissolved oxygen indicating
that there is dynamism among the different layers, even dur-
LQJWUDWLFDWLRQ7KLVLVOLNHOWRUHVWNLQSDUWUL
water column and may allow nutrient exchanges between the
epilimnion and the hypolimnion.

Seasonal changes in water quality were also investigated.
RQGWLYLWZDVFKDUDFWHULVHGEANEWLRQVEHWZ
cool-dry season and the hot-dry and hot-wet seasons. The lower
conductivities measured during the wet season occur because

of rainfall, during the few contiguous months of the year during
which precipitation occurs. This results in a high dilution fac-
WRUDVULYHULQKZVHQWUWVKHUHVHUYRLU/DWHULQWKHHDU
LQKZVKDYHFHDVHGLRQLFFRQFHQWUDWLRQVLFUHDVHDVZDW
levels drop. This concentration effect has been observed and
reported in other studies (Nhiwatiwa and Marshall, 2007; Moss
and Moss, 1969; Osborne et al., 1987). The temporal and verti-
cal patterns of pH in the reservoir were mediated by processes
of photosynthesis (production) and respiration (consumption).
The high pH observed during the cool-dry season (June to July)
could be attributed to photosynthetic uptake of CO₂ESUROLF
algal blooms observed during the same period, while decompo-
sition and respiration tended to decrease pH during the hot-wet
and hot-dry seasons.

Secchi disk transparency is an important feature of water
quality and has important ecological implications. Secchi disk
transparency ranged from 0.2–1.8 m in Malilangwe Reservoir
and was comparable to the characteristic modal range of
0.1–1.6 m recorded in 2 small reservoirs in the Manyame
catchment (Nhiwatiwa and Marshall, 2007), as well as in Oyun
QCServoir, Nigeria (Mustapha, 2008). Secchi disc transpar-
ency was low during the rainy season (February to March)
and, in particular, at Site 5, throughout the study. The rainfall
season is naturally characterised by high runoff resulting in
VHGLPHQWODGHQLQKZVLQWRWKHUHVHUYRLU6LWHKDGULYHU
FKDUDFWHULVWLFVDQGGZDVWKHSRLQWZKHUHWKHPDMRULQKZ
into the reservoir. Higher water transparencies, observed in the
GUVHDVRQUHAFWHGVXSHQGHGSDUWLFQVHVVHWWOLQJWRWKH
of the reservoir. The range of water transparency (0.2–1.8 m)
indicates that depth of light penetration is generally adequate
IRUWKHDEWLFVRUJDLQVPSODQNWRQDQGYKWKDWWKULYHLQ
epilimnetic regions of Malilangwe Reservoir (Mustapha, 2008).

7KHULYHULQKZVZHUHFOHDUOOLQNHGWRKLIJKHUSKRVSKRU
concentrations during the hot-wet season. These higher concen-
trations are most likely linked to the resultant algal blooms that
PSOLFDMRULQKZ
cool-dry season and which contribute to the
high level of productivity in the reservoir. Additional nutrients
were also likely to be released during turnover, contribut-
ing to the overall increase in productivity (Mustapha, 2008).
The overall decline in phosphorus concentrations, similarly,
is linked to uptake by algae and macrophytes and, during the
hot-dry season, retention in the hypolimnion. The decrease in
water levels in the reservoir corresponded with an increase in
phosphorus concentration, but this relationship was confounded
by UDWH
current effects of turnover.

ILWURJHQFRQFHQWUDWLRQVZHUHJHQHUDOOORZ7KLVQGLO
supports the suggestion that nitrogen does not accumulate in
tropical lakes and reservoirs due to the occurrence of anoxic
hypolimnia (Bootsma and Hecky, 2003). Anoxia and warm
WHPSHUDWKHVSURPRWUDSLGGHQLWULFDWLRQDQGHQKQDQFH
phosphorus mobilisation in tropical lakes, leading to the greater
prevalence of nitrogen limitation in the tropics (Bootsma and
Hecky, 2003).

Nitrogen to phosphorus (N:P) ratios observed in the reservoir
were relatively unchanged during the study period. According
to Smith (1979), nitrogen is limiting when the N:P ratio is less
than 10:1 and phosphorus is limiting when N:P is greater than
LDPTLQJRIWKN
Malilangwe Reservoir, nitrogen was found to
be the limiting factor, as shown by the relatively low N:P ratio,
of less than 10.9, at all study sites. Nevertheless, the trophic status
of the reservoir is likely to change in the short- to medium-term
IHDQWPH
as the reservoir continues to accumulate nutrients.
Nutrient loadings from the catchment are currently low; thus, the
reservoir has not yet become eutrophic.

7KL VVVWZDVPDGH SRV VLEOHWKURKWKHQDQFLDOVSSRUWR
 the Malilangwe Trust Research Grant and German Academic Exchange Service (DAAD – A/10/02914). Special thanks go to Esther S Jairos (University of Pretoria, RSA) for guidance and for providing most of the relevant literature used. Warm thanks go to Clemence Chakuya and Patrick Mutizamhepo of the University of Zimbabwe; Philemon Chivambu, Pandeni Chitimela, and Pamushana Lodge guides of the Malilangwe :LOGOLIH5HVHUYHZKRDVVLVWHGLQWKHHOG2KDDSSUHFLLDWR
 also goes to Elizabeth Munyoro and the technical staff of the Department of Biological Sciences, University of Zimbabwe, for all their technical support during the study.

5HIHUHQFHV

1/021(08.PSDFWRIVKPHUWKHUPDOVWUDWLFD -
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