UNIVERSITY OF CAPE TOWN
DEPARTMENT OF BOTANY

A PRELIMINARY SEASONAL STUDY OF PHOSPHORUS CYCLING IN A FRESHWATER AQUATIC SYSTEM

N. TYSON

Project submitted in partial fulfilment of
the requirements for the degree of

B.Sc. Hons.

in the Faculty of Science

1985

Abstract

The quality of the water entering two successive dams on a farm (Meerlust) near Stellenbosch in the S.W. Cape has been found to be extremely poor. However, on entering the dams, the quality of the water was found to improve considerably. The smaller of the two dams (M3) supports an extremely large macrophyte community (*Potamogeton pectinatus*) in summer which dies back completely at the beginning of winter. A preliminary study of the cause of the improvement in water quality in M3 has been conducted by measuring the concentrations of phosphorus in the water (both Soluble Reactive Phosphorus as well as Total Phosphorus>0.45μ), the sediment, as well as in the plant macrophyte community in late summer (April) and late winter (September). The relation between these various compartments has been discussed with particular emphasis given to the effect of the seasonal die-back of *Potamogeton pectinatus* on the system.

Acknowledgements

I express my appreciation and gratitude to:

Professor D. Mitchell, my supervisor, for his help and guidance.

Dr. J. King and Dr. B. Davies for their help, especially with the collection of the monthly water samples.

Mr. E. Witkowski, for his help with the phosphorus analyses.

Mrs. E.J. Tyson and Mr. L. Robinson for typing the manuscript.

Table of Contents

1 INTRODUCTION:

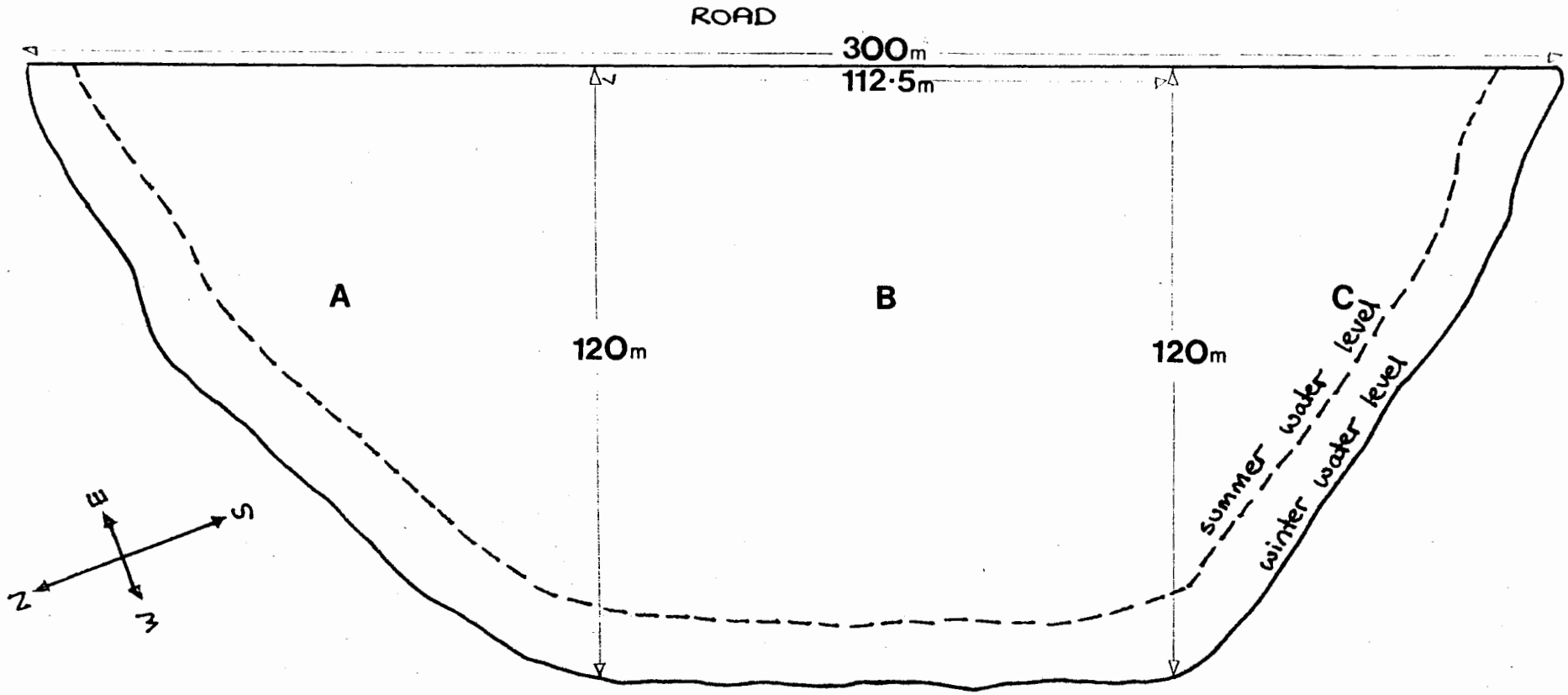
The study site is located on the farm "Meerlust", approximately 16 km out of Stellenbosch in the S.W. Cape. Of the two dams found on this farm, the dam on the east side of the R310 "Lynedoch Road" to Stellenbosch is the larger one and is fed seasonally by the Eerste River via a concrete channel. This dam will be referred to as M2. The second and smaller dam (M3), was however the focus of study for this project. It is found on the west side of the road and has an approximate area of 24750m (See Figure 1). Water from M2 seeps into M3 and it is therefore indirectly supplied by the Eerste River. The dam supports extensive reed beds, Potamogeton pectinatus, some microscopic algae, a varied and healthy aquatic fauna and numerous coots. (See Figure 2).

Water analyses of the concrete channel, as well as the dams M2 and M3, were done in November 1983 (King, unpublished). The quality of the incoming water was found to be extremely poor with high concentrations of nitrogen and phosphorus. On entering the dams, the quality of the water was found to improve considerably. (See Table 1).

Table 1: The concentrations of nutrients [µmoles l^{-1}] in the conduit from the Eerste River, the large dam - M2, and the smaller dam - M3 in November 1983. (King, unpublished)

	Conduit from Eerste River	Large Dam M2	Smaller Dam M3
Silicate µ mol l^{-1}	55.50	8.00	1.20
Phosphate µ mol l^{-1}	140.40	26.60	9.00
Phosphate µg l^{-1}	4348.72	823.90	278.76
Ammonia µ mol l^{-1}	309.40	12.20	5.63
Nitrate µ mol l^{-1}	46.68	2.17	0.22
Nitrite µ mol l^{-1}	269.79	11.44	0.61

Several questions arose: Firstly, is the improvement in the water quality due to a movement of the nutrients into the vegetation and sediments? Secondly, what happens to the nutrients when the Potamogeton dies back in late summer? Are the nutrients released into the water or sediments, and is this nutrient pool accumulating over the years? Thirdly, with the continuous input of nutrients and no large apparent loss of nutrients from the system, will it remain stable, or is it likely to experience some type of collapse in the future?



Area A = $\frac{1}{2} \cdot 120 \times 112 \cdot 5$

= 6750 m^2

Area B = $120 \times 112 \cdot 5$

= 13500 m^2

Area C = $\frac{1}{2} \cdot 120 \times 75$

= 4500 m^2

Aproximate Total Area = Area A + Area B + Area C

= 6750 m^2 + 13500 m^2 + 4500 m^2

= <u>24750 m^2</u>

Figure 1: Diagramatic representation of the smaller dam-M3 showing the approximate dimensions of it's area.

Figure 2: Photograph of the smaller dam-M3 showing it's border with the road on the left (lined with Willow trees), it's reedbeds in the foreground and the surrounding farmland.

The aim of this project was to provide preliminary data to act as a base for a more extensive research programme in the future. The investigation was confined to a seasonal study (late summer and late winter) of the major components of the system, namely the water, the sediment and the community of Potamogeton pectinatus.

The concentration of phosphorus was determined for each of these components, and the seasonal variation was examined. It is recognised that a future research programme should also involve the study of other nutrients (such as nitrogen), and that data collection should occur more frequently. The summer (April) and winter (September) collection of data for this project was supplemented by a more regular monitoring of the concentration of phosphorus in the water. Water samples were collected at monthly intervals.

Phosphorus is an essential element for plant and animal growth. It occurs in low concentrations relative to other essential elements in the environment (Wetzel, 1975) and is important as an element controlling biological activity. It may be combined into a variety of ionic, molecular and colloidal forms, often mediated by biological processes (Rigler, 1973). The dynamics of phosphorus exchanges and transformations in aquatic environments are therefore complex, and this complexity has led to widely divergent results (Twinch, 1980). The limitations of analytical

techniques has also hindered the identification and measurement of phosphorus fractions occurring in water as has the confusion of terminology and lack of standardisation of procedures.

Early analyses indicated that phosphorus levels in inland waters were low and it was only after the introduction of colorimetric analyical procedures in 1923 that the presence of a number of phosphorus fractions became apparent (Hutchinson, 1957). The recent use of 0.45µ membrane filters in limnology has led to greater standardisation of procedures and terminology as the definitions of different phosphorus fractions are based on the procedures of fractionation. These fractions are outlined in the review of Rigler (1973) as follows:

-Soluble reactive phosphorus (SRP) refers to the value when membrane filtered water is analysed by one of the variants of the molybdenum blue technique. This term implies neither that the orthophosphate measured was in solution before the addition of the reagents nor that the intensity of the blue colour is exclusively a function of orthophosphate concentrations rather than that of interfering ions. When orthophosphate phosphorus is used it will not refer to the results of chemical analyses but to free orthophosphate in solution, the concentration of which is assumed to be as yet unmeasurable in the trophogenic zone of most lakes.

-Soluble phosphorus (SP) refers to the value obtained when membrane filtered water (0.45μ) is analysed after being digested with an oxidizing acid solution.

-Soluble unreactive phosphorus (SUP) is the difference between SP and SRP.

-Total phosphorus (TP) is obtained by analysing the whole lake water after acid digestion. It is assumed that the values obtained by this technique are indicative of the true phosphorus content of the sample.

Twinch and Breen (1980) state that changes in the concentration of different phosphorus fractions result from processes which can be categorized into three distinct but nevertheless independent spheres of influence. These three categories are:

1) Phosphorus cycling in the water;
2) Phosphorus exchange between sediment and water;
3) Allochthonous phosphorus loading.

Although the relative importance of biological components and the macrophyte communities in particular are mentioned in the first section, it is felt that this aspect warrants a category of its own. Category 1) would then involve the importance of abiotic particles in the exchange of phosphorus between particulate, colloidal and soluble forms. This

aspect of phosphorus cycling is poorly understood at present. A separate category would deal with the role of plankton and macrophyte communities.

In this project, an attempt has been made to study these four categories in order to obtain an idea of their relations one to another over time.

2. MATERIALS & METHODS:

2.1 Sampling:

2.1.1 Potamogeton pectinatus:

Due to the key role that Potamogeton is assumed to play in the overall nutrient economy of the dam (M3), an attempt was made not only to sample plant material for later phosphorus analyses, but also to obtain a quantitative estimate of the mass of Potamogeton in M3.

A rotary sampler, designed and tested by Howard-Williams and Longman (1976) was used to sample the Potamogeton. It is a rotary cutter with a blade designed to cut all the erect stems within 625cm at the sediment surface. Collecting hooks are placed strategically to collect and wind in all the shoots. A locating pin below the blade keeps the device in one place on rotation (See Figure 3).

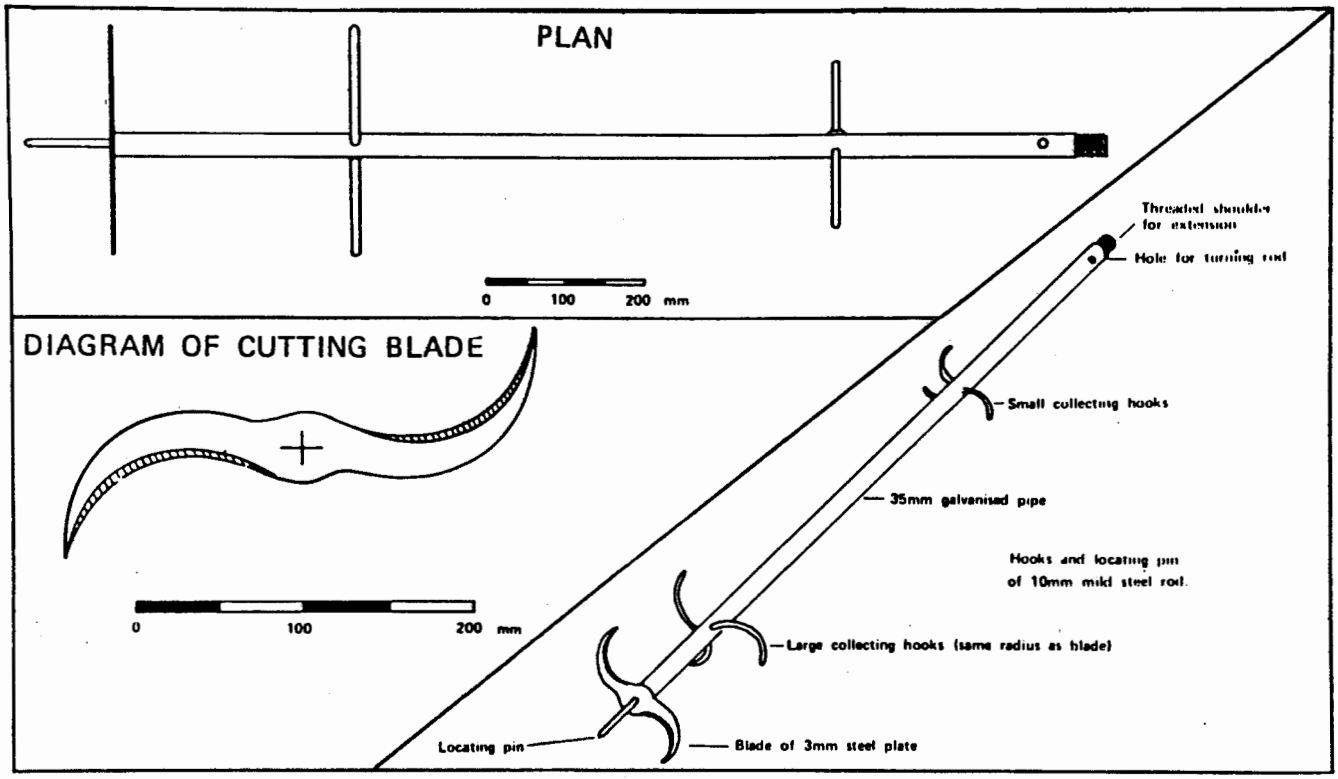


Figure 3: A diagram of the rotary sampler and a detailed drawing of the cutting blade (from Howard-Williams and Longman, 1976).

On the basis of the study by Howard-Williams and Longman (1976) a sample size of 24 was chosen for the purposes of this study in the summer. For the summer sample, the dam was not found to be deeper than 1-1.5m and, as such, fell into the "shallow" depth category which was recognised at Swartvlei by Howard-Williams and Longman (1976). Due to the clumped distribution of Potamogeton in shallow water, this large sample size was found to be necessary in order to

reduce the standard error to approximately 10% of the mean.

It was not found to be necessary to take as large a number of samples in the winter as in the summer because the mass of Potamogeton in the dam was so reduced that the range of variation was much smaller than in the summer. Large areas of the dam were completely clear of Potamogeton. It was therefore decided that a number of line transects would be taken through portions of the dam in order to estimate the percentage cover of Potamogeton. The presence or absence of Potamogeton was recorded at 1m intervals for twelve 10m long transects.

The harvested Potamogeton was washed with water in a bucket in an attempt to rinse off any organisms which had been living amongst the shoots. It must however be stressed that these measures were fairly crude, and that when either the mass or the phosphorus content of Potamogeton is referred to, the values may include a contribution from material other than Potamogeton. The samples were then oven dried for three days at 80° C and the dry mass of each was determined.

2.1.2 Sediment:

Sediment was collected with a spade from the surface of the dam floor. Two samples were collected in summer (April) and three in winter (September). The samples were collected with the aim of measuring the concentration of Total P present in the samples and using this as an indication of the quantity of decaying material present on the dam floor. The variation between summer and winter was anticipated to be fairly substantial due to the large mass of *Potamogeton* which has been observed to die back during winter. The samples were oven dried at 80°C for three days.

2.1.3 Water:

The water samples were collected at monthly intervals from M2 and M3. 1dm^3 of water was immediately filtered through 0.45µ membrane filters. The filter papers were retained and frozen, as was the water.

2.2 Phosphorus Analyses:

2.2.1 Potamogeton pectinatus: Total P analysis

15 of the 24 samples were selected for phosphorus analysis. A portion of each of the 15 samples was milled, first through a coarse mesh and then through a fine mesh. Finally, two 0.1g sub-samples were taken from each of the 15 dried and milled portions.

The 0.1g sub-samples of plant material were placed in boiling tubes and the phosphorus was solubilized from the plant material by means of two-step acid digestion procedure (Jackson, 1958).

After the tubes had cooled having been removed from the digestion block, the acid digest was diluted with distilled water up to the $25cm^3$ mark on the boiling tubes. The boiling tubes were capped with parafilm and mixed thoroughly.

For the colorimetric assays of phosphorus, an aliquot of 2ml of the diluted digest was dispensed into a 50ml volumetric flask. 8ml of the mixed colour reagent (Murphy and Riley, 1962) was added, and these were mixed well. Finally, the solution was made up to 50ml with the addition of distilled water. The blue colour of the phospho-molybdate complex develops immediately, but the absorbance readings (measured at 882nm on a Unicam S.P.500 spectrophotometer) were only measured after approximately 40 minutes.

Using the concentation curve, (See Table 4 and Figure 5) the concentration of phosphorus (~~μMolar~~)? was determined. The concentration of phosphorus was then expressed as μg P g^{-1} dry mass of sample. (See Tables 12 and 13). This conversion was calculated from the following equation:

$$\mu g\ P\ g^{-1}\ \text{dry mass sample} = \frac{\mu M \times \text{dilution factor} \times \text{At.wt.P}}{\text{dry mass sample(g)}}$$

2.2.2 Sediment Total P Analysis:

Two sub-samples of 0.1g were taken from each of the 5 samples. The two-step acid digestion as well as the colorimetric assays were conducted in precisely the same manner as the procedure described for the plant material analysis except for the use of a 5ml aliquot of the acid digest instead of a 2ml one.

2.2.3 Water P Analysis:

2.2.3.1 Analysis of Soluble Reactive Phosphorus (S.R.P.)

10ml of the 0.45μ membrane filtered water was dispensed into a 50ml volumetric flask. 8ml of the mixed colour reagent (Murphy and Riley, 1962) was added and these were mixed well. The solution was then made up to 50ml with the addition of

distilled water.

The absorbance reading (measured at 882nm on a Unicam S.P.500 Spectrophotometer) were measured after 40 minutes. Using the concentration curve, (See Table 4 and Figure 5) the concentration of phosphorus was determined. The concentration of phosphorus was then expressed as $\mu g\ P\ \ell^{-1}$. (See Table 5 and 6 and Figure 6). This conversion was calculated from the following equation:

$\mu g\ P\ l^{-1} = \mu M \times$ dilution factor x At.wt. of P.

2.3.3.2 Analysis of Total P >0.45µ:

The 0.45µ membrane filter papers were solubilized by means of a two step acid digestion procedure (Jackson, 1958). A 5ml aliquot of the acid digest was used for the colorimetric assay and the concentration was finally expressed as $\mu gP.l^{-1}$. (One litre of water had originally been filtered through the 0.45µ membrane filters). See Tables 7 and 8.

The conversion of the expression of concentration from µMolar to $\mu gP.l^{-1}$ was calculated from the following equation:

$\mu gP.l^{-1}$ =molarity x dilution factor x At.wt.of P.

3 RESULTS & DISCUSSION:

3.1 Seasonal Mass and % Cover of Potamogeton:

It has already been mentioned that Howard-Williams and Longman (1976) recommended a sample size of approximately 25 in order to reduce the %S.E. to 10% of the mean for shallow water. By shallow water, they implied a depth category of 0.75-1m. When the summer sample was conducted the dam was not found to be deeper that 1m. 24 samples were therefore taken, but as a large area of the dam was even shallower than 0.75m, many of the samples were taken from a depth category which had not been sampled by Howard-Williams and Longman. It was subsequently discovered that due to the fact that a wider range of depths had been sampled (all below 1m), the variability of the samples was even greater than that predicted by Howard-Williams and Longman.

The 24 samples were therefore divided into two depth categories, the first being 10-50cm depth and the second being 50-100cm depth, as a greater uniformity was found in the samples of the latter group. (Despite the fact that only 5 samples had been taken at this depth, they had a lower %S.E. than had te 19 samples taken at the shallower depth. See Table 2).

Table 2: Mean Dry Mass *Potamogeton* [g.625cm^{-2}] for summer and winter samples in M3.

		No Samples	Mean Dry Mass(g)	Std. Dev.	S.E.	%S.E.
Summer	Shallow 10-50cm	19	113.1	107.6	24.7	21.8
	Deep 50-100cm	5	366.18	128.5	57.5	15.7
Winter	Shallow & Deep	6	4.32	1.95	0.80	18.5

It should be mentioned that if a %S.E. of 10% of the mean is to be achieved then a greater sample size would have to be taken than was recommended by Howard-Williams and Longman.

In the summer it was found that wherever the rotary sampler as placed, a quantity of *Potamogeton* was harvested. This suggested that the percentage cover of the dam must have been close to 100%.

In the winter however, vast areas of the dam were clear of *Potamogeton*. In order to obtain an estimate of the percentage cover, twelve 10m long line transects were taken. (See Table 3). In this manner, a percentage cover of 40% was estimated.

How was % cover estimated?

Table 3: Raw data for calculation of Percentage Cover of Potamogeton in M3 in winter.

		12 line transects of 10m length											
		1	2	3	4	5	6	7	8	9	10	11	12	Total
Records of cover at 1m intervals	HIT	2	2	1	2	3	4	5	3	4	3	3	4	36
	MISS	8	8	9	8	7	6	5	7	6	7	7	6	84

The winter samples were therefore only taken from a possible 40% of the total dam area and whereas the mean dry mass per $625cm^2$ of each of the two depth categories in summer represent an estimate which may be extended over the area of the entire dam, the mean dry mass per $625cm^2$ of the winter samples may only be extended over 40% of the total area of the dam.

Therefore, in a comparison of the mean dry mass of Potamogeton present in M3 in summer and winter, a large change can be seen. (See Figure 4).

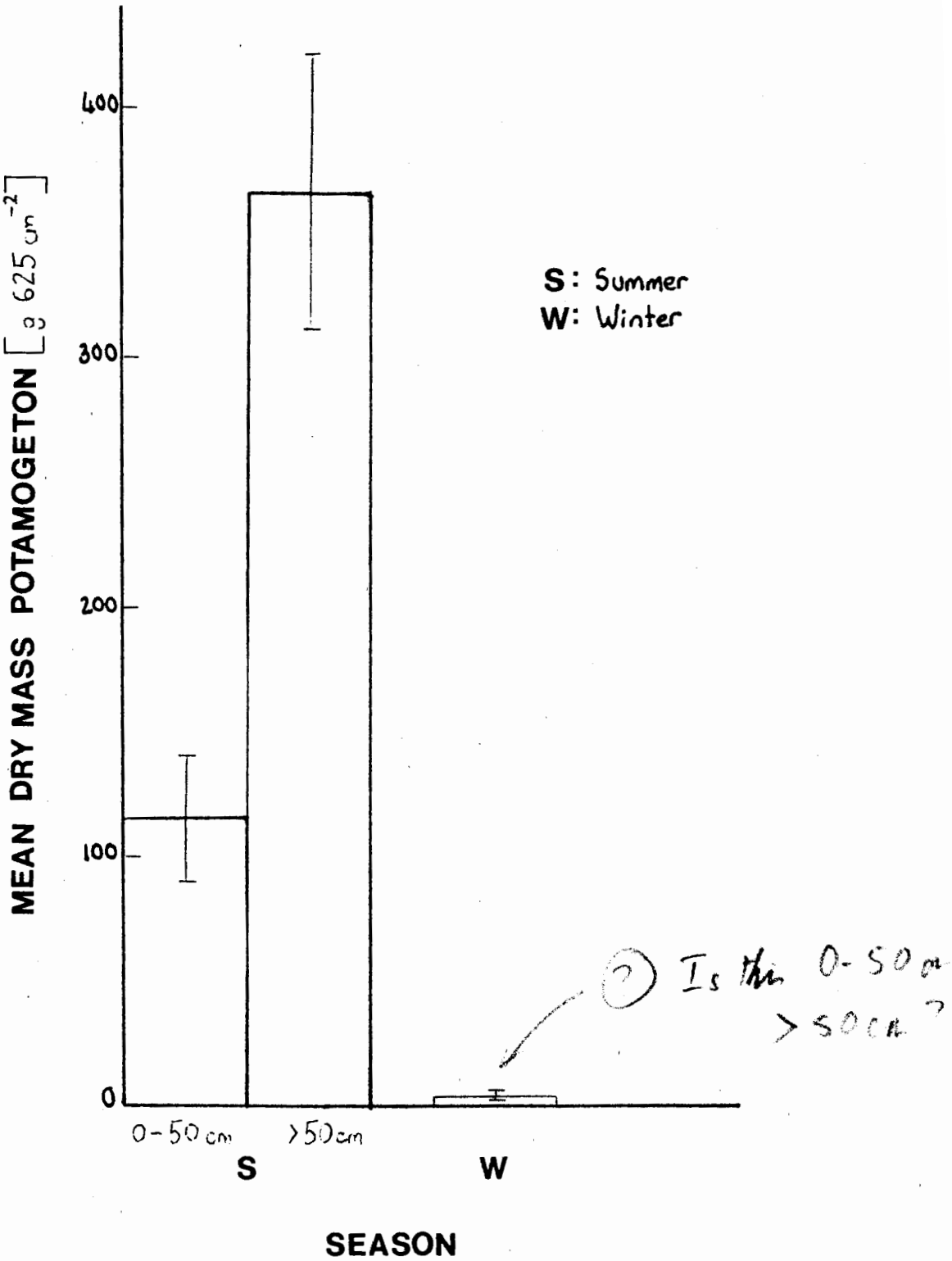


Figure 4: Mean Dry Mass Potamogeton [g.625cm] for summer and winter samples in M3.

Not only did the percentage cover of Potamogeton decrease from approximately 100% to 40%, but the mean dry mass per $625cm^2$ decreased from 113.1g (at 10-50cm) or 366.18g (at 50-100cm) in summer to 4.32g (both depth categories) in winter.

3.2 Analyses of Phosphorus Concentrations in Water:

It has already been established that a large seasonal turnover of plant material occurs in M3. Such a large body of plant material is likely to absorb a large quantity of the nutrients from the system during its growth phase. This appears to be verified by the relatively low concentrations of nutrients in the water of M3 in comparison with the incoming water from the Eerste River. (See Table 1).

When the Potamogeton dies back at the beginning of winter, these nutients would be released into the system. By measuring the concentrations of both Soluble Reactive Phosphorus as well as Total Phosphorus > 0.45µ in the water at monthly intervals, an indication of the rate and extent of release of the nutrients is obtained.

Table 4: The Absorbance Readings [O.D.U.] (882nm) for standard solutions of phosphorus [0-20µMolar].

Conc. Phosphorus [µ.Molar]	Absorbance [O.D.U.] 882nm
0.0	0.000
0.2	0.001
0.5	0.0033
1.0	0.0067
2.0	0.013
4.0	0.026
6.0	0.040
8.0	0.053
10.0	0.067
20.0	0.1347

Material & Method

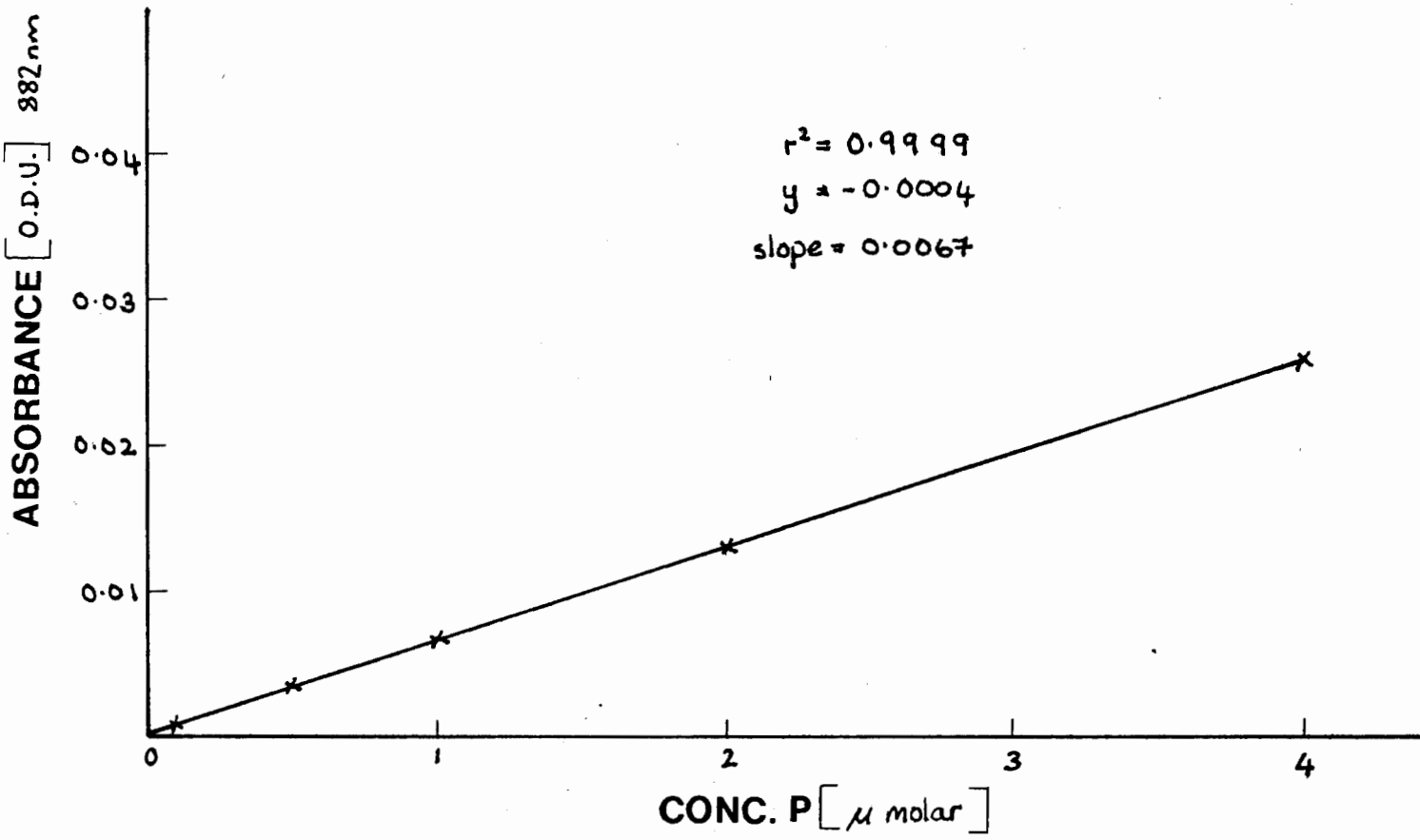


Figure 5: Standard curve for phosphorus determinations measured at 882nm.

Why is the line ? It should be
in the middle of the

3.2.1 Analysis of Soluble Reactive Phosphorus (S.R.P.):

The concentrations of S.R.P. were determined for both M2 and M3. For the months April, May and June, the concentrations of S.R.P. remained fairly constant. (See Figure 6 and Tables 5 and 6).

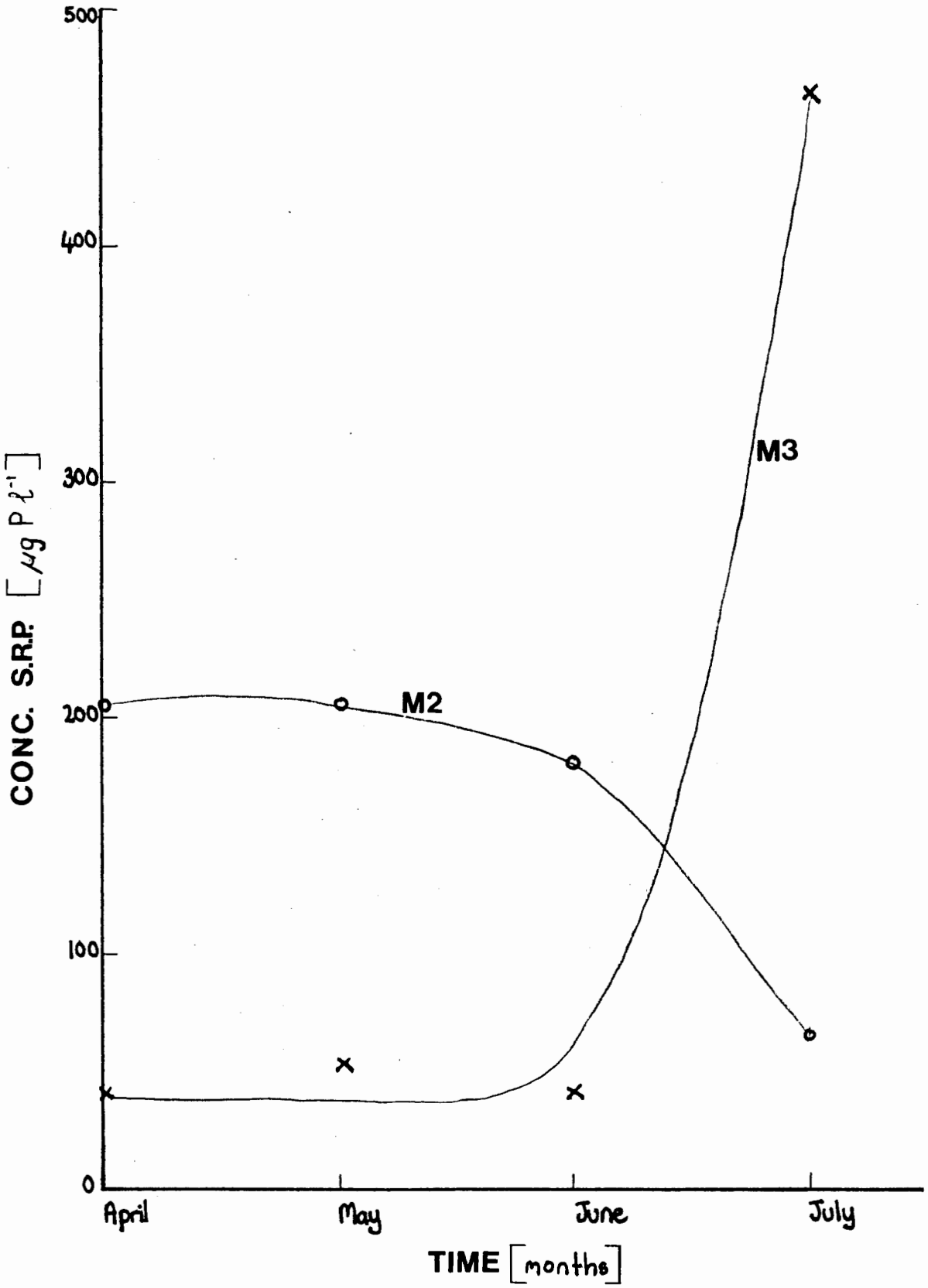


Figure 6: Concentration of Soluble Reactive Phosphorus (S.R.P.)[µgP.l^{-1}] in M2 and M3 from April to July.

Table 5: The Concentration of Soluble Reactive Phosphorus (S.R.P.)[µMolar] in M2 from April to July. Calculated from the Absorbance Readings of the samples (measured at 882nm) and converted to Concentration expressed in $\mu gP.l^{-1}$.

		Abs [882nm]	Conc. [µ Molar]	Dilution Factor	Atomic wt. of P[g/Mole]	Conc. [µg.P l^{-1}]
April	a	0.010	1.5371			238.0491
	b	0.007	1.0917	5	30.9738	169.0705
	Av	0.0085	1.3144			203.5598
May	a	0.010	1.5371			238.0491
	b	0.007	1.0917	5	30.9738	169.0705
	Av	0.0085	1.3144			203.5598
June	a	0.007	1.0917			169.0705
	b	0.008	1.2402	5	30.9738	192.0685
	Av	0.0075	1.16595			180.5695
July	a	0.002	0.3494			54.1112
	b	0.003	0.4979	5	30.9738	77.1093
	Av	0.0025	0.42365			65.6103

Table 6: The Concentration of Soluble Reactive Phosphorus (S.R.P.) [µMolar] in M3 from April to July. Calculated from the Absorbance Readings of the samples (measured at 882nm) and converted to concentration expressed in $ugP.l^{-1}$.

		Abs [882nm]	Conc. [µ Molar]	Dilution Factor	Atomic wt. of P[g/Mole]	Conc. [µg.P l^{-1}]
April	a	0.001	0.2010			31.1287
	b	0.002	0.3494	5	30.9738	54.1112
	Av	0.0015	0.2752			42.6200
May	a	0.002	0.3494			54.1112
	b	0.002	0.3494	5	30.9738	54.1112
	Av	0.002	0.3494			54.1112
June	a	0.001	0.2010			31.1287
	b	0.002	0.3494	5	30.9738	54.1112
	Av	0.0015	0.27525			42.6200
July	a	0.021	3.1702			490.9657
	b	0.019	2.8733	5	30.9738	444.9851
	Av	0.020	3.02175			467.9754

M2, which was the larger dam with less Potamogeton, had a relatively higher average concentration of S.R.P. than M3. (195µgP.l^{-1} in comparison to 46µgP.l^{-1}). The lower concentrations of S.R.P. in M3 are attributed to the action of the large macrophyte community in absorbing nutrients from the water during their growth phase.

This hypothesis is further supported by the changes in concentration of S.R.P. measured in July. Two weeks previous to the collection of the water samples in July there had been heavy rains and the water levels in the dams had risen appreciably although they were not yet full. Portions of the dam were clear of Potamogeton.

In M2, the concentration of S.R.P. dropped to an average of 65µgP.l^{-1}. This dilution effect could be accounted for by the influx of fresh rain water.

In M3 however, despite the influx of fresh rain water and the consequent dilution of the nutrients in the system, the concentration of S.R.P. was found to increase considerable (from 42µgP.l^{-1}in June to 467µgP.l^{-1} in July).

This ten-fold increase in S.R.P. concentration in M3 was associated with the senescence of the Potamogeton. The release of phosphorus into the water in a soluble form suggests that the decomposition rate of Potamogeton is extremely rapid.

In a more detailed study of this system in the future, it is recommended that frequent water samples be taken over this period. A study of the rate of decomposition of Potamogeton would also be of interest.

3.2.2 Analysis of Total Phosphorus >0.45µ in water:

Total Phosphorus >0.45µ could include colloidal or particulate phosphorus fractions.

In both M2 and M3, the concentration of Total P was found to decrease from March to July. (See Tables 7 and 8 and Figure 7).

Table 7: Concentration of Total Phosphorus >0.45μ [μMolar] in M2 from April to July. Calculated from the Absorbance Readings of the samples (measured at 882nm) and converted to concentration expressed in $\mu gP.l^{-1}$.

	Abs [882nm]	Conc. [μM]	Dilution Factor	Atomic wt.P [g/mole]	Conc. [$\mu gP.g^{-1}$]
March			0.25	30.9738	
April	0.055	8.2179	0.25	30.9738	63.3490
May	0.039	5.8425	0.25	30.9738	45.2411
June	0.043	6.4364	0.25	30.9738	49.8399
July	0.026	3.9125	0.25	30.9738	30.2962

Table 8: Concentration of Total Phosphorus >0.45µ [µMolar] in M3 from March to July. Calculated from the Absorbance Readings of the samples (measured at 882nm) and converted to concentration expressed in $\mu gP.l^{-1}$.

	Abs [882nm]	Conc. [µM]	Dilution Factor	Atomic wt.P [g/mole]	Conc. [$\mu g.p\ l^{-1}$]
March	0.067	9.9995	0.25	30.9738	77.4306
April	0.058	8.6633	0.25	30.9738	67.0838
May	0.052	7.7725	0.25	30.9738	60.1860
June	0.037	5.5456	0.25	30.9738	42.9421
July	0.018	2.7248	0.25	30.9738	21.0994

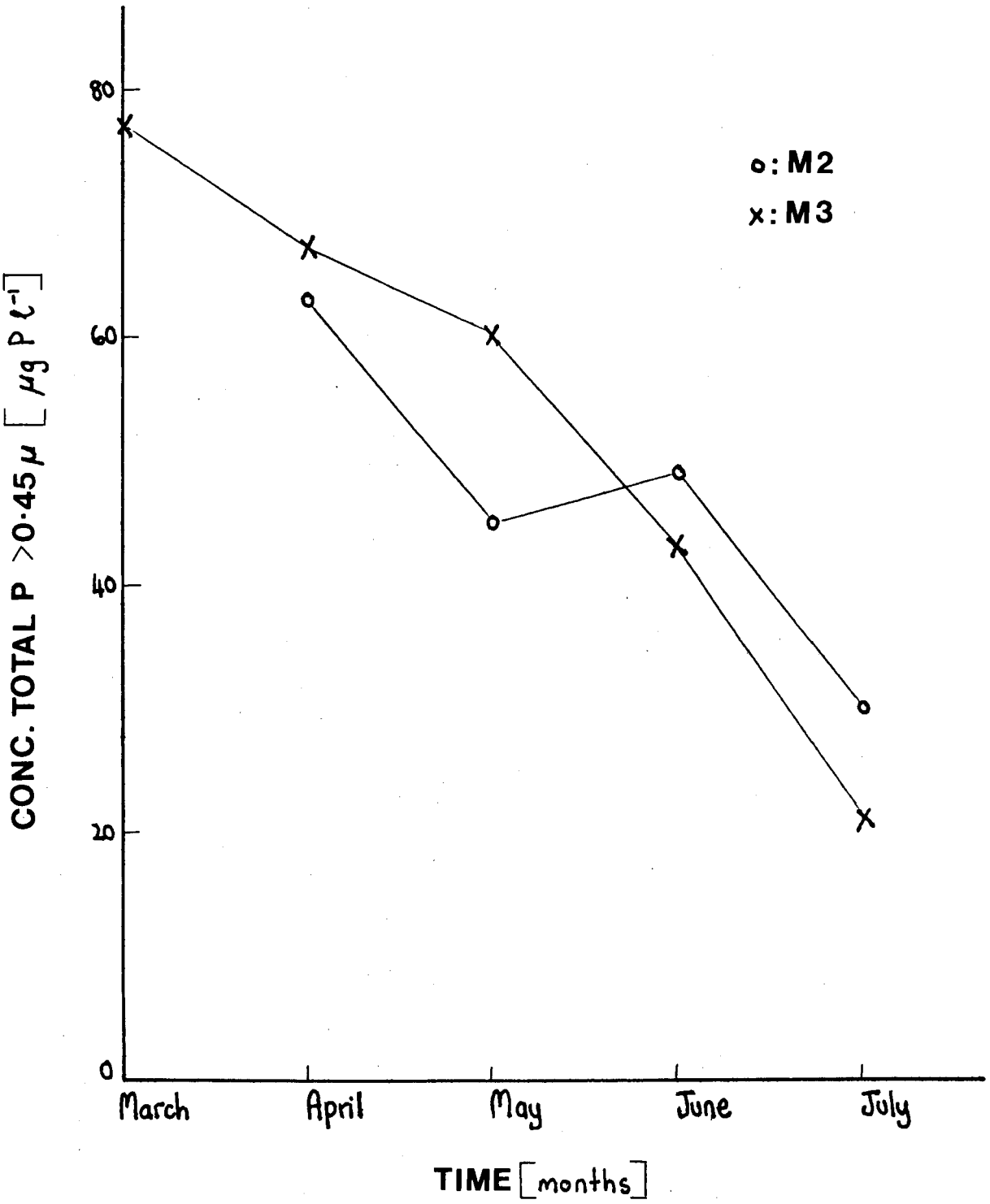


Figure 7: Concentration of Total Phosphorus >0.45μ [μgP.l^{-1}] in M2 and M3 from March to July.

This could be the result of a dilution effect although it is improbable in the light of the fact that the concentration of S.R.P. in M2 remained constant from April to June.

In M3 with senescence and decomposition of Potamogeton, an increase in the amount of colloidal and particulate particles might have been expected.

This would have reflected in an increase in the concentration of Total P >0.45µ in the water.

The opposite trend was however detected which would suggest once again, the rapid decomposition rate of Potamogeton.

The decrease in the concentrations of Total P >0.45µ might also be the result of a seasonal decline in one or several plankton populations. This is entirely speculative and further work is required, because if the opposite was proved to be true, this could have serious consequences for the long-term stability of the system. Macrophytes are seldom found to occur below a limit of 5-10% of surface light intensity. (Howard-Williams and Liptrot, 1980). Bourne (1932) found that Potamogeton pectinatus was limited in growth to areas with 4% of surface illumination. A minimum light intensity is therefore required for the growth of aquatic macrophytes. The continual influx of water

containing high concentrations of nutrients might result in a plankton bloom when the nutrients are released into the water following the die-back of Potamogeton. If this bloom was large enough, it would reduce the light intensity below the water surface, and might prevent the regrowth of Potamogeton.

3.3 Analysis of Phosphorus Concentrations in Sediment

The concentration of Total P in the summer and winter sediment samples was determined. (See Tables 9,10 and 11 and Figure 8). With the large amount of plant material senescing and decomposing in early winter, the concentration of phosphorus in the sediment might be expected to increase at some stage between senescence of the Potamogeton and complete decomposition (which appears to result in an increase in concentration of S.R.P. but no significant increase in the phosphorus concentration in the sediment or in the particulate water fraction).

Table 9: Concentration of Total Phosphorus is Sediment [μMolar] for summer samples in M3. Calculated from the Absorbance Readings of the Samples measured at 882nm) and converted to concentration expressed in $\mu gP.l^{-1}$.

Sample No.		Abs [882nm]	Conc. [μM]	Dilution Factor	Atomic wt.P [g/mole]	Dry wt.of Sample[g]	Conc. [$\mu gP.g^{-1}$]
S#1	a	0.032	4.8033	0.25	30.9738	0.1	371.94
	b	0.033	4.9518				383.44
	Av	0.0325	4.87755				377.69
S#2	a	0.050	7.4756	0.25	30.9738	0.1	578.87
	b	0.060	8.9602				693.83
	Av	0.055	8.21795				636.35

Table 10: Concentration of Total Phosphorus in Sediment [μMolar] for winter samples (measured in 882nm) and converted to concentration expressed in $\mu gP.l^{-1}$

Sample No.		Abs [882nm]	Conc. [μM]	Dilution Factor	Atomic wt.P [g/mole]	Dry wt.of Sample[g]	Conc. [$\mu gP.g^{-1}$]
W#1	a	0.051	7.6241	0.25	30.9738	0.1	590.37
	b	0.056	8.3664				647.85
	Av	0.0535	7.99525				619.11
W#2	a	0.103	15.3441	0.25	30.9738	0.1	1188.16
	b	0.112	16.6803				1291.63
	Av	0.1075	16.0122				1239.895
W#3	a	0.037	5.5456	0.25	30.9738	0.1	429.42
	b	0.045	6.7333				521.39
	Av	0.041	6.13945				475.405

Table 11: Mean Concentration of Total Phosphorus in Sediment [$\mu g P g^{-1}$] for summer and winter samples in M3.

	No Samples	Mean Conc Total P [$\mu g.P.g^{-1}$]	Std Dev	S.E.	%S.E.
Summer	4	507.02	156.61	78.31	15.45
Winter	6	778.14	366.48	149.61	19.23

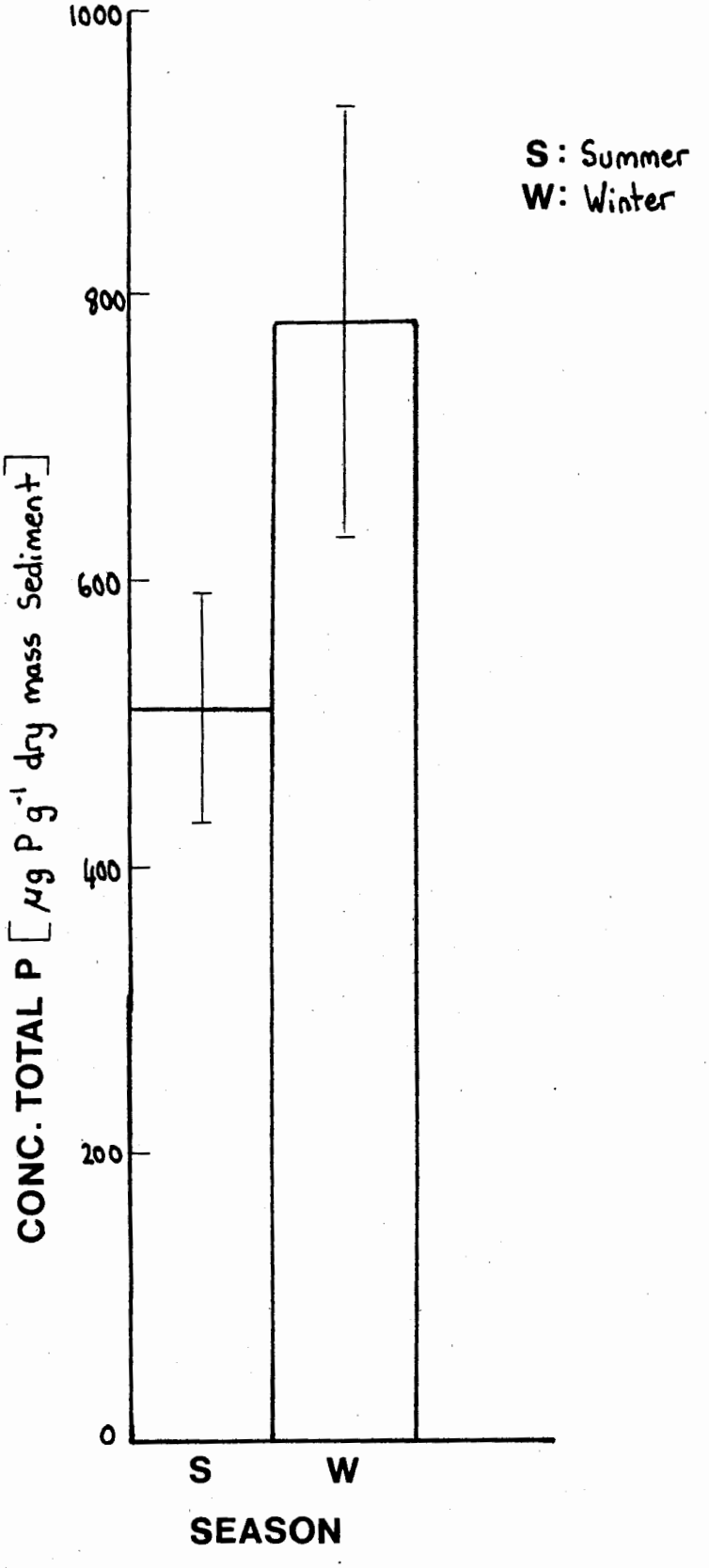


Figure 8: Average Concentration of Total Phosphorus in Sediment [µgP.g^{-1} dry mass Sediment] for summer and winter samples in M3.

The sediment samples were collected in late summer (April) and late winter (September). When the sediment sample was collected in September, the floor of the dam was completely clear of decomposing organic material and no significnt difference at the 95% confidence level was detected in the Total P concentration of these samples and those taken in April. (See Appendix A)

It is suggested that sediment samples should be taken at more regular intervals between July and September. This would provide some indication of the rate of decomposition of Potamogeton.

3.4 Analysis of Phosphorus Concentrations in Potamogeton:

The concentration of Total Phosphorus in the summer and winter samples of Potamogeton was found to be significantly different (at the 95% confidence level - see Appendix B).

The winter samples had an average concentration of 323µgP.g^{-1} dry mass while the summer samples had a higher concentration of 388µgP.g^{-1} dry mass. (See Tables 12,13 and 14 and Figure 9).

Table 12: Concentration of Total Phosphorus in Potamogeton [μMolar] for summer samples in M3. Calculated from Absorbance Readings of the samples (measured at 882nm) and converted to concentration expressed in $ugP.g^{-1}$.

Sample No.		Abs [882nm]	Conc. [μM]	Dilution Factor	Atomic wt.P [g/mole]	Dry wt.of Sample[g]	Conc. $[ugP.g^{-1}]$
S#2	a	0.015	2.2794	0.625	30.9738	0.1	441.26
	b	0.015	2.2794				441.26
	Av	0.015	2.2794				441.26
S#3	a	0.015	2.2794	0.625	30.9738	0.1	441.26
	b	0.013	1.9825				383.78
	Av	0.014	2.13095				412.52
S#4	a	0.010	1.5371	0.625	30.9738	0.1	297.56
	b	0.011	1.6856				326.31
	Av	0.0105	1.61135				311.94
S#6	a	0.012	1.8341	0.625	30.9738	0.1	355.06
	b	0.008	1.2402				240.09
	Av	0.010	1.53715				297.58
S#8	a	0.018	2.7248	0.625	30.9738	0.1	527.48
	b	0.018	2.7248				527.48
	Av	0.018	2.7248				527.48
S#21	a	0.013	1.9825	0.625	30.9738	0.1	383.78
	b	0.013	1.9825				383.78
	Av	0.013	1.9825				383.78
S#22	a	0.012	1.8341	0.625	30.9738	0.1	355.06
	b	0.013	1.9825				383.78
	Av	0.0125	1.9083				369.42
S#23	a	0.010	1.5371	0.625	30.9738	0.1	297.56
	b	0.013	1.9825				383.78
	Av	0.0115	1.7598				340.67
S#24	a	0.015	2.2794	0.625	30.9738	0.1	441.26
	b	0.013	1.9825				383.78
	Av	0.014	2.13095				412.52

Table 13: Concentration of Total Phosphorus in Potamogeton [µMolar] for winter samples in M3. Calculated from the Absorbance Readings of the samples (measured in 882nm) and converted to concentration expressed in $\mu gP.g^{-1}$.

Sample No.		Abs [882nm]	Conc. [µM]	Dilution Factor	Atomic wt.P [g/mole^{-1}]	Dry wt.of Sample[g]	Conc. [$\mu gP.g^{-1}$]
W#1	a	0.005	0.7948	0.625	30.9738	0.1	153.86
	b	0.007	1.0917				211.34
	Av	0.006	0.94325				182.60
W#2	a	0.009	1.3887	0.625	30.9738	0.1	268.83
	b	0.008	1.2402				240.09
	Av	0.0085	1.31445				254.46
W#3	a	0.013	1.9825	0.625	30.9738	0.1	383.78
	b	0.011	1.6856				326.31
	Av	0.012	1.83405				355.06
W#4	a	0.010	1.5371	0.625	30.9738	0.1	297.56
	b	0.014	2.1310				412.53
	Av	0.012	1.83405				355.06
W#5	a	0.010	1.5371	0.625	30.9738	0.1	297.56
	b	0.014	2.1310				412.53
	Av	0.012	1.83405				355.06
W#6	a	0.015	2.2794	0.625	30.9738	0.1	441.26
	b	0.015	2.2794				441.26
	Av	0.015	2.2794				441.26

Table 14: Mean Concentration of Total Phosphorus in Potamogeton [$ugP.g^{-1}$] for summer and winter samples in M3.

	No Samples	Mean Conc. Total P [$ug.P.g^{-1}$]	Std Dev	S.E.	%S.E.
Summer	18	388.57	74.58	17.54	4.52
Winter	12	323.91	95.29	27.51	8.49

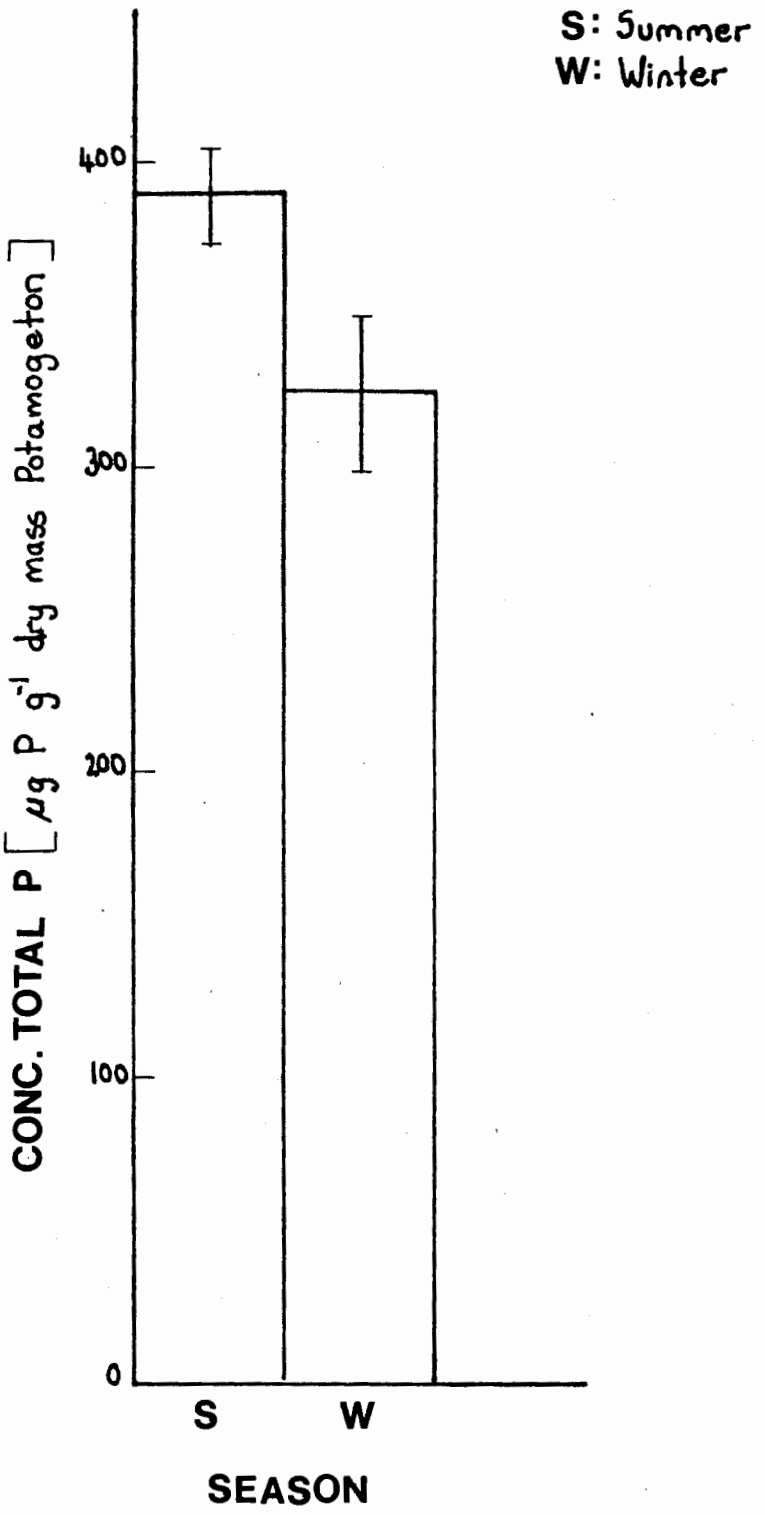


Figure 9: Average Concentration of Total Phosphorus in Potamogeton [µgP.g dry mass Potamogeton] for summer and winter samples in M3.

The reason for this decrease in phosphorus concentration in the plant material in winter (despite the increase in available phosphorus in the water) was assumed to be the fact that in summer, the Potamogeton is in a growth phase and therefore, assimilating nutrients, whereas in September the little remaining Potamogeton was already in a senescent phase.

4. CONCLUSION:

The Macrophyte community (Potamogeton pectinatus) plays an important role in nutrient cycling in M3. It is assumed that the improved water quality in this system (in comparison with that of the incoming water from the Eerste River) is due to the uptake of nutrients by the macrophyte community.

Potamogeton pectinatus dies back in early winter and the previously assimilated nutrients are released back into the system. The rate of decomposition and therefore release of nutrients appears to be extremely rapid with little retention of organic matter or phosphorus on the surface of the dam floor. The concentration of phosphorus in the small amount of plant material found in winter is lower than that of the plant material in summer. The reason for this may be due to the fact that the Potamogeton is in a senescent phase in winter.

With the continuous influx of water with high concentrations of nutrients from the Eerste River, the long-term stabiltiy of the system might be in jeopardy.

Future research should determine whether nutrients are removed from this system in any way and the possibility of

harvesting the Potamogeton in order to remove nutrients from the system is suggested.

Appendix A: One Tailed T. Test for Summer and Winter Sediment Samples.

Summer: $\bar{x}_1 = 507.02$ $\quad S.D_1^2 = 24526.7$ $\quad N_1 = 4$

Winter: $\bar{x}_2 = 778.14$ $\quad S.D_2^2 = 134307.6$ $\quad N_2 = 6$

where: $\bar{x}$ = Mean Conc. Total P [$\mu g\ P.\ g^{-1}$ dry mass]

$S.D^2$ = Standard deviation^2

N = sample size

degrees of freedom = $4 + 6 - 2 = 8$

$$t_8 = \frac{(\bar{x}_2 - \bar{x}_1)\sqrt{(N_1 + N_2 - 2)(N_1 N_2)}}{\sqrt{(N_1 S_1^2 + N_2 S_2^2)(N_1 + N_2)}}$$

$$= \underline{1.25} \rightarrow$$

t_8 crit 95% = $\underline{1.86}$ (One Tailed)

$\therefore\ t_8 < t_{8\,crit.}$

$\therefore$ There is no difference between the samples. Any difference is due to random error.

Appendix B: One Tailed T-Test for Summer and Winter Sediment Samples

Summer: $\bar{x}_1 = 388.57$ $\quad S.D._1^2 = 5562$ $\quad N_1 = 18$

Winter: $\bar{x}_2 = 323.91$ $\quad S.D._2^2 = 9080$ $\quad N_2 = 12$

where: $\bar{x}$ = Mean Conc. Total P [$\mu g\, P.\, g^{-1}$ dry mass]

$S.D.^2$ = Standard deviation^2

N = Sample size

degrees of freedom $= 18 + 12 - 2 = 28$

$$t_{28} = \frac{(\bar{x}_1 - \bar{x}_2)\sqrt{(N_1 + N_2 - 2)(N_1 N_2)}}{\sqrt{(N_1 S_1^2 + N_2 S_2^2)(N_1 + N_2)}}$$

$$= \underline{2.008}$$

t_{28} crit at 95% $= \underline{1.701}$ (One Tailed)

$\therefore\ t_{28} > t_{28}$ crit

$\therefore$ Samples are different.

REFERENCES:

Bourne W.S.(1932). Ecological and physiological studies of certain aquatic angiosperms. Contrib. Boyce Thompson Inst.,4;pp.425-496.

Howard-Williams C. and Allanson B.R.(1978). Institute for Freshwater Studies Special Report No 78/3, Part II. The limnology of Swartvlei with special reference to production and nutrient dynamics in the littoral zone. Institute for Freshwater Studies, Rhodes University, Grahamstown.

Howard-Williams C. and Liptrot M.R.M.(1980). Submerged Macrophyte Communities in a Brackish South African Estuarine-Lake System. Aquatic Botany, 9; pp101-116.

Howard-Williams C. and Longman T.G.(1976). A Quantitative Sampler for Submerged Aquatic Macrophytes. Journal of the Limnological Society of Southern Africa, Vol.2 No.1. pp31-33.

Hutchinson G.E.(1957). A treatise on Limnology, Volume I. Geography, Physics and Chemistry. Wiley and Sons, New York, pp727-752.

Jackson M.L.(1958). Soil Chemical Analysis. Prentice-Hall Inc. Englewood Cliffs, New Jersey.

Murphy J. and Riley J.P.(1962). A modified single solution method for the determination of phosphate in natural waters. Anal. Chem. Acta 27, pp31-36.

Noble R.G. and Hemens J.(1978). Inland water ecosystems in South Africa - a review of research needs. South African National Scientific Programmes Report No.34.

Rigler F.H.(1973). A dynamic view of the phosphorus cycle in lakes. In. Environmental phosphorus handbook. Griffith et al (eds). Wiley and Sons, New York, pp539-572.

Toerien D.F.(1977). A review of eutrophication and guidelines for its control in South Africa. CSIR Special Report WAT 48.

Twinch A.J.(1980). Some Aspects of Phosphorus Cycling in Midmar Dam. PhD Thesis. Department of Botany, University of Natal, Pietermaritzburg.

Twinch A.J. and Breen C.M.(1980). Advances in understanding phosphorus cycling in inland waters - their significance for South African limnology. South African National Scientific Programmes Report No.42.

Wetzel R.G.(1975). Limnology. W.B. Saunders Co., Philadelphia. pp215-245.