Landnote

Department of Conservation & Land Management

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WATER QUALITY AT MONKEY MIA, SHARK BAY

A Report and Recommendations Based on the 1991 Monitoring Programme

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SUMMARY

Nutrient and bacterial levels in the beachwater and seawater were monitored monthly over a twelve month period at Monkey Mia, Shark Bay in 1991. The data suggests an overall improvement in both nutrient and bacterial levels since the modification of the sewage disposal system. However, nitrate levels remain high and it is unclear whether these result from the sewage system or other sources in the area.

INTRODUCTION

In 1989 the death of one dolphin and disappearance of six others, which were regular visitors to Monkey Mia, prompted the Environmental Protection Authority to investigate the possible cause. It was found that both the interstitial (beach) water and seawater immediately adjacent to the beach contained elevated levels of faecal bacteria and had extremely high nitrogen concentrations (E.P.A. 1989). The source of the contamination was thought to be the septic systems of the Monkey Mia Caravan Park and the Visitor Centre which were both in close proximity to the beach. Although it was not proven that the high levels of contamination were the cause of the dolphin disappearance, it was recommended that the treatment of wastewater at Monkey Mia be modified. As a consequence, the area's septic systems were adapted to direct the sewage effluent further away from groundwater sources where interchange with seawater was thought to occur. In August 1989 the Department of Conservation and Land Management (Stoddart 1989) conducted an investigation to assess whether water quality had improved as a result of the modifications and found that nitrogen levels in both the beachwater and seawater were considerably lower than that recorded by the E.P.A (1989). However, bacterial counts were found to be higher in some beachwater sites and, as a consequence, Stoddart (1989) recommended that further sampling was required.

Subsequently, a twelve month monitoring programme was established in January 1991 to examine the temporal variation in nutrient parameters and bacterial counts and to provide baseline data for future reference. The results of this monitoring programme are presented here. In addition, the results of two intensive sampling sessions over two week tidal cycles in both winter and summer are presented and considered in terms of the critical timing and frequency of sampling for any future investigation.

METHODS

Each month, between January and December 1991, six water samples were taken from the seawater adjacent to the Monkey Mia caravan park and four from the beachwater at sites marked in Figure 1. In addition, during a two week tidal cycle in July 1991 and again in January 1992, water samples were taken from those same sites every two days. On each occasion, all samples were taken within five hours of each other, between 8am and 1pm. The procedures used in sampling were identical to that used by Stoddart (1989). All samples were analysed for total coliforms, faecal coliforms, faecal streptococci and salmonella bacteria at the WA State Health Laboratories. Seawater samples were analysed for orthophosphate (PO_4) total phosphorus (TP), ammonium–N (NH_4), nitrate-nitrite-N (NO_3-NO_2-N), total nitrogen (TN), chlorophyll-*a* and phaeophytin. Beachwater samples were analysed for orthophosphate, ammonium and nitrate-nitrite only. All nutrient analyses were performed by the Nutrient Analysis Laboratory at Murdoch University.

RESULTS

Monthly monitoring programme

Salmonella bacteria was not isolated from samples taken from either the beachwater or seawater sites. Faecal coliform and streptococci counts at the beachwater sites were similar to those recorded by the E.P.A. (1989) but were lower than that recorded by Stoddart (1990; Table 1). However, bacterial counts at the beachwater 'control' site (BW4) were significantly ($P<0.05$) higher than the other sites and were also greater than that recorded previously (Table 1). Seawater concentrations of faecal bacteria were generally low (<2 bacteria / 100mL).

Nutrient concentrations at the seawater 'control' site (SW6) were similar to those of the other sampling sites (SW 1-5) with the exception of nitrogen which tended to be lower at the 'control' site (Table 1) . While orthophosphate levels in the seawater were lower than that recorded previously, nitrogen concentrations were higher than that recorded by Stoddart (1990), but lower than that recorded by the E.P.A. (1989) (Table 1). At the beachwater sites, nitrate-nitrite levels were particularly high with a average concentration in excess of 15000µg/L, six times higher than that recorded at the 'control' site. Although this concentration is much lower than that recorded by the E.P.A. (1989) it is an order of magnitude higher than that recorded by Stoddart (1990) after the modification of the sewage system (Table 1).

Monthly variation in water quality parameters for both the beachwater and seawater zones are shown in Figure 2. Overall, the parameter concentrations within the seawater were at least one order of magnitude lower than that of the beachwater. High concentrations within the beachwater did not necessary correspond with high levels in the seawater in the same period. Nitrate-nitrite levels in the beachwater were relatively high throughout the year with the highest concentration being recorded in January (44917 ± 3468µg/L) and the lowest in June (4942 ± 3030µg/L; Fig. 2). Seawater concentrations of nitrate-nitrate were highest in January (80 ± 43 µg/L) and December (84 ± 38 µg/L) and lowest in November (4 ± 2 µg/L). Peak ammonium concentrations in March and October in the beachwater and seawater, respectively, did not coincide with or immediately precede peak nitrate-nitrite concentrations (Fig. 2). With the exception of February, average orthophosphate concentrations in the seawater and in the beachwater were relatively constant, remaining below 3 and 300µg/L, respectively (Fig. 2). The average nitrogen : phosphorus ratio recorded in the seawater was 24:1. It should be noted that chlorophyll-*a* and phaeophytin concentrations did not exceed 1µg/L throughout the year.

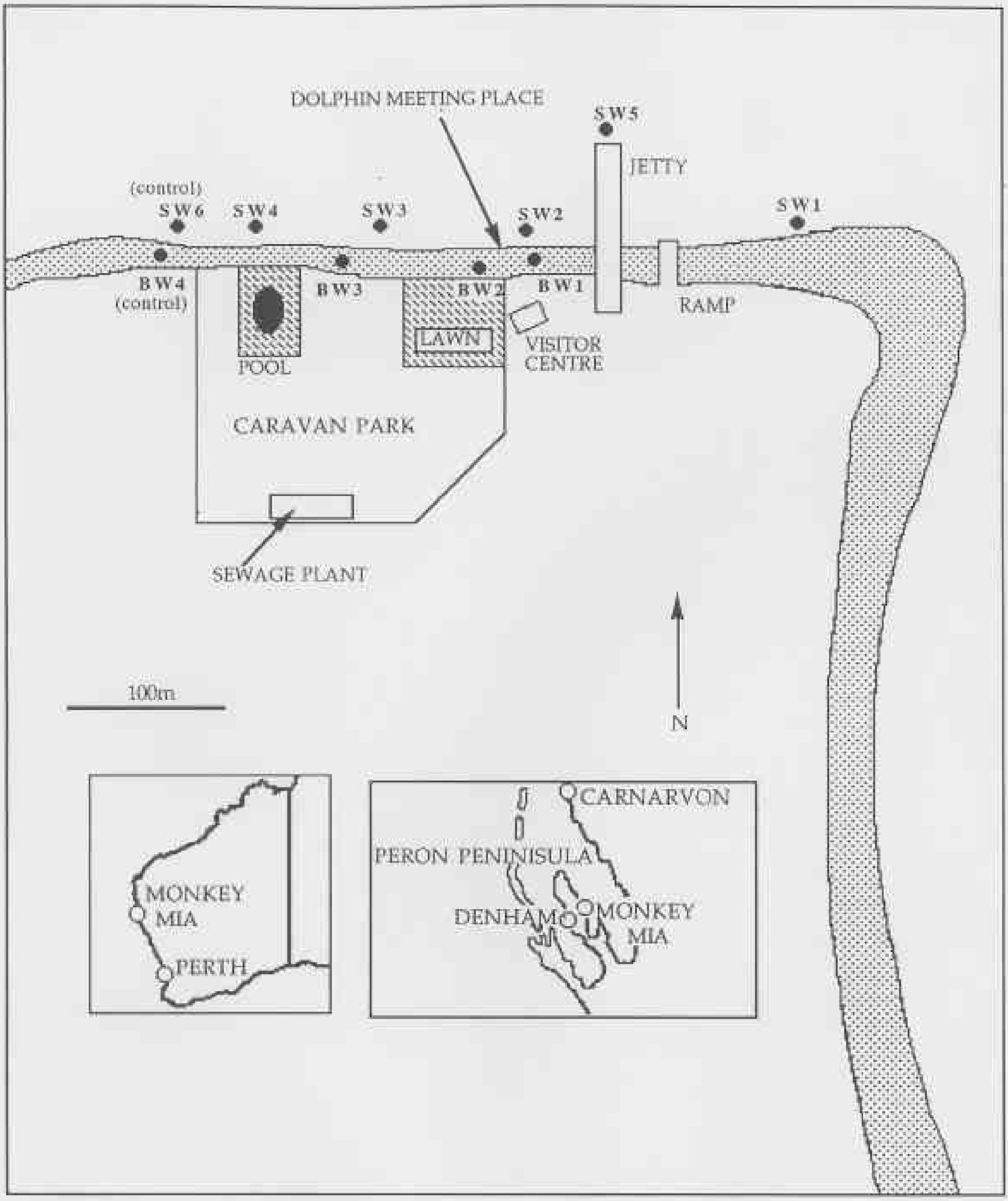

Figure 1: Map showing the location of the sampling sites in relation to the Monkey Mia caravan park and sewage plant.

Faecal bacterial concentrations were also low throughout the year with peak concentrations of both streptococci and coliforms accompanied by large error terms and likely due to sample contamination (Fig. 2).

In 1991, visitor numbers to Monkey Mia were lowest in February and highest in July and October (Fig. 3). There was no correlation between visitor numbers and nitrate–nitrite concentrations in the beachwater ($r^2=0$). However, it appears that to some extent, high visitors numbers were followed, belatedly, by increased levels of this nutrient (Fig. 3).

Tidal Cycle

Since nitrate-nitrite had the highest concentration of the parameters measured, this was used to illustrate tidal variation. During both winter (Fig. 4) and summer (Fig. 5) the concentration of nitrate-nitrite in the beachwater and seawater remained relatively constant over the two week tidal cycles. The incidence of neap tides appeared to make little difference to the concentration of nitrate-nitrite in either the beachwater or the adjacent seawater (Fig. 4 and 5).

DISCUSSION

Although elevated levels of faecal bacteria at the beachwater 'control' site (BW4) were likely due to contamination, this might also be the result of spatial variability in groundwater flow or bacterial survival. Excluding that site, faecal bacteria and orthophosphate levels recorded in the beachwater and seawater suggest an general improvement in the water quality at Monkey Mia since changes to the drainage system. However the nutrient levels are still higher than that found by Crossland (1983) for temperate waters. Although there was no evidence of any planktonic algal bloom throughout the year, the high N:P ratio of 24 would facilitate rapid growth of phytoplankton in these waters, given the right conditions (Goldman 1976). In the long term, there might also be a marked reduction in seagrass density within the shallow embayment as the incidence of epiphytic algal growth upon seagrasses increases and reduces productivity (Silberstein *et al.* 1986). The source of the nitrate will need to be determined. The trend illustrated in Figure 3 suggests that the sewage plant may still be causing this input although it remains to be explained why nitrate levels would remain high when orthophosphate, ammonium and bacterial levels had dropped.

An alternative source of nitrate may result from the practice of fertilizing the lawned area adjacent to the beach. Lawn fertilizers are rich in nitrates which may be easily leached into the groundwater following periods of heavy rainfall. The lawned area was fertilized on four occasions during 1991 (R. Shepherd, pers. comm.). These are thought to have occurred during early February and May, late July and mid October, at which time 40kg of either the slow release "Richglow Custom Blend" or "Organic Gro–Well" were applied. While there was no apparent increase in beachwater nitrate levels following these applications (Fig. 3) any increase might not have occurred until after a period of rain. However, it is difficult to ascertain the exact period between the fertilizer application and the occurrence of rain. The months of June and July recorded the highest rainfall (>80mm), but more than 20mm of rainfall was also recorded in February, April and May (Appendix 1).

With the paucity of information available, it is not possible to ascertain absolutely the source of the high nitrate concentrations in the beachwater. Since lawn fertilizing is a probable source the requirement for the lawned area should be considered in terms of whether it could be replaced with some other ground covering. If the lawn is necessary, then the practice of fertilizing it should be stopped or reduced. It may be possible to monitor levels of nutrient within the lawn and only apply fertilizer when it is required.

Table 1: Beachwater and seawater concentrations of faecal bacteria and nutrients (average ± standard error) as determined by the E.P.A. (1989), Stoddart (1990) and the 1991 monitoring program respectively.

Parameter	BEACHWATER Control	BEACHWATER Sites	SEAWATER Control	SEAWATER Sites
Faecal Coliforms (bacteria/100mL)	* 0	13.3 ± 7.7	0.0	0.0
	** 0	51.0 ± 20.9	0.0	0.0
	***** 33.8 ± 20.4**	**3.2 ± 0.7**	**0.0**	**1.7 ± 0.7**
Faecal Streptococci (bacteria/100mL)	0.0	20.0 ± 9.4	0.0	0.0
	19.0	404.3 ± 311.7	0.0	0.0
	189.8 ± 108.7	**14.3 ± 9.8**	**0.2 ± 0.2**	**0.9 ± 0.4**
Orthophosphate (µg/L)	-	-	7.0	9 ± 2.1
	-	-	3.0	7.5 ± 2.5
	83.7±10.0	**214.3 ± 14.4**	**1.8 ± 0.6**	**1.7 ± 0.2**
Total Phosphorus (µg/L)	-	-	19.0	28.5 ± 4.6
	-	-	42.0	40 ± 4.9
	-	-	**13.2 ± 1.1**	**18.4 ± 0.8**
Nitrate - Nitrite - N (µg/L)	263.0	77666.7 ± 24387.3	6.0	250.0
	7.0	1500.0 ± 204.1	2.0	6.5 ± 3.9
	2356.2±755.2	**15761.3 ± 1199.4**	**23.5 ± 8.7**	**56.6 ± 7.8**
Ammonium - N (µg/L)	-	-	6.0	9.0
	-	-	1.0	2.0
	29.6 ± 13.5	**14.0 ± 4.2**	**2.3 ± 1.1**	**2.4 ± 0.4**
Total Nitrogen (µg/L)	-	-	267.0	482.0
	-	-	140.0	147.5 ± 0.4
	-	-	**239.2 ± 23.4**	**320.8 ± 11.4**

* E.P.A. (1989)
** Stoddart (1990)
*** 1991 monitoring

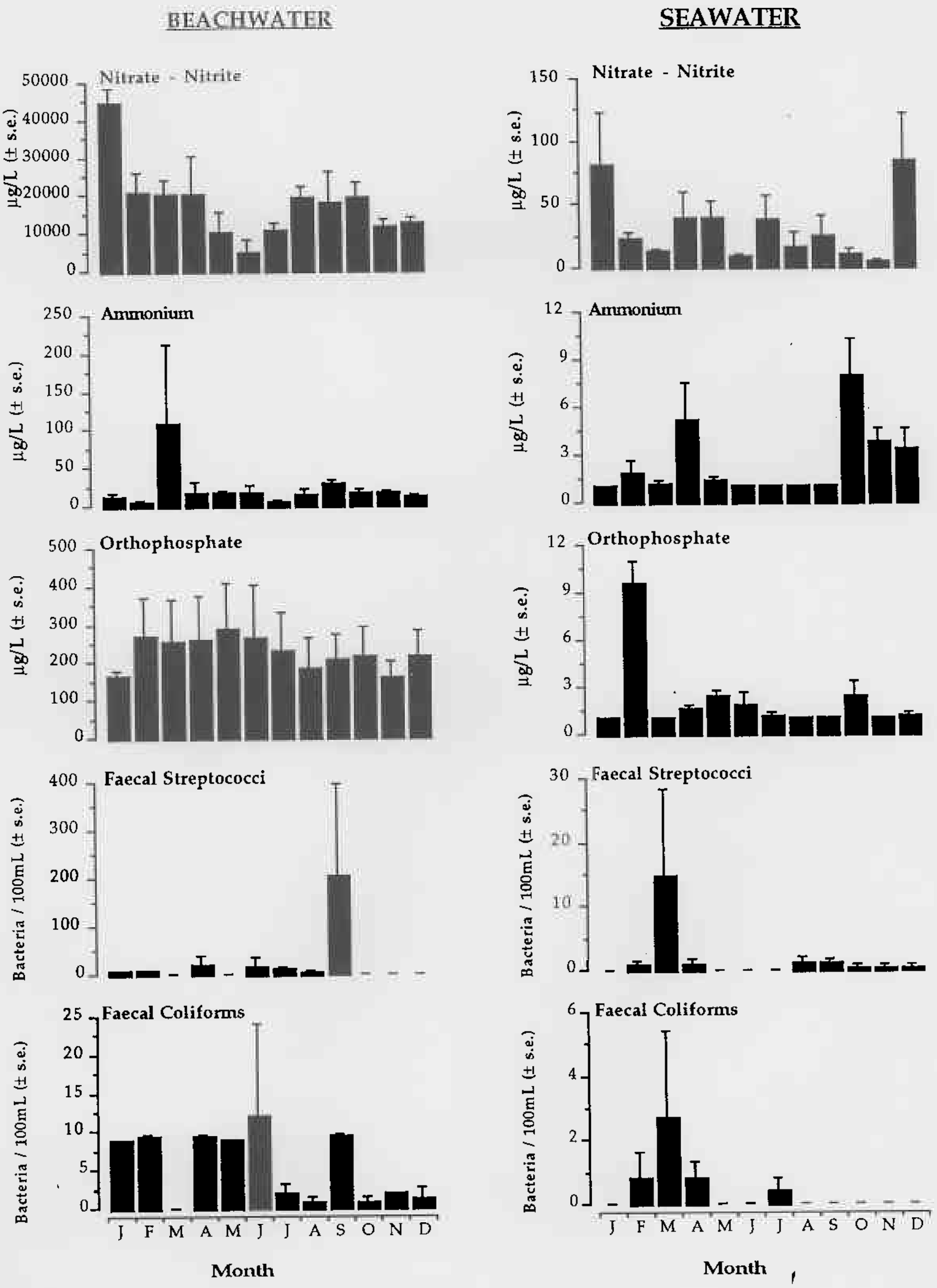

Figure 2: Monthly variation in water quality parameters of beachwater and seawater sites during 1991.

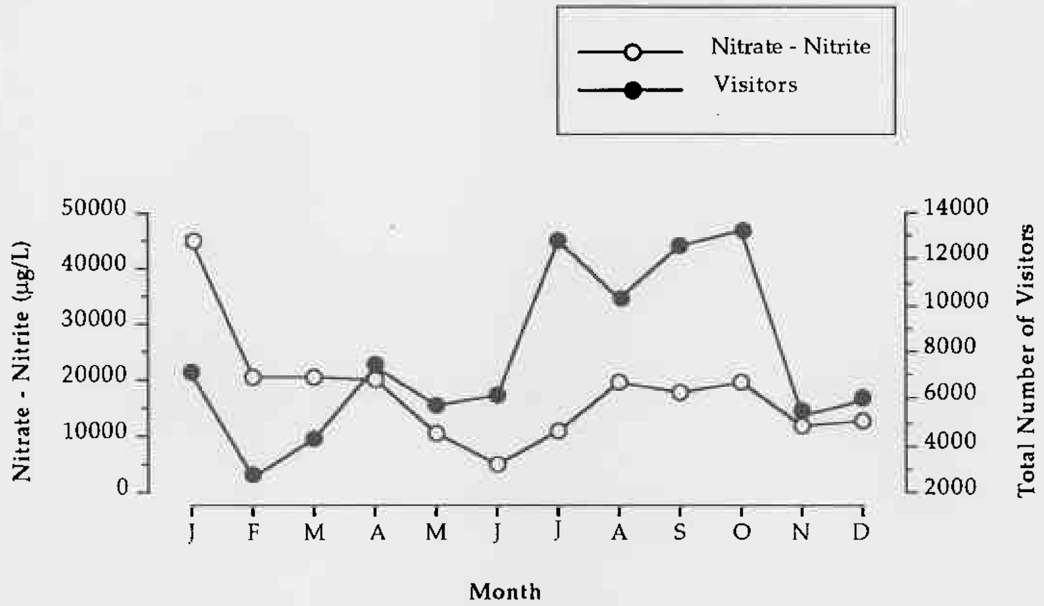

Figure 3: Relationship between nitrate - nitrate concentration in the beachwater samples and monthly visitor numbers.

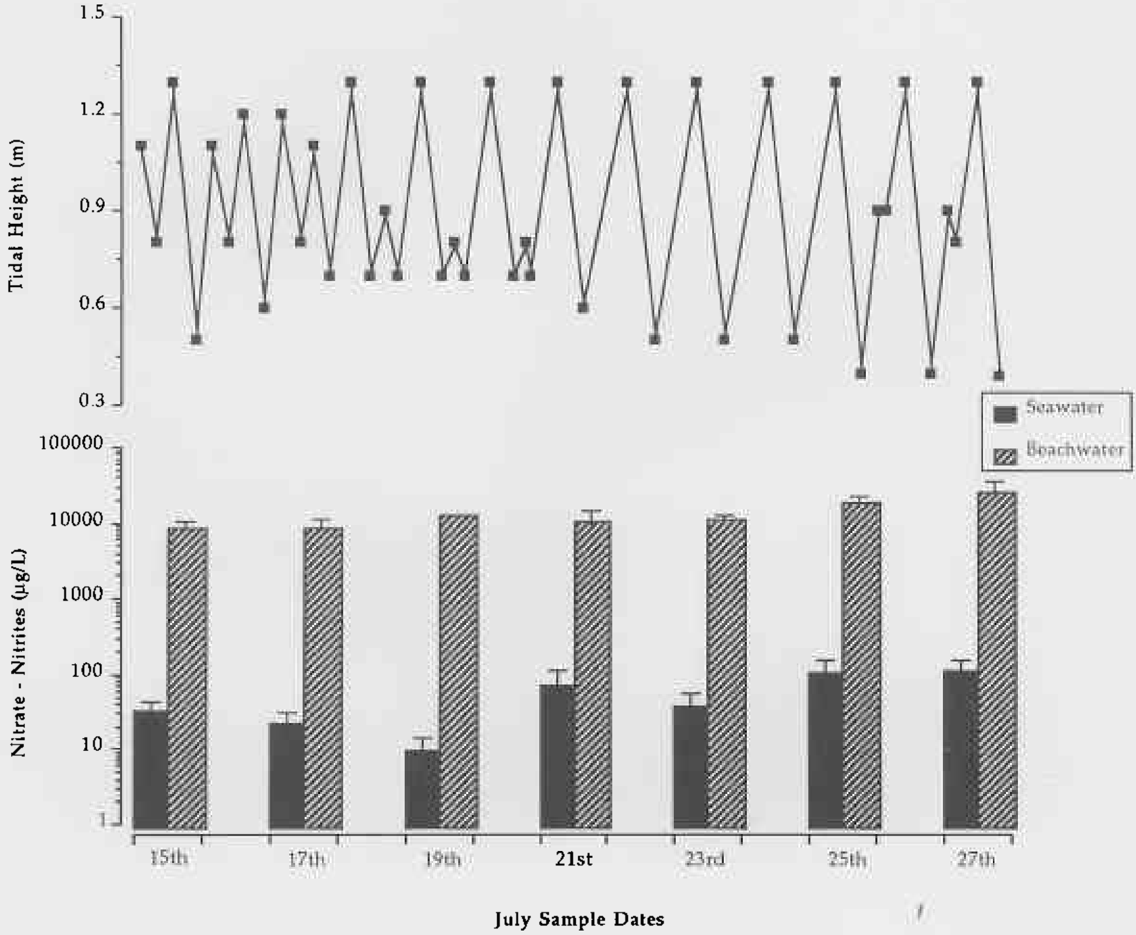

Figure 4: Variation in the concentration of nitrate - nitrate in seawater and beachwater over a two week tidal cycle in July 1991. Note log scale.

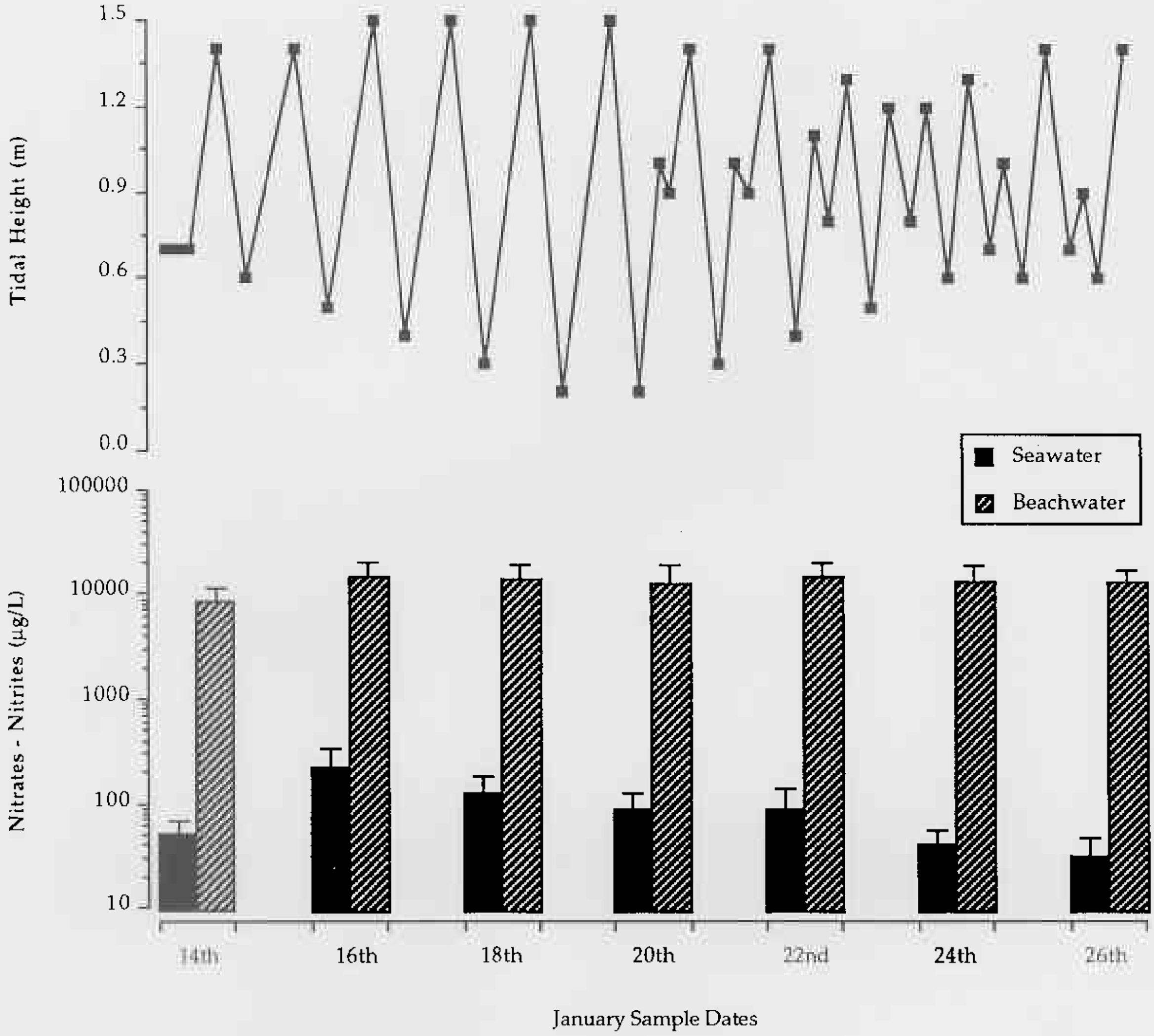

Figure 5: Variation in the concentration of nitrate - nitrate in seawater and beachwater over a two week tidal cycle in January 1992. Note log scale.

Monitoring of the seawater and beachwater at Monkey Mia should be continued but the sampling regime could be reduced. Levels of nitrate in the beachwater and seawater should continue to be monitored at regular intervals for a year in order to determine if a change has occurred, particularly where changes to the lawn fertilizing practice are anticipated. However, other parameters could be monitored less frequently (eg. twice per season). Control sites should be located further from the caravan park in order to be of use in comparative terms. This would prevent the contamination of the beachwater sites and also reduce the incidence of mixing in the seawater. A minimum of two control samples should be taken.

In this study there was no indication of an ideal time in the tidal cycle at which to sample the physico-chemical parameters. Changing tidal heights appeared to have little influence on the the parameters measured during this study. In part, this may have been due to the time taken to sample all beachwater and seawater sites which occurs a 5 hour period over which the tide is changing. The tidal survey should be repeated using fewer sites and, in order to minimize cost, fewer parameters should be measured.

The reliability of the coliform test as an adequate indicator of sewage contamination has been questioned due to its time consuming nature and the extreme variability for coliform survival under varying environmental conditions (Rhodes and Katur 1988). Techniques are currently being developed to trace sewage derived 'biomarkers' as more sensitive indicators of pollution. One such compound is coprostanol, produced in the intestine of higher mammals by the breakdown of cholesterol (Nichols and Espey 1991). It is possible to distinguish this compound produced by humans from similar such compounds produced by seals and dolphins (R. Leeming pers comm.) Ultimately, this will become a management tool, with the development of a reliable 'litmus-type' technique for the rapid detection of sewage pollution. With such techniques it should be possible to conclusively determine whether the sewage plant at Monkey Mia is polluting the adjacent marine environment.

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APPENDIX ONE

Rainfall data for 1991 collected at Denham weather station

Month	Total Rain (mm)	No. Rain Days
January	0	0
February	24.2	3
March	2.6	1
April	52.6	4
May	22.6	3
June	83.4	13
July	84.2	15
August	7.8	5
September	7.8	5
October	3.6	3
November	2.4	2
December	5.6	2

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