Ground water in the Alexandria dune field and its potential influence on the adjacent surf-zone

EE Campbell* and GC Bate
Department of Botany, University of Port Elizabeth, PO Box 1600, Port Elizabeth 6000, Republic of South Africa.

Abstract

Water quality of the ground water in the Alexandria dune field was monitored with the aim of estimating the amount of nutrient input from this source into the adjacent surf-zone. Soluble reactive phosphorus contents of the ground water were not significantly different from that of the adjacent sea water. Ammonia levels were about twice that of surf water while nitrate levels were about ten times higher than that of the sea. On average, the ground water enters the surf-zone at a rate of 1 000 ℓ per running metre of beach. This results in a net flow of nitrogen from the dune ground water to the surf-zone of 1 050 g $N.a^{-1}$ for each metre of beach. This makes the ground-water flow from the dune aquifer an important source of nitrogen for surf-zone phytoplankton, in that it replaces much of the nitrogen lost from the surf-zone ecosystem. This link represents an interdependence between these two apparently distinct ecosystems.

Introduction

The Alexandria dune field is still relatively unaffected by interference from man. Many studies have been published which refer to the nature of dune slack plant and animal communities (e.g. Van der Laan, 1979; Ascaray, 1982; McLachlan *et al.*, 1982; Sykes and Wilson, 1987); however, only recently has dune water been recognised as a potential source of nutrients for the adjacent surf-zone (McLachlan and Illenberger, 1985). These latter authors reported a flow of dune water which was about 1 000 ℓ per running metre of beach per day. The water was shown to contain 1,9 mg NO_3^- $-N.m^{-3}$; 0,2 mg NH_4^+ $-N.m^{-3}$; and 0,06 mg PO_4^{3-} $-P.m^{-3}$ but almost no NO_2^- N. No indication was given regarding the spatio-temporal variance of the nutrient contents.

The ecology of the Sundays River beach surf-zone has received much attention in recent years (Talbot *et al.*, 1990 and references contained therein). A question not yet answered, however, is what the source of nutrients is that supports the high rates of phytoplankton productivity which have been measured in the surf-zone (Campbell and Bate, 1988a). The importance of a constant influx of nutrients will vary depending on the nature of the surf ecosystem. For example, if the system is open with nutrients able to escape to the open sea, then a constant influx is essential to maintain a continued rate of new primary production. If the system is closed, then nutrients would be recycled and the requirement for an inflow would depend more on the extent of any leakage from the system. Talbot and Bate (1987) have indicated that there is little loss of the major phytoplankton species, *Anaulus australis* Drebes *et* Schulz from the surf-zone. These authors have also shown a half residence time of approximately 3,6 h. With the ground water entering the surf-zone just below the swash line, and with the *A. australis* cells being epipsammic at night (Talbot *et al.*, 1990) any nutrient entering the system from the dunes would probably be efficiently absorbed rather than flushed out of the system.

The purpose of undertaking this study was to investigate the potential for man-made damage to the surf and dune environments, should water be removed from the dunes. While the overall study continues, we report here on the results of an investigation into changes in dune slack water nutrient concentrations.

---

*To whom all correspondence should be addressed.
Received 20 June 1990; accepted in revised form 15 November 1990

Materials and methods

The study area

The Alexandria dune field is situated within Algoa Bay in the Eastern Cape and extends from the Sundays River mouth in the west to Woody Cape in the east (Fig. 1). It includes a 40 km stretch of coastline and covers an area of approximately 120 km^2. Although there are four river valleys which end behind the high slipface of the dune field, they seldom contain water on the surface because the annual rainfall is between 400 and 600 $mm.a^{-1}$ from west to east (Illenberger and Rust, 1988).

The dune slacks

Along the western 10 km of the seaward section of the Alexandria dune field is a series of 40 wet interdune depressions known as dune slacks. These slacks, described by Tinley (1985), form as hollows between parallel longitudinal dunes which run almost perpendicular to the coast for a distance of about 200 m (McLachlan *et al.*, 1982) before giving way to wind-blown dunes.

Each slack is about 50 m wide but altogether they cover only about 1% of the total dune field (Ascaray, 1982). The vegetation is relatively sparse and is dominated by *Sporobolus virginicus* (L.) Kunth, *Gazania rigens* (L.) Gaertn., *Arctotheca populifolia* (Berg.) T. Norl. and *Juncus krausii* Hochst (McLachlan *et al.*, 1982; Young, 1987). Young (1987) showed that the vegetation at the seaward end of the slacks receives much more salt than at the landward end. Altogether the slacks receive more salt than the bushpocket vegetation further into the dune field but less than the foredune hummocks. Over a short distance of about 100 m over the berm, the salinity in the ground water decreases from that of sea water to just above zero.

Water wells

Wells were installed to a depth of approximately 1 m in one of the slacks. A well was placed at the seaward and landward side of the slack. The wells were lined with 110 mm diameter unperforated plastic pipe, which means that water entered them from underneath only. They were kept covered to prevent sand from blowing into the mouth of the pipe.

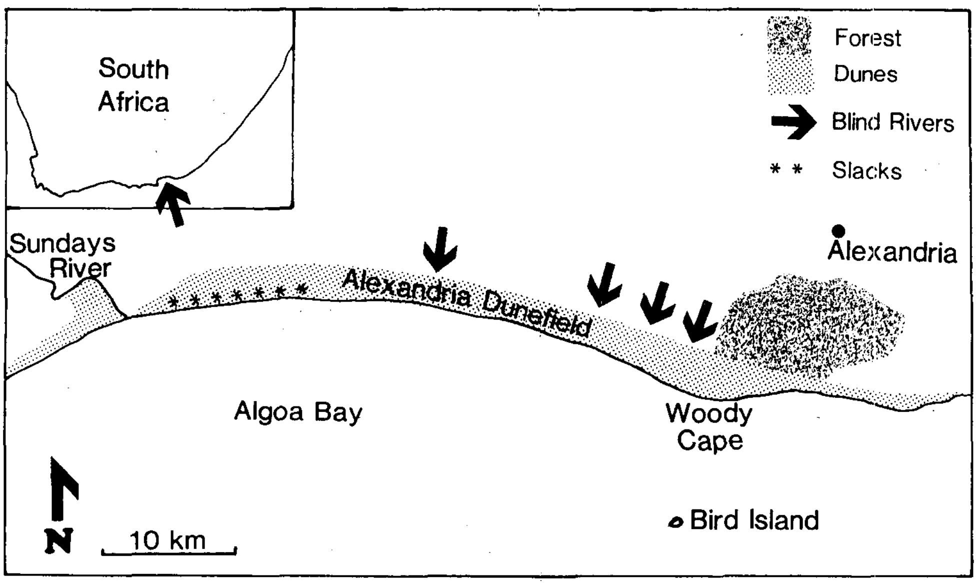

Figure 1
A map of the study area showing the Alexandria dune field and the region of slacks on the westward end

Water quality

Salinity was measured to the nearest 1‰ using a hand-held refractometer (accurate to 1‰: Atago) in order to determine how much the sea water diluted the nutrients measured in the ground water. In addition to the salinity of the well water, measurements were also made of the salinity of the sea and the interstitial water in the swash zone. This latter water was sampled by digging a hole in the intertidal zone, just above the high tide mark, and taking water from this hole.

Nitrate concentration in the water was measured according to the method outlined by Bate and Heelas (1975), ammonium by the method of Solarzano (1969) and soluble reactive phosphorus by the method of Strickland and Parsons (1972).

Results

Water quality

The salinity of the sea and the ground water as determined on three days is presented in Fig. 2. The intertidal zone showed little difference from that of the sea which was around 34‰. In the wells at the back of the slacks, the salinity was always less than 1‰. In the pipes planted in the front of the slacks, the salinity was below 5‰, indicating some influence of the sea water on the ground water.

The soluble reactive phosphorus content of the ground water taken from both the front and back of the slacks showed little difference during any of the 24 h periods or between the 3 d on which measurements were made (Fig. 3). The soluble reactive phosphorus concentrations in the ground water were, on average, slightly lower than in the sea (Fig. 4).

Ammonium concentrations in the ground water also showed no temporal or spatial pattern (Fig. 5) with values ranging between 10 and 80 μg NH_4^+ -N.ℓ^{-1} which is similar to that of the sea. On average, however, the ground water had concentrations 1,3 times higher than that of the sea (Fig. 6).

The nitrate content of the ground water in the slacks showed no temporal pattern (Fig. 7). On the first day (23 April), the nitrate

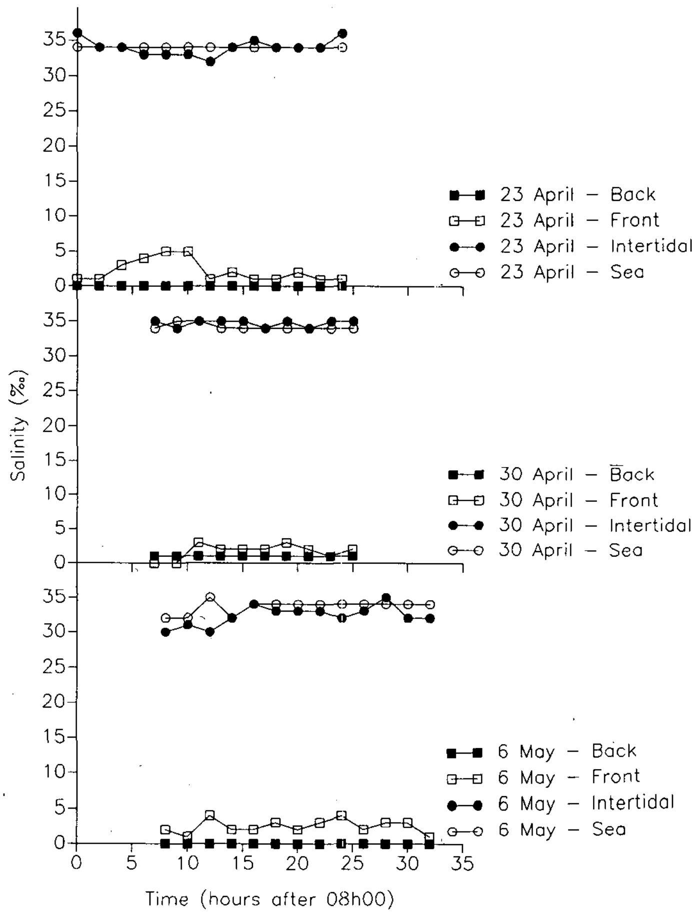

Figure 2
The salinity of the water in the wells in the front and back of the slack as well as in the sea and intertidal interstitial water measured for 24 h on 3 different days

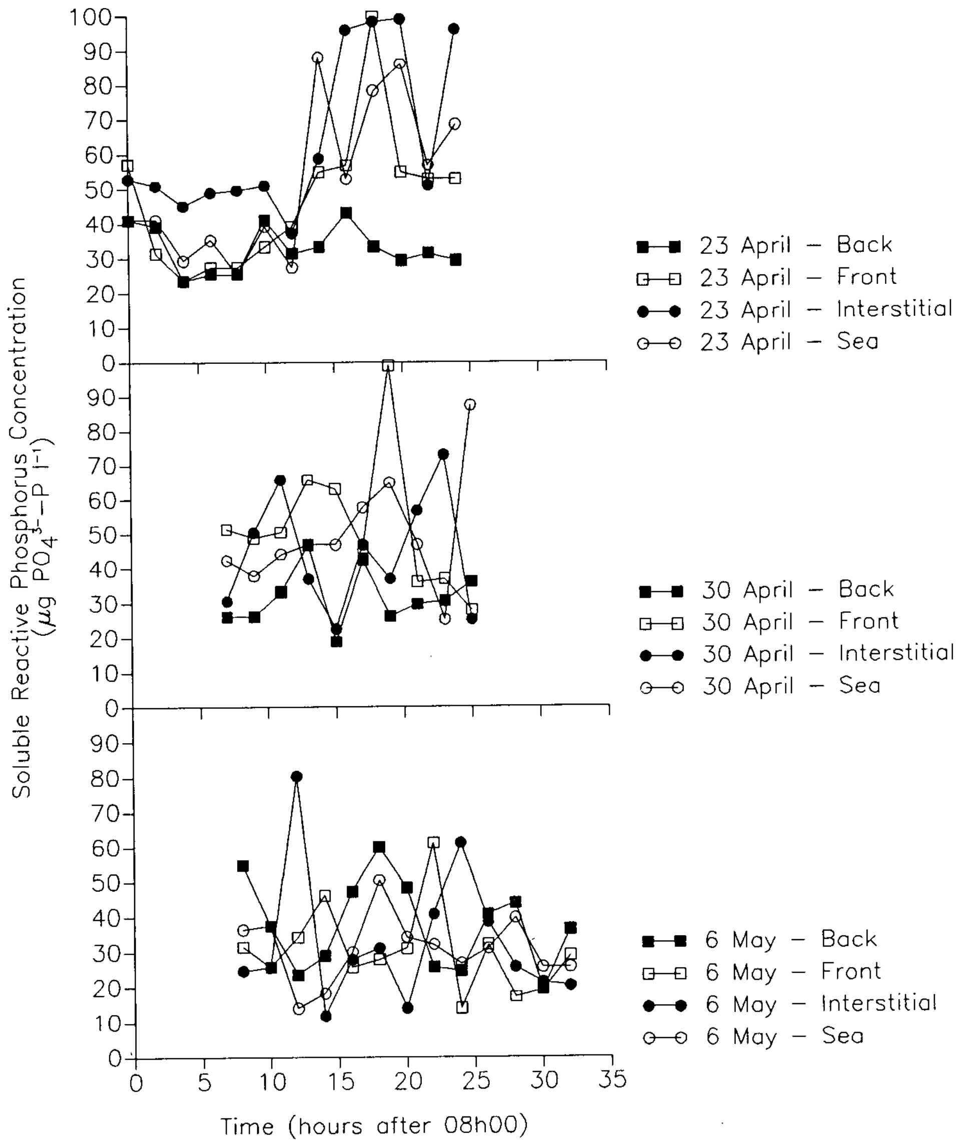

Figure 3
The soluble reactive phosphorus concentration of the water in the wells in the front and back of the slack as well as in the sea and intertidal interstitial water measured for 24 h on 3 different days

content of the water at the back of the slack was similar to that at the front of the slack. On the second day (30 April), the nitrate in the water at the front of the slack was almost twice as high as that at the back during the whole 24 h period. However, on the third day (6 May), the situation was reversed, with higher concentrations at the back of the slack. In contrast to the ammonium contents, there was a high mean concentration of nitrate in the ground water (Fig. 8), with almost 10 times as much nitrate in the ground water than in the sea.

Discussion

Because soluble reactive phosphate concentrations in ground water are lower, on average, than in the sea water, the ground water flowing into the sea is no source of phosphate for surf-zone organisms.

Ammonium concentrations in the ground water are slightly higher than in the sea water, but the nitrate concentration are much higher than that of the sea; on average 10 times higher. Nitrate concentrations measured in the ground water did not show a consistent relationship between front and back wells. It is possible that pulses of nitrate move towards the sea with aquifer flow. However, research needs to be undertaken to determine the source

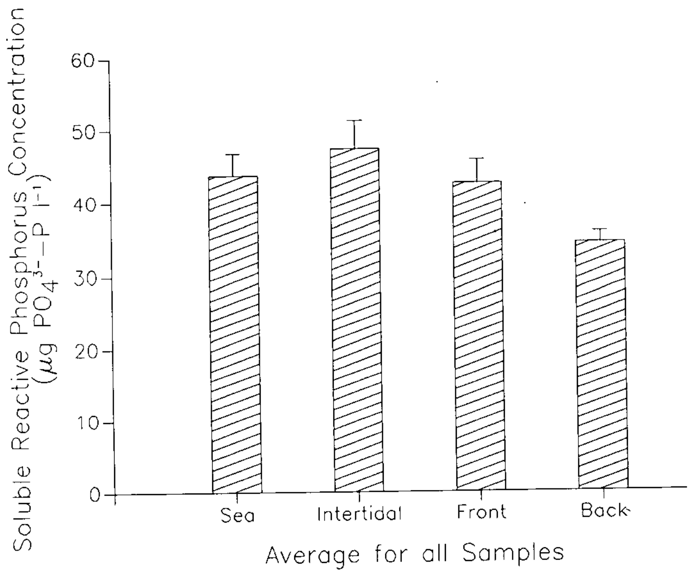

Figure 4
The average soluble reactive phosphorus concentration of the water in the wells in the front and back of the slack as well as in the sea and intertidal interstitial water measured for 24 h on 3 different days. The vertical bar indicates 1 standard error

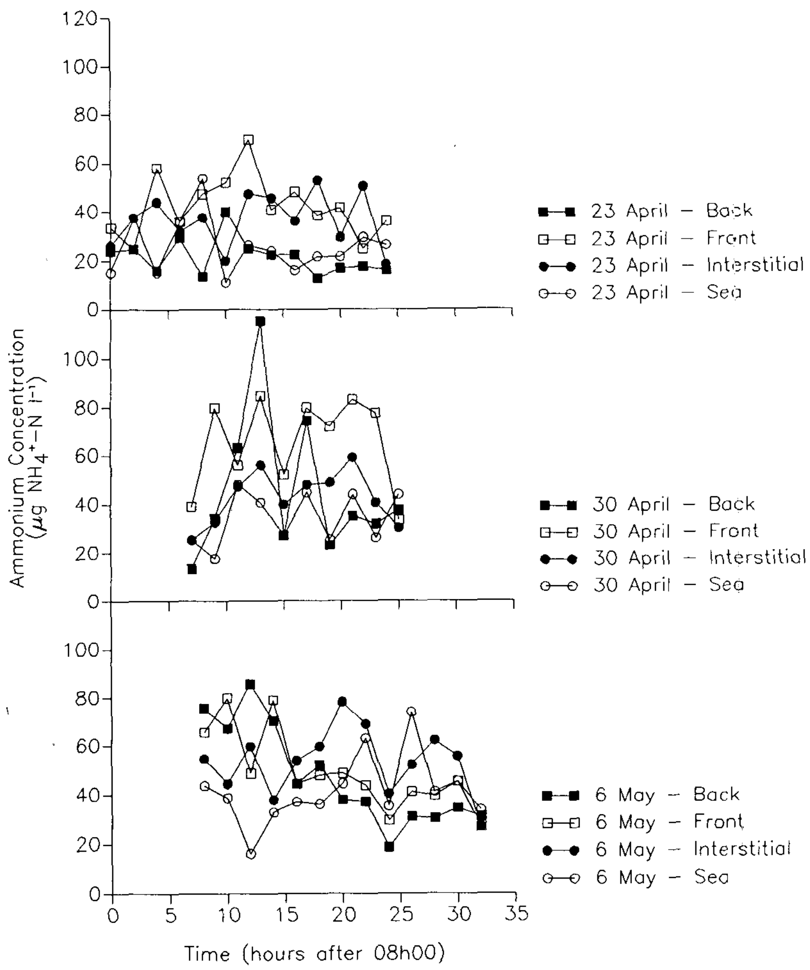

Figure 5
The ammonium concentration of the water in the wells in the front and back of the slack as well as in the sea and intertidal interstitial water measured for 24 h on 3 different days

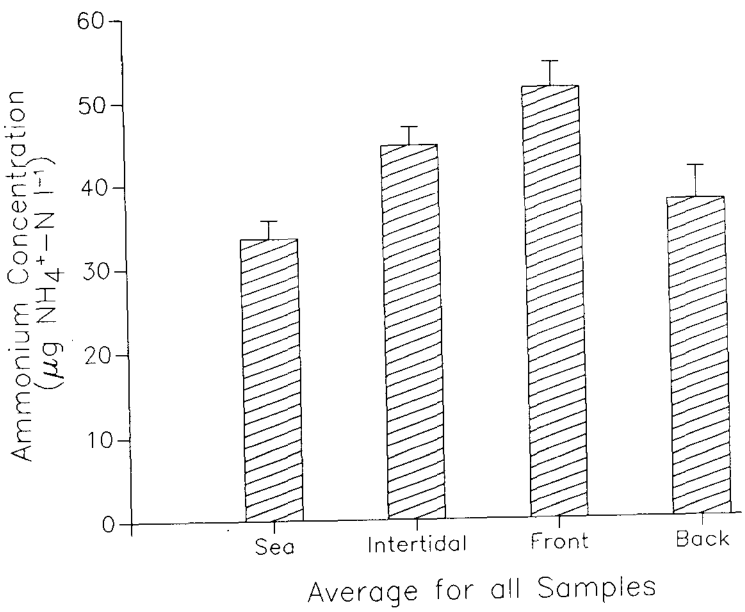

Figure 6
The average ammonium concentration of the water in the wells in the front and back of the slack as well as in the sea and intertidal interstitial water measured for 24 h on 3 different days. The vertical bar indicates 1 standard error

of the nitrate in the aquifer water before this phenomenon can be explained.

The rate at which the aquifer water seeps into the surf-zone has been estimated at 1 $m^3.m^{-1}.d^{-1}$ (McLachlan and Illenberger, 1985). At this rate of flow the nitrogen supply would be approximately 1 055 g $N.m^{-1}$ a^{-1}.

The primary production of the surf ecosystem has been estimated at 120 kg C per running meter of beach per year (Campbell and Bate, 1988a). Using the estimates calculated by Campbell (1987) the nitrogen requirements of the surf phytoplankton would be 10,1 kg $N.m^{-1}$ a^{-1}. Because the surf ecosystem is a closed system on the seaward side (Talbot and Bate, 1987) and an estimated 11% of the primary producers are lost from the end of the ecosystem (Campbell and Bate, 1988b), the nitrogen leaving the surf-zone would be 1 110 g $N.m^{-1}$. This means that the nitrogen entering the ecosystem from the dunes would make up most, if not all, of the nitrogen requirements of surf phytoplankton.

Conclusions

The importance of these data is that where highly productive surf-zone ecosystems have been identified, a thorough study of surf-zone nutrient requirements should be undertaken before ground water is utilised for human consumption or industrial use in that this water is a significant source of nutrients to the adjacent surf ecosystem. The requirements of associated ecosystems for ground-water nutrients should be taken into account along the whole Cape

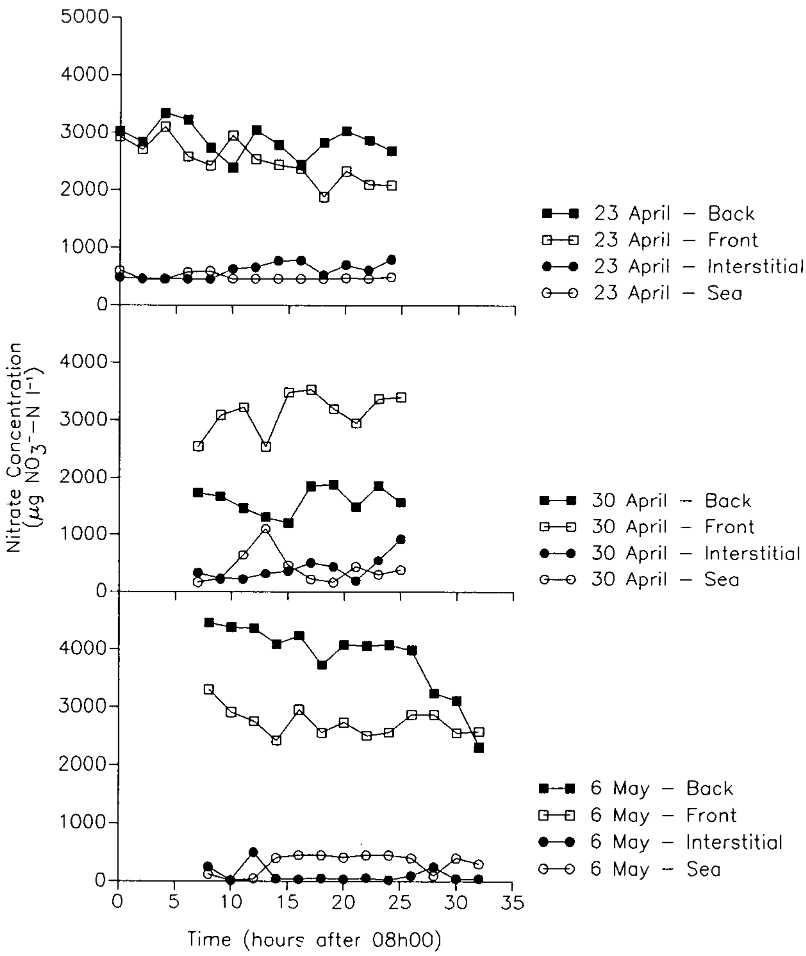

Figure 7
The nitrate concentration of the water in the wells in the front and back of the slack as well as in the sea and intertidal interstitial water measured for 24 h on 3 different days

south coast. There is a need for this requirement to be investigated before the aquifers are tapped for the water which is becoming so precious in South Africa.

Acknowledgements

This study was funded by the South African National Committee for Oceanographic Research. S de Waal, D Matthewson, B Newman and J Paterson assisted with the field work.

References

ASCARAY, D (1982) Dunefield on our doorstep. *The Naturalist* **27** 31-34.

BATE, GC and HEELAS, BV (1975) Studies on the nitrate nutrition of two indigenous Rhodesian grasses. *J. Appl. Ecol.* **12** 941-952.

CAMPBELL, EE (1987) The Estimation of Phytomass and Primary Production of a Surf-zone. Unpublished Ph.D. Thesis, University of Port Elizabeth, South Africa.

CAMPBELL, EE and BATE, GC (1988a) The estimation of annual primary production in a high energy surf-zone. *Bot. Mar.* **31** 337-343.

CAMPBELL, EE and BATE, GC (1988b) The influence of current direction on longshore distribution of surf phytoplankton. *Bot. Mar.* **31** 257-262.

ILLENBERGER, WK and RUST, IC (1988) A sand budget for the Alexandria coastal dune field, South Africa. *Sedimentology* **3** 513-521.

McLACHLAN, A and ILLENBERGER, W (1985) Significance of groundwater nitrogen input to a beach/surf zone ecosystem. *Stygologia* **2** 291-296.

McLACHLAN, A, SIEBEN, P and ASCARAY, C (1982) Survey at a major coastal dune field in the Eastern Cape. Zoology Dept. Report

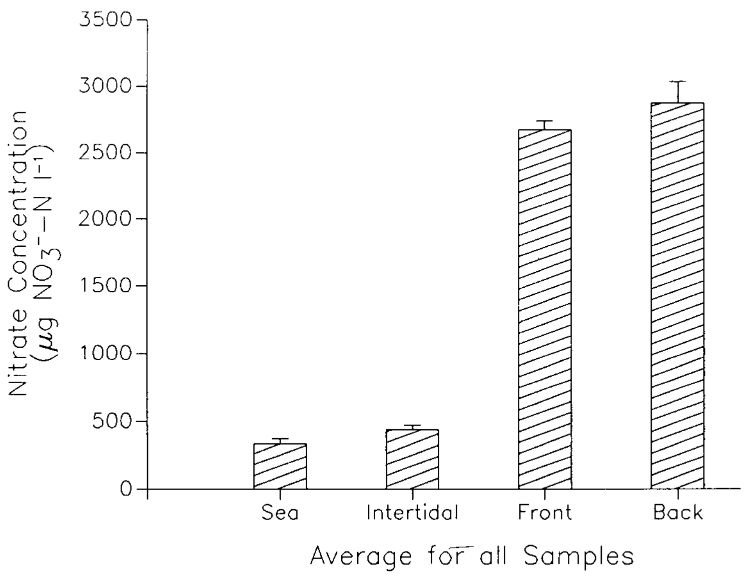

Figure 8
The average nitrate concentration of the water in the wells in the front and back of the slack as well as in the sea and intertidal interstitial water measured for 24 h on 3 different days. The vertical bar indicates 1 standard error

No 10. University of Port Elizabeth, South Africa.
SOLARZANO, L (1969) Determination of ammonia in natural waters by the phenolhypochlorite method. *Limnol. Oceanogr.* **14** 799-801.
STRICKLAND, FDH and PARSONS, TR (1972) *A Practical Handbook of Seawater Analysis.* Fisheries Research Board of Canada. Ottawa.
SYKES, MT and WILSON, JB (1987) The vegetation of a New Zealand dune slack. *Vegetatio* **71** 13-19.
TALBOT, MMB and BATE, GC (1987) Rip current characteristics and their role in the exchange of water and surf diatoms between the surf-zone and nearshore. *Est. Coast. Shelf Sci.* **25** 707-720.
TALBOT, MMB, BATE, GC and CAMPBELL, EE (1990) A review of the ecology of surf-zone diatoms, with specific reference to *Anaulus australis. Oceanogr. Mar. Biol. Annu. Rev.* **28** 155-175.
TINLEY, KL (1985) Coastal dunes of Southern Africa. South African National Scientific Programmes Report No. 109. Foundation for Research Development, CSIR, Pretoria, South Africa.
VAN DER LAAN, D (1979) Spatial and temporal variation in the vegetation of dune slacks in relation to the ground water regime. *Vegetatio* **39** 43-51.
YOUNG, MM (1987) The Alexandria Dune field Vegetation. Unpublished M.Sc. Thesis, University of Port Elizabeth, South Africa.