THE FLORA OF THE SANDY BEACHES OF SOUTHERN AFRICA.
IV. THE EAST COAST MICROFLORA.

E.E. Campbell and G.C. Bate

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TABLE OF CONTENTS

1. INTRODUCTION

1.1 The Surf-Zone Ecosystem

It is a widely held view concerning the phytoplankton of the littoral and inner sublittoral zones of the ocean that high standing stocks only occur in areas having a stable substrate to which benthic plants can attach. Consequently, exposed sandy beaches, where the shifting substratum precludes attachment of macroalgae, have been regarded as zones of low primary production (Brown, 1964). Sandy beaches which do not host phytoplankton accumulations are considered to be "subsidized" to some extent from oceanic and landwater sources (McLachlan, 1980). Those beaches which contain phytoplankton accumulations constitute an exception to this rule (Lewin and Schaefer, 1983).

Because of the presence of rich phytoplankton accumulations in the surf, maintained by special cell mechanisms together with water gyres which retain nutrients, McLachlan (1980; McLachlan *et al.*, 1981) proposed that the sand and water envelope of the surf-zone is a viable, semi-closed ecosystem. This ecosystem had the drift line and outer limit of water gyres as its boundaries. Talbot and Bate (1986) took this concept further and reported that no surf diatoms could be found in the nearshore behind the breaker line except on a single occasion, making the system closed at least with respect to surf diatoms.

In this report, terminology is used which has developed following investigations at the Sundays River beach surf ecosystem. The surf-zone terminology used by McLachlan, (1980, 1983) and Talbot (1986) has been adapted as follows: The surf-zone ecosystem comprises the entire subaerial beach and the breaker zone. For the purposes of the present study, because the study was undertaken from the beach without the facilities to sample the nearshore, the area of exchange by rip currents is excluded. The ecosystem is considered to be a closed or semi-closed system, the dimensions of which are shown in Figure 1.

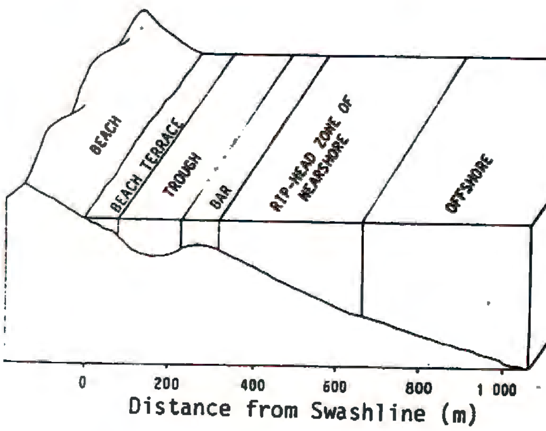

Figure 1. The dimensions of, and terminology used in describing surf-zones in this report.

In the past, the term "bloom" has been used to describe the brown water phenomenon in surf-zones. This has caused some confusion with the result that the following terms are applied strictly in this work:

Bloom	- High cell concentrations resulting from exponential cell division of a phytoplankton species.
Accumulation	- High cell concentrations caused by physical concentrating forces, such as water currents.
Patch	- The discolouration of water due either to bloom formation or accumulating forces.

1.2 The Importance of the Coastline

The coastline is a junction between the sea and land, yet it is much more than just a physical meeting. Man has been fascinated by the seashore for millennia and today it forms an important economic entity in the financial structure of all countries bounded by a coastline. Historically, the coast became especially important when international trade expanded with the development of ships capable of negotiating the hazards of the sea and its storms. For this reason, the early importance of the coast was related to the industrial and commercial development of areas with suitable ports.

With the increase in the population around the world, the coast, which was previously more important as an industrial and trade area, began to be settled more densely. Many of the people who moved to these areas were no longer directly associated with shipping. This led to the expansion of facilities in these areas which in turn resulted in increased development.

With settlement came housing, roads, pollution and a build-up of pressure in an area which, from the point of view of stability, was equated to inland areas. Inexperience in coastal zone management resulted in exceeding the carrying capacity of many of such coastal areas. This, in turn, resulted in an increase in engineering works to keep the coastline stable.

Today, the coastline is recognized as a sensitive zone and legislation has been enacted in many parts of the world to enforce suitable strategies for coastal use and management, controlling the dumping of noxious wastes, the use of estuaries as sewer lines and the development of coastal dunefields. The artificial stabilization of wind-blown dunefields has been recognised as having potentially adverse effects at other points along the coast. The abstraction of water from coastal aquifers is no longer seen as merely the use of water which would otherwise flow wastefully into the sea; such water is now recognised as having a role to play in the holistic environment in which Man and all other life-forms exist on earth.

At present much is being written about the possibility of an imminent substantial change in the level of the sea - a phenomenon which has indeed been going on since the oceans were formed. All developments in the coastal zone will be greatly affected by such an event and the ripple-effect will spread to all parts of the world, both physically and economically. An understanding of the impacts of such an occurrence in both the long-term and the short-term is needed. Only with such an understanding will advance planning reduce the impact of the phenomenon.

An understanding of the coastal zone does not necessarily follow a purely philosophical consideration of the coast. Such understanding is born out of experience and knowledge following investigation and study. This report supplies information on some aspects of the coastal zone which will extend our understanding of the ecosystem involved and raise other questions to spur us on to examine the coast in even greater detail to facilitate future planning.

1.3 Past International Research on Surf-Zones

Early reports on surf-zones containing high concentrations of phytoplankton date from the 1960's (Cassie and Cassie, 1960). There have been other reports since then (Lewin and Norris, 1970; Gunter and Lyles, 1979). In all these early reports the occurrence of brown patches caused by phytoplankton in the water were referred to as "blooms", now known to be accumulations (Talbot and Bate, 1987). Accumulations have been reported from all around the world (listed in Campbell, 1987).

The phytoplankton which accumulate in surf-zones all belong to one of the following genera: *Anaulus*, *Asterionella*, *Aulacodiscus* or *Chaetoceros* (McLachlan, 1983). The occurrence of overwhelming dominance by a single species in coastal water has also been reported for species of other genera such as *Skeletonema costatum* (Greville) Cleve (Hulburt, 1985) and *Ceretaulina pelagica* (Cleve) Hendey, which have both been reported to bloom off the north-east coast of New Zealand (Taylor *et al.*, 1985). The cell concentrations of 10^3 to 10^6 cells l^{-1} (Hulburt, 1985) measured on these occasions do not approach those recorded for accumulating-type phytoplankton (10^9 cells l^{-1}; Schaefer and Lewin, 1984; Campbell and Bate, 1987).

A list of international literature referring to sandy beach surf-zone phytoplankton is given in Appendix 1.

1.4 Past Research on the South African Coastline

Research on the South African coastline can be divided into two sections. The nature and ecology of our rocky shore coastline has been studied in great detail by Branch and his group. "The Living Shores of Southern Africa" (Branch and Branch, 1981) is perhaps their best-known publication.

With regard to sandy beaches, work began in 1979 when Lewin visited South Africa and initiated studies on the ecology of sandy beaches under the leadership of McLachlan (McLachlan and Lewin, 1981). The botanical work lagged behind until 1982 when, following the initial report of McLachlan and Lewin, (1981) an investigation began into the distribution of phytoplankton accumulations in the surf-zone of the Sundays River beach (Sloff *et al.*, 1984). At this stage the dominant phytoplankter was considered to be *Anaulus birostratus* (sic), later identified as *Anaulus australis* sp. nov. Drebes *et* Schulz.

Subsequent to 1983, detailed work described the phytoplankton ecology, physiology and population dynamics for the Sundays River beach. The ecology has been summarized in a review by Talbot *et al.* (1990). More detailed physiological work to explain the ecology is still in progress.

A list of local literature referring to sandy beach surf-zone phytoplankton is given in Appendix 2.

Following an initial aerial survey of the coast (Campbell and Bate, 1990a) during which features potentially linked to surf-zone phytoplankton dynamics were mapped, studies of selected beaches on the east coast were planned. The coast was subdivided into three sections on the basis of presence or absence of phytoplankton patches. No phytoplankton accumulations were observed on the west coast from Cape Cross to Cape Point although brown patches of "gilven-foam" (storm foam: Kirk, 1983) were common. The phytoplankton standing stock along this section of coast is high (Hart and Currie, 1960). The east coast had no patches of any type and generally has extremely clear water, indicative of the low phytomass.

The three phytogeographic zones are (Fig. 2):

West Coast : Cunene River to Cape Point
(17°15'S:11°45'E to 34°22'S:18°30'E)
South Coast: Cape Point to Cintsa Bay
(34°22'S:18°30'E to 32°50'S:28°07'E)
East Coast : Cintsa Bay to Kosi Bay
(32°50'S:28°07'E to 26°51'S:32°53'E)

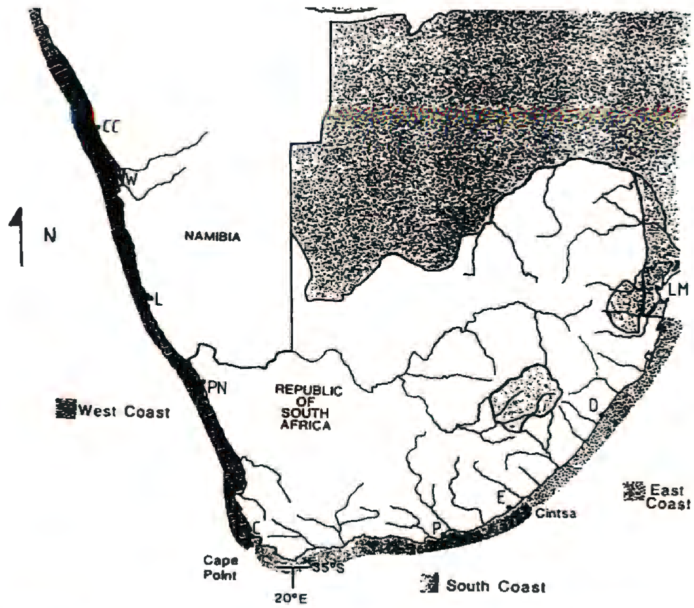

Figure 2. The three phytogeographic zones based on the presence or absence of phytoplankton accumulations.

The studies of west coast beaches are reported in Campbell and Bate (1990b) and the south coast studies in Campbell and Bate (1990c), while this report is concerned with the data collected on the east coast beaches.

Before this study it was unknown which surf phytoplankton occur in the clear waters of the east coast. The east coast study was aimed at answering the following key questions:

1. How far east does *Anaulus australis* occur?
2. Which other species become dominant?
3. Why are there no accumulations of surf phytoplankton along the east coast?

2. MATERIALS AND METHODS

2.1 Sites

The beaches chosen for investigation were assigned a numeric value which is listed as the southern latitude converted to a decimal (eg. Sodwana, which is 27°30'S, is referred to as 27.5°S). The list of beaches with their co-ordinates is given in Table 1 and their location is shown in Figure 3. Table 2 gives the dates on which each beach was visited and lists the various analyses undertaken on each occasion. The beaches covered the whole range of latitudes (Fig. 3).

Table 1. The list of beaches investigated: co-ordinates given as decimal degrees latitude.

Number	Beach	Co-ordinate (°S)
1	Port St Johns	31.60
2	Ifafa	31.50
3	Amanzimtoti	30.10
4	Tongaat	29.60
5	Blythedale	29.40
6	Tugela	29.20
7	Mtunzini	29.00
8	Richard's Bay	28.80
9	St Lucia	28.38
10	Cape Vidal	28.13
11	Sodwana	27.50

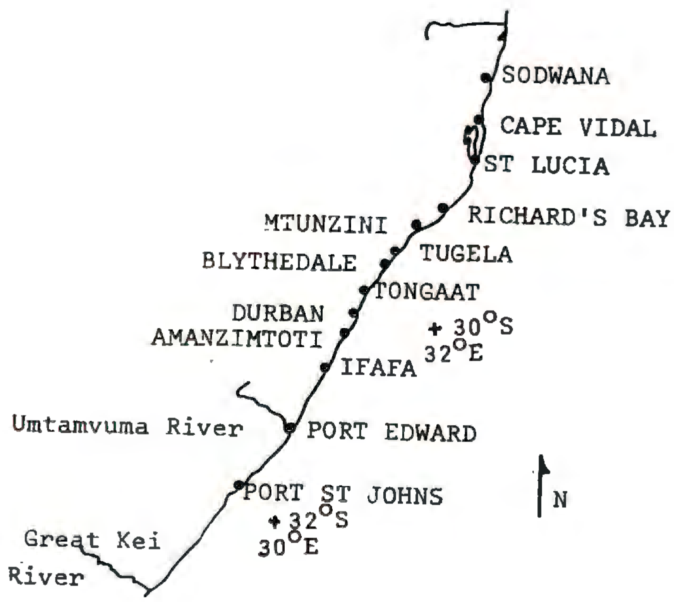

Figure 3. The location of the east coast beaches at which samples were taken.

Table 2. The analyses done at each of the beaches. The analyses are given as 1: Environmental Variables; 2: Slope of the groundwater table; 3: Nutrients; 4: Species Composition; 5: Biomass and 6: Primary Production.

Beach	1	2	3	4	5	6
Port St Johns	*	*	*	*	*	*
Ifafa	*	*	*	*	*	*
Amanzimtoti	*	*	*	*	*	*
Tongaat	*	*	*	*	*	*
Blythedale	*	*	*	*	*	*
Tugela	*	*	*	*	*	*
Mtunzini	*	*	*	*	*	*
Richard's Bay	*	*	*	*	*	*
St Lucia	*	*	*	*	*	*
Cape Vidal	*	*	*	*	*	*
Sodwana	*	*	*	*	*	*

2.2 Environmental Variables

Wave height was estimated visually. The topography of the substrate was classified into four states. They are, in order of high to low energy: dissipative, longshore bar-trough, rhythmic bar, and reflective beach states (Wright and Short, 1983). The surf-zone width was estimated visually by counting the number of wave bores. The wind velocity and direction was measured using a hand-held anemometer and a compass. These variables were used in a multiple linear regression to determine which was correlated to standing stock.

2.3 The Slope of the Groundwater Table

The groundwater slope was determined by drilling a hole in the sand close to the foredune using an auger. When water was found, the difference in height between the water table and sea level was measured with a dumpy level. The slope was calculated as this difference in height, corrected to mean sea level, divided by the vertical distance of the hole from the water line. This procedure assumes a free ground water table terminating at sea level at the time.

2.4 Nutrients

Nitrate was determined according to Bate and Heelas (1975) by reduction to nitrite and the nitrite analyzed by the method of Greiss (1879) and Ilosvay (1889). Ammonium, phosphorus and silicon were determined according to Strickland and Parsons (1972).

2.5 Species Composition

All samples collected for the determination of phytoplankton composition were fixed in Lugol's iodine solution (Saraceni and Ruggiu, 1974). Samples of foam and the water column were collected. Samples were settled and examined for species composition using an inverted light microscope (Zeiss IM 35) at 630x magnification. Samples were identified as far as possible in this fashion and an artificial key was drawn up for use with the light microscope (Campbell and Bate, 1990e). Scanning electron microscopy identification of the samples viewed under the light microscope enabled us to assign specific epithets to most of the species.

The species composition was analysed using several methods. Indices of species diversity and dominance were determined using the equations given in Odum (1971) as follows:

$$DI = \frac{S-1}{\log(N)} \qquad \text{....(1)}$$

where DI = the diversity index of the community
S = the number of species and
N = the number of all individuals

Also,

$$DO = \Sigma \left(\frac{n}{N}\right)^2 \qquad \text{....(2)}$$

where DO = the dominance index of the community
n = the number of individuals of a species and
N = the total number of all individuals.

Detrended canonical correspondence (CANOCO; Ter Braak, 1986) and TWINSPAN (Hill, 1979) analyses were also performed on the species composition data.

2.6 Chlorophyll *a* Concentration

Chlorophyll *a* analyses were performed on ethanol extracts, using the spectrophotometric method recommended by Nusch (1980). The chlorophyll *a* concentration of some of the samples was also measured by high performance liquid chromatography (HPLC) using a 1608 Micro Pak HCH-5n reverse-phase column and isocratic elution with 70% methanol:30% acetone. Duplicate samples showed less than 5% difference using the two methods.

2.7 Primary Production

Access to high energy surf-zones for the purpose of collecting samples is limited by the extreme turbulence in this area. For this reason the *in situ* method of measuring primary production could not be used in this study. Even though this method is considered by many to be the most accurate, the so-called "simulated *in situ*" method is the most widely used (Harrison *et al.*, 1985). In the study of a system over a period of time, *in situ* measurements only approximate the real values if they represent time-integrated environmental conditions. In a high energy surf-zone where it is not possible to apply the *in situ* method, a combination of the "simulated *in situ*" and modelling approaches is more suitable. This involves the assessment of abiotic and biotic variables over the period of estimation, followed by an assessment of the physiological responses of the organism to these variables (Harrison *et al.*, 1985). An accounting model may then be used to integrate the rate of primary production over the period during which the abiotic variables were monitored. This approach was used to estimate the annual rate of primary production by the phytoplankton of the Sundays River beach ecosystem (Campbell and Bate, 1988a) and the model used for the Sundays River beach surf-zone was used in this study. The model was run within the interactive modelling aid programme DRIVER (Furniss, 1977) with the PASCAL implementation by Hahn (1987). Values for biomass and the surf-zone states were used from this study. All the remaining variables were used as for the Sundays River beach model (Campbell, 1987; Campbell and Bate, 1988a).

3. RESULTS

3.1 Environmental Variables

Temperature decreased from 24.5°C in the north to as low as 21°C in the south (Fig. 4). The only high temperature in the south was recorded at Port St Johns where the sample was collected in the mouth of an estuary which influenced the water temperature. The decrease in temperature along the east coast occurred sharply at 29.3°S. The water north of the Tugela River mouth was above 23°C and that south of the Tugela was below 21.5°C.

Wave heights estimated in the surf-zones were generally low in the north (Fig. 5). The one site, Port St Johns, was in an estuary mouth where the estuary headlands reduced the wave energy. The only surf-zone with 3 m waves was at Blythedale beach (Fig. 5). In general, wave heights decreased from 2.0 m to 0.5 m waves from south to north.

The surf-zone topography at time of sampling was mostly in either a rhythmic bar beach or longshore bar-trough state (Fig. 6). The surf-zone was reflective at Cape Vidal, Port St Johns and Ifafa.

Surf-zones at all beaches were about 250 m wide, except for Cape Vidal, which was only 50 m wide (Fig. 7).

3.2 The Slope of the Groundwater Table

An estimation of the slope of the water table is given in Figure 8. The steeper slopes were measured at Sodwana Bay in the north and at Ifafa in the south. There was no aquifer at Port St Johns, the water table being at sea level. The slopes at all the other beaches were similar (0.003) except for Blythedale beach, where the groundwater table level was below that of the mean sea level resulting in no freshwater flowing into the surf-zone.

3.3 Nutrients

3.3.1 Phosphate

The phosphate concentration of river water was low, all four rivers which enter surf-zones having phosphate contents of less than 0.3 $\mu mol\ l^{-1}$ (Fig. 9). This was not much higher than that of the adjacent seawater in the north (Fig. 10). North of the Tugela river phosphate concentrations were below

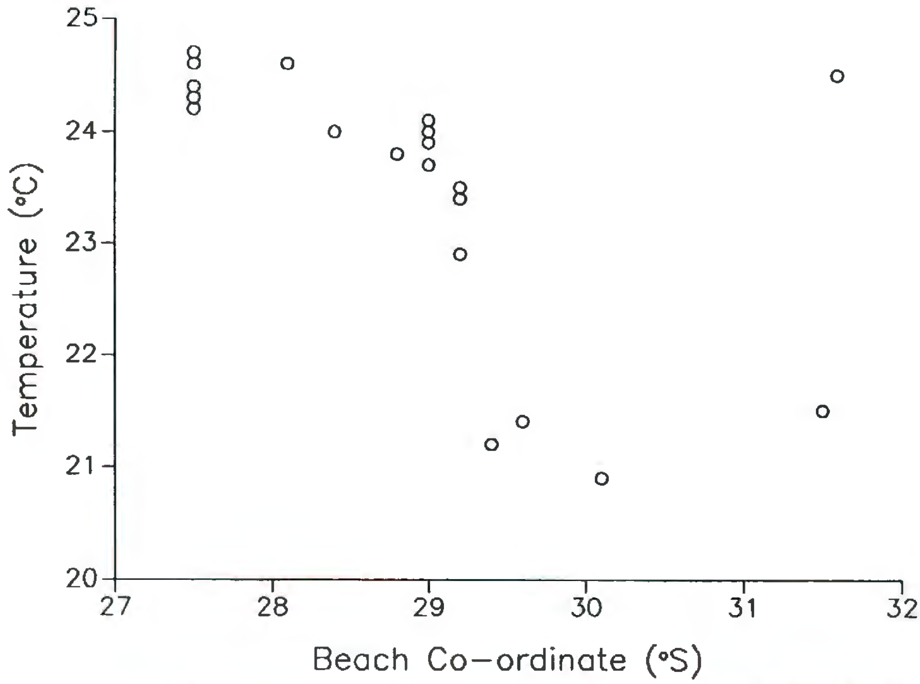

Figure 4. The water temperature of the surf-zones on the east coast of South Africa.

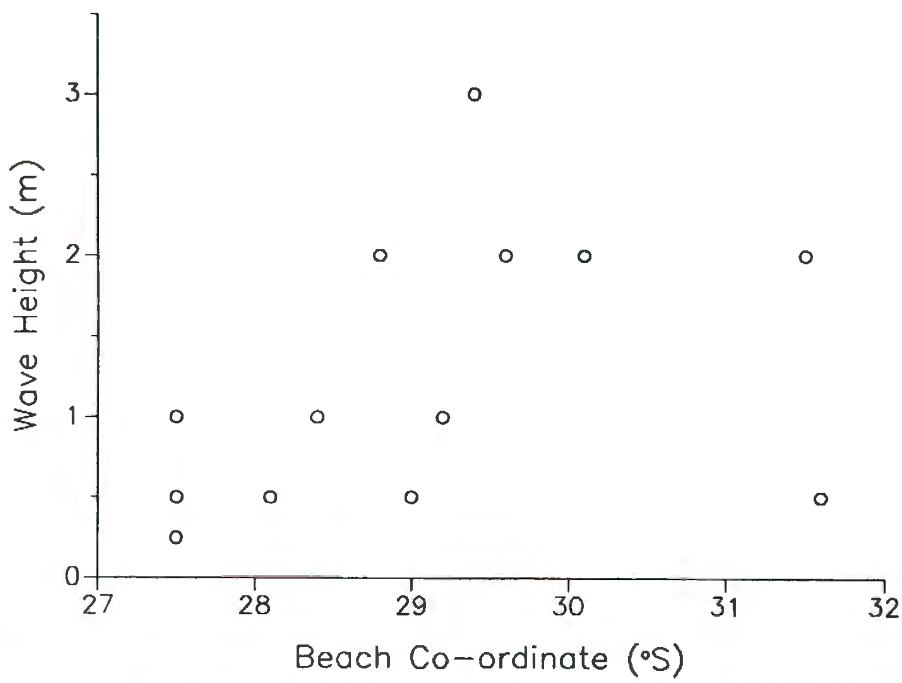

Figure 5. The wave height estimated visually in the surf-zones on the east coast of South Africa.

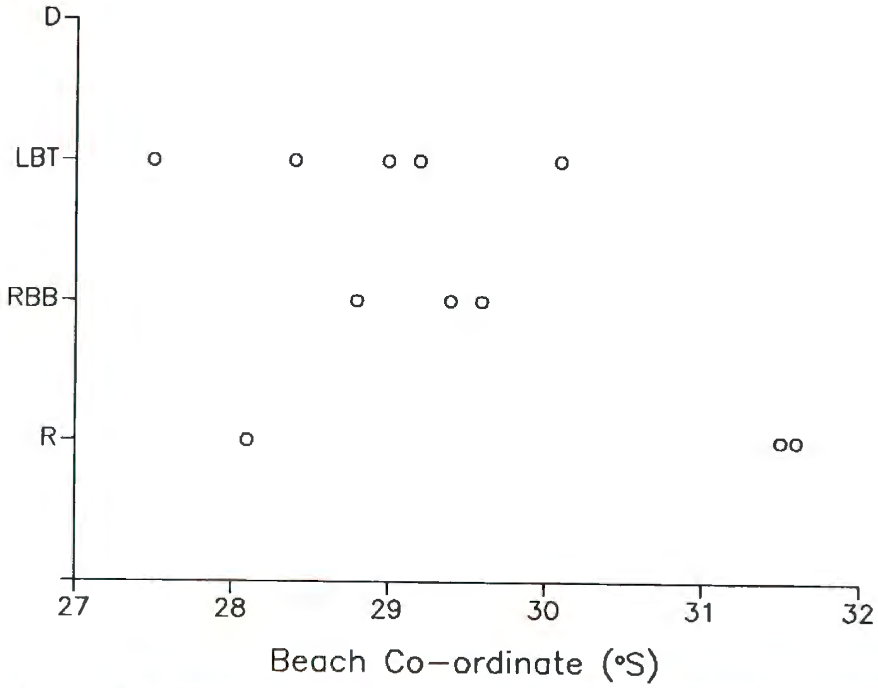

Figure 6. The surf-zone topography at beaches on the east coast of South Africa. D = Dissipative; LBT = Longshore Bar-Trough; RBB = Rhythmic Bar Beach and R = Reflective beach topography.

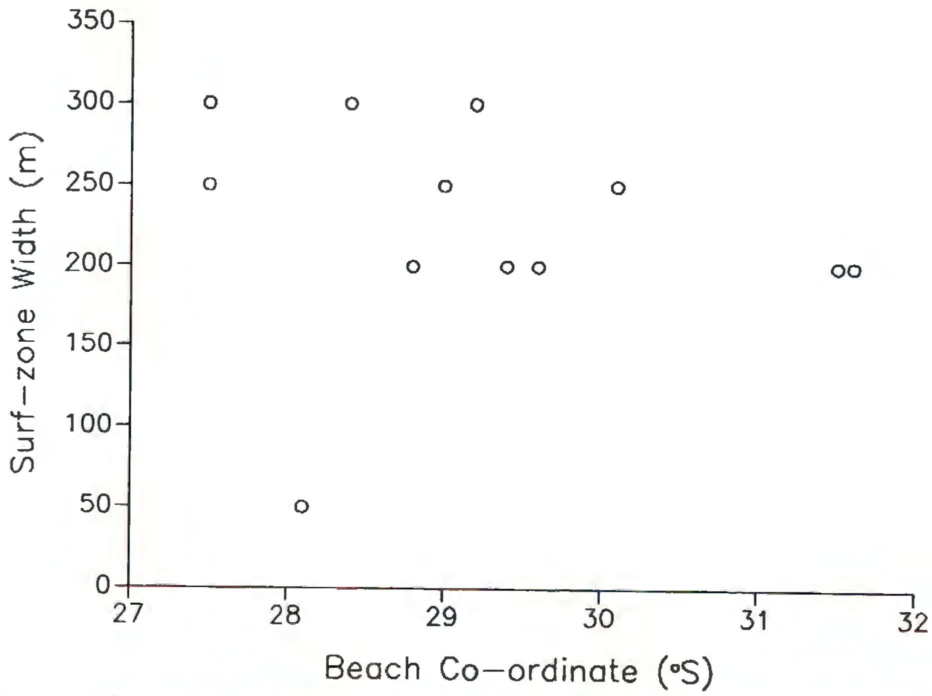

Figure 7. The surf-zone width estimated at beaches on the east coast of South Africa.

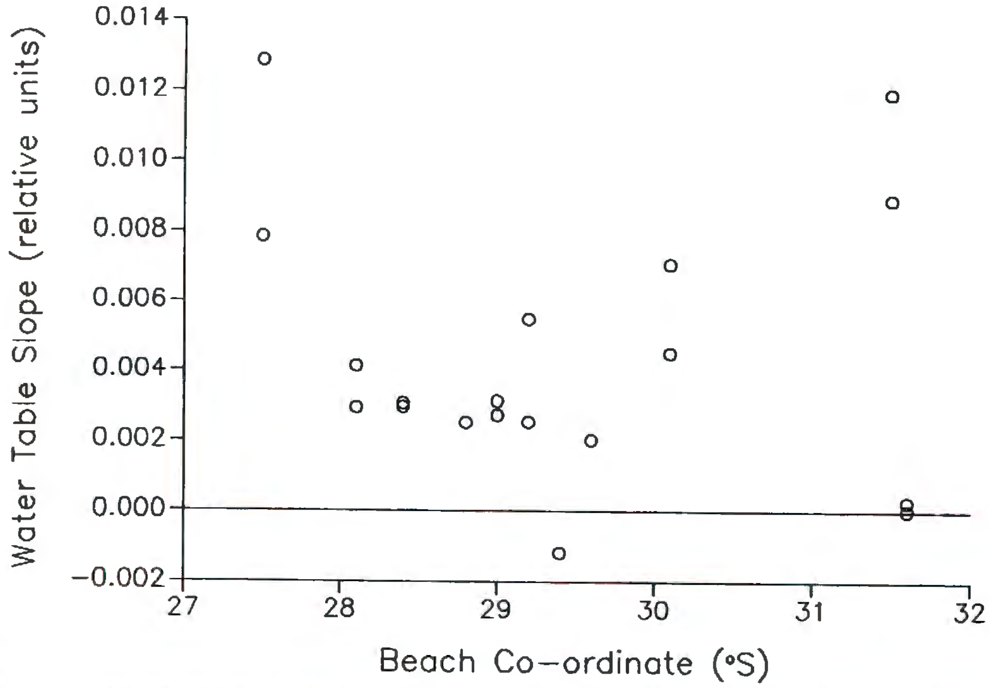

Figure 8. **An estimation of the slope of the groundwater table in the beaches on the east coast of South Africa.**

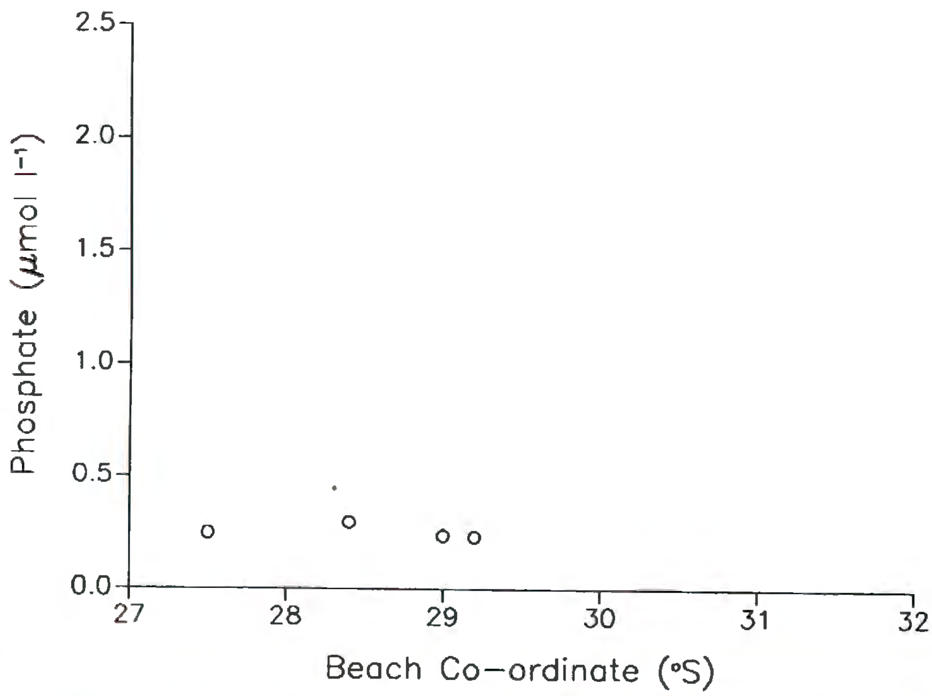

Figure 9. **The phosphate concentration in river water of rivers entering the surf-zones on the east coast of South Africa.**

0.3 $\mu mol\ l^{-1}$, while south of the Tugela the phosphate concentrations increased in the seawater to values as high as 2.0 $\mu mol\ l^{-1}$. This difference is also found in the groundwater (Fig. 11), values of around 0.2 $\mu mol\ l^{-1}$ recorded in the north and values of around 0.6 $\mu mol\ l^{-1}$ in the south.

3.3.2 Ammonium

Ammonium concentration values in the river water (5 $\mu mol\ l^{-1}$; Fig. 12) were similar to that of seawater (5 $\mu mol\ l^{-1}$; Fig. 13) in the north. The ammonium concentration in the seawater south of 29.3°C was higher, between 10 and 17 $\mu mol\ l^{-1}$.

The ammonium in the groundwater along the east coast contained between 1 and 45 $\mu mol\ l^{-1}$ (Fig. 14), the highest value being recorded at Tongaat. There does not appear to be any geographic or other pattern in the distribution of ammonium concentration values in the groundwater.

3.3.3 Nitrate

The nitrate in the rivers decreased from around 35 $\mu mol\ l^{-1}$ in the Tugela River (the southern most river measured; Fig. 15) to 2.5 $\mu mol\ l^{-1}$ in the river at Sodwana Bay.

The nitrate concentration in the seawater was around 10 $\mu mol\ l^{-1}$ south of Richard's Bay. At Richard's Bay and St Lucia the concentration was high (above 20 $\mu mol\ l^{-1}$; Fig. 16). At the two northern beaches the nitrate concentration was below 5 $\mu mol\ l^{-1}$.

The groundwater contained more nitrate, values of between 150 and 280 $\mu mol\ l^{-1}$ (Fig. 17) being recorded in the south. The beaches north of the Tugela contained less nitrate in the groundwater, values reaching 70 $\mu mol\ l^{-1}$ at most. On average the groundwater contained about 9 times more nitrate than the seawater.

3.3.4 Silicon

Soluble reactive silicon content varied greatly in the river water sampled (Fig. 18). Values were as low as 25 $\mu mol\ l^{-1}$ but near Sodwana bay the river contained 380 $\mu mol\ l^{-1}$.

The seawater along the east coast contained very little silicon, all the values, except Port St Johns, being below 20 $\mu mol\ l^{-1}$ (Fig. 19).

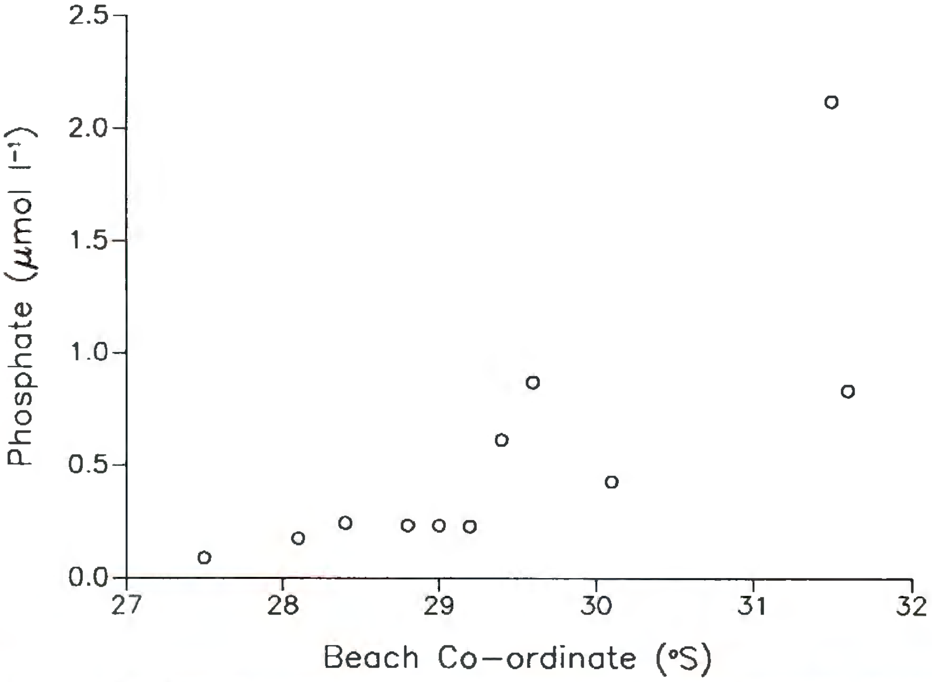

Figure 10. The phosphate concentration in the seawater of the surf-zones on the east coast of South Africa.

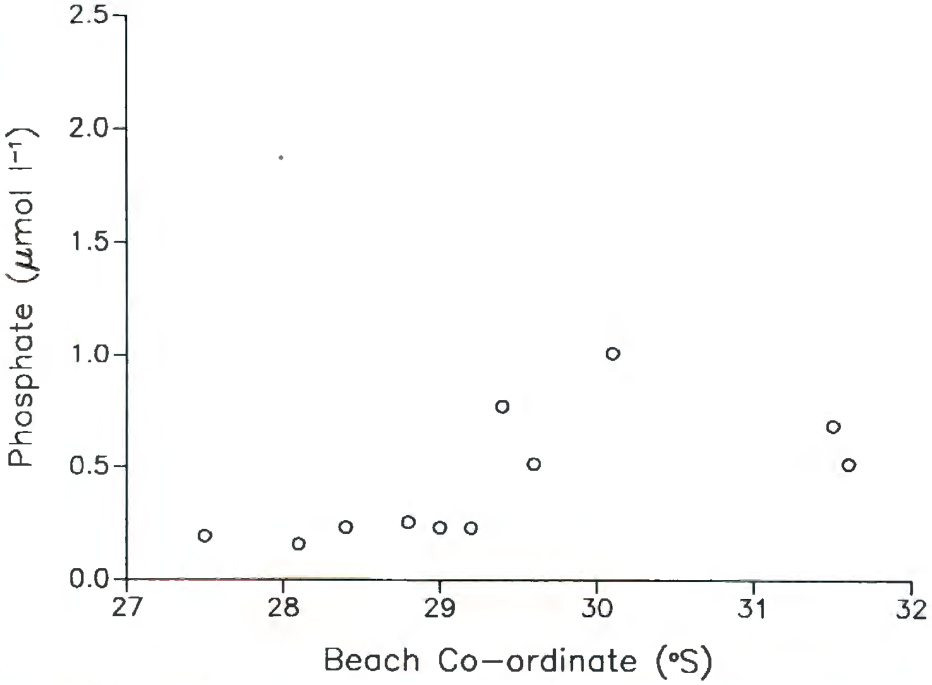

Figure 11. The phosphate concentration in groundwater entering the surf-zones on the east coast of South Africa.

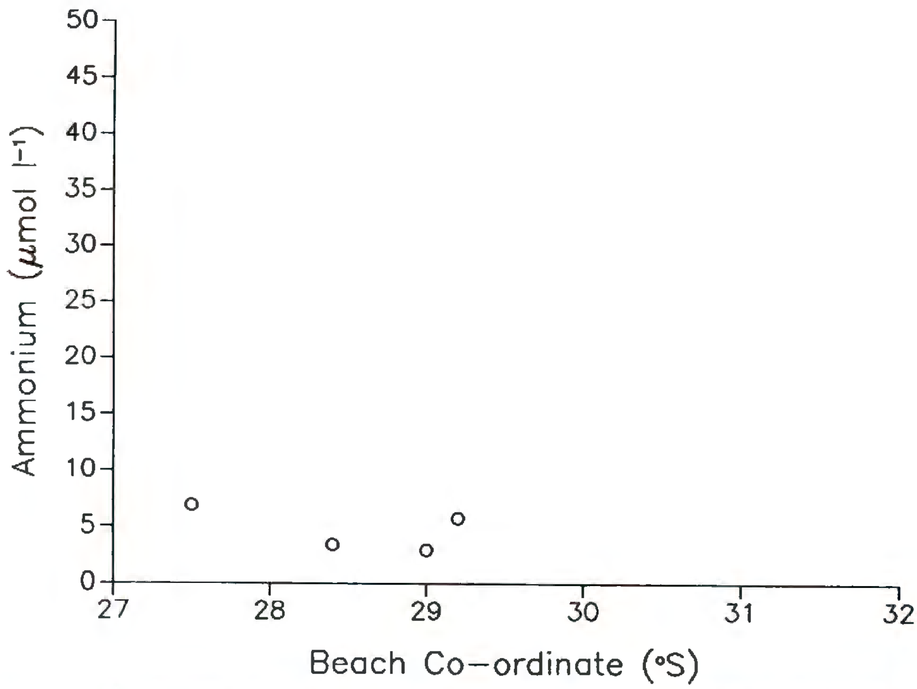

Figure 12. The ammonium concentration in river water entering the surf-zones on the east coast of South Africa.

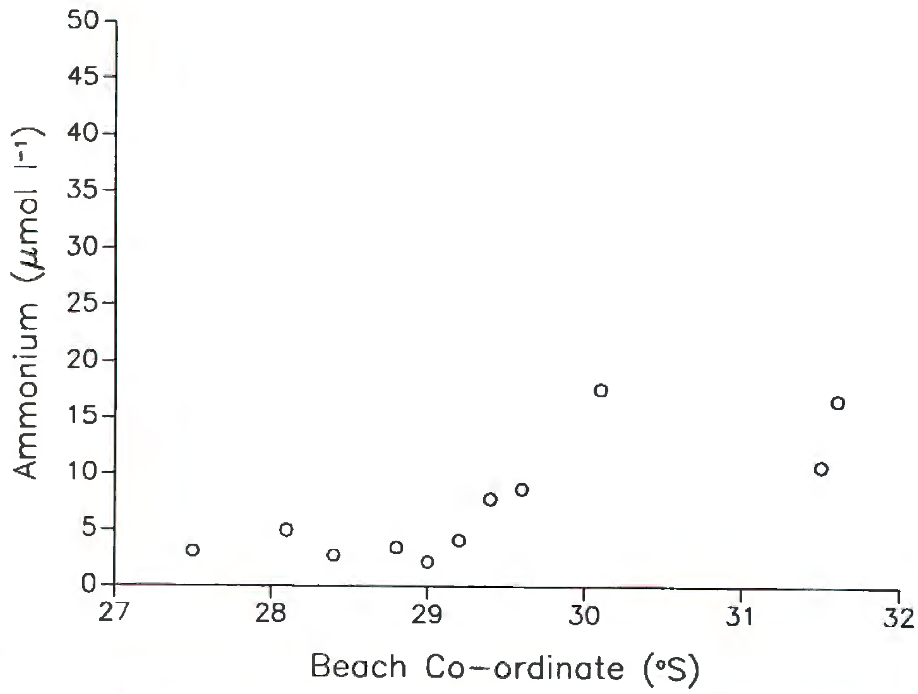

Figure 13. The ammonium concentration in the seawater of the surf-zones on the east coast of South Africa.

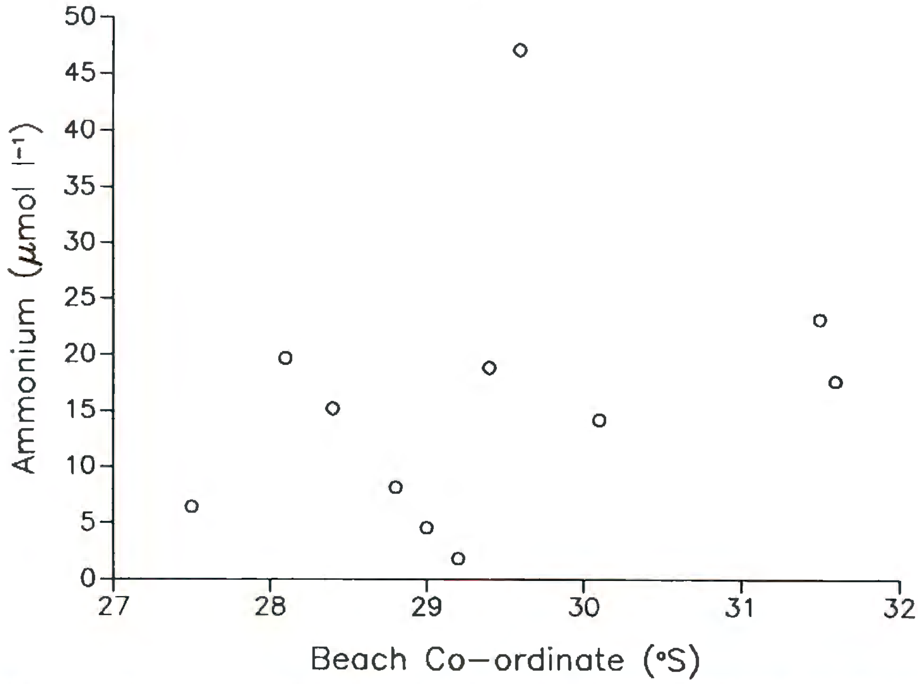

Figure 14. The ammonium concentration in the groundwater entering the surf-zones on the east coast of South Africa.

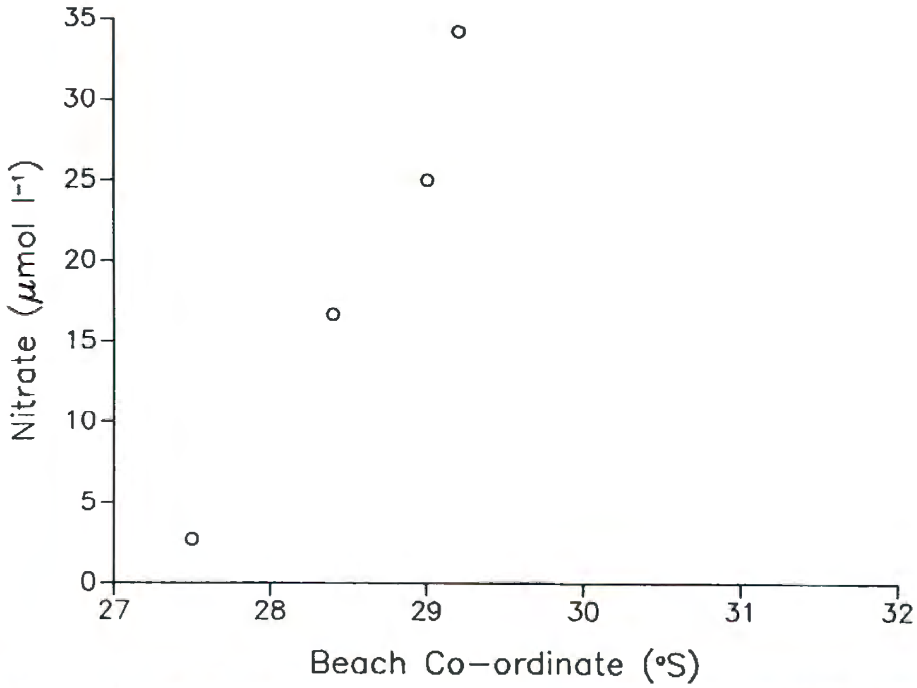

Figure 15. The nitrate concentration in river water entering the surf-zones on the east coast of South Africa.

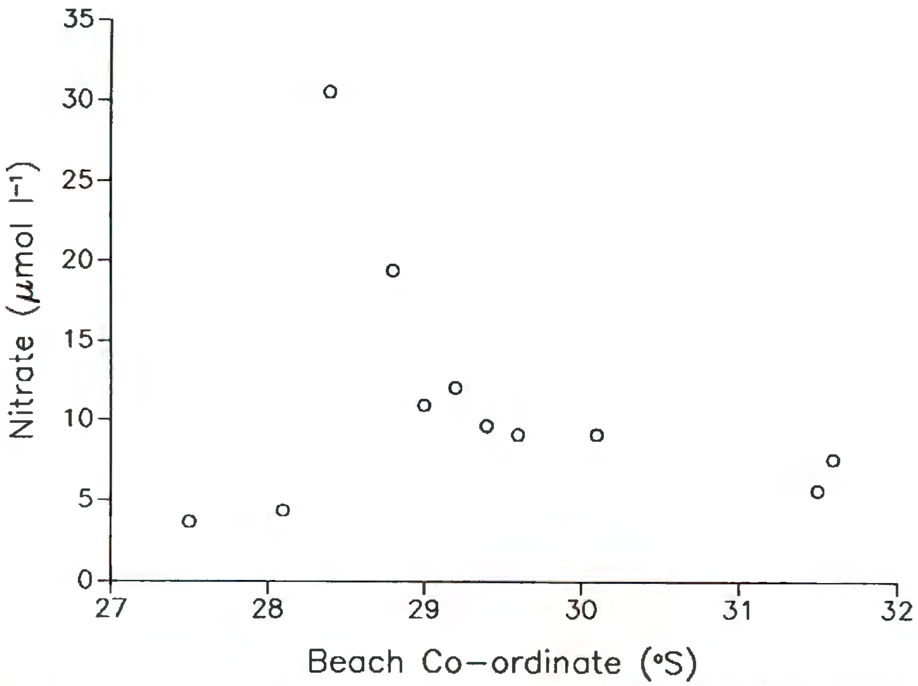

Figure 16. **The nitrate concentration in the seawater of the surf-zones on the east coast of South Africa.**

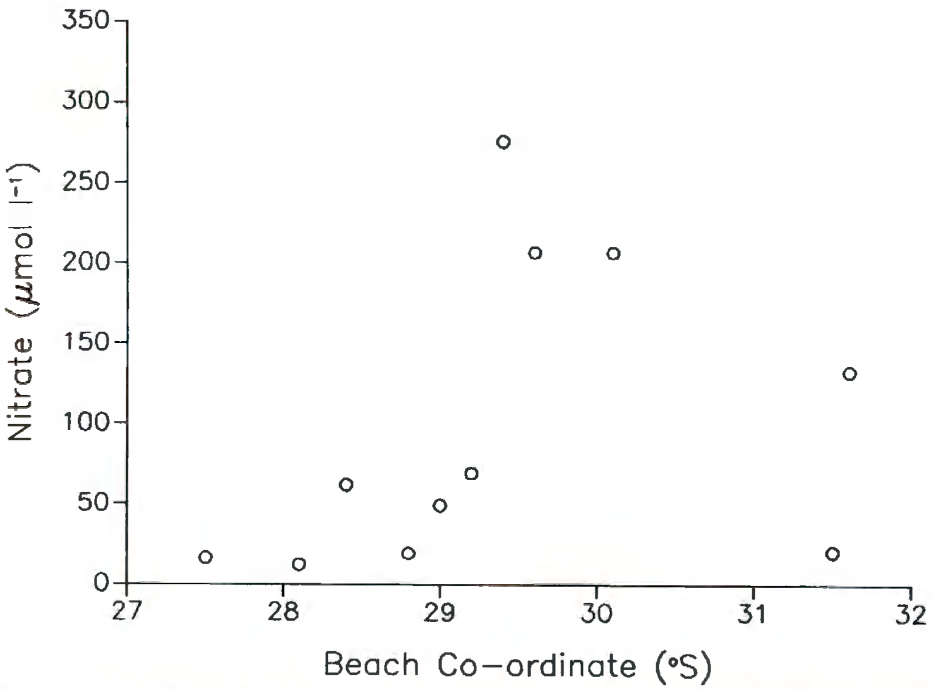

Figure 17. **The nitrate concentration in the groundwater entering the surf-zones on the east coast of South Africa.**

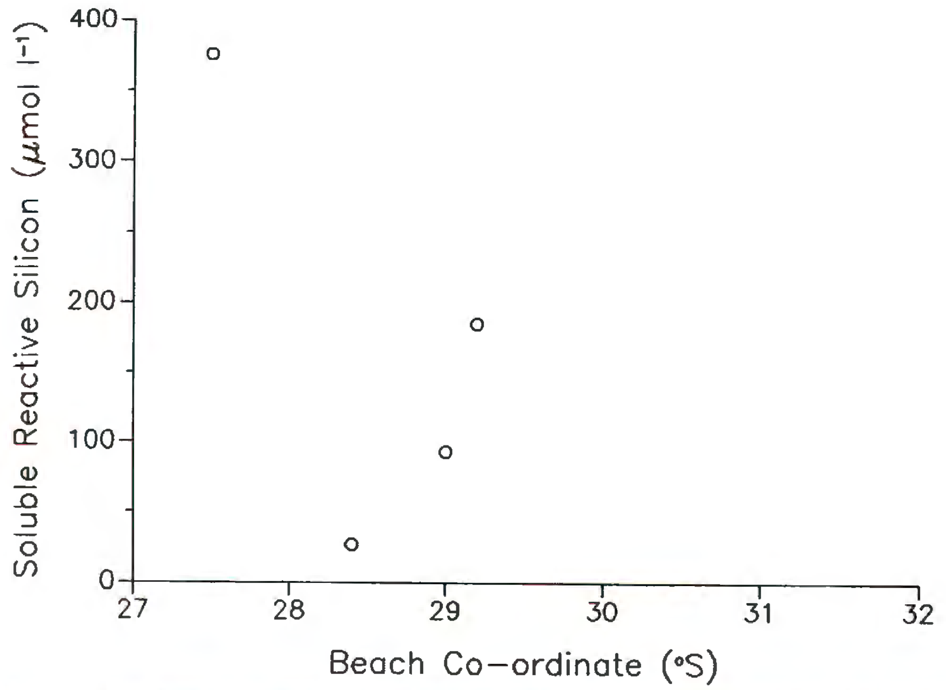

Figure 18. The soluble reactive silicon concentration in river water entering the surf-zones on the east coast of South Africa.

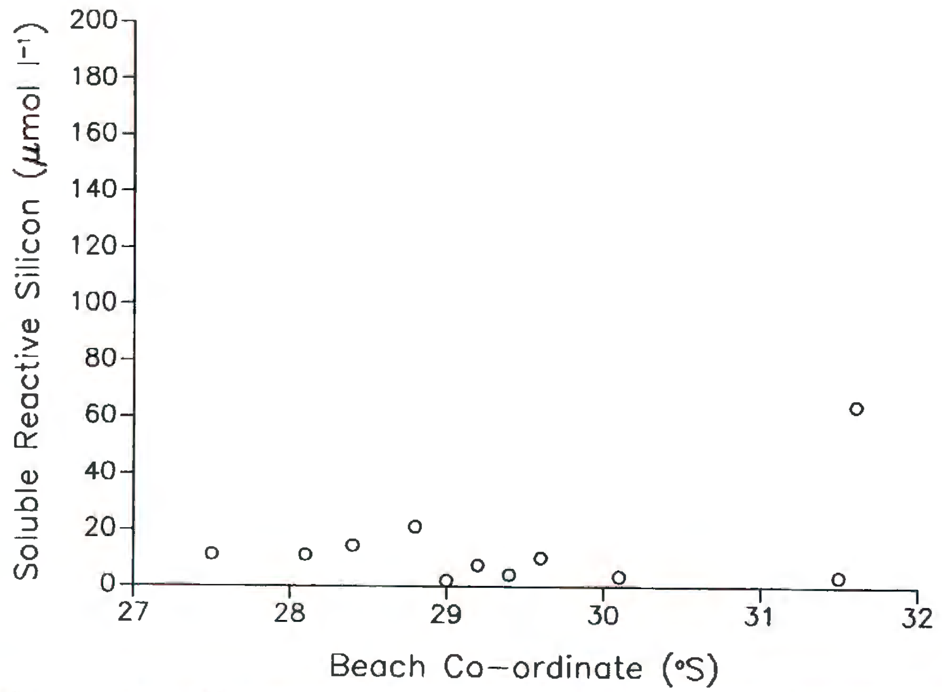

Figure 19. The soluble reactive silicon concentration in the seawater of the surf-zones on the east coast of South Africa.

The soluble reactive silicon content in the groundwater (Fig. 20) decreased from south to north, values ranging from 18 μmol l^{-1} to 160 μmol l^{-1}. On average the silicon content was 4.7 times greater than the seawater.

3.3.5 Salinity

From the salinity data (Fig. 21), it is evident that only one of the rivers sampled was estuarine, viz. St Lucia estuary.

The salinity of the seawater was always 34 ppt (Fig. 22) except at Port St Johns where the sample was collected in an estuary mouth. The groundwater salinities were always high, the lowest being 10 ppt, and the highest a hypersaline 36 ppt (Fig. 23).

3.4 Species Composition

The phytoplankton species composition is given below.

3.4.1 The Species Found in the Water

No.	Species	Assigned Number
1	*Achnanthes* sp.	1
2	*Anaulus australis*	7
3	*Asterionella glacialis*	8
4	*Aulacodiscus johnsonii*	10
5	*Biddulphia alternans*	12
6	*Biddulphia mobiliensis*	13
7	*Biddulphia pulchella*	14
8	*Biddulphia* A	15
9	*Biddulphia* B	16
10	*Campylosira cymbelliformis*	20
11	*Chaetoceros* medium	22
12	*Chaetoceros* small	23
13	*Climacopshenia* sp.	36
14	*Cocconeis* epiphyte	37
15	*Coscinodiscus* sp.	38
16	*Eucampia zoodiacus*	49
17	*Euglena* sp.	50
18	*Grammatophora marina*	55
19	*Gyrodinium* sp.	57
20	*Hemiaulus hauckii*	59
21	*Leptocylindrus danicus*	60
22	*Licmophora* sp.	62
23	*Melosira sulcata*	65
24	*Navicula* A	69

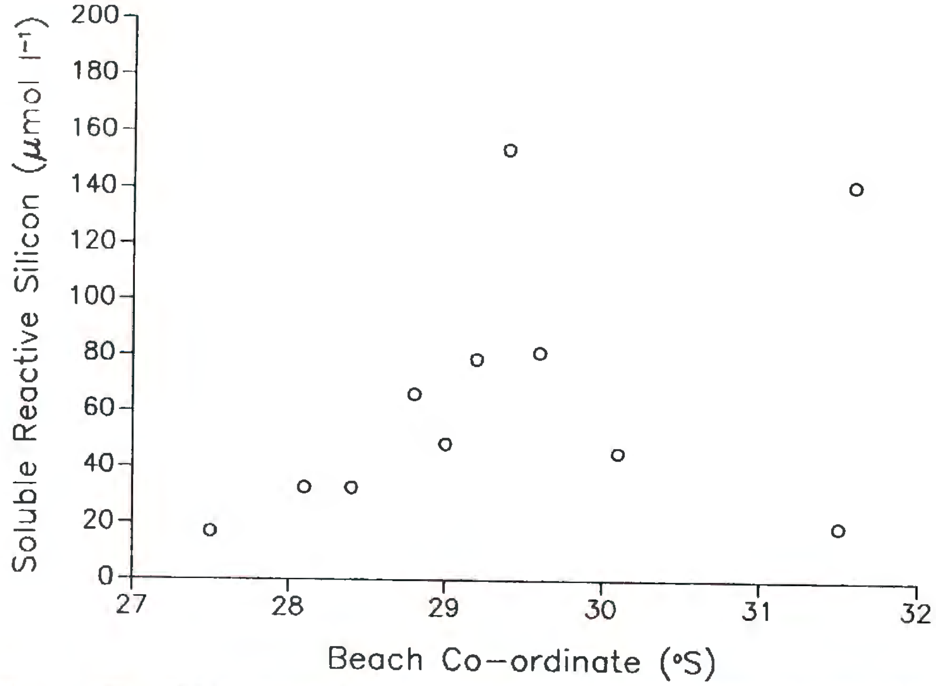

Figure 20. **The soluble reactive silicon concentration in the groundwater entering the surf-zones on the east coast of South Africa.**

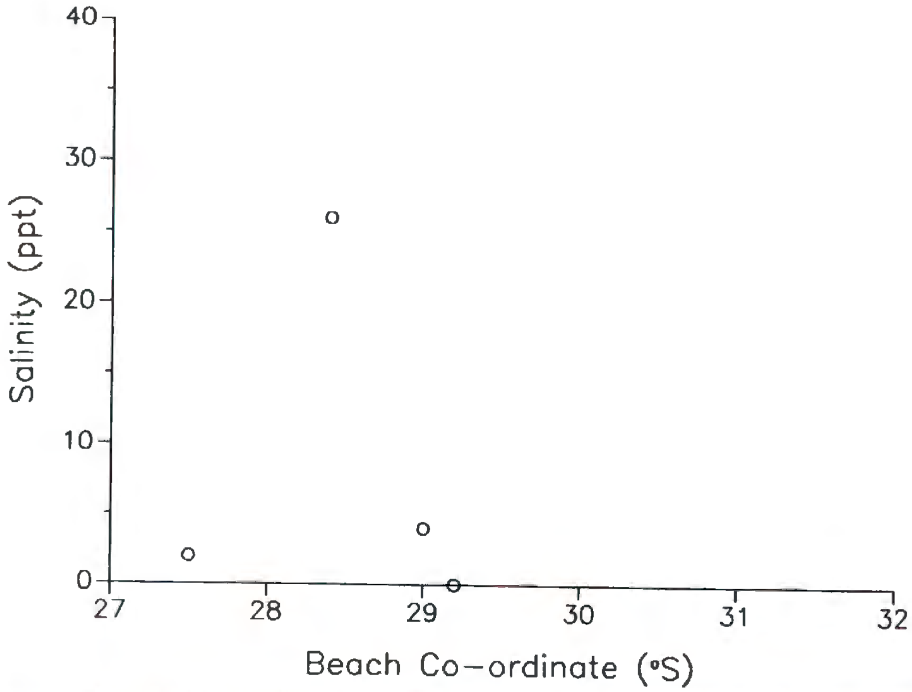

Figure 21. **The salinity of the river water entering the surf-zones on the east coast of South Africa.**

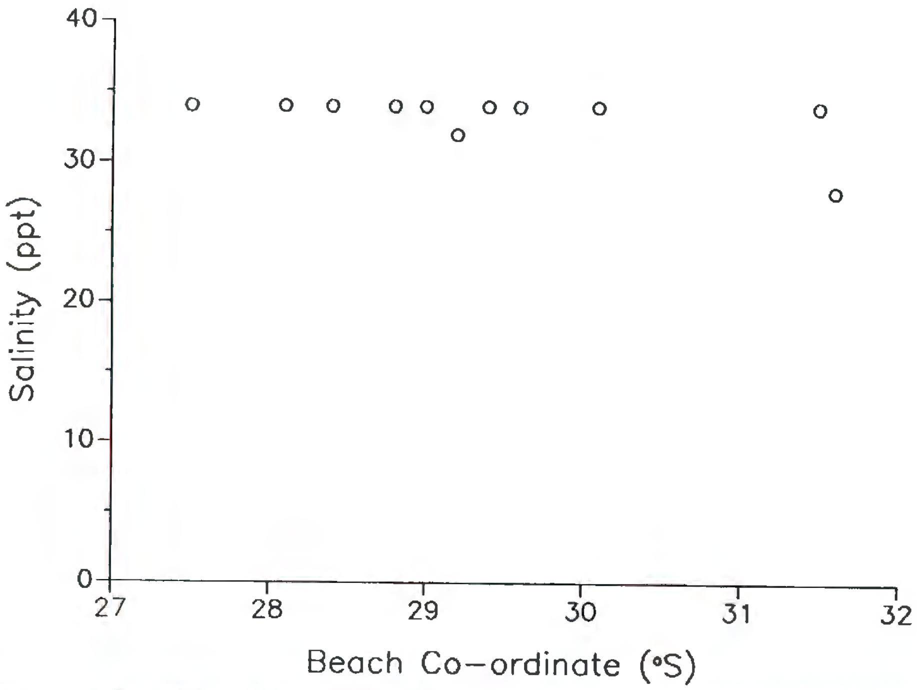

Figure 22. **The salinity of the seawater in the surf-zones on the east coast of South Africa.**

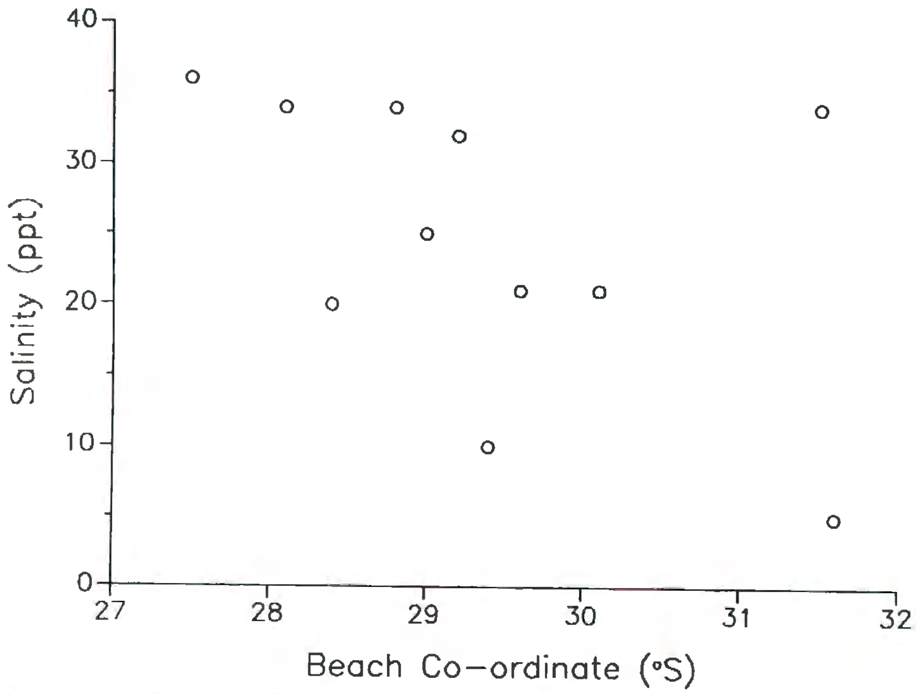

Figure 23. **The salinity of the groundwater entering the surf-zones on the east coast of South Africa.**

3.4.2 The Species Found in the Foam

26	*Nitzschia closterium*	77
27	*Nitzschia delicatissima*	78
28	*Nitzschia longissima*	79
29	*Nitzschia seriata*	81
30	*Nitzschia* B	82
31	*Nitzschia* C	83
32	*Peridinium* sp.	87
33	*Plagiogramma van heurckii*	92
34	*Pleurosigma* sp.	93
35	*Prorocentrum micans*	94
36	*Rhizosolenia alata*	95
37	*Rhizosolenia* sp.	98
38	*Rhizosolenia stolterfothii*	99
39	*Skeletonema costatum*	104
40	*Thalassionema nitzschioides*	110
41	*Thalassiosira decipiens*	111
42	*Thalassiothrix* sp.	114
43	Unknown A	117

3.4.3 The Species Found in the Sand

1	*Amphiprora*	4
2	*Asterionella glacialis*	8
3	*Aulacodiscus johnsonii*	10
4	*Aulacodiscus petersii*	11
5	*Biddulphia alternans*	12
6	Bluegreens	16
7	*Campylosira cymbelliformis*	20
8	*Chaetoceros* spores	22
10	Centric	21
11	*Cocconeis* epiphyte	37
12	Flagellates	51
13	*Gyrodinium* sp.	57
14	*Leptocylindrus danicus*	60
15	*Licmophora* sp.	62
16	*Navicula* A	69
17	*Navicula* B	70
18	*Navicula* C	72
19	*Navicula* F	118
20	*Nitzschia delicatissima*	78
21	*Nitzschia longissima*	79
22	*Nitzschia seriata*	81
23	*Plagiogramma van heurckii*	92
24	*Rhizosolenia* sp.	98

3.4.4 Community Analysis

The number of species recorded in the surf water ranges from 6 to 26 with a mean of 14 (Fig. 24). The number of species recorded in the foam decreased from north to south, values ranging from 6 to 24 with a mean of 12. (Fig. 25). There were few species recorded in the sand (between 1 and 10; Fig. 26) but this could be an artifact due to extremely low cell numbers in the samples.

The diversity index of water samples ranged from 1.2 to 5.5 (Fig. 27; a mean of 2.73). The foam had similar values ranging from 1.0 to 4.8 (Fig. 28; a mean of 2.49). The sand samples on average had slightly higher diversity indices ranging from 1.5 to 5.5 and a mean of 3.11 (Fig. 29).

The indices of dominance were generally low, values varying between 0.08 and 0.50 recorded in the water (Fig. 30; a mean of 0.29). The only high value (0.88) was recorded at the Tugela. In this sample *Asterionella glacialis* was the dominant phytoplankter. The foam had similar indices of dominance, values ranging from 0.08 to 0.63 (Fig. 31; with a mean of 0.29). In the sand all but two samples had indices of dominance below 0.35 (Fig. 32). At Port St Johns only one species of *Navicula* was found and at Sodwana, the same *Navicula* was dominant and indices of dominance above 0.7 were recorded. The remainder had a mean of 0.37.

Over 97% of the phytoplankton resident in the water were diatoms (Fig. 33) except at Richard's Bay. The foam contained less diatoms (Fig. 34), an average of 82, and a range of 45-100%. The sand samples contained mostly (over 97%) diatoms (Fig. 35) in all but three samples, viz. one of the St Lucia, Ifafa, and Blythedale beaches.

Dinoflagellates were rare in the water (an average of 1%; Fig. 36) but common in the foam (average of 18%, Fig. 37). Only one of the sand samples contained any dinoflagellates, viz. Blythedale beach (Fig. 38).

Flagellates were scarce in all the samples, being recorded in one water sample (Fig. 39), one foam sample (Fig. 40) and two sand samples (Fig. 41). Where they were recorded, they were found in large numbers.

Community analysis of the species composition using CANOCO separated the bluegreen and green algae on the x-axis (Fig. 42). The species only recorded in the samples south of the Transkei border separated out on the y-axis. Only one sand species, a *Navicula*, separated out. Three other species separated from the east coast species, *Aulacodiscus johnsonii*, *Biddulphia alternans* and *Dinophysis acuminata*. The two surf diatoms, *Anaulus australis* and *Asterionella glacialis*, fell in the main group of species.

TWINSPAN analysis separated out the sand species first, including the three species which separated out in the CANOCO analysis, and then separated a small group which appears to occur equally in the water and the sand (Fig. 43). Once again, the two surf diatoms, *Anaulus australis* and *Asterionella glacialis*, fell in main group of species which occurs mostly in the water column.

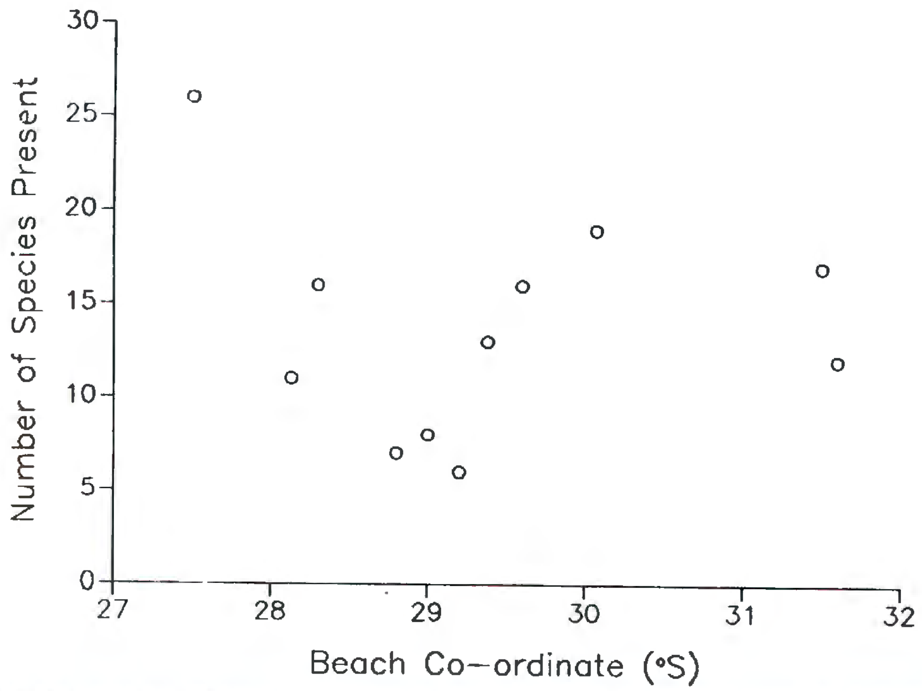

Figure 24. The number of species recorded in the surf water of the surf-zones on the east coast of South Africa.

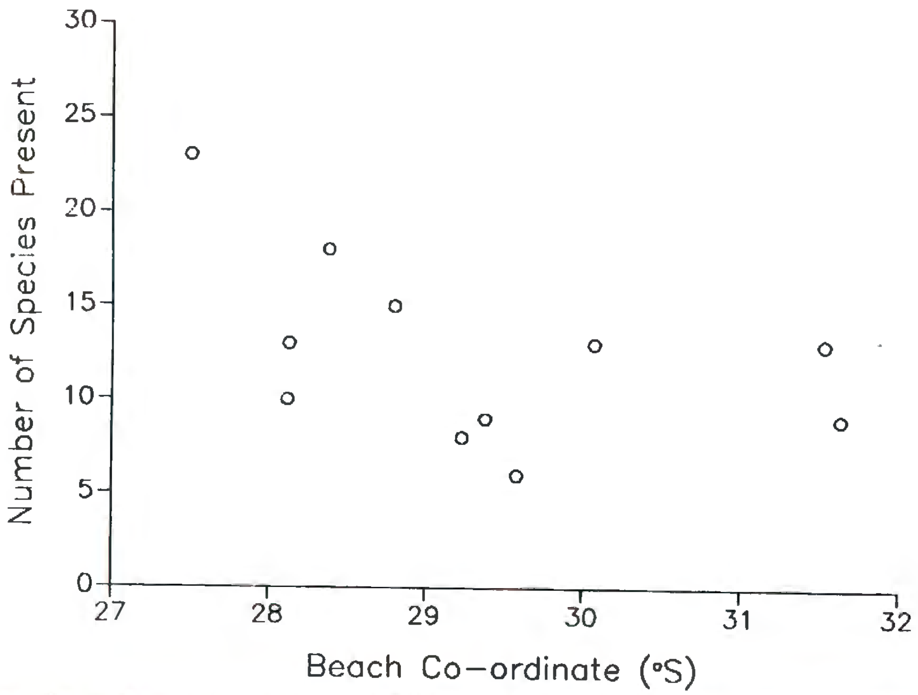

Figure 25. The number of species recorded in the surf foam of the surf-zones on the east coast of South Africa.

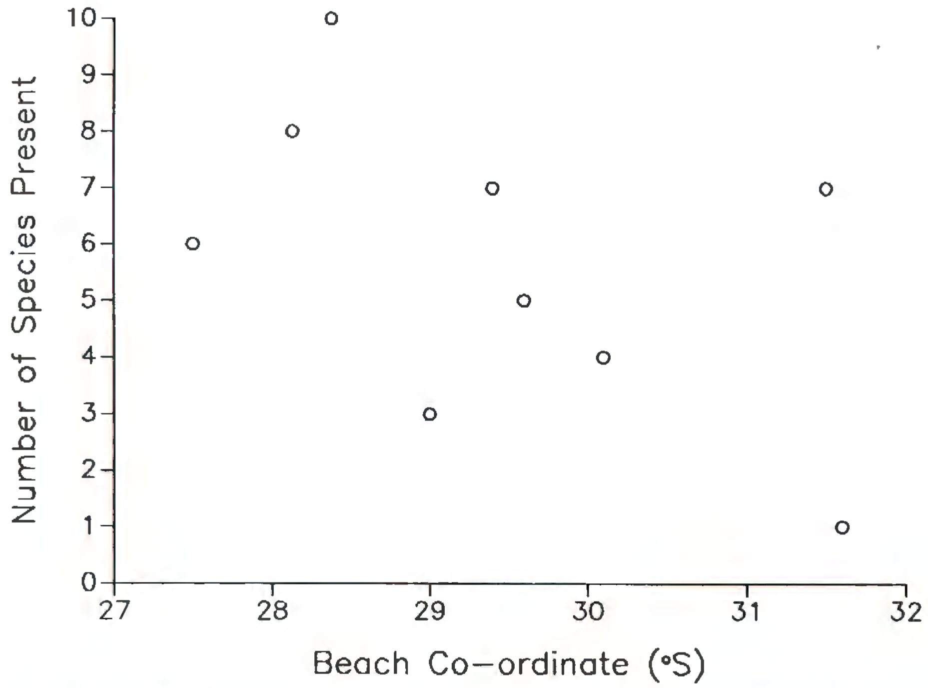

Figure 26. The number of species recorded in the surf sand of the surf-zones on the east coast of South Africa.

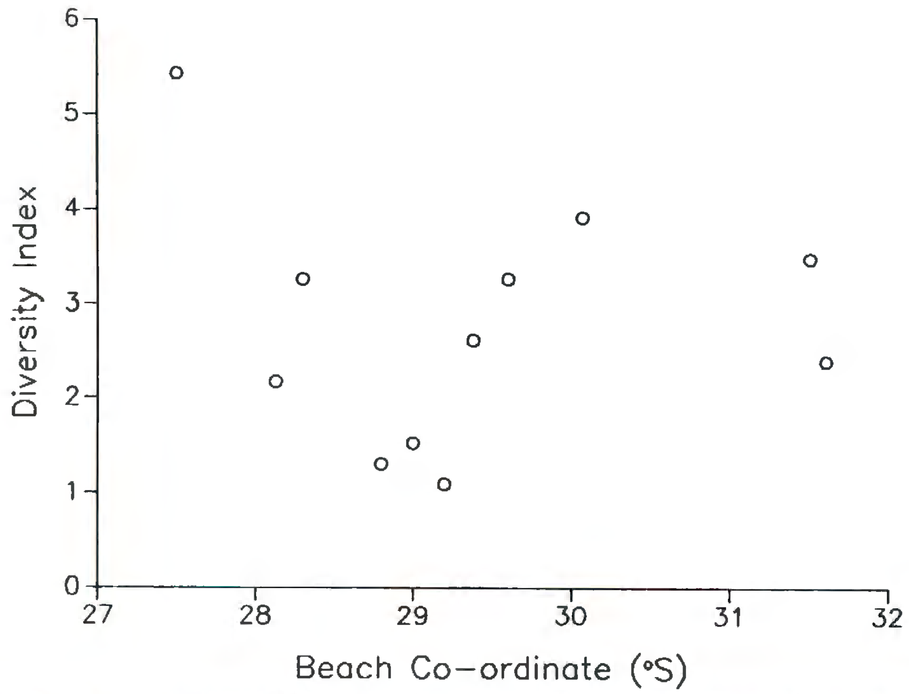

Figure 27. The diversity index of the populations recorded in the surf water of the surf-zones on the east coast of South Africa.

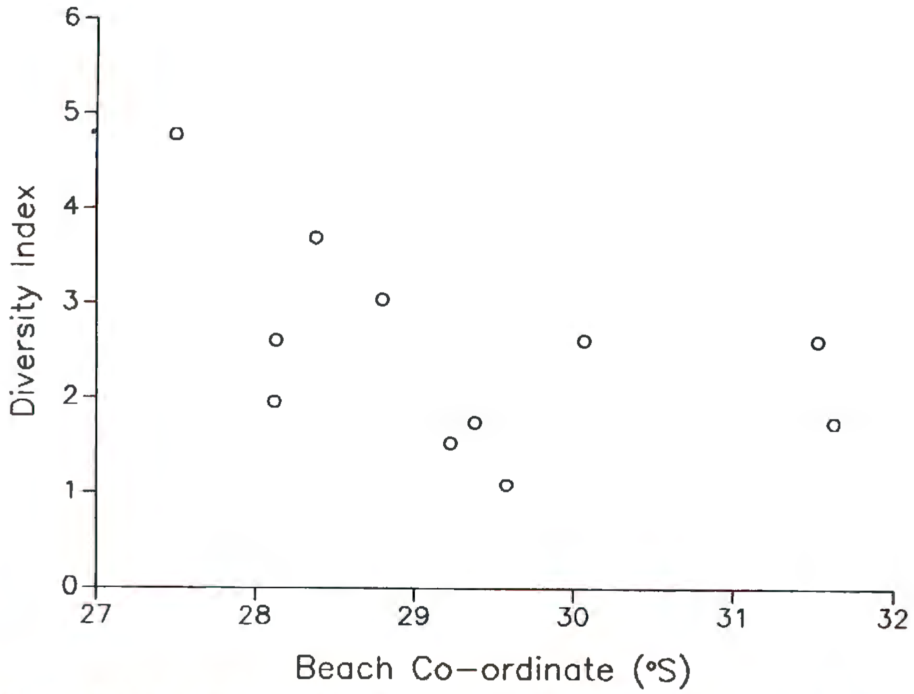

Figure 28. The diversity index of the populations recorded in the surf foam of the surf-zones on the east coast of South Africa.

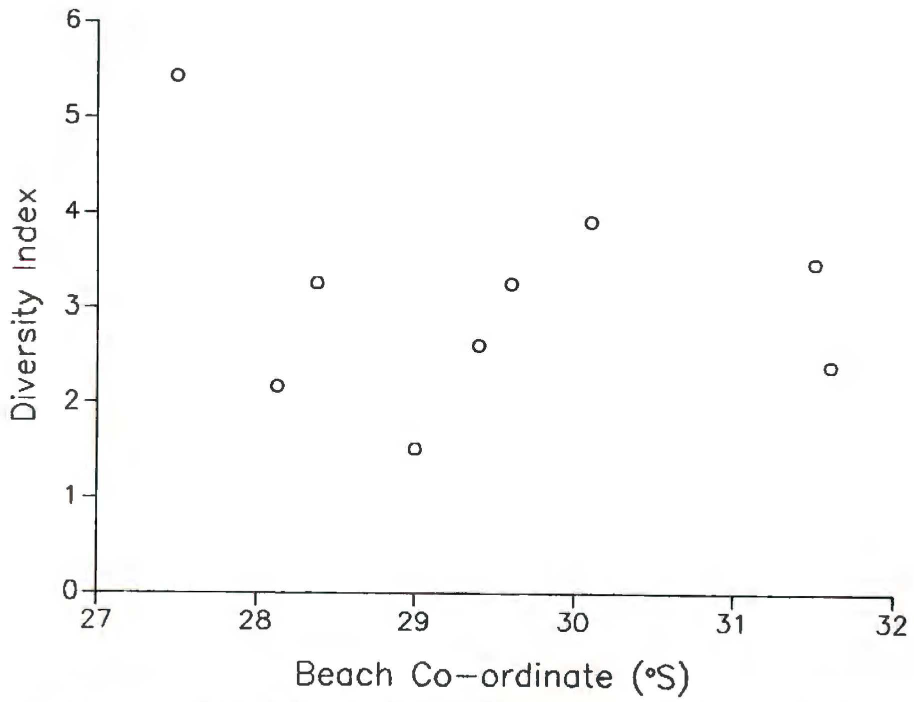

Figure 29. The diversity index of the populations recorded in the surf sand of the surf-zones on the east coast of South Africa.

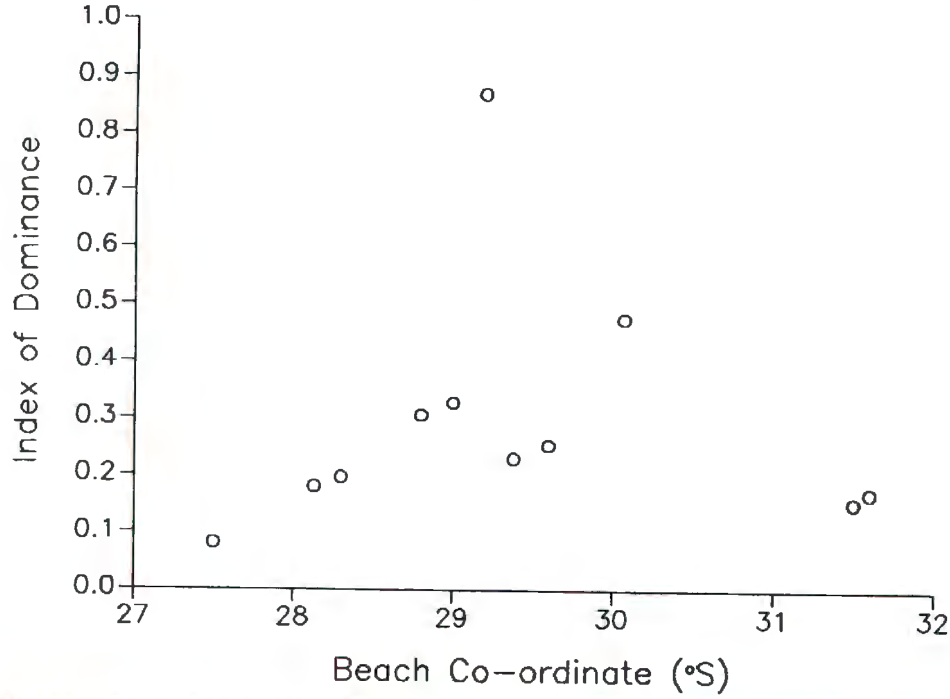

Figure 30. The index of dominance in the populations recorded in the surf water of the surf-zones on the east coast of South Africa.

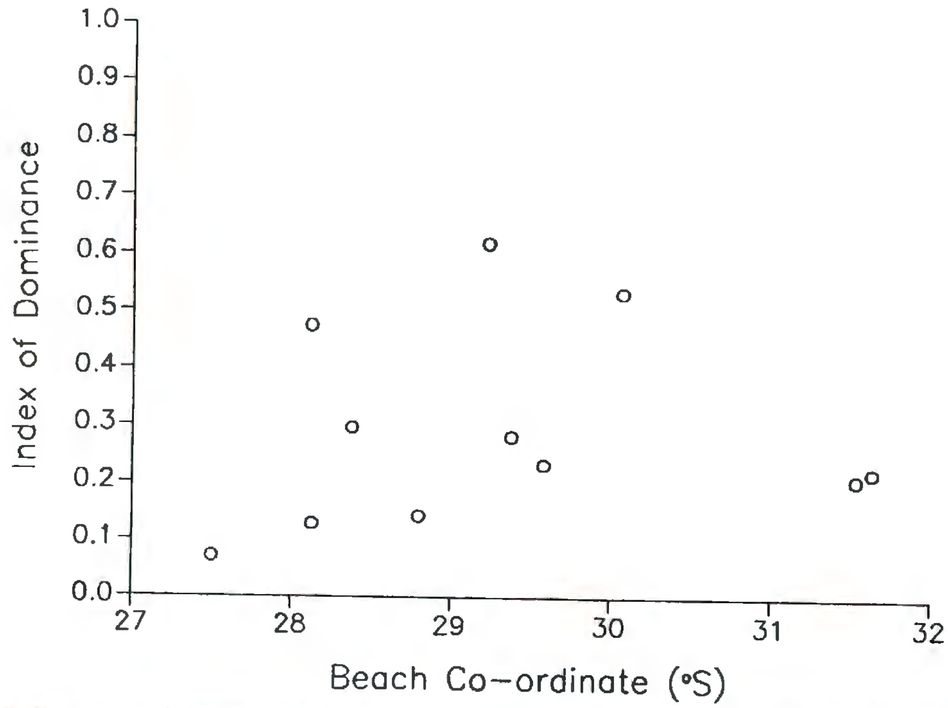

Figure 31. The index of dominance in the populations recorded in the surf foam of the surf-zones on the east coast of South Africa.

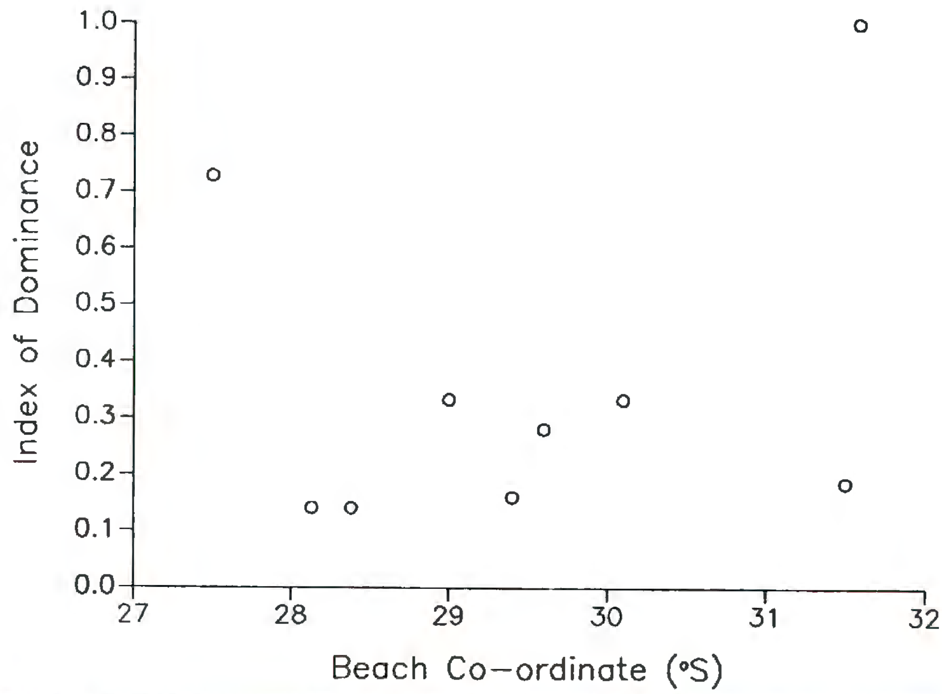

Figure 32. The index of dominance in the populations recorded in the surf sand of the surf-zones on the east coast of South Africa.

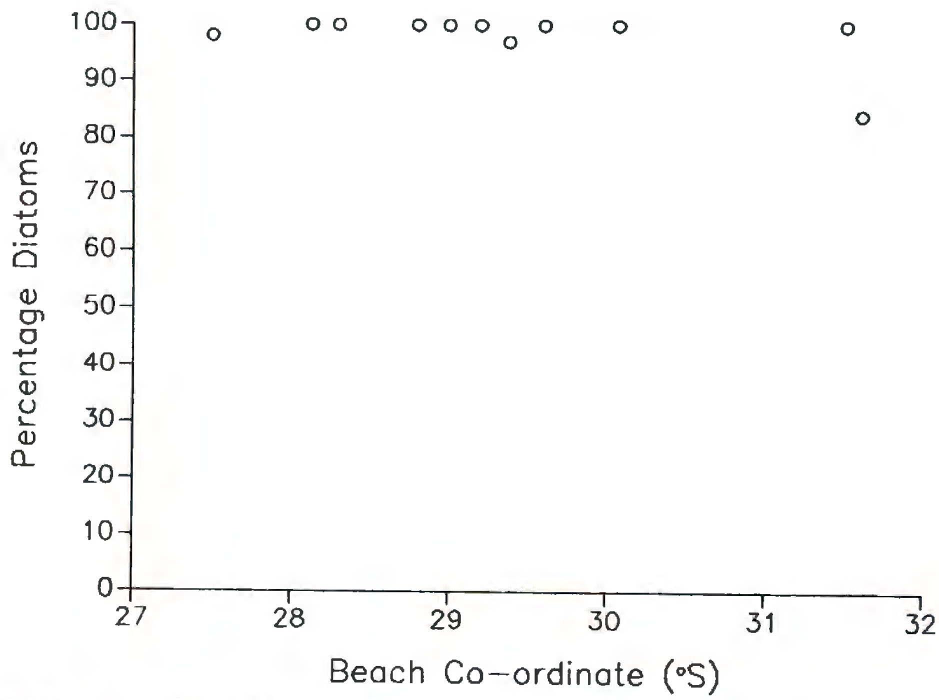

Figure 33. The proportion of diatoms in the populations recorded in the surf water of the surf-zones on the east coast of South Africa.

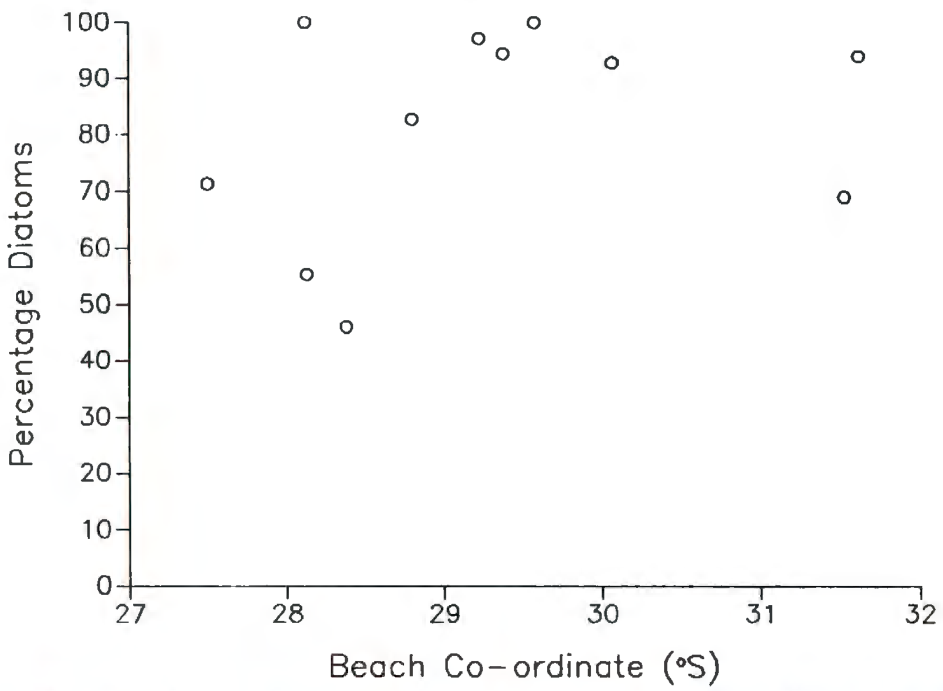

Figure 34. The proportion of diatoms in the populations recorded in the surf foam of the surf-zones on the east coast of South Africa.

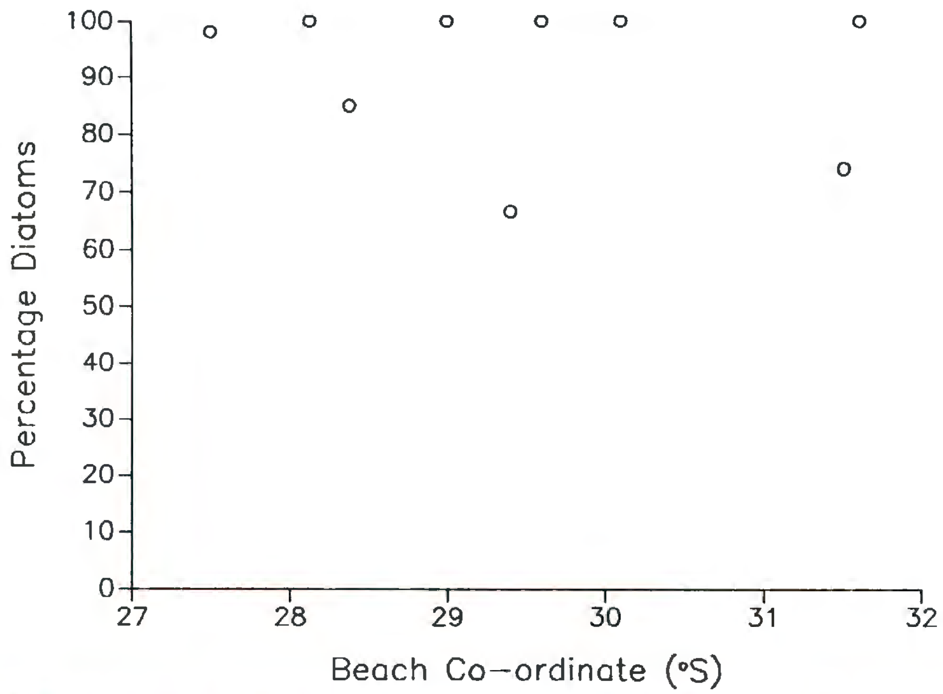

Figure 35. The proportion of diatoms in the populations recorded in the sand of the surf-zones on the east coast of South Africa.

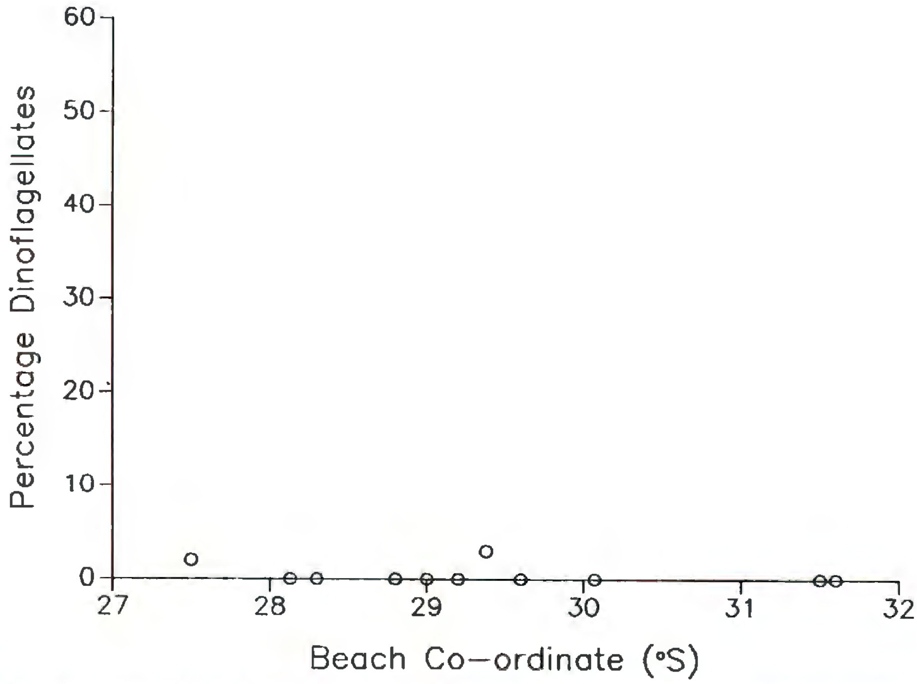

Figure 36. The proportion of dinoflagellates in the populations recorded in the surf water of the surf-zones on the east coast of South Africa.

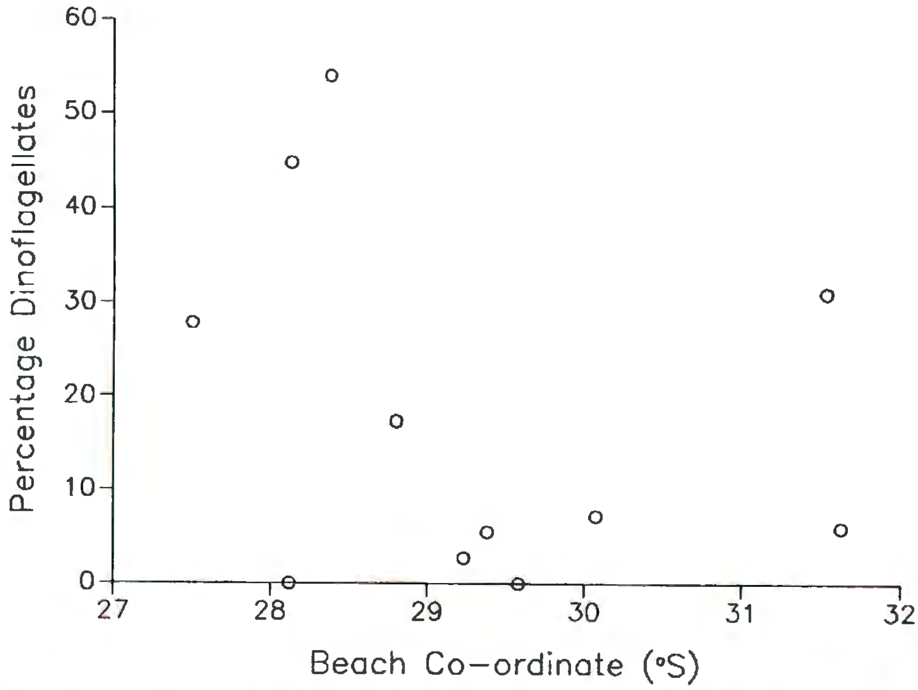

Figure 37. The proportion of dinoflagellates in the populations recorded in the surf foam of the surf-zones on the east coast of South Africa.

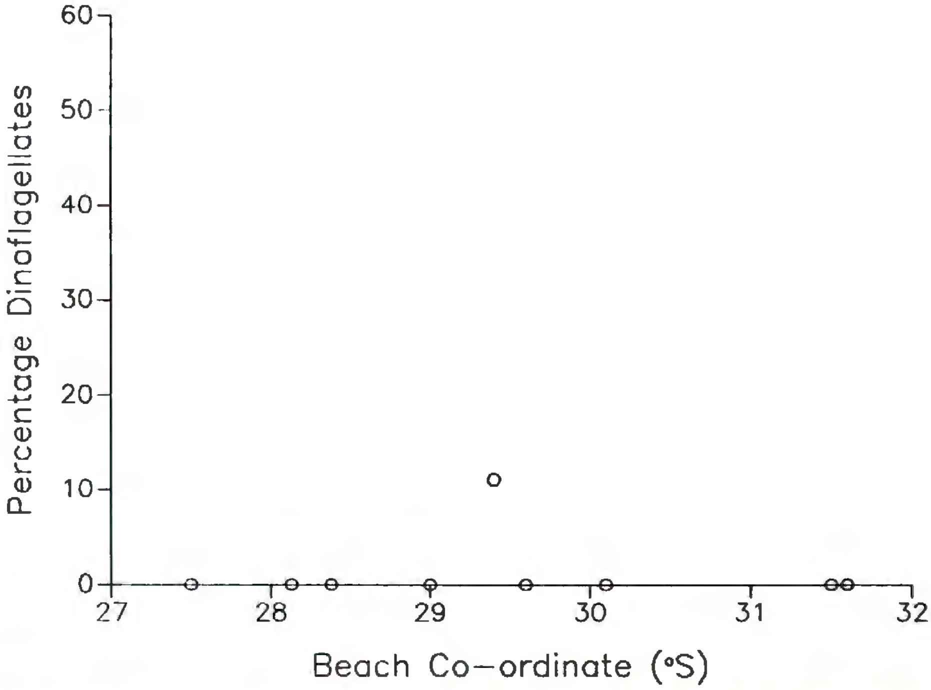

Figure 38. The proportion of dinoflagellates in the populations recorded in the sand of the surf-zones on the east coast of South Africa.

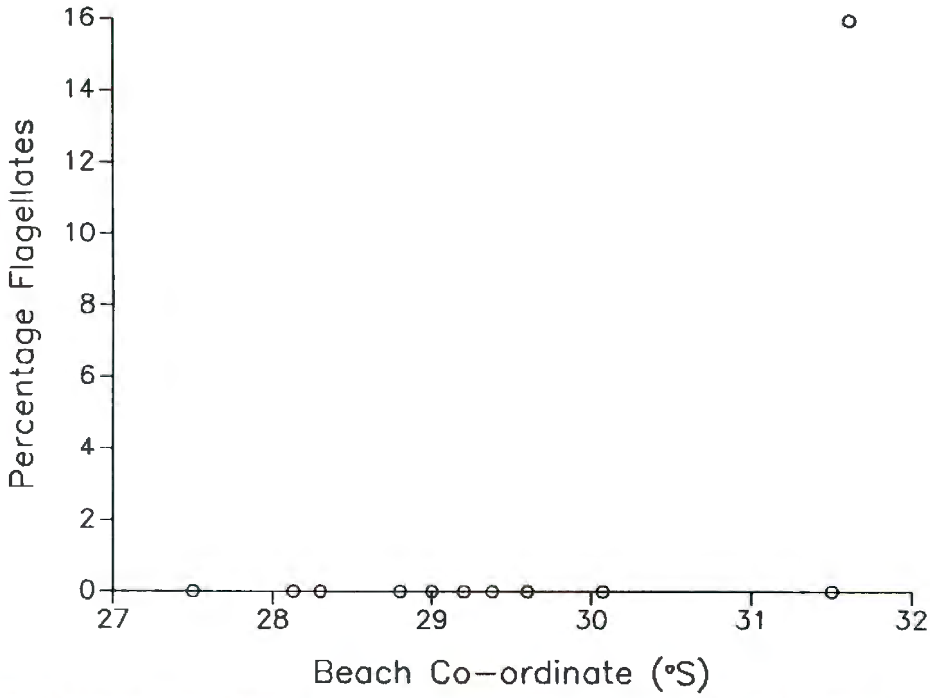

Figure 39. The proportion of flagellates in the populations recorded in the surf water of the surf-zones on the east coast of South Africa.

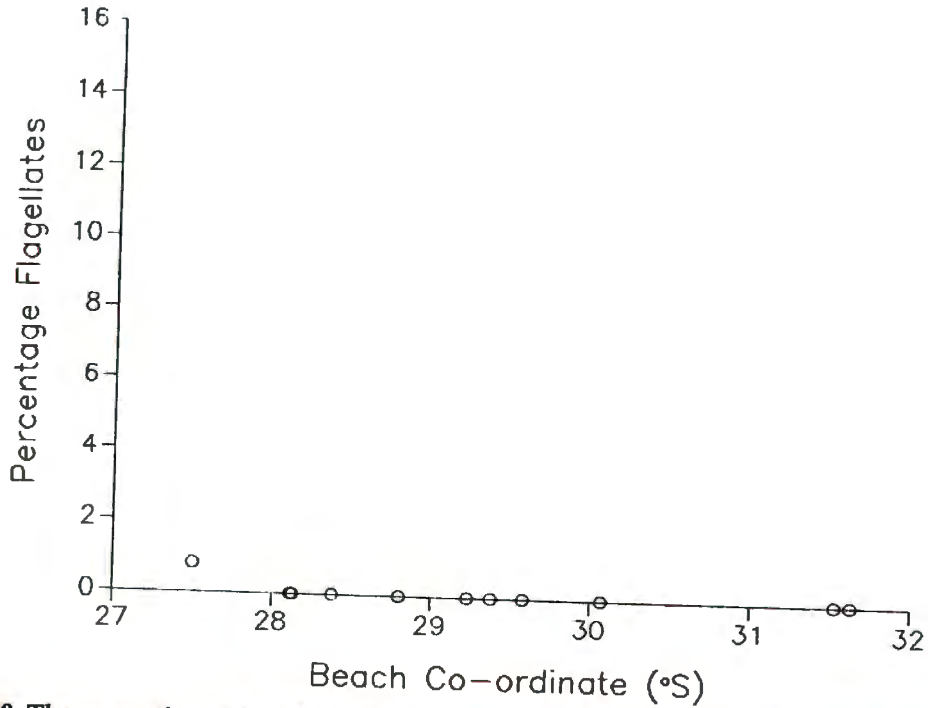

Figure 40. The proportion of flagellates in the populations recorded in the surf foam of the surf-zones on the east coast of South Africa.

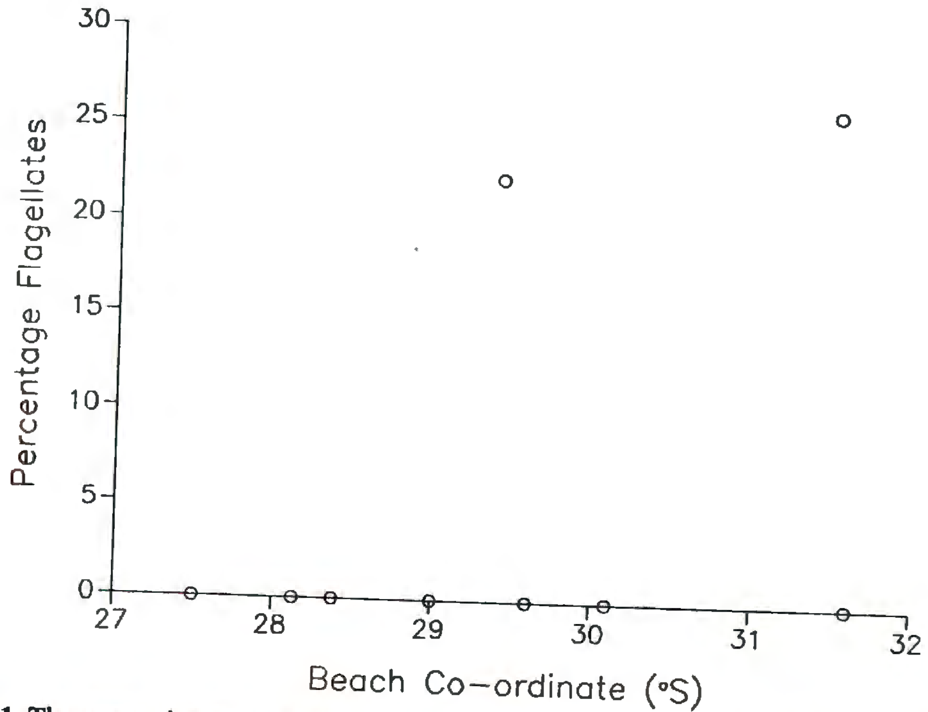

Figure 41. The proportion of flagellates in the populations recorded in the sand of the surf-zones on the east coast of South Africa.

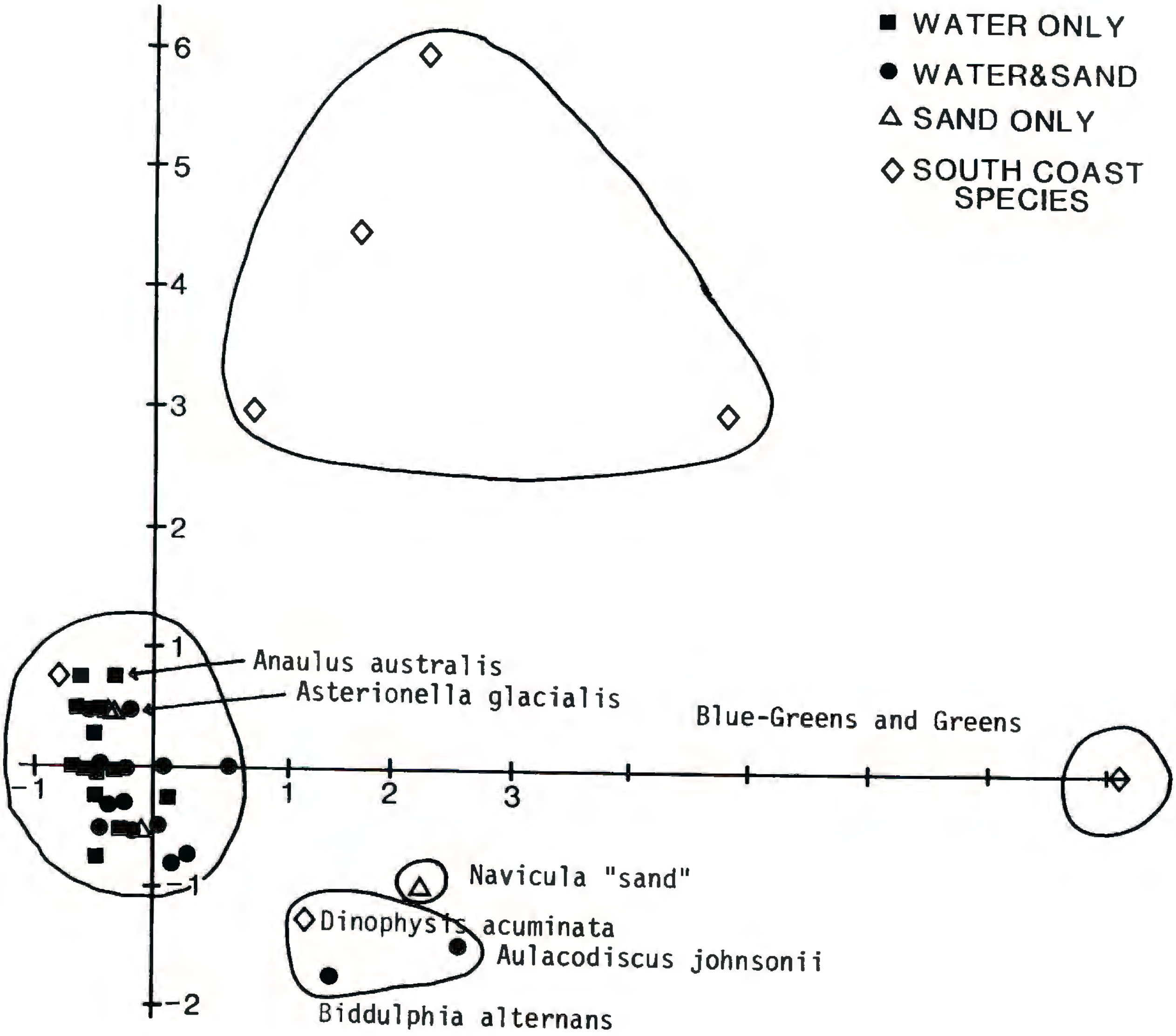

Figure 42. Detrended canonical correspondence analysis of the species found in the water and sand of the surf-zones on the east coast of South Africa.

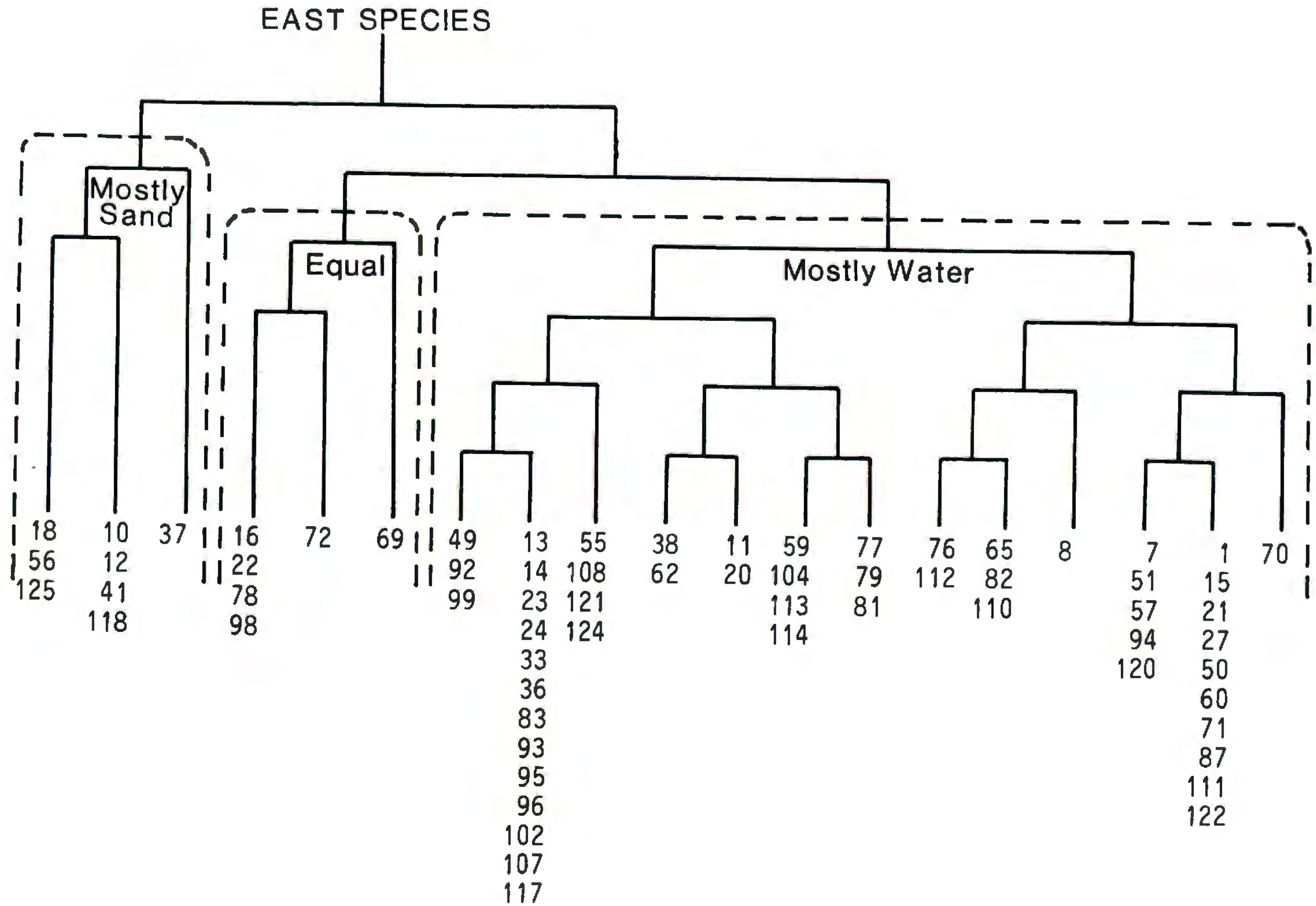

Figure 43. Dendrogram of the TWINSPAN analysis of the species found in the water and sand of the surf-zones on the east coast of South Africa.

When the sample location was analysed by CANOCO, the sand samples were shown to be significantly different from the water samples (Fig. 44). Foam and water samples were not different but formed a closely associated group. TWINSPAN analysis also showed a difference between the sand and water samples (Fig. 45). No other groups could be identified.

Because the sand samples were different from the water samples, the analysis was repeated excluding the sand samples. In this CANOCO analysis the Bonza Bay samples were shown to be different (Fig. 46). The second division was between south and east coast samples, with the division between south and east coasts at the Cape Province and Transkei border. The TWINSPAN analysis separated the Bonza Bay samples in the first division (Fig. 47). The second division separated south coast and east coast samples at the Transkei border (Fig. 47). In the south coast samples, there was a transition group which comprised the foam and water samples from Port St Johns.

3.5 Chlorophyll *a* Concentration

The chlorophyll *a* concentration measured in the water of the east coast surf-zones ranged from 2-17 μg chl *a* l^{-1} (Fig. 48; a mean of 7.6 μg chl *a* l^{-1}). The chlorophyll *a* concentrations increased from around 5 μg chl *a* l^{-1} north of the Tugela to a mean of 10 μg chl *a* l^{-1} south of the Tugela.

In the foam (Fig. 49) chlorophyll *a* concentations were not much higher than the water, values ranging from 3-32 μg chl *a* l^{-1} (a mean of 13.2 μg chl *a* l^{-1}). Only at two sites was the chlorophyll *a* concentration much higher than that of the water, viz. at Port St Johns and Amanzimtoti. At these two sites *Asterionella glacialis* was dominant but at Port St Johns, two other species (*Euglena* and *Navicula* species) were co-dominant.

The sand samples collected north of the Tugela contained less than 0.02 μg chl *a* cm^{-2} except at two of the Sodwana Bay sites (Fig. 50). Three sites south of the Tugela had high chlorophyll *a* concentrations and the Port St Johns and Ifafa samples were similar to those north of the Tugela.

The degree of concentration of phytoplankton in the foam can be shown as a ratio of chlorophyll *a* concentration in the foam to that in the water (Fig. 51). Most of the foam samples were slightly more concentrated than the water samples (ratio values between 1 and 2; Fig. 51). In two samples, the surface enrichment was 5 fold, viz. one sample taken at Mtunzini and one taken at Port St Johns.

The ratio of foam:sand chlorophyll *a* was calculated on a mass:mass basis. This ratio ranged from 1 000 to 20 000 (Fig. 52), except for one of the Mtunzini sites (600 000). The ratio of water:sand chlorophyll *a* was more variable around 60 000 (Fig. 53).

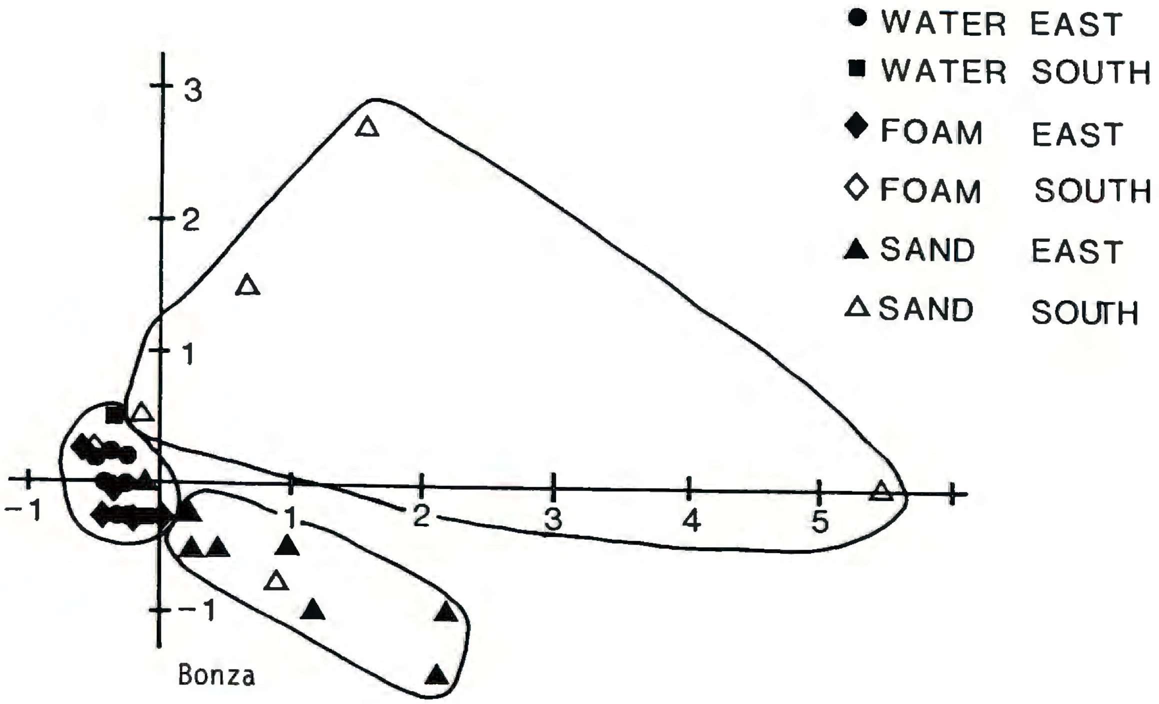

Figure 44. Detrended canonical correspondence analysis of the sites at which samples were taken on the east coast of South Africa.

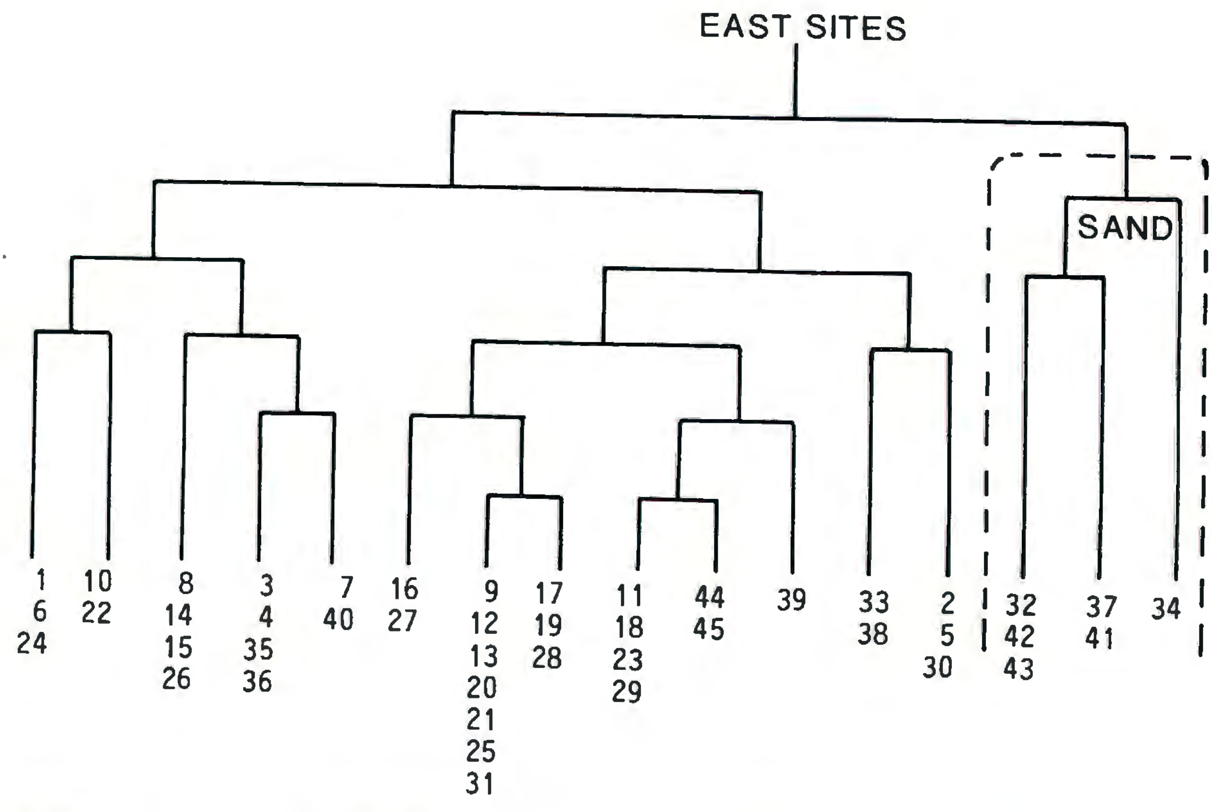

Figure 45. Dendrogram of the TWINSPAN analysis of the sites at which samples were taken on the east coast of South Africa.

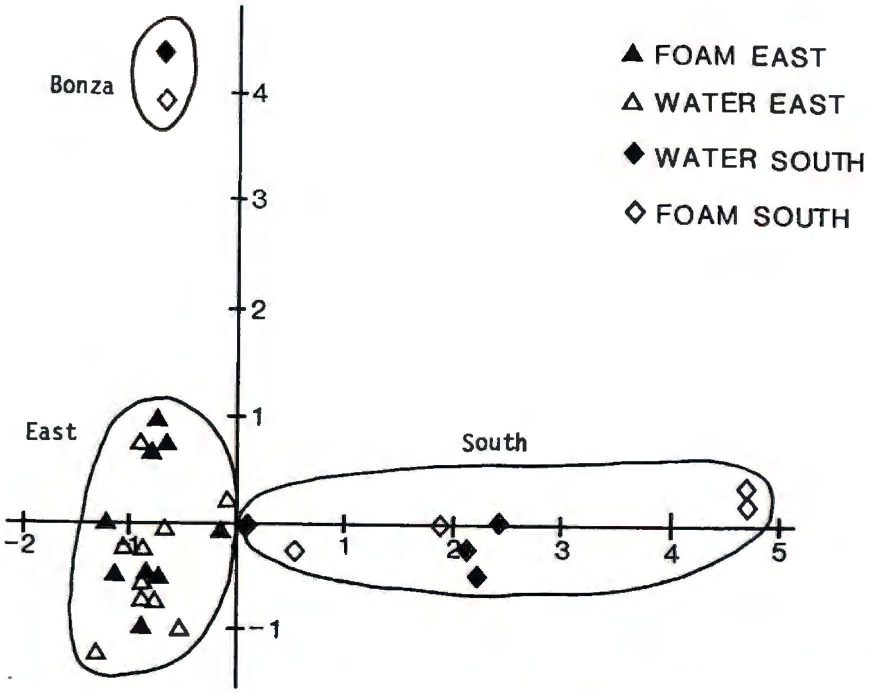

Figure 46. Detrended canonical correspondence analysis of the water samples collected from the surf-zones on the east coast of South Africa.

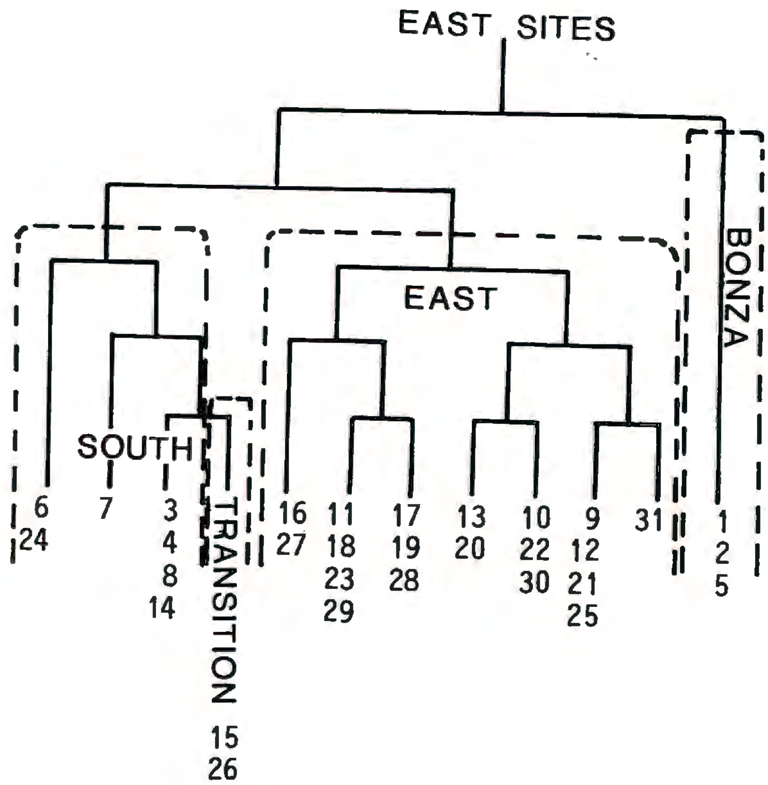

Figure 47. Dendrogram of the TWINSPAN analysis of the water samples taken from the surf-zones on the east coast of South Africa.

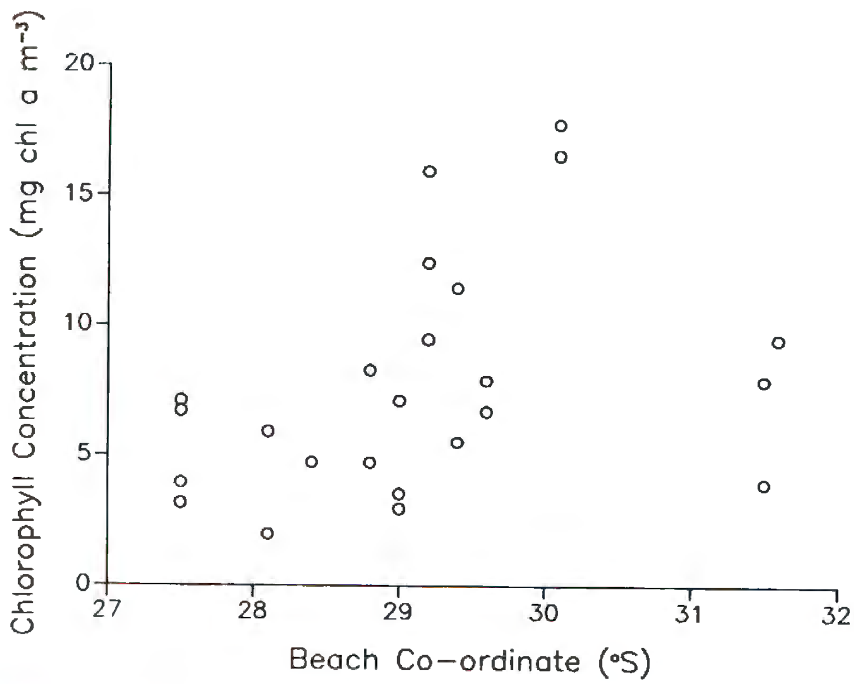

Figure 48. The chlorophyll *a* concentration in the water of the surf-zones on the east coast of South Africa.

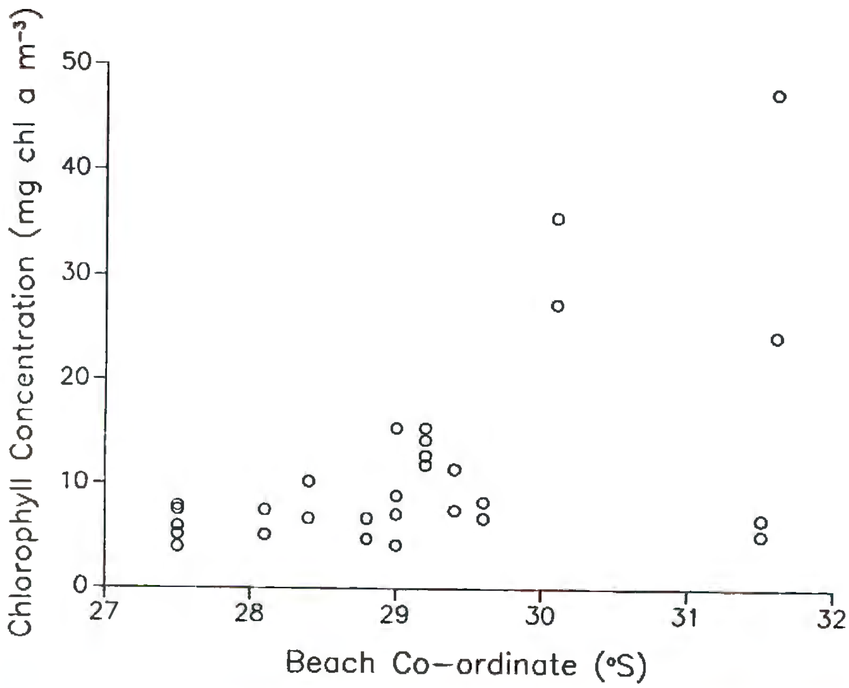

Figure 49. The chlorophyll *a* concentration in the foam of the surf-zones on the east coast of South Africa.

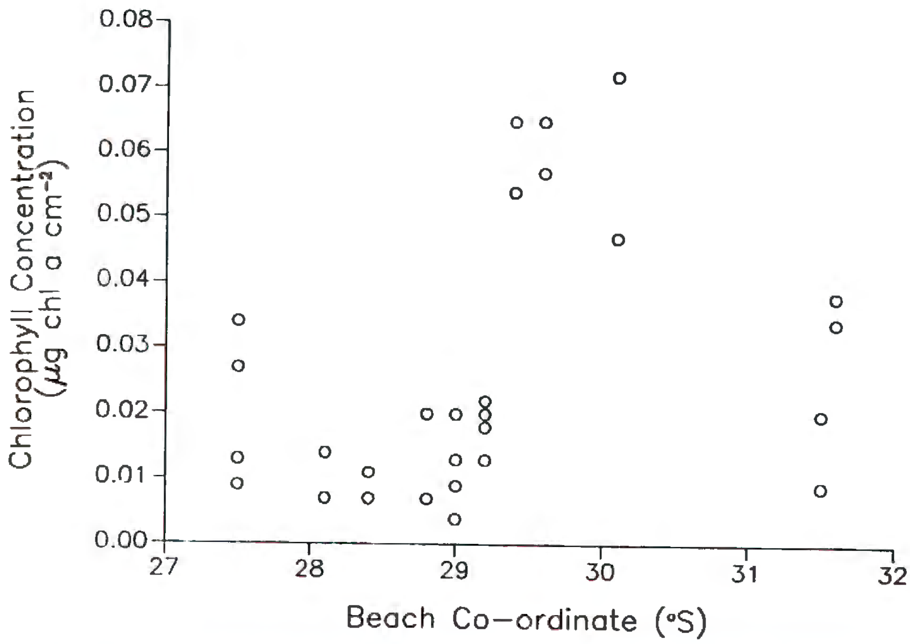

Figure 50. The chlorophyll *a* concentration in the sand of the surf-zones on the east coast of South Africa.

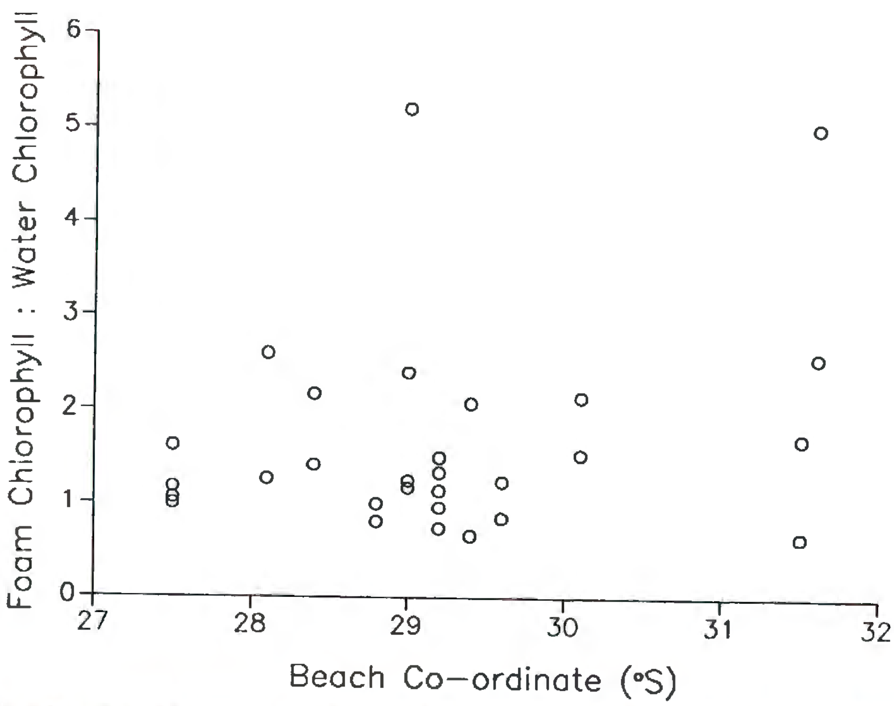

Figure 51. The ratio of foam:water chlorophyll *a* concentration in the water of the surf-zones on the east coast of South Africa.

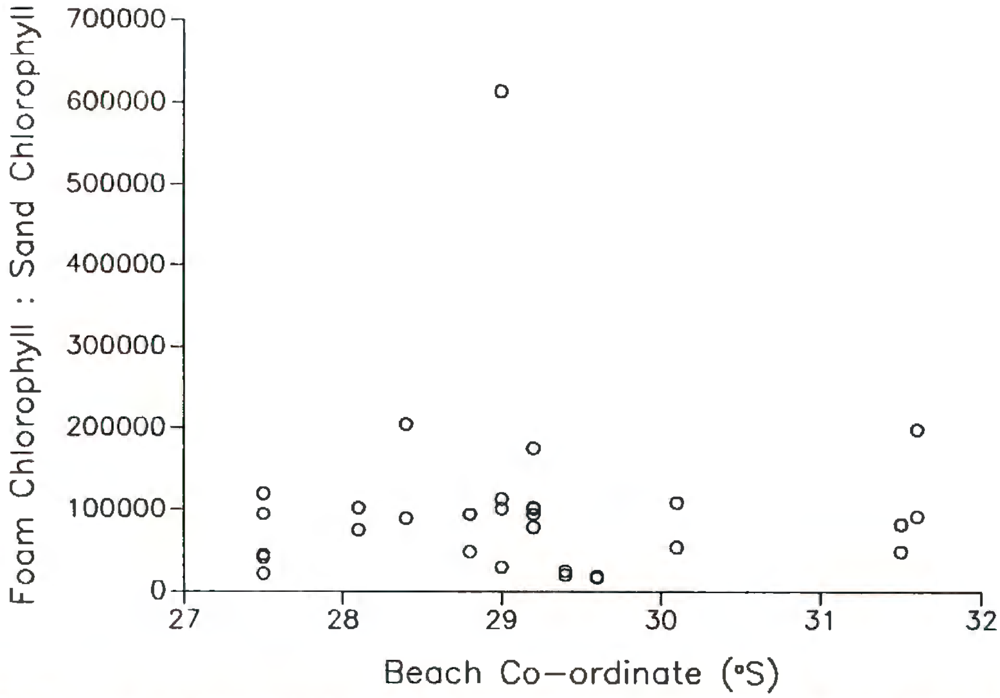

Figure 52. The ratio of foam:sand chlorophyll *a* concentration in the water of the surf-zones on the east coast of South Africa.

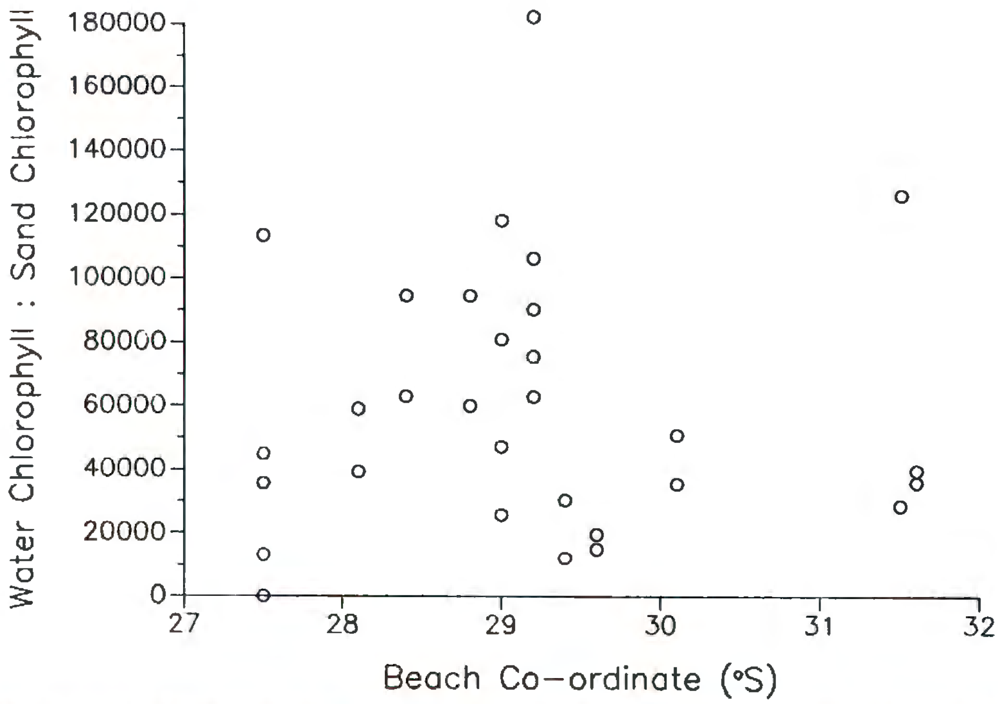

Figure 53. The ratio of water:sand chlorophyll *a* concentration in the water of the surf-zones on the east coast of South Africa.

The standing stock calculated as the chlorophyll *a* per running metre of beach was calculated for the phytoplankton in the water. The standing stock varied from 1 000-10 000 mg chl *a* m^{-1} (Fig. 54). Standing stock increased from around 2 500 mg chl *a* m^{-1} north of the Tugela River to 10 000 at Amanzimtoti. Values were low (around 4 000 mg chl *a* m^{-1}) at Ifafa and Port St Johns.

3.6 Primary Production

The annual primary production was calculated from the mean cholorophyll *a* concentrations and the mean topographic state. The remainder of the data was used from the Sundays River beach model (Campbell and Bate, 1988). The primary production is presented in Figure 55.

Primary productivity rates ranged from 10-70 kg C m^{-1} y^{-1} except at the Tugela River and Amanzimtoti. Here primary productivity was higher. Cape Vidal had the lowest value, followed by Ifafa and Port St Johns.

4. Discussion

The east coast has warm water north of the Tugela (Fig. 4), the continental shelf narrowing at the Tugela, thereby allowing warm Agulhas Current water to reach the surf-zone. North of the Tugela, the surf-zone has lower energy (Fig. 5). Even the beaches which were in the longshore bar-trough states had low wave energy (cf. Fig. 5 and 6).

Groundwater slopes are extremely low (Fig. 8); maxima recorded at Sodwana Bay and Ifafa. These aquifers are unlikely to provide a significant source of nutrients to the adjacent surf-zones because the flow of freshwater is low. This may explain why the east coast has such low phytoplankton standing stocks compared to the south and west coasts.

The east coast has many rivers which deliver large volumes of river water into the coastal waters. The rivers, however, contain concentrations of phosphate (Fig. 9), ammonium (Fig. 12) and nitrate (Fig. 15) similar to that of seawater. Of the nutrients measured, only silicon (Fig. 18) will be added to the coastal waters by river input.

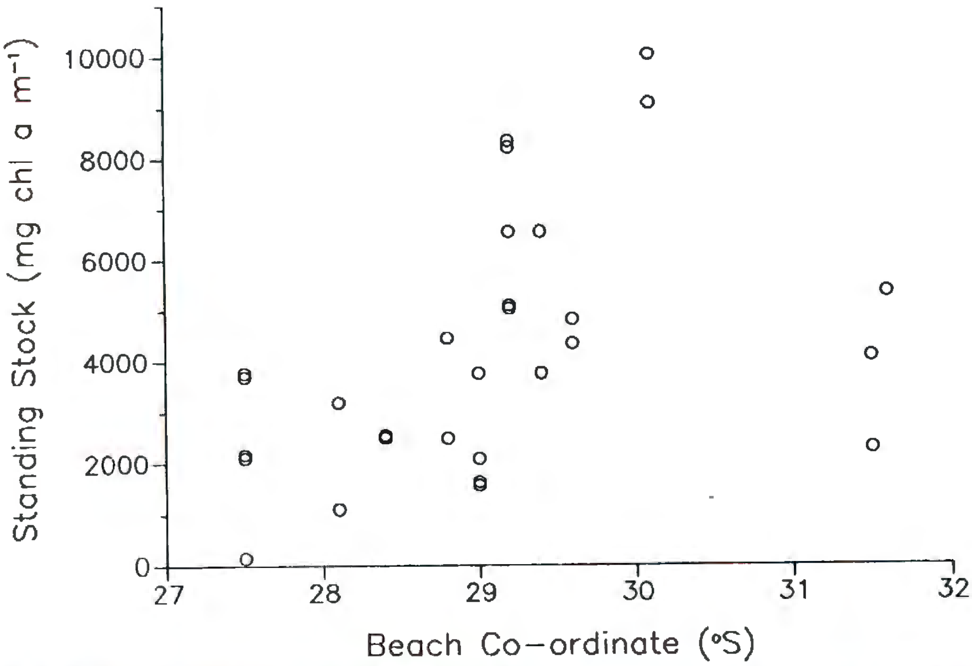

Figure 54. The standing stock given as total chlorophyll *a* per running metre of beach in the surf-zones on the east coast of South Africa.

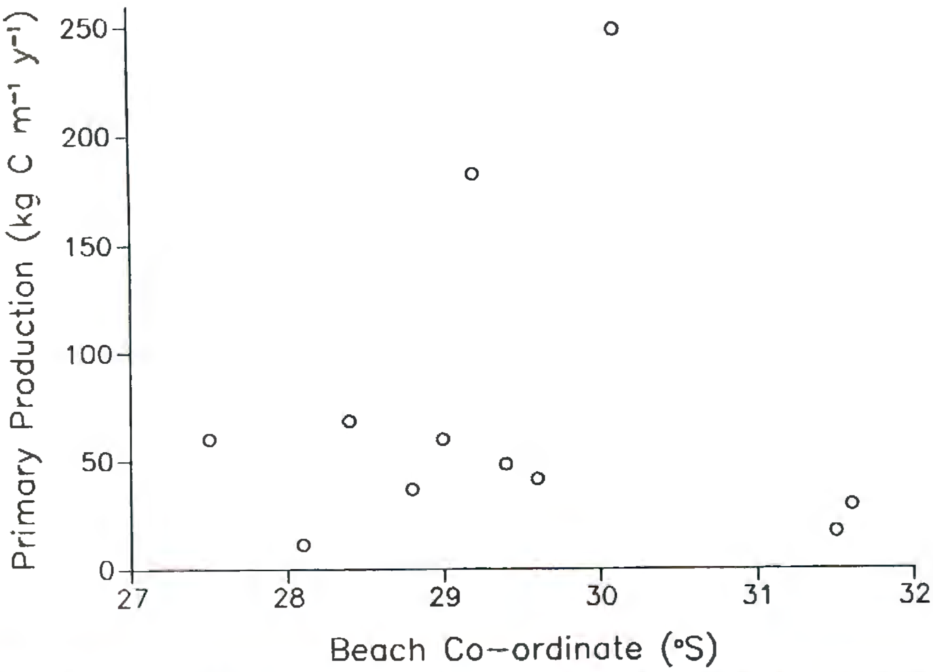

Figure 55. The annual primary production estimated for the surf-zones on the east coast of South Africa.

Groundwater contained similar phosphate (Fig. 11) and ammonium (Fig. 14) concentrations to that of the sea. Nitrate concentrations in the groundwater were ten times higher (Fig. 17) and silicon was four times higher (Fig. 20) than that of seawater. The beaches can be compared (Table 3) on the basis of a value which is indicative of the nutrient supply by groundwater into surf-zones. This value is calculated as a product of the nutrient content (given, firstly, as the total inorganic nitrogen and secondly, the total inorganic nutrients) and the groundwater slope. Because the salinity indicates the degree of dilution of the aquifer water at the point of sampling, the value is then divided by the salinity of the water tested. These data are given in Table 3. The Ifafa beach would have the highest nutrient input from coastal aquifers, followed by Tongaat and Amanzimtoti. The rest of the beaches are unlikely to have significant nutrient influx from coastal aquifers.

Fifty-one species were recorded in the surf water (section 3.4.1) and 43 in the foam (section 3.4.2) of which only one species was not recorded in the water. Twenty-four species were recorded in the sand (section 3.4.3), of which 6 species were never found in the water. On average, 14 of these species were recorded at the same time.

There were very few cells in the sand with the result that the species analyses of sand samples cannot be considered to be highly significant. In future sampling, a greater volume of sand should be extracted for species analysis.

On average 14 species were recorded per water sample (Fig. 24) and 6 species recorded per sand sample (Fig. 26). Diversity decreased from north to south (Fig 27-29). High dominance was rare in all samples (Fig. 30-32). *Asterionella glacialis* was the dominant species by far in the east coast water by far, representing 32.5% of all the water phytoplankton and 29.4% of the foam species (see Appendix 3). In the sand, one of the *Navicula* species represented 26.5% of all the species (see Appendix 3).

Anaulus australis comprised only 4.4% of all the foam phytoplankton and 1.3% of the species found in the water. No *Anaulus australis* cells were recorded in the sand.

Diatoms were the dominant group in both the phytoplankton and phytopsammon (epipsammic microalgae; Fig. 33-35). Dinoflagellates were mostly absent from the water and sand, but attained high numbers in the foam (Fig. 36-38). To date no surf accumulations of dinoflagellates have been recorded. The substantial surface enrichment of dinoflagellates can be seen in the mean value of 17.9% dinoflagellates in the foam as opposed to a mean of 0.6% in the water, and 1.2% in the sand. This represents a surface enrichment of 20 times for dinoflagellates. Other flagellates were rare (Fig. 39-41). Bluegreen algae were only recorded in the sand (Appendix 3) and comprised 1.9% of the sand populations.

Table 3. The ranking of the beaches on the basis of the potential input of nutrients from coastal aquifers into the east coast surf-zones.

Beach	Total Nitrogen	All Nutrients	Nitrogen/ Salinity	Nutrients/ Salinity
Ifafa	6.314	9.041	0.186	0.266
Tongaat	1.274	1.534	0.061	0.073
Amanzimtoti	1.274	1.534	0.061	0.073
Mtunzini	0.316	0.596	0.013	0.024
Sodwana	0.311	0.540	0.009	0.015
Tugela	0.284	0.600	0.009	0.019
St Lucia	0.231	0.330	0.011	0.017
Cape Vidal	0.112	0.228	0.003	0.007
Richard's Bay	0.070	0.235	0.002	0.007
Port St Johns	0.023	0.045	0.005	0.009
Blythedale	0.000	0.000	0.000	0.000

The CANOCO and TWINSPAN analyses of the species data showed that the south coast species, i.e. species only found in samples collected south of the Cape Province/Transkei border, separated out strongly (Fig. 42). Species found in the sand separated out strongly (Fig. 42 and 43). One of the surf diatoms, *Aulacodiscus johnsonii*, separated with the sand species, indicating that this species is strongly epipsammic on the east coast, 5.6% being recorded in the sand as opposed to 0.1% in the water and 0.2% in the foam. An analysis exluding the sand samples does not show any distinct communities (data not shown).

CANOCO and TWINSPAN analyses of the sites at which samples were taken separated the sand samples primarily (Fig. 44 and 45). The CANOCO analysis separated the south and east coast sand samples as well (Fig. 44). Excluding the sand samples, south and east coast samples were shown to be different (Fig. 45 and 46). There was no difference between foam and water samples. The TWINSPAN analysis showed that the Port St Johns samples were different to the rest (Fig. 47), probably due to Port St Johns being in a transition zone or because the sample was taken in an estuary mouth. The separation of the Bonza Bay samples is most likely due to the presence of green algae in large proportions in these samples.

A characteristic of the east coast is the lack of surface enrichment of phytoplanktonic diatoms, chlorophyll *a* values in the foam were approximately 1.5 times higher than those of the water (Fig. 48-51). In the two samples where there was surface enrichment, this was found to be due to surface enrichment of *Asterionella glacialis* which is an accumulating diatom. *Anaulus australis* cells comprised only 4.4% of the population in the foam and 1.3% of the population in the water.

An insignificant number of microplankton occurred in the sand (Fig. 52 and 53). The average chlorophyll *a* concentration of east coast water was 7.6 μg chl *a* l^{-1}.

The mean annual primary production is 73 kg C m^{-1} y^{-1} for the east coast surf-zones. Considering that the sandy coastline comprises 510 km of the coast (Campbell and Bate 1990a), the total primary production for the east coast beaches is calculated at 38 250 tonnes of carbon fixed per annum.

Campbell and Bate (1990d) discuss the comparison between the data for the east coast, and the south and west coasts.

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APPENDIX 3. THE SPECIES COMPOSITION OF SAMPLES COLLECTED ON THE EAST COAST OF SOUTH AFRICA.

WATER

Beach	Amanz	Blythe	Cape V	Ifafa	Mtunz	PAlf	PSJ
Coord	30.07	29.38	28.13	28.12	31.53	31.63	28.8
Achnanthes sp.						1.9	
Anaulus australis						3.7	3.4
Asterionella glacialis	67.4	22.0	3.6	29.1	53.2	17.6	25.4
Aulacodiscus johnsonii							
Biddulphia alternans							
Biddulphia mobiliensis	0.6						
Biddulphia pulchella							
Biddulphia sp.							
Biddulphia amazing							
Campylosira cymbelliformis	1.0		25.3		6.4	5.6	
Chaetoceros medium	6.7			3.5	6.4		
Chaetoceros small				3.1			
Climacopshenia Cupp 178							
Cocconeis epiphyte						5.6	
Coscinodiscus sp.							
Eucampia zoodiacus							
Euglena sp.							15.9
Grammatophora marina				1.2			
Gyrodinium sp.		6.0					
Hemiaulus hauckii	2.2			2.7			0.4
Leptocylindrus danicus						4.6	4.2
Licmophora sp.	1.2	6.0		0.4			
Melosira sulcata		14.0			17.0		
Navicula classic	0.3	1.0	3.6	2.7			
Navicula football	0.3		3.6			1.9	2.3
Navicula large							23.5
Navicula sp.			21.7	3.5	6.4	1.9	1.9
Nitzschia A (Drawing)							
Nitzschia closterium	0.7	2.0	3.6	1.2			
Nitzschia delicatissima	12.0		24.1	16.6			7.6
Nitzschia longissima				2.5	4.3		
Nitzschia seriata	0.9	2.0		14.6		1.9	
Nitzschia sp.						10.2	2.7
Nitzschia very small			4.8				
Peridinium sp.							
Plagiogramma van heurckii							
Pleurosigma sp.		1.0					
Prorocentrum micans		3.0				1.9	
Rhizosolenia alata	0.1		4.8				
Rhizosolenia delicatula	0.4						
Rhizosolenia sp.	0.3		3.6				
Rhizosolenia stolterfothii				2.5			
Schroederella 1				0.6			
Skeletonema costatum	2.5			10.8			
Striatella Cupp 172							
Surirella sp.							
Thalassionema nitzschioides	1.9	39.0	1.2	4.4	2.1		
Thalassiosira decipiens	0.8					43.5	12.5
Thalassiosira rotula	0.6	1.0					
Thalassiosira/Coscinodiscus		1.0			4.3		
Thalassiothrix sp.	0.3	2.0		0.4			0.4

	Rich B 27.5	Sodw 28.38	St Lu 29.58	Tong 29.23	Tugela 29.93
Achnanthes sp.					
Anaulus australis			4.5	3.9	
Asterionella glacialis	30.8		1.7	46.6	93.2
Aulacodiscus johnsonii		1.5			
Biddulphia alternans		0.5		0.5	
Biddulphia mobiliensis				0.5	
Biddulphia pulchella		3.0			
Biddulphia sp.			0.7		
Biddulphia amazing					0.8
Campylosira cymbelliformis		5.8	10.9	30.8	12.3
Chaetoceros medium					
Chaetoceros small					
Climacopshenia Cupp 178			3.0		
Cocconeis epiphyte				1.0	
Coscinodiscus sp.					2.2
Eucampia zoodiacus				1.4	
Euglena sp.					
Grammatophora marina			1.5		1.5
Gyrodinium sp.					
Hemiaulus hauckii		1.0	1.0		
Leptocylindrus danicus		3.5			
Licmophora sp.		4.5		8.3	
Melosira sulcata					
Navicula classic		3.5	0.7	7.8	
Navicula football	1.9	2.5	1.4	1.0	
Navicula large					
Navicula sp.		1.5	10.6	1.5	
Nitzschia A (Drawing)		2.0			
Nitzschia closterium	3.8	3.5	1.7		
Nitzschia delicatissima		10.0	13.7		
Nitzschia longissima		1.5	0.3		
Nitzschia seriata		0.5	1.7		
Nitzschia sp.		7.5		2.0	
Nitzschia very small	44.2				
Peridinium sp.		2.0			
Plagiogramma van heurckii		9.6			
Pleurosigma sp.	3.8				2.9
Prorocentrum micans					
Rhizosolenia alata		19.4	1.0		0.8
Rhizosolenia delicatula		6.5			
Rhizosolenia sp.			2.7		1.5
Rhizosolenia stolterfothii		1.5	26.0		
Schroederella 1					
Skeletonema costatum					
Striatella Cupp 172		2.0			
Surirella sp.	1.5		1.5		
Thalassionema nitzschioides		3.5		2.9	1.5
Thalassiosira decipiens					
Thalassiosira rotula					
Thalassiosira/Coscinodiscus				5.9	
Thalassiothrix sp.	2.0				

FOAM

Beach	Amanz	Blythe	Cape V	Cintsa	Ifafa	PSJ	Rich B	Sodw
Coord	30.07	29.38	28.13	28.12	31.53	31.63	28.8	27.5
Anaulus australis		13.9	5.3	26.3				3.3
Asterionella glacialis	72.2	48.6	2.6	3.4	28.2	27.3	30.3	1.6
Aulacodiscus johnsonii			2.6					
Aulacodiscus petersii			1.3					
Biddulphia alternans								0.8
Biddulphia mobiliensis								
Biddulphia amazing			5.3					
Biddulphia sp.							0.8	
Campylosira cymbelliformis	0.4	5.6	19.7				10.8	6.6
Ceratium furca/marina								0.8
Chaetoceros medium	5.3				2.8			2.5
Coscinodiscus sp.						1.1	0.8	
Eucampia zoodiacus							4.3	
Euglena sp.					26.2			
Grammatophora marina	0.6						2.6	2.5
Gyrodinium sp.				63.5				
Hemiaulus hauckii					1.4			3.3
Leptocylindrus danicus						6.6		
Licmophora sp.	1.5	11.1	5.3	0.7	0.6		0.9	6.6
Melosira sulcata								
Navicula classic	0.4	4.2	13.2	0.5	2.5		4.8	3.3
Navicula football			1.3			1.1		5.7
Navicula large						25.7		
Navicula sp.			13.2				4.3	2.5
Nitzschia A (Drawing)				0.9				0.8
Nitzschia closterium				2.3	2.3			2.5
Nitzschia delicatissima	5.3		5.3		31.0		6.5	8.2
Nitzschia longissima					2.0			4.1
Nitzschia seriata	3.1	2.8		1.6	14.4			
Nitzschia sp.	1.5		19.7			6.0		13.1
Nitzschia very small							13.0	
Peridinium sp.		4.2				3.8	0.9	
Plagiogramma van heurckii							5.2	
Pleurosigma sp.							5.6	
Prorocentrum micans		2.8						
Rhizosolenia alata	1.0						2.2	12.3
Rhizosolenia sp.			5.3				4.3	
Rhizosolenia stolterfothii	0.4				1.1			6.6
Skeletonema costatum	2.2			0.5	5.6			
Thalassionema nitzschioides	6.0	6.9		0.5	7.3		4.3	8.2
Thalassiosira decipiens					2.2			
Thalassiothrix sp.				0.8				
Unknown Club								3.3

	St Lu	Tong	Tugela
	28.38	29.58	29.23
Anaulus australis			
Asterionella glacialis	0.2	31.1	77.9
Aulacodiscus johnsonii			
Aulacodiscus petersii			
Biddulphia alternans			
Biddulphia mobiliensis			0.9
Biddulphia amazing	0.7		
Biddulphia sp.			
Campylosira cymbelliformis	52.2		
Ceratium furca/marina			
Chaetoceros medium			
Coscinodiscus sp.	0.5	4.9	5.2
Eucampia zoodiacus	0.5		
Euglena sp.			
Grammatophora marina			
Gyrodinium sp.			
Hemiaulus hauckii	0.7		
Leptocylindrus danicus			
Licmophora sp.	2.9	29.5	
Melosira sulcata		14.8	
Navicula classic	5.4	14.8	
Navicula football			
Navicula large	6.1		
Navicula sp.	8.1		
Nitzschia A (Drawing)			
Nitzschia closterium	0.9		
Nitzschia delicatissima	1.8		2.8
Nitzschia longissima	1.1		
Nitzschia seriata			
Nitzschia sp.			
Nitzschia very small			
Peridinium sp.			
Plagiogramma van heurckii	6.7		
Pleurosigma sp.			
Prorocentrum micans			
Rhizosolenia alata	1.4		0.7
Rhizosolenia sp.	5.6		
Rhizosolenia stolterfothii	2.2		
Skeletonema costatum			1.3
Thalassionema nitzschioides	3.1	4.9	7.2
Thalassiosira decipiens			
Thalassiothrix sp.			3.9
Unknown Club			

SAND

Beach	Amanz	Blythe	Cape V	Ifafa	Mtunz	PSJ	Sodw	St Lu	Tong
Coord	30.07	29.38	28.13	28.12	31.53	28.8	28.38	29.58	29.23
Amphiprora								5.0	
Asterionella glacialis		11.1		25.9					
Aulacodiscus johnsonii	16.7				33.3				
Aulacodiscus petersii			10.0						
Biddulphia alternans	16.7				33.3				30.0
Bluegreens							1.9	15.0	
Campylosira cymbelliformis								15.0	10.0
Chaetoceros spores	50.0		10.0					10.0	
Centric				7.4					
Cocconeis epiphyte	16.7	11.1					1.9	5.0	10.0
Flagellates		22.2		25.9					
Gyrodinium sp.		11.1							
Leptocylindrus danicus				7.4					
Licmophora sp.		22.2	10.0						
Navicula classic							1.9	5.0	10.0
Navicula football			10.0	14.8			1.9		
Navicula sp.		11.1	20.0	7.4			7.5	5.0	40.0
Navicula Sand			10.0		33.3	100.0	84.9	10.0	
Nitzschia delicatissima								5.0	
Nitzschia longissima				11.1					
Nitzschia seriata			10.0						
Plagiogramma van heurckii								25.0	
Rhizosolenia sp.		11.1	20.0						