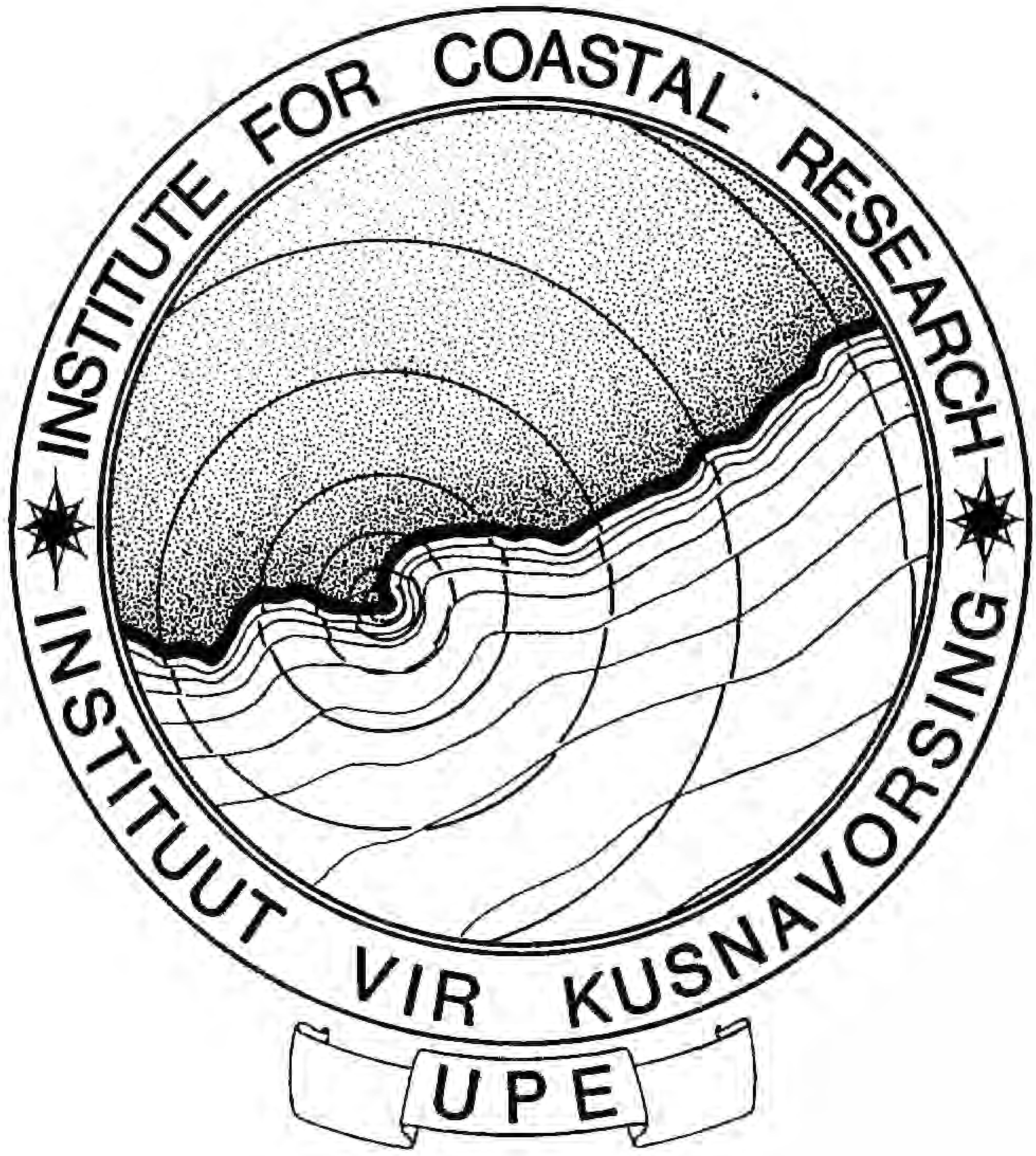
THE FLORA OF THE SANDY BEACHES OF SOUTHERN AFRICA.
III. THE SOUTH COAST MICROFLORA.

E.E. Campbell and G.C. Bate
1991



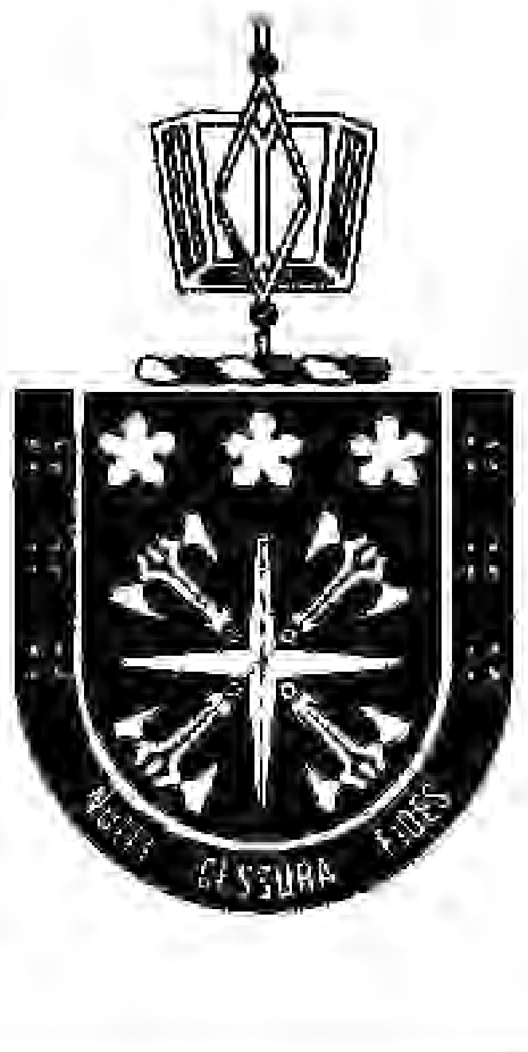


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TABLE OF CONTENTS

1. INTRODUCTION 2
- **1.1 The Surf-Zone Ecosystem** 2
- **1.2 The Importance of the Coastline** 3
- **1.3 Past International Research on Surf-Zones** 4
- **1.4 Past Research on the South African Coastline** 4

2. MATERIALS AND METHODS 8
- **2.1 Sites** 8
- **2.2 Environmental Variables** 8
- **2.3 The Slope of the Groundwater Table** 8
- **2.4 Nutrients** 13
- **2.5 Species Composition** 13
- **2.6 Chlorophyll *a* Concentration** 14
- **2.7 Phytoplankton Patch Analysis** 14
- **2.8 Phytoplankton Chemical Composition** 14
- **2.9 Primary Production Estimates** 14

3. RESULTS 15
- **3.1 Environmental Variables** 15
  - 3.1.1 Temperature 15
  - 3.1.2 Wave Height 15
  - 3.1.3 Surf-zone Topography and Width 15
  - 3.1.4 Groundwater Slope 15
  - 3.1.5 Nutrients 19
    - 3.1.5.1 Phosphate 19
    - 3.1.5.2 Ammonium 24
    - 3.1.5.3 Nitrate 24
    - 3.1.5.4 Silicon 29
    - 3.1.5.5 Salinity 34
  - 3.1.6 Total Inorganic Nutrients in Groundwater 34
- **3.2 Species Composition** 34
  - 3.2.1 The Species Found in the Foam 34
  - 3.2.2 The Species Found in the Patch Foam 39
  - 3.2.3 The Species Found in the Water 40
  - 3.2.4 The Species Found in the Sand 42
  - 3.2.5 Community Analyses 43
- **3.3 Chlorophyll *a* Concentration** 62
- **3.4 Phytoplankton Patch Analysis** 70
- **3.5 Phytoplankton Elemental Composition** 70
- **3.6 Primary Production** 75

4. DISCUSSION 81

Acknowledgements 86
References 87

APPENDIX 1. **INTERNATIONAL LITERATURE LIST** 91
APPENDIX 2. **LOCAL LITERATURE LIST** 94
APPENDIX 3. **THE SPECIES COMPOSITION OF SAMPLES COLLECTED ON THE SOUTH COAST OF SOUTH AFRICA** 98

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.

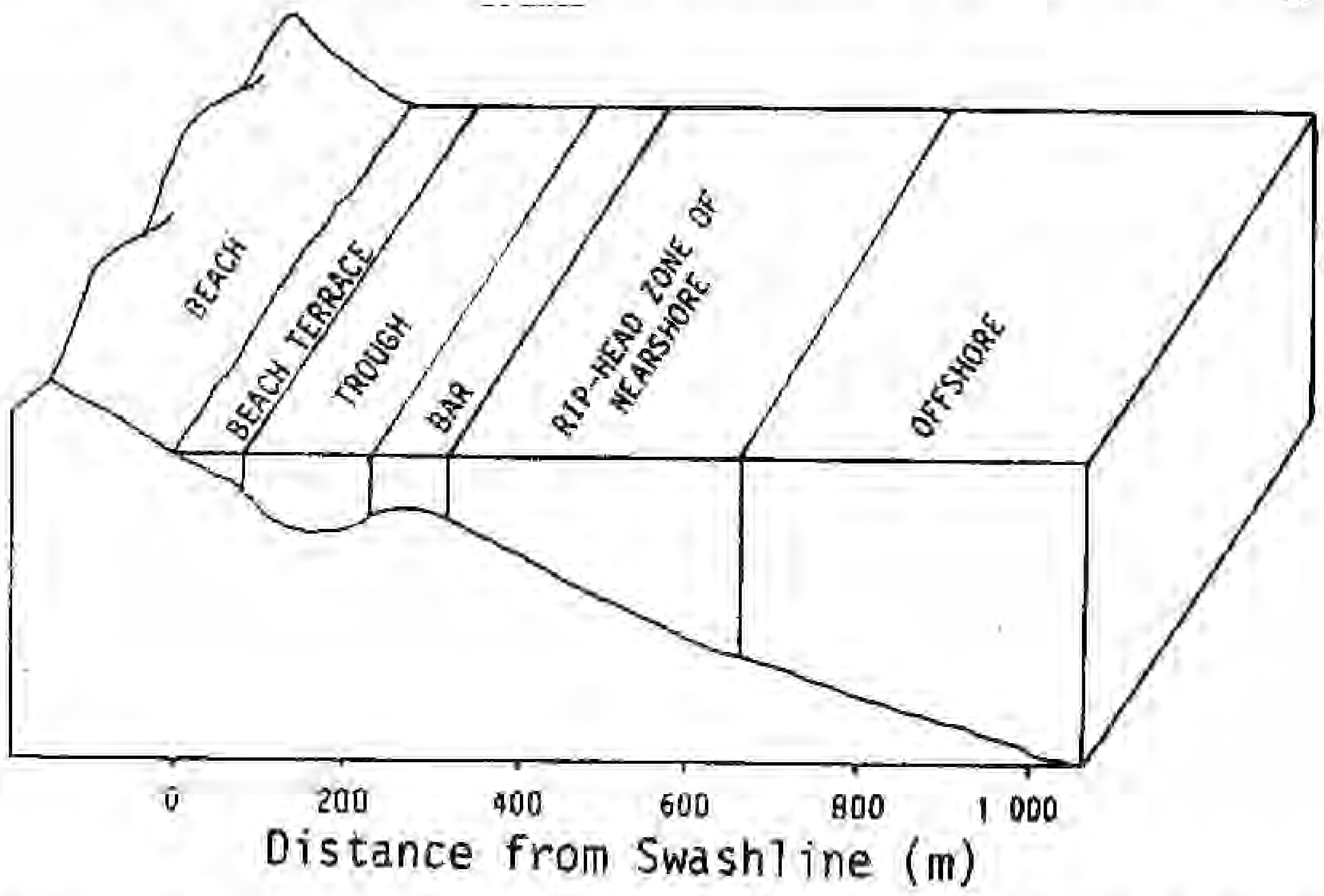


Figure 1. The dimensions of, and terminology used in describing surf-zones in this report.

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 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 had extremely clear water, indicative of the low phytomass. The south coast has been classified as a phytogeographic zone on the basis that it comprises log-spiral bays, many of which contain phytoplankton patches formed by diatom accumulations.

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)

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

The south coast is unique in that it comprises log-spiral bays with specific features which can be considered to cause the formation of the surf diatom accumulations. Initial studies (Campbell and Bate, 1990a) have shown that the following features must be present for phytoplankton accumulations to occur:

1. Surf-zone mostly in a longshore bar-trough state,
2. Rip activity, and
3. Adjacent active dunefields.

This observation required experimental verification. Because some of the beaches on the south coast have phytoplankton accumulations and some do not, the south coast study was aimed at answering the following key questions by investigating both types of beaches:

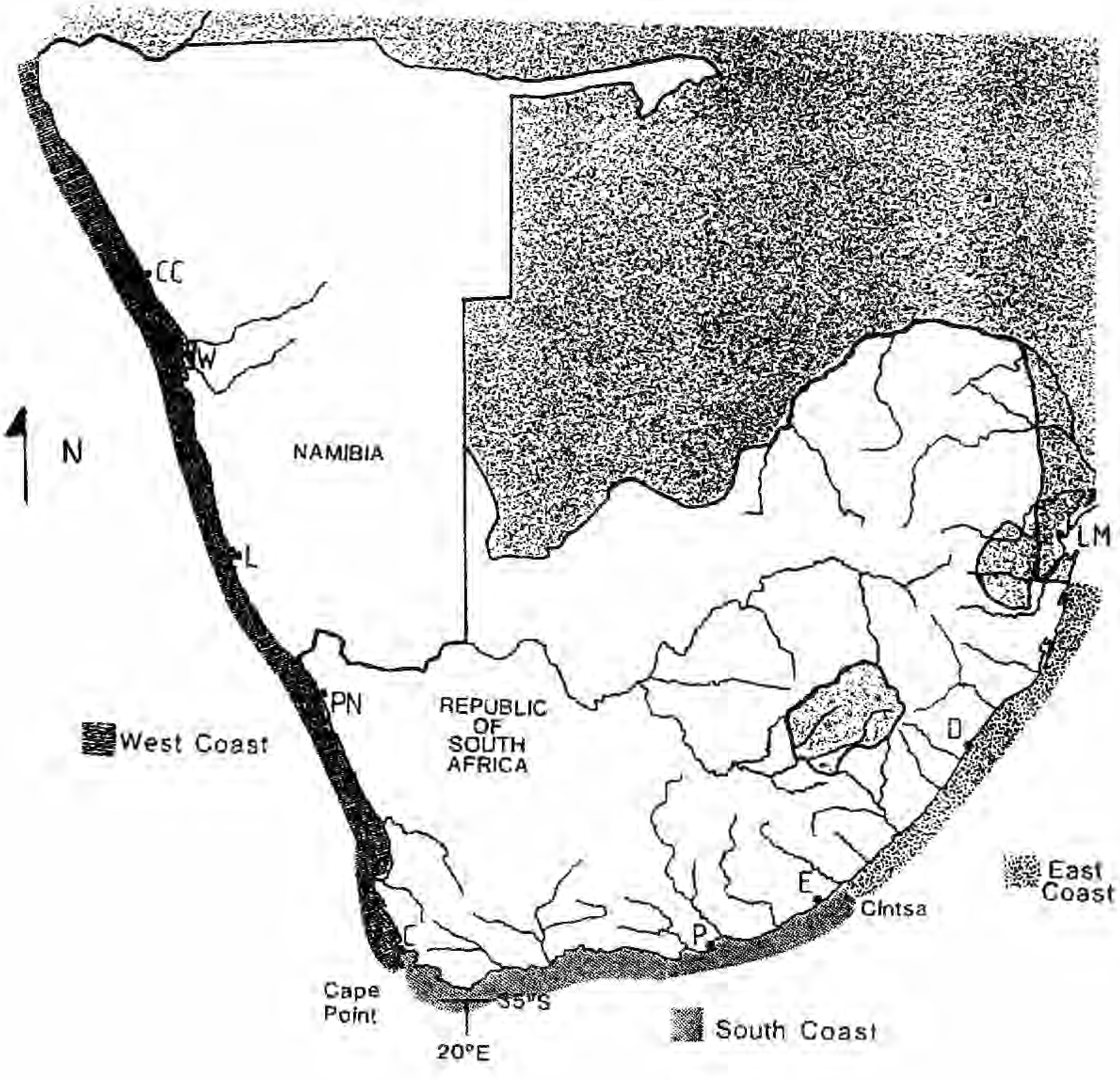


Figure 2. The three phytogeographic zones based on the presence or absence of phytoplankton accumulations.

1. Where does *Anaulus australis* occur?
2. Where does *Anaulus australis* form accumulations?
3. Why do the accumulations form where they do?

The possible mechanisms of cell accumulation have been described by Lewin and Rao (1975), McLachlan and Lewin (1981), Kindley (1983), Lewin and Schaefer (1983), Sloff *et al.* (1984) and in detail by Talbot and Bate (1986). The generalized model is as follows: The cells divide in the early morning. At this period they acquire a mechanism whereby they attach to bubbles caused by breaking waves. They rise into the foam with the bubbles. On the surface they alter the surface tension of the bubbles, causing the foam to become more stable. The result is the formation of a visibly discernable patch in the foam containing high concentrations of phytoplankton cells. The rip currents aid in the maintenance of these patches in that the rips balance the stress of the wave bores. In this model, the direct importance of hydrodynamics and turbulence and the indirect importance of beach topography and wind are evident. A further requirement for the development of accumulations is length of beach (McLachlan, 1981; Jijina and Lewin, 1983) for which a mechanism has been suggested by Campbell and Bate (1988b).

Because of the presence of rich surf phytoplankton accumulations, maintained by special cell mechanisms together with water gyres which retain nutrients, McLachlan (1981; 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 the outer limit of water gyres as its boundaries. Talbot and Bate (1986) reported that no surf diatoms could be found in the nearshore behind the breaker line except in the rip heads, making the system closed at least with respect to *Anaulus australis*.

Certain factors appear to influence the occurrence of surf-zone phytoplankton accumulations. These have been postulated by Lewin and Schaefer (1983) as being:

1. *Topography of the coast*: There must be a broad, shallow surf-zone with a sufficiently long beach (Garver and Lewin, 1981). Natural barriers such as rocky headlands also play a role. Garver and Lewin (1981) observed no accumulations at a beach south of Cape Blanco. The reason proposed for this is that cell inoculum rarely reaches that beach. Drift bottles released north of the Cape never reached the southern beach.
2. *Onshore winds*.
3. *Nutrient supply*.
4. *High rainfall*: This is possibly due to increase groundwater flow as a result of rain (also in McLachlan and Illenberger, 1986).
5. *Physiological adaptations of the surf-zone species*: The cells have the ability to become attached to bubbles, thereby retaining their position in the surf-zone.

This study was undertaken with the aim of testing these hypotheses along the southern coast of Africa.

2. MATERIALS AND METHODS

2.1 Sites

The beaches chosen for investigation were assigned a numeric value which is listed as the east longitude converted to a decimal (eg. Cape Point, which is 18°30'E, is referred to as 18.5°). The list of beaches with their co-ordinates is given in Table 1 and their location shown in Figure 3. Table 2 gives the dates on which each beach was visited and lists the various analyses were undertaken on each occasion.

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 were correlated to standing stock.

2.3 The Slope of the Groundwater Table

The slope of the groundwater table 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. This procedure assumes a free groundwater table terminating at sea level at the time of sampling.

The slope was calculated as this difference in height, corrected to mean sea level, divided by the horizontal distance of the hole from the water line.

Table 1. The list of beaches investigated; co-ordinates given as decimal longitude east of Greenwich.

Number	Beach	Co-ordinate (°E)
1	Muizenberg	18.57
2	Macassar	18.78
3	Walker Bay	19.30
4	Struisbaai	20.05
5	De Hoop	20.87
6	Stilbaai	21.45
7	Vleesbaai	21.93
8	Glentana	22.17
9	Wilderness	22.57
10	Sedgefield	22.77
11	Buffalo Bay	23.00
12	Keurboomstrand	23.38
13	Oyster Bay	24.65
14	Van Stadens	25.12
15	Sundays	26.00
16	Port Alfred	26.88
17	East London	27.90
18	Bonza Bay	27.97
19	Cintsa Bay	28.12

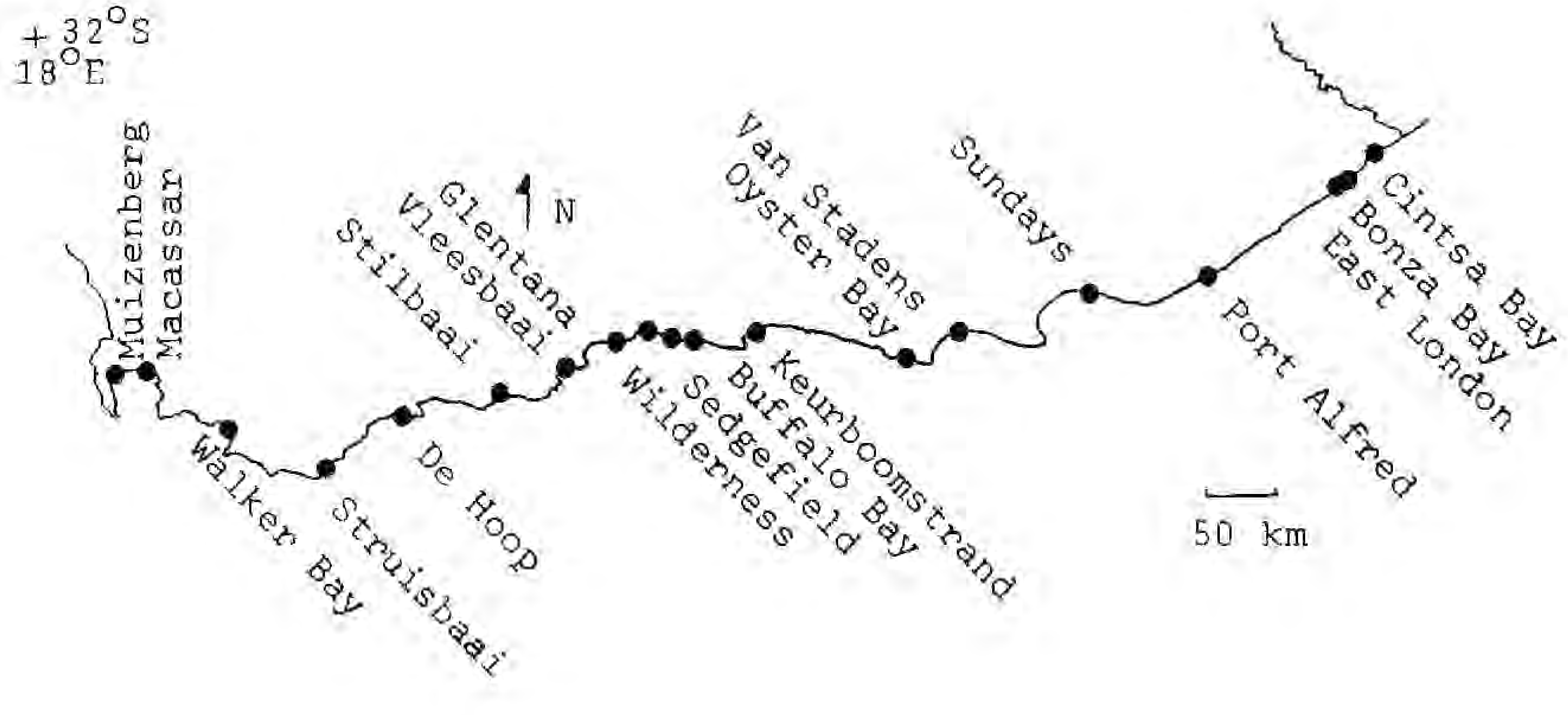


Figure 3. The location of the beaches sampled along the south coast of South Africa.

Table 2. The dates (month and year) on which each of the beaches were visited and the types of analyses done on each occasion. The analyses are coded according to the section number in Materials and Methods.

Beach	Date	2.2	2.3	2.4	2.5	2.6	2.7	2.8
Muizenberg	07.88	*	*	*				
	07.88	*		*	*	*	*	*
	07.88	*		*	*	*	*	
	07.88	*		*	*	*	*	*
	07.88	*		*	*	*	*	*
	11.88	*	*	*	*	*	*	
Macassar	07.88	*		*	*	*	*	
	11.88	*	*	*	*	*	*	
Walker Bay	07.88	*	*	*	*	*	*	
	11.88	*	*	*	*	*	*	
Struisbaai	07.88	*	*	*	*	*	*	
	11.88	*	*	*	*	*	*	
De Hoop	07.88	*	*	*	*	*	*	
	11.88	*	*	*	*	*	*	
Stilbaai	07.88	*	*	*	*	*	*	
	11.88	*	*	*	*	*	*	
Vleesbaai	07.88	*	*	*	*	*	*	
	11.88	*	*	*	*	*	*	

Table 2 (cont).

Beach	Date	2.2	2.3	2.4	2.5	2.6	2.7	2.8
Glentana	07.88	*	*	*	*	*	*	
	11.88	*	*	*	*	*	*	
Wilderness	07.88	*	*	*	*	*	*	
	11.88	*	*	*	*	*	*	
Sedgefield	07.88	*	*	*	*	*	*	
	11.88	*	*	*	*	*	*	
Buffalo Bay	07.88	*	*	*	*	*	*	
	11.88	*	*	*	*	*	*	
Keurbooms	07.88	*	*	*	*	*	*	
	11.88	*	*	*	*	*	*	
Oyster Bay	11.88	*	*	*	*	*	*	
Van Stadens	11.88	*	*	*	*	*	*	
Sundays	Annual Means for 1986, 1987 and 1988							
	11.88	*	*	*	*	*	*	
Port Alfred	11.88	*	*	*	*	*	*	
East London	09.88	*			*	*	*	
	11.88	*	*	*	*	*	*	
Bonza Bay	09.88	*			*	*	*	
	11.88	*	*	*	*	*	*	
Cintsa Bay	09.88	*			*	*	*	*
	11.88	*	*	*	*	*	*	

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 taken for the determination of phytoplankton composition were fixed in Lugol's iodine solution (Saraceni and Ruggiu, 1974). Samples of brown foam, white foam, the water column and the sand were taken. Samples were settled and examined for species composition and cell numbers 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, 1990d). Scanning electron microscopy identification of the samples viewed 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:

$$d = \frac{S-1}{\log(N)} \quad \text{.. (1)}$$

where d = diversity index
S = the number of species and
N = the number of inidividuals

Also,

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

where d = dominance index
n = the number of individuals of a species and
N = the total number of 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 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 Phytoplankton Patch Analysis

All patches at each beach were vissually assessed for size and intensity of colour. Standing stock was calculated from these data using the method of Campbell and Bate (1988a).

2.8 Phytoplankton Chemical Composition

Cells filtered onto GF/C filters were dried and the total nitrogen was determined by the semi-micro Kjeldahl method (Black, 1965). Total carbon was measured on similarly filtered, dried samples according to Strickland and Parsons (1972).

2.9 Primary Production Estimates

Access to high energy surf-zones for the purpose of incubating 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 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

3.1.1 Temperature

Despite the fact that the beaches are spread over 10° of longitude (Table 1), the sea temperature varied only by 4.3°C for the November sampling session (between 16.2°C and 20.5°C; Fig. 4). The beaches with cold water were Macassar (eastern end of False Bay), Walker Bay (which has a western facing aspect), Buffalo Bay, Oyster Bay and Port Alfred.

3.1.2 Wave Height

Wave heights ranged from 0.5 m to 3 m, with wave heights being lowest east of Sundays River beach (Fig. 5).

3.1.3 Surf-zone Topography and Width

Surf-zones ranged from narrow reflective surf-zones to wide dissipative ones as defined by Wright and Short (1983). Most of the surf-zones were in a longshore bar-trough state (Fig. 6), 24 out of 40, 9 were dissipative, 5 were rhythmic-bar beach states and 2 had no distinctive morphology.

Width of the surf-zone tended to decrease when moving from the west to the east (Fig. 7).

3.1.4 Groundwater Slope

The slope of the groundwater above mean sea level was determined at the beaches (Fig. 8). This slope can be considered to be an index of the groundwater flow from the dunes into the surf-zone assuming that the particle size is similar at all the beaches (McLachlan and Illenberger, 1986). Only one beach, at the western end of Walker Bay, had no net flow of water. Muizenberg and De Hoop beaches had steep

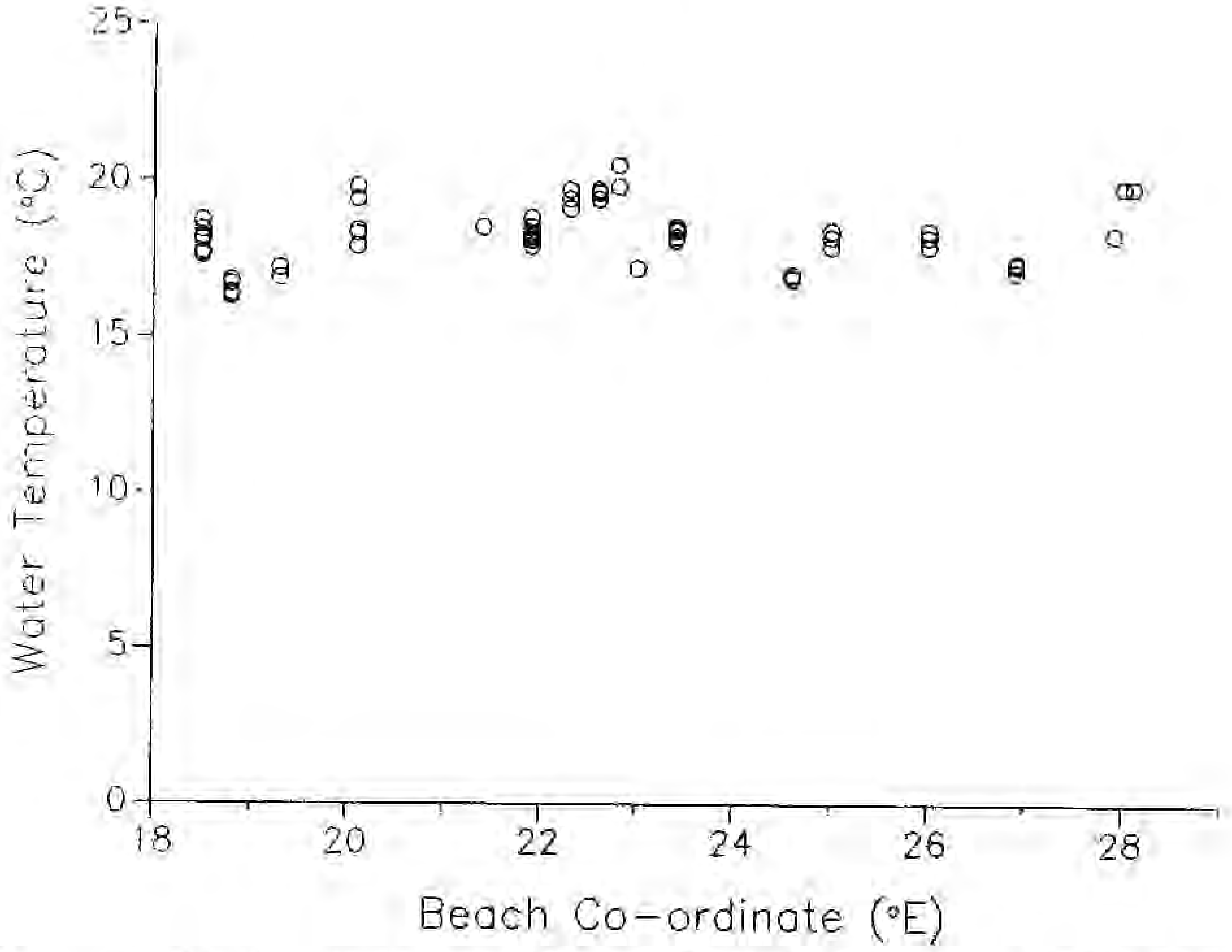


Figure 4. The water temperature of the surf-zones of the south coast of South Africa.

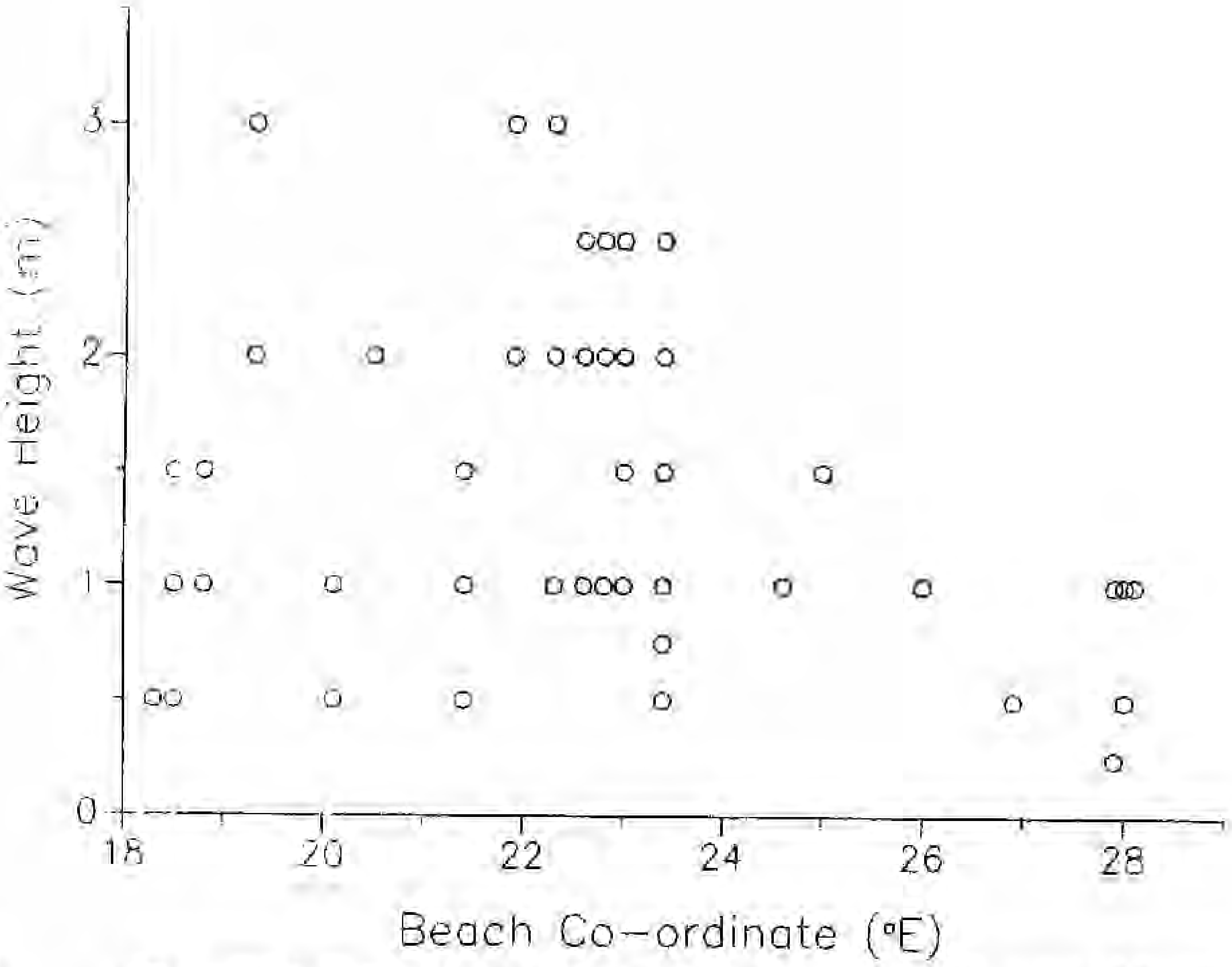


Figure 5. The wave height estimated at beaches along the south coast of South Africa.

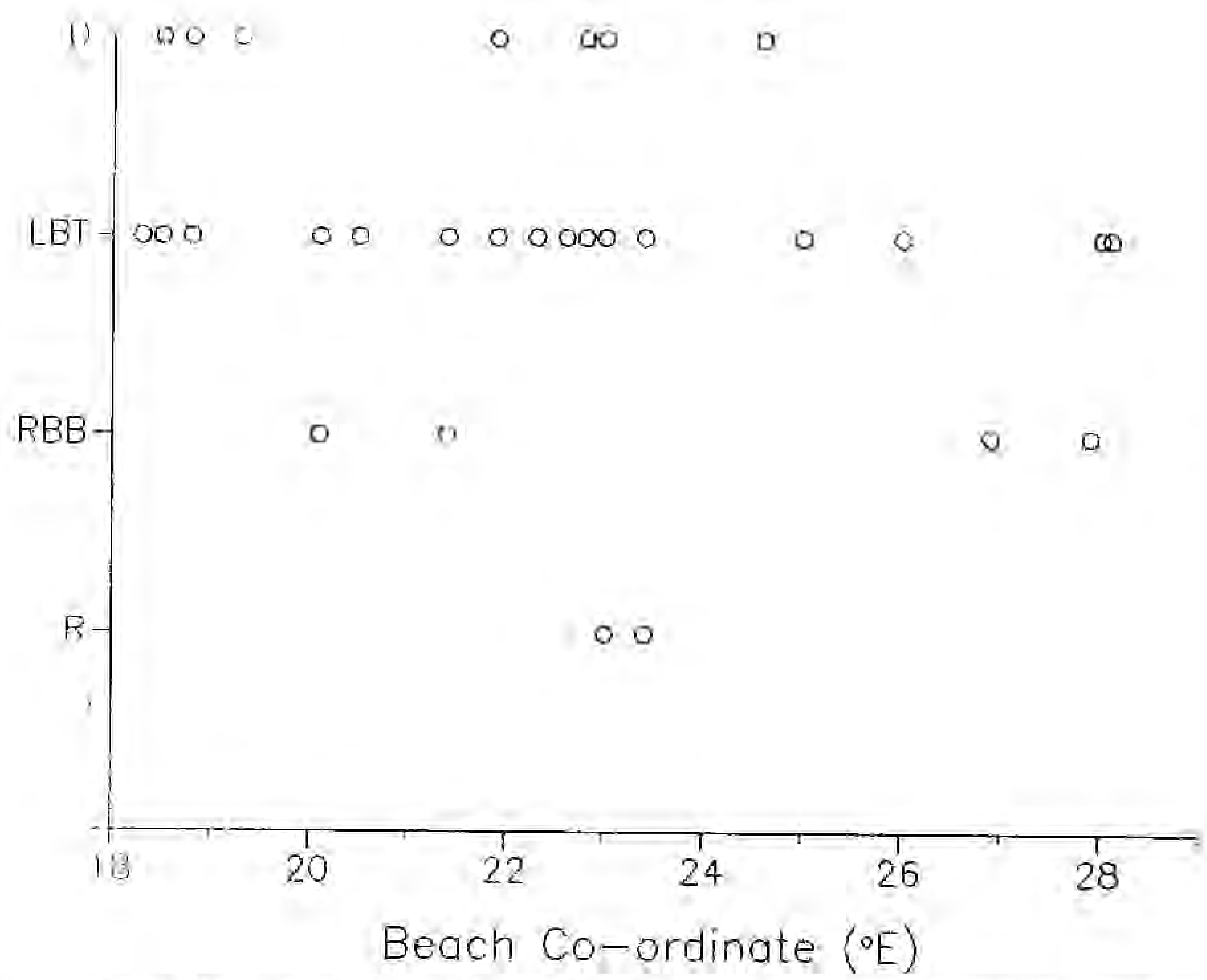


Figure 6. The surf-zone topography at beaches along the south coast of South Africa. R = reflective; RBB = rhythmic bar beach; LBT = longshore bar-trough and D = Dissipative states.

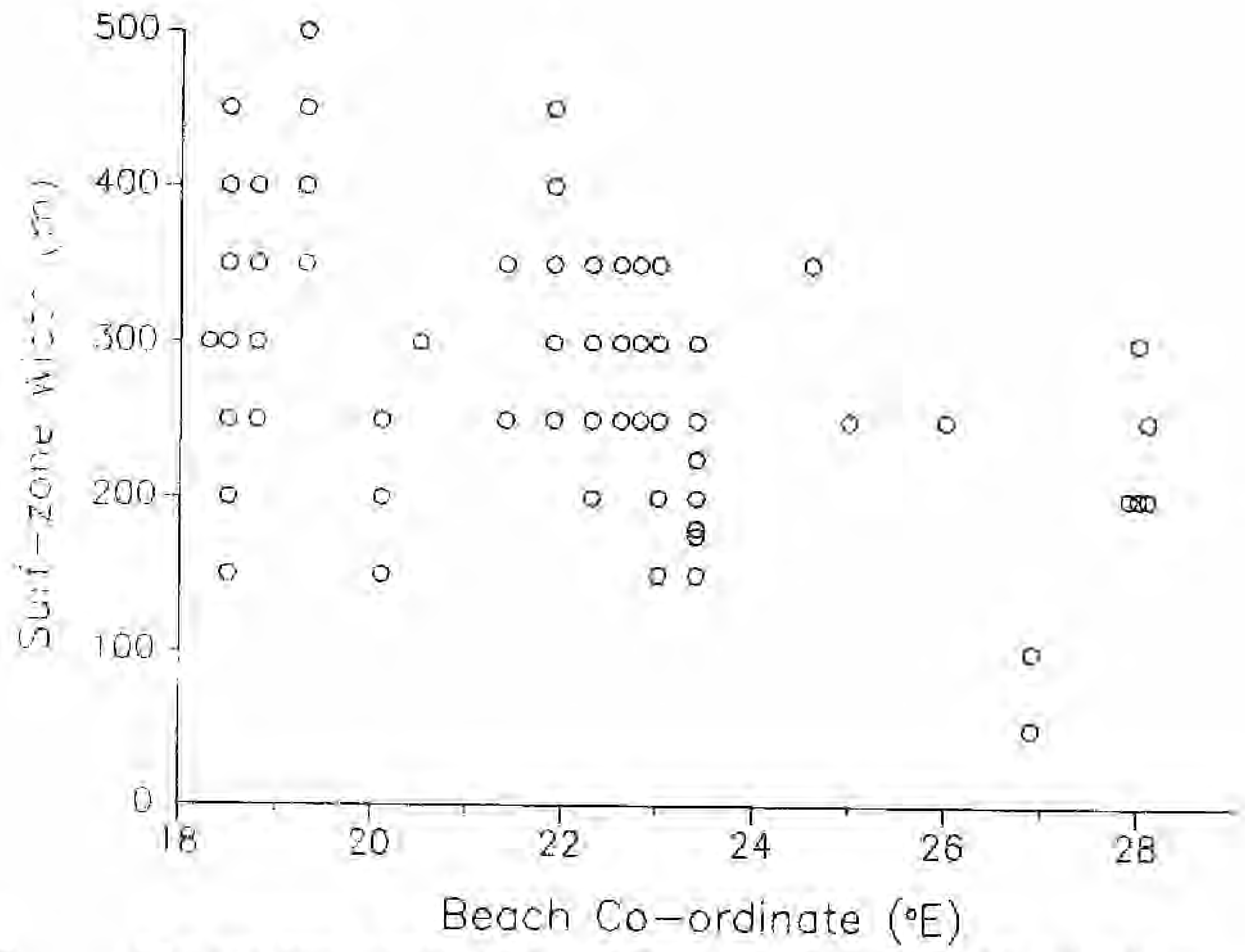


Figure 7. The surf-zone width at beaches along the south coast of South Africa.

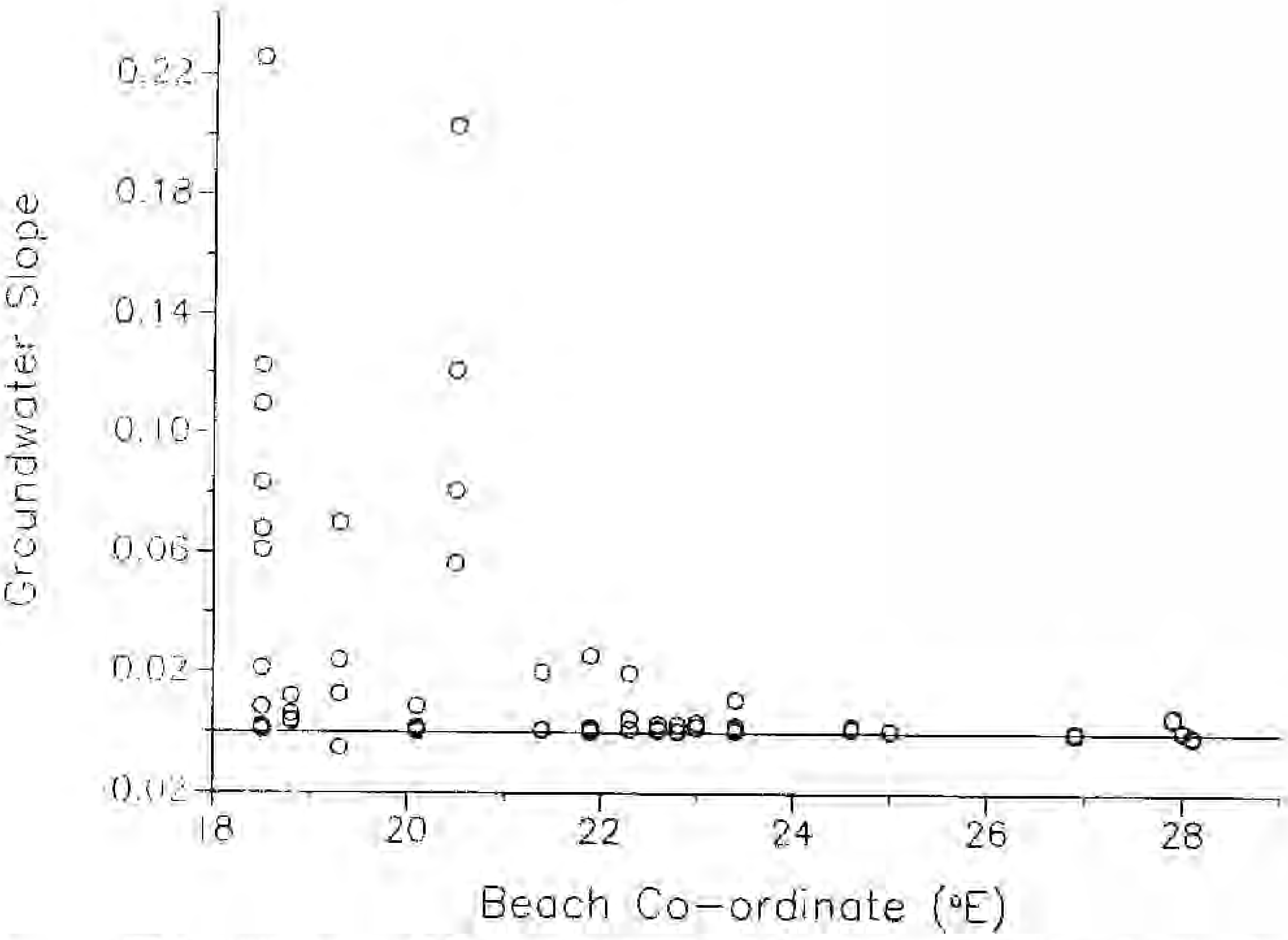


Figure 8. The groundwater table slope measured in the beach sand adjacent to the surf-zones of the south coast of South Africa.

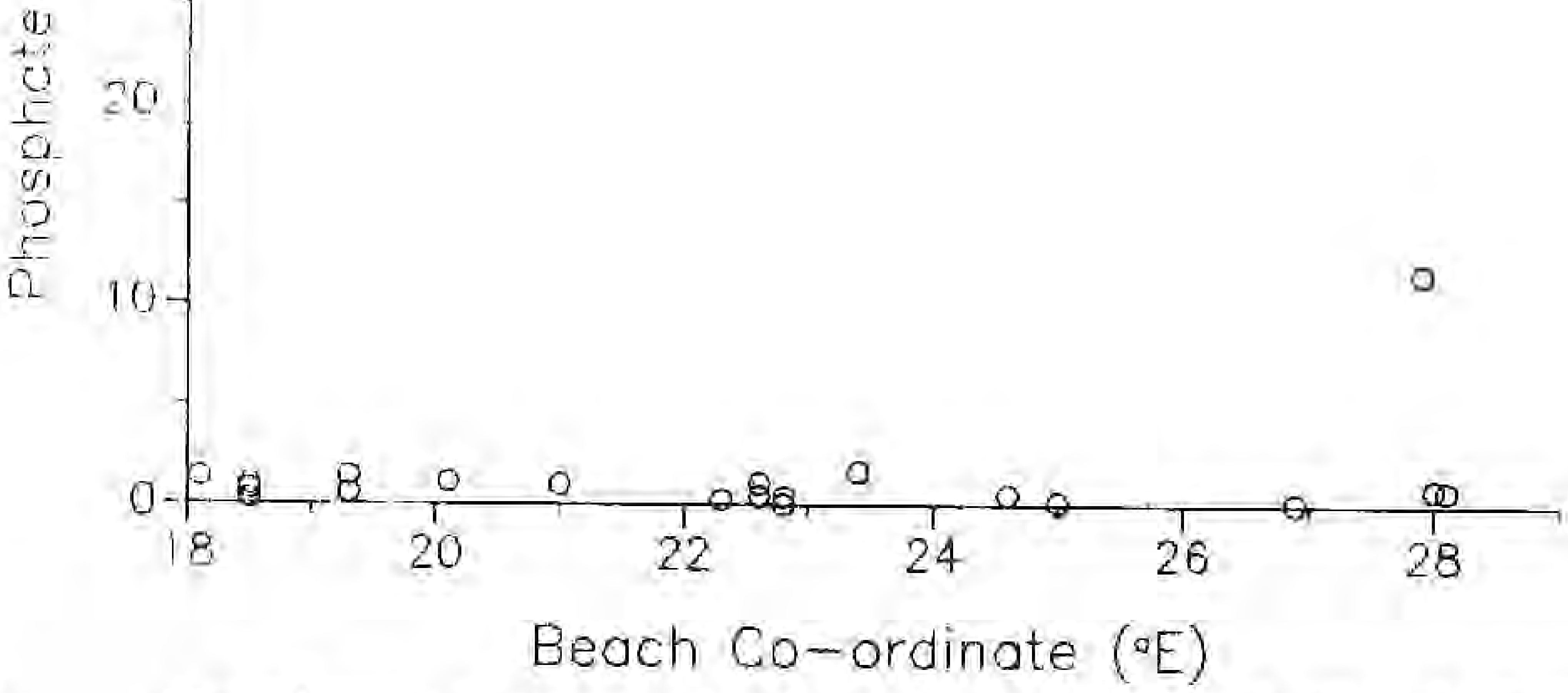


Figure 9. The phosphate concentration in rivers, estuaries and other freshwater sources entering the surf-zones of the southern coast of South Africa.

slopes and the groundwater flow would therefore be high. Macassar, Struisbaai, Vleesbaai and Glentana had intermediate slopes. The other beaches had shallow slopes which implies that not much groundwater flow would be expected.

3.1.5 Nutrients

False Bay appears to have a nutrient regime different from the other beaches due to several high-nutrient outfalls and because of the sewage settling ponds behind the fore-dunes. For this reason special attention was given to the Muizenberg beach.

3.1.5.1 Phosphate

The phosphate concentration in river water along the south coast of South Africa was below 2 μmol l^{-1} in all cases (Fig. 9) except in the river at East London beach (12 μmol l^{-1}) and the Zeekoevlei outfall (46 μmol l^{-1}). The phosphate concentration in the surf water was generally less than 3 μmol l^{-1} (Fig. 10), high values being recorded opposite river outfalls at Muizenberg, Macassar, Vleesbaai and East London. The mean phosphate concentration of seawater was 4.9 μmol l^{-1}. The phosphate concentration in the groundwater was not much higher, values between 0.5 and 7 μmol l^{-1} having been measured. At Walker Bay, Sedgefield and Port Alfred high phosphate concentrations were recorded (Fig. 11). At the latter two beaches there was almost no groundwater flow and so groundwater can be excluded as a source of phosphate for surf phytoplankton. At Muizenberg the phosphate concentration in the groundwater was high at the point where seepage of water from the ponds behind the foredune caused a foul smell (station 5, Fig. 12) but this point was the only one where the groundwater phosphate concentration was in excess of 8 μmol l^{-1}. Considering the high standing stock measured at Muizenberg beach, this groundwater input should not be considered a significant source of phosphate because much more is entering from the outfalls. The most important phosphate input into the False Bay beaches is from the river outfalls of Macassar and Zeekoevlei (Fig. 13). The Macassar outfall contained around 19 μmol l^{-1} and the Zeekoevlei outfall around 50 μmol l^{-1}. In contrast, the Sandvlei samples contained between 0.2 and 12 μmol l^{-1}, with a mean of 4 μmol l^{-1}. The high phosphate concentrations in the Zeekoevlei outfall produced high levels of phosphate in the sea water (Fig. 14) opposite the outfall (station 2; 42 μmol l^{-1}) and at the site to the east of the outfall (station 3; 17 μmol l^{-1}).

An estimate of the amount of phosphate provided to a surf-zone by groundwater can be ranked by calculating for each beach the product of two parameters: groundwater slope and phosphate content of the groundwater (Table 3). Muizenberg and Walker Bay are the only two beaches that are likely to have groundwater as a source of phosphate.

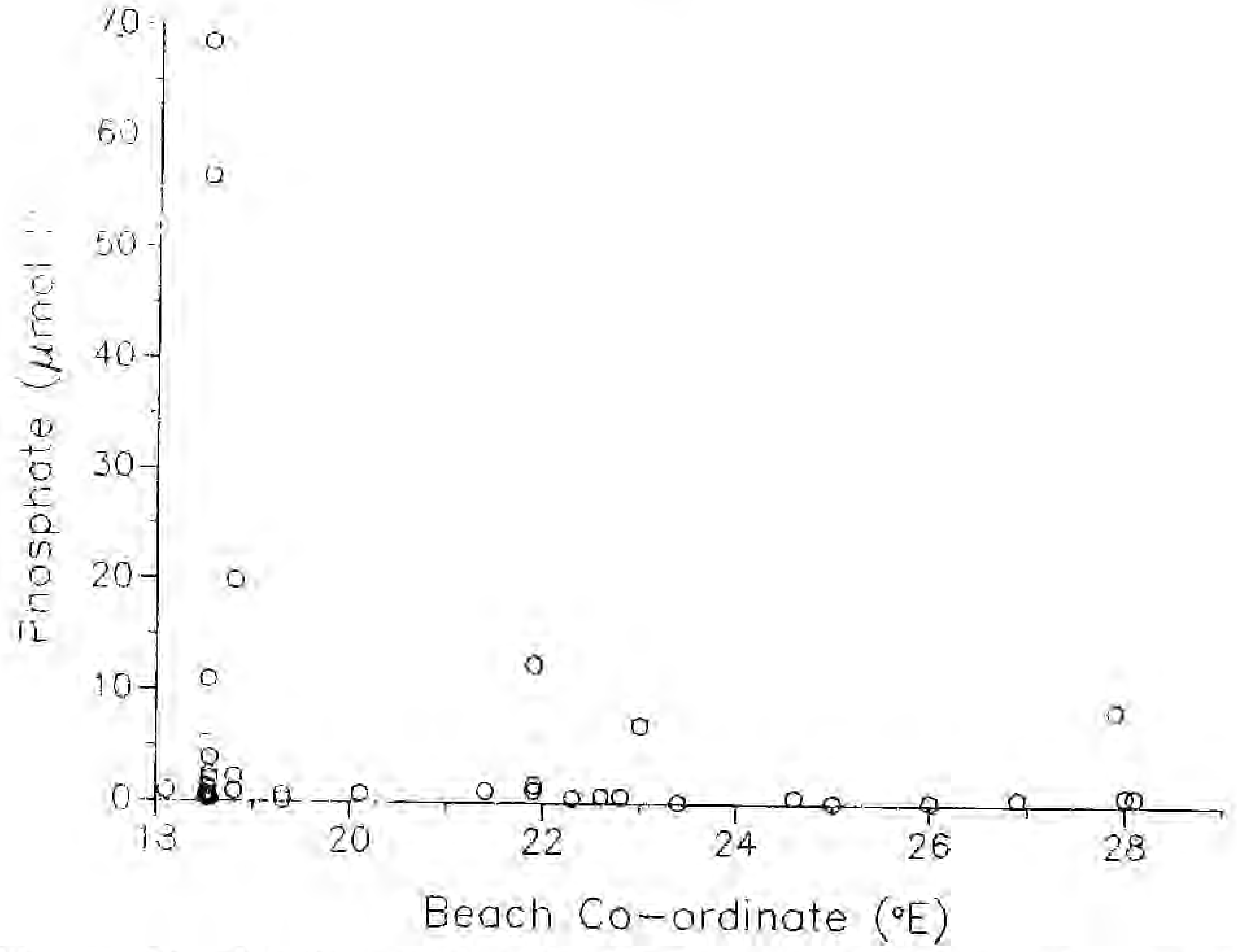


Figure 10. The phosphate concentration in the seawater of the surf-zones of the coast of southern South Africa.

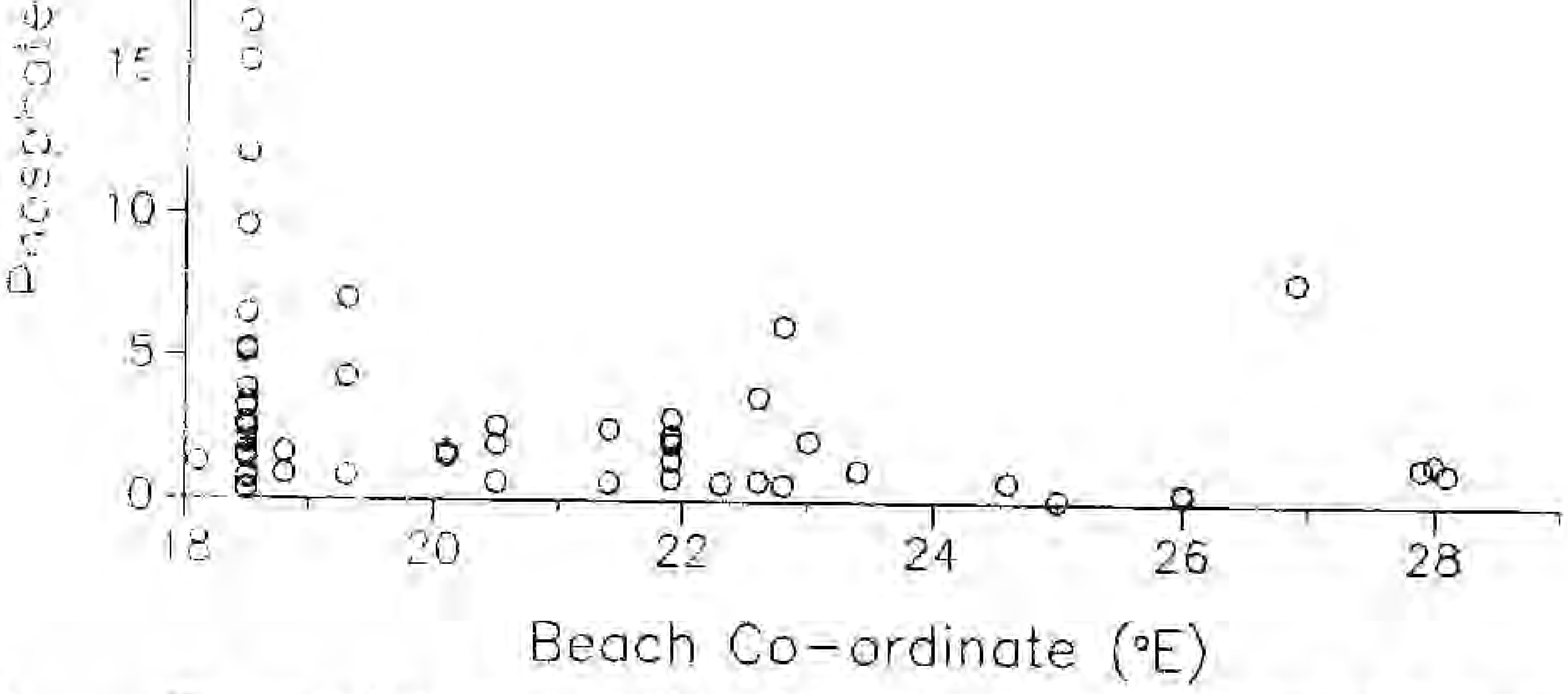


Figure 11. The phosphate concentration of the groundwater at beaches of the southern coast of South Africa.

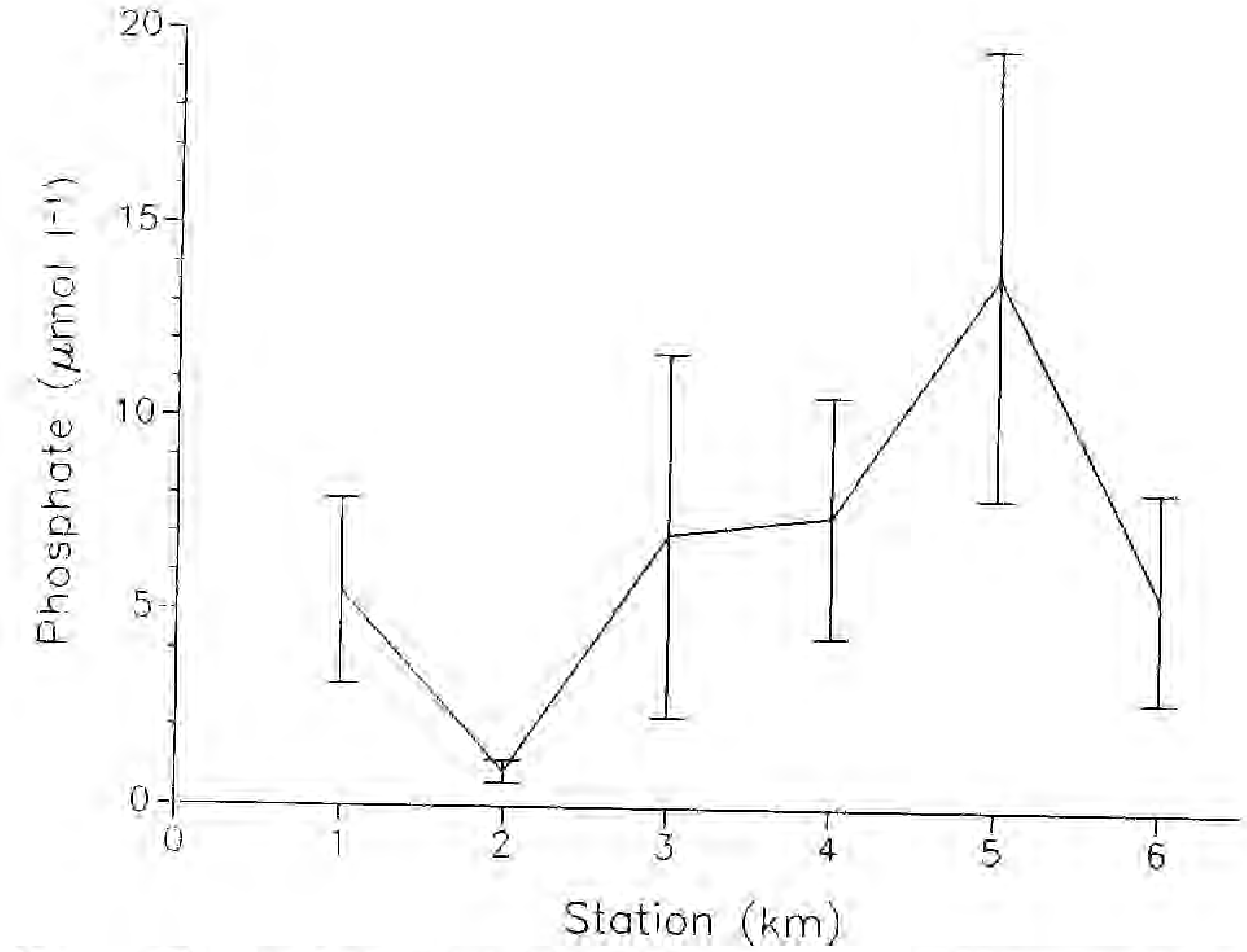


Figure 12. The phosphate concentration of the groundwater at Muizenberg beach.

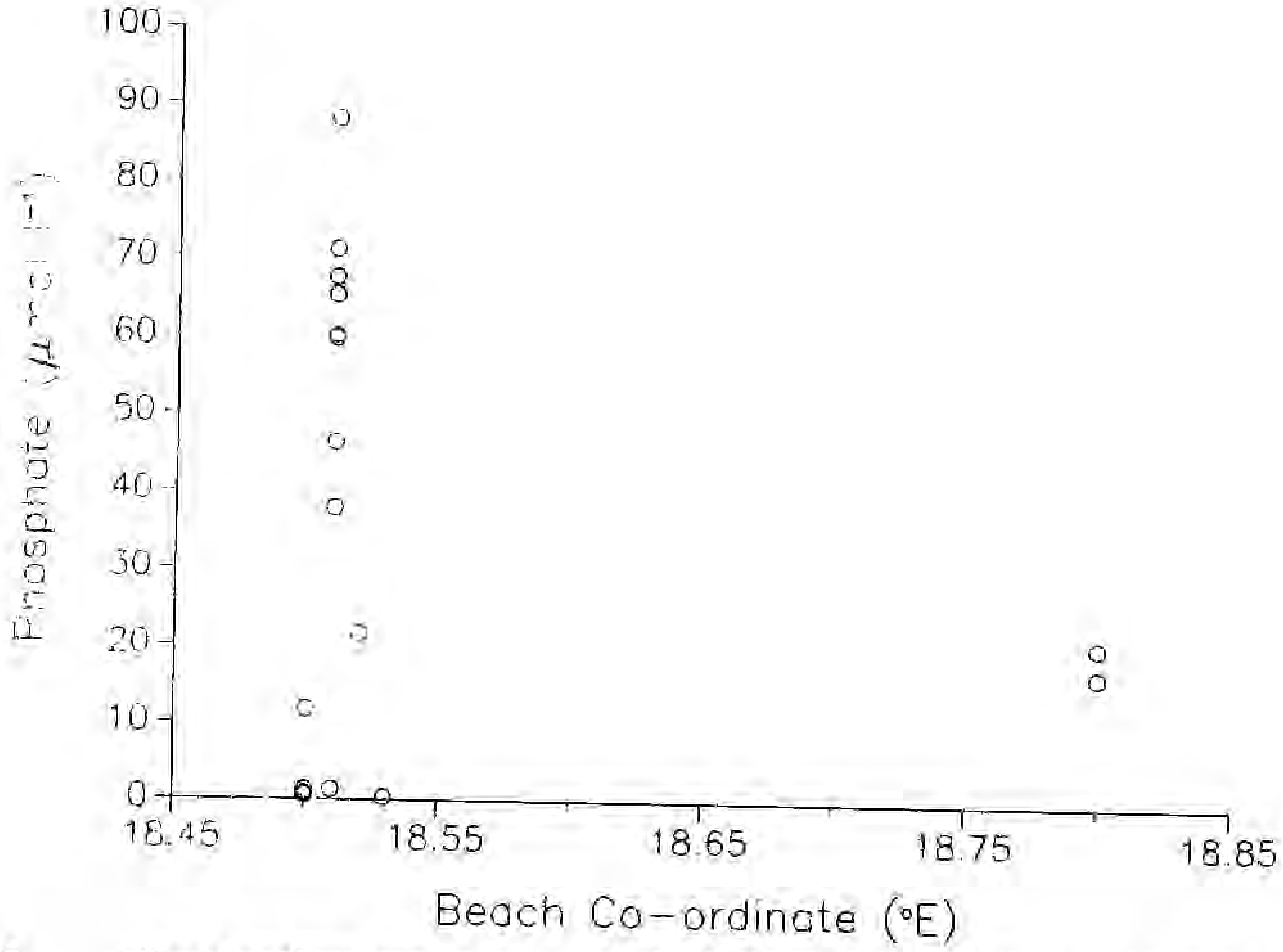


Figure 13. The phosphate concentration of the high nutrient outfalls which enter False Bay beaches.

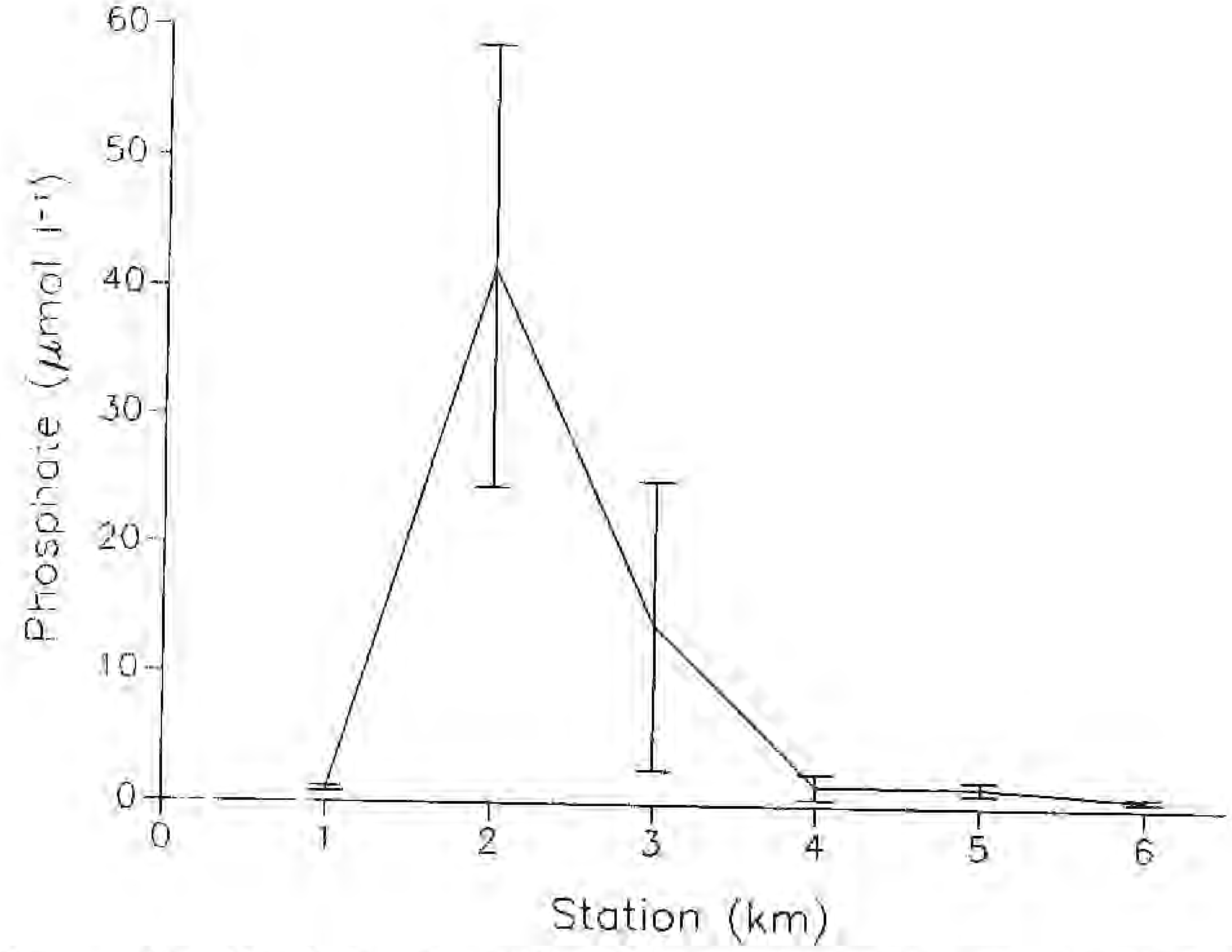


Figure 14. The phosphate concentration of the seawater at the Muizenberg beach.

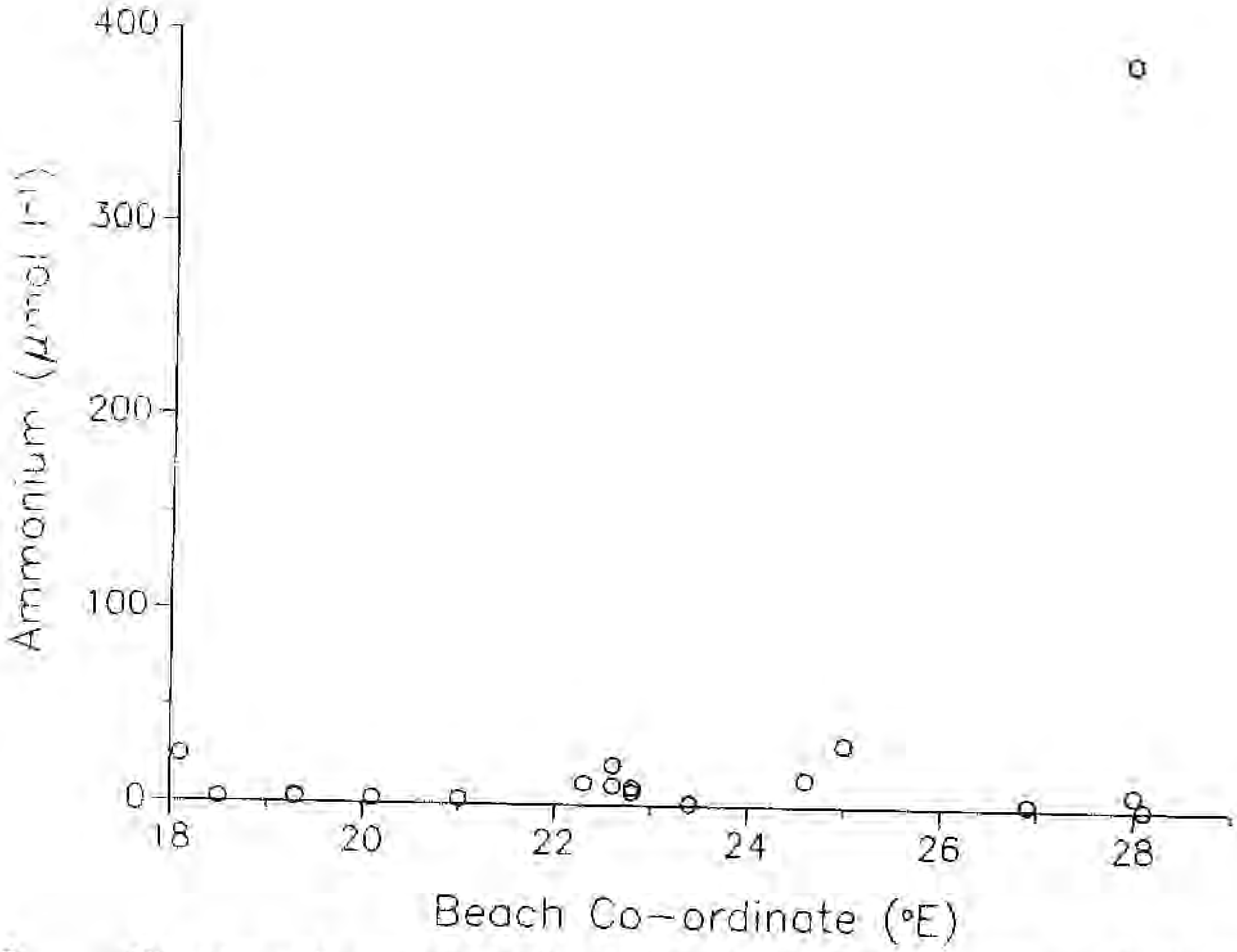


Figure 15. The ammonium concentration of river water, estuarine water and other freshwater sources entering the surf-zones of the south coast of South Africa.

Table 3. A ranking of the potential nutrient input into the beaches of the south coast of South Africa calculated as a product of the nutrient concentration and the groundwater slope multiplied by 10.

Beach	Slope x 100 (S)	PO_4^-.S	NH_4^+.S	NO_3^-.S	Si.S
Muizenberg	59	427	1 820	2 380	4 909
Macassar	6	8	50	306	65
Walker Bay	26	106	57	260	809
Struisbaai	3	5	9	297	93
De Hoop	12	21	35	164	200
Stilbaai	7	11	25	38	240
Vleesbaai	4	7	378	32	341
Glentana	9	6	110	407	816
Wilderness	2	4	18	239	161
Sedgefield	2	6	16	238	46
Buffalo Bay	3	6	64	284	191
Keurboomstrand	4	4	17	8	122
Oyster Bay	2	2	40	226	111
Van Stadens	1	0	3	3	52
Sundays	5	2	6	990	722
Port Alfred	1	8	4	64	60
East London	6	8	81	678	207
Bonza Bay	1	1	21	6	30
Cintsa Bay	1	1	9	166	175

3.5.1.2 Ammonium

Ammonium in freshwater sources along the south coast of South Africa was below 50 μmol l^{-1} (Fig. 15) in all cases except in the river at East London (380 μmol l^{-1}).

The ammonium concentrations in the seawater were always below 12 μmol l^{-1} except in False Bay (Fig. 16).

The ammonium concentrations of the groundwater of south coast beaches were generally low with values below 40 μmol l^{-1} for all beaches except at Vleesbaai (Fig. 17), where black anaerobic sediments were present in the western corner of the bay. At this beach values were around 210 μmol l^{-1}. At Muizenberg the groundwater had higher ammonium concentrations near the Zeekoevlei outfall (Station 2, Fig. 18). The seawater had a high level of ammonium (above 500 μmol l^{-1}, Fig. 19) compared to other beaches (24.6 $\pm$ 5.9 μmol l^{-1}).

A major source of ammonium at the False Bay beaches is high nutrient outfalls. All the outfalls in False Bay had highly variable ammonium concentrations reaching values as high as 275 μmol l^{-1} (Fig. 20).

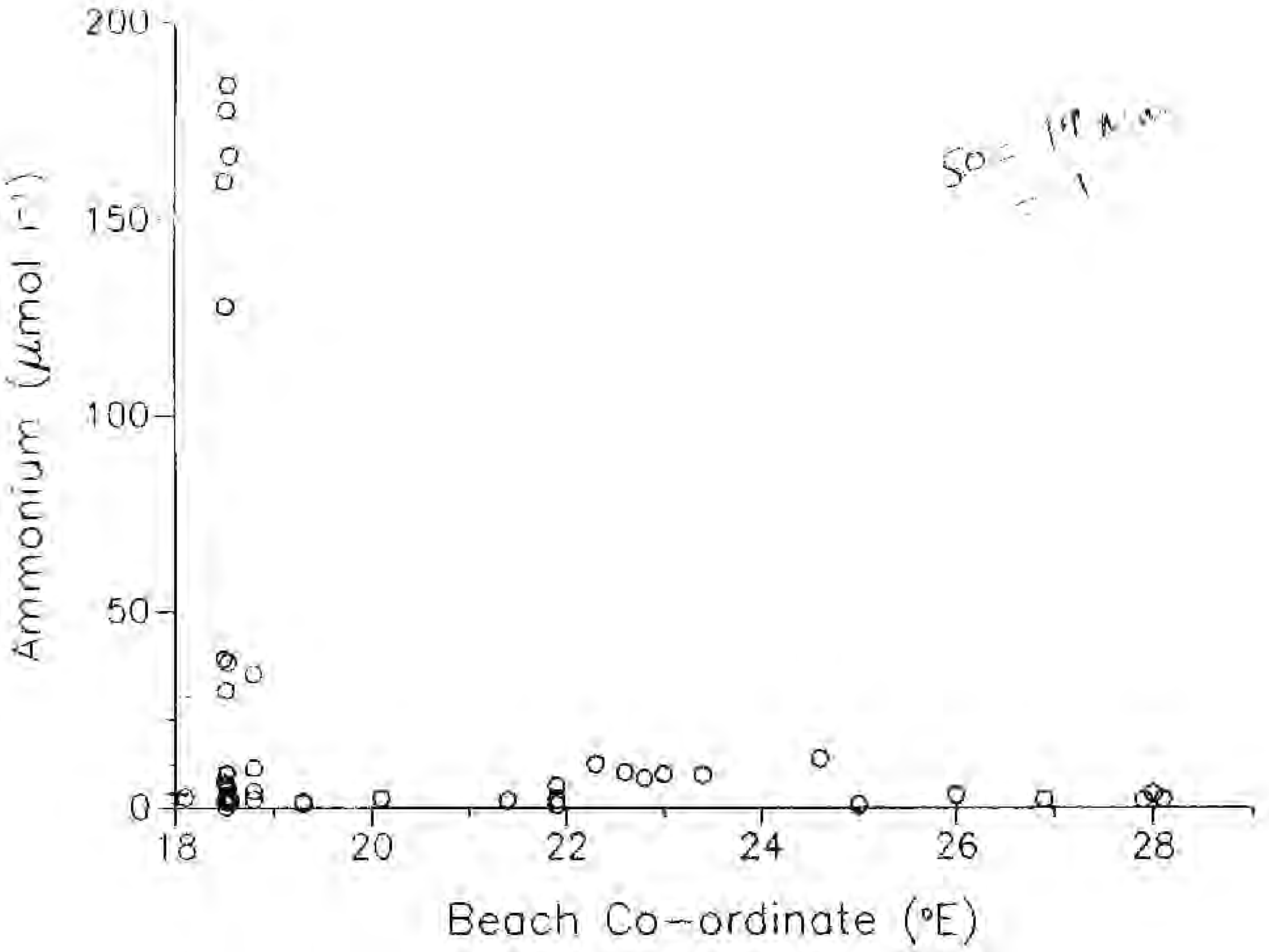
The beaches were ranked according to the product of the ammonium content of the groundwater and the groundwater slope in order to provide an estimate of ammonium provided by this source (Table 3). The beaches which are likely to have a substantial input of ammonium from the groundwater are Muizenberg, Vleesbaai, Glentana, Buffalo Bay and East London.

3.5.1.3 Nitrate

Nitrate in river water along the south coast of South Africa was below 10 μmol l^{-1} in all cases (Fig. 21) except in the river at East London Main beach (80 μmol l^{-1}) and the Van Stadens River (90 μmol l^{-1}).

The nitrate in the seawater was consistantly low (Fig. 22) except at Muizenberg. Average values were 6.3 μmol l^{-1}. There was an increase in concentration west of Knysna.

The nitrate concentration in the groundwater of the south coast beaches varied greatly (Fig. 23), Muizenberg, Struisbaai, Wilderness, Sundays and Cintsa Bay having high concentration values (120 - 300 μmol l^{-1}). At Muizenberg the average was only 40 μmol l^{-1} whereas at the remainder of the beaches it was 53 μmol l^{-1}.



50 = [illegible]
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Figure 16. The ammonium concentration in the seawater of the surf-zones of the south coast of Southern Africa.

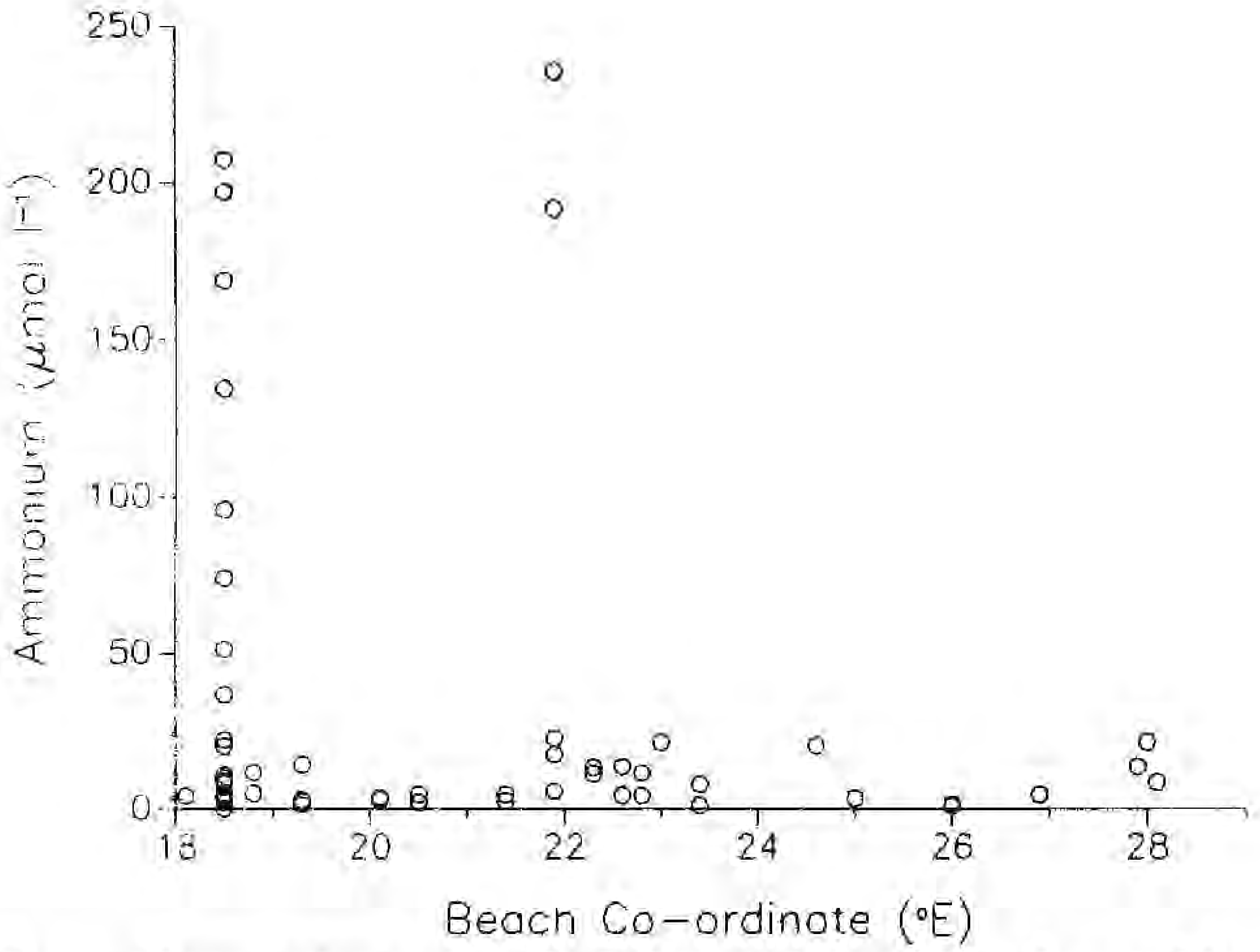

Figure 17. The ammonium concentration in the groundwater of the surf-zones of the south coast of Southern Africa.

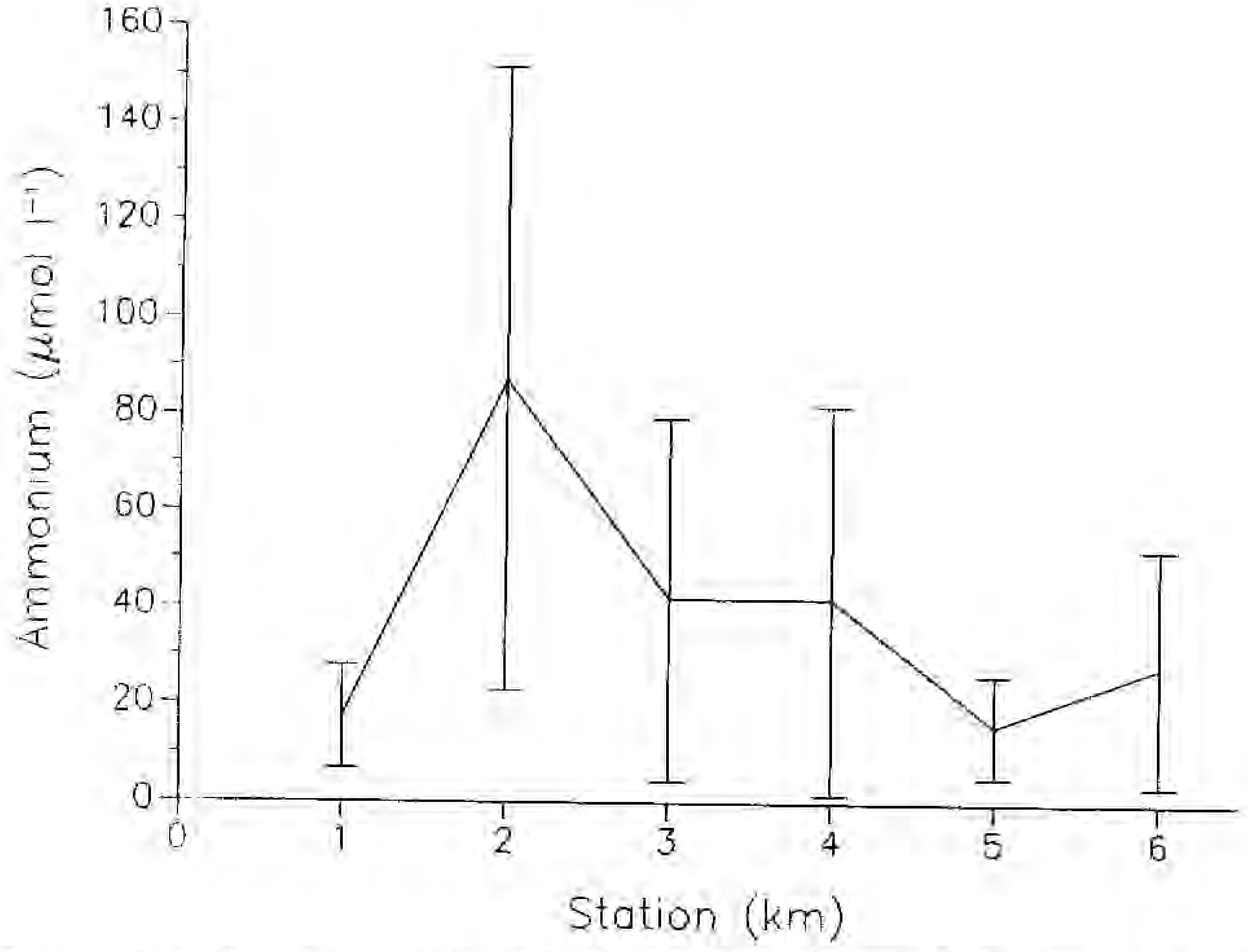

Figure 18. The ammonium concentration in the groundwater of the Muizenberg beach.

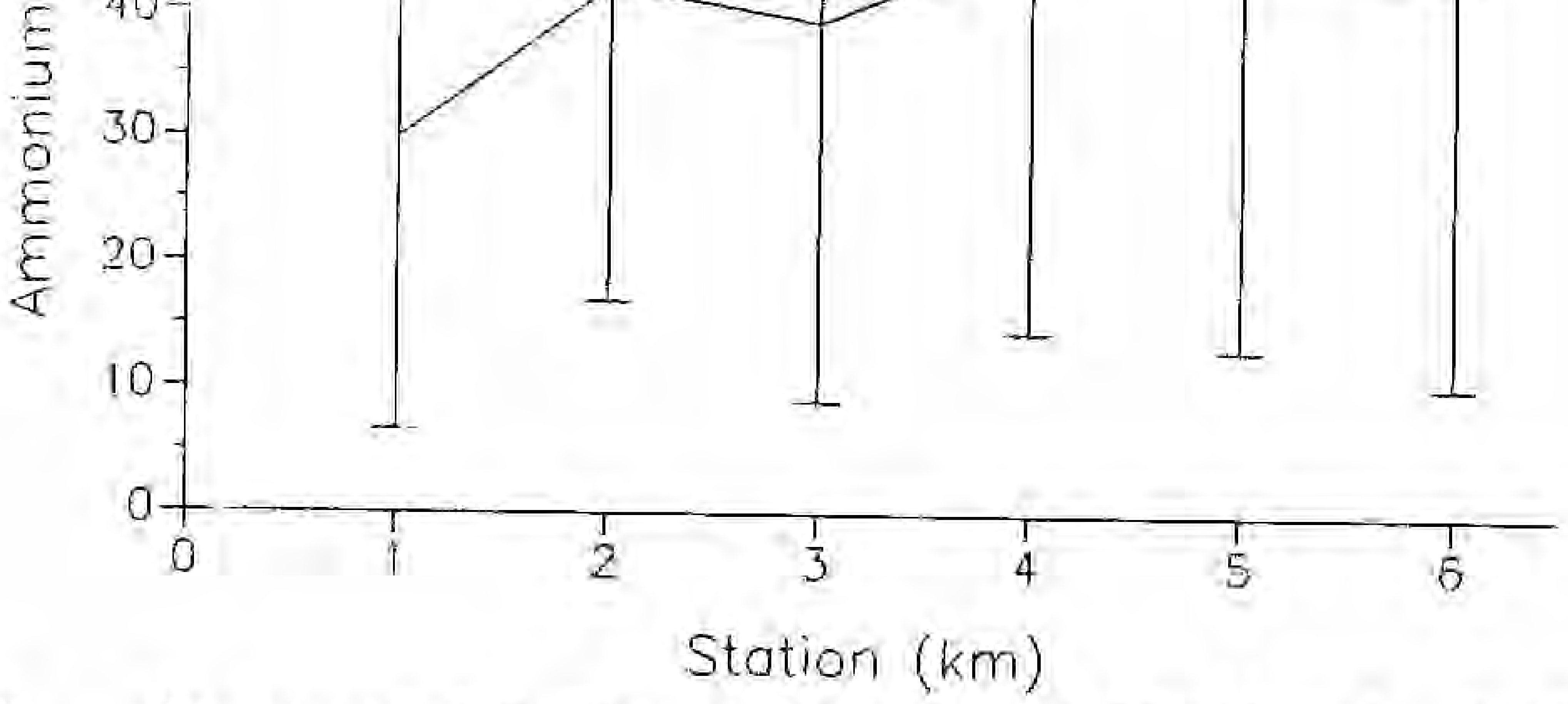

Figure 19. The ammonium concentration in the seawater of the Muizenberg beach.

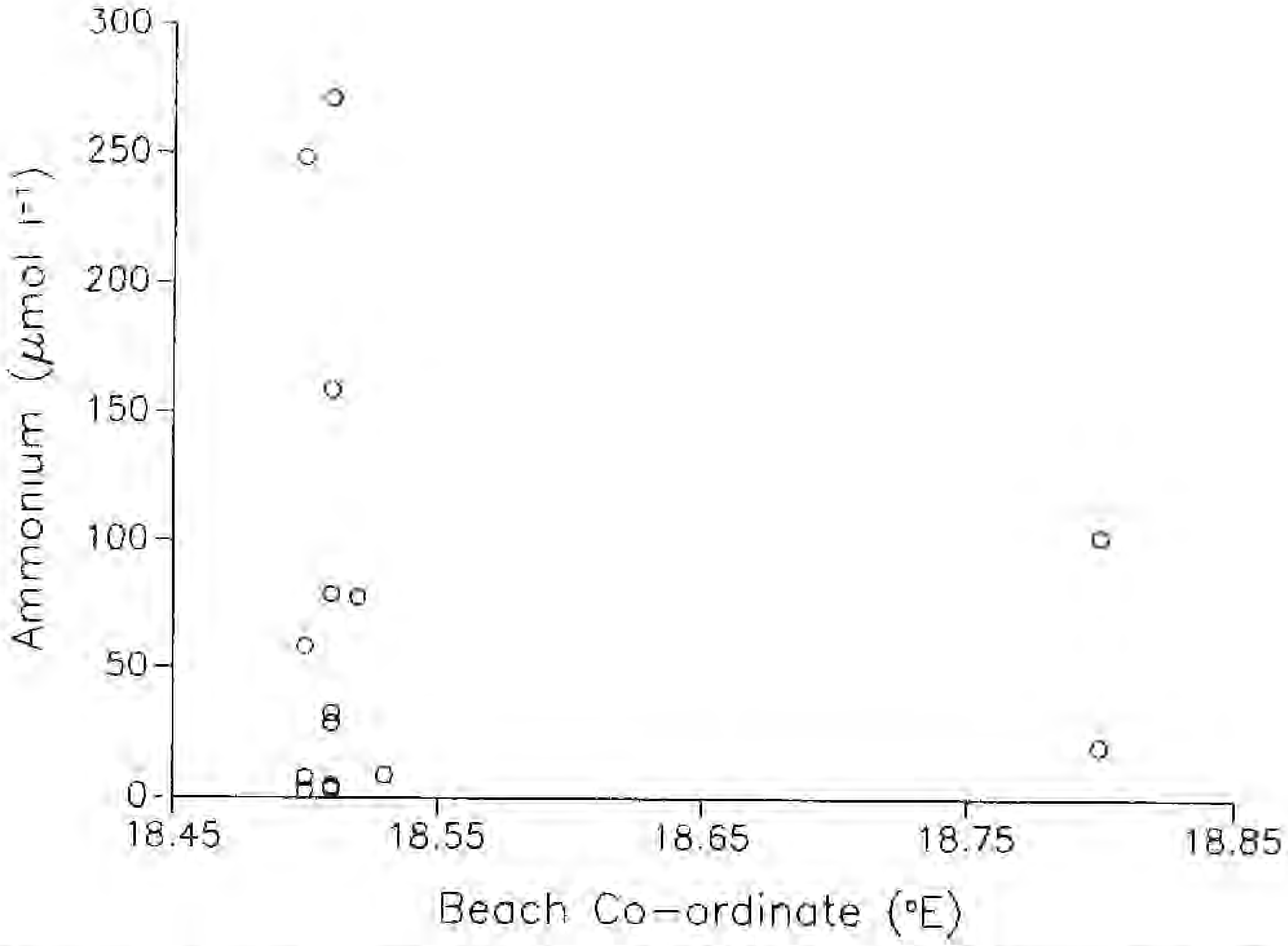

Figure 20. The ammonium concentration in the high nutrient outfalls entering False Bay.

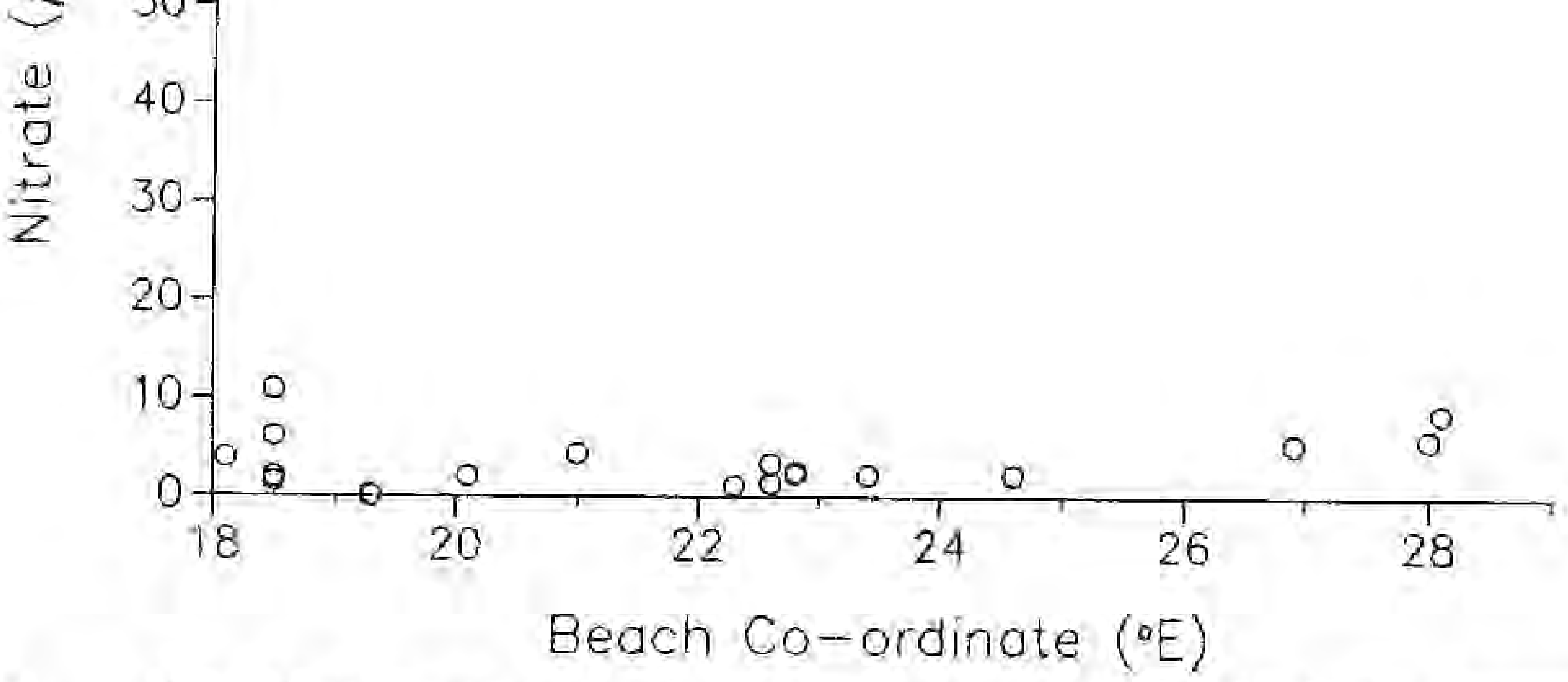

Figure 21. The nitrate concentration in rivers, estuaries and other freshwater sources entering the surf-zones of the south coast of South Africa.

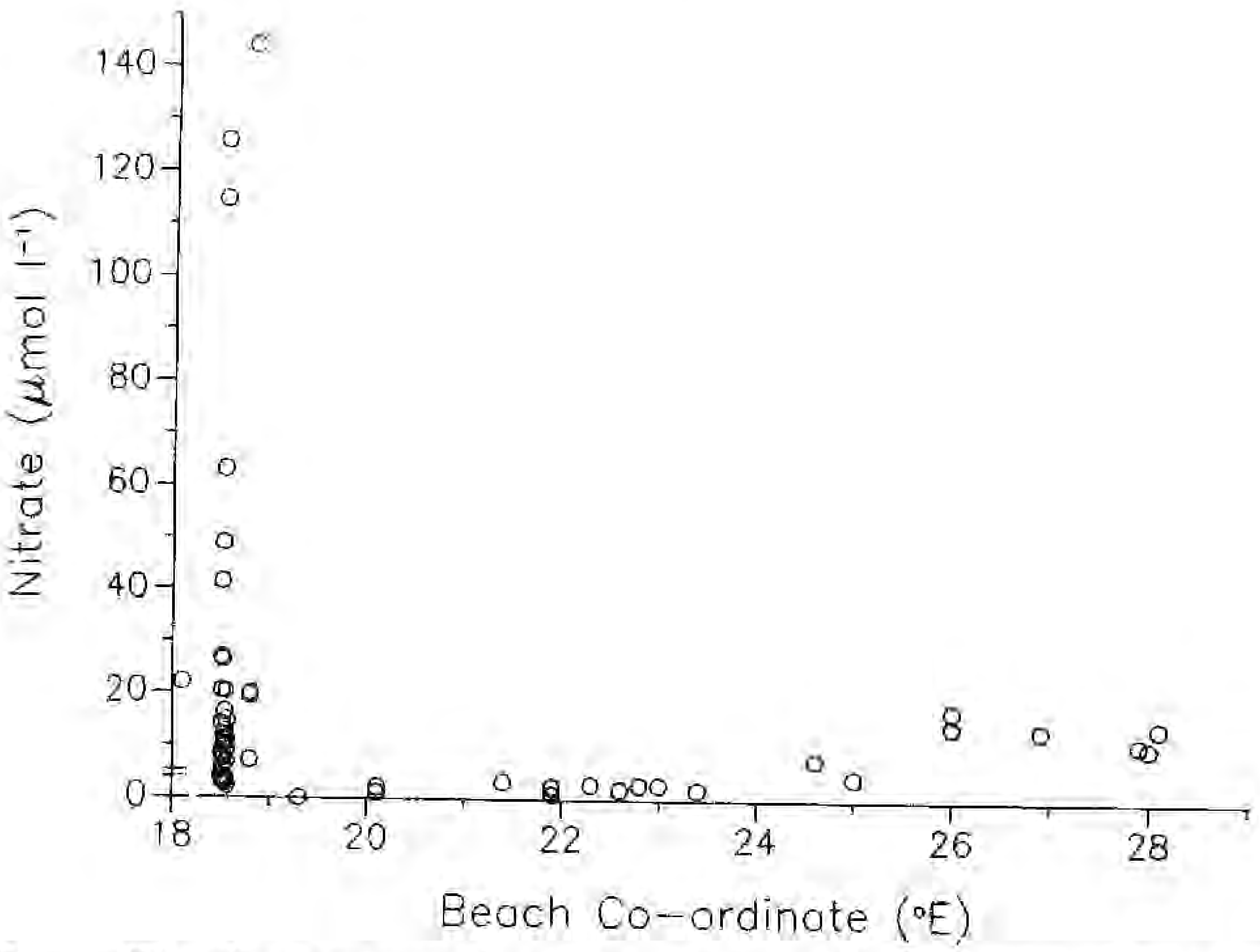

Figure 22. The nitrate concentration in the seawater of the surf-zones of the south coast of South Africa.

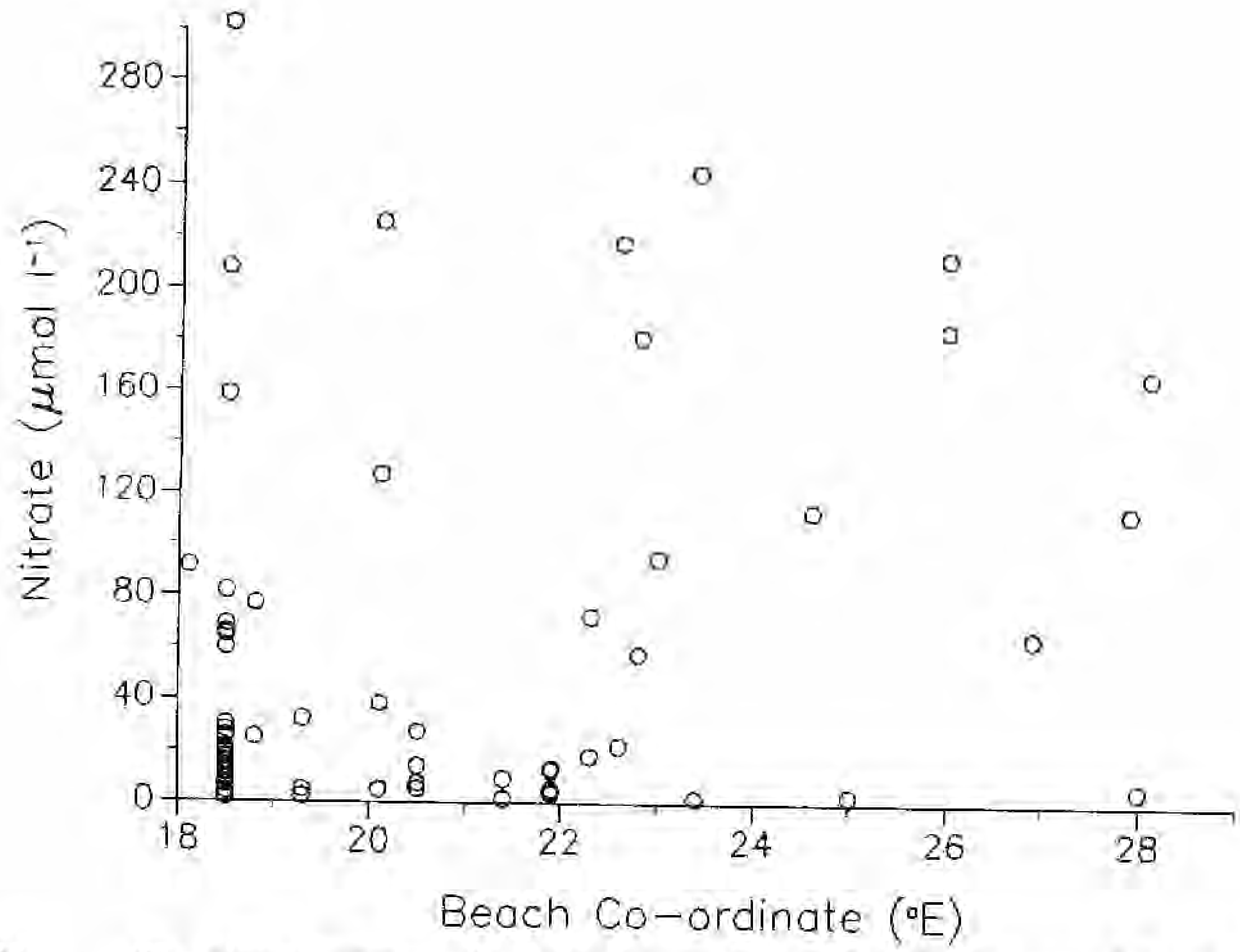

Figure 23. The nitrate concentration in the groundwater of the surf-zones of the south coast of South Africa.

The nitrate in the groundwater at Muizenberg was high near the Zeekoevlei and Sandvlei outfalls and at the point seaward of the sewage settling ponds (Station 5; Fig. 24). The outfalls in False Bay had high nitrate concentration (Fig. 25), the Macassar outfall having a value just over 140 µmol l^{-1}, and the Zeekoevlei outfall around 143 µmol l^{-1}. The Sandvlei outfall water contained only 18 µmol l^{-1}. One of the little streams opposite the sewage settling ponds contained 830 µmol l^{-1}, but this stream does not always flow. The nitrate in the outfall water caused elevated levels in the sea water (Fig. 26).

There are numerous ponds on the Cape Flats. These mostly had a low nitrate content compared to the groundwater or outfall water near Muizenberg. They had a mean of 6 µmol l^{-1} (range from 2 to 11 µmol l^{-1}). Many of these ponds had nitrate concentrations not much more than that of rainwater (2 µmol l^{-1}), and seepage from them cannot be considered to be a significant source of nitrogen.

The beaches were ranked according to the potential source of nitrate from groundwater (Table 3). The beaches which are likely to have a substantial input of nitrate from the groundwater are Muizenberg, Macassar, Walker Bay, Struisbaai, Dewoop, Glentana, Wilderness, Sedgefield, Buffalo Bay, Oyster Bay, Sundays, East London and Cintsa Bay.

3.5.1.4 Silicon

The concentration of soluble reactive silicon was measured on the last sampling trip only. The silicon in river water and estuaries increased from around 10 µmol l^{-1} in the west to as high as 160 µmol l^{-1} in the east (Fig. 27).

Soluble reactive silicon in the seawater was between 1 and 20 µmol l^{-1} (Fig. 28) except for 3 sites. At Muizenberg, where the Zeekoevlei outfall contained 120 µmol l^{-1} (Fig. 29), the seawater silicon content was elevated to 35 µmol l^{-1}. Macassar beach had 100 µmol of silicon per litre while East London Main beach had 30 µmol l^{-1}.

The silicon concentration in the groundwater soluble was higher than that of the seawater (7 - 175 µmol l^{-1} in groundwater, Fig. 30). Excluding the False Bay beaches, the concentration increased from west to east.

When the beaches are compared according to the potential silicon input from groundwater (Table 3), Muizenberg, Walker Bay, Glentana and the Sundays River beach would have substantial inputs of silicon into the surf-zone.

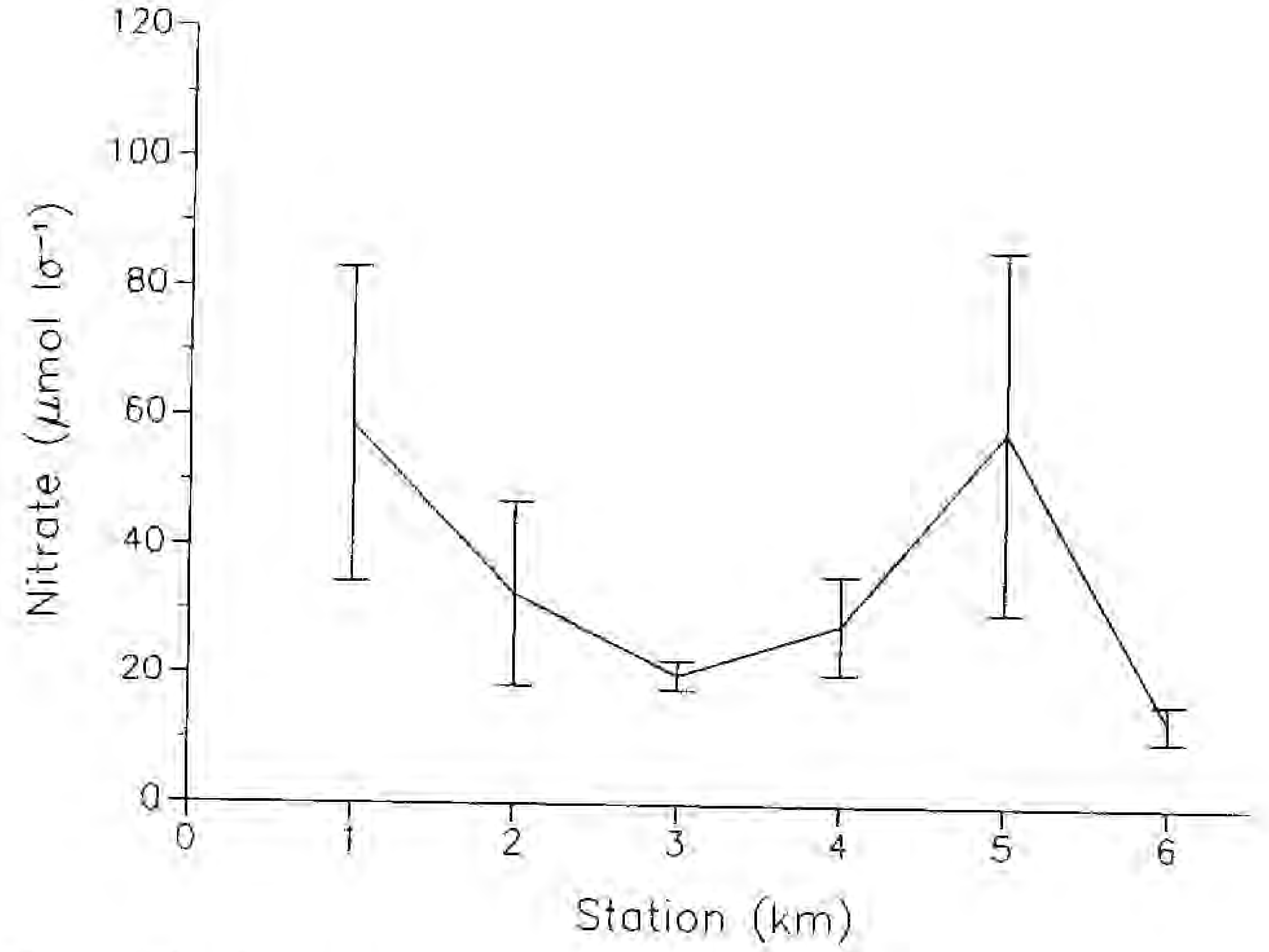

Figure 24. The nitrate concentration in the groundwater of the Muizenberg beach.

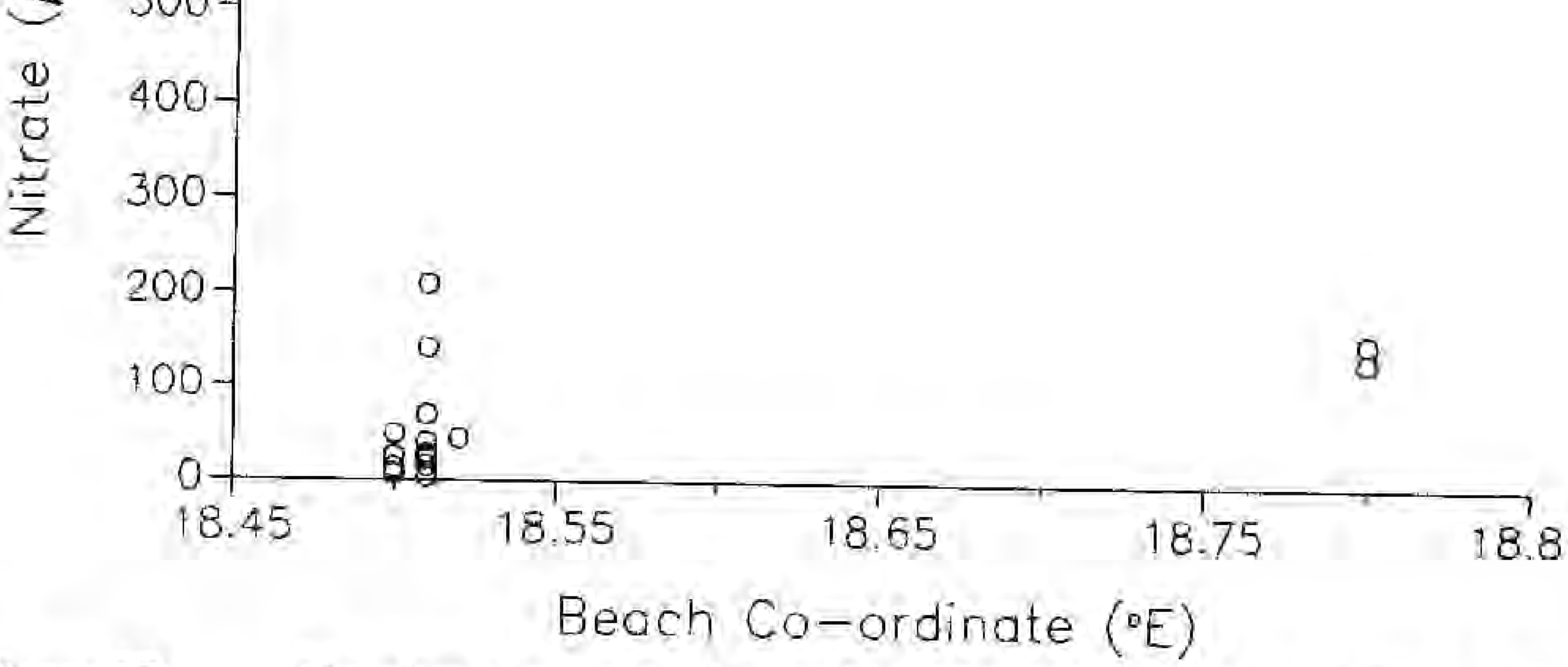

Figure 25. The nitrate concentration in the high nutrient outfalls of False Bay.

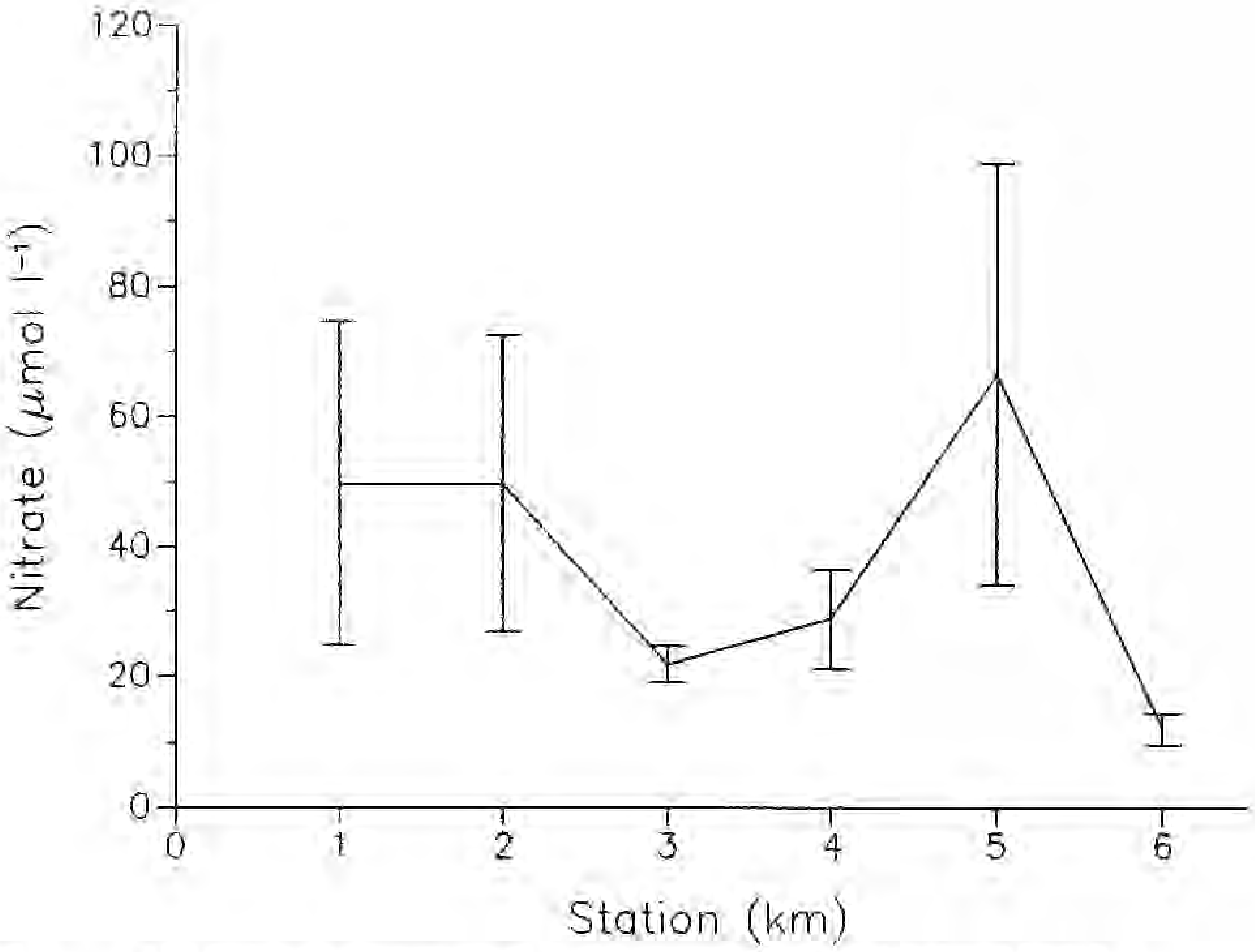

Figure 26. The nitrate concentration in the seawater at Muizenberg beach.

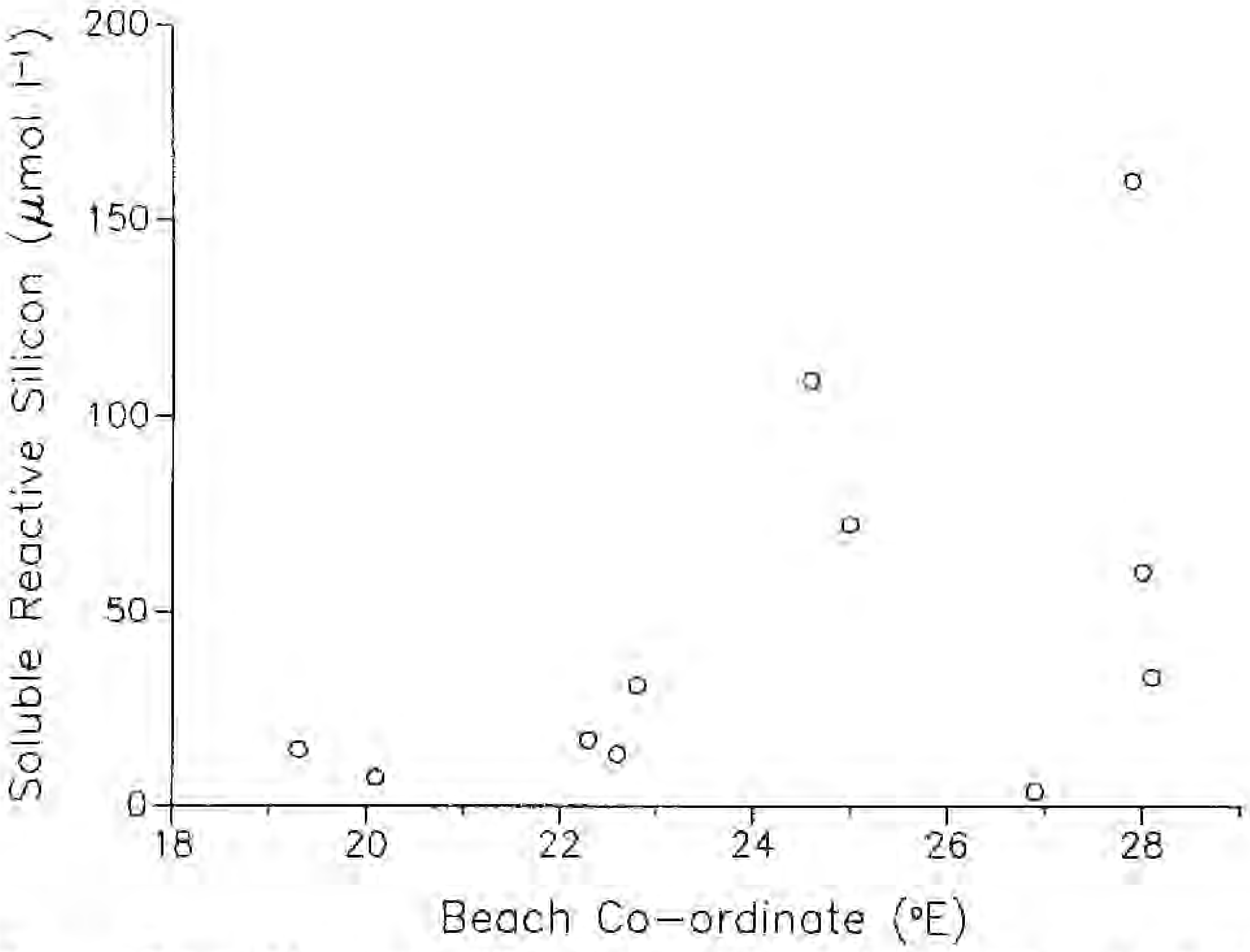

Figure 27. The soluble reactive silicon concentration in the rivers, estuaries and freshwater sources entering the surf-zones of the south coast of South Africa.

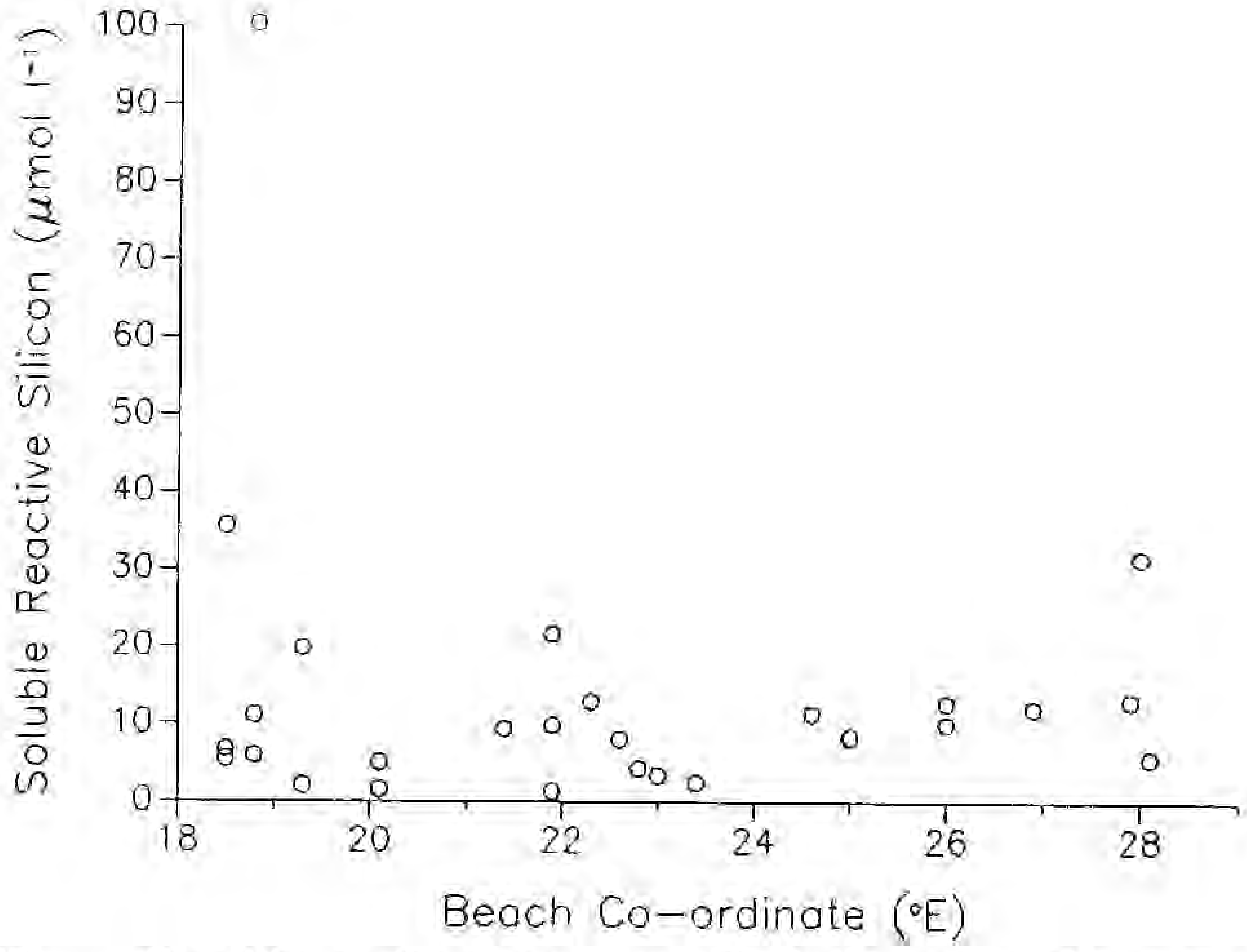

Figure 28. The soluble reactive silicon concentration in the seawater of the surf-zones of the south coast of South Africa.

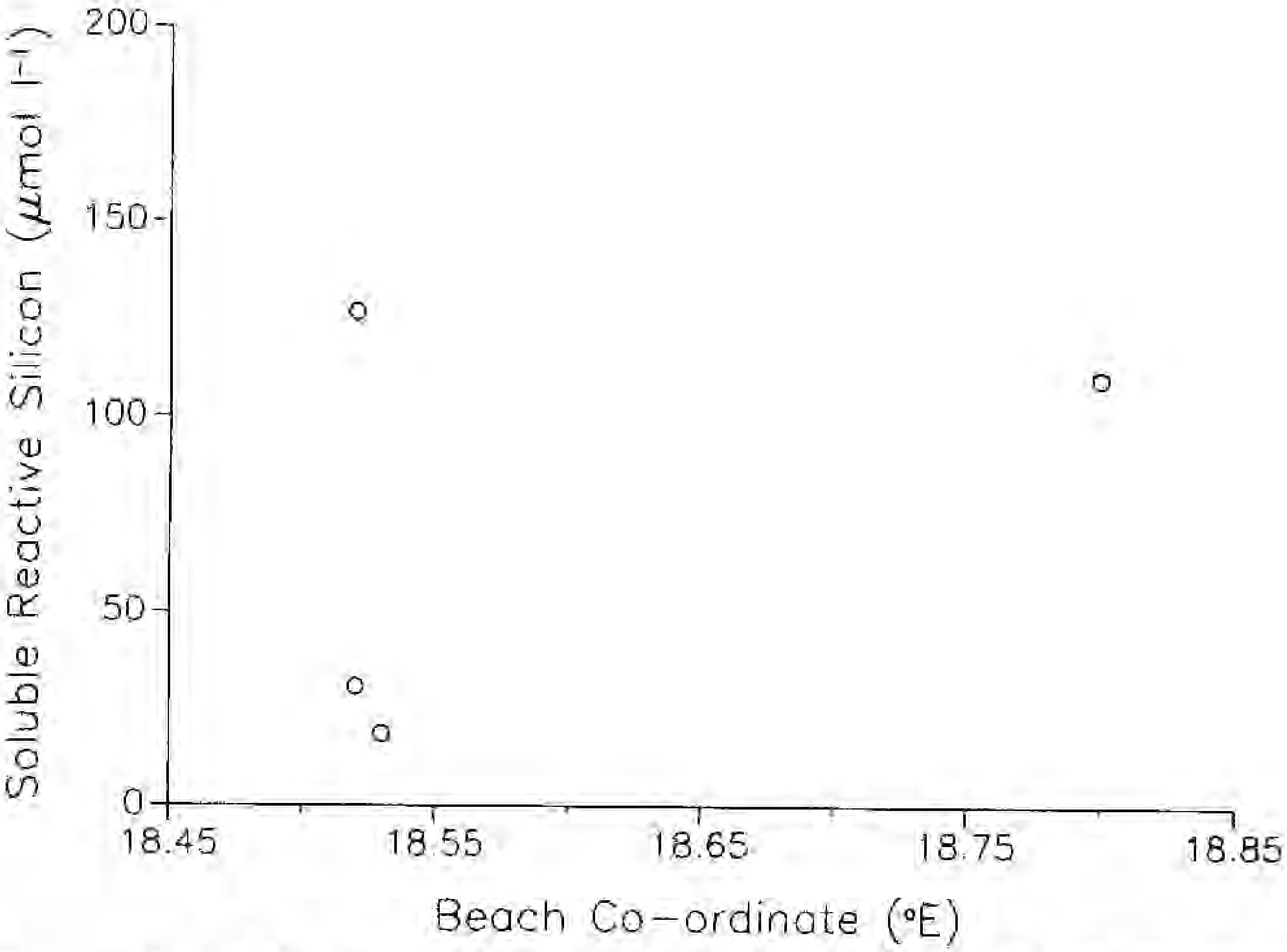

Figure 29. The soluble reactive silicon concentration in the high nutrient outfalls entering False Bay.

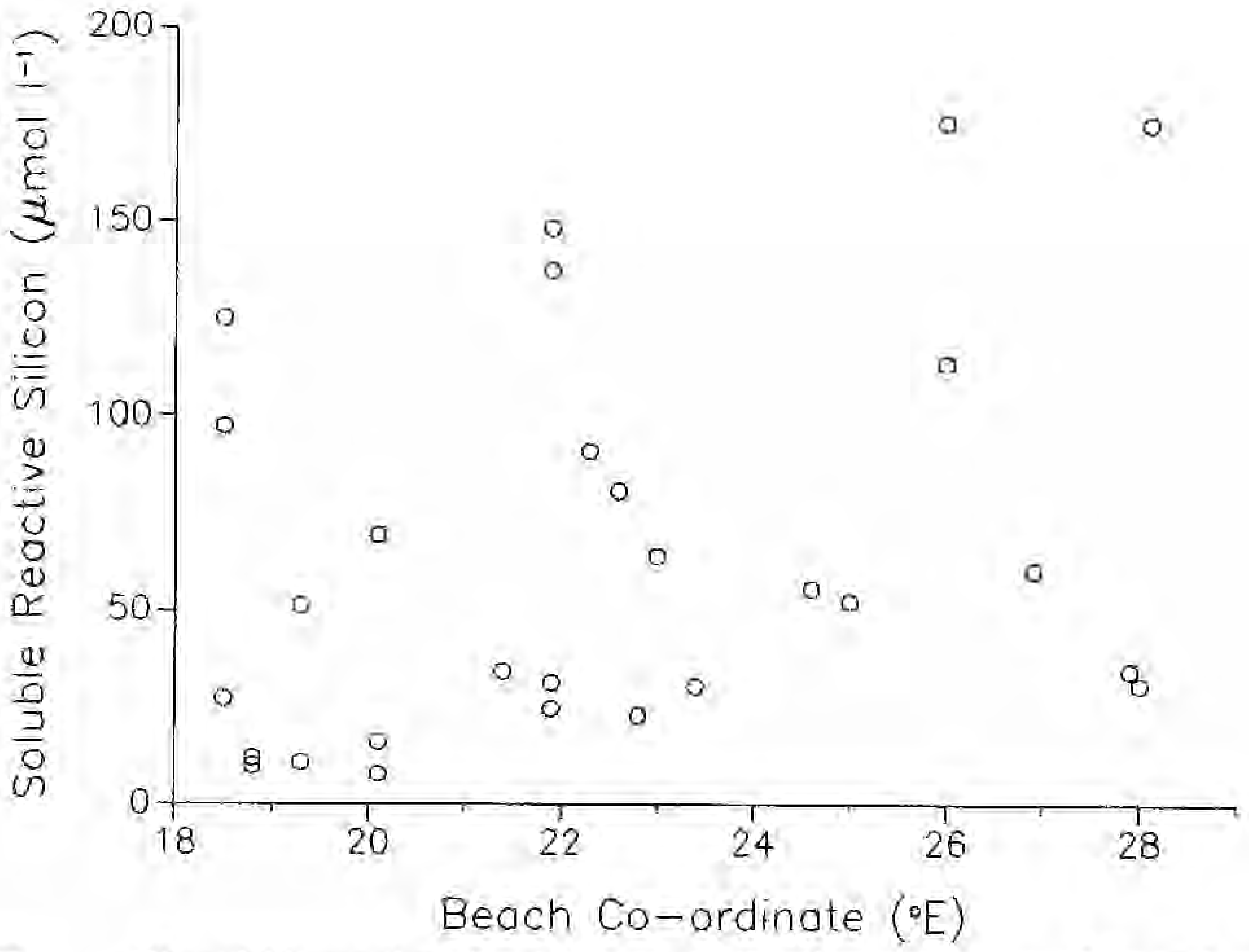

Figure 30. The soluble reactive silicon concentration in the groundwater of the surf-zones of the south coast of South Africa.

3.1.5.5 Salinity

The salinity of rivers and estuaries is given in Figure 31. All of the rivers sampled were estuaries, salinity values ranging from 10 to 34 ppt. The salinity of the seawater was consistantly 34-35 ppt (Fig. 32) while that of the groundwater ranged from 0 ppt to 40 ppt (Fig. 33). The False Bay high nutrient outfalls had a little exchange with the sea. Their salinities were below 10 ppt (Fig. 34).

3.1.6 Total Inorganic Nutrients in Groundwater

The beaches can be ranked according to the potential input of nutrients from groundwater (Table 4). In order to account for the dilution of the nutrients by seawater the values from Table 3 are multiplied by the inverse of the salinity (Equation 3). The beaches which had low total inorganic nitrogen content were Stilbaai, Buffalo Bay, Keurboomstrand, Van Stadens, Port Alfred and Bonza Bay.

Ranking parameter = (total inorganic nutrient in groundwater) x (1/salinity) x (slope of groundwater table x 100) ...(3)

3.2 Species Composition

A list of species is given below for the different types of samples taken. The complete species composition data are given in Appendix 3.

3.2.1 The Species Found in the Foam

No.	Species	Assigned Number
1	*Achnanthes* sp.	1
2	*Actinastrum* sp.	2
3	*Amphiprora* sp.	4
4	*Amphora* sp.	5
5	*Anacystis* sp.	6
6	*Anaulus australis*	7
7	*Asterionella glacialis*	8
8	*Asteriomphalus* sp.	9
9	*Aulacodiscus johnsonii*	10
10	*Aulacodiscus petersii*	11
11	*Biddulphia alternans*	12
12	Bluegreen chain	18
13	Bluegreen circular	19
14	*Campylosira cymbelliformis*	20
15	Centric large	21
16	Centric small	23

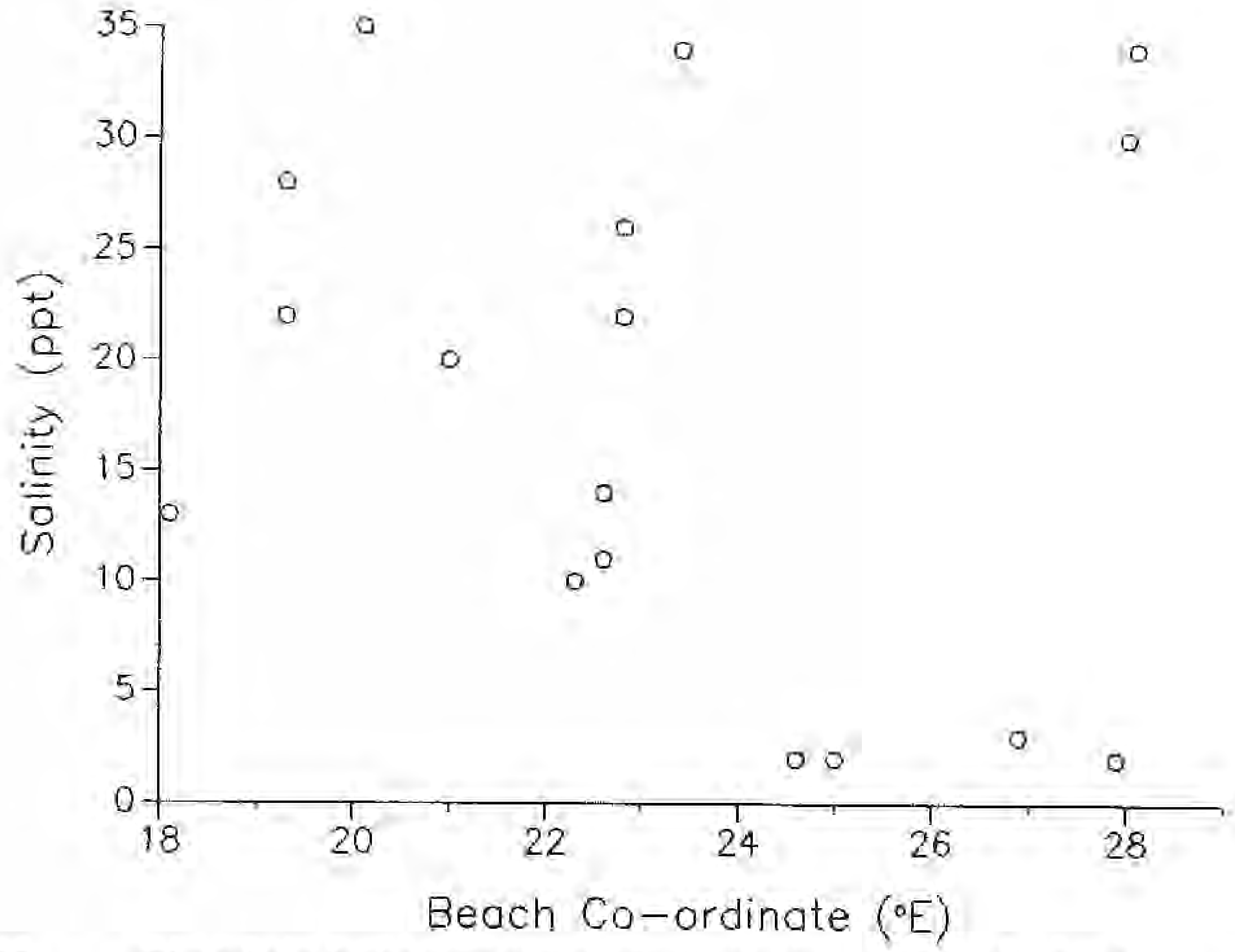

Figure 35. The salinity in the river water, estuarine water and other freshwater sources entering the surf-zones of the south coast of South Africa.

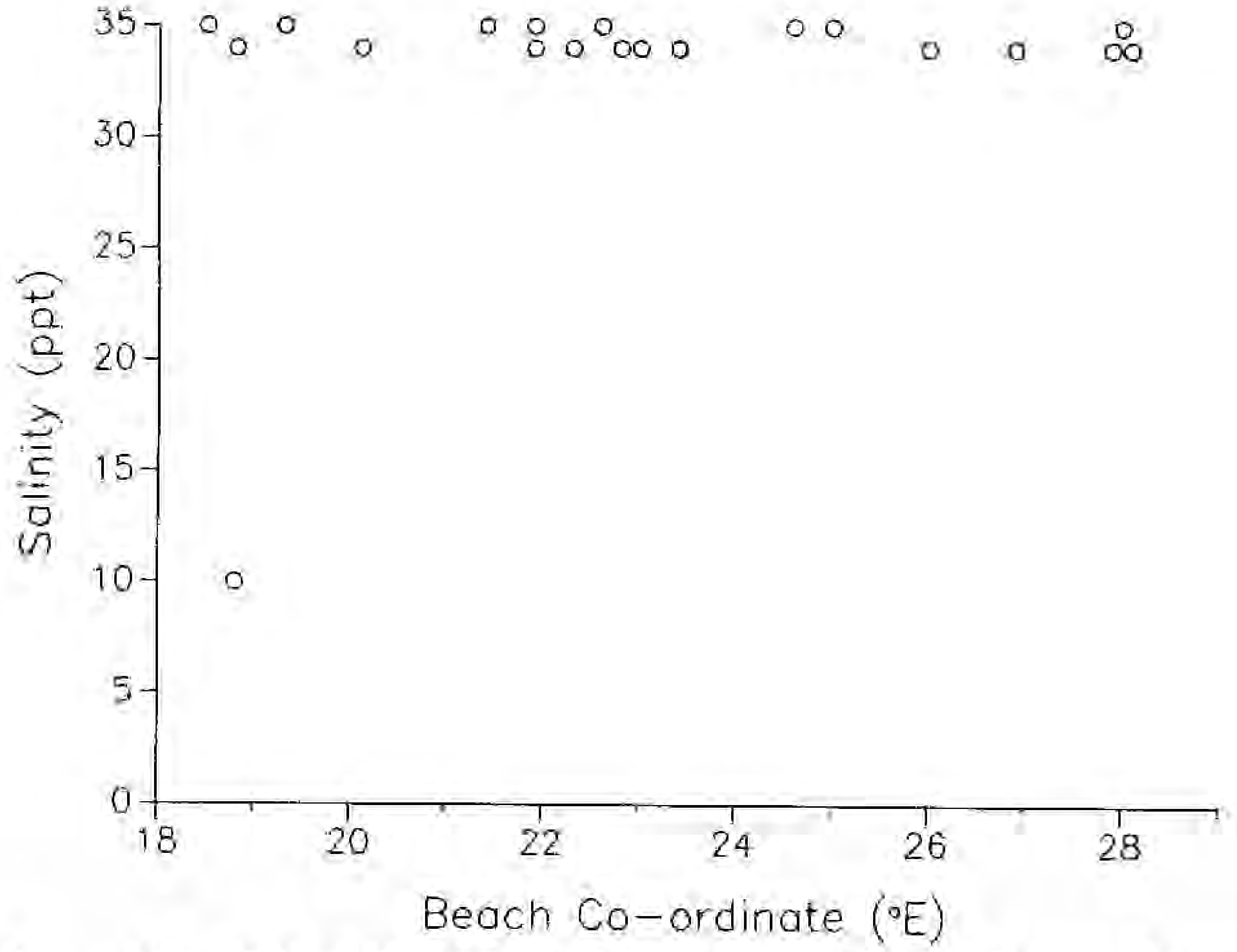

Figure 36. The salinity in the seawater of the surf-zones of the south coast of South Africa.

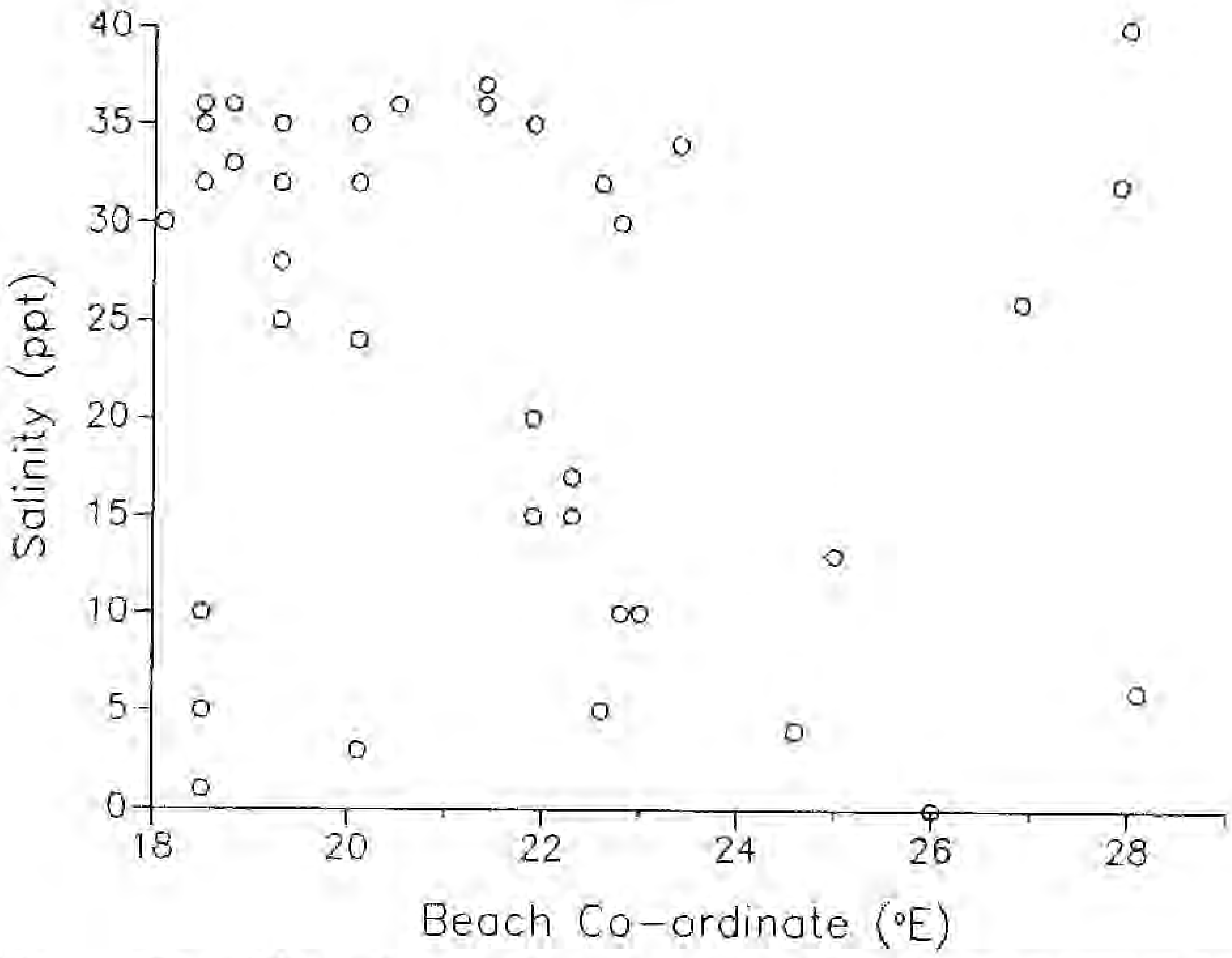

Figure 37. The salinity in the groundwater in the beaches of the south coast of South Africa.

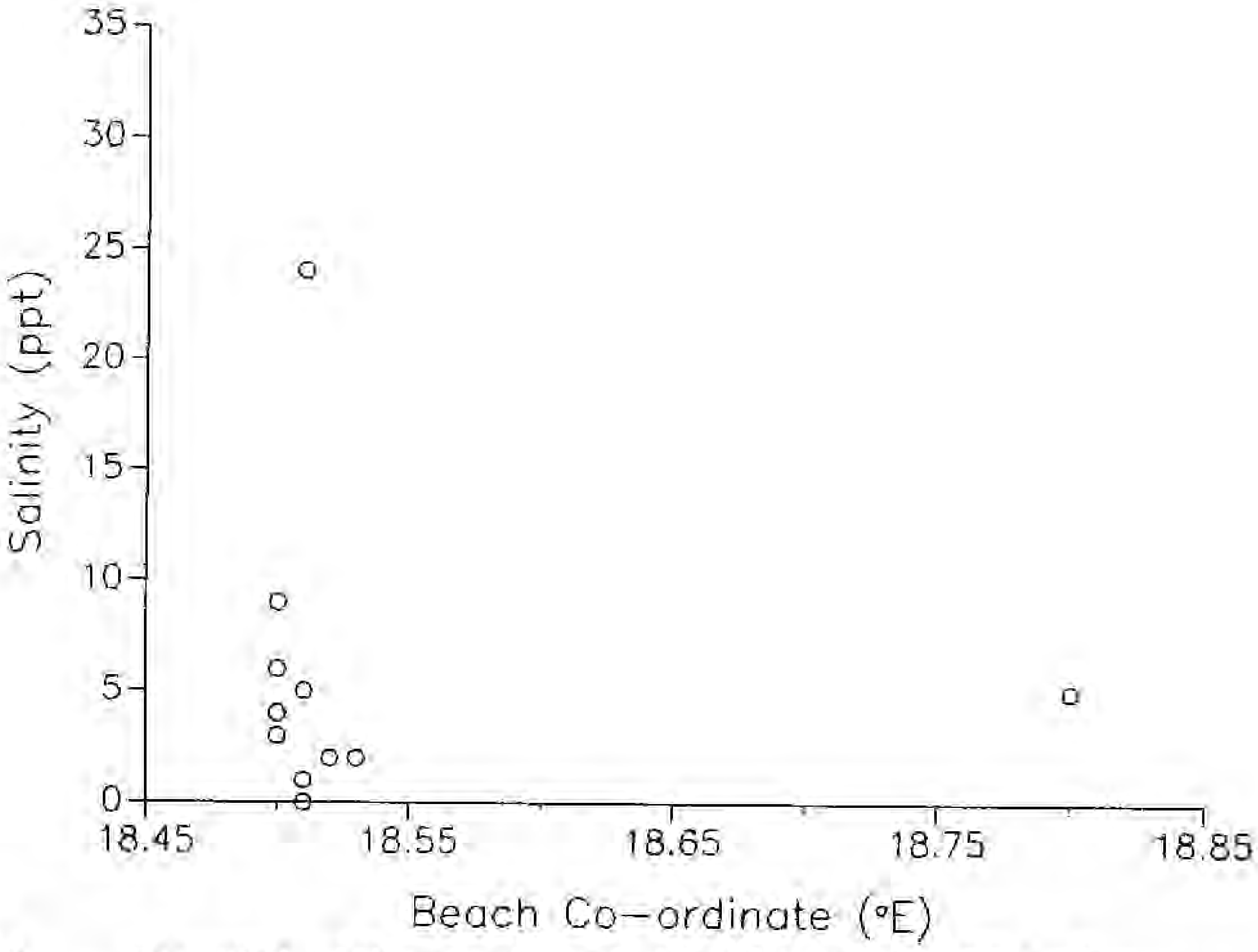

Figure 38. The salinity of the water in the high nutrient outfalls of False Bay.

Table 4. The ranking of the beaches according to the product of inorganic nutrients in the groundwater multiplied by the groundwater slope.

Beach	Inorganic Nitrogen	All Nutrients
Muizenberg	4 200	9 536
Sundays	996	1 720
East London	759	974
Glentana	517	1 339
Vleesbaai	410	758
Macassar	356	429
Buffalo Bay	348	545
Walker Bay	317	1 232
Struisbaai	306	404
Oyster Bay	266	379
Wilderness	257	422
Sedgefield	254	306
De Hoop	199	420
Cintsa Bay	175	351
Port Alfred	68	136
Stilbaai	63	314
Bonza Bay	27	58
Keurboomstrand	25	151
Van Stadens	6	58

17	*Ceratium furca*	24
18	*Chaetoceros affinis*	27
19	*Chaetoceros* large	28
20	*Chaetoceros* medium	29
21	*Chaetoceros* small	30
22	*Chaetoceros* paired	31
23	*Chaetoceros protuberans*	33
24	*Cocconeis* sp.	37
25	*Cocconeis* epiphyte	47
26	Desmid	39
27	*Dinophysis acuminata*	41
28	*Diploneis* sp.	42
29	*Distephanus* sp.	43
30	*Ditylum* sp.	44
31	*Eucampia zoodiacus*	49
32	Flagellate large	51
33	Flagellate medium	52
34	Flagellate small	53
35	*Grammatophora marina*	55
36	Greens	56
37	*Gyrodinium* sp.	57
38	*Gyrosigma* sp.	58
39	*Hemiaulus hauckii*	59
40	*Leptocylindrus danicus*	60
41	*Leptocylindrus* sp.	61
42	*Licmophora* sp.	62
43	*Melosira sulcata*	65
44	*Merismopedia* sp.	66
45	*Micractinium* sp.	67
46	*Navicula* A	69
47	*Navicula* B	70
48	*Navicula* C	71
49	*Navicula* D	72
50	*Navicula* E	73
51	*Nitzschia* A	76
52	*Nitzschia closterium*	77
53	*Nitzschia delicatissima*	78
54	*Nitzschia longissima*	79
55	*Nitzschia pacifica*	80
56	*Nitzschia seriata*	81
57	*Nitzschia* B	82
58	*Nitzschia* C	83
59	*Pediastrum* sp.	86
60	*Peridinium* A	87
61	*Peridinium* B	90
62	*Peridinium* C	91
63	*Plagiogramma van heurckii*	92
64	*Pleurosigma* sp.	93
65	*Prorocentrum micans*	94
66	*Rhizosolenia alata*	95
67	*Rhizosolenia delicatula*	96
68	*Rhizosolenia robusta*	97
69	*Rhizosolenia* sp.	98
70	*Rhizosolenia stolterfolthii*	99
71	*Rhizosolenia styliformis*	100

72	*Scenedesmus* sp.	101
73	*Schroederella* A	102
74	*Schroederella* B	103
75	*Skeletonema costatum*	104
76	*Striatella* sp.	105
77	*Surirella* sp.	108
78	*Thalassionema nitzschioides*	110
79	*Thalassiosira decipiens*	111
80	*Thalassiosira rotula*	112
81	*Thalassiosira* A	113
82	*Thalassiosira* B	38
83	*Thalassiothrix* sp.	114
84	Unknown A	117
85	Unknown B	46

3.2.2 The Species Found in the Patch Foam

No.	Species	Assigned Number
1	*Achnanthes* sp.	1
2	*Actinoptychus* sp.	3
3	*Anaulus australis*	7
4	*Asterionella glacialis*	8
5	*Aulacodiscus johnsonii*	10
6	*Aulacodiscus petersii*	11
7	*Biddulphia mobiliensis*	13
8	*Campylosira cymbelliformis*	20
9	*Ceratium furca*	24
10	*Chaetoceros* medium	29
11	*Distephanus* sp.	43
12	Flagellates	51
13	*Gyrodinium* sp.	57
14	*Hemiaulus hauckii*	59
15	*Leptocylindrus danicus*	60
16	*Licmophora* sp.	62
17	*Melosira sulcata*	65
18	*Navicula* A	69
19	*Navicula* B	70
20	*Navicula* D	72
21	*Navicula* F	75
22	*Nitzschia closterium*	77
23	*Nitzschia delicatissima*	78
24	*Nitzschia longissima*	79
25	*Nitzschia seriata*	81
26	*Nitzschia* B	82
27	*Pediastrum* sp.	83
28	*Peridinium* sp.	87
29	*Plagiogramma van heurckii*	92
30	*Prorocentrum micans*	94
31	*Rhizosolenia delicatula*	96
32	*Scenedesmus* sp.	101
33	*Schroederella* A	102
34	*Skeletonema costatum*	104
35	*Thalassionema nitzschioides*	110
36	*Thalassiosira decipiens*	111

37	*Thalassiosira* large	38
38	*Thalassiosira rotula*	112
39	*Thalassiosira* small	113

3.2.3 The Species Found in the Water

No.	Species	Assigned Number
1	*Achnanthes* sp.	1
2	*Amphiprora* sp.	4
3	*Amphora* sp.	5
4	*Anacystis* sp.	6
5	*Anaulus australis*	7
6	*Asteriomphalus* sp.	9
7	*Asterionella glacialis*	8
8	*Aulacodiscus johnsonii*	10
9	*Aulacodiscus petersii*	11
10	*Biddulphia alternans*	12
11	*Biddulphia* A	16
12	*Biddulphia mobiliensis*	13
13	*Biddulphia pulchella*	14
14	*Biddulphia* B	15
15	Bluegreens	18
16	*Campylosira cymbelliformis*	20
17	Centric large	21
18	Centric medium	22
19	Centric small	23
20	*Ceratium furca*	24
21	*Ceratium tripas*	25
22	*Chaetoceros* A	26
23	*Chaetoceros* large	28
24	*Chaetoceros* medium	29
25	*Chaetoceros* B	31
26	*Chaetoceros peruvianus*	32
27	*Chaetoceros protuberans*	33
28	*Chaetoceros* small	30
29	*Chaetoceros vanheurkii*	34
30	Chain	35
31	*Climacopshenia* sp.	36
32	*Cocconeis* epiphyte	37
33	*Cocconeis* sp.	47
34	Desmid	39
35	*Dinophysis acuminata*	41
36	*Diploneis* sp.	42
37	*Distephanus* sp.	43
38	*Ditylum brightwellii*	45
39	*Eucampia zoodiacus*	49
40	*Euglena* sp.	50
41	Flagellate large	51
42	Flagellate medium	52
43	Flagellate small	53
44	*Grammatophora marina*	55
45	Greens	56
46	*Gyrodinium* sp.	57
47	*Hemiaulus hauckii*	59

48	*Leptocylindrus danicus*	60
49	*Leptocylindrus* sp.	61
50	*Licmophora* sp.	62
51	*Melosira sulcata*	65
52	*Merismopedia* sp.	66
53	*Micractinium* sp.	67
54	*Navicula* A	69
55	*Navicula* B	70
56	*Navicula* C	71
58	*Navicula* D	72
57	*Navicula* F	75
59	*Navicula* G	64
60	*Navicula* H	105
61	*Navicula* I	74
62	*Nitzschia* A	76
63	*Nitzschia closterium*	77
64	*Nitzschia delicatissima*	78
65	*Nitzschia longissima*	79
66	*Nitzschia pacifica*	80
67	*Nitzschia seriata*	81
68	*Nitzschia* sp.	82
69	*Nitzschia* very small	83
70	*Noctiluca milearis*	84
71	*Pediastrum* sp.	86
72	*Peridinium* A	90
73	*Peridinium palidum*	89
74	*Peridinium* B	87
75	*Plagiogramma van heurckii*	92
76	*Pleurosigma* sp.	93
77	*Prorocentrum micans*	94
78	*Rhizosolenia alata*	95
79	*Rhizosolenia delicatula*	96
80	*Rhizosolenia robusta*	97
81	*Rhizosolenia* sp.	98
82	*Rhizosolenia stolterfothii*	99
83	*Rhizosolenia styliformis*	100
84	*Scenedesmus* sp.	101
85	*Schroederella* A	102
86	*Schroederella* B	103
87	*Skeletonema costatum*	104
88	*Stephanopyxis turris*	106
89	*Striatella* sp.	107
90	*Surirella* A	108
91	*Surirella* B	109
92	*Thalassionema nitzschioides*	110
93	*Thalassiosira decipiens*	111
94	*Thalassiosira* large	38
95	*Thalassiosira rotula*	112
96	*Thalassiosira* small	113
97	*Thalassiothrix* sp.	114
98	Unknown A	115
99	*Zygobikodinium* sp.	116

3.2.4 The Species Found in the Sand

No.	Species	Assigned Number
1	*Amphiprora* sp.	4
2	*Amphora* sp.	5
3	*Anacystis* sp.	6
4	*Anaulus australis*	7
5	*Asterionella glacialis*	8
6	*Aulacodiscus johnsonii*	10
7	*Aulacodiscus petersii*	11
8	*Biddulphia* sp.	15
9	Blue-greens	18
10	*Campylosira cymbelliformis*	20
11	Centric large	21
12	Centric medium	22
13	Centric Smal	123
14	*Chaetoceros* spores	120
15	*Climacopshenia* sp.	36
16	*Cocconeis* sp.	37
17	*Delphineis* sp.	121
18	*Dinophysis acuminata*	41
19	*Diploneis* sp.	42
20	*Euglena* sp.	50
21	Flagellate	51
22	Flagellate medium	52
23	Greens	56
24	*Gyrosigma* sp.	58
25	*Leptocylindrus danicus*	60
26	*Melosira sulcata*	65
28	*Navicula* A	69
29	*Navicula* B	70
27	*Navicula* I	123
30	*Navicula* J	118
32	*Navicula* K	72
33	*Navicula* L	73
34	*Navicula* M	64
35	*Navicula* N	105
36	*Navicula* O	125
31	*Navicula spatulata*	124
37	*Nitzschia bicapitata*	127
38	*Nitzschia bilobata*	126
39	*Nitzschia delicatissima*	78
40	*Nitzschia longissima*	79
41	*Pediastrum* sp.	86
42	*Peridinium* sp.	87
43	*Plagiogramma van heurcki*	92
44	*Rhizosolenia* sp.	98
45	*Scenedesmus* sp.	101
46	*Thalassiosira decipiens*	111
47	*Thalassiosira* small	113
48	Unknown A	117
49	Unknown B	119
50	Unknown C	122
51	Unknown D	128

52	Unknown E	129

3.2.5 Community Analyses

The number of species recorded in each sample ranged from 3-21 for water samples (Fig. 35). The number of species tended to be greater in the Wilderness area (between 22 and 24°E) but the variance is great. In the sand there were between 2 and 11 species recorded per sample, except for the False Bay beaches, where the number of species varied from 4 to 20, most of the values being above 9 (Fig. 36). The number of species recorded in the foam and in phytoplankton patches was similar to that of the water, foam ranging from 2 to 21 species recorded per sample (Fig. 37), and patch foam between 3 and 19 different species (Fig. 38).

The diversity indices calculated for water samples ranged from 4 to 24 (Fig. 39), indices being higher in the Wilderness area. In the sand diversity indices were much lower, values ranging from 2 to 11 for all the beaches other than the False Bay beaches (Fig. 40), where values were as high as 20. Diversity indices in foam and patch foam samples were low, a maximum of 4.6 being recorded (Fig. 41 and 42).

Two levels of dominance were recorded in the samples. In the water (Fig. 43) indices of dominance were low (below 0.5) at most of the beaches on occasion. The dominance index was high on three occasions at beaches where no accumulations of *Anaulus australis* have been recorded, viz. Walker Bay, Stilbaai and East London. At all three these sites *Anaulus australis* was dominant. The same situation occurred in the sand (Fig. 44), values being around 0.2 generally, but reaching values as high as 0.97 in some cases. In all these cases either *Anaulus australis* or *Asterionella glacialis* were dominant. In the foam the separation between the two groups was distinct (Fig. 45), most of the samples having values below 0.5, a group west of 24°E having values between 0.62 and 0.99. Patch foam had indices of dominance above 0.9 in most cases (Fig. 46). In four cases the index was 0.7, and in two cases (Buffalo Bay and Walker Bay) 0.3. In general the water had a diversity index of 0.47, the sand 0.45, the foam 0.52 and patch foam 0.78.

Diatoms were the dominant group of microalgae in the surf-zones along the south coast. Most of the water samples contained more than 90% diatoms (Fig. 47). The Muizenberg samples contained several species of freshwater algae, thus reducing the percentage of diatoms. Four other sites had less than 70% diatoms: Walker Bay, Wilderness, Van Stadens and Struisbaai.

The sand samples could be divided into two groups (Fig. 48). Some of the samples had between 90 and 100% diatoms whereas 8 samples had less than 80% diatoms.

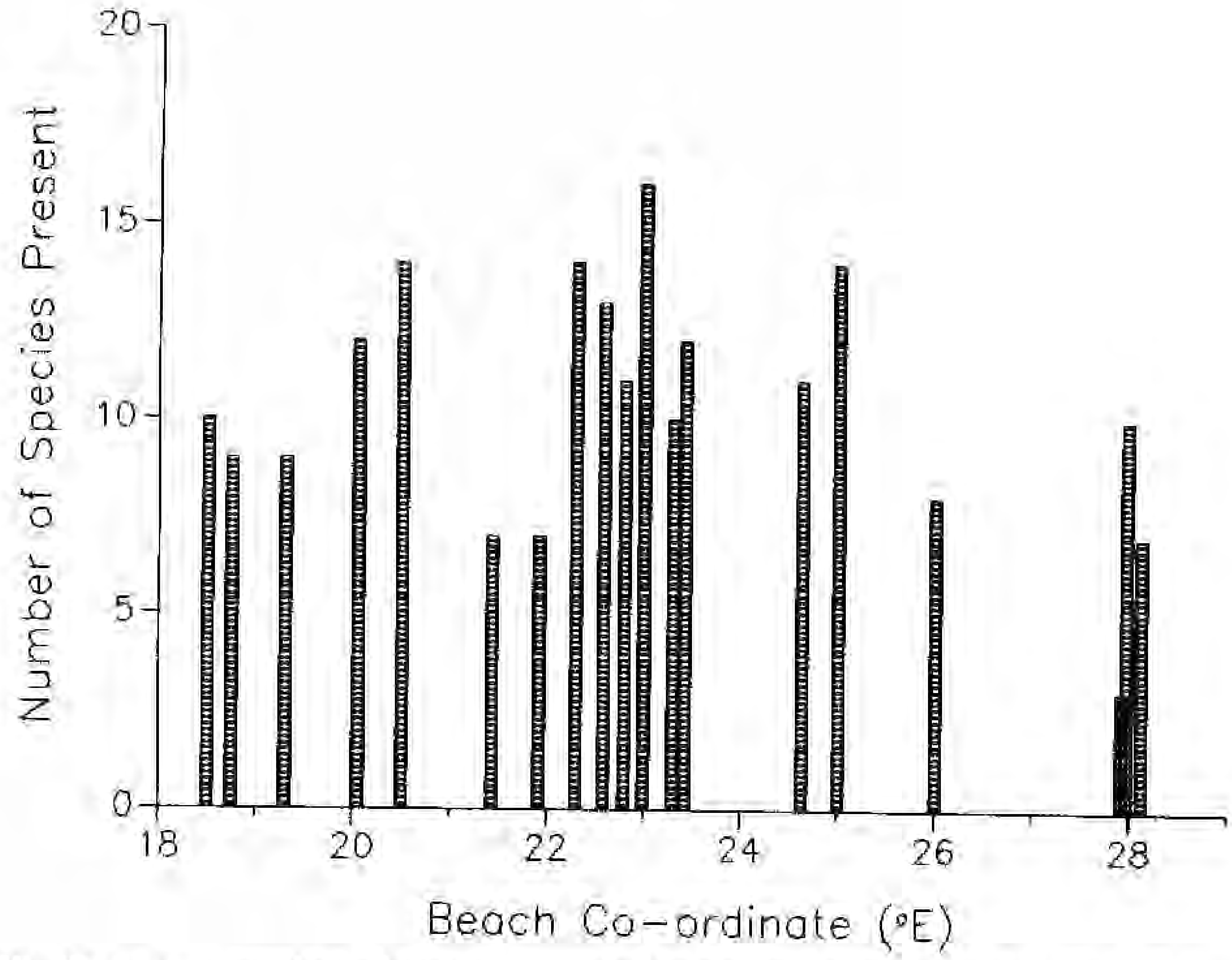

Figure 35. The mean number of species recorded in the surf water samples along the south coast of South Africa.

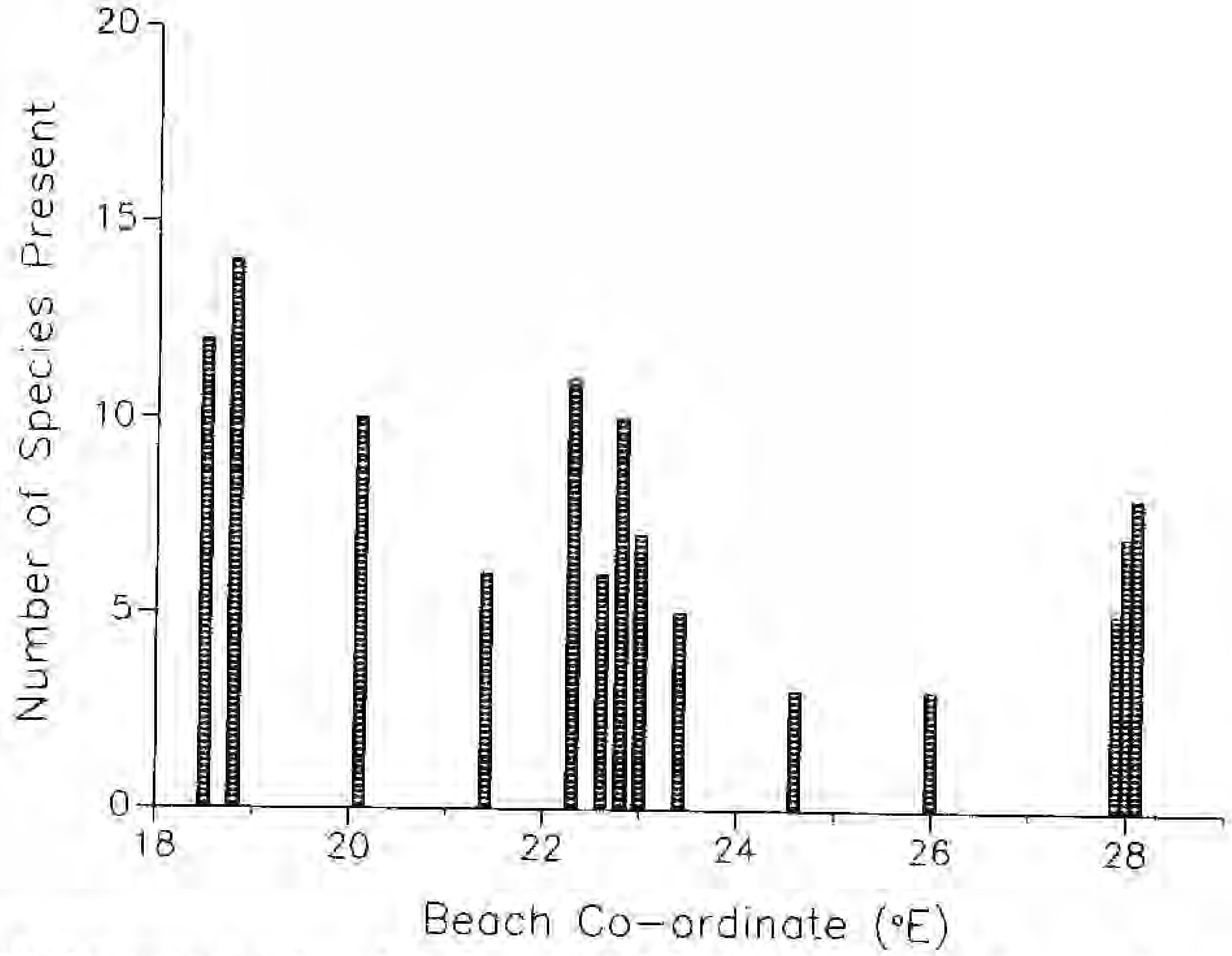

Figure 36. The mean number of species recorded in the surf sand samples along the south coast of South Africa.

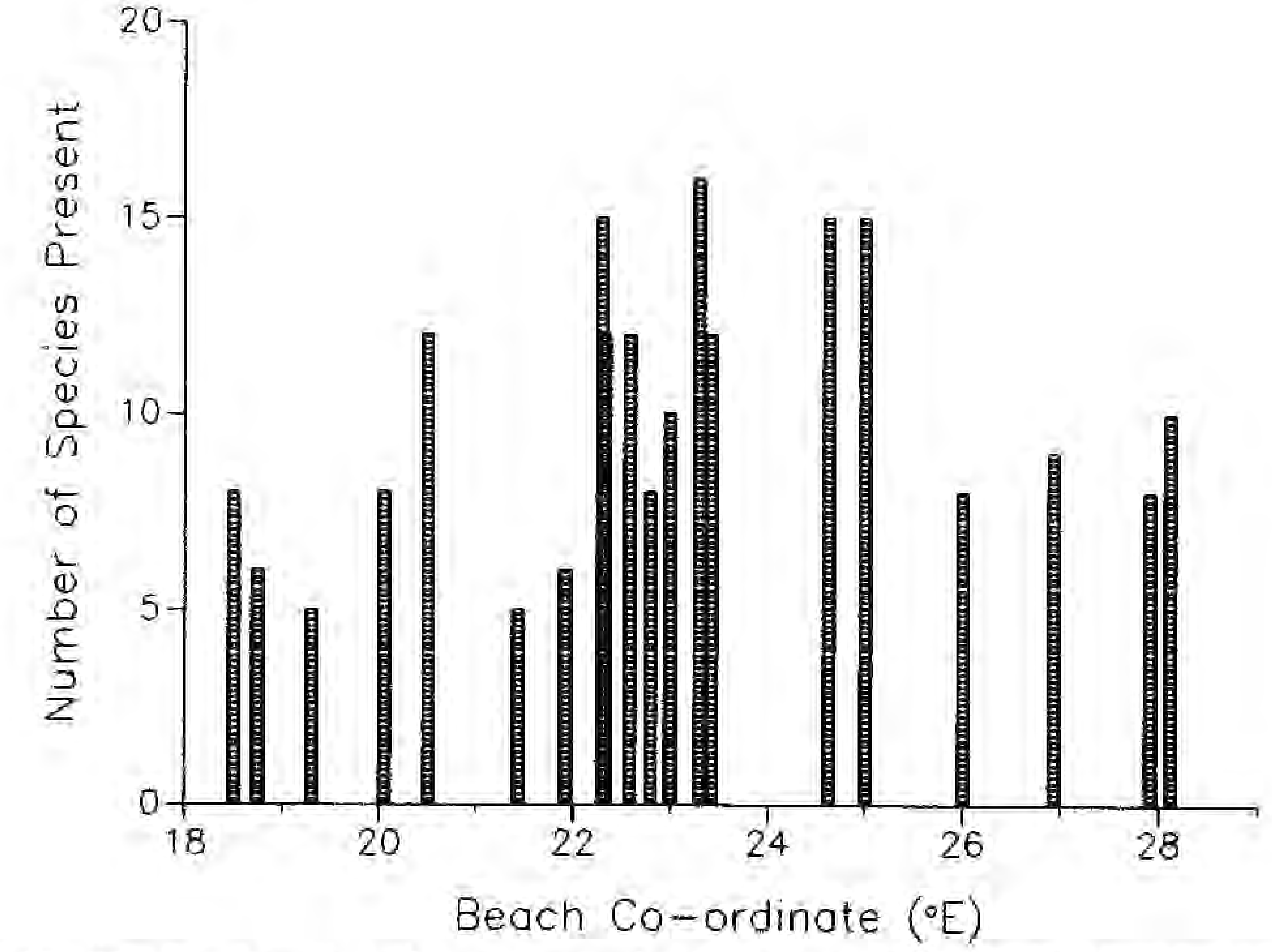

Figure 37. The mean number of species recorded in the surf foam samples along the south coast of South Africa.

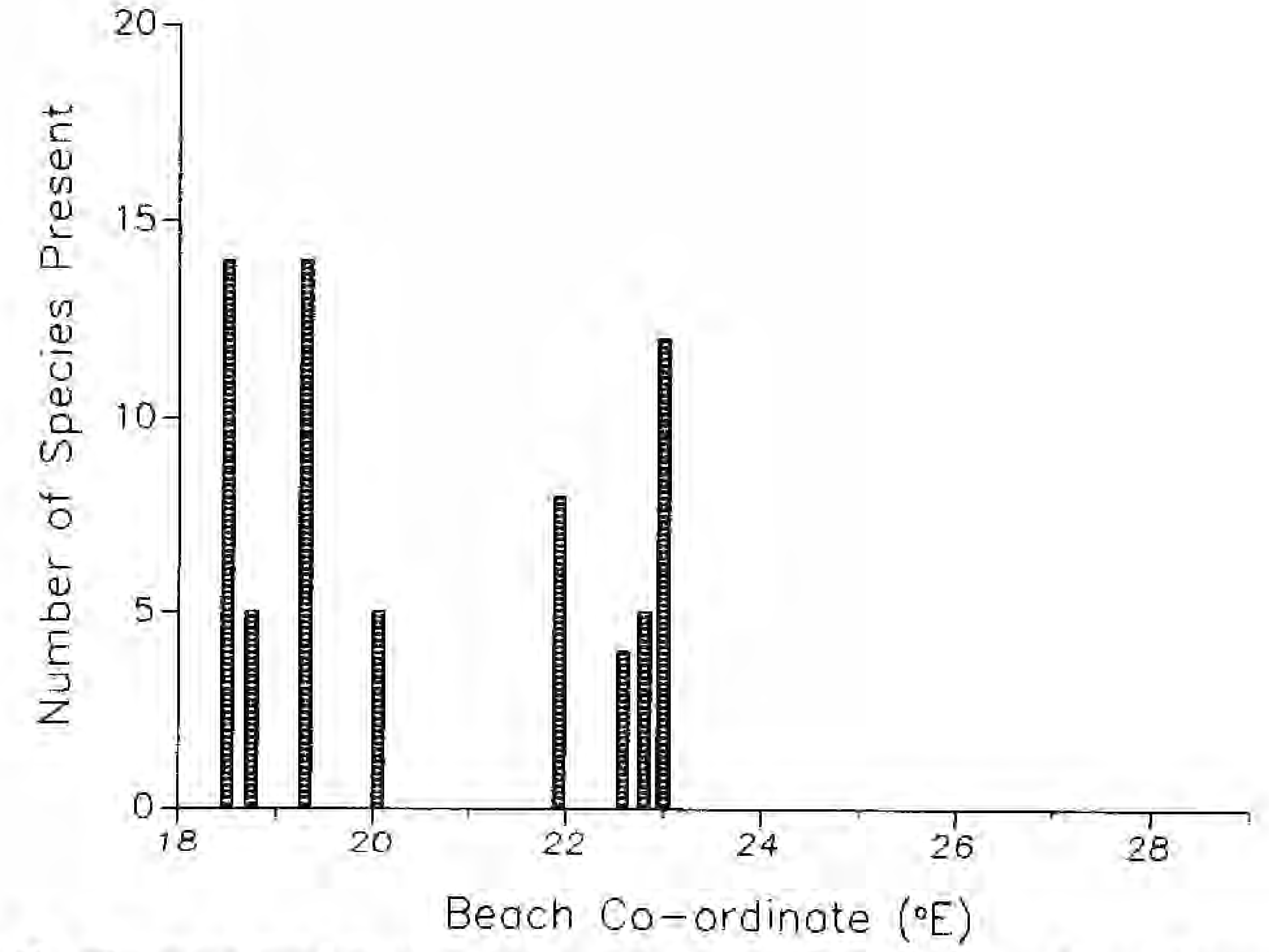

Figure 38. The mean number of species recorded in patch foam along the south coast of South Africa.

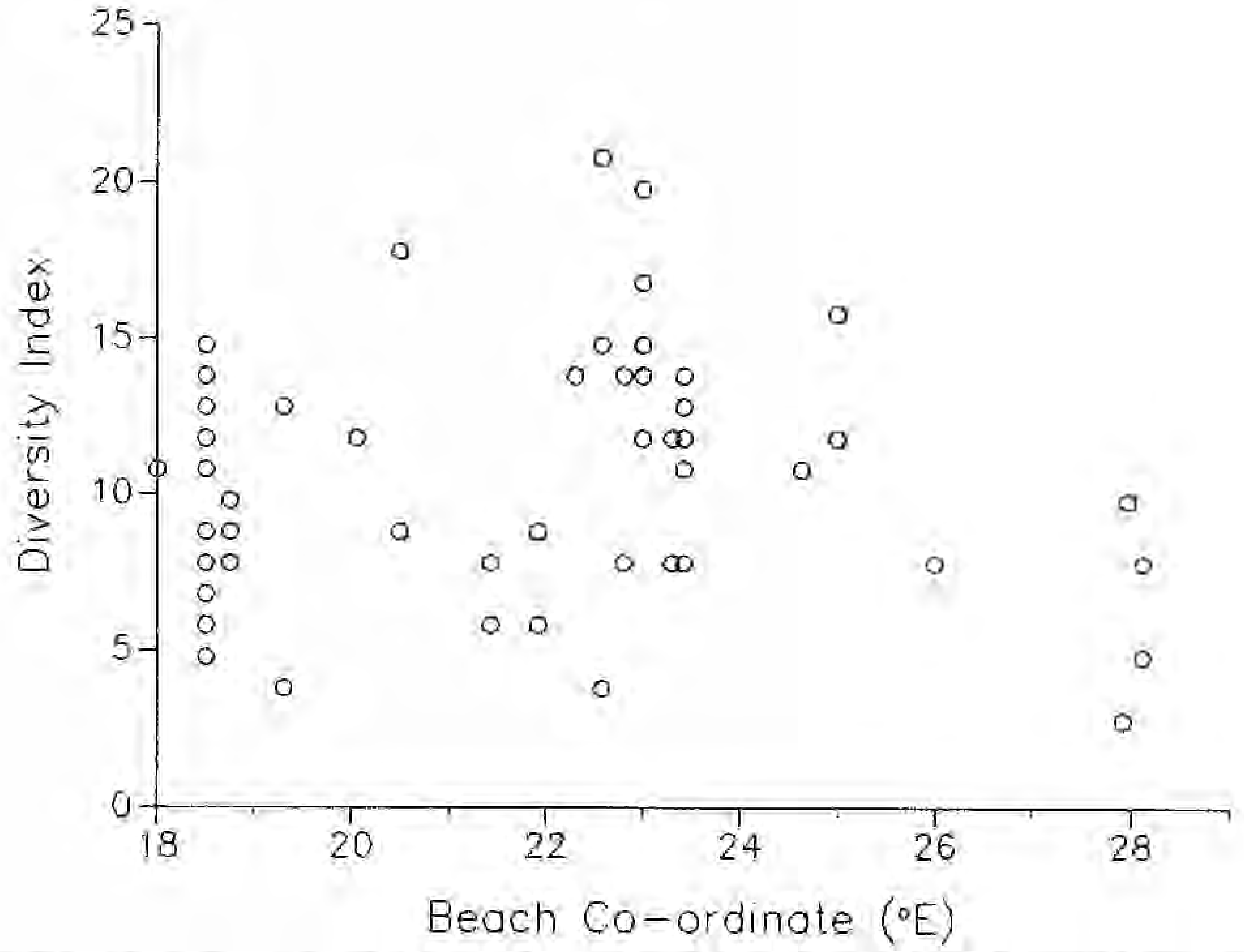

Figure 39. The diversity index of the populations in surf water samples collected along the south coast of South Africa.

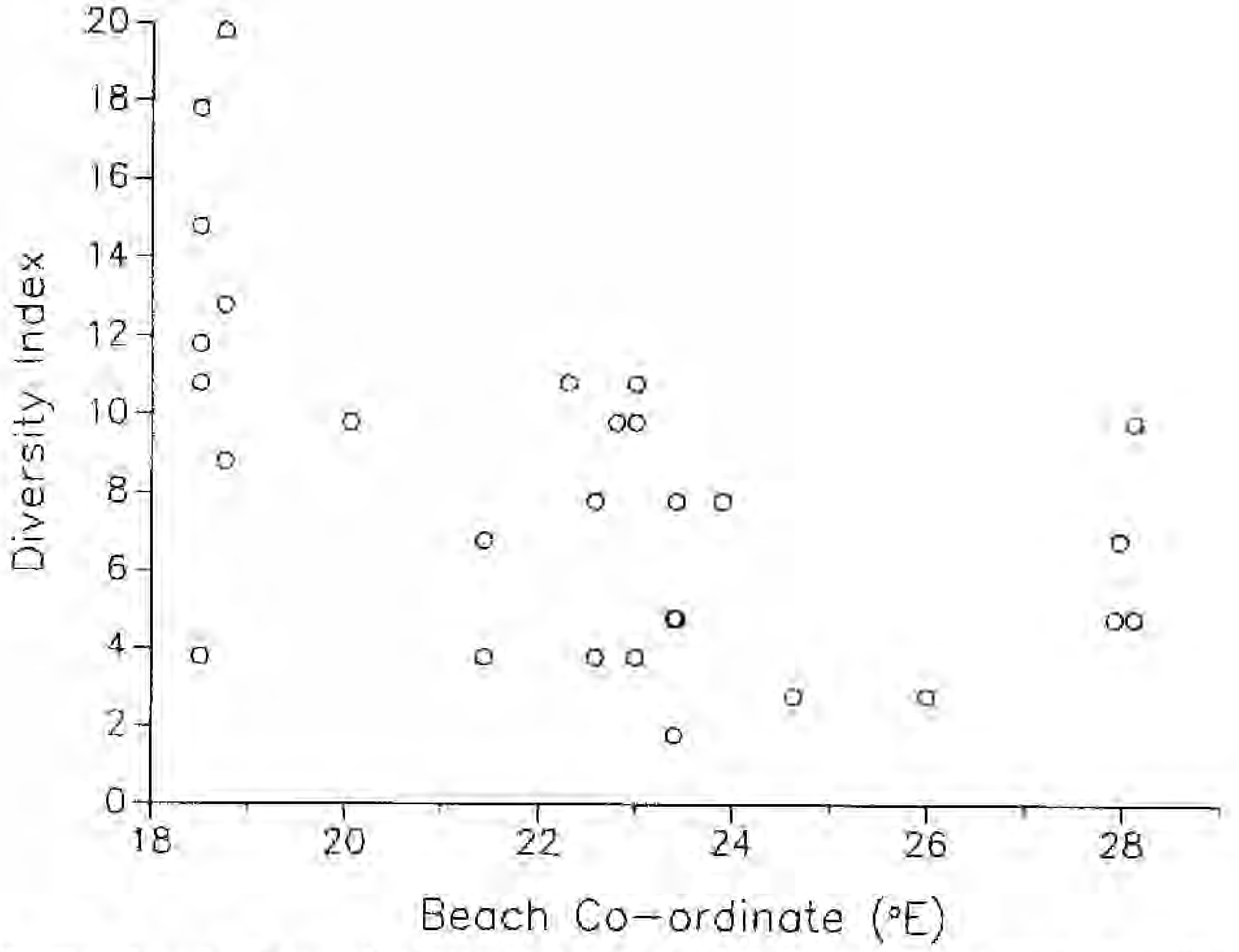

Figure 40. The diversity index of the populations in surf sand samples collected along the south coast of South Africa.

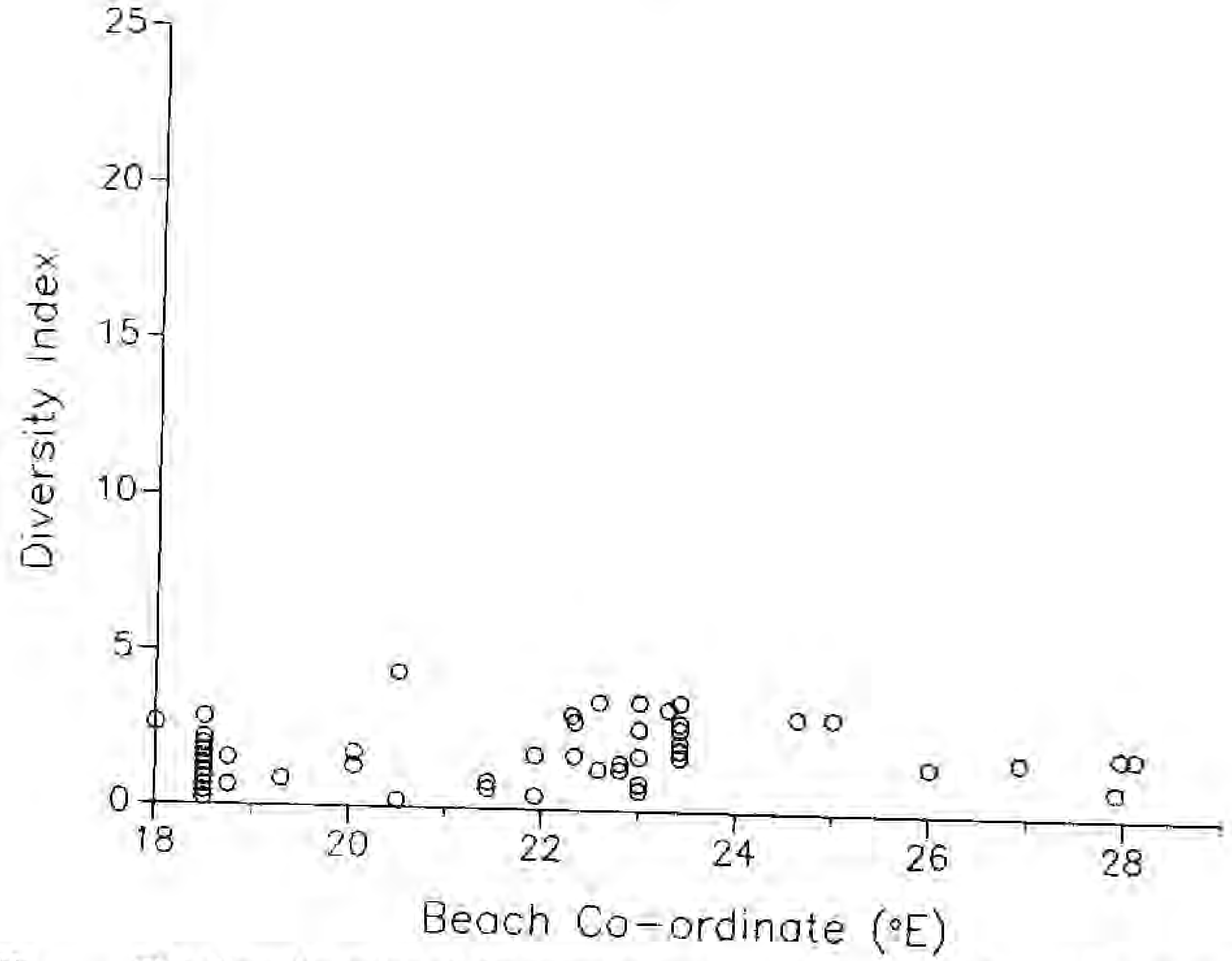

Figure 41. The diversity index of the populations in surf foam samples collected along the south coast of South Africa.

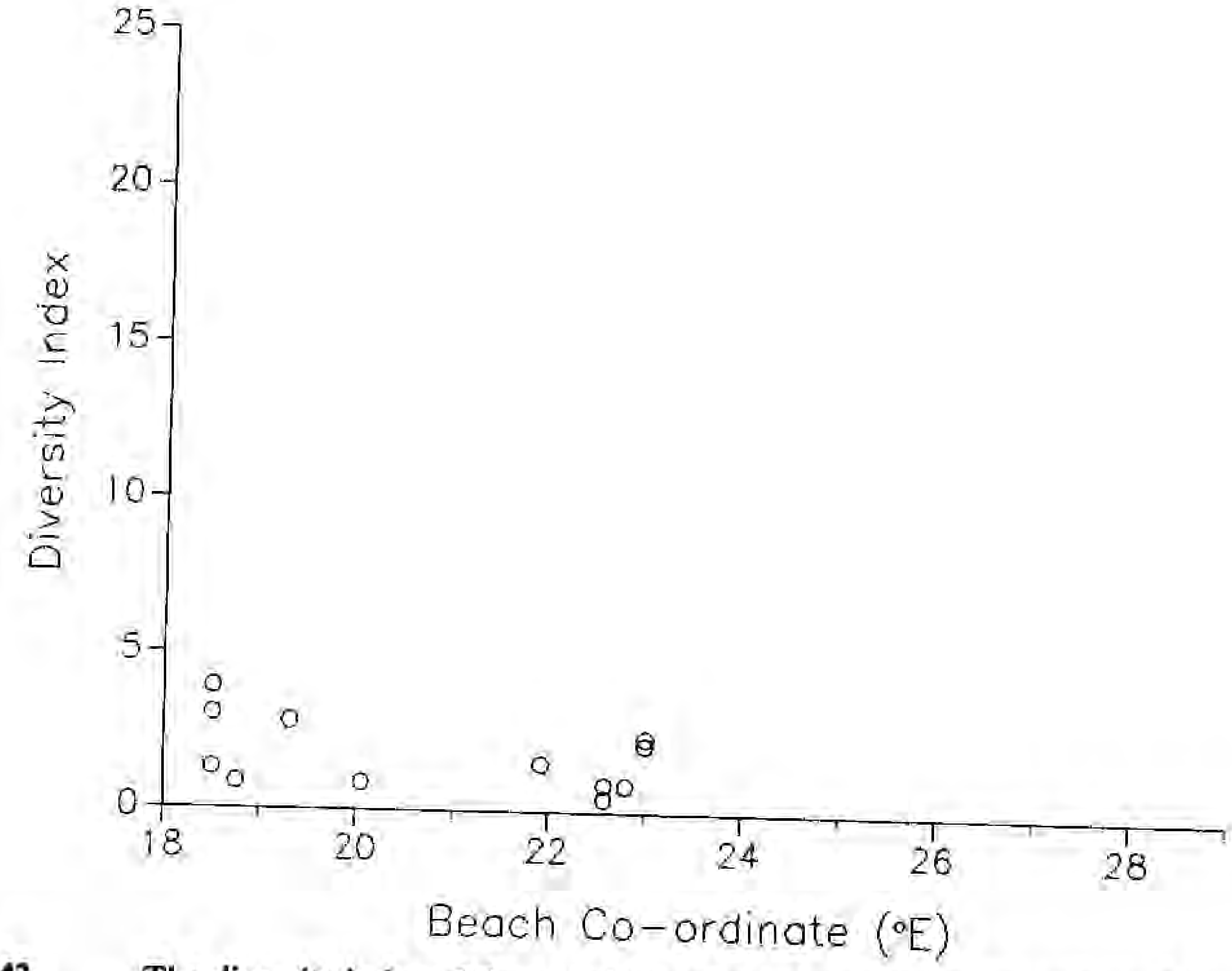

Figure 42. The diversity index of the populations in surf patch samples collected along the south coast of South Africa.

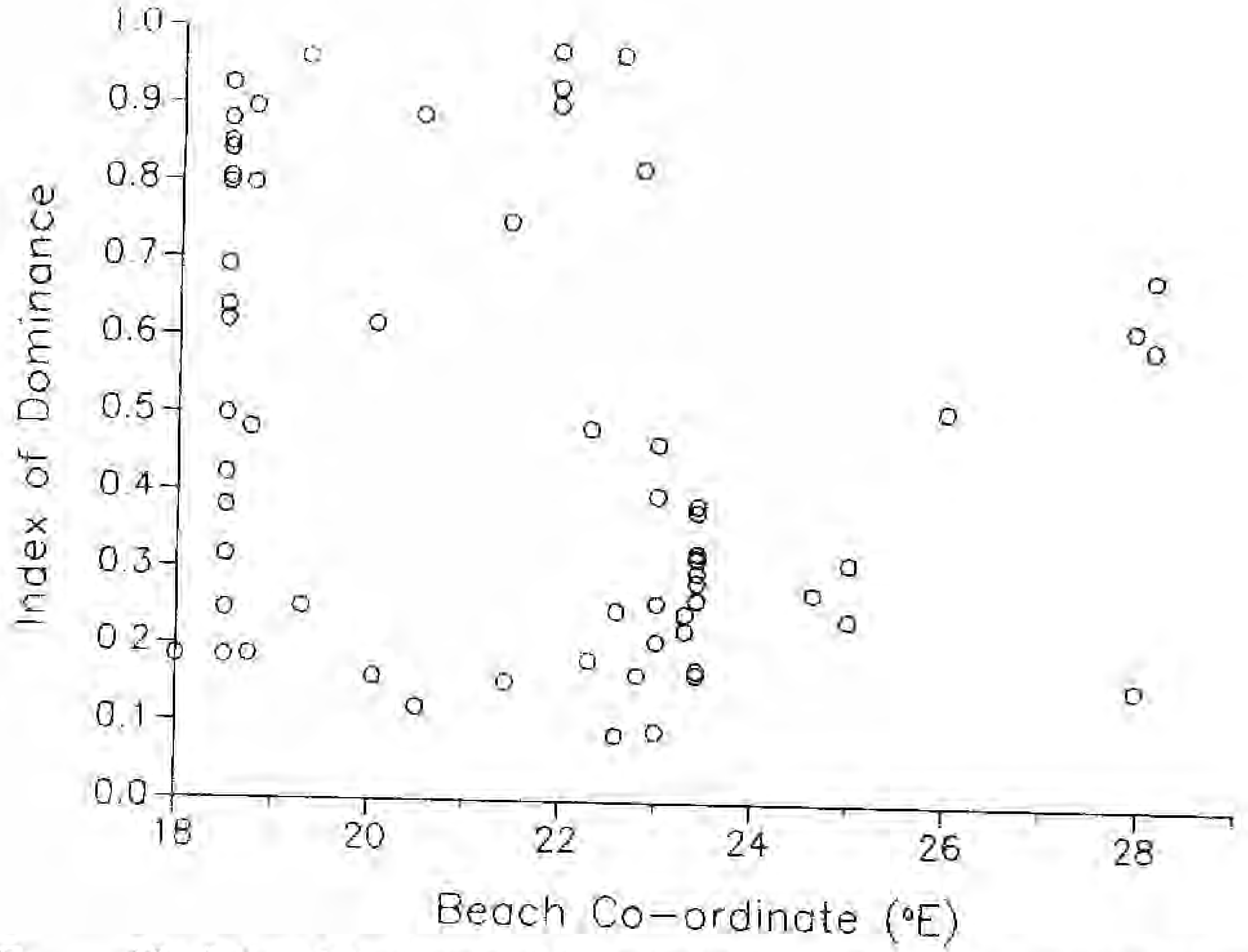

Figure 43. The index of dominance of the populations in the surf water along the south coast of South Africa.

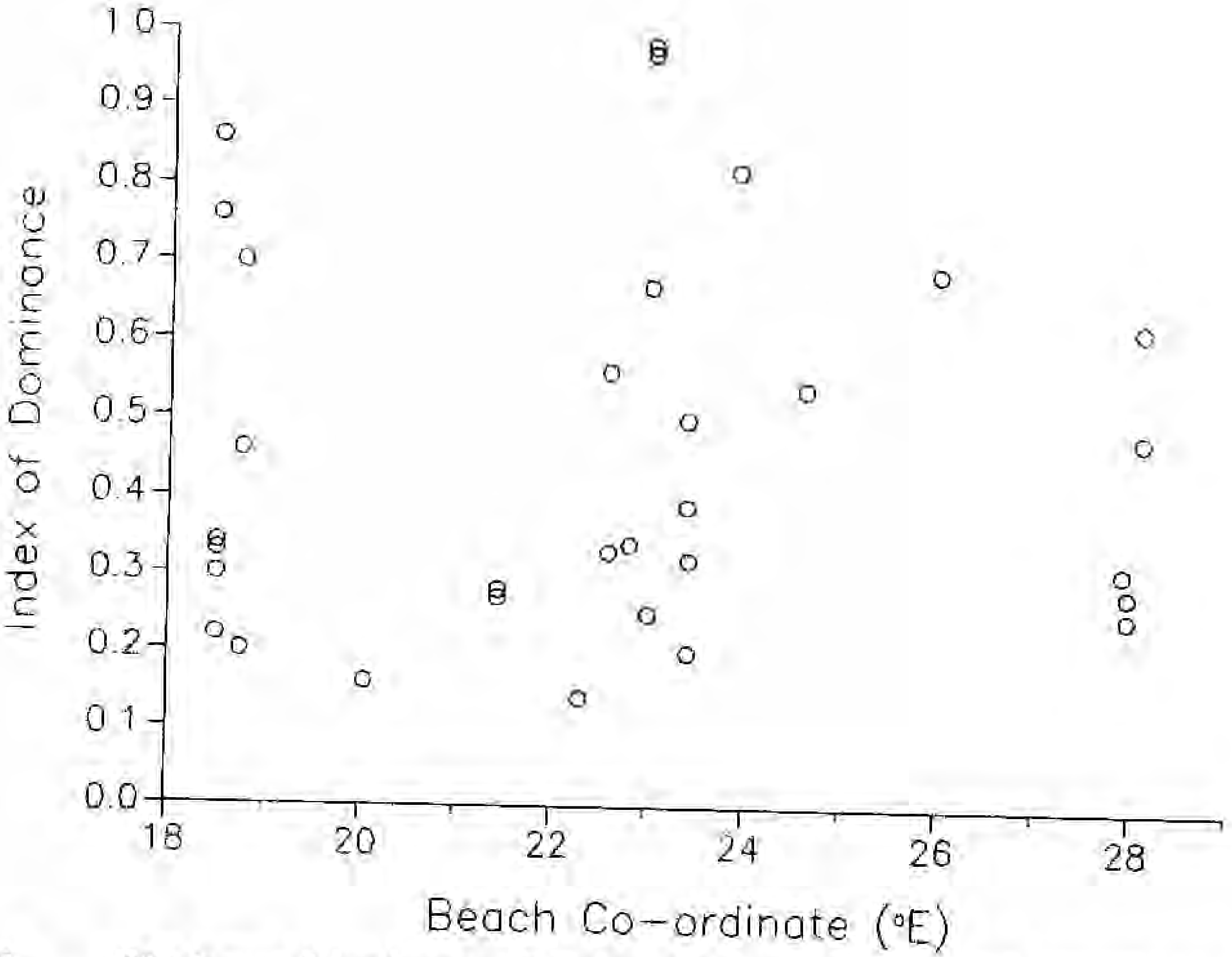

Figure 44. The index of dominance of the populations in the surf sand along the south coast of South Africa.

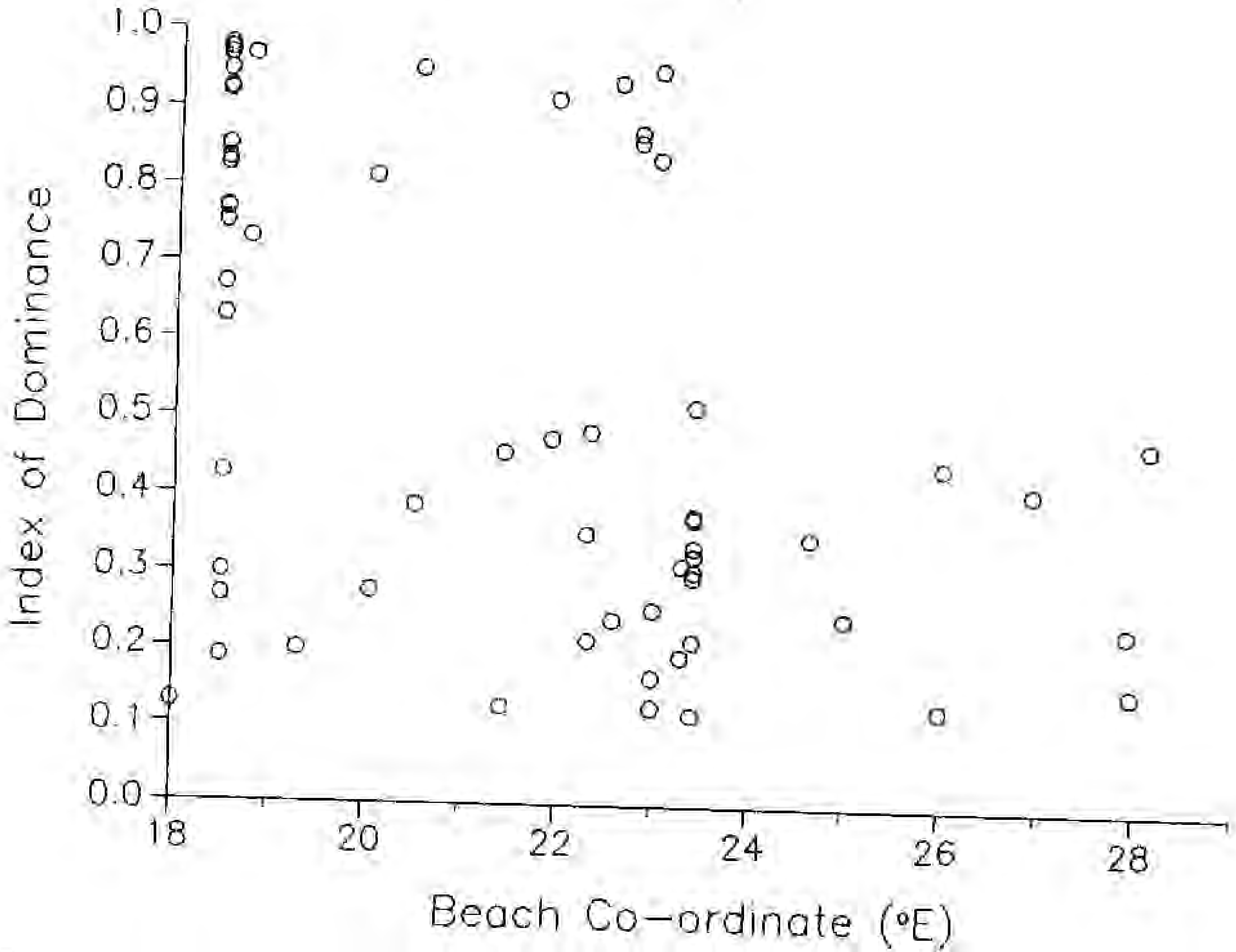

Figure 45. The index of dominance of the populations in the surf foam along the south coast of South Africa.

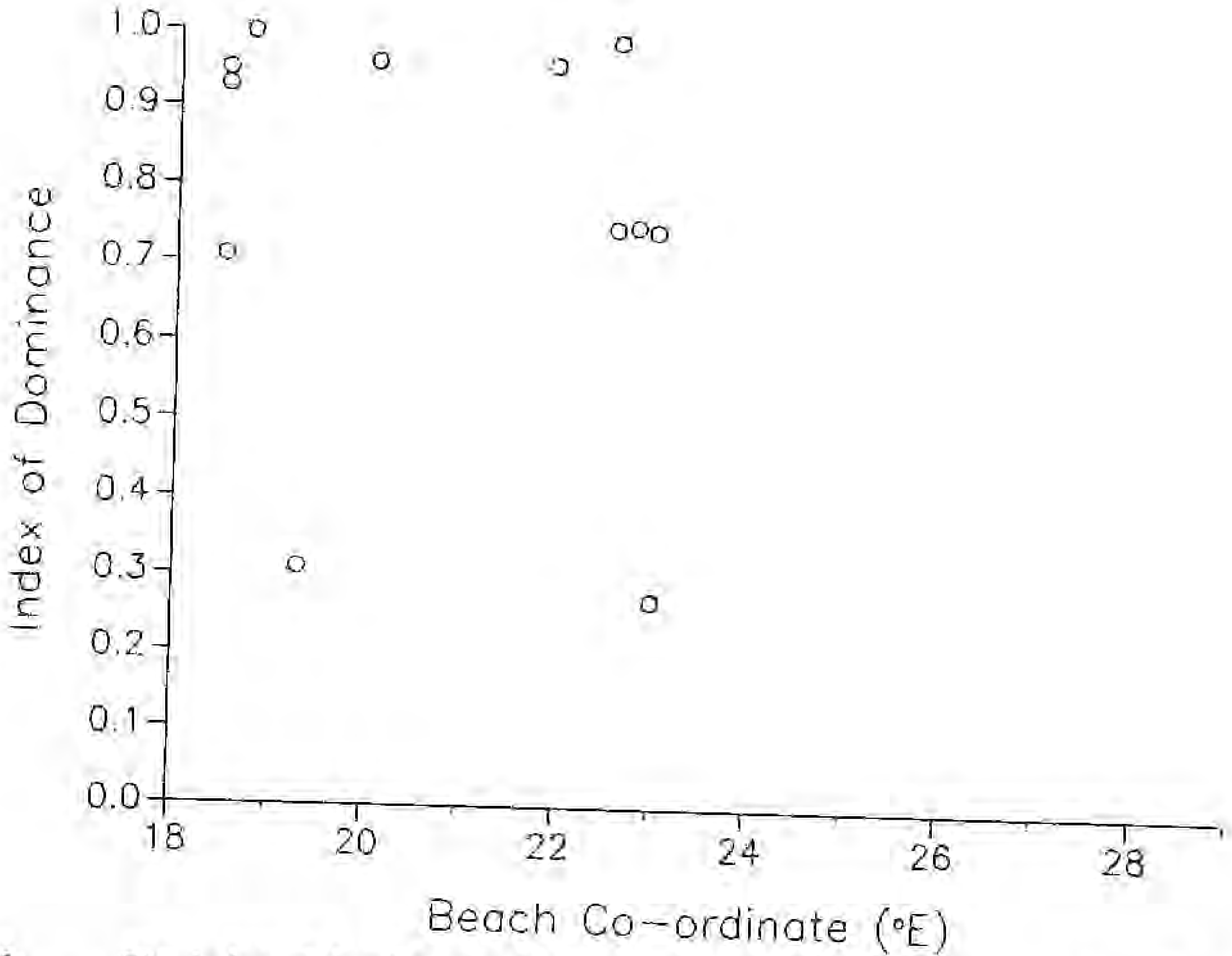

Figure 46. The index of dominance of the populations in the surf patches along the south coast of South Africa.

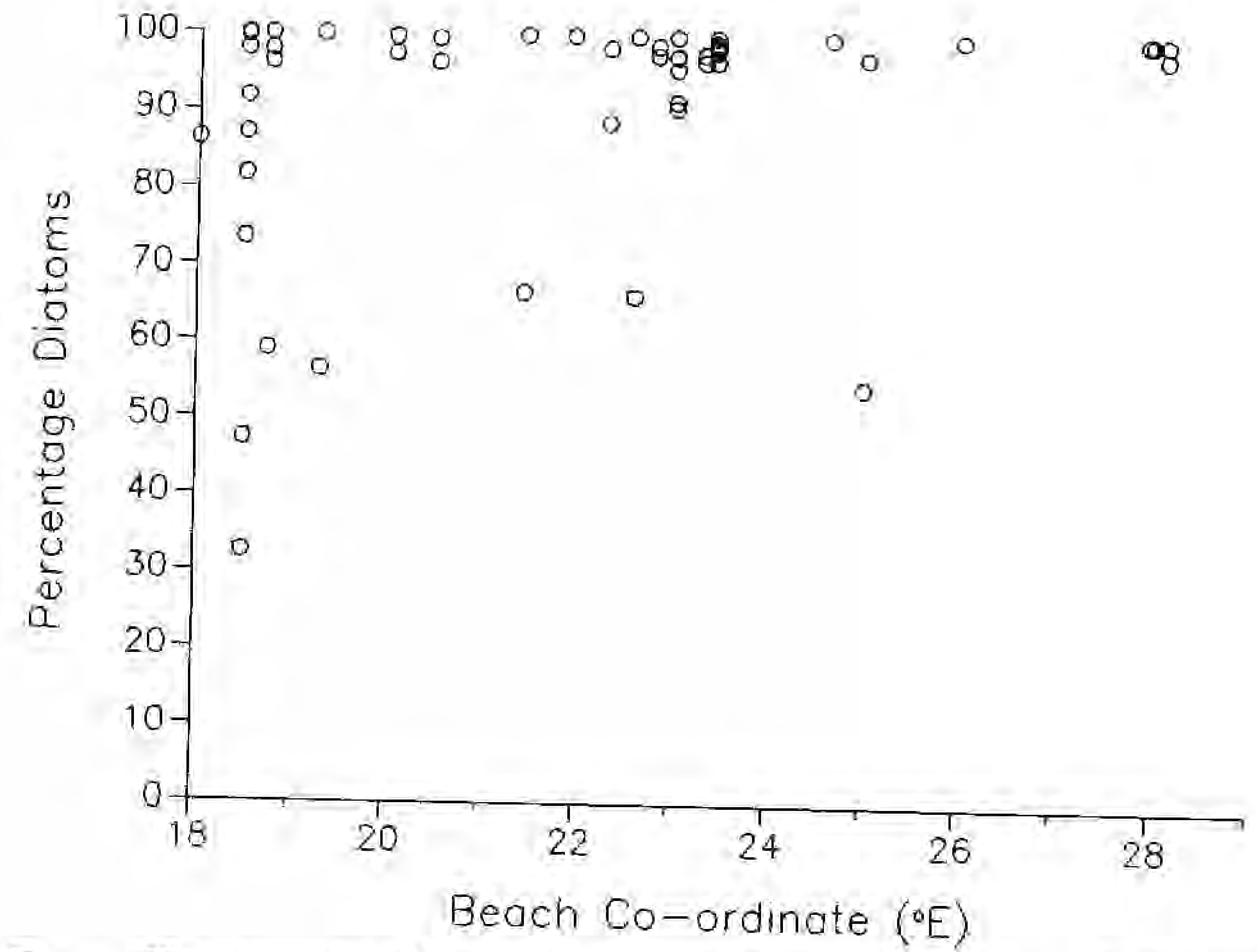

Figure 47. The percentage of diatoms in the populations in the surf water along the south coast of South Africa.

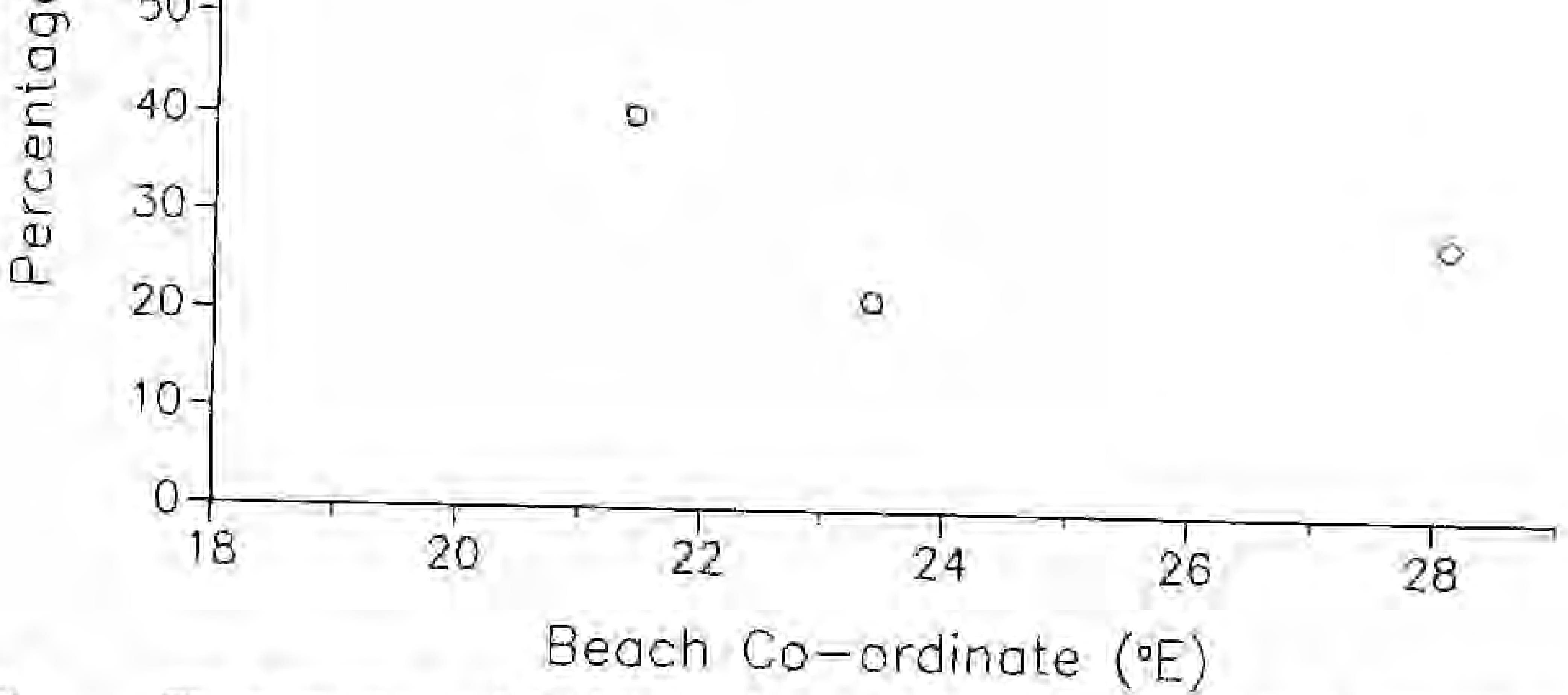

Figure 48. The percentage of diatoms in the populations in the surf sand along the south coast of South Africa.

In the foam only three sites outside False Bay had less than 90% diatoms (Fig. 49); they are Keurboomstrand, Glentana and Cintsa Bay. Patch foam contained only diatoms except in one (Fig. 50) of the samples taken at Buffalo Bay, which contained mostly flagellates.

Dinoflagellates were always below 5% in the water except in the Knysna-Wilderness area (Fig. 51), but were a substantial proportion of the sand populations in many samples (Fig. 52). In the foam, dinoflagellates comprised than 10% only at Glentana and Cintsa Bay (Fig. 53). They were absent from patches except in two samples collected at Buffalo Bay (Fig. 54).

Whan present flagellates always occurred in large numbers (Fig. 55 to 58), attaining up to 88% of the population. Green microalgae were common in False Bay (Fig. 59-62) but were negligible in all other samples. Bluegreen algae only occurred in False Bay water (Fig. 61-63) but were common in the sand (Fig. 64).

The CANOCO analysis of the south coast species showed a primary separation between the freshwater species recorded in surf-zones near river mouths (Fig. 65). The marine species were divided on an axis which can be taken to be from sand to water (axis A, Fig. 65). In this grouping the two surf diatoms *Anaulus australis* and *Asterionella glacialis* both fall in the "mostly water" group (Fig. 65). The group of species which were recorded only in the sand (filled in dots, Fig. 65) formed a distinct group including only four species which were also recorded in the water, viz. *Biddulphia* sp., *Gyrosigma* sp., *Cocconeis* epiphyte and an unknown club-shaped species (triangles, Fig. 65).

The division between species resident in water and sand is also evident in the TWINSPAN division of species. The first group that separated out contains species recorded only in the water (Fig. 66). The next division is between species recorded in both water and sand, and the species recorded in sand only together with those recorded near river mouths (Fig. 66). Included in the group of species recorded in both sand and water is a group of surf species including *Anaulus australis*, *Asterionella glacialis*, *Campylosira cymbelliformis*, *Flagellate* small, *Nitzschia closterium*, *Nitzschia longissima* and *Thalassiosira rotula*. The species resident in sand and freshwater separate out last, with the freshwater species separating out the furthest (Fig. 66).

Because the species resident in the sand strongly influenced the ordination of species, the CANOCO and TWINSPAN analyses were run excluding the sand samples. The CANOCO analysis separated rare species, freshwater species and ubiquitous species from the coastal species. There was a large group of species which could be considered to be surf species. They were *Achnanthes* sp., *Anaulus australis*, *Asterionella glacialis*, *Asteromphalus* sp., *Aulacodiscus petersii*, *Biddulphia* sp., a circular blue-green sp.,

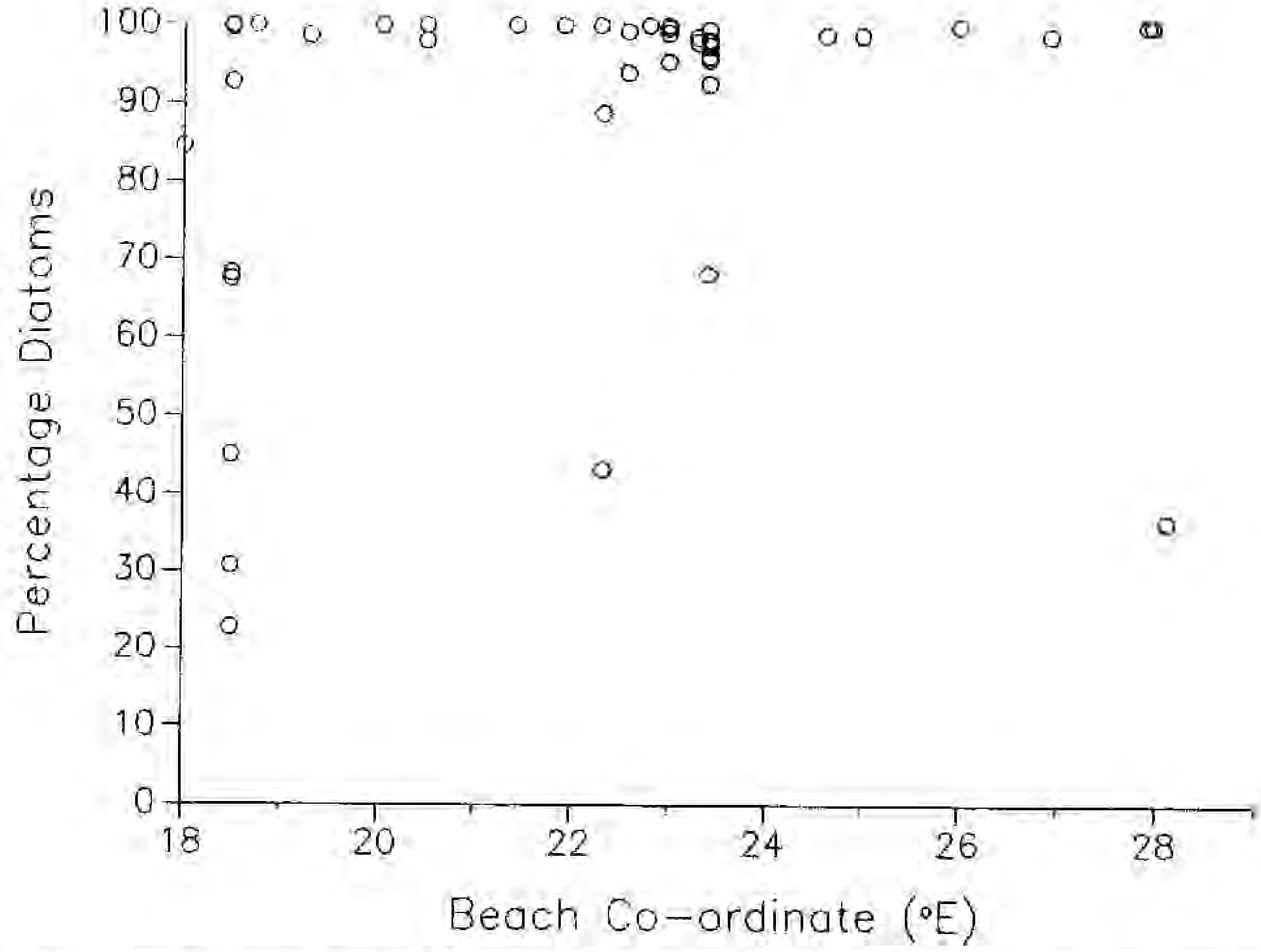

Figure 49. The percentage of diatoms in the populations in the surf foam along the south coast of South Africa.

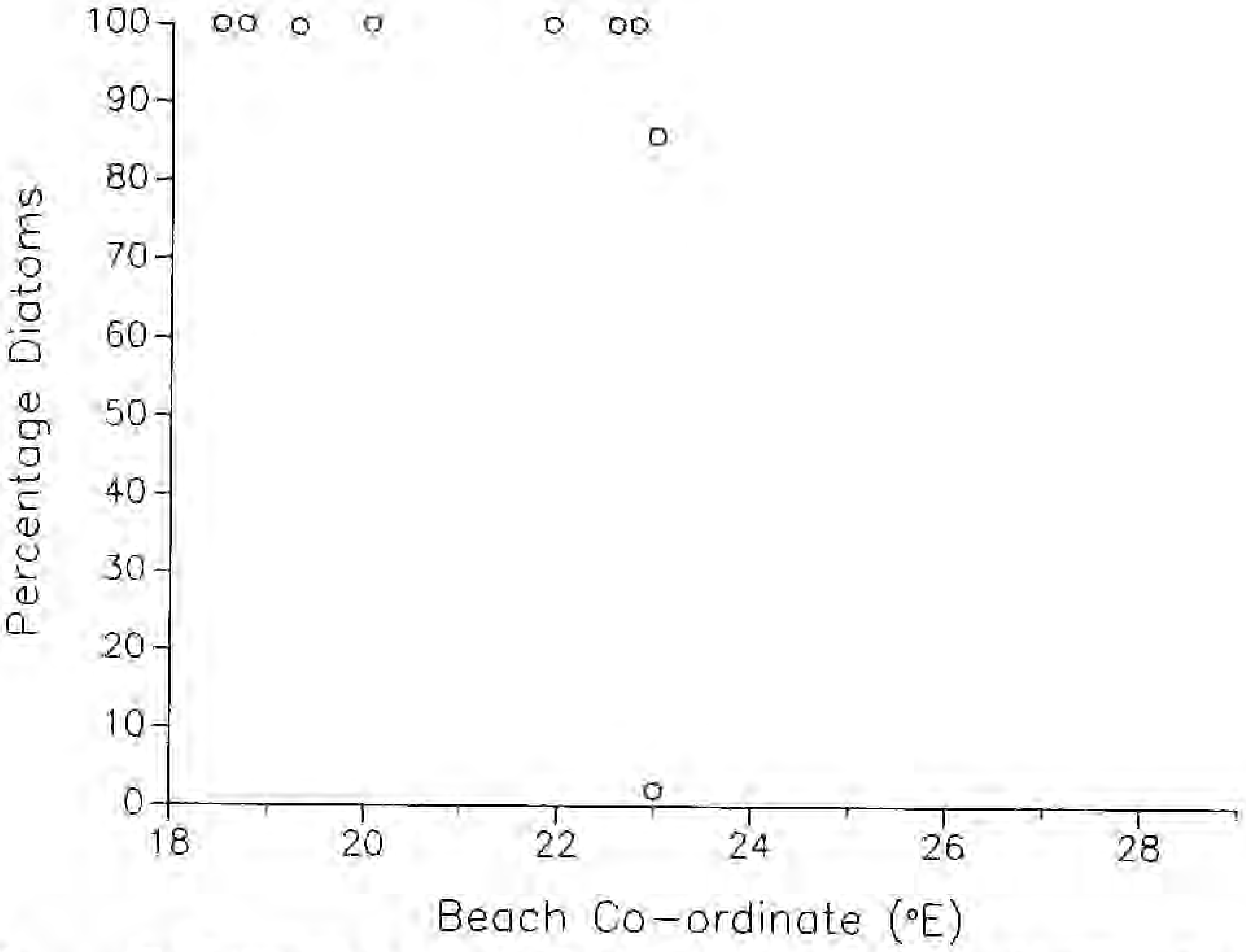

Figure 50. The percentage of diatoms in the populations of the surf patches along the south coast of South Africa.

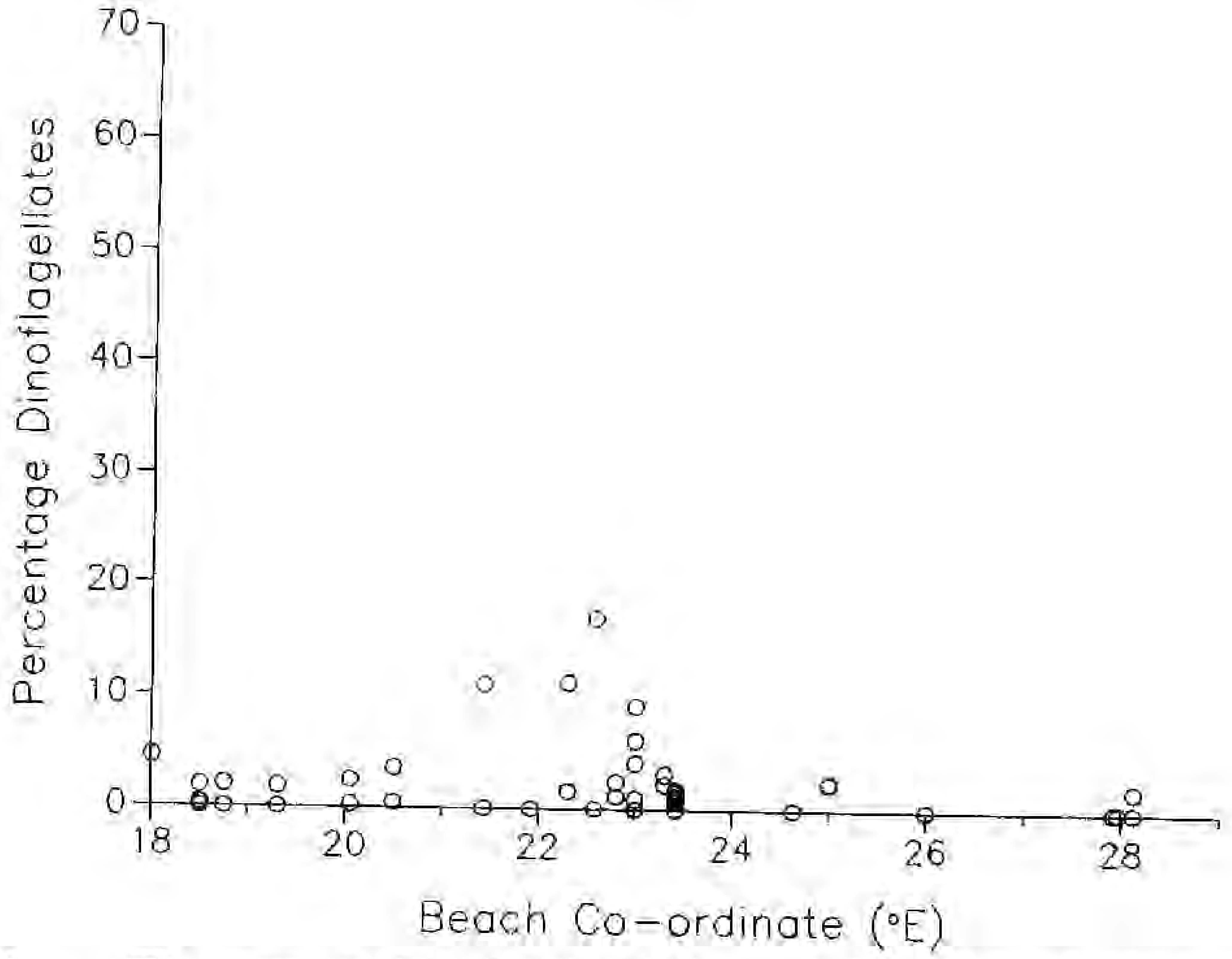

Figure 51. The percentage of dinoflagellates in the populations of the surf water along the south coast of South Africa.

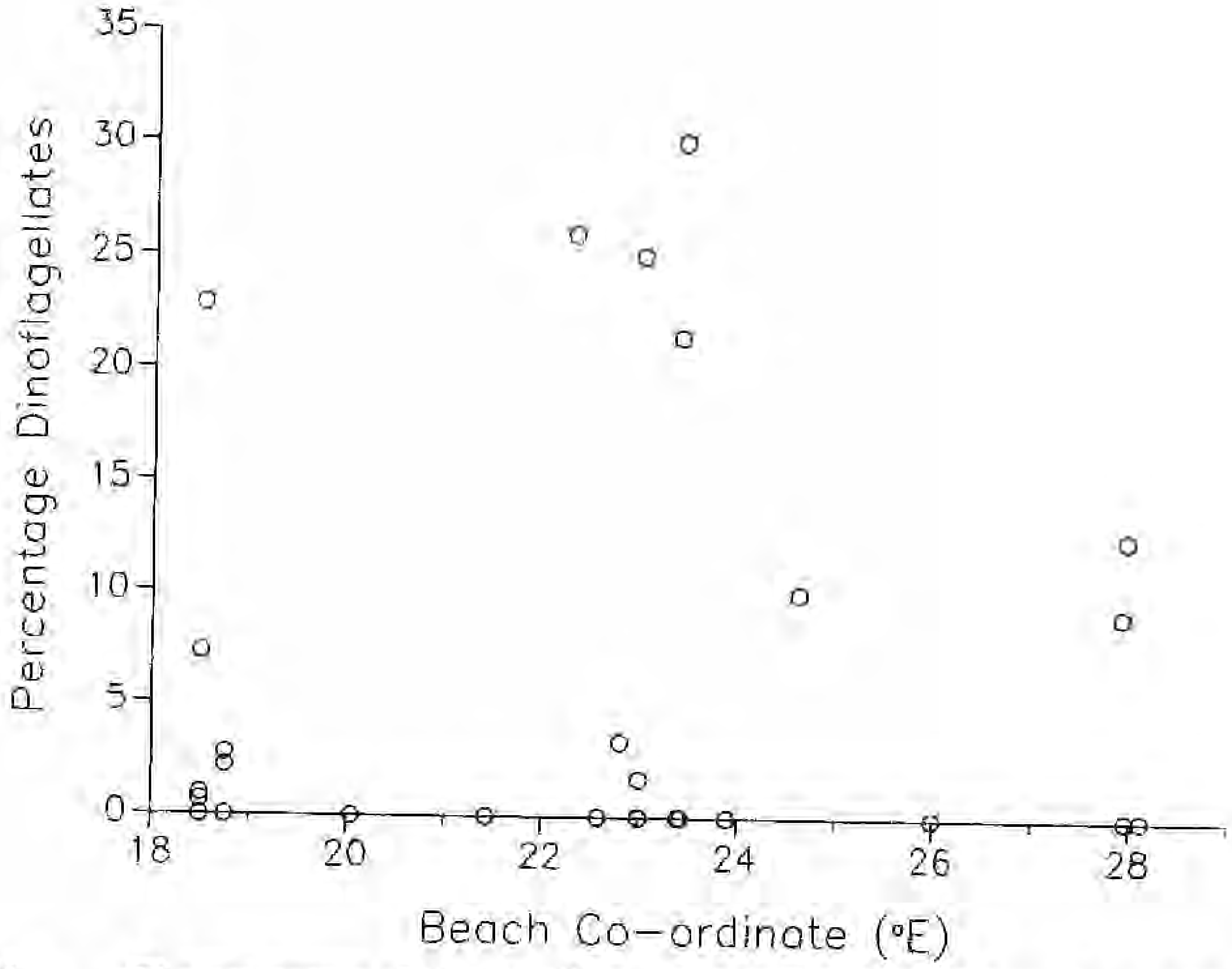

Figure 52. The percentage of dinoflagellates in the populations of the surf sand along the south coast of South Africa.

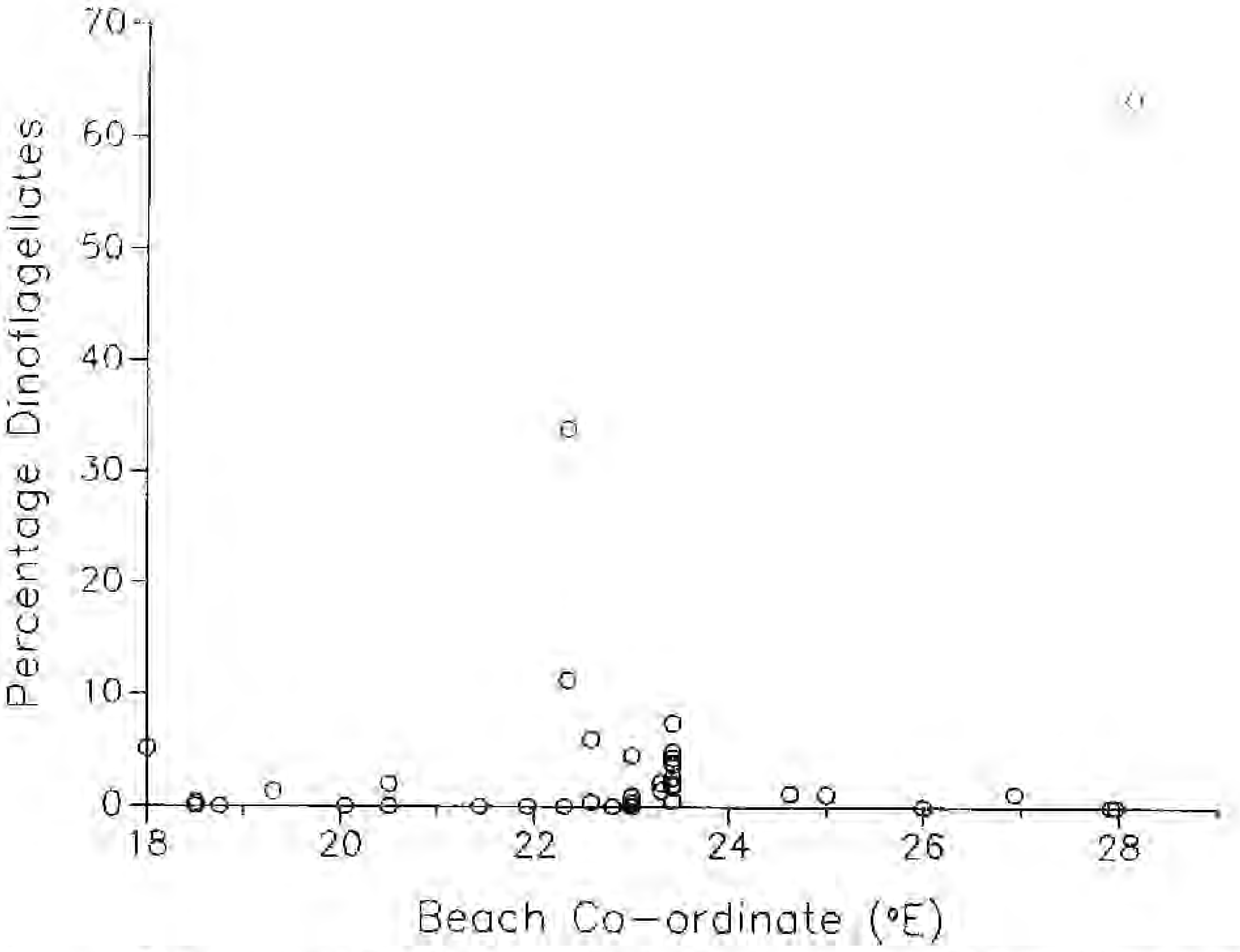

Figure 53. The percentage of dinoflagellates in the populations of the surf foam along the south coast of South Africa.

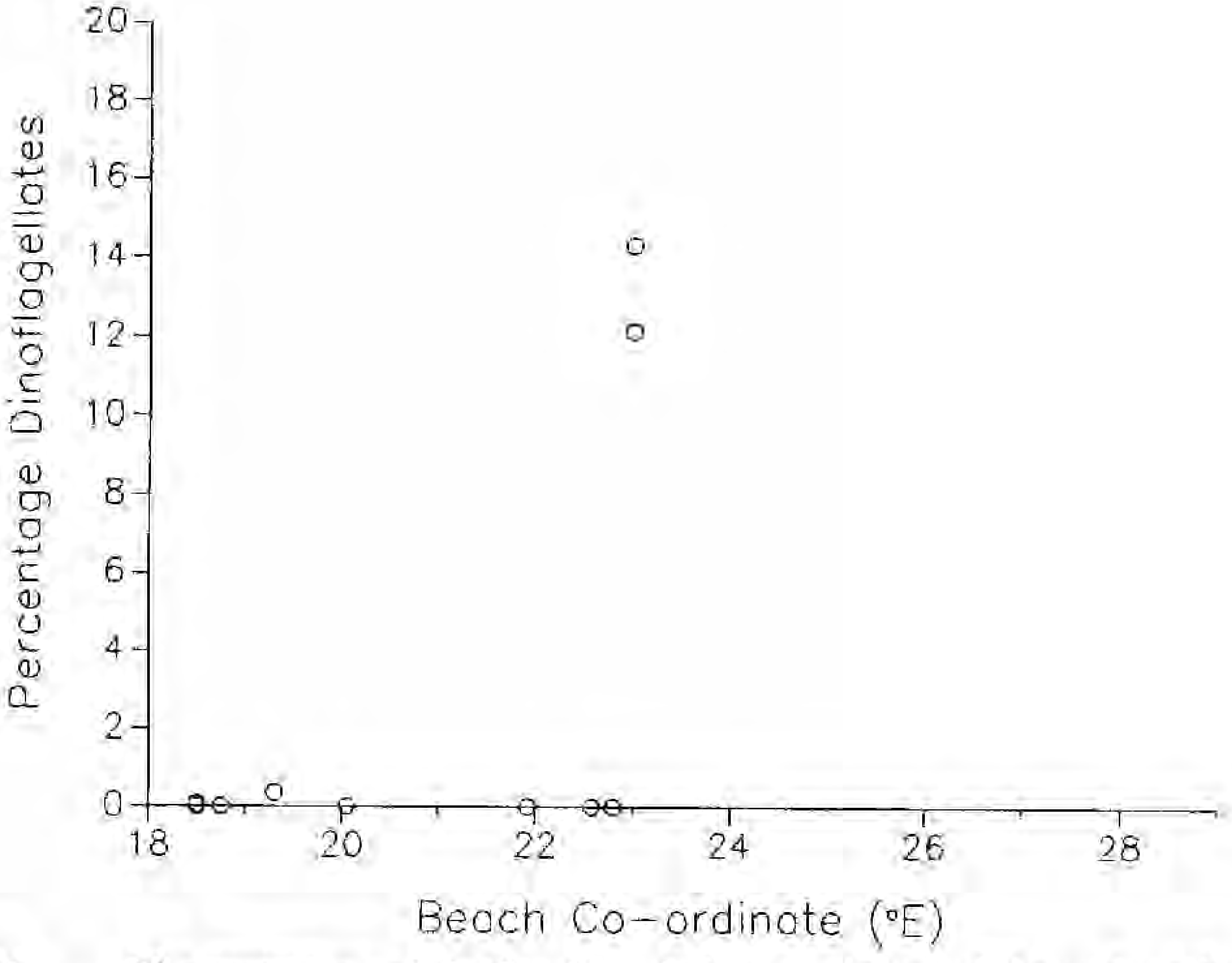

Figure 54. The percentage of dinoflagellates in the populations of the surf patches along the south coast of South Africa.

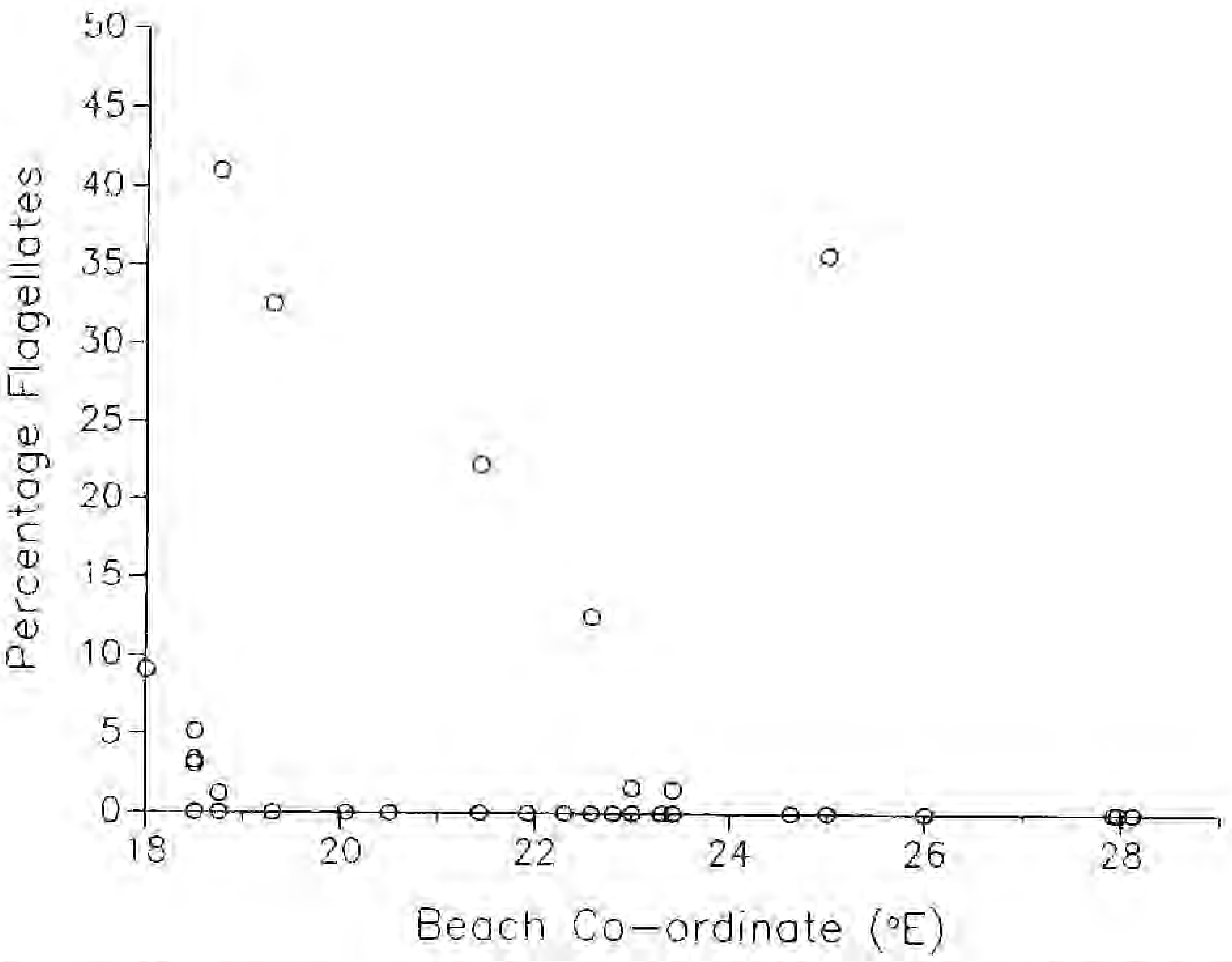

Figure 55. The percentage of flagellates in the populations of the surf water along the south coast of South Africa.

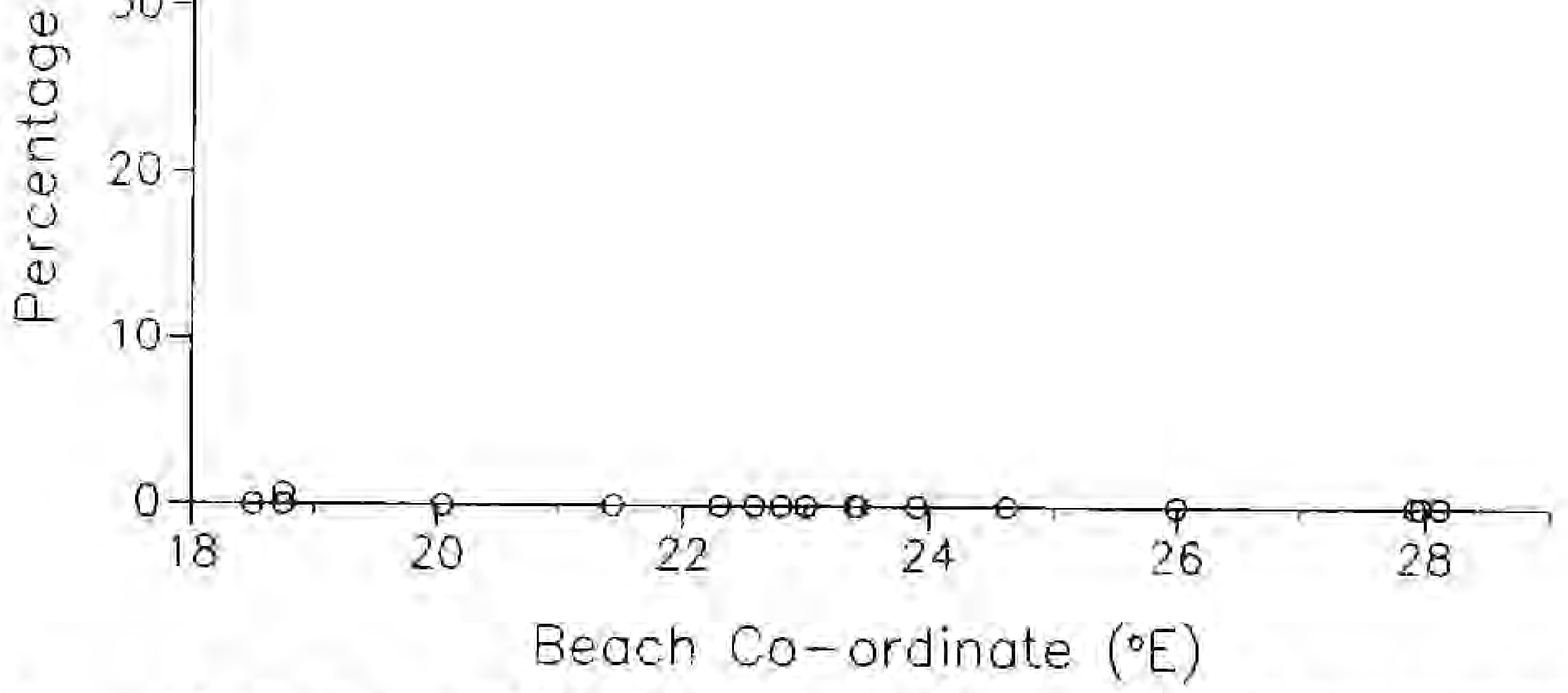

Figure 56. The percentage of flagellates in the populations of the surf sand along the south coast of South Africa.

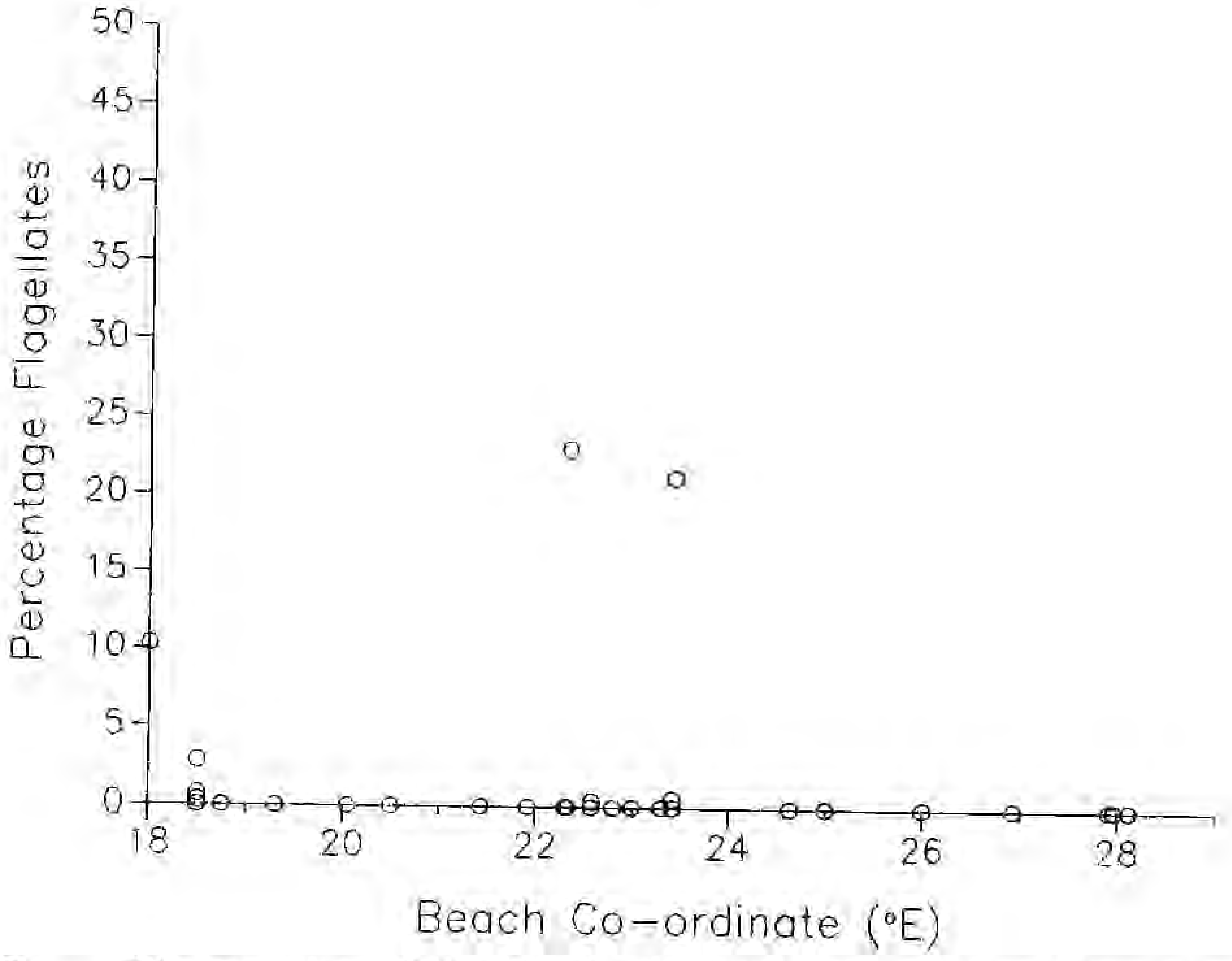

Figure 57. The percentage of flagellates in the populations of the surf foam along the south coast of South Africa.

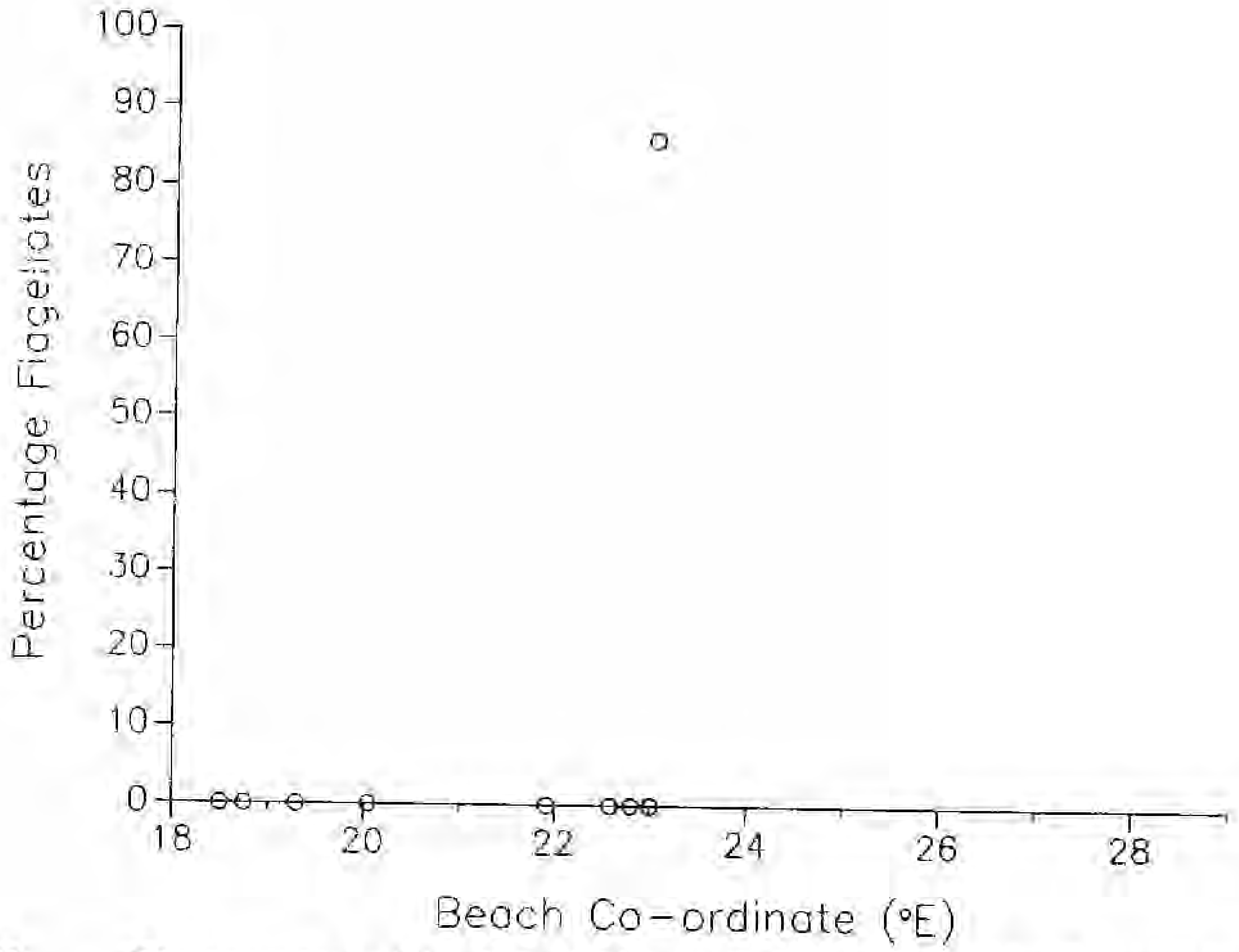

Figure 58. The percentage of flagellates in the populations in the surf patches of the south coast of South Africa.

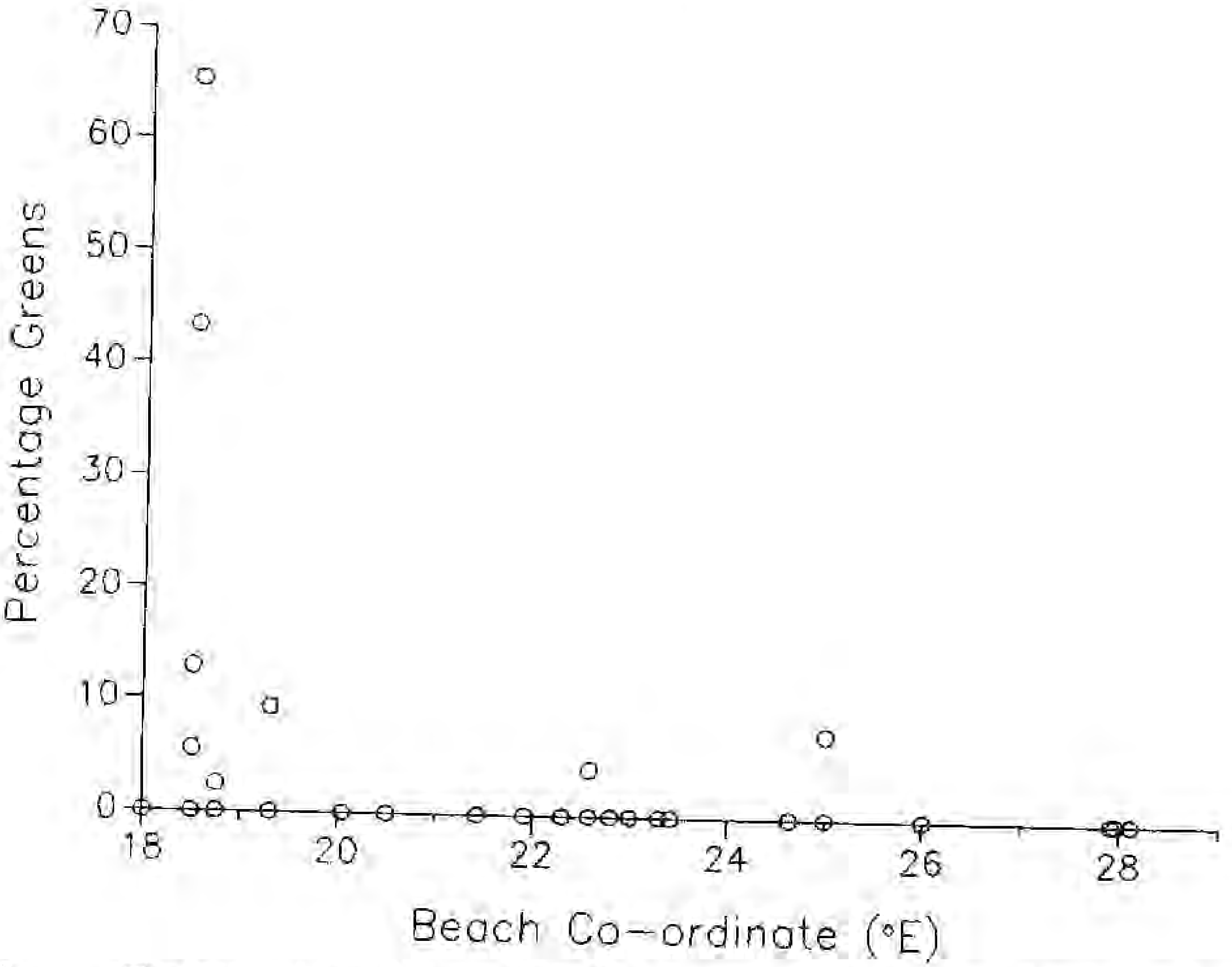

Figure 59. The percentage of green algae in the populations in the surf water of the south coast of South Africa.

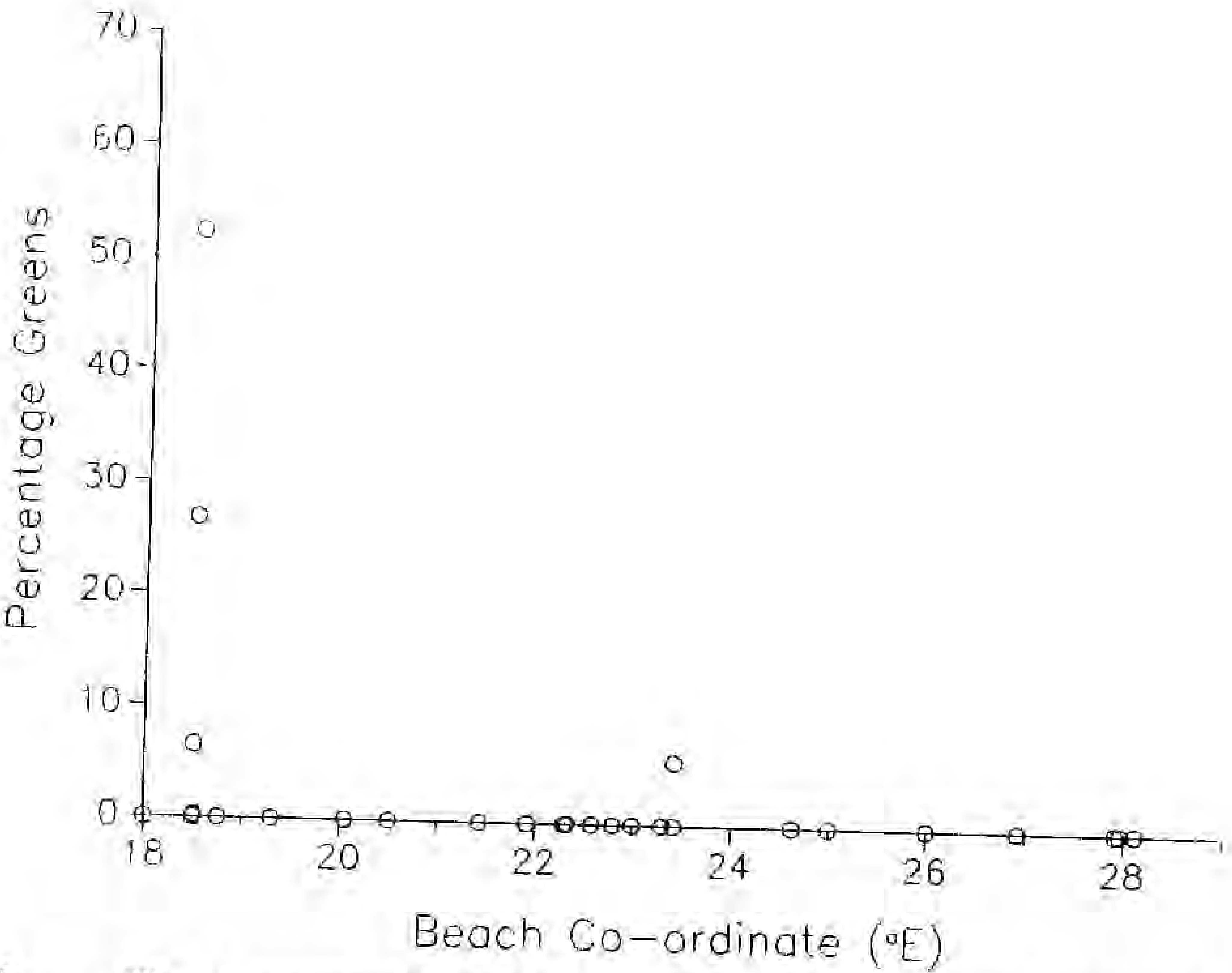

Figure 60. The percentage of green algae in the populations in the surf water of the south coast of South Africa.

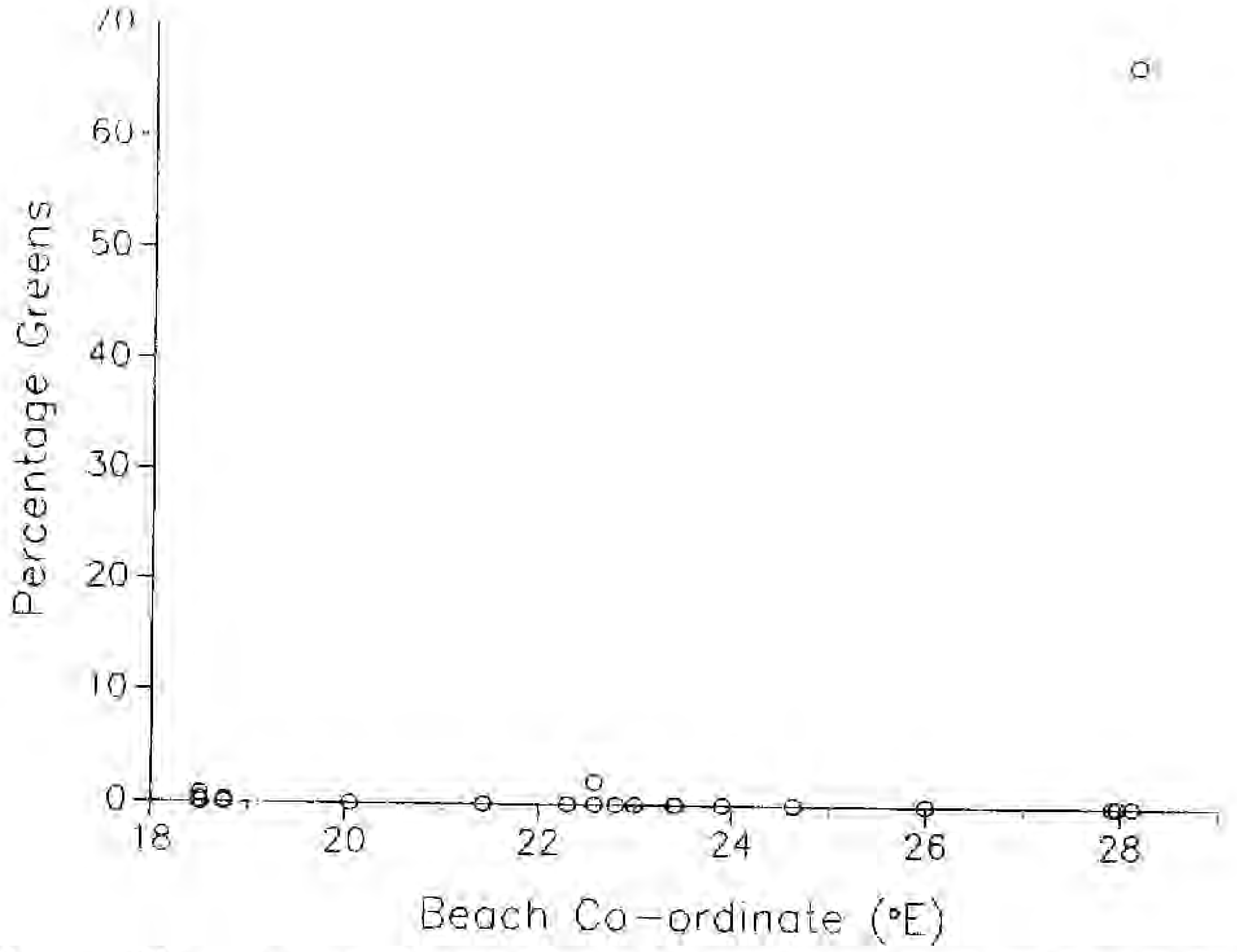

Figure 61. The percentage of green algae in the populations in the surf sand of the south coast of South Africa.

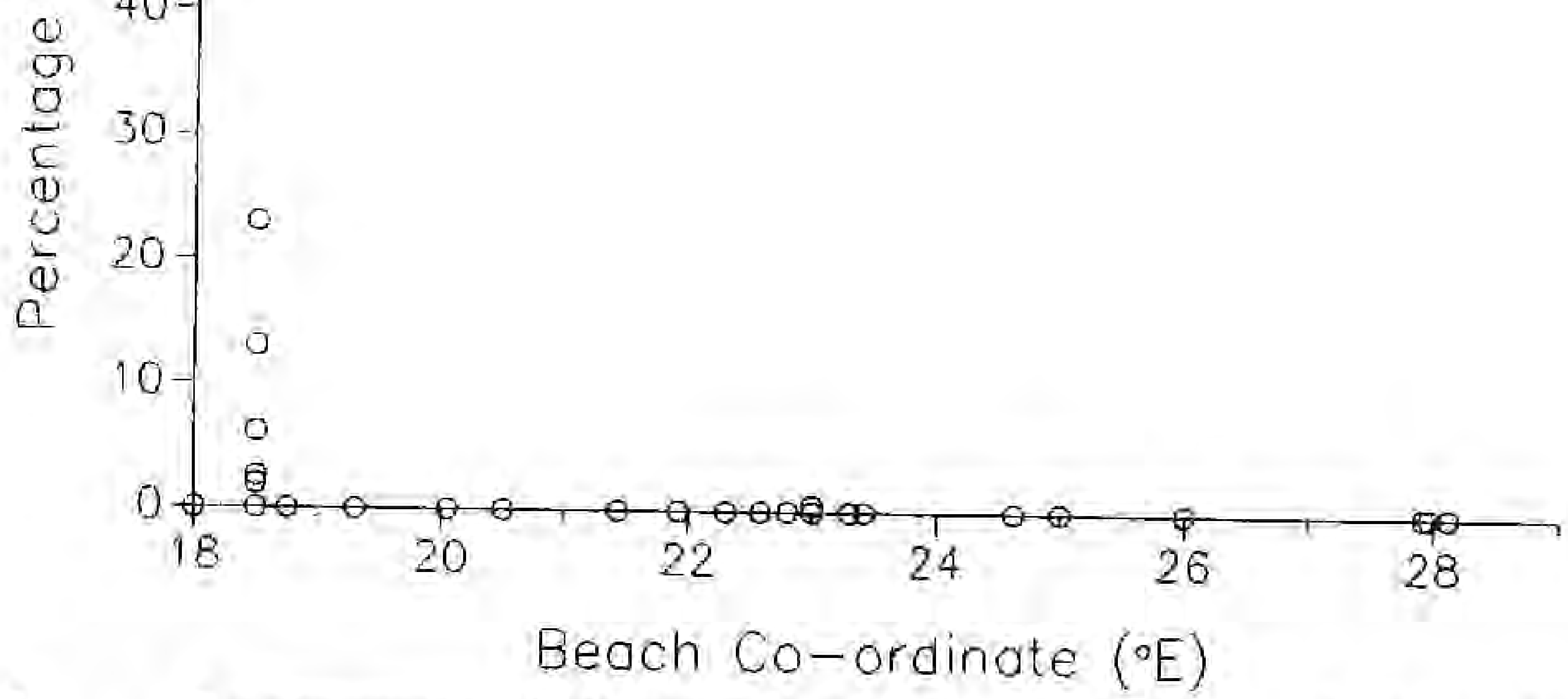

Figure 62. The percentage of bluegreen bacteria in the populations in the surf water of the south coast of South Africa.

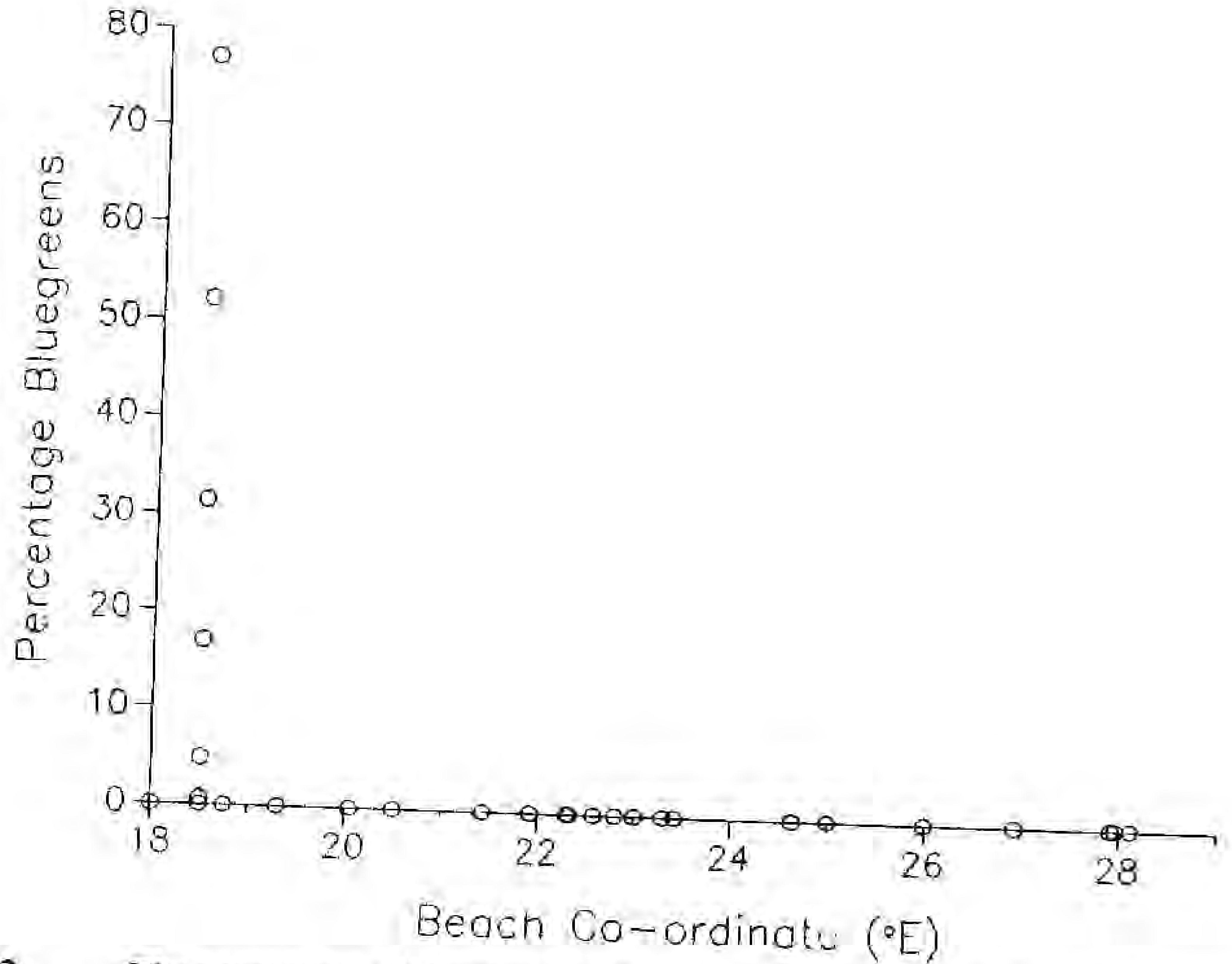

Figure 63. The percentage of bluegreen bacteria in the populations in the surf foam of the south coast of South Africa.

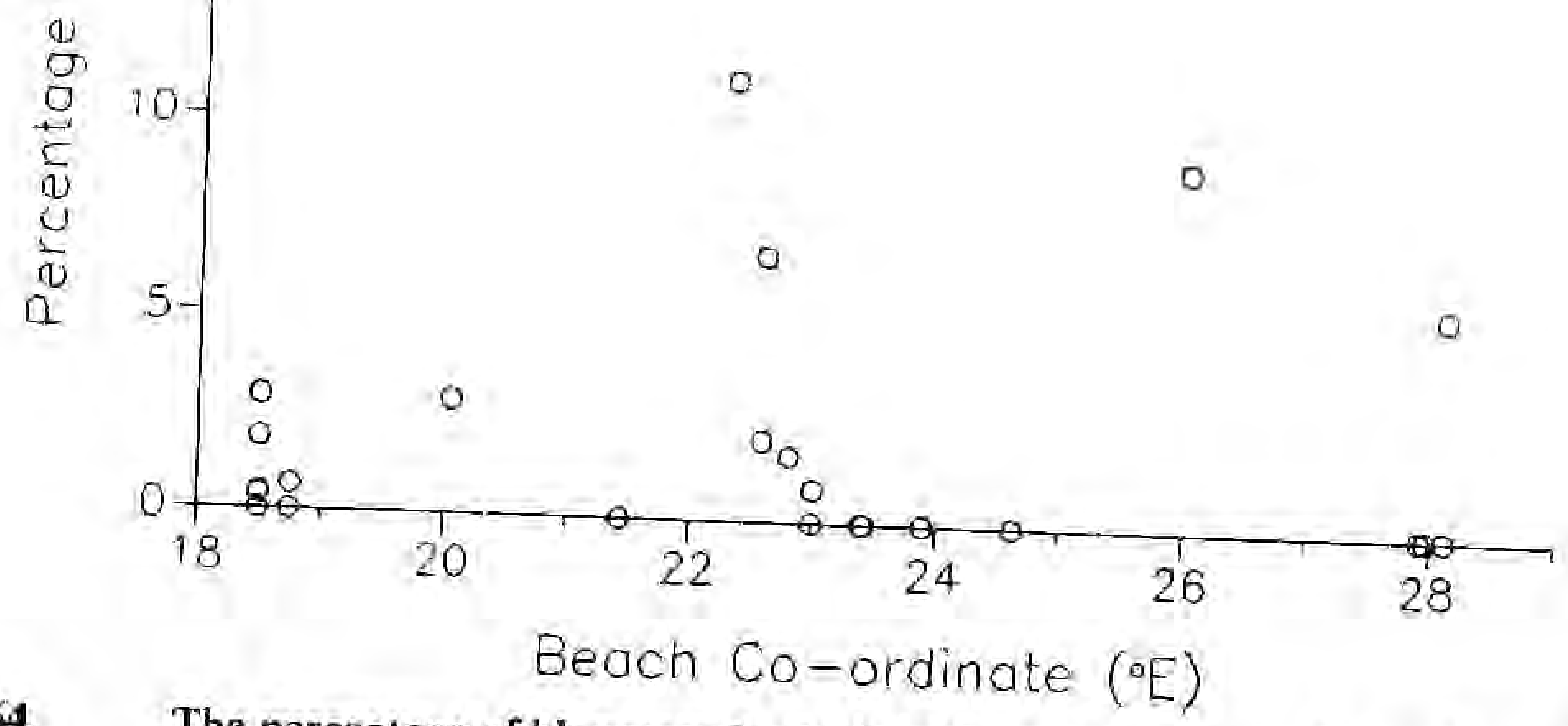

Figure 64. The percentage of bluegreen bacteria in the populations in the surf sand of the south coast of South Africa.

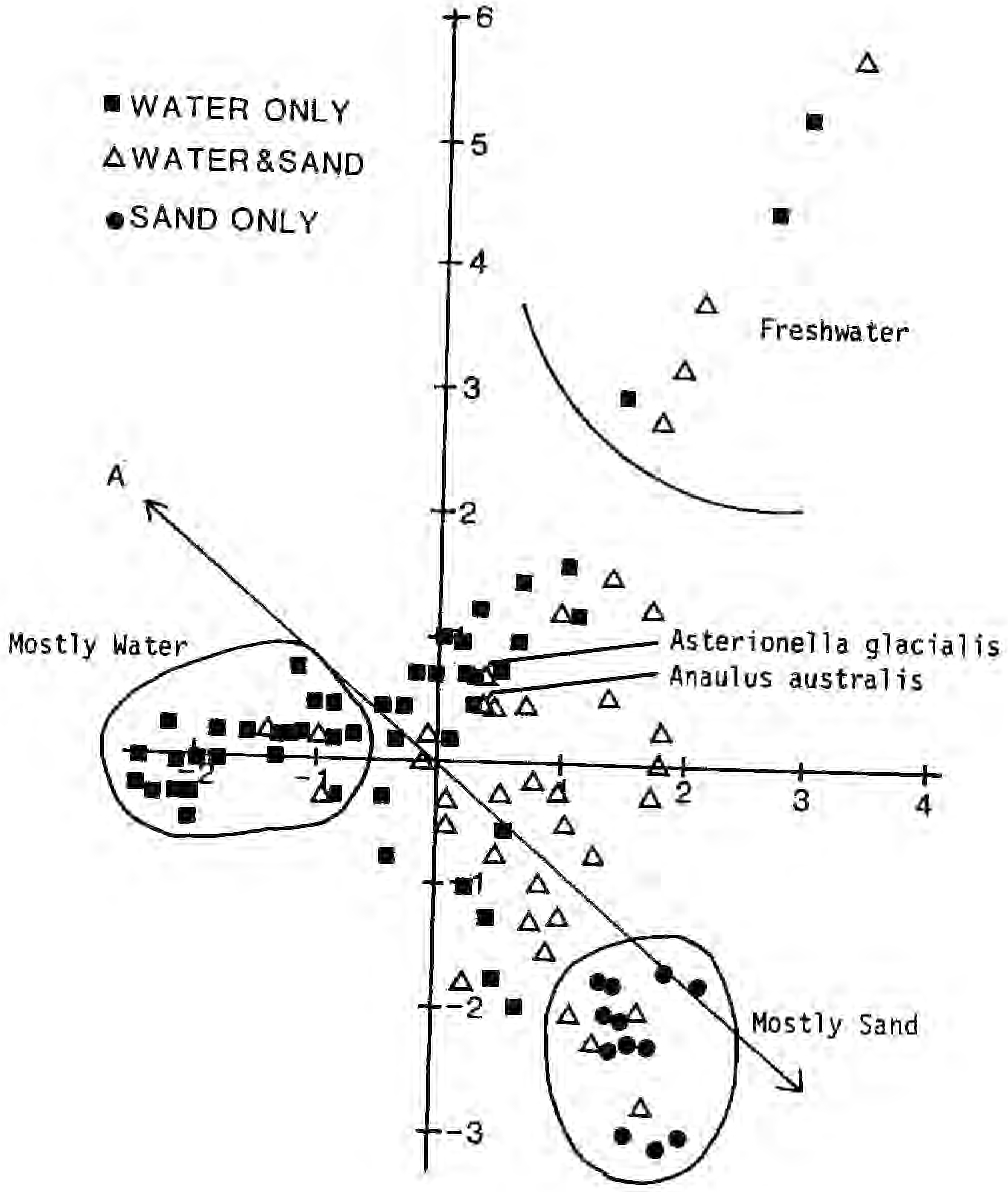

Figure 65. Detrended canonical correspondence analysis of the species found in the water and sand of the surf-zones of the south coast of South Africa.

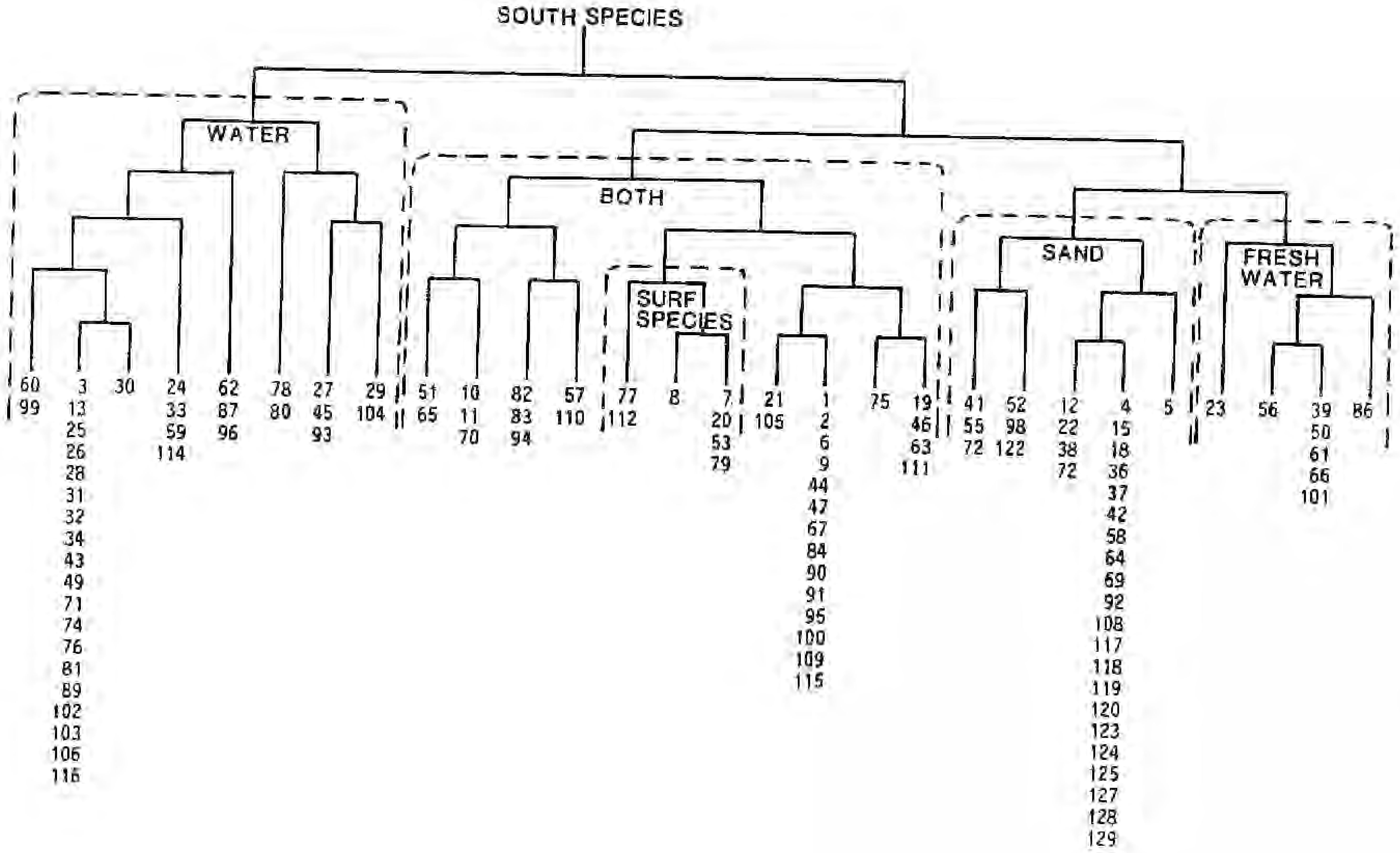

Figure 66. Dendrogram of the TWINSPAN analysis of the species found in the water and sand of the surf-zones of the south coast of South Africa.

Campylosira cymbelliformis, *Thalassiosira* large, *Gyrosigma* sp., two species of *Navicula*, a very small *Nitzschia*, *Rhizosolenia stolterfothii*, a *Surirella* species and a very small square diatom.

The TWINSPAN analysis primarily separated coastal species from inshore species. The inshore species separated into ubiquitous species, surf species and freshwater species as well as a group, including *Asterionella glacialis,*which lacks evidence of being a coherent community (Fig. 68). In the surf species group the closest association was between *Anaulus australis*, *Aulacodiscus johnsonii*, *Aulacodiscus petersii* and a football-shaped *Navicula* species. Other surf species which were less strongly associated but still separated with the surf species were *Campylosira cymbelliformis*, *Grammatophora marina*, *Melosira sulcata*, a *Navicula* species, *Nitzschia closterium*, *Nitzschia longissima*, *Noctiluca milearis*, *Prorocentrum micans*, *Thalassiosira rotula* and a small flagellate.

The analysis of the sites by CANOCO showed a separation of the sand samples as the first division and a separation between marine and freshwater samples in the water sample group (Fig. 69). The TWINSPAN analysis separated the Knysna-Wilderness area sites in the first division (Fig. 70). The next division was between the sand and water samples. In the water samples, the freshwater samples also separated into a group as in the CANOCO analysis (Fig. 69).

The CANOCO analysis of sites, excluding the sand samples, showed four primary groupings (Fig. 70). The samples collected at Bonza Bay separated strongly, flagellate-dominated samples and freshwater-influenced samples also separating. In the rest of the samples the Knysna-Wilderness area samples separated out on the x-axis (Fig. 71). The TWINSPAN analysis separated the Knysna-Wilderness area more strongly with no flagellate-dominated category (Fig. 71).

3.3 Chlorophyll *a* Concentration

Chlorophyll *a* concentration in the surf water is mostly below 100 mg m^{-3} (Fig. 73), Muizenberg beach and Vleesbaai having higher values. There was significant surface enrichment, the foam chlorophyll *a* concentration was mostly between 50 mg m^{-3} and 1 000 mg m^{-3} (Fig. 74).

Chlorophyll *a* concentration in sand samples was high in False Bay and at the Sundays River beach, values ranging between 10 mg chl *a* m^{-3} and 1 100 mg chl *a* m^{-3} (Fig. 75), but mostly below 400 mg chl *a* m^{-3}.

Comparing the foam and water chlorophyll *a* concentration using a foam:water value ratio (Fig. 76) shows up to 40 times enrichment in the surface layers. At Struisbaai, however, accumulation of *Anaulus*

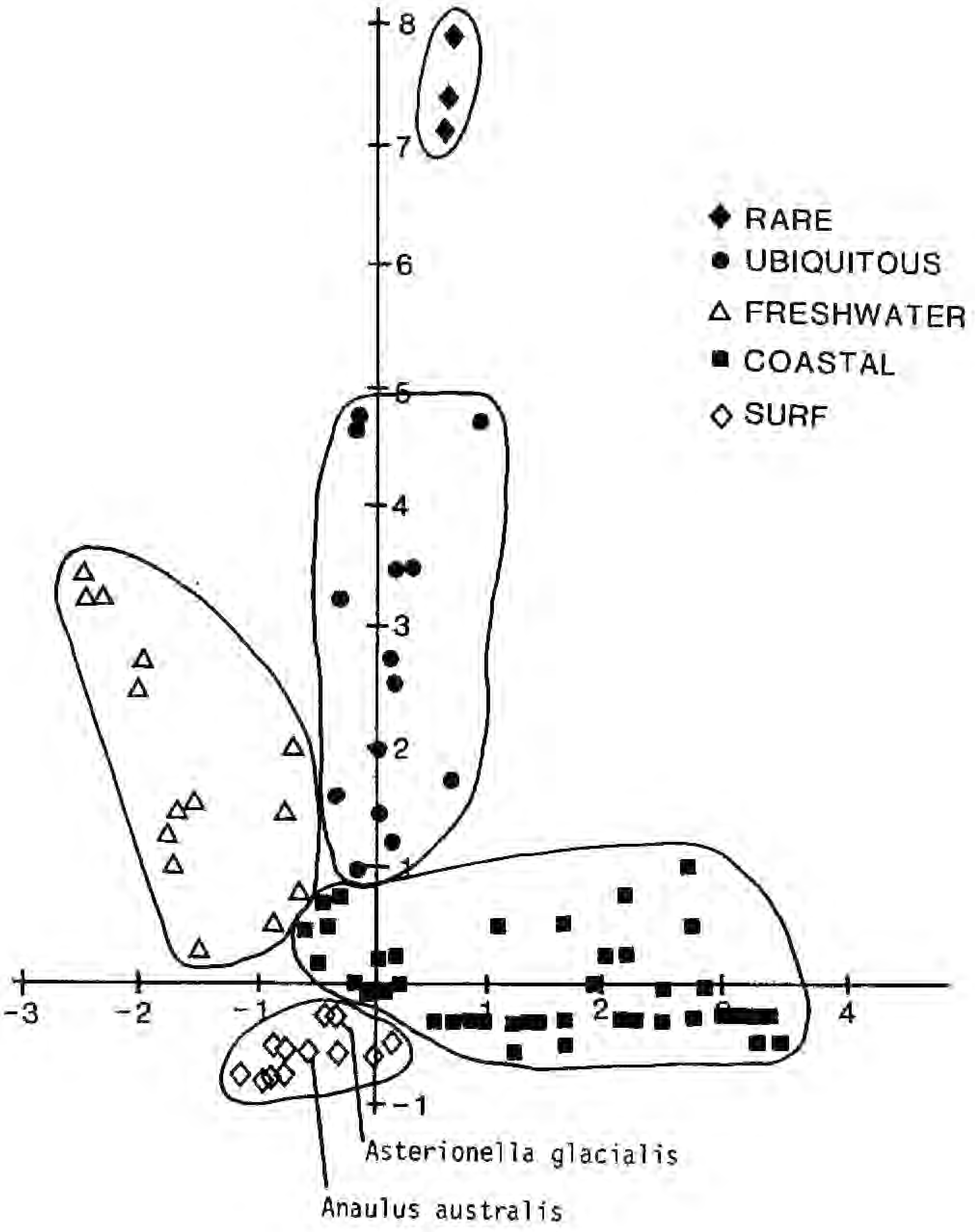

Figure 67. Detrended canonical correspondence analysis of the species found in the water of the surf-zones of the south coast of South Africa.

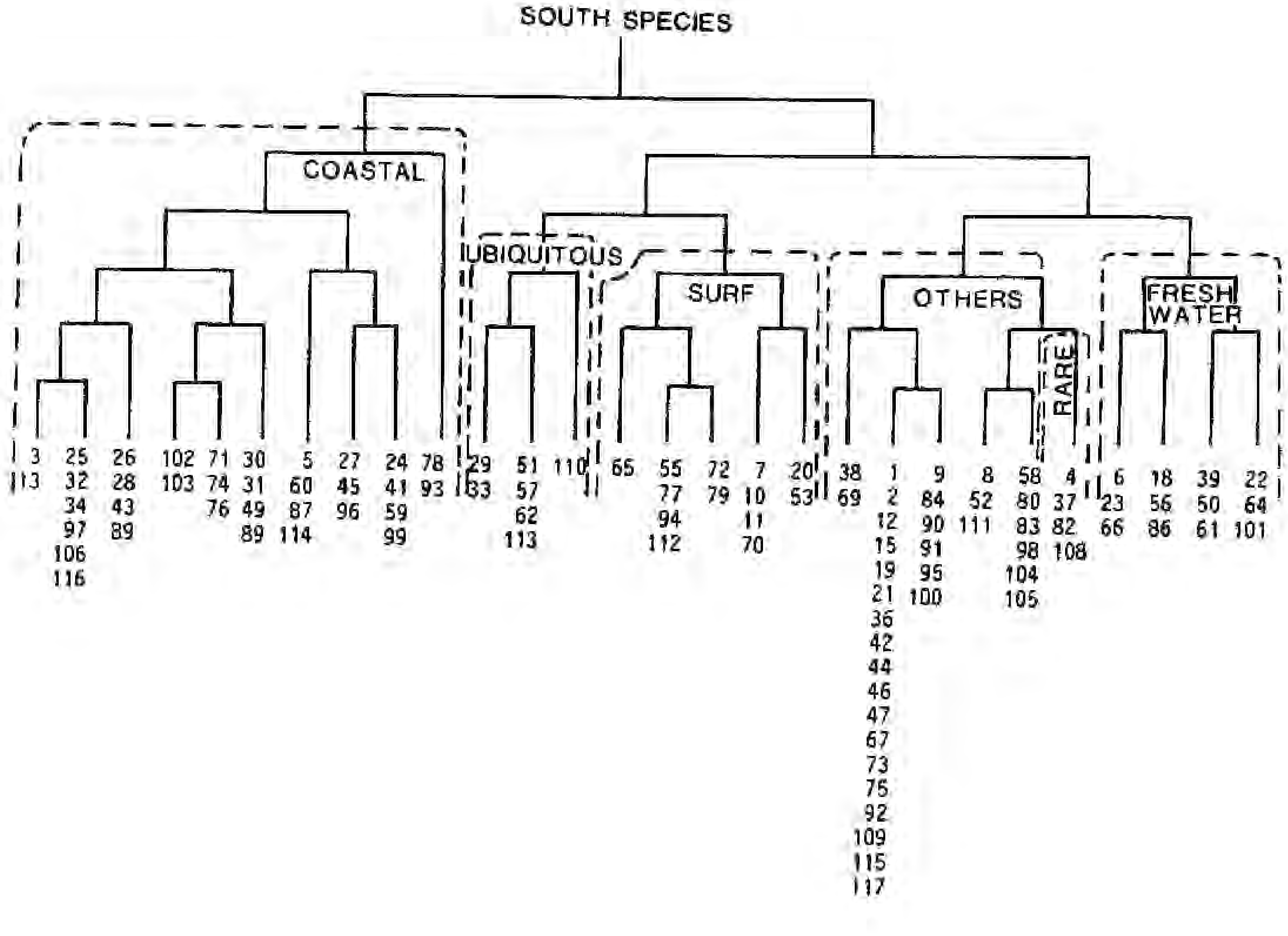

Figure 68. Dendrogram of the TWINSPAN analysis of the species found in the water of the surf-zones of the south coast of South Africa.

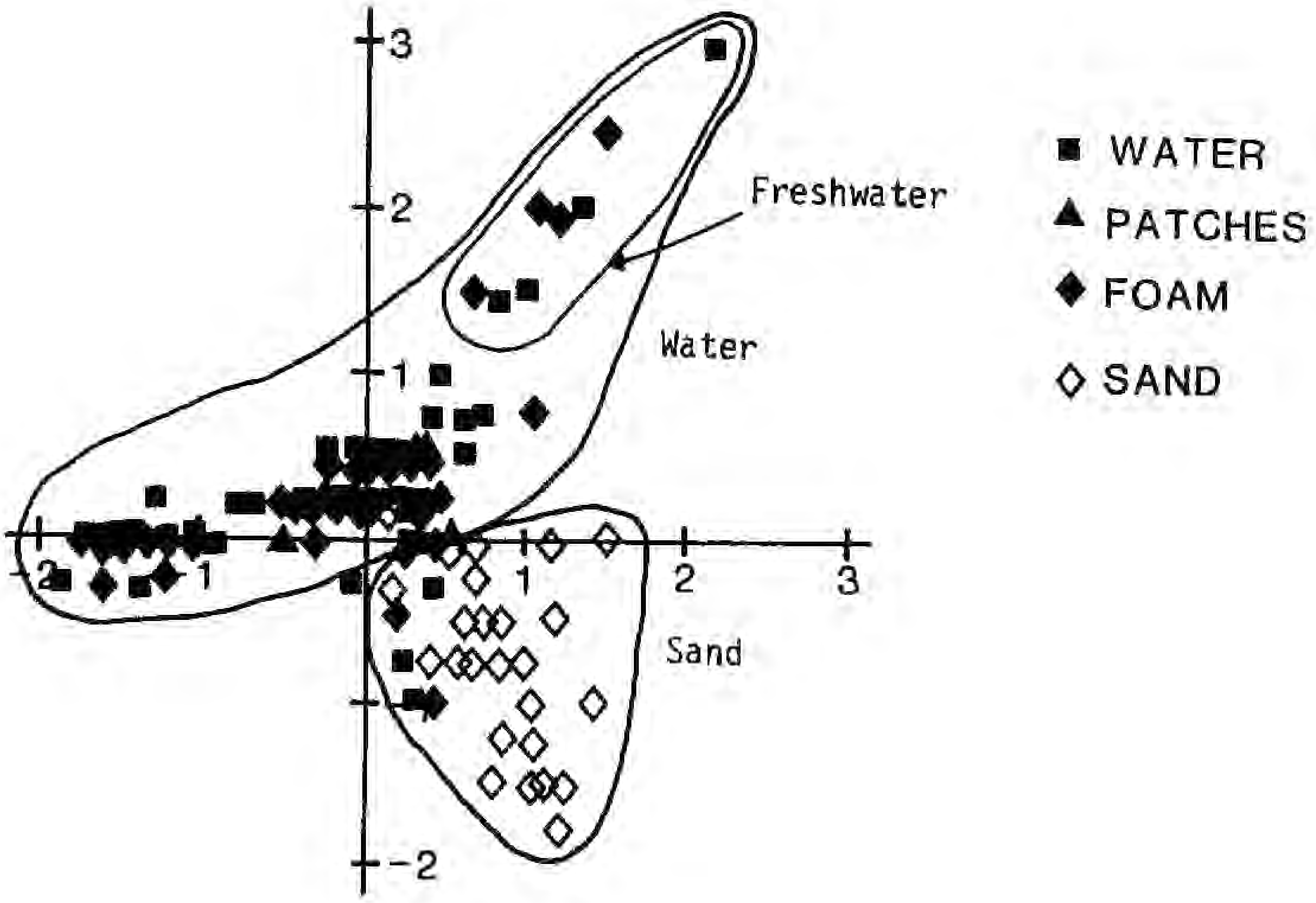

Figure 69. Detrended canonical correspondence analysis of the sites sampled along the south coast of South Africa.

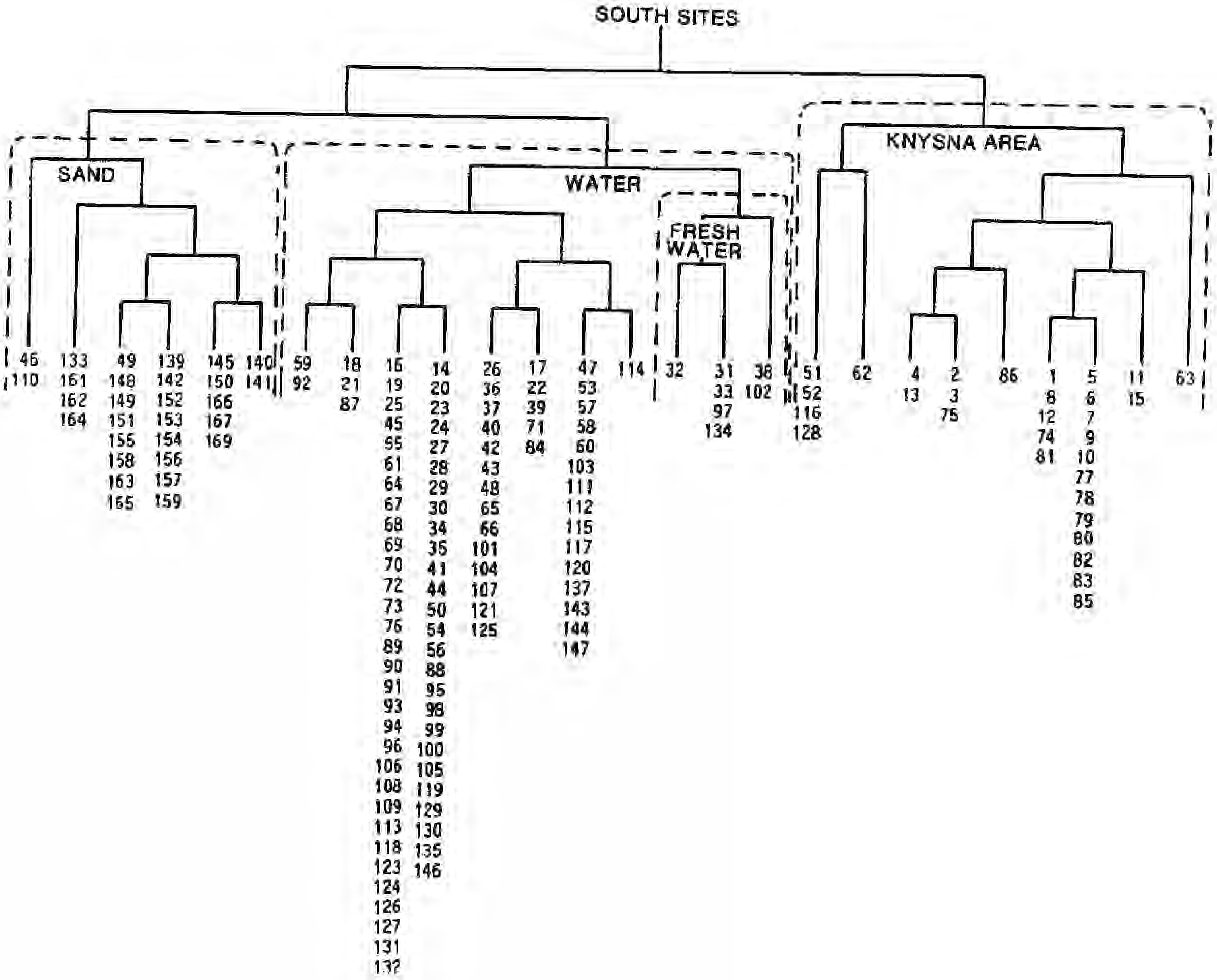

Figure 70. Dendrogram of the TWINSPAN analysis of the sites at which samples were collected along the south coast of South Africa.

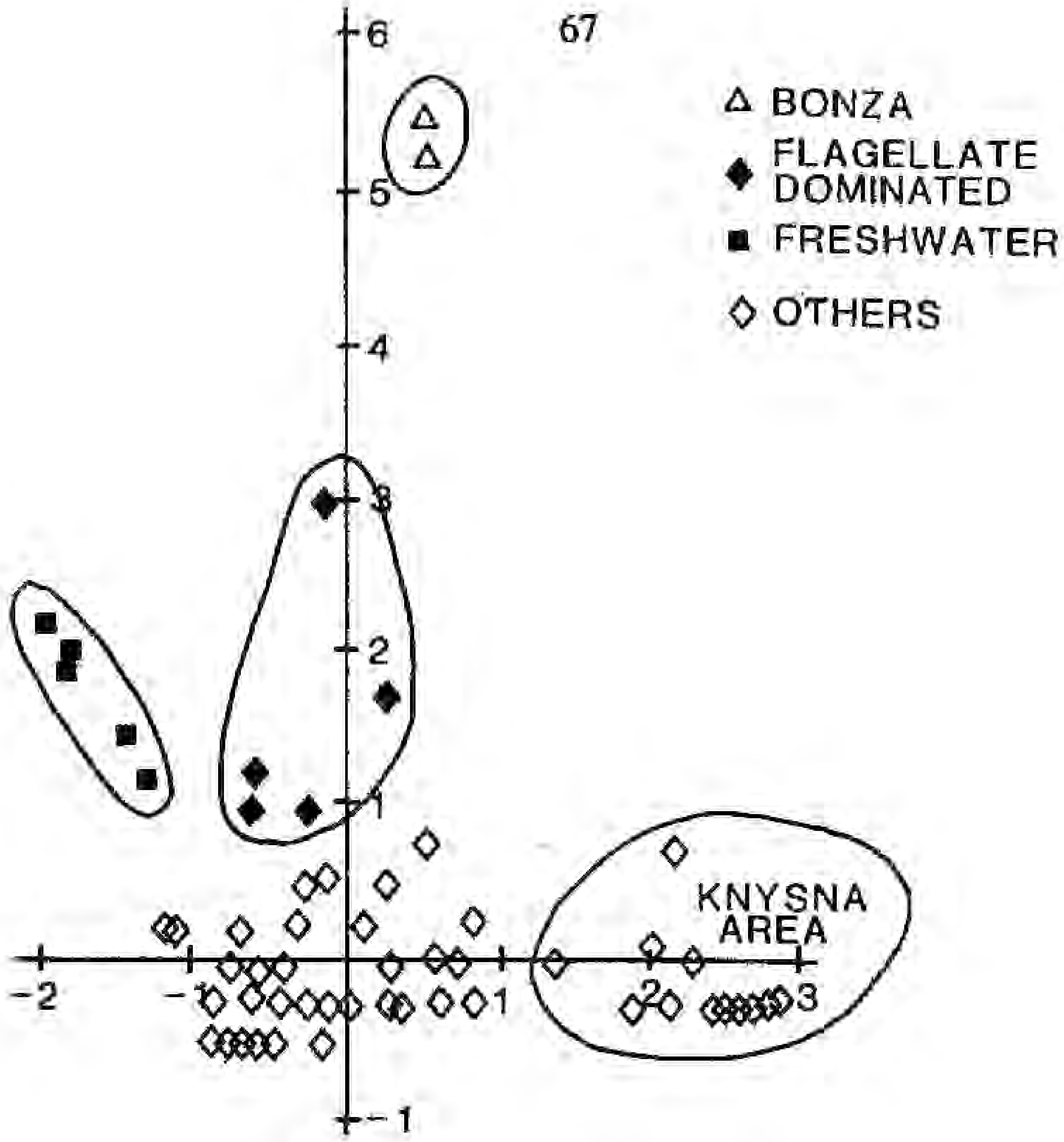

Figure 71. Detrended canonical correspondence analysis of the water sites at which samples were collected along the south coast of South Africa.

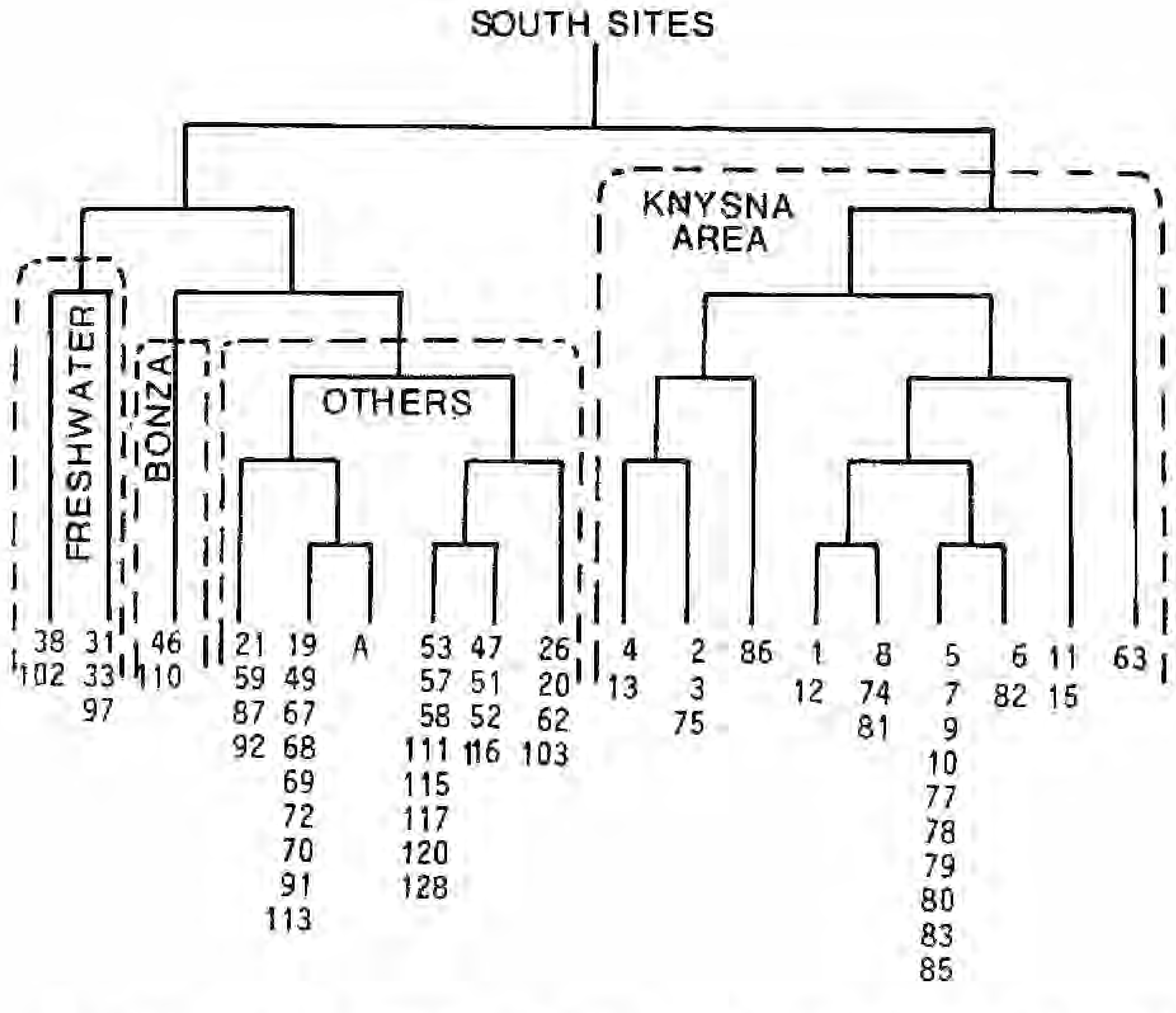

Figure 72. Dendrogram of the TWINSPAN analysis of the water sites at which samples were collected along the south coast of South Africa.

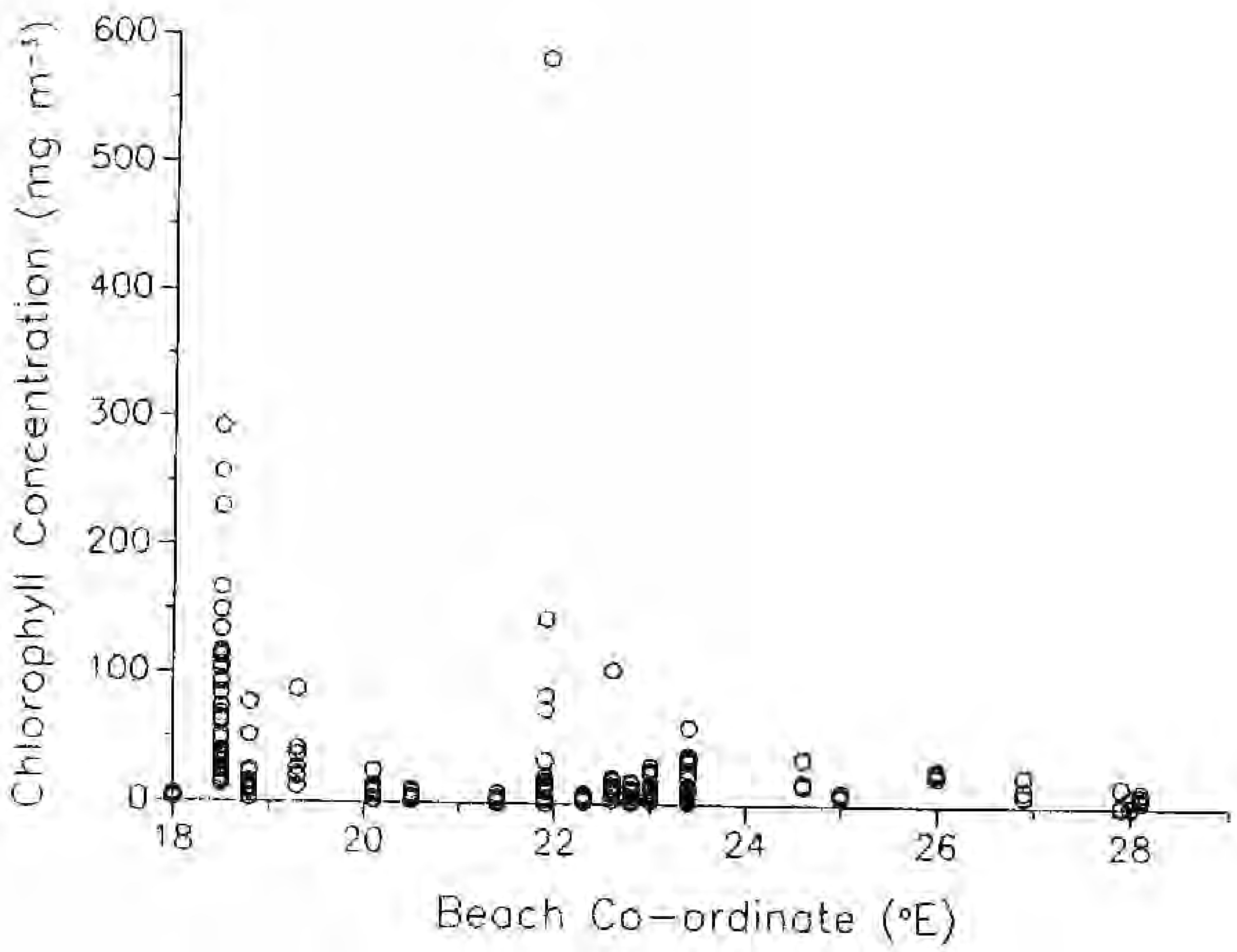

Figure 73. The chlorophyll *a* concentration in the water of the surf-zones of the south coast of South Africa.

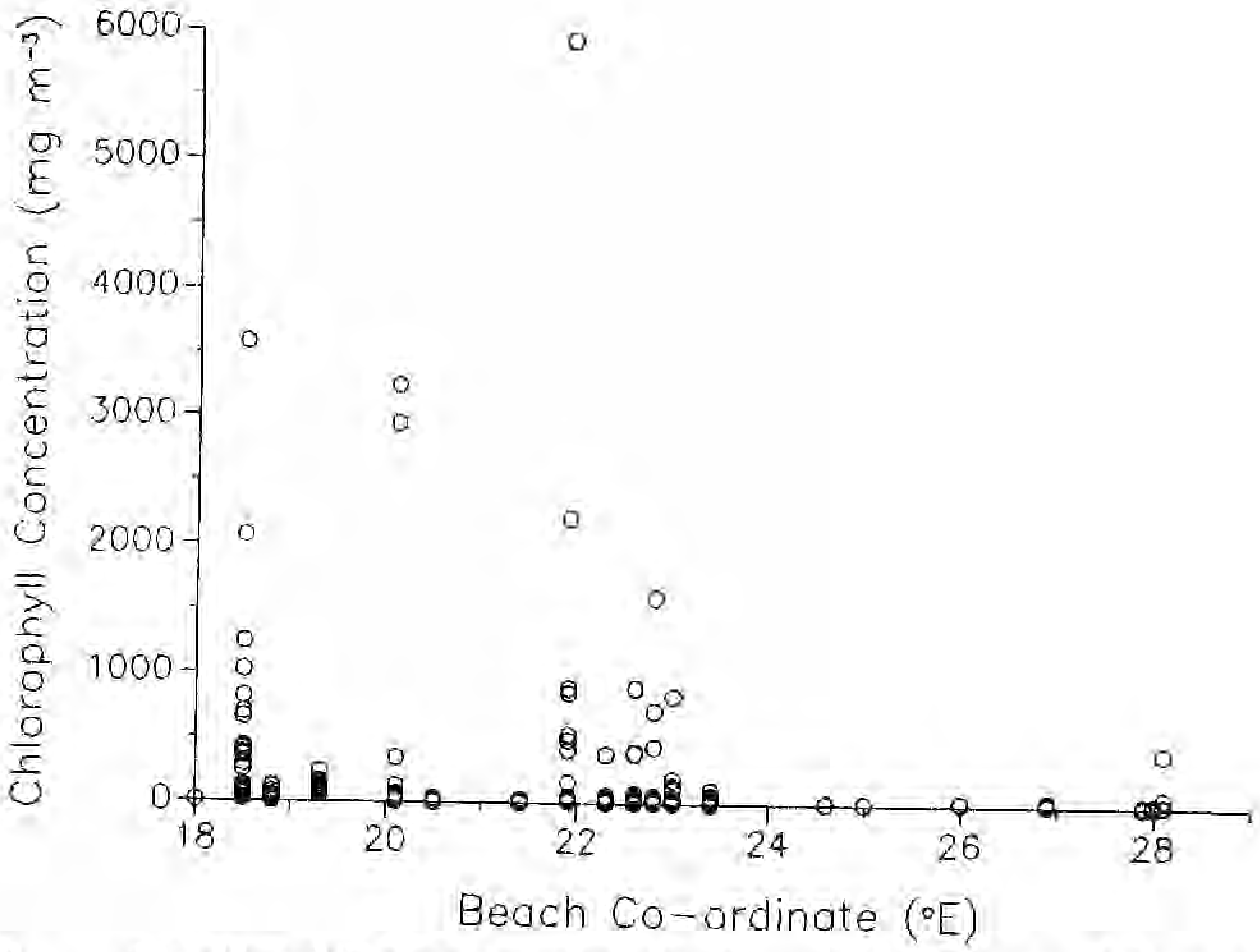

Figure 74. The chlorophyll *a* concentration in the foam of the surf-zones of the south coast of South Africa.

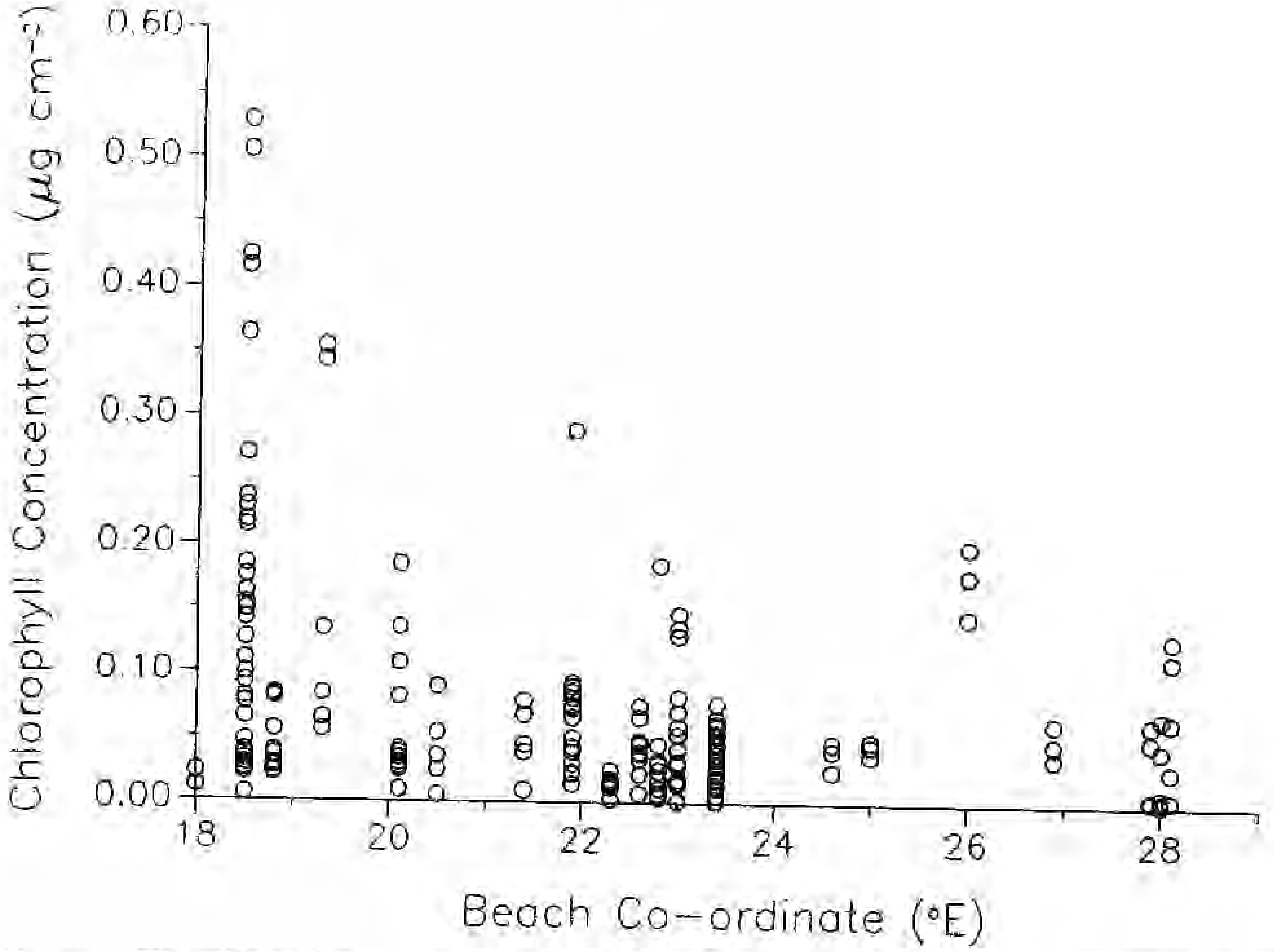

Figure 75. The chlorophyll *a* concentration in the sand of the surf-zones of the south coast of South Africa.

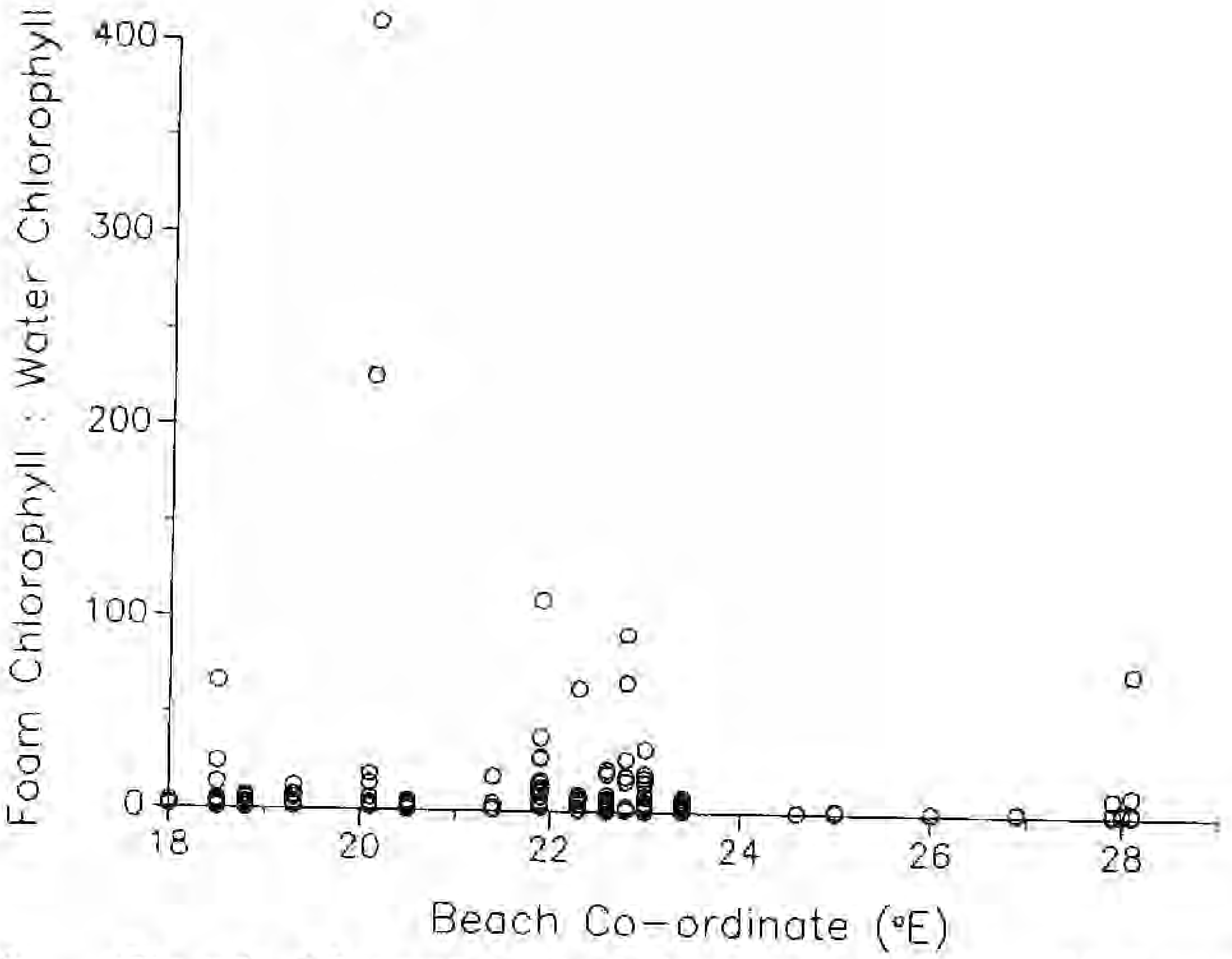

Figure 76. The ratio of foam:water chlorophyll *a* concentration measured in the surf-zones of the south coast of South Africa.

australis showed a foam enrichment value 400 times the chlorophyll concentration in the water. Muizenberg had a surface enhancement of only 7 compared to other beaches.

A similar comparison between the foam and sand (foam:sand value ratio) chlorophyll *a* concentration ranged from 0.1 to 15 (Fig. 77), high values being recorded between 21.5 and 23.5 °E. Outside this area the ratio was mostly below 1:1. A comparison between water and sand showed that the water:sand ratio was mostly below 1 (Fig. 78).

The standing stocks in the water calculated from the chlorophyll *a* data are presented in Figure 79. Because the foam represents such a small proportion of the total volume (Campbell and Bate, 1988a), the standing stock distribution has the same pattern as that of the water chlorophyll *a* concentration. The standing stocks were between 0 and 150 000 mg chl *a* m^{-1} at Muizenberg and between 0 and 20 000 mg chl *a* m^{-1} at most of the other beaches.

3.4 Phytoplankton Patch Analysis

Between 25 July and 7 September 1988 counts of accumulations were made at all the beaches between Cintsa Bay and Muizenberg. The values for the Sundays River and Van Stadens beaches are the mean of all the data collected at these beaches in the past 3 years. The mean total number of surface patches recorded on each beach is given in Figure 80. The total number for the whole south coast is 258.

The number of patches per kilometre is given in Figure 81. Muizenberg beach had 4.3 patches per kilometre, which is much more than the other beaches, except Vleesbaai. The rest of the beaches had fewer than 3 patches per kilometre.

The average patch colour intensity (on a scale of 1 to 10) is representative of the cell concentration of the foam (Campbell and Bate, 1988a). The average intensity at Muizenberg was very high, with a mean of around 5 (Fig. 82). The rest of the beaches had values between 1 and 4.

The sum of the patch volumes was high at Muizenberg, Vleesbaai and the Sundays River beach (above 1 000 m^3; Fig. 81). The rest of the beaches had values below 500 m^3.

3.5 Phytoplankton Elemental Composition

To date the physiological characteristics of the phytoplankton of only a few beaches have been investigated with respect to elemental content.

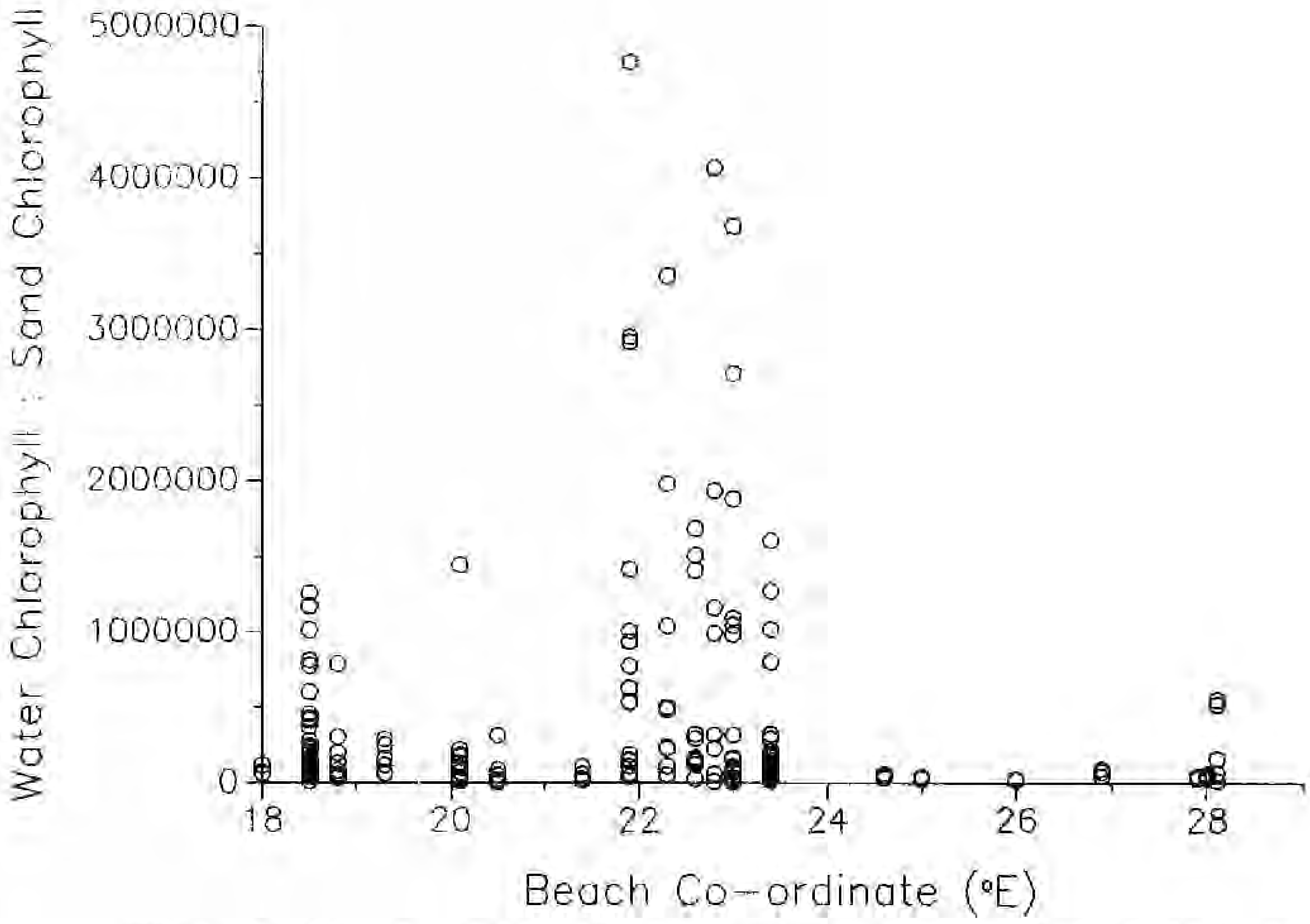

Figure 77. The ratio of foam:sand chlorophyll *a* concentration measured in the surf-zones of the south coast of South Africa.

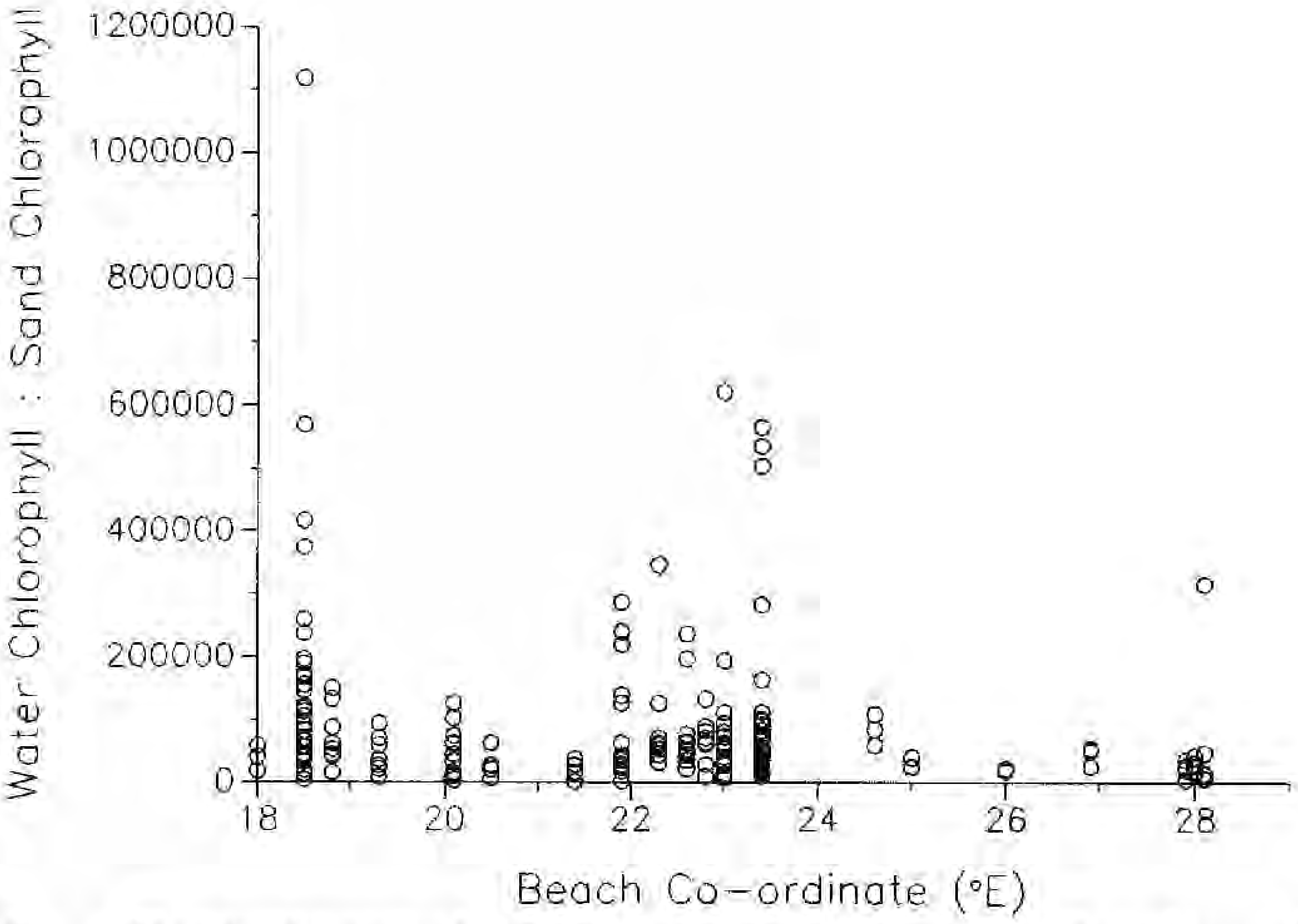

Figure 78. The ratio of water:sand chlorophyll *a* concentration measured in the surf-zones of the south coast of South Africa.

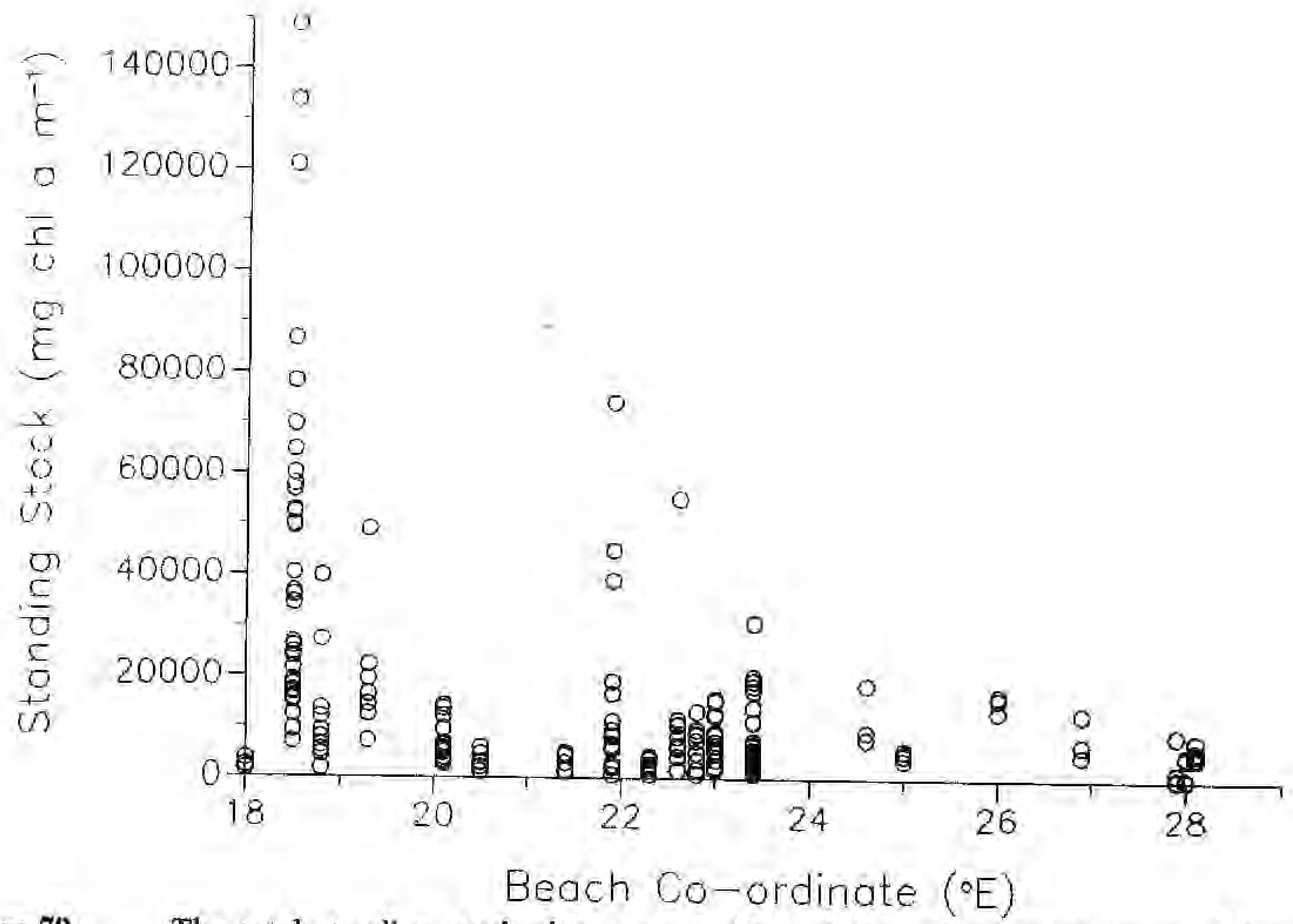

Figure 79. The total standing stock given as mg chlorophyll *a* per running metre of beach calculated for the surf-zones of the south coast of South Africa.

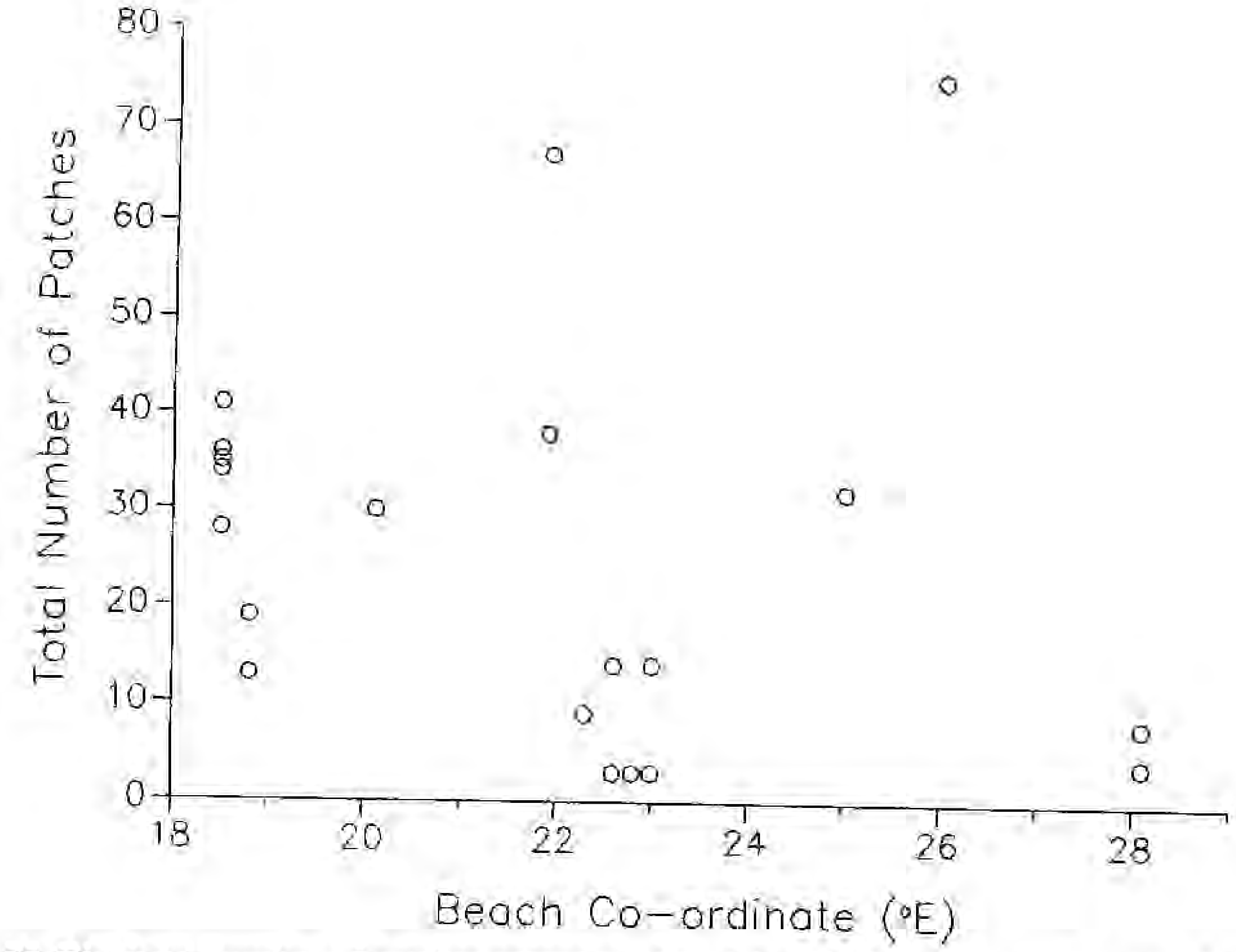

Figure 80. The total number of patches recorded at each beach along the south coast of South Africa.

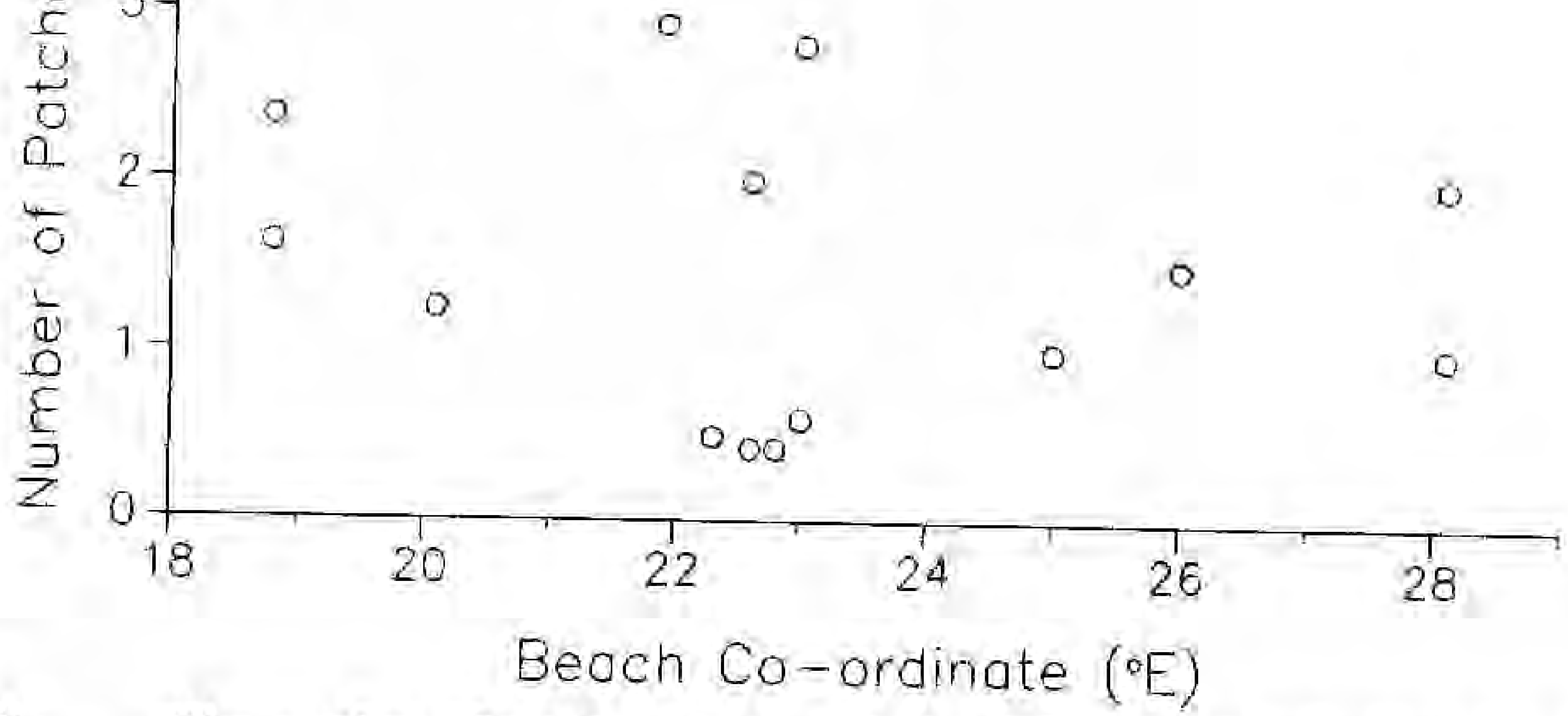

Figure 81. The number of patches per km calculated for each beach along the south coast of South Africa.

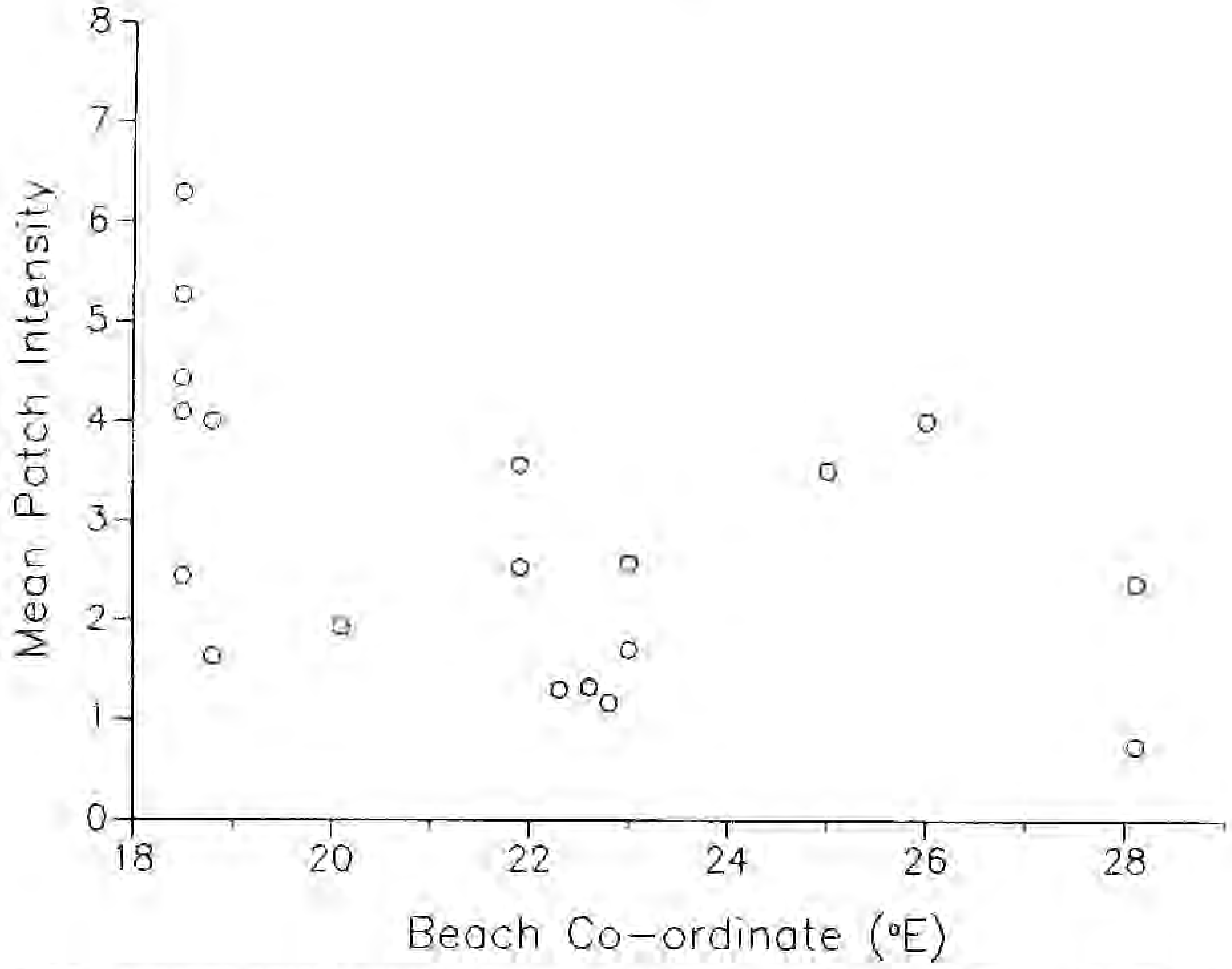

Figure 82. The average patch intensity recorded at each beach along the south coast of South Africa.

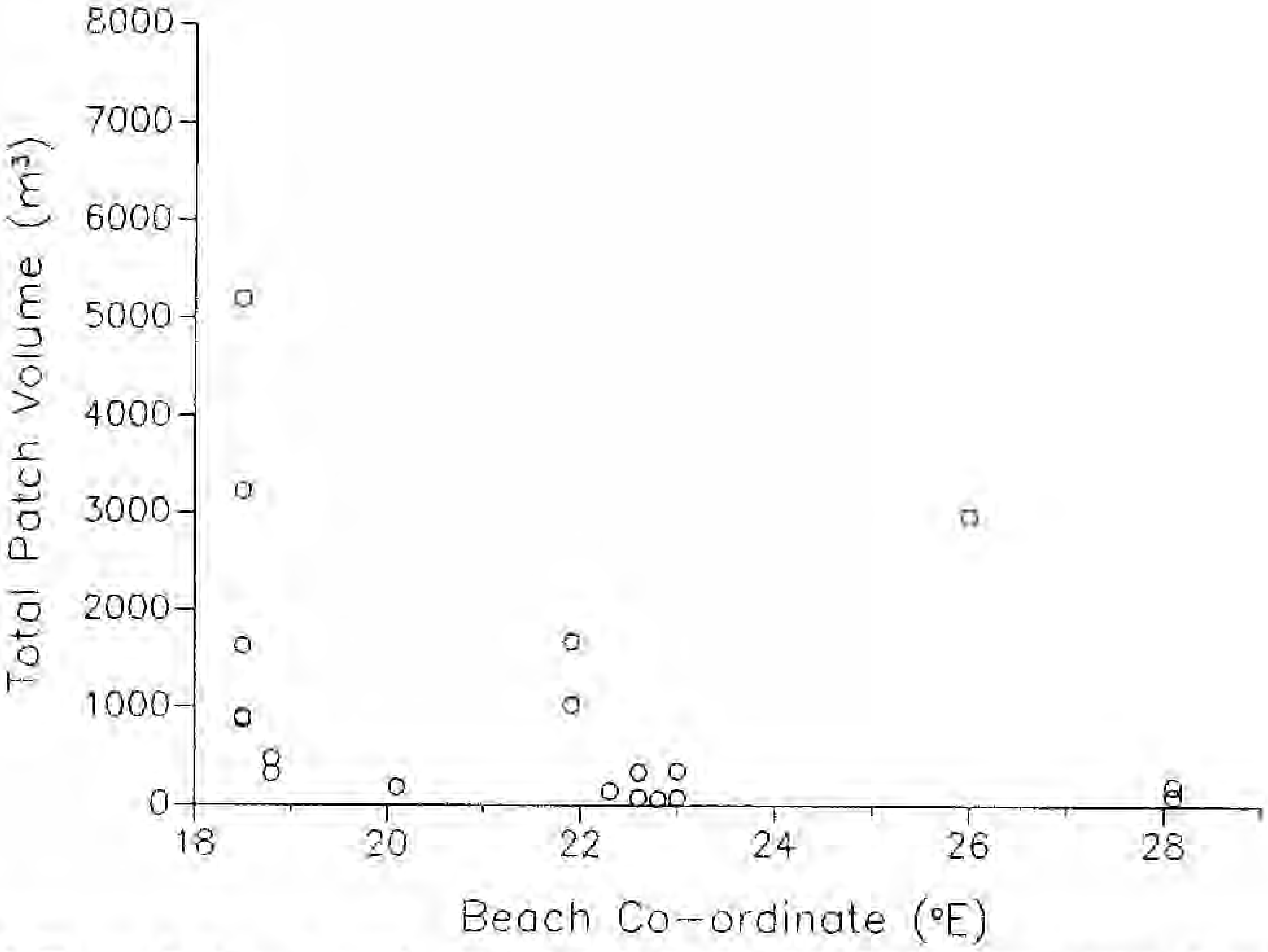

Figure 83. The total volume in patches estimated for each beach along the south coast of South Africa.

The carbon:nitrogen ratios of the cells were similar at all the beaches, with a mean of 6.6 (Fig. 84). At Muizenberg and Macassar beaches the mean was lower (about 5.5) compared to the rest of the beaches (a mean of 7.0). Flagellate and freshwater samples had a value of 10.5. Cells kept without addition of nutrients for 3 days had a carbon:nitrogen ratio of 12, showing the nutrient deficient condition.

The carbon:phosphorus ratio increases from around 7 in False Bay to 27 at the Sundays River beach (Fig. 85).

The nitrogen:phosphorus ratio showed low values west of Wilderness (1.8) with higher values (3.7 and 5) recorded to the east at Buffalo Bay and the Sundays River beach (Fig. 86).

The carbon:chlorophyll *a* ratio showed large differences, Muizenberg having a mean ratio of 20, Sundays a ratio of 35 and Vleesbaai a ratio of 80. The other beaches had values greater than 100 (Fig. 87).

The chlorophyll *a*:nitrogen ratio of Muizenberg cells was high (0.29), while at the Sundays River beach it was 0.16, and at the rest of the beaches the ratio ranged from 0.03 to 0.09 (Fig. 88). This difference is not due to low nitrogen content because the nitrogen content of the cells is higher at Muizenberg than at any other beach (Fig. 91), but rather because the chlorophyll content of the cells is much higher at Muizenberg than at Cintsa or Sundays (Fig. 90).

The carbon content of the cells varied between 0.06 and 0.17 μg C per 1 000 cells regardless of geographic location (Fig. 89).

The chlorophyll content per cell was very high at Muizenberg (0.0048 μg chl *a* per 1 000 cells, Fig. 90) compared to the rest of the beaches (a mean of 0.0008 μg chl *a* per 1 000 cells).

The nitrogen content per cell decreased from west to east (Fig. 91) while the phosphorus content per cell showed no differences with geographic location (Fig. 92).

3.6 Primary Production

The primary production of each beach, calculated using the data presented in Figures 6, 73 and 74, is given in Figure 93. The primary production of beaches depends on the topographic state (Fig. 94). Primary production ranged from 10 to 3 080 kg C m^{-1} y^{-1}.

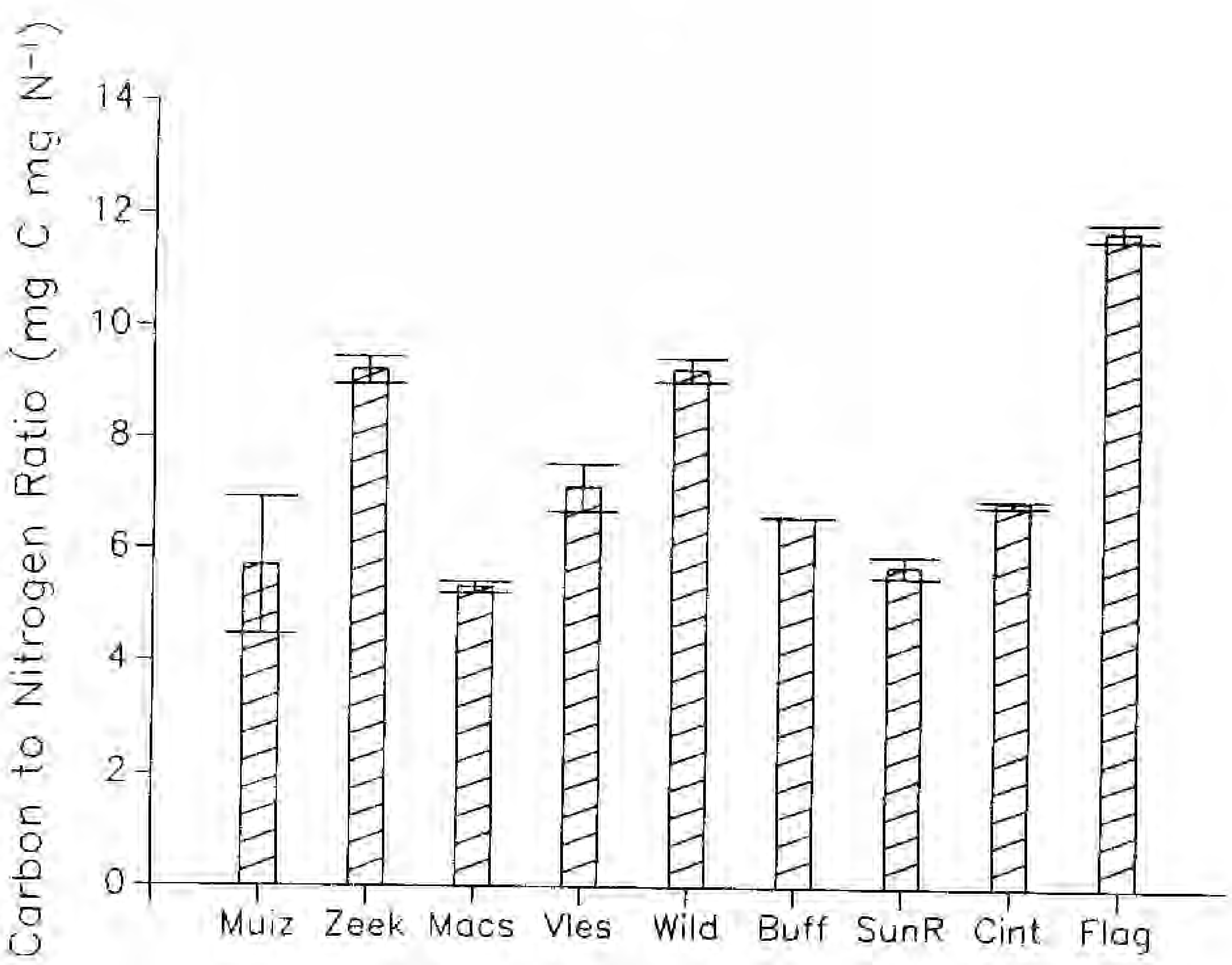

Figure 84. The carbon:nitrogen ratio of *Anaulus australis* cells collected at several beaches along the south coast of South Africa.

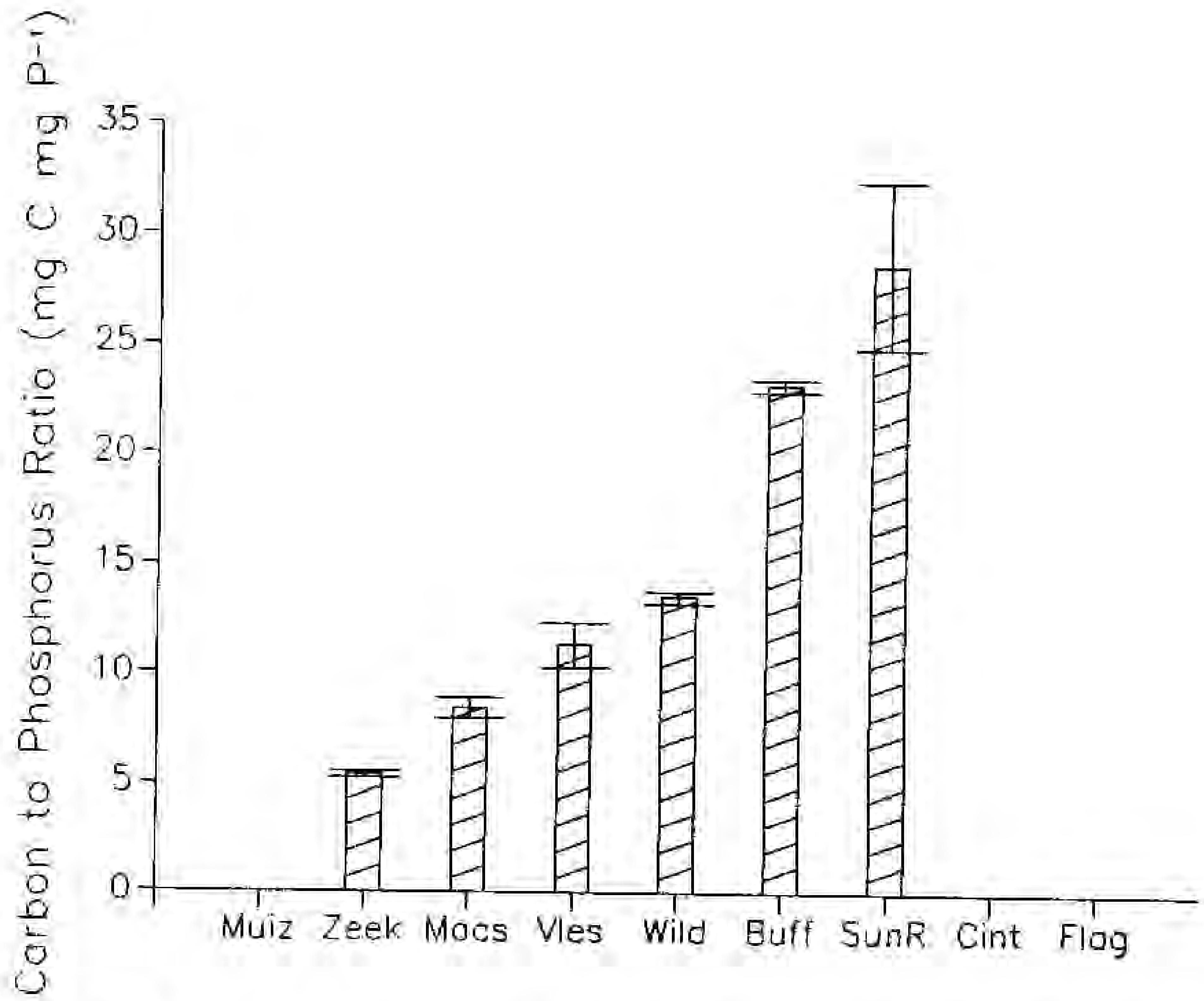

Figure 85. The carbon:phosphorus ratio of *Anaulus australis* cells collected at several beaches along the south coast of South Africa.

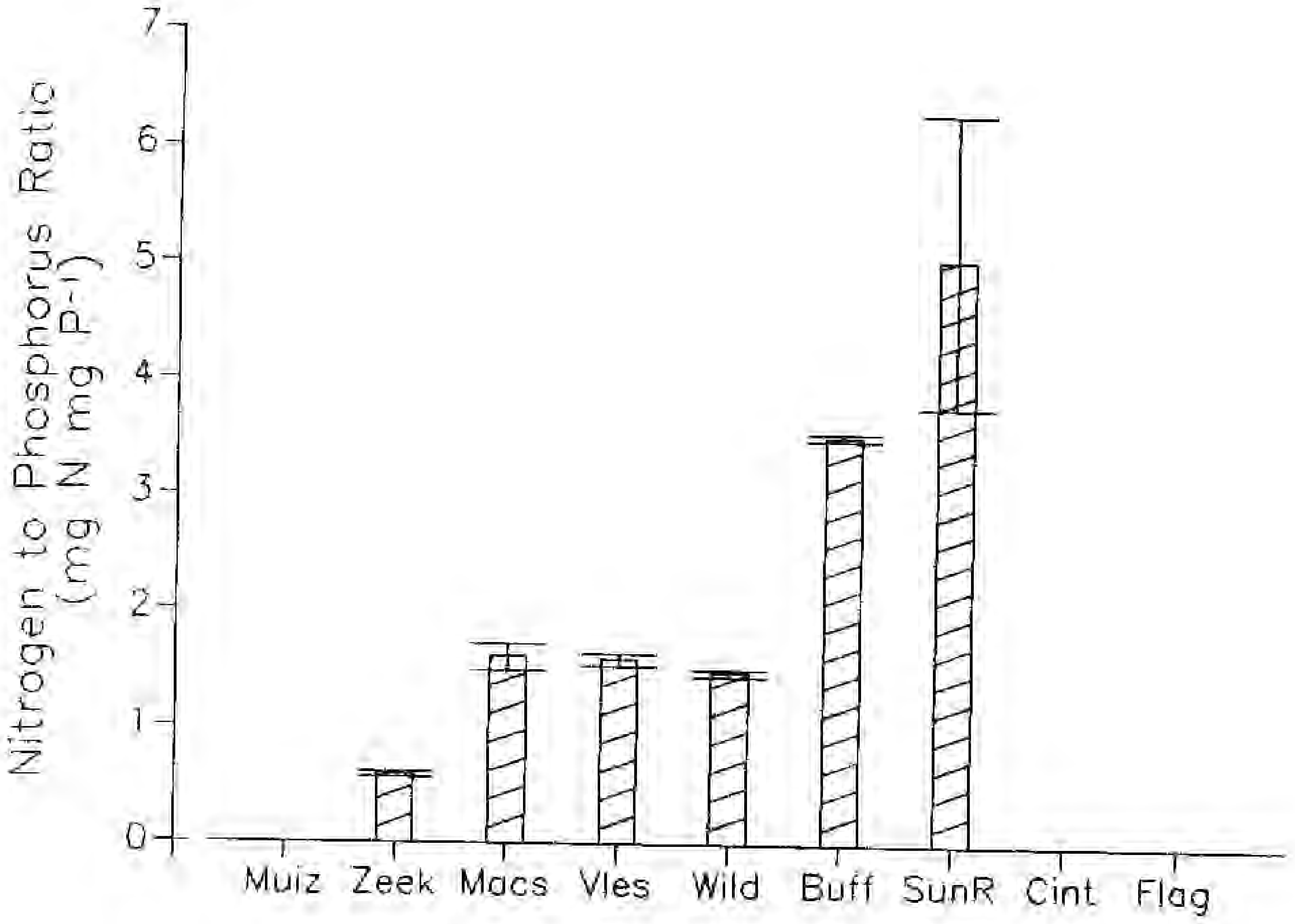

Figure 86. The nitrogen:phosphorus ratio of *Anaulus australis* cells collected at several beaches along the south coast of South Africa.

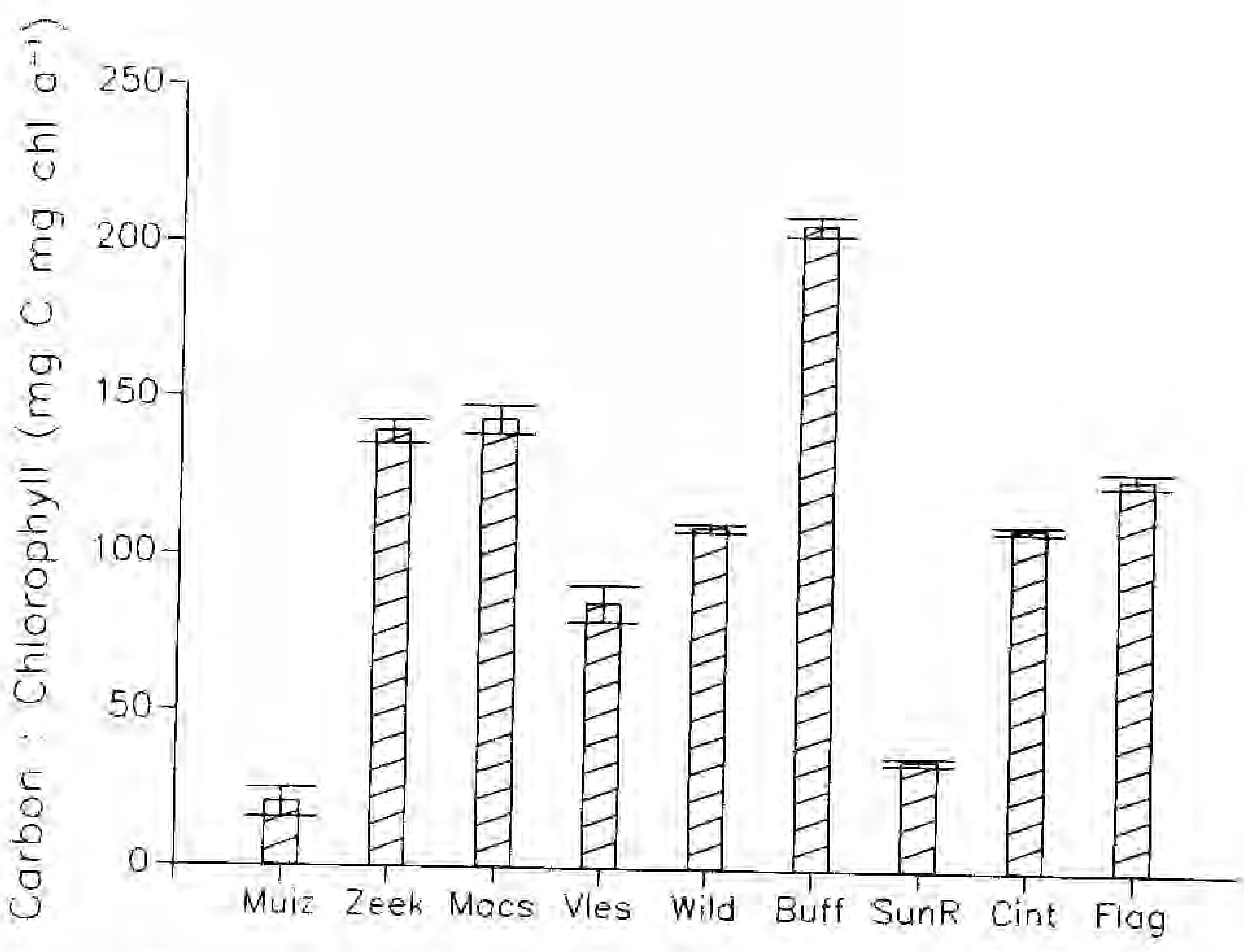

Figure 87. The carbon:chlorophyll *a* ratio of *Anaulus australis* cells collected at several beaches along the south coast of South Africa.

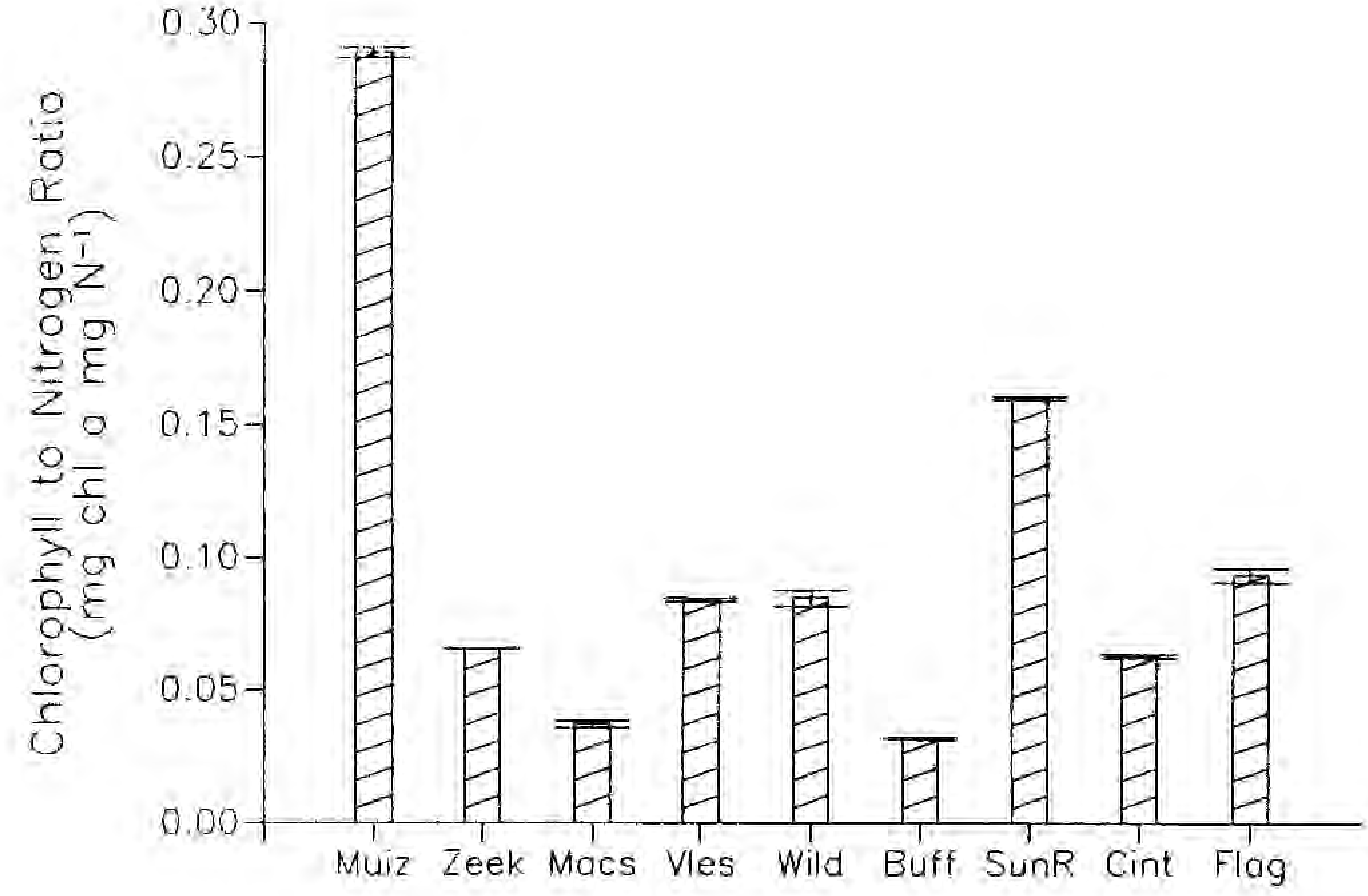

Figure 88. The chlorophyll *a*:nitrogen ratio of *Anaulus australis* cells collected at several beaches along the south coast of South Africa.

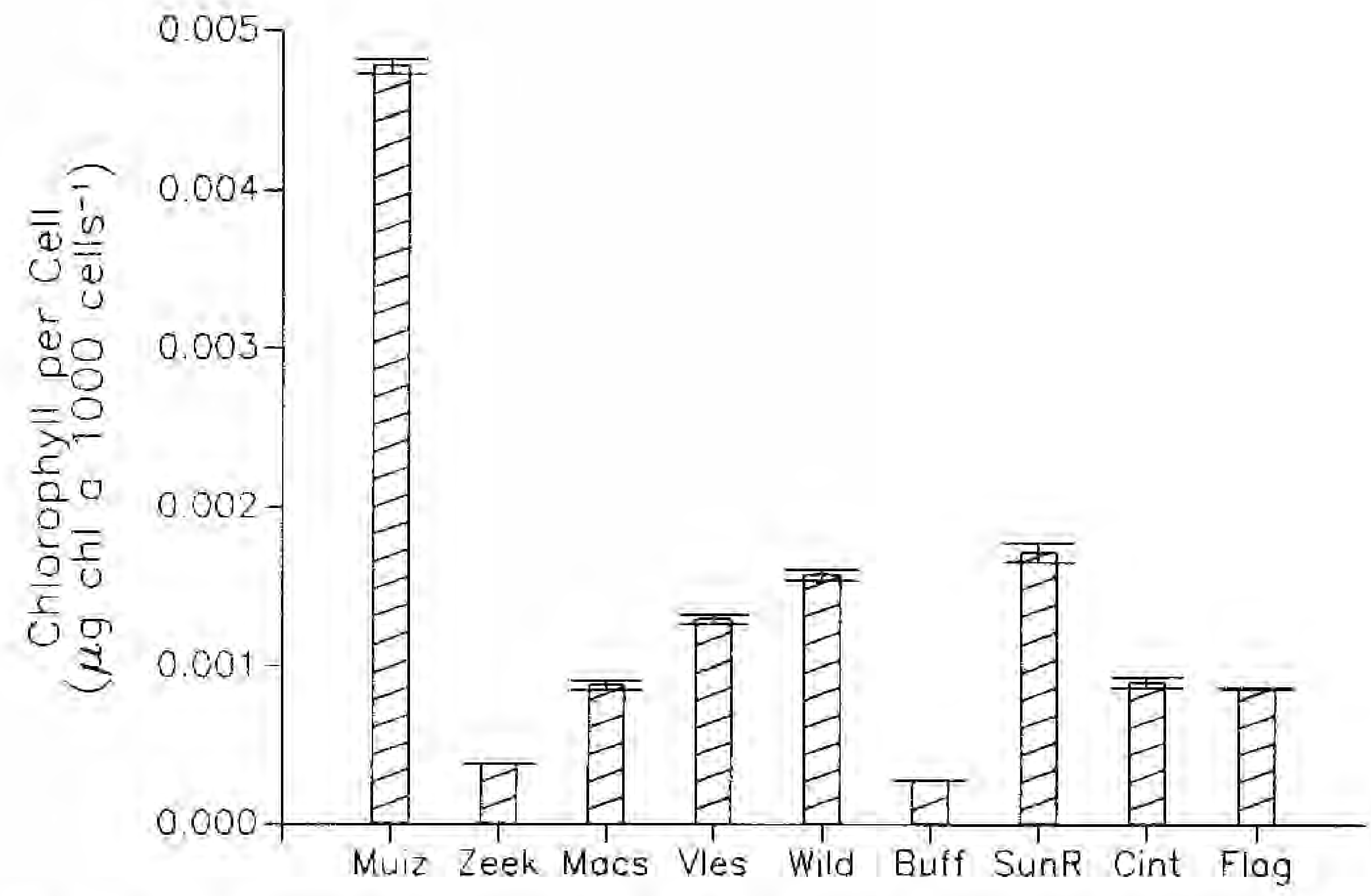

Figure 89. The chlorophyll *a* content per cell of *Anaulus australis* cells collected at several beaches along the south coast of South Africa.

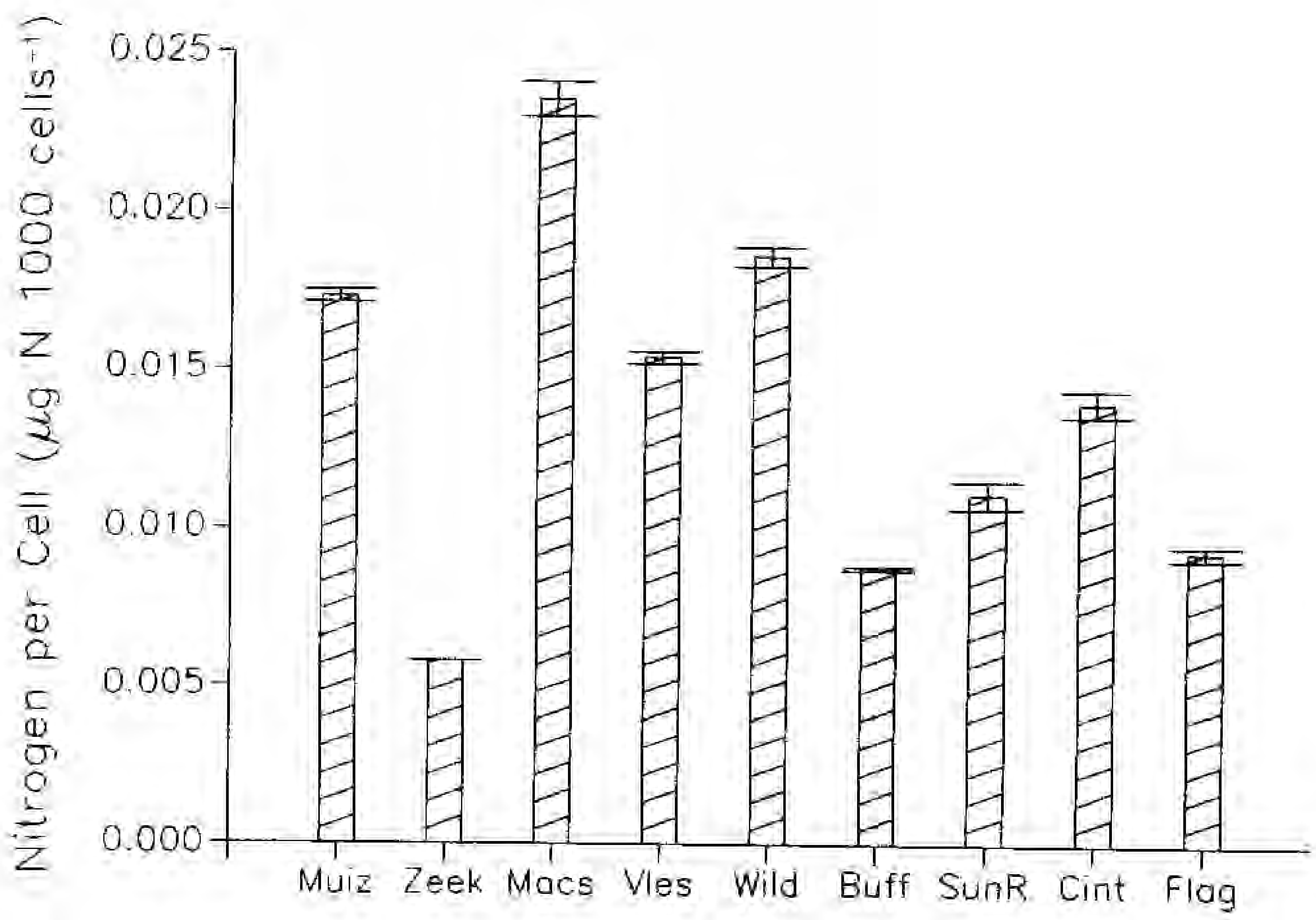

Figure 90. The nitrogen content per cell of *Anaulus australis* cells collected at several beaches along the south coast of South Africa.

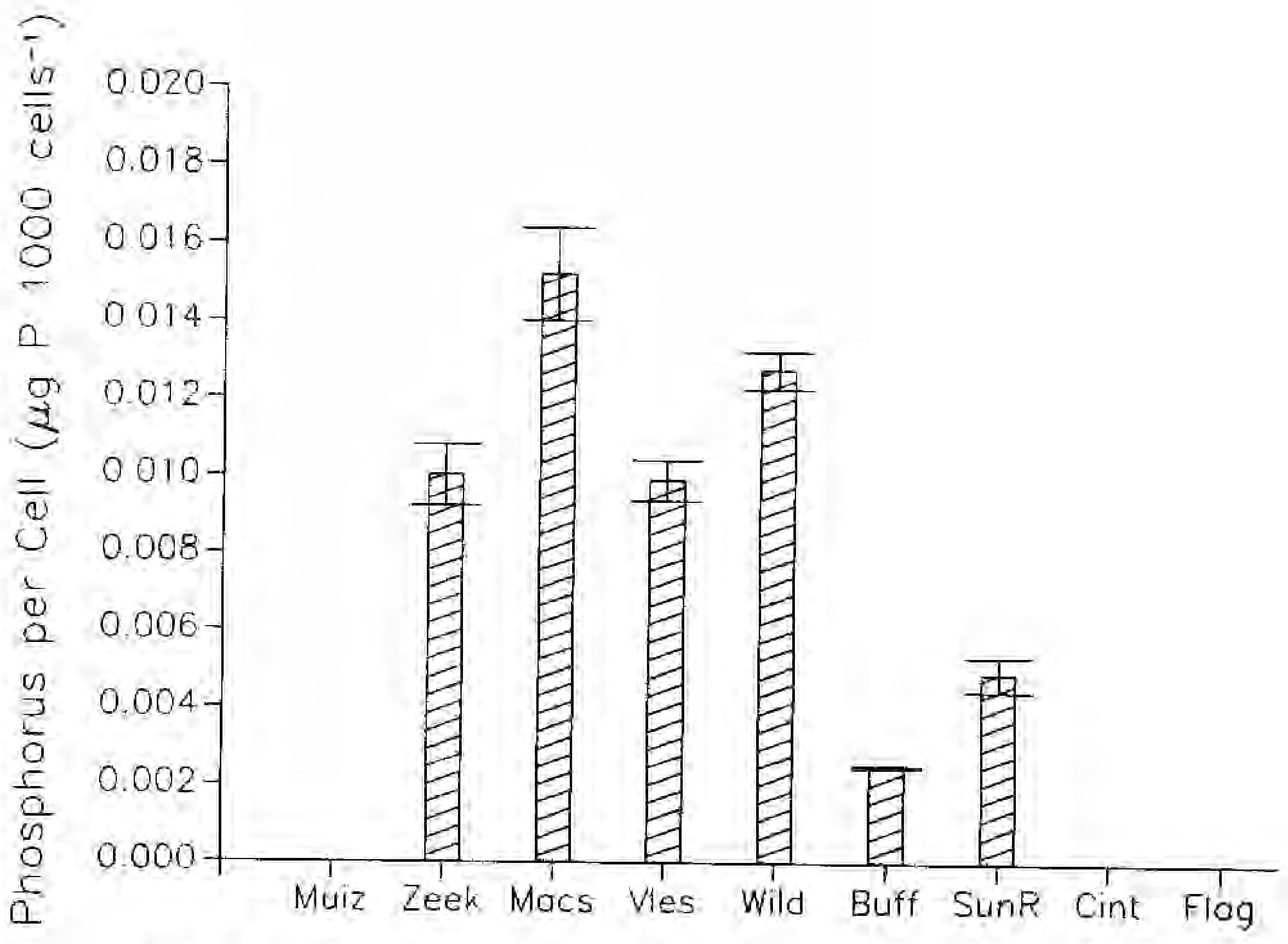

Figure 91. The phosphorus content per cell of *Anaulus australis* cells collected at several beaches along the south coast of South Africa.

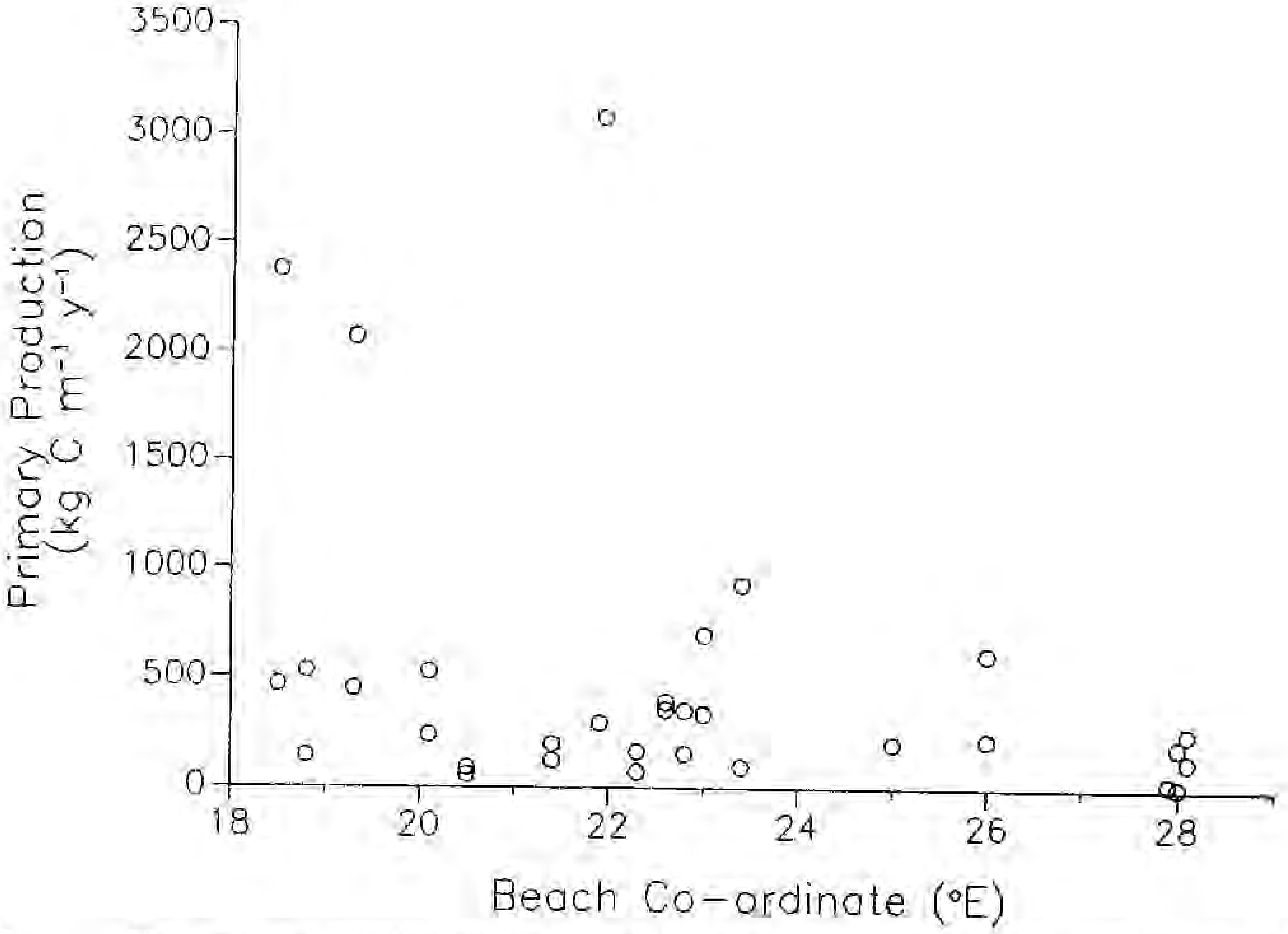

Figure 92. The primary production estimated for the surf-zones of the south coast of South Africa.

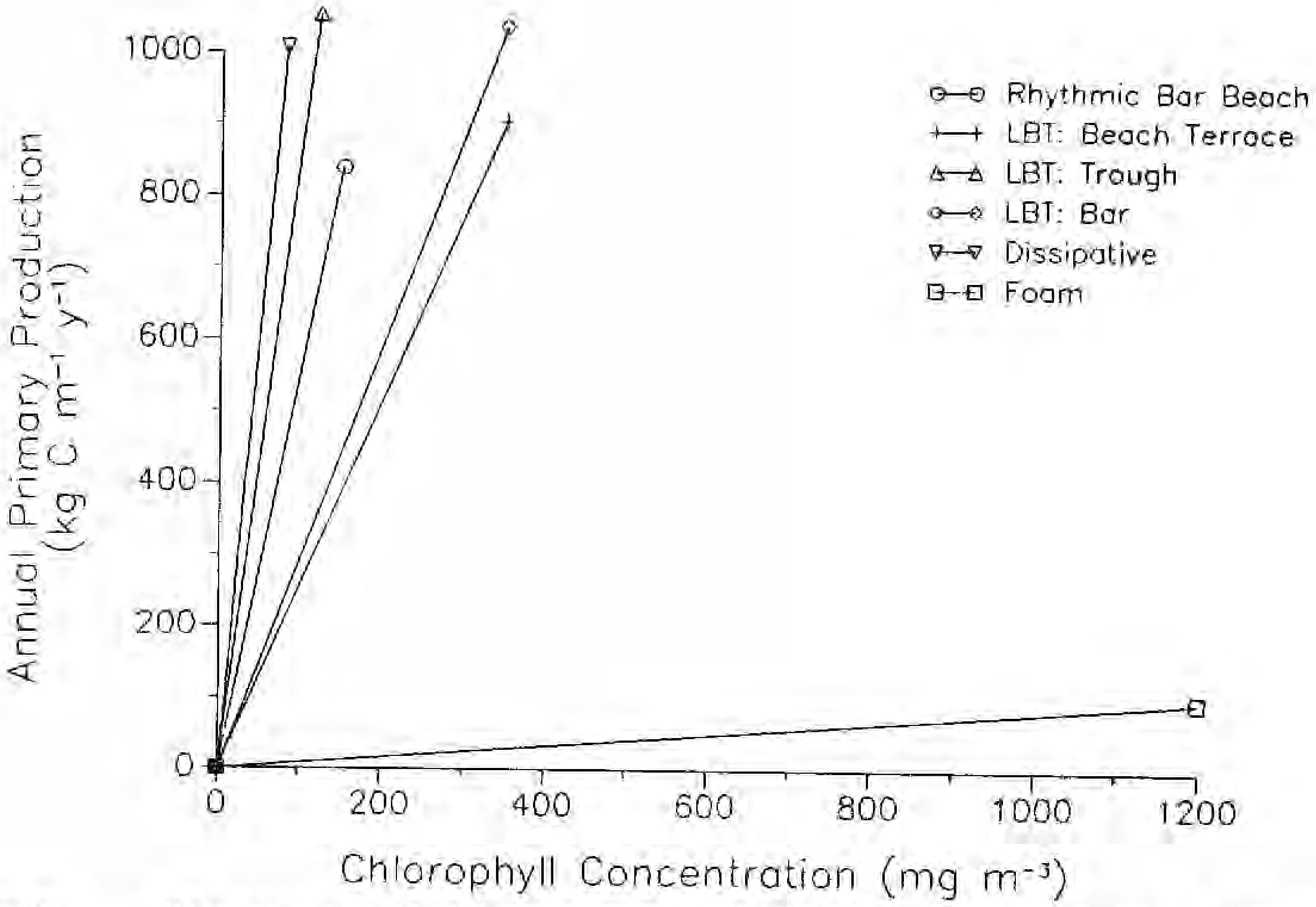

Figure 93. The primary production of the different beach states estimated from the surf-zones primary production model of Campbell and Bate (1988).

4. DISCUSSION

Except for Walker Bay and False Bay, the south coast is characterised by a series of log-spiral bays, especially the coast east of Cape Agulhas. False Bay can be classified as a "south coast bay" on the grounds of its accumulations of *A. australis*, but Walker Bay has stronger affinity with the west coast due to its seasonal upwelling (Schumann, 1984). In addition, Walker Bay has a phytoplankton population more similar to the west coast and it is characterised by a high phytomass but no accumulations of *A. australis* (Campbell and Bate, 1990b).

The south coast has little difference in temperature from west to east (Fig. 4) but a wide range of wave height (Fig. 5), topographic state (Fig. 6) and surf-zone width (Fig. 7). This section of the coast has a larger variance in these parameters than either the west or east coast.

A substantial groundwater flow from coastal aquifers appears to be associated with the formation of *A. australis* accumulations but this is not a simple relationship. At most beaches which have accumulations, the slope of groundwater table (Fig. 8) was steep, except but at Struisbaai, Sedgefield and Wilderness. The nutrient content of the groundwater affects the influence of flow in that a large amount of water containing no nutrients flowing into the surf-zone would not have any effect on the phytoplankton. The only surf-zones likely to have a significant amount of soluble inorganic phosphate contributed by groundwater would be Muizenberg and Walker Bay (Table 3). At Muizenberg large amounts of nutrients are provided through river outfalls, and at Walker Bay by upwelling. Thus, groundwater is not a source of phosphate to the south coast surf-zone.

Ammonium is likely to be source of nitrogen only to the Muizenberg, Vleesbaai and Glentana beaches (Table 3). On average the ammonium content of groundwater was only 1.2 times that of seawater (Fig. 16 and 17).

The nitrate concentration in groundwater was on average 3.2 times that of sea water (Fig. 22 and 23). However, several beaches had extremely high concentration of groundwater nitrate and steep groundwater slope (high groundwater flow; Table 3).

At Muizenberg substantial input of all the nutrients occurs by groundwater flow (Table 3; Fig. 12, 18, 25); however, not all the nutrients are taken up as indicated by elevated concentration in the surf water (Fig. 13, 19 and 26). These nutrients are probably seeping through the dunes from the sewage settling ponds behind the foredunes. Further sources of nutrients into the False Bay surf-zones can be through the Sandvlei, Zeekoevlei, the fertilizer factory and other outfalls (Fig. 13, 20, 25 and 34).

The groundwater input parameter of nitrogen to the Muizenberg beach is the highest by a factor of 4.2 above any other beach (Table 4). The high nutrient outfalls in False Bay also add to the total nutrient load, placing the False Bay surf-zone in a different category from the other beaches and explaining the extremely high standing stocks. Before the construction of the outfalls and sewage settling ponds, False Bay beaches probably had accumulations of *A. australis* in concentration comparable to that of other south coast beaches. The man-made increased nutrient input into the Bay has caused the elevation of cell numbers to such high values. In this respect the *A. australis* cells play an important role as a biological sponge, absorbing much of the nutrients which are discharged into False Bay.

At all these beaches inorganic phosphate appears to be more limiting than inorganic nitrogen. The supply of nitrogen is much higher than that of phosphorus (N_i:P_i = 16.8) compared to the cellular proportion of the two nutrients required by the cells (*A. australis* cells have a N:P of 2.6; Fig. 86). Phosphorous uptake has been shown to be non-related to the cellular C:P ratio (Harrison, 1983); the C:P ratio for assimilation can be as low as 30 while the C:P ratio for cells was 77 on average. The difference is accounted for by phosphorous regeneration which has been shown to meet up to 50% of the phosphorous requirements for production (Harrison, 1983).

The product of groundwater total inorganic nutrients and the groundwater slope (Table 4) shows that Muizenberg, the Sundays River beach, Glentana and Walker Bay have large amounts of land-derived nutrients entering the surf-zones. The beaches which lacked *A. australis* accumulations (with the exception of East London Beach and Oyster Bay) had low input of inorganic nitrogen and total inorganic nutrient (Table 4). East London Beach is a short, polluted beach (Fig. 9, 15, 21, 27), probably a low energy beach with a low flushing rate. On one occassion, well after the completion of this study, accumulations of *Anaulus australis* were reported by D.R. du Preez at Oyster Bay; so this beach occasionally develops accumulations.

Despite the exceptions, a linear regression of inorganic nitrogen input and the standing stock gives an r^2 of 0.724 (n = 19). Regressing total inorganic nutrient input and standing stock gives a slightly improved r^2 of 0.750. There is a highly significant correlation between the magnitude of the input of nitrogen into the surf-zone from coastal aquifers, making this input a prerequisite for the development of accumulations.

In the analysis of species composition 85 species were recorded in the foam (section 3.2.1), 39 in accumulation foam (section 3.2.2), 99 species in the water (section 3.2.3) and 52 species in the sand (section 3.2.4).

The dominant microplankton is *Anaulus australis*, this diatom comprising 46.3% of the population in the water, 54.6% of the foam, 75.8% of patch foam and 21.6% of the sand population.

In any given sample, on average, 11 species appear in the water and 8 in the sand (Fig. 35 and 36), an average of 9 species being recorded in the foam (Fig. 37 and 38).

The species diversity is high in the water and sand (10.6; Fig. 39 and 8.1; Fig. 40) and low in the foam and patch foam (1.8; Fig. 41 and 1.7; Fig. 42). There is no difference between the diversity indices in the foam and patch foam (Fig. 41 and 42).

Water and sand have similar degrees of dominance (0.47 and 0.45; Fig. 43 and 44). The difference between foam and patch foam was in the degree of dominance. The foam has a dominance index of 0.52 (Fig. 45), which is not much higher than that of the water but the patch foam has an index of dominance of 0.78 (Fig. 46), which is almost twice that of the water. Dominance indices are high in the water at beaches where there were accumulations.

Diatoms are the dominant phytoplankton (92.5% in water, Fig. 47; 91.9% in foam, Fig. 49; 98.0% in patch foam, Fig. 50; in sand 86.5%, Fig. 48). Much of the balance is made up of dinoflagellates: 1.7% in the water (Fig. 51), 2.7% in the foam (Fig. 52), 1.6% in patch foam (Fig. 53) and 5.5% in the sand (Fig. 54), making them an important part of the population in the sand. Flagellates were present in large numbers in selected samples (Fig. 55-58), greens were rare, and blue-greens occurred only in sand (Fig. 59-64).

Analysis of the phytoplankton community by CANOCO and TWINSPAN shows a primary separation of freshwater species in all cases (Fig. 65-68). There is a gradient from psammic to pelagic (Fig. 65 and 66). Excluding the sand species, the following species can be considered to be typical surf diatoms:

Achnanthes sp.
Anaulus australis
Asterionella glacialis
Asteriomphalus sp.
Aulacodiscus johnsonii
Aulacodiscus petersii
Biddulphia sp.
Circular blue-green sp.
Campylosira cymbelliformis
Grammatophora marina
Melosira sulcata
Thalassiosira large
Gyrosigma sp.
2 *Navicula* spp.
Nitzschia closterium
Nitzschia longissima
Noctiluca milearis
Prorocentrum micans
Thalassiosira rotula
Rhizosolenia stolterfothii
Surirella sp.
Very small square diatom.

Of these *Anaulus australis*, *Asterionella glacialis*, *Aulacodiscus johnsonii*, *Aulacodiscus petersii*, *Navicula* sp. and *Nitzschia closterium* accumulate into patches (see Appendix 3).

The analysis of the sites shows separation between the freshwater-influenced samples, the sand samples and the water samples (Fig. 69-72). The samples from the area around Knysna area (Buffalo Bay, Keurboomstrand, Wilderness, Sedgefield, Glentana) separated in the first division (Fig. 70). The area to the east of the Sundays River beach (Port Alfred, East London, Cintsa Bay) did not separate out; it did separate out from the east coast samples (Campbell and Bate, 1990c), placing this area in the south coast phytogeographic region.

The chlorophyll *a* content in standing stocks along the south coast was on average 34 ± 9 mg chl *a* m^{-3} for water samples (Fig. 73) and 187 ± 39 mg chl *a* m^{-3} for foam samples (Fig. 74) indicating a sixfold surface enrichment (Fig. 76). On average, total standing stock was 19 g chl *a* m^{-1} on average. A ratio of

0.27 ± 0.03 water:sand chlorophyll indicates that the sand contained almost 4 times (1/0.27) more chlorophyll than the water.

On the basis of species composition and standing stocks four different areas can be distinguished along the south coast: firstly, the False Bay beaches, with extremely high standing stocks of phytoplankton (Fig. 79); secondly, the section of coast from Cape Agulhas to Vleesbaai; and thirdly, the section of coast from Glentana to Keurboomstrand which has a different species composition to the rest. The fourth region is between Oyster Bay and Cintsa Bay which has a phytoplankton community similar to that of the second region. Because the communities of the False Bay beaches resembled those of the second and fourth regions, two phytogeographic regions can be identified:

1. Cape Point to Vleesbaai, and Oyster Bay to the Cape/Transkei border.
2. Mossel Bay to the Tsitsikamma.

The number of patches per kilometre ranged from 0.4 to 5.1, Muizenberg and Vleesbaai having the highest number of patches per kilometre. Distinctive features of accumulations allow the identification of three groups of beaches:

1. **Major accumulating beaches:**
   Accumulations are almost always present
   High phytoplankton concentrations in accumulations
   High standing stock of phytoplankton
   Beaches are Muizenberg, Macassar, Vleesbaai, Sundays River beach.

2. **Accumulating beaches:**
   Accumulations occur often
   High phytoplankton concentrations in accumulations
   Low standing stock of phytoplankton
   Beaches are Struisbaai, De Hoop, Wilderness, Van Stadens and Cintsa.

3. **Occasionally accumulating beaches:**
   Accumulations occur rarely
   Low phytoplankton concentrations in accumulations
   Low standing stock of phytoplankton
   Beaches are Buffalo Bay, Glentana, Sedgefield and Oyster Bay.

The vertical distribution of standing stock between foam, water and sand shows that in the Knysna area a large proportion of the standing stock was in the water column rather than in the sand (Fig. 77 and 78).

The nutrient content of cells gives an indication of their time-integrated response to the environment (Geider, 1987). If the environmental conditions on the day of sampling is atypical, the nutrient status of the cells would be a better indication of the average conditions which the cells had been experiencing.

The carbon:nitrogen ratio showed no differences along the coast (Fig. 84). The carbon:phosphorus ratio showed a linear increase from west to east (Fig. 85). This increase is also reflected in the nitrogen:phosphorus ratio (Fig. 86) and indicates that phosphorus becomes limiting towards the east. The carbon to chlorophyll *a* ratio was similar at Muizenberg and Sundays (Fig. 87), low values of less than 40 mg C mg chl a^{-1} being recorded. The rest of the values are around 100 mg C mg chl a^{-1}. The chlorophyll *a* per cell was high at Muizenberg, more than twice that measured at any other beach (Fig. 90).

The primary production estimates showed that Muizenberg, Walker Bay and Vleesbaai had high values (Fig. 93). The average primary production for south coast beaches was 472 $\pm$ 113 kg C m beach^{-1} year^{-1}.

Those beaches which had accumulations of *A. australis* had a mean primary production of 482 $\pm$ 150 kg C m beach^{-1} year^{-1} (excluding Muizenberg at 392 $\pm$ 136 kg C m beach^{-1} year^{-1}), and beaches which had no accumulations had a mean primary production of 241 $\pm$ 67 kg C m beach^{-1} year^{-1} (excluding Walker Bay at 234 $\pm$ 77 kg C m beach^{-1} year^{-1}). Thus at beaches where *A. australis* is present, it represents a major contributor to the production. Assuming the background primary production for surf-zones along the south coast to be 240 kg C m beach^{-1} year^{-1} then *A. australis* accumulations contribute 50% of the total south coast primary production in the surf-zones. With a mean rate of primary production of 472 kg C m beach^{-1} year^{-1}, and a total of 514 km of sandy coastline, the total primary production of south coast sandy beach surf-zones is estimated at 243 kilotonnes C y^{-1}.

Acknowledgements

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

FOAM

Beach	Beacon	Buff	Buff	Keurb	Keurb	Keurb	Keurb	Keurb
Coord	23.3	23	23	23.42	23.42	23.42	23.42	23.42
Achnanthes sp.								
Actinastrum (rosette BG)								
Amphiprora sp.								
Amphora sp.					3.4			
Anacystis sp.								
Anaulus australis	7.6	21.7	97.6	3.1	7.5			
Asterionella glacialis								
Asteriomphalus sp.								
Aulacodiscus johnsonii		0.3	1.1	3.1	1.1	0.8		
Aulacodiscus petersii			0.5	2.4	1.5		0.2	
Biddulphia alternans								
Bluegreen chain								
Bluegreen circular								
Campylosira cymbelliformis					2.2		1.4	
Centric Large								
Centric Small								
Ceratium furca/marina								
Chaetoceros affinis	1.4							
Chaetoceros large								
Chaetoceros medium	1.2							9.0
Chaetoceros small	14.9	7.8			2.6	2.1	10.3	17.1
Chaetoceros paired		1.6		1.0				
Chaetoceros protuberans	0.9							
Cocconeis epiphyte								
Thalassiosira large								
Desmid								
Dinophysis acuminata			0.2					
Diploneis sp.								
Distephanus sp.								
Ditylum sp.								
Unknown Epiphyte								
Cocconeis epiphyte								
Eucampia zoodiacus								
Flagellate L								
Flagellate M								
Flagellate Small								
Grammatophora marina								
Greens								
Gyrodinium sp.								
Gyrosigma sp.								
Hemiaulus hauckii		23.9						
Leptocylindrus danicus	10.2			15.7	9.7	14.5	13.7	6.3
Leptocylindrus sp.								
Licmophora sp.		0.6			0.4			
Melosira sulcata	1.7							
Merismopedia sp.								
Micractinium sp. (spikey)								
Navicula classic								
Navicula football					0.7	0.8		
Navicula large								
Navicula sp.				1.0				
Navicula sp. large								
Nitzschia drawing	1.7			3.1	3.0	2.9	0.7	1.3
Nitzschia closterium				0.3		0.6		
Nitzschia delicatissima	1.4	14.0		2.1		10.3	5.3	3.1
Nitzschia longissima								
Nitzschia pacifica								
Nitzschia seriata	35.5	15.8	0.7	49.7	37.3	57.9	53.7	50.4
Nitzschia sp		2.2						
Nitzschia very small								

Pediastrum sp.								
Peridinium sp.	2.1	0.9		1.8	2.6	3.9	2.1	0.5
Peridinium black								
Peridinium small								
Plagiogramma van heurckii								
Pleurosigma sp.								
Prorocentrum micans								
Rhizosolenia alata								
Rhizosolenia delicatula	1.9	9.6						
Rhizosolenia robusta								
Rhizosolenia sp.								
Rhizosolenia stolterfothii								
Rhizosolenia styliformis								
Scenedesmus sp.								
Schroederella 1	15.9			14.1	22.8	6.2	12.6	9.2
Schroederella 2	1.4			1.3	5.2			3.2
Skeletonema costatum								
Striatella								
Surirella sp.								
Thalassionema nitzschioides			0.3	1.0				
Thalassiosira decipiens								
Thalassiosira rotula	1.9							
Thalassiosira sp.		1.2						
Thalassiothrix sp.	0.2						0.2	
Club								

	Keurb 23.42	Keurb 23.42	Keurb 23.42	Plett 23.3	Buff 23	Glen 22.33	Macas 18.75	Muiz 18.5	Buff 23
Achnanthes sp.									
Actinastrum (rosette BG)									
Amphiprora sp.									
Amphora sp.		0.9							
Anacystis sp.									
Anaulus australis			2.7			67.2	85.4	96.0	91.2
Asterionella glacialis			11.4		0.5	0.3	2.0	2.8	8.2
Asteriomphalus sp.						1.6			
Aulacodiscus johnsonii	0.8	0.5	2.3	0.2		0.5			
Aulacodiscus petersii		0.2	0.4			1.1			0.3
Biddulphia alternans									
Bluegreen chain									
Bluegreen circular									
Campylosira cymbelliformis		0.8					4.0		
Centric Large									
Centric Small									
Ceratium furca/marina		0.5			2.6	1.6			
Chaetoceros affinis									
Chaetoceros large					5.1				
Chaetoceros medium					20.4				
Chaetoceros small	1.9	3.6		13.7	7.7				
Chaetoceros paired									
Chaetoceros protuberans									
Cocconeis epiphyte									
Thalassiosira large				0.4					
Desmid									
Dinophysis acuminata									
Diploneis sp.									
Distephanus sp.	0.5								
Ditylum sp.									
Unknown Epiphyte			3.8						
Cocconeis epiphyte									
Eucampia zoodiacus				0.7					
Flagellate L									
Flagellate M									
Flagellate Small			21.2						
Grammatophora marina									
Greens			5.7						
Gyrodinium sp.		1.4				0.3			
Gyrosigma sp.									
Hemiaulus hauckii		1.4		0.9	12.8				
Leptocylindrus danicus	11.4	14.4		7.7	9.2				
Leptocylindrus sp.									
Licmophora sp.					2.6				
Melosira sulcata			1.5			0.8			
Merismopedia sp.									
Micractinium sp. (spikey)									
Navicula classic			2.3						
Navicula football	1.1		1.9	0.9			0.8	0.2	
Navicula large									
Navicula sp.			1.5				4.6		
Navicula sp. large							2.3		
Nitzschia drawing	4.3	5.4		0.7					
Nitzschia closterium			4.5						
Nitzschia delicatissima				3.3	2.0	0.5			
Nitzschia longissima				0.2			0.2		
Nitzschia pacifica									
Nitzschia seriata	70.7	58.7		51.0	20.4				
Nitzschia sp									
Nitzschia very small									
Pediastrum sp.									
Peridinium sp.	3.8	5.6	4.9	1.5	2.0				0.3
Peridinium black						9.4			
Peridinium small									
Plagiogramma van heurckii									

Pleurosigma sp.												
Prorocentrum micans												
Rhizosolenia alata								14.8				0.2
Rhizosolenia delicatula		0.5			0.7		8.7					
Rhizosolenia robusta							0.5					
Rhizosolenia sp.												
Rhizosolenia stolterfothii							2.6					
Rhizosolenia styliformis								0.3				
Scenedesmus sp.												
Schroederella 1		5.4			16.0		2.0					
Schroederella 2	1.9	1.6			0.7							
Skeletonema costatum												
Striatella												
Surirella sp.											0.8	
Thalassionema nitzschioides				3.0		1.5			0.3			
Thalassiosira decipiens			17.0									
Thalassiosira rotula			13.3				1.0					
Thalassiosira sp.	2.7		2.7					1.3		0.9		
Thalassiothrix sp.												
Club												

	Dc Hp	Glen	Muiz 1	Muiz 2	Muiz 3	Muiz 4	Muiz 5	Muiz 6	Muiz 7
	20.5	22.33	18.5	18.5	18.5	18.5	18.5	18.5	18.5
Achnanthes sp.						0.6			
Actinastrum (rosette BG)									
Amphiprora sp.									
Amphora sp.									
Anacystis sp.									
Anaulus australis	97.6	28.0	98.7	97.4	91.2	96.2	17.1	81.5	56.9
Asterionella glacialis		4.3		0.7	2.5		6.3	1.8	
Asteriomphalus sp.									
Aulacodiscus johnsonii			0.2			0.3			
Aulacodiscus petersii	2.4								
Biddulphia alternans									
Bluegreen chain						2.9			
Bluegreen circular									
Campylosira cymbelliformis			1.2		1.9			4.4	6.0
Centric Large									
Centric Small						2.4			
Ceratium furca/marina									
Chaetoceros affinis									
Chaetoceros large									
Chaetoceros medium								0.2	1.2
Chaetoceros small									
Chaetoceros paired									
Chaetoceros protuberans									
Cocconeis epiphyte									
Thalassiosira large									
Desmid									
Dinophysis acuminata									
Diploneis sp.									
Distephanus sp.									
Ditylum sp.									
Unknown Epiphyte									
Cocconeis epiphyte									
Eucampia zoodiacus									
Flagellate L		23.0						0.3	
Flagellate M									
Flagellate Small						0.7			
Grammatophora marina									
Greens						26.8			
Gyrodinium sp.									
Gyrosigma sp.									
Hemiaulus hauckii									
Leptocylindrus danicus				1.0	3.1	1.0	4.9	2.2	1.5
Leptocylindrus sp.									
Licmophora sp.									
Melosira sulcata									
Merismopedia sp.						19.5			
Micractinium sp. (spikey)								31.4	
Navicula classic			0.7		0.6				
Navicula football		1.6			0.3		0.3		
Navicula large			0.3						
Navicula sp.				0.3					
Navicula sp. large									
Nitzschia drawing									
Nitzschia closterium									
Nitzschia delicatissima							0.9	0.3	
Nitzschia longissima		6.6							
Nitzschia pacifica									
Nitzschia seriata									
Nitzschia sp		1.6							
Nitzschia very small									
Pediastrum sp.						4.9			
Peridinium sp.				0.3			0.3		
Peridinium black		7.6							
Peridinium small		26.3							
Plagiogramma van heurckii									

Pleurosigma sp.							
Prorocentrum micans							
Rhizosolenia alata							
Rhizosolenia delicatula						0.6	0.3
Rhizosolenia robusta							
Rhizosolenia sp.							
Rhizosolenia stolterfothii							
Rhizosolenia styliformis							
Scenedesmus sp.					20.7		
Schroederella 1							
Schroederella 2							
Skeletonema costatum							
Striatella							
Surirella sp.							
Thalassionema nitzschioides	1.0			0.3	0.3		
Thalassiosira decipiens							
Thalassiosira rotula							
Thalassiosira sp.			0.3	0.6		3.1	0.3
Thalassiothrix sp.							
Club							

	Muiz 1	Muiz 2	Muiz 3	Muiz 4	Muiz 5	Muiz 6	Muiz 7	Muiz	Muiz
	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
Achnanthes sp.			0.2						
Actinastrum (rosette BG)							0.7		
Amphiprora sp.									
Amphora sp.									
Anacystis sp.						0.5			
Anaulus australis	92.2	99.0	96.2	98.4	87.5	90.6	36.7	87.5	86.7
Asterionella glacialis	1.7		1.4	0.5		1.9	0.2	1.5	3.1
Asteriomphalus sp.									
Aulacodiscus johnsonii			0.2	0.2					
Aulacodiscus petersii									
Biddulphia alternans									
Bluegreen chain									
Bluegreen circular						26.1			
Campylosira cymbelliformis	2.8	1.0	0.2	0.3	0.2	7.1	3.8	0.6	3.1
Centric Large			1.4						
Centric Small						1.4			
Ceratium furca/marina									
Chaetoceros affinis									
Chaetoceros large									
Chaetoceros medium									
Chaetoceros small									
Chaetoceros paired									
Chaetoceros protuberans									
Cocconeis epiphyte									
Thalassiosira large									
Desmid									
Dinophysis acuminata									
Diploneis sp.									
Distephanus sp.									
Ditylum sp.						0.2			
Unknown Epiphyte									
Cocconeis epiphyte									
Eucampia zoodiacus									
Flagellate L						2.8			
Flagellate M									
Flagellate Small									
Grammatophora marina									
Greens					6.6				
Gyrodinium sp.									
Gyrosigma sp.									
Hemiaulus hauckii								0.3	
Leptocylindrus danicus	2.2				1.3			6.1	0.9
Leptocylindrus sp.									
Licmophora sp.									
Melosira sulcata									
Merismopedia sp.									
Micractinium sp. (spikey)						24.9			
Navicula classic									
Navicula football			0.2	0.3		0.5			
Navicula large									
Navicula sp.									
Navicula sp. large									
Nitzschia drawing							1.5	0.9	
Nitzschia closterium								0.9	
Nitzschia delicatissima				0.3					
Nitzschia longissima	0.6				0.2	0.5	0.3		
Nitzschia pacifica									
Nitzschia seriata									
Nitzschia sp									
Nitzschia very small									
Pediastrum sp.					0.7				
Peridinium sp.									
Peridinium black									
Peridinium small									
Plagiogramma van heurckii									

Pleurosigma sp.								
Prorocentrum micans								
Rhizosolenia alata								
Rhizosolenia delicatula						1.2		
Rhizosolenia robusta								
Rhizosolenia sp.			0.3					
Rhizosolenia stolterfothii								0.6
Rhizosolenia styliformis								
Scenedesmus sp.		3.3			1.4			
Schroederella 1								
Schroederella 2								
Skeletonema costatum								
Striatella								
Surirella sp.				0.2				
Thalassionema nitzschioides							0.3	
Thalassiosira decipiens								
Thalassiosira rotula								1.2
Thalassiosira sp.	0.6	0.2				1.2		2.2
Thalassiothrix sp.								
Club								

	Muiz	Noord	Sedge	Stil	Struis	Sund	Vlees	Wild	Bonza
	18.5	18	22.8	21.43	20.05	26	21.92	22.58	27.97
Achnanthes sp.									
Actinastrum (rosette BG)									
Amphiprora sp.								23.3	
Amphora sp.									
Anacystis sp.									
Anaulus australis	4.8	18.0	93.3	51.2	90.0	44.3	95.6	96.7	
Asterionella glacialis	0.5	3.1	2.0	43.9	4.5	49.6	0.5		
Asteriomphalus sp.									
Aulacodiscus johnsonii				0.9	1.0		0.5	1.4	1.1
Aulacodiscus petersii					0.3		0.7		
Biddulphia alternans									
Bluegreen chain									
Bluegreen circular									
Campylosira cymbelliformis						2.3	1.7		
Centric Large									
Centric Small									
Ceratium furca/marina									
Chaetoceros affinis									
Chaetoceros large									
Chaetoceros medium		23.7							
Chaetoceros small		8.8							
Chaetoceros paired									
Chaetoceros protuberans									
Cocconeis epiphyte								5.6	
Thalassiosira large		1.0						4.4	
Desmid	3.3								
Dinophysis acuminata									
Diploneis sp.									
Distephanus sp.									
Ditylum sp.									
Unknown Epiphyte									
Cocconeis epiphyte									
Eucampia zoodiacus			0.4						
Flagellate L									
Flagellate M		10.3					0.4		
Flagellate Small									
Grammatophora marina									15.6
Greens	48.9								
Gyrodinium sp.		5.2							
Gyrosigma sp.									
Hemiaulus hauckii						0.2			
Leptocylindrus danicus									
Leptocylindrus sp.	4.1								
Licmophora sp.						0.4	0.2	21.1	
Melosira sulcata			0.9						
Merismopedia sp.									
Micractinium sp. (spikey)									
Navicula classic								8.9	
Navicula football				2.7	2.6	0.9	0.3		
Navicula large									
Navicula sp.			0.7				0.2		
Navicula sp. large									
Nitzschia drawing									
Nitzschia closterium		3.6	1.1		1.0				
Nitzschia delicatissima									
Nitzschia longissima	1.2	6.2	0.4	1.3				0.6	
Nitzschia pacifica									
Nitzschia seriata									
Nitzschia sp	3.3	7.2	1.1		0.6			11.1	
Nitzschia very small									
Pediastrum sp.	16.9								
Peridinium sp.							0.4		
Peridinium black									
Peridinium small									
Plagiogramma van heurckii									

Pleurosigma sp.									
Prorocentrum micans									
Rhizosolenia alata							0.2		
Rhizosolenia delicatula									
Rhizosolenia robusta									
Rhizosolenia sp.		7.7							
Rhizosolenia stolterfothii									
Rhizosolenia styliformis									
Scenedesmus sp.	15.5								
Schroederella 1									
Schroederella 2									
Skeletonema costatum									
Striatella									
Surirella sp.								3.3	
Thalassionema nitzschioides		1.5							5.6
Thalassiosira decipiens						1.6			
Thalassiosira rotula	0.5	3.6					0.3	0.4	
Thalassiosira sp.	1.0					0.7			
Thalassiothrix sp									
Club									

	Buff	Cintsa	De Hoop	EL	Glen	Keurb	Mait	Macas	Muiz
	23	28.12	20.5	27.92	22.3	23.42	25	18.75	18.5
Achnanthes sp.									
Actinastrum (rosette BG)									
Amphiprora sp.									
Amphora sp.			0.3						
Anacystis sp.									
Anaulus australis	33.1	26.3	61.2	18.9	26.3	2.6	35.3	98.4	19.0
Asterionella glacialis	33.1	3.4	1.2		3.3	16.1	32.5		
Asteriomphalus sp.									
Aulacodiscus johnsonii			2.9			1.2		0.2	
Aulacodiscus petersii			1.2			1.2			
Biddulphia alternans			2.0						
Bluegreen chain									
Bluegreen circular									
Campylosira cymbelliformis							2.3	0.8	
Centric Large									
Centric Small									
Ceratium furca/marina									
Chaetoceros affinis									
Chaetoceros large									
Chaetoceros medium		5.7			2.3	13.2	8.5		
Chaetoceros small					1.3				
Chaetoceros paired									
Chaetoceros protuberans					1.0				
Cocconeis epiphyte			0.3						
Thalassiosira large			4.7						
Desmid									
Dinophysis acuminata									
Diploneis sp.			1.2						
Distephanus sp.									
Ditylum sp.									
Unknown Epiphyte									
Cocconeis epiphyte								3.2	
Eucampia zoodiacus									
Flagellate L									
Flagellate M									
Flagellate Small									
Grammatophora marina				0.6					
Greens								0.2	
Gyrodinium sp.		63.5							
Gyrosigma sp.							0.8		
Hemiaulus hauckii			3.5			0.9			
Leptocylindrus danicus				29.7		4.4			
Leptocylindrus sp.									
Licmophora sp.		0.7	2.0		0.3				
Melosira sulcata			0.9						
Merismopedia sp.									
Micractinium sp. (spikey)									
Navicula classic		0.5	2.6				1.4		
Navicula football			4.4	21.6	0.5	1.5	1.1	0.7	
Navicula large									
Navicula sp.						2.0			
Navicula sp. large									
Nitzschia drawing		0.9							
Nitzschia closterium	2.4	2.3			5.0				
Nitzschia delicatissima	17.0			5.4	52.6	52.6	7.1		
Nitzschia longissima	0.5				1.5	0.9	0.8		0.1
Nitzschia pacifica						1.2			
Nitzschia seriata		1.6			1.3				
Nitzschia sp	2.1				2.8			0.1	
Nitzschia very small							2.8		
Pediastrum sp.								77.0	
Peridinium sp.			0.9			1.5			
Peridinium black									
Peridinium small									
Plagiogramma van heurckii				5.8					

Pleurosigma sp.		0.3							
Prorocentrum micans						2.9	1.1		
Rhizosolenia alata									
Rhizosolenia delicatula							1.1		
Rhizosolenia robusta									
Rhizosolenia sp.									
Rhizosolenia stolterfothii									
Rhizosolenia styliformis									
Scenedesmus sp.									0.1
Schroederella 1									
Schroederella 2									
Skeletonema costatum	3.5	0.5			1.3				
Striatella		0.9							
Surirella sp.									
Thalassionema nitzschioides		0.5	2.9	24.3	0.3				
Thalassiosira decipiens							2.5		
Thalassiosira rotula	2.6			0.5			0.6		
Thalassiosira sp.									
Thalassiothrix sp.									0.1
Club		0.3							

	Oyster	PAlf	Sedge	Stilb	Struis	Sund	Vlees	Walker	Wild
	24.63	26.93	22.8	21.43	20.05	26	21.92	19.3	22.58
Achnanthes sp.									
Actinastrum (rosette BG)									
Amphiprora sp.									
Amphora sp.									
Anacystis sp.									
Anaulus australis	56.1	60.6	92.6	96.3	69.2	63.9	99.8	92.7	17.2
Asterionella glacialis	5.2	3.0	2.3		4.1	32.0	0.1	3.3	18.9
Asteriomphalus sp.									
Aulacodiscus johnsonii	5.2		0.5		3.8		0.1		0.9
Aulacodiscus petersii	0.2		0.2						
Biddulphia alternans									
Bluegreen chain									
Bluegreen circular									
Campylosira cymbelliformis			1.8			0.9			
Centric Large									
Centric Small									
Ceratium furca/marina									
Chaetoceros affinis									
Chaetoceros large									
Chaetoceros medium		3.4			5.8				9.6
Chaetoceros small	3.4							5.1	
Chaetoceros paired									
Chaetoceros protuberans									
Cocconeis epiphyte		1.2							
Thalassiosira large									
Desmid									
Dinophysis acuminata									
Diploneis sp.									
Distephanus sp.									
Ditylum sp.									
Unknown Epiphyte									
Cocconeis epiphyte									
Eucampia zoodiacus									
Flagellate L									
Flagellate M									
Flagellate Small									
Grammatophora marina									
Greens									
Gyrodinium sp.									
Gyrosigma sp.									
Hemiaulus hauckii									2.6
Leptocylindrus danicus									
Leptocylindrus sp.									
Licmophora sp.	0.8	7.3		0.6					0.5
Melosira sulcata									0.7
Merismopedia sp.									
Micractinium sp. (spikey)									
Navicula classic			0.5						
Navicula football		2.4		2.2		0.3		1.7	1.5
Navicula large									
Navicula sp.					0.8				
Navicula sp. large									
Nitzschia drawing									
Nitzschia closterium	3.2				1.2	0.5			2.2
Nitzschia delicatissima	16.0		2.3						14.6
Nitzschia longissima						0.2			
Nitzschia pacifica									
Nitzschia seriata					0.3				1.0
Nitzschia sp	1.6	3.0	1.6	0.9					
Nitzschia very small								1.0	3.6
Pediastrum sp.									
Peridinium sp.									
Peridinium black									
Peridinium small									
Plagiogramma van heurckii									

Pleurosigma sp.									
Prorocentrum micans	1.2	1.2						1.3	6.0
Rhizosolenia alata					14.0				
Rhizosolenia delicatula									
Rhizosolenia robusta									
Rhizosolenia sp.									
Rhizosolenia stolterfothii									
Rhizosolenia styliformis									
Scenedesmus sp.									
Schroederella 1									
Schroederella 2									
Skeletonema costatum					0.8				14.6
Striatella									
Surirella sp.									
Thalassionema nitzschioides	0.8								
Thalassiosira decipiens	1.2	19.4				1.7			
Thalassiosira rotula	1.2								0.9
Thalassiosira sp.	0.4					0.5			
Thalassiothrix sp.									0.2
Club									

PATCH FOAM

Beach	Buff	Buff	Macas	Muiz	Muiz	Muiz	Sedge	Struis	Vlees
Coord	23	23	18.75	18.5	18.5	18.5	22.8	20.05	21.92
Achnanthes sp.				0.3					
Actinoptychus sp.		0.1							
Anaulus australis	12.2	0.7	99.9	84.0	96.4	97.5	85.8	98.0	97.9
Asterionella glacialis	8.2		0.0	3.2	1.3				
Aulacodiscus johnsonii			0.0			2.4	12.0	1.8	1.5
Aulacodiscus kittonii						0.1	2.1	0.2	0.1
Biddulphia mobiliensis		0.1							
Campylosira cymbelliformis			0.0	2.9	0.4	0.0			0.4
Ceratium furca/marina	8.2								
Chaetoceros medium	4.1								
Distephanus sp.		0.4							
Flagellates		85.8							
Gyrodinium sp.		4.6							
Hemiaulus hauckii	10.2			0.2					
Leptocylindrus danicus				2.2	0.3				
Licmophora sp.	2.0	0.1							0.0
Melosira sulcata				0.3		0.0			
Navicula classic				0.2					
Navicula football									
Navicula picture				0.9	0.2				
Navicula spp.	14.3				0.2	0.0	0.1		0.1
Nitzschia closterium					0.2				0.0
Nitzschia delicatissima	2.0								
Nitzschia longissima									
Nitzschia seriata	4.1			0.3					
Nitzschia spp.	26.5					0.0			
Pediastrum sp.				0.1					
Peridinium sp.	6.1	7.1							
Plagiogramma van heurckii				0.3	0.1				
Prorocentrum micans		0.5			0.1				
Rhizosolenia delicatula				0.2	0.2				
Scenedesmus sp.				0.4	0.0				
Schroederella sp. 1		0.3							
Skeletonema costatum				1.9					
Thalassionema nitzschioides		0.4		0.1	0.0			0.0	
Thalassiosira decipiens				0.8	0.1				
Thalassiosira L						0.0		0.0	
Thalassiosira rotula			0.0	0.3	0.2				
Thalassiosira S	2.1			1.4	0.4			0.0	

	Walker 19.3	Wild 22.58	Wild 22.58
Achnanthes sp.	1.0		
Actinoptychus sp.			
Anaulus australis	52.1	85.6	99.4
Asterionella glacialis	9.7		
Aulacodiscus johnsonii	0.4	11.3	0.5
Aulacodiscus kittonii	0.7	3.1	0.0
Biddulphia mobiliensis			
Campylosira cymbelliformis	3.5		
Ceratium furca/marina			
Chaetoceros medium			
Distephanus sp.			
Flagellates			
Gyrodinium sp.			
Hemiaulus hauckii			
Leptocylindrus danicus			
Licmophora sp.			
Melosira sulcata			
Navicula classic			
Navicula football	5.7		
Navicula picture			
Navicula spp.	21.7		0.0
Nitzschia closterium	0.7		
Nitzschia delicatissima			
Nitzschia longissima	0.5		
Nitzschia seriata			
Nitzschia spp.			
Pediastrum sp.			
Peridinium sp.			
Plagiogramma van heurckii			
Prorocentrum micans	0.4		
Rhizosolenia delicatula			
Scenedesmus sp.			
Schroederella sp. 1			
Skeletonema costatum			
Thalassionema nitzschioides	0.4		
Thalassiosira decipiens			
Thalassiosira L			
Thalassiosira rotula	0.5		
Thalassiosira S	2.8		

WATER

Beach	Beacon W	Buff W	Buff W	Buff W	Keurb W	Keurb W	Keurb W	Keurb W	Keurb W
Longi	23.3	23	23	23.42	23.42	23.42	23.42	23.42	23.42
Achnanthes sp.									
Amphiprora sp.									
Amphora sp.			0.6					0.5	
Anacystis sp.									
Anaulus australis	11.3	4.1	6.5	53.0			1.5	4.1	
Asteriomphalus sp.									
Asterionella glacialis			0.6					0.5	
Aulacodiscus johnsonii									
Aulacodiscus petersii									
Biddulphia alternans									
Biddulphia amazing									
Biddulphia mobiliensis									
Biddulphia pulchella									
Biddulphia sp.									
Bluegreens (chain/circular)									
Campylosira cymbelliformis		0.3							1.0
Centric Large									
Centric Medium									
Centric Small									
Ceratium furca/marina		1.0	0.6	1.1					
Ceratium tripas									
Chaetoceros A (Drawing)			5.5			4.5			
Chaetoceros large					6.6				
Chaetoceros medium								5.3	
Chaetoceros paired									
Chaetoceros peruvianus		0.3							
Chaetoceros protuberans									
Chaetoceros small	13.3			2.9	8.5		8.5	10.7	10.7
Chaetoceros vanheureki		7.0							
Chain, pretty chl									
Climacopshenia Cupp 178									
Cocconeis epiphyte									
Desmid									
Dinophysis acuminata				0.6					
Diploneis sp.									
Distephanus sp.		1.3	0.6	0.3	1.7	1.2			
Ditylum brightwellii								0.2	
Epiphytic Cocconeis									
Eucampia zoodiacus		1.6				0.6			
Euglena sp.									
Flagellate									
Flagellate medium									
Flagellate Small		1.6							
Grammatophora marina				0.3					
Greens									
Gyrodinium sp.			1.3						
Hemiaulus hauckii		33.4	10.6	2.9	1.1				
Leptocylindrus danicus	5.1	4.5	2.6		12.2	6.6	14.2	9.8	9.0
Leptocylindrus sp.									
Licmophora sp.			0.6		0.4				
Melosira sulcata				2.0			0.4		
Merismopedia sp.									
Micractinium sp. (spikey)									
Navicula classic			1.0						
Navicula football			1.6		0.9	0.6			
Navicula large								6.4	
Navicula picture									
Navicula sp.		3.2							
Navicula Square									
Navicula Square L									
Navicula striped (109)									
Nitzschia A (Drawing)					1.3	1.5	4.7	0.9	
Nitzschia closterium							0.2		

Nitzschia delicatissima	0.8		1.0			1.2	7.0	2.3	2.0
Nitzschia longissima							0.4		
Nitzschia pacifica									
Nitzschia seriata	31.4	36.6	61.3	30.1	52.6	51.4	53.1	49.7	42.2
Nitzschia sp.									
Nitzschia very small									
Noctiluca milearis									
Pediastrum sp.									
Peridinium black									
Peridinium palidum									1.8
Peridinium sp.	2.3		2.3		1.5	1.2	0.9	0.7	
Plagiogramma van heurckii									
Pleurosigma sp.									0.3
Prorocentrum micans									
Rhizosolenia alata	1.1								
Rhizosolenia delicatula		1.9						6.6	
Rhizosolenia robusta									
Rhizosolenia sp.									
Rhizosolenia stolterfothii									
Rhizosolenia styliformis									
Scenedesmus sp.									
Schroederella 1	29.7				10.9	19.6	7.2	8.2	24.3
Schroederella 2	1.1				1.9	4.5	0.8	1.2	
Skeletonema costatum									
Stephanopyxis turris (bones)			1.6		5.7				
Striatella Cupp 172									
Surirella									
Surirella sp. 101									
Thalassionema nitzschioides		0.6	1.6			0.4			0.5
Thalassiosira decipiens									
Thalassiosira L									
Thalassiosira rotula	1.1		0.6			0.6			0.8
Thalassiosira S	2.0		2.6	1.1		6.3	1.3		
Thalassiothrix sp.									
Unknown - Very Small									
Zygobikodinium sp.									

	Keurb W	Keurb W	Plett W	Buff W	Macas W	Noetse W	Vlees W	Walker W	Wild W
	23.42	23.42	23.3	23	18.75	23	21.92	19.3	22.58
Achnanthes sp.									
Amphiprora sp.									
Amphora sp.									
Anacystis sp.									
Anaulus australis			22.2	3.8	64.2		96.1	35.6	14.6
Asteriomphalus sp.									
Asterionella glacialis							2.5	6.3	
Aulacodiscus johnsonii							3.2		2.5
Aulacodiscus petersii							0.2		
Biddulphia alternans									
Biddulphia amazing									
Biddulphia mobiliensis									
Biddulphia pulchella									
Biddulphia sp.									
Bluegreens (chain/circular)									
Campylosira cymbelliformis					2.0		0.2	2.2	
Centric Large									
Centric Medium									
Centric Small									
Ceratium furca/marina				3.0					2.1
Ceratium tripas				0.5					
Chaetoceros A (Drawing)									
Chaetoceros large				1.4					
Chaetoceros medium				12.7					1.7
Chaetoceros paired						13.0			
Chaetoceros peruvianus									
Chaetoceros protuberans				2.7					
Chaetoceros small	21.9	1.5	6.3	11.6		7.4			
Chaetoceros vanheurcki									
Chain, pretty chl									
Climacopshenia Cupp 178									
Cocconeis epiphyte									
Desmid									
Dinophysis acuminata				0.8					
Diploneis sp.									
Distephanus sp.			0.8					1.7	
Ditylum brightwellii									
Epiphytic Cocconeis									
Eucampia zoodiacus		0.6				5.6			
Euglena sp.									
Flagellate	1.5			1.2					
Flagellate medium									
Flagellate Small			1.6				32.5	12.5	
Grammatophora marina									
Greens				2.5			9.3	4.2	
Gyrodinium sp.									
Hemiaulus hauckii	4.2	3.1		3.5		5.6			
Leptocylindrus danicus	10.9	15.5	7.9	1.6	0.5	7.4			4.2
Leptocylindrus sp.									
Licmophora sp.					11.1				
Melosira sulcata								4.2	
Merismopedia sp.									
Micractinium sp. (spikey)									
Navicula classic									
Navicula football			0.8	2.0	3.7		2.2	2.1	
Navicula large									
Navicula picture									
Navicula sp.		4.8		1.0	7.4		7.4	5.0	
Navicula Square									
Navicula Square L									
Navicula striped (109)		2.2							
Nitzschia A (Drawing)	2.2					7.4			
Nitzschia closterium							1.9		
Nitzschia delicatissima	11.8	10.8						0.8	
Nitzschia longissima		0.6					1.2	2.1	

Nitzschia pacifica									
Nitzschia seriata	47.1	58.8	41.3	40.5		11.1			0.8
Nitzschia sp.									
Nitzschia very small									
Noctiluca milearis									2.1
Pediastrum sp.									
Peridinium black									10.4
Peridinium palidum				1.1					
Peridinium sp.		1.5	3.2			9.3		1.9	2.5
Plagiogramma van heurckii									
Pleurosigma sp.									
Prorocentrum micans				0.8					
Rhizosolenia alata								0.3	14.6
Rhizosolenia delicatula			6.3						0.8
Rhizosolenia robusta							0.2		
Rhizosolenia sp.									
Rhizosolenia stolterfothii									
Rhizosolenia styliformis									
Scenedesmus sp.									
Schroederella 1	1.3		7.9			11.1			
Schroederella 2	0.5								
Skeletonema costatum		1.9							
Stephanopyxis turris (bones)				8.1					
Striatella Cupp 172									
Surirella									
Surirella sp. 101									
Thalassionema nitzschioides				0.8				0.3	5.0
Thalassiosira decipiens									
Thalassiosira L									
Thalassiosira rotula		1.9			0.7		0.2	0.6	
Thalassiosira S				3.2					
Thalassiothrix sp.									
Unknown - Very Small					25.9				
Zygobikodinium sp.				0.5					

	Cintsa WDc	Hp W	Glen W	Keur W	Macas W	Mait W	Muiz W	Muiz W1	Muiz W2
	28.12	20.5	22.3	23.42	18.75	25	18.5	18.5	18.5
Achnanthes sp.									
Amphiprora sp.	1.9								
Amphora sp.									
Anacystis sp.									
Anaulus australis	82.5	94.1	67.2	5.7	89.2	41.7	96.2	76.9	89.5
Asteriomphalus sp.			1.6						
Asterionella glacialis	1.9		0.3	22.4	1.8	1.5		16.8	4.8
Aulacodiscus johnsonii		0.5	0.5						
Aulacodiscus petersii			1.1	1.1					
Biddulphia alternans									
Biddulphia amazing									
Biddulphia mobiliensis									
Biddulphia pulchella									
Biddulphia sp.						0.3			
Bluegreens (chain/circular)									
Campylosira cymbelliformis		0.2				6.0	1.7	1.1	2.2
Centric Large									
Centric Medium									
Centric Small									
Ceratium furca/marina		0.5	1.6						
Ceratium tripas									
Chaetoceros A (Drawing)									
Chaetoceros large									
Chaetoceros medium									
Chaetoceros paired									
Chaetoceros peruvianus									
Chaetoceros protuberans									
Chaetoceros small				3.8					
Chaetoceros vanheureki									
Chain, pretty chl									
Climacopshenia Cupp 178									
Cocconeis epiphyte									
Desmid									
Dinophysis acuminata									
Diploneis sp.									
Distephanus sp.						0.6			
Ditylum brightwellii									
Epiphytic Cocconeis									
Eucampia zoodiacus									
Euglena sp.									
Flagellate									
Flagellate medium									
Flagellate Small						35.7			
Grammatophora marina									
Greens					7.4				
Gyrodinium sp.			0.3			0.9			
Hemiaulus hauckii								0.4	
Leptocylindrus danicus								1.9	
Leptocylindrus sp.									
Licmophora sp.									
Melosira sulcata			0.8						
Merismopedia sp.									
Micractinium sp. (spikey)									
Navicula classic	1.0								
Navicula football		0.8		3.5		2.4			
Navicula large									
Navicula picture									
Navicula sp.				3.2		1.4			
Navicula Square									
Navicula Square L				2.2					
Navicula striped (109)									
Nitzschia A (Drawing)					0.6				
Nitzschia closterium								0.4	
Nitzschia delicatissima		0.2	0.5			0.9		0.7	2.6
Nitzschia longissima				4.1		0.9		1.5	

Nitzschia pacifica												
Nitzschia seriata							0.6		0.6			
Nitzschia sp.	3.9											
Nitzschia very small												
Noctiluca milearis												
Pediastrum sp.												
Peridinium black				9.4								
Peridinium palidum												
Peridinium sp.							2.1		1.5	0.3		
Plagiogramma van heurckii												
Pleurosigma sp.												
Prorocentrum micans		1.9										
Rhizosolenia alata				14.8				0.6				
Rhizosolenia delicatula			0.7					0.8				1.0
Rhizosolenia robusta												
Rhizosolenia sp.												
Rhizosolenia stolterfothii												
Rhizosolenia styliformis				0.3								
Scenedesmus sp.											0.4	
Schroederella 1						7.3						
Schroederella 2												
Skeletonema costatum												
Stephanopyxis turris (bones)												
Striatella Cupp 172												
Surirella												
Surirella sp. 101							3.2					
Thalassionema nitzschioides		2.9			0.3		1.4		0.6			
Thalassiosira decipiens						29.7						
Thalassiosira L	3.9											
Thalassiosira rotula			1.0			13.0						
Thalassiosira S			2.0	1.3		2.7		0.5				
Thalassiothrix sp.												
Unknown - Very Small												
Zygobikodinium sp.												

	Muiz W3	Muiz W4	Muiz W5	Muiz W6	Muiz W7	Muiz W5	Muiz W6	Muiz W7	Muiz W
	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
Achnanthes sp.	0.7		0.6						
Amphiprora sp.									
Amphora sp.									
Anacystis sp.						0.7			
Anaulus australis	91.5	92.1	79.5	9.9	53.3	17.9	93.8	58.3	69.0
Asteriomphalus sp.									
Asterionella glacialis	1.4	2.3	5.1		1.7			0.3	3.7
Aulacodiscus johnsonii	0.3								
Aulacodiscus petersii									
Biddulphia alternans									
Biddulphia amazing									
Biddulphia mobiliensis									
Biddulphia pulchella									
Biddulphia sp.									
Bluegreens (chain/circular)				0.6	0.3	0.7		13.8	
Campylosira cymbelliformis	5.1	3.3	2.8		7.2	1.3	3.1	10.4	3.2
Centric Large									
Centric Medium				2.1		3.3			
Centric Small			2.8			19.5		1.8	
Ceratium furca/marina									
Ceratium tripas									
Chaetoceros A (Drawing)									
Chaetoceros large									
Chaetoceros medium							0.6	1.2	1.5
Chaetoceros paired									
Chaetoceros peruvianus									
Chaetoceros protuberans									
Chaetoceros small	0.7								
Chaetoceros vanheureki									
Chain, pretty chl									
Climacopshenia Cupp 178				1.1					
Cocconeis epiphyte									
Desmid									
Dinophysis acuminata									
Diploneis sp.									
Distephanus sp.									
Ditylum brightwellii									
Epiphytic Cocconeis									
Eucampia zoodiacus									
Euglena sp.									
Flagellate									
Flagellate medium								3.4	
Flagellate Small					5.2				
Grammatophora marina									
Greens				61.7					
Gyrodinium sp.									
Hemiaulus hauckii									
Leptocylindrus danicus			1.7	0.6	1.7	6.8		0.6	14.0
Leptocylindrus sp.									
Licmophora sp.									
Melosira sulcata		0.7							
Merismopedia sp.				1.4	12.7				
Micractinium sp. (spikey)						1.3		9.2	
Navicula classic			0.6		0.3				
Navicula football							0.6	0.6	
Navicula large									
Navicula picture									
Navicula sp.		0.3							
Navicula Square				1.2					
Navicula Square L									
Navicula striped (109)									
Nitzschia A (Drawing)									
Nitzschia closterium									
Nitzschia delicatissima	0.3		1.7		0.3	1.3		0.3	1.0
Nitzschia longissima		0.3	1.1	0.5	1.4	1.0	0.3		0.7

Nitzschia pacifica								
Nitzschia seriata			0.1					
Nitzschia sp.			0.1					
Nitzschia very small								
Noctiluca milearis								
Pediastrum sp.			3.7		5.5			
Peridinium black								
Peridinium palidum								
Peridinium sp.	0.3	0.3						
Plagiogramma van heurckii								
Pleurosigma sp.								
Prorocentrum micans								2.0
Rhizosolenia alata								
Rhizosolenia delicatula		1.1	0.2	1.7				2.2
Rhizosolenia robusta								
Rhizosolenia sp.								
Rhizosolenia stolterfothii								
Rhizosolenia styliformis								
Scenedesmus sp.			17.3	6.9	40.7			0.2
Schroederella 1								
Schroederella 2								
Skeletonema costatum								
Stephanopyxis turris (bones)								
Striatella Cupp 172								
Surirella								
Surirella sp. 101								
Thalassionema nitzschioides								
Thalassiosira decipiens								
Thalassiosira L								0.7
Thalassiosira rotula		1.4	0.6	3.8				1.5
Thalassiosira S	0.7			3.4		1.6		
Thalassiothrix sp.								0.2
Unknown - Very Small								
Zygobikodinium sp.								

	Muiz W	Muiz Out	Noord W	Sedge W	Stilb W	Struis W	Sund W	Vlees W	Wild W
	18.5	18.5	18	22.8	21.43	20.05	26	21.92	22.58
Achnanthes sp.									
Amphiprora sp.									
Amphora sp.									
Anacystis sp.									
Anaulus australis	89.2		10.6	90.4	86.3	78.0	63.9	94.9	98.3
Asteriomphalus sp.									
Asterionella glacialis	1.9				3.6	4.7	32.0		
Aulacodiscus johnsonii						0.8		0.3	
Aulacodiscus petersii									
Biddulphia alternans									
Biddulphia amazing									
Biddulphia mobiliensis									
Biddulphia pulchella									
Biddulphia sp.									
Bluegreens (chain/circular)		6.2							
Campylosira cymbelliformis		0.6			0.3	2.0	2.8	0.9	0.2
Centric Large									
Centric Medium									
Centric Small									
Ceratium furca/marina									
Ceratium tripas									
Chaetoceros A (Drawing)									
Chaetoceros large									
Chaetoceros medium			1.5						
Chaetoceros paired									
Chaetoceros peruvianus									
Chaetoceros protuberans									
Chaetoceros small									
Chaetoceros vanheureki									
Chain, pretty chl									
Climacopshenia Cupp 178									
Cocconeis epiphyte									
Desmid		3.1							
Dinophysis acuminata									
Diploneis sp.									
Distephanus sp.									
Ditylum brightwellii	0.2								
Epiphytic Cocconeis			19.7						
Eucampia zoodiacus									
Euglena sp.		3.1							
Flagellate		3.1	9.1						
Flagellate medium									
Flagellate Small									
Grammatophora marina									
Greens		18.6							
Gyrodinium sp.									
Hemiaulus hauckii	0.3								
Leptocylindrus danicus	1.1		1.5						
Leptocylindrus sp.		24.8							
Licmophora sp.					0.5				
Melosira sulcata						1.1			
Merismopedia sp.									
Micractinium sp. (spikey)									
Navicula classic									
Navicula football	0.6		1.5	2.1	4.1	5.8	0.3	1.5	0.6
Navicula large									
Navicula picture									
Navicula sp.	0.5		33.3		3.6			0.7	0.6
Navicula Square									
Navicula Square L									
Navicula striped (109)									
Nitzschia A (Drawing)									
Nitzschia closterium	0.2					1.9	0.5		
Nitzschia delicatissima	0.2								
Nitzschia longissima	0.2	0.9		0.9			0.2	0.3	

Nitzschia pacifica								
Nitzschia seriata			3.0					
Nitzschia sp.				0.6	1.4			0.6
Nitzschia very small								
Noctiluca milearis								
Pediastrum sp.		18.6						
Peridinium black								
Peridinium palidum								
Peridinium sp.			4.5	1.2	0.3			
Plagiogramma van heurckii								
Pleurosigma sp.								
Prorocentrum micans								
Rhizosolenia alata								
Rhizosolenia delicatula	0.8						0.5	
Rhizosolenia robusta								
Rhizosolenia sp.								
Rhizosolenia stolterfothii								
Rhizosolenia styliformis								
Scenedesmus sp.	0.3	21.7						
Schroederella 1								
Schroederella 2								
Skeletonema costatum								
Stephanopyxis turris (bones)								
Striatella Cupp 172								
Surirella								
Surirella sp. 101								
Thalassionema nitzschioides							0.2	
Thalassiosira decipiens				3.9	1.1	1.7		
Thalassiosira L	2.1				1.4			
Thalassiosira rotula	1.9		7.6	0.6	0.6			
Thalassiosira S			7.6			0.5	1.4	
Thalassiothrix sp.								
Unknown - Very Small								
Zygobikodinium sp.								

	Bonza W 27.97	Buff W 23	Cintsa W 28.12	De Hoop 20.5	EL W 27.92
Achnanthes sp.					
Amphiprora sp.	23.3		1.2		
Amphora sp.				2.9	
Anacystis sp.					
Anaulus australis		5.5	75.6	10.8	76.7
Asteriomphalus sp.					
Asterionella glacialis		66.9	14.0		16.3
Aulacodiscus johnsonii	1.1				
Aulacodiscus petersii				0.7	
Biddulphia alternans				2.2	
Biddulphia amazing					
Biddulphia mobiliensis					
Biddulphia pulchella					
Biddulphia sp.					
Bluegreens (chain/circular)					
Campylosira cymbelliformis					
Centric Large					
Centric Medium					
Centric Small					
Ceratium furca/marina					
Ceratium tripas					
Chaetoceros A (Drawing)					
Chaetoceros large					
Chaetoceros medium		4.5			
Chaetoceros paired					
Chaetoceros peruvianus					
Chaetoceros protuberans		1.5			
Chaetoceros small					
Chaetoceros vanheurcki					
Chain, pretty chl					
Climacopshenia Cupp 178					
Cocconeis epiphyte	5.6		2.3	3.6	
Desmid					
Dinophysis acuminata					
Diploneis sp.				2.2	
Distephanus sp.					
Ditylum brightwellii					
Epiphytic Cocconeis					
Eucampia zoodiacus					
Euglena sp.					
Flagellate					
Flagellate medium					
Flagellate Small					
Grammatophora marina		15.6			1.4
Greens					
Gyrodinium sp.					
Hemiaulus hauckii		1.1		6.5	
Leptocylindrus danicus		1.9			
Leptocylindrus sp.					
Licmophora sp.	21.1			0.7	
Melosira sulcata				12.2	
Merismopedia sp.					
Micractinium sp. (spikey)					
Navicula classic	8.9			1.4	
Navicula football				5.8	7.0
Navicula large					
Navicula picture					
Navicula sp.			7.0		
Navicula Square					
Navicula Square L					
Navicula striped (109)					
Nitzschia A (Drawing)					
Nitzschia closterium		0.3		0.7	
Nitzschia delicatissima		1.6			
Nitzschia longissima		0.7			

Nitzschia pacifica			1.1			
Nitzschia seriata						
Nitzschia sp.	11.1				7.9	
Nitzschia very small						
Noctiluca milearis						
Pediastrum sp.						
Peridinium black						
Peridinium palidum						
Peridinium sp.					1.4	
Plagiogramma van heurckii						13.7
Pleurosigma sp.						
Prorocentrum micans						2.2
Rhizosolenia alata						
Rhizosolenia delicatula						
Rhizosolenia robusta						
Rhizosolenia sp.						
Rhizosolenia stolterfothii						
Rhizosolenia styliformis						
Scenedesmus sp.						
Schroederella 1						
Schroederella 2						
Skeletonema costatum				9.6		
Stephanopyxis turris (bones)						
Striatella Cupp 172						
Surirella	3.3					
Surirella sp. 101						
Thalassionema nitzschioides		5.6		0.4		
Thalassiosira decipiens			4.5			
Thalassiosira L	4.4				23.7	
Thalassiosira rotula			0.6			
Thalassiosira S						
Thalassiothrix sp.						
Unknown - Very Small						
Zygobikodinium sp.						

SAND

	Beach Longi	Beacon 23.4	Bonza 27.97	Bonza 27.97	Buff 23	Buff 23	Buff 23	Buff 23	Cintsa 28.12	Cintsa 28.12
Amphiprora sp.										
Amphora sp.										
Anacystis sp.										
Anaulus australis						81.4	0.9	1.1		15.4
Asterionella glacialis				43.8			98.9	98.4		76.9
Aulacodiscus johnsonii			6.7		25.0	6.8		0.0	11.1	
Aulacodiscus petersii					25.0					1.9
Biddulphia sp.									1.2	
Bluegreens						0.8			5.6	
Campylosira cymbelliformis							0.2	0.4		2.7
Centric Large										
Centric Medium										
Centric Small										
Chaetoceros spores		21.4		12.5	25.0	1.7				
Climacopshenia Cupp 178										
Cocconeis sp.		7.1	6.7	6.3		2.5		0.0		
Delphineis sp.				12.5						
Dinophysis acuminata			6.7			1.7		0.0		
Diploneis sp.										
Euglena sp.										
Flagellate		57.1								
Flagellate medium										
Greens								66.7		
Gyrosigma sp.										
Leptocylindrus danicus										
Melosira sulcata										
Navicula cigar										
Navicula classic						0.8		0.0		0.4
Navicula football						0.8		0.0		0.4
Navicula Sand			20.0						5.6	
Navicula spatulata				6.3	25.0					
Navicula sp.			6.7	6.3		0.8		0.0		0.4
Navicula sp. large						0.8				
Navicula Square										
Navicula Square L										
Navicula Waisted Sand				12.5		1.7	0.0		11.1	0.4
Nitzschia bicapitata										
Nitzschia bilobata										
Nitzschia delicatissima			46.7							
Nitzschia longissima										0.4
Pediastrum sp.										
Peridinium sp.								0.0		
Plagiogramma van heurckii										
Rhizosolenia sp.			6.7							
Scenedesmus sp.										
Thalassiosira decipiens		7.1								
Thalassiosira Small		7.1								
Unknown Chain										
Unknown Club										
Unknown lemon										
Unknown Photo20-21										
Unknown Tophat										

	EL	Glen	Keurb	Keurb	Macas W	Macas W	Muiz	Muiz	Muiz
	27.92	22.3	23.42	23.42	18.75	18.75	18.75	18.5	18.5
Amphiprora sp.									
Amphora sp.									2.9
Anacystis sp.									
Anaulus australis	27.3	18.5				67.0	83.2	92.7	
Asterionella glacialis	45.5					1.1	0.2	0.4	
Aulacodiscus johnsonii							0.8	0.2	
Aulacodiscus petersii				5.6		3.3			
Biddulphia sp.					4.2				
Bluegreens		11.1		22.2			0.6	0.4	2.9
Campylosira cymbelliformis		3.7					0.6	0.7	
Centric Large									
Centric Medium		3.7			4.2				
Centric Small									
Chaetoceros spores	9.1	25.9	20.0			2.2	2.8	0.7	20.0
Climacopshenia Cupp 178		7.4						0.2	
Cocconeis sp.			50.0		12.5		1.5	1.1	54.3
Delphineis sp.									
Dinophysis acuminata						1.1	0.2	0.9	
Diploneis sp.							0.4		
Euglena sp.									
Flagellate							0.6		
Flagellate medium									
Greens									
Gyrosigma sp.									2.9
Leptocylindrus danicus		3.7							
Melosira sulcata					8.3				
Navicula cigar		3.7				1.1	0.4	0.4	
Navicula classic		7.4				4.4			
Navicula football		11.1		16.7	29.2	7.7	0.2	0.9	
Navicula Sand	9.1					3.3	5.3	0.2	2.9
Navicula spatulata					4.2			0.2	
Navicula sp.			10.0	5.6	4.2	4.4	1.1	0.7	5.7
Navicula sp. large									
Navicula Square									
Navicula Square L							0.2		
Navicula Waisted Sand		3.7	10.0	5.6	29.2		0.8		
Nitzschia bicapitata				5.6			0.2		
Nitzschia bilobata						1.1			2.9
Nitzschia delicatissima									
Nitzschia longissima				5.6					
Pediastrum sp.									
Peridinium sp.			10.0						2.9
Plagiogramma van heurckii						2.2			
Rhizosolenia sp.							0.2		
Scenedesmus sp.							0.2	0.2	
Thalassiosira decipiens									
Thalassiosira Small							0.2		2.9
Unknown Chain				33.3					
Unknown Club					4.2				
Unknown lemon	9.1								
Unknown Photo20-21									2.9
Unknown Tophat						1.1			

	Muiz	Muiz	Muiz	Muiz	Noetse	Oyster	Plett	Sedge W	Stil W
	18.5	18.5	18.5	18.5	23.9	24.63	23.4	22.8	21.43
Amphiprora sp.			13.0						
Amphora sp.			32.6	0.4					
Anacystis sp.									
Anaulus australis	47.8	38.2		86.9	90.3		40.0		
Asterionella glacialis									
Aulacodiscus johnsonii						70.0			
Aulacodiscus petersii					6.6				
Biddulphia sp.					0.3			20.0	
Bluegreens		1.8		0.4			1.7		
Campylosira cymbelliformis			23.6	4.3	1.1			3.3	
Centric Large				0.2					
Centric Medium									
Centric Small				0.2	0.6				
Chaetoceros spores		7.3		1.0		10.0	1.7		
Climacopshenia Cupp 178									
Cocconeis sp.	26.1	1.8	32.6	2.9					
Delphineis sp.									
Dinophysis acuminata				0.6					
Diploneis sp.				0.2					
Euglena sp.									
Flagellate							20.0		
Flagellate medium								40.0	
Greens									
Gyrosigma sp.									
Leptocylindrus danicus									
Melosira sulcata									
Navicula cigar		1.8	10.9						
Navicula classic		9.1	6.5	1.2	0.6		3.3		
Navicula football		1.8	10.9	1.9	0.3		41.7		
Navicula Sand	13.0			1.0					
Navicula spatulata									
Navicula sp.		5.5	15.2	1.5		50.0	1.7	20.0	
Navicula sp. large				0.2					
Navicula Square			2.2						
Navicula Square L									
Navicula Waisted Sand		1.8	13.0	1.0	0.3		3.3		
Nitzschia bicapitata		3.6							
Nitzschia bilobata		3.6	2.2				1.7		
Nitzschia delicatissima									
Nitzschia longissima									
Pediastrum sp.				0.4					
Peridinium sp.							1.7		
Plagiogramma van heurckii	13.0								
Rhizosolenia sp.									
Scenedesmus sp.				0.4					
Thalassiosira decipiens									
Thalassiosira Small			2.2		20.0	50.0			
Unknown Chain									
Unknown Club									
Unknown lemon				0.2					
Unknown Photo20-21									
Unknown Tophat									

	Stil W	Struis	Sundays	Wild	Wild
	21.43	20.05	26	22.58	22.58
Amphiprora sp.					
Amphora sp.					
Anacystis sp.				2.0	
Anaulus australis				22.4	
Asterionella glacialis					
Aulacodiscus johnsonii		14.3	9.1	14.3	
Aulacodiscus petersii		17.1	81.8	51.0	73.3
Biddulphia sp.	13.8				
Bluegreens		2.9	9.1		6.7
Campylosira cymbelliformis					13.3
Centric Large					
Centric Medium					
Centric Small					6.7
Chaetoceros spores					
Climacopshenia Cupp 178					
Cocconeis sp.	13.8	5.7			
Delphineis sp.		5.7			
Dinophysis acuminata		2.9		2.0	
Diploneis sp.					
Euglena sp.				2.0	
Flagellate					
Flagellate medium					
Greens					
Gyrosigma sp.					
Leptocylindrus danicus					
Melosira sulcata					
Navicula cigar					
Navicula classic	3.4				
Navicula football	44.8	28.6		4.1	
Navicula Sand		5.7			
Navicula spatulata					
Navicula sp.		11.4		2.0	
Navicula sp. large					
Navicula Square					
Navicula Square L					
Navicula Waisted Sand	13.8	5.7			
Nitzschia bicapitata					
Nitzschia bilobata					
Nitzschia delicatissima					
Nitzschia longissima					
Pediastrum sp.					
Peridinium sp.					
Plagiogramma van heurckii	6.9				
Rhizosolenia sp.					
Scenedesmus sp.					
Thalassiosira decipiens					
Thalassiosira Small					
Unknown Chain					
Unknown Club					
Unknown lemon	3.4				
Unknown Photo20-21					
Unknown Tophat					