

The seaweed flora of the Palm Beach area,
KwaZulu Natal, South Africa and its
biogeographical affinities.

Submitted By

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Abstracts

Shaw?

The aim of this investigation is to study the seaweed flora of Palm Beach and to determine its biogeographical affinities. A collection from the Palm Beach area produced a list of 130 taxa, comprising 13 Chlorophyta and 15 Phaeophyta 102 Rhodophyta. Included in this list are 56 species from neighbouring sites, Trafalgar and Port Edward. Data from existing databases were used to compare the seaweed flora of the Palm Beach area with that of other sites along the South African coastline. A PCA analysis was used to interpret the data and the Palm Beach area aligned with the south coast sites. The Palm Beach flora is primarily confined to the warmer South coast. The flora composition of the area is distinct from that of a typical transitional region. It is concluded that the biogeographical affinity of the macroalgal flora of the Palm Beach area is warm temperate.

Introduction

The South African coastline is of significant importance in studies of marine coastal biogeography, largely due to the extreme diversity of marine conditions, with biota ranging from kelp beds to coral reefs. The correlation between seawater temperature and the shore community composition has been investigated by several researchers and it is firmly established that the main defining influences are the warm Agulhas flowing down the east coast from Mozambique to the region where it meets the west coast cool Benguela current (Stephenson 1948; Bolton 1986; Bolton and Anderson, 1990). Since the large scale intertidal survey of Stephenson and colleagues (Stephenson, 1948) there have been considered to be three marine provinces on this coastline, described by him as the cold temperate west coast, warm temperate south coast, and sub-tropical east coast. More recently, seaweed biogeographers, while also recognizing three seaweed floras, have described them differently. The designation of the west coast as cold temperate has been criticized, and the seaweed flora of this coast is considered warm temperate (Bolton, 1986; Lüning, 1990) or cool temperate (Emanuel *et al.*, 1992, Bolton and Anderson, 1997). Subtropical affinities of the east coast flora are also not accepted by either Lüning (1990) or Bolton and Anderson (1997). These authors consider the seaweeds of the east coast of South Africa to be the westernmost extensions of the large Indo-west pacific tropical region, and cast doubt on the existence of a distinct subtropical flora in KwaZulu-Natal.

Whereas the transition zone between the west coast and the south coast marine provinces is well studied and characterized by a clearly defined overlap zone (Bolton & Stegenga, 1990; Jackelman *et al.*, 1991), the border of the eastern side of the Agulhas

marine province is less clear. Seawater temperatures, the main defining ecological parameter in the distribution of seaweeds, rise gradually from around East London to northern KwaZulu-Natal (Bolton 1986). At present it is believed that a distinct subtropical marine province in KwaZulu-Natal is unlikely, as the flora seems to comprise an eastwardly declining number of Agulhas province species, replaced largely by Indo-West Pacific species as the temperature rises (Bolton & Anderson, 1997). It should be noted, however, that our knowledge on the marine flora of KwaZulu-Natal is limited. Apart from a limited number of taxa which had been studied in detail by students of G.F. Papenfuss in Berkeley, California and a field guide by ^{£?} Seagrief (1980), no recent detailed studies were available on Natal algae prior to 1985. In the eighties and early nineties, however, R.E. Norris (see Norris 1992 and Silva *et al.*, 1996 for a complete reference list) reported on 63 species, which were reported in South Africa for the first time and additionally described 23 new species of which a few are thus far only known from KwaZulu-Natal. Recent work by Farrell *et al.* (1994) and several other authors (Norris & Aken, 1984; Hommersand, 1986) have shown that the macroalgal flora of KwaZulu-Natal have a link with Australia. It is therefore possible that KwaZulu-Natal is not simply a transition zone between the distinctive Agulhas and Indo-West Pacific floras, but rather comprises a well-defined flora, related to the flora of western Australia but with more endemics. ?

In a joint project between the Botany Department of the University of Cape Town and the University of Ghent, Belgium, the seaweeds of KwaZulu Natal are being studied from a biogeographical point of view. Several sites along the coast from Trafalgar in the south to Kosi river mouth near the Mozambique border were sampled between August and December 1999. The collections are now being identified, and will

eventually provide us with a better understanding of the distribution of the algae along the coast of KwaZulu-Natal and their relations to other algal flora. Presented in this paper are results from an analysis of species identified from a collection made by Dr. O. De. Clerck in December 1999 and January 2000.

The aim of this study is to characterise the macroalgal flora of the Palm Beach area and to place it in the context of the greater KwaZulu-Natal region, in relation to its biogeographical affinities.

Site description

Palm Beach is located approximately 150km due south of Durban, KwaZulu-Natal (Fig. 1). The Palm Beach area referred to in here includes collections from Palm Beach itself and from Trafalgar (3km to the north) and Port Edward (9km to the south). The area is made up of large rock outcrops and sandy channels, which create microhabitats. The microhabitats in turn result in exposed and sheltered beaches that harbour a wide variety of marine flora. The beaches have not only attracted the attention of phycologists and marine biogeographers but they also serve as a recreational centre for holidaymakers.

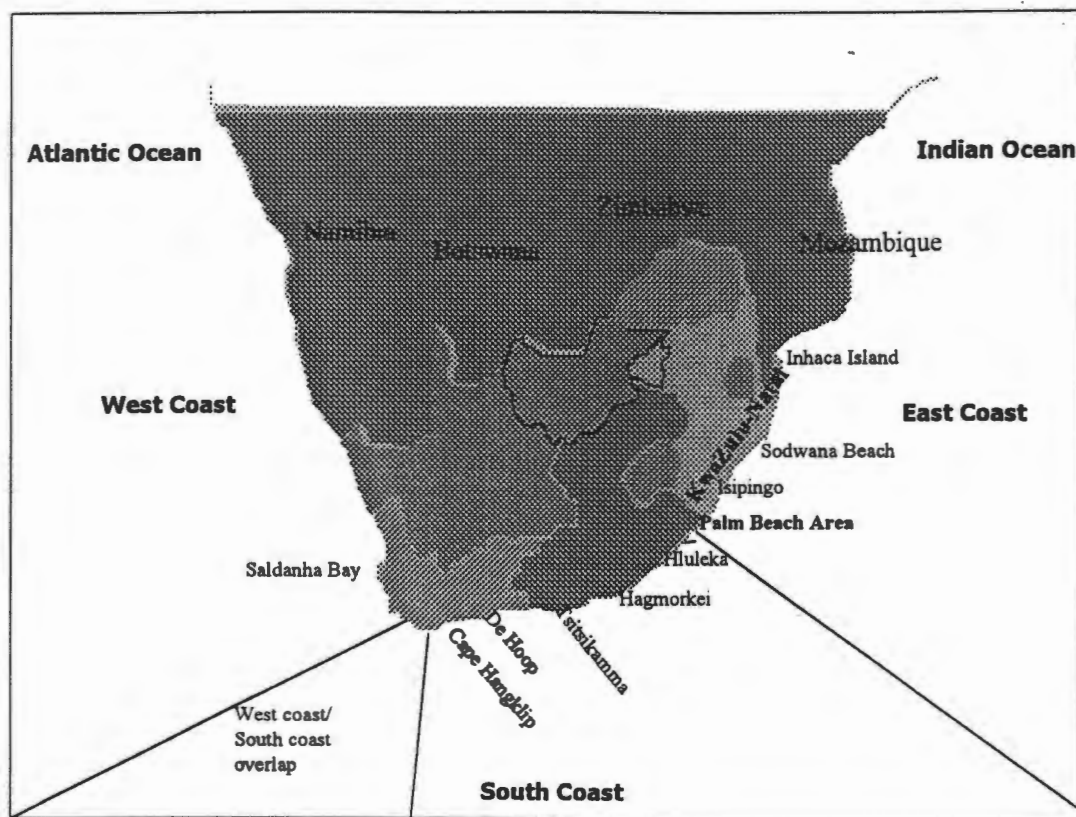


Fig. 1. A map of South Africa showing the position of the Palm Beach area and other sites referred to in the text. The lines perpendicular to the map separate the south, east and west coasts.

Materials and Methods

The seaweed collection was conducted by Dr. Olivier de Clerck at Palm Beach, KwaZulu-Natal in December 1999, in the framework of the Bilateral Scientific and Technological Cooperation between the Flemish community, Belgium and South Africa. These were identified and permanent herbarium specimens made by myself with the assistance of Dr. De Clerck. Additional specimens were collected in January 2000 from Trafalgar, Port Edward and Palm Beach, and Dr. De Clerck himself identified these. Due to the small sample size of my specimens, which only amounted to 74 species, it was deemed necessary to pool the additional 56 species from the later

collection. Because the analysis included these pooled results, the area is collectively called the Palm Beach Area.

The algae were preserved in 4% Formalin/Seawater. Permanent slides were prepared by staining in a mixture of 1 g aniline blue powder, 50 ml Karo®, 45 ml distilled water, 5 ml acetic acid. The vouchers specimens are deposited in the Bolus herbarium, University of Cape Town (BOL).

For identification purposes, Silva (1959), Seagrief (1984), Norris *et al.*, (1987), Norris (1987a, b, 1989, 1991, 1992), and Stegenga *et al.* (1997) were consulted. The nomenclature employed here was adopted from Silva *et al.* (1996). It is also against Silva *et al.* (1996) that taxonomic and nomenclatural changes were verified. A complete list of species found at the Palm Beach area, and the species authorities are presented in Appendix I. Algae that could not be identified with certainty were excluded from the analysis. Most Corallinales and other algae of which only small fragments were available, were excluded in this way.

The floral composition

The nature of the algal flora of the Palm Beach Area was assessed using the Cheney floristic ratio (See Engledow (1998) for references), *viz*:

$$\frac{R + C}{P} = \frac{\text{No. of rhodophyte species} + \text{No. of chlorophyte species}}{\text{No. of phaeophyta}}$$

From this calculation a value of 3.0 suggests cold water flora, whilst values greater than 6.0 indicate a tropical flora, where this ratio was first applied in the North Atlantic.

The biogeography of the seaweed flora of the Palm Beach area.

The Palm Beach data was compared to existing databases of seaweeds recorded from other sites along the South African coastline (Table 1) in order to determine the floral affinities of the Palm Beach area. Doubtful records in the analysis were excluded.

Table 1. The data used to layout the biogeography of the seaweed flora of Palm Beach.

Site	Source the data
Saldanha Bay	(Schils, 1998)
Cape Hangklip	Jackelman <i>et al.</i> , 1991
De Hoop nature reserve	Bolton & Stegenga, 1990
Tsitsikama coastal national park	Unpublished data (Stegenga, Anderson & Bolton)
Haga- Haga, Morgan Bay and Kei river mouth	Unpublished data (Stegenga, Anderson & Bolton)
Hluleka (Transkei)	Bolton & Stegenga, 1987
Isipingo Beach	Farrell <i>et al.</i> , 1993
Sodwana	Unpublished data (De Clerck)
Inhaca island (Mozambique)	Isaac and Chamberlain, (1958) Critchley <i>et al.</i> (1997)

Note: In this report, Haga-Haga, Morgan Bay and Kei River are collectively referred to as Hagmorkei.

The species β diversity

The Wilson and Schmida (1984) index was used to determine the beta diversity, a measure of the rate of species turnover between adjacent sites. The beta diversity represents the species turnover along an environmental gradient such as temperature (Engledow *et al.* 1992). Below is the equation used:

$$B = \frac{(g_A + 1_A)}{2S},$$

where B = Beta diversity,

g_A = Number of species gained along gradient A,

l_A = Number of species lost along gradient A, and

S = Mean sample richness of all samples along gradient

Values range from 0 to 1, a figure of 1.0 indicating complete species turnovers.

The PCA data analysis

A Principal Component Analysis (PCA) was performed with CANOCO (Ter Braak and Šmilauer, 1998). Since no environmental data was available for the analysis, a species-centered PCA was chosen. Another method that is commonly used to determine the phycogeographical affinity of regions is the TWINSpan (Two-Way Indicator Species ANalysis) classification method (consult Engledow, 1998; Farrell *et al.*, 1994). This technique was not applied to our data set because of time constraints beyond the author's control. A rather subjective method was used to determine the species affinities. Those species that were plotted on the outer limits of Axis 1 (Fig. 5.) were taken to be warm water species if above the +0.075 or cold water species if below -0.075. Species with single distribution records and the ubiquitous species clustered around the centre of the graph (axes). The South coast species were taken to be those ± 0.025 outside the centre along axis 1 and at least ± 0.075 from the centre along axis 2.

Results

The floral composition

A total of 130 taxa (see Appendix I) were recorded comprising 6 genera (13 species) of Chlorophyta, 11 genera (15 species) of Phaeophyta and 64 genera (102 species) of Rhodophyta.

The Cheney ratio commonly used to describe the correlation between sea temperature and ratios of red, green and brown algal species numbers in the North Atlantic yielded a value of 7.125, which is characteristic of a tropical flora in the North Atlantic.

The biogeography of the seaweed flora of the Palm Beach area.

The β . diversity

Of the Palm Beach flora, over 20% have been recorded as far west as Saldanha Bay and to the east, over 40% extend up to Inhaca Island (Fig. 2). What is also apparent at this stage is that neither the western nor the eastern extensions of the Palm Beach flora is more dominant. Eleven (18 %) species have their eastern limit at Palm Beach, whereas 15(12%) have their western limit at Palm Beach. Of the Palm Beach species, 22 (18%) have their distribution along the South African coastline restricted to the KwaZulu-Natal region, but occurrence in other areas along the South African sites East to South coast are possible as the records of Silva *et al.* (1996) stretches as far west as Cape Agulhas.

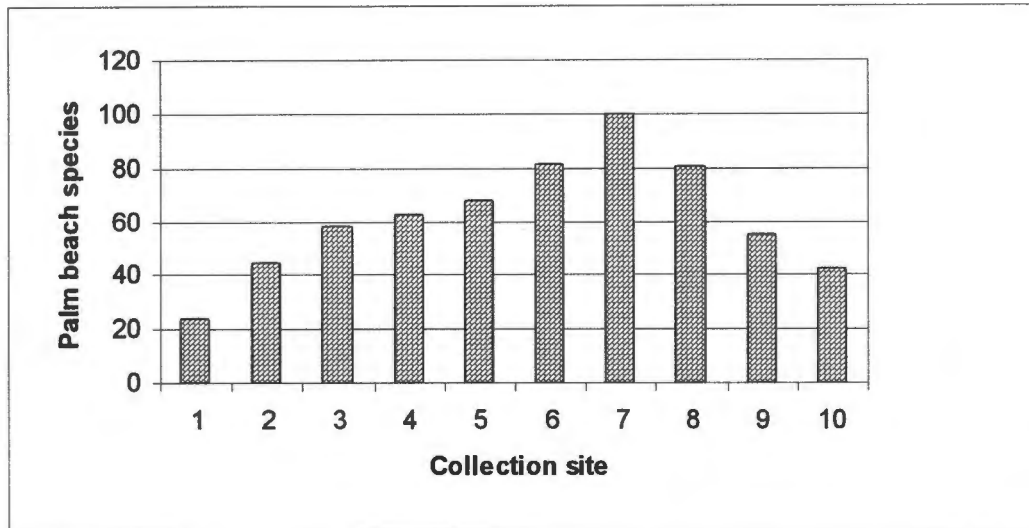


Fig. 2. The distribution of the typical Palm Beach area species along the South African coastline.

The highest species turnover (Fig. 3) occurred between Saldanha and Cape Hangklip (38%), Cape Hangklip and De Hoop (25%) in the west, and Isipingo/Sodwana (26%) and Sodwana/Inhaca (30%) in the east. Along the South coast, species turnover between sites varies generally between 15 and 19%.

Species turnover was then calculated to correct for the different distances between sites (Fig. 4). There was a fairly high turnover between the west coast and Cape Hangklip in the west/south coast overlap. The south coast proper (De Hoop to Hagmorkei) had little species change. There was consistently a fairly high turnover along the Transkei (Hagmorkei and Isipingo), and little change between between Central KwaZulu-Natal (Isipingo) and Sodwana. The highest species turnover per km was between the eastern most sites Sodwana and Inhaca (24%).

100 km

The Principal components Analysis (PCA)

Component 1 of the PCA analysis with an Eigenvalue of 10.413 accounted for 35.7% variation in the analysis, whereas component 2 with an Eigenvalue of 8.883 accounted for 24% variation, and component 3 with an Eigenvalue of 8.118 accounted for 12.5% variation in the results (Appendix 2). Thus the two presented axes accounts for almost 60% of the variation.

The outcome of the PCA analysis by locality (Fig. 5), groups the sites from Hagmorkei and eastwards according to their geographic positions on Axis 1. On Axis 1 the sites between Saldanha and Hagmorkei were, however not in geographical order. On axis 1, Saldanha is closest to Hagmorkei, while Tsitsikamma is between Hangklip and De Hoop.

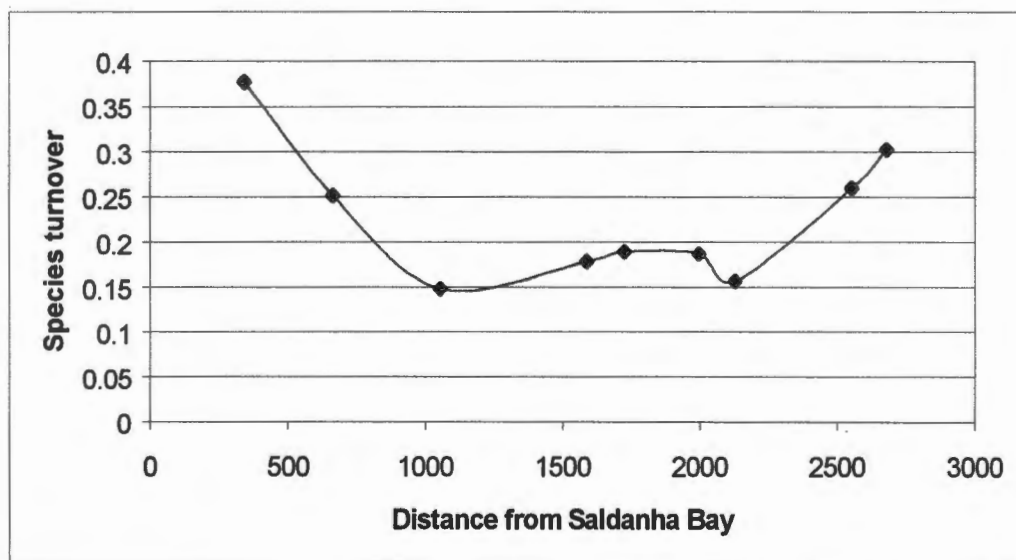
Eleven species from the Palm Beach area were classified as ubiquitous, being distributed along the length of the South African coastline, these are *Centroceras clavulatum*, *Champia compressa*, *Cheilospermum sagittatum*, *Codium duthiae*, *Colpomenia sinuosa*, *Griffithsia confervoides*, *Hypnea rosea*, *H. spicifera*, *Plocamium beckeri*, *Polysiphonia incompta* and *Rhodymenia natalensis*.

Fig. 6. shows a cluster plot of the PCA results by species, which is a bit meaningless in terms of delimiting the West, South and East coast regions, which in Fig. 5. are much clearer. According to Fig. 6. the species from the Palm Beach area that have east coast affinities are as follows; *Arthrocardia carinata*, *Botryocladia madagascariensis*, *Carpopeltis maillardi*, *Caulerpa racemosa var racemosa*, *Caulerpa zeyheri*,

Chnoospora minima, *Codium capitatum*, *Galaxaura marginata*, *Gracilaria protea*, *Halimeda cuneata*, *Hypnea viridis*, *Kuetzingia natalensis*, *Laurencia complanata*, *Lobophora variegata*, *Padina boryana*, *Polyzonia elegans*, *Pseudocodium devriesii*, *Rhodomelopsis africana*, *Spyridia hypnoides* and *Tiffaniella cymodoceae*. The following species recorded from the Palm Beach area, clustered among the south coast species; *Amphiroa anceps*, *Apoglossum spathulatum*, *Bryopsis caloglosoides*, *Callithamnion stuposum*, *Ceramium poeppigianum*, *Dictyota naevosa*, and *Endarachne binghamiae*, *Heterosiphonia arenaria*, *Platysiphonia delicata*. Apart from the ubiquitous species, none of the Palm Beach flora clustered among west coast species.

The PCA correlations indicate that the geographic pattern is most emphasized in component 1. The significance of component 2 could not be explained by any known factor.

FIG. 3. The XY (scatter) plot showing the species turnover along the South African coastline. The X-axis stands for the coastal distances between sites, where the starting point is Saldanha Bay the westernmost locality.



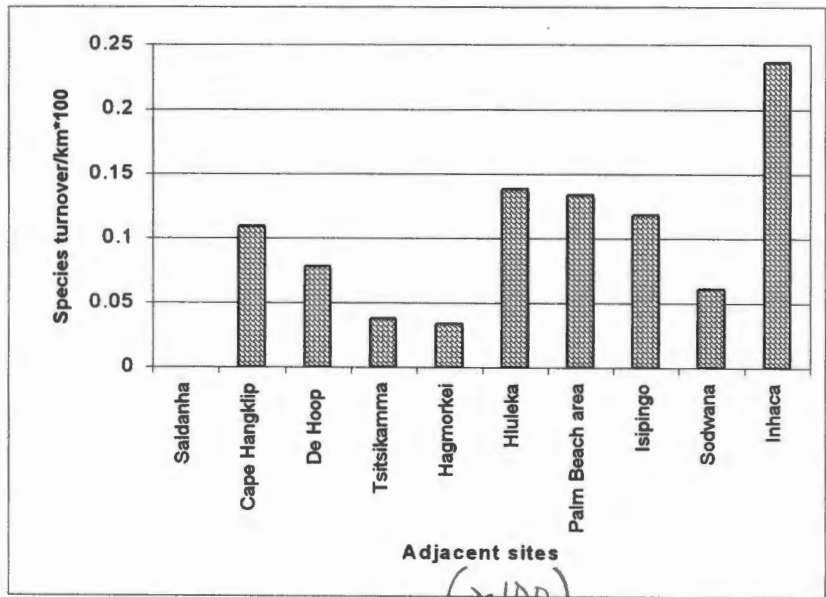


FIG. 4. The species changeover per km between adjacent sites, from Saldanha Bay to Inhaca Island. Comparisons are in a west to east direction.

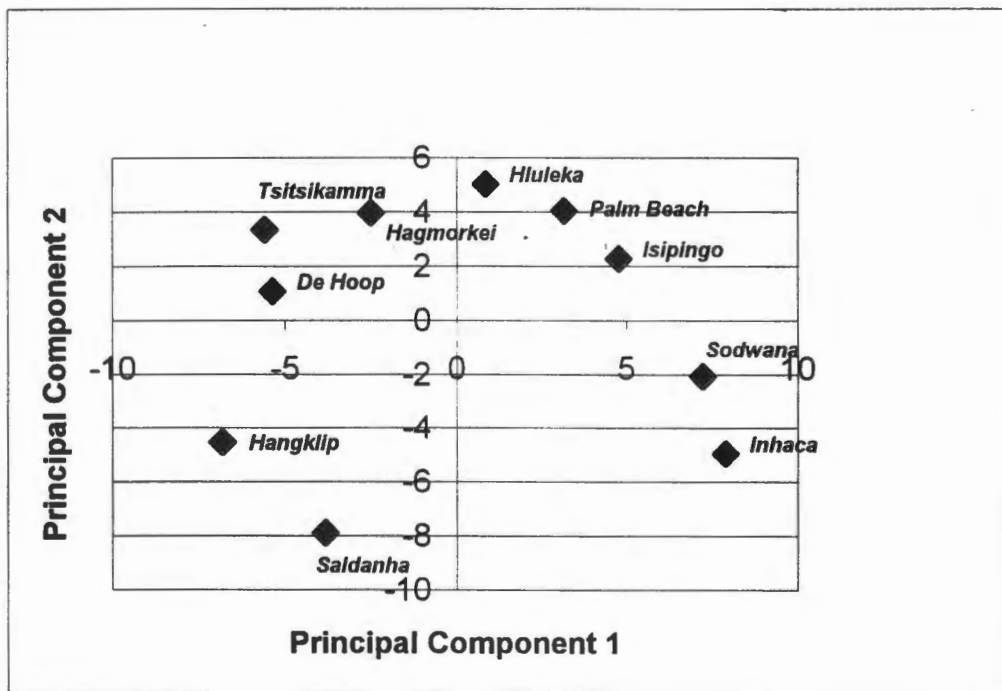


FIG. 5. PCA plot of the first two principal components for 507 species from the ten sites included in the analysis.

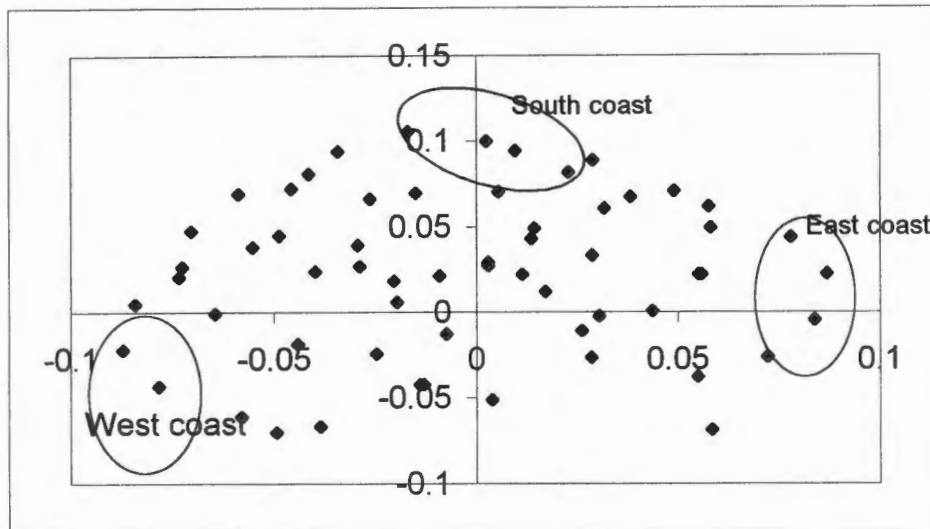


FIG. 6. The PCA plot of the first two principal components for the 507 species from ten localities included in the analysis. Each data point may represent several species that have exactly the same distributions.

Discussion

Studies have shown that there is a close link between seawater temperature and the distribution of the seaweed flora in southern Africa (Stephenson, 1948; Bolton, 1986; Bolton & Stegenga, 1987, 1991; Farrell, *et al.* 1993, 1994). In this study this fact is stressed further as we shall see later.

Floristic composition

The tropical composition of the Palm Beach flora is very unusual because KwaZulu-Natal is situated in the subtropics, although it gets some tropical influence from the Agulhas current (Critchley *et al.*, 1997). The Cheney ratio yielded a high value of 7.125, and this would have been even higher if corallinales were adequately identified and included in the analysis. As was established by Bolton (1986) and Jackelman *et al.*,

(1991), the use of the floristic ratio to the southern African flora is inappropriate because of the relative paucity of the brown algal flora in the region. Only a few (20%) of the Palm Beach flora extends to the West coast. This figure could be lower given that some of this species will be those with wide ranges of distribution in addition to the unusual occurrence of warm water species in the Saldanha Bay Lagoon (Schils *et al.*, (in press). *Langebaan*)

The biogeography of the seaweed flora of the Palm Beach area.

The β diversity

The high change in species composition between Saldanha Bay and Cape Hangklip can be attributed to the overlap that has been demonstrated to occur between the Cape Peninsula and Cape Agulhas (Jackelman *et al.*, 1991). So there is an abrupt loss of cold water species as one approaches the Cape Hangklip from the west. The species changeover between Hangklip and De Hoop is fairly high (25%) compared to the species per Km (8%) and this possibly due to the influence from the overlap region to the west of Hangklip. It is not clear as to why the overall species changeover between Isipingo and Sodwana is so high (26%) compared to the species changeover per km(6%). The overall species changeover is in agreement with the results of the PCA analysis which showed that there is a wider variation between Isipingo and Sodwana, compared to the variation between Sodwana and Inhaca. There is a very high species changeover between Sodwana and Inhaca (figs 3 and 4). This is possibly due to the tropical influence of the Mozambique Current and by warming of the shallow waters of Maputo Bay on the west coast of the Bay (consult Farrell *et al.* 1997), resulting in a very high number of siphonaceous green algae (Farrell *et al.*, 1997) that are not a common occurrence in the Sodwana or Natal in general.

The failure of the Beta diversity to recognize the distance between adjacent sites is

questionable. In actual fact it would not make much sense to compare diversities

between sites when the distances are not comparable.

Biogeographical affinities

The phytogeography of Palm Beach is warm temperate and the species composition has shown that apart from the ubiquitous flora, very few or maybe none occurs at Saldanha on the west coast. Farrell *et al.* (1993, 1994), of their study of the Isipingo Beach flora, have also established that this area, which is situated to the west of Palm Beach, is predominantly constituted of warm water species. *mean?*

Schils *et al.*, (in press) established that 30% of the ^{Lagoonan} ~~Saldanha~~ Lagoon flora grows on the South coast compared to $\pm 7\%$ species from the outer Saldanha Bay system where temperatures are lower. This finding explains the outcome of our PCA analysis, which showed that Saldanha Bay (including the Lagoon) has a relatively high affinity with the South coast flora. Another aberrant observation was that of Tsitsikamma. According to Hanekom *et al.* (1989) cool water events or minor upwelling occur at the Storms river in the Tsitsikamma National Park, and this has apparently often resulted in deaths of fish. The temperature may decline by as much as 3°C within 48 hours (Hanekom *et al.*, 1989). This could explain why the seaweed flora of Tsitsikamma has affinities for the west coast flora where temperatures are much lower due to the recurrent upwelling from the Benguela Current. Bolton (1986) has demonstrated that sea surface temperature increased gradually as one progresses from the South African ~~west coast~~ ^{South}

to the Mozambique border. This study supports this argument since most anomalies encountered are a direct result of the temperature factor.

Conclusions

Although the analysis conducted in this study falls short of the TWINSPAN classification, I am confident that the results still demonstrates the ^{or warm temperate?} subtropical nature of the Palm Beach area and the general KwaZulu-Natal region. The biogeographical affinities are with the tropics and Indo-West Pacific floras.

Apart from creating an understanding of the seaweed flora of the Palm Beach area and the Kwazulu-Natal, this study is in line with the continuing compilations of composition and distribution of the South African seaweeds.

The major setback for this study was the absence of a proper West coast flora site due to lack of detailed studies at specific sites along this coastline. The South and the East coast have received relatively a lot of attention (Bolton & Stegenga, 1987; Bolton & Stegenga, 1990; Jackelman *et al.*, 1991; Farrell, *et al.* 1993, 1994; Critchley *et al.*, 1997), but this alone is not good enough to allow for a well-informed characterisation of the South African seaweed flora. Therefore, in this paper, in most cases what is referred to as the west coast is not the proper west coast but simply the western limit of the particular flora.

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Appendix

Appendix 1: List of Algae from the Palm Beach area. The species nomenclature follows Silva *et al.* (1996). Species not marked with an asterisk are those pooled from the data set of Dr. O. de Clerck.

Division	Family	Species Name
Chlorophyta	Caulerpacaeae	<i>Caulerpa filiformis</i> var. <i>filiformis</i> (Suhr) Hering*
Chlorophyta	Caulerpacaeae	<i>Caulerpa racemosa</i> (Forssk.) J. Ag.*
Chlorophyta	Caulerpacaeae	<i>Caulerpa zeyheri</i> Kutz.
Chlorophyta	Cladophoraceae	<i>Chaetomorpha antennina</i> (Bory) Kutz.*
Chlorophyta	Cladophoraceae	<i>Cladophora prolifera</i> (Roth) Kutz.*
Chlorophyta	Cladophoraceae	<i>Cladophora</i> sp.*
Chlorophyta	Codiaceae	<i>Codium capitatum</i> P. Silva*
Chlorophyta	Codiaceae	<i>Codium duthieae</i> P. Silva*
Chlorophyta	Codiaceae	<i>Codium papenfussii</i> P. Silva
Chlorophyta	Codiaceae	<i>Codium platylobium</i> Aresch.*
Chlorophyta	Codiaceae	<i>Codium stephensiae</i> Dickinson*
Chlorophyta	Pseudocodiaceae	<i>Pseudocodium de-vriesii</i> Weber-van Bosse
Chlorophyta	Siphonocladaceae	<i>Chamaedoris delphinii</i> (Hariot) J. Feldmann & Boergesen
Phaeophyta	Chnoosporaceae	<i>Chnoospora minima</i> (Hering) Papenfuss
Phaeophyta	Dictyotaceae	<i>Dictyopteris ligulata</i> (Suhr) O. Schmidt*
Phaeophyta	Dictyotaceae	<i>Dictyota dichotoma</i> var. <i>intricate</i>
Phaeophyta	Dictyotaceae	<i>Dictyota liturata</i> J. Ag.
Phaeophyta	Dictyotaceae	<i>Dictyota naevosa</i> (Suhr) J. Ag.*
Phaeophyta	Dictyotaceae	<i>Dictyota</i> sp. nov.*
Phaeophyta	Dictyotaceae	<i>Dictyota suhrii</i> (Kutz) Papenfuss
Phaeophyta	Dictyotaceae	<i>Lobophora variegata</i> (Lamour) Womersley
Phaeophyta	Dictyotaceae	<i>Padina boryana</i> Thivy
Phaeophyta	Dictyotaceae	<i>Styopodium multipartitum</i> (Suhr) P. Silva comb. nov.
Phaeophyta	Dictyotaceae	<i>Zonaria subarticulata</i> (Lamour.) Papenfuss
Phaeophyta	Sargassaceae	<i>Anthophycus longifolius</i> (Turner) Jensen
Phaeophyta	Sargassaceae	<i>Sargassum elegans</i> var. <i>elegans</i>
Phaeophyta	Scytosiphonaceae	<i>Colpomenia sinuosa</i> (Roth) Derbas et in castagne
Phaeophyta	Scytosiphonaceae	<i>Endarachne binghamiae</i> J. Ag.
Phaeophyta	Sporochaceae	<i>Carpomitra longicarpa</i> Simons
Rhodophyta	Ceramiaceae	<i>Acrothamnion preissii</i> (Sonder) Wollaston
Rhodophyta	Ceramiaceae	<i>Antithamnion adenocladellum</i> R. E. Norris
Rhodophyta	Ceramiaceae	<i>Antithamnion eliseae</i> R. E. Norris*
Rhodophyta	Ceramiaceae	<i>Ballia beckeri</i> Schmitz ex Mazza*
Rhodophyta	Ceramiaceae	<i>Callithamnion stuposum</i> Suhr*
Rhodophyta	Ceramiaceae	<i>Centroceras clavulatum</i> (C. Ag.) Mont.*
Rhodophyta	Ceramiaceae	<i>Ceramium arenarium</i> Simons*
Rhodophyta	Ceramiaceae	<i>Ceramium codii</i> (Richards) Mazover
Rhodophyta	Ceramiaceae	<i>Ceramium dawsonii</i> (Joly)*
Rhodophyta	Ceramiaceae	<i>Ceramium obsoletum</i> C. Ag
Rhodophyta	Ceramiaceae	<i>Ceramium papenfussianum</i> Simons*
Rhodophyta	Ceramiaceae	<i>Ceramium poeppigianum</i> Grunow*
Rhodophyta	Ceramiaceae	<i>Griffithsia confervoides</i> Suhr*
Rhodophyta	Ceramiaceae	<i>Pleonosporium callicladum</i> R. E. Norris
Rhodophyta	Ceramiaceae	<i>Spyridia cupressina</i> (Harv.) Kylin*

Rhodophyta	Ceramiaceae	<i>Spyridia hypnoides</i> (Bory) Papenfuss*
Rhodophyta	Ceramiaceae	<i>Spyridia plumosa</i> Schmitz ex J. Ag.*
Rhodophyta	Ceramiaceae	<i>Tiffaniella cymodoceae</i> (Boergesen) Gordon
Rhodophyta	Champiaceae	<i>Champia compressa</i> Harv.*
Rhodophyta	Champiaceae	<i>Champia parvula</i> (C. Ag.) Harv.
Rhodophyta	Corallinaceae	<i>Amphiroa anceps</i> (Lamarck) Decaisne*
Rhodophyta	Corallinaceae	<i>Amphiroa bowerbankii</i> Harv.
Rhodophyta	Corallinaceae	<i>Amphiroa ephedraea</i> (Lamarck) Decaisne*
Rhodophyta	Corallinaceae	<i>Arthrocardia carinata</i> (Kutz.) Johansen
Rhodophyta	Corallinaceae	<i>Arthrocardia</i> sp.*
Rhodophyta	Corallinaceae	<i>Cheilosporum cultratum</i> (Harv.) Aresch. in J. Ag.*
Rhodophyta	Corallinaceae	<i>Cheilosporum sagittatum</i> (Lamour.) Aresch.*
Rhodophyta	Corallinaceae	<i>Cheilosporum</i> sp.*
Rhodophyta	Corallinaceae	<i>Haliptilon subulatum</i> (Ellis et Solander) Johansen*
Rhodophyta	Corallinaceae	<i>Jania</i> sp.*
Rhodophyta	Corallinaceae	<i>Metamastophora flabellata</i> (Sonder) Setchell *
Rhodophyta	Cystocloniaceae	<i>Calliblepharis fimbriata</i> (C. Ag.) Kutz.
Rhodophyta	Dasyaceae	<i>Dasya scoparia</i> Harv.*
Rhodophyta	Dasyaceae	<i>Heterosiphonia arenaria</i> Kylin
Rhodophyta	Delesseriaceae	<i>Acrosorium acrospermum</i> (J. Ag.) Kylin*
Rhodophyta	Delesseriaceae	<i>Acrosorium maculatum</i> (J. Ag.) Kylin
Rhodophyta	Delesseriaceae	<i>Acrosorium venulosum</i> (Zanard.) Kylin
Rhodophyta	Delesseriaceae	<i>Bartoniella crenata</i> (J. Ag. ex Mazza) Kylin
Rhodophyta	Delesseriaceae	<i>Martensia elegans</i> Hering*
Rhodophyta	Delesseriaceae	<i>Nienburgia serrata</i> (Suhr) Papenfuss
Rhodophyta	Delesseriaceae	<i>Platysiphonia delicata</i> (Clemente y Rubio) Cremades*
Rhodophyta	Delesseriaceae	<i>Pollexfenia minuta</i> (Kylin) Papenfuss
Rhodophyta	Galaxauraceae	<i>Galaxaura diesingiana</i> Zanard.*
Rhodophyta	Galaxauraceae	<i>Galaxaura marginata</i> (Ellis & Solander) Lamour.
Rhodophyta	Gelidiaceae	<i>Beckerella hildebrandtii</i> (Hauck) Kylin
Rhodophyta	Gelidiaceae	<i>Beckerella pinnatifida</i> (J. Ag.) Kylin
Rhodophyta	Gelidiaceae	<i>Gelidium abbotiorum</i> R. E. Norris*
Rhodophyta	Gelidiaceae	<i>Gelidium pteridifolium</i> R. E. Norris, Hommersand, & Fredericq*
Rhodophyta	Gelidiaceae	<i>Onikusa foliacea</i> (Okamura) R. E. Norris
Rhodophyta	Gelidiaceae	<i>Onikusa pristoides</i> (Turner) Akatsuka
Rhodophyta	Gracilariaceae	<i>Gracilaria aculeata</i> (Hering) Papenfuss*
Rhodophyta	Gracilariaceae	<i>Gracilaria denticulata</i> Schmitz ex Mazza*
Rhodophyta	Gracilariaceae	<i>Gracilaria protea</i> J. Ag.
Rhodophyta	Halimedaceae	<i>Halimeda cuneata</i> Hering in Krauss*
Rhodophyta	Halymeniaceae	<i>Carpopeltis maillardii</i> (Montagne & Millardet) Chiang
Rhodophyta	Halymeniaceae	<i>Carpopeltis phyllophora</i> (J. Hooker & Harvey) Schmitz*
Rhodophyta	Halymeniaceae	<i>Codiophyllum natalense</i> (J. Gray)
Rhodophyta	Halymeniaceae	<i>Cryptonemia natalensis</i> (J. Ag.) Chiang
Rhodophyta	Halymeniaceae	<i>Cryptonemia papenfussii</i> Chiang
Rhodophyta	Halymeniaceae	<i>Halymenia dilatata</i> Zanard.
Rhodophyta	Halymeniaceae	<i>Prionitis filiformis</i> Kylin*
Rhodophyta	Halymeniaceae	<i>Prionitis nodifera</i> (Hering) Barton*
Rhodophyta	Hypneaceae	<i>Hypnea rosea</i> Papenfuss*
Rhodophyta	Hypneaceae	<i>Hypnea spicifera</i> (Suhr) Harv. in J. Ag.*
Rhodophyta	Hypneaceae	<i>Hypnea tenuis</i> Kylin*
Rhodophyta	Hypneaceae	<i>Hypnea viridis</i> Papenfuss*
Rhodophyta	Lomentariaceae	<i>Lomentaria amplexans</i> R. E. Norris*
Rhodophyta	Peyssonneliaceae	<i>Peyssonnelia capensis</i> Montagne
Rhodophyta	Peyssonneliaceae	<i>Peyssonnelia replicata</i> Kutz.

Rhodophyta	Peyssonneliaceae	<i>Peyssonnelia simulans</i> Weber-van Bosse
Rhodophyta	Phacelocarpaceae	<i>Phacelocarpus tortuosus</i> Endlicher et Diesing
Rhodophyta	Plocamiaceae	<i>Plocamium beckeri</i> Schmitz ex Simons*
Rhodophyta	Plocamiaceae	<i>Plocamium corallorhiza</i> (Turner) J. Hooker & Harv.*
Rhodophyta	Plocamiaceae	<i>Plocamium rigidum</i> Bory de saint-Vincent*
Rhodophyta	Plocamiaceae	<i>Plocamium suhrii</i> Kutz.
Rhodophyta	Rhizophyllidaceae	<i>Portieria hornemannii</i> (Lyngbye) P. Silva*
Rhodophyta	Rhizophyllidaceae	<i>Portieria tripinnata</i> (Hering) Farrell, Critchley & Aken*
Rhodophyta	Rhodomelaceae	<i>Dictyomenia stephensonii</i> Papenfuss*
Rhodophyta	Rhodomelaceae	<i>Herposiphonia clavata</i> Wynne*
Rhodophyta	Rhodomelaceae	<i>Herposiphonia secunda forma secunda</i> *
Rhodophyta	Rhodomelaceae	<i>Kuetzingia natalensis</i> J. Ag.*
Rhodophyta	Rhodomelaceae	<i>Laurencia complanata</i> (Suhr) Kutz.*
Rhodophyta	Rhodomelaceae	<i>Laurencia flexuosa</i> Kutz.*
Rhodophyta	Rhodomelaceae	<i>Laurencia natalensis</i> Kylin*
Rhodophyta	Rhodomelaceae	<i>Ophidocladus simpliciusculus</i> (P. Crouan & H. Crouan) Falkenb.
Rhodophyta	Rhodomelaceae	<i>Osmundaria fimbriata</i> (Lamour.) R. E. Norris
Rhodophyta	Rhodomelaceae	<i>Placophora binderi</i> (J. Ag.) J. Ag.*
Rhodophyta	Rhodomelaceae	<i>Polysiphonia incompta</i> Harv.*
Rhodophyta	Rhodomelaceae	<i>Polyzonia elegans</i> Suhr*
Rhodophyta	Rhodomelaceae	<i>Pterosiphonia cloiophylla</i> (C. Ag.) Falkenb. in Schmitz*
Rhodophyta	Rhodomelaceae	<i>Pterosiphonia spinifera</i> (Kutz.) Ardre
Rhodophyta	Rhodomelaceae	<i>Rhodomelopsis africana</i> Pocock*
Rhodophyta	Rhodomelaceae	<i>Tayloriella tenebrosa</i> (Harv.) Kylin*
Rhodophyta	Rhodymeniaceae	<i>Botryocladia madagascariensis</i> G. Feldmann*
Rhodophyta	Rhodymeniaceae	<i>Erythrymenia obovata</i> Schmitz ex Mazza
Rhodophyta	Rhodymeniaceae	<i>Gelidiopsis intricata</i> (C. Ag.) Vickers*
Rhodophyta	Rhodymeniaceae	<i>Halichrysis coalescens</i> (Furrow) R. E. Norris & Millar
Rhodophyta	Rhodymeniaceae	<i>Rhodymenia natalensis</i> Kylin*
Rhodophyta	Sarcodiaceae	<i>Sarcodia dentata</i> (Suhr) R.E. Norris*
Rhodophyta	Sebdeniaceae	<i>Sebdenia flabellata</i> (J. Ag.) Parkinson
Rhodophyta	Solieriaceae	<i>Callophycus tridentifer</i> Kraft

Appendix 2: The PCA data output showing the Eigenvalues

VARIANCE EXTRACTED. FIRST 10 AXES

AXIS	Eigenvalue	Broken-stick		Eigenvalue
		% of Variance	Cum.% of Var.	
1	276.122	35.661	35.661	10.413
2	185.551	23.964	59.625	8.883
3	96.608	12.477	72.101	8.118
4	58.172	7.513	79.614	7.607
5	46.803	6.045	85.659	7.225
6	35.704	4.611	90.270	6.919
7	26.891	3.473	93.743	6.664
8	24.519	3.167	96.909	6.445
9	23.931	3.091	100.000	6.254
10	0.000	0.000	100.000	6.084