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SEAWEED SPECIES DIVERSITY IN SOUTH AFRICA

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A dataset is presented on the diversity of South African seaweed species and their distribution in contiguous 50-km coastal sections, to demonstrate current knowledge of the flora in various coastal regions. The coastline has a rich flora, consisting of some 800 species. The South Coast has the highest species diversity (between 250 and 300 species in each section) relative to the West Coast (about 140 species per section) or the East Coast (about 200 species per section). There is a considerable increase in the number of species (>240 species per section), particularly in the green algae, in the easternmost regions that border the tropics. An analysis of seaweeds present in six small stretches of coastline shows that these sites contain 80–90% of the species in the West and South coastal sections, but only 60% of species over the entire coastline. Therefore, successful conservation of relatively few sites could theoretically preserve the majority of the seaweed flora. Many of the species missing from these detailed collections are subtidal, a habitat that is generally undersampled, particularly on the South and East coasts. Although species diversity is becoming relatively well known, systematic studies on many groups, using modern techniques, are needed. Detailed core distribution data for many species are lacking, and there is no national plan for seaweed systematics or herbarium collections. The distributions of green algae are particularly poorly known. Detailed systematic and biogeographic investigations on the overlap between the seaweeds of the temperate South Coast and those of the tropical Indian Ocean are necessary, and these should include subtidal collections and vegetation descriptions.

Key words: algae, conservation, seaweeds, South Africa, species diversity

Considerable progress has been made in the past 20 years in the study of the South African seaweed flora, which is rich on a global scale. It has a high degree of endemism (Bolton and Anderson 1997), a fact attributed to long isolation and continuous residence in warm, temperate conditions for long periods in geological time (Hoek 1984, Hommersand 1986, Bolton 1994). In the 20th century, seaweeds were included as an integral part of large-scale ecological studies, which culminated in a list of 280 species and major varieties, including their distributions (Stephenson 1948). Most of the identification for these ecological studies was carried out in the laboratory of Prof. G. F. Papenfuss at the University of California, Berkeley, USA, where many of the South African seaweed specimens are housed (see Scagel 1953, Wagner 1954, Norris 1957, Sparling 1957, Silva 1959, Fan 1961, Hommersand 1963, Searles 1968, Chiang 1970, Jensen 1974). Detailed collections from around the South African coast and a number of taxonomic studies were carried out between 1950 and 1970 (e.g. Pocock 1953, 1956, Simons 1960, 1964, 1970). This work culminated in a bibliography of South African seaweeds (Seagrief and Troughton 1973) and a species list, with synonyms (547 species; Seagrief 1984). Identification guides to common species of seaweeds were produced by Day (1974), Simons (1976), Branch and Branch (1981) and Branch *et al.* (1994). These were based on drawings or photographs, with short descriptions, which were adequate for identification of many of the larger seaweeds, but characters for identification were minimal.

In the 1980s, two seaweed taxonomic projects were funded by the Coastal Processes Programme of the South African Cooperative Scientific Programmes, which provided an important stimulus to increased understanding of South African seaweed diversity. Dutch seaweed taxonomist Herre Stegenga originally came to South Africa to study a family of the smallest of the red algae, the Acrochaetiaceae (Stegenga 1985). His continued collaboration with local phycologists eventually resulted in the first comprehensive flora of the seaweeds of the southern African region (Stegenga *et al.* 1997). That work contains detailed descriptions of almost 400 species, from Port Nolloth (29°15´S, 16°52´E) to Cape Agulhas (34°49´S, 20°00´E), including one newly recorded genus and 15 new species. The project also provided initial stimulation for research on crustose (non-geniculate) coralline red algae, which can be ecologically dominant in some inshore eco-systems (e.g. Chamberlain 1993, Chamberlain and Keats 1994, Keats and Cham-

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Table I: The 58 × 50 km sections of the South African coastline, with GIS coordinates, delineation of sections, and some well-known sites included in each section

Code	X coordinates	Y coordinates	Limits	Including
1	16.72429	-28.98450	Orange River to just south of Holgats River	
2	16.94238	-29.38053	To just south of Wedge Point	Port Nolloth
3	17.08194	-29.83253	To just south of Melkbos Point	Kleinzee
4	17.25928	-30.26426	To Swartlintjies River	Skulpfontein Point, Swartlintjies River
5	17.47638	-30.67874	To 10 km north of Groen River	Hondeklip Bay, Spoeg River
6	17.72167	-31.08580	To just north of Brak River	Groen River, Island Point, Blougat
7	18.00426	-31.46252	To just north of Duiwegat	Voelklip, Sout River, Blinkwater Bay
8	18.24793	-31.84555	To just south of Doring Bay	Olifants River, Strandfontein, Doring Bay
9	18.34440	-32.30197	To just north of Elands Bay	Lambert's Bay, Lang River
10	18.19559	-32.72420	To just north of Laaiplek	Elands Bay, Die Vlei, Dwarskersbos
11	17.85142	-32.83238	To just south of Cape Columbine	Laaiplek, St Helena Bay, Paternoster
12	18.03498	-33.02889	To just east of Saldahna	
13	18.00579	-33.15480	To Postberg	Langebaan Lagoon
14	18.31646	-33.50368	To just south of Modde River	Yzerfontein, Dassen Is., Grotto Bay
15	18.46779	-33.90813	To Sea Point	Melkbosstrand, Table Bay, Green Point
16	18.36820	-34.21088	To just north of Scarborough	Camps Bay, Hout Bay, Kommetjie
17	18.46665	-34.11221	To just east of Kalk Bay	Scarborough, Cape Point, Fishoek
18	18.81859	-34.18980	To just south of Gordons Bay	Muizenburg, Strandfontein, Strand
19	19.06788	-34.35367	To just east of Kleinmond	Rooi Els, Hangklip, Betty's Bay
20	19.33624	-34.59395	To just south of Danger Point	Bot River, Sand Bay, Hermanus, Die Kelders
21	19.65776	-34.78600	To just east of Quoin Point	Danger Point, Pearly Beach, Dyer Island
22	20.07208	-34.74958	To just east of Struis Bay	Die Mond, Cape Agulhas
23	20.47732	-34.49243	To just east of Skipskop	Struis Bay, Arniston
24	20.87056	-34.38810	To just east of Cape Infanta	Koppie Alleen, Cape Infanta, Bree River, Witsand
25	21.35563	-34.42480	To just east of Grootjongensfontein	Puntjie, Skurwe Bay
26	21.82968	-34.38157	To just west of Gouritzmond	Stil Bay, Bloukrans, Bull Point
27	22.11571	-34.15734	To just north of Mossel Bay	Gouritzmond, Vlees Bay, Pinnacle Rock
28	22.53969	-34.01308	To just west of Victoria Bay	Hartenbos, Klein and Groot Brak rivers, Herolds Bay, Skuinsbank
29	23.01642	-34.07989	To just west of The Heads, Knysna	Victoria Bay, Wilderness, Platbank, Oesterbank, Walker Bay
30	23.35867	-34.10201	To Jack's Point– south of Plettenberg Bay	The Heads, Neusgate
31	23.78027	-34.00998	To Elandbos River	Plettenberg Bay, Arch Rock, Die Punt, Blousloep
32	24.26944	-34.08458	To Skuinsklip	Storms River, Voelkrans, Skietgate
33	24.73894	-34.18988	To Thys Point	Aasvoelklip, Tsitsikamma River, Klipdrif River
34	25.03553	-33.97130	To just west of Gamtoos River	Cape St Francis, Krom River, Seekoei River, Jeffreys Bay
35	25.51952	-34.03581	To just east of Sardinia Bay	Van Stadens River, Claasen Point
36	25.69996	-33.79133	To just east of St George's Beach	Chelsea Point, Port Elizabeth, Bluewater Bay
37	26.17661	-33.72051	To just west of Woody Cape	St Croix Is., Sundays River
38	26.64813	-33.70001	To just west of Kenton-on-Sea	Seal Is., Bird Is., Cape Padrone, Cannon rocks, Boknes
39	27.10371	-33.52269	To just east of Kleinemonde	Kasouga, Port Alfred
40	27.51706	-33.26662	To just east of Keiskamma River	Great Fish River, Madagascar Reef
41	27.92591	-33.01227	To just east of East London	Kayser's Beach, Kidd's Beach, Cove Rock
42	28.30072	-32.73128	To Haga-Haga	Gonubie, Cintsa River
43	28.68348	-32.43986	To Qora River	Morgans Bay, Kei Mouth, Nxaxo River, Mazeppa Bay
44	29.04811	-32.11370	To just east of Xora River	Dwesa, The Haven
45	29.37234	-31.76221	To Sharks Point	Mncwasa River, Coffee Bay, Hluleka
46	29.74337	-31.46446	To Mkozi River	Boulder Bay, Port St Johns, Montshe, Ntsubane
47	30.12123	-31.17581	To Mnyameni River	Cathedral Rock, Lambasi Bay, Wild Coast
48	30.41160	-30.80858	To just north of St Michaels-on-Sea	Mzamba, Port Edward, Southbroom, Margate
49	30.67698	-30.41392	To just south of Pennington	Port Shepstone, Mzumbe, Sezela
50	30.93173	-30.01205	To just south of Isipingo Beach	Scottburgh, Park Rynie, Umkomaas, Illovo, Amanzimtoti
51	31.14903	-29.62306	To Desainagar	Durban, Umhlanga Rocks, Umdloti Beach
52	31.46025	-29.26026	To just north of Zinkwazi Beach	Westbrook, Ballito, Blythdale Beach
53	31.81668	-28.94383	To just east of Mtunzini	Tugela River,Dunn's Reserve
54	32.21170	-28.69975	To Mbonambi Beach	Richards Bay
55	32.46202	-28.31805	To just north of First Rocks	Dawson's Rocks, Cape St Lucia, St Lucia
56	32.58902	-27.86866	To Bhukwini	Mission Rocks, Cape Vidal, Leven Point
57	32.71765	-27.41544	To just north of Gobey's Point	Liefeldts Rocks, Sodwana Bay
58	32.87288	-26.97485	To Kosimeer	Hulley Point, Black Rock

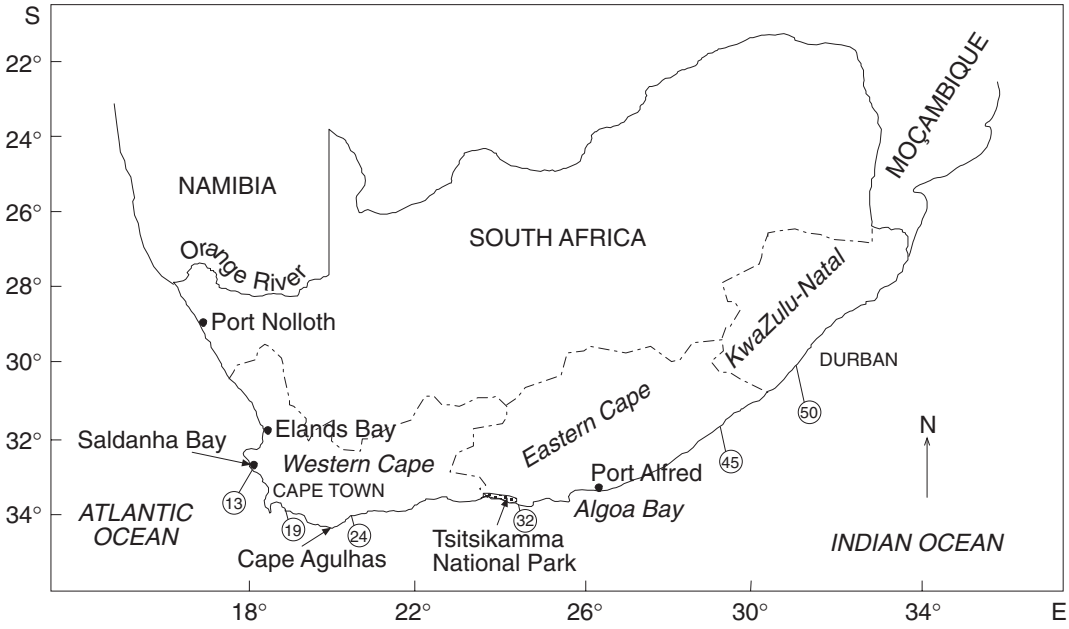

Fig 1: Map of South Africa showing the regions and locations mentioned in the text. The numbers are the positions of the six coastal sections for which detailed species data were analysed (see Table I)

berlain 1995, Keats and Maneveldt 1997). Work by Richard Norris on the seaweed flora of KwaZulu-Natal on the East Coast provided detailed descriptions of more than 100 species, with a number of newly recorded genera and species for the region (see Norris 1992 and Silva *et al*. 1996). Bolton (1999) provides a detailed account of the history of South African seaweed systematics.

A number of detailed checklists have been drawn up for specific small sections of the South African coastline, most with taxonomic notes on selected species (e.g. Bolton and Stegenga 1987, 1990, Anderson and Stegenga 1989, Jackelman *et al*. 1991, Farrell *et al*. 1993). Also, a synthesis of species of seaweeds recorded in the Indian Ocean is given by Silva *et al*. (1996), and it incorporates all records east of Cape Agulhas, with a number of nomenclatural comments.

The aims of this paper are to summarize seaweed diversity patterns in different South African regions, to indicate gaps in knowledge, and to suggest ways in which the available information can be used to facilitate a better understanding of inshore marine diversity. A dataset of the known seaweed flora of South Africa and its local distribution is presented and analysed with respect to regional diversity and potential for conservation.

MATERIAL AND METHODS

The dataset and analysis

All species considered not to be synonyms of other species (following the published suggestions of taxonomists) are included in the dataset. Distributions were compiled from the literature, from extended descriptions (e.g. Stephenson 1948, Stegenga *et al*. 1997) as well as from data in taxonomic papers and species lists for individual sites. In addition, detailed collection information from the South Coast, as far east as Hluleka in the Eastern Cape, was used (HS unpublished), as well as unpublished lists from a few sites. South Africa has three relatively distinct regions with respect to inshore marine biogeography (Stephenson 1948, Emanuel *et al*. 1992, Bolton and Anderson 1997). These were described as the West, South and East coast marine provinces by Stephenson (1948). Bolton

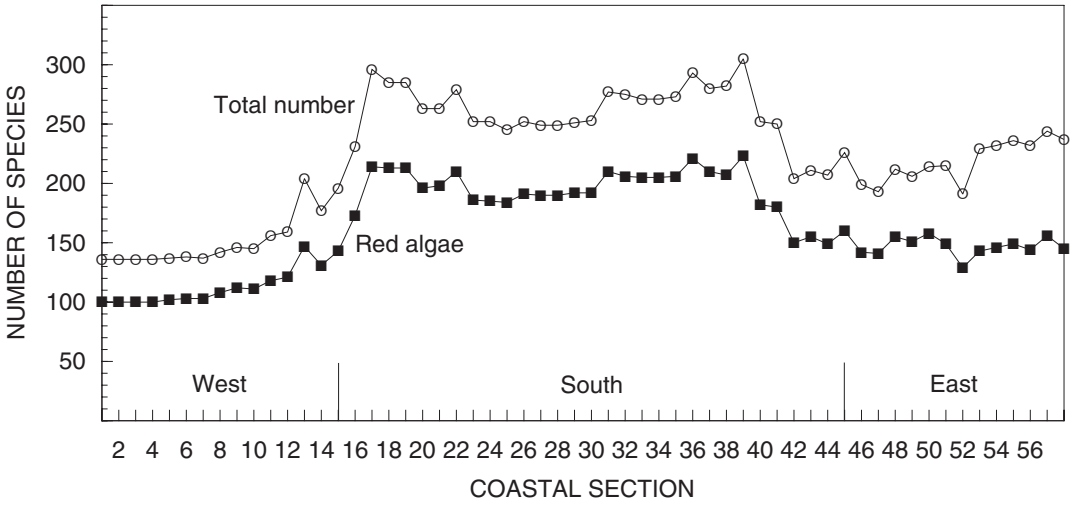

Fig 2: Total number of species and number of species of red algae (Rhodophyta) occurring in each of the coastal sections (see Table I). The West, South and East coasts are delineated

and Anderson (1997) described them as the Benguela and Agulhas marine provinces on the West and South coasts respectively, but considered the East Coast to be a long overlap region between the Agulhas province and the large Indo-West Pacific marine province. Seaweed distributions on a biogeographical scale are largely governed by water temperature (Breeman 1988, Bolton 1986). Therefore, interpolations were used for distributions when it was considered likely that a species occurred along an entire stretch of coastline within one or more of these marine provinces. Individual records that were geographically or environmentally distinct from the rest of a species' distribution were not interpolated. For example, if a species occurred on both the South Coast and in Saldanha Bay, a warm enclave on the West Coast, the distribution was not included in the data for the intervening coastal sections, unless it was specifically recorded there. Some species lists did not contain detailed distribution data (particularly those of Seagrief 1980, 1988), so these were used with caution.

Given the current unreliable state of information on South African seaweeds, it is not possible to carry out a study based on "core data", i.e. only including data points based on properly identified specimens, with localities, in herbaria). This is because of the lack of consistent, locally based seaweed taxonomy. Consequently, collections in most local herbaria are poorly curated from a taxonomic point of view. Some local collections have not been studied recently, and have out-of-date nomenclature. The procedure used here was necessary if information was to be included from publications that list distributions from stretches of coastline rather than from specific sites. A similar method was used by Emanuel *et al.* (1992) in a biogeographical study of southern African invertebrates.

The South African coastline was divided into 50-km sections and all species were recorded as being "present" or "absent" in the 58 sections (Table I). The data were initially plotted as number of species of red, green and brown seaweeds in each coastal section (the "species distribution dataset"). Six small sections of coastline (see Fig. 1), for which detailed species lists are available, were selected:

(i) West Coast National Park (127 spp.; Schils 1998) – Section 13
(ii) Cape Hangklip (199 spp.; Jackelman *et al.* 1991) – Section 19
(iii) De Hoop Nature Reserve (126 spp.; Bolton and Stegenga 1990) – Section 24
(iv) Tsitsikamma Coastal National Park (211 spp.; Stegenga, Anderson and Bolton, unpublished data) – Section 32
(v) Hluleka Nature Reserve (178 spp.; Bolton and Stegenga 1987) – Section 45
(vi) Isipingo (172 spp.; Farrell *et al.* 1993) – Section 50

Species occurring in one or more of these areas were extracted from the species distribution dataset and expressed as a percentage of the total species in

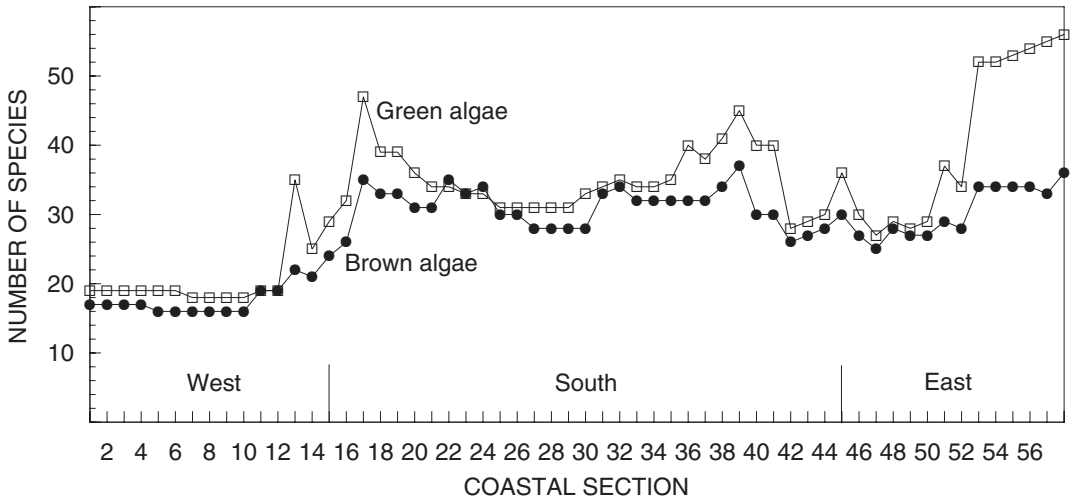

Fig. 3: Number of species of green (Chlorophyta) and brown algae (Phaeophyta) occurring in each of the coastal sections (see Table I). The West, South and East coasts are delineated

each coastal section. The geographic distribution of species not occurring in these lists was also presented. This approach provided an indication of the proportion of the seaweed flora that might benefit from conservation, if all these sections of coastline were to be selected as marine protected areas. Several of the selected sections are currently protected, albeit to differing extents (Attwood *et al*. 1997), but they were chosen because they are the only sections with reasonably comprehensive seaweed species lists available, and also provide a geographical spread.

RESULTS

The total described flora of South Africa is currently estimated at around 750–800 species. A total of 803 species was compiled from the above-mentioned lists, consisting of 101 brown algae (Phaeophyta), 149 green algae (Chlorophyta) and 553 red algae (Rhodophyta). However, because of uncertainties, such as the suspected inclusion of a number of species from Moçambique in the list of South African seaweeds by Seagrief (1984) and the possible spurious distributions of a few taxa, the final species list was refined to 748 species, consisting of 98 brown algae, 138 green algae and 512 red algae.

The distribution of the 748 species around the coast of South Africa is shown in Figure 2. The West Coast is poor in species (130–200 per section) relative to the South Coast (250–280 per section) or the East Coast (200–240 per section). There is highest diversity in overlaps between coastal regions where collections are well documented, e.g. False Bay (Cape Point to Kleinmond; Sections 17–19) and Port Elizabeth to Port Alfred in the Eastern Cape (Sections 36–39). The marked peak at the Langebaan/Saldanha system (Section 13) is attributable to the presence of warm-water South Coast species and sheltered-shore species. Minor peaks, such as those at the Tsitsikamma Coastal National Park (Sections 31–32) and Hluleka (Section 45) could be a result of the high incidence of collections in those areas.

The distribution of red algae (Fig. 2) closely mirrored that for total species, because of their predominance in the seaweed assemblage. There was, however, no increase in red algae towards Moçambique on the East Coast. Green algae (Fig. 3) exhibited low diversity on the West Coast (<20 species), but many species were specific to the Langebaan/Saldanha system (Section 13). Peaks in overlap regions between marine provinces were more pronounced in green algae, with >45 species per section. The central South Coast had marginally more species (31–40 per section) than southern sections of the East Coast (28–38 per section). There was a marked increase in the extreme northern sections of the east coast (52–56 per section). The diversity distribution of brown algae (Fig. 3) closely followed that of green algae. However, there were few specific

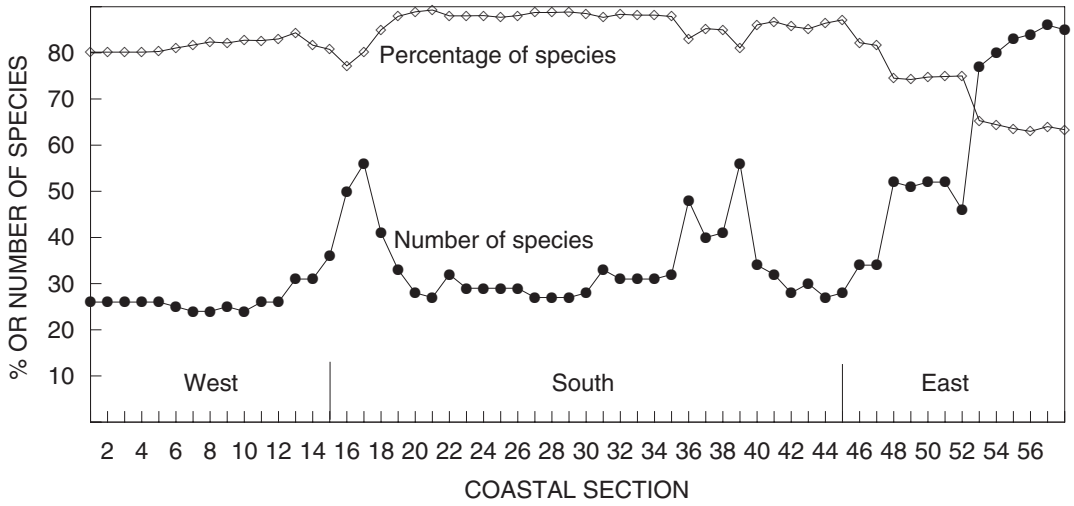

Fig. 4: Species in the six detailed species lists, expressed as the percentage of species in each section that are included and the number of species in each section that are not present at the six sites. The West, South and East coasts are delineated

Langebaan/Saldanha brown algae, major peaks were less pronounced and the increase in diversity to the east was less marked.

The six selected sites contained more than 80% of the species in the West Coast sections and almost 90% of the species in the South Coast sections (Fig. 4). Eastwards, in KwaZulu-Natal (Sections 48–58), there was a dramatic drop to around 65%. The number of species in each coastal section that were not collected in the six areas was around 25–30 for most of the coastline, with the exception of the marine province overlap areas (around 50–55 species) and KwaZulu-Natal (around 50 species in central regions and more than 80 species in the north). Despite encompassing >80% of the species from each section over most of the coastline, the six selected regions contained only 60% of the total seaweed flora in the list.

DISCUSSION

Species diversity

In discussing his list of 280 species and major varieties, Stephenson (1948) considered that the seaweed flora of South Africa was fairly well known, but that many forms remained to be described. This number was increased to 547 species by Seagrief (1984) and is currently at around 800 species. Lüning (1990) considered 600–800 species to be a rich flora for a geographical region. In a global study of seaweed floras, Bolton (1994) showed that the richest floras had around 1 000 species (in southern Australia, Japan, the Mediterranean and the Philippines). Of the richer floras, some occur in geographical regions with a wide range of water temperatures and thus have a number of geographically separated sub-floras (such as Japan, the Mediterranean and South Africa), whereas others have relatively similar temperatures throughout (e.g. southern Australia and the Philippines). These comparisons are problematic, because marine provinces and political entities often do not coincide. South Africa has one of the richer seaweed floras, as shown by the large number of species obtained in careful collections along small sections of coastline; around 180–210 species on the South and East coasts (the highest being 211 species for Tsitsikamma Coastal National Park; unpublished data). These regional quantities are comparable to the total number of species recorded for countries with poor seaweed floras (e.g, Tropical West Africa, John & Lawson 1997). For example, a detailed study of the flora of Ghana (John and Lawson 1997) lists 209 species there, and Critchley *et al*. (1997) recorded 224 species for Inhaca Island, Moçambique, a region of the rich Indo-West Pacific marine province. Thus, a small section of species-rich coastline (e.g. Tsitsikamma, Inhaca) have more recorded species than stretches of coastline many times longer in species-poor areas (e.g. Ghana, Namibia).

It should be considered whether the general pattern

of species diversity shown in Figure 2 is realistic, i.e. are the two apparent peaks, referred to by Stephenson (1948) as the "western overlap" and the "eastern overlap", real or a result of better collecting intensity? The observed peaks, particularly in brown and green algae, in Section 45 (which includes Hluleka) are probably a result of different collecting intensities. The diversity of green algae around the coast is relatively poorly known, resulting in more distinct peaks in well-collected regions. The diversity of green algae is particularly difficult to quantify because green macroalgae are common in estuarine and freshwater habitats. Thus, the Saldanha/Langebaan system, although being a sheltered bay and lagoon rather than truly estuarine, has a relatively large number of green algae. Also, the higher in the intertidal zone that detailed collections are made, the more green algae are likely to be found. Thus, a detailed collection at a single site, which includes the upper intertidal, may result in an artificial peak when compared with data with neighbouring sections where this habitat has not been fully studied. Species in some groups of green algae, such as *Ulva*, *Enteromorpha* and smaller species of *Cladophora*, are difficult to identify, and the taxonomy has not been properly clarified.

The Cape Peninsula and the area around Port Alfred are perhaps the most well-collected regions of the coastline. On the other hand, there is no doubt that False Bay on the Cape Peninsula, being an overlap region between two major seaweed floras, contains species from both, and thus has a particularly rich flora. The region from just north of Scarborough to Kleinmond (Sections 17–19) has 352 species in the present dataset. Similarly, the region around Port Alfred (Section 39) is well known for its diverse flora. Therefore, although the peaks in Figure 2 at the overlap regions may be to some degree artifacts, it is likely that the overlap regions at a scale of c. 100–150 km will be generally richer than other parts of the coastline.

It is clear that the South Coast (Sections 23–42) has a richer seaweed flora than the West Coast (Sections 1–16). This pattern was not demonstrated by Stephenson (1948), who showed similar numbers of seaweed species on the West and South coasts, but with a peak around the Cape Peninsula (see also Engledow *et al.* 1992 and Bolton and Stegenga 1994). In the North Atlantic, there is a proliferation of brown algae in cooler waters, which makes the ratio of red and green algae to brown algae ([R+C]/P) a useful indicator of the temperate or tropical nature of the seaweed flora (Cheney 1977). This is not the case in South Africa, because there are dramatic westward reductions of all three groups, with few brown algal species on the West Coast (Bolton 1986). Bolton (1996) noted that major upwelling regions such as those on the west coasts of South Africa and Chile have reduced numbers of seaweed species, particularly brown algae, compared to adjoining coastlines. This could be explained by the selection of species tolerant to the inherent environmental variability in these regions. For example, Bolton (1996) noted the low endemism, lack of fucoids and dominance of widespread members of the Scytosiphonales in the brown algal floras of both the west coasts of South Africa and Chile, where the (R+C)/P ratio is around six, equivalent to that in tropical floras in the North Atlantic (Bolton 1986, Critchley *et al.* 1998).

Whether the East Coast has fewer species per coastal section than the South Coast, as indicated here, is open to question. Recent studies on the seaweeds of KwaZulu-Natal (see Norris 1992) describe almost exclusively specific groups or interesting new records of red algae. It is difficult from available information to ascertain the eastward limits of many South Coast species in other groups. Perhaps the largest gap in knowledge of the South African seaweed flora is the lack of data on the distribution and ecology of many of the seaweeds of KwaZulu-Natal. In their review of marine vegetation in South Africa, Bolton and Anderson (1997) were unable to find a single description of subtidal marine vegetation on the East Coast. It is possible that a long stretch of coastline with gradually changing seaweed temperature regimes, as along most of the KwaZulu-Natal coast (Bolton 1986), will have generally fewer species at any one site than in a large region with more stable conditions, like most of the South Coast. This is, however, speculative because distributional data for northern KwaZulu-Natal are poor; the major publication on the seaweeds of Maputaland (Seagrief 1980) is mainly a species list with illustrations. The current study shows that there are changes in the seaweed flora in that region, indicated by a general increase in diversity (Fig. 2) as a result of increases in the numbers of green algae (Fig. 3).

Data on endemism are not included in this study. Stegenga *et al.* (1997) noted that, of the almost 400 species they described from the West Coast, 58% of the red algae, 33% of the brown algae and 28% of the green algae were endemic to temperate southern Africa. There are also high levels of endemism on the South Coast, although moving eastwards there are increasing numbers of taxa with affinities in the tropical Indo-West Pacific (Hommersand 1986).

Conservation aspects

It was considered unwise to discuss conservation aspects of species that had been assumed (by interpolation) rather than demonstrated to be present. Therefore, only

authentic species lists were used for the conservation study. Unfortunately, only one such list is available for the East Coast, at Isipingo, and it is described as an intertidal list only (Farrell *et al*. 1993). Therefore, the seaweeds of KwaZulu-Natal, particularly the northern regions, are not adequately covered in this analysis. More than 80% of the species extrapolated to be present in coastal sections on the West and South coasts were included in the six detailed collections. Figure 4 shows the percentage of species in each coastal section that occur in the six sites for which detailed species lists were available. The number of species included in the "species distribution dataset" present in each coastal section, but which do not occur in any of the six detailed collections, are also shown in Figure 4. Moving eastwards along the KwaZulu-Natal coast, the number of species present decreases because of the increasing number of Indo-West Pacific species and the lack of a detailed list from north of the region. On the West and South coasts, generally only 25–30 species in each coastal section were not collected at the six sites. The exceptions to this are again in the western and eastern overlap areas. It is likely that many species from the western overlap, which are missing in the lists for the six sites, are subtidal species from collections taken in False Bay by Stegenga *et al*. (1997). Many of these seaweeds were collected in drift or in samples hauled up by trek-net fishers. Similarly, in the eastern overlap, many of those missing from the six lists were likely to be subtidal species, either from the detailed collections (including drift) of Pocock (1953, 1956) or the exclusively subtidal study of Anderson and Stegenga (1989) at Bird Island.

Sedentary marine organisms are very different from terrestrial organisms from the point of view of protection in marine reserves. Because geographical distributions of seaweeds are controlled largely by water temperature, provided each reserve has a large enough coastline (including the necessary variety of microhabitats) and the reserves properly encompass the variety of biogeographic regions, it is possible to include the majority of the species in few reserves. It is noteworthy that some 60% of the entire seaweed flora of South Africa was collected in relatively short visits to six sites. It is likely that, if detailed lists, including subtidal collections, were also available for three other sites: the southern Cape Peninsula/western False Bay region, around Port Alfred (Three Sisters/Riet River) and around Sodwana in northern KwaZulu-Natal, these nine sites would include the vast majority of the seaweeds of South Africa. Whether conservation of only nine short stretches of coast would preserve these seaweeds is a difficult question, one that cannot be answered here.

CONCLUSIONS

In discussing the South African seaweed flora, Critchley *et al*. (1998, p. 415) stated that "as yet there is no comprehensive and up to date species list which unifies our knowledge of the separate regions". The list compiled here goes a step towards this. It was not intended as a taxonomic study, such as those of Stegenga *et al*. (1997), which includes the basionyms of the taxa and many taxonomic decisions, or Seagrief's (1984) list, which includes the synonyms of all taxa. There are many groups of seaweeds in South Africa that have not been subject to detailed taxonomic studies. Those that have been studied are often taxonomically incomplete. For example, of the eight species of *Gigartina* recorded for the West Coast by Stegenga *et al*. (1997), six were included in the comprehensive morphological, molecular and biogeographic systematic studies of the Gigartinaceae by Hommersand *et al*. (1993, 1994), although South African specimens of only five were studied. Of the six, three remained in the genus *Gigartina*, whereas the others were placed in *Sarcothalia* or *Chondracanthus*. Therefore, although the seaweed species diversity of South Africa is becoming fairly well known, there is a large amount of taxonomic work still to be done on many groups.

Although taxonomic studies are being carried out at the University of the Western Cape, Cape Town, on a portion of one family of red seaweeds (the non-geniculate members of the Corallinaceae), there is still little scope for developing an indigenous group of seaweed taxonomists. There is currently no government agency in South Africa that considers the taxonomy of seaweeds (or indeed any other "algae") as part of its brief, as the South African Museum encompasses the taxonomy of animals and the National Botanical Institute the taxonomy of flowering plants. Detailed core distributional data for species are lacking, and there is no national plan for seaweed (or indeed algal) systematics or herbarium collections. Algae are generally excluded from, or neglected in, local botanical systematic initiatives (see Bolton 1997).

Along with the need for this taxonomic work, vegetation studies and species lists are required for many regions, with a need for emphasis on the subtidal. This is particularly necessary on the East Coast, from the former Transkei region of the Eastern Cape (Sections 43–47) to the Moçambique border. Ideally these should be combined with studies in Moçambique and farther north to document properly the overlap between the rich floras of temperate southern Africa and the tropical Indo-West Pacific.

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