Macroalgal assemblages of the Socotra Archipelago

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Abstract: Two phycological campaigns to the Socotra Archipelago (spring 1999 and 2000) revealed a diverse marine macroflora, which is presented here in a preliminary checklist. The main island shows a marked difference in macroalgal species richness between the north and south coast. The algal assemblages of the north coast are dominated by taxa that are characteristic for the East African coast. The vegetation structure along the south coast is similar to that of other upwelling areas in the Arabian Sea and shows an interesting number of species with a disjunct distribution pattern. A synopsis of prospective studies on Socotra's marine flora is included.

INTRODUCTION

Recent phycological surveys in the Arabian Sea and the northern Indian Ocean resulted in many new records (Wynne & Banaimoon 1990, Wynne & Jupp 1998, Wynne 1999 b) and the description of new species (Wynne 1999 a). This indicates that the area is understudied and harbours a peculiar marine flora. The south-west monsoon that results in coastal upwelling along the south-eastern coastline of the Arabian Peninsula (Ormond & Banaimoon 1994) is an important physical phenomenon influencing these coastal ecosystems and its biota. Publications on the marine flora of the Socotra Archipelago are scarce, as noted by Leliaert (2000).

As a continuation of the previous phycological collection by Leliaert, a more ecological approach was used during the second survey (20 March to 13 May 2000) to gather ecological data on the algal assemblages and to relate these to the environmental conditions around the islands.

MATERIAL AND METHODS

Vegetation relevés were used to compare the different algal assemblages around the Socotra Archipelago. Quadrats (0.25 m²) were randomly placed in homogenous subtidal macroalgal assemblages. After recording the different vegetation (Table 1) and environmental parameters, the quadrats were cleared and the algae were collected in fine-meshed plastic bags. In the laboratory the mesh bags were sorted by species and fresh weight was measured. Subsequently the specimens were pressed as herbarium specimens, preserved in a 5 % formaldehyde-seawater solution or dried in silica gel for molecular analysis purposes.

The wet specimens were stained using aniline blue, fast green, and Wittmann's haematoxylin solution (Wittmann 1965) and prepared as whole-mounts in a mixture of corn syrup and phenol (50:1). The specimens were identified using a light microscope (Leitz Diaplan) and the appropriate literature.

In order to execute biogeographical and ecological analyses two types of databases (MS Access 2000) were designed: a taxonomical database (Phycobase) with the collection data and hyperlinks to more elaborate systematical HTML pages; and a relevé database that combines the relevé data sheets of the various sites. SPSS 7.0 was used to analyse the species richness of three coastal regions. A Tukey HSD test (significant at the 0.05 level) was chosen, as a result of the normal distribution and the homogeneity of variances of the dataset. In this analysis only algal records were included, animal and seagrass records were excluded.

Table 1: Vegetation parameters recorded for the species in a relevé. After SCHAMINÉE et al. (1995).

Braun-Blanquet's combined estimation		
	Number of individuals	Cover
r	very few	< 5 %
+	few	< 5 %
1	numerous	< 5 %
2	very numerous	< 5 %
	or arbitrarily	5-25 %
3	arbitrarily	25-50 %
4	arbitrarily	50-75 %
5	arbitrarily	75-100 %

Braun-Blanquet's sociability scale	
1	solitary
2	in small groups or tufts
3	in larger groups, cushions or humps
4	in mats or very large groups
5	covering approximately the entire quadrate

Tansley scale	
d	dominant
c	co-dominant
a	abundant
f	frequent
o	occasional
r	rare
s	sporadic

Phenology	
k	germling
v	vegetative
fl	fertile
dis	old thallus parts remain
✞	thallus almost vanished

RESULTS

Taxonomy and biogeography

Phycobase now contains 1134 specimen entries from the Socotra Archipelago, of which 240 duplicates are deposited in the marine laboratory of the PIU in Hadibo. Table A 1 (see Annex) shows a preliminary species list (algae and seagrasses) for the Socotra Archipelago.

During the second survey, a new species of *Reticulocaulis* was collected west of Bidholeh (Nojid). In a previous expedition to Masirah Island, Oman (SCHILS 1999), *Reticulocaulis mucosissimus* Abbott 1985 had been collected. This species was so far the sole representative of the monospecific genus *Reticulocaulis* and was considered to be endemic to the Hawaiian Islands. These two observations are the first Naccariaceae records for the Indian Ocean. The Naccariaceae consist of three genera (*Atractophora* Crouan frat., *Naccaria* Endlicher and *Reticulocaulis* Abbott) that are rarely encountered due to (1) the seasonal appearance of the macrothallic gametophytes, (2) the occurrence in specific subtidal habitats and (3) the fragile thallus organisation. The description, generic characteristics and carposporophyte development, biogeography and ecology of the *Reticulocaulis* species from the northern Indian Ocean are under study (SCHILS et al., submitted). *Dudresnaya capricornica* Robins & Kraft is another characteristic gelatinous red alga that occurs in these subtidal habitats. *Dudresnaya capricornica* has been described from Australia (ROBINS & KRAFT 1985) and has recently been recorded for Papua New Guinea (MILLAR et al. 1999) and Tanzania (COPPEJANS et al. 2000).

Small specimens of *Zellera tawallina* G. Martens were collected in great abundance along the southern coasts of the islands. Tufts of this alga grow in an understory layer of larger seaweeds like *Botryocladia leptopoda* (J. Agardh) Kylin, *Dictyopteris macrocarpa* (Areschoug) O. Schmidt, *Halimeda* spp. and *Nizamuddinia zanardinii* (Schiffner) P. Silva. The monotypic genus *Zellera* has so far been considered to be endemic to Far East Asia (MASUDA et al. 2000, WYNNE 1988) and the Socotra observations would result in a remarkable range extension. The specimens do, however, need further study as they differ in some characters from typical Asian material. According to

Table 2: Species richness analysis (Tukey HSD) of the quadrats from three coastal regions: north coast (Socotra), south coast (Socotra) and the outer islands. * = The mean difference is significant at the 0.05 level.

Region I	Mean	Region J	Mean difference (I-J)	Significance
North coast	8.1 ± 4.9	South coast	–8.3856 *	0.000
		Outer islands	–3.4706	0.129
South coast	16.4 ± 7.5	North coast	8.3856 *	0.000
		Outer islands	4.9150 *	0.025
Outer islands	11.5 ± 5.2	North coast	3.4706	0.129
		South coast	–4.9150 *	0.025

Wynne (pers. comm.) there might be two taxa present under the name *Zellera tawallina*. Another noteworthy species of the *Hypoglossum* group is *Chauviniella coriifolia* (Harvey) Papenfuss, known from southern and western Australia (HARVEY 1860) and collected at Rhiy Di Erisseyl and on the south coast of Darsa.

A recent study of the *Padina* species from the western Indian Ocean including Socotra (MUYLLE 2000) revealed that the upwelling area around Socotra harbours species with an affinity to the Australian marine flora (*Padina boergesenii* Allender & Kraft, *P. elegans* Koh ex Womersley).

Algal assemblages

Multivariate analyses, including the different vegetation parameters, will be performed when the specimens of the 84 quadrats have been identified to species level. In a preliminary data treatment, the quadrats were combined into three site groups or coastal regions: Socotra's north coast, Socotra's south coast and the outer islands. Table 2 shows an analysis of the nominal data, i.e. species richness, of the different records in a coastal region. The north coast vs. south coast and the south coast vs. outer islands showed a significant difference (0.05 level), but the north coast vs. outer islands did not differ significantly.

DISCUSSION AND CONCLUSION

The brief quadrate analysis shows a significant difference in species richness between Socotra's north and south coast. The north coast is characterised by a mixture of well-developed coral assemblages (e.g. at Howlef) and algal communities (e.g. at Di Hamdh). The marine macroflora consists of characteristic East African / Indian Ocean elements. The algal assemblages along Socotra's south coast are characterised by high species richness. The community structure and species composition are similar to those of other upwelling areas in the Arabian Sea (e.g. the east coast of Masirah Island, Oman). A remarkable feature of these communities is the apparent presence of gelatinous red algae (e.g. *Dudresnaya capricornica* Robins & Kraft, *Predaea* spp., *Scinaia moniliformis* J. Agardh, *Sebdenia flabellata* (J. Agardh) Parkinson). Additionally, this area contains an interesting number of species that reflect an affinity to geographically distant areas (Australia, Hawaii, South Africa). The disjunct distribution pattern of these algae could be a result of (1) the upwelling phenomenon and the resulting peculiar environmental conditions, (2) places of refuge where algae (e.g. *Reticulocaulis)* could persist subtidally over a long duration in time (MILLAR & KRAFT 1984) or (3) the lack of subtidal studies of the marine macroflora in the Indian Ocean.

Following a thorough taxonomical study of the specimens, biogeographical comparisons should clarify the link between Socotra's marine flora and those of the eastern and western Indian Ocean. Other pending topics towards a better understanding of the islands' macroalgal flora are multivariate analyses and molecular studies.

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Annex

Table A 1: Preliminary species list of the macroalgae and seagrasses of the Socotra Archipelago; authors according to SILVA et al. (1996) and DEN HARTOG (1984).

Chlorophyceae

- Bryopsidales
  - Bryopsidaceae
    - *Bryopsis hypnoides*
    - *Bryopsis indica*
    - *Bryopsis pennata*
  - Caulerpaceae
    - *Caulerpa brachypus*
    - *Caulerpa cupressoides*
    - *Caulerpa elongata*
    - *Caulerpa lanuginosa*
    - *Caulerpa lentillifera*
    - *Caulerpa mexicana*
    - *Caulerpa peltata*
    - *Caulerpa racemosa*
    - *Caulerpa scalpelliformis*
    - *Caulerpa serrulata*
    - *Caulerpa sertularioides*
    - *Caulerpella ambigua*
  - Codiaceae
    - *Codium arabicum*
    - *Codium duthieae*
    - *Codium dwarkense*
    - *Codium extricatum*
    - *Codium geppiorum*
    - *Codium papillosa*
  - Derbesiaceae
    - *Pedobesia simplex*
  - Udoteaceae
    - *Avrainvillea* sp.
    - *Chlorodesmis fastigiata*
    - *Halimeda cuneata*
    - *Halimeda discoidea*
    - *Halimeda opuntia*
    - *Halimeda renschii*
    - *Halimeda stuposa*
    - *Halimeda tuna*
    - *Udotea indica*
    - *Udotea orientalis*
- Cladophorales
  - Anadyomenaceae
    - *Microdictyon okamurae*
  - Cladophoraceae
    - *Chaetomorpha antennina*
    - *Chaetomorpha spiralis*
    - *Cladophora vagabunda*
    - *Cladophora* sp.
  - Siphonocladaceae
    - *Boodlea composita*
    - *Chamaedoris auriculata*
    - *Chamaedoris delphinii*
    - *Cladophoropsis* sp.
    - *Siphonocladus tropicus*
    - *Struvea* sp.
    - *Struveopsis siamensis*
  - Valoniaceae
    - *Valonia utricularis*
    - *Valonia ventricosa*
    - *Valoniopsis pachynema*
- Dasycladales
  - Dasycladaceae
    - *Neomeris van-bosseae*
  - Polyphysaceae
    - *Acetabularia* sp.
- Ulvales
  - Ulvaceae
    - *Enteromorpha* sp.
    - *Ulva* sp.

Phaeophyceae

- Dictyotales
  - Dictyotaceae
    - *Dictyopteris delicatula*
    - *Dictyopteris macrocarpa*
    - *Dictyopteris* sp.
    - *Dictyota bartayresiana*
    - *Dictyota cervicornis*
    - *Dictyota ceylanica*
    - *Dictyota ciliolata*
    - *Dictyota crispata*
    - *Dictyota friabilis*
    - *Dictyota stolonifera*
    - *Dictyota* sp.
    - *Lobophora variegata*
    - *Padina australis*
    - *Padina boergesenii*
    - *Padina elegans*
    - *Spatoglossum asperum*
    - *Stoechospermum polypodioides*
- Fucales
  - Cystoseiraceae
    - *Hormophysa cuneiformis*
  - Sargassaceae
    - *Nizamuddinia zanardinii*
    - *Sargassum asperifolium*
    - *Sargassum cristaefolium*
    - *Sargassum* sp.
    - *Turbinaria ornata*
    - *Turbinaria tanzaniensis*
    - *Turbinaria* sp.
- Scytosiphonales
  - Chnoosporaceae
    - *Chnoospora implexa*
  - Scytosiphonaceae
    - *Colpomenia sinuosa*
    - *Hydroclathrus clathratus*
    - *Rosenvingea intricata*

Rhodophyceae – Florideophycidae

- Bonnemaisoniales
  - Bonnemaisoniaceae
    - *Asparagopsis taxiformis*
  - Naccariaceae
    - *Reticulocaulis* sp.
- Ceramiales
  - Ceramiaceae
    - *Balliella* sp.
    - *Centroceras clavulatum*
    - *Ceramium* sp.
    - *Euptilota fergusonii*
    - *Griffithsia* sp.
    - *Haloplegma* sp.
    - *Halurus* sp.
    - *Spyridia filamentosa*
    - *Spyridia hypnoides*
    - *Spyridia* sp.
  - Dasyaceae
    - *Amphisbetema* sp.
    - *Dasya elongata*
    - *Dasya pilosa*
    - *Dasya* sp.
    - *Dictyurus purpurascens*
    - *Heterosiphonia crispella*
  - Delesseriaceae
    - *Acrosorium* sp.
    - *Chauviniella coriifolia*
    - *Claudea elegans*
    - *Duckerella ferlusii*
    - *Hypoglossum* sp.
    - *Martensia elegans*
    - *Vanvoorstia coccinea*
    - *Zellera* sp.
  - Rhodomelaceae
    - *Acanthophora muscoides*
    - *Acanthophora* sp.
    - *Amansia rhodantha*
    - *Chondria armata*
    - *Chondria dasyphylla*
    - *Herposiphonia parca*
    - *Laurencia arbuscula*
    - *Laurencia collumellaris*
    - *Laurencia elata*
    - *Laurencia filiformis*
    - *Laurencia majuscula*
    - *Laurencia papillosa*
    - *Laurencia pedicularioides*
    - *Lophocladia* sp.
    - *Melanamansia* sp.
    - *Melanothamnus somalensis*
    - *Neurymenia fraxinifolia*
    - *Osmundea pinnatifida*
    - *Polysiphonia* sp.
    - *Tolypiocladia glomerulata*
- Corallinales
  - Corallinaceae
    - *Amphiroa anceps*
    - *Amphiroa* sp.
    - *Haliptilon roseum*
    - *Jania* sp.
  - Sporolithaceae
    - *Sporolithon* sp.
- Gelidiales
  - Gelidiaceae
    - *Gelidium caerulescens*
    - *Gelidium heteroplatos*
    - *Pterocladia nana*
    - *Pterocladia* sp.
  - Gelidiellaceae
    - *Gelidiella acerosa*
    - *Gelidiella* sp.

- Gigartinales
  - Dumontiaceae
    - *Dudresnaya capricornica*
  - Hypneaceae
    - *Hypnea boergesenii*
    - *Hypnea pannosa*
    - *Hypnea spinella*
    - *Hypnea valentiae*
    - *Hypnea* sp.
  - Nemastomataceae
    - *Predaea* sp.
  - Rhizophyllidaceae
    - *Portieria hornemannii*
  - Sarcodiaceae
    - *Sarcodia montagneana*
    - *Sarcodia* sp.
  - Schizymeniaceae
    - *Titanophora weberae*
  - Solieriaceae
    - *Callophycus serratus*
    - *Meristotheca* sp.
    - *Sarconema filiforme*
    - *Sarconema* sp.
    - *Solieria dura*
    - *Solieria robusta*
- Gracilariales
  - Gracilariaceae
    - *Gracilaria corticata*
    - *Gracilaria edulis*
    - *Gracilaria* sp.
- Halymeniales
  - Halymeniaceae
    - *Carpopeltis maillardii*
    - *Halymenia dilatata*
    - *Halymenia durvillei*
    - *Halymenia jelinekii*
    - *Halymenia maculata*
    - *Halymenia* sp.
  - Sebdeniaceae
    - *Sebdenia flabellata*
- Nemaliales
  - Galaxauraceae
    - *Actinotrichia fragilis*
    - *Galaxaura marginata*
    - *Galaxaura obtusata*
    - *Galaxaura* sp.
    - *Scinaia furcellata/tsingalensis*
    - *Scinaia hatei/bengalica*
    - *Scinaia moniliformis*
    - *Scinaia* sp.
    - *Tricleocarpa cylindrica*
    - *Tricleocarpa fragilis*
  - Liagoraceae
    - *Liagora* sp.
- Rhodymeniales
  - Champiaceae
    - *Champia compressa*
    - *Champia indica*
    - *Champia somalensis*
    - *Champia* sp.
    - *Chylocladia* sp.
  - Lomentariaceae
    - *Lomentaria* sp.
  - Rhodymeniaceae
    - *Botryocladia leptopoda*
    - *Botryocladia skottsbergii*
    - *Chrysymenia* sp.
    - *Coelarthrum* sp.
    - *Fauchea* sp.
    - *Gelidiopsis* sp.
    - *Halichrysis* sp.
    - *Rhodymenia leptophylla*
    - *Rhodymenia pacifica*
    - *Rhodymenia* sp.

Magnoliophyta – Liliopsida

- Alismatales
  - Cymodoceaceae
    - *Cymodocea rotundata*
    - *Cymodocea serrulata*
    - *Halodule uninervis*
    - *Thalassodendron ciliatum*
  - Hydrocharitaceae
    - *Halophila ovalis*