# Towards an understanding of the shallow-water echinoderm biodiversity of KwaZulu-Natal, Republic of South Africa

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**ABSTRACT**

Prior to this study, 130 shallow-water (*i.e.* less then 50 m deep) species of echinoderms were reported from the subtropical (26°S/32°E - 30°S/30°E) east coast of South Africa. The Indo-Pacific and the endemic components of this fauna made up 93 % of the species, while the circumtropical, the Atlantic and the cosmopolitan components represented only 7 % of the echinoderm fauna. A current study in the KwaZulu-Natal province has added some 39 % of new records (excluding the Crinoidea) to the echinoderm fauna of this province, changing its endemic component from 26 to 21 %, the Indo-Pacific component from 68 to 73 % with the other components remaining more or less stable. Total echinoderm species distribution of KwaZulu-Natal was analyzed with the second Kulczynski coefficient, a measurement of similarity between two bioassociational areas. This analysis reveals that while the faunistic components of KwaZulu-Natal seem rather homogeneous, the area in the region of St. Lucia Bay appears to be characterized by a high species turn-over.

## Introduction

The province of KwaZulu-Natal, on the east coast of South Africa, is well known to harbour a mixture of tropical, subtropical and southern African endemic echinoderms. An understanding of this southern african marine region is of paramount importance in allowing us to determine the southern extent of the tropical province further north, the structure of the general Indo-West Pacific region, the origin of the southern African marine fauna, the development of a secondary evolutionary area in the shallow West Indian Ocean, and the transition between the southern African subtropical province and the warm temperate province further south.

Despite several comprehensive efforts by various workers (H.L. Clark 1923; Mortensen 1933, Deichmann 1948; Cherbonnier 1952; Clark & Courtman-Stock 1976 and Thandar 1989a), it is regrettable that the southern African echinoderm biodiversity and biogeography remain poorly investigated. Clark & Courtman-Stock's (1976) authoritative guide compiled all the available information for the echinoderms of southern Africa (excluding the holothuroids), while the zoogeographic paper by Thandar (1989a) summarised this effort with inclusion of the Holothuroidea and A.M. Clark's (1977) further additions to the fauna. Thandar (1989a) recorded no less then 407 species of echinoderms in the waters (both shallow and deep) south of the tropic of Capricorn. These comprised 17 crinoids, 99 asteroids, 124 ophiuroids, 59 echinoids and 108 holothuroids. The distribution pattern of continental shelf species (those occurring in waters less than 200 meters deep) obtained from this dataset, largely supported the division of Day (1967) in recognizing four more or less discrete faunistic provinces in the southern Africa marine region. These are: (1) the tropical Mozambique-Madagascar Province reaching Delagoa Bay; (2) the warm subtropical Natal Province south of Delagoa Bay to Bashee River; (3) the temperate Cape-South West African Province south of Port St. Johns to Walvis Bay; and (4) the CapeSouth West African Province north of Walvis Bay.

The main aim of the current investigation was to re-evaluate the echinoderm biodiversity of southern Africa by *de novo* collections of shallow-water (*i.e.* not deeper than 50 m) echinoderms along the poorly investigated coastline of KwaZulu-Natal. The results of this effort not only yielded significant new insights into the taxonomy and systematics of the echinoderms (mainly in the Holothuroidea, Samyn & Massin in press; Massin *et al.* in prep.), but also allowed re-evaluation of the hypothesis that KwaZulu-Natal is an important transitional zone between the tropical Indian Ocean and the cooler temperate South African south coast (Thandar 1989a). In this context, different latitude and longitude squares of one degree were compared with each other using the second Kulczynski coefficient, which measures the percentage similarity between two bioassociational areas (Price 1982). The second Kulczynski coefficient (KC) is given by the following formula:

$$KC = 1/2[s/(s+u)+s/(s+v)]x100$$

where s is the number of species common to area A and area B; u is the number of species found in area A and absent from area B and, v is the number of species found in area B but absent in area A. This index of similarity has the advantage that it takes into account the disproportionate number of species reported from the different areas (Price 1982).

The Crinoidea resulting from these collections are not included since they still need to be identified.

## Study region

The area considered in the present study is the warm subtropical KwaZulu-Natal Province on the north-east coast of South Africa, stretching from the southern border of Mozambique, just north of Kosi Bay, to Port Edward (Fig. 1). Sampling was done from Bhanga Nek to Palm Beach.

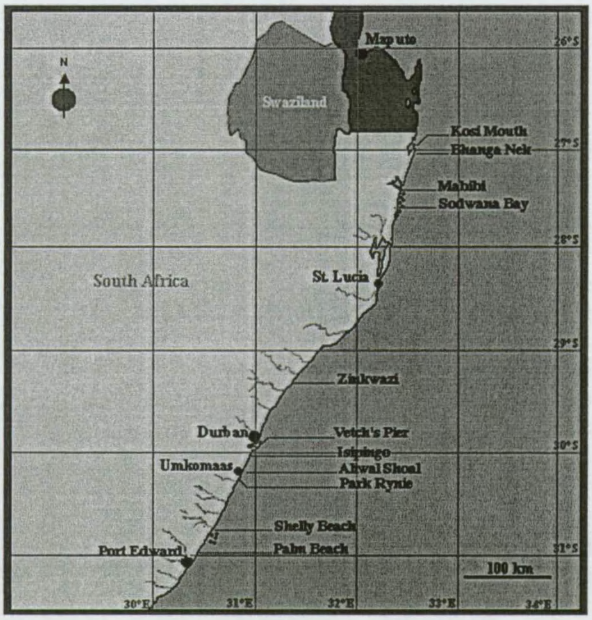


**Figure 1.** Map of the KwaZulu-Natal coastline indicating sampling sites (on right of map).

## Materials and methods

### *Specimen acquisition and preservation*

All the specimens in the present study were collected by hand-picking while skin-diving in intertidal pools or by SCUBA-diving up to depths of 45 m, from 2.VIII.1999 to 21.VIII.1999, 13.VII.2000 to 30.VII.2000, and 4.II.2001 to 13.II.2001. Notes on specific depth, substrate and ecology were made *in situ* for every specimen collected. Holothurian specimens were anaesthesized in 5 % magnesium chloride during 4 hours, transferred to 100 % buffered alcohol for 24 hours, and finally to 70 % buffered alcohol for permanent storage. Asteroids, echinoids and ophiuroids were anaesthesized in fresh water, transferred to 100 % buffered alcohol for 24 hours, transferred to 70 % buffered alcohol for transport and then dried for permanent storage.

*Presentation of data*

It was thought desirable to express distribution of echinoderms along the coast of KwaZulu-Natal in terms of latitude and longitude degree squares of one degree - a system designed by Day (1967) and later adopted by Clark & Courtman-Stock (1976) and Thandar (1989a) - as this allows easy comparison with previous distribution records.

## Results

*Biodiversity reconsidered*

Table 1 lists the different sampling localities (see also Fig. 1) with the respective sampling effort.

**Table 1.** Sampling sites, depth ranges and duration of sampling times along the KwaZulu-Natal coastline

| Locality | Depth range (m) | Sampling time (minutes) |
|---|---|---|
| *South Coast* | | |
| Palm Beach | intertidal | 95 |
| Shelly Beach | | |
| Uvongo Rocks | 18-22 | 37 |
| Orange Rocks | ±18 | 48 |
| Protea Bank | 30-36 | 90 |
| BoBoyi Reef | 16-18 | 46 |
| Broker Reef | ±25 | 29 |
| Old River Bed | intertidal | 10 |
| Various localities | 8-16 | 102 |
| Park Rynie | intertidal | 60 |
| Aliwal Shoal | 12-26 | 432 |
| Isipingo | intertidal | 60 |
| *Central KwaZulu-Natal* | | |
| Vetch's Pier | 3-5 | 72 |
| Zinkwazi | intertidal | 105 |
| *North Coast* | | |
| Sodwana Bay | | |
| Adlam's Rock | intertidal | 35 |
| Diep Gat | 8-10 | 51 |
| 1/4 Mile Reef | 10-14 | 138 |
| 2 Mile Reef | 8-36 | 711 |
| 5 Mile Reef | 19 | 11 |
| 7 Mile Reef | 18-24 | 85 |
| 9 Mile Reef | 6-18 | 83 |
| Mabibi | 14-21 | 107 |
| Bhanga Nek | | |
| Linckia Reef | 30-34 | 20 |
| Sexton Reef | 20-21 | 38 |
| Tiger Reef | ± 16 | 63 |

Prior to our sampling 130 species of echinoderms were known with certainty from KwaZulu-Natal, in waters less than 50 m deep (Clark & Courtman-Stock 1976; Thandar 1977, 1984, 1985, 1986, 1987a,b, 1989a-c, 1990, 1991, 1994, 1996; Thandar & Rowe 1989; Rajpal & Thandar 1998). After our study this number has risen by just over 39 %, to 181 species. Figure 2 shows that the main increase is found within the Ophiuroidea (+56.1%) and the Asteroidea (+53.8%), while the Holothuroidea (+24.4%) and the Echinoidea (+21.0%), as they were better known, increased less significantly.

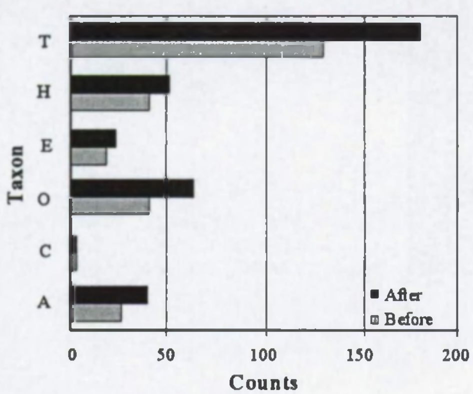


**Figure 2.** Species counts for the different classes of echinoderms before and after the present study. A - Asteroidea, C - Crinoidea, E - Echinoidea, O - Ophiouroidea , H - Holothuroidea and T - Total (A+C+O+E+H).

*Biodiversity re-examined*

As our sampling effort resulted in a significant increase in species richness for KwaZulu-Natal, it was thought desirable to plot the faunistic composition before and after the present study (Fig. 3).

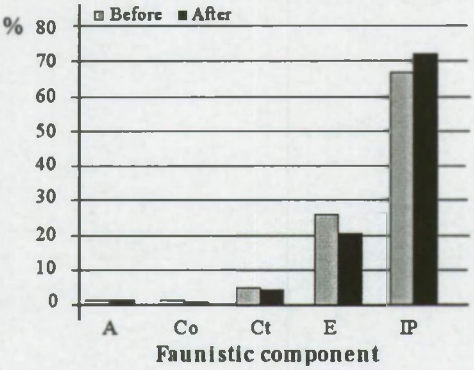


**Figure 3.** Faunistic components per class, prior to and after the present study. A-Atlantic, Co-Cosmopolitan, Ct-Circumtropical, E-Endemic, IP-Indo-Pacific.

From this figure it is clear that the Indo-Pacific component rises (+5.2%) to the same extent as the endemic component drops (-5.15%), while the other components vary only slightly as almost no additional species belonging to these components were found.

The hypothesis that KwaZulu-Natal is a transitional zone between the tropical Indian Ocean and the cooler temperate waters to the south is tested by calculating the faunistic similarity (expressed as the second Kulczynski coefficient) between the different latitude and longitude squares of one degree.

In the present analysis we used five areas (A-E), which we compared with each other: A represents latitude/longitude squares 30/30 & 30/31, B represents 29/31 & 29/32; C represents 26/31 & 26/32; D represents 27/32 & 27/33 and E represents 26/32 & 26/33 (Fig. 4).

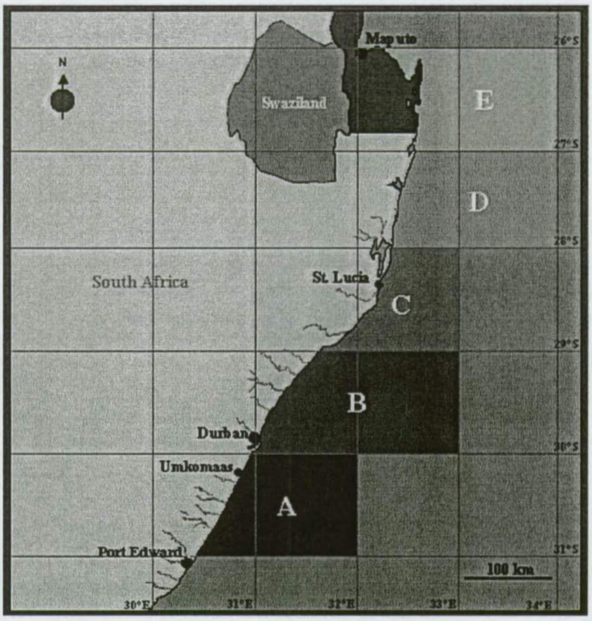


**Figure 4.** Map of the KwaZulu-Natal coastline indicating the combinations of latitude/longitude squares of one degree.

This cross-wise comparison of faunistic similarity yields a matrix (Tab. 2) with a confusing interpretation. For instance if area A (the most southern part of KwaZulu-Natal) is compared with the adjoining area B, a Kulczynski coefficient (KCij) of 48.1 is found; similarly the $KC_{AC}$, $KC_{AD}$ and $KC_{AE}$ remain high (42.5 to 47.9), indicating that the five areas have a large faunistic similarity. However, the results $KC_{BC}$=38.7, $KC_{BD}$=24.5 and $KC_{CD}$=28.9 seem to indicate that there is a large species turn-over at the top of area C (area opposite to St. Lucia Bay), which contradicts the large overall faunistic similarity.

**Table 2.** Kulczynski coefficient as calculated between the different areas (intertidal and shallow-water records combined). The numbers between brackets represent species counts in the different areas.

| KC | A<br>(82) | B<br>(59) | C<br>(21) | D<br>(98) | E<br>(132) |
|---|---|---|---|---|---|
| A | - | | | | |
| B | 48.1 | - | | | |
| C | 47.9 | 38.7 | - | | |
| D | 47.0 | 24.5 | 28.9 | - | |
| E | 42.5 | 40.5 | 41.4 | 51.6 | - |

In an attempt to resolve this ambiguity we separated the intertidal from the shallow-water species. From the dataset with the intertidal species only (Tab. 3) we observe similar patterns: $KC_{AB}$, $KC_{AC}$ and $KC_{AD}$ remain high (from 41.3 to 50.1), $KC_{BC}$ and $KC_{CD}$ are also high (39.0 and 35.7 respectively), while $KC_{BD}$ is exceptionally low (10.4). However, very disproportionate numbers of species in the different areas certainly cloud the indices as indicated by $KC_{AE}$ and $KC_{DE}$ (28.6 and 26.8 respectively).

**Table 3.** Kulczynski coefficient as calculated between the different areas (intertidal records only). The numbers between brackets represent species counts in the different areas.

| KC | A<br>(25) | B<br>(25) | C<br>(14) | D<br>(6) | E<br>(83) |
|---|---|---|---|---|---|
| A | - | | | | |
| B | 48.0 | - | | | |
| C | 50.1 | 39.0 | - | | |
| D | 41.3 | 10.4 | 35.7 | - | |
| E | 28.6 | 44.2 | 41.7 | 26.8 | - |

The dataset with the intertidal species excluded (Tab. 4), shows similar trends and again seems to indicate that area C (area opposite to St. Lucia Bay) has a high species turnover.

**Table 4.** Kulczynski coefficient as calculated between the different areas (shallow-water records only). The numbers between brackets represent species counts in the different areas.

| KC | A<br>(64) | B<br>(44) | C<br>(4) | D<br>(93) | E<br>(64) |
|---|---|---|---|---|---|
| A | - | | | | |
| B | 32.6 | - | | | |
| C | 39.8 | 40.9 | - | | |
| D | 46.2 | 21.1 | 13.0 | - | |
| E | 34.4 | 19.2 | 13.3 | 46.2 | - |

## Discussion

### *Biodiversity reconsidered*

Our addition of some 39 % new records to the shallow-water fauna of KwaZulu-Natal indicates the importance of drawing up a comprehensive checklist of all echinoderms in this region of the South African coastline. To date no complete checklist exists for the shallow-water echinoderms of this stretch of coast. The one given by Clark & Courtman-Stock (1976) was incomplete as it excluded the holothuroids, a deficiency now compounded with the discovery of numerous new records. It is not surprising that most of these latter additions are extensions of range from the tropical Indo-West Pacific, as previous knowledge pointed in the same direction (Clark & Courtman-Stock 1976, Clark 1977, Thandar 1989a). With the addition of numerous new records to the southern African region the percentage of endemics recorded by Thandar (1989a) drops significantly but what is noteworthy is that the degree of endemism in the subtropical province of KwaZulu-Natal increases. This is borne out by the fact that prior to our study only

23.5 % (8 of 34 species) southern African endemics were restricted to KwaZulu-Natal. With the discovery in KwaZulu-Natal of four more, yet undescribed new species, increases this figure of endemism to 31.6 % (12 of 38 species).

*Biodiversity re-appraised*

Interpretation of the local faunistics of the KwaZulu-Natal region is not easy. While, on the one hand, the present analyses indicate that faunal similarity across the different areas is large, on the other hand, existing and present data indicate that there is apparently a large species turn-over in the area opposite St. Lucia Bay, an area referred to as the Natal Bight. The low number of species reported from this area clouds the observed pattern of species diversity north and south of this region. In this preliminary phase of our investigations we are not in a position to conclusively state whether the low diversity here is an artefact due to the low sampling efforts conducted in this region (in the recent expeditions, it was logistically impossible to sample in the St. Lucia Marine Reserve), or whether it is a reflection of the environmental conditions that are known to persist here (Natal Bight). We do note that it is generally conceded that the distribution of the KwaZulu-Natal biota is under the controlling effect of the south-bound warm Agulhas current as evidenced by numerous workers (MacNae 1962, Thandar 1989a, Bolton et al. 2002 and many more). In this respect it is interesting to note that the Agulhas current runs close to the coast in northern KwaZulu-Natal, but as it reaches Cape St. Lucia it moves offshore, due to the widening of the continental shelf in the Natal Bight. Here, the change in the topography induces upwellings and lowering of the water temperature. In addition, the shallower shelf and the increased river discharges in this area induce high levels of turbidity. These changes in physical factors might influence the distribution of many local species dramatically, thus lowering species density.

*Biodiversity awaited*

In a recently accepted extension of the current project we intend focusing on the physical and biological conditions of the St. Lucia Marine Reserve in order to resolve the duality in the echinoderm distribution pattern of the KwaZulu-Natal coast.

## Conclusions

The addition of some 39% new records clearly demonstrates that the shallow-water echinoderm fauna of KwaZulu-Natal was hitherto poorly known and that collecting with the aid of SCUBA yields good results. As the majority of the KwaZulu-Natal echinoderms have an Indo-Pacific character, it is certain that the southern African east coast echinoderms moved in from the north and north-east under the influence of the Agulhas current and perhaps also the East Madagascar current (Thandar 1989a).
At this preliminary phase, it remains impossible to state whether the low resolution in our faunistic analyses is the result of under-sampling of the St. Lucia Marine Reserve or a natural phenomenon linked to the oceanographic conditions that persist in this region. For now, the working hypothesis that the south-east African echinoderm fauna is Indo-Pacific in origin and that its high endemicity may be a reflection of active speciation in this part of the west Indian Ocean is upheld.

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### References

Bolton, J.J., Coppejans, E., Anderson, R.J., De Clerk, O., Samyn, Y., Leliaert, F. & Thandar, A.S. 2002. Biodiversity studies on seaweeds and echinoderms in the transition zone between temperate southern Africa and the tropical western Indian Ocean. *South African Journal of Science* 97: 453-454.

Cherbonnier, G. 1952. Contribution à la connaissance des Holothuries de l'Afrique du Sud. *Transactions of the Royal Society of South Africa* 33 (part IV): 469-509, pls XXXV-L.

Clark, A.M. 1977. The South African Museum's *Meiring Naude* cruises. 4. Echinoderms. *Annals of the South African Museum* 76: 133-147.

Clark, A.M. & Courtman-Stock, J. 1976. The echinoderms of southern Africa. *Trustees of the British Museum (Natural History), London.* 277 p.

Clark, H.L. 1923. The echinoderm fauna of South Africa. *Annals of the South African Museum* 13: 221-435.

Day, J.A. 1967. A monograph of the Polychaeta of Southern Africa. Part 1. *British Museum (Natural History) London*, 458 pp.

Deichmann, E. 1948. The Holothurian Fauna of South Africa. *Annals of the Natal Museum* 9 (part 2): 325-375, plsXVII-XXI.

MacNae, W. 1962. The fauna and flora of the eastern coasts of southern Africa in relation to ocean currents. *South African Journal of Science* 58: 208-212.

Massin, C., Samyn, Y., Thandar, A.S. in prep. The holothurian genus *Labidodemas* (Aspidochirotida: Holothuriidae) revisited.

Mortensen, Th. 1933. Echinoderms of South Africa (Asteroidea and Ophiuroidea). *Videnskabelige Meddelelser fra Dansk naturhistorisk Forening i København* 93: 215-400.

Price, A.R.G. 1982. Echinoderms of Saudi Arabia. Comparison between Echinoderm faunas of Arabian Gulf, SE Arabia, Red Sea and Gulfs of Aqaba and Suez. *Fauna of Saudi Arabia* 4: 3-21.

Rajpal, V. & Thandar AS. 1998. *Neocucumis kilburni* sp. nov. (Echinodermata: Holothuroidea: Cucumariidae) from the east coast of South Africa, with a key to the genus *Neocucumis. South African Journal of Zoology* 33: 195-199.

Samyn, Y. & Massin, C. in press. The holothurian subgenus *Mertensiothuria* (Aspidochirotida: Holothuriidae) revisited. *Journal of Natural History.*

Thandar, A.S. 1977. Descriptions of two new species of Holothuroidea from the east coast of South Africa. *Annals of the Natal Museum* 23: 57-66.

Thandar, A.S. 1984. The holothurian fauna of southern Africa. Ph.D. thesis. Univ. of Durban-Westville, South Africa. 566 pp.

Thandar, A.S., 1985. A new southern African genus in the holothurian family Cucumariidae (Echinodermata: Holothuroidea) with the recognition of two subspecies in *Cucumaria frauenfeldi* Ludwig. *South African Journal of Zoology* 20: 109-114.

Thandar, A.S. 1986. A new genus and species of a dendrochirotid holothurian from southern Africa. *Journal of Zoology, London (A)* 210: 483-488.

Thandar, A.S. 1987a. The southern African stichopodid holothurians, with notes on the changes in spicule composition with age in the endemic *Neostichopus grammatus* (H.L. Clark). *South African Journal of Zoology* 22: 278-286.

Thandar, A.S. 1987b. The status of some southern African nominal species of *Cucumaria* (s.e.) referable to a new genus and their ecological isolation. *South African Journal Zool* 22: 287-296.

Thandar, A.S. 1989a. Zoogeography of the southern African echinoderm fauna. *South African Journal of Zoology* 24: 11-18.

Thandar, A.S. 1989b. The sclerodactylid holothurians of southern Africa, with the erection of one new subfamily and two new genera (Echinodermata: Holothuroidea). *South African Journal of Zoology* 24: 290-304.

Thandar, A.S. 1989c. A study of two apodous holothurians from Southern Africa. *South African Journal of Science* 85: 451-454.

Thandar, A.S. 1990. The phyllophorid holothurians of southern Africa with the erection of a new genus. *South African Journal of Zoology* 25: 207-223.

Thandar, A.S. 1991. The cucumariid holothurians of southern Africa with the erection of a new genus. *South African Journal of Zoology* 26: 115-139.

Thandar, A.S. 1994. A new species of the holothurian genus *Phyllophorus* from South Africa with a key to subgenus *Phyllophorella. Journal of Zoology, London* 234: 341-351.

Thandar, A.S. 1996. *Chiridota durbanensis* new species and new record of *Neothyonidium arthroprocessum* from the east coast of South Africa (Echinodermata: Holothuroidea). *South African Journal of Zoology* 31: 208-213.

Thandar, A.S. & Rowe, F.W.E. 1989. New species and new records of apodous holothurians (Echinodermata, Holothuroidea) from southern Africa. *Zoologica Scripta* 18: 145-155.