Islands, an island group off Leyte, Philippines was discussed. Sea cucumber processing in the Philippines is treated as a minor chapter in Espejo-Hermes (1998) and Schoppe (in press).

This paper follows up initial efforts of the Philippine Council for Aquatic and Marine Research and Development, which encouraged the implementation of a management scheme for the sea cucumber fishery in the Philippines (PCAMRD, 1991). It is an appeal for further studies on stock assessment and catch statistics of sea cucumbers in the Philippines. The author started a long-term study on the sea cucumber fishery in Palawan in order to determine the current situation and to suggest management schemes appropriate for the local setting.

References

ALCALA, A.C. & S. ALCAZAR. (1984). Edible molluscs, crustaceans and holothurians from North and South Bais Bays, Negros Oriental, Philippines. Silliman Journal 31(1–4): 25–45.

Conand, C. & M. Byrne. (1993). A review of recent developments in the world sea cucumber fisheries. Marine Fisheries Review 55(4): 1–13.

CONAND, C. (in press). Overview on the last decade of sea cucumber fisheries, what means for a durable management? **In:** Barker, M. (ed.) Proc. 10th Inter. Echinoderm Conference, University of Otago, Dunedin, New Zealand. Balkema, Rotterdam.

ESPEJO-HERMES, J. (1998). Fish Processing Technology in the Tropics. Tawid Publications, Philippines, 336 p.

FAO. (1996). Yearbook of Fishery Statistics 1996. Food and Agriculture Organization of the United Nations, Rome, Italy.

PCAMRD. (1991). Management of sea cucumber resources of the Philippines. Currents, a weekly publication of the Philippine Council for Aquatic and Marine Resources and Development, Department of Science and Technology, Los Baños, Laguna, Philippines, July 26, 1991.

SCHOPPE, S. (in press). Guide to the common shallow water sea stars, brittle stars, sea urchins, sea cucumbers and feather stars (Echinoderms) of the Philippines. Times Edition, Singapore.

SCHOPPE, S., J. GATUS, P.P. MILAN & R. SERONAY. (1998). Gleaning activities on the islands of Apid, Digyo and Mahaba, Inopacan, Leyte, Philippines. Philipp. Scient. 35: 130–140.

TRINIDAD-ROA, M.J. (1987). Bêche-de-mer fishery in the Philippines. NAGA, the ICLARM Quarterly, Oct. 1987, 15–17.

Conservation of aspidochirotid holothurians in the littoral waters of Kenya

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Abstract

Aspidochirotid sea cucumbers (Echinodermata: Holothuroidea) are heavily fished in the littoral waters of Kenya, and stocks have plummeted. In order to conserve and manage these natural resources, appropriate conservation and management plans must to be developed. This can only occur if high quality research on different levels is done. This paper discusses five layers of understanding that should be achieved before holothurian conservation in East Africa can be effective.

Introduction

Along the Kenyan coast most aspidochirotid sea cucumbers are collected *en masse* and sold to foreign markets (sea cucumbers are not part of the Kenyan diet). Ferdouse (1999) reported on beche-de-mer imports in Hong Kong and Singapore, the two main retailing centres. According to this source, Kenya exports only to Singapore, albeit in increasing levels (1.1 % of the total import in 1993; 2.9% in 1994; and 3.9 % in 1995). From the same data set it is clear that the Kenyan export is rising

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while other East African countries like Madagascar and Tanzania are decreasing their exports. Reasons for this decrease are basically unknown but are probably caused by overfishing, which has decreased the stocks dramatically (Massin, pers. comm.; pers. observ.). It appears that there is a shift from the collection sites of Madagascar and Tanzania to mainly Kenya. However, in Kenya collecting is taking place in a rather unbridled way since: (a) no regulations whatsoever exist for collecting sea cucumbers outside the protected marine parks, and (b) the immediate financial benefits for the collector and trader are considerable.

It is clear that if a sustainable exploitation of the large sea cucumber market is desired, good conservation and management plans will need to be made. Only then will it be possible to conserve and replenish Kenya's plummeting stocks (e.g. in Gazi Bay, some 60 km south of Mombasa all holothurians have disappeared since fishing started in 1995, pers. observ.).

This paper discusses some of the basic levels of scientific understanding that are essential in the fine tuning of conservation efforts for marine biota (and especially of sea cucumbers in the western Indian Ocean).

Level one: *Nomenclature & taxonomy*

In conserving biodiversity, the first step is to know what to conserve. For that, we need to correctly identify the species in an unequivocal and universally understood way. However, nomenclature and taxonomy are scientific disciplines that are often neglected by a large number of biologists, since these disciplines are often seen as a burden rather than a facility. The necessity for respecting the rules of nomenclature, whose aim is 'to provide the maximum universality and continuity in the scientific names of animals compatible with the freedom of scientists to classify according to taxonomic judgements', can be illustrated with the following example of a commercially important species from the family Stichopodidae.

The large species, bright-olive green with numerous conical light green papillae with dark green stripes and yellow to orange distal tips, bears the name *Stichopus variegatus* Semper, 1868 in a large part of the literature before 1995. *S. variegatus* is, however, not a valid name since Rowe & Gates (1995) stated that *S. horrens* Selenka, 1867 is the senior synonym of *S. variegatus* Semper, 1868. The same authors elevated the variety *S. variegatus hermanni* Semper, 1868 to the species level. When mapping holothurian biodiversity, based on species accounts in literature, all records regarding *S. variegatus* (and *S. horrens*) must be regarded as doubtful and cannot be assigned to one or the other species unless one is able to examine the specimens per se.

Level two: *Systematics*

Systematics is the discipline that describes and interprets the patterns that are produced by taxonomy. Systematics aims at understanding the relationships between lineages, the evolutionary trajectories, and the biogeographic distributions of organisms. This knowledge is crucial for understanding, for example, the ecological role of a species within an ecosystem.

The following two examples show that a profound knowledge of systematics and the existing literature is also necessary in naming, ordering and understanding biodiversity.

The species *Stichopus variegatus* Semper, 1868 is known to be an invalid species (see above). The specimens collected as *S. variegatus* before 1995 are known to belong to at least two different species (Massin, 1999; pers. comm.): *Stichopus hermanni* Semper, 1868 and *Stichopus monotuberculatus* (Quoy & Gaimard, 1833). The reef-dwelling species *Pearsonothuria graeffei* (Semper, 1868) was originally described as *Holothuria graeffei* Semper, 1868. Examination of spicule morphology showed that this species is unrelated to the species in the genus *Holothuria*. Hence, it was transferred to the genus *Bohadschia* since the rosettes of the body wall bear some resemblance to the rosettes found in the genus *Bohadschia*. The taxonomic status of *Bohadschia graeffei (*Semper, 1868) was critically examined later by Levin *et al.* (1984),

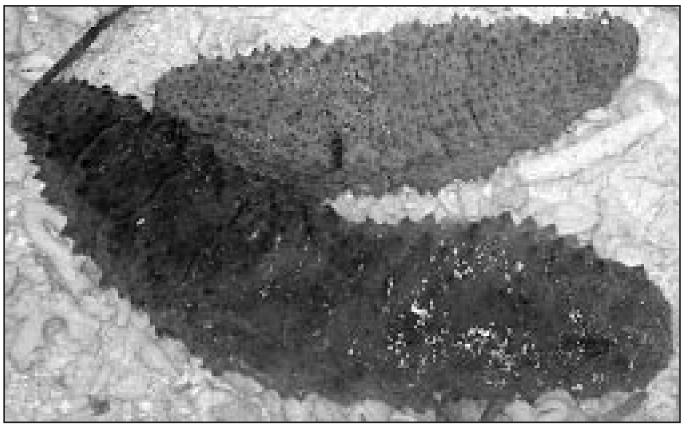

Figure 1.

Stichopus hermanni Semper, 1868 can be seen in the shallow reef lagoons of Kanamai, Kenya.

who found that the nature of the chemical characters of this species needed a new genus name: *Pearsonothuria* Levin, Kalinin & Stonik, 1984. Indeed, by assigning the genus name of *Pearsonothuria*, the anomalous structure of the typical 'racket-shaped' spicules, and the translucent and weakly developed calcareous ring, now get a more appropriate systematic position. However, the name *Bohadschia graeffei* still appears in numerous papers that deal with conservation of holothurians.

The consequence of such different classifications can easily be grasped if one considers the following hypothetical example. Suppose you were given a grant to study the inductive potential of diatoms on the metamorphosis of a sea cucumber that thrives in your study area: a species identified by specialists as *Bohadschia graeffei*. From the literature you know that all the species studied thus far within your study area hold a sensitivity towards induction by diatoms. If you are unaware that *Bohadschia graeffei* and *Pearsonothuria graeffei* are synonymous, you might deduce the following:

- That each individual genus (and species) has a well-defined niche and that, as a consequence, larval metamorphosis will hardly be induced by the same diatom genera. In which case you would look for different diatoms, but end up wasting precious time and many thousands of dollars, and with a failed project.

- That, because *Bohadschia* and *Pearsonothuria* belong to the same family, susceptibility to diatoms as a means of inducing metamorphosis is a monophylogenetic character at the family level. It is quite possible, however, that you would make erroneous conclusions about phylogeny.

Incorrect taxonomy and systematics can bring erroneous conclusions at the fundamental and applied level. Unfortunately, more grants are given to applied research than to fundamental. The result is taxonomic and systematical errors are often perpetuated over time.

Level three: *Faunistics*

Assessing holothurian biodiversity of a narrow geographical entity like the Kenyan Coast is not a simple endeavour because only few studies have recently been devoted to this region (Levin, 1979; Humphreys; 1981; Rowe & Richmond, 1997). Our team, in collaboration with the Kenya Wildlife Service and WWF Kenya, is currently re-evaluating the biodiversity of the Kenyan holothurian fauna. Our first results from the Kiunga Marine National Reserve (Samyn & Van den Berghe, submitted), the largest marine reserve in Kenya (250 km^2), show that the biodiversity of the aspidochirotid sea cucumbers in Kenya is currently underestimated (see Figure 2).

In the Kiunga Marine National Reserve we observed 24 different aspidochirotid holothurians, and deduced from literature that two more species were to be found within the boundaries of the Reserve. Our published (Massin *et al.*,

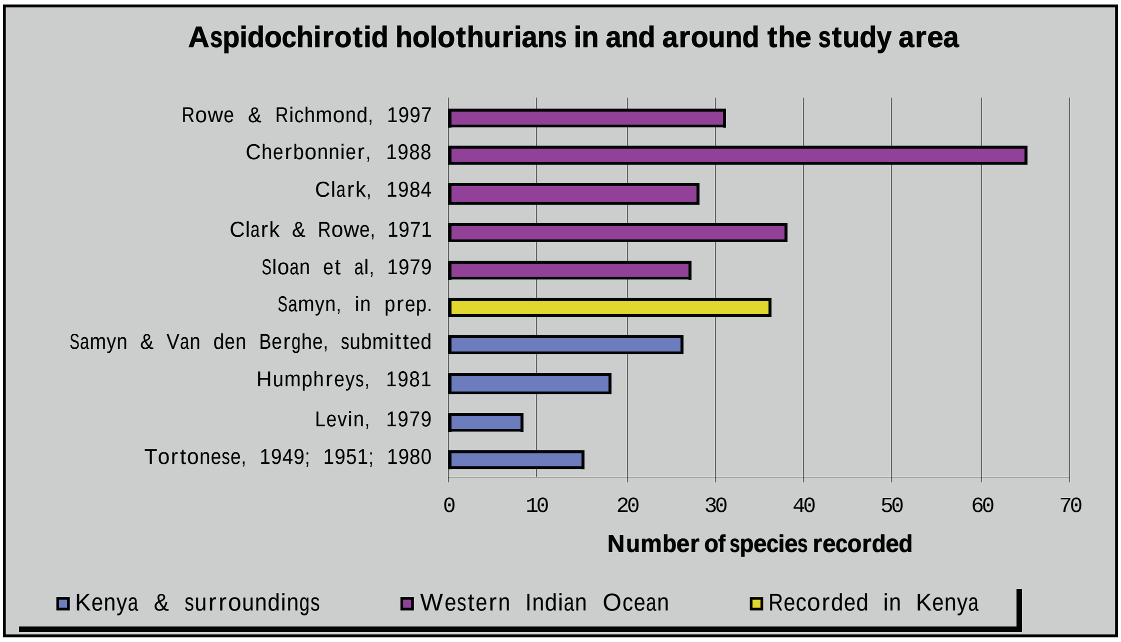

Figure 2 .

Biodiversity of aspidochirotid sea cucumbers in and around Kenya as deduced from literature and sampling.

1999) and unpublished data on the entire Kenyan coastline adds at least seven more species to that list, and a search through the literature indicates that three additional species can be added, bringing the total aspidochirotid fauna to 36 species (Table 1).

When the holothurian fauna of the western Indian Ocean is examined, some 40 additional aspidochirotids have to be considered (see Cherbonnier, 1988). Whether these species also occur in the littoral waters of Kenya can only be known if further systematical sampling is done in the region.

Table 1 . Aspidochirotid sea cucumbers from Kenya, as deduced from literature and sampling.
x indicates records from the Kiunga Marine National Reserve (Samyn & Van den Berghe, submitted);
xx indicates unpublished records from Kenya.

Currrent species name	Kenyan records by our team	Kenyan records by others	Known geographical distribution
HOLOTHURIIDAE			
1 *Actinopyga echinites* (Jaeger, 1833)	x	x	Indo-West Pacific
2 *Actinopyga lecanora* (Jaeger, 1833)	xx	x	Indo-West Pacific
3 *Actinopyga mauritiana* (Quoy & Gaimard, 1833)	x	x	Red Sea; Indo-West Pacific
4 *Actinopyga miliaris* (Quoy & Gaimard, 1833)	x	x	Red Sea; Indo-West Pacific
5 *Actinopyga plebeja* (Selenka, 1867)		x	Red Sea; Mombasa; Zanzibar; Querimba; Madagascar; Mauritius
6 *Bohadschia atra* Massin *et al.* , 1999	x		Western Indian Ocean
7 *Bohadschia cousteaui* Cherbonnier, 1954	xx		Red Sea, Madagascar
8 *Bohadschia marmorata* Jaeger, 1833	x	x	Red Sea; Indo-Pacific
9 *Bohadschia similis* (Semper, 1868)	xx	x	Mauritius, Réunion, Philippines, New Caledonia, Tahiti
10 *Bohadschia subrubra* (Quoy & Gaimard, 1833)	x	x	Western Indian Ocean
11 *Holothuria (Acanthotrapeza) pyxis* Selenka, 1867		x	Mombasa, Bay of Bengal; east Indies
12 *Holothuria (Cystipus) rigida* (Selenka, 1867)	x		Red Sea; Indo-West Pacific
13 *Holothuria (Halodeima) atra* Jaeger, 1833	x	x	Red Sea; Indo-Pacific
14 *Holothuria (Halodeima) edulis* Lesson, 1830	x		Red Sea; Indo-Pacific
15 *Holothuria (Lessonothuria) pardalis* Selenka, 1867	x	x	Red Sea; Indo-Pacific
16 *Holothuria (Mertensiothuria) fuscocinerea* Jaeger, 1833	x	x	Red Sea; Indo-West Pacific
17 *Holothuria (Mertensiothuria) leucospilota* Brandt, 1835	x	x	Red Sea; Indo-Pacific
18 *Holothuria (Mertensiothuria) pervicax* Selenka, 1867	xx	x	Red Sea; Indo-Pacific
19 *Holothuria (Metriatyla) scabra* Jaeger, 1833	x	x	Red Sea; Indo-West Pacific
20 *Holothuria (Microthele) fuscopunctata* Jaeger, 1833	xx		Indo-West Pacific
21 *Holothuria (Microthele) nobilis* (Selenka, 1867)	x	x	Red Sea; Indo-Pacific
22 *Holothuria (Platyperona) difficilis* Semper, 1868	x		Red Sea, Indo-Pacific
23 *Holothuria (Selenkothuria) parva* Lampert, 1885		x	Red Sea, Indian Ocean
24 *Holothuria (Semperothuria) cinerascens* (Brandt, 1835)	x	x	Red Sea; Indo-Pacific
25 *Holothuria (Theelothuria) turriscelsa* Cherbonnier, 1980	x		Indo-West Pacific
26 *Holothuria (Thymiosycia) arenicola* Semper, 1868	x		Red Sea; Indo-West Pacific
27 *Holothuria (Thymiosycia) hilla* Lesson, 1830	x	x	Red Sea; Indo-West Pacific
28 *Holothuria (Thymiosycia) impatiens* (Forskal, 1775)	x	x	Mediterranean Sea; Red Sea; Indo-Pacific
29 *Labidodemas pertinax* (Ludwig, 1875)	x		Kenya, Glorioso Isl; Maldives; Java; Samoa
30 *Labidodemas semperianum* (Selenka, 1867)		x	Red Sea; Indo-West Pacific
31 *Pearsonothuria graeffei* (Semper, 1868)	xx		Red Sea; Indo-West Pacific
STICHOPODIDAE			
32 *Stichopus chloronotus* Brandt, 1835	x		Indo-West Pacific
33 *Stichopus hermanni* Semper, 1868	x	x	Red Sea; Indo-West Pacific
34 *Stichopus monotuberculatus* (Quoy & Gaimard, 1833)	x	x	Red Sea; Indo-West Pacific
35 *Thelenota ananas* (Jaeger, 1833)	xx	x	Indo-West Pacific
36 *Thelenota anax* H.L. Clark, 1921	xx		Indo-West Pacific

Level four: *Ecology*

Protecting and managing the holothurian fauna of Kenya is not a simple endeavour, as conservation measures cannot be limited to one group of interest alone. The interconnectivity in ecosystems forces us to study not only in an 'autoecological' way but also in a 'synecological' way. Indeed, both theoretical and experimental studies have shown that the stability of an ecosystem is influenced directly by the interactions between the various players. In coral reefs, echinoderms are unmistakably important actors (reviewed by Birkeland, 1988); however, a lack of knowledge of the species (see the three levels above) and on the interactions between the other actors in the ecosystem, hinders in-depth understanding of the ecological roles of sea cucumbers in coral reefs. As a consequence, the impact of overfishing sea cucumbers from coral reefs is largely unknown.

Despite the large gaps in our knowledge of holothurians, we are not starting from nil; the biology and ecology of tropical holothurians were already reviewed by Bakus in 1973. Since then, the ecology of several species is better known, although the need for further studies can be demonstrated with examples on the feeding biology of holothurians.

It is assumed that the ecological distribution of sea cucumbers on coral reefs is largely dependent on microhabitat structure rather than on the type of food selected. Still, the literature indicates that aspidochirotid sea cucumbers are selective for organic matter content in the sediment. The impact herewith on the environment appears to be temporarily and spatially variable and above all, taxon-specific. For instance, in Kenya we observed that *Pearsonothuria graeffei* is often found grazing on dead coral and sponges, and that *Actinopyga mauritiana* and *A. lecanora* are often found grazing on live and dead coral. Such observations, however, are seldom made by reef ecologists since they are hindered by the lack of correct species lists and descriptions for holothurians in their study area.

Level five: *Education*

Conservation of holothurians depends on the participation of local communities, a fact that the Kenyan Government acknowledged by creating the Community Wildlife Program (Western & Wright, 1994). This programme allows local communities to benefit from conservation efforts, for instance through sustainable use of the natural resources (Muthiga, pers. comm.).

For generations, coastal peoples of Kenya have developed traditional management strategies that enable them to conserve and protect their natural heritage and resources. The impetus for these local customs is however not conservation, but soothing of the spirits (McClanahan *et al.*, 1997). In recent and future times these traditional conservation plans are or will not longer be sufficient for four main reasons: 1) Coastal urban populations in Kenya are increasing rapidly, and are putting demands on the environment. 2) In Kenya, the Islam religion is rapidly replacing the traditional culture where traditional leaders had more power (McClanahan *et al.*, 1997). As a consequence, authority has shifted towards national organisations like Kenya Wildlife Services, which local communities show increasing resistance to because it is thought that these instances will prohibit access to resources (McClanahan *et al.*, 1997). 3) The harvesting techniques employed by the sea cucumber fishermen are not 'traditional': with the advent of motorised boats and SCUBA gear, local fishermen can now reach areas that were formerly unreachable or inaccessible. In Gazi, we witnessed local SCUBA-divers (not using depth gauges) at 45 m collecting holothurians. 4) Not only 'locals' collect sea cucumbers on the fishing grounds. In Kenya, SCUBA-divers are hired to go fishing on grounds that are hundreds of kilometres away from their native fishing grounds. Obviously, these fishermen do not have an incentive towards sustainable resource utilisation. Education at all levels (from local resource users to biology students to policy makers) can help trigger awareness of the problems and make for the loss of traditional management strategies. Therefore, our team makes it the highest priority to inform local people on the purposes and consequences of our research.

Conclusions

Conservation and management plans will be optimal if the five, above mentioned, levels are grasped. First, a correct naming according to the rules of zoological nomenclature allows communication between scientists in an unbiased way. Second, because scientific naming implies ordering of the living world, understanding of the observed biological patterns within biodiversity becomes possible. Third, complete faunal lists must be constructed both for narrow political areas and for broader zoogeographical provinces, since these hold information that enables scientists to understand the faunal make-up of the landscapes and regions that need conservation. Fourth, because zoogeography is not only the consequence of history but also of ecological interactions a clear understanding of the current ecological interactions is needed. Fifth, education at all levels, from scientists to policy makers to fishermen, will ensure that conservation efforts will be understood and evaluated and that sustainable management will replace unthoughtful environmental rape.

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References

BAKUS G.J. (1973). The biology and ecology of tropical holothurians. **In:** Jones O.A. & Endean R. (eds.), Biology and Geology of Coral reefs. Vol 2. (Biol. 1): 325–367. Academic Press, New York.

BIRKELAND C. (1988). The influence of echinoderms on coral-reef communities. **In:** Jangoux M. & Lawrence J.M. (eds.), Echinoderm Studies 3: 1–79. A.A. Balkema, Rotterdam.

CHERBONNIER, G. (1988). Echinodermes: Holothurides. Faune de Madagscar 70: 1–292.

CLARK A.M. (1984). Echinodermata of the Seychelles. **In:** D.R. Stoddart (ed.). Biogeography and Ecology of the Seychelles Islands. Dr. W. Junk Publishers, The Hague: 83–102.

CLARK, A.M. & F.W.E. ROWE. (1971). Monograph of Shallow-water Indo-West Pacific Echinoderms. London, Trustees of the British Museum (Natural History), London. 238 p.

FERDOUSE, F. (1999). Beche-de-mer markets and utilisation. SPC Beche-de-mer Information Bulletin No. 11: 3–9.

HUMPHREYS, W.F. (1981). The Echinoderms of Kenya's Marine Parks and Adjacent Regions. Zoologische documentatie Koninklijk Museum voor Midden Africa, Tervuren 19: 1–39.

LEVIN, V.S. (1979). Aspidochirote holothurians of the upper sublittoral zone of Indo-West Pacific: species composition and distribution. Biologia Moria 5: 17–23.

LEVIN, V.S., V.I. KALININ & V.A. STONIK. (1984). Chemical characters and taxonomic revision of holothurian *Bohadschia graeffei* (Semper) as refer to erection of a new genus. Biologia Moria, Vladivostok 3: 33–38.

MASSIN, C. (1999). Reef-dwelling Holothuroidea (Echinodermata) of the Spermonde Archipelago (South-West Sulawesi, Indonesia). Zoologische Verhandelingen 329: 1–144.

MASSIN C., R. RASOLOFONIRINA, C. CONAND & Y. SAMYN. (1999). A new species of *Bohadschia* (Echinodermata: Holothuroidea) from the Western Indian Ocean with a redescription of *Bohadschia subrubra* (Quoy & Gaimard, 1833). Bull. Inst. Roy. Sci. Nat. Belg. 69: 151-160,+ 1 pl.

MCCLANAHAN T.R., H. GLAESEL, J. RUBENS & R. KIAMBO. (1997). The effects of traditional fisheries management on fisheries yields and the coral-reef ecosystems of southern Kenya. Environmental Conservation 24(1): 1–16.

ROWE, F.W.E. & J. GATES. (1995). Echinodermata. In: A. Wells (ed.), Zoological Catalogue of Australia: vol. 33(i-xiii): 1-510. CSIRO Australia, Melbourne.

ROWE, F.W.E. & M.D. RICHMOND. (1997). Echinodermata. **In:** M.D. Richmond (ed.), A guide to the seashores of eastern Africa and the western Indian Ocean Islands: 290-321. The SEA Trust, Zanzibar. 448 p.

SAMYN, Y. & E. VAN DEN BERGHE. (submitted). Annotated Checklist of the Echinoderms from the Kiunga Marine National Reserve, Kenya. Part I: Echinoidea and Holothuroidea.

SLOAN, N.A., A.M. CLARK & J.D. TAYLOR. (1979). The echinoderms of Aldabra and their habitats. Bull. Brit. Mus (Nat. Hist.), Zool Ser. 37(2): 81–128.

TORTONESE, E. (1949). Echinodermi della Somalia Italiana. Ann. Mus. civ. Stor. nat. Giacoma Doria, Genova 64: 30–42

TORTONESE, E. (1951). Contributo allo studio dell'Echinofauna della Somalia. Atti Soc. Ital. Sci. Nat. Vol. 90: 237–250.

TORTONESE, E. (1980). Researches on the coast of Somalia. Littoral Echinodermata. Italian Journal of Zoology 5: 99–139.

WESTERN, D. & R.M. WRIGHT. (1994). The background to community-based conservation. **In:** Western D., Wright R.M. & Strums S.C. (eds.). Perspectives in Community-based Conservation: 1–12. Island Press, Washington, USA.