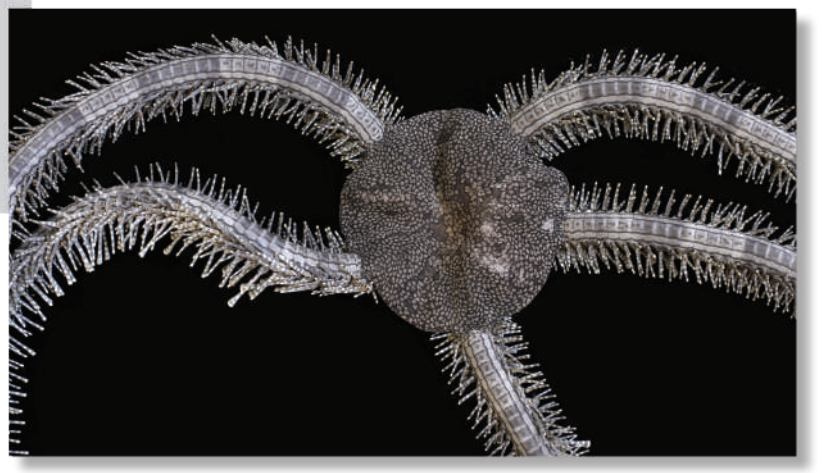
Abc Taxa

Field guide to the brittle and basket stars (Echinodermata: Ophiuroidea) of South Africa

J.M. Olbers
C.L. Griffiths
T.D. O'Hara
Y. Samyn



Volume 19 (2019)

Abc Taxa

the Series of Manuals
Dedicated to Capacity Building
in Taxonomy and
Collection Management

CEBioS

Belgium
partner in development

Editors

Yves Samyn - Zoology (non African)
Curator of Recent Invertebrate Collections
Royal Belgian Institute of Natural Sciences
Rue Vautier 29, B-1000 Brussels, Belgium
yves.samyn@sciencesnaturelles.be

Didier VandenSpiegel - Zoology (African)
Head of Biological Collection and Data Management Unit
Royal Museum for Central Africa
Chaussée de Louvain 13, B-3080 Tervuren, Belgium
dvdspiegel@africamuseum.be

Jérôme Degreef - Botany
Scientific Director
Meise Botanic Garden
Nieuwelaan 38, B-1860 Meise, Belgium
jerome.degreef@botanicgardenmeise.be

Instructions to authors

http://www.abctaxa.be

Cover illustration: dorsal view of *Ophiarachna affinis* Lütken, 1869 from the shallow-waters of KwaZulu-Natal (photo by Yves Barette).

Inner page photograph: top: upon re-surfacing, one is reminded of the recreational value of the scenery and its biodiversity; **bottom left**: a colony of mushroom soft-coral (*Sarcophyton* sp.), with a small giant clam (*Tridacna* sp.) in the middle of the picture and with, a.o., colonial tunicates (*Didemnum molle* Herdmann, 1866) at the top of the picture; **bottom right**: close encounters of a fish kind: big-eye stumpnoses (*Rhabdosargus thorpei* Smith, 1979) swarm around; not known if this species feeds on ophiuroids.

Volume published by RBINS' Scientific Publication Unit
Printed by Peeters (Belgium) on FSC papers

ISSN 1784-1283 (hard copy); ISSN 1784-1291 (on-line pdf)
ISBN 978-9-0732-4245-6 (hard copy); ISBN 978-9-0732-4246-3 (on-line pdf)
D/2019/0339/3 (hard copy); D/2019/0339/4 (on-line pdf); NUR 910

Field guide to the brittle and basket stars (Echinodermata: Ophiuroidea) of South Africa

Jennifer M. Olbers
Ezemvelo KZN Wildlife & Department of Biological Sciences, University of Cape Town, Rondebosch,
7700, South Africa; jennifer.olbers@kznwildlife.com

Charles L. Griffiths
Department of Biological Sciences, University of Cape Town, Rondebosch,
7700, South Africa; charles.griffiths@uct.ac.za

Timothy D. O'Hara
Museums Victoria, GPO Box 666E, Melbourne, 3001 Australia;
tohara@museum.vic.gov.au

Yves Samyn
Royal Belgian Institute of Natural Sciences, Rue Vautier 29, 1000 Brussels,
Belgium; yves.samyn@naturalsciences.be

Abstract

Brittle and basket stars (ophiuroids) are one of five extant classes of the phylum Echinodermata and have a fossil record dating back almost 500 million years to the Early Ordovician. Today, they remain diverse and widespread, with over 260 described genera and 2,077 extant species globally (Stöhr *et al*. 2018), more than any other class of echinoderm. Ophiuroid species are found across all marine habitats from the intertidal shore to the abyss. In southern Africa, the ophiuroid fauna has been studied extensively by a number of authors and is relatively well-known. The last published review of the southern African Ophiuroidea however was by Clark & Courtman-Stock in 1976. It included 101 species reported from within the boundaries of South Africa. In the 40 years since that publication the number of species has risen to 136. This identification guide includes a taxonomic key to all 136 species, and gives key references, distribution maps, diagnoses, scaled photographs (where possible), and a synthesis of known ecological and depth information for each. The guide is designed to be comprehensive, well illustrated and easy to use for both naturalists and professional biologists. Taxonomic terms, morphological characteristics and technical expressions are defined and described in detail, with illustrations to clarify some aspects of the terminology. A checklist of all species in the region is also included, and indicates which species are endemic (33), for which we report significant range extensions (23), which have been recorded as new to the South African fauna (28) since the previous monograph of Clark & Courtman-Stock (1976) and which have undergone taxonomic revisions since that time (28).

Keywords

Taxonomy, biodiversity, new records, Indian Ocean

Preface

The Republic of South Africa is widely recognized as being highly bio-diverse. With a coastline of some 3,650 km and an Exclusive Economic Zone of just over 1 million km^2, South Africa is bordered by the Southern Atlantic and Indian Oceans and dominated by the cold Benguela Current along the Atlantic coast to the west and the warm Agulhas Current along the Indian Ocean coast to the east. This offers marine life diverse habitats in which to flourish: cold and warm water, strongly wave exposed and sheltered coastlines, areas of low (nutrient poor) and high (upwelling) productivity with known biodiversity hotspots both in the water and on adjacent surrounding coastal plains.

Despite its status as a developing nation, South Africa has a relatively strong history of marine taxonomic research maintaining well-curated museum collections totaling over 291,000 records (Griffiths *et al*. 2010). The coastline is divided into five regions nine marine bioregions, with 33% of the biota listed as endemic species. Marine speciation in general, gets progressively richer to the (more tropical) east, whereas some taxa attain maximum species richness in the temperate southwest, with range-restricted species strongly concentrated on the boundaries or ‘‘ecoregions’’ where the Atlantic and Indian Oceans meet, especially around Cape Point.

The volume here reports on the diversity of the most species rich group of echinoderms, the ophiuroids. At the level of major phyla, Echinodermata surprisingly have some of the lowest levels of endemism on the current record (3.6%), so what did they find in the current studies? Importantly, what opportunities do ophiuroids offer man in further understanding the productivity and sustainability of our oceans, especially at this time when man-made pressures, like the impacts from direct exploitation, the introduction of non-native marine species, climate change, habitat modification, pollution, and habitat alternation, harmful invasive species are rapidly changing our marine systems? Questions of food security, livelihoods, economic and socio-cultural benefits that productive and sustainable marine systems offer are critical to South Africa’s development, and also central to the strategic objective of the United Nations Food and Agriculture Organization. FAO invests to ensure that fisheries and aquaculture ensure food security of the world’s peoples, with all its implications for resource conservation, livelihoods and maintaining sustainability and ecosystem services.

So why examine and gain further understanding of ophiuroid biodiversity? Why bother? What we have found is that we need to develop better tools and indicators of human pressures, to describe a consolidated view of impacts of human pressures on the health of benthic and pelagic communities. We also have to continue to look for potential species to support the livelihoods of a growing world population. Are there eco-tourism opportunities, potential pre-cursors for the development of new medicines, or other opportunities (e.g., supply the aquarium industry) that such taxonomic enquiry can offer? Might ophuiroids be a good taxon group to help train our future marine scientists? What insights or opportunities can and will they offer?

The South African marine biota supports a wide range of fisheries and ecotourism and recreation based on South Africa's marine environment that has developed significantly along with its growing population. FAO has a relatively long history when it comes to the taxonomy of edible taxa (http://www.fao.org/fishery/fishfinder/en), mainly to improve the capacity of countries to identify and record artisanal and commercially exploited fish species, for improving the definition of country fish records. FAO also supports countries in gaining a greater understanding of the scope and importance of their biodiversity, not just of target species in fisheries but also for 'associated' and 'dependent' species. The work reported here aims to drive better understanding, communication and action to manage and conserve our marine environment.

Luckily a new generation of taxonomists[1] is being supported by the South African National Biodiversity Institute (SANBI) and the South African Biosystematics Initiative (SABI) that are increasing the availability of funding for such work, and encouraging young researchers to enter this field. For, a.o., ophiuroids, these budding taxonomists also can count on the support of the Belgian Development Cooperation and this through the Belgian Global Taxonomy Initiative (www.taxonomy.be), through for instance its flagship capacity building product: *Abc Taxa* (www.abctaxa.be). Such enquiry will no doubt lead to greater care, and resilience of our oceans.

Kim Friedman[2]
December 2017

---

1) The primary marine invertebrate collections in the region are housed at the Iziko South African Museum in Cape Town and comprise some 129,000 records, offering significant coverage of all major marine taxonomic groups.

2) Dr Kim Friedman (Kim.Friedman@fao.org) is a Senior Fishery Resources Officer with the Fisheries and Aquaculture Department of the Food and Agriculture Organization of the United Nations (FAO). Kim leads the FishFinder program and has leadership and coordination responsibilities for biodiversity issues within the Marine and Inland Fisheries Branch of FAO.

Table of contents

1. Introduction

Brittle and basket stars in southern Africa have been relatively well-documented (Clark 1923; Mortensen 1925; Mortensen 1933a; Clark A.M. 1952; Balinsky, 1957; Clark 1974; Clark & Courtman-Stock 1976; Clark 1977; Olbers & Samyn 2012; Olbers *et al*. 2014; Olbers *et al*. 2015; Olbers 2016). Unfortunately, until now, Clark & Courtman-Stock's monograph of 1976 was the last comprehensive guide to the ophiuroids of southern Africa. It is not confined to South Africa, making a clear assessment of the South African fauna challenging and the available identification keys also lack images of many species and are riddled with jargon that is too technical for most users. Furthermore, since the publication of Clark & Courtman-Stock (1976), an extensive number of samples have been collected and have accumulated unidentified in museum collections. These unidentified collections have been tackled in this work and form the principal basis for this guide.

The primary aim of this guide is to provide a well-illustrated and easy to use field guide with a taxonomic key to the ophiuroids of South Africa.

The geographic coverage (Fig. 1) of this guide is limited to the South African coast and its Exclusive Economic Zone (EEZ), for which maps are provided for each species. Global distribution as well as known depth range information for all species are also given.

The bulk of the book is an easy-to-use guide to the identification of South African ophiuroids. This guide targets the general public, biologists and naturalists and is designed to be comprehensive for scientists to obtain accurate and useful information, while easy enough for a naturalist to understand. For this reason, technical terms have been kept to a minimum, although taxonomic terms are essential, therefore all morphological characters referred to have been explained

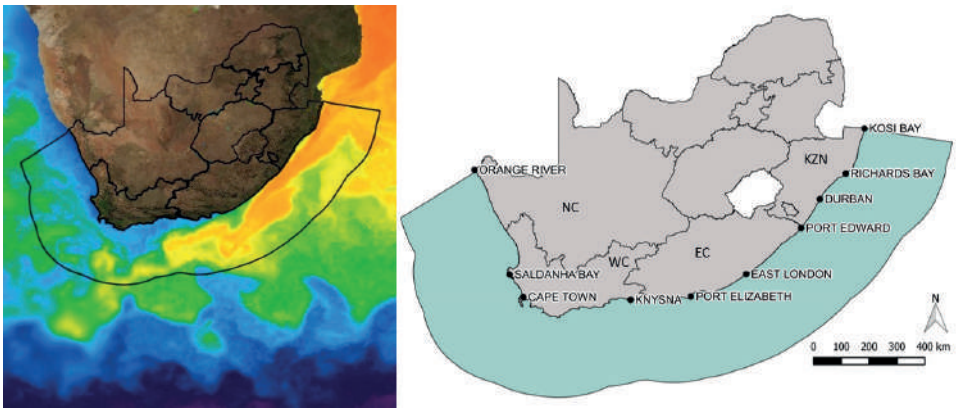


Fig. 1. Exclusive Economic Zone (EEZ) of mainland South Africa showing provincial boundaries overlaid on a MODIS satellite sea surface temperature image (June 2002–June 2019; daily average) illustrating the warm Agulhas current flowing down the east coast and the colder Benguela Current on the west coast of southern Africa (right), with major coastal towns being indicated (left); NC: Northern Cape; WC: Western Cape; EC: Eastern Cape; KZN: KwaZulu-Natal.

and illustrated. The formal taxonomy of the species, which makes up the bulk of the guide, includes descriptions of families, genera and species. Information for each species includes taxonomic synonymies, diagnostic features, distribution (including maps), depth range, known habitat and any additional remarks that are considered noteworthy. Each species is represented by at least one photograph or illustration.

In addition to the taxonomy, the procedures of collecting, transporting and storing brittle and basket stars are also outlined and supported by illustrations.

The majority of new records and data were sourced from previously unidentified specimens deposited in the Iziko South African Museum collection, while additional records were obtained from photographic evidence sourced from the South African National Biodiversity Institute (SANBI) iSpot programme, and the University of Cape Town Animal Demographic Unit EchinoMAP programme.

Taxa are arranged according to their currently known classification, as given by Stöhr *et al.* (2018). Orders are as defined by O'Hara *et al.* (2018). Species are presented under the binomen considered valid by Stöhr *et al.* (2018).

1.1. Abbreviations used in the text

A.L. = Arm length.
AM = Australian Museum, Sydney, Australia.
BMNH = British Museum (Natural History), London, United Kingdom (now NHMUK).
CSIRO = Commonwealth Scientific and Industrial Research Organisation, Australia.
DEFF = Department of Environment, Fisheries and Forestry, South Africa.
DEA = Department of Environmental Affairs, South Africa.
D.D. = Disc diameter.
D.D./A.L. = Disc diameter to arm length ratio.
EC = Eastern Cape province, South Africa.
EKZNW = Ezemvelo KZN Wildlife, South Africa.
GMNH = Muséum d'Histoire naturelle, Genève, Switzerland (See MHNG)
KZN = KwaZulu-Natal province, South Africa.
MCZ = Museum of Comparative Zoology, Harvard University, Massachusetts, United States of America.
MHNG = Muséum d'Histoire naturelle (Natural History Museum), Genève, Switzerland (See GMNH).
MNHN = Muséum national d'Histoire naturelle, Paris, France.
Naturalis = Naturalis Biodiversity Centre, Leiden, The Netherlands (incorporating ZMA and RMNH).
NC = Northern Cape province, South Africa.
NHMUK = Natural History Museum, London, United Kingdom (see BMNH).
RBINS = Royal Belgian Institute of Natural Sciences, Brussels, Belgium.
RMCA = Royal Museum for Central Africa, Tervuren, Belgium.
RMNH = Rijksmuseum van Natuurlijke Historie (National Museum of Natural History), Leiden, The Netherlands (see Naturalis).

SAMC = Iziko South African Museum, Cape Town, South Africa.
SANBI = South African National Biodiversity Institute.
SEM = Scanning Electron Microscope.
SMNH = Swedish Museum of Natural History, Stockholm, Sweden.
UCT = University of Cape Town, South Africa.
USNM = Smithsonian Institution, National Museum of Natural History, Washington, D.C., United States of America.
WC = Western Cape province, South Africa.
ZMA = Zoölogisch Museum Amsterdam (Zoological Museum Amsterdam), The Netherlands (see Naturalis).
ZMB = Museum für Naturkunde (Museum of Natural History of Berlin), Berlin, Germany.
ZMUC = Natural History Museum of Denmark, Copenhagen, Denmark.
ZSM = Zoologische Staatssammlung München (Zoological State Collection Munich), Munich, Germany.

1.2. Echinoderms

Echinodermata (from the ancient Greek, ἐχῖνος, ekhinos - meaning spine or hedgehog and δέρμα, derma - meaning skin) is largely a marine phylum, belonging to the Deuterostomia branch of the Animal Kingdom. Echinoderms are the only pentamerous or five-rayed organisms. Although they are radially symmetrical, their larvae are bilateral, later developing into radially symmetrical adults. Other unique characters of the echinoderms include their water vascular system: a complex system of channels and reservoirs that form a hydraulic skeleton, their almost hollow interior, dermal endoskeleton and haemal system (Hyman 1955; Hickman 1998).

Some 6,950 extant and 13,000 fossil species of echinoderms are known (Pawson 2007). There are five accepted echinoderm extant classes, with the morphology of each class being quite different (Fig 2). The feather stars or sea lilies (Class Crinoidea: Greek *krinoeidēs,* lily-like) which are either free-living or sessile, have a central body with five or more long, feather-like arms and are the only echinoderm class where the mouth is directed upwards in adults. The sea stars or starfish (Class Asteroidea: Gr. *asteroeidēs,* star-like) have five or more hollow arms radiating from the centre of the body. They are flattened, with a distinctly differentiated dorsal and ventral surface. The sea urchins, heart urchins and sand dollars (Class Echinoidea: Gr. *ekhinos*, spine) have no arms but a single calcareous test which is armed with spines. The sea cucumbers (Class Holothuroidea: Gr. *holothurum*, Gr. *holos*, whole + *thureos*, oblong shield) do not possess arms or spines, and have a more-or-less cylindrical body that lies on its side with the mouth, which is encircled by feeding tentacles, at one end and the anus at the other. The serpent stars, basket stars and brittle (Class Ophiuroidea: Gr. *ophis*, snake + *ura*, tail) have a small disc and long mobile arms; gaining their name from the serpentine-like movements of their arms which have the tendency to break off or autotomise.

Table 1. Number of echinoderm species recorded globally, for southern Africa and for South Africa. Global data from Horton *et al.* (2018) and Pawson (2007) [Crinoidea]; southern African data from Clark & Courtman-Stock (1976) and Thandar (2015); South African data from Griffiths *et al.* (2010); Filander & Griffiths (2014), Olbers (2016), Ahmed Thandar and Erich Koch, pers. comm.

Class	Number of species		
	Global	***Southern Africa***	***South Africa***
Crinoidea	~650	17	19
Asteroidea	1,879	99	116
Echinoidea	1,012	59	71
Holothuroidea	1,711	163	143
Ophiuroidea	2,076	124	136
Total	**~7,328**	**462**	**485**

Ophiuroidea are all benthic, but can be found on all types of bottom substrata, at all depths, and in all oceans and seas. They inhabit both open and secluded habitats and can range in size from large to very small, sometimes making them difficult to collect in comparison to other echinoderm classes, such as the more conspicuous Asteroidea and Echinoidea. Together with their negative response to light (Cowles 1910) and their high level of stereotropism (Hyman 1955), they are found in most habitats, concealing themselves by day under stones, rocks, boulders, in sediment or among seaweeds (Hyman 1955).

The number of species recorded globally, for southern Africa and for South Africa are listed in Table 1. Until recently, published data on echinoderms have been for the southern African region (i.e., south of the Tropic of Capricorn), which included parts of Mozambique, Namibia and South Africa and not within the political boundaries of South Africa *per se*.

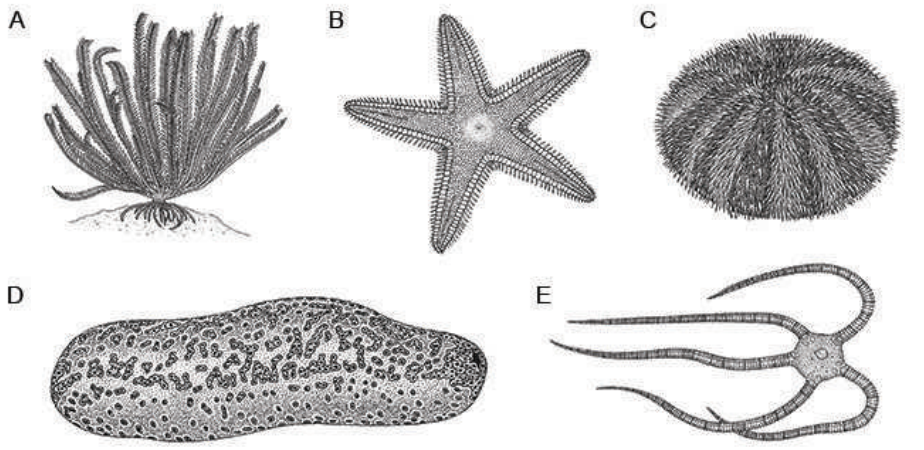


Fig. 2. Representatives of the five echinoderm classes. **A**. Crinoidea. **B**. Asteroidea. **C**. Echinoidea. **D**. Holothuroidea. **E**. Ophiuroidea. Adapted from Rowe & Gates (1995).

1.3. Ecological and economic importance of the brittle and basket stars

Although brittle and basket stars have little economic value, the function of brittle and basket stars in a broad ecological context is poorly understood, but does offer some value in marine conservation management planning by acting as indicators of impact or as surrogates for seafloor communities.

The Ophiuroidea have a variety of ecological roles with one of their main roles being that of biodegradation or the process of breaking down and decomposition of dead plants and/or animals. Other roles include being scavengers or detritivores, whereby they feed on decaying material (Aronson 1989, 1992) but are also suspension feeders (Roushdy & Hansen 1961) in which they feed upon diatoms, phytoplankton, plant material and other particles in the water column (Eichelbaum 1910; Wintzell 1918). Eichelbaum (1910) found that the stomach contents of several European brittle and basket stars included detritus, diatoms, foraminiferans, dinoflagellates, tintinnoids, polychaete worms, small crustaceans, young echinoderms, bivalves and other molluscs. Later Wintzell (1918) reported that some species feed primarily on kelp fronds but also the other fauna which inhabits the same fronds, such as hydroids and other small invertebrates.

Brittle and basket stars are also prey items for various fish and invertebrates. Fish species known to prey on brittle and basket stars in European waters include the common dragonet *(Callionymus lyra* Linnaeus, 1758*)*, the ballan wrasse (*Labrus bergylta* Ascanius, 1767) and the cuckoo wrasse (*Labrus mixtus* Linnaeus, 1758), whereas common invertebrates include the velvet crab (*Necora puber* (Linnaeus, 1767)), brown crab (*Cancer pagurus* Linnaeus, 1758*),* spiny starfish (*Marthasterias glacialis* (Linnaeus, 1758)), common starfish (*Asterias rubens* Linnaeus, 1758), seven-armed sea star (*Luidia ciliaris* (Philippi, 1837)) and five-armed sea star (*Luidia sarsii* Düben & Koren in Düben, 1844) (Aronson 1989; Brun 1972 and Fenchel 1965).

Brittle star beds, which are well-documented in European waters, can harbour up to thousands of individuals per m^2, living epifaunally on bedrock, boulders, gravel or sedimentary substrata. These beds create shelter for other species, such as the bivalve *Abra alba* (W. Wood, 1802) (Warner 1971; Davoult & Gounin 1995; Hughes 1998).

There is evidence to suggest that the massive aggregations of suspension-feeding brittle and basket stars can influence the water quality in coastal environments and possibly assist in counteracting potentially harmful effects of eutrophication caused by anthropogenic activities (Hughes 1998).

Brittle and basket stars are also host to several ectoparasites, the best documented group of these being the copepods (Boxshall 1988; Stöhr & Hansson 2010; Boxshall 2001).

Stöhr *et al.* (2012) stated that given brittle and basket stars occur in all marine habitats, have a range of trophic and life history strategies and have a high abundance and diversity, they make prime candidates for scientific studies. For

continental Australasia, the brittle and basket stars have been used extensively (O'Hara 2007; O'Hara 2008a; O'Hara 2008b) in macro-ecological and biogeographic studies. In addition, Stöhr *et al.* (2012) suggested that brittle and basket stars have the potential to act as indicators of palaeoceanographic events because their skeletons are taxonomically identifiable in sediment cores.

1.4. History of taxonomic research on brittle and basket stars in South Africa

The current state of knowledge for brittle and basket stars in South Africa is a result of numerous contributions from authors since the late 1700s. The first record of an ophiuroid from South Africa was that by Retzius (1783) who reported *Asterias euryale* Retzius, 1783 (= *Astrocladus euryale*) from the Cape of Good Hope, followed by Müller & Troschel (1842) who reported two species and then Ljungman (1867) who added five additional species to the South African fauna.

The *Challenger* expedition between 1873 and 1876, sampled seven stations within South African waters (excluding the Prince Edward and Marion Islands) and as a result 21 new ophiuroid records were reported by Lyman (1878; 1882). Later, Bell (1888; 1905) described six additional new records of Ophiuroidea to South Africa in two subsequent papers. In 1910, Döderlein wrote the first consolidated account of South African echinoderms, reporting on 29 ophiuroids. More than a decade later, Clark (1923) reported a total of 57 ophiuroid species as being known for South Africa, including six new species which were largely derived from the *Pieter Faure* expedition. Mortensen (1925) added two more species to the fauna from a collection sent to him from the Durban Museum (*Asteroschema capensis* Mortensen, 1925 (= *Astromorpha capensis*) and *Ophiactis savignyi* (Müller & Troschel 1842), the former being new to science. Hertz (1927a, b) added four new species to the South African fauna, but two of these were soon synonymized by Mortensen (1933a) in his significant contribution to the Ophiuroidea and Asteroidea of South Africa. Mortensen (1933a) recorded 36 new ophiuroid species from material collected mostly off the *Pickle* and the *John. C. Meikle*, bringing the total number of ophiuroids known for South Africa to 82 species. Mortensen (1936) reported on collections from the *Discovery* expedition (1901-1904) to Antarctica and added two new species from South Africa. Clark (1952) described an additional three species collected during the University of Cape Town (UCT) Ecological Surveys and from the *Africana*. Later, Clark (1974) summarized records from 22 years of collections undertaken during the UCT Ecological Surveys and the *Anton Bruun* expedition that had accumulated since the Clark (1952) report by describing three new species and adding four new records to South Africa.

Clark & Courtman-Stock (1976) reported on 115 species of Ophiuroidea for southern Africa, but only 101 of these species were recorded within the political borders of South Africa. Shortly afterwards, Clark (1977) reported on a number of deep-water species collected by the *Meiring Naude*, which added ten new ophiuroid species to the South African fauna. Madsen (1977) reported *Ophiernus quadrispinus* Koehler (1907) from off Cape Point, a new record for South Africa.

Following this, no taxonomic work was undertaken for 35 years until recently when Olbers & Samyn (2012) reported four new ophiocomid species as new records for South Africa. Later that year, Milne (2012) reported *Ophiactis picteti* (de Loriol 1893), *Macrophiothrix demessa* (Lyman 1862) and *M. propinqua* (Lyman 1862) as occurring at Sodwana Bay. These two reports raised the total number of ophiuroids reported in the published literature for South Africa to 119. In 2015, Olbers *et al.* published a consolidated report on all new species to South Africa, raising the total number to 137. Examined material of *Ophiactis flexuosa* Lyman 1879 from South Africa and consideration of H.L. Clark's (1923) synonymy of *O. flexuosa* with *O. plana* Lyman, 1869, Olbers (2016) revised the list and excluded *O. flexuosa*, amended the number of known brittle and basket stars for South Africa to 136.

2. Taxonomic study of Ophiuroidea

2.1. Collecting

Collecting brittle and baskets stars can be challenging, as they often 'fall to pieces' when handled. With careful handling and gentle manipulation, they generally can be collected by hand without damaging them. Lifting specimens with a scraper or knife or by lifting them by the disc can assist in handling.

They occur in a wide variety of habitat types, under rocks, inside crevices and crannies (Fig. 3), within sediment, on open reef (Hyman 1955), and amongst algae and other organisms, such as jellyfish, soft corals and sponges. In some cases, brittle and basket stars may be cryptic and nocturnal, but are relatively easy to find and collect by hand by breaking rocks and by lifting boulders or rocks.

When collecting, these shelters should be carefully returned to their original position to avoid crushing other organisms and to minimize any damage or disturbance to their habitat. The marine environment is under immense pressure so it is important, when collecting, to only take what you need, do not waste samples and take proper care of your samples to maximise the data obtained.

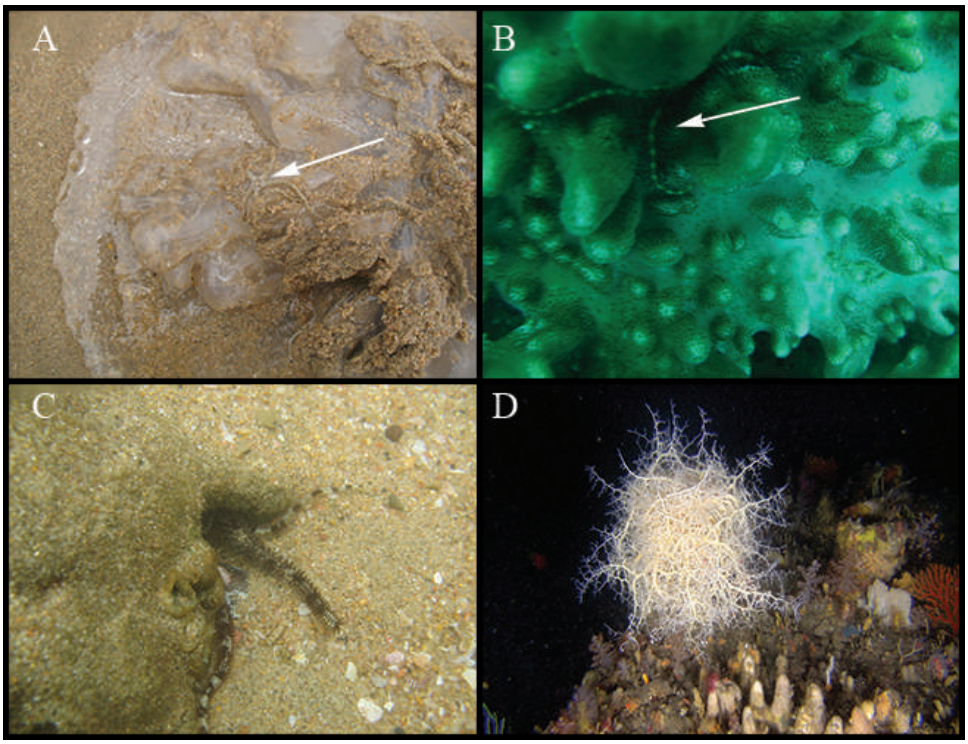


Fig. 3. Ophiuroidea are found in many habitat types and together with other organisms. **A**. On jellyfish. **B**. On soft coral. **C**. In crevices, under rocks and boulders. **D**. On open reef.

In the field, buckets, plastic resealable bags, collecting mesh bags and plastic bottles are good temporary storage items. When collecting, plastic bags are effective in that they form a protective water-balloon around the specimens. Mesh bags can also be used, but basket stars become tangled in the mesh and may prove difficult to remove from the bag. It is preferable to keep specimens separated from each other to avoid antagonistic effects.

If specimens need to be studied alive in the laboratory, it is preferable they are returned alive once the study is complete. However if the specimens have been kept in a laboratory together with alien species, or the laboratory has had a recent disease outbreak, it is better to destroy the specimens or have them lodged in a museum for taxonomic studies. Specimens should not be returned to sites other than the one from which they were collected, as this can spread diseases, result in disruption of genetic structure of populations or spread species to sites in which they would not naturally occur.

When specimens are collected for purposes where they are required to be killed or specimens which die during a study, it is important to deposit representative samples in a natural history museum, where they will be preserved and used for future reference.

2.2. Photography

Photographs of specimens in their environment are incredibly valuable and hold an immense amount of information, but the cryptic nature of these animals is such

Fig. 4. Photographing the specimens alive or soon after being collected to capture the natural colour, together with labels and scale bars.

that photography is not always possible. Where specimens are required to be preserved, they should be photographed soon after collection (Fig. 4) before they lose their natural colouration. When photographing, a scale bar should be placed adjacent to the specimen. Photographs taken with the specimen placed beneath some water, may enhance the quality of the image. To avoid reflections on the surface of the water, place light source at a 45 degree angle.

Photographs of this nature can add immense value to online platforms such as iSpot (https://www.ispotnature.org/communities/southern-africa) and EchinoMAP (http://vmus.adu.org.za/), which hold distribution records and assist in species distributions.

2.3. Relaxation, fixation and preservation

Relaxing specimens can be somewhat time-consuming, but is worth the effort as this greatly enhances the scientific value of the specimens. It is essential to anesthetise or relax the specimens before fixation. Often they contort, crunch up or release their arms when chemicals are added to the water while they are un-anesthetised. To relax them, several methods exist, but adding Magnesium Chloride ($MgCl_2$) or Magnesium sulphate ($MgSO_4$; 4% being the desired concentration) to a basin of sea water allows the specimens to expire. If the concentration of $MgCl_2$ is too high, they will crunch their arms, but this can be counteracted by diluting the solution with more sea water and by placing pressure on the arms until the specimens relax. As the specimen begins to expire and relax more, slowly add more $MgCl_2$ to the solution until the specimens perish; ii) use a fresh and sea water solution, in the same manner as above iii) place specimens in the refrigerator overnight. All three processes can take a relatively long time, i.e., a few hours.

Relaxation is complete once the tube feet or arms no longer react to nudging or prodding. At this point, they need to be preserved in either 70-99% ethanol (C_2H_6O) or in 4% formaldehyde (CH_2O) solution. Ethanol (EtOH) is the preferred chemical because formaldehyde is acidic, hazardous to human health and damages the integrity of DNA, obstructing future molecular studies. After fixation, the fixative needs to be replaced with the preservation fluid, i.e., 70-80% ethanol. One can also opt to dry the specimens, a procedure that is less costly and saves precious museum shelf space. The disadvantage of dry preservation is the internal anatomy becomes largely unaccessible and the molecular integrity is reduced for study. Furthermore, if preserved dry, fixation in formaldehyde is preferred. Dry specimens are prone to insect infestations while collections in warm and humid climates are prone to mould, both of which, can destroy a specimen.

2.4. Molecular studies

For molecular studies, the specimens are required to be subsampled, which is recommended practice for all collection trips. This should take place after relaxation but before fixation and preservation. Depending on the size of the specimen, a small piece of the arm is cut off with sterilised scissors or scalpel and

placed in 99% ethanol. These are stored separately from the specimen in vials or Polymerase Chain Reaction (PCR) vials for further processesing. It is imperative that subsamples can be tracked back to the original specimen, see labelling below.

2.5. Labelling and record keeping

Data should be logged from the moment a collection trip begins until the specimens are preserved for long term storage in a museum. Every specimen should be accompanied with a label detailing collection information. Specimen labels (Fig. 5) should contain at least the following information: genus and species (if known), unique number, expedition name, locality, GPS coordinates, depth, habitat, collection date, collector name, collection method and if identified, who by. Special alcohol and water-proof paper must be used (i.e., Xerox NeverTear paper), while the label must be written using a soft lead pencil or in indelible Indian ink or printed with ink that will not dissolve in alcohol.

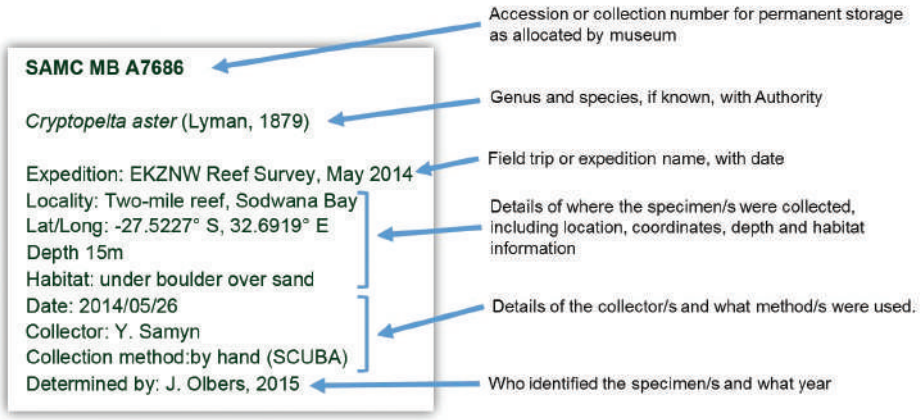


Fig. 5. Example of label with essential information.

2.6. Transportation

If the specimens are being transported locally, then storing them in ethanol in plastic resealable bags in a bucket is acceptable. Labels with data are required for each specimen or lot of specimens, even during transportation or temporary storage.

If specimens are to be couriered or posted, then specimens will require correct packaging procedures (Fig. 6), relevant permits (transportation, import, export) and will be required to meet shipping standards and codes, as per shipping regulations and the courier company.

The International Air Transport Association (IATA) has shipping standards which specimens are required to be packaged in accordance with. Natural history

Fig. 6. Packing specimens for transportation requires correct procedures. **A**. Each specimen / lot to be packaged separately in a bag of the correct size, this can be made with plastic and a heat sealer. **B**. Seal three sides of the bag for the specimens. **C**. Insert specimens, ethanol (not more than 30 ml in inner package) and label. **D**. Seal bag and check for leaks. **E**. Make and seal specimen in a triple bag, placing some absorbent material in the third bag. **F**. Wrap in bubble wrap. **G**. Place in box with packaging material. **H**. Place additional packaging material around specimen. **I**. Seal the box and attach necessary documentation or permits.

specimens are considered to be in the IATA category of 'dangerous goods' when in ethanol. Specimens will require an IATA SP A180 shipping declaration to accompany the package. An example of a shipping declaration, to be placed on the outside of the package, is given on page 22.

2.7. Storage

Once the specimens reach their destination for identification and/or permanent storage, it is imperative that specimens are not muddled up and the labels with data are kept meticulously together with the samples and/or specimens

Museums and institutions around the world have different storage techniques and facilities. Brittle and basket stars can be stored wet or dry. If wet, they should be

Cape Town, 18 December 2018

SHIPPING DOCUMENTATION/CUSTOMS DECLARATION

"scientific research specimens, not restricted, special provision A180 applies"

Full description of goods: Ophiuroidea specimens preserved in a minimal quantity of 70 % ethanol. These biological samples are non-toxic, non-pathogenic and are derived from non-CITES listed species. They are on loan from the Iziko South African Museum in Cape Town to the Royal Belgian Institute of Natural Sciences in Brussels (Belgium).

The scientific research specimens are not restricted and have been packed according to IATA SP A180 (triple heat-sealed packing, no more then 30 mL of free ethanol in inner package, outer packing not exceeding 1 L, absorbent material included)". Class 3/UN1170/PG III.

Declared value: ZAR 100

Iziko South African Museum
Collections Manager
25 Queen Victoria Street
Cape Town
8001
South Africa
Email address:
Tel: +2721 481 3800

Important

Postal inspectors: This package contains dead, preserved material for scientific research without commercial value. If this shipment is inspected, it is absolutely imperative that the packages are sealed tightly again. If not, the material will dry rapidly and become useless for scientific research. We thank you very much for taking good care of this important resource.

Très important

**Précautions à Prendre à l`inspection postale**: Ce colis contient du matériel biologique fixé dans un produit de conservation et est destiné à des études scientifiques. S`il est ouvert pour une inspection il est très important que les sacs en plastiques doivent de nouveau être soigneusement scellés. Si non, le matériel biologique dessèchera rapidement et deviendra alors inutile pour étude. Nous vous en remercions beaucoup.

Convention on International Trade in Endangered Species of Wild Fauna and Flora: *Include Institutional CITES Number*
HS-Code: 9705.00 (Collections of zoological/botanical/ mineralogical/archaeological/paleontological interest)

preserved in 70-96% ethanol, which covers the specimen, in well-sealed jars, after which the ethanol regularly needs to be topped up, if evaporation occurs. If the climate is not excessively humid then specimens can be dried for storage, which is often the case when large specimens are being stored. Drying brittle and basket stars can compromise the integrity of the DNA and the morphology of many internal features, conversely, examination of skelatal features is often enhanced.

2.8. Permits and legislation

South Africa is a signatory to the Nagoya Protocol on Access and Benefit Sharing and collecting any marine plant or animal can be undertaken with two types of permits. A recreational permit allows for collection for food, bait and/or for use in home aquaria, this is for personal use only. The second permit is for scientific research which needs to be applied for from the Department of Environment, Forestry and Fisheries. In some cases, permission from the marine protected area management authority is also required.

All collecting requires a permit, regardless of whether the specimen will be released alive after the study or not. The National Environmental Management Act (107 of 1998) creates the framework for environmental law in South Africa together with its associated regulations and Specific Environmental Management Acts. For all marine species, including brittle and basket stars, the following legislation applies:

– National Environmental Management: Biodiversity Act 10 of 2004;
– National Environmental Management: Protected Areas Act 57 of 2003;
– National Environmental Management: Integrated Coastal Management Act 24 of 2008; and the
– Marine Living Resources Act 18 of 1998.

Permits for scientific research are applied for to the Permits for scientific research are applied for to the Department of Environment, Forestry and Fisheries, at the following email address: researchpermits@daff.gov.za.

For further queries:

Dr. Kim Prochazka
Director: Resources Research
Tel: +27 (0)21 402-3546
Email: kimpro@environment.gov.za

Ms Melleney Cope
Personal Assistant to Dr. Kim Prochazka
E-mail: melleneyC@daff.gov.za

2.9. Morphology, biology and taxonomic terminology of brittle and basket stars

There are 33 families arranged into six orders as per O'Hara *et al.* (2018): Euryalida, Ophiurida, Ophioscolecida, Ophiacanthida, Ophioleucida and Amphilepidida. All six orders and 26 families are represented in the South African Ophiuroidea fauna.

The Ophiuroidea are most similar in body shape to the Asteroidea and can be differentiated from them by a number of features, but most importantly because the arms of an asteroid are usually confluent with one another and the body cavity between the arm and disc is open. To identify Ophiuroidea, knowledge of the terminology used to describe their anatomy is necessary. A glossary of terms used can be found at the end of this guide.

The morphology of the ophiuroid is illustrated in Fig. 7 with additional figures below. It is important to understand the location of features when referring to the body plan of an ophiuroid. Proximal is closest to the centre of the disc and distal is furthest from the centre or the disc.

The water vascular, nervous and haemal systems are similar to those of asteroids. Each arm contains a small coelom, a radial nerve, and a radial canal of the water vascular system. In contrast to other echinoderms, the ambulacral grooves are enclosed and covered by plates. A pair of tube feet are present on each arm joint on the ventral surface, which in many cases are protected by one or more modified spines or tentacle scales.

Five pairs of invaginations called bursae open toward the ventral surface through genital slits at the bases of the arms. They can be variable in size and shape but they generally extend from the disc margin to the oral shields, supported either side by a genital plate. These plates may be distinct, but the shield adjacent to the arm base is usually indistinct. The genital slit edges may be smooth, have scallops, or bear genital papillae. Externally, these slits may be long and narrow, short and wide, or be divided into pairs. Water circulates in and out of the bursae for exchange of gases. Gonads occur on the coelomic walls of each bursa and

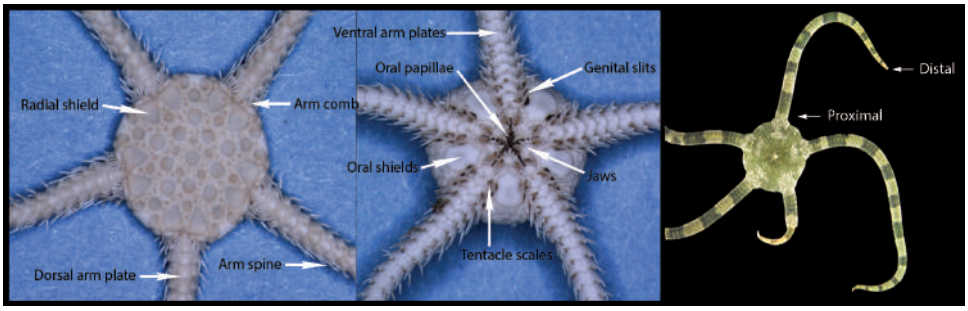


Fig. 7. General morphology of an ophiuroid, also indicating position of distal and proximal in relation to disc.

discharge their ripe sex cells, passing through the genital slits into the water for fertilization.

In most cases, the organs are confined to the disc, with the stomach being sac-like. There is no anus, thus any indigestible material is expelled through the mouth. The disc can be round or pentagonal, flat or puffy, excavated or indented radially or interradially. The disc is covered in plates and may be covered with thickened skin, scales, spines, granules, stumps, or a combination of these.

The main taxonomic characters on the dorsal disc are the radial shields (Fig. 8) and the primary scales or primary rosettes, including the central scale, which may or may not be distinct (Fig. 9). The armament of the dorsal disc is also of prime importance and may include granules, spines or tubercles. Figure 8 shows some of the dorsal characters and a composite of the dorsal disc armament of some common families.

The ventral surface of the disc (Fig. 10) holds more taxonomically informative characters. Adjacent to the jaws, the main characters visible are the genital slits, with some taxa also bearing genital papillae.

On the arms, the dorsal, ventral and lateral arm plates are taxonomically significant. The arm plates are taxon-indicative in width: length ratio and the curvature of the plates distally and/or proximally. Lateral arm plates support the arm spines, in

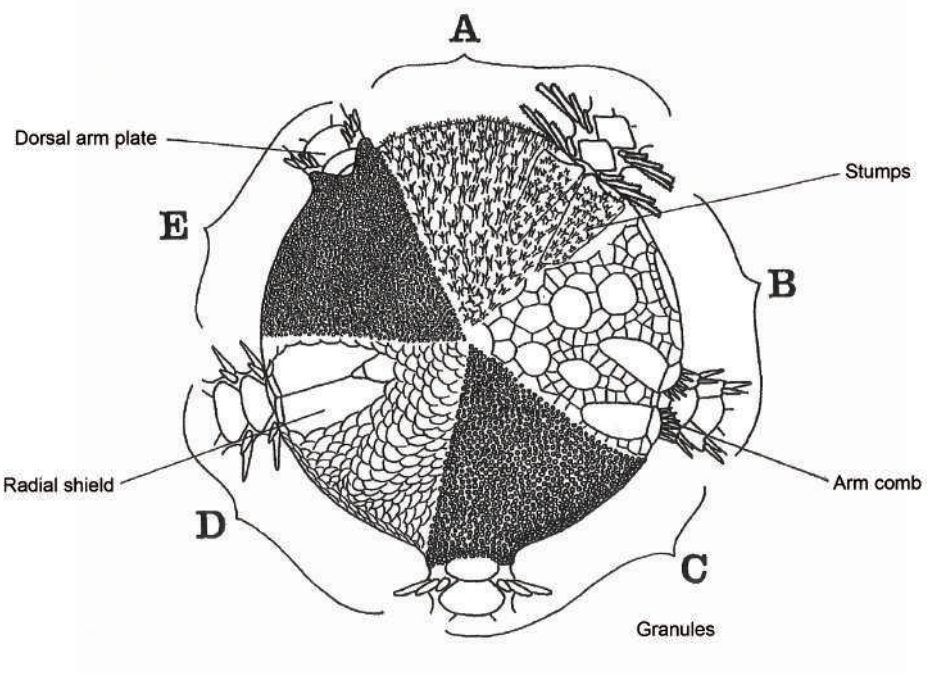


Fig. 8. Composite diagram showing characters of the dorsal surface of the disc in the following families. **A**. Ophiotrichidae. **B**. Ophiuridae. **C**. Ophiocomidae. **D**. Amphiuridae. **E**. Ophiodermatidae. From Clark & Rowe (1971).

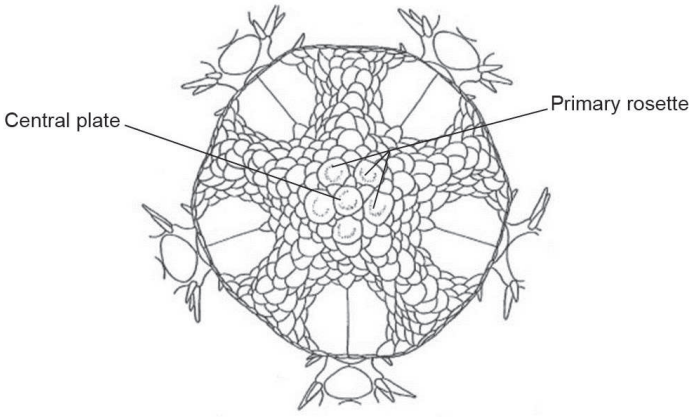


Fig. 9. Plates forming part of the primary rosette including the central plate. Adapted From Clark & Rowe (1971).

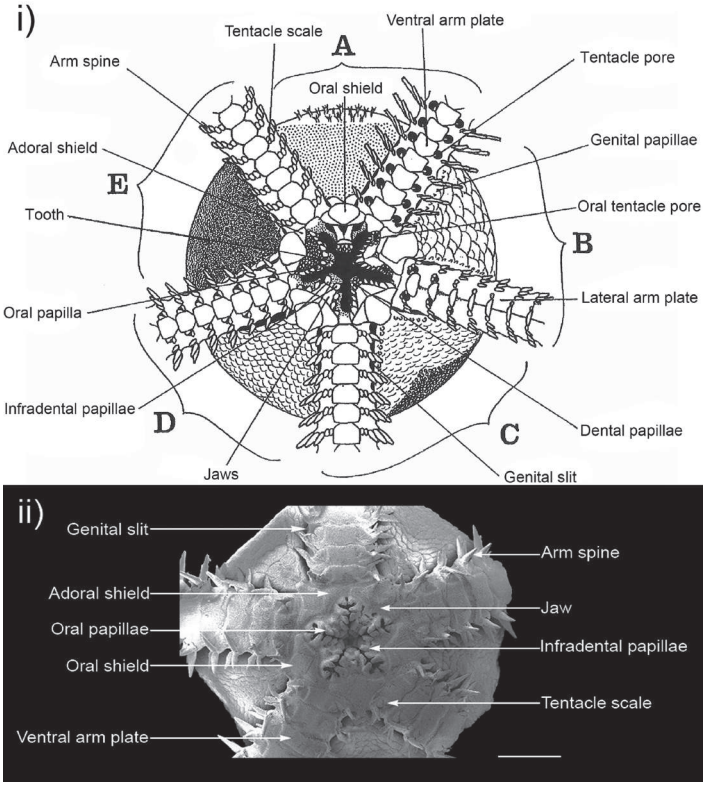


Fig. 10. Composite diagram (i) showing characters of the ventral surface of the disc in the following families. **A**. Ophiotrichidae. **B**. Ophiuridae. **C**. Ophiocomidae. **D**. Amphiuridae. **E**. Ophiodermatidae. From Clark & Rowe (1971). Ventral disc of an amphiurid (ii). Scale bar: 1 mm. Photo: Didier VandenSpiegel.

which some species, the number and sequence have been used as important features (Devaney 1970).

The ventral interradial areas may also be covered in a combination of granules, spines, tubercles and scales. Figure 10 shows the main ventral characters and a composite of typical ventral disc armament for some common families.

In this guide, the primary characters by which most families are distinguished from each other are with the jaws. Jaw features include the oral papillae, dental papillae, oral tentacle pores, oral tentacle scales, teeth, oral shields, dental plates at the tip of the jaws, and adoral shields, which flank the oral shields on either side. Figure 11, a side view of the jaw, shows the placement of the dental plate, teeth and dental papillae, while Figure 12 shows the placement of teeth, dental papillae

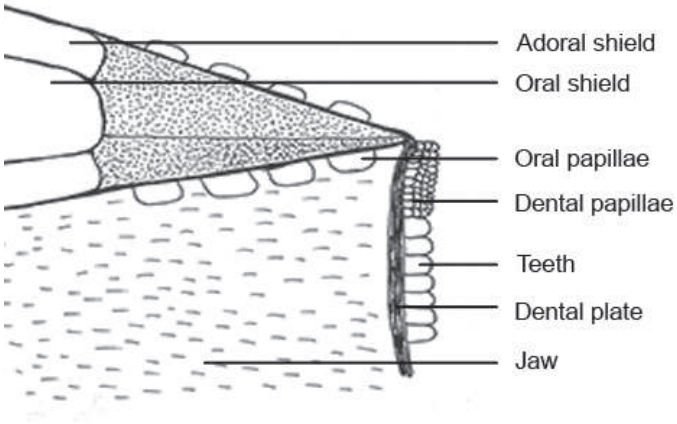


Fig. 11. Side view of the jaw, indicating placement of the dental plate, dental papillae, teeth, oral shield, adoral shields and oral papillae.

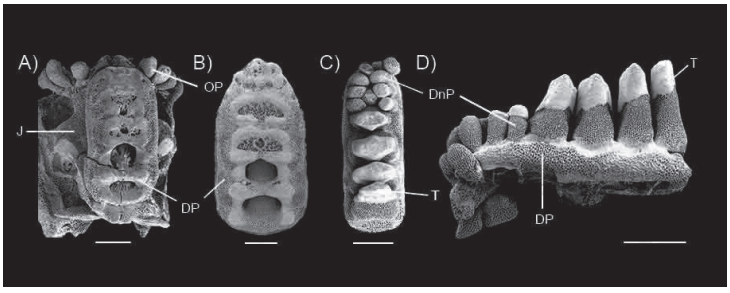


Fig. 12. Placement of dental plate, dental papillae, oral papillae and teeth. **A**. Dental plate attached to jaw (*Breviturma brevipes*). **B**. Dental plate with no teeth or dental papillae attached, showing structures to which teeth and papillae would attach (*O. scolopendrina*). **C**. Dental plate with teeth and dental papillae attached (*Ophiocoma erinaceus*). **D**. Side view of dental plate with teeth and dental papillae attached (*Ophiocoma erinaceus*). Abbreviations: J = jaw; OP = oral papillae; DP = dental papillae; DnP = dental papillae; T = teeth.
Scale bar: 0.5 mm. Photos: Didier VandenSpiegel.

and oral papillae on the jaw. The madreporite, a modified oral shield, is located in the vicinity of the mouth. In combination with the jaws, the arrangement, number, shape and size of various other external characters determine genera and species. The dental plate requires dissection to view and is used as a taxonomic character for some species.

There are usually five arms, but sometimes more, and these can be long and slender, short and stout and may be smooth or spiny. While the majority of species have simple arms, basket stars have branching arms, producing a network of tree-like branches. To the eye, the ophiuroid arms appear to be segmented, but these correspond to internal articulated ossicles or vertebrae (Fig. 13) which are connected by soft tissue. They are usually covered dorsally, ventrally and laterally by arm plates (Fig. 14).

In some families or genera, there are supplementary plates or shields adjacent to the dorsal arm plates, ventral arm plates or the oral shields (Fig. 15).

The distal, lateral and/or proximal shape of the arm plate edges are of significance in taxonomy. The plate edges may be concave (curving in), convex (curving out) or straight (Fig. 16).

Most often the lateral arm plates bear arm spines, varying in number, forming a vertical series. The arm spines may be positioned at right angles, or they can be appressed to the arm. The arm spines (Fig. 17) can vary in length and shape and may be tapering, pointed, blunt, clavate or hooked. In addition, the spines can be smooth, serrated, or bear hooks to varying degree.

In some cases (except in the girdle hooks of Gorgoncephalidae) arm spines transform into hooks in various forms and number. The terminal or primary tooth is on the distal end of the hook, while the secondary, additional teeth and the lamina of the structure are proximal to the base of the hook or spine (Fig. 18).

Radial shields (dorsal side of the disc) and oral shields (ventral side of the disc) are described in length and width (Fig. 19) and in some cases in colouration and armament (e.g., granules, spines). The distinction between width and length is important for both these skeletal structures.

The terminology used for describing the shape and form of various plates, shields and papillae is illustrated in Figure 20.

Various terms used to describe disc armament, arm spines and protrusions are illustrated in Figure 21.

As explained above, the combination of jaw characters are important in distinguishing between many Ophiuroidea families. Table 2 illustrates the position and arrangement of the oral papillae, dental papillae, oral tentacle pores, oral tentacle scales, teeth, oral shields and adoral shields in 26 Ophiuroidea families where the differences are most obvious.

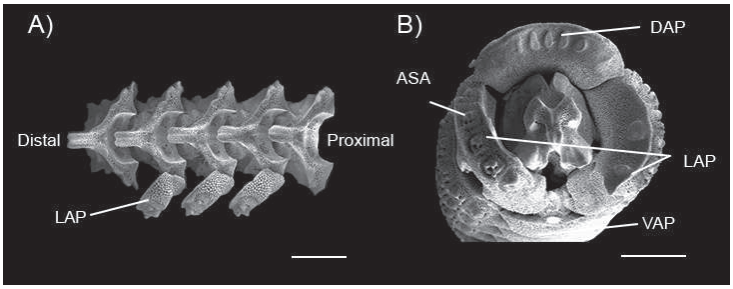


Fig. 13. Arm vertebrae of Ophiuroidea. **A**. Series of vertebrae, dorsal view, three lateral arm plates attached (Ophiotrichidae). **B**. Section of arm with arm plates attached around vertebra (*Ophiarachnella* sp.). Abbreviations: ASA = Arm spine articulation; DAP = dorsal arm plate; LAP = lateral arm plate; VAP = ventral arm plate. Scale bars: 1 mm. Photos: Didier VandenSpiegel.

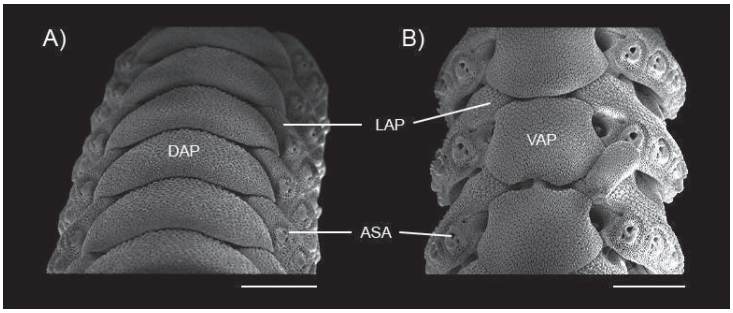


Fig. 14. View of dorsal and ventral arm of *Ophirachnella* sp. **A**. Dorsal and lateral arm plates. **B**. Ventral and lateral arm plates. Abbreviations: ASA = Arm spine articulation; DAP = Dorsal arm plates; VAP = Ventral arm plates; LAP = Lateral arm plates. Scale bars: 1 mm. Photos: Didier VandenSpiegel.

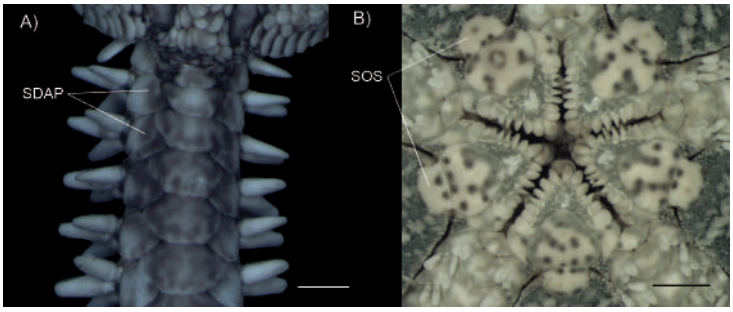


Fig. 15. Placement of supplementary plates and shields. **A**. Supplementary dorsal arm plates (*Ophionereis porrecta*) on dorsal arm. **B**. Supplementary oral shields (*Ophiarachnella gorgonia*) adjacent to oral shields. Abbreviations: SDAP = Supplementary dorsal arm plates; SOS = Supplementary oral shields. Scale bars: A = 1 mm; B = 2 mm. Photos: Didier VandenSpiegel.

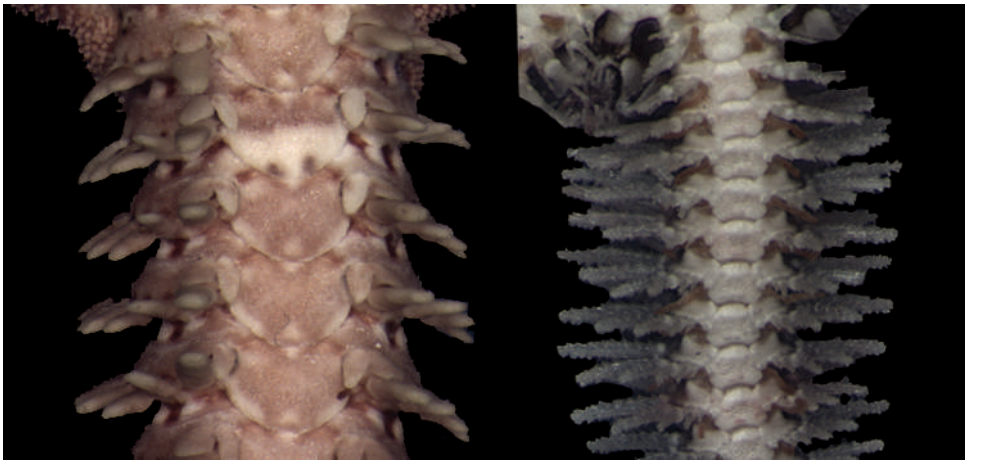


Fig. 16. Section of ventral arms showing arm plate edges which are distally convex (left) and distally concave (right). Photos: Didier VandenSpiegel.

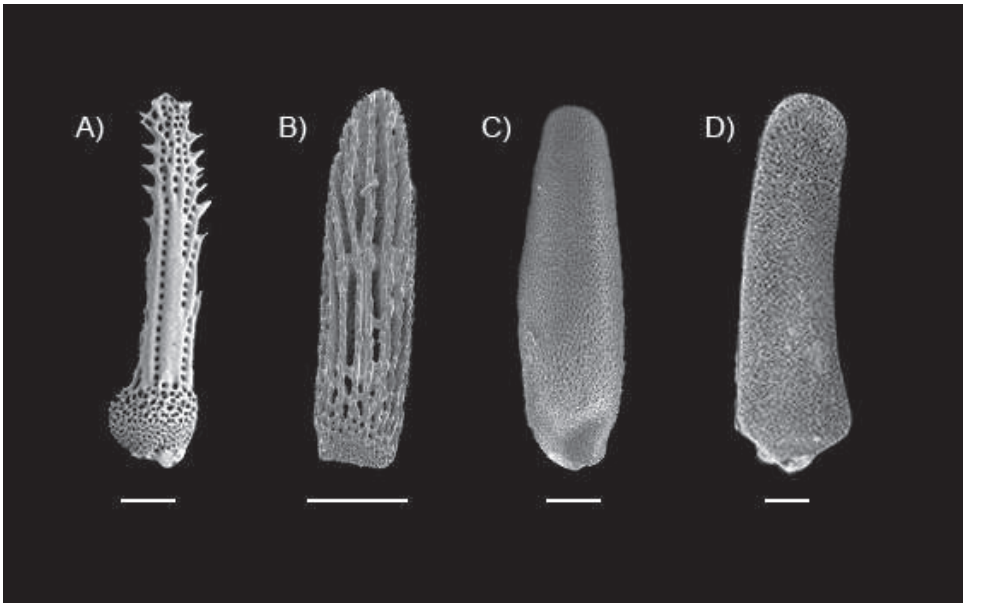


Fig. 17. Arm spines illustrating the different forms and shape. Tapering (A, B and C), pointed (A and B), blunt (C, D), cigar (D), smooth (C, D) and serrated (A). **A**. *Macrophiothrix* sp. **B**. *Ophioconis cupida*. **C**. *Ophiocoma* sp. **D**. *Ophionereis* sp. Scale bar: A, C, D = 200 µm; B = 50 µm. Photos: Didier VandenSpiegel.

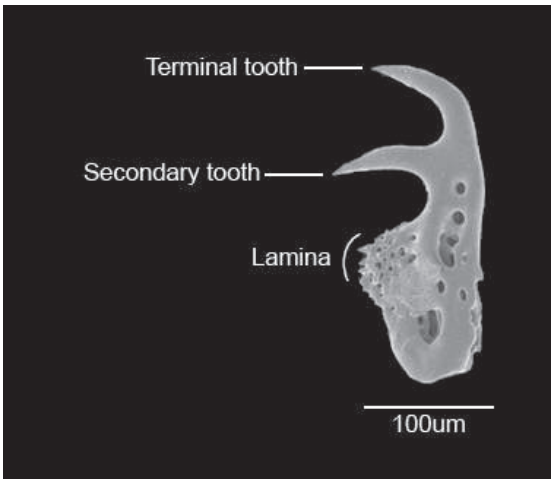


Fig. 18. Hooked arm spine showing placement of terminal tooth, secondary tooth and lamina. Photo from Okanishi *et al.* (2013).

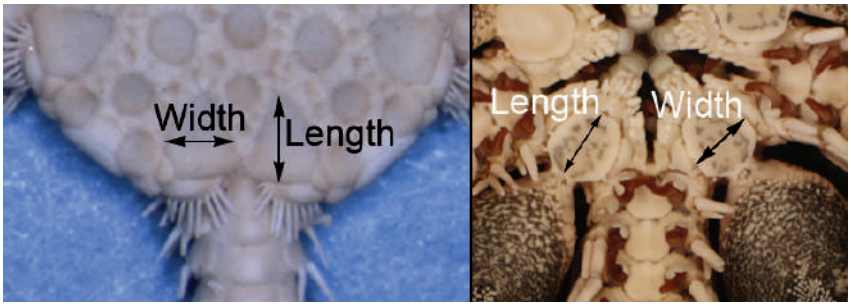


Fig. 19. A pair of radial shields (left) and two jaws with their oral shields (right) illustrating their width and length.

Table 2. Representative jaws and key features of South African Ophiuroidea families. Papillae and teeth are colour coded: Yellow: infradental papillae, blue: apical papillae, green: oral papillae, purple: dental papillae, orange: teeth, pink: oral tentacle scales. Illustrations adapted from Mortensen (1933a), Clark & Rowe (1971), Clark & Courtman-Stock (1976) and O'Hara *et al.* (2018).

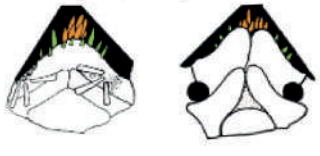
Asteronychidae Multiple columns of spiniform oral papillae. 	**Euryalidae** Single column of teeth and sometimes some papillae either side which may or may not be considered as true oral papillae. 	**Gorgonocephalidae** Multiple, more or less spiniform, oral papillae in irregular columns. 	**Ophiomusaidae** Oral papillae almost appear fused, structure of each papilla still visible. 
Astrophiuridae Single apical papillae with numerous oral papillae either side. 	**Ophiuridae** Numerous oral and apical papillae, oral tentacle scales both sides of second oral tentacle pore, often within series. 	**Ophiopyrgidae** Oral papillae close together or may appear fused, lowermost tooth distinct or apical papillae present. 	**Ophioscolecidae** Both teeth and oral papillae serrated, may be broad or narrow and appear similar. Oral papillae either side of jaws, teeth apical 
Ophiotomidae Clusters of short oral papillae, sometimes papilliform. 	**Ophiacanthidae** Single pointed apical papilla flanked by three or more oral papillae, often with distalmost papillae being enlarged. Teeth below apical papillae. No clusters. 	**Ophiodermatidae and Ophiopezidae** Teeth not particularly broad, oral papillae in a vertical series down sides of the jaw and, if present, in series with oral tentacle scale towards the distal end. 	**Ophiomyxidae** Both teeth and oral papillae serrated, may be broad or narrow and appear similar. Oral papillae either side of jaws, teeth apical. 

Table 2 (continued).

Ophiocomidae Teeth broad and square (not illustrated here) with a number of dental papillae and oral papillae present. 	**Ophiernidae & Ophioleucidae** Oral papillae may be pointed or opercular. Teeth present, tapering to blunt point. 	**Ophiolepididae** Rounded oral papillae with distalmost being broadest and in series with single tentacle scale. 	**Hemieuryalidae** Oral papillae, distalmost being broadest, remaining papillae elliptical leaf-shaped, apical papillae bluntly pointed. Teeth four, rounded (not illustrated here). 
Amphilimnidae Apical oral papillae asymmetrical, distalmost oral papillae on edge of adoral shield. Teeth single, broad. 	**Ophionereididae** Broad quadrangular teeth blunt angled apices. The four or more oral papillae may be in series or overlap the tentacle scale of second oral pore. 	**Ophiopsilidae** Oral papillae separated from apical tooth by diastema. 	**Amphiuridae** Two infradental papillae spaced apart and symmetrical, teeth may be broad or tapering and flanked by one, two or three oral papillae either side. 
Amphilepididae Two infradental papillae spaced apart, oral papillae, distalmost elongated and much longer than proximal-most. Teeth triangular and long. 	**Ophiothamnidae** Numerous oral papillae, distalmost broad and opercular, single large apical papillae. 	**Ophiactidae** Single, apical, broad and blunt papillae and broad, rounded or rectangular teeth with a diastema between these and the one or two oral papillae. 	**Ophiotrichidae** Cluster of dental papillae superficial to the broad rectangular teeth (not illustrated here) and no oral papillae present. 

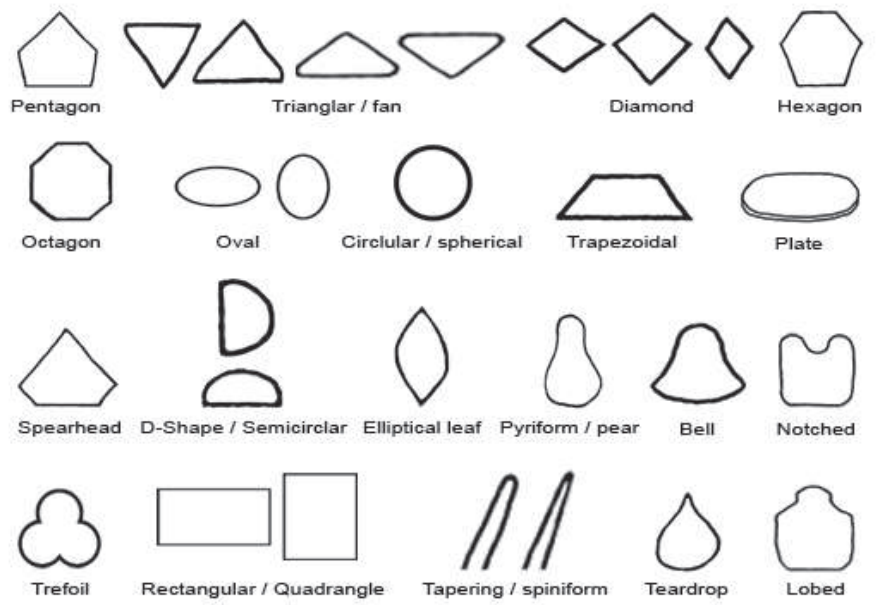


Fig. 20. Terms describing various shapes of plates, shields and papillae.

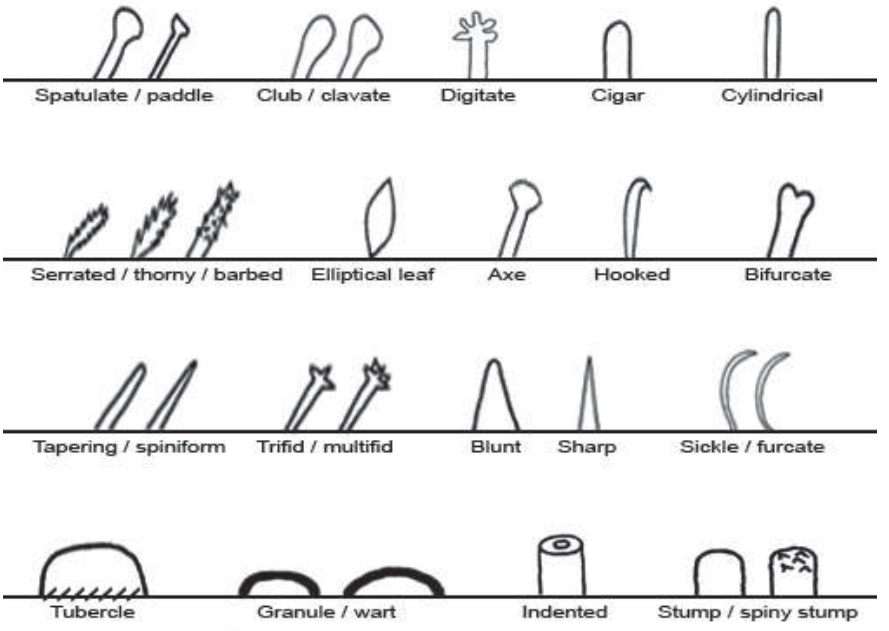


Fig. 21. Terms describing various disc armament, arm spines and protrusions.

3. Key to South African Ophiuroidea

This dichotomous key requires a basic knowledge of ophiuroid taxonomy, which can be gained using the instructions above. Each pair of statements or 'couplet' provides alternate descriptions of some characteristic of the specimen being identified. Choose the statement that closest describes the character of the specimen in question and this leads you to another numbered couplet, where another choice is made, until eventually an identification is arrived at. Reference figures are provided for each species in the main guide and once you have arrived at an identification using the key you should check that the specimen corresponds to the diagnosis and figure of that species in the main guide. It should be noted that this key cannot reliably be used for species found outside South Africa.

A full checklist of all species occurring in South Africa is available at the end of the guide.

1. Disc and arms covered in thick skin ……2
– Disc and arms covered in thin skin ……21

2. Arms always simple ……3
– Arms branched ……9

3. Skin concealing radial shields ……16
– Skin covered but radial shields distinct ……4

4. Radial shields narrow or bar-like ……5
– Radial shields broad, may be tapering ……***Asteromorpha capensis*** (Fig. 27)

5. Disc and radial shields naked ……***Asteronyx loveni*** (Fig. 23)
– Disc and radial shields with armament ……6

6. Disc or radial shields armed with low tubercles / granules / warts ……7
– Disc or radial shields armed with stumps ……8

7. Disc and arms covered in coarse and fine granules intermixed ……
……***Astrothorax papillatus*** (Fig. 45)
– Disc and arms covered in low minute granules …***Asteroschema salix*** (Fig. 25)

8. One pair of stumps per arm segment ……***Astroceras spinigerum*** (Fig. 31)
– More than two stumps per arm segment …***Asterostegus tuberculatus*** (Fig. 29)

9. Madreporites five, deep in interradius …***Astroglymma* cf. *sculptum*** (Fig. 43)
– Madreporites less than five, indistinct ……10

10. Oral papillae in distal notches ……11
– Oral papillae absent in distal notches ……13

11. Dorsal arms armed with tubercles ……12
– Dorsal arms smooth, with flat platelets ……***Astrocladus africanus*** (Fig. 35)

12. Arm armament fine and smooth ……***Astrodendrum capensis*** (Fig. 41)
– Arm armament distinct, variable in size surrounded by dark rings …… ……***Astrocladus euryale*** (Fig. 37)

13. Arm spines begin after at least second fork ……14
– Arm spines begin before first fork ……15

14. Belt of hooks complete from fifth fork ……***Astrocladus hirtus*** (Fig. 39)
– Belt of hooks complete from third fork ……***Astroboa nuda*** (Fig. 33)

15. Papillae on genital slits in series with papillae of oral area; no gap in tubercles between radial shields and disc …***Gorgonocephalus chilensis*** (Fig. 47)
– Papillae on genital slits randomly spaced / placed, distinct gaps in tubercles between radial shields and disc …***Gorgonocephalus pustulatum*** (Fig. 49)

16. Oral papillae broad, serrated, flattened ……17
– Oral papillae spiniform ……19

17. Arm spines slender and serrated ……18
– Arm spines long, with lowermost club- or cigar-shaped ……20

18. Two arm spines on segments 3–4 ……***Ophiomyxa australis*** (Fig. 141)
– One arm spine on segments 3–4 …***Ophiomyxa vivipara capensis*** (Fig. 147)

19. Second oral tentacle pore outside oral slit ……***Ophioscolex inermis*** (Fig. 91)
– Second oral tentacle pore inside oral slit ……***Ophiolycus dentatus*** (Fig. 89)

20. Dorsal arm plates fragmented ……***Ophiomyxa tenuispina*** (Fig. 145)
– Dorsal arm plates not fragmented ……***Ophiomyxa bengalensis*** (Fig. 143)

21. Single, pointed apical papilla ……22
– No apical papilla, or if present then not pointed ……37

22. Radial shields not naked, or only partly naked ……23
– Radial shields naked ……29

23. Jaws granulated ……***Ophiolimna perfida*** (Fig. 109)
– Jaws not granulated ……24

24. Two tentacle scales distally ……25
– One tentacle scale distally ……26

25. Disc covered in dense spines only ……***Ophiotreta matura*** (Fig. 99)
– Disc covered in granules, sometimes with interspersed spines …… ……***Ophiotreta durbanensis*** (Fig. 97)

26. Arms moniliform ……***Ophiacantha baccata*** (Fig. 101)
– Arms not moniliform ……27

27. Ventral arm plates fan-shaped ……28
– Ventral arm plates pentagonal, distal edge straight …… ……***Ophiacantha nerthepsila*** (Fig. 103)

28. Ventral and lateral arm plates with concentric striations …… ……***Ophiacantha scutigera*** (Fig. 105)
– All arm plates with concentric striations ……***Ophiacantha striolata*** (Fig. 107)

29. Dorsal arm plates contiguous on the proximal arm …… ……**‘Ophiophthalmus*’ relictus*** (Fig. 115)
– Dorsal arm plates not contiguous proximally ……30

30. Ventral interradial areas with no armament ……33
– Ventral interradial areas with armament (granules, stumps and / or spines)…31

31. Oral shields triangular or heart-shaped ……32
– Oral shields diamond-shaped, wider than long …… ……***Ophiothamnus remotus*** (Fig. 247)

32. Arm spines exceeding segment length, jaws sunken …… ……***Ophiomitrella corynephora*** (Fig. 111)
– Arm spines not exceeding segment length, jaws flat …… ……***Ophiomitrella hamata*** (Fig. 113)

33. Arm spines four, smooth ……34
– Arm spines seven, thorny, lowermost shortest ……36

34. Six arms ……***Ophioplinthaca sexradia*** (Fig. 121)
– Five arms ……35

35. Oral shields spearhead-shaped, with distinct lobe, much wider than long; tentacle scales 5–6, spinose; dorsal arm plates triangular, as long as wide, not contiguous ……***Ophiotoma*** cf. ***gracilis*** (Fig. 95)
– Oral shields D-shaped with slight lobe; tentacle scales needle-like or round, small if not absent; dorsal arm plates triangular to bell-shaped, twice as wide as long ……***Ophiotoma* cf. *alberti*** (Fig. 93)

36. Disc margin may have scattered spines; radial shields only just contiguous distally if at all; tentacle scales large, flat, pointed …… ……***Ophioplinthaca papillosa*** (Fig. 117)
– Disc margin spines absent; radial shields not contiguous; tentacle scales large, thick and pointed ……***Ophioplinthaca rudis*** (Fig. 119)

37. Pair of symmetrical papillae at apex of each jaw ……40
– Multiple or single apical papillae, rarely two, but if so papillae asymmetrical …38

38. Oral papillae fused, forming a serrated flange …… ……***Ophiodaphne scripta*** (Fig. 241)
– Oral papillae not fused ……39

39. Apical papillae symmetrical, offset laterally …***Amphilepis scutata*** (Fig. 245)
– Apical papillae may be present, if a pair then asymmetrical ……61

40. Basal arm spines form a flange ……41
– Basal arm spines do not form a flange ……42

41. All segments which border genital slits have fused arm spines (except lowest arm spine) forming curved flange on each side of arm …… ……***Amphilimna cribriformis*** (Fig. 187)
– On first segment, two lowest arm spines each side of arm unmodified, but upper spines flattened and fused, forming curved flange which borders genital slits ……***Amphilimna valida*** (Fig. 189)

42. Four oral papillae ……43
– One to three oral papillae ……46

43. Four oral papillae with a gap between infradental papillae and second oral papillae revealing second oral tentacle scale, which is in series …… ……***Amphioplus* (*Amphioplus*) *pectinatus*** (Fig. 203)
– Four oral papillae in series, third papilla enlarged and no distinct oral tentacle scale ……44

44. Disc margin with no armament …***Amphioplus* (*Lymanella*) *integer*** (Fig. 209)
– Disc margin vertical with small spines or projections ……45

45. Thirteen disc scales between radial shields …… ……***Amphioplus* (*Lymanella*) *furcatus*** (Fig. 207)
– 9–11 disc scales between radial shields …… ……***Amphioplus* (*Lymanella*) *depressus*** (Fig. 205)

46. Three oral papillae with a single oral tentacle scale in series, second oral papilla on lower level than other two, third papilla large and broad …… ……***Amphioplus* (*Unioplus*) falcatus** (Fig. 211)
– Three oral papillae, outermost very broad and opercular ……47

47. Radial shields narrow, bar-like ……48
– Radial shields broad, D-shaped; may be missing dorsal disc ‘lid’ ……49

48. Three arm spines ……***Amphipholis similis*** (Fig. 213)
– Four arm spines ……***Amphipholis squamata*** (Fig. 215)

49. Ventral disc partially skin covered, with incomplete scaling ……50
– Ventral disc fully scaled ……51

50. Six or more arm spines proximally, middle spine with glassy hook; distal oral papillae broad and semicircular …***Amphiura* (*Amphiura*) *uncinata*** (Fig. 239)
– Four or five arm spines proximally, none hooked; distal oral papillae elliptical leaf-like ……***Amphiura* (*Amphiura*) *albella*** (Fig. 221)

51. Two tentacle scales ……52
– Tentacle scale single or absent ……55

52. Tentacles scales moderate to large in size ……53
Tentacle scales small in size or absent ……54

53. Tentacle scales very large, ventral arm plates broad pentagonal ……
……***Amphipholis strata*** (Fig. 217)
– Tentacle scales moderate, ventral arm plates truncated pentagonal ……
……***Amphiura*** **(*Amphiura*)** ***acutisquama*** (Fig. 219)

54. Disc scales coarse and thick; arm spines blunt and flattened ……
……***Amphiura*** **(*Amphiura*)** ***incana*** (Fig. 231)
– Disc scales moderately coarse; arm spines pointed, some with terminal hook ……***Amphiura*** **(*Amphiura*)** ***otteri*** (Fig. 235)

55. One distal oral papilla, tentacle scales absent or rudimentary ……
……***Amphiura*** **(*Amphiura*)** ***atlantica*** (Fig. 225)
– One distal oral papilla, single tentacle scale ……56

56. Tentacle scale oval ……57
– Tentacle scale pointed, spiniform ……58

57. Radial shields tapering proximally, may be only just separated distally ……
……***Amphiura*** **(*Amphiura*)** ***grandisquama natalensis*** (Fig. 229)
– Radial shields contiguous for at least half-length ……
……***Ophionephthys lowelli*** (Fig. 243)

58. At least one arm spine flattened ……59
– Arm spines stout, blunt, tapering …***Amphiura*** **(*Amphiura*)** ***angularis*** (Fig. 223)

59. Arm spines flattened, second lowest spine conspicuously curved; no more than five arm spines ……***Amphiura*** **(*Amphiura*)** ***simonsi*** (Fig. 237)
– Arm spines flattened, more than five arm spines ……60

60. Radial shields long, narrow, well-separated and almost parallel, more than one–third disc radius, six arm spines …***Amphiura*** **(*Amphiura*)** ***linearis*** (Fig. 233)
– Radial shields longer than wide, diverging and tapering distally, contiguous at distal ends, less than half disc radius; seven arm spines ……***Amphiura*** **(*Amphiura*)** ***capensis*** (Fig. 227)

61. Teeth broad and square–tipped, single apical papilla or reduced tooth …62
– Teeth broad and square–tipped, rounded or conical, one or many papillae …68

62. Disc scaling overlapping and armament absent……
……***Histampica duplicata*** (Fig. 249)
– Disc with coarse scaling and armament present ……63

63. One distal oral papilla ……64
– Two or three distal oral papillae ……65

64. Oral shields almost circular, as long as wide; fissiparous (usually six arms) ……***Ophiactis plana*** (Fig. 259)
– Oral shields diamond-shaped, five arms, not fissiparous, radial shields contiguous distally, ventral arm plates fan-shaped …… ……***Ophiactis carnea*** (Fig. 253)

65. Up to four arm spines ……66
– More than four arm spines, usually six ……67

66. Dorsal arm plates diamond-shaped, twice as wide as long, not contiguous distally; not fissiparous ……***Ophiactis abyssicola*** (Fig. 251)
– Dorsal arm plates narrow fan-shaped, broadly in contact, longer than wide; fissiparous ……***Ophiactis nidarosiensis*** (Fig. 255)

67. Dorsal arm plates oval, becoming elliptical, rounded distally with median lobe emphasized by two dark spots after first two to three segments; fissiparous, up to seven arms but usually hexamerous ……***Ophiactis savignyi*** (Fig. 261)
– Dorsal arm plates oval, becoming elliptical, arms marbled with dark spots; not fissiparous, five long arms ……***Ophiactis*** cf. ***picteti*** (Fig. 257)

68. No oral papillae, each jaw with cluster of apical dental papillae ……69
– Oral papillae present on sides of jaws, apically either a cluster of dental papillae or one or a few larger oral papillae ……84

69. Disc and arms covered in skin, sometimes with granules ……70
– Disc scales and arm plates distinct, unless covered in armament such as spines or stumps ……73

70. Arms mostly flexible horizontally; dorsal and ventral arm plates present beneath skin, but dorsal arm plates may be fragmented; longest arm spines easily exceeding segment length ……71
– Arms flexible dorso-ventrally; dorsal and ventral arm plates rudimentary/ absent; arm spines short, barely exceeding single segment length ……72

71. Dorsal arm plates mostly entire; seven arm spines …… ……***Ophiogymna fulgens*** (Fig. 275)
– Dorsal arm plates fragmented; eight arm spines …… ……***Ophiogymna capensis*** (Fig. 273)

72. Fissiparous, usually six arms; armament on disc margin usually more granuliform than spinose ……***Ophiothela danae*** (Fig. 277)
– Not fissiparous, usually five arms; disc armament usually includes marginal spines ……***Ophiothela venusta*** (Fig. 279)

73. Radial shields naked, very large, taking up most of dorsal side; narrow interradial areas and centre of disc scales covered in granules …… ……***Ophiocnemis marmorata*** (Fig. 271)
– Radial shields may or may not be covered in armament, but usually smaller in area than remainder of disc, which may be covered in spines or stumps …74

74. Dorsal arm plates wide and broadly contiguous, arms long, 8–20 times D.D ……75
– Dorsal arm plates less than twice as long as wide, narrowly in contact, arm length moderate, 4–8 times D.D ……76

75. Radial shields densely covered in stumps or spines ……77
– Radial shields naked, or mostly so ……78

76. Disc covered in stumps; colour grey and dark blue or purple, both dorsally and ventrally; dorsal arms with a longitudinal light stripe bordered by two dark blue lines, ventral arms with similar stripe but less conspicuous, radial shields variegated with blue ……***Macrophiothrix hirsuta cheneyi*** (Fig. 265)
– Only disc margin with stumps; colour pink, purple with patterns on disc, arms banded every three to four segments; radial shields reddish, sometimes with blue patches, distal edge outlined with white, no longitudinal line down arms, arm spines with long thorn near tip …***Macrophiothrix propinqua*** (Fig. 269)

77. Ventral armament not reaching proximal edges of genital slits; dorsal side of disc greyish with more or less conspicuous dark pink spots, ventrally lighter and less spots. Arms banded purple, pink or red with white dorsally and lighter ventrally, with two to three arm segments between bands; may have white longitudinal band from *c.* half way down arms ……***Macrophiothrix demessa*** (Fig. 263)
– Ventral armament reaching edges of genital slits; disc dorsally and ventrally blue or purple with blue or purple spots and blotches, radial shields spotted, ventrally similar but lighter, arms banded with white, or spotted with purple ……***Macrophiothrix longipeda*** (Fig. 267)

78. Arms marked with one or more longitudinal lines running down arms ……79
– Arms patterned, but not with longitudinal lines ……81

79. Arms with either faint white longitudinal line, or light line with two darker lines either side ……80
– Arms with single thin dark longitudinal line along length of arm both dorsally and ventrally, dorsal arm plates with some lateral whitish patches ……***Ophiothrix* (*Acanthophiothrix*) *purpurea*** (Fig. 283)

80. Dorsal arm plates hexagonal or fan-shaped, wider than long; colour brownish green with yellow or white line bordered by two dark lines of dark purple or green, longitudinal white stripe along entire length of arm with two darker lines either side ……***Ophiothrix* (*Acanthophiothrix*) *proteus*** (Fig. 281)

– Dorsal arm plates fan, rhomboidal or diamond-shaped, distal side strongly convex, equally wide as long or slightly wider; colour grey, red, pink, arms similar, light white longitudinal line, sometimes bordered by pink or red striped ……***Ophiothrix* (*Ophiothrix*) *aristulata*** (Fig. 285)

81. Dorsal arm plates armed with single short rugose stump between successive dorsal arm plates ……***Ophiothrix* (*Ophiothrix*) *echinotecta*** (Fig. 287)
– No stump between successive dorsal arm plates ……82

82. Disc and radial shields patterned with dark purple lines and pinkish patches with adradial edges of radial shields accentuated with dark lines, arms not banded ……***Ophiothrix* (*Ophiothrix*) *foveolata*** (Fig. 289)
– No linear patterns on disc or radial shields, arms banded and often with dots associated with dorsal arm plates ……83

83. Spines and stumps intermixed on disc ……***Ophiothrix fragilis*** (Fig. 291)
– Spines and stumps not intermixed on disc …… ……***Ophiothrix fragilis*** var. ***triglochis*** (Fig. 293)

84. Both oral and dental papillae present ……85
– Only oral papillae present, usually only single apical papilla below teeth, but sometimes two or three ……97

85. Two tentacle scales, beyond basal arm tentacle scale/s elongated or sword-like, aligned obliquely across ventral arm plate, forming a cross with corresponding tentacle scale ……86
– One or two tentacle scales, both oval ……87

86. Only inner tentacle scale spiniform, distal oral papillae small, papilliform with rounded tips ……***Ophiopsila seminuda*** (Fig. 201)
– Both tentacle scales spiniform, distal oral papillae also spiniform …… ……***Ophiopsila bispinosa*** (Fig. 199)

87. Five arms, not fissiparous ……88
– Six arms, fissiparous ……***Ophiocomella sexradia*** (Fig. 169)

88. Disc covered at least dorsally with dense granules ……89
– Disc smooth or with granules and spines, upper arm spines club / clavate in shape ……96

89. One tentacle scale ……***Ophiocomella valenciae*** (Fig. 171)
– Two tentacle scales ……90

90. On one to three consecutive segments at about one–third of length of arm, uppermost arm spine enlarged or clavate …***Breviturma pusilla*** (Fig. 163)
– Uppermost arm spines one–third of the length along arm, not enlarged …91

91. Disc dark with radiating golden lines[1] ……***Breviturma pica*** (Fig. 161)
– Disc light and mottled, uniformly dark, or with spots or speckles ……92

92. Disc light with patterns / mottles of greens, whites, yellows, similar number of arm spines on each arm segment ……***Breviturma brevipes*** (Fig. 155)
– Disc brown / dark in colour ……93

93. Disc with speckles / spots ……94
– Disc uniformly dark above and below, tube feet red, white when preserved … ……***Ophiocoma erinaceus*** (Fig. 165)

94. Arm spine annulation very faint, if at all ……***Breviturma dentata*** (Fig. 157)
– Arm spine annulation strong / broken if present ……95

95. Colour greyish brown dorsally and ventrally, either with fine black reticulating lines, white–ringed black spots, or speckled with light spots; two or three tentacle scales along arms ……***Breviturma doederleini*** (Fig. 159)
– Colour broken or uniform brown; two oval tentacle scales …… ……***Ophiocoma scolopendrina*** (Fig. 167)

96. Arm spines 3–4, spines annulated; disc uniformly dark …… ……***Ophiomastix koehleri*** (Fig. 173)
– Arm spines 2–4, dark longitudinal lines on spines, disc light brown with radiating lines ……***Ophiomastix venosa*** (Fig. 175)

97. Arms inserted below disc, arm spines rarely much shorter than segment, projecting sideways from arm, pair of supplementary dorsal arm plates present ……98
– Arms fused to disc edge, arm spines usually shorter than segment and usually appressed to arm, but may be long and outstanding, supplementary dorsal arm plates only present if arm spines short and appressed to arms ……101

98. Genital papillae absent ……99
– Genital papillae present ……100

99. Colour pattern reticulated with a well–marked ‘V’ or ‘Y’ opposite base of each arm; supplementary dorsal arm plates triangular, length of dorsal arm plate becoming smaller distally ……***Ophionereis dubia dubia*** (Fig. 193)
– Disc white with large reddish–brown dense spot or star in middle of disc; supplementary dorsal arm plates large …***Ophionereis vivipara*** (Fig. 197)

100. Supplementary dorsal arm plates small and only well-developed on proximal part of arms; disc scales coarse, subequal …***Ophionereis australis*** (Fig. 191)
– Supplementary dorsal arm plates well-developed for most of arm, interradial disc scales distinctly smaller than radial and marginal plates … ……***Ophionereis porrecta*** (Fig. 195)

[1] Some species of *Breviturma* have a different night and day colouration (Hendler 1984)

101. Disc densely granulated, including jaws and sometimes including oral shields and adoral shields ……102
– Disc scales naked and most often distinct ……113

102. Oral shields mostly covered in granules ……103
– Oral shields naked ……106

103. One tentacle scale ……104
– Two or three tentacle scales ……105

104. Teeth wide with hyaline edges; disc concealed by granules, no granules on basal arm segments ……***Ophioconis cupida*** (Fig. 149)
– Teeth pointed, no hyaline edges; disc concealed by granules, granules extending onto basal arm segments ……***Cryptopelta aster*** (Fig. 123)

105. Disc covered in granulation and spinelets; arm spines all shorter than one segment length; tentacle scales two proximally, one along most of arm …… ……***Ophiochaeta hirsuta*** (Fig. 135)
– Disc covered in granulation; arm spines less than half segment length; tentacle scales three basally, two distally…… ***Ophiodyscrita acosmeta*** (Fig. 125)

106. Genital slits single (two in each interradius ……107
– Genital slits two (four in each interradius) …… ……***Ophioderma wahlbergii*** (Fig. 133)

107. Radial shields naked ……108
– Radial shields covered in armament ……111

108. Oral shields and supplementary oral shields naked; radial shields moderate to small ……109
– Oral shields and supplementary oral shields concealed by granules, easily rubbed off; radial shields very large ……***Ophiochasma nitida*** (Fig. 131)

109. Arm spines same length as segment except lowermost, which is twice as long as segment; colour bright red ……***Ophiarachna septemspinosa*** (Fig. 153)
– Arm spines short, no longer than half segment length, colour combination of browns, greens and / or whites ……110

110. Arm spines conical, with lowermost shorter than half segment length, colour irregular patterns of browns, sometimes with irregular dark spot or blotch in middle of disc ……***Ophiarachnella capensis*** (Fig. 127)
– Arm spines tapering, all half segment length; colour greens, greys and whites … ……***Ophiarachnella gorgonia*** (Fig. 129)

111. Arm spines long and flaring, all exceeding segment length …… ……***Ophiarachna affinis*** (Fig. 151)
– Arm spine length never exceeding segment length ……112

112. Marginal plates enlarged, few but large, supplementary oral shields covered in granules ……***Ophiopeza fallax fallax*** (Fig. 137)
– Marginal plates enlarged, many but small, supplementary oral shields not covered by granules ……***Ophiopeza spinosa*** (Fig. 139)

113. Oral slits generally tightly closed, oral papillae not in continuous series with oral tentacle scales, no true tentacle scales, disc scales thick ……114
– Oral slits may be closed, oral papillae in continuous series with oral tentacle scales, disc scaling usually distinct, but not necessarily thick ……118

114. Disc scales smooth or tumid, low granules, oral papillae not fused ……115
Disc scales smooth, oral papillae fused ……116

115. Dorsal interradial area covered by a single scale, many scales of various sizes on remainder of dorsal disc, low and tumid tubercles present on disc … ……***Ophiomusa lymani*** (Fig. 51)
– Dorsal interradial area with many scales, disc scales naked ……117

116. Dorsal interradial area covered by a single scale, but remainder of disc with many scales of various sizes, three arm spines, one separated from other two ……***Anophiura simplex*** (Fig. 75)
– Dorsal interradial margin covered by a single scale with remainder of dorsal disc scales few and of similar size; three arm spines, equally spaced ……***Aspidophiura corone*** (Fig. 77)

117. Disc scales surrounded by smaller scales both dorsally and ventrally, colour pink to brown, irregularly marbled with grey, white or silver patches …… ……***Ophiolepis cincta cincta*** (Fig. 183)
– Disc scales naked, imbricating, colour dark green or grey with irregular patterns and patches on dorsal disc conforming to interradial areas …… ……***Ophioplocus imbricatus*** (Fig. 185)

118. Disc extending into flat pentagon, lateral arm plates extremely modified, interradial edges straight, fringed by modified arm plates, free arm segments very reduced ……***Astrophiura permira*** (Fig. 53)
– Disc not extending beyond normal limits, no modification to lateral arm plates or arm spines, free arm segments not reduced ……119

119. Disc scaled, granules at least on disc margin or on jaws ……120
– Disc scaled, granules absent ……122

120. Oral shields huge, reaching into ventral interradial area, disc with granules and jaws with scattered granules ……***Ophiopallas paradoxa*** (Fig. 181)
– Oral shields not extending into interradial area, disc margin with scattered granules, usually extending onto radial shields, no granules on jaws ……121

121. Arm spines three, longest spine as long as ventral arm plate, but others shorter than segment; bristles present on lateral arm plates ……
……***Ophiernus vallincola*** (Fig. 179)
– Arm spines four, shorter than segment, decreasing distally; no bristles on lateral arm plates ……***Ophiernus quadrispinus*** (Fig. 177)

122. Single tentacle scale, tentacle pores stopping abruptly after first 2–5 arm segments; oral papillae two, fused each side of triangular apical papillae ……***Ophiomisidium pulchellum*** (Fig. 55)
– One or more tentacle scales on basal pores, but often only one along arms; oral papillae three or more, not fused ……123

123. Oral shield distal lobe not well-developed or enlarged; three (*Ophiura kinbergi* only) or five or more tentacle scales on second oral pore ……128
– Oral shield distal lobe well-developed; one to three tentacle scales on second oral pore if present ……124

124. Arm spines short, none more than one–third segment length ……125
– Arm spines with at least one exceeding segment length ……126

125. Dorsal arm plates fan-shaped with rounded distal edge, contiguous, up to six arm spines, subequal, short and blunt …***Amphiophiura sculptilis*** (Fig. 71)
– Dorsal arm plates bell-shaped, twice as long as wide proximally, first 4–5 plates contiguous, arm spines no more than three, one spine (usually uppermost) becoming hooked ……***Amphiophiura trifolium*** (Fig. 73)

126. Three arm spines, uppermost spine exceeding segment length ……127
– Three arm spines, uppermost two spines exceeding segment length ……
……***Ophiocten affinis simulans*** (Fig. 57)

127. Uppermost spine usually thicker than other two spines ……
……***Ophiocten hastatum*** (Fig. 61)
– Uppermost spine not thicker than other two spines ……
……***Ophiocten amitinum*** (Fig. 59)

128. Radial shields contiguous, double arm combs ……
……***Dictenophiura anoidea*** (Fig. 69)
– Radial shields not contiguous or only just touching; arm combs single …129

129. Uppermost arm spines much longer and stouter than others, exceeding segment length, dorsal arm plates oval and small …***Ophiura trimeni*** (Fig. 67)
– Arm spines similar, longest spines not longer than segment ……130

130. Three arm spines, middle spine becoming upturned hook on distal segments; genital papillae squat and broad ……131
– Three arm spines, all similar, genital papillae small and tapering ……134

131. Disc scales large, few interstitial scales ……132
– Disc scales medium or small, many interstitial scales ……133

132. Arm combs separated radially by more than half width of first free arm segment, disc scales not convex and dorsal arm plates almost flat in profile and contiguous……***Ophiuroglypha costata*** (Fig. 79)
– Arm combs approximating mid–radially, larger disc and dorsal arm plates not contiguous, swollen and convex in side view …… ……***Ophiuroglypha tumida*** (Fig. 81)

133. Arm combs present but not distinct, widely separated, papillae stout and short, disc scales small, many and irregular, supplementary ventral arm plate present on basal segments …… ……***Ophiuroglypha irrorata irrorata*** (Fig. 83)
– Arm combs not widely separated, distinct, papillae large, square; disc scales thick, medium-sized, irregular ……***Ophiuroglypha schmidtotti*** (Fig. 85)

134. Deep hollows between basal ventral arm plates …***Ophiura kinbergi*** (Fig. 63)
– No hollows between basal ventral arm plates ……135

135. Radial shields almost half disc radius, not widely separated, small spines on disc, small in size ……***Ophiura ljungmani*** (Fig. 65)
– Radial shields small, oval, partly covered by disc scales, widely separated, no disc spines, large in size ……**‘Ophiura’** ***flagellata*** (Fig. 87)

4. Taxonomic account

Phylum ECHINODERMATA Bruguière, 1791 (ex Klein, 1734)
Class OPHIUROIDEA Gray, 1840

4.1. Order EURYALIDA Lamarck, 1816
4.1.1. Family ASTERONYCHIDAE Ljungman, 1867

Genus ***Asteronyx*** Müller & Troschel, 1842

Diagnosis – Adapted from Müller & Troschel (1842) and McKnight (2000). Arms simple, covered in naked skin. Dorsal disc covered with naked skin, arm spines more than three, usually modified as simple hooklets. Oral papillae spiniform.

Asteronyx loveni Müller & Troschel, 1842

Asteronyx loveni Müller & Troschel, 1842: 119-120, pl. 10, figs 3-5; Bell 1892: 136-137; Koehler 1907: 348; Clark 1913: 219; Clark 1915a: 180; Clark 1923: 314-315; Döderlein 1927: 59, 97, pl. 7, figs 7, 8; Mortensen 1927: 158-160; Mortensen 1933a: 300-301; Clark A.M. 1952: 199, 212; Clark & Courtman-Stock 1976: 100, 108, 129; Baker 1980: 12, 16-18, figs 2, 3 (upper); Paterson 1985: 13-15, fig. 9a-d; Alva & Vadon 1989: 828-831, fig. 1a, b; Liao & Clark 1995: 165-166, fig. 71; McKnight 2000: 8, 13-15, pl. 1; Laguarda-Figueras *et al.* 2009: 46, fig. 5.

Ophiuropsis lymani Studer 1885: 55-46, pl. 5, fig. 12a-d; Clark 1913: 213; Clark 1915a: 180; Clark 1923: 315, pl. 5, fig. 12a-d; Döderlein 1930: 389, pl. 2, figs 11, 11a.

Asteronyx locardi Koehler 1895: 470-471, fig. 10; Koehler 1907: 348.

Asteronyx Cooperi Bell 1909: 22.

Asteronyx dispar Lütken & Mortensen 1899: 185, pl. 21, figs 1, 2, pl. 22, figs 10-12; Koehler 1907:348; Clark 1913: 218-219; Clark 1915a: 180.

Ophiuraster patersoni Litvinova 1998: 441-444, fig. 3.

Diagnosis – Adapted from Clark & Courtman-Stock (1976). D.D. up to 20 mm. Disc inflated, pentagonal in shape, rounded margin. Disc and arms covered with naked skin. Radial shields narrow, smooth, almost meeting at centre of disc. Ventral disc sometimes with irregular plates. Oral shields seldom distinct, small or lacking in larger specimens, proximal margin bluntly pointed while distal margin rounded. Oral papillae on lateral side and apex of jaw, irregular, numerous, blunt. Teeth pointed, sometimes in single or multiple vertical series. Arms flexible dorso-ventrally, unequal in length, *c.* 10 times D.D. No dorsal arm plates, vertebrae distinct. Ventral arm plates small, square to rectangular with rounded corners, but obscured by skin. Lateral arm plates large. Arm spines 3-9, hook-shaped, lowest arm spine largest, long, club-shaped, thorny. Genital slits short, *c.* single segment length, lying well within ventral interradial area. No tentacle scales on first pair of pores. Madreporite distinct. Colour in life red.

Distribution and habitat – Almost cosmopolitan, Indian Ocean, discontinuous in Pacific and Atlantic Oceans (Rowe & Gates 1995; McKnight 2000), South Africa: Orange River (NC) to Cape Town (WC); depth range: 62-4721 m. Habitat: mud and sand, associated with gorgonians and pennatulids.

Fig. 22. Distribution of *Asteronyx loveni* in South Africa.

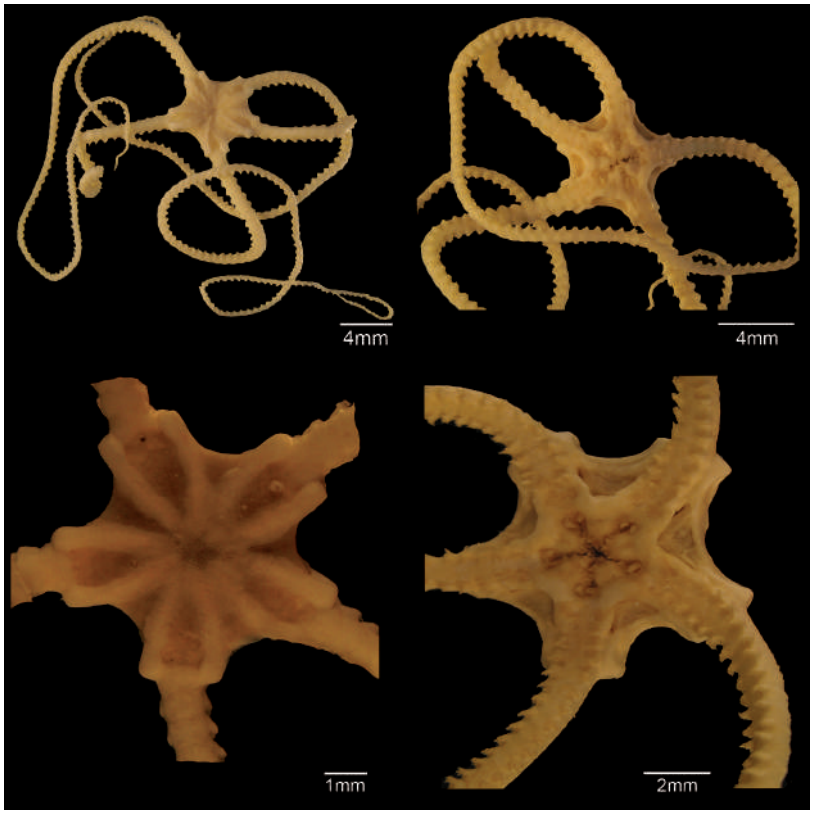


Fig. 23. Dorsal whole (top left), ventral whole (top right), dorsal disc (bottom left), ventral disc (bottom right) views of *Asteronyx loveni* (SAMC A22013).

Remarks – Known to cling to pennatulids and gorgonians (Mortensen 1927; Hyman 1955). Clark (1923) reported that the only difference between the southern African form and the northern form are that the oral papillae are shorter, flatter and more regularly arranged in the southern African form. Genetic data indicates that this is a species complex and there could be more than one species of *Asteronyx* from South Africa. *Asteronyx luzonicus* has been recorded from southern Mozambique (Baker *et al.* 2018).

Syntypes are in the Swedish Museum of Natural History, SMNH Type-3288 (Finnmark); SMNH Type-3732 (Kattegat); SMNH Type-3287 (Kattegat; south west Sweden as 'Bohuslän, Norway as far as Hammerfäst') (Stöhr 2007c), Bay of Biscay (Clark & Courtman-Stock 1976).

4.1.2. Family EURYALIDAE Gray, 1840

Genus ***Asteroschema*** Oersted & Lütken, 1856

Diagnosis – Adapted from Oersted & Lütken (1856); McKnight (2000) and Okanishi *et al. (*2011a). Disc covered in skin with embedded platelets or ossicles, being either granule-shaped and slightly in contact or cone-shaped and completely in contact. Radial shields covered by tubercles or naked distally. Arms simple with ability to coil. Ventral arm plate on middle to distal part of arms absent. Lateral arm plates large, contiguous ventrally. Longest arm spines twice as long as corresponding arm segment. Gonads extend into arms.

Asteroschema salix Lyman, 1879

Asteroschema salix Lyman, 1879: 66-67, pl. 17, figs 466-469; Baker 1980: 23-24; McKnight 2000: 21, 22. pl. 6, fig. 7; Olbers *et al.* 2015: 85, pl.1A, B.

Diagnosis – Adapted from Lyman (1879), McKnight (2000) and Olbers *et al*. (2015). D.D. up to 10 mm. Disc round, indented interradially, lateral interradial surface almost vertical, body surface covered with skin covered platelets with rounded granules. Radial shields elongated, narrow, raised, covered in plates, converging and almost meeting at centre of disc. Oral shields absent, adoral shields indistinct. Jaws covered by minute granules. Teeth seven, broad, triangular, lowermost appearing to be paired. Genital slits short, wide. Arms five, slender, flexible dorso-ventrally, narrow, higher than wide. No arm spines from first pair of tentacle pores to segment 15, then two arm spines, one slightly smaller. Arm spines short, innermost longest and cigar-shaped, finely serrated. Colour in life pink.

Distribution and habitat – New Zealand (McKnight 2000), South Africa: off Glenmore (KZN); depth range 341-1800 m. Habitat: no habitat details recorded.

Remarks – Recorded as new record to South Africa by Olbers *et al.* (2015). Single specimen recorded off KZN south coast, previously only known from New Zealand

and thus a noteworthy range extension into the Indian Ocean. According to Baker (1980), type locality is West of Raoul Island, Kermadecs, depth 1152 m. Holotype is in the Natural History Museum, London (NHMUK 82.12.23.271B) but was not located.

Fig. 24. Distribution of *Asteroschema salix* in South Africa.

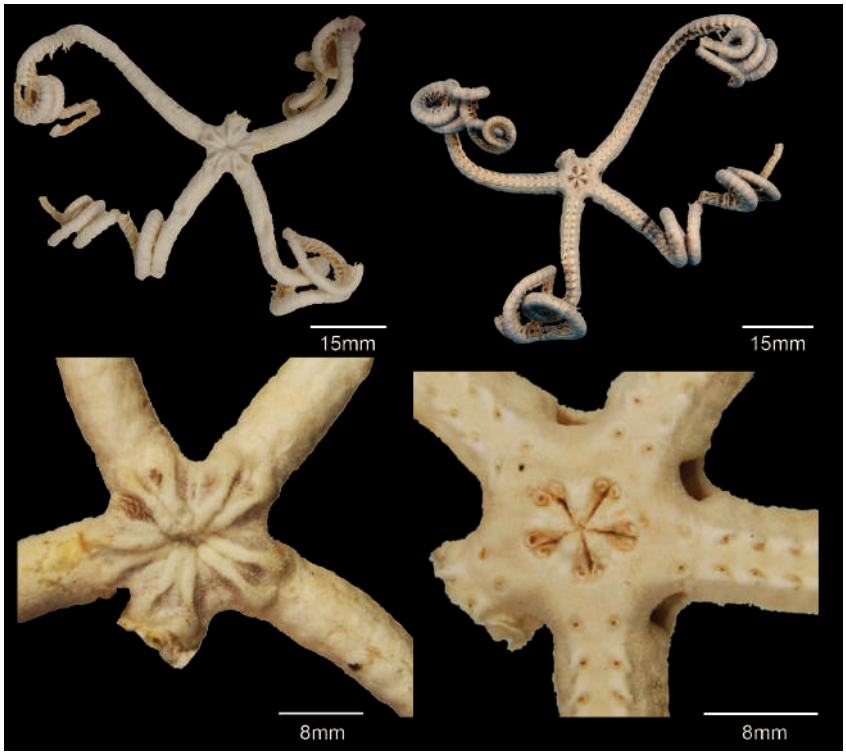


Fig. 25. Dorsal whole (top left), ventral whole (top right), dorsal disc (bottom left), ventral disc (bottom right) views of *Asteroschema salix* (SAMC A28143).

Genus ***Asteromorpha*** Lütken, 1869

Diagnosis – Adapted from Lütken (1869) and Okanishi *et al*. (2013). Disc with skin covered ossicles, either plate-shaped (in full contact) or granule-shaped (partly in contact). Radial shields may have large domed tubercles. Teeth triangular or square. Oral papillae domed, granule-shaped. Vertebrae with oral bridge. Lamina of distal arm spines smooth. Tentacle pores with two arm spines from fourth (rarely fifth) arm segment.

Asteromorpha capensis (Mortensen, 1925)

Astroschema capensis Mortensen, 1925: 152-155, pl. 8, figs 4-5, text-fig. 5; Mortensen 1933a: 221, 227.
Asteroschema capensis: Clark & Courtman-Stock 1976: 100, 108, 130; Sink *et al.* 2006: 469-470.
Asteroschema capense: Okanishi & Fujita 2009: 116, 119, 123, 125; Okanishi & Fujita 2011: 149 (*lapsus calami*).
Asteromorpha capensis Okanishi *et al.* 2013: 462-467, figs 2-5; Olbers *et al.* 2014: 14, pl. 1F; Baker *et al.* 2018: 4-5.

Diagnosis – Adapted from Okanishi *et al*. (2013). D.D. up to 8 mm; dorsal disc with skin covered ossicles, plate-shaped, polygonal, tessellated. Lateral interradial surface almost vertical. Radial shields tumid, with skin covered ossicles, almost meeting at centre of disc. Arms five, simple, flexible dorso-ventrally, no regular transverse rows of skin covered ossicles on dorsal and lateral surface, furrow to at least mid-arm. First to third tentacle pores lack arm spines, fourth pair with one spine, from fifth pair, two spines. Oral papillae 6-7, domed. Teeth 4-6, broad, triangular. Oral shields and adoral shields indistinct. Genital slits broad. Colour in life reddish purple with creamy white spots on dorsal disc, white bands on dorsal and lateral surface of the arms, or body light brown dorsally and white ventrally.

Distribution and habitat – Mozambique, Madagascar, Somalia (Okanishi *et al.* 2013), South Africa: Umvoti River (KZN) to Sodwana Bay (KZN); depth range: 64-500 m. Habitat: rock, epizoic on gorgonians and other anthozoans. Sodwana Bay specimens associated with the gorgonian *Nicella dichotoma* (Sink *et al.* 2006).

Fig. 26. Distribution of *Asteromorpha capensis* in South Africa.

Remarks – The holotype of *Astroschema capensis* has an oral bridge on the ventral side of the vertebrae on the distal portion of the arms, as well as two arm spines from the fifth arm segment. These morphological features confirm an affiliation with the Euryalinae (Mortensen 1933e; Okanishi & Fujita 2011; Okanishi *et al.* 2013). In addition, the disc and arms are covered mostly by skin covered ossicles, with the distal arm spines having a smooth basal lamina. These features required this species to be transferred to the genus *Asteromorpha* of the family Euryalidae (Okanishi *et al.* 2013). The holotype (examined), is in the Durban Natural Science Museum, as *Astroschema capensis* (DNSM ECH1). It is from 18-20 miles off Umvoti River Mouth, South Africa, depth 64-73 m.

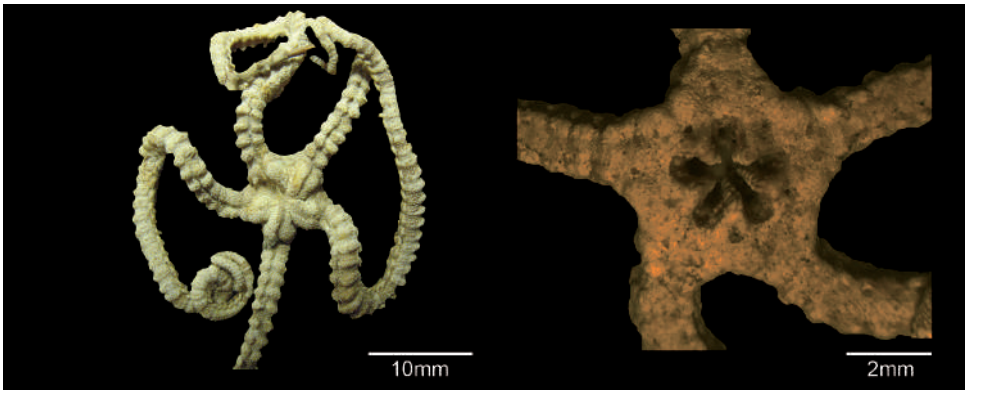


Fig. 27. Dorsal (left) and ventral (right) views of *Asteromorpha capensis* (DNSM ECH1).

Genus ***Asterostegus*** Mortensen, 1933

Diagnosis – Adapted from Mortensen (1933a) and Okanishi & Fujita (2014). Arms simple, flexible dorso-ventrally, covered in tubercles dorsally. Radial shields covered in tubercles. Teeth present, triangular. Oral papillae domed, minute. Ventral interradial area with plates on distal side of adoral shields. Arm spines present from fourth arm segment. Vertebrae with oral bridge. Lamina of distal arm spines smooth.

Asterostegus tuberculatus Mortensen, 1933

Asterostegus tuberculatus Mortensen, 1933a: 298-300, figs 24-26; Clark & Courtman-Stock 1976: 100, 108, 128, figs 87, 96; Okanishi & Fujita 2013: 568, 572, 575, fig. 1; Okanishi & Fujita 2014: 1, 3-4, 12-17, figs 7-10.

Diagnosis – Adapted from Mortensen (1933a) and Okanishi & Fujita (2014). D.D. up to 23 mm. Disc round, slightly notched interradially, covered in skin with stumps that are granule-shaped in centre and club-shaped on disc margin. Radial shields narrow, covered in skin and stumps. Arms five, simple, flexible dorso-ventrally.

Dorsal arm plates indistinct, proximal lateral arm plates narrow with 2-3 club-shaped stumps. Ventral arm plates more distinct, 4-5 ossicles on each segment, decreasing in size distally, absent at arm tips. Proximal lateral arm plates with 2-3 stumps. Arm spines two from fourth pore, ovoid and small proximally, club-shaped at mid-arm and hook-shaped with smooth lamina on distal side. Oral shields small, not distinct, adoral shields large, hexagonal. 5-8 interradial plates forming two rows between disc margin and adoral shields. Jaws short, single vertical series of well-spaced spearhead-shaped teeth. Oral papillae 6-7, dome-shaped. Lateral interradial surface almost vertical. Madreporite one. Colour in life unknown.

Distribution and habitat – Reunion (Okanishi & Fujita 2014), South Africa: Durban (KZN); depth range: 382-500 m. Habitat: no notes recorded.

Remarks – No specimen was found or examined in the South African collections. According to Mortensen (1933a) and Clark & Courtman-Stock (1976) only a single specimen is known from the region (Natural History Museum of Denmark, holotype ZMUC OPH-307); off Durban, 382 m. Okanishi & Fujita (2014) later redescribed *A. tuberculatus* based on a specimen found off the west coast of Reunion at 500 m, in the Swedish Museum of Natural History (SMNH-123461). *Asterostegus* is similar to *Astroceras* but with a stronger and more robust skeleton.

Fig. 28. Distribution of *Asterostegus tuberculatus* in South Africa.

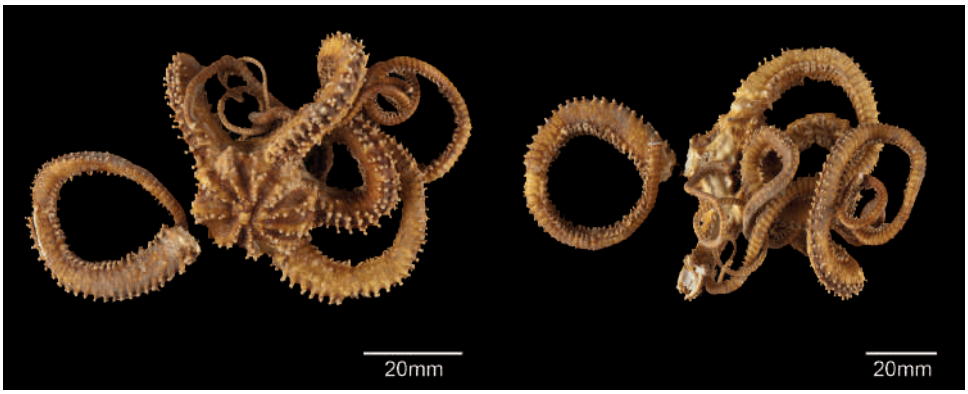


Fig. 29. Dorsal (left) and ventral (right) views of *Asterostegus tuberculatus* (ZMUC OPH-307).

Genus ***Astroceras*** Lyman, 1879

Diagnosis – Adapted from Lyman (1879), Clark & Courtman-Stock (1976) and McKnight (2000). Body covered in smooth skin. Disc naked or with spines or tubercles. Arms simple, flexible dorso-ventrally, scattered tubercles or spines on dorsal lateral ridge of arms. Radial shields narrow, tall, almost meeting in centre of disc, containing spines, tubercles or naked. Genital slits two, gonads ribbon-like extend into base of each arm. No true oral papillae but a clump of tubercles on lateral sides of jaws giving appearance of oral papillae. Teeth broad, triangular.

Astroceras spinigerum Mortensen, 1933

Astroceras spinigerum Mortensen, 1933a: 296-297, fig. 23, pl. 28 figs 8, 9; Clark & Courtman-Stock 1976: 100, 111, 128-129, fig. 94.

Diagnosis – Adapted from Mortensen (1933a) and Clark & Courtman-Stock (1976). D.D. up to 13 mm. Radial shields narrow, rib-like with 3-5 thick, cylindrical, smooth spines, outermost largest, tips rugose. Disc margin with scattered stumps, remainder of disc naked. Oral papillae small, warty. Infradental oral papillae slightly larger and elongated than oral papillae. Teeth five, conical, elliptical leaf-shaped. Adoral shields short, square. Oral shields rudimentary or absent. Arms simple, moderate in length, flexible dorso-ventrally, spines from radial shields continue down arms becoming smaller distally, one pair per segment. Dorsal arm plates indistinct. Ventral arm plates small, not contiguous. Lateral arm plates meeting on ventral side between ventral arm plates. Arm spines two from second pair of pores, short, cylindrical with thorny tip, hooked distally. Colour in life uniform greyish-brown.

Distribution and habitat – Mozambique (Clark & Courtman-Stock 1976), South Africa: Durban (KZN) to Leven Point (KZN); depth range: 112-411 m. Habitat: associated with sand, mud and sponges.

Remarks – No South African specimens were available for examination but Mozambican specimens were examined. Holotype is in the Natural History

Fig. 30. Distribution of *Astroceras spinigerum* in South Africa.

Museum of Denmark (ZMUC OPH-281), type locality off Durban, depth 411 m. The genetic data presented in Okanishi & Fujita (2013) suggest that *A. spinigerum* belongs in the genus *Asterostegus*.

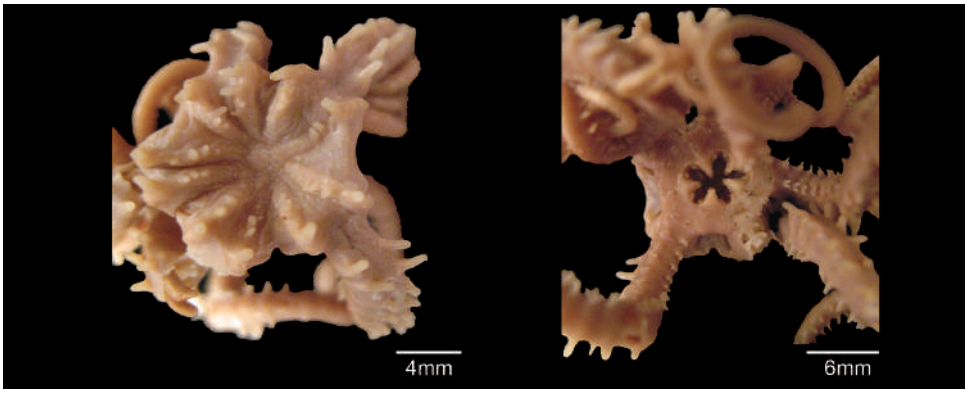


Fig. 31. Dorsal (left) and ventral (right) views of *Astroceras spinigerum* (SAMC A23233).

4.1.3. Family GORGONOCEPHALIDAE Ljungman, 1867

Genus ***Astroboa*** Döderlein, 1911

Diagnosis – Adapted from Döderlein (1911) and McKnight (2000). Radial shields elongated, converging towards centre, may be covered with small tubercles. Interradial areas usually have small tubercles, not uniformly placed. Arms branched, flexible dorso-ventrally. Belts of hooks (girdle belts) present as patches on lateral sides of arm then becoming continuous after fifth fork, girdle hooklets with curved terminal tooth and secondary tooth. No arm spines before the fourth fork, initially two then increasing up to five, with glassy tips, distally becoming flattened multi-tooth hooklets. Madreporite one.

Astroboa nuda (Lyman, 1874)

Astrophyton nudum Lyman, 1874: 251-252, pl. 6, figs 4-5.
Astrophyton elegans Koehler, 1905b: 123-125, pl. 13, fig. 2, pl. 18, fig. 1.
Astroboa nuda: Döderlein 1911: 86-88; Mortensen 1940: 67; Tsurnamal & Marder 1966: 9-17, figs 1-4; Clark & Courtman-Stock 1976: 100, 108, 130-131; Cherbonnier & Guille 1978: 17-18, pl. 1, figs 3-4; Baker 1980: 60, fig. 22; Guille & Vadon 1985: 62; Marsh 1986: 70; Olbers *et al.* 2015: 85, 88.
Astroboa nigra Döderlein, 1911: 83-86, pl. 9. Figs 9, 9a.
Astroboa nuda var. *elegans*: Döderlein 1927: 45.
Astroboa nuda var. *nigra*: Döderlein 1927: 44; Balinsky 1957: 2-3.

Diagnosis – Adapted from Clark & Courtman-Stock (1976) and Baker (1980). D.D. up to 92 mm. Disc depressed interradially and centrally, interradial and radial areas naked towards centre of disc, but with increasing presence of tiny tubercles towards disc margin. Radial shields narrow, paved densely with low granules giving smooth appearance, raised at disc margin, slightly broader on distal side, terminating in oval slightly concave plate, converging to centre of disc. Ventral interradial areas densely covered with tiny tubercles. Oral papillae short, narrow, no continuous fringe in distal notches. Teeth 3-5, thicker than oral papillae but elongated. Arms higher than wide basally, branched, first fork close to disc base, 4-8 segments between forks with up to 28 forks along arm, flexible dorso-ventrally. Arms covered in small, smooth, polygonal plates. Bands of hooks (girdle belts) present on arms from after second fork, but continuous before third branch, girdle hooklets with secondary tooth. Arm spines absent before fifteenth fork on main arm stem, but may occur from fourth fork on secondary stems, spines 3-4 with distal spines becoming hooks with two hooklets. Genital slits small, wide. Genital papillae present on inner edge. Madreporite one. Colour in life black, white or yellow.

Distribution and habitat – Western Indian Ocean, Red Sea, East Indies, Persian Gulf, China and south Japan, Philippines, Australia (Balinsky 1957; Kalk 1958; Macnae & Kalk 1958; Tsurnamal & Marder 1966; Clark & Rowe 1971; Clark & Courtman-Stock 1976; Cherbonnier & Guille 1978; Rowe & Gates 1995; Richmond 2002), South Africa: Sodwana Bay (KZN) (Sink *et al.* 2006); depth range: intertidal -120 m. Habitat: found on coral reefs, both within deep crevices and on open reef.

Remarks – Reported as new record for South Africa by Olbers *et al.* (2015). Previously known from Mozambique and hence not surprisingly recorded in South Africa. According to Rowe & Gates (1995), type locality is Philippines, with the holotype being in the Museum of Comparative Zoology (MCZ OPH-2911).

Two specimens were found at Sodwana Bay by Olbers *et al.* (2015) which only reported up to 20 forks, as opposed to 28 as reported by Baker (1980).

A notable difference between *Astroboa* and *Astrocladus* is that the arm spines in *Astroboa* are found after the fourth fork, while in *Astrocladus*, they occur from either first or second forks, however, this difference is not obvious in young specimens (Baker 1980).

Fig. 32. Distribution of *Astroboa nuda* in South Africa.

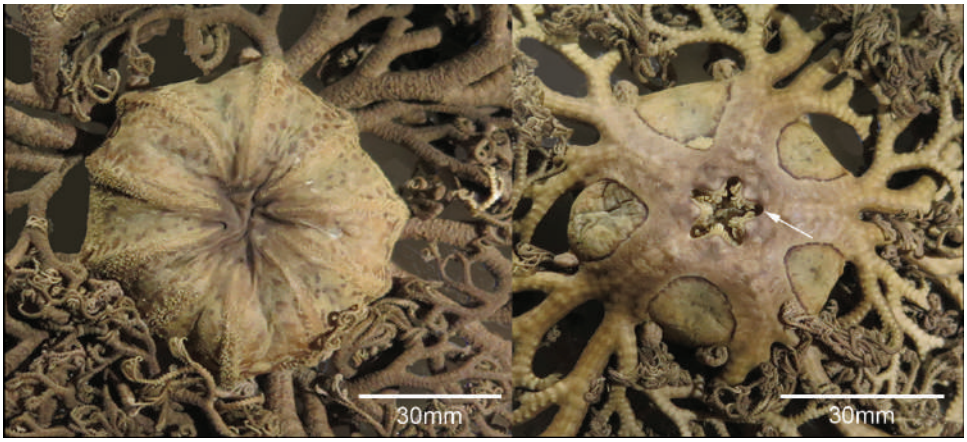


Fig. 33. Dorsal (left) and ventral (right) views of *Astroboa nuda* (SAMC A081578). Arrow indicates the distal notch.

Genus ***Astrocladus*** Verrill, 1899

Diagnosis – Adapted from Verrill (1899a) and McKnight (2000). Disc armed with flat or conical tubercles, no belts of marginal platelets. Oral papillae present in distal notches (except in *A. hirtus*). Arms branched, belts of hooks (girdle belts) present, flexible dorso-ventrally. Often more arm segments before the first fork than between first and second forks, no more than 11 segments between successive forks distally. Arm spines small, begin after segments bearing second or third pores.

Astrocladus africanus Mortensen, 1933

Astrocladus africanus Mortensen, 1933a: 291-293, fig. 20, pl. 17, figs 1, 2; Clark & Courtman-Stock 1976: 108, 131, fig. 92.

Diagnosis – Adapted from Mortensen (1933a). D.D. = 58 mm, dorsal disc with moderately sized conical tubercles, denser on radial shields and centre of disc, interradial areas with fewer tubercles. Radial shields converge towards centre of disc. Ventral interradial areas with few scattered tubercles, mouth frame and ventral arms covered with small irregular plates. Jaws thick, elevated. Oral papillae clustered on apex of jaw and fringe mouth slits including in distal notches. Arms flexible dorso-ventrally, first arm forks lie at disc edge, distance between successive forks short, 7-8 segments between forks, arms with more than eight forks. Dorsal arms with dense, uniform mosaic of small, smooth, almost flat plates, no larger tubercles, distinct sunken dorsal midline, spaces between segments somewhat sunken, with irregular larger oval plates found in sunken rings. Belts of hooks (girdle belts) present. Arm spines at first branch, sometimes at second and third pores, two, short, slightly curved and ending in a single thorn. Spines become hook-shaped distally, with 2-4 teeth or hooklets, serrated on convex edge. Genital

slits short. Genital papillae absent. Madreporite close to edge of mouth frame, scarcely protruding into interradius. Colour in life unknown.

Distribution and habitat – South Africa; depth range: unknown. Habitat: unknown.

Remarks – Considered endemic, only a single specimen is known, which was found during a South African Fisheries Survey (Mortensen, 1933b) but for which more detailed locality data are not available. Holotype in the Natural History Museum of Denmark (ZMUC OPH-74), type locality 'South Africa'.

Fig. 34. Distribution of *Astrocladus africanus* in South Africa.

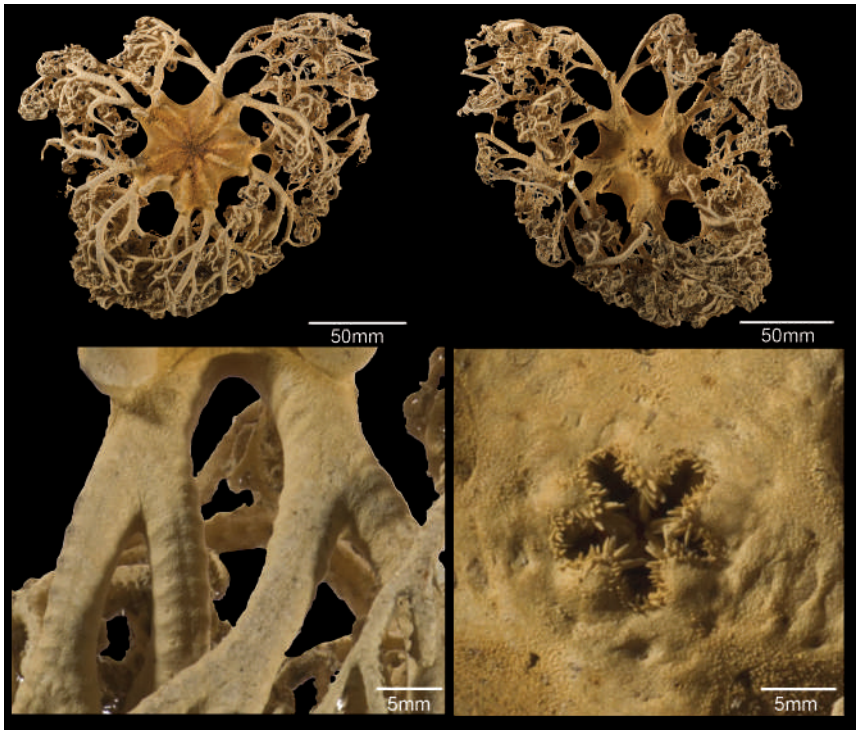


Fig. 35. Dorsal whole (top left), ventral whole (top right), proximal dorsal arms (bottom left), jaws (bottom right) views of *Astrocladus africanus* (ZMUC OPH-74).

Astrocladus euryale (Retzius, 1783)

Asterias euryale Retzius, 1783: 243-244.
Astrocladus euryale: Döderlein 1911: 6, 75; Clark 1923: 319; Mortensen 1933a: 293-296, figs 21, 22, pl. 18, fig. 7; Clark A.M. 1952: 199; Day *et al.* 1952: 412; Day *et al.* 1970: 80; Clark 1974: 440-441, pl. 3, figs 1, 2; Clark & Courtman-Stock 1976: 100, 108, 131, figs 89, 90, 91; Branch *et al.* 2010: 230, fig. 103.1.

Diagnosis – Adapted from Clark & Courtman-Stock (1976). D.D. up to 75 mm, disc smooth. Radial shields armed with moderate to large round tubercles, converging towards centre of disc. Dorsal arms coated with similar tubercles, continued down arm, tubercles absent distally, belts of hooks (girdle belts) present proximally. Arms branched, flexible dorso-ventrally, first fork beyond base, 6-9 segments between forks. Lateral arm plates short, barely reaching edge of the arm, ventral arm plates not well-developed. Ventral disc smooth, naked skin including jaws, oral and adoral shields indistinct. Oral papillae spiniform, fringe oral area including distal notches. Arm spines at first fork, sometimes before. Arm spines conical, becoming hook-shaped distally. Genital slits small, no genital papillae. Colour in life white and / or grey with black surrounding tubercles on disc and arms, arms and radial shields dark brown to black with white tubercles, interradial areas white.

Distribution and habitat – South Africa: Cape Town (WC) to Amatikulu (KZN); depth range: 11-555 m. Habitat: rock, sand, shell, mud and sponge.

Remarks – The most common basket star in South Africa and frequently seen and photographed by divers. When live, the arms and radial shields are dark brown to black with white tubercles and white interradial areas. The colouration is distinctive and easily identified positively by divers. When preserved, colouration often duller, but the darker areas are accentuated in comparison to the white / lighter areas.

Astrocladus euryale is endemic to South Africa. There have been three reports of distribution outside South Africa, namely Providence Island, Northern Madagascar (Bell 1905), Jobi, New Guinea and the Moluccas (Stiasny & Groenewegen 1929), but Mortensen (1933a) dispelled these records based on corrected identification of Bell's specimens and this was confirmed by Dr Stiasny saying that the specimen labels were unreliable.

Fig. 36. Distribution of *Astrocladus euryale* in South Africa.

The location of the type specimen is unknown, type locality, ‘Cape of Good Hope’, depth unknown.

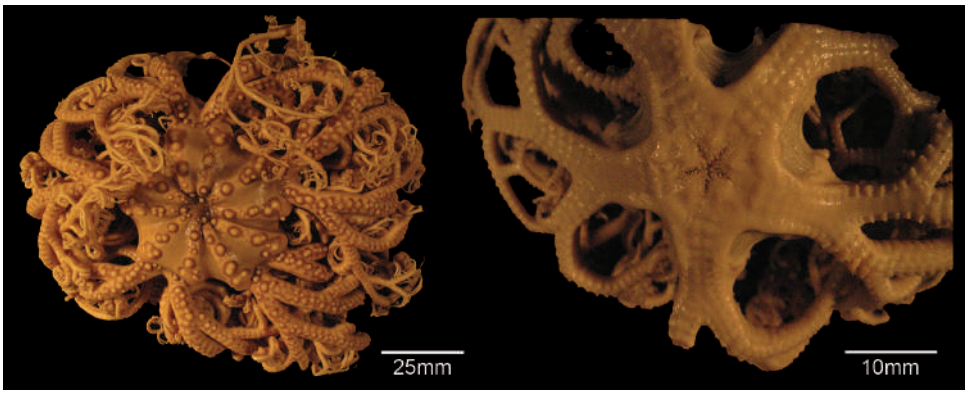


Fig. 37. Dorsal (left) and ventral (right) views of *Astrocladus euryale* (SAMC A084243).

Astrocladus hirtus Mortensen, 1933

Astrocladus hirtus Mortensen, 1933a: 288-290, fig. 17, pl. 19, figs 1-3; Clark & Courtman-Stock 1976: 101, 132.
Astrocladus hirtus var. *reticulatus* Mortensen 1933a: 290-291, pl. 18, figs 5, 6.

Diagnosis – Adapted from Mortensen (1933a) and Clark & Courtman-Stock (1976). D.D. up to 25 mm, disc pentagonal. Radial shields elevated, narrow, almost reaching centre of disc, not parallel, covered by small conical tubercles terminating in one or two very small thorns. Dorsal interradial areas and between radial shields coated in granules with some conical tubercles, tubercles becoming slightly larger on distal ends of radial shields. Ventral disc covered in small granules, few scattered conical granules in interradial areas. Oral papillae forming dense cluster at apex of jaws, no oral papillae in distal notches, lowermost papillae with sharp pointed tips, remaining papillae blunt or round. Arms five, branched, flexible dorso-ventrally, smooth, first fork within disc, 3-6 segments between forks, up to 12 forks. Arm spines 2-3 basally then 4-5 distally, short, with one or several hyaline thorns; arm spines begin at the second fork, but more developed from third fork. Ventral groove along most of the length of the arms. Dorsal sides of arms covered by granules, belts of hooks evident both dorsally and laterally, belts becoming complete after fifth fork, belts indistinct on most specimens. Genital slits small and restricted to edge of disc, adjacent to first fork, no genital papillae, but spines present on radial side of each genital slit. Single madreporite at edge of interradius close to jaws. Colour in life brown to yellow, lighter ventrally.

Distribution and habitat – South Africa: Aliwal Shoal (KZN) to Sodwana Bay (KZN); depth range: 12-111 m. Habitat: seen at night, attached to firm substrates; often in crevices (Yves Samyn, pers. comm.) and / or under large coral boulders.

Remarks – Endemic to South Africa, in northern KZN waters. This study increased the known depth range from 24 to 111 m. A syntype is housed at the Natural History Museum of Denmark (ZMUC OPH-125). The type locality is uncertain, but is possibly the Natal coast or Mozambique (Clark & Courtman-Stock 1976). A paratype (examined), from the Tugela Banks (SAMC A22382) is in the Iziko South African Museum.

Fig. 38. Distribution of *Astrocladus hirtus* in South Africa.

Fig. 39. Dorsal (left) and ventral (right) views of *Astrocladus hirtus* (RMCA MT2186).

Genus ***Astrodendrum*** Döderlein, 1911

Diagnosis – Adapted from McKnight (2000) and Döderlein (1911). Teeth, oral papillae and dental papillae similar, spiniform. Genital slits small, often pore-like and close to disc margin. Arms flexible dorso-ventrally, basal vertebrae not very small, belts of hooks present, hooklets in patches on dorsal side at base of arms.

Astrodendrum capensis (Mortensen, 1933)

Astroconus capensis Mortensen, 1933a: 285-288, fig. 18a-d, pl. 18, figs 3, 4; Clark & Courtman-Stock 1976: 100, 132; Alva & Vadon 1989: 829-830, 831, fig. 1c, d.
Astrodendrum capensis: Baker 1980: 58.

Diagnosis – Adapted from Mortensen (1933a) and Baker (1980). D.D. up to 90 mm. Disc and arms covered in fine granules. Disc with few intermixed conical and warty tubercles towards disc margin and radial shields, denser in centre of disc. Radial shields narrow, slightly broader on distal side, converging towards centre. Mouth frame covered in dense mosaic of small, flat, polygonal plates, arms similar. Oral papillae long, spiniform and stout on apex, forming continuous fringe including in distal notches. Arms branched, flexible dorso-ventrally. First fork beyond base, 8-9 segments between first and second forks, up to 20 segments distally. Belts of hooks begin on third to fourth fork. Arm spines short, begin on second pair of oral pores. Genital slits small, pore-like and close to disc margin. Genital papillae present.

Distribution and habitat – Namibia, South Africa: Orange River (NC) to Leven Point (KZN); depth range: 161-420 m. Habitat: found in sandstone, rubble, broken shell, coarse sand and attached to gorgonians.

Remarks – Distribution range here extended north-east from Durban (KZN) to Leven Point (KZN) and west from Durban to the Orange River (NC).

Baker (1980) placed *Astroconus capensis* Mortensen, 1933 in the genus *Astrodendrum* Döderlein 1911 after re-examination of the holotype in the Natural History Museum of Denmark (ZMUC OPH-80), because of the presence of girdle

Fig. 40. Distribution of *Astrodendrum capensis* in South Africa.

hooklets in patches on the dorsal side at the base of the arms, which is a character unknown in *Astroconus,* but present in all *Astrodendrum* species. Type locality is off Durban, depth 420 m.

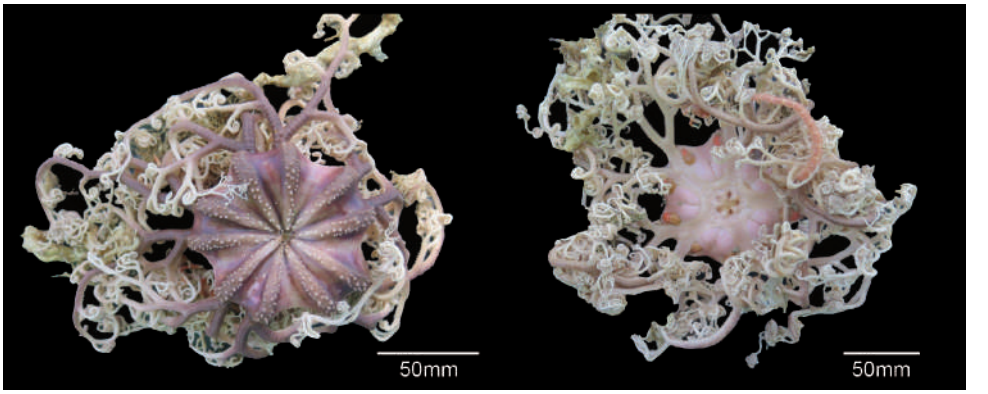


Fig. 41. Dorsal (left) and ventral (right) views of *Astrodendrum capensis* (SAMC A088481).

Genus ***Astroglymma*** Döderlein, 1927

Diagnosis – Adapted from Döderlein (1927). Disc tubercles fine, all similar in size. Arms branched, flexible dorso-ventrally, *c.* 16 forks. Arm spines 2-3, minute. Madreporites five, equal in size.

Astroglymma cf. ***sculptum*** (Döderlein, 1896)

Astrophyton sculptum Döderlein, 1896: 299, pl. 18, fig. 29a, b; Baker 1980: 66, 74, figs 19, 28, 31.
Gorgonocephalus robillardi de Loriol, 1899: 31-34, pl. 3, fig. 3.
Astrodactylus robillardi: Döderlein 1911: 96-98.
Astroglymma sculptum: Döderlein 1927: 47-50, pl. 1, figs 3, 4; pl. 5, fig. 13; Koehler 1930: 15, pl. 2, figs 10-12; Guille & Vadon 1985: 62; Liao & Clark 1995: 170, fig. 74; Okanishi *et al.* 2011b: 380-381, fig. 7; Olbers *et al.* 2015: 88-89, pl. 1C, D.
Astroglymma robillardi: Mortensen 1933e: 34, pl. 3, figs 1, 2; pl. 4, fig. 1.
Astroglymna sculptum: Rowe & Gates 1995: 365 (*lapsus calami*).

Diagnosis – Adapted from Baker (1980). D.D. up to 50 mm. Disc deeply excavated interradially. Radial shields long, slender, widely separated distally, almost touching proximally, almost reaching centre of disc. Disc and radial shields covered in minute conical tubercles, ventral interradial area may bear long spinelets. Oral shields smooth, adoral shields not distinct, deep pits bordering jaws. Oral papillae unequal, small, mostly spiniform. Teeth small, spatulate. Arms branched, flexible dorso-ventrally, first fork just beyond disc, forking at least 20 times along arm. Dorsal arms covered in low polygonal plates. Belts of hooks (girdle belts) narrow, present from arm bases, girdle hooklets with secondary

tooth. Arm spines present from sixth fork as two stumps, becoming three with one or two terminal points, distally becoming hooklets with terminal tooth and smaller secondary tooth. Ventral arms covered with smaller flat polygonal plates, ventral arms have ladder-like pits on first 2-3 forks. Genital slits short, D-shaped. Genital papillae blunt-tipped on outer edge. Five madreporites present in angle of ventral interradial area.

Distribution and habitat – Mauritius, India, China Sea, Malaysian Archipelago, Australia (Baker 1980; Imaoka *et al.* 1991; Rowe & Gates 1995), South Africa: off Durban (KZN); depth range: 68-70 m. Habitat: no notes recorded.

Remarks – Reported as new to South Africa by Olbers *et al.* (2015), found off Durban in KZN. Another specimen from off Durban in the Smithsonian Institution, National Museum of Natural History (USNM) was reported by Baker *et al*. (2018).

Fig. 42. Distribution of *Astroglymma* cf. *sculptum* in South Africa.

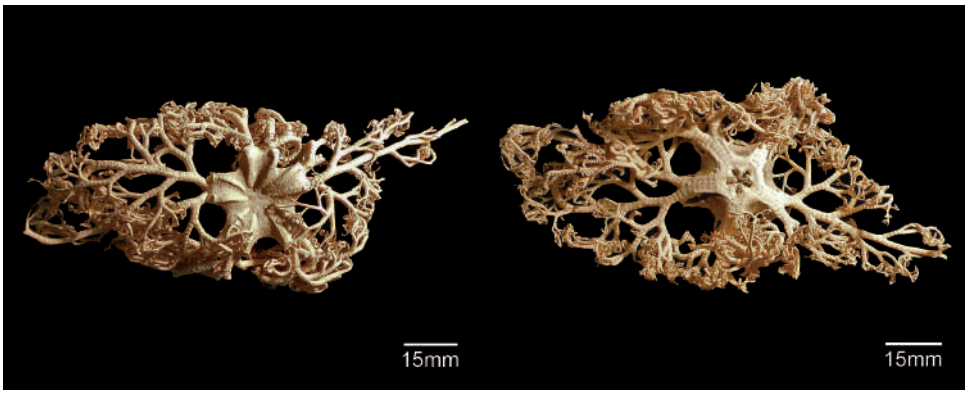


Fig. 43. Dorsal (left) and ventral (right) views of *Astroglymma* cf. *sculptum* (USNM 1072476).

Genus ***Astrothorax*** Döderlein, 1911

Diagnosis – Adapted from Döderlein (1911) and McKnight (2000). Arms simple, flexible dorso-ventrally, disc covered in tubercles, arm spines 5-10, hooklets with single secondary tooth.

Astrothorax papillatus H.L. Clark, 1923

Astrothamnus papillatus Clark, 1923: 316-318, pl. 20, figs 5, 6.
Astrothorax waitei (Benham, 1909): Baker 1980: 30-32, figs. 8, 31 (in part).
Astrothorax papillata: Mortensen 1933a: 279-280, fig. 15; Clark A.M. 1952: 199; Clark & Courtman-Stock 1976: 100, 108, 132.

Diagnosis – Adapted from Clark & Courtman-Stock (1976). D.D. up to 20 mm. Disc tumid dorsally, flat ventrally, with interradial areas slightly excavate. Radial shields form distinct ridges, upper surface with coarse and fine tubercles intermixed, tubercles wider than high, rounded or truncated, smooth or have fine glassy, prickly protrusions. Ventral disc tubercles abruptly finer, conceal oral shields. Disc margin paved with low smooth tubercles. Arms five, long, simple, flexible dorso-ventrally, dorsally rounded, alternating bands of fine and coarse tubercles, fine tubercles bear numerous hooks and hooklets, while coarser tubercles more or less smooth. Arm spines begin at second tentacle pore, two, short, thorny, increasing in number up to ten. Arm spine shape changes from thorny-tipped stumps proximally to F-shaped hooks distally. Distal arm spines have large terminal tooth with smaller secondary tooth. Jaws covered by uniform fine tubercles, coarsest interradially. Teeth, tooth-papillae and oral papillae similar, spiniform, teeth larger, oral papillae small. Genital slits small, no genital papillae.

Distribution and habitat – South Africa: Cape Point (WC) to Durban (KZN); depth range: 43-650 m. Habitat: mud, sand and attached to coral or coralline algae.

Remarks – Holotype, as *Astrothorax papillatus* (SAMC A6443), type locality off Cape Hangklip, depth 110 m. Genetic data (O'Hara *et al*. 2017; unpublished) indicates that the South African records are distinct from those of *A. waitei*

Fig. 44. Distribution of *Astrothorax papillatus* in South Africa.

Bentham, 1909 from Australian/New Zealand, and here *A. papillatus* is recognised as distinct.

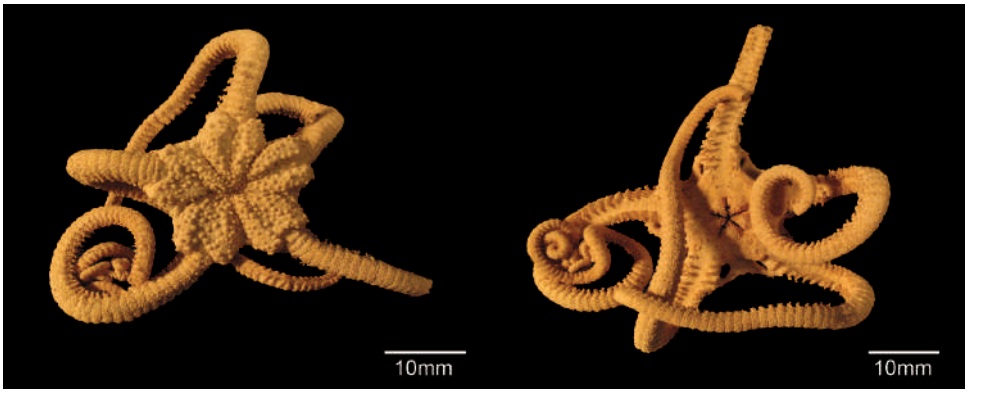


Fig. 45. Dorsal (left) and ventral (right) views of *Astrothorax papillatus* (SAMC A7519).

Genus ***Gorgonocephalus*** Leach, 1815

Diagnosis – Adapted from Leach (1815) and McKnight (2000). Disc and arms covered with small spiny or thorny tubercles, disc margin contains plates. Radial shields narrow, elongated. Arms five, flexible dorso-ventrally, first fork near disc, dorsally with annulated bands of hooks (girdle belts) well-developed distally. Arm spines present before first fork. Madreporite usually one.

Gorgonocephalus chilensis (Philippi, 1858)

Astrophyton chilense Philippi, 1858: 268.
Astrophyton pourtalesii Lyman, 1875: 28-29, pl. 4, figs 41-43.
Gorgonocephalus chilensis: Lyman, 1882: 261; Koehler 1908b: 142; Clark 1915a: 185; Clark 1923: 318, Döderlein 1927: 30-31; Zirpolo 1932: 1-16, figs 1, 2; Mortensen 1936: 240-241; Fell 1958: 20; Seno & Irimura 1968: 148-149; Monteiro & Tommasi 1983: 33-54; McKnight 2000: 45-46, fig. 20, pl. 19.
Gorgonocephalus pourtalesii: Lyman 1882: 261-262, pl. 45.
Gorgonocephalus chilensis var. *novaezelandiae* Mortensen, 1924: 93, 109-110, pl. 4, fig. 1.

Diagnosis – Adapted from Lyman (1882) and McKnight (2000). D.D. up to 64 mm. Disc slightly inflated, interradial areas slightly indented. Radial shields conspicuous, narrow, extend more or less to centre of disc, tapering at distal ends, densely covered in conical tubercles, mostly higher than wide, remainder of disc covered in skin with numerous scattered tubercles, sometimes smaller in size. Disc margin with few larger tubercles, forming continuous series with those of radial shields. Ventral interradial areas covered in skin with small, scattered, low tubercles, few scattered tubercles towards oral area. Oral shields triangular, covered in smooth

skin, sometimes with few scattered tubercles, adoral shields square. Oral papillae and teeth spiniform, fringe oral frame, but absent in distal notches. Arms branched, flexible dorso-ventrally, forks *c.* ten times, rounded dorsally with small round or dome-shaped tubercles, proximal segments with naked plates. First fork at base of disc, approximately six segments between forks. Arm spines lacking on first arm segment, increasing to two on segment two and three, increasing again to four or five then decreasing to two or three from about fifth fork, spines shorter than the arm width, slightly flattened, pointed becoming multi-toothed hooks. Ventral arm surface flat, relatively smooth near base, becoming scattered with small tubercles. Genital slits short, wide. Papillae on edge of slits present, in series with disc papillae, large, usually higher than wide. Madreporite one, at edge of oral frame. Colour uniform creamy white, disc pale brown, arms, radial shields and tubercles cream (Baker 1980; McKnight 2000).

Distribution and habitat – New Zealand, Ross Sea, Falklands, Chile (Philippi 1858; Mortensen 1924; Mortensen 1936; Seno & Irimura 1968; McKnight 2000), South Africa: Cape Town (WC) to Port Edward (KZN); depth range: 22-900 m. Habitat: mud, fine sand.

Remarks – Distribution here extended into southern KZN from Cape Town (WC).

Clark (1923), Seno & Irimura (1968) and Mortensen (1936) reported that a number of specimens had younger individuals attached to them. Clark reported they were adults and were viviparous, while Mortensen (1933a, 1936) disputed this and suggested that the presence of smaller individuals on, or attached, to larger individuals has nothing to do with viviparity or brood protection, but was rather a function of the smaller individual using the larger animal in a similar way to gorgonians.

The type material is in the Museum of Comparative Zoology (syntype: MCZ OPH-2954), type locality off Cape Raso, Argentina, depth 100 m. Genetic data is required to determine whether one or more species is included within this taxa. It is unusual for the same species to be recorded all the way from Antartica to subtropical latitudes.

Fig. 46. Distribution of *Gorgonocephalus chilensis* in South Africa.

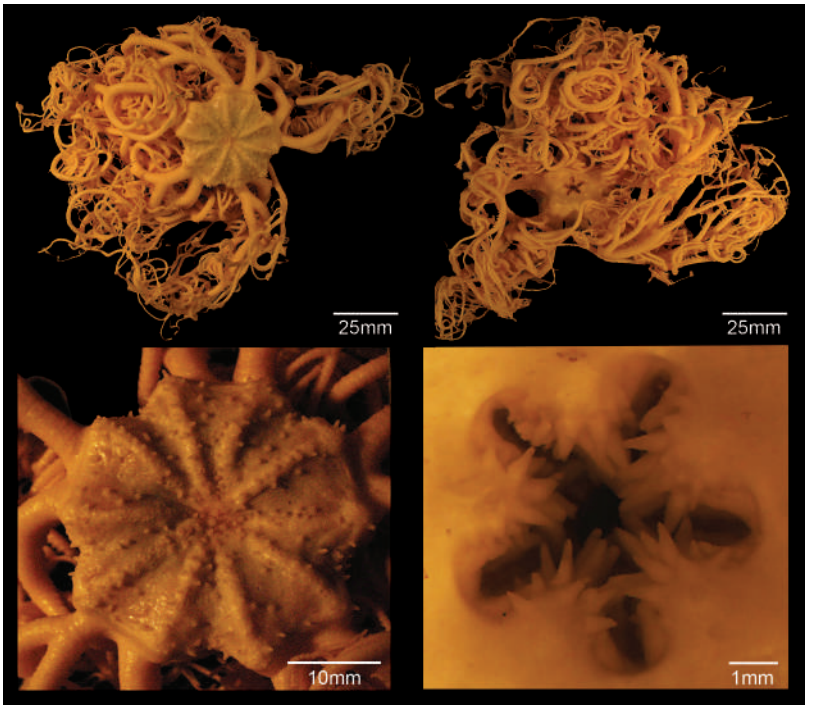


Fig. 47. Dorsal whole (top left), ventral whole (top right), dorsal disc (bottom left), jaws (bottom right) views of *Gorgonocephalus chilensis* (SAMC A084240).

Gorgonocephalus pustulatum (Clark, 1916)

Astrodendrum pustulatum Clark, 1916: 84-85, pl. 34, figs 1, 2; Döderlein 1927: 32-33, pl. 1, figs 5, 6; Clark 1946: 181.
Gorgonocephalus moluccanus Döderlein, 1927: 26-27, pl. 2, fig. 2.
Gorgonocephalus pectinatus Mortensen, 1933a: 281-285, figs 16, 17, pl. 18, figs 1, 2; Clark & Courtman-Stock 1976: 133, 100, 108, figs 86, 88.
Gorgonocephalus pustulatum: Baker 1980: 54-56, fig. 20; Rowe & Gates 1995: 368; McKnight 2000: 49-51, pl. 21.

Diagnosis – Adapted from Mortensen (1933a), Baker (1980) and McKnight (2000). D.D. up to 54 mm. Dorsal disc covering variable, some specimens naked interradially, while others with numerous tubercles, conical or almost spine-like, interradial areas excavate, disc margin of mostly thin, naked plates, sometimes with tubercles. Radial shields prominent, narrow, uniform in width, converge towards centre, tubercles irregular. Ventral surface flat, naked. Jaws with small low tubercles, with remaining area naked covered in skin. Oral papillae slender, spiniform, teeth stouter, with slightly flattened tips, papillae forming continuous fringe, but not within distal notches. Arms branched, flexible dorso-ventrally, with at least eight forks, first fork just beyond disc, approximately 8-11 segments

between forks, then between 10-33 segments between forks distally. Dorsal arms round, smooth and covered with fairly large irregular plates sometimes with tubercles. Ventral arms flat, smooth, with few, low scattered tubercles. Belts of hooks continuous from near the arm base, slightly raised above arm surface, hooklets with small secondary tooth. Arm spines begin on second arm segment, with segments 4-6 with two spines, and then 3-4 spines continuing down arm, only one spine distally. Spines short, cylindrical, blunt multi-pointed tips becoming multi-toothed hooks distally. Genital slits large, conspicuous, papillae slightly larger than disc tubercles, randomly spaced. Colour from deep pinkish-brown (Clark & Courtman-Stock 1976) to dull brown, with the radial shields and ventral surface lighter or red (McKnight 2000).

Distribution and habitat – Western Indian Ocean, Indonesia, Australia, New Zealand, West Pacific (Baker 1980; Rowe & Gates 1995), South Africa: Cape Town (WC) to Folokwe (EC); depth range: 78-860 m. Habitat: fine sand, rock, rough substrata and one specimen attached to an anemone.

Remarks – The type material is in the Museum of Comparative Zoology (holotype: MCZ OPH-3952), type locality east of Flinders Island, Australia, depth 183-549 m.

The differences between *Gorgonocephalus chilensis* and *G. pustulatum* are not obvious. Baker (1980) stated that tubercle density on the disc cannot be used as the single character to differentiate between gorgonocephalid species. Since then, authors have put forward a variety of characters to differentiate between the two species, however, it seems that there still is no easy-to-use character to differentiate between them. Okanishi (2012) proposed that *G. pustulatum* had tubercles only on the radial shields, while *G*. *chilensis* also had tubercles scattered on the dorsal disc. In *G. pustulatum*, the dorsal interradial areas were relatively narrow with clusters of small granule-shaped epidermal ossicles. The interradial areas in *G. chilensis* are relatively wide, while the hooklets on the arms are discontinuous from the base of the arms.

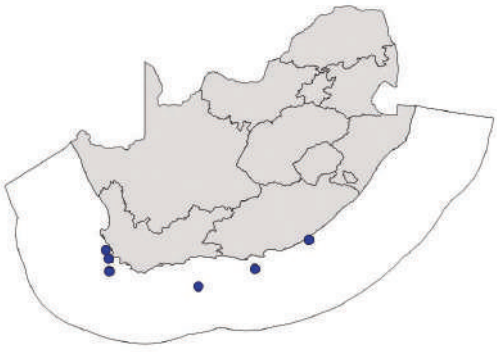


Fig. 48. Distribution of *Gorgonocephalus pustulatum* in South Africa.

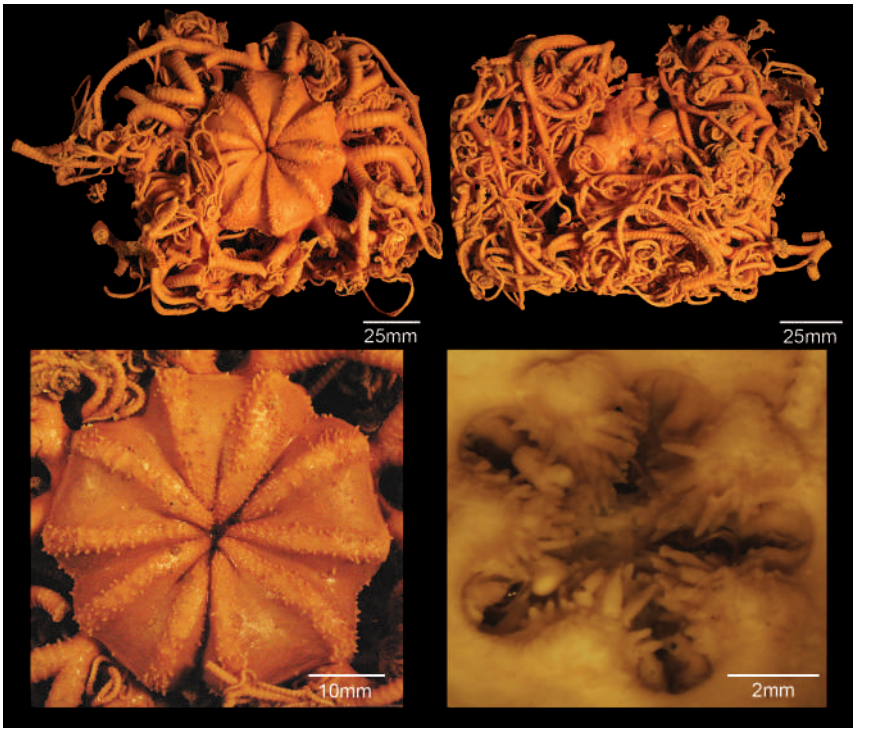


Fig. 49. Dorsal whole (top left), ventral whole (top right), dorsal disc (bottom left), jaws (bottom right) views of *Gorgonocephalus pustulatum* (SAMC A084227).

4.2. Order OPHIURIDA Müller & Troschel, 1840
4.2.1. Family OPHIOMUSAIDAE O'Hara *et al.*, 2018

Genus ***Ophiomusa*** Hertz, 1927

Diagnosis – Adapted from Lyman (1869).Disc covered by large, naked scales. Radial shields relatively large. Oral papillae fused, apical papillae present, teeth present. Ventral arm plates restricted to the proximal 1-2 arm segments. Dorsal arm plates very small, not contiguous. Ventral arm plates present basally only. Lateral arm plates meeting above and below. Tentacle pores absent beyond basal arm segments. Arm spines small.

Ophiomusa lymani (Wyville Thomson, 1873)

Ophiomusium lymani Wyville Thomson, 1873: 174-175, fig. 33; Koehler 1904a: 58; Clark 1911: 107-108; Clark 1913: 213-214; Matsumoto 1917: 289; Koehler 1922b: 411, pl. 86, figs 5, 7-9; Clark 1923: 364; Mortensen 1927: 253-254, fig. 138; Mortensen 1933a: 394; Clark & Courtman-Stock 1976: 107, 125, 191,

fig. 211; Baker 1979: 30; Paterson 1985: 147-148, fig. 58a, b; Alva & Vadon 1989: 828; Imaoka *et al.* 1990: 95; Garcia-Diez *et al.* 2005: 49; Laguarda-Figueras *et al.* 2009: 100, fig. 32.

Ophiomusa lymani: Hertz 1927a: 103-105; Clark H.L. 1939: 128.

Diagnosis – Adapted from Mortensen (1927). D.D. up to 48 mm. Disc round, covered dorsally and ventrally with scales of various sizes, some tumid, others flat but with tubercles, cluster of flat scales in centre of disc, primary rosette sometimes distinct. Radial shields with embedded tubercles, triangular, longer than wide, *c.* half disc radius. Oral shields triangular, longer than wide, proximal lobe sharp, distal edge straight, bordered distally by pentagonal plate covering most of interradial area. Adoral shields broad and large, contiguous. Oral papillae 5-6 but almost appear fused, structure of each papilla still visible. Oral tentacle pore bordered by first arm plate. Genital slits half-way to disc margin, thin and narrow, genital plates present. Dorsal arm plates diamond or triangular, distal edge convex, widely separated, longer than wide, becoming smaller and entirely absent for much of the arm. Ventral arm plates only present on first three segments, pentagonal. Lateral arm plates meet dorsally and ventrally, very large. Arms slender but stiff. Arm spines up to 13, very small, conical. Tentacle scales one, oval, large, present on first two arm segments only.

Distribution and habitat – Arabian Sea, Indonesia, Australia, New Zealand, Chile, Gulf of Mexico, Caribbean and Atlantic Ocean (Baker 1979; Rowe & Gates 1995), South Africa: off Orange River (NC) to St Lucia (KZN); depth range: 130-4829 m. Habitat: mud and sand.

Remarks – The DNA-based revision of O'Hara *et al.* (2018) indicates that the type species of *Ophiomusium* is distinct from all other species previously placed in this genus. These species have been placed in the genus *Ophiomusa* pending a full revision. The type species of *Ophiomusa* is *O. lymani.*

At first glance, this species is superficially similar to *Ophiomisidium* (Astrophiuridae), but they differ in a number of characters. The basal lateral arm plates are much expanded on *Ophiomisidium* and the ventral disc area much reduced. The ventral arm plates are typically absent on *Ophiomusa* after two segments near the arm base.

Fig. 50. Distribution of *Ophiomusa lymani* in South Africa.

The distribution range is here extended westwards from off Saldanha Bay (WC) to off the Orange River (NC) and eastwards from off Cape Agulhas (WC) to St Lucia (KZN).

According to Rowe & Gates (1995), the syntypes are most probably housed in the Natural History Museum, London, however these were not located. The type locality is off the coast of Ireland, depth unknown (Rowe & Gates 1995).

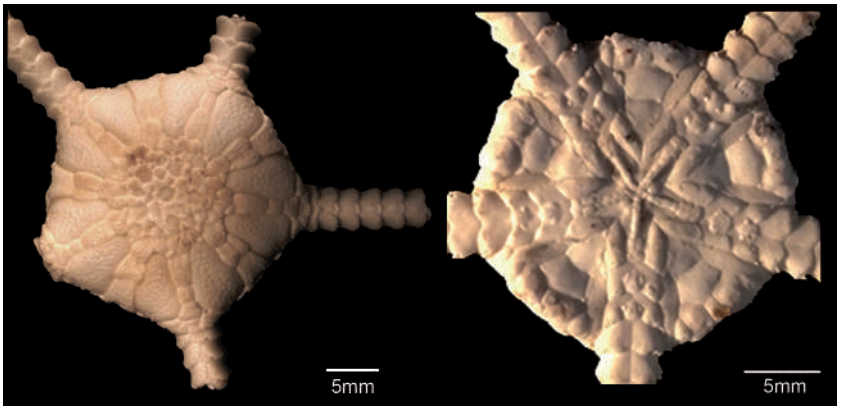


Fig. 51. Dorsal (left) and ventral (right) views of *Ophiomusa lymani* (SAMC A22044).

4.2.2. Family ASTROPHIURIDAE Sladen, 1879

Genus ***Astrophiura*** Sladen, 1879

Diagnosis – Adapted from Sladen (1879), Matsumoto (1917) and Fujita & Hendler (2001). Dorsal disc covered with scales, while modified lateral arm plates appear to form remainder of disc or umbrella, fringed with modified spines along whole disc margin. Radial shields half true disc radius. Oral papillae up to seven. Teeth and dental papillae absent. Dorsal and ventral arm plates rudimentary external to umbrella, but well-developed within. Arms short. Tentacle scales only present within umbrella, tentacle pores very large within umbrella.

Astrophiura permira Sladen, 1878

Astrophiura permira Sladen, 1878: 456-457; Sladen 1879: 401-415, pl. 20; Hertz 1927a: 83-85, pl. 7, figs 4, 5; Mortensen 1933a: 394-396, figs 90, 91; Clark & Courtman-Stock 1976: 125, 107, 188, fig. 207; Clark 1977: 143-144.
Astrophiura cavellae Koehler, 1915:1-15, figs 1-6; Clark 1923: 354-356.

Diagnosis – Adapted from Clark & Courtman-Stock (1976). D.D. up to 10 mm, disc pentagonal, concave below, central plate with protrusion, disc scales distinct.

Disc expanded from modified lateral arm plates, creating an umbrella effect on disc. Single triangular interradial segment with five segments either side, longer than wide, with undulating distal edges meeting arms at right angles. Spines modified to form fringe on expanded disc margin. Undulating edges and modified spines make disc appear to have a double fringe. Oral shields not always distinct, small, triangular. Adoral shields large, more distinct than oral shields, contiguous. Oral papillae four, apical papillae two on apex. Dorsal arm plates not contiguous, triangular, convex distally, distal plates very far apart, separated by large lateral arm plates. First ventral arm plate bell-shaped, other non-free plates square, slightly longer than wide, all plates constricted by large tentacle pores, plates becoming reduced distally by large lateral arm plates. Arm spines short, blunt. No genital slits, genital organs present, sometimes visible through ventral disc. Tentacle scales two, round.

Distribution and habitat – Indo-West Pacific, Madagascar (Sladen 1878), Australia (Rowe & Gates 1995), South Africa: Cape Town (WC) to Black Rock (KZN); depth range: 164-1300 m. Habitat: sand, stones, rock and coral (Clark & Courtman-Stock 1976).

Remarks – Sladen (1878) briefly described the characters of this species, completing his description in a separate publication in 1879, in which he argues that this species forms a link between the Ophiuroidea and Asteroidea.

Type material is in the Museum of Natural History of Berlin (syntype of *Astrophiura cavellae*: ZMB Ech 7079), type locality being Madagascar.

Fig. 52. Distribution of *Astrophiura permira* in South Africa.

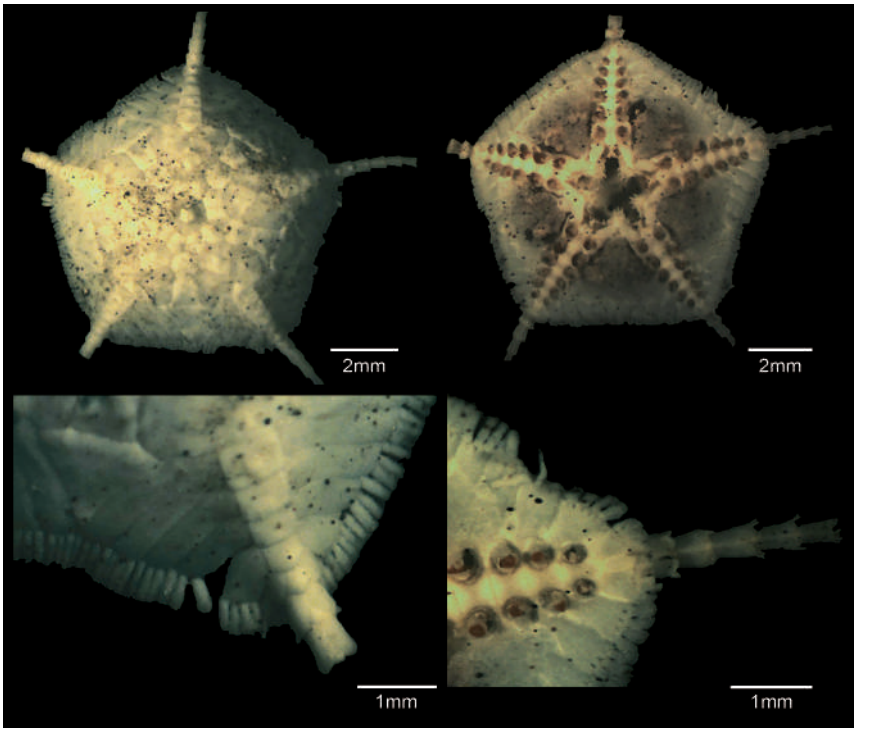


Fig. 53. Dorsal whole (top left), ventral whole (top right), dorsal basal arms (bottom left), ventral arms (bottom right) views of *Astrophiura permira* (SAMC A6460).

Genus ***Ophiomisidium*** Koehler, 1914

Diagnosis – Adapted from Wyville Thomson (1878) and Borges & de Siqueira Campos (2011). Adults small, D.D. up to 5 mm, disc covered dorsally with medium-sized plates in addition to a primary rosette. Number of tentacle pores varies, but usually more than two. Dorsal and ventral proximal arm plates wider than distal plates, first three ventral arm plates well-developed. Ventral interradial areas reduced or absent. Genital slits reduced or absent.

Ophiomisidium pulchellum (Wyville Thomson, 1878)

Ophiomusium pulchellum Wyville Thomson, 1878: 65-67, figs 18, 19; Lyman 1882: 96-98, pl. 3, figs 1-3.

Ophiomisidium pulchellum Koehler 1914a: 37; Clark 1915a: 308; Clark & Courtman-Stock 1976: 190-191, 125, 107, fig. 211; Clark 1923: 356-357; Hertz 1927a: 82; Clark 1974: 476; Paterson 1985: 141, fig. 53; Borges & de Siqueira Campos 2011: 222-224, figs 6-10; Hernández-Herrejón *et al.* 2008: 102-104, fig. 4a, b; Laguarda-Figueras *et al.* 2009: 84, fig. 24.

Diagnosis – Adapted from Lyman (1882) and Clark & Courtman-Stock (1976). D.D. up to 5 mm, D.D./A.L. = *c.*1/1-2, disc round, slightly inflated. Primary rosette distinct, plates large, thick, taking up most of dorsal disc. Radial shields oval, not contiguous distally, separated by two plates or scales, distalmost plate triangular. Two plates in dorsal interradial areas, distal plate on disc margin with small, semi-circular, knob-like tubercle extending beyond disc margin. Ventral interradial area covered in elongated trapezoid plate, from edge of oral shield to disc margin. Oral shields diamond-shaped with rounded distal edge, equally long as wide. Adoral shields larger, contiguous. Oral papillae two, fused each side of triangular apical papillae. Genital slits with very small opening between genital plate and first lateral arm plate. Genital plates may touch each other near oral shield. Arms short, only consisting of *c.*15 segments. First dorsal arm plates twice as wide as long, with proximal side touching a triangular plate which separates radial shields, distal margin of remaining dorsal arm plates rounded, plates decreasing in size distally. First four ventral arm plates bell-shaped, not contiguous, decreasing in size distally, becoming triangular. Lateral arm plates well-developed, joined both dorsally and ventrally. First lateral arm plate with 2-4 enlarged, flattened arm spines, remaining arm segments with three short, blunt spines, rapidly decreasing in size down arm. Five pairs of tentacle pores with a single, large tentacle scale, being lost abruptly after first 2-5 segments.

Distribution and habitat – Canary Islands, Atlantic Ocean (Lyman 1882; Clark & Courtman-Stock 1976; Borges & de Siqueira Campos 2011), South Africa: Cape Town (WC) to Amanzimtoti (KZN); depth range: 70-3065 m. Habitat: sand and stones.

Remarks – The distribution range within South Africa here extended to KZN. The diagnostic features between *Ophiomusa* Hertz, 1926 (Ophiomusaidae) and *Ophiomisidium* Koehler, 1914 (Astrophiuridae) result in these genera often being confused. In *Ophiomisidium*, the tentacle pore associated with the first ventral arm plate is outside the oral slit, while in *Ophiomusium*, it is inside the oral slit and is seldom seen. The basal lateral arm plates are swollen in *Ophiomisidium* and often reach the disc margin. In addition, in *Ophiomusa*, there are only two (or less) pairs of tentacle pores. In the past, *Ophiomisidium pulchellum* (Wyville

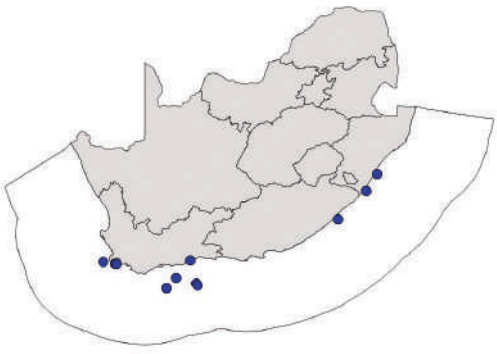


Fig. 54. Distribution of *Ophiomisidium pulchellum* in South Africa.

Thomson, 1878) was included in *Ophiomusium* until Koehler (1914) created the genus *Ophiomisidium*.

Type whereabouts are unknown. Type locality south-west of the Canary Islands, depth 3063 m (Clark & Courtman-Stock 1976).

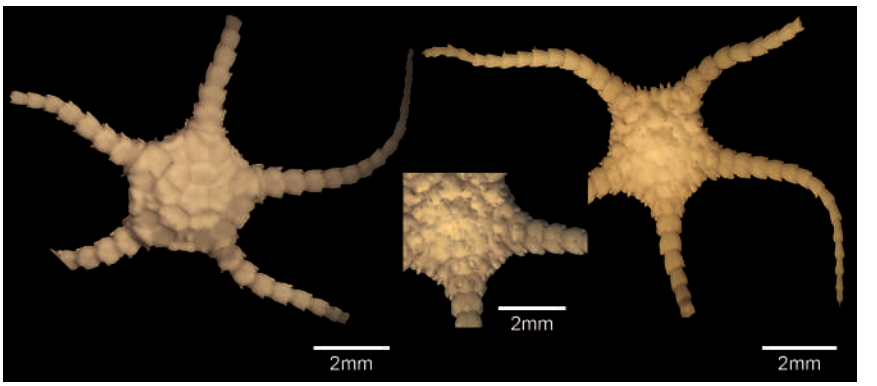


Fig. 55. Dorsal (left) and ventral (right) views of *Ophiomisidium pulchellum* (SAMC A084246). Inset shows ventral interradial areas.

4.2.3. Family OPHIURIDAE Müller & Troschel, 1840

Genus ***Ophiocten*** Lütken, 1855

Diagnosis – Adapted from Lütken (1855) and Lyman (1882). Disc round, with radial indentations, disc covered in plates and distinct primary rosette. Radial shields may or may not be separated by overlapping plates, ventral interradial areas covered in overlapping plates. Papillae on genital slits may form arm combs over base of arm. Distalmost oral papillae wider than 2-3 proximal lateral papillae, teeth present. Lateral arm plates meeting ventrally, but not dorsally. Tentacle scales present, usually each oral tentacle pore with more than one papilla.

Ophiocten affinis simulans (Mortensen, 1936)

Ophiocten amitinum var. *simulans* Mortensen, 1936: 337, fig. 48b; Day *et al.* 1970: 81.
Ophiocten amitinum var. *microplax* Mortensen, 1933a: 391-393, fig. 88b.
Ophiura (*Ophiura*) *affinis simulans*: Clark & Courtman-Stock 1976: 192-193, 125, 107.
Ophiura affinis simulans: Guille 1982: 79, fig. 7e, f.

Diagnosis – Adapted from Mortensen (1936) and Clark & Courtman-Stock (1976). D.D. up to 2 mm. Disc flattened, large symmetrical circular plates, including rosette, all encircled by smaller plates. Radial shields approximating

distally, separated by plates. Edge of disc slightly indented radially, arm combs distinct, some additional papillae also present in indentation. Oral shields longer than wide, sometimes twice as long as wide, distal lobe only slightly tapering to broadly rounded tip, surface textured with folds. Adoral shields contiguous and narrow. Oral papillae three each side of apical papillae, distalmost broad. Oral tentacle pore slightly set back, with one scale either side of pore. Dorsal arm plates carinate, trapezoidal, proximal plates broadly contiguous. Ventral arm plates semi-circular, small, not contiguous, separated by lateral arm plates. Arm spines three, slender and pointed, uppermost two spines only slightly exceeding segment length, if at all, not thicker than adjacent spine. Tentacle scales two on first two pairs of tentacle pores, then one, broad and rounded, not longer than wide, tentacle pores and scales distinct for most of arm.

Distribution and habitat – South Africa: Lambert's Bay (WC) to Port Elizabeth (EC); depth range: 55-273 m. Habitat: coarse to fine sand, shell and rock.

Remarks – Endemic to South Africa. Clark & Courtman-Stock (1976) suggested that the differences between South African *Ophiura* and *Ophiocten* species are very slight, while the difference between *affinis* and *simulans* were that *affinis* had slightly smaller arm spines on the proximal arm segments and with the upper arm comb papillae were less tapered than in *simulans*. Clark & Courtman-Stock (1976) placed *affinis simulans* in *Ophiura* but O'Hara *et al.* (2017) found that affinis was closer to *Ophiocten*.

The relationship between *Ophiura* and *Ophiocten* has been debated by various authors (Mortensen 1927; Mortensen 1936, Clark & Courtman-Stock 1976; Paterson *et al.* 1982 and Martynov 2010). In 1936, Mortensen erected *Ophiocten amitinum* var. *simulans* for the South African variety of *Ophiura affinis*. Later, *Ophiura affinis* Lütken, 1855 was placed into the genus *Ophiocten* Lütken, 1855 by Sumida *et al.* (1998). A distribution record for South Africa of *Ophiura affinis* exists in the Natural History Museum of Denmark, but it is unlikely this was identified correctly and it is most probably *Ophiocten affinis simulans* (Mortensen, 1936). Until examination of this specimen takes place, this distribution record is not

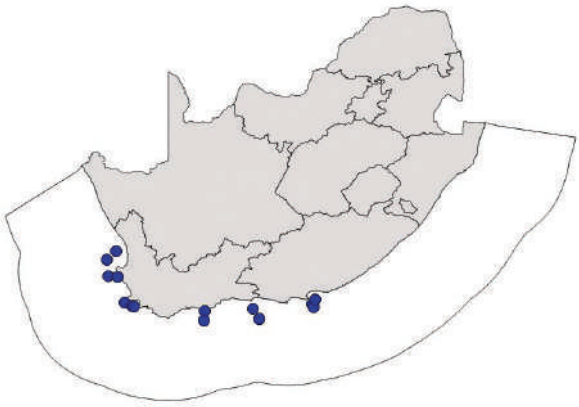


Fig. 56. Distribution of *Ophiocten affinis simulans* in South Africa.

recognised in this account. Further investigation of the validity of the South African *O. amitinum* and *O. affinis simulans* specimens is recommended.

The type material is in the Museum of Comparative Zoology (paratype: MCZ OPH-5912), type locality Port Elizabeth, South Africa. Syntypes of *Ophiocten amitinum* var. *microplax* are in the Natural History Museum of Denmark (ZMUC OPH-200) with the type locality as Roman Rock, False Bay, depth 35 m. The two specimens accessioned in the Iziko South African Museum were registered as 'cotypes' (examined).

Fig. 57. Dorsal (left) and ventral (right) views of *Ophiocten affinis simulans* (SAMC A088402).

Ophiocten amitinum Lyman, 1878

Ophiocten amitinum Lyman, 1878: 100-101, pl. 5, figs 129-130. Lyman 1882: 79-80, pl. 9, figs 7-9; Studer 1882: 16, pl. 2, fig. 8a-f; Murray 1896: 359, 369, 416, 436; Ludwig 1899, 4; Koehler 1907: 288; Clark 1915a: 328; Clark 1923: 363-364, Mortensen 1933a: 390-391, fig. 88a; Madsen 1967: 138; Clark & Courtman-Stock 1976: 192; Dahm 1999: 429; Gutt *et al.* 1999: 160; De Castro Manso 2010: 192-193, fig. 8a.
Ophiura amitina: Guille 1982: 78-79, figs 6a-c, 7c, d.

Diagnosis – Adapted from Lyman (1878) and Clark & Courtman-Stock (1976). D.D. up to 10 mm. Disc round, flattened, primary rosette plates encircled by smaller overlapping plates. Radial shields approximating on distal side, narrowly separated by plates. Edge of disc indented, arm combs distinct, with some additional papillae also present in indentation. Ventral interradial areas with overlapping plates. Oral shields longer than wide, distal lobe tapering to rounded tip (trefoil-shaped). Adoral shields contiguous and narrow. Oral papillae 3-4 each side of apical papillae, elliptical leaf-shaped, distalmost broadest. Teeth 3-4, similar in shape to apical papillae. First oral tentacle pore large, with 2-4 tentacles scales. Genital slits elongated, papillae present. Dorsal arm plates wider than long proximally and

equally wide as long distally, broadly contiguous. Ventral arm plates semi-circular, not contiguous, separated by large lateral arm plates. Arm spines three, slender and pointed, uppermost spine only slightly exceeding segment length, if at all, not thicker than adjacent spine. Tentacle scales one, broad and rounded with a slight tip.

Distribution and habitat – Patagonia, Southern Ocean (Lyman 1878; Murray 1896; Clark 1915a), South Africa: Lambert's Bay (WC) to East London (EC); depth range: 110-3566 m. Habitat: sand, mud, stones or gravel.

Remarks – The specimens collected at stations FAL185P and TRA74L (University of Cape Town Ecological Survey) were originally identified as *O. affinis simulans* (unknown determinant) but were changed to *O. amitinum* in 1973 by A.M. Clark. Clark & Courtman-Stock (1976) recorded only slight differences between *O. amitinum* and *O. affinis simulans,* such as the radial shields, arm comb papillae, cross section of the arms, uppermost arm spine and tentacle scales. The major differences in all the above characters were not consistent in all the *O. amitinum* specimens examined in the Iziko South African Museum collection. The easiest character to differentiate between species is the tentacle scale arrangement. Clark & Courtman-Stock (1976) recorded that the tentacle scales in *O. amitinum* were longer than wide and tapered to a point, while those in *O. affinis simulans* were evenly rounded. This was observed in all the *O. amitinum* specimens examined. The number of tentacle scales on the first tentacle pore was also inconsistent.

The type material is in the Museum of Comparative Zoology (syntype: MCZ OPH-761), type locality Kerguelen Islands, depth unknown.

Fig. 58. Distribution of *Ophiocten amitinum* in South Africa.

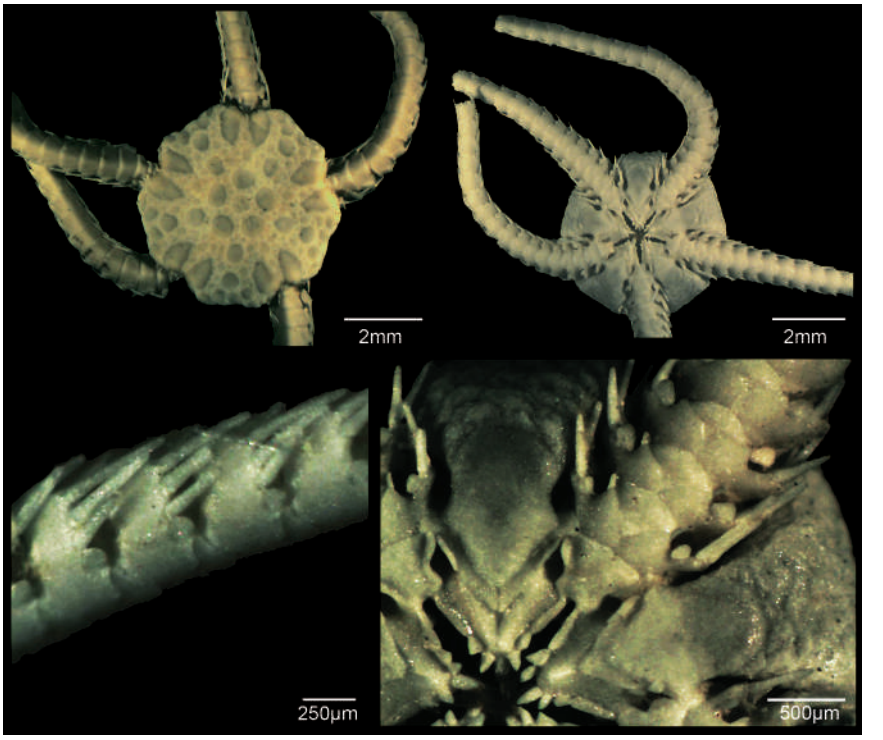


Fig. 59. Dorsal disc (top left), ventral disc (top right), arm spines (bottom left), basal arms (bottom centre), ventral interradial areas (bottom right) views of *Ophiocten amitinum* (SAMC A084234).

Ophiocten hastatum Lyman, 1878

Ophiocten hastatum Lyman, 1878: 103, pl. 5, figs 133-134; Lyman 1882: 82-83, pl. 9, figs 10-11.
Ophiocten longispinum Koehler, 1896a: 204-205b; Koehler 1896b: 243.
Ophiocten pacificum Lütken & Mortensen, 1899: 131-132, pl. 3, figs 5-7; Clark 1923: 364.
Ophiocten latens Koehler, 1906: 13, pl. 1, figs 9, 10; Mortensen 1927: 246; Mortensen 1933a: 392-393; Clark & Courtman-Stock 1976: 189, 107, 125, figs 215, 219.
Ophiocten australis Baker, 1979: 26-28, fig. 3a-c.
Ophiura hastata: Guille 1982: 80, figs 6d, e, 7a, b.

Diagnosis – Adapted from Lyman (1878) and Clark & Courtman-Stock (1976). D.D. up to 14 mm. Disc round, flat dorsally and rounded ventrally. Disc plates medium in size, primary rosette present, not distinct in all specimens, interspersed with smaller overlapping plates. Radial shields triangular in shape with rounded angles, length less than half disc radius, not contiguous, separated by fine overlapping

scales. Arm combs or papillae may be present, but easily lost. Ventral interradial areas covered in fine overlapping scales. Oral shields large, as long as wide but usually much wider, five-sided, distal edge rounded, proximal edge pointed. Adoral shields narrow and contiguous. Oral papillae 3-5 either side of pointed apical papillae, square. Teeth four, similar in shape to apical papillae. Genital slits long, reaching to almost dorsal side. Arms carinate dorsally, dorsal arm plates flat pentagonal, wider than long, distally equally long as wide, broadly contiguous. Ventral arm plates semi-circular, not contiguous, separated by large lateral arm plates. Arm spines three, uppermost much longer than segment and adjacent spines, sometimes thicker than other spines, remaining spines thin, pointed and about one segment length. Oral tentacle pore adjacent to adoral shield with 4-5 rounded scales, remaining pores with single tiny tentacle scale.

Distribution and habitat – Atlantic Ocean, Bay of Biscay, Spain, southern Australia, New Zealand, Kerguelen Islands, Pacific Ocean (Mortensen 1927; Clark & Courtman-Stock 1976), South Africa: Saldanha Bay (WC) to Gansbaai (WC); depth range: 910-4060 m. Habitat: *Globigerina* ooze (Lyman 1882); green and grey mud.

Remarks – Specimens examined were missing their arm combs, but Clark & Courtman-Stock (1976) (as *O. latens*) noted that these were easily lost.

The type material is in the Museum of Comparative Zoology (syntypes: MCZ OPH-1019, MCZ OPH-765, MCZ OPH-767), type locality is west of Marion Island, depth 2514 m.

Fig. 60. Distribution of *Ophiocten hastatum* in South Africa.

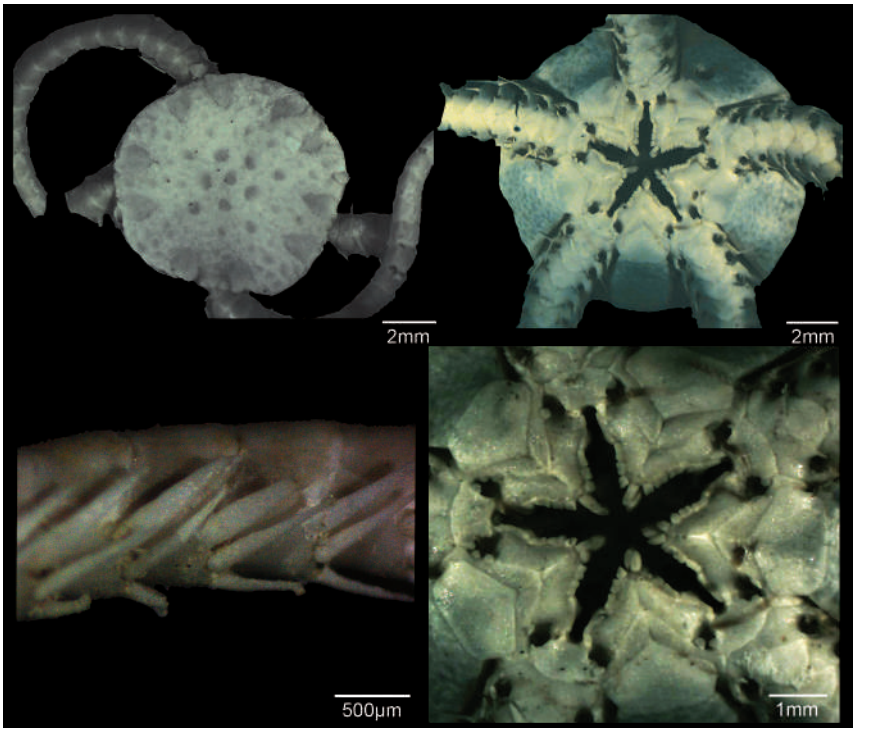


Fig. 61. Dorsal disc (top left), ventral disc (top right), arm spines (bottom left), jaws (bottom right) views of *Ophiocten hastatum* (SAMC A7475).

Genus ***Ophiura*** Lamarck, 1801

Diagnosis – Adapted from Matsumoto (1917) and Clark & Courtman-Stock (1976). Disc flat, covered with scales, usually small, sometimes armed with scattered spines, primary rosette usually distinct. Radial shields mostly not contiguous. Genital papillae well-developed, arm combs usually present. Second oral tentacle pore usually outside the oral slits, sometimes opening into oral slit on adradial side with numerous scales and may form a continuous series with oral papillae. Arms flat or cylindrical, tapering, not stout. Dorsal arm plates usually well-developed, usually broadly contiguous. Ventral arm plates small, usually separated from one another by large lateral arm plates bearing 3-7 arm spines, tapering but blunt or needle-like, appressed or flaring. Proximal tentacle pores large, with numerous scales. Tentacle scales one, two or many, becoming very small distally.

Ophiura kinbergi Ljungman, 1867

Ophiura kinbergi Ljungman, 1866: 166; Lyman 1882: 38-39, pl. 4, fig. 7; Koehler 1905a: 22-24; Koehler 1907: 294; Clark 1911, 37, fig. 9; Matsumoto 1917: 271-272, fig. 73; Rowe & Gates 1995: 437-438; Clark & Rowe 1971: 128, fig. 46b,

pl. 22, figs 5, 6. Ludwig 1901: 925; Price 1981: 7; Vine 1986: 195; Imaoka *et al.* 1991: 96, fig. 54; Liao & Clark 1995: 303-304, fig. 173.

Ophioglypha kinbergi Ljungman 1867: 166.

Ophioglypha sinensis Lyman, 1871: 12-14, pl. 1, figs 1, 2; Lyman 1878, 99; Döderlein 1896, 283-284, pl. 15, figs 3, 3a; Koehler 1898b: 60, pl. 2, fig. 6, pl. 4, fig. 39.

Ophioglypha ferruginea Lyman, 1878: 68, pl. 3, fig. 76.

Ophiura (*Ophiura*) *kinbergi*: Clark & Courtman-Stock 1976: 194, 127, 107, fig. 222.

Diagnosis – Adapted from Clark & Courtman-Stock (1976). D.D. up to 9.5 mm. Disc round, disc plates thick, primary rosette distinct and surrounded by slightly smaller plates. Radial shields oval, tapering slightly on distal side, longer than wide, *c.* one-third to half disc radius, approximating distally but not contiguous, separated by scales. Arm combs present, distinct with long, sharp, tapering papillae. Ventral interradial area covered in overlapping plates. Oral shields large, pentagonal, constricted in vicinity of genital slits. Adoral shields narrow, contiguous. Oral papillae three, either side of apical papillae, pointed. Teeth five, same shape as apical papillae. Genital slits long, single and armed with small, conical, blunt genital papillae. Dorsal arm plates trapezoid, wider than long proximally, becoming longer than wide, contiguous. Ventral arm plates small, oval, wider than long, pointed on proximal side, separated by large lateral arm plates which meet ventrally and form cavity or hollow on first 3-5 segments. Arm spines three, one segment length, tapering. Oral tentacle pores with *c.* three rounded tentacle scales. Tentacle scales 2-3 on first few segments, then single rounded large scale for length of arm. Colour in life uniformly grey (Rowe & Gates 1995).

Distribution and habitat – Red Sea, Gulf of Thailand, Andaman Sea, Japan, Australia, Indo-Pacific southwards towards and including Bass Strait, south east Arabia, Persian Gulf, West India, Pakistan, Ceylon, Bay of Bengal, East Indies, Philippines, China, South Pacific Islands and Hawaii (Lyman 1878; Matsumoto 1917; Clark & Rowe 1971; Tortonese 1977; Rowe & Gates 1995; Putchakarn & Sonchaeng 2004), South Africa: Amatikulu (KZN) to Sodwana Bay (KZN); depth range: 0-500 m. Habitat: sand and sea grass beds.

Remarks – Distribution of this species here extended from Amatikulu to Sodwana Bay. Several species have been synonymised under *Ophiura kinbergi*, however, genetic data indicates the presence of several species. Tropical Australian specimens differ genetically from those from Southern Australia (Sydney is the type locality of *O. kinbergi*) and could be called *O. indica* (Brock, 1888) (type locality Indonesia) or *Ophiura sinsensis* (type locality Hong Kong) depending on how these clades are found to be distributed. The relationships of the specimens from the south-western Indian Ocean are unknown, and in the interim we retain the name *O. kinbergi*. The type specimens of *O. kinbergi* are SMNH type-1416, *O. sinensis* are holotype: MCZ OPH-623, paratypes: MCZ OPH-4114, MCZ OPH-975, and the types of *Ophiura indica* are presumably in the Zoological Museum Göttingen.

Fig. 62. Distribution of *Ophiura kinbergi* in South Africa.

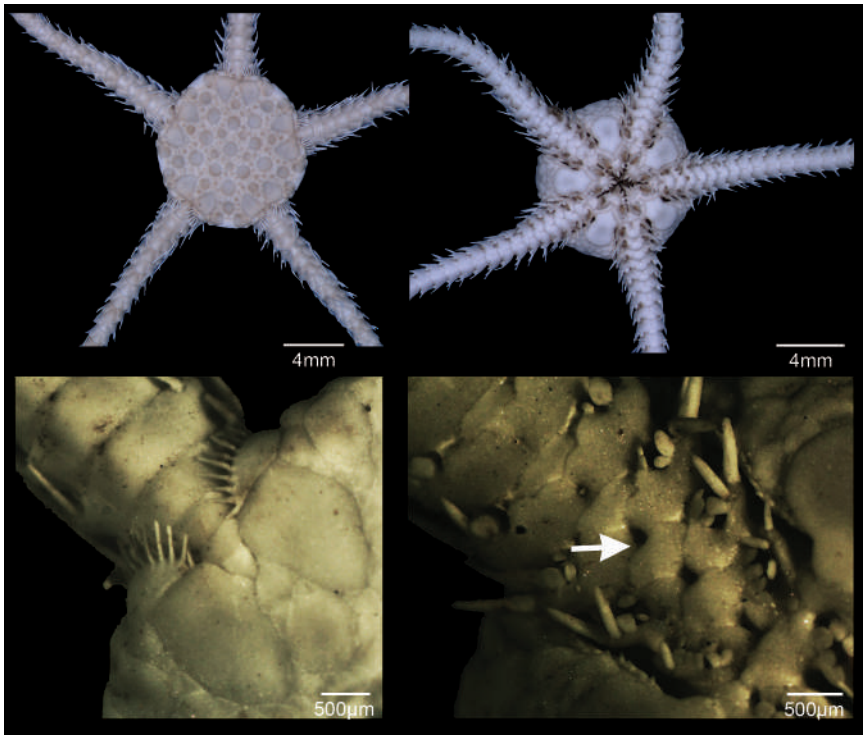


Fig. 63. Dorsal whole (top left), ventral whole (top right), arm combs (bottom left), cavity on ventral arms (bottom right) views of *Ophiura kinbergi* (RMCA MT1566). Arrow indicating cavity between lateral arm plates.