

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

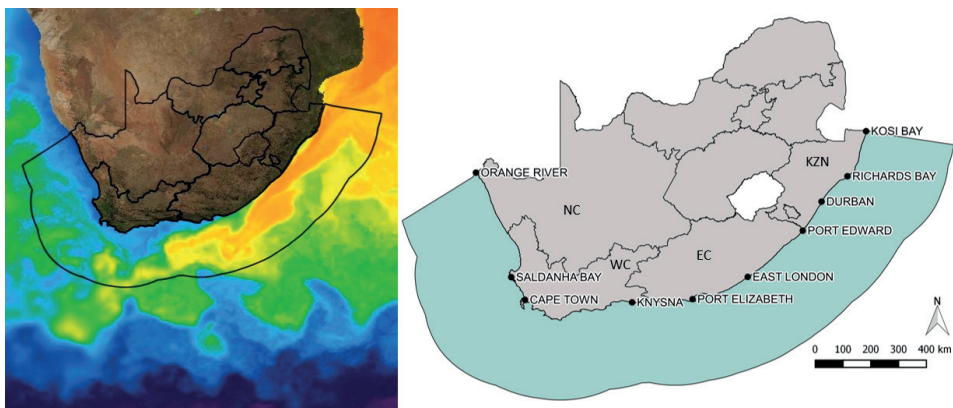


Fig. 1. Exclusive Economic Zone (EEZ) of mainland South Africa showing provincial boundaries overlaid on a MODIS satellite sea surface temperature image (June 2002–June 2019; daily average) illustrating the warm Agulhas current flowing down the east coast and the colder Benguela Current on the west coast 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, ἔχινος, *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
Astroidea	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*.

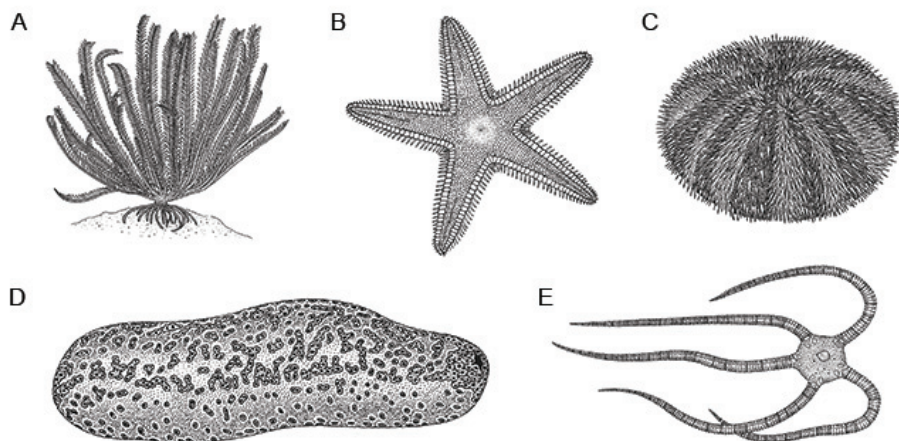


Fig. 2. Representatives of the five echinoderm classes. **A.** Crinoidea. **B.** Asteroidea. **C.** Echinoidea. **D.** Holothuroidea. **E.** Ophiuroidea. Adapted from Rowe & Gates (1995).

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 m², 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.

