
Deep-sea life
of Tanzania
Andrew Gates

Deep-sea Life of Tanzania

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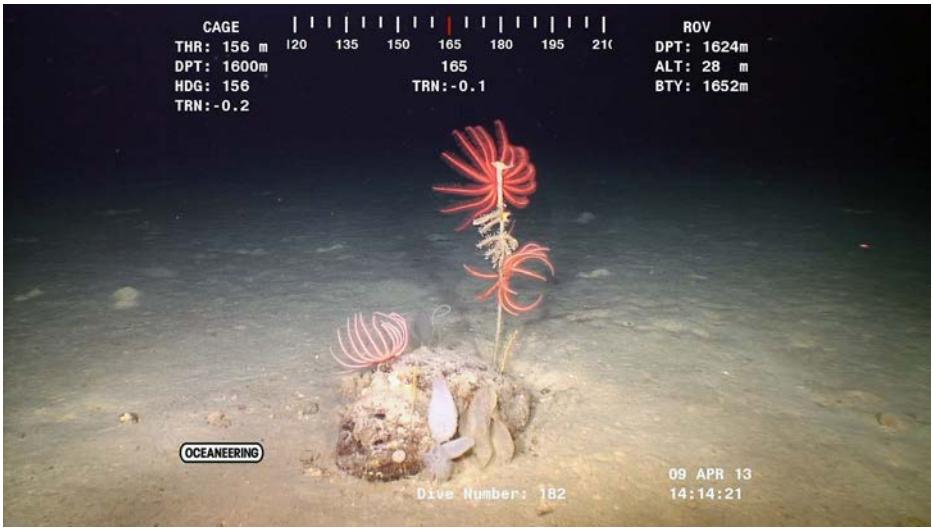
SERPENT
SCIENTIFIC AND ENVIRONMENTAL ROV PARTNERSHIP USING EXISTING INDUSTRIAL TECHNOLOGY

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

Deep-sea Life of Tanzania



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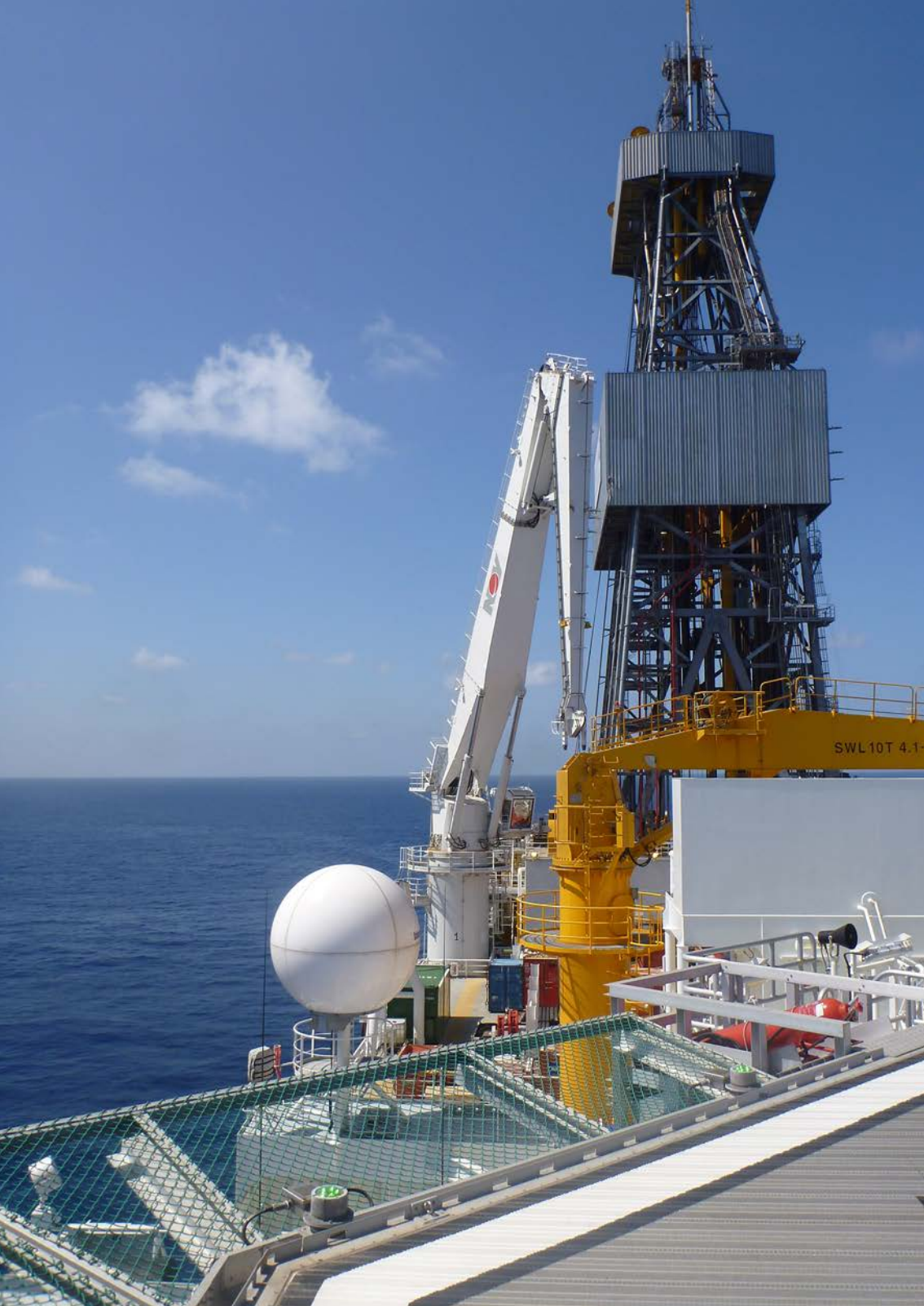
2016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Foreword

BG has been operating a drilling campaign in Tanzania since 2011. To date we have drilled 16 exploration and appraisal wells, which have all been successful, resulting in the discovery of *circa* 16 trillion cubic feet of recoverable gas. An exploration track record which makes offshore Tanzania one of the most prolific hydrocarbon basins in the BG portfolio.

Exploration activities in a previously unexplored region like offshore Tanzania create a series of unforeseen challenges. For example historical data are not available to provide guidelines for safe and successful operations. This latter challenge is also applicable to the environment in which we operated. BG's operations are guided by our business principles and we are committed to:

- Making a positive contribution to the protection of the environment
- Going beyond compliance with respect to local environmental regulations to meet internationally accepted best practice
- Reducing to the minimum practicable any adverse effects of our operations on the environment

In light of these principles we contacted SERPENT to assist us with obtaining a better understanding of the environmental impacts associated with our drilling operations. SERPENT worked closely with our environmental team and other consultants on several wells and as a result we have developed an accurate database on the fauna to depths of 2000 m below the ocean's surface.

As a result we now know a lot more about life in one of the least known environments on our planet. In order to make a contribution to a better understanding of the deep-sea environment and to share this knowledge with the general public we asked SERPENT to produce this guide. We hope that you will enjoy looking at all the unique creatures that inhabit the ocean's depths and that this guide will be a testimony to BG's commitment to the environment.

Derek Hudson,

President & Asset General Manager, BG East Africa

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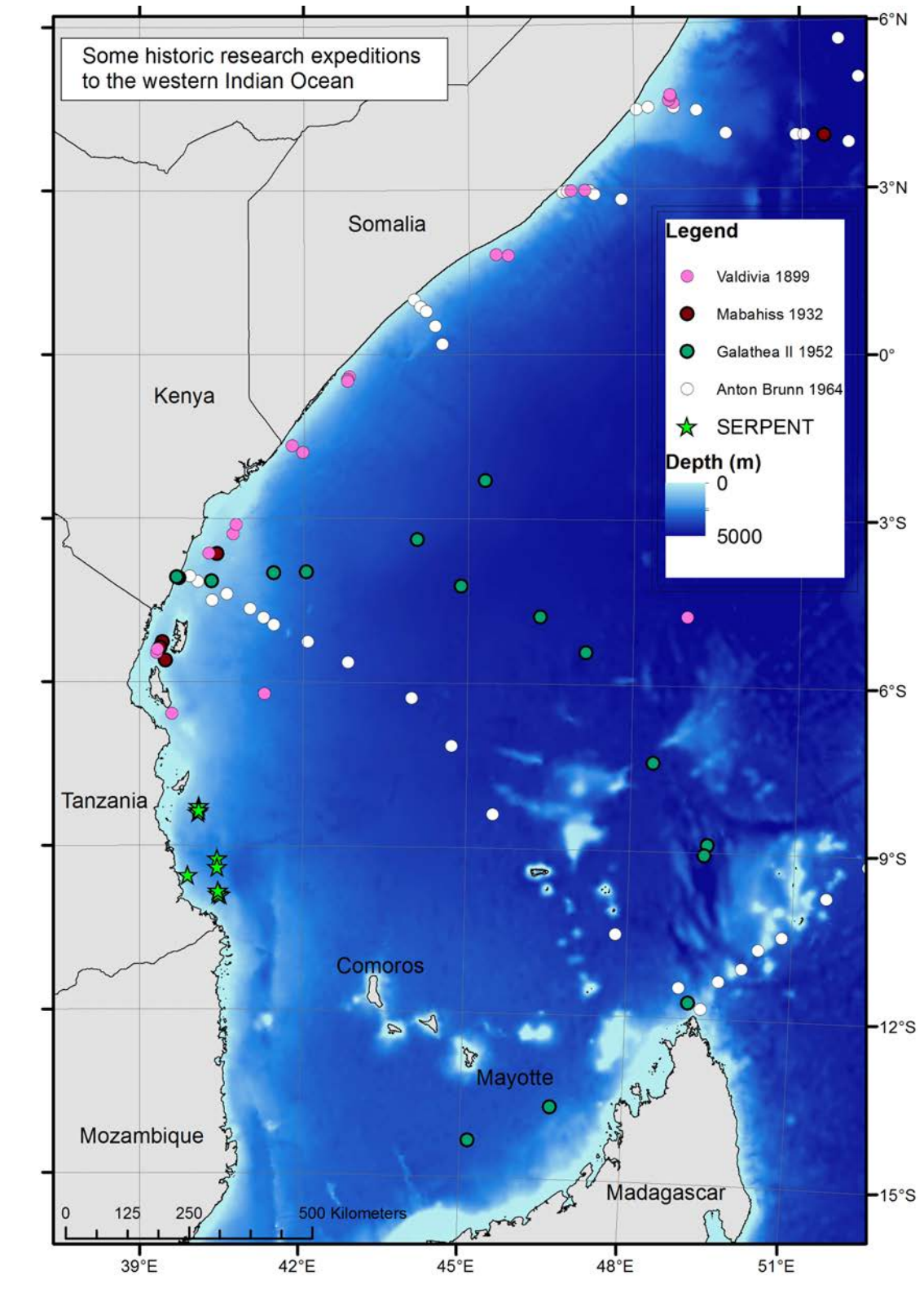
Full page images

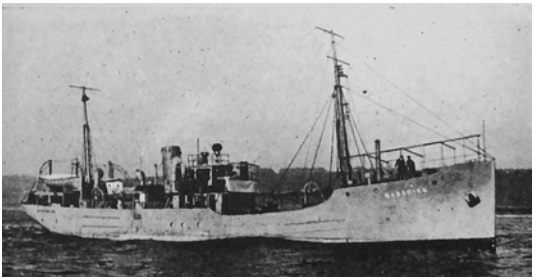

Some historic research expeditions
to the western Indian Ocean
Somalia
Kenya
Tanzania
Comoros
Mayotte
Mozambique
Madagascar
Legend
Valdivia 1899
Mabahiss 1932
Galathea II 1952
Anton Brunn 1964
SERPENT
Depth (m)
0
5000
0 125 250 500 Kilometers
6°N
3°N
0°
3°S
6°S
9°S
12°S
15°S
39°E
42°E
45°E
48°E
51°E

Introduction

The biology of the deep western Indian Ocean has received little attention from deep-sea ecologists. As a result, even the larger animals living at the seabed in the area are poorly understood and many are unknown to science. The existing knowledge of the deep-sea biology of the western Indian Ocean owes much to some early research voyages. In her 1898-1899 global voyage the German ship *Valdivia* sampled between Dar es Salaam in Tanzania and the Seychelles. The John Murray *Mabahiss* expedition to the Indian Ocean (1932-1934) sampled the seabed on legs from Mombasa in Kenya to Zanzibar and then onwards to Sri Lanka. The *Galathea II* expedition (1950-1952) contributed samples collected between Sri Lanka and the Kenyan coast and from Mozambique to South Africa. Many of the deep-sea species known from the area were described from the *Galathea II* samples. A number of cruises aboard the *Vityaz* (1959-1964) provide further information and cruises 7, 8 and 9 of the 1964 International Indian Ocean Expedition (IIOE) aboard the RV *Anton Bruun*, although largely oceanographic, also collected fauna from the seabed along the African and Madagascan coast, from Mombasa, Kenya to Durban in South Africa. The western Indian Ocean sampling stations of these voyages are shown on the map opposite. The data and samples gathered by these cruises remain extremely valuable but advances in equipment and modern methods mean there is much more to learn about deep western Indian Ocean.

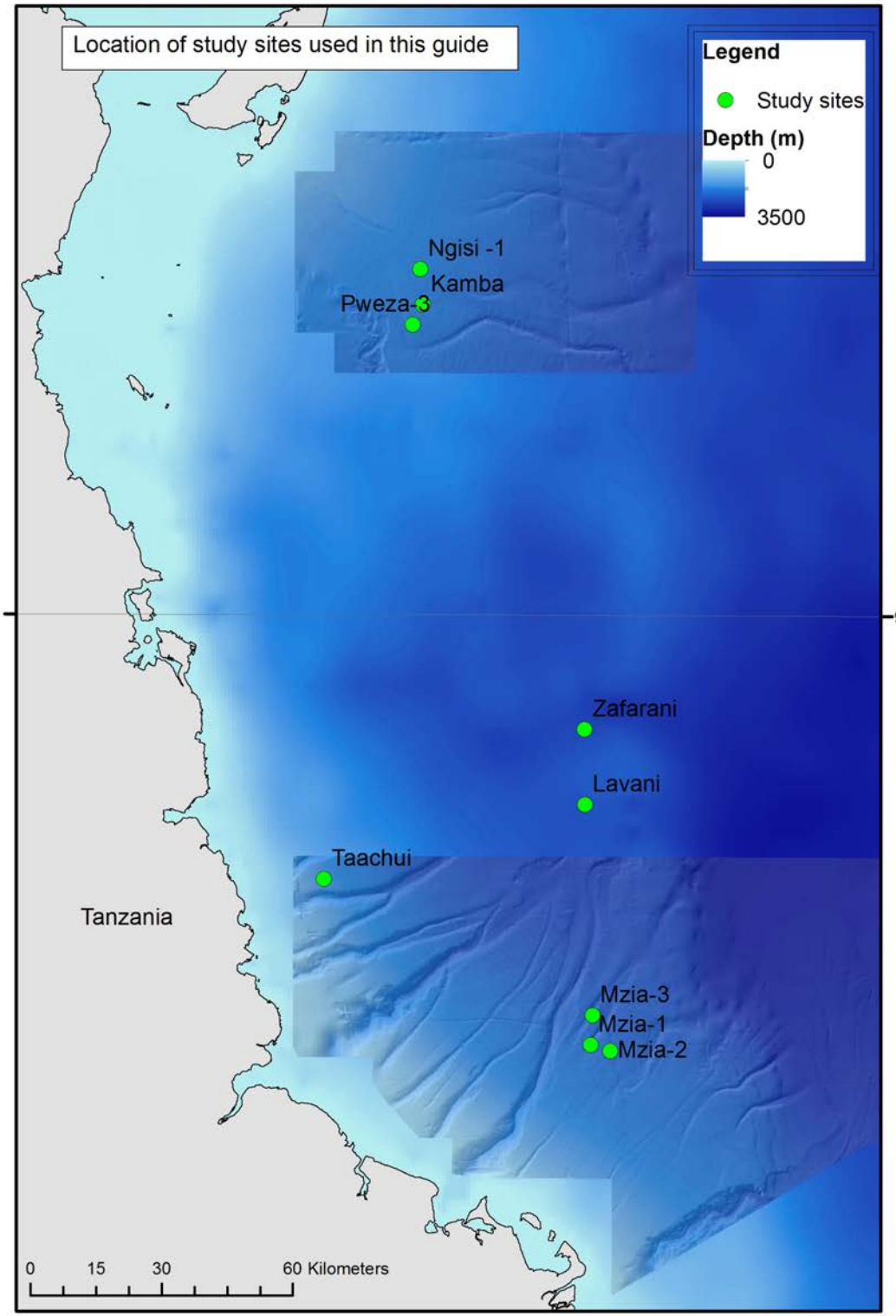
The advent of hydrocarbon exploration in deep water off Kenya, Tanzania and Mozambique highlights the need to increase the information available about the area. It also provides an opportunity to collect valuable samples and data. This guide presents the findings from a three year collaborative project in which marine biologists have worked with hydrocarbon exploration companies operating off Tanzania to collect a large quantity of video observations and other data from the deep sea in an effort to begin to address the paucity of knowledge about the area.

Through the SERPENT Project (**S**cientific and **E**nvironmental **R**OV **P**artnership using **E**xisting i**N**dustrial **T**echnology) scientists from the National Oceanography Centre in the United Kingdom worked with remotely operated vehicles (ROVs) during standby time to explore sites at a range of depths in active hydrocarbon exploration fields. The guide presents examples of the marine fauna encountered in deep water of the western Indian Ocean on the continental slope off Tanzania. A small number of additional examples are taken from northern Mozambique.



The *Mabahiss* during the 1932-1934 John Murray expedition to the Indian Ocean

This is by no means a definitive


Location of study sites used in this guide
Legend
Study sites
Depth (m)
0
3500
Ngisi -1
Kamba
Pweza-3
Zafarani
Lavani
Taachui
Tanzania
Mzia-3
Mzia-1
Mzia-2
0
15
30
60 Kilometers

Above: The *Deepsea Metro 1* ultra deepwater drillship during the drilling campaign in the Indian Ocean

guide, different and fascinating species have been encountered on every field visit and as exploration of the region continues new habitats will be found which will support different species.

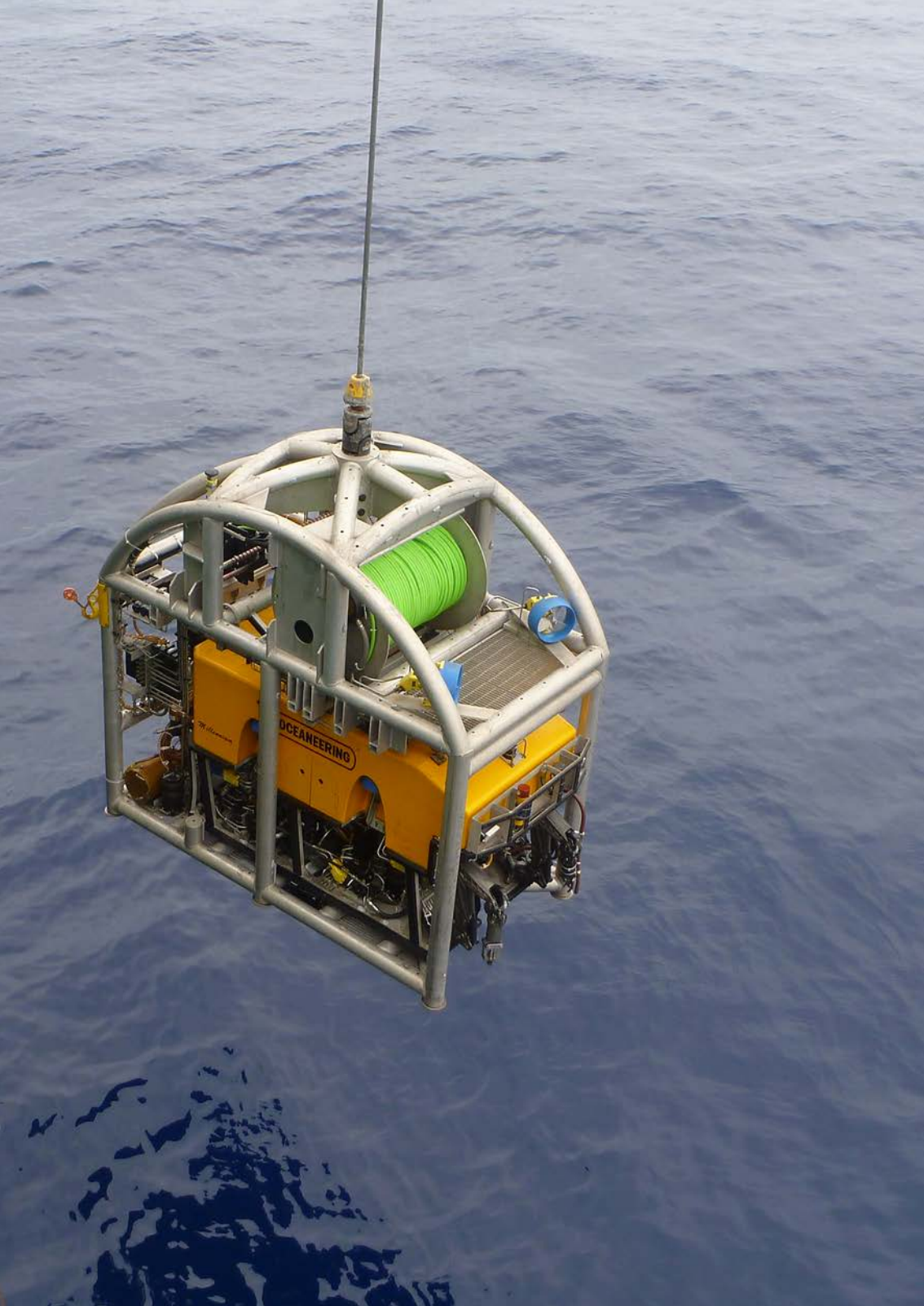
Collaboration with industry

BG Tanzania carried out the first deep-sea exploration campaign in East African waters. Over a period of about 5 years BG Tanzania drilled 16 wells in blocks 1, 3 and 4 offshore Tanzania. These blocks cover an area of some 20,000 square kilometres and wells were drilled at water depths ranging from 1000 m to over 1700 m.

The BG Tanzania environmental manager was aware of the limited knowledge of the ecology of the deep-water environment so initiated collaboration with the SERPENT Project to assist with addressing this knowledge gap. With the support of the exploration and well engineering teams a collaborative approach was developed.

The author meets with BG Tanzania environmental advisor Josia Moirana to discuss upcoming fieldwork on the *Deepsea Metro 1*

BG Group facilitated visits to the drillship


OCEANEERING

Deepsea Metro I, a modern ultra deep-water drillship capable of operating in 3000 m water depth. SERPENT was present at seven different well locations. On the drillship the well engineering team supported SERPENT's collection of ROV video footage of marine life and seabed samples throughout the drilling campaign.

Above: The *Ocean Rig Poseidon* drillship

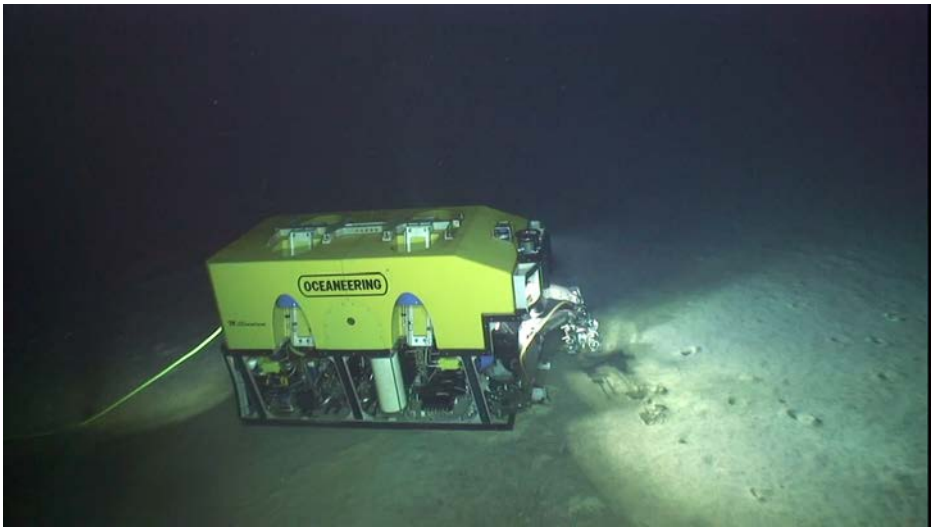
The project aimed to describe the changes that occur at the seabed following drilling activity and to describe the habitats and deep-sea fauna in the exploration area. Additional data was collected at two wells through a similar collaboration with Norwegian oil company Statoil. In this case the work was carried out aboard the *Ocean Rig Poseidon*, another modern drillship with equally impressive facilities.

This work has succeeded in improving the understanding of this unexplored ecosystem. Collaborative projects such as this between SERPENT and BG Tanzania offer scientists increased access to technology and the opportunity to gather information directly from the deep sea. Alongside this research, presentations to offshore workers, articles and a publicly available database of the observations, this guide aims to illustrate the remarkable and fascinating biodiversity of the deep sea.

Remotely Operated Vehicles

The *Deepsea Metro 1* and *Ocean Rig Poseidon* are equipped with two high specification Oceaneering Millennium work-class ROVs (opposite). These vehicles are required to carry out work on the subsea infrastructure and at the seabed. The ROVs are about the size of a family car. They are operated by skilled technicians viewing high-definition (HD) video feeds on monitors, from a control room on board the vessel at the surface

During drilling operations the ROVs dive regularly to inspect the infrastructure at the seabed. They monitor the drilling activity and perform tasks to maintain the equipment. ROVs are highly versatile tools. As well as being essential to industry they are important in scientific exploration and experimentation in unknown, hostile habitats to which humans are unable to travel safely. They are equipped with tools needed to investigate marine biodiversity on the seafloor. The cameras and lights enable scientists to see the environment, the navigation systems ensure the location of any observations and samples is known. The manipulator arms are dexterous and can be used to deploy and operate experimental equipment or collect samples and delicate specimens. The regular inspections of equipment at the seabed carried out by the ROVs during offshore drilling operations enables plenty of opportunities to collect biological data.



Oceaneering Millennium ROV collecting sediment samples at the seabed at over 1700 m depth off Tanzania

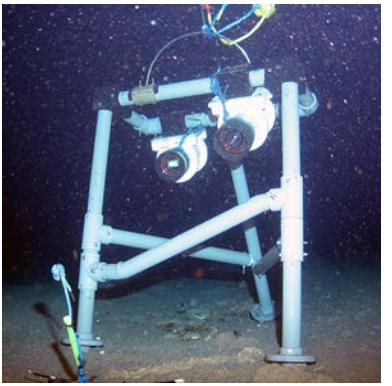
Survey methods

The nature of work carried out through the SERPENT Project, taking place on a working drillship, means it is opportunistic. A selection of techniques is required to maximize the scientific data that can be collected when the opportunities arise. The techniques vary depending on the availability of ROVs, the facilities on the rig or drillship and the weather conditions at the time of the visits. Fortunately the weather off Tanzania was generally very good. Only a few days lost to poor conditions across all the offshore visits.

A technique used on all SERPENT offshore visits is to document the appearance of the seabed and the abundance of the megafauna (larger animals that can be seen in video) using video transects. To do this the operator moves the ROV slowly in a straight line at consistent height above the bottom with the camera viewing the seabed. The video feed is recorded to disc. Observations are noted at the time but the real analysis is completed when the video footage is reviewed on return to the laboratory. This consistent methodology means that each section of video transect is considered a sample. Multiple samples are collected at each site visited. These can then be compared with others taken at a different time or location.

The video transects are of most value if there is sufficient detail about the species encountered. Therefore, in separate surveys the ROV operators are asked to stop at every species or feature of interest and a selection of stills and video footage is taken from all possible angles. It is these images that make up the majority of this guide.

SERPENT scientists provide some additional specialist equipment to improve the data collection. Push core samplers can be held in the ROV manipulator arms to collect material from the seabed. This is returned to the surface and used to describe the seabed environment or identify species. The ROV in the image opposite is collecting seabed samples using this equipment at over 1700 m depth. Additional data about the physical environment can be collected by fitting sensors to the vehicles to record the depth, temperature, salinity and oxygen concentration of the water.



Baited time-lapse camera experiment on the seabed

Off Tanzania a major part of the work involved the use of a standalone time-lapse camera (right). It was deployed during all the visits to the *Deepsea Metro I* to investigate what happens away from the disturbance of a large, brightly lit vehicle moving around on the seabed. This approach proved valuable to observe seabed features or the behaviour of a sessile organisms over time. The most guaranteed results come when time-lapse equipment is deployed with bait placed in front. This captures images of scavenging megafauna and fishes that may otherwise be missed from photographic surveys. The feeding frenzy that ensues can be quite spectacular, as the images on page 38 demonstrates.

Identification and taxonomy

The organisms shown in the guide were seen in the western Indian Ocean in deep water off Tanzania, with a limited number of additional observations from Mozambique. Identifications were made from the photographs and video footage by comparison with literature and consultation with taxonomic experts for the appropriate groups. The taxonomy is based on the World Register of Marine Species. Where data were available other records of organisms encountered in the western Indian Ocean are reported using the Ocean Biogeographic Information System (www.iobis.org) among other resources. The species are grouped by Phylum and Class but the availability of good quality photographs surpasses other taxonomic classification in the presentation and order of images.

Aim of this guide

The aim of this guide is to highlight the most common and conspicuous species in seabed photography off Tanzania in order to raise awareness of the seabed habitat in an area in which drilling activity is taking place. The guide is a first attempt to document deep-sea megafauna of the area and should serve as a reminder of the importance of good environmental practice during offshore drilling.

The physical environment

The continental shelf off the east African coast from Somalia to South Africa and Madagascar is incised by deep canyons and gullies. Some of these features can be seen in the Tanzanian study area, in the higher resolution bathymetry, in the map on page 10. Such data, gathered as part of hydrocarbon industry operations, are of great importance to understand the deep-sea ecosystems of the western Indian Ocean. Submarine canyons have received significant research attention globally and are considered important hotspots for biodiversity because of the habitat heterogeneity associated with them. Their role as conduits of nutrients and other material to deeper water is also important. South of the Tanzania study area the canyons of the KwaZulu-Natal shelf edge off South Africa are the subject of increasing geological study owing to their importance as habitat for coelacanths.

The observations presented in this guide covered a depth range of nearly 2000 m from 660 m (Mozambique) to 2580 m off Tanzania. Water temperature decreased with depth from around 28^{0}C at the surface to 2.5^{0}C at the seabed at the deepest site. None of the observations were made in submarine canyons but there was variation in the seabed slope across the sites. The seabed was almost flat at Kamba-1 whereas at Mzia-3, closest to a canyon, there was a 7° slope over the area studied. At most sites the seabed sediment was soft deep-sea mud with burrows, tracks, deposits and other traces of animals living in or on the sediment (below).

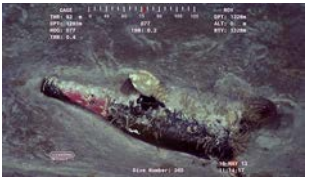
Above: Rocks on the seabed at 1380 m

Above: Bedform at 1320 m

There was some variation in the grain size; particles were generally smaller in size with increasing depth. The Ngisi-1 site, at around 1330 m to the north of the study area, was something of an

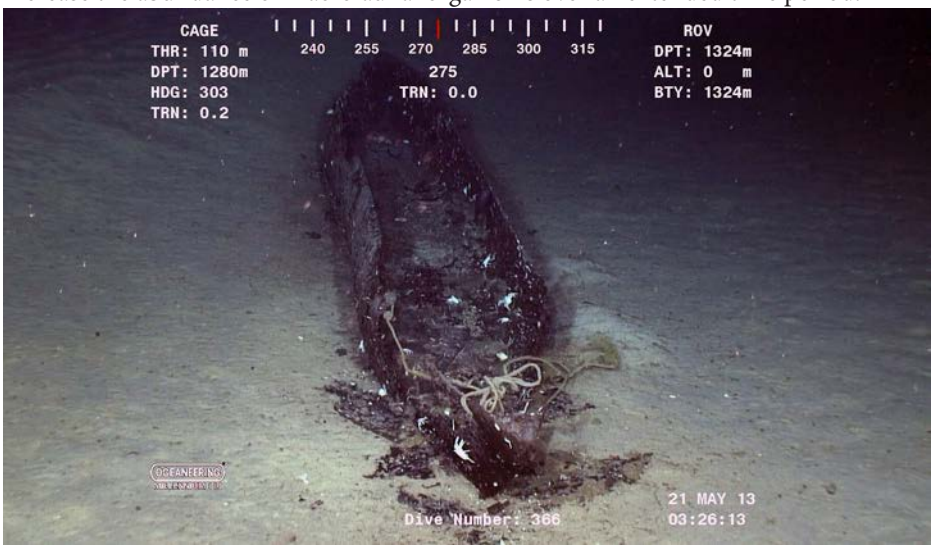
anomaly because it demonstrated particularly coarse sediment and notable bedforms reminiscent of a dynamic seabed environment. Other bedforms were noted at the deepest sites but these are better described as more gently undulating seafloor, with occasional topographic highs that supported increased suspension feeder abundance.

Above: Sessile invertebrates on a sponge stalk at 2400 m



Above: Glass bottle providing hard substratum at 1320 m

The availability of hard substratum was variable in the study area. It was the most important factor for sessile suspension feeder abundance. A small rock would support a diverse community of organisms (e.g. opposite page and title page image, page 3). At Pweza-3 small rocks were abundant and supported many sponges, anemones, corals and barnacles. No rocks were encountered at the two deepest sites, Zafarani and Lavani. At these sites the stalks of tall glass sponges were common, persisting long after the sponge itself dies. These stalks provide substratum for many sessile invertebrates. Elsewhere sessile suspension feeders were also found attached to items of litter (champagne bottle, right) or other objects of anthropogenic origin such as the sunken canoe (below), a traditional wooden fishing dhow found on the seabed at 1320 m depth. The dhow was the largest of a number of "wood-falls" observed off Tanzania, the rest of which were more natural and probably originating from the vast East Africa coastal forest. As well as hard substratum, wood can provide an important food source in a food limited habitat. The wood itself can support numerous organisms and the enrichment of the sediment in the immediate vicinity of wood can increase the abundance of macrofaunal organisms over an extended time period.



***Syringammina* sp.**

Chromista (Kingdom) > Foraminifera (Phylum) > Monothalamea (Class) > Xenophyophoroidea (Superfamily) > Syringamminidae (Family)

The specimens in the images shown here are a type of single celled organism called a xenophyophore. Xenophyophores are the only organisms from outside the animal kingdom considered in this guide. The single cell branches and splits into hundreds of tubes that ramify and interconnect into a complex network. The delicate structure that is visible in the images is called the test. This builds up as the organism proliferates, secreting a slimy organic cement.

Syringammina at Mzia-3 (1700 m)

Xenophyophores were found throughout the study area. They were seen at all the study sites off Tanzania with the exception of Ngisi-1. They were most abundant at the deeper sites, Mzia-2, Mzia-3, Zafarani and Lavani where they were the most abundant organisms encountered in video surveys.

The tests built by xenophyophores are the largest known structures produced by a single cell. The specimen shown, and the majority of those seen off Tanzania, were about 3-4 cm in diameter. Specimens collected at Mzia-3 resemble *Syringammina fragilissima* but further work is being carried out on the specimens to determine the species. They are of particular interest because xenophyophores have never previously been recorded in this area of the western Indian Ocean.

Porifera

Animalia (Kingdom) > Porifera (Phylum)

The first animals considered here are the sponges (Phylum Porifera). With the exception of a few freshwater species, the vast majority of sponges are marine. Adult sponges are sessile and live attached to the seabed or some sort of substratum. Often they encrust rocks or other structures. Others, like many off Tanzania, grow on stalks that raise the main body of the animal into the water column.

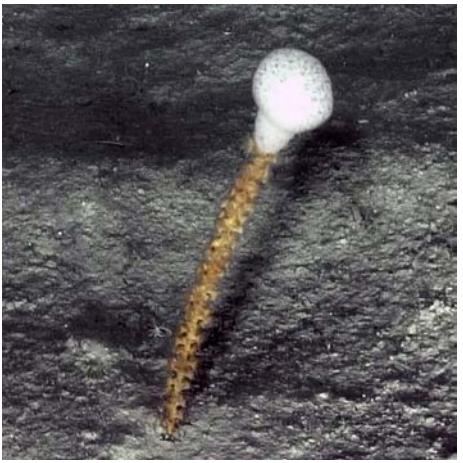
Unidentified sponge

With a body built around a series of water canals and lacking any organs, sponges are the most primitive multicellular animals. Cells with a flagellum (tiny tail-like structure) called choanocytes draw water through the canals to ventilate the sponge and catch food. Sponge classification is based on the composition of the structures that physically support them, known as spicules. The majority of sponges have spicules composed of a protein called spongin and are in the class Demospongiae. Small calcium carbonate spicules characterise the sponges from the class Calcarea. Sponges with silica spicules are commonly known as glass sponges. They belong to the class Hexactinellida. Hexactinellids are principally found in the deep sea and are prevalent off East Africa. They were reported from *Valdivia* Expedition (1898-1899), the *Galathea II* expedition (1952-53) and others that sampled in the area. Some of the hexactinellids seen with the ROVs in this work off Tanzania were spectacular. They often provide a structure on which suspension feeders such as crinoids and brisingids can reach stronger currents slightly higher in the water column. As noted previously, the stalks of some hexactinellids are important hard substratum in an environment dominated by soft sediment.

Stalked sponge (*Hyalonema* sp.)

Euplectellid sponge on a rock at 1380 m

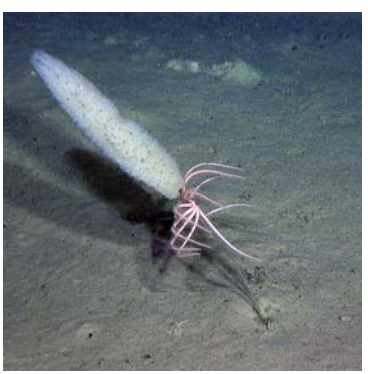
Examples of sponges were seen at all the study sites but they are difficult to identify. This is particularly true when attempting to identify from photographs and video footage because of the wide variety of sizes and shapes they can attain. This can even vary depending on conditions they are growing in. Despite this, some of the hexactinellids have a distinct appearance and experts can determine their identity from the images. It is these animals that are shown in this section.



***Hyalonema* sp.**

Porifera (Phylum) > Hexactinellida (Class) > Amphidiscophora (Subclass) > Amphidiscosida (Order) > Hyalonematidae (Family)

These small hexactinellid sponges were more frequent in the deeper water at Lavani, Zafarani and the Mzia sites. Identification is not certain because inspection of the spicules is required but it is most likely *Hyalonema* sp. The dense covering of zoanthids (small anemone-like organisms) on the sponge above left have been recorded previously on other *Hyalonema* specimens from other study areas.



Monorhaphis chuni

Porifera (Phylum) > Hexactinellida (Class) > Amphidiscophora (Subclass) > Amphidiscosida (Order) > Monorhaphididae (Family)

The only accepted species in the genus *Monorhaphis* is anchored to the sediment by a single giant basal siliceous spicule which can be up to three metres in length. These are the largest biogenic siliceous structures known on Earth. These sponges are slow-growing and extremely long-lived, among the longest living organisms known. A specimen from the China Sea was estimated to be 11,000 years old. The basal spicule increases in diameter as the animal grows and the environmental conditions at the time are reflected in the chemistry of the structure. Analysis of these spicules shows promise as a paleoenvironmental archive. Such data can be used to estimate water temperature at different times during the life of the animal, which can then be used to indicate past climatic conditions.

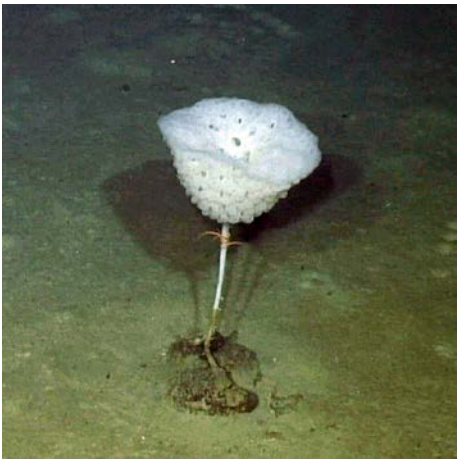
Platylistrum platessa

Hexactinellida (Class) > Amphidiscophora (Subclass) > Pheronematidae (Family)

Platylistrum platessa is a distinctive hexactinellid sponge with a spoon-like body shape. It can grow up to 60 cm in length. Some of the specimens seen in ROV footage off Tanzania were close to this size. There is only one known species in the genus *Platylistrum* so species identification is confident.

Platylistrum platessa is unusual because it is a deep-sea species that was originally described from waters off Tanzania and Zanzibar. The description is based on specimens collected during the German global deep-sea exploration expedition on the *Valdivia* in 1898-1899. *Platylistrum platessa* specimens were collected in trawls at stations ranging in depth from 740 to 1660 m on the leg from the Chagos Islands to Dar es Salaam. Other specimens have been collected more recently from South Africa and elsewhere in the western Indian Ocean in water from 660-1700 m depth.

The ROV observations off Tanzania indicate that this sponge is relatively abundant locally. It was encountered on numerous occasions at the Kamba-1 and Pweza-3 locations (1300-1400 m) but, like the literature suggests, was not seen at the deeper sites. Like other hexactinellids seen in ROV footage, *P. platessa* provides a surface on which suspension feeding invertebrates can reach higher into the water column, as shown in the middle image where a small comatulid crinoid is perched on the top of the sponge.



Saccocalyx pedunculatus

Hexactinellida (Class) > Hexasterophora (Subclass) > Lyssacinosida (Order) > Euplectellidae (Family)

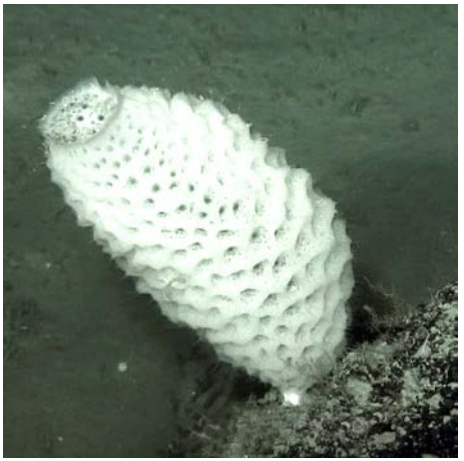
This glass sponge most closely resembles *Saccocalyx pedunculatus* which, in the Indian Ocean, is known from samples collected east of India. Throughout its range *S. pedunculatus* lives between 840 and 2640 m depth. It grows attached to rocks on the seabed and, like other hexactinellids shown here, provides a structure that other organisms, such as the brittle stars, seen here can use as substratum to reach the stronger water currents higher in the water column in order to increase the efficiency of suspension feeding.

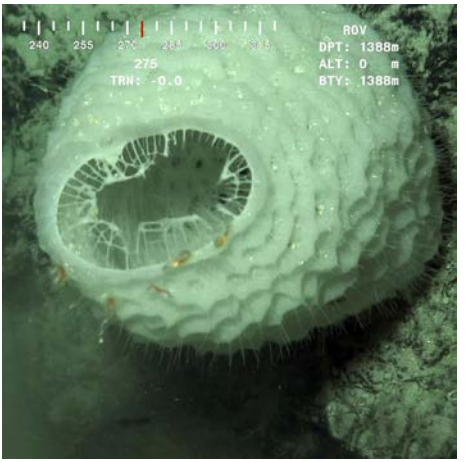
***Malacosaccus* sp.**

Hexactinellida (Class) > Hexasterophora (Subclass) > Lyssacinosida (Order) > Euplectellidae (Family)

The image on the left shows a small hexactinellid, most probably *Malacosaccus* sp. It is not possible to determine the species without examination of the spicules of a specimen under a microscope.

The genus *Malacosaccus* contains seven known species that are widely distributed globally in deep water. They are found from 1000 m down to at least 5000 m. The individual shown, seen at 2600 m depth at Zafarani, was approximately 10 cm tall. *Malacosaccus* sp. was uncommon, this was the only example encountered in the fieldwork off Tanzania.





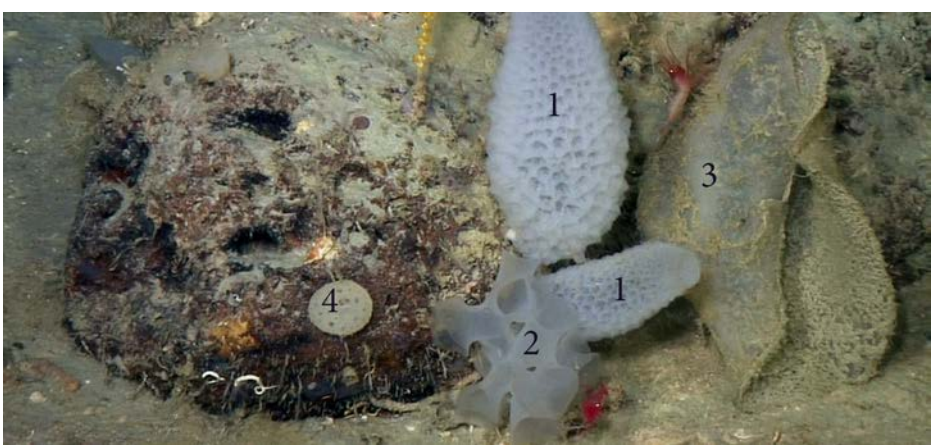
Corbitellinae Hexactinellida (Class) > Hexasterophora (Subclass) > Lyssacinosida (Order) > Euplectellidae (Family)

The glass sponge above was occasionally attached to rocks at Mzia-2 (1620 m) and more frequent at Pweza-3 (1380 m), where hard substratum was more abundant. The specimens may represent one of several genera within the sub-family Corbitellinae but it is most likely *Regadrella* sp. In the image below the rock provides substratum for several species of sponge including the conspicuous *Regadrella* sp. (1) as well as the following:

(2) ***Farrea* sp.** Hexactinellida (Class) > Hexasterophora (Subclass) > Hexactinosida (Order)> Farreidae (Family)

(3) Hexasterophora (Subclass) > Lyssacinosida (Order) > Rossellidae (Family)

(4) Unknown Hexactinellid



Cnidaria

The Cnidaria include a wide variety of familiar organisms such as the corals, anemones and jellyfish. A generalized cnidarian body plan is radially symmetrical and consists of a ring of tentacles surrounding a central mouth. The mouth leads to a gastrovascular cavity, the only opening to the gut. The gastrovascular cavity's function includes both digestion and circulation. This structure is repeated over a diverse range of organisms across two body forms: the polyp and medusa. Polyps are familiar as the sessile animals that live attached to rocks, like anemones, or form large colonies, such as corals. Jellyfish demonstrate the other body form as free living medusae. Some cnidarians, such as certain colonial hydrozoans, have both polyp and medusa stages during their life cycle.

Cnidarians possess stinging cells called cnidocytes. They are located throughout the epidermis but are most abundant in the tentacles. They contain hollow coiled threads called nematocysts. The cnidocytes are sensitive to chemical stimulus or mechanical pressure (or a combination) and eject when another organism, enemy or prey, is close. When discharged the nematocysts eject and entangle or pierce their prey, immobilizing it by injecting toxins. There are several forms of nematocyst and they often have barbs to ensure they pierce the epidermis of their target. The effectiveness of the stinging cells is demonstrated by ROV observations showing that deep-sea anemones can catch fish almost as large as the anemone itself. If seabed videos of anemones are viewed at increased speed they can often be seen drawing their arms through their mouths to remove and digest tiny food particles.

At some of the sites off Tanzania, most notably Pweza-3, areas of hard substratum dramatically increased the available habitat for anemones and corals. Other groups, such as seapens and burrowing anemones, inhabit soft sediment and were more common at the deeper sites like Mzia, Lavani and Zafarani. Some groups, such as the zoanthids, make use of the hard substratum available on other living organisms and encrust structures such as sponge stalks and hermit crab shells.

Benthocodon sp.

Actinernus sp.

Poralia rufescens

Paragorgia sp.

Poralia rufescens

Cnidaria (Phylum) > Scyphozoa (Class) > Semaeostomeae (Order) > Ulmaridae (Family)

The relatively flat disc with short peripheral skirt suggest this is most likely *Poralia rufescens*. Although little is known about its ecology, *P. rufescens* appears to be widely distributed in deep water. Evidence from Japan suggests that the water mass structure, particularly temperature and salinity, was more important than depth in explaining the animal's distribution. There are not enough observations from Tanzania to describe distribution patterns but it was observed only at the two deepest sites, Zafarani and Lavani where the temperature was comparable with the Japanese observations.

Unknown medusa

Cnidaria (Phylum) > Scyphozoa (Class)

Another large jelly encountered briefly in ROV footage. This observation is distinct from *Poralia* (above) and may be an undescribed species. The recently discovered *Tiburonia* or "Big Red" reported from the Pacific demonstrates how little is known about even rather large deep-sea jellies.

***Benthocodon* sp.**

Cnidaria (Phylum) > Hydrozoa (Class) > Trachylinae (Subclass) > Trachymedusae (Order) > Rhopalonematidae (Family)

The small jellyfish shown here is likely *Benthocodon* sp. It is not possible to identify these animals with any certainty without a higher resolution image or a preserved specimen. These gelatinous zooplankton are common in the benthic boundary zone in all oceans. They were recorded at all the study sites off Tanzania but were more common at some sites but this did not appear to be depth related. Research suggests they feed on copepods, and perhaps, the organic material that carpets the sea floor. Images from time-lapse footage suggest that they sit on the seabed for periods of time, which may support the theory that they feed in this way. Stable isotope analyses on specimens from elsewhere have confirmed a benthopelagic trophic role.

***Actinoscyphia* sp. (Venus fly-trap anemone)**

Cnidaria (Phylum) > Anthozoa (Class) > Hexacorallia (Subclass) Actiniaria (Order) > Actinoscyphiidae (Family)

Known as the "Venus fly-trap anemone" because it has some resemblance to the carnivorous terrestrial plant, *Actinoscyphia* can modify its base to grasp structures upon which it attaches. This is demonstrated in these images, particularly where it is attached to the stalk of a glass sponge (it can also be found attached to rocks). It was uncommon during field work off Tanzania but observations at 1370 m and 2400 m suggest it is likely to be found throughout the study area. There are records of the genus *Actinoscyphia* in the Atlantic and Pacific Oceans but until these observations, none in the Indian Ocean.

There is discussion in the scientific literature about this animal's taxonomy. The group it belongs to has structures called acontia, thread-like extensions rich in stinging cells. These are absent from *Actinoscyphia* sp. and a few other species in the group. Genetic evidence supports its affinity with the acontia bearing species and it is suggested that they may have been lost.

A yellow anemone (lower image) was encountered on several occasions at 1600 m but does not resemble other images closely, and may be from a different taxonomic group.

Unknown Actiniaria

Cnidaria (Phylum) > Anthozoa (Class) > Hexacorallia (Subclass) > Actiniaria (Order)

This spectacular anemone was found on the sediment surface at 1380 m depth. The lower of its two layers of tentacles surrounding the oral disc appear to lie on the sediment. At 30–50 cm in diameter it was the largest anemone encountered in this study. Similar animals have been photographed in the Atlantic Ocean and it is so distinctive that is should be identifiable from photographs but the name of this species is unknown. Anemones captured in a trawl or in core samples and brought to the surface can look very different to living examples, they are often everted and the tentacles damaged. The determination of species is primarily based on internal anatomy which requires microscopic examination. It is therefore not clear if this animal is a species that has been described from a specimen recovered to the surface or whether it is genuinely unknown.

***Actinernus* sp.** Cnidaria (Phylum) > Actiniaria (Order) > Actinernidae (Family)

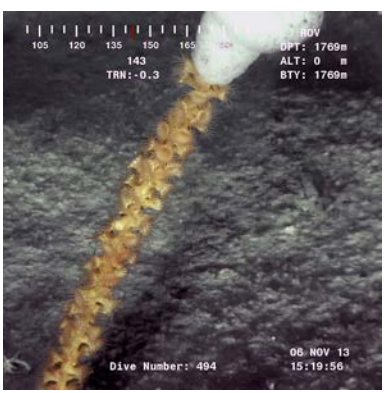
There are four species of *Actinernus* living in deep seas across the globe. None are recorded from the Indian Ocean until this observation. *Actinernus* sp. was seen occasionally deeper than 1600 m. In each case it was attached to a small item of hard substratum. The organism here is drawing one of its tentacles through its mouth to feed on plankton it has caught from the water column.

***Epizoanthus* sp.**

Cnidaria (Phylum) > Anthozoa (Class) > Hexacorallia (Subclass) > Zoantharia (Order) > Epizoanthidae (Family)

The animal shown here is an cnidarian called a zoanthid. Zoanthids superficially resemble the anemones (Order Actiniaria) but are generally colonial, with multiple polyps arising from shared tissue on the substratum. This animal is most likely *Epizoanthus* sp. Remarkably, when encountered in ROV video footage it appeared that this bizarre, almost hand-shaped zoanthid colony was scuttling along the seabed. Although difficult to distinguish in this image, it is actually an association between two species. The polyps of the zoanthid arise from their substratum, the shell of a hermit crab. The zoanthid settles on the hermit crab, growing as the crab increases in size. This reduces the crab's requirement to change its shell when it out-grows it. While the zoanthid provides extra protection to the crab, it benefits from the crab's ability to move, probably accessing greater feeding opportunities.

Off Tanzania this zoanthid-hermit crab association was seen at most sites. It was often encountered in video transects and opportunistic video observations. The number of polyps ranged from one to fourteen. At Mzia-3 a specimen was attracted to the baited camera, this was the largest example seen in the fieldwork with fourteen polyps visible in the photographs. It spent several hours around the bait, moving away and returning several times over the course of the deployment. This animal is shown, along with discussion of the identity of the crab on page 41.



Unknown zoanthid colony

Cnidaria (Phylum) > Anthozoa (Class) > Hexacorallia (Subclass) > Zoantharia (Order)

Zoanthid colonies encrust a variety of types of hard substratum on the deep-sea floor. Here, a colony of zoanthids is shown covering the stalk of the hexactinellid sponge *Hyalonema* sp., a rare hard surface on the seafloor at more than 1700 m depth. This image is a close up of the stalk of the sponge shown on page 20.

This association was only encountered on a single occasion off Tanzania but very similar images have been taken collected at study sites elsewhere in the deep sea.

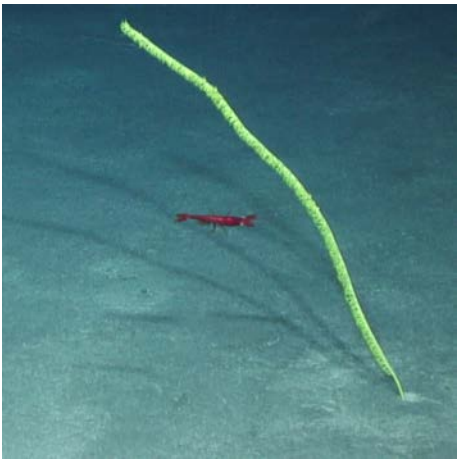
***Schizopathes* sp.**

Cnidaria (Phylum) > Anthozoa (Class) > Hexacorallia (Subclass) > Antipatharia (Order) > Schizopathidae (Family)

Antipatharia are deep water species. They are commonly known as black corals because, unlike other corals, the skeleton is very dark in colour. The genus *Schizopathes* sp. has a distinct triangular shape as displayed here. There are three described species in the genus, with *S. amplispina* described from specimens collected east of Madagascar, at similar depth to our study area (1500-1600 m), from the RV *Anton Bruun* International Indian Ocean Expedition. Comparison of these photographs with the descriptions suggest this is the same species.

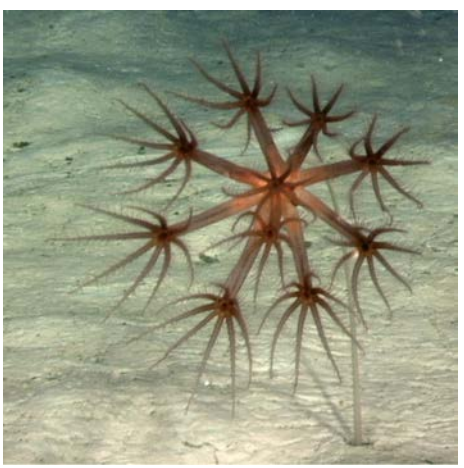
The examples seen off Tanzania appear to be associated with *Bassozetus* sp. fishes. In one case the same specimen was always observed with an attendant fish over a week-long field visit. This was documented by time-lapse photography and the fish remained under the antipatharian for over 36 hours.

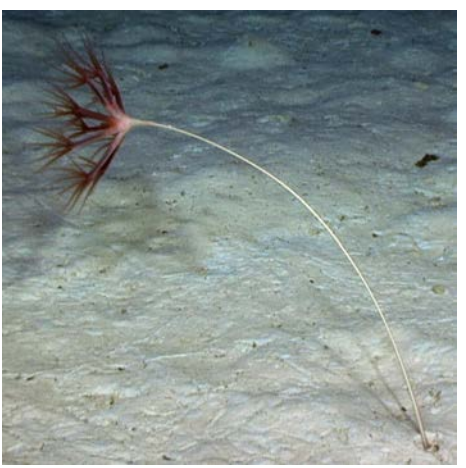
A possible second antipatharian species, with notably different morphology was encountered at Pweza-3 (see lower image).



Pennatulids (Sea pens) Cnidaria (Phylum) > Anthozoa (Class) > Octocorallia (Subclass) > Pennatulacea (Order) > Pennatulidae (Family)

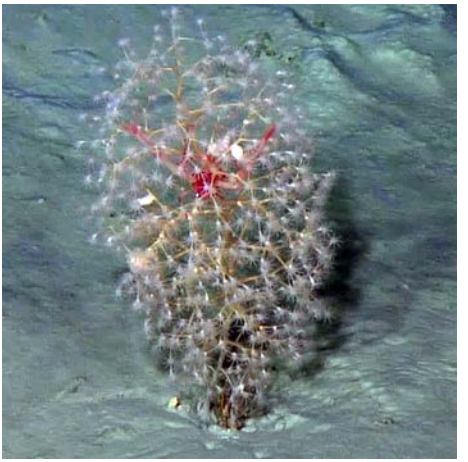
Sea pens (Pennatulacea) are named for the resemblance of some species to old fashioned quill pens. They were not common off Tanzania but several different types were seen. Perhaps the most striking were the bright yellow individuals seen at Pweza-3 and Lavani (above). The specimen above right was at least one metre tall.





***Umbellula* sp.** Cnidaria (Phylum) > Anthozoa (Class) > Octocorallia (Subclass) > Pennatulacea (Order) > Umbellulidae (Family)

Umbellula (above) is a distinctive sea pen in which all the polyps are found clustered at the extreme upper end of the stalk. This is in contrast to being distributed all over as in most sea pens. *Umbellula* was only seen at the deeper sites Zafarani and Lavani.



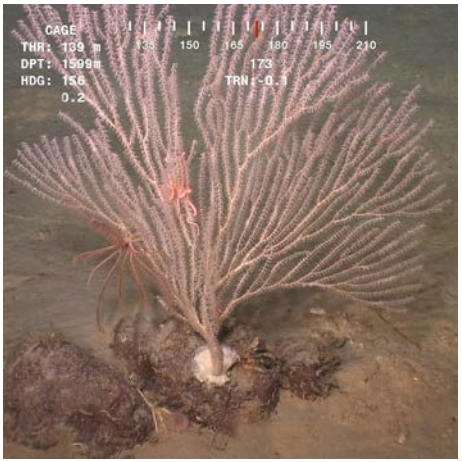
Chrysogorgiidae Cnidaria (Phylum) > Anthozoa (Class) > Octocorallia (Subclass) > Alcyonacea (Order) > Chrysogorgiidae (Family)

There are more than 60 known species of *Chrysogorgia* and species identification requires examination of sclerites and other anatomical features not visible in the images. The pictures shown here were taken at Kamba-1 (left) and Pweza-3 (right) in approximately 1380 m water depth. In each case the coral provided habitat for Chirostylid squat lobsters. The fish on the upper left image most resembles *Dicrolene* or *Bassozetus*.

Unknown coiled coral
Anthozoa (Class) > Octocorallia (Subclass) > Alcyonacea (Order)

Unidentified white corals with coiled structure were found at several of the sites off Tanzania. In some cases they are seen on rocks but most often they are found on soft sediment. They may represent several species, it is not possible to identify from the video.

The colour and coiled structure superficially resembles *Radicipes* sp. but *Radicipes* has only one polyp at each location. Some of the images from Tanzania show more than one (up to three). A possible alternative identification is the primnoid *Convexella* sp. The images here resemble video images of *Convexella* sp. recorded off the Bahamas. Although the identification is not clear, they are important components of the megafauna at the sites in Block 4 off Tanzania, where it was the most abundant animal on the soft sediment at Pweza-3 and Kamba-1.



Bamboo coral with crinoids and brittle stars

Isididae

Cnidaria (Phylum) > Anthozoa (Class) > Octocorallia (Subclass) > Alcyonacea (Order) > Isididae (Family)

This bamboo coral resembles the genus *Jasonisis* sp., named after the research ROVs that facilitated its discovery. The common name, bamboo coral, reflects the growth pattern of the animal when the internal structure is examined.

The animal here is making use of rare hard substratum on the otherwise soft sediment at Mzia-2. The three dimensional structure of the coral provides habitat to ophiuroids (brittle stars) and a comatulid crinoid among other smaller organisms not visible in the image. A superficially similar coral is shown on p. 47. Despite the resemblance the animal on p. 47 it is likely a species from the family Primnoidae.


Paragorgia coral and "Blobfish" *Psychrolutes* sp.

***Paragorgia* sp.**

Cnidaria (Phylum) > Anthozoa (Class) > Octocorallia (Subclass) > Alcyonacea (Order) > Paragorgiidae (Family)

The fan shaped corals with thick branches from the genus *Paragorgia* are found in a range of colours including pink, orange and white. They are known as bubblegum corals. Their distribution is global and they are found over a large depth range from tens of metres depth (e.g. in Norwegian fjords) to several thousand metres. They are particularly well known from continental slopes, canyons and seamounts.

Paragorgia was observed infrequently off Tanzania, this image from Pweza-3 was one of only two records. It may be more common in areas where there is more available hard substratum. Like the *Jasonisis* above, and *Paragorgia* elsewhere, its three dimensional structure appears to provide important habitat to other organisms like the ophiuroids and comatulid crinoids seen here. In this case a "blobfish" (*Psychrolutes* sp.) appeared to be using the structure (for further information about blobfish see p. 74).

Ctenophora

Ctenophores are gelatinous organisms found over a range of depths from shallow coastal waters to the deep sea. In deep water ROV video, ctenophores are regularly encountered drifting over the sediment in the benthic boundary currents where they are important predators of smaller zooplankton. Despite their resemblance to jellyfish the Ctenophora is a actually a separate phylum characterised by the rows of cilia which can be seen reflecting the ROV lights in the images below. These structures give the animals their common name "comb jellies" or "sea gooseberries".

***Lampocteis* sp.**

Ctenophora (Phylum) > Tentaculata (Class) > Lobata (Order) > Lampoctenidae (Family)

Remarkably the two images of *Lampocteis* sp. shown here are the same individual viewed from different angles. Known by the ROV teams as the "TIE-fighter" because if its resemblance to fictional Star Wars space ships it is probably in the genus *Lampocteis*. Whether it is the same or different to the described species is impossible to determine without a specimen to examine under a microscope.

Ctenophore in front of sub-sea strucre

"Tortugas red"

The image on the left was recorded at Ngisi-1 and a similar individual was observed at Lavani. These two sites cover almost the full depth range studied off Tanzania.

This species has been known to deep sea ctenophore experts for some time but it remains undescribed scientifically. Informally it has been called Tortugas Red. The long trailing tentacles, clearly visible against the white structure in the background are retractable and are used to catch small planktonic invertebrate prey organisms.

Annelida

Calcareous tubes of serpulid tube-worms on a rock at the seabed

Segmented worms such as earthworms, ragworms and leeches are part of the phylum Annelida. Each segment of the annelid body contains the same set of organs, repeating along the body.

The majority of annelid worms visible in photography off Tanzania were polychaetes or "bristle worms", which includes the "ragworms" from shallow-water muddy habitats. The Polychaeta is the most diverse class of annelids. In most polychaetes each segment supports a set of appendages (parapodia) with chaetae, or bristles. The chaetae are visible in the larger animals seen in photography, clearly demonstrating the repeating segments along the annelid body (see the "squidworm" images below).

Although some are large, the majority of polychaetes are tiny. Most live within the sediment so they are not seen in photography but the tell-tale signs of their presence, such as tubes and burrows on the sediment surface, are often visible in seabed photographs.

Within the restrictions of the annelid body plan there is wide diversity of body shape. Thus diversity reveals the variety of polychaete life-history strategies including predators and suspension feeders, free-swimming pelagic animals, tube dwelling animals and those living within the sediment. The different feeding apparatus and parapodia of some can be spectacular when examined under a microscope.

***Teuthidodrilus* sp.** Annelida (Phylum) > Polychaeta (Class) > Terebellida (Order) > Acrocirridae (Family)

While many polychaetes are small and live in the sediment or in tubes attached to hard substratum, some are pelagic, living in the water column. One such species is *Teuthidodrilus* sp., which was seen on occasions in the water column within 10 m of the sediment.

Teuthidodrilus sp. is known as the "squidworm" because of the squid-like appearance of its branchiae and palps. At around 10 cm in length it is a relatively large polychaete but it was usually difficult to collect good images as they drift past in the current. In the upper image the animal was hanging motionless in the water. The animal in the lower image was much more actively swimming.

Mollusca

Molluscs are bilaterally symmetrical and often secrete a calcareous shell. The phylum includes a wide diversity of familiar animals including gastropods like slugs, snails and limpets, bivalves such as clams and oysters and cephalopods like squid and octopus. Other less familar members are the Chitons (below).

Unidentified deep-sea squid at 1300 m depth

The phylum is second only to the Arthropoda in the number of living species it includes. Despite this, few mollusc species were photographed in the fieldwork off Tanzania. This is partly because many are small and live within the sediment. The more conspicuous were the were octopus and squid described in this section.

Chiton from seabed sample (approx 5 mm)

Gastropod with unusually large foot, seen at 2600 m

Several of the more well known, popular deep-sea species are molluscs. These including the piglet squid and the dumbo octopus which were both encountered during field work off Tanzania.

***Helicocranchia* sp. (Piglet Squid)**

Mollusca (Phylum) > Cephalopoda (Class) > Oegopsida (Order) > Cranchiidae (Family)

Heliocranchia sp. has a rather endearing appearance. It is known as a piglet squid because of the resemblance of the long funnel, extending beyond the beak, to the snout of a pig. An example of a piglet squid photographed off Nigeria is perhaps the most popular image collected through the SERPENT Project to date.

Piglet squid

Piglet squid were only occasionally encountered at the study sites and these likely represent the first records from the western Indian Ocean. They are so rarely seen that any video footage is valuable for improving understanding of their behaviour and ecology. On one occasion a piglet squid was spotted by the ROV team whilst collected some sediment samples. The team were able to watch the animal for several minutes as it swam erratically around the equipment.

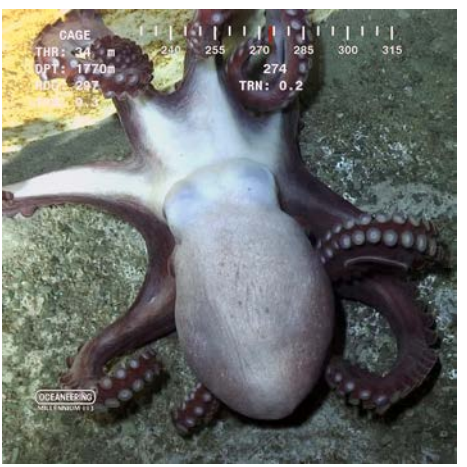
***Echinoteuthis* sp. (Whiplash squid)**

Echinoteuthis glaukopis? Perhaps the first observation of this animal since the original description of the species.

Mollusca (Phylum) > Cephalopoda (Class) > Oegopsida (Order) > Mastigoteuthidae (Family)

The taxonomy of the Mastigoteuthidae is complicated and undergoing research to clarify the number of species. The family is restricted to the deep sea so observations are rare and their behaviour is poorly understood.

The example here was seen on a single occasion. It seems to hang motionless in the water column a few metres above the seabed. It is a member of the genus *Echinoteuthis.* The species *E. glaukopis* was originally collected from the waters off the east African coast by the 1898-1899 *Valdivia* expedition. It is still only known from the original description in 1908 of that specimen. More recent work suggests that *E. glaukopis* may not be a separate species to *E. atlantica.* More specimens, particularly from the Indian Ocean, are required in order to carry out the DNA analysis needed to determine the correct taxonomy.



***Muusoctopus* sp.**

Mollusca (Phylum) > Cephalopoda (Class) > Octopoda (Order) > Octopodidae (Family)

The animal shown above was observed next to the blow-out preventer on the seabed at 1780 m water depth at Mzia-2 . An important feature in the identification of the genus is the two rows of suckers, clearly visible in the image on the right. This specimen is most likely *Muusoctopus* sp. and the image most resembles *M. johnsonianus*, a species widespread in the deep Atlantic but poorly known in the Indian Ocean.

Opisthoteuthidae

Mollusca (Phylum) > Cephalopoda (Class) > Octopoda (Order) > Opisthoteuthidae (Family)

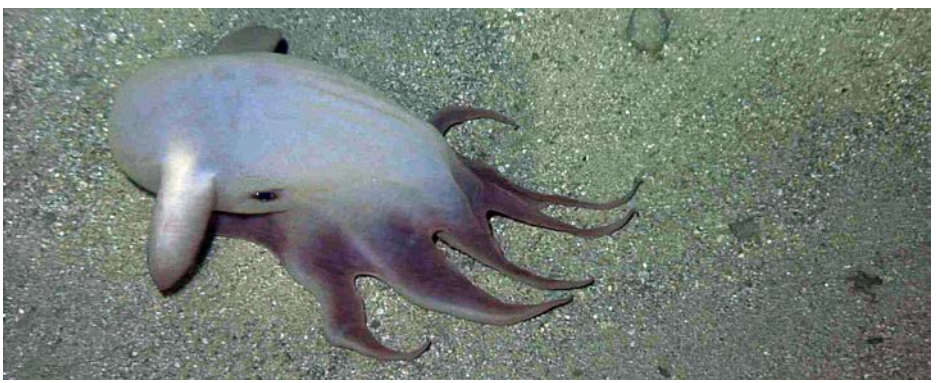
Cirrate octopods are popular deep-sea animals because of recent high-profile images and video clips. They are known as "Dumbo Octopus" because of the resemblance of their fins to the ears of Disney's fictional flying elephant. Cirrate octopods were not common off Tanzania, the images on this page were only examples. Cirrate octopods move their fins gently up and down to aid swimming. The examples shown here were sitting on the sediment in a similar manner to cirrate octopods observed during SERPENT studies in the north-east Atlantic. This may be a feeding behaviour. In each case, as the ROV approached the cirrate octopods lifted up into the water column and swam away slowly.

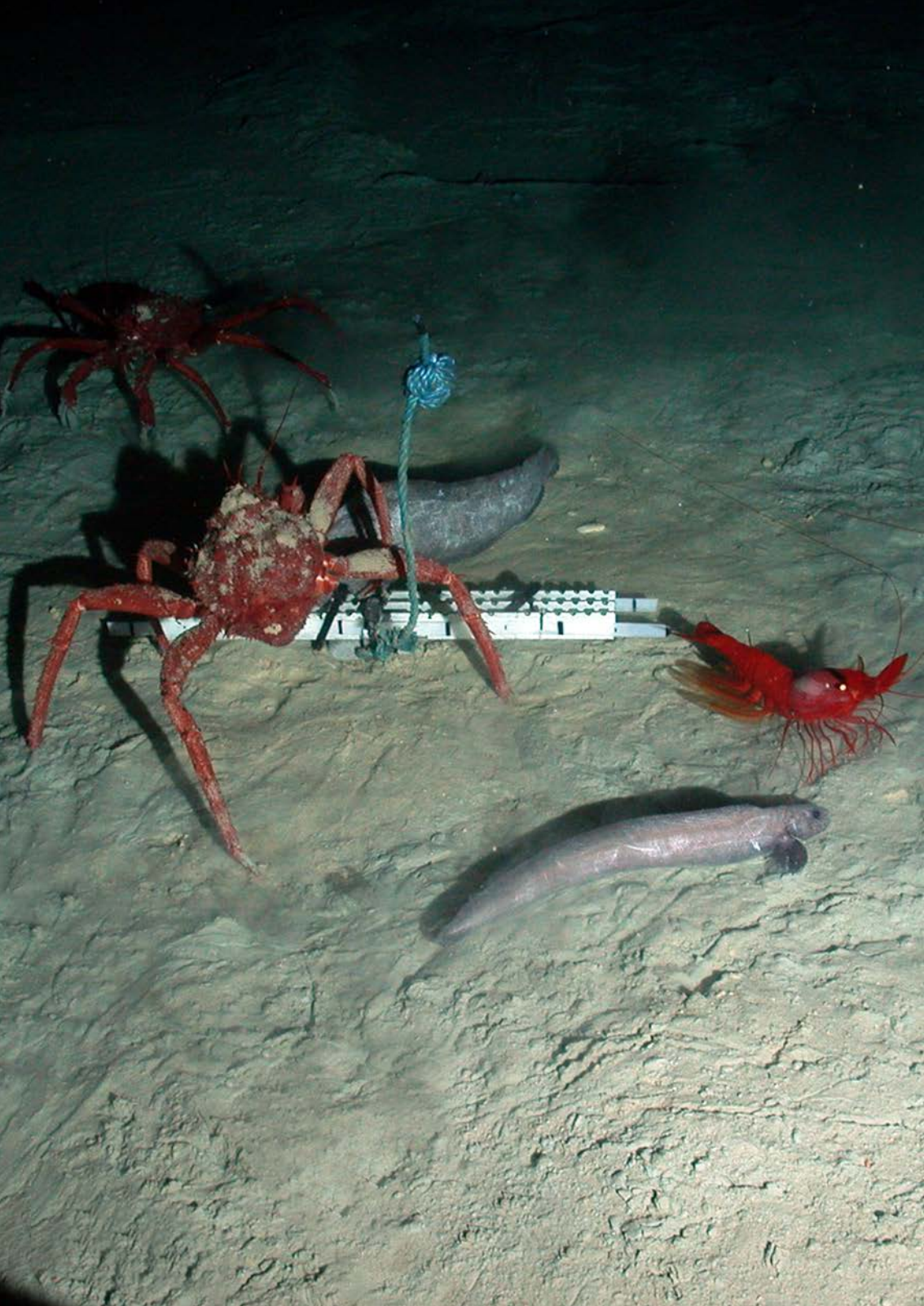
***Grimpoteuthis* sp.**

Mollusca (Phylum) > Cephalopoda (Class) > Octopoda (Order) > Opisthoteuthidae (Family)

This example (right) is a member of the genus *Grimpoteuthis* sp. It was the only *Grimpoteuthis* sp. observed off Tanzania in this fieldwork and it likely represents the first record from the western Indian Ocean. It is not possible to identify the animal to species. A specimen is required in order to count suckers and dissect out the shell to confirm the identification.

The cirrate octopod below is likely a different species. This photograph looks like it may be a *Luteuthis* sp. or *Cryptoteuthis* sp., two new genera that have been described recently in the family Opisthoteuthidae. Again, examination of a specimen would be required to confirm the identification.





Crustacea

Mysid crustacean at 1300 m

The Phylum Arthropoda contains the insects, arachnids and crustaceans. It is the largest of the animal phyla containing around 80% of all known animal species. The arthropods have a segmented body, with paired appendages on each segment. They have a characteristic chitinous exoskeleton covering the body that is periodically shed or moulted as they grow.

Unidentified decapod at a baited camera experiment

The group has diverged to adapt to almost all habitats on Earth. Terrestrial and freshwater habitats are the realm of the insects, but in the oceans it is the crustaceans that dominate. The Crustacea includes animals as diverse as copepods, shrimps, crabs, lobsters, barnacles and a variety of parasitic groups.

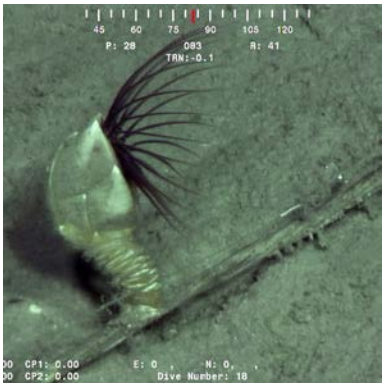
In the water column crustaceans are represented in the zooplankton by, among others, calanoid copepods, mysids, krill and the larval stages of benthic forms such as large stone crabs opposite. Many are tiny and only apparent as backscatter from the ROV's lights but some planktonic groups, like the mysids (above), are relatively large and can be seen in photographs. Planktonic crustaceans are an important food source for many of the species described in this guide.

The larger decapod crustaceans are often important components of the scavenging assemblage (see large stone crabs and shrimp feeding at a baited camera experiment opposite). Along with the scavenging amphipods these animals recycle nutrients as material such as fish carcasses arrive at the seafloor. On deployment of the baited camera experiments, essentially a simulated large food-fall, scavenging crustaceans would often arrive and begin feeding within minutes.

Other crustaceans are associated with different food sources such as sunken wood. Wood was quite frequently encountered on the seabed off Tanzania, the East Africa coastal forest is a likely source. Wood can provide food source to squat lobsters adapted to digest it and it is a source of hard substratum on an otherwise generally soft sediment seabed.

The seabed provides habitat for many small species that live within the sediment itself. Mud samples show crustaceans to be the second most abundant meiofaunal and macrofaunal group after the annelid worms. Harpacticoid copepods, isopods and amphipods made up the majority of the species within the sediment.

Barnacles on a sponge stalk. The large barnacles are from the family Scalpellidae while the small one are Poecilasmatidae.



Alcockianum sp. attached to a dead glass sponge on the seabed at 2400 m depth

Barnacles

Arthropoda (Phylum) > Crustacea (Subphylum) > Cirripedia (Infraclass)

Barnacles are sessile, suspension feeding crustaceans. They are more recognizable as crustaceans during their larval stage, before they settle on hard substratum. Owing to their requirement for hard substratum on which to attach, barnacles were rarely encountered at the study sites off Tanzania. However, when they were found they could be locally abundant (upper image, this page). The very small barnacles in this image are most likely from the family Poecilasmatidae.

The hard substratum that barnacles were found attached to varied and included natural and anthropogenic structures. In the image on the left, like in several cases, *Alcockianum* sp. (Family Scalpellidae) was found attached to the stalk of a dead glass sponge (hexactinellid). The image at the bottom of the page shows two *Arcoscalpellum* sp. (also Family Scalpellidae) barnacles, as well as tubeworms and hydroids, attached to a piece of litter (champagne bottle) encountered during a video survey at 1300 m depth.

***Parapagurus* sp.**

Arthropoda (Phylum) > Malacostraca (Class) > Decapoda (Order) > Parapaguridae (Family)

These hermit crabs associate with a zoanthid (anemone-like cnidarian, see p. 28) that grows over their shell. Given the depth, the hermit crabs are almost certainly of the genus *Parapagurus*.

Four species of *Parapagurus* are known from the western Indian Ocean. The most likely are *P. bouvieri* or *P. andreui* (or perhaps both species). The differences between species are subtle so it is impossible to identify with any certainty from the images as the animal obscured by the zoanthid. Both associate with the anemone *Epizoanthus* and they can occasionally be found in shells where the cnidarian is not as well developed and only partially covers the housing (e.g. middle image).

In the deep water off Tanzania these animals appear to be quite common. They have been encountered at most sites, either during video observations or in baited time-lapse deployments. In the time-lapse footage the crab was seen to feed for an extended time period before leaving the bait and returning later, presumably maximizing feeding opportunities from a rare food fall. In an extremely unusual piece of footage one large individual (below) was seen carrying a smaller animal in its chelipeds (claws).

***Neolithodes* sp. (Stone Crab)**

Arthropoda (Phylum) > Malacostraca (Class) > Decapoda (Order) > Lithodidae (Family)

These stone crabs, *Neolithodes* sp., were encountered at one site when they attended the baited camera experiment. It is the first time *Neolithodes* sp. has been recorded in the deep western Indian Ocean.

The specimens here were large animals, up to 20 cm carapace length and a leg span of nearly a metre. A maximum of three individuals was seen feeding on the bait at any time. Like the hermit crab on the previous page, they appeared to feed for a period of time, move away and then return later. When feeding at the bait they were dominant over the other species present, consuming most of the food available. It may be that the protection provided by the sharp spines on the carapace and legs of the crabs deter other species from feeding.

***Paralomis* sp.**

Arthropoda (Phylum) > Malacostraca (Class) > Decapoda (Order) > Lithodidae (Family)

Paralomis sp. is another lithodid. This specimen was seen at a wood-fall at 1300 m depth. It is not possible to identify to species from the image. The closest geographical record of this genus is *Paralomis roeleveldae* which has been recorded from 700 m depth off South Africa.

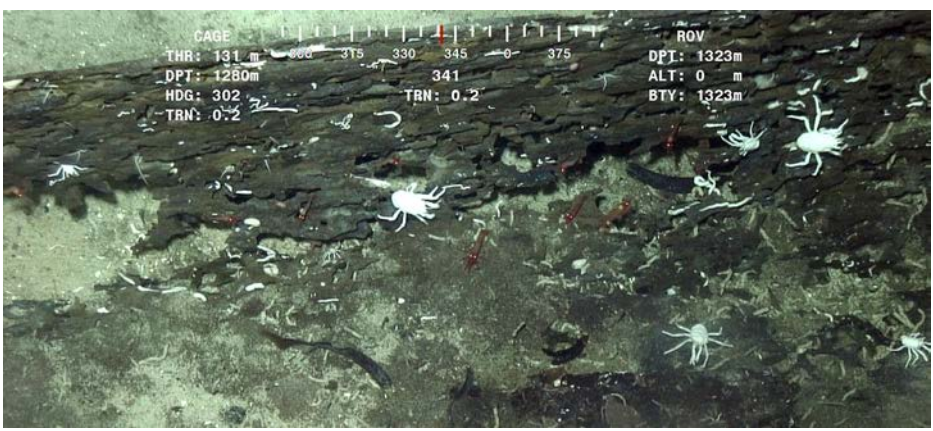
Munidopsis squat lobsters at a wood-fall at 2400 m depth

***Munidopsis* sp.**

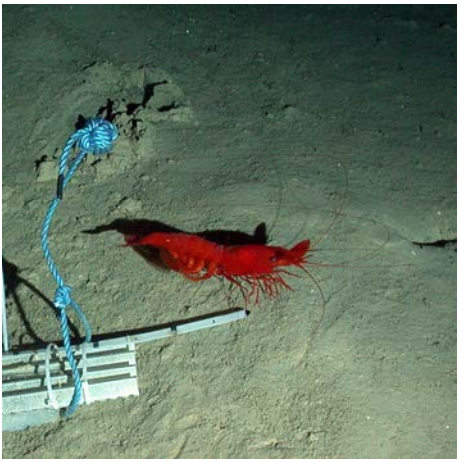
Arthropoda (Phylum) > Malacostraca (Class) > Decapoda (Order) > Munidopsidae (Family)

Munidopsid squat lobsters were seen only occasionally off Tanzania and in each case they were associated with sunken wood. They feed on fragments of the wood as it is broken down by bacteria. Some species have gut bacteria that further assist this process. Many species demonstrate spoon shaped chelipeds (claws). These are thought to be specialised to aid scraping pieces off the surface of the wood to feed on.

Twelve species of *Munidopsis* have been recorded in the western Indian Ocean, mostly off the coast of Madagascar, at depths from 250 – 3800 m. Other squat lobsters (Chirostylidae) were associated with the Chrysogorgiid corals shown on page 31.



***Cerataspis* sp.**

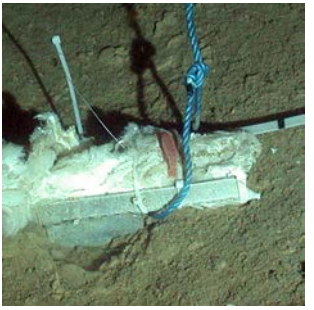


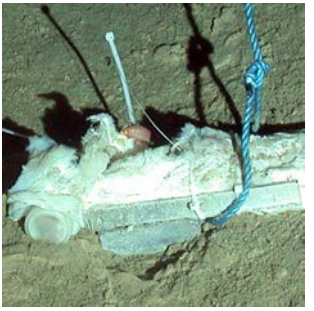
Arthropoda (Phylum) > Malacostraca (Class) > Decapoda (Order) > Aristeidae (Family)

This large decapod is from the family Aristeidae. It is perhaps more familiar to marine biologists as *Plesiopenaeus* sp. but recent studies have shown that it the adult animal of a larval stage known as *Cerataspis* sp.

It is widely distributed in the deep sea and was frequently observed at all the sites off Tanzania, especially when the baited time-lapse camera was deployed. It is a large animal, up to 20 cm in length, which has previously been recorded off Tanzania and elsewhere in the western Indian Ocean.

Scavenging amphipods





Arthropoda (Phylum) > Malacostraca (Class) > Peracarida (Superorder) > Amphipoda (Order) > Lysianassoidea (Superfamily) > Eurytheneidae (Family)

The pink animal shown feeding at the baited camera experiment on the right is a large amphipod crustacean. It is approximately 5-6 cm in length. Large amphipods like this are likely to be *Eurythenes* sp., a widely distributed genus and common member of the scavenging assemblage. Most of the scavenging amphipods attending the baited camera experiments were much smaller than those visible the images here, their presence only detected as dots on the image. More familiar amphipods are the sand-hoppers, which are often seen on the strand line of beaches (they are usually 1-2 cm in length).

Amphipods are important scavengers in the deep sea. They will appear in their thousands and rapidly devour bait placed at the seabed, or a natural food-fall. They were seen in very large numbers in photographs from the baited time-lapse camera deployments off Tanzania. Baited traps deployed alongside the camera at a number of the sites captured many species of amphipods and the related (peracarid) isopods. These samples provide valuable new distribution records for numerous species.

Echinodermata

Echinoderms are exclusively marine, found at all depths in the oceans. The phylum includes familiar organisms such as starfishes and sea urchins. Uniquely, echinoderms have a water vascular system that terminates at tube feet. Locomotion and gripping prey or surfaces are achieved by altering the pressure in the water vascular system. They also have the unique ability to rapidly adjust the stiffness of their connective tissues. There are five classes of echinoderm, all of which were represented at the study sites in the western Indian Ocean: Crinoidea, Asteroidea, Ophiuroidea, Echinoidea and Holothuroidea.

Crinoidea - Sea lilies and feather stars are the two types of crinoid. Sea lilies are stalked animals found exclusively in the deep sea. Both were found off Tanzania but the feather stars were more common.

Asteroidea - The familiar starfishes or sea stars are star shaped with arms projecting from a central disc. Their mouth is in the centre under the disc and they move by means of their tube feet (podia). Starfishes, are common deep-sea inhabitants and were well represented at all the study sites off Tanzania.

Ophiuroidea - Brittle stars and basket stars have long arms projecting from a central disc but ophiuroid arms do not grade into the disc as the starfishes do. Ophiuroid arms are more flexible than starfishes and locomotion is by means of pushing or pulling themselves along. They demonstrate various feeding modes including suspension feeding (notably the basket stars), deposit feeding, scavenging and predation.

Echinoidea - The echinoids include the sea urchins, sand dollars and heart urchins. They are either regular (radially symmetrical - sea urchins) or irregular (bilaterally symmetrical - heart urchins and sand dollars).

Holothuroidea - Sea cucumbers, appear quite different from other echinoderms. They are not radially symmetrical, instead they are elongated with a mouth at one end. The hard calcareous plates that make up the sea urchins and starfishes are smaller in the sea cucumbers meaning they have a softer epidermis. Holothurians are important components of deep-sea invertebrate assemblages off Tanzania. They are deposit feeders, moving around on the seabed feeding on material that has settled from the surface waters.

Stalked crinoids (Sea lilies)

Echinodermata (Phylum) > Crinoidea (Class)

The Crinoidea comprise the sea lilies (below) and feather stars (opposite page). Sea lilies flourished in the Paleozoic era and they are one of the oldest animal groups with living representatives. They are sometimes described as "living fossils" owing to their age in the fossil record and conserved body plan. Modern species are restricted to the deep sea.

In the study area off Tanzania sea lilies were uncommon but examples were seen at three of the sites across a depth range of 1300-2600 m.

Hyocrinida

Echinodermata (Phylum) > Crinoidea (Class) > Hyocrinida (Order)

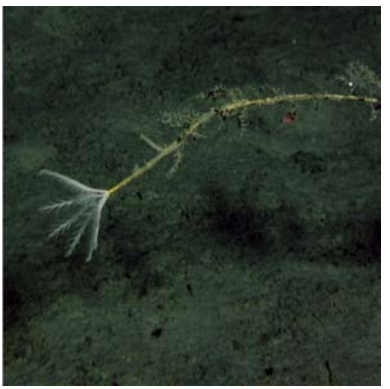
This pale yellowish stalked crinoid with darker arms appears to be a hyocrinid. It is unusual with such proportionally short rays. It was seen on two occasions on rocks at the Pweza-3 site in 1380 m water depth. The specimen here is approximately 50 cm in length.

Hyocrinid on a rock at Pweza-3

Bathycrinidae

Echinodermata (Phylum) > Crinoidea (Class) > Comatulida (Order) > Bathycrinidae (Family)

Seen only at the deepest sites, this animal is unusual because it has a very small "head". It appears to be a bathycrinid, perhaps *Bathycrinus* or *Monachocrinus*. The growth on its stalk includes barnacles and hydroids. An amphipod crustacean also appears to be making use of this habitat.



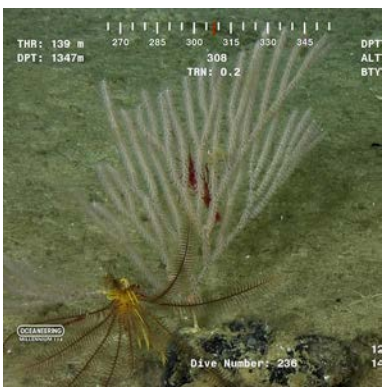
Bathycrinid at over 2400m water depth

Feather stars

Above - *Glyptometra*?

Echinodermata (Phylum) > Crinoidea (Class) > Comatulida (Order)

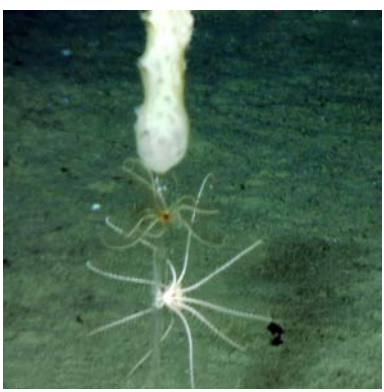
Feather stars were relatively common at Pweza-3 where they were often seen on rocks, like the large animal in the image above or perched on sessile organisms (right). The specimen above appears to be a member of Charitometridae. A likely genus is *Glyptometra,* of which several species are known from over 1000 m in the Indian Ocean and immediate vicinity. The taxonomy of *Glyptometra* is complicated and requires further research.



Thalassometridae? on a Primnoid coral

Feather stars were seen at all the study sites but often they were too small distinguish from each other or identify even to family. The one on the primnoid coral (upper right) could be a thalassometrid rather than a charitometrid. Similarly coloured thalassometrids have been documented in the Caribbean, but examination of the hook-like cirri is required to correctly identify the family they belong to. Thalassometrids have much longer, more slender cirri than the charitometrids.

The lower image is from one of the deeper sites (2400 m) showing feather stars (Antedonidae) on the stalk of a glass sponge.



Antedonidae? comatulid crinoids on a hexactinellid sponge

Unusual ophiuroid posture seen at 2600 m

Ophiuroidea (Brittle stars)

Echinodermata (Phylum) > Ophiuroidea (Class)

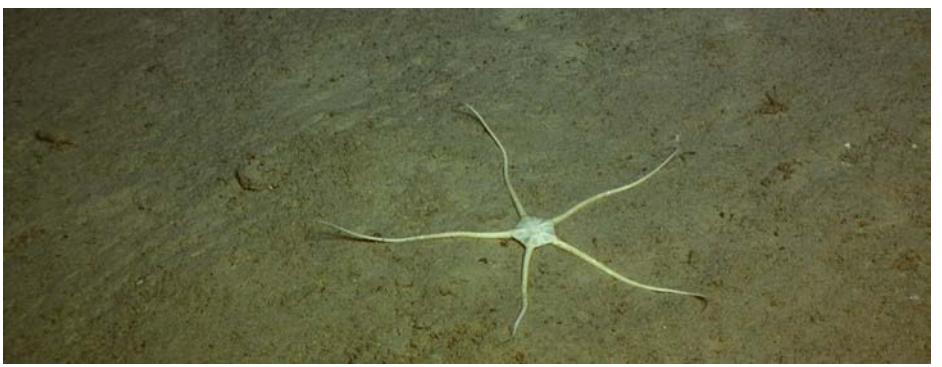
The Ophiuroidea includes the brittle stars and basket stars. It is the echinoderm class with the most species. Ophiuroids have long arms projecting from a central disc, but ophiuroid arms do not grade into the disc as the asteroids do. Ophiuroid arms are also more flexible than starfishes and locomotion is by means of pushing or pulling themselves along in a motion reminiscent of rowing. This is demonstrated by the tracks left in the sediment by the animal in the lower of the images on the left.

"Pink ophiuroid" at Zafarani

"White ophiuroid" showing tracks in the sediment as it moves over the seabed

Ophiuroids demonstrate various feeding modes including suspension feeding (notably the basket stars, but others too), deposit feeding, scavenging and predation.

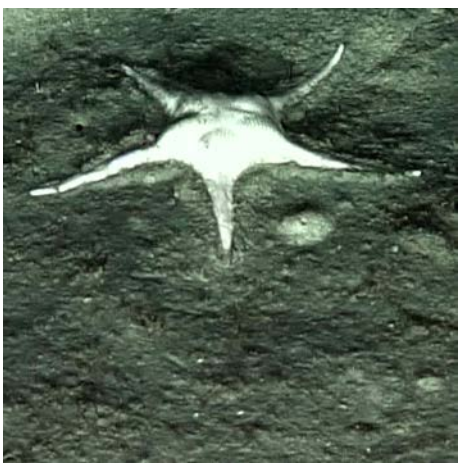
Basket stars were not seen off Tanzania but brittle stars were. They were most common at the deeper sites (Zafarani and Lavani). It is not possible to identify these small echinoderms from video footage but two distinct colour types were documented at Zafarani and Lavani. The white ophiuroids, shown at the bottom of this page were more common than the pink animals (upper images). (The observations probably represent several species).



Porcellanasteridae

Echinodermata (Phylum) > Asteroidea (Class) > Paxillosida (Order) > Porcellanasteridae (Family)

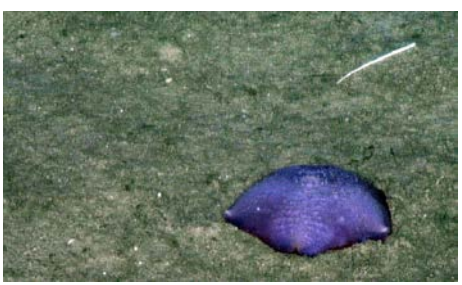
This image from 2400 m depth is a starfish from the family Porcellanasteridae. A possible species identification is *Thoracaster cylindratus* which has been recorded in the western Indian Ocean, albeit at greater depth (>3000 m). If this image is of *T. cylindratus* it is probably the first ever *in situ* picture of the species.



Paxillosida

Echinodermata (Phylum) > Asteroidea (Class) > Paxillosida (Order)

This asteroid is from the Order Paxillosida. It is not possible to identify further with any certainty but *Dytaster* sp. (Family Astropectinidae) or *Pseudarchaster* sp. (Family Pseudarchasteridae) are possibile identifications. It was observed at Pweza-3 and analysis of video footage suggests it was the most abundant asteroid at that site.

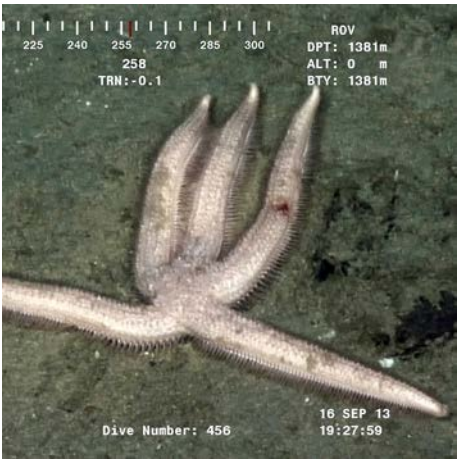


Hymenaster sp.

Pterasteridae

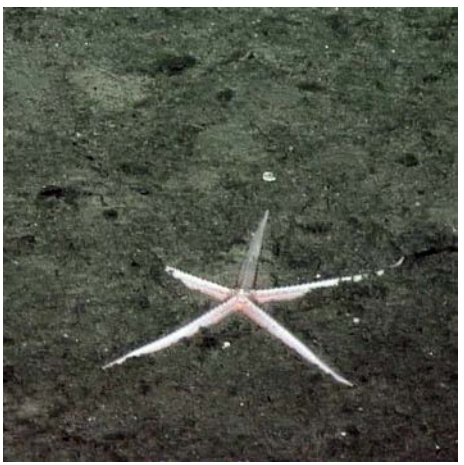
Asteroidea (Class) > Velatida (Order) > Pterasteridae (Family)

This purple starfish seen at 1600 m depth at Mzia-2 looks like *Hymenaster* sp. (Pterasteridae). It is not possible to identify with certainty from the image but a possible species based on known distribution is *Hymenaster alcocki*.



Zoroasteridae

Echinodermata (Phylum) > Asteroidea (Class) > Forcipulatida (Order) > Zoroasteridae (Family)



The starfish above were both seen at 1380 m water depth at the Pweza-3 site. They are members of the family Zoroasteridae, which is in the same Order (Forcipulatida) as some familiar shallow water species such as the common starfish (*Asterias rubens*).

The upper images both appear to be the same species, possibly *Bythiolophus* sp. or *Zoroaster* sp. (a genus known from offshore Kenya). Interestingly, the two separate individuals in the observations above are exhibiting the same posture.

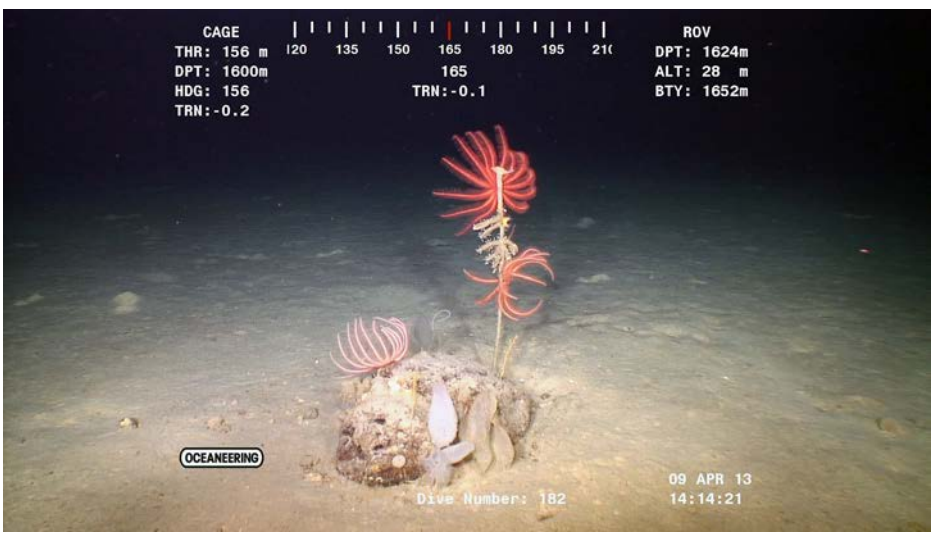
The image on the left (middle) shows a partially buried specimen of what is most likely *Zoroaster adami* and further evidence of burrowing activity by asteroids is seen as prints left in the seabed (lower left). Observations of burrowing by members of the Zoroasteridae at other SERPENT sites suggest this is a typical behaviour in the group.

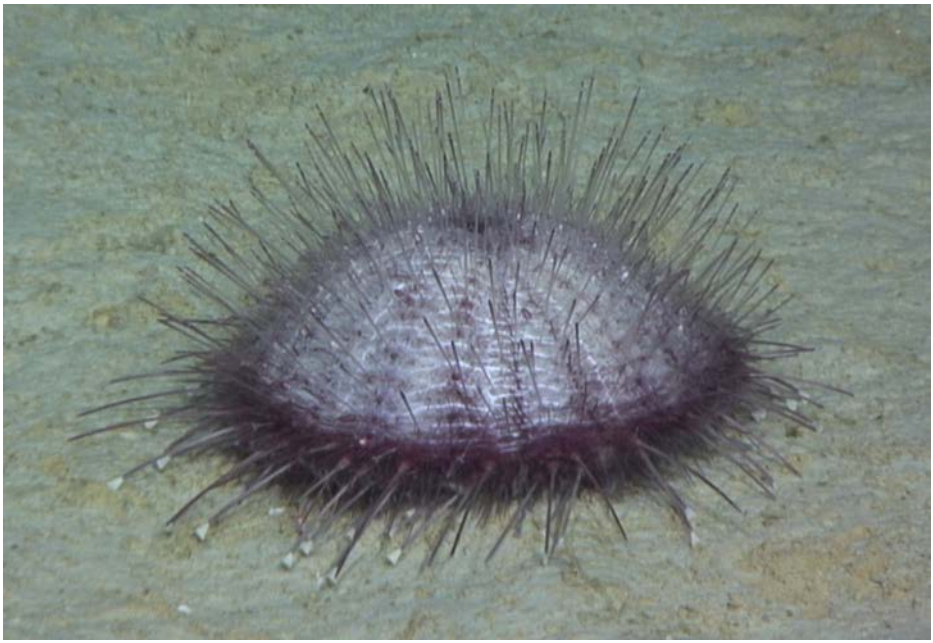
Brisingida

Echinodermata (Phylum) > Asteroidea (Class) > Brisingida (Order)

The Brisingida is an order of seastars found exclusively in the deep sea. There are two families within the Brisingida: the Brisingidae and the Freyellidae. Off Tanzania they were relatively frequently observed at the deeper sites (>1600 m). Identification is difficult from photographs but the images on the left are Freyellids. The middle image is possibly *Colpaster* sp. (based on the number of arms).

Brisingids are suspension feeders. They use their arms to capture particles of food from the water column. At the study sites off Tanzania they were often seen demonstrating behaviours to increase their feeding efficiency by raising their arms into the water column to access greater current speeds above the seabed. They often utilize structures to reach higher into the water column, as demonstrated by the brisingid on the stalk of the *Monorhaphis* glass sponge above (and on page 20). In the image at the bottom of the page two brisingids are on the upright structure and one is on the rock. When other structures were not available they appeared to make a basket-like shape with their arms as shown in the upper image on this page. This is thought to be a typical feeding posture.





***Tromikosoma* sp.**

Echinodermata (Phylum) > Echinoidea (Class) > Euechinoidea (Subclass) > Echinothurioida (Order) > Echinothuriidae (Family)

The taxonomy of the Echinothurioida is complicated and taxonomists are working to revise the understanding of the group. Based on the most recent data the hooves visible on the spines in this animal exclude it from the *Phormosoma* group. There are eight possible genera with hooves on the spines but the ambulacral plating strongly suggests a *Sperosoma* or a *Tromikosoma. Tromikosoma australe* is a possible species. The dark tips of the aboral spines are venom-bearing tissues. Echinothuriids are deposit feeders, they move over the sediment, feeding on material that has settled on the seabed from the water column. The image below shows the track this animal has made during this process.

***Phormosoma* sp.**

Echinodermata (Phylum) > Echinoidea (Class) > Euechinoidea (Subclass) > Echinothurioida (Order) > Phormosomatidae (Family)

This is a species of *Phormosoma* (note the absence of hooves on the spines). If it is a described species, which is not guaranteed owing to the lack of study in this area, it is most likely *P. rigidum* because of the straight aboral spines evident in the images. The dark, swollen spine tips mark the poison-bearing spines. Hypertrophied pedicellariae can be seen around the periphery.

Phormosoma is relatively well documented around Africa. At some deep sites off West Africa it is the most abundant species on gently sloping seabed.

Note the small purple animal next to the echinoid. This appears to be a small annelid or holothurian associated with these animals. A very similar animal was seen in images of a number of different specimens including the holothurian *Benthodytes* (right).

***Benthothuria* sp.**

Echinodermata (Phylum) > Holothuroidea (Class) > Aspidochirotida (Order) > Synallactidae (Family)

Benthothuria sea cucumbers can be quite large and their watery connective tissue means that out of water they have the feel of a football. This high water content means they are almost neutrally buoyant at the seabed and use this to easily rise into the water column to avoid disturbance or to move to new food sources.

Two species of *Benthothuria* were observed off Tanzania, the pale purple one in the upper image was seen on more than one occasion at the deeper sites (2400 and 2600 m) while the dark purple specimen (lower image) was found occasionally at 1600 m depth.

Benthothuria cristata is a possible species identification for the upper image. It is well known from the northern Indian Ocean, recorded on the Pakistan margin and the Bay of Bengal. No *Benthothuria* species have been reported from the previous expeditions to the western Indian Ocean.

***Paelopatides* sp.**

The only observation of this animal from the Tanzania field work. It is likely *Paelopatides* sp.

Echinodermata (Phylum) > Holothuroidea (Class) > Aspidochirotida (Order) > Synallactidae (Family)

Paelopatides sp. was seen on a single occasion at 2600 m, the deepest of the sites visited for this work. The genus has not been recorded before off East Africa.

The taxonomy of *Paelopatides* is complicated and identification from photographs is not possible without a specimen to examine but a number of other members of the genus have been found in the wider Indian Ocean. These include *Paelopatides dissidens* (1269 m, Indian margin), *P. gelatinosus* (4787 m, Andaman Sea), *P. insignis* (1220 m, Bay of Bengal), *P. mammillatus* (2710 m, Arabian Sea), *P. modestus* (896m, Indian margin), *P. mollis* (477 m, Bay of Bengal), *P. ovalis* (815-930 m Bay of Bengal), *P. quadridens* (660-3035 m, Indonesia, Sumatra) and *P. verrucosus* (896-1251m, Indian margin).

***Synallactes* sp.**

Synallactes sp. moving over hard substratum

Echinodermata (Phylum) > Holothuroidea (Class) > Aspidochirotida (Order) > Synallactidae (Family)

This holothurian was seen at 675 m water depth off Mozambique. It is a species of *Synallactes*. *Synallactes horridus* and *S. laguardai* are reported from the area with *S. horridus* collected from similar depth (900 m) off Mozambique.

The photograph shows this holothurian has four rows of dorsal papillae, a row of larger papillae laterally and a row of smaller tube feet ventrolaterally. The appendages are close to the description of *S. horridus*, but examination of the ossicles of a specimen under a microscope would be required to confirm the species identification.

***Benthodytes* sp.**

Echinodermata (Phylum) > Holothuroidea (Class) > Elasipodida (Order) > Psychropotidae (Family)

The sea cucumbers shown on this page are species of the genus *Benthodytes*. There are twelve recognized species in the genus of which at least two were encountered off Tanzania (images above and right). *Benthodytes* was found at all the depths studied.

The individuals shown the upper images are unidentified. The *Benthodytes* in the lower images on the right were the most abundant of the benthic megafauna at the deeper sites and were occasionally encountered at the shallower locations. A likely identification is *Benthodytes typcia,* which is known from samples collected from slightly deeper water (2700-3600 m) off South Africa, Mozambique and Madagascar during the 1950-1952 *Galathea II* expedition. Also known from South Africa and Mozambique are *B. plana* and *B. sanguinolenta* (widely distributed globally).

Benthodytes was observed to swim on a number of occasions during ROV video observations. In these cases swimming may have been in response to physical disturbance caused by turbulent water from the vehicle's thrusters but it is thought that they may also swim in order to travel short distances to reach richer feeding areas.

***Psychropotes* sp.**

Echinodermata (Phylum) > Holothuroidea (Class) > Elasipodida (Order) > Psychropotidae (Family)

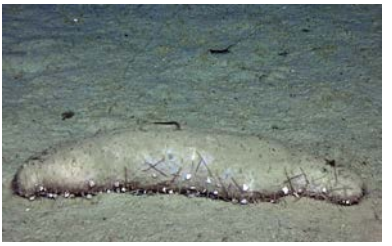
This poor quality image is included because it is the only observation of *Psychropotes* sp. from the Tanzania fieldwork. *Psychropotes* sp. is a cosmopolitan genus of holothurian found throughout the deep oceans of the world.

The large sail-like structure is a single extended dorsal papilla which it may use like a sail to aid movement to other feeding locations. Four species of *Psychropotes* were collected in the western Indian Ocean during the *Galathea II* (1952) and *Mabahiss* (1934) expeditions; *P. belyaevi*, *P. longicauda*, *P. semperiana* and *P. verrucosa*.

***Mesothuria* sp.**

Echinodermata (Phylum) > Holothuroidea (Class) > Aspidochirotida (Order) > Mesothuriidae (Family)

Mesothuria was only encountered at the sites deeper than 2000 m off Tanzania. There are three deep-sea species of *Mesothuria* described in the Indian Ocean – *Mesothuria oktaknemoides* (2253m off India), *M. multipes* (Sri Lanka, Laccadives and Pacific Ocean 724-4066m) and *M. rugosa* (448-1463 Sumatra and off Zanzibar).



Mesothuria multipes has a covering of small evenly distributed tube feet which may not be apparent in photos. *Mesothuria rugosa* is the closest geographically in terms of previously recorded species. It is reported to have a uniform covering of very thin papillae arranged in broad bands, but these are probably difficult to see in photos. Other Indian Ocean *Mesothuria* species, found shallower than these observations are *M. abbreviata* (550m), *M incerta* (648m) and *M. squamosa* (802m).

Mesothuria and some other holothurians are known to place foreign particles over their body. This appears to the be case in these images, where the *Mesothuria* specimens are covered with foraminiferans, possibly *Rhabdammina* sp.

Enypniastes exima

Echinodermata (Phylum) > Holothuroidea (Class) > Elasipodida (Order) > Pelagothuriidae (Family)

The red, barrel-shaped body and large veil with twelve podia indicate that this is the one known species in the genus *Enypniastes*. It is a cosmopolitan species found over a depth range from 700-5000 m globally. Although juveniles may be found further up in the water column adult animals are generally within a few metres of the seabed; they are benthopelagic. It is thought that they feed on the seabed sediment but then lift up into the water column when not feeding, perhaps to avoid predators or move to new areas to feed. Off Tanzania they have only been seen swimming. The gut, visible through the transparent epidermis, appears full of sediment in each case.

Enypniastes exima is occasionally encountered by ROV teams operating at deep-sea oil and gas exploration and production sites off east and west Africa. Owing to its appearance in video, in the industry it has been dubbed the "headless-chicken-fish" and the ROV video clips of this unfamiliar creature can be famous on board oil rigs.



Pelagothuria natatrix

Echinodermata (Phylum) > Holothuroidea (Class) > Elasipodida (Order) > Pelagothuriidae (Family)

Photographs and footage of this animal are very rare. It is the only true pelagic holothurian known (probably the only truly pelagic echinoderm). It spends its entire life in the water column. Swimming is not only a means to find a new feeding area on the seabed as is the case with most of the other swimming sea cucumbers. The "Umbrella" structure is used to propel the animal as it swims. The body of the animal hangs below it. The animal's mouth is facing upwards in the centre of the umbrella to catch food particles. It is a poorly known species but it appears to be widely distributed in the world's oceans from 600-4500 m depth.

***Peniagone* sp.**

Echinodermata (Phylum) > Holothuroidea (Class) > Elasipodida (Order) > Elpidiidae (Family)

This small animal was encountered at 1600 m in time-lapse photography, apparently feeding on the seabed. It was also recorded at 2600 m swimming in the water column. Although *Peniagone* can make up important contributions to deep sea biomass it was not common off Tanzania. There are over thirty described species of *Peniagone* and identification to species requires inspection of dorsal papillae and examination of calcareous deposits (ossicles) within the epidermis. This is not possible from photographs. The genus *Peniagone* has also been recorded off Mozambique at 1550 m depth but again, it was not identified to species.

Industry ROV observations have been valuable to scientists working to understand the ecology of this species. The first record of high densities of *Peniagone* in the water column were made by scientific submersible dives off California but subsequently such aggregations have been reported by ROV teams operating at hydrocarbon exploration sites off west Africa.

Chordata

The term "fish" encompasses both jawless and jawed fishes. The jawless fish (Agnatha) include the hagfish (opposite) which were attracted to the baited camera experiments at several of the sites. The hagfish aside, most fishes recorded in the fieldwork were jawed (Gnathostomata) of which there are four classes: Elasmobranchii (sharks, rays and skates), Holocephali (ghost sharks and rabbitfish), Sarcopterygii (lobe-finned fish) and the Actinopterygii (ray-finned fishes). Species from three of these classes were found at the study sites.

Elasmobranchs have cartilaginous skeletons, rigid dorsal fins, and 5-7 sets of gills opening individually to the outside. The body form varies between the streamlined sharks and the flattened body of the rays and skates. There was interesting elasmobranch diversity off Tanzania, with several observations the first for the area. The examples shown in this section include some typical deep-sea shark species, some unusual skates and even a deep water observation of a hammerhead normally expected at much shallow depths.

The class Holocephali are the Chimaeras, which were formerly grouped within the Elasmobranchii. The Holocephali was represented by three species, one of which forms an important part of the scavenging assemblage.

Most commercially important fish are actinopterygians (bony fish). The class is highly diverse, from the "typical", torpedo-like fish shape of the tuna or mackerel, to the flatfishes and many others such as the bizarre ocean sunfish. Actinopterygians were encountered throughout the water column. Schools of yellowfin tuna aggregating in the surface waters (below) would follow the ROV to over 1000 m depth while eelpouts and cusk-eels appeared to be attracted to the subsea structures at the seabed.

Finally the lobe-finned fish (Sarcopterygii) are largely a fossil group. Living representatives include coelacanths and lungfish. Famously, living coelacanths were first rediscovered off South Africa in a fisherman's catch in 1938. They have since been discovered in various locations in the western Indian Ocean off Madagascar, the Comoros Islands and Tanzania. Suitable coelacanth habitat was not encountered in ROV studies off Tanzania. Theyrequire rocky areas and caves and are found in shallower water than this study area.

Above: *Eptatretus* sp?

Above: *Myxine* sp?

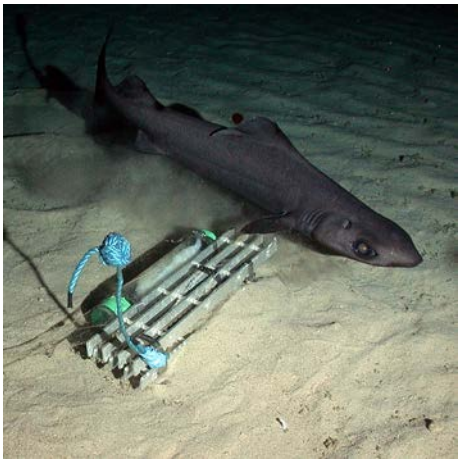
Hagfish

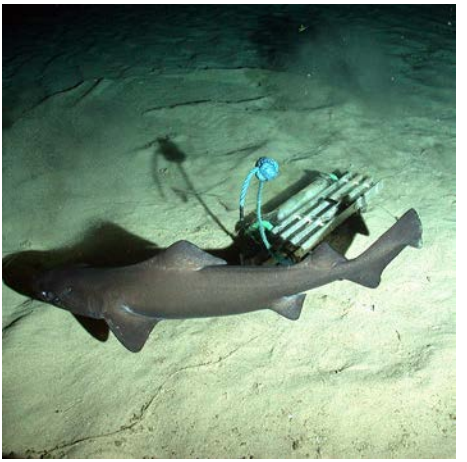
Chordata (Phylum) > Agnatha (Superclass) > Myxini (Class) > Myxiniformes (Order) > Myxinidae (Family)

At least two distinct hagfish species were recorded in images from the baited time-lapse camera deployments at Ngisi-1, Kamba-1 and Pweza-3. These are the first records of hagfish from the deep western Indian Ocean. Famous for the quantities of slime they can produce, hagfish are prolific scavengers that can be found in high abundances at food falls in the deep sea.

The pink animal shown above left and at the bottom is a species of *Eptatretus*. Unusually it has nine pairs of gill openings. No nine-gilled hagfish has been described in the scientific literature. There can be variation of plus/minus one gill opening for these species but it is possible that this is an undescribed species.

The paler, more slender hagfish (centre) is likely a species of *Myxine.* Albinism has been recorded in *Eptatretus* but the slender appearance of these individuals suggests they are a separate genus.

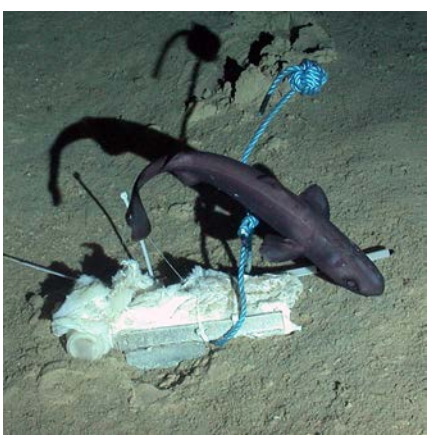




***Centrophorus granulosus* (Gulper shark)**

Chordata (Phylum) > Elasmobranchii (Class) > Squaliformes (Order) > Centrophoridae (Family)

Gulper sharks were seen almost exclusively at baited camera experiments revealing their use of scavenging as a feeding strategy. They attended the baited cameras at all the sites at which it was deployed. There was a variety of subtly different colours and sizes of the gulper sharks in the photographs (above and main image opposite). These could be interpreted as different species but differences in ROV lighting and cameras must not be discounted. Recent molecular evidence indicates that these morphological variants are not separate species, but different stages of maturity within the same species – *C. granulosus*. Very little is known about these deep-sea sharks despite their wide distribution, so photographic data, such as these, are valuable to help to understand their distribution and behaviour.



***Centroscymnus* sp.**

Chordata (Phylum) > Elasmobranchii (Class) > Squaliformes (Order) > Somniosidae (Family)

Most of the sharks photographed at the baited camera experiments were gulper sharks but this one is different. *Centroscymnus coelolepis* is a likely species identification but this shark is small for that species.

Sphyrna lewini at the seabed at over 1000 m depth

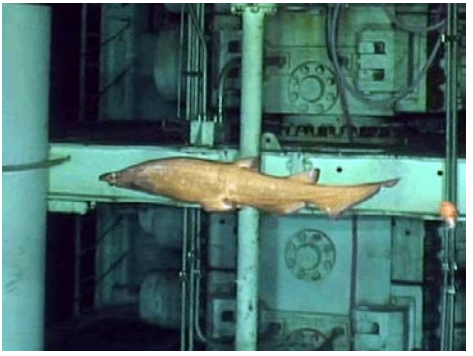
***Sphyrna lewini* (Scalloped Hammerhead)**

Chordata (Phylum) > Elasmobranchii (Class) > Carcharhiniformes (Order) > Sphyrnidae (Family)

The scalloped hammerhead (*Sphyrna lewini*) is distinguished from other species of hammerhead by the median and two smaller lateral indentations on the cephalic foil and the relative size and shape of its fins.

Sphyrna lewini is well documented from surface waters of the open ocean and from shallow waters off Tanzania. This observation is notable because of its depth. At the seabed 1042 m below the surface, this is the deepest accurately reported occurrence of the species and first deep-water record from the Indian Ocean.

Along with data from animals studied elsewhere with pop-up satellite tags there is increasing evidence that deep diving is an important behaviour for *S. lewini*. This behaviour may enable it to feed on deep-water fishes and cephalopods.



Brief sighting of *Apristurus* in front of a subsea structure at 1300 m depth

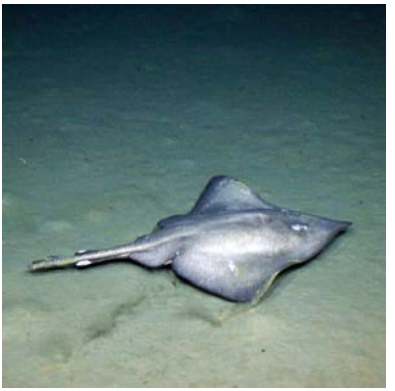
***Apristurus* sp.**

Chordata (Phylum) > Elasmobranchii (Class) > Carcharhiniformes (Order) > Pentanchidae (Family)

This image shows a catshark of the genus *Apristurus* in front of the blow-out preventer at the seabed. It was a fleeting view of the shark which swam away rapidly as the ROV approached only allowing a few seconds of footage to be collected.

This individual is fairly stout with a dorsal "hump" which tapers down to the head. There are several species that have a similar shape with coloration ranging from dark grey to brown, but none that quite match the colour and shape of this individual (care must be taken in interpretation of colours described from captured specimens when identifying from photographs collected with ROV cameras and lights).

***Bathyraja* sp.**

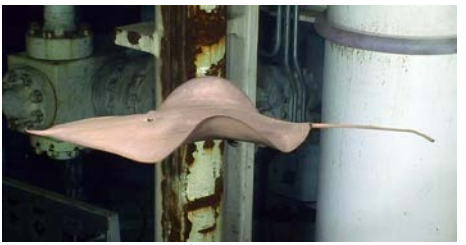


Bathyraja at the seabed at over 2400 m depth

Chordata (Phylum) > Vertebrata (Subphylum) > Elasmobranchii (Class) > Rajiformes (Order) > Arhynchobatidae (Family)

This large skate was observed swimming gracefully over the seabed at 2400 m water depth. It is impossible to identify with any certainty from the images but based on its general appearance experts (including the scientist who described the species) suggest it is most likely *Bathyraja tunae* which was first described from deep water in the Mozambique Channel in 2005.

***Anacanthobatis ori* (Legskate)**



View of the ventral side of the legskate in which the modified pelvic fin is clearly visible

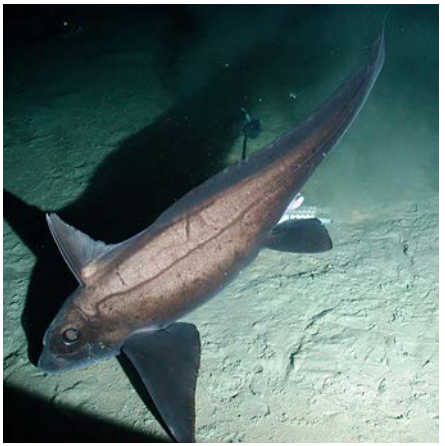
Rajiformes (Order) > Anacanthobatidae (Family)

A "legskate" near the blow-out preventer at 1620 m depth. This fish generated much interest among offshore workers because they joked they had found "the missing link", a fish with legs. In fact, in the family Anacanthobatidae (legskates), the "leg" is the modified pelvic fin, which is divided into two distinct lobes.

The example shown here is likely a *Sinobatis* or *Anacanthobatis* species. This is based on the elongated pointed snout, very slender tail and elongated low caudal fin. *Anacanthobatis ori*, a small species, is the most likely identification based on the plain brown colour, nasal curtains which do not overlap the mouth corners. The water depth and known distribution (Mozambique) also support this identification.

If it is *Anacanthobatis ori* this observation from Tanzania would be a new locality record, as it is currently only known from further south.

Chimaera (Ghost Sharks) Chordata (Phylum) > Holocephali (Class) > Chimaeriformes (Order) > Chimaeridae (Family)



Opposite and above: *Hydrolagus affinis*

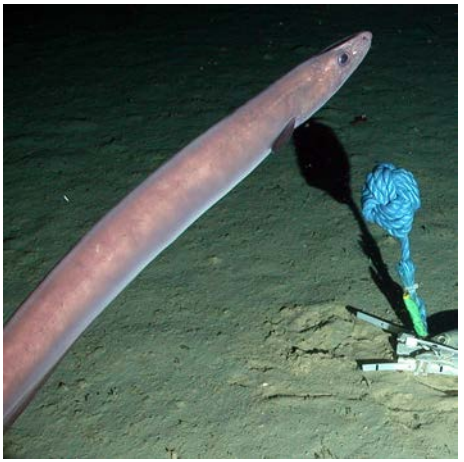
Above: *Hydrolagus africanus?*

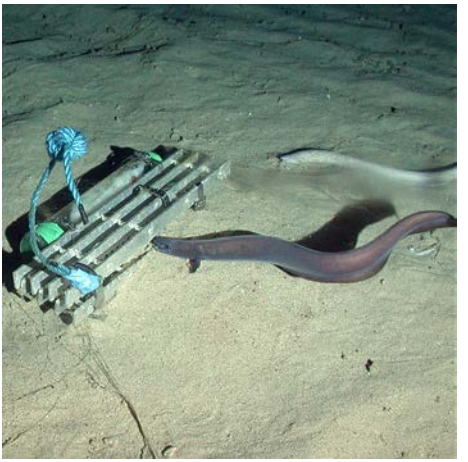
Three species of chimaera were observed off Tanzania from two families. The animals in the image opposite and the upper image on this page are likely *Hydrolagus affinis*, a widely distributed chimaera found at water depths from 1000-3000 m (including the western Indian Ocean). The middle image is a separate species, seen only on a single occasion. The proportionally larger eye (one third the size of its head), large pectoral fins, overall size and colour and long tail filament (whip) as well as the characteristic dip in the second dorsal fin indicate that it could be *Hydrolagus africanus.*

Hydrolagus was only seen at the Mzia sites (1600-1770m). They are generally considered opportunistic benthic feeders, based on the presence of bottom sediment in the guts of captured specimens. It seems that they can feed on fish and invertebrates (both hard and soft) and are likely to make use of scavenging, based on their appearance at baited cameras here. They have also been observed feeding on hydrothermal vent mussels at the Mid-Atlantic Ridge. They feed by crushing their prey against hypermineralised plates in their mouth. Males are clearly distinguished from females by having fleshy claspers behind the pelvic fins, as seen in the upper image. Fertilization in females appears to be internal, with the female subsequently releasing the fertilised eggs.

Longnose/Paddlenose Chimaera Rhinochimaeridae (Family)

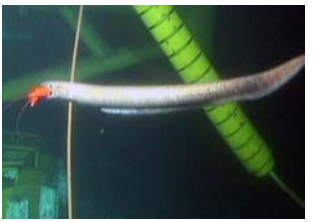
This image shows the only fleeting view of a member of the family Rhinochimaeridae as it swam past the ROV. There are eight species in the family and the ecology is poorly known. The species *Rhinochimaera africana* is reported from South Africa, Mozambique and Madagascar but experts suggest this is a different, possibly new species.





Synaphobranchidae (Cutthroat eels)

Chordata (Phylum) > Actinopterygii (Class) > Anguilliformes (Order) > Synaphobranchidae (Family)



The cutthroat eels, as the synaphobranchids are known, are a large family of deep-sea eels. They are well reported from the western Indian Ocean and were seen on numerous occasions off Tanzania. They were most common at the baited time-lapse camera experiments but were also occasionally seen elsewhere.

The two upper images are individuals are from the genus *Synaphobranchus*, possibly *S. kaupii*, a deep, cold water species. They feed on benthopelagic crustaceans, cephalopods and small fish, indeed SERPENT observations have captured images of them during feeding on a decapod (above right). Their appearance at baited cameras shows they also utilize scavenging opportunities, but studies have suggested that they can only access food-falls once sharks have pierced the tough skin of the carcass. The lower images show a different, less common, species at the baited camera. Its dorsal fin originates much closer to its head. It may be a species of *Ilyophis*.

***Nettastoma* sp. (Sorcerer eel)**

Chordata (Phylum) > Actinopterygii (Class) > Anguilliformes (Order) > Nettastomatidae (Family)

This eel was observed at 600 m depth off Mozambique. It is most likely *Nettastoma* sp. This identification is based on the elongate body that is cylindrical in the anterior part and compressed posteriorly. It has a long head and pale whitish-brown ventral colour. The posterior part of dorsal and anal fins have a black margin. They are known as duckbill eels because of the shape of their snout, or alternatively, sorcerer eels.

Halosaur (Spiny eel)

Chordata (Phylum) > Actinopterygii (Class) > Notacanthiformes (Order) > Nettastomatidae (Family)

Known as a spiny eel, the example shown here resembles *Aldrovandia* sp., of which there are six known species. As demonstrated by the animals in the video footage collected off Tanzania, halosaurs have a distinctive swimming motion in which it appears that only the tail moves. They swim slowly just above the sediment, supporting data that suggests halosaurs feed on benthic crustaceans and polychaetes.

It was difficult to collect images of halosaurs because they were easily disturbed by the presence of the ROV and they did not appear to feed at the bait in the time-lapse camera experiments (there were a couple of chance distant observations in the background of images). Despite this, many fleeting glances of individuals at all of the study sites suggest halosaurs are important components of the fish fauna in the deep western Indian Ocean.

Ophidiidae (Cusk-eels)

Bassozetus sp. swimming slowly past the ROV

Chordata (Phylum) > Actinopterygii (Class) > Ophidiiformes (Order) > Ophidiidae (Family)

The Ophidiidae (commonly known as cusk-eels) is a diverse family of over 250 species of eel-like fishes. The image on the right shows a typical ophidiid body shape, with a large head and mouth tapering to thin tail.

Ophidiids are distributed globally over a large depth range, from shallow water to hadal depths, indeed, the family includes some of the deepest recorded fishes. They are omnivorous, reportedly feeding on invertebrates and small fish. Although one of the more common groups of fish in the area, they were not regularly observed at baited camera experiments but studies by other scientists have suggested they may utilise food-falls to feed on the smaller scavenging organisms attracted to the food source.

Several representatives of the Ophidiidae were observed off Tanzania. The most distinctive, and those of which sufficient video footage was obtained, are shown here but there were no doubt others.

Dicrolene sp. at 1300 m depth

***Dicrolene* sp.**

Chordata (Phylum) > Actinopterygii (Class) > Ophidiiformes (Order) > Ophidiidae (Family)

Dicrolene sp. is identified by the large eye and prominent white spotted lateral line. The elongate pectoral and pelvic fin rays are also important but not visible in this image. Zoomed in video footage was required to see those features.

Off Tanzania it was seen at the Ngisi-1 site, close to a large wood-fall (p. 17). As noted elsewhere in this guide, wood-falls in the deep sea serve as a food source and hard substratum, dramatically increasing the benthic biological diversity in the immediate vicinity

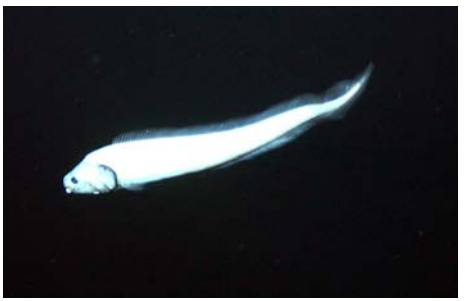
***Acanthonus armatus* (Bony-eared Assfish)**

Chordata (Phylum) > Actinopterygii (Class) > Ophidiiformes (Order) > Ophidiidae (Family)

With its large head, tapering body and distinct opercular spine *Acanthonus armatus* is readily identifiable. Unusually for a deep-sea fish it has a common name: "bony-eared assfish".

It is found in the deep waters of the topics between 1100 and 4400 m, where it can be common. Indeed, it was the most common fish encountered at the deeper sites off Tanzania but was not seen at all shallower than 2400 m. The observations at Zafarani and Lavani support the suggestion that it lives in the water column just above the seabed (benthopelagic). The individuals shown here are small, approximately 20 cm in length but they can reach up to 37 cm.

This species is reported to have the smallest relative brain size of all the teleost fish.



***Bassogigas* sp.**

Chordata (Phylum) > Actinopterygii (Class) > Ophidiiformes (Order) > Ophidiidae (Family)

Bassogigas sp. is a poorly known species with few specimens studied by scientists. There are two accepted species in the genus but the taxonomy has undergone recent revision so older literature may refer to several other members of the genus.

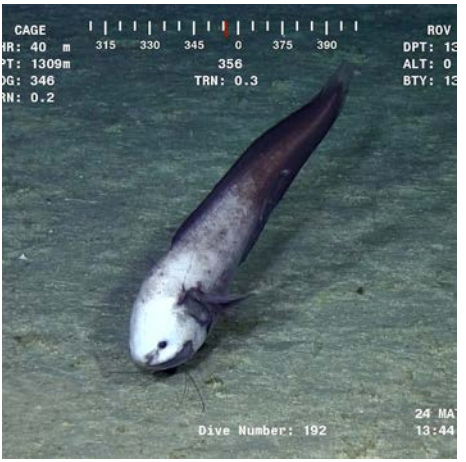
In the western Indian Ocean, *Bassogigas* has been collected from deep water to the north of Madagascar and it is has been found in low numbers at several other sites in the Atlantic, Indian and Pacific Oceans. Off Tanzania at the sites studied here, it was only observed at the deepest locations.

***Bassozetus* sp.**

Chordata (Phylum) > Actinopterygii (Class) > Ophidiiformes (Order) > Ophidiidae (Family)

There are thirteen described species of *Bassozetus,* six of which are known from the western Indian Ocean. They have been recorded from deep water off Kenya, Madagascar and Mozambique at depths similar to the study sites described here. They were mostly collected during the *Galathea II* Expedition in 1952 and the International Indian Ocean Expedition in 1964. *Bassozetus galatheae* (named after the ship that discovered it), *B. glutinosus*, *B. compressus, B. elongatus, B. levistomatus* and *B. robustus* are the species known from the western Indian Ocean. It is not clear which species the individuals shown here belong to, if they are the same species or even if they belong to one of the described species. To determine the species identification it is necessary to count the fin rays, among other characteristics not visible in the photographs and videos.

In the upper image there appeared to be an association between the antipatharian (black coral) and the cusk-eel (also see p. 29). Time-lapse footage showed the fish remaining in close proximity to the antipatharian for an extended period of time. The individual shown in the image on the right was seen at the deepest study site. It was the only example of an ophidiid attracted to bait deployed at the seabed but did not attempt to feed during the observation. It was approximately 0.5 m in length. The modified pelvic fins characteristic of the group can be seen clearly in the lower image.



***Xyelacyba myersi* (Gargoyle cusk-eel)**

Chordata (Phylum) > Actinopterygii (Class) > Ophidiiformes (Order) > Ophidiidae (Family)

Typically gargoyle cusk-eels (*Xyelacyba myersi*) are white in colour, grading back to a darker brown tail with brown fins as shown by the specimen in the image on the right. Assuming the brown animal in the left-hand image is the same species, the coloration is unusual. The white animal in the left-hand image is the same individual as the animal in the right-hand image.

Based on records to date, *Xyelacyba myersi* is expected to be globally distributed on continental slopes in tropical and sub-tropical latitudes, at water depths between approximately 900 and 2500 m. It has not yet been recorded over large parts of the expected range, including the eastern Pacific. These observations from 1300 m at the Ngisi-1 site are likely the first records from the western Indian Ocean. Previous observations of *Xyelacyba myersi i*n the Indian Ocean are limited but there are some records from the continental slope west of Australia.

These *Xyelacyba myersi* specimens were seen swimming over bedforms (note left-hand image). The bedforms comprised dune-like features of relatively coarse sediment. There were few benthic megafaunal organisms inhabiting this area but benthopelagic animals were more common (e.g. *Benthocodon* p. 25). The swimming motion demonstrated here, in which the fish drifts slowly in the current with its head towards the seabed, is consistent with feeding on suprabenthic invertebrates.

***Psychrolutes* sp. (Blobfish)**

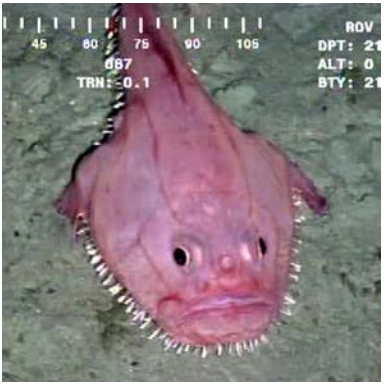
Chordata (Phylum) > Actinopterygii (Class) > Scorpaeniformes (Order) > Psychrolutidae (Family)

Famously voted the world's ugliest animal in 2013 based on the photograph of a specimen captured and returned to the surface, *Psychrolutes* sp. has the common name "Blobfish". It appears to be relatively common locally off East Africa. It was seen at the Kamba and Pweza sites in Block 4 at around 1300 m sites off Tanzania but it was not encountered at the deeper sites.

When *Psychrolutes* was found, it was invariably associated with some kind of structure. This would either be a rock with some coral epifauna or even the blow-out preventer (part of the drilling infrastructure). It was also attracted to the baited time-lapse camera experiments but did not appear to feed. The blobfish is a "sit and wait" ambush predator and probably doesn't have jaws that can rip apart a fresh carcass. It most likely employs a strategy of attending a food-fall (in this case the bait) in order to feed on smaller organisms that are also attracted in great numbers.

Three species of *Psychrolutes* are known from the Indian Ocean. *Psychrolutes macrocephalus* has been recorded off Mozambique to 1300 m depth while *P. marcidus* (to 1700 m) and *P. occidentalis* (to 700 m) were found off Australia.

***Chaunax* sp. (Tasselled coffinfish)**



Chordata (Phylum) > Actinopterygii (Class) > Lophiiformes (Order) > Chaunicidae (Family)

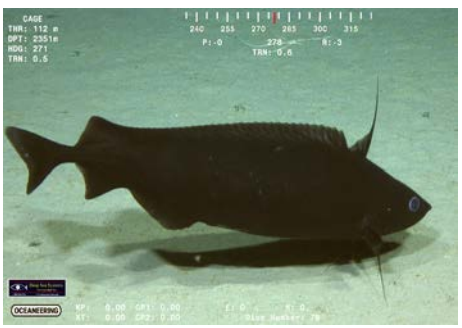
The specimen in the photograph was observed at 670m water depth off Mozambique, just south of the southern most Tanzania study sites. It is a member of the *Chaunax fimbriatus* group, and perhaps even *C. fimbriatus*. The systematics of the Indo-Pacific chaunacids has yet to be resolved.

***Pachycara* sp. (Eelpout)**

Chordata (Phylum) > Actinopterygii (Class) > Perciformes (Order) > Zoarcidae (Family)

These eelpouts were often seen close to the blow-out preventer and at some locations several individuals were seen at the baited camera. In each case they are rather inactive. In the time-lapse footage an individual would often remain in the same position for several hours.

The eelpouts seen here are a species of *Pachycara*. The genus is well documented off the west coast of Africa but given the intervening area and different slope fauna in the tropical western Indian Ocean, the Tanzanian species could be undescribed. The nearest known Indian Ocean *Pachycara* are abyssal (>4000 m) from the Arabian Sea.

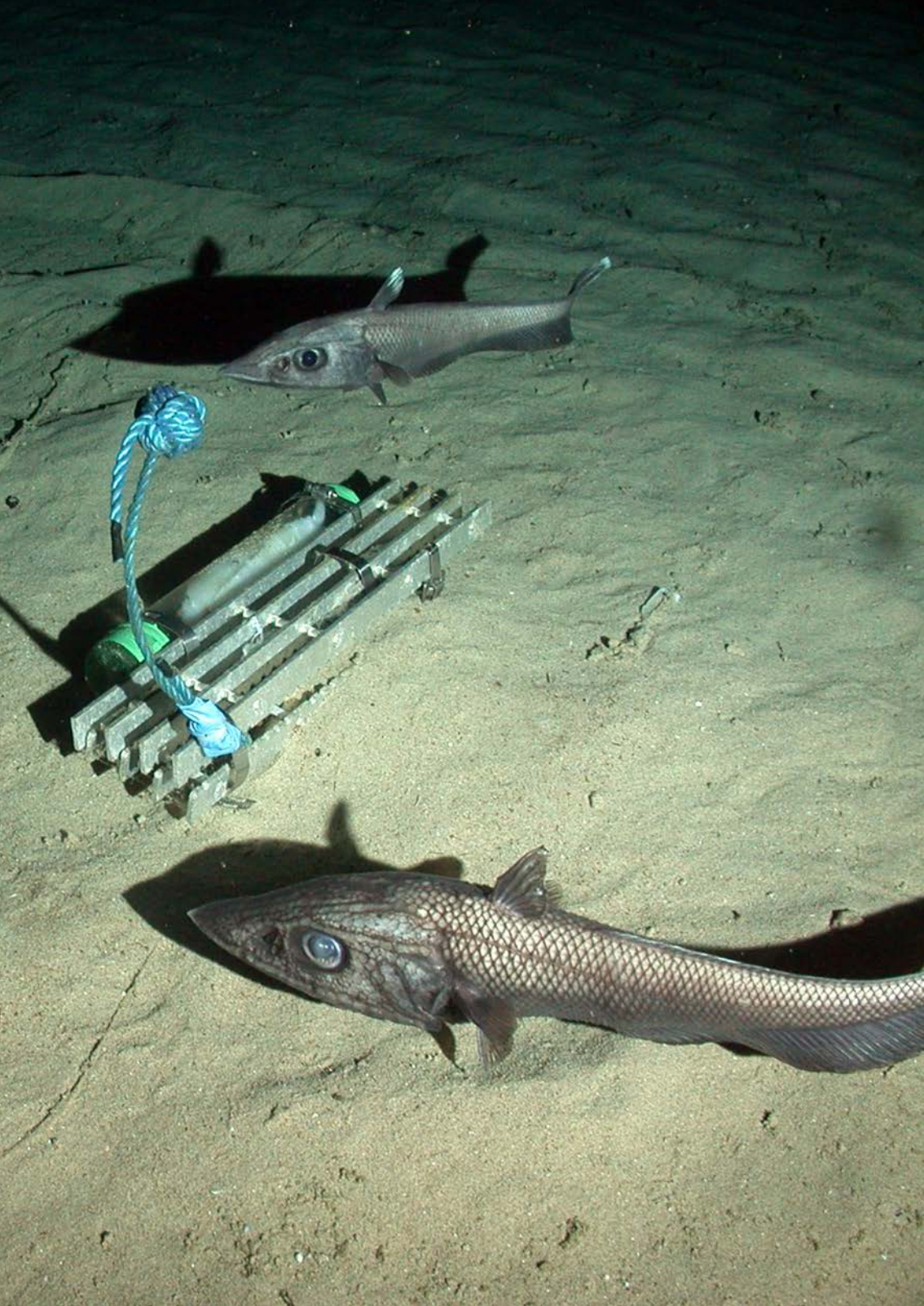


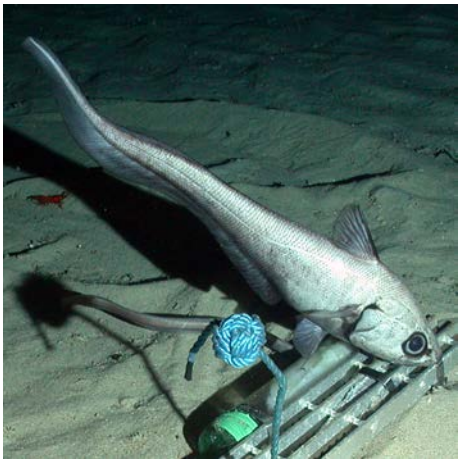
***Antimora rostrata* (Blue Hake)**

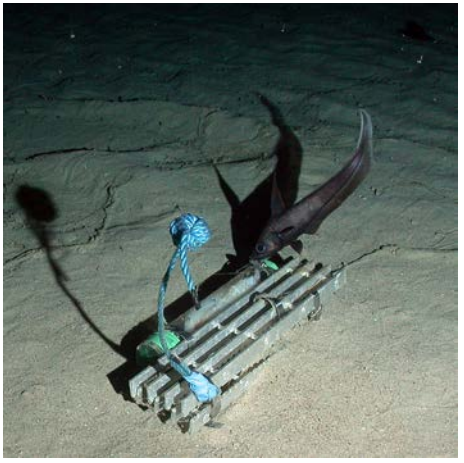
Chordata (Phylum) > Actinopterygii (Class) > Gadiformes (Order) > Moridae (Family)

Known as a blue hake or black (or violet) cod, *Antimora rostrata* is widely distributed globally on the continental slope to depths of over 3000 m. In the western Indian Ocean it is recorded from Mozambique and Madagascar, and now Tanzania.

Off Tanzania *A. rostrata* was an occasional visitor to baited time-lapse camera deployments (Mzia-2 and Pweza-3), suggesting that it utilizes scavenging as a feeding strategy, as documented in other deep-sea studies. In addition, *A. rostrata* was sometimes seen during routine ROV operations. Across both observation methods *A. rostrata* was recorded over the full depth range studied here with the exception of the shallowest site off Mozambique.





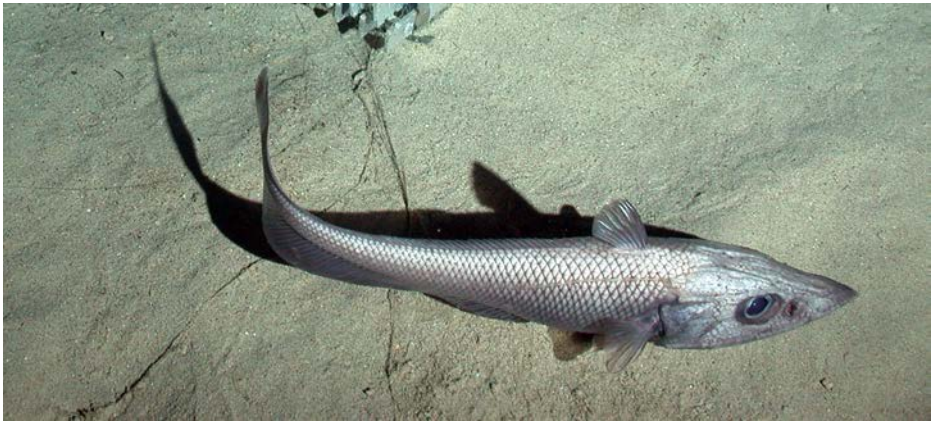


Macrouridae (Grenadiers)

Chordata (Phylum) > Actinopterygii (Class) > Gadiformes (Order) > Macrouridae (Family)

The Macrouridae, known as grenadiers or rattails, is a large, widely distributed family of deep-sea fishes with nearly 400 described species. As demonstrated on the left macrourids have a large head and long tapering body.

Off Tanzania macrourids were seen mostly in still images from the baited time-lapse camera, predominantly at Ngisi-1 and Pweza-3. With so many different species described, and species identity determined by examination of specimens, identification has not been attempted here. However, up to eight separate body shapes were documented suggesting there were multiple species. The three main body shapes are shown here indicating that individuals of the genera *Coryphaenoides* (upper image on this page), *Coelorinchus* (opposite and below) and *Nezumia* (middle image on this page) are present in relatively high abundance between 1000-2000 m in the western Indian Ocean.



***Bathysaurus ferox* (Deep-sea Lizardfish)**

Chordata (Phylum) > Actinopterygii (Class) > Aulopiformes (Order) > Bathysauridae (Family)

Off Tanzania the deep sea lizardfish, *Bathysaurus ferox* was seen in low numbers at the limits of the depth range studied. The lower image is from Kamba-1 at 1380 m depth and the upper is from Zafarani (2600 m). These, and one other example were the only individuals seen but they indicate that it is found throughout the study area. It has been known from the area since the 1930s, there is an excellent drawing in the reports of the *Mabahiss* expedition.

The Kamba-1 observation is shallower than might be expected. *B. ferox* is most commonly found below 2000 m in water cooler than 4°C. At 2.5°C Lavani and Zafarani are well below this and although shallower, Kamba is only slightly warmer (4.4°C).

The identification is confident because there are only two known species of *Bathysaurus* worldwide. *Bathysaurus ferox* is pigmented, as demonstrated in these photographs, but its congener *B. mollis* is neotenic and largely unpigmented (typically a ghostly pale white, with translucent flesh). *B. mollis* extends to greater depths than *B. ferox* but both would be possible in this range.

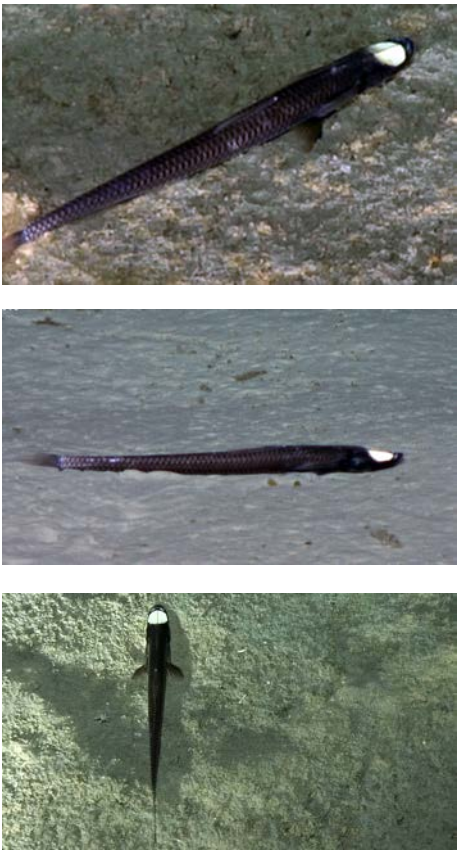
As seen in the images here *B. ferox* tends to rest on the seabed with its head slightly elevated. It is thought to feed primarily on smaller fish and decapod crustaceans, presumably catching those that pass by in the current. These individuals seemed undeterred by the presence of the ROV, remaining in position until the vehicle moved away.

***Ipnops* sp. (Grideye)**

Chordata (Phylum) > Actinopterygii (Class) > Aulopiformes (Order) > Ipnopidae (Family)

The unusual but distinctive fish *Ipnops* sp., with its "eye" and body of starkly contrasting colours appears to be relatively abundant in the western Indian Ocean. It was encountered on multiple occasions in ROV surveys at all of the sites off Tanzania. Despite being one of the more common deep-sea fish in the western Indian Ocean, *Ipnops* is poorly known globally and there are very few images and there is hardly any video footage of it.

There are three described species of *Ipnops* with *I. meadi* and *I. agassizi* the most likely to be found this area. In deeper water off Kenya *I. meadi* (which is known from over 3000 m depth) was collected by the *Galathea II* expedition (1950-52) while *I. agassizi* has been found shallower than 2000 m. In this work off Tanzania *Ipnops* sp. has been recorded from 1300-2600 m. It may therefore represent examples of both species or increase the known range of on or the other.



Examples of *Ipnops* sp. from three sites off Tanzania. Images of this genus were collected at all of the study sites deeper than 1300 m

All the specimens seen off Tanzania have been approximately 10 cm in length. When encountered they often seem undeterred by the presence of the ROV and it is unusual to see them swimming. On the occasions that they do swim it is only for very short distances, approximately 1-2 m, and the motion seems inefficient. They are thought to be sit-and-wait "ambush" predators, like other members of the Aulopiformes.

The eyes are extremely modified into flat, cornea-like organs that cover most of the head, the distinctive white areas shown in the images above. The exact function is unclear but they are light sensitive and may detect bioluminescent prey. Another hypothesis suggests that the eyes may be luminescent themselves and act as lures.

***Bathypterois* sp. (Tripodfish)**

Chordata (Phylum) > Actinopterygii (Class) > Aulopiformes (Order) > Ipnopidae (Family)

Tripodfish (*Bathypterois* sp.) were seen at the shallower sites off Tanzania (Ngisi-1, Pweza-3 and Kamba-1 at approximately 1300-1400 m depth). The species seen here most resembles *B. dubius* but definitive identification is not possible from photographs. Tripodfish are adapted for life on the seafloor. They have highly modified pectoral fins with extended fin rays containing a network of spinal nerves. Tripodfish orientate these modified pectoral fins upwards and forwards in the water column as demonstrated in the images here. Marine biologists have hypothesised that these serve a sensory purpose and are used to detect prey. Primarily *Bathypterois* sp. feed on small benthopelagic, planktonic crustaceans including various shrimp-like organisms that live in the water column just above the sediment.

The pelvic and caudal (tail) fins of tripodfish also have elongate fin rays. These are used by *Bathypterois* to perch on the sediment. In the species shown here the extended pelvic and caudal fin rays are relatively short for the group but in one species, *Bathypterois grallator,* they are very long and the animal is perched well above the sediment surface on three fin rays resembling a tripod, hence the common name. This adaptation is thought to reduce the energy required for this ambush predator to access higher current speeds above the sediment surface and therefore increasing encounters with benthopelagic prey items.

Although tripodfish appear to spend much of their time stationary, waiting for interactions with prey, they do occasionally swim, particularly when disturbed. ROV observations from 1400 m depth off Brazil, collected through the SERPENT Project, have been used to describe the swimming motion in tripodfish. The study showed that the long fin rays affect the mechanics of swimming, making locomotion appear awkward and inefficient. They demonstrate a unique swimming motion, described as "bathypteroiform" in which undulations include the majority of the body. The anal and dorsal fins appear to be only used for stabilisation. To land on the sediment the caudal fin element is lowered from parallel with the seabed during swimming and placed on the seabed after landing of the pelvic fins.

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Study sites

Data were collected at the following hydrocarbon drilling sites. The well names are Kiswahili words. English Translations in brackets. The depth quoted is at the well location, there was some variation in depth with distance from the well.

BG Tanzania:
Ngisi-1 (Cuttlefish): 8° S, 1320 m
Kamba-1 (Lobster): 8° S, 1340 m
Pweza-3 (Octopus): 8° S, 1380 m
Mzia-1* (Barracuda): 9° S, 1580 m
Mzia-2 (Barracuda): 10° S, 1620 m
Mzia-3 (Barracuda): 10° S, 1750 m
Taachui-1* (Manta Ray): 10° S, 980 m
Jodari* (Tuna): 10° S, 1040 m

Statoil:
Zafarani (Saffron) 9° S, 2580 m
Lavani (Vanilla) 9° S, 2400 m
Cachalote*: 12° S, 660 m

*Data collected but no SERPENT visit to the drillship

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Dr Andrew Gates is a deep-sea ecologist based at the National Oceanography Centre in the UK. Andrew has worked extensively off the UK, Ireland and Norway as well as the eastern Mediterranean (Egypt and Libya), East Africa (Tanzania and Mozambique) and in the Pacific (Clarion Clipperton Fracture Zone). Much of his work uses oil industry infrastructure, accessed through the SERPENT Project, to explore the deep sea around exploration drilling operations. Andrew's main aim is to understand the diversity of fauna in these areas and how the species may be impacted by, and recover from, anthropogenic activity.

Left to right: Robert Makowichuk, Andrew Gates, Wlademar Ribiero, Richard Stones and Thierry Matthieu in front of the Millennium 114 ROV on board the *Deepsea Metro 1* on the last field visit of this programme.


BG EAST AFRICA