Submersible observations on the deep-sea fauna of the south-west Indian Ocean: preliminary results for the mesopelagic and near-bottom communities

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The near-bottom and/or mesopelagic communities of three sites in the south-west Indian Ocean were investigated. Vertical stratification of the crow shark (*Etmopterus pusillus*), Gilchrist's orange roughy (*Hoplostethus gilchristi*) and the big-eye dory (*Allocyttus verrucosus*) was extremely pronounced over the Atlantis Bank. Sightings of other members of the near-bottom fauna at both the Atlantis Bank and the Northern Ridge Transform Intersection were also recorded in detail for depths between 750m and 5365m. The mesopelagic community at the third site was compared with similar communities in waters near Japan, namely Sagami Bay and the Sanriku Offing. The single midwater dive illustrated not only our lack of knowledge concerning hydroidomedusae in the midwater zone of the Indian Ocean, but both the cnidarian and ctenophore communities in general. In comparison to Sagami Bay and the Sanriku Offing ctenophores were scarce and calycophorans rather than physonects were the dominant siphonophores. The lobate ctenophores *Kiyohimea* and *Bathocyroe* were reported for the first time in the Indian Ocean, as was the ctenophore class Thalassocalycidae, proving the cosmopolitan distributions of these groups. A comparison of both species composition and vertical distribution data was done between this study and previous reports. This illustrated that a great deal of work still needs to be done in order to even partially understand the species compositions, structure, and ecological interactions shaping the midwater community of the south–west Indian Ocean and indeed, the Indian Ocean in general.

Key words : Indian Ocean, submersible, near-bottom, midwater, mesopelagic, gelatinous

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1. Introduction

Information on the meso- and bathypelagic fauna of the Indian Ocean is sparse and confined almost exclusively to that which can be characterized by towed nets and dredges (e.g. Bekker and Chuvasov, 1988, Duhamel, 1984, Parin and Prut'ko, 1985, Vereshchaka, 1990). This is especially true of the gelatinous midwater community where information is practically restricted to the hydrozoan medusae (see Navas-Pereira and Vannucci, 1991, and references therein). During 1998, the Japan Marine Science and Technology Center conducted a series of cruises in the southwest Indian Ocean - MODE '98 Legs 3 and 4. One of the authors (D.L.) was present on Leg 4 of the MODE '98 cruises and, although all but one of the crewed submersible dives focused on geology and geophysics, the video record was kindly made available to him for analysis of the biological communities. The majority of dives focused on the Atlantis Bank (32º43'S, 57º17'E) although several dives were also made at the Northern Ridge-Transform Intersection (31º58'S, 57º07'E). The single midwater dive was conducted over a rise in the ocean floor south of Mauritius (29º43.40'S, 59º04.00'E) (Fig. 1).

2. Materials and Methods

Leg 4 of the MODE '98 cruise took place from the 21st of October to the 17th of November 1998. During this period, a total of 11 dives were conducted using the Shinkai 6500 crewed submersible. Seven dives focused on the geology and geophysics of the Atlantis Bank (32º43'S, 57º17'E), three dives investigated the geology and geophysics of the Northern Ridge-Transform Intersection (31º58'S, 57º07'E), and a single midwater dive investigated the mesopelagic community south of Mauritius (29º43.40'S, 59º04.00'E) on the16th of November 1998. During the geological dives at the Atlantis Bank, the lights of the Shinkai 6500 were turned on at 100m and a video record was taken of the water column during descent at 60m/min. Transects were conduced up the Atlantis Bank from a depth of 4910m to the summit at 750m. The depths investigated at the Northern Ridge-Transform Intersection were between 5365m and 4440m. The single midwater dive reached a depth of 1063m over a bottom depth greater than 3000m. Detailed information on each dive is recorded in the MODE '98 Legs 4 cruise report.

The Shinkai 6500 observational platform included two

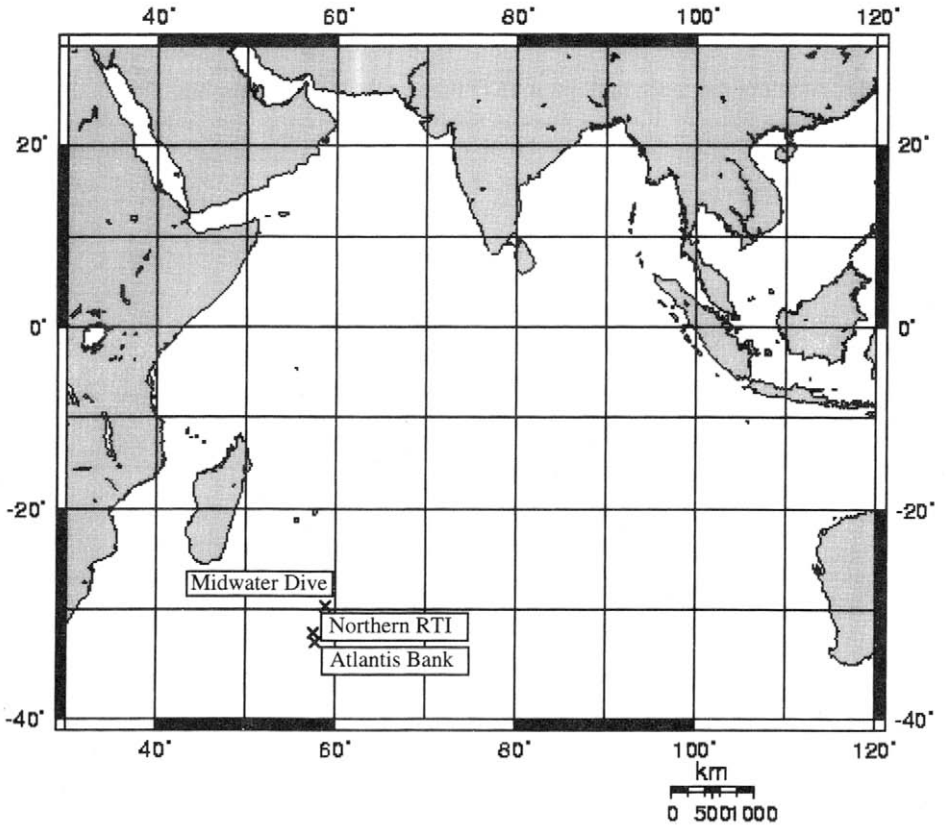

Fig. 1 Map of the survey areas in the south-western Indian Ocean.

3-chip CCD video cameras, one fixed to the forehead of the vehicle and the second on a pan-tilt unit close to the pilot's window. Video footage was recorded onto S-VHS videotapes, which were viewed in their entirety, animals being identified wherever possible. During the midwater dive (6K#468), comments by the observing scientist (D.L.) were recorded on the audio portion of these tapes and the observational database that resulted from this dive therefore consisted both of video-recorded data and live observations made through the observation port of the vehicle. For all other dives, only the video-recorded data were used.

Fig. 2 The gate sampler array attached to the *Shinkai 6500*.

The Shinkai 6500 was outfitted with seven lights: four 500W halogen lamps, two 1000W halogen lamps and one 250W thallium lamp. Physico-chemical data were recorded during all dives by a Seabird SBE-16 CTD unit attached to a dissolved oxygen meter and fastened to the sample basket. A six-cannister suction sampler was attached to the Shinkai 6500 for the midwater dive to enable the collection of fragile mesopelagic organisms. A series of 4 box-shaped gate samplers (Fig. 2; also Hunt, et al., 1997) were attached in parallel to facilitate capture and in situ observations of large and/or fragile gelatinous organisms.

The dive profile for Dive 6K#468 is shown in Figure 3 with the raw observational data for the common trachymedusa *Colobonema sericeum* overlaid. In previous reports (e.g. Hunt and Lindsay, 1999), only definite identifications were included in the observational database. However, as only a single dive was allocated to midwater surveys in the south-west Indian Ocean, both definite and probable identifications were used. When a probable identification was made that lay outside the distributional range determined using only definite identifications, the video record was reviewed. If identification at the definite level was indeed impossible, this data point was discarded. Abundance data for midwater organisms was normalized over 100m depth intervals to account for the variable times spent in different depth layers.

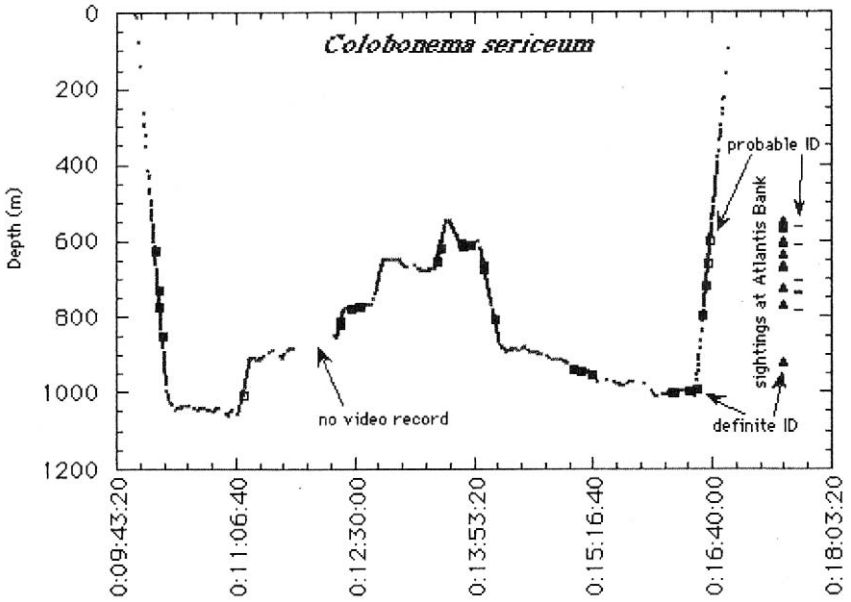

Fig. 3 The dive path for *Shinkai 6500* Dive 468 with raw distributional data for the trachymedusa *Colobonema sericeum* overlaid.

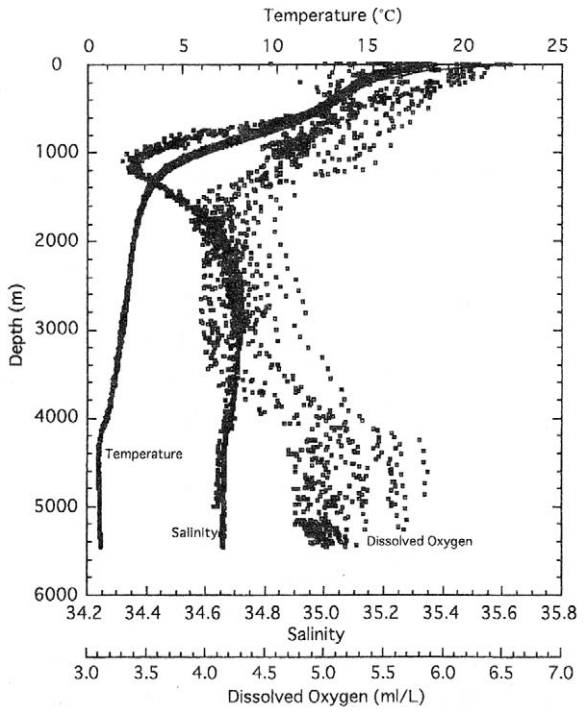

Fig. 4 CTD-DO profile of the water column around the Atlantis Bank (32°43'S, 57°17'E) in October/November 1998.

Comparisons between mesopelagic faunas were conducted using data from the present dive, Shinkai 2000 Dive 945 in Sagami Bay (35º00.5'N, 139º22.0'E) on the 21st of May 1997, and ROV/Kaiko Dive 115 off the Sanriku Coast (39º10.0'N, 144º7.0'E) on the 23rd of April 1999. These dives were chosen for comparison as they correspond to the seasonal equivalents in the Northern Hemisphere for the period during which Leg 4 of the MODE '98 cruise took place.

3. Results

3.1 Atlantis Bank Biological Community

3.1.1 Gelatinous Community

The CTD profile of the water column around the Atlantis Bank is outlined in Figure 4. On descent of the Shinkai 6500 at a speed of ca. 60m/min, the most commonly observed gelatinous animals were the trachymedusa *Colobonema* at depths between 550 and 920m, and the narcomedusa *Solmissus* at depths between 520 and 990m. Sightings were also made of the physonect siphonophore *Forskalia* at 520m, the coronate scyphozoan medusae *Atolla* at 950m and *Periphylla* (w/eggs) at 870m, a ctenophore of the family Cestidae at 365m, the lobate ctenophore *Kiyohimea* at 680m, a lobate ctenophore (*?Bathocyroe*) at 4900m, a red/blue lobate ctenophore (*?Lampoctena*) at 990m, a frittilarid larvacean at 1285m and salps at 430 and 640m. Numerous other sightings of both cydippid and lobate ctenophores, physonect and calycophoran siphonophores and various medusae attest to the high biomass of gelatinous organisms at this site.

3.1.2 Fish Community

Crow shark (*Etmopterus pusillus*) individuals (Fig. 5A) were observed between 1812 and 985m depth with the highest abundance found from 1350 to 985m depth. Gilchrist's orange roughy (*Hoplostethus gilchristi*, Fig. 5B) congregated in greatest numbers between 990 and 940m, usually being observed in twos and threes. Large schools of greater than 500 individuals of the big-eye dory (*Allocyttus verrucosus*, Fig. 5C) were observed between 845 and 765m depth. The vertical stratification of these species was extremely pronounced. Other major fish species included three pattern morphs/species of bellowsfish (*?Centriscops* spp., Fig. 5D) between 860 and 760m depth, cutthroat eels (*Synaphobranchus* spp.) obseved between 2830 and 760m, and rattail fishes of the genera *Coryphaenoides* (incl. *subserrulatus*) and possibly *Hymenocephalus* or *Ventrifossa* at all depths. Sightings were made of a tripodfish (*Bathypterois atricolor*) at 4910m, chimaera at 1055 and 790m, the roundhead grenadier (*Squalogadus modificatus*) at 1590m and 1445m, a halosaur (*?Aldrovandia*) at 1315m, a morid cod (*Lepiodon capensis*) at 1030m, several individuals of a Perciform fish (Haemulidae) between 810 and 750m depth, and two false cat sharks (*Pseudotriakis microdon*) at 2430 and 2255m.

3.1.3 Other members of the biological community

Several species of shrimp were observed. In the benthopelagic layer at depths from 4910 to 1275m, multiple observations were made of an aristeinid prawn (*Hepomadus* sp.), and two observations were made of long-legged shrimp (*?Nematocarcinus*) resting on the seafloor at 4850 and 4800m. Another benthopelagic shrimp that was often observed swimming in circles with its side facing the ocean floor (*?Acanthephyra)* was found at depths shallower than 1300m. Lobsters were seen on outcrops at 850 and 760m depth. Sergestid shrimp were present in the midwater between 500 and 1200m. Schools of euphausiids were observed intermittently with the largest school observed at 840m the same depth as a large school

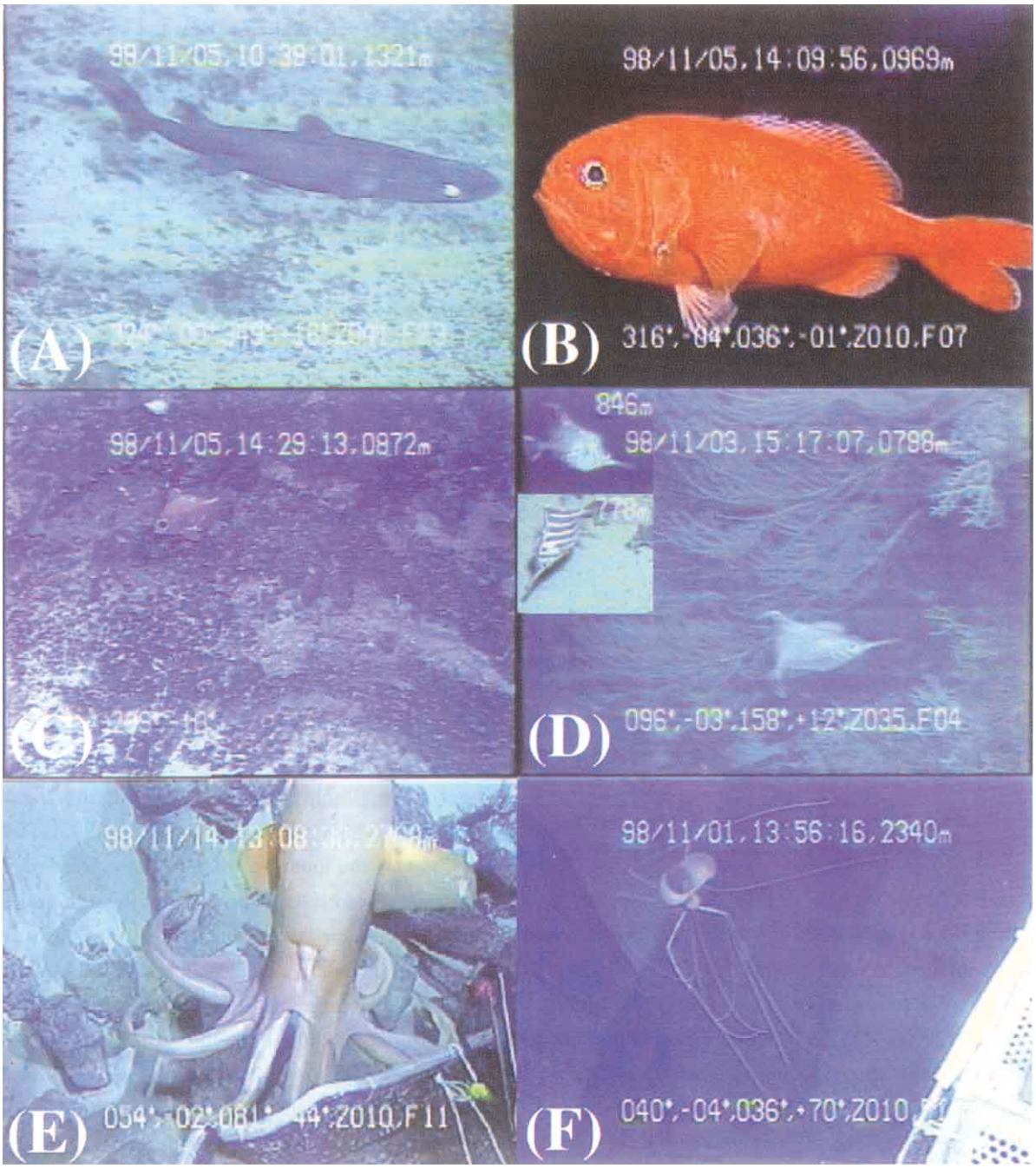

Fig. 5 Members of the near-bottom fauna of the Atlantis Bank. (A) Crow shark *Etmopterus pusillus*, (B) Gilchrist's orange roughy *Hoplostethus gilchristi*, (C) Big-eye dory *Allocyttus verrucosus*, (D) Bellowsfish *?Centriscops* spp., (E) Cirrate octopod (*?Cirroteuthis ?magna*), (F) Squid ?Joubiniteuthidae.

of the big-eye dory *Allocyttus verrucosus*. Several cirrate octopods were observed, the most notable examples being of *Cirrothauma* spp. at 2440 and 2295m, and of an extremely large (1.9m TL) cirrate octopod (*?Cirroteuthis ?magna*, Fig. 5E) at 2770m. A squid, possibly of the family Joubiniteuthidae (Fig. 5F), was observed at 2340m depth. A pelagic sea-cucumber (*?Enypniastes*) was seen at 4195m.

3.2 Northern Ridge-Transform Intersection Biological Community

No video record was taken of the water column but the benthic and benthopelagic fauna at bottom depths between 5365 and 4440m were characterized. The most common macroscopic organisms at these depths were tripodfish (*Bathypterois atricolor*), the holothurians *Psychropotes* sp. and *?Achlyonice* sp., an aristeinid prawn (*Hepomadus* sp.),

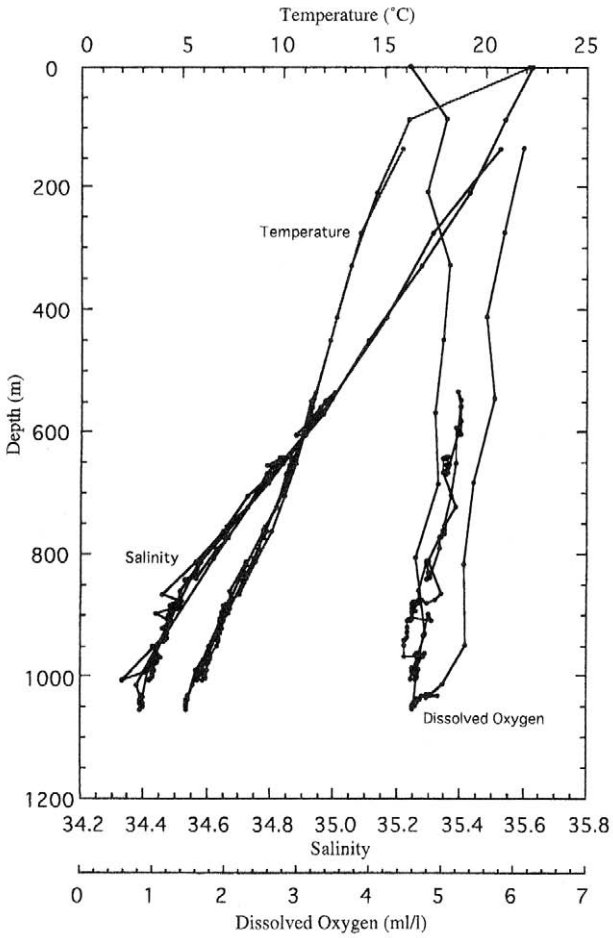

Fig. 6 CTD-DO profile of the water column south of Mauritius (29°43.40'S, 59°04.00'E) on 16th November 1998.

and a long flexible-spined sea urchin species. Organisms that were observed in smaller numbers included two species of pelagic holothurian belonging to the genus *?Enypniastes*, rattails of the genus *Coryphaenoides* and other genera, long-legged shrimps (*?Nematocarcinus*), several lobate ctenophores, a cydippid ctenophore at 5175m, a cirrate octopod of the genus *Opistoteuthis* at 5190m, and two species of deep-water benthopelagic polychaetes of the type observed in the Japan Trench on Shinkai 6500 Dive 372 - one a flottid polychaete and the other a member of an as yet undescribed group. Three medusae were observed in the benthopelagic layer at 5340, 5078 and 5062m, respectively.

3.3 Mesopelagic Biological Community South of Mauritius

3.3.1 Gelatinous Community

The CTD profile of the water column at the survey point south of Mauritius (29º43.40'S, 59º04.00'E) is shown in Figure 6. Although there are fewer data points, the structure of the upper 1000m of the water column is similar identical to that found at the Atlantis Bank. The gelatinous community at this site was also indistinguishable from that found at the Atlantis Bank, given the scant of the data available. This gelatinous community was characterized by a rich cnidarian fauna, far surpassing the numbers of ctenophores present.

The predominance of cnidarians over ctenophores has been noted in several other mesopelagic ecosystems, such as off the Sanriku Coast in north-eastern Japan and in Sagami Bay in central Japan (Fig. 7). However, the relative proportion of the total gelatinous macroplankton below 300m depth that was comprised of ctenophores, when normalized and integrated over that portion of the water column, was only 14% at the survey point in the south-west Indian Ocean, compared to 22% for the waters off the Sanriku Coast and 26% for the mesopelagic zone of Sagami Bay. Data for depths above 300m were not used in this analysis due to a bloom of the physonect siphonophore *Nanomia bijuga* in the shallower depths of Sagami Bay following the spring phytoplankton bloom.

The relative proportions of cnidarians comprised by the hydrozoan subclasses of the Siphonophora and the Hydroidomedusae *sensu* (Bouillon et. al., 1992) at the survey point in the south-west Indian Ocean were similar to those observed off the Sanriku Coast in north-eastern Japan and in Sagami Bay in central Japan (unpublished data). However, the relative abundances of the siphonophoran orders Physonectae and Calycophorae differed considerably (Fig. 8). Although the Physonectae dominated the siphonophoran fauna off both the Sanriku Coast and in Sagami Bay, the Calycophorae were the most numerous siphonophores at the survey point in the south-west Indian Ocean.

The most abundant calycophoran form at the Indian Ocean survey site was a diphyid species. It comprised over 25% of the calycophoran population in the depth layers of highest calycophoran abundance (Fig. 9A). Of the physonects, members of the genus *Forskalia* were both easily recognizable and relatively abundant (Fig. 9B). The novel Agalmatid shown during its escape response in Figure 10A with 10-11 pairs of nectophores was observed at 898m. Although ctenophores were relatively scarce, the lobate ctenophore *Bathocyroe* was often encountered at depths greater than 580m (Fig. 9C). Other ctenophores

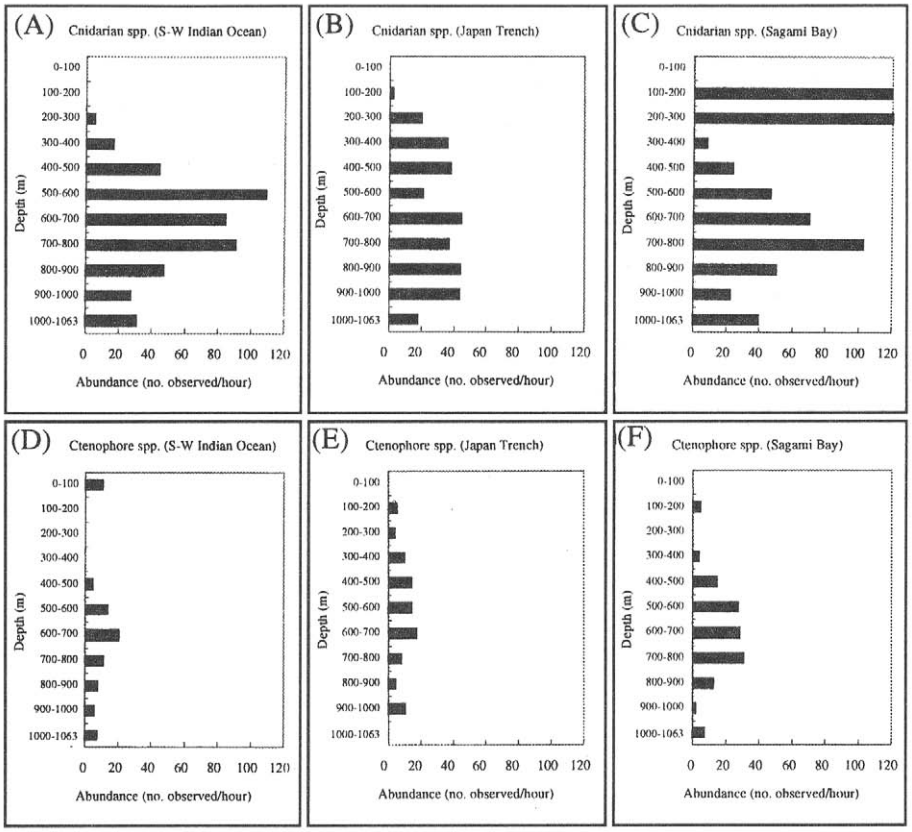

Fig. 7 Relative abundances of cnidarians and ctenophores in (A & D) the south-west Indian Ocean, (B & E) the Japan Trench, and (C & F) Sagami Bay.

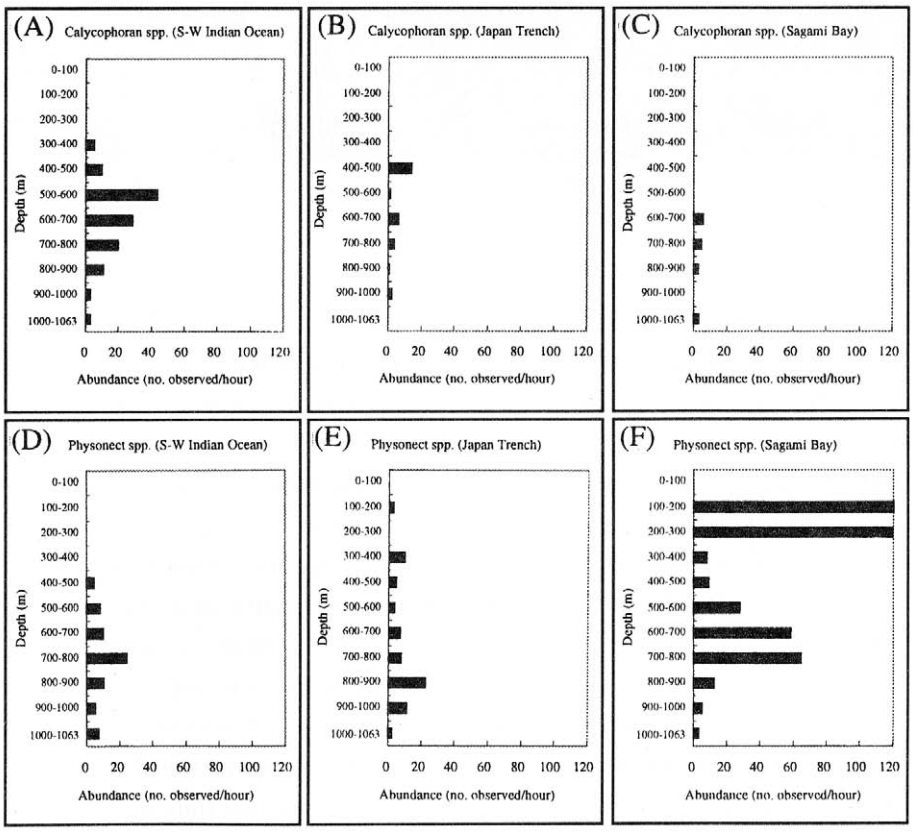

Fig. 8 Relative abundances of calycophoran and physonect siphonophores in (A & D) the south-west Indian Ocean, (B & E) the Japan Trench, and (C & F) Sagami Bay.

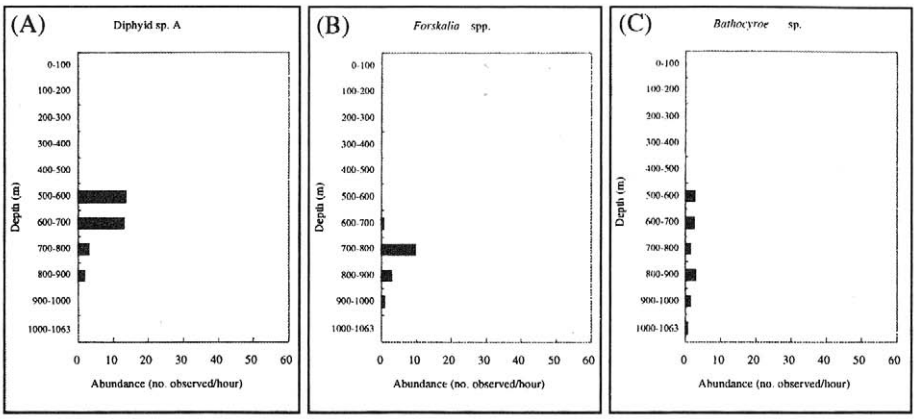

Fig. 9 The vertical distributions of members of the midwater community south of Mauritius (29°43.40'S, 59°04.00'E). (A) Diphyid siphonophore sp. A, (B) Physonect siphonophore *Forskalia* spp., (C) Lobate ctenophore *Bathocyroe* sp., a first record for the Indian Ocean.

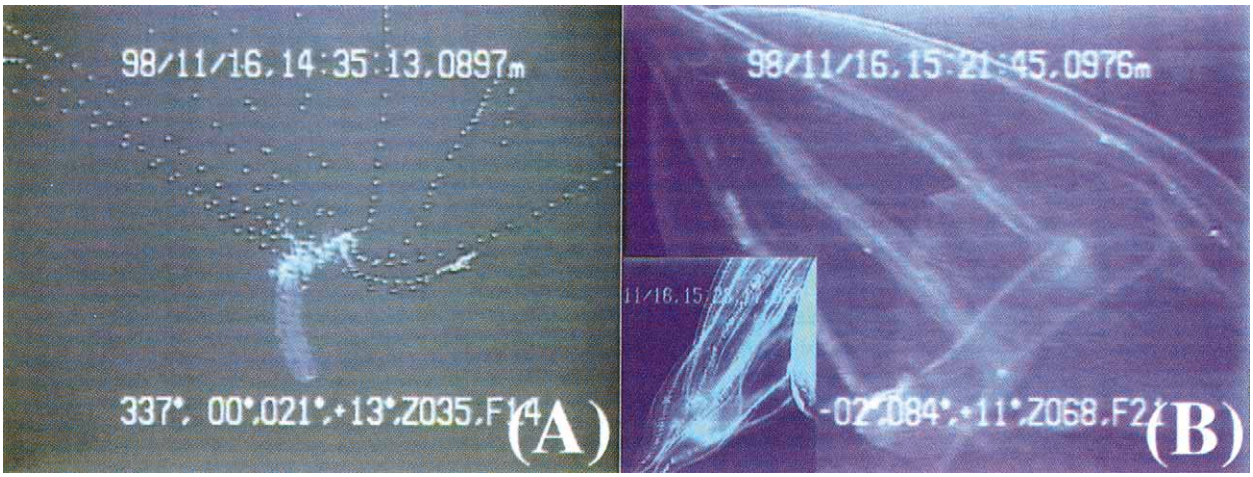

Fig. 10 Members of the mesopelagic community south of Mauritius (29°43.40'S, 59°04.00'E). (A) Novel Agalmatid siphonophore, (B) Lobate ctenophore *Kiyohimea*, a first record for the Indian Ocean.

included two individuals of the lobate ctenophore *Kiyohimea* which were observed at 974m and 998m, respectively. The shallower of these two was collected and measured over 70cm from the aboral processes to the tips of the lobes (Fig. 10B). Additionally, an undescribed species of thalassocalycid ctenophore was observed at 493m, 726m and 1008m depth. Lobate ctenophores in general were most abundant in the 600-700m depth layer, while cydippid ctenophores were most abundant between 500m and 700m.

Hydroidomedusae were sobserved throughout the water column below 200m, with the maximum abundance of 60 individuals/hour observed in the 500-600m layer. The most common Leptomedusae were several species or forms of *Aequorea*. These were most abundant between 500 and 800m depth (Fig. 11A). One individual captured at 907m was 30mm in diameter with a stomach diameter of 16mm. It had between 14 and 16 radial canals and over 50 tentacles, most of which were lost during collection. The umbrella was low and the gonads occupied the distal portion of the radial canals. Possibly due to the current taxonomic state of disorder in the genus *Aequorea*, no positive identification of this species was possible, although it is tentatively recorded here as *A. australis*.

Trachymedusae were most abundant below 500m. The trachymedusa *Colobonema sericeum* was most abundant between 600 and 800m (Fig. 11B). Three individuals of the trachymedusa *Halicreas minimum* were observed: at 578m, 596m and 690m. Narcomedusae were also abundant, with largest numbers observed in the 500-600m layer.

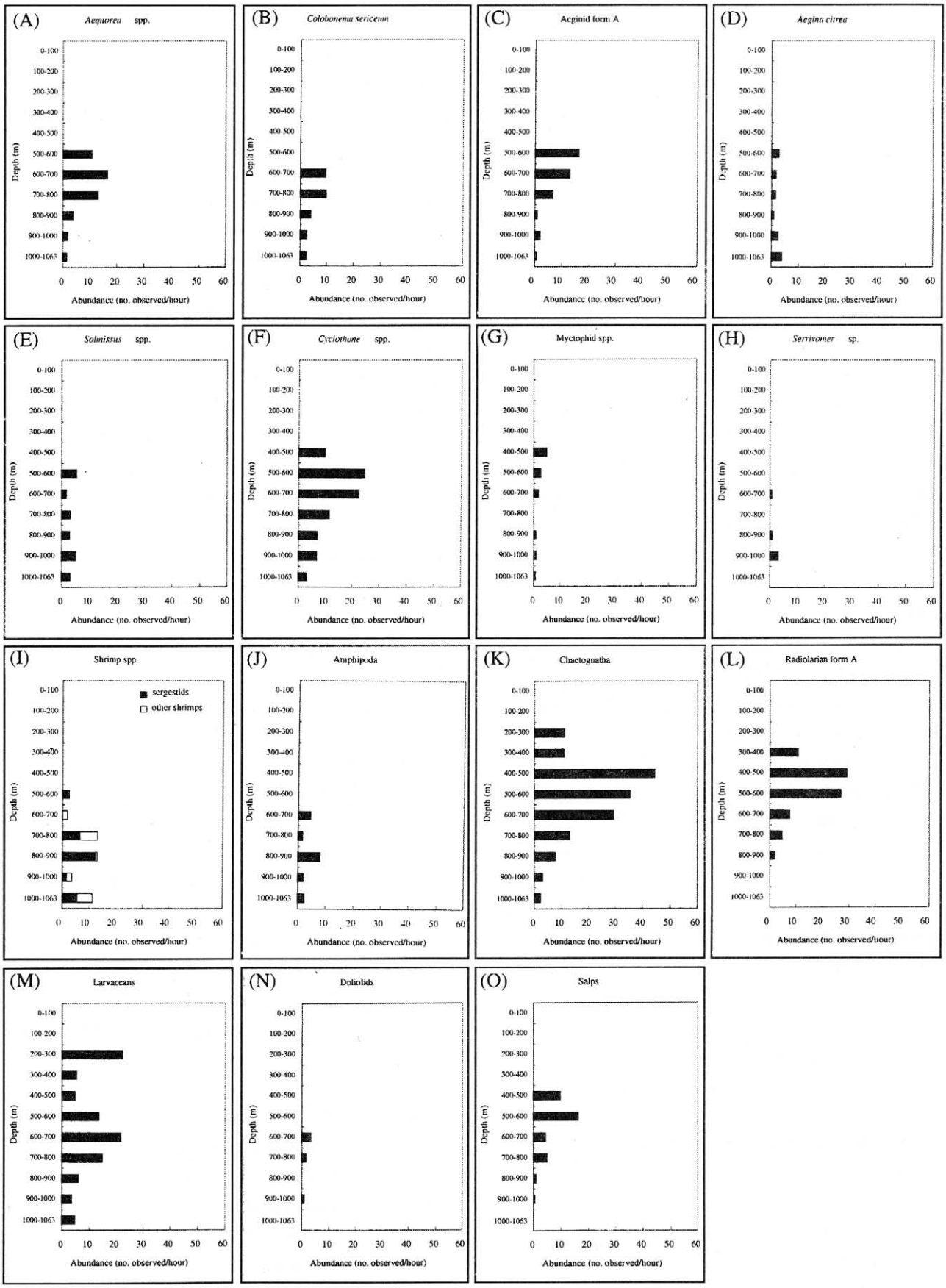

Fig. 11 The vertical distributions of members of the midwater community south of Mauritius (29º43.40'S, 59º04.00'E). (A) *Aequorea* spp., (B) *Colobonema sericeum*, (C) Aeginid form A, (D) *Aegina citrea*, (E) *Solmissus* spp., (F) *Cyclothone* spp., (G) Myctophid spp., (H) *Serrivomer* sp., (I) Shrimp spp., (J) Amphipods, (K) Chaetognaths, (L) Pelagic radiolarian form A, (M) Larvaceans, (N) Doliolids, and (O) Salps.

The most common narcomedusa was an Aeginid with four tentacles and a bell diameter of 2-5mm (Fig. 11C). The tentacles were between four and five times as long as the bell diameter. *Aegina citrea* was found throughout the water column below 575m (Fig. 11D). A single individual of *Solmundella bitentaculata* was observed at 685m. Two or more species of *Solmissus* (incl. *S. marshalli*) were observed at depths below 520m (Fig. 11E). One species of 46mm diameter was sampled at 891m depth. The body was biconvex with square to rectangular stomach pouches and tentacles of approximately the same length as the disc diameter.

The only scyphomedusan encountered on Dive 6K#468 was a small specimen of the coronate medusa *Atolla*, which was seen dragging its hypertrophied tentacle (see Hunt and Lindsay, 1998) at 823m. Although a Poralia-like medusa was seen at 1613m on 30th October and a *Periphylla* at 870m on 3rd November at the Atlantis Bank, neither of these species were observed during the midwater dive.

3.3.2 Fish Community

The most common fishes observed at the survey site were of the genus *Cyclothone* (Fig. 11F). Black individuals (*C. ?microdon*) occurred only below 708m. Myctophids were the next most common fish group (Fig. 11G). Although attracted to the submersible, they kept a certain distance from the lights. The sawtooth eel *Serrivomer* was observed repeatedly (Fig. 11H), always in a vertical attitude with its beak pointing towards the surface. The scaly dragon fish *Chauliodus* was observed four times at 750m, 807m, 914m and 1003m. It was stationary three of the four times in a near horizontal attitude. Hatchetfish of the genus *Sternoptyx* were observed at 492m, 560m, 581m and 1038m. They appeared to be negatively phototactic. A grey shark of ca. 1.5m SL was fleetingly observed at 920m depth. Several bathylagids were observed below 1000m depth and a leptocephalus larva was seen at 695m.

3.3.3 Other members of the biological community

Sergestids, the majority with a reddish carapace and clear abdomen, as well as other shrimps were observed below 500m depth (Fig. 11I). Two pasiphaeids were observed: at 1048m and 1055m. Other crustaceans included amphipods (Fig. 11J) such as members of the families Oxycephalidae and Platyscelidae, several species of euphausiids below 520m, and numerous copepods that included individuals of a red-headed species floating with its head down (*?Paraeuchaeta*) seen at 820m. Chaetognaths were most abundant in the 400-500m depth layer (Fig. 11K). At least two forms of pelagic radiolarians were present: form A which had numerous long spines, and form B which had fewer abd sgirter spines. The distribution of form A is outlined in Figure 11L. Several squids were observed including two unidentified cranchids at 981m and 987m, and the cranchid squid *Belonella belone* which was sampled at 886m. Non-cranchid squids were observed at 715m and 976m (ca. 35cm ML), and a larger species with a mantle length greater than 60cm was seen at 1035m. A white/cream tomopterid polychaete worm was observed at 1013m. Pelagic tunicates of the class Appendiculata (the larvaceans) were common (Fig. 11M), and although fewer in number, thaliaceans of the orders Doliolida (Fig. 11N) and Salpida (Fig. 11O) were also observed.

4. Discussion

Previous records (see Navas-Pereira and Vannucci, 1991, and references therein) have reported the most common deep water hydroidomedusan species collected in the Indian Ocean as the trachymedusa *Colobonema sericeum*. *Colobonema sericeum* was indeed common at the present survey site, although at an average depth greater than that reported by Navas-Pereira and Vannucci (1991). However, species of *Aequorea* were considerably more abundant (Fig. 11A). No *Aequorea* species had been reported to inhabit depths below 500m in the Indian Ocean - the depth at which all records occurred in this study. Given the dominance of this genus during the present survey, it is obvious that our understanding of the deep water medusan fauna of the Indian Ocean is greatly biased.

This lack of understanding is further illustrated when comparisons of the vertical distributions hitherto reported for several hydroidomedusan species (Navas-Pereira and Vannucci, 1991) are compared with data gained in the present study. The narcomedusa *Solmissus marshalli* has been reported to be most abundant at depths between 250m and 500m in the Indian Ocean. In our study, not a single specimen was observed above 500m (Fig. 11E). Data for *Aegina citrea* might lead us to believe that 75% of the population was found at depths above 500m (Fig. 8 in Navas-Pereira and Vannucci, 1991). In the present study, no individuals were observed above 500m depth (Fig. 11D).

Not only has this single midwater dive illustrated our lack of knowledge concerning Indian Ocean hydroidomedusae, but both the cnidarian and ctenophore communities in general. The lobate ctenophores *Kiyohimea* and *Bathocyroe* are reported for the first time in the Indian Ocean, as is the ctenophore class Thalassocalycidae, proving the cosmopolitan distributions of these groups. The reasons for the relative paucity of ctenophores in general and the dominance of calycophoran siphonophores are yet to be discovered. It is obvious that a great deal of work still needs to be done in order to even partially understand the species compositions, structure, and ecological interactions shaping the midwater community of the south -west Indian Ocean and indeed, the Indian Ocean in general.

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