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Meiofauna from Marine and Anchialine Caves

T.K.A Arunimaand and P.M Mohan*
Department of Ocean Studies and Marine Biology, Pondicherry University Off Campus, Brookshabad, Port Blair – 744112 Andaman and Nicobar Islands, India
**Email: pmmtu@yahoo.com;pmmnpu@rediffmail.com*

Abstract

Sea caves are one of the integral parts of the marine environment. The studies on faunal presence in this cave are one of the interesting studies, which deprived in this environment. An attempt is made to know the status of this study in Indian marine environment, a review was carried out and the results are presented in this research article. The results showed that, this area of research is not carried out in Indian waters and highly needed for this marine environment

Keywords: *Meiofauna; Marine Environment; Caves: Anchialine*

Introduction

Marine habitats have always been fascinating with their captivating beauty and the enormous diversity comprising distinctive flora and fauna. Sea caves are one of the marine environments which aboard a large array of organisms and are an integral part of marine hotspots (Gerovasileiou and Voultsiadou, 2012). The world's longest sea cave is the Matainaka Cave, situated on the South Island of New Zealand with 5051 feet in length. The surging and thrusting of the waves on the carbonate rocks cause them to erode for more extended time periods leading to the formation of a cave. They are pristine environments characterized by broad gradients of environmental eccentricity that records climate through time (Illif*et al*., 1984). Many limestone caves containing Fresh water and salt water have been identified extensively as a part of anchialine habitats in the past years (Iliffe and Kornicker, 2009). The absence of light, inadequate nutrient supply, steeper salinity levels, presence of active sulphuric acid, fluctuating pH, carbon and nitrogen conditions are some extreme features of a Sea cave (D'Angeli*et al.,*2019, Zeppilli*et al.,* 2018). Chemoautotrophic microbes use the steep redox interfaces in the cavern water section to reduce inorganic carbon mixing using sulphides or ammonium as electron benefactors in the sulfur-rich, deoxygenated cave environments. (Canganella*et al.,* 2006, Jamie and Boxshall, 2009). Food in the stygobitic condition might be scant or inconsistent, so the stygofauna need to adapt to the worldly periodicity of food accessibility and conceivably endure significant stretches of starvation (Bishop and Iliffe, 2005). There are a lot of meiobenthic organisms like Nematodes, Polychaetes, Copepods, Foraminifera, Tardigrades, Gastrotrichs, Kinorhynchs, Ostracods, etc. which are found profusely in the caves than the macrobenthic organisms (Fichez, 1990;Sandulli*et al.,* 2014;Todaro*et al.,* 2006).

Studies on macrofauna have been carried out in different anchialine and marine caves. Macrofauna also has survival instincts to live in the hypoxic and anoxic conditions of different caves (Iliffe and Kornicker, 2009). A marked increase in studies of the occurrence, biology, DNA barcoding, and distribution of macro invertebrates, especially crustaceans, has been observed in recent years (Iliffe and Kornicker, 2009). Exclusion or absence of optical organs, lack of pigmentation, sensory functions that do not reckon on radiant energy for food or predator detection, and other behavioral adaptations aid their continued existence (Bishop and Illiffe, 2007). A higher number of discoveries on sessile and mobile macrofauna has been reported from the caves found in the Caribbean and Meditteranean regions (Bussotti, 2004; Gerovasileiou and Voultsiadou, 2012). Unique cavefish assemblages are identified in Mediterranean Sea caves with exclusive patterns of compositional diversity (Bussotti*et al.,* 2015; Guarnieri*et al.,* 2012). Similarly, investigations proved that even snails, sponges, worms, fishes, Echinoderms that show endemism, etc., colonize in anchialine caves and marine caves (Solis *et al.,* 2010; Vacelet and Perez, 1998). Thus the macrofauna diversity studies prove them as the vital organisms in caves that help us to enhance our

knowledge on endemic cave biota (Gerovasileiou *et al.,* 2015).

Foraminifera

Foraminiferans are ubiquitous group of organisms that are considered as paleoenvironmental indicators having the ability to secrete tests that are made of CaCO3, mucopolysaccharide and SiO2 (Van Hengstum*et al.,* 2008). Studies conducted in Yucatan Peninsula where extensive anchialine cave networks with tidally influenced surface pools containing salt water formed by Spleogenesis revealed the presence of foraminiferans like *Jadamminam acrescens, Tritaxis sp.,Ammonia tepida, Elphidium sp.,* abundantly (Holthuis, 1973; Van Hengstum*et al.,* 2008). Foraminiferan study reports collected fromAktun Ha caves in Mexico documented *Bolivina* sp., assemblage as dominant followed by *Elphidium sp., Rosalina subaracuana* et which might have got transported into the marine caves by coastal upwelling and Ocean circulation (Alve and Goldstein, 2003; Van Hengstum*et al.,* 2019,). The change in salinity in the coastal aquifier may be the primary factor in the environment that affects the presence of foraminiferan groups and the peripheral factors includes the sources and flux of sediment materials and natural issues (Van Hengstem*et al.,* 2011). Bel Torrento and Bue Marino caves of Italy are recognized as ecozones and the environmental conditions had a similarity with Mediterranean shallow water environments. (Romano *et al.,* 2018). These caves have a transitional environment where the entrance zones had higher natural inconsistency with predominance of lenient species aiding with high energy floods and diminishing oxygen availability where a greater number of porcelaneous and hyaline assemblages were found than in the Transitional zone where agglutinated taxa was prevalent because of the alteration in salinity and temperature (Bergamin*et al.,* 2018).

Bermudan limestone is the ancient aeolianite bedrock developed through diagenesis, which is renowned for both unsaturated and phreatic caves (Land *et al.,* 1967). *Spiropthalmidium* sp., assemblages were having elevated abundance from the sediment samples collected from phreatic caves of Bermuda having high concentration of ammonia (Van Hengstum*et al.,* 2009). In some cases, like the Green Bay cave system where Anchialine and sub marine cave environments were connected forming an exceptional environment with a difference in physico-chemical parameter, the ecology and habitat variability of for amineferans were analyzed and it was found that the benthic forms like *Rosalina* sp.,*Bolivina*sp., dominated Anchialine caves and *Quinqueloculina* sp*.,* and *Spirophthalmidium emaciatum* were abundant in sub-marine caves (Van Hengstumand Scott, 2011).

Nematodes

Nematodes are the foremost abundant meiofaunal organisms in thesea water sediments, extending from a variety of the water line into the deepest oceanic trenches and epigean ecosystems (Nicholas, 1975). As dominant life forms of soil nutrient cycles nematodes enhance the rate of plant litter putrefaction and turnover of nutritive substances from soil unprocessed organic materials and also, they play a predominant role in Epigean surroundings (Baldwin *et al.,* 2000; Du Preez*et al.,* 2017). The species richness of nematodes that are free-living in nature may be lower in the sub-marine caves than in the outside environment because of the shortage in food resources providing convenient conditions for non-selective deposit feeders and omnivore species (Zhou and Zhang, 2008). A nematode species *Chronogaster troglodytes* was reported as the first cavernous nematode of Movile caves in Romania which was found to surviving in hydrogen-sulphide rich thermo mineral waters (Poinar and Sabru, 1994) In a comparative meiofaunal study involving two different caves the nematode species were different in the inner caliginous part which had lesser nematodes and outer areas with more density. Nematodes being widely distributed can be abundant in numbers too reaching more than 500 ind./10cm2 (Janssen *et al.,* 2013; Todaro*et al*., 2006). The Nematode families, Xyalidae, Desmodoridae, Comesomatidae and Linhomoeidae were reported as the dominant families which survived thermocline environment along with anoxic conditions and high level of sulphides in the deeper parts of the Blue hole cave in the Maldivian Archipelago (Sandulli*et al.,* 2014). Sixteen species of Nematodes were documented from Anchialine caves of Cuba, where *Stenonchulus troglodytes* and

Chronogaster troglodytes were truly steno biotic (Perez-García*et al.,* 2018; Perez-García*et al.,* 2020).

Polychaetes

Meiofaunal polycheates from marine caves are studied for ecotoxicological investigation because of their sensitive nature to different environmental disturbances (Nipper *et al.,* 2003). In Cave dwelling expedition in Canary Islands 1984, a polychaete species in the family Scalibregmatidae, was described from a marine lava tube cave (Bertelsen, 1986; Iliffe*et al.,* 1984). Later in the same unique subterranean ecosystem of Canary Islands, incorporating both dry and submerged cave section a greater number of Polychaetes like *Gesiella jameensis, Speleobregmalan zeroteum Miscellania dentata, Syllisgarciai, S. gerlachi, Miscellania dentata* and *Exogone gambiae* were documented (Wilkens*et al.,* 2009). DNA studies of *Axiokebuita cavernicola* and *Spleobregmala zaroteum* belonging to poorly known lineages having a globular pygidium in addition to adhesive glands and ungrooved ciliated palps were exclusively procured from gravelly sediments of marine cave habitat (Martinez *et al.,* 2013). Suspension feeding species families in class Polychaete, Protodrilidae and Nerillidae are reported from various cave environments with, remarkable differences seen in the primary interstitial genealogies in contrast to the other families, pointing to different adaptive evolutionary pathways related to natural fitness contradictory to the formerly proposed speculations focusing on chorographical and time-dependant processes (Gerovasileiou and Voultsiadou, 2012; Martinez *et al.,* 2017; Nunez *et al.,* 1997). Benthic Polychaetes have been reported from Mediterranean Sea caves and in studies, species allocation pattern reflected the habitat condition of the caves (Bussotti*etal.,* 2007;Denitto and Licciano, 2006). Polychaetes are important since they have been found as leading meio faual groups along with Nematodes and Copepods (Riera*et al.*. 2018)

Gastrotricha

Being a cosmopolitan phylum, Gastrotricha is known for its distribution in various extreme environments including marine caves (Curini-Gallett*iet al.,* 2012; Sandulli*et al.,* 2014). Even though found scarcely they play a role in the community structure of meiofauna marine caves where dysoxic conditions exist (Balsamo *etal.,* 2007, Sandulli*et al.,* 1999). A comprehensive investigation on the gastrotrich fauna completed in an ocean cavern, 'GrottaPiccola del Ciolo', by Todaro*et al.,* (2006), discovering cavern environments as the hotspots of biodiversity and endemism for marine Gastrotrichs. 29 species of Gastrotrichs were obtained from a biodiversity assessment studies conducted Salento submarine caves in Italy (Onorato and Belmonte, 2018).

Copepods

Harpacticoid copepods ranging from a size of 1-2mm are known to be living in low food environment where lipid metabolism is engaged as an adaptive feature, which aids them to save energy (Iliffe*et al.,* 1984). They are comparitively lesser sensitive to anoxic codition, which makes them very abundant among the benthic communities (Sandulli*et al.,*2014, Wilkens*et al.,* 2009). *Speleophriopsis canariensi* and *Expanso phriasarda* are two copepods which are exclusively stenotypic species collected from anchialine caves in Canary Islands (Huys and Iliffe, 1998, Jaume and Boxshall, 1996). There have been more reports of copepods surviving the harsh conditions of Mediterranean Sea caves (Jaume and Boxshall, 1996a, b, 1995;Jenssen*et al.,* 2013). More than hundred number of copepods from family Boholiniidae were found from Anchialine caves of Philippines, among them *Ridgewayis sp*.,is known to live in association with Actinarians (Fosshagen and Iliffe, 1989, Humesand Wayne, 1974). The copepods obtained from a Bermuda remarkably retained the primitive characters in their body appendages (Fosshagen and Iliffe, 1988). Based on the inferences from Cave dwelling marine and anchialine copepods of Jamaica, Cuba, Bahamas, Caicos Islands and West Indies, 2 new sub families were identified by Fosshagen et al., (2001). *Stygonitocrella* sp., was a new harpacticoid copepod emerged from marine interstitial ancestors that was first seen in fresh waters (Saurez and Iliffe, 2005).

Tardigrades

Tardigrades are commonly known as 'water bears' that are adapted to survive extreme environmental

conditions by Cryptobiosis that helps them to stay in a reversible metabolic state(Mojerg*et al.,* 2011, Sorensen *et al.,* 2018). In an investigative study of 2 caves, Tadigrades were found as the second most abundant meiobenthic group with 21 species belonging to Family Halichiniscidae, Family Stygarctidae, and Family Echinicoididae (Sandulli*et al.,* 1999). Apomorphic and plesiomorphic characters were exhibited by tardigrades of the Stygarctidae family found from the conservative cave habitats of San Domino Island (Gallo *et al.,* 2001). Tardigrade species of Australian marine caves have high dispersal capacity along with similarities to deep-sea species, and the investigative information suggests that marine caves survive as a shelter for prehistoric Tethyan fauna (Jørgensen*et al.,* 2014). Deep sea-like conditions were a characteristic feature of the caves found in Japan where new tardigrades, *Quisarctusya sumurai* and *Cyaegharctu skitamurai* have been reported, but their evolutionary significance is unknown because adequate ultrastructure comparative studies did not taken place till now (Fujimoto, 2015; Fujimoto and Jimi, 2020).

Kinorhyncha

Kinorhynchs are exclusively marine meiobenthic organisms having about 1mm size distributed worldwide, and many still are not discovered (Dal *et al.,* 2016; Neuhaus*et al.,* 2019; Sanchez *et al.,* 2014). *Echinoderes cavernus* was the first reported Kinorhynch which is an exclusive cave-dwelling species found in the coralliferous sediments of a submarine cave in New South Wales, Australia (Sorensen *et al.,* 2000*). Echinoderes gama, Echinoderes kajihari, Echinoderes uozumii, Ryuguderesie jimaensis*, etc., were recently reported from Daidokutsu caves in Japan which are about 8000 years old (Yamasaki *et al.,* 2020). *Pycnophyesku kulkan* was the first reported Kinorhynch from anchialine caves, which have enhanced sensory structures as an adaptive feature for feeding in the oligotrophic environment. *Ryuguderesiema jiensis* has brush-like structures in the oral region that helps them to eat small-sized organic substances (Sanchez and Martinez, 2019).

Ostracods

Ostracods are used in paleontological studies since they are common in various marine habitats and are distinguished by the presence of a bivalved calcareous exoskeleton (Smith *et al.,* 2018). They are distributed in anchialine caves and are known to survive very low temperatures at the deeper parts (Danielopol, 1990). In a study of Ostracods in anchialine caves and blue holes, 33 cave-dwelling species existed, and a few of them were only reported from the subterranean habitats (Kornicker*et al.,* 2007; Kornicker and Iliffe, 1989). The complex biological and morphological traits like regressed eye construction, body pigments, body shape, and extra optic sensorial traits help them to survive in the aphotic cave environment (Becerra, 1999; Smith *et al.,* 2014). They are also known to live in association with cavernicolous crayfishes for feeding purposes (Hobbs, 1975). The ontogenic study of Ostracod *Deeveyamedix* helped to understand its phylogenic history (Kornicker*et al.,* 2009).

Conclusion

This study identified ninety two references belongs to anchialine caves studies and also discussed only eight groups of faunal communities. Further, these studies mainly covers the coastlines of Mexico, Bermuda and Japan in large than other coastlines. Indian coastlines, this study was not taken up till date and it is essential to look this factor as an important study by marine scientists.

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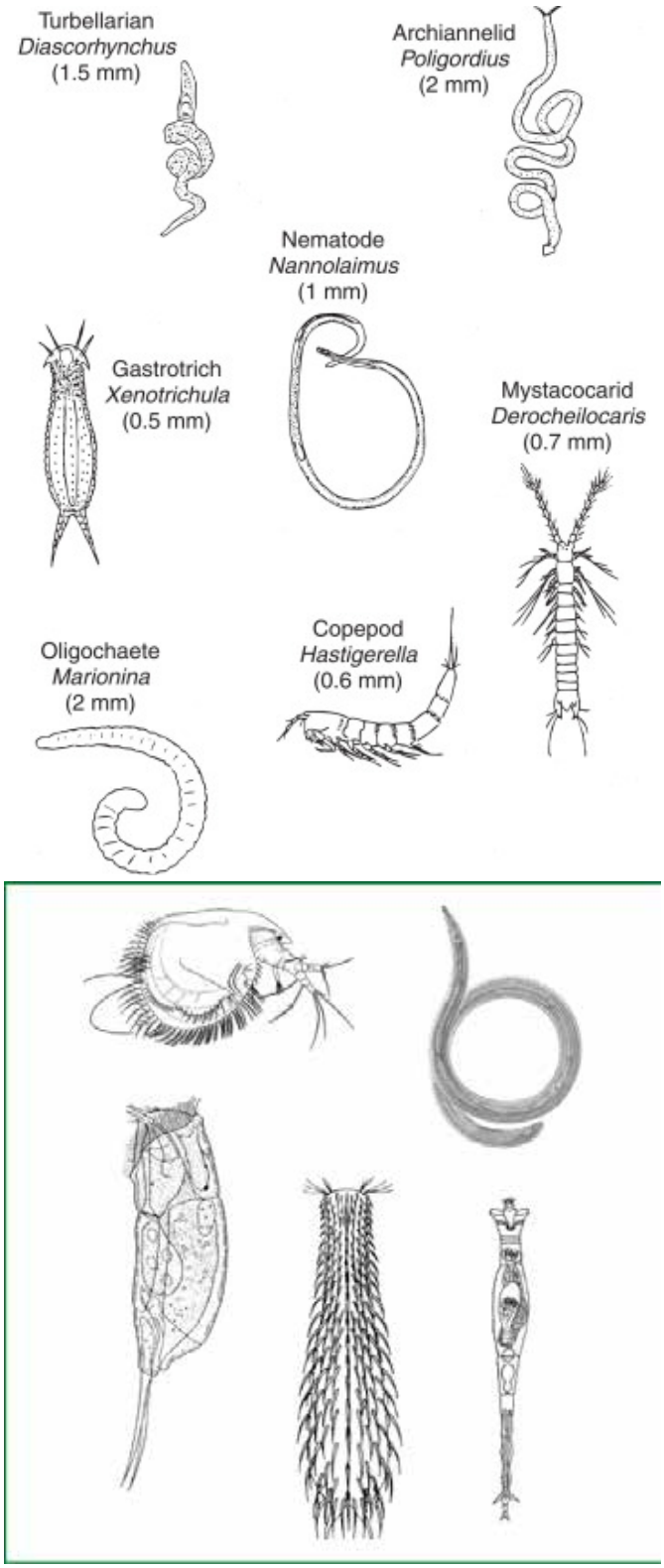

Fig. 1. A glimpse of some of the Meiofauna

References

Alve, E., and Goldstein, S.T.,(2003)Propagule Transport as a Key Method of Dispersal in Benthic Foraminifera (Protista). Limnology and Oceanography, 48(6), pp.2163–2170.

Baldwin, J. G., Nadler, S. A., andFreckman, D. W. (2000) Nematodes - pervading the earth and linking all life. In: Raven, P. and Williams, T. (Eds.) Nature and Human Society, the Quest for a Sustainable World. National Academy Press, Washington, DC, pp.176–191.

Balsamo, M., Guidi, L.,Pierboni,L., Marotta, R., Todaro, M., and Ferraguti, M. (2007) Living without Mitochondria: Spermatozoa and Spermatogenesis in Two Species of Urodasys (Gastrotricha, Macrodasyida) from Dysoxic Sediments. Invertebrate Biology, 126(1), pp.1-9.

Becerra G. E. (1999) The darkness syndrome in subsurface-shallow and deep-sea dwelling Ostracoda (Crustacea). 1965, pp.123–143.

Bergamin, L.,Marassich, A., Provenzani, C., and Romano, E. (2018) Foraminiferal Ecozones in Two Submarine Caves of the Orosei Gulf (Sardinia, Italy). RendicontiLincei, 29(3), pp.547–57.

Bertelsen, R. (1986) *Speleobregmalan zaroteum*, a new genus and species of Scalibregmatidae (Polychaeta) from a marine cave in the Canary Islands. Proceedings of the Biological Society of Washington, 99(3), pp.375–379.

Bowman, T.E., and Ilie, T.M. (1985) *Mictocarishalope*, a new unusual peracaridan crustacean from marine caves on Bermuda.Journal of Crustacean Biology,V.5, pp.58-73.

Bussotti, S., Terlizzi, A., Fraschetti, S., Belmonte, G., and Boero, F. (2006) Spatial and temporal variability of sessile benthos in shallow Mediterranean marine caves. Marine Ecology Progress Series, V.325, pp.109–119., https://doi.org/10.3354/meps325109

Bussotti, S., Di Franco, A., Francour, P., and Guidetti, P. (2015) Fish assemblages of mediterranean marine caves. PLoS ONE, V.10(4), pp.1–16. https://doi.org/10.1371/journal.pone.0122632

Bussotti, S., Terlizzi, A., Fraschetti, S., Belmonte, G., and Boero, F. (2006) Spatial and temporal variability of sessile benthos in shallow Mediterranean marine caves. Marine Ecology Progress Series, V.325, pp.109–119.

Canganella, F., Bianconi, G., Kato, C., and Gonzalez, J. (2006) Microbial ecology of submerged marine caves and holes characterized by high levels of hydrogen sulphide. Reviews in Environmental Science and Bio/Technology, V.6(1-3), pp.61–70., doi:10.1007/s11157-006-910-2

Curini-Galletti, M., Artois, T., Delogu, V., de Smet, W.H., Fontaneto, D., Jondelius, U., Leasi, F., Martínez, A., Meyer-Wachsmuth, I., Nilsson, K.S., Tongiorgi, P., Worsaae, K., and Todaro, M.A. (2012) Patterns of diversity in soft-bodied meiofauna: Dispersal ability and body size matter.PLoS ONE, V.7(3). https://doi.org/10.1371/journal.pone.0033801

D'Angeli, I.M.,Ghezzi, D., Leuko, S.,Firrincieli, A.,Parise, M.,Fiorucci, A., and others, Geomicrobiology of a Seawater-Influenced Active Sulfuric Acid Cave, PLoS ONE, 2019, https://doi.org/10.1371/journal.pone.0220706.

Dal, M., Santulli, A., Simonini, R., and Todaro, M.A. (2016) Focus on Kinorhyncha. Zoologischer Anzeiger - A Journal of Comparative Zoology, https://doi.org/10.1016/j.jcz.2016.03.013.

Danielopol, D.L. (1990) The origin of the anchialine cave fauna — the "deep sea" versus the "shallow water" hypothesis tested against the empirical evidence of the *Thaumatocyprididae* (Ostracoda). Bijgraden Tot de Dierkunde, 60(3/4), pp.137–143.

Denitto, F., Terlizzi, A., and Belmonte, G. (2007) Settlement and primary succession in a shallow submarine cave: Spatial and temporal benthic assemblage distinctness. Marine Ecology, 28(1), pp.35–46. https://doi.org/10.1111/j.1439-0485.2007.00172.x

Du Preez, G., Majdi, N., Swart, A., Traunspurger, W., andFourie, H. (2017) Nematodes in caves: a historical

perspective on their occurrence, distribution and ecological relevance. Nematology, 19(6), pp.627–644, doi:10.1163/15685411-00003068

Fichez, R. (1990) Decrease in allochthonous organic inputs in dark submarine caves, connection with lowering in benthic community richness. Hydrobiologia, 207(1), pp.61–69,https://doi.org/10.1007/BF00041441

Fosshagen, A., and Iliffe, T.M. (1988) A new genus of *Platycopioida* (Copepoda) from a marine cave on Bermuda. Hydrobiologia, 167–168(1), pp.357–361,https://doi.org/10.1007/BF00026325

Fosshagen, A., and Iliffe, T.M. (1989) *Boholina*, a new genus (Copepoda: Calanoida) with two new species from an anchialine cave in the Philippines. Sarsia, 74(3), pp.201–208,https://doi.org/10.1080/00364827.1989.10413429.

Fosshagen, A., Boxshall, G. A., &Iliffe, T. M. (2001) The Epacteriscidae, a cave-living family of calanoid copepods. Sarsia, 86(4–5), pp.245–318, https://doi.org/10.1080/00364827.2001.10425520.

Fujimoto, S., and Jimi, N. (2020) A new marine tardigrade genus and species (Arthrotardigrada, Styraconyxidae) with unique pockets on the legs.Zoosystematics and Evolution, 96(1), pp.115-122,https://doi.org/10.3897/zse.96.49676

Fujimoto, S. (2015) *Quisarctusya sumurai* gen. Et sp. Nov. (Arthrotardigrada: Halechiniscidae) from a submarine cave, off Iejima, Ryukyu Islands, Japan. Zootaxa, 3948(1), pp.145–150,https://doi.org/10.11646/zootaxa.3948.1.10

Gallo, M.D., Grimaldi, S.D., and Sandulli, R. (2001) Heterotardigrada of two submarine caves in S. Domino Island (Tremiti Islands) in the Mediterranean Sea with the description of two new species of Stygarctidae. Zoologischer Anzeiger, 240(3–4), pp.361–369,https://doi.org/10.1078/0044-5231-00043

Gerovasileiou, V., andVoultsiadou, E. (2012) Marine caves of the mediterranean sea: A sponge biodiversity reservoir within a biodiversity hotspot. PLoS ONE, 7(7), pp.1–17, https://doi.org/10.1371/journal.pone.0039873

Gerovasileiou, V., Chintiroglou, C.C., Vafidis, D., Koutsoubas, D., Sini, M., Dailianis, T., Issaris, Y., Akritopoulou, E., Dimarchopoulou, D., and Voultsiadou, E. (2015) Census of biodiversity in marine caves of the eastern Mediterranean Sea. Mediterranean Marine Science, 16(1),pp.245–265, https://doi.org/10.12681/mms.1069

Guarnieri, G., Terlizzi, A., Bevilacqua, S., andFraschetti, S. (2012) Increasing heterogeneity of sensitive assemblages as a consequence of human impact in submarine caves. Marine Biology, 159(5), pp.1155–1164, https://doi.org/10.1007/s00227-012-1895-8

Hobbs, H. (1975) Distribution of Indiana cavernicolous crayfishes and their ecto-commensal ostracods. International Journal of Speleology, V.7(3), pp.273–302,https://doi.org/10.5038/1827-806x.7.3.3

Holthuis, L.B. (1973)Caridean Shrimps Found in Land-Locked Saltwater Pools at Four Indo-West Pacific Localities (Sinai Peninsula, Funafuti Atoll, Maui and Hawaii Islands), with the Description of One New Genus and Four New Species. ZoologischeVerhandelingen, V.128, pp.1–48.

Humes, A.G.,and Wayne, L.S. (1974) *Ridgewayiafosshagen*in.sp. (Copepoda:Calanoida) associated with an actiniarian in Panama, with observation on the nature of the association. Caribbean Journal of Science, V.14, pp,125-139.

Huys, R., and Iliffe, T.M. (1998) Novocriniidae, a new family of harpacticoid copepods from anchihaline caves in Belize. ZoologicaScripta, V.27(1), pp.1–15, https://doi.org/10.1111/j.1463-6409.1998.tb00425.x.

Iliffe, T.M., and Kornicker, L.S. (2009) Worldwide diving discoveries of living fossil animals from the depths of anchialine and marine caves. Smithsonian Contributions to the Marine Sciences, V.38,pp. 269–280,http://smithsonianrex.si.edu/index.php/scms/article/view/470

Iliffe, T. M., and Bishop, R.E.(2007) Adaptations to Life in Marine Caves. In: Fisheries and Aquaculture: Towards

Sustainable Aquatic Living Resources Management, (Ed.) P. Safran, pp. 1– 26. In: Encyclopedia of Life Support Systems (EOLSS). Oxford: UNESCO–EOLSS Publishers.

Iliffe, T.M., Wilkens, H., Parzefall, J., and Williams, D. (1984) Marine Lava Cave Fauna: Composition, biogeography and origins. Science, V.225, pp.309–31, doi: 10.1126/science.225.4659.309.

Janssen, A., Chevaldonné, P., and Martínez A,P. (2013) Meiobenthic copepod fauna of a marine cave (NW Mediterranean) closely resembles that of deep-sea communities. Marine Ecology Progress Series, V.479, pp.99–113, doi:10.3354/meps10207.

Jaume, D., andBoxshall, G.A. (2009) Life in extreme ocean environments: anchialine caves. In: Duarte, C.M., andHelgueras, A.L. (Eds.) Marine Ecology - – Encyclopedia of Life Support System (EOLSS), pp 230–251.

Jaume, D. and Boxshall, G.A., (1995) A new species of *Exumella* (Copepoda: Calanoida: Ridgewayiidae) from anchihaline caves in the Mediterranean, Sarsia, V.80, pp.93-t05.

Jaume, D., and Boxshall, G.A., (1996a) A new genus and two new species of cavedwellingmisophrioid copepods from the Balearic Islands (Mediterranean). Journal of Natural History – Biology, DOI:10.1080/00222939633770531.

Jaume, D., and Boxshall, G.A., (1996b), Two new genera of cyclopinid copepods (Crustacea) from anchihaline caves on western Mediterranean Islands, Zoological Journal of the Linnean Society, V.117, pp.283–304.

Jaume, D.,and Boxshall, G.A. (1996c). The persistence of an ancient marine fauna in Mediterranean waters: New evidence from misophrioid copepods living in anchihaline caves. Journal of Natural History, V.30(11), pp.1583–1595,https://doi.org/10.1080/00222939600770921

Jørgensen, A., Boesgaard, T.M., Møbjerg, N., and Kristensen, R.M. (2014) The tardigrade fauna of Australian marine caves: With descriptions of nine new species of Arthrotardigrada,Zootaxa, V.3802(4), pp.401–443, https://doi.org/10.11646/zootaxa.3802.4.1.

Kornicker, L. S., and Iliffe, T.M. (1989) Ostracoda (Myodpcopid, Cladocopina, Halocypridina) Mainly from Anchialine Caves in Bermuda.Smithsonian Contributions to Zoology, 475.

Kornicker, L. S., Iliffe, T. M., and Harrison-Nelson, E. (2007) Ostracoda (Myodocopa) from anchialine caves and ocean blue holes.Zootaxa,V.1565,https://doi.org/10.11646/zootaxa.1565.1.1

Kornicker, L. S., Iliffe, T. M., and Harrison-Nelson, E. (2009) Ontogeny of *Deeveyamedixkornicker,* 1990, collected in anchialine and marine caves in the Bahama Islands (Ostracoda: Halocypridae: Deeveyinae). Proceedings of the Biological Society of Washington, V.122(2), pp.171–205. https://doi.org/10.2988/08-37.1

Land, L.S., Mackenzie, F.T., Gould, S.J., (1967) The Pleistocene history of Bermuda. Geological Society of America, Bulletin. V.78, pp.993–1006.

Martí, R., Uriz, M.J., Ballesteros, E., and Turon, X. (2004) Benthic assemblages in two Mediterranean caves: Species diversity and coverage as a function of abiotic parameters and geographic distance. Journal of the Marine Biological Association of the United Kingdom, V.84(3), pp.557–572, https://doi.org/10.1017/S0025315404009567h

Martínez, A., Di Domenico, M., andWorsaae, K. (2013) Evolution of cave *Axiokebuita* and *Speleobregma* (Scalibregmatidae, Annelida).ZoologicaScripta, V.42(6), pp.623–636,https://doi.org/10.1111/zsc.12024

Møbjerg, N., Halberg, K.A., Jørgensen, A., Persson, D., Bjørn, M., Ramløv, H., and Kristensen, R.M. (2011) Survival in extreme environments - on the current knowledge of adaptations in tardigrades. ActaPhysiologica, V.202(3), pp.409–420, doi:10.1111/j.1748-1716.2011.02252.x

Neuhaus, B., Zotto, M.D.A.L., Yamasaki, H., and Higgins, R.P. (2019) Revision of Condyloderes (Kinorhyncha, Cyclorhagida) including description

of *Condyloderesshirleyi* sp. Nov. Zootaxa, V.4561, https://doi.org/10.11646/zootaxa.4561.1.1

Nicholas, W.L. (1975)The biology of free-living nematodes. London & New York: Oxford University Press.

Nipper, M., and Scottcarr, R. (2003) Recent advances in the use of meiofaunalpolychaetes for ecotoxicological assessments. Hydrobiologia, V.496, pp. 347–353,https://doi.org/10.1023/A:1026129806435

Núñez, J., Ocaña, O., &Brito, M.D.C. (1997) Two new species (Polychaeta: Fauveliopsidae and Nerillidae) and other polychaetes from the marine Lagoon cave of Jameos del Agua, Lanzarote (Canary Islands). Bulletin of Marine Science, 60(2), pp.252–260.

Onorato, M., and Belmonte, G. (2018) Submarine caves of the Salentopensinsula: faunal aspects.Thalassia Salentina, 39(0), pp.47–72, https://doi.org/10.1285/I15910725V39P47

Pérez-García, J.A., Díaz-Delgado, Y., García-Machado, E., Martínez-García, A., Gonzalez, B.C., Worsaae, K., andArmenteros, M. (2018) Nematode diversity of freshwater and anchialine caves of Western Cuba. Proceedings of the Biological Society of Washington, V.131(1), pp.144–155, doi:10.2988/17-00024

Pérez-garcía, J.A., Ruiz-abierno, A., andArmenteros, M. (2020) A checklist of aquatic nematodes from Cuban Archipelago.Zootaxa, V.4731(3), pp.301–320, doi:10.11646/zootaxa.4731.3.1

Pesta, O. (1959) Harpacticoiden (Crust. Copepoda) aussubmarinenHöhlen und den Benachbartenlitoralbezirken am Kap von Sorrent (Neapel). PubblStnZool Napoli, V.30, pp.95–177.

Poinar, G., and Sarbu, S. (1994)*Chronogaster troglodytes* sp. n. (Nemata: Chronogasteridae) from Movile Cave, with a review of cavernicolous nematodes. Fundamental and Applied Nematology, V.17(3), pp.231–237.

Riera, R., Monterroso, Ó.,Núñez, J., andMartínez, A. (2018) Distribution of meiofaunal abundances in a marine cave complex with secondary openings and freshwater filtrations. Marine Biodiversity, V.48(1), pp.203–215,https://doi.org/10.1007/s12526-016-0586-y

Romano, E.,Bergamin, L.,Pierfranceschi, G., Provenzani, C. and Marassich, A.(2018)The Distribution of Benthic Foraminifera in Bel Torrente Submarine Cave (Sardinia, Italy) and Their Environmental Significance. Marine Environmental Research, V.133, pp.114–27.

Sánchez, N., and Martínez, A. (2019) Dungeons and dragons: Two new species and records of Kinorhyncha from anchialinecenotes and marine lava tubes. ZoologischerAnzeiger, V.282, pp.161–175,https://doi.org/10.1016/j.jcz.2019.05.012

Sánchez, N., Pardos, F., and Sørensen, M.V. (2014) Deep-sea Kinorhyncha: Two new species from the Guinea Basin, with evaluation of an unusual male feature. Organisms Diversity and Evolution, V.14(4), pp.349–361,https://doi.org/10.1007/s13127-014-0182-6

Sandulli, R., Addabbo, M.G., Morone, M.R.D., D'Addabbo, R., Pietanza, R.,andGrimaldi de Zio, S. (1999) Preliminary investigations on meiofauna of two caves in San Domino Island (Tremiti Archipelago, Adriatic Sea).Biologica Marina Mediterranean, V.6, pp.437-440.

Sandulli, R., Semprucci, F., and Balsamo, M. (2014) Taxonomic and functional biodiversity variations of meiobenthic and nematode assemblages across an extreme environment: a study case in a Blue Hole cave. Italian Journal of Zoology, V.81(4), pp.508–516, doi:10.1080/11250003.2014.95235

Smith, A.J., Horne, D.J., Martens, K., andSchön, I. (2015) Class Ostracoda. In: Thorp and Covich's Freshwater Invertebrates: Ecology and General Biology: Fourth Edition. Elsevier.https://doi.org/10.1016/B978-0-12-385026-3.00030-9

Solís-Marín, F.A., Laguarda-Figueras, A., Gutierrez, F.V., Mejía, L., andYáñez, G. (2010) Echinoderm fauna of anchialine caves in Cozumel Island, Mexico. In:Echinoderms: Durham - Proceedings of the 12th International Echinoderm Conference, pp. 259–261, https://doi.org/10.1201/9780203869543-c42

Sørensen, M.V., Jørgensen, A., and Boesgaard, T.M. (2000) A new Echinoderes (Kinorhyncha: Cyclorhagida) from a submarine cave in New South Wales, Australia. Cahiers de Biologie Marine, V.41(2), pp.167–179.

Sørensen-Hygum, T.L., Stuart, R.M., Jørgensen, A., andMøbjerg, N. (2018) Modelling extreme desiccation tolerance in a marine tardigrade. Scientific Reports, V.8(1), doi:10.1038/s41598-018-29824-6

Suárez-Morales, E., and Iliffe, T.M. (2005) A new *StygonitocrellaPetkovski* (Copepoda: Harpacticoida) from a cave in Northern Mexico with comments on the taxonomy of the genus. Hydrobiologia, V.544(1), pp.215–228, doi:10.1007/s10750-005-0621-7

Thomas, M., (2007) Adaptations to life in marine caves, In: Fisheries and Aquaculture, [Ed. Patrick Safran], in Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO,Eolss Publishers, Oxford, UK, http://www.eolss.net.

Todaro, M.A., Leasi, F., Bizzarri, N., andTongiorgi, P. (2006) Meiofauna densities and gastrotrich community composition in a Mediterranean sea cave. Marine Biology, V.149(5), pp.1079–1091,https://doi.org/10.1007/s00227-006-0299-z

Van Hengstum, P.J., and Scott, D.B. (2011) Ecology of foraminifera and habitat variability in an underwater cave: Distinguishing anchialine versus submarine cave environments. Journal of Foraminiferal Research, V.41(3), pp.201–229,https://doi.org/10.2113 gsjfr.41.3.201

Van Hengstum, P.J., Scott, D.B., and Javaux, E.J.,(2009a) Foraminifera in Elevated Bermudian Caves Provide Further Evidence for +21 m,Eustatic Sea Level during Marine Isotope Stage 11. Quaternary Science Reviews, 28(19–20), pp.1850–1860.

Van Hengstum, P.J., Reinhardt, E.G.,Beddows, P.A., Schwarcz, H.P., and Gabriel, J.J.(2009 b) Foraminifera and *Testate Amoebae* (Thecamoebians) in an Anchialine Cave: Surface Distributions from Aktun Ha (Carwash) Cave System, Mexico. Limnology and Oceanography,V.54(1), pp.391–396.

Wilkens, H., Iliffe, T.M., Oromí, P., Martínez, A., Tysall, T. N., and Koenemann, S. (2009) The Corona lava tube, Lanzarote: Geology, habitat diversity and biogeography. Marine Biodiversity, V.39(3), pp.155–167,https://doi.org/10.1007/s12526-009-0019-2

Yamasaki, H., Fujimoto, S., and Tanaka, H. (2020) Three new meiobenthic species from a submarine cave in Japan: *Echinoderesgama*, *E. kajiharai* and *E. uozumii* (Kinorhyncha: Cyclorhagida). Journal of the Marine Biological Association of the United Kingdom, pp.1–22.https://doi.org/10.1017/ S0025315420000429

Zeppilli, D., Leduc, D.,Fontanier, C., Fontaneto,D., Fuchs, S., Gooday, A.J., and others, (2018) Characteristics of Meiofauna in Extreme Marine Ecosystems: A Review. Marine Biodiversity, V.48.1, pp.35–71, https://doi.org/10.1007/s12526-017-0815-z

Zhou, H., and Zhang, Z.N. (2008) Nematode assemblages from submarine caves in Hong Kong. Journal of Natural History, V. 42(9–12), pp. 781–795,https://doi.org/10.1080/00222930701850448

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