Drivers of biodiversity associated with rhodolith beds from euphotic and mesophotic zones: insights for management and conservation

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**Table S1** Presence (X) and absence (-) of macroinvertebrate taxa found in rhodoliths from euphotic (15m depth) and mesophotic zones (40m depth) in the Fernando de Noronha Archipelago and their respective records in collections. Maxillopoda, Malacostraca and Echinodermata were deposited in the Museum of Zoology of the Universidade de São Paulo (MZUSP), the Mollusca are in the Museum of Zoology of the Universidade Estadual de Campinas (ZUEC), the Crustaceans are in the Crustaceans Collection of Museum of Zoology of the Universidade Federal da Bahia (UFBA), and Polychaeta are in the National Museum of Rio de Janeiro.

|  |  |  |  |
| --- | --- | --- | --- |
| **Taxa** | **Euphotic** | **Mesophotic** | **Number** |
| **ARTHROPODA** |
| CRUSTACEA |
| **Ostracoda** |
|  Myodocopa | X | X | UFBA 2185-2194 and MZUSP 34328 |
|  Podocopa | X | X | UFBA 2195-2200 and MZUSP 34332 |
| **Maxillopoda** |
| Copepoda |
| Harpacticoida |
|  Morphotype SP1 | X | - | UFBA 2203-2204 and MZUSP 34333 |
|  Morphotype SP2 | X | - | UFBA 2205-2208 and MZUSP 34333 |
|  Peltidiidae | X | - | UFBA 2210 and MZUSP 34334 |
|  Cylindropsyllidae | X | - | UFBA 2209 |
| Syphonostomatoida  |
|  Artotrogidae | X | - | UFBA 2201-2202 and MZUSP 34335 |
| **Malacostraca** |
| Tanaidacea |
|  Apseudidae | X | X | UFBA 2211-2213 and MZUSP 34336 |
|  *Leptochelia* sp. | X | X | UFBA 2214-2221 and MZUSP 34337 |
| Decapoda |
|  Caridea | X | - |  |
|  *Processa* spp. | X | - | UFBA 2244-2260 and MZUSP 34338 and 34354 |
|  Brachyura  | X | X | UFBA 2261-2273 and MZUSP 34339-34340 |
|  Anomura | X | X | MZUSP 34341 |
| Isopoda |
|  Cirolanidae | X | - | UFBA 2222-2223 and MZUSP 34343 |
|  Coralanidae cf. | X | X | UFBA 2224-2231 and MZUSP 34344 |
|  Anthuridae cf. | X | X | UFBA 2232-2243 and MZUSP 34345 |
| Amphipoda |
|  *Cymadusa* sp. | X | X | UFBA 2293-2307 and MZUSP 34346 |
|  *Tiron* sp*.* | X | - | UFBA 2288-2292 and MZUSP 34347 |
|  *Stenothoe* sp. | X | X | UFBA 2285-2287 and MZUSP 34348 |
|  *Pariphinotus* sp. | X | X | UFBA 2280 and MZUSP 34349 |
|  *Elasmopus* cf. *longipropodus* Senna and Souza-Filho 2011 | X | X | UFBA 2308-2327 and MZUSP 34350 |
|  *Quadrimaera* sp*.* | X | - | UFBA 2282 |
|  *Pseudaeginella montoucheti* (Quitete 1971) Mayer 1890 | X | X | UFBA 2283 |
| Stomatopoda | X | - | UFBA 2329-2331 and MZUSP 34351 |
| Cumacea |
|  Diastylidae | - | X | UFBA 2184 |
|  Nannastacidae | X | - | UFBA 2180-2183 and MZUSP 34352 |
|  Mysida | X | X | UFBA 2178-2179 and MZUSP 34353 |
| **MOLLUSCA** |
| **Gastropoda** | X | X |  |
|  Rissoidae |  |  |  |
|  Simulamerelina caribaea (d'Orbigny, 1842) |  |  | ZUEC-GAS 7272 |
|  Alvania auberiana (d'Orbigny, 1842) |  | X | ZUEC-GAS 7275 |
|  Barleeidae Pseudodiala sp. |  |  | ZUEC-GAS 7277 |
|  Eulimidae |  |  |  |
|  Eulima auricincta (Abbott, 1958) |  |  | ZUEC-GAS 7300 |
|  Litiopidae |  |  |  |
|  Alaba sp. | X | X | ZUEC-GAS 7302 |
|  Marginellidae |  |  |  |
|  Marginellidae sp1 |  | X | ZUEC-GAS 7305 |
|  Marginellidae sp2 |  | X | ZUEC-GAS 7306 |
|  Marginellidae sp3 |  | X | ZUEC-GAS 7309 |
|  Columbellidae |  |  |  |
|  Astyris lunata (Say, 1826) |  | X | ZUEC-GAS 7317 |
|  Mitrella sp. |  | X | ZUEC-GAS 7336 |
|  Pyramidellidae |  |  |  |
|  Pyramidellidae sp. |  | X | ZUEC-GAS 7345 |
|  Eulimastoma sp. |  | X | ZUEC-GAS 7348 |
|  Muricidae |  |  |  |
|  Muricidae sp. |  | X | ZUEC-GAS 7349 |
|  Raphitomidae |  |  |  |
|  Raphitomidae sp. |  | X | ZUEC-GAS 7350 |
|  Triphoridae |  |  |  |
|  Cosmotriphora melanura (C. B. Adams, 1850) |  | X | ZUEC-GAS 7351 |
|  Triphoridae sp. |  | X | ZUEC-GAS 7353 |
|  Phasianelidae |  |  |  |
|  Eulithidium affine (C. B. Adams, 1850) |  | X | ZUEC-GAS 7354 |
|  Triviidae |  |  |  |
|  Pusula pediculus (Linnaeus, 1758) |  | X | ZUEC-GAS 7360 |
|  |  |  |  |
| **Bivalvia** | X | X |  |
| **Polyplacophora** | X | X |  |
| **ANNELIDA** |
| **Polychaeta** |
|  Glyceridae |  |  |  |
|  *Glycerella* sp. | X | X | MNRJP-002242 and MNRJP-002243 |
|  *Hemipodia* sp. | X | X | MNRJP-002238 and MNRJP-002239 |
|  Chrysopetalidae |  |  |  |
|  *Chrysopetalum* sp | X | X | MNRJP-002244 to MNRJP-002251 |
|  Nereididae |  |  |  |
|  *Ceratonereis mirabilis* Kinberg, 1865  | X | X | MNRJP-002503 to MNRJP-002507 |
|  Syllidae |  |  |  |
|  *Branchiosyllis* sp. | X | X | MNRJP-002349 and MNRJP-002351 |
|  *Haplosyllis* sp  | X | X | MNRJP-002334, MNRJP-002344 and MNRJP-002354 |
|  *Megasyllis procera* (Hartman, 1965) | X | X | MNRJP-002356 and MNRJP-002357 |
|  *Nuchalosyllis maiteae* Fukuda & Nogueira, 2013  |  | X |  |
|  *Opisthosyllis brunnea* Langerhans, 1879  | X | X | MNRJP-002395 |
|  *Opisthosyllis* sp. | X | X | MNRJP-002360 |
|  *Syllis aciculigrossa* (San Martín, 1990)  | X | X | MNRJP-002371, and MNRJP-002266 to MNRJP-002280  |
|  *Syllis* cf. *gerlachi* | X | X | MNRJP-002338, MNRJP-002345 and MNRJP-002339 |
|  *Syllis corallicola* Verrill, 1900  | X | X | MNRJP-002350 |
|  *Syllis garciai* (Campoy, 1982)  | X | X | MNRJP-002348 |
|  *Syllis glandulata* Nogueira & San Martín, 2002  | X | X | MNRJP-002348 |
|  *Syllis hyllebergi* (Licher, 1999) | X |  | MNRJP-002355 |
|  *Syllis lutea* (Hartmann-Schröder, 1960)  | X | X | MNRJP-002353 |
|  *Syllis maryae* San Martín, 1992  | X | X | MNRJP-002363 |
|  *Syllis ortizi* San Martín, 1992 | X | X | MNRJP-002381 |
|  *Syllis pseudormillaris* Nogueira & San Martín, 2002  | X |  | MNRJP-002375 |
|  *Syllis sclerolaema* Ehlers, 1901 | X | X | MNRJP-002340 |
|  *Syllis* sp. | X | X | MNRJP-002319, MNRJP-002320, MNRJP-002324, MNRJP-002328, MNRJP-002329, MNRJP-002332 |
|  *Syllis truncata* Haswell, 1920  | X | X | MNRJP-002346 and MNRJP-002347 |
|  *Trypanosyllis zebra* (Grube, 1860)  | X | X | MNRJP-002293 to MNRJP-002302 |
|  *Breviarrosyllis* sp. |  | X | MNRJP-002312 |
|  *Eusyllis* sp. | X | X | MNRJP-002337 |
|  *Odontosyllis* cf *fulgurans* | X | X | MNRJP-002285 to MNRJP-002292 |
|  *Odontosyllis* sp. | X | X | MNRJP-002406 |
|  *Parexogone* sp.  | X |  | MNRJP-002362 |
|  *Procerea* sp. | X |  | MNRJP-002307 to MNRJP-002310 |
|  Amphinomidae |  |  |  |
|  *Branchamphinome* sp. | X | X | MNRJP-002552 to MNRJP-002560 |
|  *Hippone* sp. | X | X | MNRJP-002549, MNRJP-002561, MNRJP-002562, MNRJP-002566, MNRJP-002567 and MNRJP-002571 |
|  *Notopygos* sp. | X | X |  |
|  Dorvilleidae |  |  |  |
|  *Protodorvillea* sp. | X |  |  |
|  *Dorvillea* sp. | X | X | MNRJP-002419 and MNRJP-002420 |
|  Eunicidae |  |  |  |
|  *Nematonereis* sp. | X | X | MNRJP-002431, MNRJP-002436 and MNRJP-002437 |
|  *Eunice* sp. | X | X | MNRJP-002423 to MNRJP-002425, MNRJP-002427, MNRJP-002430, MNRJP-002432 to MNRJP-002434 |
|  *Marphysa* sp. | X | X | MNRJP-002435, MNRJP-002455 |
|  *Lysidice* sp. |  | X | MNRJP-002439, MNRJP-002443, MNRJP-002443, MNRJP-002444, MNRJP-002451 and MNRJP-002453 |
|  *Palola* sp. |  | X | MNRJP-002440 |
|  Sabellidae |  |  |  |
|  *Bispira* sp. | X | X | MNRJP-002459, MNRJP-002461 to MNRJP-002463, MNRJP-002467 and MNRJP-002468 |
|  *Megaloma* sp. | X | X | MNRJP-002460, MNRJP-002464, MNRJP-002470 |
|  *Notaulax* sp. |  | X |  |
|  *Paradialychone* sp. | X | X | MNRJP-002466 |
|  *Pseudopotamilla* sp. | X | X | MNRJP-002475 to MNRJP-002480 |
|  Terebelidae |  |  |  |
|  *Artacama* sp. | X | X | MNRJP-002484 |
|  *Nicolea* sp. | X | X | MNRJP-002483, MNRJP-002485 to MNRJP-002487 |
| **ECHINODERMATA** |  |  |  |
| **Ophiuroidea**  | X | X | MZUSP 01309-01343 and 01347 |
| **Echinoidea** | X | X | MZUSP 01344-01346 |
| **FORAMINIFERA** | X | X |  |
|  **SIPUNCULA** | X | X |  |

**Table S2** Abundance and number of taxa of macroinvertebrates recorded by us and by other authors in in different rhodolith beds, soft bottoms, rocky shore, seagrass and coral reefs.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Region** | **Locality** | **Habitat** | **Abundance** | **Number of taxa** | **Sampling** | **Authors** |
| South Atlantic | Fernando de Noronha Archipelago | Rhodolith bed | 4,683 individuals of vagile macrofaunal (>500µm): 2,982 from the euphotic zone and 1,701 from the mesophotic zone | 15.19 ± 0.75 taxa.rhod-1 from euphotic zone and 8.92 ± 0.71 taxa.rhod-1 from mesophotic zone | Individual sampling of 40 rhodoliths with nylons bags | This study |
| South Atlantic | Arvoredo Island, southern Brazil | Rhodolith bed | 23,570 individuals of solitary macrofaunal (>1mm) | 105 species or genera of vagile invertebrates  | Manual sampling of 70 rhodoliths | Metri (2006) |
| South Atlantic | Arvoredo Island, southern Brazil | Rhodolith bed | **-** | 31 Decapoda species | Active search of specimens | Bouzon and Freire (2007) |
| South Atlantic | Southern coast of Espírito Santo State and Abrolhos Marine National Park, eastern Brazil | Rhodolith bed | 1,361 individuals from Abrolhos bank and 167 specimens from Espírito Santo | 26 Polychaeta Families (45 species from Abrolhos bank and 30 species from Espírito Santo)  | Rhodoliths collected in 10 quadrats (0.25m²) placed along of 20m transects in five different localities and 20 core (10 X 20cm) disposed along of four 10m transects | Berlandi et al. (2012) |
| South Atlantic | João Pessoa city, north-eastern Brazil | Rhodolith bed | 7,678 individuals of epifauna | 122 macrofauna taxa | Rhodoliths collected in 5 quadrats placed in each of the 9 stations  | Riul (2007) |
| South Atlantic | Peregrino oil field, southeastern Brazil | Rhodolith bed | - | 76 taxa vagile invertebrates | Van veen grab of 20L and dredge of 160L | Tamega et al. (2013) |
| South Atlantic | São Sebastião and Ubatuba, southeastern Brazil | Rocky shore (bryozoan) | 1,824 and 5,396 individuals from São Sebastião and Ubatuba, respectively  | 88-115 species from São Sebastião and Ubatuba, respectively | 26 Colonies collected individually in plastic bags | Morgado and Tanaka (2001) |
| North Atlantic | Gulf of California, Mexico | Rhodolith bed and soft bottom | 1.44 ± 0.72 individuals.m-2 from rhodolith bed and 0.72 ± 0.32 individuals.m-2 from sand  | 7 epifauna taxa from rhodolith bed and 9 from sand | Active search of specimens (>0.5mm) along six 30m transects in both habitats | Steller et al. (2003) |
| North Atlantic | Nova Scotia, Canada | Rocky shore (intertidal mussels) | - | 50 taxa (individuals > 0.5mm) | Mussels collected in 15 quadrats (10 X 10cm) I each of the 6 stations | Arribas et al. (2014) |
| North Pacific | Bahía Concepción, Mexico | Rhodolith and *Sargassum* beds | 741.3 and 165.3 individuals per transect from rhodolith and *Sargassum* beds, respectively | - | Active search of specimens in 30 m long X 2 m wide X 2 m height belt transects placed in 72 stations | Hinojosa-Arango et al. (2014) |
| North Pacific | Northern Line Islands | Coral reef | - | 24 species of mobile macroinvertebrates (>5cm) | Active search of specimens in 120m2 transects placed in 10 stations | Sandin et al. (2008) |
| South Indian | Kahuwhera Bay and Te Miko Reef, New Zealand | Rhodolith bed | 8-36 individuals per quadrat of epifauna | 6-20 taxa per quadrat  | Rhodoliths collected in 48 quadrats of 25 X 25cm | Nelson et al. (2012) |
| South Indian | Western Port, Victoria, Australia. | Rhodolith bed | 0.4 ± 0.09 individuals.cm–3 of crytofauna | - | 24 rhodoliths individually bagged | Harvey and Bird (2008) |
| South Indian | The Great Barrier Reef, Australia | Soft Bottom | 36,725 individuals (3115-43690 individuals.m-2; >0.5mm) | 154 taxa | 985 Cores (55 x 200-250mm) placed in 19 stations | Riddle (1988) |
| North Indian | Tawi-Tawi, Philippines | Coral reef | 22,677-61,538 individuals | 111-128 taxa | Active search of specimens in 100m2 placed in 60 stations | Genito and Campos (2013) |
| North Indian | Lakshadweep coral reef lagoons, Arabian Sea | Seagrass | 20,115 individuals (8,411-1,041 individuals.m-2; >0.5mm) | 9 taxa | 125 cores (8.5cm diameter) to a depth of 10cm below the rhizomes, placed in 25 stations | Ansari et al. (1991) |

**References**

Ansari, Z.A., Rivonker, C.U., Ramani, P., Parulekar, A.H. 1991. Seagrass habitat complexity and macroinvertebrate abundance in Lakshadweep coral reef lagoons, Arabian Sea. Coral Reefs 10, 127–131. http://dx.doi.org/10.1007/BF00572170.

Arribas, L.P., Donnarumma, L., Palomo, M.G., Scrosati, R.A. 2014. Intertidal mussels as ecosystem engineers: their associated invertebrate biodiversity under contrasting wave exposures. Mar. Biodivers. 44, 203–211. http://dx.doi.org/10.1007/s12526-014-0201-z.Berlandi, R.M., Figueiredo, M.A.O., Paiva, P.C. 2012. Rhodolith morphology and the diversity of Polychaetes off the southeastern Brazilian coast. J. Coastal. Res. 28, 280–287. http://dx.doi.org/10.2112/11T-00002.1.

Bouzon, J.L., Freire, A.S. 2007. The Brachyura and Anomura fauna (Decapoda; Crustacea) in the Arvoredo Marine Biological Reserve on the southern Brazilian coast. Braz. J. Biol. 67, 321–325. <http://dx.doi.org/10.1590/S1519-69842007000200018>.

Genito, G., Campos, W. 2013. Temporal patterns of reef macroinvertebrate communities Tawi-Tawi, Philippines. Galaxea, J. Coral Reef Stud. 15, 143–153. <http://dx.doi.org/10.3755/galaxea.15.143>.

Harvey, A.S., Bird, F.L. 2008. Community structure of a rhodolith bed from cold-temperate waters (southern Australia). Aust. J. Bot. 56, 437–450. <http://dx.doi.org/10.1071/BT07186>.

Hinojosa-Arango, G., Rioja-Nieto, R., Suárez-Castillo, A.N., Riosmena-Rodríguez, R. 2014. Using GIS methods to evaluate rhodolith and *Sargassum* beds as critical habitats for commercially important marine species in Bahía Concepción, BCS, México. Cryptogamie Algol. 35, 49–65, http://dx.doi.org/ 10.7872/crya.v35.iss1.2014.49.

Metri, R. 2006. Ecologia de um banco de algas calcárias da Reserva Biológica Marinha do Arvoredo, SC, Brasil. Dissertation, Universidade Federal do Paraná.

Morgado, E.H., Tanaka, M.O. 2001. The macrofaunal associated with the bryozoan *Schizoporella errata* (Walters) in southeastern Brazil. Sci. Mar. 65, 173-181.

Riddle, M.J. 1988. Patterns in the distribution of macrofaunal communities in coral reef sediments on the central Great Barrier Reef. Mar. Ecol. Prog. Ser. 47, 281–292.

Riul, P. 2007. Aspectos da biologia e ecologia de rodolitos e comunidade associada na grande João Pessoa, PB. Dissertation, Universidade Federal da Paraíba.

Tamega, F.T.S., Oliveira, P.S., Figueiredo, M.A.O. 2013. Catalogue of the benthic marine life from Peregrino oil field, Campos basin, Brazil. Instituto Biodiversidade Marinha, Rio de Janeiro.

Morgado, E.H., Tanaka, M.O. 2001). The macrofaunal associated with the bryozoan *Schizoporella errata* (Walters) in southeastern Brazil. Sci. Mar. 65, 173–181.

Nelson, W.A., Neill, K., Farr, T., Barr, N., D’Archino, R., Miller, S., Stewart, R. 2012. Rhodolith beds in northern New Zealand: Characterization of associated biodiversity and vulnerability to environmental stressors. New Zealand Aquatic Environment and Biodiversity Report, Wellington.

Sandin SA, Smith JE, DeMartini EE, Dinsdale EA, Donner SD, Friedlander AM, Konotchick T, Malay M, Maragos JE, Obura D, Pantos O, Paulay G, Richie M, Rohwer F, Schroeder RE, Walsh S, Jackson JBC, Knowlton N, Sala E (2008) Baselines and degradation of coral reefs in the Northern Line Islands. PLos ONE 3: e1548. doi: 10.1371/journal.pone.0001548Steller, D.L., Riosmena-Rodríguez, R., Foster, M.S., Roberts, C. 2003. Rhodolith bed diversity in the Gulf of California: The importance of rhodolith structure and consequences of anthropogenic disturbances. Aquat. Conserv. 13: S5–S20. http://dx.doi.org/10.1002/aqc.564.