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Review

An Overview of Rhodoliths: Ecological Importance and Conservation Emergency

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Abstract: Red calcareous algae create bio-aggregations ecosystems constituted by carbonate calcium, with two main morphotypes: geniculate and non-geniculate structures (rhodoliths may form bio-encrustations on hard substrata or unattached nodules). This study presents a bibliographic review of the order Corallinales (specifically, rhodoliths), highlighting on morphology, ecology, diversity, related organisms, major anthropogenic influences on climate change and current conservation initiatives. These habitats are often widespread geographically and bathymetrically, occurring in the photic zone from the intertidal area to depths of 270 m. Due to its diverse morphology, this group offers a special biogenic environment that is favourable to epiphyte algae and a number of marine invertebrates. They also include holobiont microbiota made up of tiny eukaryotes, bacteria and viruses. The morphology of red calcareous algae and outside environmental conditions are thought to be the key forces regulating faunistic communities in algae reefs. The impacts of climate change, particularly those related to acidification, might substantially jeopardise the survival of the Corallinales. Despite the significance of these ecosystems, there are a number of anthropogenic stresses on them. Since there have been few attempts to conserve them, programs aimed at their conservation and management need to closely monitor their habitats, research the communities they are linked with and assess the effects they have on the environment.

Keywords: Corallinales; rhodolith beds; bioengineers; algae reefs; climate change

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1. Introduction

Red calcareous algae create bio-aggregation ecosystems constituted by calcium carbonate ($CaCO_3$), with two main morphotypes: (i) geniculate forms (i.e., articulate, "with uncalcified flexible genicula alternating with rigid calcareous inter-genicula" [1]) and (ii) non-geniculate structures [2–4], including bio-encrustations (CCA—crustose coralline algae) on hard-bottom substrata, such as rocks, boulders and pebbles, as well as unattached nodule aggregation morphotypes [5,6], designated here as "rhodoliths *stricto sensu*" (Figures 1 and 2). When coralline red algae make up more than 50% of the volume of a biogenic nodule, the nodule is referred to as a "rhodolith". The biogenic structure is otherwise referred to as a "coating". [7–9]. As these algae reefs have calcium carbonate in their structure, similar to corals [10], they are important sinks for this chemical substance [11].



Figure 1. Rhodolith beds (remarkably, unattached nodule aggregation morphotypes) at the coast of the state of Paraíba, northeast Brazil. Photo: Massei, K.

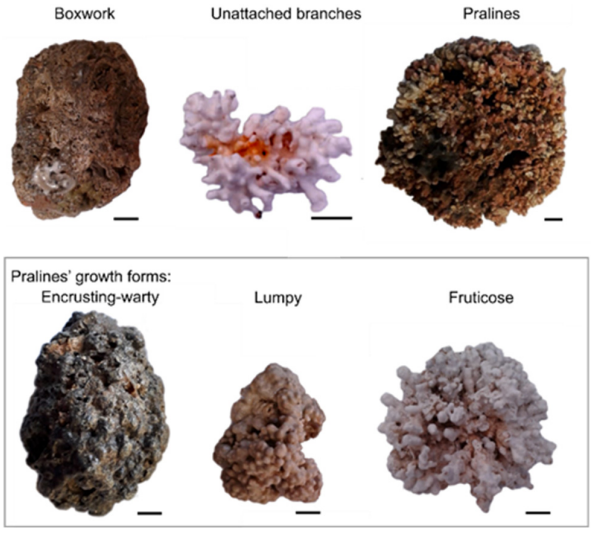

Figure 2. Rhodoliths' morphology and pralines' growth forms, collected along the shore of the Brazilian northeast state of Paraíba; scale: 1 cm. Photos: Costa, D.A.; Pereira, A.R.; Silva, F.A.; Silva, M.P.

"Maërl" is another term for these biogenic formations, both alive and dead, that originated in Brittany (on the northwest coast of France) [5,12,13]. The term rhodolith is more prevalent worldwide, and the name "maërl" is mostly employed in research near the European Atlantic coast [7,14,15]. Rhodoliths are also known as "algaliths", which are nodules the size of pebbles or non-articulate granules (also known as "oncoids") produced from algae that exude carbonate [16]. Over time, several other names have also been employed, including numerous colloquial and scientific expressions. [17]. These different designations have contributed to hampering their definition, such as "boxwork rhodoliths", "coatings", "nucleated rhodoliths", "gravels", "nodules", "rhodolites/rhodoliths", "prâlines", "algal balls", "marls/maërls", "coralline algal nodules", "oncoliths/onkoids", "rhodoids", "algal-encrusted grains", "rubbles", "unattached branches" and "glagla" [9,18–20].

Although rhodoliths and maërl are quite similar in semantic terminology [21–23], rhodoliths include dead and alive unattached coralline red algae, whereas maërl only represents living, branched coralline thalli [24,25]. When its palaeoecological relevance

was recognized, the word "rhodolith" was coined to describe a particular form of red stone [14,26]. Rhodoliths have become trustworthy markers in paleoenvironmental and palaeoecological surveys due to their low growth rate (between 0.01 and 5.0 mm per year) and carbonate nature, as well as their good preservation in fossil deposits [27–34]. These coralline algae have been extant across the earth for at least 55 million years, according to fossil evidence [35].

Rhodoliths are biogenic aggregations, which can have organic or inorganic nuclei that are either monospecific or multispecific in terms of the coralline algae they are composed of. In fact, it is possible that a number of non-articulate species are to blame for the extensive rhodolith beds that have formed on the ocean floor [17,36,37]. Other organisms may occasionally play an equal or even greater role as builders than coralline algae. For instance, benthic Foraminifera and coralline algae work together to generate "for-algaliths" [38,39]. The tubes of serpulid polychaetes may also be embedded into the nodules by the laminar thalli of coralline algae [38,40].

2. Geographical Distribution

One of the taxonomic groups with a wider geographic distribution range and larger climatic and bathymetric amplitudes include the rhodolith-forming algae [41]. The oceanic photic area is home to both living and dead calcareous structures, which are found from the intertidal zone to depths of 270 m [5,7,17,42]. Rhodoliths have been deemed suitable for studies on thermogeography because coralline algae undergo a mechanism known as "thermal control", which causes their growth and reproduction rates to rise in warmer water [43].

The rhodolith beds are distributed from the Gulf of Alaska (Prince William Sound) to the Gulf of Mexico in North and Central America, [5,7,44,45] at depths of 50–90 m on the continental shelf [46]. These algae are also found along the Pacific coast of the southern hemisphere, from the Gulf of California to the South of Chile [47]. Rhodolith beds are widespread along the southern hemisphere's Atlantic coast. On the Brazilian coast, for example, rhodolith beds may be the largest $CaCO_3$ depositional area in the world (approximately 2×10^{11} tons) [48,49], particularly in the Abrolhos Bank region in northeast Brazil [4,48]. Additionally, rhodolith beds were found in the coral reef systems off the mouth of the Amazon River, covering an area of one thousand kilometres in length and 50 km in width, from French Guiana to the State of Maranhão (Brazil) [50].

On the European continent, these algae may be found on the Atlantic coastline—in passageways scoured by the tides and in protected regions with light currents, from the intertidal to 60 m depth—including Iceland, the Norwegian Sea (in deepest waters), the North Sea, the Baltic Sea, France, the United Kingdom, the Iberian Peninsula and the Canary Islands [44,51,52]—constituting a remarkably cold-adapted species [3], with a predominance of CCA forms (while Canary/Macaronesian rhodoliths are predominantly unattached forms/rhodoliths *stricto sensu*). Furthermore, along the Mediterranean coasts [51,53,54], e.g., in the Aegean Sea, Sardinia (Italy) and in Corsica and Marseille (France) [55], rhodolith-forming species are mainly represented by warm water-adapted and unattached red calcareous algae, which accumulate on the sea floor, from 9 to 150 m depths [3]. On this continent, Scotland features the most widespread rhodolith beds known, with 8000-year-old fossil records [56].

In Africa, rhodolith beds are widespread in the Gulf of Guinea, South Africa (such as on Príncipe's island), and they can be found at depths of 5 m to 30 m [18,57,58]. In the Gulf of Aden, Northeastern Ethiopia [59] and in the Cape Verde islands [60], fossil rhodolith formations and sedimentary features that provide evidence for this habitat in the Pleistocene interglacial can be found.

Few of these non-geniculate red algae have been reported in Asia, from India to Russia [61–64]. Rhodolith beds, both alive and dead, are primarily found in Japan [65].

Finally, in Oceania, on the Great Australian Bight shaved shelves, rhodolith beds form a stable substrate conditions [66], being the primary successional coral-reef building stage

for damaged reefs [67–69]. Rhodoliths can also be found in New Zealand, e.g., around the North Island [70]. These rhodolith beds are approximately 6500 years old [71], and are integral parts of the processes of building, erosion, burial, and recolonization [72].

Regarding algae species composition, the order Corallinales Silva & Johansen, 1986, represents the largest group in Rhodophyta, with around 840 species [73–75], classified systematically on the AlgaeBase website [74].

3. Rhodoliths' General Morphological Characteristics

The rhodoliths' morphology and phytal composition (i.e., related fauna in algae) and, consequently, the heterogeneity of rhodolith beds, are strongly influenced by hydrodynamism and light [76]. Rhodoliths are usually more common in zones with moderate to high-energy currents (excluding the *L. corallioides* and *P. calcareum* mentioned above) [21,77]. However, they may exhibit significant morphological polymorphism, which is associated with hydrodynamism: the size, shape and the pattern of the ramification of the rhodoliths are mostly influenced by local hydrodynamics [7,36]. The species composition of rhodolith beds, on the other hand, is also influenced by light penetration and depth, sedimentation, the temperature of the water, salinity and water quality [21], among other factors. This complexity of conditions commonly causes sporadic and irregular distribution patterns of rhodoliths on the ocean floor [36], where the rhodolith beds intercalate with sandy bottoms, forming mosaics within marine environments [78].

Rhodoliths can be divided into three types based on their morphology: boxwork, unattached branches and pralines (Figure 2, e.g., [1,8,41,79]):

(a) Boxwork: multi-specific and irregular nodules with inside spaces filled by sediment and a core containing a small pebble or biogenic remnant;
(b) Unattached branches: rhodoliths lacking a macroscopic nucleus and potentially characterized by a high degree of protuberance;
(c) Pralines: compact mono (oligo)specific nodules, with a lytic or biogenic nucleus, with protuberances that have developed strongly on the surface.

The growth pattern of rhodoliths of the pralines type can be used for further classification (Figure 2, [8,80,81]):

(a) Warty growth: branches can be cylindrical or compact, and are typically organized radially;
(b) Lumpy growth: protuberances are enlarged, numerous and contiguous and rarely branched;
(c) Fruticose growth: branches are remarkably detached from each other.

Other species, both fauna and flora, are provided with shelter and safety by the complexity formed by the accumulation of the rhodolith nodules of various shapes (i.e., spherical and elliptical shapes of distinct sizes, ranging from a few millimetres to several centimetres). The associated flora also increases the complexity of the rhodolith, which serves as a micro-ecosystem [82] and may contain different fauna. This micro-ecosystem may be fundamentally dependent on indirect positive interactions (such as mutualism and commensalism), which involve successions of positive interspecific interactions, a phenomenon known as "facilitation cascades" [83]. This process is applied in hierarchically organized communities where a basal habitat-former (characteristically a large primary producer, e.g., the rhodolith) creates living space for an intermediate habitat-former (e.g., an algal epiphyte), which in turn produces living space for the focal organisms (e.g., polychaetes, echinoderms, molluscs and crustaceans).

4. Associated Biota

Rhodoliths are bioengineers ("biological builders" or "ecosystem engineers"), that supply an irregularly shaped three-dimensional environment [76,84] and provide food for multiple marine organisms [4]. Due to the variety of niches it offers, the rhodolith provides shelter and protection for associated fauna against physical disturbances and predators and allows coexistence [75,85]. Rhodoliths have been recognised as places of the recruitment of marine species, providing refuge for the early stages of growth of commercially

significant fishes [17] and for several species of marine invertebrates [17,82,86–89], such as polychaetes, bivalves, molluscs and echinoderms [81,85,90–92]. A rhodolith's internal space may further contain particles of organic matter for filtering organisms and may provide microphytobenthos for herbivorous scavengers [93].

The rhodolith's inhabiting organisms can be divided into endobionts and ectobionts. The endobiota inhabit the interior of the rhodoliths, being represented mostly by the following taxonomic groups: Mollusca, Echinodermata and Polychaeta. The ectobiota living on its surface belong primarily to cnidaria, crustacea and lithophytic/epilithic algae.

The composition of macroalgal assemblages on rhodolith beds can vary greatly, depending on the habitat and the depth at which the bed develops. The associated macroalgal assemblages are normally characterized by sciaphilous and reophilous species in deeper beds (e.g., *Osmundaria* spp., *Sargassum* spp., *Sporochnus* spp. and *Phyllariopsis* spp.) and by more generalist species in shallower beds (such as the genera *Corallina* spp., *Gelidium* spp., *Gracilaria* spp., *Caulerpa* spp., *Codium* spp., *Halimeda* spp., *Dictyota* spp. and *Padina* spp.) [94–97].

The key factors controlling the faunistic communities connected to rhodolith beds are both the morphological characteristics of the rhodolith and the environmental characteristics in which they are found [98,99]. Usually, the abundance and diversity of the associated fauna may increase with the size and heterogeneity of the rhodolith [22,82,100,101]. Yet, studies confirming this hypothesis are still incipient [102].

Functional Approach

Regarding the functional composition of the associated fauna with rhodoliths, few studies have attempted to understand their dynamics and how the external environment may affect them. However, information on functional diversity can lead to a better understanding of the ecological trade-offs and roles of the species within the ecosystem [103], particularly when considering the rhodolith as a micro-ecosystem. Most studies tackling functional aspects have focused on feeding or trophic guilds and interactions [12].

Still, a more comprehensive approach may provide a deeper understanding of the interplay between rhodoliths and their associated fauna [90]. For instance, a recent study from northeast Brazil (with 144 analysed rhodoliths), combining different traits for the associated invertebrates' communities, found differences in their functional identity when comparing three beaches with different anthropogenic impacts [90]. Most invertebrates living on the rhodoliths of less polluted beaches were polychaetes and echinoderms that were predators and biodiffusors with slow free movement and high fecundity [90]. These characteristics appear to be beneficial for a three-dimensional environment like rhodoliths, fostering food, habitat and protection for the resident fauna, while the fauna might benefit from the rhodolith itself via oxygenation and sediment remobilization. However, the invertebrate community from the most contaminated beach had distinctive traits, including a higher occurrence of suspended feeder bivalves with restricted mobility and the absence of several functions seen on the two better preserved beaches, which may be crucial for the survival of rhodolith habitats [90].

5. Ecological Importance as Regulation Services

Besides the fundamental role of rhodolith beds as habitat for a variety of biota, as detailed above, from an environmental perspective, rhodolith beds serve an essential function in maintaining marine pH levels [28,104], due to the high concentrations of carbonates that accumulate in their structures.

Rhodoliths also play a crucial role for climate regulation processes by intervening in the global cycles of diverse chemical elements [4]. An example is the biogenic gas dimethylsulphide (DMS), which plays "an important role in the Earth's albedo, and thus climate regulation, through the formation of aerosols and cloud condensation nuclei" [105]. Recent studies have also highlighted their potential as blue carbon by sequestering atmospheric CO_2 and storing it for millennia [106,107]. This process of carbon storage may occur within

the rhodolith tissue and through the sediment with organic material trapped within the bed, yet the stability of these stores are still being assessed [107].

Additionally, the production of dissolved organic carbon and calcium carbonate promotes the proliferation of other organisms within the ecosystem [107]. When associated with rhodoliths, a group of organisms formed by bacteria, viruses and small eukaryotes acts as an ecological unit and is designated as holobiont [108], whose function is intimately related to the associated microbiome [109]. This symbiotic microbiota may react quickly to changes in the ambient conditions, offering an effective mechanism for acclimatization through mechanisms of adaptation (i.e., phenotypic plasticity). For instance, under the conditions of increased carbon dioxide partial pressure (pCO_2) and seawater temperature, specific host-associated microorganisms may experience changes in abundance, altering the fitness and function of the holobiont [110]. However, it is still unknown how certain climate change factors, such as ocean acidification, may affect the holobiont community [109]. Additionally, due to the importance of calcium carbonate substrates in the life cycle of many macroalgae, this community (microorganisms and rhodoliths) is crucial for the maintenance of marine ecosystems [46].

Generally, the ecological services offered by rhodoliths vary depending on the geographic area. In tropical areas, these algae serve as calcified substrates for other organisms [111]. Additionally, they can have a physical stabilizing effect that facilitates coral settlement and the establishment of coral reefs across geologic timescales [112]. Water filtration and pH regulation in waters and sediments, as well as additives for animal food (raw material production), are among the described ecosystem services related to the rhodoliths beds [21,113].

6. Climate Change and Anthropogenic Impacts

The reduction in marine biodiversity, including calcareous organisms (such as coral reefs and rhodoliths beds), is ultimately caused by ocean acidification and global warming and their associated effects, such as changes in carbon chemistry and sea level rise, leading to changes in the way the marine ecosystem functions [75,114–116]. These algae's capacity for carbon sequestration (the absorption and storage of atmospheric CO_2) may be equivalent to the coral reefs in extent and productivity [48], so that rhodolith have been considered "algae reefs" [35]. The calcification of the rhodoliths, however, may be negatively impacted by ocean acidification through the increase in pCO_2 levels due to the high dissolubility of their calcite and magnesium structures [117], the phenomenon known as "coralline algae bleaching", which results in the depletion of photosynthetic pigments and may lead to necrosis [118]. Nevertheless, dissolved inorganic carbon may favour the growth of foliose algae ("fleshy algae") to the detriment of calcareous algae [117,119].

Additionally, the levels of dissolved inorganic carbon, alkalinity and oxygen, besides affecting the calcification rates of the coralline algae, may also affect photosynthesis and respiration rates [117], whose effects may be intensified by the increase in temperature, as documented, e.g., for *Porolithon onkodes* (Heydrich) Foslie 1909 from Australia [120] and *Lithophyllum cabiochae* (Boudouresque & Verlaque) Athanasiadis 1999 from the Mediterranean Sea (France) [121].

Still, the effects of the climate conditions could be very species-specific. Some species, such as *Bossiella orbigniana* (Decaisne) Silva 1957, *Neogoniolithon* sp., *Lithothamnion glaciale* and *Lithophyllum cabiochae*, have the ability to maintain high internal pH to precipitate $CaCO_3$, despite the reduction in environmental pH [122–124]. But as a result, these species would be more susceptible to pathogens [125]. Additionally, these negative effects could result in a decline in photosynthetic activity, compromising the algae metabolism, ultimately resulting in the death of rhodoliths and the associated fauna [126].

In addition to the climate impacts, rhodolith beds have low resilience and, consequently, they are extremely susceptible to anthropogenic activities, such as dredging/trawling, aquaculture, coastal chemical pollution, petroleum exploration/drilling activities, tourism activities, overexploitation, and the indirect effects of invasive species [95,127,128]. These an-

thropogenic activities and their potential effects on rhodolith beds are summarized in Table 1 and Figure 3.

Table 1. Examples of consequences from the main anthropogenic activities affecting rhodoliths beds.

Drivers	Examples of Consequences/Impacts	References
Dredging/trawling	Production of a plume of fine sediment that amplifies the effect on the remaining organisms; physical perturbation in the fauna and associated algae; release of blue carbon stored in the beds	[129–131]
Coastal chemical pollution	Impacts the carbon cycle and algae's ability to sequester carbonate	[117]
Aquaculture (including fish farming)	Due to deposition of fine sediments with high organic matter content/waste dispersion, the associated fauna changes, decreasing their complexity and biodiversity	[26,132,133]
Petroleum exploration/drilling activities	Disturbs photosynthesis due to sediment suspension; induces the burial of the algae	[134,135]
Overexploitation—rhodolith as raw material	Declines rhodoliths and associated fauna	[134]
Tourism activities	Alterations in the associated fauna due to increased and seasonal organic pollution; the trampling of the sediment beds containing rhodoliths	[136]
Indirect effects of invasive species/ecological competition	Excrement from invasive molluscs (e.g., *Crepidula fornicuta*) cover the spaces between the stalks of the rhodoliths or the ocean floor is covered by fleshy and/or invasive algae that make rhodoliths more vulnerable [95]	[12,44]

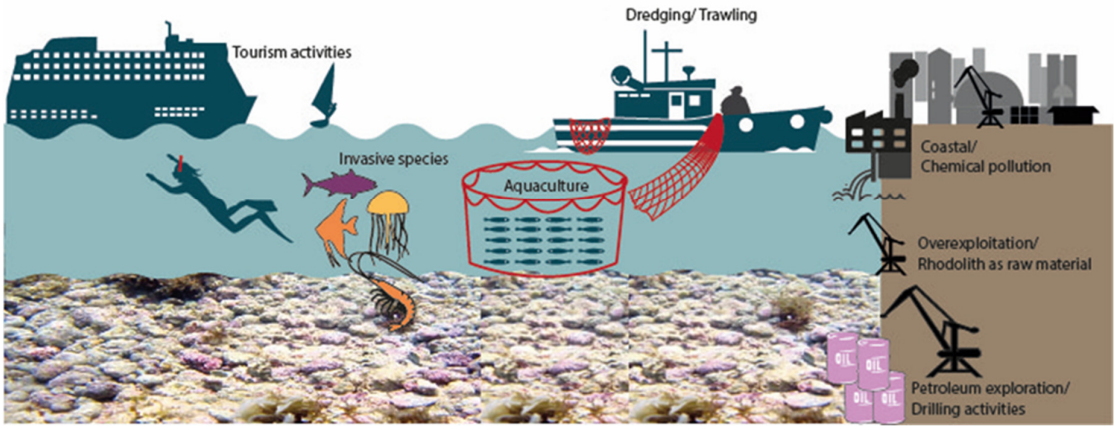

Figure 3. Schematic representation of main anthropogenic factors affecting the rhodolith beds. Figure produced using Canva software (https://www.canva.com/, accessed on 15 February 2023), with a Creative Commons (CC BY 4.0) license for images/drawings. Photo (rhodolith beds): Massei, K.

Environmental Stressors

$CaCO_3$-ionized availability in marine water is essential for rhodolith-forming red algae species to build their three-dimensional carbonate structures via assimilation process/carbon sequestration, which is dependent on the ocean balance [4]. In this way, rhodolith beds are very sensitive to variations in chemical–physical parameters, which in turn affect their growth and survival. As example, pH decreases linked to the release of pollutant gas is the main factor ("our emphasis") that drives the "health" of the beds.

Hydrodynamic forces correspond a fundamental driver for distribution and shape-delineation of the rhodolith beds through a phenomenon that relocates and creates the unattached nodules. Wave activity, intensified by storms, promotes significant rhodolith beds mobility and morphology-formation [137].

Many rhodolith-forming red algae species are adapted to water temperature conditions that dictate the occurrence of colder and warmer taxa worldwide. In temperate areas, rhodolith beds are abundant, particularly in Europe, where the species *Lithothamnion*

glaciale Kjellman, 1883; *Lithothamnion corallioides* (Crouan & Crouan) Crouan & Crouan, 1867; *Lithothamnion tophiforme* (Esper) Unger 1858; and *Phymatolithon calcareum* (Pallas) Adey & McKibbin ex Woelkering & Irvine, 1986, dominate [12,21,44,53]. The similar ecological niches of *L. corallioides* and *P. calcareum* are influenced by environmental drivers, such as wave motion and seabed currents—resulting from rivers, tides and salinity differentials—and the interaction between depth, light accessibility and water quality in general [21,41,138,139]. These coralline algae are typically better adapted to low-energy oceanographic environments (they usually do not occur when exposed to strong wave activity), more frequently found in coves and bays [21].

Water temperature also has a significant impact on the species composition of rhodoliths, principally in the North Atlantic [140]. For example, the absence of *L. corallioides* in Scotland has been attributed either to the wintertime low temperatures not allowing the survival of this species (ideal value between 2 and 5 °C) or to the lack of high temperatures lasting long enough to support the species' annual growth [21]. On the other hand, *L. glaciale* appears to be restricted to areas on the north of the British Isles [21], requiring low temperatures for reproduction (<9 °C, e.g., [141]).

Indeed, ocean warming can trigger tropicalization events [138], which are characterized by the gradual replacement of cold-adapted rhodoliths with warm-adapted ones.

7. Rhodolith Bed Preservation and Protection Initiatives

Rhodoliths are a unique biotope in the world, yet despite this, they are constantly endangered due to climate change and anthropogenic pressures (as stated above). Additionally, there are insufficient protection measures and a general lack of understanding of how these structures function as an ecosystem [17]. Nevertheless, to prevent the extinction of such unique and significant environments, considered an unrenewable resource, various conservation and protection programs are expanding globally [142]. Examples of such protection measures are the habitat directives of the European Commission, i.e., Directive n° 82/72/EEC—Bern Convention [143]; 92/43/EEC—'Natura 2000' [2,144], category 1170: reefs [17,145]; and Council Regulation 1967/2006 [146]. All 28 countries of the European Union are covered by Natura 2000, which has authority over both land and sea [145].

The goal of these habitat directives is to ensure both the maintenance of conservation status and its expansion, and the rhodolith-forming algae species *L. corallioides* and *P. calcareum* are species included in priority habitats [144]. In Europe, there is also the 'Biomaërl' programme, which was started in 1996 in the United Kingdom, France, Spain and Malta, the primary goals of which are to protect and monitor biodiversity related to the maërl beds in the NE Atlantic and Mediterranean, as well as to evaluate principal anthropogenic impacts [53].

Only a few protected marine areas in the Eastern Pacific consider rhodolith-forming algae as important habitats for preservation, e.g., in Mexico [23] and in isolated areas in Costa Rica and Panama [147].

In Asia, there are certain UNESCO global geoparks that comprise rhodolith banks, e.g., Shimabara Peninsula in Kyushu, Japan (Unzen Volcanic Geopark), the Jeju Island in Korea (Jeju Island Geopark) [148] and certain local parks in Japan [149].

"ReBentos" ("Rede de Monitoramento de Habitats Bentônicos Costeiros") is a marine monitoring network in Brazil that aims to establish an integrated network of studies on benthic habitats along the Brazilian coastline, including vegetated submerged sea floors, rocky shores, beaches, marshes, mangroves, coral reefs, rhodolith benches and estuaries, all integrated with environmental education activities [150]. ReBentos is linked to the National Institute of Science and Technology for Climatic Changes ("Instituto Nacional de Ciência e Tecnologia para Mudanças Climáticas", INCT-MC) and to the "Coastal Zones Subnet from CLIMATE Network" (Brazilian Ministry of Science, Technology, Innovation and Communications). This organization's mission is to provide scientific bases for identifying the effects of regional and global environmental changes in the stated benthic habitats, including rhodolith beds, and to serve as vital tool for the implementation of effective

environmental management strategies. This organisation has thus begun the collection of historical data of marine biodiversity along the Brazilian coast [150,151]. Nevertheless, the studies are still ongoing, with no results published so far.

Moreover, in the context of conservation, environmental education can be a crucial technique for raising local understanding among those who are enjoying these marine communities [152], including the rhodolith beds and associated biota [153,154]. In this sense, safeguarding coastal regions could benefit the tourist sector by preventing deterioration through visitors in such zones [136].

8. Conclusions

Rhodolith beds, composed of non-geniculate red calcareous algae, are essential marine habitats due to their remarkable ability to assimilate calcium carbonate and to shelter resident biota. The main taxon that makes up calcareous algae is the order Corallinales, which is found in all oceans, mainly in tropical and temperate zones. The habitat is known for variety of ecosystem services, such as steaming from nursery areas, as a habitat for a variety of species and sediment stabilization, as well as their important role in balancing biogeochemical cycles, including blue carbon potential and stabilizing pH. Nonetheless, this calcareous habitat is sensitive to a variety of human activities, such as dredging, pollution, aquaculture, tourism effects and, ultimately, climate change, from which ocean acidification is among the major stressors compromising $CaCO_3$ assimilation. Thus, it is crucial to continue conducting studies on rhodolith beds to gain a better understanding of their ecosystem service potential, including blue carbon; to adopt functional diversity in order to understand the dynamics of rhodolith-associated fauna; and to develop more comprehensive protection actions schemes to ensure their conservation.

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References

1. Basso, D. Carbonate production by calcareous red algae and global change. *Geodiversitas* **2012**, *34*, 13–33. [CrossRef]
2. Hernández-Kantún, J.J.; Riosmena-Rodriguez, R.; Hall-Spencer, J.M.; Peña, V.; Maggs, C.A.; Rindi, F. Phylogenetic analysis of rhodolith formation in the Corallinales (Rhodophyta). *Eur. J. Phycol.* **2015**, *50*, 46–61. [CrossRef]
3. Riosmena-Rodríguez, R.; Nelson, W.; Aguirre, J. *Rhodolith/Maërl Beds: A Global Perspective*; Riosmena-Rodríguez, R., Nelson, W., Aguirre, J., Eds.; Coastal Research Library; Springer International Publishing: Cham, Switzerland, 2017; Volume 15, ISBN 978-3-319-29313-4.
4. Costa, D.A.; Massei, K.; Moura, A.; Christoffersen, M.L.; Dolbeth, M. Rhodoliths: Our "rock-and-rolling" underwater friends. *Front. Young Minds* **2022**, *10*, 675695. [CrossRef]
5. Bosence, D.W.J. The occurrence and ecology of recent rhodoliths—A review. In *Coated Grains*; Peryt, T.M., Ed.; Springer: Berlin/Heidelberg, Germany, 1983; pp. 225–242. ISBN 9783642688690.
6. Darrenougue, N.; De Deckker, P.; Payri, C.; Eggins, S.; Fallon, S. Growth and chronology of the rhodolith-forming, coralline red alga *Sporolithon durum*. *Mar. Ecol. Prog. Ser.* **2013**, *474*, 105–119. [CrossRef]
7. Foster, M.S. Rhodoliths: Between rocks and soft places. *J. Phycol.* **2001**, *37*, 659–667. [CrossRef]
8. Sañé, E.; Chiocci, F.L.; Basso, D.; Martorelli, E. Environmental factors controlling the distribution of rhodoliths: An integrated study based on seafloor sampling, ROV and side scan sonar data, offshore the W-Pontine Archipelago. *Cont. Shelf Res.* **2016**, *129*, 10–22. [CrossRef]
9. Steneck, R.S. The ecology of coralline algal crusts: Convergent patterns and adaptative strategies. *Annu. Rev. Ecol. Syst.* **1986**, *17*, 273–303. [CrossRef]
10. Krayesky-Self, S.; Schmidt, W.E.; Phung, D.; Henry, C.; Sauvage, T.; Camacho, O.; Felgenhauer, B.E.; Fredericq, S. Eukaryotic life inhabits rhodolith-forming coralline algae (Hapalidiales, Rhodophyta), remarkable marine benthic microhabitats. *Sci. Rep.* **2017**, *7*, 45850. [CrossRef]
11. Amado-Filho, G.M.; Pereira-Filho, G.H.; Bahia, R.G.; Abrantes, D.P.; Veras, P.C.; Matheus, Z. Occurrence and distribution of rhodolith beds on the Fernando de Noronha Archipelago of Brazil. *Aquat. Bot.* **2012**, *101*, 41–45. [CrossRef]
12. Grall, J.; Hall-Spencer, J.M. Problems facing maerl conservation in Brittany. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **2003**, *13*, S55–S64. [CrossRef]
13. Lemoine, M.D.B. *Répartition et Mode de Vie du Maërl ("Lithothamnium calcareum") Aux Environs de Concarneau (Finistère), par Mme Paul Lemoine*; Lemoine, M.D.B., Ed.; Institut Océanographique: Paris, France, 1910.
14. Bosellini, A.; Ginsburg, R.N. Form and internal structure of recent algal nodules (Rhodolites) from Bermuda. *J. Geol.* **1971**, *79*, 669–682. [CrossRef]
15. Peña, V.; Bárbara, I. Los fondos de maërl en Galicia. In *Proceedings of the Boletín de la Sociedad Española de Ficología*; Congresso Europeo de Ficología; Sociedad Española de Ficología: Barcelona, Spain, 2007; pp. 11–17.
16. Leeder, M. *Sedimentology and Sedimentary Basins*, 2nd ed.; Leeder, M., Ed.; John Wiley & Sons Ltd.: Chichester, UK, 2011; ISBN 978-1-405-17783-2.
17. Riosmena-Rodríguez, R. Natural history of rhodolith/maërl beds: Their role in near-shore biodiversity and management. In *Rhodolith/Maërl Beds: A Global Perspective*; Riosmena-Rodríguez, R., Nelson, W., Aguirre, J., Eds.; Springer International Publishing: Cham, Switzerland, 2017; pp. 3–26. ISBN 978-3-319-29313-4.
18. Forever-Príncipe. Assess the Importance of Príncipe's Rhodolith Beds (as Soon as Possible). Available online: https://forever-principe.com/conservation-projects/rhodolith-beds/ (accessed on 20 June 2022).
19. Mazzullo, S.J.; Cys, J.M. Unusual algal-crystalline carbonate coated grains from the Capitan Reef (Permian, Guadalupian), New Mexico, USA. In *Coated Grains*; Peryt, T.M., Ed.; Springer: Berlin/Heidelberg, Germany, 1983; pp. 599–608.
20. McCoy, S.J.; Kamenos, N.A. Coralline algae (Rhodophyta) in a changing world: Integrating ecological, physiological, and geochemical responses to global change. *J. Phycol.* **2015**, *51*, 6–24. [CrossRef] [PubMed]
21. Birkett, D.A.; Maggs, C.; Dring, M.J. *An Overview of Dynamic and Sensitivity Characteristics for Conservation Management of Marine SACs*; Birkett, D.A., Maggs, C., Dring, M.J., Eds.; UK Marine SACs Project: Oban, Scotland, 1998; Volume 5.
22. Steller, D.L.; Riosmena-Rodríguez, R.; Foster, M.S.; Roberts, C.A. Rhodolith bed diversity in the Gulf of California: The importance of rhodolith structure and consequences of disturbance. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **2003**, *13*, S5–S20. [CrossRef]
23. Riosmena-Rodríguez, R.; Steller, D.L.; Hinojosa-Arango, G.; Foster, M.S. Reefs that rock and roll: Biology and conservation of rhodolith beds in the Gulf of California. In *The Gulf of California: Biodiversity and Conservation*; Brusca, R.C., Ed.; Arizona University Press and the Arizona Sonora Desert Museum: Tucson, AZ, USA, 2010; pp. 49–71. ISBN 9780816527397.
24. Rendina, F.; Buonocore, E.; di Montanara, A.C.; Russo, G.F. The scientific research on rhodolith beds: A review through bibliometric network analysis. *Ecol. Inform.* **2022**, *70*, 101738. [CrossRef]
25. Montefalcone, M.; Tunesi, L.; Ouerghi, A. A review of the classification systems for marine benthic habitats and the new updated Barcelona Convention classification for the Mediterranean. *Mar. Environ. Res.* **2021**, *169*, 105387. [CrossRef]
26. Peña, V. *Estudio Ficológico de Los Fondos de Maërl y Cascajo en el Noroeste de la Península Ibérica*; Universidade da Coruña: A Coruña, Spain, 2010.
27. Blake, C.; Maggs, C.A. Comparative growth rates and internal banding periodicity of maerl species (Corallinales, Rhodophyta) from northern Europe. *Phycologia* **2003**, *42*, 606–612. [CrossRef]

28. Bosence, D.; Wilson, J. Maerl growth, carbonate production rates and accumulation rates in the ne atlantic. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **2003**, *13*, S21–S31. [CrossRef]
29. Rivera, M.G.; Riosmena-Rodríguez, R.; Foster, M.S. Age and growth of *Lithothamnion muelleri* (Corallinales, Rhodophyta) in the southwestern Gulf of California, Mexico. *Ciencias Mar.* **2004**, *30*, 235–249. [CrossRef]
30. Steller, D.L.; Hernández-Ayón, J.M.; Riosmena-Rodríguez, R.; Cabello-Pasini, A. Effect of temperature on photosynthesis, growth and calcification rates of the free-living coralline alga *Lithophyllum margaritae*. *Ciencias Mar.* **2007**, *33*, 441–456. [CrossRef]
31. Bassi, D.; Nebelsick, J.H.; Checconi, A.; Hohenegger, J.; Iryu, Y. Present-day and fossil rhodolith pavements compared: Their potential for analysing shallow-water carbonate deposits. *Sediment. Geol.* **2009**, *214*, 74–84. [CrossRef]
32. Braga, J.C.; Bassi, D. Neogene history of *Sporolithon* Heydrich (Corallinales, Rhodophyta) in the Mediterranean region. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2007**, *243*, 189–203. [CrossRef]
33. Kamenos, N.A.; Cusack, M.; Huthwelker, T.; Lagarde, P.; Scheibling, R.E. Mg-lattice associations in red coralline algae. *Geochim. Cosmochim. Acta* **2009**, *73*, 1901–1907. [CrossRef]
34. Kamenos, N.A.; Cusack, M.; Moore, P.G. Coralline algae are global palaeothermometers with bi-weekly resolution. *Geochim. Cosmochim. Acta* **2008**, *72*, 771–779. [CrossRef]
35. Erickson-Davis, M. Revealed for the First Time: The Surprising Biodiversity of Algae 'Reefs'. Available online: https://news.mongabay.com/2014/03/revealed-for-the-first-time-the-surprising-biodiversity-of-algae-reefs/ (accessed on 20 June 2022).
36. Aguado-Giménez, F.; Ruiz-Fernández, J.M. Influence of an experimental fish farm on the spatio-temporal dynamic of a Mediterranean maërl algae community. *Mar. Environ. Res.* **2012**, *74*, 47–55. [CrossRef] [PubMed]
37. Villas-Bôas, A.B.; Tâmega, F.T.D.S.; Andrade, M.; Coutinho, R.; Figueiredo, M.A.D.O. Experimental effects of sediment burial and light attenuation on two coralline algae of a deep water rhodolith bed in Rio de Janeiro, Brazil. *Cryptogam. Algol.* **2014**, *35*, 67–76. [CrossRef]
38. Aguirre, J.; Braga, J.C.; Martín, J.M.; Betzler, C. Palaeoenvironmental and stratigraphic significance of Pliocene rhodolith beds and coralline algal bioconstructions from the Carboneras Basin (SE Spain). *Geodiversitas* **2012**, *34*, 115–136. [CrossRef]
39. Prager, E.J.; Ginsburg, R.N. Carbonate nodule growth on Florida's outer shelf and its implications for fossil interpretations. *Palaios* **1989**, *4*, 310–312. [CrossRef]
40. Aguirre, J.; Braga, J.; Martín, J. Algal nodules in the Upper Pliocene deposits at the coast of Cadiz (S Spain). In *Studies on Fossil Benthic Algae*; Barattolo, F., De Castro, P., Parente, M., Eds.; Bollettino della Società paleontologica italiana: Modena, Italy, 1993; Volume 1, pp. 1–7. ISBN 9788870002171.
41. Costa, D.A. Environmental Education and the Ecological-Taxonomic Study of Marine Invertebrates Associated with Rhodoliths/Maërl Beds in Tropical Coast. Ph.D. Thesis, Federal University of Paraíba (UFPB), João Pessoa, Paraíba, Brazil, 2020.
42. Littler, M.M.; Littler, D.S. Models of tropical reefs biogenesis: The contribution of algae. In *Progress in Phycological Research*; Round, F.E., Chapman, V.J., Eds.; Biopress: London, UK, 1984; pp. 323–364. ISBN 9780948737091.
43. Adey, W.H.; Steneck, R.S. Thermogeography over time creates biogeographic regions: A temperature/space/time-integrated model and an abundance-weighted test for benthic marine algae. *J. Phycol.* **2001**, *37*, 677–698. [CrossRef]
44. Hernandez-Kantun, J.J.; Hall-Spencer, J.M.; Grall, J.; Adey, W.; Rindi, F.; Maggs, C.A.; Bárbara, I.; Peña, V. North Atlantic rhodolith beds. In *Rhodolith/Maërl Beds: A Global Perspective*; Riosmena-Rodríguez, R., Nelson, W., Aguirre, J., Eds.; Springer International Publishing: Cham, Switzerland, 2017; pp. 265–279. ISBN 9783319293158.
45. Konar, B.; Riosmena-Rodriguez, R.; Iken, K. Rhodolith bed: A newly discovered habitat in the North Pacific Ocean. *Bot. Mar.* **2006**, *49*, 355–359. [CrossRef]
46. Fredericq, S.; Krayesky-Self, S.; Sauvage, T.; Richards, J.; Kittle, R.; Arakaki, N.; Hickerson, E.; Schmidt, W.E. The critical importance of rhodoliths in the life cycle completion of both macro- and microalgae, and as holobionts for the establishment and maintenance of marine biodiversity. *Front. Mar. Sci.* **2019**, *5*, 502. [CrossRef]
47. Henriques, M.C.; Villas-Boas, A.; Rodriguez, R.R.; Figueiredo, M.A.O. New records of rhodolith-forming species (Corallinales, Rhodophyta) from deep water in Espírito Santo State, Brazil. *Helgol. Mar. Res.* **2012**, *66*, 219–231. [CrossRef]
48. Amado-Filho, G.M.; Moura, R.L.; Bastos, A.C.; Salgado, L.T.; Sumida, P.Y.; Guth, A.Z.; Francini-Filho, R.B.; Pereira-Filho, G.H.; Abrantes, D.P.; Brasileiro, P.S.; et al. Rhodolith beds are major CaCO3 bio-factories in the Tropical South West Atlantic. *PLoS ONE* **2012**, *7*, e35171. [CrossRef] [PubMed]
49. Milliman, J.D.; Amaral, C.A.B. Economic potential of Brazilian continental margin sediments. In *Proceedings of the Anais do XXVIII Congresso Brasileiro de Geologia*; Sociedade Brasileira de Geologia: Porto Alegre, Brazil, 1974; pp. 335–344.
50. Moura, R.L.; Amado-Filho, G.M.; Moraes, F.C.; Brasileiro, P.S.; Salomon, P.S.; Mahiques, M.M.; Bastos, A.C.; Almeida, M.G.; Silva, J.M.; Araujo, B.F.; et al. An extensive reef system at the Amazon River mouth. *Sci. Adv.* **2016**, *2*, e1501252. [CrossRef] [PubMed]
51. Gomes, N.; Antunes, C.; Costa, D.A. Insights into the migration routes and historical dispersion of species surviving the Messinian Crisis: The case of *Patella ulyssiponensis* and epizoic rhodolith *Lithophyllum hibernicum*. *Hydrobiology* **2022**, *1*, 10–38. [CrossRef]
52. OBIS. Corallinales P.C. Silva & H.W. Johansen. 1986. Available online: https://obis.org/taxon/15308 (accessed on 17 January 2023).
53. BIOMAERL Team. *BIOMAERL: Maerl Biodiversity; Functional Structure and Anthropogenic Impacts*; BIOMAERL: Millport, Scotland, 1999.

54. Hernandez-Kantun, J.J.; Rindi, F.; Adey, W.H.; Heesch, S.; Peña, V.; Le Gall, L.; Gabrielson, P.W. Sequencing type material resolves the identity and distribution of the generitype *Lithophyllum incrustans*, and related European species *L. hibernicum* and *L. bathyporum* (Corallinales, Rhodophyta). *J. Phycol.* **2015**, *51*, 791–807. [CrossRef]
55. European Red List of Habitats. *Rhodolith Beds in the Mediterranean*; European Environment Agency: Copenhagen, Denmark, 2016.
56. NatureScot. Scotland's Nature Agency. Available online: https://www.nature.scot/ (accessed on 17 January 2023).
57. Maneveldt, G.W.; Van der Merwe, E.; Keats, D.W. Updated keys to the non-geniculate coralline red algae (Corallinophycidae, Rhodophyta) of South Africa. *S. Afr. J. Bot.* **2016**, *106*, 158–164. [CrossRef]
58. Peña, V.; Rousseau, F.; De Reviers, B.; Le Gall, L. First assessment of the diversity of coralline species forming maerl and rhodoliths in Guadeloupe, Caribbean using an integrative systematic approach. *Phytotaxa* **2014**, *190*, 190–215. [CrossRef]
59. Braga, J.; Jaramillo-Vogel, D.; Foubert, A.; Atnafu, B.; Kidane, T.; Negga, H. Coralline algae in Pleistocene reefs in the Danakil Depression (Afar Triangle, Ethiopia). In *Proceedings of the Abstract Book of the VI International Rhodolith Workshop*; Marine Station of Roscoff: Roscoff, France, 2018; p. 32.
60. Johnson, M.E.; Ledesma-Vázquez, J.; Ramalho, R.S.; da Silva, C.M.; Rebelo, A.C.; Santos, A.; Baarli, B.G.; Mayoral, E.; Cachão, M. Taphonomic range and sedimentary dynamics of modern and fossil rhodolith beds: Macaronesian realm (North Atlantic Ocean). In *Rhodolith/Maërl Beds: A Global Perspective*; Riosmena-Rodríguez, R., Nelson, W., Aguirre, J., Eds.; Springer International Publishing: Cham, Switzerland, 2017; pp. 221–261. ISBN 978-3-319-29313-4.
61. Kato, A.; Baba, M.; Matsuda, S.; Iryu, Y. Western Pacific. In *Rhodolith/Maërl Beds: A Global Perspective*; Riosmena-Rodríguez, R., Nelson, W., Aguirre, J., Eds.; Springer International Publishing: Cham, Switzerland, 2017; pp. 335–347. ISBN 978-3-319-29313-4.
62. Rösler, A.; Pretkovic, V.; Novak, V.; Renema, W.; Braga, J.C. Coralline algae from the Miocene Mahakam Delta (East Kalimantan, Southeast Asia). *Palaios* **2015**, *30*, 83–93. [CrossRef]
63. Teichert, S. Rhodoliths (Corallinales, Rhodophyta) as a Biosedimentary System in Arctic Environments (Svalbard Archipelago, Norway). Ph.D. Thesis, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany, 2013.
64. Teichert, S.; Woelkerling, W.; Rüggeberg, A.; Wisshak, M.; Piepenburg, D.; Meyerhöfer, M.; Form, A.; Büdenbender, J.; Freiwald, A. Rhodolith beds (Corallinales, Rhodophyta) and their physical and biological environment at 80°31′N in Nordkappbukta (Nordaustlandet, Svalbard Archipelago, Norway). *Phycologia* **2012**, *51*, 371–390. [CrossRef]
65. Matsuda, S.; Iryu, Y. Rhodoliths from deep fore-reef to shelf areas around Okinawa-jima, Ryukyu Islands, Japan. *Mar. Geol.* **2011**, *282*, 215–230. [CrossRef]
66. Ryan, D.A.; Brooke, B.P.; Collins, L.B.; Kendrick, G.A.; Baxter, K.J.; Bickers, A.N.; Siwabessy, P.J.W.; Pattiaratchi, C.B. The influence of geomorphology and sedimentary processes on shallow-water benthic habitat distribution: Esperance Bay, Western Australia. *Estuar. Coast. Shelf Sci.* **2007**, *72*, 379–386. [CrossRef]
67. Harvey, A.S.; Harvey, R.M.; Merton, E. The distribution, significance and vulnerability of Australian rhodolith beds: A review. *Mar. Freshw. Res.* **2016**, *68*, 411–428. [CrossRef]
68. Pereira-Filho, G.H.; Francini-Filho, R.B.; Pierozzi-Jr, I.; Pinheiro, H.T.; Bastos, A.C.; de Moura, R.L.; Moraes, F.C.; Matheus, Z.; da Gama Bahia, R.; Amado-Filho, G.M. Sponges and fish facilitate succession from rhodolith beds to reefs. *Bull. Mar. Sci.* **2015**, *91*, 45–46. [CrossRef]
69. Perry, C.T.; Edinger, E.N.; Kench, P.S.; Murphy, G.N.; Smithers, S.G.; Steneck, R.S.; Mumby, P.J. Estimating rates of biologically driven coral reef framework production and erosion: A new census-based carbonate budget methodology and applications to the reefs of Bonaire. *Coral Reefs* **2012**, *31*, 853–868. [CrossRef]
70. Nalin, R.; Nelson, C.S.; Basso, D.; Massari, F. Rhodolith-bearing limestones as transgressive marker beds: Fossil and modern examples from North Island, New Zealand. *Sedimentology* **2007**, *55*, 249–274. [CrossRef]
71. Marshall, J.F.; Tsuji, Y.; Matsuda, H.; Davies, P.J.; Iryu, Y.; Honda, N.; Satoh, Y. Quaternary and Tertiary subtropical carbonate platform development on the continental margin of southern Queensland, Australia. In *Reefs and Carbonate Platforms in the Pacific and Indian Oceans*; Camoin, G.F., Davies, P.J., Eds.; Blackwell Publishing Ltd.: Oxford, UK, 1998; pp. 163–195.
72. Martin, J.M.; Braga, J.C.; Konishi, K.; Pigram, C.J. A model for the development of rhodoliths on platforms influenced by storms: The Middle Miocene carbonates of the Marion Plateau (Northeastern Australia). In *Proceedings of the Ocean Drilling Program, Scientific Results*; McKenzie, J.A., Davies, P.J., Palmer-Julson, A., Betzler, C.G., Brachert, T.C., Chen, M.-P.P., Crumière, J.-P., Dix, G.R., Droxler, A.W., Feary, D.A., et al., Eds.; Ocean Drilling Program: Townsville, Australia, 1993; Volume 133, pp. 455–460.
73. Brodie, J.; Zuccarello, G.C. Systematics of the species rich algae: Red algal classification, phylogeny and speciation. In *Reconstructing the Tree of Life: Taxonomy and Systematics of Species Rich Taxa*; Hodkinson, T.R., Parnell, J.A.N., Eds.; CRC Press, Taylor and Francis Group: Boca Raton, FL, USA, 2007; pp. 317–330. ISBN 139780849395796.
74. Guiry, M.D.; Guiry, G.M. Order Corallinales. Available online: https://www.algaebase.org/browse/taxonomy/#4621 (accessed on 25 May 2023).
75. Horta, P.A.; Riul, P.; Amado Filho, G.M.; Gurgel, C.F.D.; Berchez, F.; Nunes, J.M.d.C.; Scherner, F.; Pereira, S.; Lotufo, T.; Peres, L.; et al. Rhodoliths in Brazil: Current knowledge and potential impacts of climate change. *Braz. J. Oceanogr.* **2016**, *64*, 117–136. [CrossRef]
76. Sciberras, M.; Rizzo, M.; Mifsud, J.R.; Camilleri, K.; Borg, J.A.; Lanfranco, E.; Schembri, P.J. Habitat structure and biological characteristics of a maerl bed off the northeastern coast of the Maltese Islands (central Mediterranean). *Mar. Biodivers.* **2009**, *39*, 251–264. [CrossRef]
77. Dias, G.T.M. Marine bioclasts: Calcareous algae. *Rev. Bras. Geofísica* **2000**, *18*, 307–318. [CrossRef]

78. García-Sanz, S.; Navarro, P.G.; Landeira, J.M.; Tuya, F. Colonization patterns of decapods into artificial collectors: Seasonality between habitat patches. *J. Crustac. Biol.* **2014**, *34*, 431–441. [CrossRef]
79. Basso, D. Deep rhodolith distribution in the Pontian Islands, Italy: A model for the paleoecology of a temperate sea. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **1998**, *137*, 173–187. [CrossRef]
80. Woelkerling, W.J.; Irvine, L.M.; Harvey, A.S. Growth-forms in non-geniculate coralline red algae (Coralliinales, Rhodophyta). *Aust. Syst. Bot.* **1993**, *6*, 277–293. [CrossRef]
81. Costa, D.A.; Dolbeth, M.; Prata, J.; Silva, F.A.; Silva, G.M.B.; Freitas, P.R.S.; Christoffersen, M.L.; Lima, S.F.B.; Massei, K.; Lucena, R.F.P. Marine invertebrates associated with rhodoliths/maërl beds from northeast Brazil (State of Paraíba). *Biodivers. Data J.* **2021**, *9*, e62736. [CrossRef] [PubMed]
82. Figueiredo, M.A.O.; Santos de Menezes, K.; Costa-Paiva, E.M.; Paiva, P.C.; Ventura, C.R.R. Experimental evaluation of rhodoliths as living substrata for infauna at the Abrolhos Bank, Brazil. *Ciencias Mar.* **2007**, *33*, 427–440. [CrossRef]
83. Thomsen, M.S.; Wernberg, T.; Altieri, A.; Tuya, F.; Gulbransen, D.; McGlathery, K.J.; Holmer, M.; Silliman, B.R. Habitat cascades: The conceptual context and global relevance of facilitation cascades via habitat formation and modification. *Integr. Comp. Biol.* **2010**, *50*, 158–175. [CrossRef]
84. Basso, D.; Babbini, L.; Kaleb, S.; Bracchi, V.A.; Falace, A. Monitoring deep Mediterranean rhodolith beds. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **2016**, *26*, 549–561. [CrossRef]
85. Prata, J.; Costa, D.A.; Manso, C.L.C.; Crispim, M.C.; Christoffersen, M.L. Echinodermata associated to rhodoliths from Seixas Beach, State of Paraíba, Northeast Brazil. *Biota Neotrop.* **2017**, *17*, e20170363. [CrossRef]
86. Costa, D.A. Assembleias de Poliquetas (Annelida), Associados aos Rodolitos (Corallinophycidae, Rhodophyta), na Praia do Seixas, João Pessoa, Paraíba, Brasil. Master's Thesis, Federal University of Paraíba (UFPB), João Pessoa, Paraíba, Brazil, 2016.
87. Hinojosa-Arango, G.; Riosmena-Rodriguez, R. Influence of rhodolith-forming species and growth-form on associated fauna of rhodolith beds in the Central-West Gulf of California, Mexico. *Mar. Ecol.* **2004**, *25*, 109–127. [CrossRef]
88. Riul, P.; Lacouth, P.; Pagliosa, P.R.; Christoffersen, M.L.; Horta, P.A. Rhodolith beds at the easternmost extreme of South America: Community structure of an endangered environment. *Aquat. Bot.* **2009**, *90*, 315–320. [CrossRef]
89. Scherner, F.; Riul, P.; Bastos, E.; Bouzon, Z.L.; Pagliosa, P.R.; Blankensteyn, A.; Oliveira, E.C.; Horta, P.A. Herbivory in a rhodolith bed: A structuring factor? *Panam. J. Aquat. Sci.* **2010**, *5*, 358–366.
90. Costa, D.A.; Lucena, R.F.P.; Silva, F.A.; Silva, G.M.B.; Massei, K.; Christoffersen, M.L.; Dolbeth, M. Importance of rhodoliths as habitats for benthic communities in impacted environments. *Reg. Stud. Mar. Sci.* **2021**, *48*, 102055. [CrossRef]
91. Gagnon, P.; Matheson, K.; Stapleton, M. Variation in rhodolith morphology and biogenic potential of newly discovered rhodolith beds in Newfoundland and Labrador (Canada). *Bot. Mar.* **2012**, *55*, 85–99. [CrossRef]
92. Perry, F.; Tyler-Walters, H.; Garrard, S.L. Lithothamnion corallioides Maerl Beds on Infralittoral Muddy Gravel. Available online: https://www.marlin.ac.uk/habitats/detail/219/lithothamnion_corallioides_maerl_beds_on_infralittoral_muddy_gravel (accessed on 31 May 2023).
93. Berlandi, R.M.; Figueiredo, M.A.O.; Paiva, P.C. Rhodolith Morphology and the Diversity of Polychaetes Off the Southeastern Brazilian Coast. *J. Coast. Res.* **2012**, *28*, 280–287. [CrossRef]
94. Amado-Filho, G.M.; Maneveldt, G.W.; Pereira-Filho, G.H.; Manso, R.C.C.; Bahia, R.G.; Barros-Barreto, M.B.; Guimarães, S.M.P.B. Seaweed diversity associated with a Brazilian tropical rhodolith bed. *Ciencias Mar.* **2010**, *36*, 371–391. [CrossRef]
95. Klein, J.C.; Verlaque, M. Macroalgal assemblages of disturbed coastal detritic bottoms subject to invasive species. *Estuar. Coast. Shelf Sci.* **2009**, *82*, 461–468. [CrossRef]
96. Joher, S.; Ballesteros, E.; Rodríguez-Prieto, C. Contribution to the study of deep coastal detritic bottoms: The algal communities of the continental shelf off the Balearic Islands, Western Mediterranean. *Mediterr. Mar. Sci.* **2015**, *16*, 573–590. [CrossRef]
97. Otero-Ferrer, F.; Cosme, M.; Tuya, F.; Espino, F.; Haroun, R. Effect of depth and seasonality on the functioning of rhodolith seabeds. *Estuar. Coast. Shelf Sci.* **2020**, *235*, 106579. [CrossRef]
98. De Grave, S. The influence of sedimentary heterogeneity on within maerl bed differences in infaunal crustacean community. *Estuar. Coast. Shelf Sci.* **1999**, *49*, 153–163. [CrossRef]
99. Hall-Spencer, J. Conservation issues relating to maerl beds as habitats for molluscs. *J. Conchol.* **1998**, *36*, 271–286.
100. Kamenos, N.A.; Moore, P.G.; Hall-Spencer, J.M. Maerl grounds provide both refuge and high growth potential for juvenile queen scallops (*Aequipecten opercularis* L.). *J. Exp. Mar. Bio. Ecol.* **2004**, *313*, 241–254. [CrossRef]
101. Steller, D.L.; Cáceres-Martínez, C. Coralline algal rhodoliths enhance larval settlement and early growth of the Pacific calico scallop *Argopecten ventricosus*. *Mar. Ecol. Prog. Ser.* **2009**, *396*, 49–60. [CrossRef]
102. Otero-Ferrer, F.; Mannarà, E.; Cosme, M.; Falace, A.; Montiel-Nelson, J.A.; Espino, F.; Haroun, R.; Tuya, F. Early-faunal colonization patterns of discrete habitat units: A case study with rhodolith-associated vagile macrofauna. *Estuar. Coast. Shelf Sci.* **2019**, *218*, 9–22. [CrossRef]
103. Lueder, S.; Narasimhan, K.; Olivo, J.; Cabrera, D.; Jurado, J.G.; Greenstein, L.; Karubian, J. Functional traits, species diversity and species composition of a neotropical palm community vary in relation to forest age. *Front. Ecol. Evol.* **2022**, *10*, 678125. [CrossRef]
104. Martin, S.; Clavier, J.; Chauvaud, L.; Thouzeau, G. Community metabolism in temperate maerl beds. II. *Nutrient fluxes. Mar. Ecol. Prog. Ser.* **2007**, *335*, 31–41. [CrossRef]
105. Kamenos, N.A.; Strong, S.C.; Shenoy, D.M.; Wilson, S.T.; Hatton, A.D.; Moore, P.G. Red coralline algae as a source of marine biogenic dimethylsulphoniopropionate. *Mar. Ecol. Prog. Ser.* **2008**, *372*, 61–66. [CrossRef]

106. Mao, J.; Burdett, H.L.; McGill, R.A.R.; Newton, J.; Gulliver, P.; Kamenos, N.A. Carbon burial over the last four millennia is regulated by both climatic and land use change. *Glob. Chang. Biol.* **2020**, *26*, 2496–2504. [CrossRef] [PubMed]
107. van der Heijden, L.H.; Kamenos, N.A. Reviews and syntheses: Calculating the global contribution of coralline algae to total carbon burial. *Biogeosciences* **2015**, *12*, 6429–6441. [CrossRef]
108. Hester, E.R.; Barott, K.L.; Nulton, J.; Vermeij, M.J.; Rohwer, F.L. Stable and sporadic symbiotic communities of coral and algal holobionts. *ISME J.* **2016**, *10*, 1157–1169. [CrossRef]
109. Cavalcanti, G.S.; Shukla, P.; Morris, M.; Ribeiro, B.; Foley, M.; Doane, M.P.; Thompson, C.C.; Edwards, M.S.; Dinsdale, E.A.; Thompson, F.L. Rhodoliths holobionts in a changing ocean: Host-microbes interactions mediate coralline algae resilience under ocean acidification. *BMC Genom.* **2018**, *19*, 701. [CrossRef]
110. Webster, N.S.; Reusch, T.B.H. Microbial contributions to the persistence of coral reefs. *ISME J.* **2017**, *11*, 2167–2174. [CrossRef]
111. Gherardi, D.F.M.; Bosence, D.W.J. Modeling of the ecological succession of encrusting organisms in recent coralline-algal frameworks from Atol Das Rocas, Brazil. *Palaios* **1999**, *14*, 145–158. [CrossRef]
112. Tierney, P.W.; Johnson, M.E. Stabilization role of crustose coralline algae during Late Pleistocene reef development on Isla Cerralvo, Baja California Sur (Mexico). *J. Coast. Res.* **2012**, *28*, 244–254. [CrossRef]
113. UK Marine SACS Project. Nature and Importance of Maerl Beds. Available online: http://www.ukmarinesac.org.uk/communities/maerl/m1_1.htm (accessed on 27 August 2022).
114. IPCC. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., et al., Eds.; Cambridge University Press: Cambridge, UK; Intergovernmental Panel on Climate Change: New York, NY, USA, 2014; ISBN 9781107641655.
115. Kelaher, B.P.; Mamo, L.T.; Provost, E.; Litchfield, S.G.; Giles, A.; Butcherine, P. Influence of ocean warming and acidification on habitat-forming coralline algae and their associated molluscan assemblages. *Glob. Ecol. Conserv.* **2022**, *35*, e02081. [CrossRef]
116. Millero, F.J. The marine inorganic carbon cycle. *Chem. Rev.* **2007**, *107*, 308–341. [CrossRef] [PubMed]
117. Martin, S.; Hall-Spencer, J.M. Effects of ocean warming and acidification on rhodolith/maërl beds. In *Rhodolith/Maërl Beds: A Global Perspective*; Riosmena-Rodríguez, R., Nelson, W., Aguirre, J., Eds.; Springer International Publishing: Cham, Switzerland, 2017; pp. 55–85. ISBN 978-3-319-29313-4.
118. Martone, P.T.; Alyono, M.; Stites, S. Bleaching of an intertidal coralline alga: Untangling the effects of light, temperature, and desiccation. *Mar. Ecol. Prog. Ser.* **2010**, *416*, 57–67. [CrossRef]
119. Fredericq, S.; Arakaki, N.; Camacho, O.; Gabriel, D.; Krayesky, D.; Self-Krayesky, S.; Rees, G.; Richards, J.; Sauvage, T.; Venera-Ponton, D.; et al. A dynamic approach to the study of rhodoliths: A case study for the Northwestern Gulf of Mexico. *Cryptogam. Algol.* **2014**, *35*, 77–98. [CrossRef]
120. Anthony, K.R.N.; Kline, D.I.; Diaz-Pulido, G.; Dove, S.; Hoegh-Guldberg, O. Ocean acidification causes bleaching and productivity loss in coral reef builders. *Proc. Natl. Acad. Sci. USA* **2008**, *105*, 17442–17446. [CrossRef]
121. Martin, S.; Gattuso, J.-P. Response of Mediterranean coralline algae to ocean acidification and elevated temperature. *Glob. Chang. Biol.* **2009**, *15*, 2089–2100. [CrossRef]
122. Cornwall, C.E.; Hepburn, C.D.; Pilditch, C.A.; Hurd, C.L. Concentration boundary layers around complex assemblages of macroalgae: Implications for the effects of ocean acidification on understory coralline algae. *Limnol. Oceanogr.* **2013**, *58*, 121–130. [CrossRef]
123. Hurd, C.L.; Cornwall, C.E.; Currie, K.; Hepburn, C.D.; McGraw, C.M.; Hunter, K.A.; Boyd, P.W. Metabolically induced pH fluctuations by some coastal calcifiers exceed projected 22nd century ocean acidification: A mechanism for differential susceptibility? *Glob. Chang. Biol.* **2011**, *17*, 3254–3262. [CrossRef]
124. Ries, J.B.; Cohen, A.L.; McCorkle, D.C. Marine calcifiers exhibit mixed responses to CO2-induced ocean acidification. *Geology* **2009**, *37*, 1131–1134. [CrossRef]
125. Martin, S.; Cohu, S.; Vignot, C.; Zimmerman, G.; Gattuso, J.-P. One-year experiment on the physiological response of the Mediterranean crustose coralline alga, *Lithophyllum cabiochae*, to elevated pCO2 and temperature. *Ecol. Evol.* **2013**, *3*, 676–693. [CrossRef] [PubMed]
126. Horta, P.A.; Berchez, F.A.S.; Nunes, J.M.D.C.; Scherner, F.; Pereira, S.M.B.; Riul, P.; Lotufo, T.M.C.; Peres, L.M.C.; Sissini, M.N.; Rosa, J.; et al. Monitoramento de banco de rodolitos. In *Protocolos Para o Monitoramento de Habitats Bentônicos Costeiros*; Turra, A., Denadai, M.R., Eds.; Instituto Oceanográfico da Universidade de São Paulo: São Paulo, Brazil, 2015; pp. 48–61. ISBN 978-85-98729-25-1.
127. Hall-Spencer, J.; Bamber, R. Effects of salmon farming on benthic Crustacea. *Ciencias Mar.* **2007**, *33*, 353–366. [CrossRef]
128. Peña, V.; Bárbara, I. Maërl community in the north-western Iberian Peninsula: A review of floristic studies and long-term changes. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **2008**, *18*, 339–366. [CrossRef]
129. Riul, P.; Targino, C.H.; Farias, J.N.; Visscher, P.T.; Horta, P.A. Decrease in *Lithothamnion* sp. (Rhodophyta) primary production due to the deposition of a thin sediment layer. *J. Mar. Biol. Assoc. United Kingd.* **2008**, *88*, 17–19. [CrossRef]
130. Hilmi, N.; Chami, R.; Sutherland, M.D.; Hall-Spencer, J.M.; Lebleu, L.; Benitez, M.B.; Levin, L.A. The role of blue carbon in climate change mitigation and carbon stock conservation. *Front. Clim.* **2021**, *3*, 710546. [CrossRef]
131. Bordehore, C.; Ramos-Esplá, A.A.; Riosmena-Rodríguez, R. Comparative study of two maerl beds with different otter trawling history, southeast Iberian Peninsula. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **2003**, *13*, S43–S54. [CrossRef]

132. Peña, V.; Bárbara, I.; Grall, J.; Maggs, C.A.; Hall-Spencer, J.M. The diversity of seaweeds on maerl in the NE Atlantic. *Mar. Biodivers.* **2014**, *44*, 533–551. [CrossRef]
133. Sanz-Lázaro, C.; Belando, M.D.; Marín-Guirao, L.; Navarrete-Mier, F.; Marín, A. Relationship between sedimentation rates and benthic impact on maërl beds derived from fish farming in the Mediterranean. *Mar. Environ. Res.* **2011**, *71*, 22–30. [CrossRef]
134. Amado-Filho, G.M.; Bahia, R.G.; Pereira-Filho, G.H.; Longo, L.L. South Atlantic rhodolith beds: Latitudinal distribution, species composition, structure and ecosystem functions, threats and conservation status. In *Rhodolith/Maërl Beds: A Global Perspective*; Riosmena-Rodríguez, R., Nelson, W., Aguirre, J., Eds.; Springer International Publishing: Cham, Switzerland, 2017; pp. 299–317. ISBN 978-3-319-29313-4.
135. Figueiredo, M.A.O.; Coutinho, R.; Villas-Boas, A.B.; Tâmega, F.T.S.; Mariath, R. Deep-water rhodolith productivity and growth in the southwestern Atlantic. *J. Appl. Phycol.* **2012**, *24*, 487–493. [CrossRef]
136. Costa, D.A.; Silva, F.A.; Silva, J.M.L.; Pereira, A.R.; Dolbeth, M.; Christoffersen, M.L.; Lucena, R.F.P. Is tourism affecting polychaete assemblages associated with rhodolith beds in Northeastern Brazil? *Rev. Biol. Trop.* **2019**, *67*, S1–S15. [CrossRef]
137. Lavenère-Wanderley, A.A.; Asp, N.E.; Thompson, F.L.; Siegle, E. Rhodolith mobility potential from seasonal and extreme waves. *Cont. Shelf Res.* **2021**, *228*, 104527. [CrossRef]
138. Carvalho, V.F.; Assis, J.; Serrão, E.A.; Nunes, J.M.; Anderson, A.B.; Batista, M.B.; Barufi, J.B.; Silva, J.; Pereira, S.M.B.; Horta, P.A. Environmental drivers of rhodolith beds and epiphytes community along the South Western Atlantic coast. *Mar. Environ. Res.* **2020**, *154*, 104827. [CrossRef]
139. OSPAR Commission. Maerl Beds. Available online: https://www.ospar.org/ (accessed on 3 April 2023).
140. Adey, W.H.; Adey, P.J. Studies on the biosystematics and ecology of the epilithic crustose Corallinaceae of the British Isles. *Br. Phycol. J.* **1973**, *8*, 343–407. [CrossRef]
141. Hall-Spencer, J.M. *Biological Studies on Nongeniculate Corallinaceae*; University of London: London, UK, 1994.
142. Barbera, C.; Bordehore, C.; Borg, J.A.; Glémarec, M.; Grall, J.; Hall-Spencer, J.M.; de la Huz, C.; Lanfranco, E.; Lastra, M.; Moore, P.G.; et al. Conservation and management of northeast Atlantic and Mediterranean maerl beds. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **2003**, *13*, S65–S76. [CrossRef]
143. Council of the European Union. Council Decision 82/72/EEC of 3 December 1981 Concerning the Conclusion of the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention). Available online: https://eur-lex.europa.eu/EN/legal-content/summary/bern-convention.html (accessed on 25 May 2023).
144. Council of the European Union. Council Directive 92/43/EEC of 21 May 1992 on the Conservation of Natural Habitats and of Wild Fauna and Flora. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31992L0043 (accessed on 20 June 2022).
145. European Commission. Natura 2000. Available online: http://ec.europa.eu/environment/nature/natura2000/index_en.htm (accessed on 23 March 2023).
146. Council of the European Union. Council Regulation (EC) No. 1967/2006 Concerning Management Measures for the Sustainable Exploitation of Fishery Resources in the Mediterranean Sea, Amending Regulation (EEC) No. 2847/93 and Repealing Regulation (EC) No. 1626/94. Available online: https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32006R1967 (accessed on 25 May 2023).
147. Robinson, N.M.; Fernández-García, C.; Riosmena-Rodríguez, R.; Rosas-Alquicira, E.F.; Konar, B.; Chenelot, H.; Jewett, S.C.; Melzer, R.R.; Meyer, R.; Försterra, G.; et al. Eastern Pacific. In *Rhodolith/Maërl Beds: A Global Perspective*; Riosmena-Rodríguez, R., Nelson, W., Aguirre, J., Eds.; Springer International Publishing: Cham, Switzerland, 2017; pp. 319–333. ISBN 978-3-319-29313-4.
148. Global Geoparks Network. Global Geoparks Network. Available online: https://globalgeoparksnetwork.org/ (accessed on 20 January 2023).
149. Ministry of the Environment of Japan. National Parks & Important Biodiversity Areas of Japan. Available online: http://www.env.go.jp/park/topics/review/attach/pamph1/en_full.pdf (accessed on 23 August 2022).
150. Turra, A.; Denadai, M.R. *Protocolos Para o Monitoramento de Habitats Bentônicos Costeiros*; Turra, A., Denadai, M.R., Eds.; Instituto Oceanográfico da Universidade de São Paulo: São Paulo, Brazil, 2015; ISBN 9788598729251.
151. Rodolitos-Projeto. ReBentos Rodolitos: Um Oásis de Biodiversidade Marinha. Available online: https://rodolitos.wordpress.com/ (accessed on 20 January 2023).
152. McKinley, E.; Fletcher, S. Improving marine environmental health through marine citizenship: A call for debate. *Mar. Policy* **2012**, *36*, 839–843. [CrossRef]
153. Costa, D.A.; Lucena, R.F.P.; Christoffersen, M.L.; Piñeiro-Corbeira, C.; Dolbeth, M. Improving environmental awareness and ocean literacy through hands-on activities in the tropics. *Appl. Environ. Educ. Commun.* **2022**, *21*, 120–139. [CrossRef]
154. Rodolitos. Rodolitos na Educação. Available online: https://rodolitos.wordpress.com/category/rodolitos-na-educacao/ (accessed on 19 January 2023).

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