Marine Habitat Assessment in Cyprus: Spatial Distribution and Ecological Observations

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Abstract

The Mediterranean Sea, renowned for its cultural and ecological diversity, faces increasing threats from human activities and environmental changes. Coastal regions experience habitat destruction and the introduction of invasive species that endanger marine biodiversity and ecosystem stability. Habitats play a vital role in sustaining biodiversity and providing ecosystem services essential to marine and human well-being. The European Nature Information System (EUNIS) provides a standardized framework for habitat classification, facilitating international conservation strategies. EUNIS classifies habitats into five levels, progressing from general marine benthic habitats to detailed species-specific habitats. While the western Mediterranean hosts diverse ecosystems identified up to the fifth classification level, the eastern Mediterranean, particularly the Levantine Basin, faces unique challenges due to oligotrophic waters, higher temperatures, and invasive species. In the coastal zone of Cyprus, habitats that fall within our 23 transects habitats were investigated up to the fourth level. Invasive foraminifera species, *Amphistegina lobifera*, dominate sediment composition in the eastern Mediterranean, forming unique habitats that remain unclassified by EUNIS or other systems. These sediments significantly alter rocky seabed structures, creating hybrid sandy and algal habitats with distinct faunal communities. Field studies, especially on the northern coast of Cyprus also highlight the presence and ecological importance of vermetid reefs, especially in the Rizokarpaso peninsula, as biodiversity hotspots and ecosystem health indicators. However, limited data on Cyprus' coastal habitats hinder conservation efforts. Therefore, comprehensive large-scale studies are urgently needed to identify and protect critical habitats, ensuring the preservation of marine ecosystems and biodiversity in the region.

Keywords Biodiversity · Conservation · Classification · Mediterranean · Vermetid reefs

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Introduction

Habitats, where all organisms dwell, reproduce and flourish, are very important for the continuity and sustainability of living organisms within. Habitat destruction and fragmentation are the most important factors that drive the loss of species diversity. Habitat fragmentation is an ecological process in which a large patch of habitat is divided into smaller patches (Gomi et al., 2002). Usually, this process is caused by human activities, and it also reduces the value of the landscape as habitat for many species. Fragmentation alters natural habitat in many ways, including reduction of the sizes of the patches, increasing distances between similar patches, and increment of edges and predation (Robinson et al. 1995). It was found out that 32% of the marine habitats in the Mediterranean Sea are threatened, which constitutes the highest proportion of threatened habitats in the European marine environment (Gubbay et al. 2016).

Along with the habitat destruction, the introduction of alien species is the second to blame for the destruction of biodiversity (Katsenavakis et al., 2014). Eastern Mediterranean Sea including Cyprus coastal waters witnessed the pressure of invasive alien species introduced via Suez Canal, which is called "the Lessepsian migration" (Raitsos et al. 2010; Galanidi et al. 2023; Galil et al. 2017). Zenetos et al. (2017) stated that the rate of introduction from Red Sea between 1991 and 2010 was one species per month. The number of Lessepsian species continuously increasing, which may also occur in the Cyprus waters (Galil et al. 2017; Mavruk et al. 2017; Zenetos, 2017). Within such a dynamic ecosystem equilibrium, the mapping of benthic habitats becomes particularly important.

Habitat mapping provides important data concerning the distribution and abundance of species and the relationship between the species and specific habitats, enabling habitat-based management, such as marine spatial planning and nature conservation (Bianchi et al. 2012; Sokołowski et al. 2021). The long-term monitoring of the habitats allows one to compare how long it takes for a certain habitat type to develop and deteriorate (Ware and Downie 2020). One can also figure out the impact of environmental factors, changes in communities' distribution, identify hot-spots of biodiversity and determine the critical or sensitive areas, which are the key elements for impact assessments, quantifying ecosystem services, and ecosystem-based management (Vassallo et al. 2018). To date, many different marine habitat classification schemes have been developed for the Mediterranean (reviewed in Montefalcone et al., 2021). But without a common structure and a standardized approach, they are not based on the same classification system (Strong et al. 2019).

Marine habitat studies that have been done so far on the coasts of Cyprus have been very limited. A total of 10 "sensitive" habitats of conservation interest have been reported from the littoral to circalittoral zones on Larnaka coast (Ramos 2008). The preliminary study on vermetid reefs along the north of Cyprus provided the only available data concerning the marine habitats found on the northern coasts of the island (Hüseyinoğlu et al. 2020). As there are untouched areas away from settlements, as well as coastal areas exposed to intense urbanization pressure, the northern coast of Cyprus is important for analysing the human impact on the Mediterranean coastal areas. Identifying and mapping marine habitats on these coasts is vital for the protection of the coastal ecosystems of Cyprus.

In this study, we present the preliminary results from the marine habitat mapping study conducted on the north coast of Cyprus. Observed habitat types were classified according to the recently updated and most adopted, EUNIS (EUNIS 2022), SPA/RAC (SPA/RAC-UN Environment/MAP 2019) and IUCN (IUCN, 2012) habitat classification systems.

Materials and methods

Six sites representing the major shallow coastal habitat types observed on the north coast of Cyprus were chosen for this study (Fig. 1). Diverse habitat expectance, intensity of recreational use, fishing pressure, oceanographic conditions, and remarkable landmarks such as vermetid reef formations were taken into consideration while determining the exact locations.

At each site 200 m long transects were set 500 m apart from each other and perpendicular to the shore. The beginning of each transect was fixed on the high tide line and its end was fixed on the sea bottom with an anchor, which was marked with a buoy. Each transect was made of 2 cm thick sinking rope, tagged at every 5 m, showing the distance from the starting point. The coordinates of the transects were taken by GPS instrument (Garmin eTrex 10, USA). At each site transects were set in parallel, 500 m apart from each other. A total of 20 transects were set in six sites (Table 1).

The standard scuba equipped two-diver team started diving from the starting point of the transects on the shore and swam towards the end point (Fig. 2). While taking notes on the habitat characteristics and depths, the divers filmed the benthic structure, covering 5 m from the right side and 5 m from the left side of the transect. Therefore, an area of 10 m x 200 m was recorded along each transect. Divers also collected sediment, dominant invertebrate, and algae samples along the transects. Collected samples were stored in fixatives such as 70% and 95% ethanol or 4% formaldehyde until laboratory analysis.

The area between two transects were investigated by two scuba diving teams which started diving at the 100 m and 200 m marks of the transects and swam towards the neighboring transects. The aim of these examinations was to evaluate the continuity and variance of the habitats recorded alongside the transect lines (Fig. 2).

Supralittoral surveys were carried out in a total area of 50 m^2, 5 m to the right, 5 m to the left and 5 m towards inland from the beginning of each transect with thorough observations, and samples were obtained. Observed habitat types were classified according to updated EUNIS (EUNIS 2022), SPA/RAC (SPA/RAC-UN Environment/MAP 2019) and IUCN (IUCN, 2012) habitat classification systems.

Results and discussion

Transect mapping revealed the presence of 23 coastal habitats, 12 littoral and 11 infralittoral (Table 2; See Appendix). The maximum depth recorded during the survey was 17.4 m. Therefore, lower limits of the infralittoral zone and circalittoral habitats were excluded from the research.
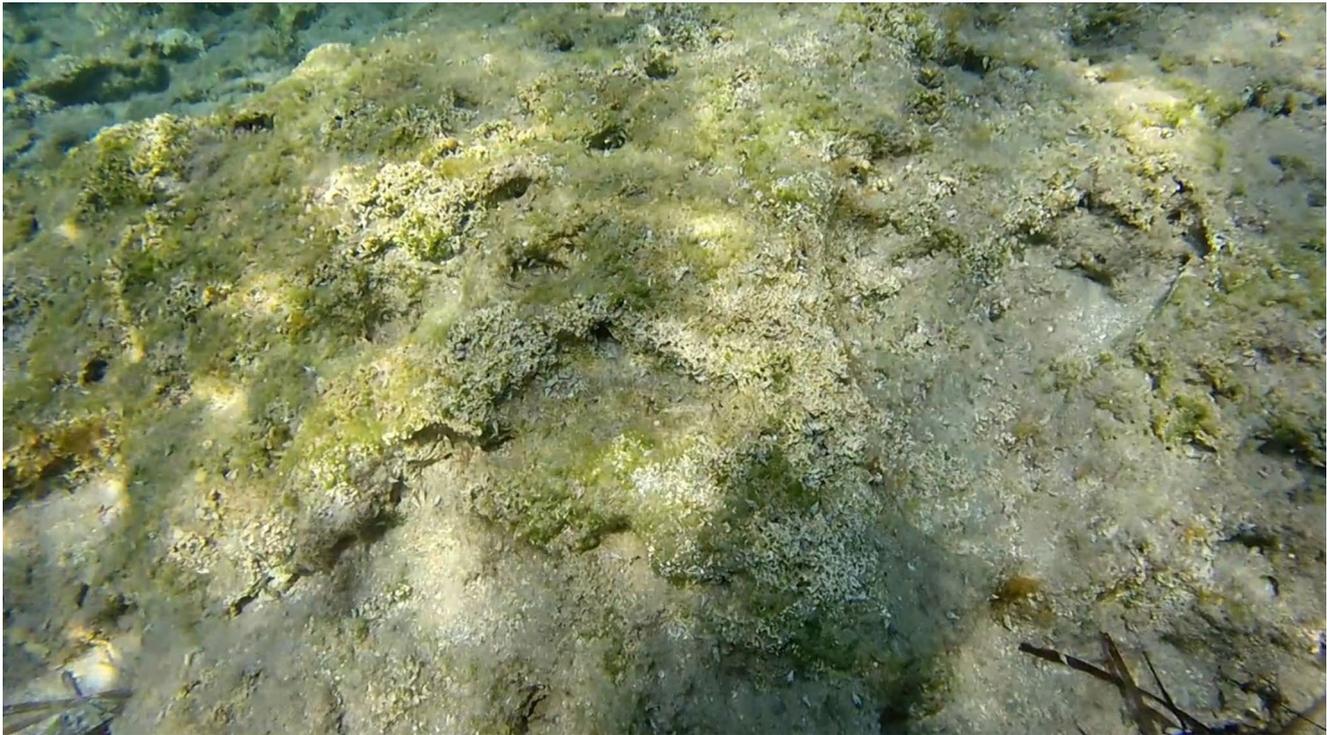
Fig. 1 Study area and locations of the transects

Table 1 Coordinates of the transects.

	Start		End	
Transect	Latitude (*N*)	Longitude (E)	Latitude (*N*)	Longitude (E)
1	35°24'03.64"	32°55'13.99"	35°24'04.95"	32°55'06.20"
2	35°24'18.23"	32°55'11.88"	35°24'19.18"	32°55'04.26"
3	35°21'26.93"	33°11'58.70"	35°21'32.97"	33°11'56.63"
4	35°21'30.46"	33°12'15.71"	35°21'35.75"	33°12'12.36"
5	35°20'13.68"	33°20'29.42"	35°20'19.36"	33°20'33.05"
6	35°20'10.31"	33°20'46.20"	35°20'16.10"	33°20'48.82"
7	35°21'21.51"	33°36'04.58"	35°21'27.19"	33°36'08.16"
8	35°21'32.95"	33°36'21.23"	35°21'30.52"	33°36'13.85"
9	35°41'31.46"	34°33'34.28"	35°41'38.19"	34°33'36.22"
10	35°41'33.77"	34°33'53.98"	35°41'40.11"	34°33'53.93"
11	35°41'34.28"	34°34'17.78"	35°41'40.65"	34°34'16.48"
12	35°41'34.26"	34°34'38.95"	35°41'40.68"	34°34'36.59"
13	35°41'40.87"	34°34'51.81"	35°41'46.86"	34°34'49.34"
14	35°41'50.07"	34°35'35.29"	35°41'44.49"	34°35'38.64"
15	35°41'27.83"	34°35'09.49"	35°41'22.31"	34°35'11.42"
16	35°41'14.61"	34°34'54.87"	35°41'12.28"	34°35'01.43"
17	35°40'59.17"	34°34'39.76"	35°40'55.82"	34°34'46.58"
18	35°40'47.49"	34°34'38.96"	35°40'48.36"	34°34'46.08"
19	35°13'35.40"	33°54'13.36"	35°13'35.24"	33°54'21.26"
20	35°13'19.29"	33°54'13.30"	35°13'17.07"	33°54'20.71"

It was observed that the supralittoral zone did not show much variation in the stations examined within the scope of the study. The biodiversity in the supralittoral zone was found to be quite low due to the homogeneous ground structure and high temperature. In addition, the fact that a narrow part of the supralittoral zone was investigated was one of the reasons for the lack of habitat diversity.

The mediolittoral zone observed during the study covered a belt of approximately 40 cm. In sheltered areas, habitats are exposed to excessive sunlight and high temperature
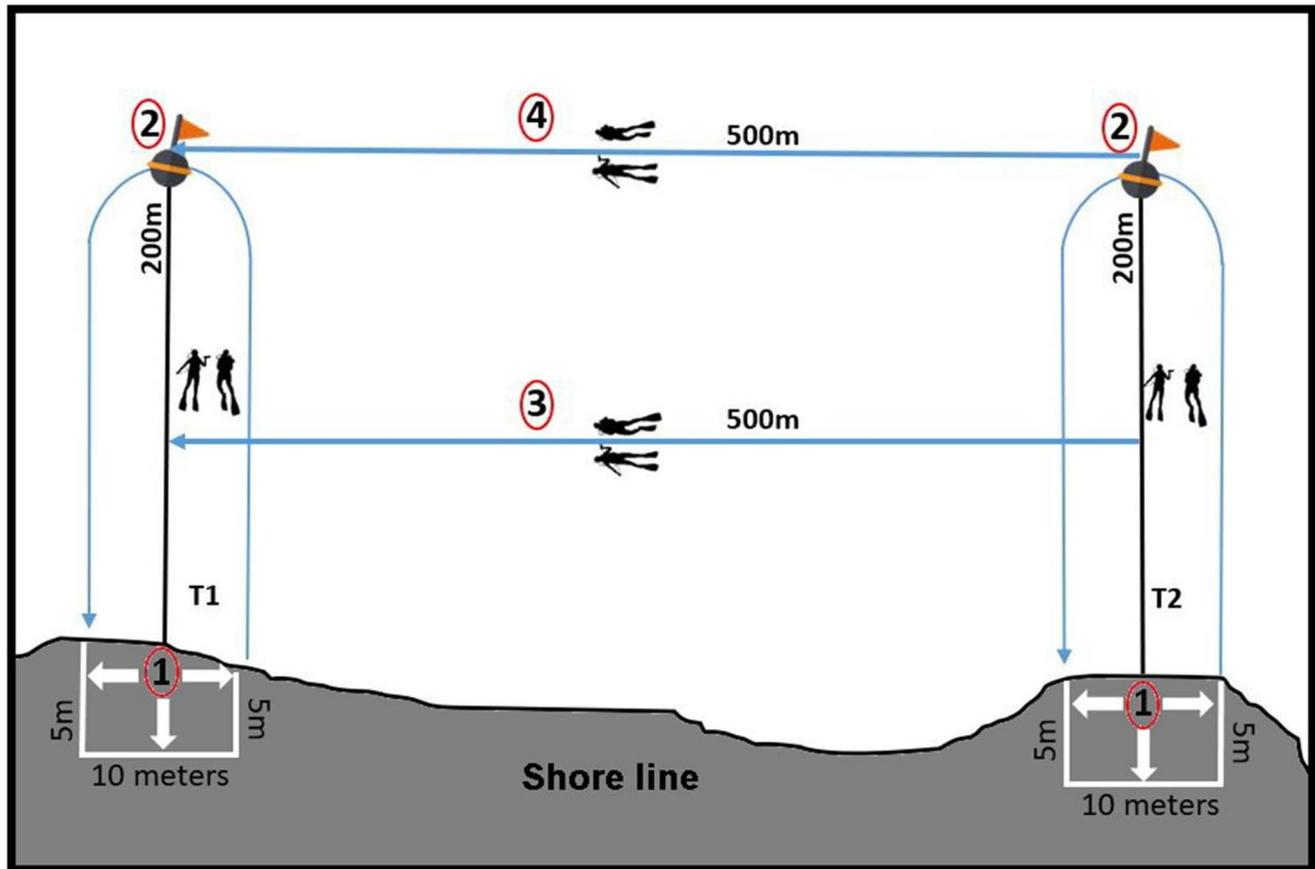
Fig. 2 Examination methodology. 200 m long transects were established perpendicular to the shoreline, beginning from the high-tide zone. Surveys were conducted by SCUBA divers along each transect

during low tide, while habitats in wave-exposed areas are constantly wet. In addition, *Dendropoma cristatum* and *Neogoniolithon brassica-florida* deposits were recorded growing on abrasion platforms. The invasive alien foraminifera species *Amphistegina lobifera* was also observed in the supralittoral and infralittoral zones.

Supralittoral habitats

Supralittoral inorganic sand

The investigated part is the lowest level of the supralittoral, 5 m away from the high tide limit, but not reaching the drift line (Fig. 3). Very sparsely dispersed dead phanerogam leaves may be found, but they do not form wracks. This section of the supralittoral zone is unvegetated. Most of the sandy beaches found along the coasts of the island, the sand particles are of rocky origin and fine sized. The top 5–10 cm of the sand may dry out due to extreme temperatures during summer, but the deeper part remains damp because of the seawater table beneath. Talitrid amphipods can be found in the vicinity of organic or anthropogenic debris. *Ocypode cursor* burrows are common in this supralittoral section. The shore is not steep, and the beach smoothly extends to infralittoral zone. In addition to the phanerogams, shells of bivalves and gastropods were also sparsely found within the organic debris. The habitat is used for nesting by loggerhead turtle, *Caretta caretta* and green turtle, *Chelonia mydas*.

Supralittoral foraminiferal sand

The second type of supralittoral sand is composed of the alien foraminifera *Amphistegina lobifera* tests (Fig. 4). These types of sandy beaches are observed on the northeastern coast of Rizokarpaso. The main structure of the coast is made of bedrock, and the foraminiferal tests are washed up to the shore during storms and accumulated over the bedrock. The thickness of the sand layer can exceed 30–40 cm. Since the upper sandy part of the beach is not connected to the sea because of the bedrock beneath, all the sand layers may dry out during the summer season. The test size ranges between 0.2 and 2.2 mm, forming a coarse sediment. These

Table 2 Coastal habitats investigated within the framework of this study.

	Habitat	Codes		
		EUNIS 2022	RAC/SPA	IUCN
Supralittoral	Inorganic sand	MA5511	MA5.51	13.3?
	Foraminiferal sand	MA5511	MA5.51	13.3?
	Mixed sediment	MA351	MA4.51a	-
	Rock	MA151	MA1.513	13.1
Mediolittoral	Sand	MA5	MA5.52	12.2
	Mixed sediment	MA452	MA4.52	12.3
	Upper mediolittoral rock facies with gastropods	MA1535	MA1.534	12.1
	Lower mediolittoral rock facies with gastropods	MA154	MA1.547	12.1
	Association with *Ericaria amentacea*	MA154	MA1.542	12.1
	Association with algae other than *Sargassaceae*	MA154	MA1.543	12.1
	Rockpools	MA154A	MA1.54a	12.6
	Abrasion platforms	MA2551	MA2.53	?
Infralittoral	Fine sand	MB551	MB5.511	9.4
	Mixed sediment	MB45	MB4.5	9.3
	Cystoseira spp. communities on bedrock	MB151	MB1.511a	9.7
	Cystoseira spp. communities on sands	-	-	-
	Calcerous algae reefs	MB25	MB2.5	9.2
	Mixed algae community	MB151	MB1.512a	9.7
	Algae community dominated by *Stypopodium schimperi* or *Padina pavonica*	MB151	MB1.512a	9.7
	Algae community dominated by *Dictyota fasciola*	MB151	MB1.512a	9.7
	Algae community dominated by *Jania rubens*	MB151	MB1.513a	9.7
	Posidonia oceanica beds	MB252	MB2.54	9.9
	Barren rocks	MB15	MB1.5	9.2

Fig. 3 Supralittoral inorganic sand beach. Ghost crab (Ocypode cursor) burrowing (right)

Fig. 4 Supralittoral foraminiferal sand beach. Close-up photo of sand composed of abundant Amphistegina lobifera tests

types of beaches are found above the abrasion platforms, which include diverse mollusk fauna, especially gastropods. Thus, on the lower limits of this region dense shell grits are found over the *Amphistegina lobifera* test layer.

Supralittoral mixed sediment

The habitat is composed of pebbles, cobbles, and a limited amount of sand (Fig. 5). Washed up algae (mainly *Jania rubens*) and phanerogams during storms can sometimes form wracks. Decaying organic materials enable the formation of amphipod and insect communities. However, in the summer, excessive sun rays and heat cause the top layer to dry completely. No vegetation is observed. In the upper supralittoral zone, this habitat belt is usually

followed by a rocky elevation, which may reach 2–3 m in height, creating a barrier and causing extensive accumulation of marine litter, as well as petroleum waste in this limited zone.

Supralittoral rock

This is the habitat type that is formed by steep rocky walls or very large boulders along the coastline and surrounding islets located off the coast (Fig. 6). The supralittoral protrusions of the abrasion platforms also extend inland, forming supralittoral bedrocks with rough and perforated surfaces. The habitat is in the spray zone above the high tide level, and it is highly exposed to wave action. *Echinolittorina punctata* and *Melarhaphe neritoides* are commonly found in the first meter above intertidal zone. *Ligia italica*, which
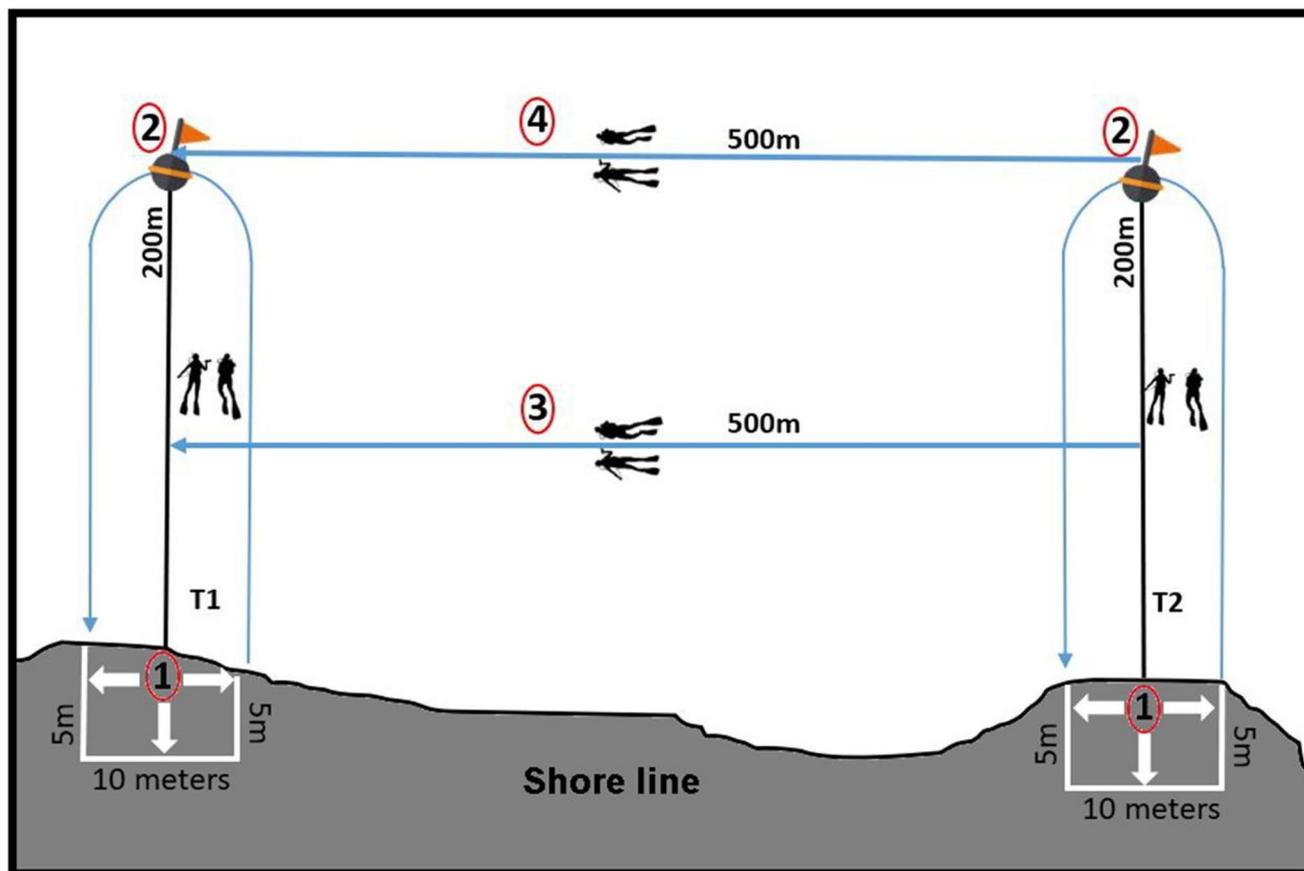
Fig. 5 Supralittoral mixed sediment. Washed up marine litter and *Jania rubens*

is seen in dense populations, has a wider range of distribution within this habitat zone.

Mediolittoral habitats

Mediolittoral sands

This habitat type is a transition zone between dry supralittoral sand and permanently submerged infralittoral sand habitats (Fig. 7). A major part of the sediment is fine inorganic sand, mixed with foraminiferal tests and shell grits. Talitrid amphipods are characteristic species. Bivalves *Donax semistriatus* and *Donax trunculus* are rarely found in the lower part of the zone. The habitat is also vital for the endangered *Ocypode cursor*.

Mediolittoral mixed sediment

This habitat includes shores of mobile pebbles and gravel with small amounts of coarse sand (Fig. 8). The sediment in the upper parts is subject to high degrees of drying between tides during calm days. There are no characteristic macrofaunal elements associated with this habitat, but in the low tide limits, gastropods *Phorcus richardi* and *Steromphala adansonii* are rarely observed on the less mobile pebbles and the bivalve *Donacilla cornea* is occasionally found in coarse sand. Very few amphipods and isopods may be found washed to the shore.

Upper mediolittoral rock facies with gastropods

The habitat is made of bedrock, boulders, and stones, highly exposed to wave action, as well as extreme sunlight (Fig. 9). The species inhabiting this habitat are resistant to high temperatures and desiccation. No macrophytes were observed. *Rivularia atra* was observed at sheltered places. Dominant faunal species are composed of mollusks, such as *Patella caerulea*, *Patella rustica*, *Patella ulyssiponensis*, *Phorcus articulatus* and *Phorcus turbinatus*. *Echinolittorina punctata* and *Melarhaphe neritoides* are rarely observed in this zone. The crustacean decapod *Pachygrapsus marmoratus* can also be locally abundant. During the low tide dense colonies of *Ligia italica* can be observed above the water level.

Fig. 6 Supralittoral rock made of rocky cliffs and boulders. Melarhaphe neritoides is abundant in the splash zone

Lower mediolittoral rock facies with gastropods

This habitat type is a continuation of the habitat type described above. Besides the *Patella* spp. and *Phorcus* spp., *Thericium lividulum* and *Cerithium scabridum* are dominant gastropod species found in the pits filled with sand on the rocky substrate (Fig. 10). The habitat does not include *Echinolittorina punctata* and *Melarhaphe neritoides*. It is also poor in terms of macrophytes. Very rarely, small clusters

of *Ericaria amentacea* and *Cystoseira* spp., *Cladophora* spp. and *Cladophoropsis membranacea* are found.

Lower mediolittoral communities associated with Ericaria amentacea

The habitat is found in the intertidal zone on big boulders and bedrock, highly exposed to wave action (Fig. 11). It is exposed to air during wavy days and at low tide. *Ericaria*

Fig. 7 Talitrid amphipod burrowings on mediolittoral sands Supralittoral rock made of rocky cliffs and boulders. Melarhaphe neritoides is abundant in the splash zone

amentacea forms very dense forests on the rocky surface, together with *Palisada perforata* and *Laurencia obtusa*. At the lower limits of the mediolittoral zone the coverage of *Ericaria amentacea* decrases, and *Laurencia* spp. are rarely found, where *Centroceras clavulatum*, *Polysiphonia* spp., *Spyridia filamentosa*, *Cladophora* spp., *Cladophoropsis membranacea*, *Valonia utricularis*, *Ectocarpus* spp., *Jania rubens* and *Halopteris scoparia* become more abundant.

Lower mediolittoral communities associated with algae other than sargassaceae

The habitat is found in the intertidal zone very similar to the habitat described above, however, *Ericaria amentacea* is very rare or totally absent (Fig. 12). *Jania rubens* and *Laurencia* spp. usually form a dense mat on the bedrock. *Valonia utricularis*, *Ectocarpus* spp. and *Cladophora* spp. are sparsely found. At the lower limits, the algal diversity decreases and *Jania rubens* remains the only mat forming algae, which continues down to infralittoral zone.

Mediolittoral rockpools

A large rockpool area was found at Station 4 (Fig. 13). The majority of the area was influenced by high tide. However, there were also enclosed areas that were not washed by waves during calm days. The most abundant algae species is found to be *Digenea simplex*. The other common species

observed within the rockpools are; Algae: *Acanthophora nayadiformis*, *Palisada perforata*, *Jania rubens*, *Padina pavonica*, *Digenea simplex*, *Ulva* spp.; Invertebrates: *Actinia equina*, *Palaemon elegans*, *Palaemon serratus*, *Porcellana platycheles*, *Pachygrapsus marmoratus*, *Eriphia verrucosa*, *Xantho poressa*, *Gonioinfradens paucidentatus*, *Ampelisca* spp., *Caprella* spp., *Chiton magnificus*, *Phorcus turbinatus*, *Phorcus articulatus*, *Steromphala adansonii*, *Steromphala divaricata*, *Bittium latreillii*, *Rissoa splendida*, *Rissoa variabilis*, *Cerithium scabridum*, *Ergalatax junionae*; Fish: *Atherina boyeri*, *Parablennius gattorugine*, *Chelon auratus*, *Gobius bucchichi*, *Gobius cobitis*.

Abrasion platforms

Mediterranean abrasion platforms are made of calcareous sandstones and limestones. The rims of the platforms, which are higher than the platform surface, are formed by the vermetid gastropods *Dendropoma cristatum* and the algae *Neogoniolithon brassica-florida*, creating the vermetid reefs (Fig. 14). The top of the platform is intertidal and usually exposed during low tide. The outer parts of the platforms are surrounded by walls that go straight down to 1–3 m of depth. The platforms surrounding the coast can be hundreds of meters long and their width can reach 40 m, especially on the north coast of Rizokarpaso. In addition to the calcareous biogenic components of the platforms, substantial amounts of sand were carried by the waves and accumulated on the

Fig. 8 Mediolittoral mixed sediment

intertidal zone, creating a diverse benthic structure and supporting a rich biota.

During low tide, a considerable part of the platform is usually exposed, but there are many potholes found in the intertidal part, which are usually deeper than a meter. A diverse array of floral and faunal elements was observed in these potholes and other intertidal parts of the platforms that remained submerged during low tide, including Algae: *Acetabularia acetabulum*, *Cystoseira* spp., *Ericaria amentacea*, *Treptacantha barbata*, *Dictyota* spp., *Acanthophora nayadiformis*, *Palisada perforata*, *Jania rubens*, *Digenea simplex*; Cnidaria: *Actinia equina*, *Anemonia viridis*, *Exaiptasia diaphana*, *Cereus pedunculatus*, *Balanophyllia (Balanophyllia) europaea*; Polychaeta: *Hermodice carunculata*,

Serpula spp., *Protula* spp.; Crustacea: *Palaemon elegans*, *Palaemon serratus*, *Pachygrapsus marmoratus*, *Pachygrapsus transversus*, *Eriphia verrucosa*, *Portunus segnis*, *Xantho poressa*; Fish: *Atherina boyeri*, *Scorpaena maderensis*, *Serranus hepatus*, *Serranus cabrilla*, *Epinephelus marginatus* (juveniles), *Chelon auratus*, *Symphodus roissali*, *Aidablennius sphynx*, *Parablennius gattorugine*, *Gobius bucchichi*, *Gobius cobitis*.

The outer margin of the reef is the active part, growing outwards and upwards, forming the rim of the platform, where floral diversity is high. Besides the algae species found in the intertidal part, *Titanoderma trochanter* and *Tenarea tortuosa* are also very common on the rims. Very few alive *Dendropoma cristatum* and *Vermetus triquetrus*

individuals were observed, suggesting that, still today, calcerous algae species play a major role in the formation of these reefs. The outer walls of the platforms are often overshadowed by the protruding upper edge, allowing the growth of coralligenous algae (such as *Mesophyllum philippii*, *Mesophyllum lichenoides*, *Lithophyllum* spp., *Peyssonnelia* spp.) and bryozoans (*Calpensia nobilis*, *Celleporina* spp., *Schizoporella* spp., *Schizomavella* spp., *Smittina cervicornis*, *Hornera frondiculata*). Decapod crustaceans: *Maja crispata*, *Dromia personata*, *Palaemon serratus*; Echinoderms: *Diadema setosum*, *Arbacia lixula*, *Echinaster (Echinaster) sepositus*, *Coscinasterias tenuispina*; Tunicates: *Halocynthia papillosa*, *Microcosmus* spp., *Herdmania momus* are the invertebrates commonly observed on the outer walls of the platforms. A total of 74 Mollusk species were either identified from the alive individuals or from the shell grits collected on the transects that were set on the abrasion platforms (unpublished data). The most abundant alive collected species were *Phorcus* spp., *Steromphala* spp., *Bittium latreillii*, *Rissoa variabilis*, *Alvania cimex*, *Thericium lividulum*, *Cerithium scabridum*, *Ergalatax junionae*, *Vexillum* spp., *Columbella rustica*, *Striarca lactea*, *Brachidontes pharaonis*, *Septifer bilocularis*, *Ctena decussata*, and *Chama pacifica*.

Infralittoral habitats

Infralittoral fine sand

This habitat is formed by clean fine sands at depths between 1 and 18 m in the studied stations (Fig. 15). Most of the mediolittoral sandy beaches have this type of infralittoral extensions. But the presence of this kind of habitat is not always limited to sandy beaches, it can also be observed off the rocky coasts or in empty spaces between *Posidonia oceanica* meadows. Faunal community is dominated by the mollusks; *Loripes orbiculatus*, *Ctena decussata*, *Mactra stultorum*, *Spisula* spp., *Pecten jacobaeus*, *Donax semistriatus*, *Glycymeris glycymeris*, *Chamelea gallina*, *Neverita josephinia*, *Tonna galea*, *Bolinus brandaris*, *Naticarius hebraeus*, *Nassarius circumcinctus*, *Tritia pellucida* and *Tritia gibbosula* are the most abundant species. The decapod crustaceans: *Diogenes pugilator*, *Coleusia signata*, *Liocarcinus* spp., *Portunus segnis*, *Thalamita poissonii;* Echinoderms: *Astropecten* spp., *Synaptula reciprocans*, *Echinocardium mediterraneum;* Fishes: *Gobius bucchichi*, *Gobius niger*, *Gobius geniporus*, *Bothus podas Trachinus draco*, *Bothus podas* and *Xyrichtys novacula* are also commonly observed.

Infralittoral mixed sediment

The habitat is a mixture of sand, pebbles, and cobbles (Fig. 16). It is below low tide and extends from 1.5 m to 3.5 m of depth. The size of the sediment decreases with increasing depth. The algae composition is very limited, *Acetabularia acetabulum*, *Amphiroa rigida* and *Jania rubens* are sparsely found on shallow rocks. Fauna is not very rich. *Anemonia viridis* and *Balanophyllia (Balanophyllia) europaea* are common at the upper boundary and *Condylactis aurantiaca* is seldom observed where coarse sand is abundant. The dominant mollusks are *Cerithium scabridum*, *Tritia pellucida*, *Hexaplex trunculus*, *Pisania striata*, *Ctena decussata*, *Striarca lactea*, *Pinctada radiata* and *Chama pacifica*, *Maja crispata* and *Xantho poressa* are commonly observed crustacean decapods.

Algal-dominated infralittoral rock

A large percentage of algae species detected in rocky areas in the infralittoral zone show a wide depth distribution. However, it was observed that the dominant algae species in the environment changed depending on the depth, forming different belts of algal associations.

Infralittoral mixed algae community

The habitat is usually a continuation of the lower mediolittoral communities associated with *Ericaria amentacea* in the infralittoral zone. However, *Ericaria amentacea* is mostly replaced with other *Sargassaceae* species such as *C. compressa*, *C. foeniculacea*, *Treptacantha barbata* but none of them is dominant in the habitat. *Jania rubens*, *Laurencia* spp., *Dictyota* spp., *Palisada perforata*, *Digenea simplex*, *Chondracanthus acicularis*, *Anadyomene stellata*, *Ceramium* spp., and *Polysphonia* spp. are common algae species and collectively form a dense mat on the rocky surfaces. The habitat is subtidal and observed at 0.3–1.5 m depth range, but it can be exposed to strong wave action, usually during storms. (Fig. 17). The habitat is also rich in gastropods and crustaceans. The invasive alien bivalve species *Chama pacifica* and *Pinctada radiata* are common. *Eriphia verrucosa*, *Pachygrapsus marmoratus* and *Pachygrapsus transversus* are observed in the upper part.

Infralittoral algae community dominated by *Jania Rubens*

Jania rubens shows a wide distribution of depth in the infralittoral region investigated within the scope of this study. However, it has been observed that the most intense depth
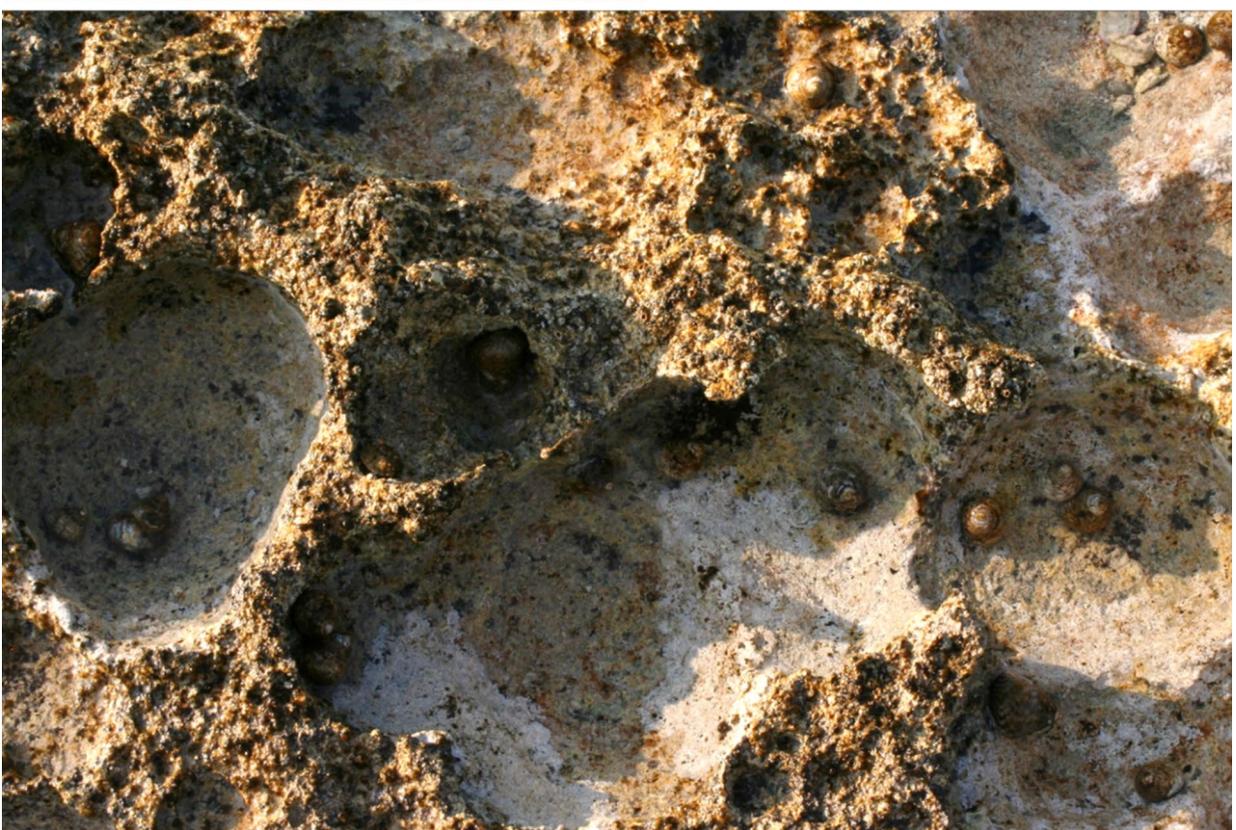
range is 0–3 m (Fig. 18). Although it is found together with other algae species such as *Sargassaceae* spp., *Laurencia* spp., *Palisada perforata*, *Dictyota* spp., *Acanthophora nayadiformis* in the uppermost layer of the infralittoral zone, it has been observed that it can form a dominant cover alone in the 0.5–1.5 m depth range, with up to 23% coverage on the hard surfaces. *Amphiroa rigida* and encrusting corallinales are also observed on the boulders, with a total coverage of less than 1%.

IInfralittoral algae community dominated *by dictyota fasciola*

Dictyota fasciola is found in the mediolittoral pools and on the abrasion platforms. It also shows a wide distribution range in the infralittoral zone. But it becomes the dominant species at 1.5–2.5 m depth range, below *Jania rubens* belt (Fig. 19). Encrusting corallinales and other erect, but not canopy forming algae species, such as *Padina pavonica*, *Stypopodium schimperi* and *Ganonema farinosum* may be found in very small percentages, but *Dictyota fasciola* may have a 6–18% coverage on the well illuminated surfaces of the boulders and the rocks.

Infralittoral algae community dominated by *Stypopodium schimperi* and *Padina Pavonica*

The bedrock and boulders covered by dense mat of the alien algae, *Stypopodium schimperi* and/or native *Padina pavonica* (Fig. 20). Turf forming algae species, mainly *Sphacelaria* spp., are also abundant. The dense turf captures fine sand on the rocky surface, creating a mixed microenvironment on the rocks, where infaunal organisms can survive. The alien foraminifera *Amphistegina lobifera* and *Amphisorus hemprichii* growing on the turf enhance the sand accumulation.

Infralittoral *cystoseira spp.* Communities on bedrock

This habitat occurs at 1–12 m depth range and is characterized by dense *Cystoseira* forests. *Cystoseira* spp., are the only canopy forming algae species, turf forming algae is also not observed (Fig. 21). The rocky substrate typically consists of flat bedrock, lacking any sheltered caverns or crevices. Thus, the habitat is poor for invertebrates other than gastropods. *Tricolia pullus*, *Jujubinus* spp., *Calliostoma laugieri*, *Bittium* spp., *Alvania* spp., *Rissoa* spp., *Cerithium scabridum*, *Conomurex persicus*, *Muricopsis cristata*, *Ergalatax junionae*, *Enginella leucozona*, *Vexillum* spp., *Conus ventricosus* are commonly observed in this habitat.

Palaemon spp., *Hippolyte* spp., *Eualus cranchii* and *Pagurus anachoretus* are the dominant decapod crustacean species. The echinoderms *Arbacia lixula* and *Diadema setosum* are sparsely found.

Infralittoral *cystoseira spp.* Communities on sand

In the present study extensively accumulated *A. lobifera* tests were observed in some stations on the north coast of Rizokarpaso, making up to 80–95% of the infralittoral sediment, totally covering bedrock on the sea bottom. Because of the test size (0.2–2.2 mm), foraminiferal sand forms loose and coarse sediment and its thickness on the bedrock may reach 5–10 cm, enabling the *Cystoseira* forests to hold on the rocky surface and grow over the sand (Fig. 22). In addition to the foraminiferal sand, a similar habitat was also observed over inorganic fine sand at Station 1, at shallow depths between 0.4 m and 1.2 m. Sand dwelling invertebrates and fish species are commonly observed in this habitat. But, since it allows the growth of *Cystoseira* forests fields, faunal characteristics are more diverse compared to sandy habitats that lack vegetation. Besides the species observed in the *Cystoseira* forests on the rocky benthos, some sand dwelling species are also common in this habitat, such as, Polychaeta: *Hermodice carunculata*, Crustacea: *Coleusia signata*, *Liocarcinus* spp., *Portunus segnis*, *Diogenes pugilator*, Gastropoda: *Conomurex persicus*, *Neverita josephinia*, *Tritia pellucida*, *Retusa* spp., *Bulla striata*.; Bivalvia: *Loripes orbiculatus*, *Moerella pulchella*, *Chamelea gallina* and *Ctena decussata*.

Infralittoral *calcareous* algae reefs

Bedrock and boulders covered by various encrusting algal species are the main characteristics of the habitat (Fig. 23). The thickness of the calcareous deposits may reach several centimeters. The soft deposit is easily carved by the boring sponge *Cliona viridis*, creating a rough and porous appearance. There are no canopy forming algae except the very limited amount of *Laurencia* spp. concentrated on the shaded areas. Turf forming *Sphacelaria* spp. are abundant, *Dasycladus vermicularis* is rarely found at shallow depths. Due to the algal mat and porous surface, the habitat contains substantial number of amphipods and polychaetes. *Bittium* spp. and *Cerithium scabridum* are the dominant gastropod species.

Posidonia oceanica beds

The habitat is created by the Mediterranean endemic *Posidonia oceanica* (Fig. 24). It can grow on silt, sand, and coarse material, as well as on rock. It was observed at depths from

Fig. 10 Lower mediolittoral rock facies with gastropods. Cerithium spp. are commonly found on accumulated sand over the rocky surface

2 m to 20 m, which represented the maximum depth of this study; however, the meadows extend much deeper. At 13 out of 20 stations, *Posidonia oceanica* was recorded either as large and healthy meadows with 90–100% coverage or as a few small patches.

Infralittoral barren rocks

This habitat is found at 6–10 m depth range, between the *Cystoseira* forests facies and infralittoral sands or seagrass meadows (Fig. 25). The habitat is made of solid barren rock, without any algae on it. The faunal community is very poor, dominated by the alien gastropod species, *Conomurex persicus* and *Cerithium scabridum*. The only fish species observed in this habitat is the alien orange-spotted toadfish *Torquigener hypselogeneion*.

Anthropogenic effects on coastal habitats

The northern coasts of Cyprus face significant environmental challenges, largely due to inadequate regulations and insufficient enforcement. Properly managed waste-disposal facilities are critically limited, and recycling practices are nearly absent (Emirzade and Huseyinoglu 2025). As a result, beach-litter densities in this region are among the highest in the Mediterranean, surpassed only by Zaglev, Croatia in terms of litter items per m² (Özden et al. 2021). During our present study, marine litter sourced from both land-based runoff and localized point sources was widespread. Pelagic micro- and macroplastics, together with ship and port-derived debris such as rope fragments, plastic tools, and styrofoam, were consistently recorded even in remote areas such as the tip of the Rizokarpaso Peninsula. Furthermore, dense objects found on the seabed, including food cans, glass bottles, and metal cutlery, indicate strong contributions from daily touristic activities, responsible for the point origins of such observed litter.

Coastal ecosystems in Cyprus are simultaneously under heavy pressure from invasive alien species (IAS) (Huseyinoglu et al. 2024). Nearly all examined habitats during the study were found to be colonized by Indo-Pacific alien species, which are expected to be expanding to other regions. The ecological impact of these species is further exacerbated by the overfishing of native keystone predators such as *Epinephelus marginatus*, *Dentex dentex*, and *Seriola dumerili*. As these native predators decline, invasive mesopredators, most notably *Pterois miles*, *Fistularia commersonii*, and *Lagocephalus sceleratus*, have increasingly assumed top-predator roles within eastern Mediterranean coastal ecosystems (Giakoumi et al. 2019; Huseyinoglu et al. 2024).

Despite these pressures, Cyprus still supports numerous coastal habitats of high conservation value, along with several protected marine species, including the Mediterranean monk seal *Monachus monachus* and the green turtle *Chelonia mydas*, both listed under multiple international conservation frameworks. Several habitat features of particular ecological importance remain well represented throughout
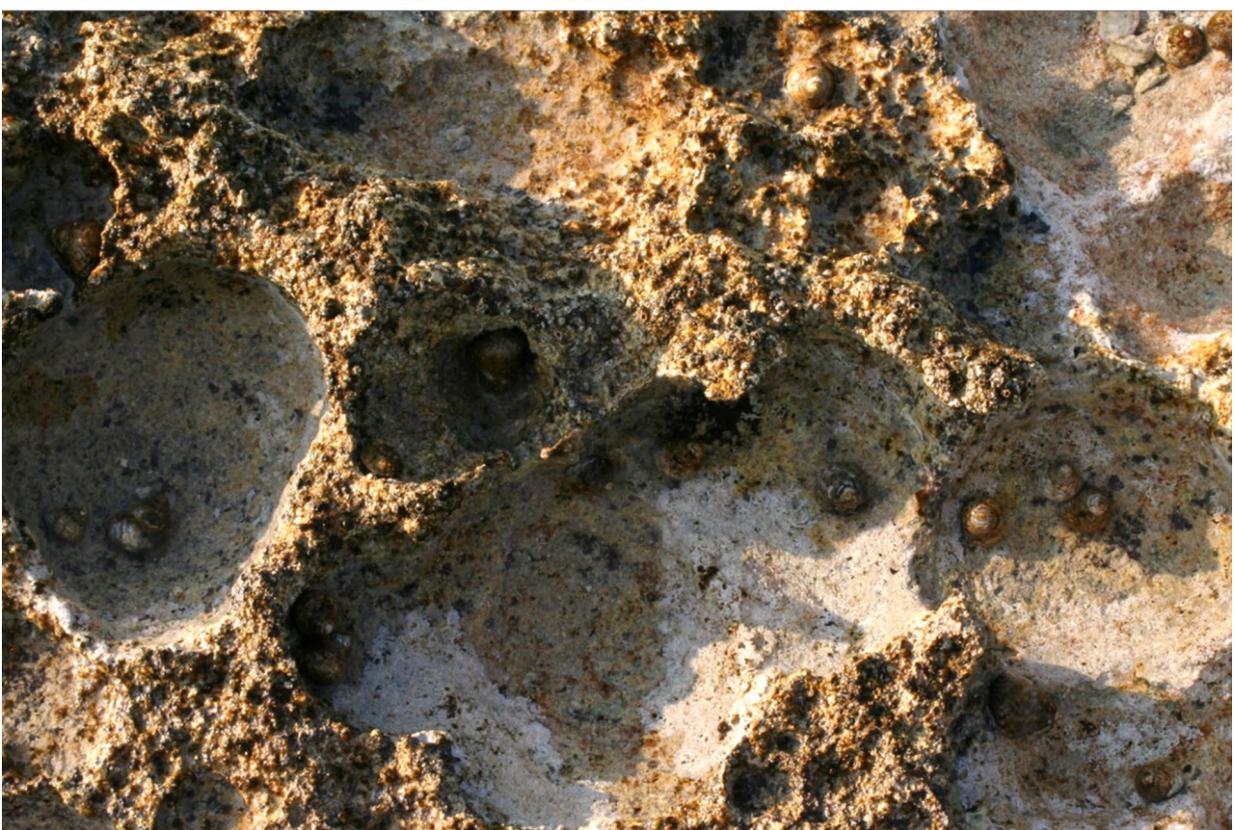
Fig. 11 Lower mediolittoral communities associated with Ericaria amentacea

the Cypriot coastline. Extensive vermetid reef formations occur along substantial portions of the shore, with some reefs extending uninterrupted for more than 5 km (Husey-inoglu et al., 2020). Additionally, the island hosts nesting sites for two marine turtle species, *Caretta caretta* and *Chelonia mydas* (Palmer et al. 2021), both of which were frequently observed during this study. Another notewor-thy finding was the distribution of *Posidonia oceanica*, with healthy and widespread meadows beginning around 2 m depth and present in nearly all assessed regions. These observations highlight both the ecological richness and the vulnerability of the coastal habitats of Cyprus, underscor-ing the urgent need for effective environmental management and conservation strategies.

Conclusion

The Mediterranean Sea, including the coastal areas of Cyprus, harbors diverse marine habitats which are increas-ingly threatened by anthropogenic pressures and environ-mental changes, such as habitat destruction and invasive alien species (Dailianis et al. 2018; Katsanevakis et al. 2014). These habitats are critical for maintaining biodiver-sity and ecosystem services that support both marine and human well-being. Standardized frameworks, such as the European Nature Information System (EUNIS), provide essential tools for classifying and understanding these eco-systems, facilitating the development of coordinated con-servation strategies across the Mediterranean region.

◀ **Fig. 12** Lower mediolittoral communities associated with algae other than Sargassaceae

The EUNIS Habitat Classification is intended to reach as much consensus as possible among those interested in habitat classification by providing a common and easy-to-understand language for the description of all marine habitats in Europe. In this system classification of habitats are made at five levels, the general definition of marine benthic habitat is given at the first level, depth zones and sediment types at the second level, the marine region, such as Mediterranean/Black Sea, at the third level. At the fourth level, the definitions of the communities found in the subdivisions of the depth zones are given, which are followed by the habitats associated with characteristic species at the fifth level. The western Mediterranean waters support a wide range of ecosystems, hosting a variety of well-defined marine coastal habitats characterized by high biodiversity. As a result of detailed ecosystem and habitat studies, many habitat types have been identified up to fifth level (EUNIS 2022).

On the other hand, the eastern Mediterranean's marine coastal habitats, especially in the Levantine basin, also display significant biodiversity but highly oligotrophic waters, high surface temperatures and intensive alien invasion create different challenges. The community structures are quietly differ compared to western Mediterranean. Thus, of the 23 habitats observed in this study, only two of them could be identified up to fifth level. It is also thought that the habitats formed by the invasive alien foraminifera *Amphistegina lobifera* are specific for the Levantine basin and not classified in the EUNIS, RAC/SPA or IUCN classification systems. Foraminifera test is one of the principal sources of $CaCO_3$ in the tropical and subtropical seas and the percentage in the sand may reach as high as 90% in certain locations in the Pacific (Hallock et al., 1995). *A. lobifera* is considered as the most expansive and abundant alien foraminifera in the eastern Mediterranean (Langer et al. 2012). It has been reported that the *A. lobifera* deposits may form up to 80 cm thick sand on the sea bottom on the southwestern coasts of Turkey (Yokeş and Meriç 2009). *A. lobifera* has also been

Fig. 13 Mediolittoral rockpools include mixed sediment type. Digenea simplex is the dominant algae species with high coverage. (Anemonia sulcata) usually forms dense colonies

Fig. 14 Abrasion platforms are intertidal and usually exposed during low tide. However, the pits, which are always submerged in water, contribute to the development of the Sargassaceae mat, providing shelter for many vertebrate and invertebrate species during low tide. The rims of the platforms are formed by the vermetid gastropods Dendropoma cristatum and the algae Neogoniolithon brassica-florida
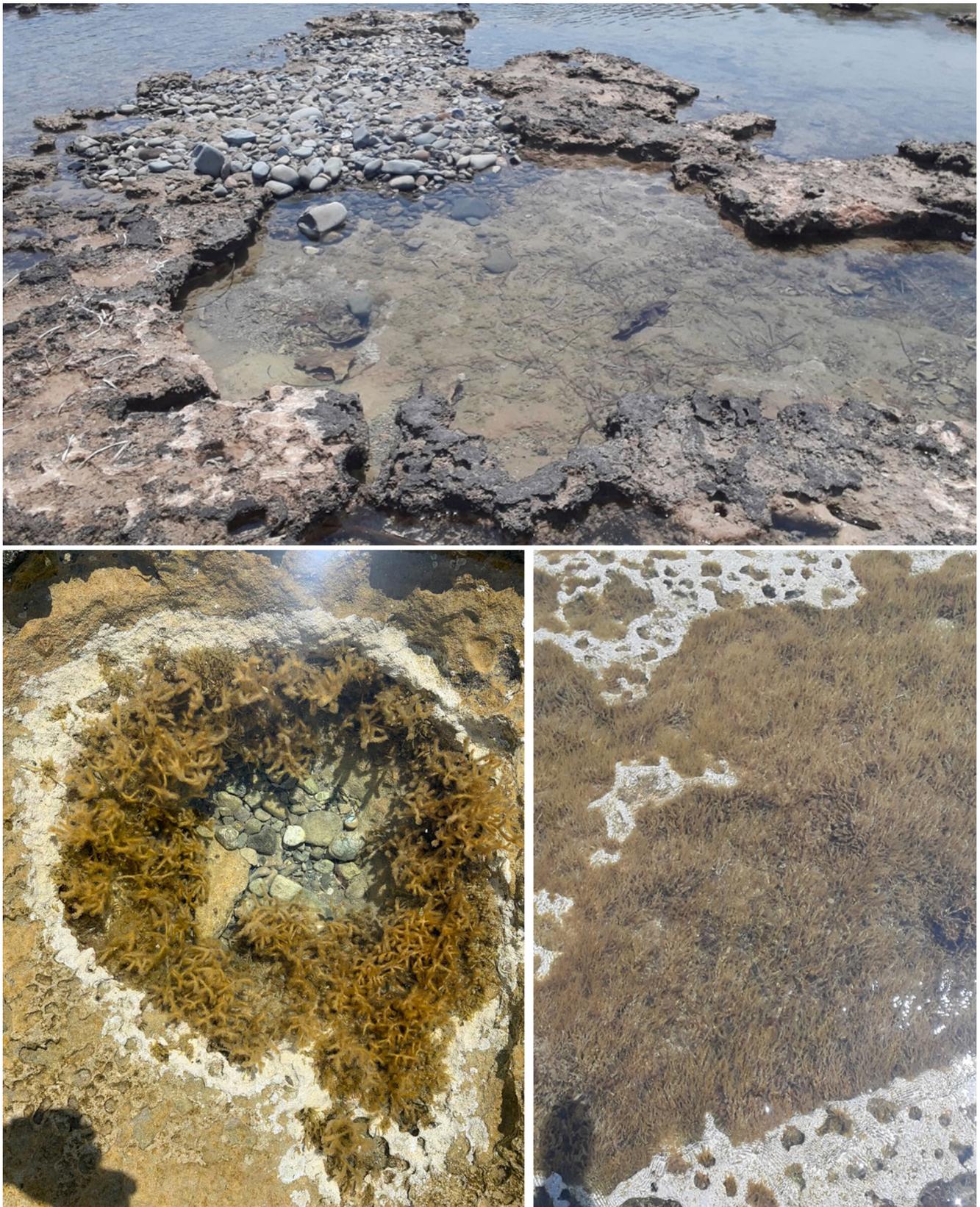

**Fig. 15** Infralittoral fine sand

Fig. 16 Infralittoral mixed sediment

Fig. 17 Infralittoral mixed algae community

reported from northern coastal zones of Cyprus (Meriç et al. 2021). In the present study extensively accumulated *A. lobifera* tests were also observed, making up to 80–95% of the sediment, totally covering bedrock on the sea bottom, changing rocky structures to littoral, as well as supralittoral sandy habitats (Figs. 4 and 22). Highly accumulated *Amphistegina* tests form a looser structure than the sand consisting of stones and mollusk shell fragments, allowing algae to grow on the rocky ground underneath. For this reason, both sandy and algal (mainly *Cystoseira* spp.) habitats can be found together in areas with dense *Amphistegina* sediments. The resulting habitat differs in faunal communities compared to sandy and *Cystoseira* spp. habitats.

Recent field studies on the northern coasts of Cyprus have highlighted the prevalence of vermetid reefs, particularly on the Rizokarpaso peninsula, underscoring their significance as ecological hotspots (Huseyinoglu et al., 2020). These reefs not only contribute to local biodiversity but also serve as indicators of ecosystem health. Protecting these unique habitats is essential for maintaining the integrity of the coastal ecosystems they support. However, due to very limited literature information about coastal habitat types and their distributions in Cyprus, measures to be taken to protect existing habitats can be insufficient. For this reason, it is essential to conduct more detailed and large-scale studies to determine the habitats of protection concern.

Fig. 18 Infralittoral algae community dominated by *Jania rubens*
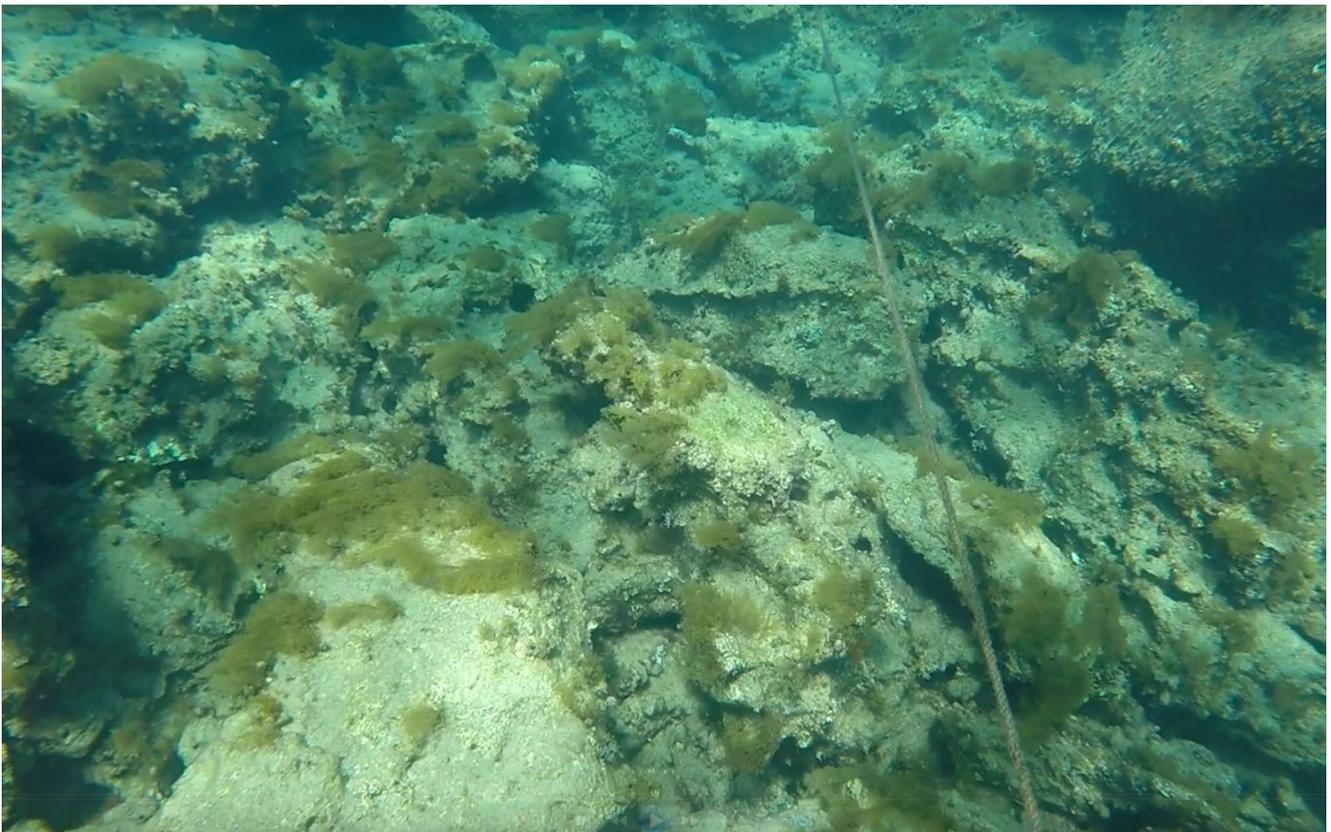
Fig. 19 Infralittoral algae community dominated by Dictyota fasciola

Fig. 20 Infralittoral algae community dominated by Stypopodium schimperi and Padina pavonica

Fig. 21 Infralittoral Cystoseira spp. communities on bedrock

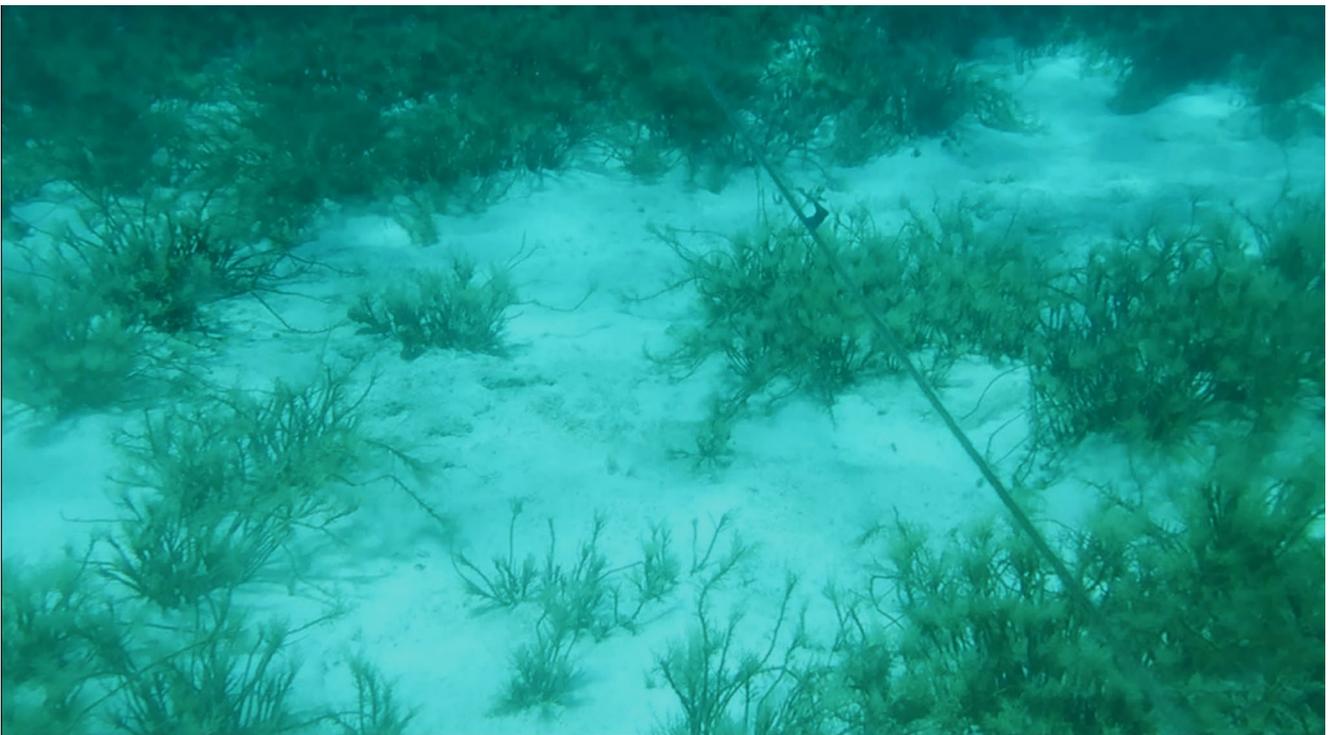**Fig. 22** Infralittoral Cystoseira spp. communities on sand. The main axis is actually attached to the bedrock covered with foraminiferal sand, mainly composed of Amphistegina lobifera tests. The loose and coarse sediment of 5–10 cm thickness enables the sand dwelling organisms inhabit the Cystoseira forests

Fig. 23 Infralittoral *calcerous* algae reefs

Fig. 24 *Posidonia oceanica* meadows

Fig. 25 Infralittoralbarren rocks

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