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Considerations on the marine dimension of the Maltese Islands

A miniature ocean – the Mediterranean Sea

Due to their geographic position, the Maltese Islands can be considered as the quintessential Mediterranean archipelago and hence a brief overview of the Mediterranean Sea, which bathes 23 countries (including Gibraltar, UK), three continents and 200 million inhabitants, is warranted in any marine-oriented argument concerning our islands.

As a regional sea, the Mediterranean's dimensions are quite significant, spanning for a maximum length of ca. 4000km, a maximum breadth of ca. 900km and a surface area of 2.5 million km^2. However, when one frames such dimensions in the global scenario, the dimensions almost pale into insignificance – in fact, the Mediterranean's surface area and volume comprise just 0.82% of the total ocean surface area and 0.32% of the total ocean volume.

Despite its limited dimensions, the Mediterranean harbours a disproportionately rich marine biota, with an equally disproportionate degree of endemism. In fact, Boudouresque (2004) estimates that the total number of marine macroscopic species to be found in the Mediterranean stands at around 12,000. If one was to go by the estimate for the global number of marine species given by the 2,000-strong community of Census of Marine Life scientists from 82 nations convened in Valencia, Spain, in November 2008 for the World Conference on Marine Biodiversity – i.e. 230,000 to 250,000 – then the Mediterranean share would represent an impressive 5%. The fraction of marine endemics is equally as stunning, with circa 20% of all marine species ploughing the sea being endemic to it. The animal phylum Porifera (the sponges) boasts the highest fraction of endemic species – 50.1%.

The only region in the world that compares with the Mediterranean in terms of the species diversity of its marine flora is the southern coast of Australia – as a result, the Mediterranean Sea can be considered as a hotspot of marine biodiversity (Bianchi & Morri, 2000).

The perception that the Mediterranean Sea behaves like a series of lakes is reinforced by the fact that, like the Baltic Sea, it is almost a tideless sea. In fact, most coastal areas around the Mediterranean are classified as being microtidal – i.e. tidal amplitude is less than 2m – with a few sites, such as Venice Lagoon and the Gulf of Gabes (Tunisia), making it to the mesotidal (i.e. tidal amplitude ranges from 2m to 4m) category in view of their extensive continental shelf area (i.e. less than 200m deep). Incidentally, just 20% of the Mediterranean falls within the precincts of the continental shelf (Mojetta, 2005), making the Mediterranean a relatively deep sea. In fact, the average depth of the Mediterranean is that of 1502m, significantly higher than that of the North Sea (75m) and Baltic Sea (55m), yet nowhere near the average ocean depth which stands at 3800m. The deepest point of the Mediterranean is located at the Hellenic Trough in the Aegean Sea and measures up to a depth of 5092m (corresponding depths for the North Sea and the Baltic Sea stand at 700m and 459m, respectively).

Other defining characteristics of the physico-chemical nature of the Mediterranean include its oligotrophic nature, with low concentrations of dissolved nutrients (nitrates and phosphates mainly) and consequent low levels of primary production and phytoplankton densities. The oligotrophy of the Mediterranean can be ascribed to two main factors: (1) the fact that surface water from the East Atlantic Ocean which feeds the Mediterranean Sea is already poor in nutrients and since relatively few major rivers (generally considered as windfalls of nutrients), such as the Nile, Ebro, Rhone and Po, empty into the Mediterranean Sea. Whilst phytoplankton populations in most oceans are nitrogen-limited, those in the Mediterranean are phosphorus-limited.

The Mediterranean Sea is also characterized by high water temperatures and high salinities and by a pronounced West-East gradient in physico-chemical factors, which sees a spiraling of water salinity, temperature and oligotrophy the further east one goes and a counter fall in dissolved nutrient concentrations and primary productivity. The water salinity reaches a maximum of 39.1 parts per thousand in the extreme eastern part of the Levatine Basin, higher than incoming surface Atlantic water (36.3 parts per thousand) and significantly higher than the average salinity of the Black Sea (18.5 parts per thousand) which is profusely fed by rivers discharging into it.

The high degree of solar radiation received by the Mediterranean, coupled with the low freshwater input, result in a negative water balance, where the loss from evaporation is three times greater than the gain from rivers and precipitation. For this reason, the Mediterranean Sea is sometimes described as an "evaporation basin". Tchernia (1978) estimates that the total riverine freshwater input into the Mediterranean corresponds to a water layer thickness of just 1m when spread over the entire basin. In fact, it has been calculated, in an uncanny evocation of the Messinian salinity crisis (which occurred ca. 5.6 million years ago and during which large swathes of the Mediterranean Sea dried up due to an interruption of the Atlantic connection), that if the Straits of Gibraltar were to be sealed off, the Mediterranean would dry up entirely within 3000 years (Boudouresque, 2004).

The oceanography of the Mediterranean Sea is anything but simple. The Mediterranean Sea behaves like a series of interconnected water bodies, each of which has a distinctive seabed topology. Different sectors within the Mediterranean Sea may also be distinguished on the basis of biogeographical characteristics, with biogeography being defined as 'The scientific study of the past and present geographical distribution of plants and animals at different taxonomic levels.'

There is disagreement in literature as to the exact number of such sectors within the Mediterranean Sea, with Bianchi (2007) listing thirteen, namely: (1) Alboran Sea; (2) Algeria and north Tunisia coasts; (3) southern Tyrrhenian Sea; (4) Balearic Sea to Sardinia Sea; (5) Gulf of Lions and Ligurian Sea; (6) northern Adriatic Sea; (7) central Adriatic Sea; (8) southern Adriatic Sea; (9) Ionian Sea; (10) northern Aegean Sea; (11) southern Aegean Sea; (12) Levant Sea; (13) Straits of Messina.

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Nudibranchsare molloscs without a shell and which mesmerise the underwater visitor with their grace

The variety of seabed topologies and features is equally as intriguing. Each of the Mediterranean sub-basins is a silled one. Sills are underwater ridges or rocky ledges (defined depressions) which define the boundary between two adjacent basins. Sills restrict water flow between adjacent basins so that water within a particular sub-basin assumes a unique hydrology which is distinguishable from that of water in other sub-basins. Notorious sills within the Mediterranean include the Otranto Sill, which defines the Adriatic Sea from the Ionian Sea, the 'double sill' separating the East Mediterranean from the Sea of Marmara and from the Black Sea and comprised of the Dardanelles Sill and the Bosphorus Sill and the Siculo-Tunisian Sill, separating the Mediterranean Sea into two halves. In fact, the various biogeographical sectors and seabed topographic basins are grouped into two main basins – the West Mediterranean and the East Mediterranean – separated by the shallow 150km-wide Sicilian Channel.

The Central Mediterranean is characterised by frequent past instances of tectonic activity, such as rifting and submarine volcanism, which have chiselled the seabed into a variety of topologies. The Maltese Islands and the island of Lampedusa lie on opposite sides of the main rift system in this part of the basin - the NW-SE-trending Pantelleria Rift System or Sicily Channel Rift Zone (SCRZ). The rift system is in turn characterised by deep water and by a number of submerged valleys, known as grabens – the Pantelleria Graben, the Malta Graben and the Linosa Graben, where the sea depth reaches a maximum of 1700m (Reuther & Eisbacher, 1985). The Maltese Islands are located on a shallow shelf, known as the Malta-Ragusa rise, which in turn is part of a submarine ridge known as the Pelagian Block and which extends from the Ragusa peninsula of Sicily (the Hyblean Platform) southwards to the coasts of Tunisia and Libya. As a result, the Ragusa Peninsula of Sicily, the Maltese Islands and the Pelagian Islands (Lampedusa, Linosa and Lampione) are geophysically considered to be part of the African continental plate (Schembri, 1993) and share a common carbonate rock composition. The Pelagian Platform forms a shallow shelf separating the deep Ionian Basin from the Western Mediterranean (Galea, 2007).

Approximately 100km to the east of the Maltese Islands, the Malta Escarpment marks a drastic increase in sea depth, over a spatial scale of tens of kilometers, from hundreds of metres to the 2-4km of the Ionian Abyssal Plain in the Eastern Mediterranean Basin. The depth of the marine area between the Maltese Islands and Sicily (the Sicilian Channel) does not surpass 200m and not even 90m in most places, whilst the marine area between the Maltese Islands and the north African coast (the Malta Channel) is much deeper, surpassing 1,000m in some areas (Morelli et al, 1975).

Despite the widespread perception that the column of water in our seas is simply a homogenous mass of water, scientific evidence suggests that the same water column is stratified into a number of distinct water layers – the surface layer, the intermediate layer and the deep water layers. The Mediterranean Sea thermohaline circulation can be described as a large scale anti-estuarine (the inflow of low-salinity surface water over a deeper outflowing dense, high-salinity water layer) buoyancy-driven circulation, with fresher surface waters (from the Atlantic Ocean) inflowing and subsurface denser saline waters outflowing over the shallow (250m) sill at Gibraltar. The average sea-level of the Atlantic Ocean is slightly higher (3cm in July, 11cm in January) than that of the Mediterranean Sea.

The relatively fresh water (and thus less dense) from the Atlantic flows through the Strait of Gibraltar and becomes Modified Atlantic Water (MAW) due to intense air-sea exchanges with the atmosphere. The MAW, crossing the Strait of Sicily, reaches the eastern basin and ends up in the Levantine. Here, cooling in winter causes convection to intermediate depths (up to 500 m) mainly in the Rhodes area, forming Levantine Intermediate Water (LIW, Lascaratos *et al.*, 1993). The Levantine Intermediate Water, forms the main component of the Mediterranean outflow to the Atlantic. LIW also provides for the formation of the Eastern Mediterranean Deep Water (EMDW) and the Western Mediterranean Deep Water (WMDW), the two locally formed deep waters of the basin. In addition to the vertical water circulation patterns, the horizontal circulation structure within the Mediterranean Sea is also rather complex.

Modern telemetric techniques conducted by sophisticated satellite sensors have allowed oceanographers to visualise and follow the path taken by water currents. There is no single surface current regime which is uniform throughout the Mediterranean Sea – rather, seabed topography and metereological factors combine to split the main incoming (from the Straits of Gibraltar) surface sea current into two branches – one flowing northwards towards the Balearics and other larger (in terms of volume) current flowing along the north African coast, termed the Algerian current, and heading for the Sicilian Channel. Throughout its passage in the Mediterranean, surface waters diverge yet again for an innumerable number of times. According to Drago (1991), the Atlantic flow to the west of Malta results in a southeast surface current to the south of Malta, thus supplying water to the Malta Channel in a southeast direction with a mean speed of 0.2-0.3 m/s.

The Mediterranean is graced by a large number of islands – around 12,000 in total. The vast majorty of these (9835 – 82%) are Greek, with 10% (1246) gracing the Dalmatian coast of Croatia and seven (Italy, Spain, France, Turkey, Tunisia, Malta and Cyprus) other countries hosting groups of islands.

The marine biodiversity of Maltese coastal waters

The geographical location of the Maltese Islands, literally at the crossroad between the Western and Eastern Basins of the Mediterranean Sea, have endow the waters of the archipelago with a diverse array of marine life. The last comprehensive census of local marine biodiversity dates back to 2002 (Schembri *et al,* 2002). Citing such a census, the total marine species count for local waters stood at around 2200 species in 2002, with the proviso that no counts exist for the lesser-known marine taxa, such as the esoteric Tardigrada ("water bears") and Phoronida ("horseshoe worms"), about which we can only state that they probably occur in local coastal waters, with no assertion regarding their abundance or species diversity. The most species-rich of local marine taxa include the Gastropoda (which include marine snails and slugs), with over 600 marine species being recorded locally, the marine phytobenthos (which includes the algal species but not seagrasses) with ca. 360 recorded species, the Bivalvia (which include the bivalves, such as oysters and clams) with over 230 species being recorded locally and the Osteichthyes (bony fish) with ca. 250 species being recorded from local waters.

Of the 5 species of seagrasses (phanerogams – marine flowering plants) known from the Mediterranean, at least 3 have been recorded from local waters too – these include *Posidonia oceanica* (Neptune Grass; Alka, Posidonja), which is endemic to the Mediterranean, *Cymodocea nodosa* (Lesser Neptune Grass;

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Echinoderms such as this red star specimen, are completely marine and are absent from freshwater habitats

Cimodocja, Alka Rqiqa) and *Halophila stipulacea*. The conservation importance of seagrass meadows has been well documented, with these serving as important fish nurseries and breeding ground for other marine species, as coastal buffers against wave and storm attack, as substrate stabilisers as well as a useful source of organic matter for marine herbivores as well as of dissolved oxygen. The G.A.S (2003) survey has mapped out the extent of *Posidonia oceanica* meadows in Maltese waters and it is known that these are more preponderant in shallow waters along the eastern side of the islands due to a more favourable bathmyetry. A recurrent observation is that *C. nodosa* occurs more frequently in bays, inlets and harbours in view of its higher tolerance to salinity fluctuations.

Some estimates have it that *Posidonia oceanica* meadows span over just 2-3% of the seabed of the Mediterranean, whilst harbouring many hundreds of macrobenthic species. In view of the meadows's sensitivity to changes in water parameters, the extent of the same meadows has been deployed as an indicator of various human-induced changes to the marine system. A most intriguing and recent development is the proposed synchrony between *P. oceanica* flowering (normally a very rare event) and sea temperatures. In fact, the high sea temperature anomaly that occurred in the summer of 2003 coincided with an extensive flowering event, both in the western and in the eastern basins. The onset of successful *P. oceanica* flowering might be correlated with the trend in global warming (CIESM, 2008).

With reference to some of the more 'charismatic" marine taxa, of the seven species of marine turtles in the world, five occur in the Mediterranean: the Loggerhead [*Caretta caretta*- Fekruna Komuni , Green [*Chelonia mydas* – Fekruna Hadra], Kemp's Ridley [*Lepidochelys kempi*)], Hawksbill [(*Eretmochelys imbricata*] and Leatherback [*Dermochelys coriacea*] (UNEP/IUCN, 1990; Arnold & Ovenden, 2002). Of these, only the first two listed now breed in the Mediterranean. The Leatherback is mainly an Atlantic species that regularly enters the Mediterranean in small numbers and apparently used to occasionally breed there, although there are no recent records of it doing so; the Hawksbill is a tropical species that only very rarely enters into the Mediterranean, while Kemp's Ridley is an Atlantic species for which there is only a single record from the Mediterranean (UNEP/IUCN, 1990; Arnold & Ovenden, 2002).

All the five species recorded from the Mediterranean have also been recorded from Maltese waters (Gramentz, 1989; Baldacchino & Schembri, 2002) and indeed the only Mediterranean record of Kemp's Ridley is from Malta (Brongersma & Carr, 1983). However, all apart from the Loggerhead may be considered as either vagrants (Leatherback and Green turtles) or as accidental (Hawksbill and Kemp's Ridley – Deidun & Schembri, 2005). On the other hand, the Loggerhead forms part of the Maltese fauna since it is relatively common in Maltese waters and, until it was declared a protected species in 1992 (Legal Notice 76 of 1992), it was regularly landed and offered for sale at the Fish Market in Valletta. The last record of a loggerhead turtle nesting on a Maltese beach dates back to 1960, when a single loggerhead turtle female was observed laying close to 100 eggs on Golden Bay (Ramla tal-Mixquqa – Deidun & Schembri, 2005).

In a comprehensive census of local echinoderm species (sea urchins, starfish, sea cucumbers, brittle stars, crinoids), Tanti & Schembri (2006) report a total of 65 species, which represented a 45% share of the total 153 echinoderm species recorded from the Mediterranean. Of the 65 locally-recorded species, 16 species were asteroids (starfish), 20 were echinoids (sea urchins) and 2 were alien species. Schembri *et al.* (2003) record a total of 26 shark species and 14 ray species from Maltese waters, including the great white shark (*Carcharodon carcharias* - specimens caught in 1964, 1973 and ca. 1984, and a further specimen possibly responsible for the fatal attack on a bather in St. Thomas Bay in 1956), the seven-gilled shark (*Heptranchias perlo* – commonly encountered for sale in fish markets), the six-gilled shark (*Hexanchus griseus* – not uncommonly caught by artisanal fisheries) and even the basking shark (*Cetorhinus maximus* – highly infrequent in local waters and frequently confused with other shark species; its occurrence was validated through a photograph of a specimen caught in local waters and published by Despott, 1930). In view of their endangered status (mainly arising from their capture in trawls, even as bycatch), a number of cartilaginous fish species are protected by local and/or regional legislation, including the great white shark, the basking shark and the devil ray.

All of the eight cetacean species known to be common in the Mediterranean - the common bottlenose dolphin (*Tursiops truncatus*; Denfil Geddumu Qasir), the short-beaked common dolphin (*Delphinus delphis*; Denfil), the striped dolphin, Risso's dolphin, the sperm whale, the fin whale, the long-finned pilot whale and Cuvier"s beaked whale - are also known to occur in Maltese waters. Other less common cetacean species have also been recorded in the vicinity of the Maltese archipelago, especially in the wider Strait of Sicily, close to the island of Lampedusa. These species include the minke whale, the killer whale, the false killer whale and the rough-toothed dolphin.

The monk seal (*Monachus monachus*) is considered to be the rarest pinniped in the Mediterranean and one of the rarest marine mammals in the world. It was last sighted in local waters in the 1980's close to Xgħajra, with the first scientific record of this pinniped being attributed to Giulia (1890), who reported a sighting at Rinella. The first purported local sighting of a monk seal dates back to 1642 when an animal described as 'half man and half animal" washed up dead on a sandy beach at Aħrax in Mellieha. Presumably, the record in question refers to a monk seal. Maltese vernacular names used to refer to the species, including "Monka" and "Bumerin" have been used indiscriminately to refer to other marine mammals, including Risso's Dolphin (Savona Ventura, 1981).

Our anomalous coastline

Despite our limited terrestrial dimensions, our islands are endowed with a coastline spanning over 270km. Such a coastline is mainly rocky in nature, with just 2.4% being sandy in nature. This is an anomalous situation, especially when different authors estimate a global preponderance of sandy coastlines. In fact, according to Reise, 2000, and according to Bascom, 1980, two-thirds and three quarters (respectively) of the global coastline of 350,000km is sandy in nature.

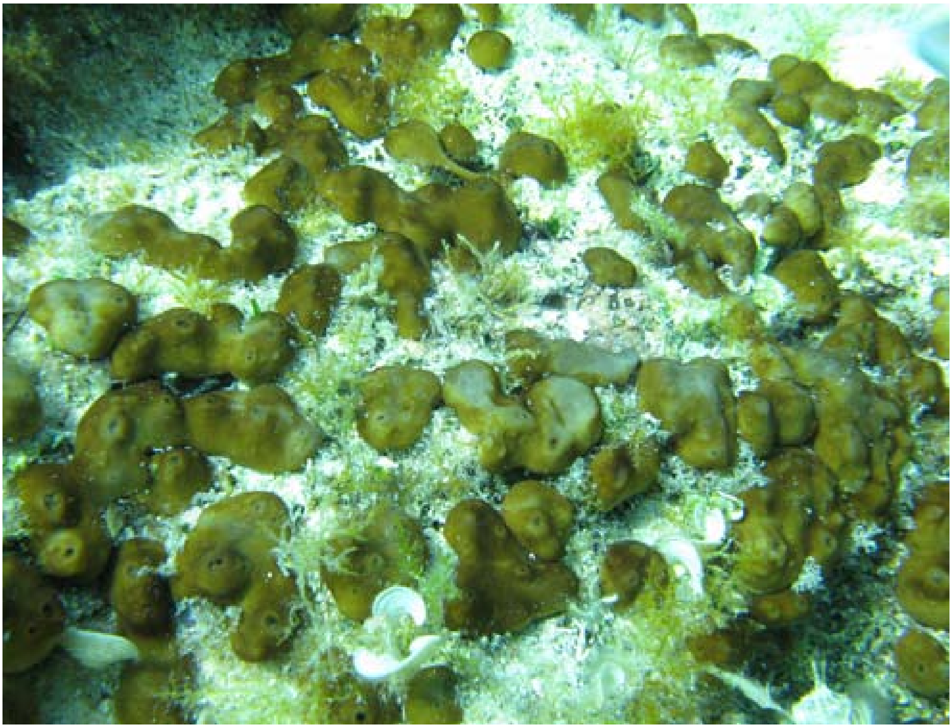
The local dearth of sandy coastline, coupled with its amenity value for tourism, contrive to ensure that supralittoral (i.e. the part of the coastline which is never inundated and which is only impinged upon by seaspray) assemblages, including sand dunes and bare sand assemblages, are amongst the most impacted of local marine habitats. The local regress of the sand dune habitat has been spectacular – whilst originally all local beaches harboured some form of sand dune habitat, in 1991 Schembri notes that only some thirteen localities still supported some form of sand dune ecosystem, of which only five localities supported dunes with a relatively intact characteristic dune vegetation community (Schembri, 1991). Of the original 13 sand dune remnants, two are extinct today.

The sandy portion of the Maltese coastline is anomalous on another count too – local sandy beaches are best described as being pocket beaches, which are flanked on both sides by headlands and which usually have a limited extent, normally occurring on sedimentary islands, like those of the Maltese archipelago. Diffraction by headlands prevents the occurrence of longshore (shore-parallel) currents and thus the exchange of sediments and suspended fauna between adjacent pocket beaches. Consequently, pocket beaches can be considered as 'sediment-tight' systems, which harbour distinct faunal assemblages (Deidun, 2009). The concept that no beach faunal assemblage is expendable is novel in islands where beaches are valued as a tourist industry asset!

The changing sea

According to the new scientific Report 'Climate warming and related changes in the Mediterranean biota' just released by the Mediterranean Science Commission (CIESM, 2008), global warming is transforming the Mediterranean into a much different sea than it was only 20 years ago. This well-documented, 152-page Monograph is the outcome of a recent CIESM Exploratory Workshop where the multidisciplinary expertise of international scientists was drawn together to produce a synthesis on the impacts of climate change on Mediterranean marine species.

Since the 1980s the Mediterranean marine biota has known rapid, dramatic changes, illustrated by alteration of food webs, mass mortalities, or population explosions such as jellyfish outbreaks. According to experts, these changes cannot be ascribed solely to the intense anthropogenic activities. As the Mediterranean



Sponges are one of the most ubiquitous components of our marine heritage

Sea hosts species with affinity to cold waters (of boreal origin), as well as species with affinity to warm waters (of sub-tropical and tropical origin), these two sets predictably respond to climate warming in a different way. In-situ long-term measurements of temperature and salinity recorded at the Straits of Gibraltar have shown that the deep water outflow through the same straits is warmer (ca. $0.3^{0}C$) and saltier (ca. 0.06 units) than ten years ago (CIESM, 2008).

As described in the CIESM Monograph, native thermophilic species, usually restricted to the southern, warmer sectors of the Mediterranean Sea are now moving northwards. This phenomenon (meridionalization) is particularly evident in fish, where over 30 native species have already spread in the northern areas of the Basin. Similarly, climate warming facilitates the establishment and spread of tropical, exotic species that are introduced *via* the Suez Canal or maritime transport. This process (tropicalization) is fast advancing and more than 500 exotic species have been recorded of late in the Mediterranean Sea, with most of tropical or subtropical affinity (CIESM, 2008).

Sciberras & Schembri (2007) list some 49 confirmed records of marine alien species from the Maltese Islands – to these, one must add a further four alien species (a fish, a sponge, a nudibranch and a jellyfish species) recorded since

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Shaded (sciaphillic) communities offer a diverse array of colours - shown here is the starcoral aptly called Qroll tad-dell *in Maltese*

then. Perhaps the most well-known of these are the marine green alga *Caulerpa racemosa*, native to south-western Australia and whose extent in local waters increased greatly between 1997 and 2000, and the crab *Percnon gibbesi*, of tropical western Atlantic Ocean affinity, for which established populations have been recorded from submerged boulder habitats in local waters ever since 1999. The majority of marine alien species recorded locally have entered the Mediterranean from the Red Sea through the Suez Canal (the so-called Lessepsian migrants, after Ferdinand de Lesseps, the French diplomat and engineer so instrumental in the development of the Suez Canal), with a significant portion of alien species also being introduced inadvertently through shipping (e.g. as larvae transported in ballast water) or as a result of aquacultural activities (Sciberras & Schembri, 2007). The environmental impact of invasive marine species may be so severe that the introduction of aliens has been identified as one of the four greatest threats to the world's oceans (IMO, 2000-2007).

Challenges being faced by local coastal and marine natural resources

With limited terrestrial resources, a population density which is ranked amongst one of the highest in the world and with the number of annual tourists

Satellite image of the Mediterranean basin

totalling three times the local population, the anthropogenic impact on the natural environment in the Maltese Islands is expected to be significant.

In addition to the impact posed by the rise in sea temperatures already described, the major pressures being faced by local marine natural resources can be summarised as follows (the forthcoming list is far from being exhaustive): anchoring impacts, especially on seagrass meadows, where these result in detachment of rhizomes and so-called "halos"; trawling impacts, dredging impacts; associated with coastal constructions such as wharves and ferry terminals and with seadepth-maintenance inports and harbours; marine pollution, from existing coastal open landfills, discharge of untreated sewage, thermal effluent from operating powerstations, hydrocarbons at yacht marinas, operational oil discharge from tankers; misguided "recreational activities", such as harpoon fishing, marine specimen collection for private collections, "grooming" of beaches (clearing of seagrass wrack) from popular beaches, trampling on dune habitats and diving in vulnerable marine habitats such as those located within submerged caves; ribbon coastal development for touristic purposes and for construction of leisure houses. Only some 40% of the rocky coastline is gently sloping and easily accessible - 96% of this segment of the coastline is dominated by tourist-related or by maritime activities (Schembri *et al.*, 2005).

Despite the Maltese Islands having a submerged area (up to 100m) of 1940km^2, which is equivalent to over six times the terrestrial extent, just two areas within local waters have been formally designated as MPA's – that of Rdum Majjiesa and within the heritage park of Dwejra (Gozo). Of these, although both are recognised as Special Areas of Conservation (SAC's), only the former is recognized as a Site of Community Interest (SCI).

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