Water Column Habitats

1.1 Introduction

The Mediterranean Sea exhibits an oligotrophic nutrient regime, mainly due to the very low concentration of inorganic phosphorus, which is assumed to limit primary production. Oligotrophy increases from west to east and north to south directions in the Mediterranean basin[1]. This oligotrophy can be explained on the basis of the exchange of water flows between the Atlantic and the Mediterranean and the negative thermohaline circulation occurring in the Mediterranean basin (for more details see Millot & Taupier-Letage, 2005[2]). In fact, the water masses present in this region are characterised by an eastward surface flow of fresh Modified Atlantic Water (MAW)[3] in the upper 200 m, below which a westward flow of the saltier Levantine Intermediate Water (LIW) crosses the Straits of Sicily before entering the Tyrrhenian Sea. The entrance of the LIW from the east occurs mainly at the Medina sill to the southeast of Malta. The central position of the Malta Channel plays a crucial role in this passage of these surface and intermediate water masses[4] in transit between the eastern and the western Mediterranean sub-basins. It also prevents the direct mixing of the water masses from the deep and bottom layers of the two sub-basins.

It is beyond the scope of this review to describe the complex circulation occurring within the central Mediterranean region (see for instance Drago, Sorgente & Olita, 2010[5]). However, this complex circulation of the Mediterranean Sea and its interaction with biological processes defines the various marine water column habitats from the surface to the deeper waters[6]. Water column habitats are characterised by highly variable hydrological conditions, both spatially and temporally as well as by the diversity of planktonic communities they host. Seasonal changes in species' occupancy of habitat type can also be observed depending on the stage of the species' life cycle.

This report provides a review of the water column habitat type "marine waters: coastal" and associated communities, with a focus on plankton. The current data scenario does not allow consideration of other water column habitat types as identified by the Commission Staff Working Paper[7].

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1 There is also west to east decrease, and north to south decrease of chlorophyll a as evident from both satellite data and *in situ* studies in both the eastern and western basins. (See Mazzoggi *et al*., 2010, mentioned later in this Review)

2 Millot, C. & Taupier-Letage, I. 2005. Circulation in the Mediterranean Sea. Hdb Env Chem Vol. 5, Part K: 29–66.

3 The Atlantic Water (AW) entering the Mediterranean basin is referred to as Modified Atlantic Water (MAW) to account for the progressive eastward change in its temperature and salinity properties.

4 Seven water masses have been documented in the northern area of the Strait of Sicily and the northwest Ionian Sea: Modified Levantine Intermediate Water (MLIW) at the bottom followed by the successive overlying layers of the Transitional, Fresh, Mixed, Modified Atlantic,
Upper and Surface water masses.

5 Drago, A., Sorgente, R., Olita, A. 2010. Sea temperature, salinity and total velocity climatological fields for the south-central Mediterranean Sea. GCP/RER/010/ITA/MSM-TD-14. *MedSudMed Technical Documents*, 14: 35 pp.

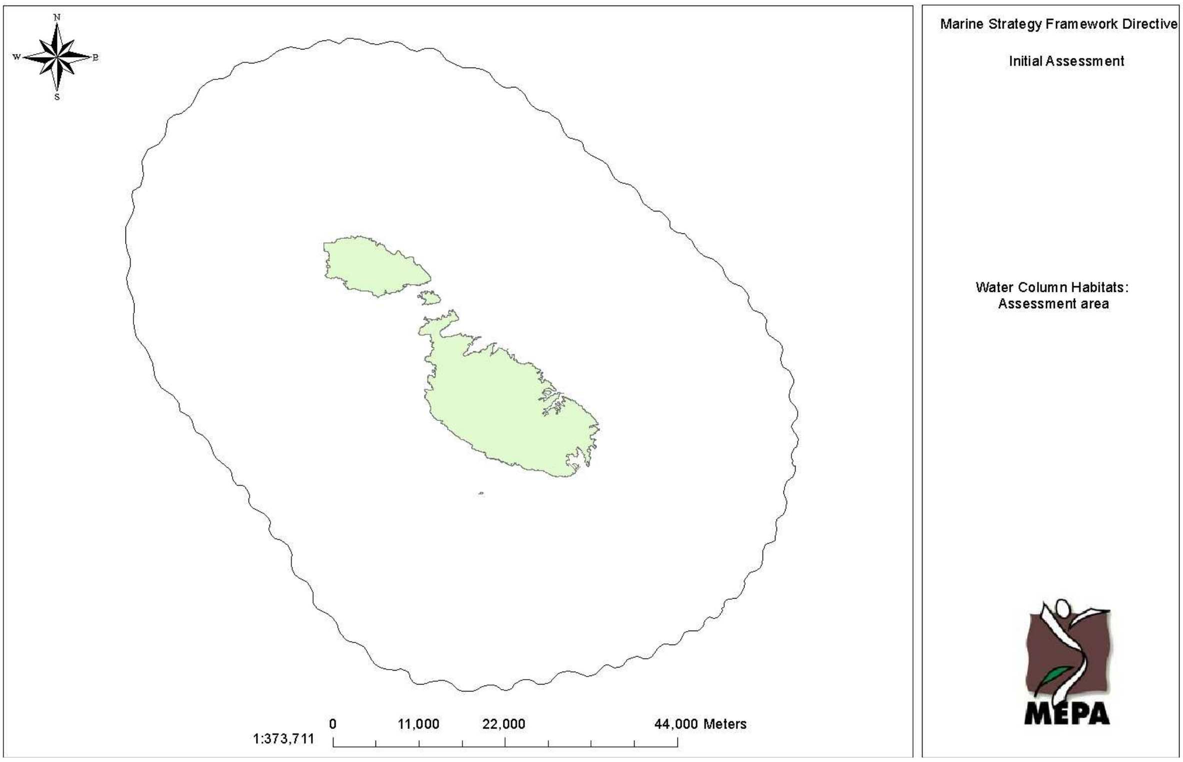
6 Würtz, M. 2010. *Mediterranean Pelagic Habitat: Oceanographic and Biological Processes - An Overview.* Gland, Switzerland and Malaga, Spain: IUCN.

7 Commission Staff Working Paper: Relationship between the initial assessment of marine waters and the criteria for good environmental status. SEC(2011)1255 final

The spatial/assessment area considered in this Review is indicated in Figure 1. The assessment area may be adjusted once new data becomes available. The following sections attempt to address the data requirements of the GES criteria and indicators of MSFD Descriptor 1 for this water column habitat, where possible, depending on data availability:

- Habitat distribution: Distributional range (1.4.1) and Distributional pattern (1.4.2);
- Habitat extent : Habitat area (1.5.1) and Habitat volume, where relevant (1.5.2);
- Habitat condition: Physical, hydrological and chemical conditions (1.6.3).
- Habitat condition: Condition of the typical species and communities (1.6.1), Relative abundance and/or biomass, as appropriate (1.6.2).

Figure 1: Water Column Habitats assessment area used for the purposes of the MSFD Initial Assessment



1.2 Description of relevant legislation and management measures

Water quality for marine waters is advocated by both the MSFD (pursuant to requirement of achieving good environmental status) and the Water Framework Directive (pursuant to requirements to achieve good ecological status and good chemical status of coastal waters[8]). The WFD is transposed by the Water Policy Framework Regulations, 2004 (LN 194 of 2004, as amended). Surface waters within the River Basin District (RBD; the equivalent of RBD in Malta is the Water Catchment District) are split into water bodies (smallest management units within the RBD). The status of the waters within the River Basin District is determined at the water body level. Typology of water bodies is a necessary precursor to the development of national assessment methods and classification systems of ecological

[8] "Coastal water" means surface water on the landward side of a line, every point of which is at a distance of one nautical mile on the seaward side from the nearest point of the baseline from which the breadth of territorial waters is measured, …

status. The purpose of assigning water bodies to a physical type is to ensure that valid comparisons of ecological status of water bodies can be made among water bodies that exhibit the same physical characteristics. On the basis of exposure and depth, 3 coastal water body types were identified:

- Type I – Very exposed, deep waters
- Type II – Exposed, intermediate
- Type III – Exposed, intermediate to deep waters

On further consideration it was decided to introduce a fourth type to take into consideration the particular physical environmental conditions of the Comino Channel that may significantly influence its ecology:

- Type IV – Exposed, intermediate to deep waters with channel mixing

Nine coastal water bodies are identified for Malta. The following parameters for coastal waters that are required to be monitored under the WFD and which are relevant to the water column habitat under this Review include the following:

- Biological elements - composition, abundance and biomass of phytoplankton;
- Hydromorphological elements supporting the biological elements; and
- Chemical and physico-chemical elements supporting the biological elements – transparency, thermal conditions, oxygenation conditions, salinity, nutrient conditions and specific pollutants.

For the phytoplankton biological quality element, the following criteria are employed to assess the status of coastal waters:

- High status - The composition and abundance of phytoplanktonic taxa are consistent with undisturbed conditions. The average phytoplankton biomass is consistent with the type-specific physico-chemical conditions and is not such as to significantly alter the type-specific transparency conditions. Planktonic blooms occur at a frequency and intensity which is consistent with the type specific physico-chemical conditions.
- Good status - The composition and abundance of phytoplanktonic taxa show slight signs of disturbance. There are slight changes in biomass compared to type-specific conditions. Such changes do not indicate any accelerated growth of algae resulting in undesirable disturbance to the balance of organisms present in the water body or to the quality of the water. A slight increase in the frequency and intensity of the type-specific planktonic blooms may occur.
- Moderate status - The composition and abundance of planktonic taxa show signs of moderate disturbance. Algal biomass is substantially outside the range associated with type-specific conditions, and is such as to impact upon other biological quality elements. A moderate increase in the frequency and intensity of planktonic blooms may occur. Persistent blooms may occur during summer months.

Considering other relevant legislation, activities that can pose impacts on the water column are regulated by other EC policies including the Common Fisheries Policy (in the case of aquaculture) and the Urban Waste Water Treatment Directive (Council Directive 91/271/EEC as amended by 98/15/EC; transposed by the "Urban Waste Water Treatment Regulations, 2001" - LN 340 of 2001, as amended), in the case of sewage effluent.

1.3 Characteristics Analysis of the Habitat

The "marine waters: coastal" water column habitat type under the MSFD may be described in terms of criteria used for the EUNIS Habitat – A7 Pelagic Water Column[9]. In the case of Malta, this water column habitat will be classified differently at different times of the year and this is due to the hydrodynamics in the area, which are mainly dictated by the general flow in the Sicilian Channel, and thermal stratification of the water column that characterises the Mediterranean basin.

Water column biological communities are strongly dependent on the physical characteristics of the water column, hence the need for this report to describe the hydrological, physical and chemical characteristics of the water column in Malta.

1.3.1 Hydrological Features & Upwelling

The surface circulation throughout the year is mainly characterised by the energetic, meandering and topographically controlled Atlantic Ionian Stream (AIS)[10] in the Sicilian Channel, which carries the relatively fresher MAW across the Malta Channel. The contrast in temperature of the exiting MAW with the warmer Ionian Sea produces the Maltese Front. The general surface circulation of the AIS results in the formation of a series of anticyclonic and cyclonic vortices off the southern coast of Sicily and Malta. The maintenance of a cyclonic vortex implies the existence of upwelling at its centre to counterbalance the effects of friction. Indeed, frequent coastal upwelling occurs along the whole southern coast of Sicily and generally extends for a considerable distance offshore, including on the Malta platform. Such upwelling provides nutrients to the surface layer and enhances primary production by vertically transporting cool, nutrient-rich water from the depths. Although the upwelling events peak in summer and early autumn (when the water column becomes well stratified - see next section), such events tend to be year round, with a period of attenuation in spring. Thus, the ecosystem in this zone is not limited to a single productivity event per year, and primary production is significantly greater both in period and rate (Drago, Sorgente & Ribotti, 2003)[11]. Between 200m and 280m depth, there is a quite stable distribution of LIW, which circulates from south-east to north-west of the Maltese Islands. This westward current at the edge of the shelf may shift vertically upward along the outer

9 The water column of shallow or deep sea, or enclosed coastal waters.

10 Exhibits seasonal variability mainly in its spatial distribution rather than its strength - It is stronger in summer, whereas in winter, it is more constrained and flows farther north from Malta. The consequence is that warmer and saltier water flowing down from the coast of Sicily is found in the north-eastern part during summer and autumn.

11 Drago, A.F., Sorgente, R. & Ribotti, A. 2003. A high resolution hydrodynamic 3-D model simulation of the Malta shelf area. *Annales Geophysicae*, **21**: 323–344

shelf and enhance the biological productivity south of the Maltese Islands. Favourable surface conditions can further produce some consistent upwelling south of Gozo, especially in summer (Camilleri *et al*., 2008) [12].

1.3.2 Physical and Chemical Features with a Focus on Thermal Stratification

The thermal structure of the Mediterranean Sea is characterised by strong stratification in the summer and well-mixed waters in the winter. In Malta, during the summer period, there is clear water stratification with a thermal step of 2.4°C at a depth of 25 to 30m depth. The nearshore summer water column structure is dominated by a solar heated upper mixed layer, averaging 20m in depth. Sustained sea surface evaporation rates increase the salinity in the surface MAW which reaches maximum values of S=38.0 to the south of Malta and a high surface temperature ranging between 20°C to 27°C from north to south. In the underlying layer, the water mass has a characteristic temperature of 15°C and a salinity of S=38.4, which indicates the influence of the modified LIW. The latter has maximum salinity in the western and southwestern approaches of Malta. Thermal stratification is gradually eroded as the winter season approaches, and strong surface cooling and vertical mixing come into action which result in the homogenisation of the water column up to depths of 100m, with temperatures around 15°C; to the south the upper layer temperatures are around 2°C higher (homogeneous up to 60 m) mainly due to the advection of warmer water from the south. The Maltese Islands are thus, very often situated within a frontal zone, with differences in temperature between the northern and southern shores. In early spring the presence of the fresh MAW starts to regain its evidence between Malta and Sicily, but its temperature in the upper layer remains greatly conditioned by surface forcing. On account of the afore-mentioned, the summer period the EUNIS habitat "A7.9 - Vertically stratified water column with full salinity"[13] would apply, while in the winter period the EUNIS habitat "A7.3 - Completely mixed water column with full salinity"[14], would apply.

Further information at a local scale may be obtained by referring to Drago (1997). This work provides the first synoptic Conductivity (to compute salinity), Temperature and Depth (CTD) data set obtained during summer 1992 in the northwest coastal area of the Maltese Islands, comprising Mellieħa Bay and St. Paul's Bay. In this study, the nature of the summer water structure in the upper 50m depth revealed strong water column stratification with significant horizontal gradients both in temperature (T) and salinity (S). This study confirmed a diurnal vertical oscillation of the thermocline by comparison with subsurface temperature time series recorded at an open sea station in the area of study. The T, S profiles are

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[12] Camilleri, M., Dimech, M., Drago, A., Fiorentino, F., Fortibuoni, T., Garofalo, G., Gristina, M., Schembri, P.J., Massa, F., Coppola, S., Bahri, T., Giacalone, V. 2008. Spatial distribution of demersal fishery resources, environmental factors and fishing activities in GSA 15 (Malta Island). GCP/RER/010/ITA/MSM-TD-13. *MedSudMed Tech. Doc.*, 13, 97 pp.

[13] EUNIS Description – 'A water column which is unmixed or only partially mixed because the depth of the water body is greater than the depth of mixing. Salinity is the same as that in adjacent seawater. This habitat type shows pronounced vertical stratification (e.g. caused by atmospheric temperature).'

[14] EUNIS Description – 'A water column which is completely and actively mixed, not influenced by freshwater, so that the salinity is the same as that in adjacent seawater. This habitat type is usually found in relatively shallow, coastal situations, without river inflow or ice melt'.

characterised by very sharp salinity reversals at the subsurface layer where a stepwise micro-structure is developed.[15]

1.4 Characteristics Assessment of the Habitat Condition with a focus on Planktonic Communities

"Plankton" is the collective name for microscopic and small free-floating life forms that passively drift with the currents of the sea. Although plankton are unable to move independently of such currents, they do however change their depth via active swimming and changes in buoyancy (vertical migration). Plankton vary greatly in size and different classes are defined[16]. Picoplankton plays a key role in oligotrophic waters such as found in the Mediterranean. The configuration of a generalised pelagic food web for an oceanic system exhibiting an oligotrophic nutrient regime, such as found in the Mediterranean Sea, is proposed by Sommer *et al*. (2002)[17,18]. A review of plankton in the open Mediterranean Sea is provided by Sikou-Francou *et al*. (2010)[19,20]. A brief review of past and present research of the planktonic element (phytoplankton and zooplankton) from Malta is provided in the following paragraphs.

[15] Drago, A.F. 1997. Hydrographic Measurements in the North Western Coastal Area of Malta, *Xjenza*; **2**(1): 6-14.

[16] picoplankton (< 2µm); nanoplankton (2-20 µm); microplankton (20-200 µm); mesoplankton (0.2-2 mm) and macroplankton (> 2mm)

[17] Sommer, U., Stibor, H., Katechakis, A., Sommer, F. & Hansen, T. 2002. Pelagic food web configurations at different levels of nutrient richness and their implications for the ratio fish production: primary production; *Hydrobiologia*; 484 (1-3): 11-20, DOI: 10.1023/A:1021340601986

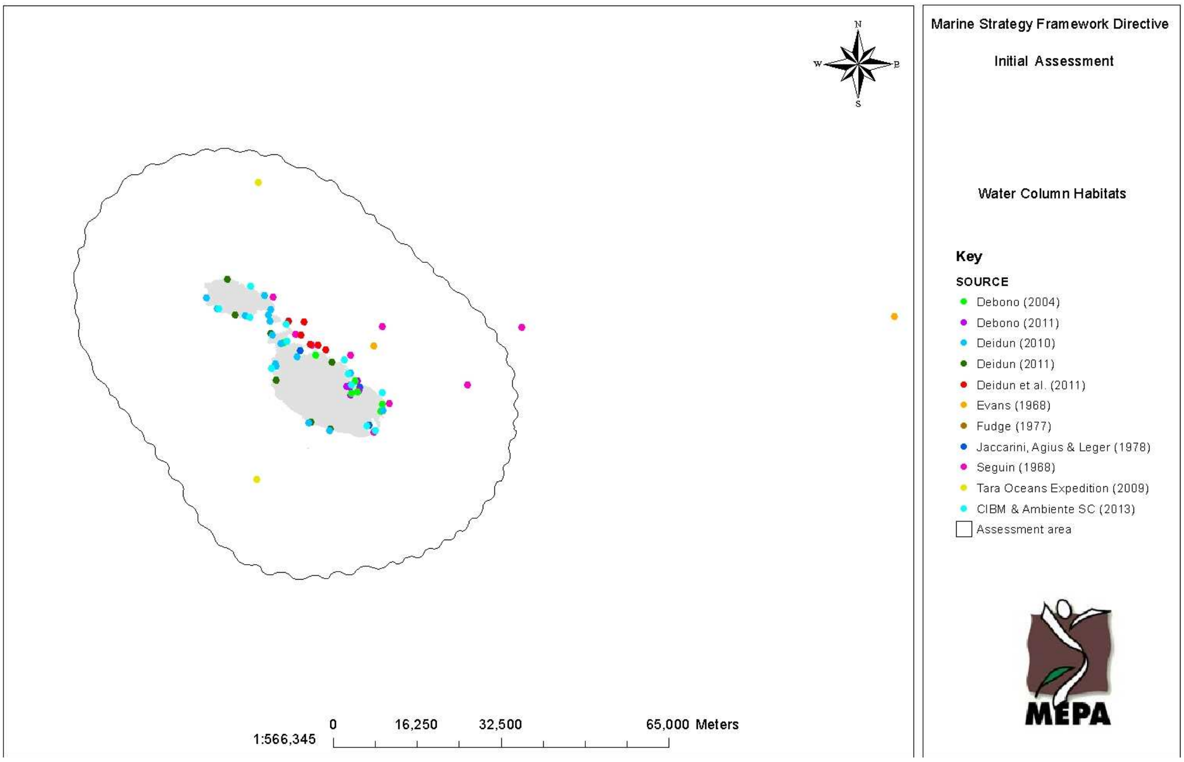
[18] These authors mention the following: "Phytoplankton in oligotrophic oceanic systems is dominated by picoplankton, which are too small to be ingested by copepods. Most primary production is channeled through the 'microbial loop' (picoplankton – heterotrophic nanoflagellates – ciliates). Sporadically, pelagic tunicates also consume a substantial proportion of primary production. Herbivorous crustaceans feed on heterotrophic nanoflagellates and ciliates, thus occupying a food chain position between 3 and 4, which leads to a food chain position between 4 and 5 for zooplanktivorous fish."

[19] Sikou-Francou, I., Christaki, U., Mazzocchi, M.G., Montresor, M., Ribera d'Alcala, M., Vaque, D. & Zingone, A. 2010. Plankton in the open Mediterranean Sea: a review; *Biogeosciences*; **7**: 1543-1586.

[20] These authors mention that the basin is largely dominated by small autotrophs, microheterotrophs and egg-carrying copepod species. The diversity and temporal and spatial variability of microorganisms (phytoplankton, flagellates and ciliates) and zooplankton components are noted in this review, such as the wide diversity of dinoflagellates and coccolithophores, the varied role of diatoms, and the distinct seasonal or spatial patterns of the species-rich copepod genera or families which dominate the basin. Major dissimilarities between western and eastern basins have been highlighted in species composition of phytoplankton and mesozooplankton, but also in the heterotrophic microbial components and in their relationships.

Figure 2 illustrates locations from where plankton samples have thus far been collected in relation to the various studies carried out to date. Relevant studies in the Mediterranean Sea are also briefly mentioned in this Review, where of informative value.

Figure 2: Locations from where plankton has been sampled within and outside the proposed assessment area



1.4.1 Phytoplankton: Ecological Role, Taxonomy, and Productivity in terms of Chlorophyll a

Phytoplankton[21] (along with other photoautotrophs) through the photosynthesis they perform, constitute the primary producer of the marine pelagic food web. The first quantitative analysis of phytoplankton was carried out by Jaccarini, Agius & Leger (1978)[22]. These authors collected 41 samples between April 1975 and February 1976 from three inshore localities in Malta – Marsaxlokk Bay (at depths of 3m and 8m from the surface), Mistra Bay and Rinella Creek (both a 3m depth)[23], in connection with experiments on oyster cultures. The phytoplankton community in Malta is shown in Table 1, and comprised diatoms (58%), dinoflagellate species (38%), coccolithophores (3%) and silicoflagellate species (1%). The dominance of diatoms in this Study was attributed to the timing of sampling. Inconsistent variations in quantitative richness and specific diversity were noted between the various areas sampled and also between depths. Overall however the Rinella sampling station exhibited a higher number of cells per unit volume of sea water. They attribute this observation to the eutrophic conditions which prevailed at Rinella (where *Skeletonema costatum* comprised 70% of the phytoplankton assemblage in February 1976) when compared to the oligotrophic nature of the other two stations.

21 microscopic and unicellular plant-like plankton such as diatoms, dinoflagellates, coccolithophorids and silicoflagellates

22 Jaccarini, V., Agius, C. & Leger, G. 1978. A Preliminary Survey of the Phytoplankton on Inshore Marine Waters from Malta (Central Mediterranean); *Memorie di Biologia Marina e di Oceanografia*, VIII (1/2), 12pp.

23 Considering the WFD Water Bodies for Malta; these sampling locations fall within MTC107, MTC104 and MTC105 respectively.

Table 1: Species composition of phytoplankton in Malta. This table lists the species of phytoplankton recorded from Malta on the basis of Jaccarini, Agius & Leger (1978), CIBM and Ambiente SC (2013) and AIS (2013)[24], and on the basis of updated and accepted taxonomy as checked against the World Register of Marine Species (http://www.marinespecies.org/). Any potential species misidentifications at the time the study was undertaken cannot be excluded and would only be confirmed through further and more recent taxonomic studies.

Documented Species on the basis of updated and accepted taxonomy (Brackets indicate species as documented by Jaccarini, Agius & Leger, 1978)	
Diatoms	**Dinoflagellates**
Achnanthes longipes	*Amphidinium flagellans*
Achnanthes parvula	*Amphidinium* sp.
Amphora marina	*Amphisolenia bidentata*
Amphora obtusa	*Centrodinium intermedium*
Amphora proteus	*Ceratium furca* var. *eugrammum*
Amphora sp.	*Ceratocorys armata*
Asterionella notate	*Ceratocorys horrida*
Asterionellopsis glacialis (= *Asterionella japonica*)	*Cladopyxis brachiolata*
Asterolampra grevillei	*Dinophysis circumsuta*
Asterolampra marylandica	*Dinophysis ovata*
Auricula sp.	*Dinophysis tripos*
Bacillaria paxillifera	*Goniodoma polyedricum*
Bacteriastrum delicatulum	*Gonyaulax digitale*
Bacteriastrum elegans	*Gonyaulax pacifica*
Bacteriastrum elongatum	*Gonyaulax polygramma*
Diatoms (cont.)	**Dinoflagellates (cont.)**
Bacteriastrum hyalinum	*Gonyaulax* sp.
Biddulphia alternans	*Gymnodinium rhomboides*
Caloneis linearis	*Gymnodinium* sp.
Caloneis sp.	*Heterodinium mediterraneum*
Cerataulina pelagica	*Histioneis joergensenii*
Chaetoceros affinis	*Mesoporos perforatus* (=*Mesoporos adriaticus*)
Chaetoceros atlanticus var. neapolitanus	*Neoceratium azoricum* (=*Ceratium azoricum*)
Chaetoceros compressus	*Neoceratium candelabrum*
Chaetoceros constrictus	*Neoceratium carriense*
Chaetoceros costatus	*Neoceratium concilians*
Chaetoceros curvisetus	*Neoceratium euarcuatum*
Chaetoceros dadayi	*Neoceratium falcatum*
Chaetoceros decipiens	*Neoceratium furca*
Chaetoceros didymus	*Neoceratium fusus Neoceratium gibberum*
Chaetoceros diversus	*Neoceratium hexanthum*
Chaetoceros gracilis	*Neoceratium horridum*
Chaetoceros laciniosus	*Neoceratium karstenii*
Chaetoceros messanensis	*Neoceratium limulus*
Chaetoceros pendulus	*Neoceratium pentagonum*
Chaetoceros peruvianus	*Neoceratium ranipes*
Chaetoceros protuberans	*Neoceratium setaceum*
Chaetoceros pseudocurvisetum	*Neoceratium symmetricum*
Chaetoceros rostratus	*Neoceratium trichoceros*
Chaetoceros socialis	*Neoceratium tripos*
Chaetoceros tenuissimus	*Oxytoxum cristatum*
Chaetoceros tortissimus	*Oxytoxum minutum*
Chaetoceros wighamii	*Oxytoxum sceptrum* (=*Oxytoxum longiceps*)
Chaetoceros willei (= *Chaetoceros affinis var. willei*)	*Oxytoxum scolopax*
Chaetoceros sp.	*Oxytoxum tessellatum*
Climacosphenia moniligera	*Phalacroma argus* (= *Dinophysis argus*)
Cocconeis molesta	*Phalacroma cuneus* (= *Dinophysis cuneus*)
Cocconeis scutellum	*Podolampas bipes*
Cocconeis sp.	*Podolampas palmipes*

[24] AIS Environmental. 2013. Monitoring of Nutrient Status and Eutrophication Status of Selected Coastal Areas. Draft Technical Report.

Documented Species on the basis of updated and accepted taxonomy (Brackets indicate species as documented by Jaccarini, Agius & Leger, 1978)	
Coscinodiscus centralis *Coscinodiscus excentricus* *Coscinodiscus marginatus* *Coscinodiscus radiatus* *Cylindrotheca closterium* *Dactyliosolen fragilissimus* (= *Rhizosolenia fragilissima*) *Detonula pumila* (= *Schroederella delicatula*) *Dimerogramma fulvum* *Diploneis fusca* *Diploneis* sp. *Fragilaria* sp. *Eucampia zodiacus* *Gossleriella tropica* *Grammatophora angulosaGrammatophora marina* *Guinardia delicatula* (= *Rhizosolenia delicatula*) *Guinardia flaccid* *Guinardia striata* (= *Rhizosolenia stolterfothii*) *Gyrosigma attenuatum* *Gyrosigma lineare* *Gyrosigma* sp. *Helicotheca tamesis* (= *Streptotheca thamesis*) *Hemiaulus hauckii* *Hemiaulus sinensis* *Lauderia borealis* *Leptocylindrus danicus* **Diatoms (cont.)** *Leptocylindrus mediterraneus* (= *Dactyliosolen mediterraneus*) *Licmophora abbreviata* *Licmophora ehrenbergii* *Licmophora gracilis* *Licmophora hastate* *Licmophora paradoxa* *Lithodesmium undulatum* *Navicula crucifera* *Navicula goppertiana* *Navicula gracilis* *Navicula gregaria* *Navicula rhombica* *Navicula rhynchocephala* *Navicula* sp. *Navicula transitans* *Nitzschia acicularis* *Nitzschia closterium* *Nitzschia lanceolata* *Nitzschia longissima* *Nitzschia paleacea* *Nitzschia recta* *Nitzschia scalpelliformis* *Nitzschia sigma* *Nitzschia* cf. *vermicularis* *Nitzschia* cf. *vitrea* *Nitzschia* sp. *Odontella aurita* (= *Biddulphia aurita*) *Odontella mobiliensis* (= *Biddulphia mobiliensis*) *Opephora* sp. *Plagiotropsis lepidoptera* *Planktoniella sol* *Pleurosigma elongatum*	*Podolampas spinifer* *Prorocentrum compressum* (=*Exuviaella compressa*) *Prorocentrum gracile* *Prorocentrum lima* (=*Exuviaella marina*) *Prorocentrum micans* (= *Prorocentrum schillerii*) *Prorocentrum scutellum* *Prorocentrum* sp. *Protoperidinium bipes* (= *Peridinium miniscculum*) *Protoperidinium cerasus* (=*Peridinium cerasus*) *Protoperidinium crassipes* (=*Peridinium crassipes*) *Protoperidinium depressum* (=*Peridinium depressum*) *Protoperidinium diabolum* (= *Peridinium diabolus*) *Protoperidinium granii* (= *Peridinium granii*) *Protoperidinium inflatum* *Protoperidinium oceanicum* (= *Peridinium oceanicum*) *Pyrophacus horologicum* *Torodinium* sp. **Prasinophycean flagellates** *Cymbomonas* sp. **Silicoflagellates** *Dictyocha fibula* *Dictyocha speculum* **Other flagellates** **(Chlorophyceae)** *Cryptaulax* sp. *Eudorina* sp. *Teleaulax* sp. **(Chrysophyceae)** *Chromulina* sp. **Coccolithophore species** *Coronosphaera mediterranea* (= *Syracosphaera mediterranea*) *Emiliania huxleyi* (=*Pontosphaera huxleyi*) *Rhabdosphaera clavigera* (= *Rhabdosphaera stylifera*) *Syracolithus dalmaticus* (=*Syracosphaera dalmatica*) *Syracosphaera pulchra*

Documented Species on the basis of updated and accepted taxonomy (Brackets indicate species as documented by Jaccarini, Agius & Leger, 1978)	
Pleurosigma sp. *Podocystis adriatica* *Proboscia alata* (= *Rhizosolenia alata*) *Pseudonitzschia delicatissima* (= *Nitzschia delicatissima*) *Pseudonitzschia pungens* (= *Nitzschia pungens*) *Pseudonitzschia seriata* (= *Nitzschia seratia*) *Pseudonitzschia* sp. *Pseudosolenia calcar-avis* (= *Rhizosolenia calcar-avis*)*Rhizosolenia castracanei* *Rhizosolenia hebetata* *Rhizosolenia imbricata* *Rhizosolenia robusta* *Rhizosolenia setigera* *Rhizosolenia styliformis* *Skeletonema costatum* *Skeletonema pseudocostatum* *Stephanopyxis palmeriana* *Striatella delicatula* *Striatella interrupta* *Striatella unipunctata* *Surirella* sp. *Surirella fastuosaSurirella ovalis* *Surirella smithii* *Synedra* sp. *Synedra undulata* **Diatoms (Cont.)** *Thalassionema frauenfeldii* (= *Thalassiothrix frauenfeldii*) *Thalassionema nitzschioides* *Thalassiosira angulata* (= *Thalassiosira decipiens*) *Thalassiosira leptopus* (= *Coscinodiscus lineatus*) *Thalassiothrix mediterranea* *Toxarium undulatum* (= *Synedra undulata*) *Tropidoneis elegans*	

Light variability, surface and subsurface nutrient concentrations and organic enrichment, turbidity of the water column, the extent and duration of the vertical flux of nutrients to the euphotic zone of the water column, as well as depth of mixing are the main agents governing phytoplankton production in an area as well as seasonal variability. Indeed, a dominance of diatoms is generally observed during winter–spring periods (also confirmed by Jaccarini, Agius & Leger, 1978 as above), when mixing increases nutrient availability, whereas picophytoplankton and small flagellates would dominate in the summer period when strong stratification and oligotrophic conditions prevail (see for instance Lasternas, Agustí & Duarte, 2010)[25]. For this reason the thermal stratification in the Mediterranean Sea is of note when assessing the status of plankton biomass and production[26]. Due to the fact

[25] Lasternas, S., Agustí, S. & Duarte, C. M. 2010. Phyto- and bacterioplankton abundance and viability and their relationship with phosphorus across the Mediterranean Sea. Aquatic Microbial Ecology, 60: 175–191.

[26] The thermal stratification observed in the Mediterranean basin in fact delimits a warm surface mixed layer with high light intensity but depleted in nutrients and a sub-superficial layer with low light levels and more nutrients. The nutrient-depleted surface layer is separated from a layer of abundant nutrients, at some distance below the euphotic depth, by a nutricline layer in which nutrient concentrations increase rapidly with depth. Depending on light intensity

that phytoplankton composition is affected by such physical and chemical environmental conditions, phytoplankton is considered a key element in the assessments of water quality and eutrophication[27] of the water column.

Changes in oligotrophy within the Mediterranean basin are reflected in the abundance of the planktonic biomass. Both nitrogen and phosphorous are documented to be potentially limiting nutrients for phytoplankton and bacterial growth in the Mediterranean. Agius & Jaccarini (1982)[28] employed the technique of artificial enrichment of seawater to define nutrients critically limiting the growth of phytoplankton in Marsaxlokk Bay by assessing the responses to various enrichment regimes in terms of chlorophyll a. While noting the scarcity of both nitrates and phosphates, they report that phosphate is the primary factor limiting phytoplankton growth. No major changes in the relative composition of the phytoplankton populations were observed in all enrichment experiments, nor were there seasonal variations in the respective roles of phosphates and nitrates.

One of the Biological Quality Elements (BQE's) that are required to be monitored under the EC Water Framework Directive comprises the composition, abundance and biomass (as surface chlorophyll a) of phytoplankton. A number of studies have been undertaken or are ongoing which involve chlorophyll a sampling in coastal waters. The findings of such studies are relevant to the assessment of GES under the MSFD and are hence included in this Review and described in the following paragraphs.

Imagery of ocean colour provides key information on the temporal and spatial distribution of phytoplankton biomass as chlorophyll a, the magnitude of primary production in an area as well as on timing and spatial distribution of phytoplankton blooms. Deidun *et al*. (2011)[29] attempts to statistically compare MODIS ocean colour data obtained through satellite imagery for a nearshore marine area (2km) off the north-east coastline of Malta, with *in situ* surface chlorophyll a measurements (at depths of 50cm) taken from 6-grid positions during April and September 2010. The purpose of this research was to then extract a twelve-month ocean colour data series for the same marine area. The highest *in situ* chlorophyll a value obtained (over both sampled months) was 0.511mg/m^3, such that all surface chlorophyll a

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at the surface and the turbidity of the water, the displacements of nutricline and pycnocline determine abundance and productivity of phytoplankton. Chlorophyll concentrations remain high in the upper layer and coincide with nutrient depletion. The influx of nutrients to the euphotic zone in winter causes the magnitude and composition of biota, and hence the behaviour of the ecosystem, to change. More information is available from: Chapter 4: Ionian Sea and Central Mediterranean Subregion – UNEP(DEPI)/MED WG.363/Inf.21.

[27] Eutrophication is a process driven by enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, leading to: increased growth, primary production and biomass of algae; changes in the balance of organisms; and water quality degradation. The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health and/or the sustainable provision of goods and services. *Definition extracted from Ferreira, J.G.; Andersen, J.H.; Borja, A.; Bricker, S.B.; Camp, J. ; Cardoso da Silva, M.; Garces, E.; Heiskanen, A.S.; Humborg, C.; Ignatiades, L.; Lancelot, C.; Menesguen, A.; Tett, P.; Hoepffner, N. & Claussen, U. Marine Strategy Framework Directive Task Group 5 report on Eutrophication. Joint Report Prepared under the Administrative Arrangement between JRC and DG ENV (no 31210 ² 2009/2010), the Memorandum of Understanding between the European Commission and ICES managed by DG MARE and JRC's own institutional funding; Editor: N. Zampoukas.*

[28] Agius, C. & Jaccarini, V. 1982. The effects of nitrate and phosphate enrichments on the phytoplankton from Marsaxlokk Bay, Malta (Central Mediterranean); *Hydrobiologia*; **87**(1): 89-96.

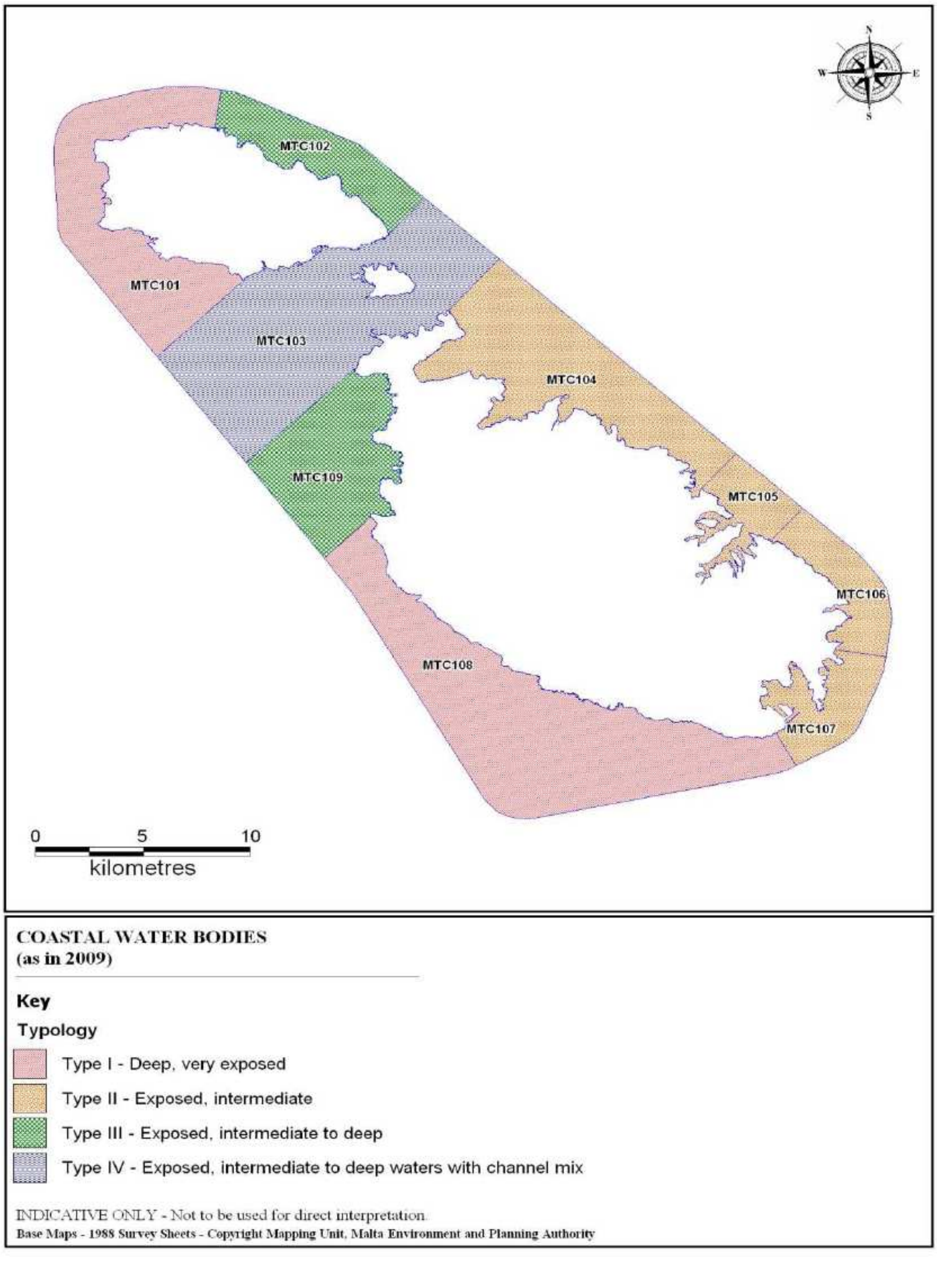
[29] Deidun, A., Drago, A., Gauci, A., Galea, A., Azzopardi, J. & Mélin, F. 2011. A first attempt at testing correlation between MODIS ocean colour data and *in situ* chlorophyll-a measurements within Maltese coastal waters; In: Bostater Jr., C.R., Mertikas, S.T., Neyt, X. & Velez-Reyes, M. (eds). *Remote Sensing of the Ocean, Sea Ice, Coastal Waters, and Large Water Regions*; Proc. of SPIE Vol. 8175.

values obtained are consistent with those of an oligotrophic, optically non-complex, Class/Type I water body, of which the Mediterranean Sea is a typical example. The mean annual ocean colour value for the six grid positions under scrutiny ranged from 0.247mg/m^3 to 0.361mg/m^3. Two peaks in ocean colour values could be observed, with the most pronounced of these peaks being observed in late January/early February, and a second less well-defined peak being observed in late August/early September. The ocean colour values obtained ranged from 0.040mg/m^3 to 1.370mg/m^3, with the lowest values generally being recorded during the April-May period. A winter surface chlorophyll a peak is typical of the Mediterranean Sea.

Azzopardi *et al*. (2013)[30] classify the nine coastal water bodies of the Maltese Islands within the WFD Framework (Figure 3) through the assessment of spatial and seasonal variability in the ocean colour values for the period 2003 to 2011. All water bodies were consistent with an oligotrophic water body, with seasonal mean values ranging from 0.06 mg/m^3 to 0.35 mg/m^3. The seasonal pattern of variability within ocean colour values across the different coastal water bodies over a single year was highly homogenous, with highest values being recorded during the December-February period, and lowest values being recorded during the May-August period, with very few exceptions (solely recorded in 2010 and 2011). Spatial variations were statistically significant only in the spring and summer seasons, over the entire nine-year period, and most of these significantly different comparisons were registered during the 2010-2011 summer seasons. The authors explain these spatial differences on the basis of either an artefact (the 2010 and 2011 ocean colour datasets were derived using a different chlorophyll a algorithm than the 2003-2009 ones) or due to the fact that some of the coastal water bodies exhibiting higher ocean colour values (e.g. MTC107) are optically more complex since they host large coastal embayments, intensive aquaculture activities, treated sewage discharges and other anthropogenic activities.

[30] Azzopardi J., Deidun A., Gianni F., Gauci A. P., Angulo Pan, B. & Cioffi M. 2013. Classification of the coastal water bodies of the Maltese Islands through the assessment of decadal ocean colour data set. In: *Proceedings 12th International Coastal Symposium* (Plymouth, England), *Journal of Coastal Research*, Special Issue No. 65

Figure 3: Water Types and Water Bodies for Malta under the WFD Framework[31]
MTC 101 - L'Irdumijiet t'Għawdex; MTC 102 - Ir-Ramla l-Ħamra; MTC 103 - Il-Fliegu ta' Kemmuna; MTC 104 - Il-Mellieħa/Tas-Sliema; MTC 105 - Il-Port il-Kbir/Marsamxett; MTC 106 - Ix-Xagħjra; MTC 107 - Il-Port ta' Marsaxlokk; MTC 108 - L'Irdumijiet ta' Malta and MTC 109 - Ir-Ramla tal-Mixquqa



31 First Water Catchment Management Plan for Malta – Technical Document 1 – Characterisation and Designation of Coastal Waters, April 2011

Monitoring surveys in coastal waters are currently being undertaken as part of an ERDF funded study to develop an Environmental Monitoring Strategy[32]. The dataset generated from the baseline surveys will provide the benchmark for long term monitoring programmes and assessments that are required to implement the WFD. Chlorophyll-a concentrations and abundance of planktonic species were assessed for water samples collected from the WFD sampling stations on three occasions: the pilot survey carried out in May-June 2012, the first baseline survey carried out in August 2012 and the second baseline survey carried out in October–November 2012. Identification of plankton composition for these sampling stations was also carried out, with the identified taxa falling mainly in the following groups: diatoms, dinoflagellates, coccolithophores and a mixed group named ‘other plankton’ including nanoflagellates belonging to cryptophyceans, prasinophyceans and other flagellates.

When considering the pilot sampling that was done between 30th May and 4th June 2012 in 12 sampling stations distributed along the coastlines of the Maltese Archipelago at 5m depth (Figure 4) and the performed spectrophotometric/spectrofluorometric analysis and phytoplankton analysis within 1 month from sampling, the results obtained, were similar to the work of Deidun *et al*. (2011) in that all the sampling sites are oligotrophic, while the sampling site inside the Grand Harbour (WFD body MTC 105) is eutrophic (maximum value of 1.01 $\mu g\ L^{-1}$, with phytoplankton abundance at 4.7×10^5 cell L^{-1}). At this sampling site, the percentage abundance of diatoms was 98%, due to the bloom of the small centric *Skeletonema* cf *pseudocostatum*, together with lower abundances of *Chaetoceros tenuissimus* and *Chaetoceros* spp., thus confirming the eutrophic conditions. Percentage abundances at the different sampling sites are compared in Figure 5.

[32] CIBM and Ambiente SC (2013) Development of Environmental Monitoring Strategy and Environmental Monitoring Baseline Surveys – Water Lot 3 – Surveys of Coastal Water – August 2012. ERDF156 - Developing national environmental monitoring infrastructure and capacity

Figure 4: Total phytoplankton abundances by microscopic counts in sampling stations[33]

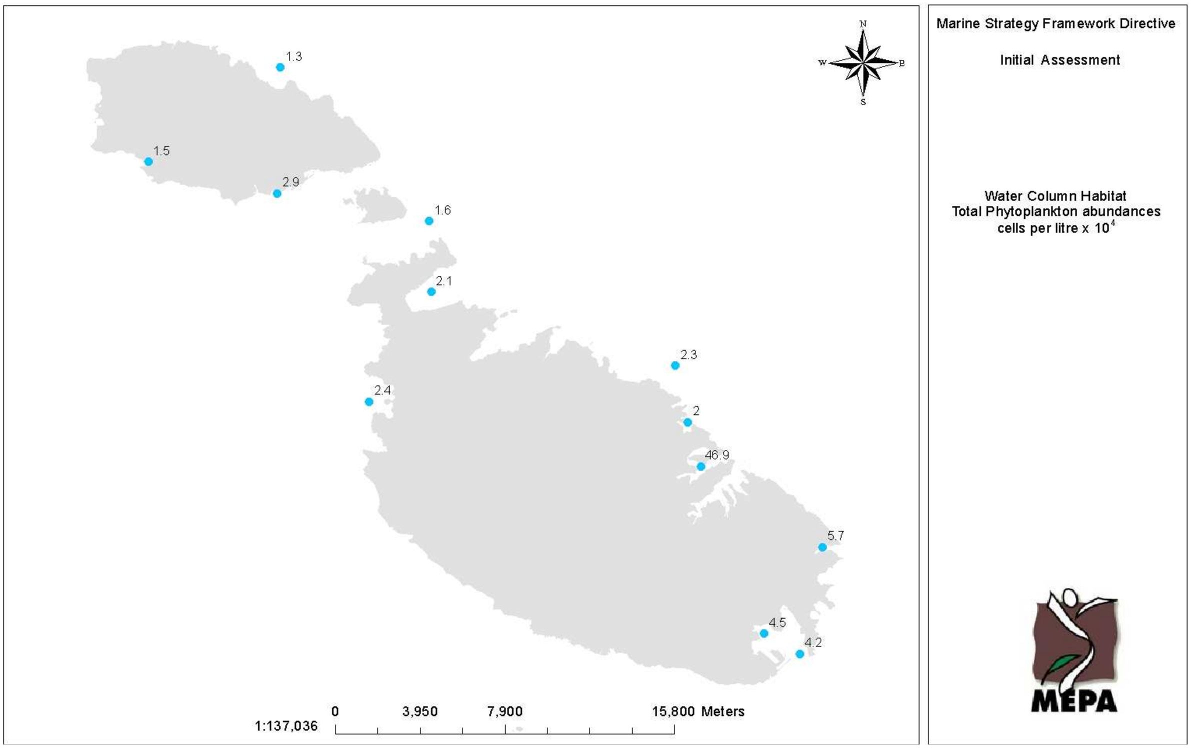
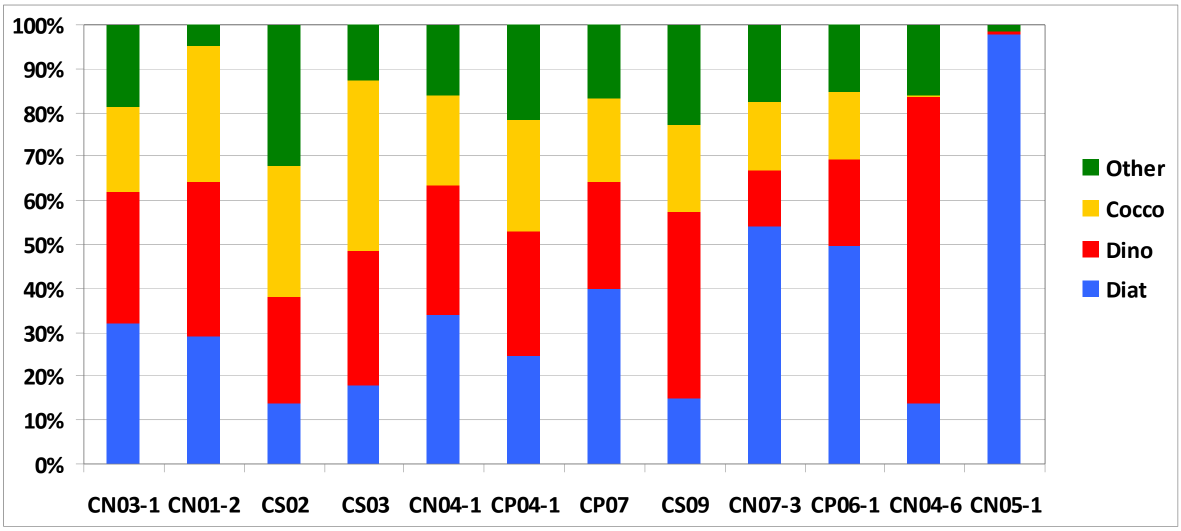


Figure 5: Percentage abundances of the different phytoplanktonic groups: diatoms (Diat), dinoflagellates (Dino), coccolithophores (Cocco) and other plankton (Other) (as extracted from CIBM and Ambiente SC, 2013[34]).



33 CIBM and Ambiente SC (2013) Development of Environmental Monitoring Strategy and Environmental Monitoring Baseline Surveys – Water Lot 3 – Surveys of Coastal Water – August 2012. ERDF156 - Developing national environmental monitoring infrastructure and capacity

34 CIBM and Ambiente SC (2013) Development of Environmental Monitoring Strategy and Environmental Monitoring Baseline Surveys – Water Lot 3 – Surveys of Coastal Water – August 2012. ERDF156 - Developing national environmental monitoring infrastructure and capacity

Diatoms were the most abundant class in the sampling sites exposed to harbour activity CP07 (40%, 1.7 x 10^4 cell L^{-1}) and CN07-3 (54%, 2.4 x 10^4 cell L^{-1}) in Marsaxlokk Bay, and CP06-1 (50%, 2.8 x 10^4 cell L^{-1}) out of the Grand Harbour. Common diatoms were *Chaetoceros tenuissimus*, *Cylindrotheca closterium*, *Leptocylindrus danicus*, *Licmophora* spp., *Skeletonema* cf *pseudocostatum* and *Pseudonitzschia* spp. Observations made in this Study are comparable to Jaccarini *et al*. (1978), who found *Chaetoceros* spp., *L. danicus*, *Nitzschia* spp. and *S. costatum* in Marsaxlokk Bay in June 1975. Conversely, diatoms contributed the least (< 15%) at the two reference sites CS02 and CS03, and at the site CS09 in the Protected Area at Ġnejna Bay.

When considering the results of the baseline surveys, measured chlorophyll-a concentrations are generally very low and vary between 0.03µg per litre – 0.82µg per litre, with a mean value of 0.21µg per litre in August and between 0.01µg per litre – 0.54µg per litre, with a mean value of 0.16µg per litre in October/November. Chlorophyll-a concentrations higher than 0.7µg per litre are reported for harbour areas, particularly that of Marsamxett, as expected.

With respect to species composition, the results of the pilot and baseline surveys were interpreted as follows:

- Dinoflagellates are generally the most abundant group in sites considered to be oligotrophic during the first baseline survey with most abundant species being *Gymnodinium* spp. and *Heterocapsa* spp. Dinoflagellates were however scarce during the second baseline survey.
- The ‘other plankton’ group (which includes flagellate species) contribute to >50% of the microalgal assemblages in many stations known to be subject to diffuse sources of pollution;
- Diatoms constitute a low abundance group in sites considered to be oligotrophic and in stations known to be subject to diffuse sources of pollution. However diatoms dominated in sites subject to harbour activities.
- Coccolithophores are very scarce throughout all sampling stations;
- A few individuals belonging to potentially harmful taxa were observed, however their abundances were scarce.

In terms of seasonal variation, it was noted that large percentages of dinoflagellates and ‘other plankton’ were recorded in August. Given their generally heterotrophic nature, the abundance of these taxonomic groups can be uncoupled to nutrients, especially in late-spring and summer in stratified nutrient-depleted waters in the open Mediterranean Sea (Siokou-Frangou *et al*., as quoted in CIBM and Ambiente, 2013[35]). Longer-term data is necessary however to interpret the available data for local waters. As indicated by CIBM & Ambiente (2013), assessment of natural regional-specific phytoplankton assemblages can only be achieved after multi-year high-frequency data collection throughout the different seasons.

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[35] CIBM and Ambiente SC. 2013. Development of Environmental Monitoring Strategy and Environmental Monitoring Baseline Surveys – Water Lot 3 – Surveys of Coastal Water – November 2012. ERDF156 - Developing national environmental monitoring infrastructure and capacity

Figure 6 indicates all sampling of phytoplankton to date in relation to the WFD coastal water bodies.

Figure 6: Locations of all phytoplankton sampling in this Review overlaid with the WFD water bodies.

Recently, phytoplanktonic communities were assessed for Marsaxlokk, Salini and Xlendi during the months of February, August, November and December[36]. All three sites are predominantly characterised by diatoms, which are most abundant during the cold months. This is considered to be indicative of a normal input of nutrients. Flagellate abundance only exceeds that of diatoms at Salini during August, which month is overall associated with low plankton abundance, attributed to lower nutrient availability during this period. More information on this study is presented in the MSFD Initial Assessment Paper report on 'Nutrient Enrichment'.

1.4.2 Zooplankton – Ecological Role, Taxonomy and Biomass

Zooplankton[37], in particular mesozooplankton and microzooplankton represent a key linkage between the lower (phytoplankton) and higher (seabirds, turtles, sharks and marine mammals) trophic levels of the marine pelagic ecosystem. Zooplankton also regulates larval fish development and hence sustains adult fish recruitment (e.g. of small pelagic fish such as

36 AIS Environmental. 2013. Monitoring of Nutrient Status and Eutrophication Status of Selected Coastal Areas. Draft Technical Report.

37 microscopic animals such as protozoa (zooflagellates, foraminifera, radiolaria, and ciliates), cnidarians and ctenophores

anchovy and sardine). During their larval stages, fish consume zooplankton while some adult fish continue to be partly planktivorous. Synchrony between the peak in plankton abundance and the arrival of fish larvae in the plankton is thought to be crucial in determining the survival and development of fish larvae. As the basis of the marine food web, changes in the abundance, community structure and timing of seasonal abundance and geographic range of zooplankton are then reflected in the higher trophic levels. Such changes would not only have a great effect on the marine food web when considering that different taxonomic groups have different feeding habits but would also have knock-on effects on commercial fisheries. For instance, as part of the FAO Regional Project "Assessment and monitoring of fisheries resources and the ecosystem – MedSudMed", a pilot study[38] in the waters around the Maltese Islands (Geographical Sub-Area – GSA 15) was carried out to provide an overview of the spatial distribution of different life stages of fisheries resources in relation, among others, to the oceanographic factors characterising the area. The results of the Study revealed that the spatial distribution of the main fishery resources is strictly related to environmental factors such as water currents, up- and down-welling as well as passive transportation of planktonic larvae. Surface and subsurface currents may be responsible for the transportation, from north of the Maltese Islands, of eggs and larvae of species with dispersal phases strictly linked to the surface layers.

The zooplanktonic element has been assessed in various works carried out in the 60s and in more recent years. Table 2 provides a list of documented species of zooplankton in Malta categorised according to the following taxonomic groups (Based on Evans, 1968; Seguin, 1968; and Deidun, 2010 and Deidun, 2011). The planktonic element is mainly composed of crustacea (68% - namely copepods followed by planktonic malacostraca) and cnidaria (13% - namely hydrozoans).

Table 2: Species composition of zooplankton in Malta. This table lists the species of zooplankton recorded from Malta on the basis of Evans, 1968; Seguin, 1968; and Deidun, 2010 and Deidun, 2011 and on the basis of updated and accepted taxonomy as checked against the World Register of Marine Species (http://www.marinespecies.org/). Any potential species misidentifications at the time the studies in the 60's were undertaken cannot be excluded and would only be confirmed through further and more recent taxonomic studies.

Taxonomic Group: Phylum/sup-phylum – Class/sub-class - Order **Documented Species on the basis of accepted taxonomy (Brackets indicate species names as documented by source)**	
Annelida – Polychaeta - Phyllodocida *Alciopina albomaculata* (= *Corynocephalus albomaculatus*) *Lepidasthenia grimaldi* *Tomopteris (Johnstonella) helgolandica* *Tomopteris planktonis* *Vanadis crystallina* Cnidaria – Cubozoa – Carybdeida *Carybdea marsupialis* Cnidaria – Hydrozoa – Anthoatecata *Codonium proliferum* (= *Sarsia prolifera*) *Hydractinia borealis* (=*Podocoryne borealis*)	Crustacea – Copepoda – Cyclopoida *Oithona hebes* *Oithona plumifera* *Oithona setigera* Crustacea – Copepoda – Harpacticoida *Clytemnestra rostrata* *Clytemnestra scutellata* Crustacea – Copepoda – Mormonilloida *Neomormonilla minor* (= *Mormonilla minor*) *Mormonilla phasma*

[38] Camilleri, M., Dimech, M., Drago, A., Fiorentino, F., Fortibuoni, T., Garofalo, G., Gristina, M., Schembri, P.J., Massa, F., Coppola, S., Bahri, T., Giacalone, V. 2008. Spatial distribution of demersal fishery resources, environmental factors and fishing activities in GSA 15 (Malta Island). GCP/RER/010/ITA/MSM-TD-13. *MedSudMed Tech. Doc.*, 13, 97 pp.

Taxonomic Group: Phylum/sup-phylum – Class/sub-class - Order **Documented Species on the basis of accepted taxonomy (Brackets indicate species names as documented by source)**	
Pandea conica *Porpita porpita* *Velella velella* Cnidaria – Hydrozoa – Leptotechata *Aequorea* sp. *Clytia hemisphaerica* (= *Phialidium hemisphaericum*) Cnidaria – Hydrozoa – Limnomedusae *Olindias phosphorica* Cnidaria – Hydrozoa – Siphonophorae *Abylopsis tetragona* *Bassia bassensis* *Chelophyes appendiculata* *Eudoxoides spiralis* *Hippopodius hippopus* *Lensia multicristata* *Lensia subtilis* *Physalia physalus* Cnidaria – Hydrozoa – Trachymedusae *Aglaura hemistoma* *Liriope tetraphylla* *Phopalonema velatum* Cnidaria – Scyphozoa – Rhizostomeae *Cotylorhiza tuberculata* *Rhizostoma pulmo* Cnidaria – Scyphozoa – Semaeostomeae *Pelagia noctiluca* Ctenophora – Nuda – Beroida *Beroe cucumis* *Beroe forskalii* Ctenophora – Tentaculata – Cestida *Cestum veneris* Ctenophora – Tentacultata – Lobata *Leucothea multicornis* Crustacea – Copepoda – Calanoida *Acartia (Acartia) negligens* *Aetideus acutus* *Aetideus giesbrechti* (= *Euaetideus giesbrechti*) *Anomalocera patersoni* *Augaptilus longicaudatus* *Bradyidius armatus* (= *Undinopsis bradyi*) *Calanus helgolandicus* *Calocalanus pavo* *Candacia aethiopica* (= *Candacia ethiopica*) Crustacea – Copepoda – Calanoida (cont.) *Candacia bispinosa* (= *Paracandacia bispinos*) *Candacia elongata* *Candacia simplex* *Centropages bradyi* *Centropages hamatus* *Centropages typicus* *Centropages violaceus*	Crustacea – Copepoda – Poecilostomatoida *Copilia mediterranea* *Copilia vitrea* *Corycaeus clausi* *Corycaeus flaccus* *Corycaeus furcifer* *Corycaeus limbatus* *Corycaeus ovalis* *Corycaeus typicus* *Farranula rostrata* (= *Corycella rostrata*) *Lubbockia aculeata* *Lubbockia squillimana* *Oncaea englishi* *Oncaea media* *Oncaea mediterranea* *Oncaea ornata* *Oncaea venusta* *Sapphirina auronitens* *Sapphirina intestinata* *Sapphirina metallina* *Sapphirina nigromaculata* *Sapphirina ovatolanceolata* *Triconia conifer* *Triconia conifer* (= *Oncaea conifer*) Crustacea – Copepoda – Siphonostomatoida *Pontoeciella abyssicola* *Ratania flava* Crustacea – Phyllopoda – Diplostraca *Evadne spinifera* Crustacea – Ostracoda – Halocyprida *Mikroconchoecia curta* (= *Conchoecia curta*) *Orthoconchoecia haddoni* (= *Conchoecia haddoni*) Crustacea – Malcostraca – Amphipoda *Amphithyrus bispinosus* *Brachyscelus globiceps* *Eupronoe minuta* *Lestrigonus latissimus* (= *Hyperia hydrocephala*) *Phronimopsis spinifera* *Phrosina semilunata* *Primno macropa* (= *Euprimno macropus*) *Pseudolycaea pachypoda* *Scina borealis* *Tetrathyrus forcipatus* *Themisto gaudichaudii* (= *Parathemisto gracilipes*) Crustacea – Malacostraca – Decapoda *Alpheus glaber* (= *Alpheus ruber*) *Deosergestes corniculum* (= *Sergestes corniculum*) *Gennades elegans* (= *Amalopenaeus elegans*) Crustacea – Malacostraca – Decapoda (cont.) *Lucifer typus* Crustacea – Malacostraca – Euphausiacea *Euphausia krohni* *Stylocheiron suhmi* *Thysanopoda aequalis*

Taxonomic Group: Phylum/sup-phylum – Class/sub-class - Order **Documented Species on the basis of accepted taxonomy (Brackets indicate species names as documented by source)**	
Clausocalanus arcuicornis	Crustacea – Malacostraca – Mysida
Clausocalanus furcatus	*Leptomysis mediterranea*
Clausocalanus parapergens	*Siriella clausi*
Eucalanus elongatus	
Eucalanus hyalinus	Mollusca – Gastropoda – Littorinimorpha
Euchaeta marina	*Atlanta brunnea* (= *Atlanta fusca*)
Euchirella messinensis messinensis	*Atlanta peronii*
Euchirella rostrata	*Firoloida desmarestia*
Gaetanus kruppii	
Haloptilus longicornis	Mollusca – Gastropoda – Thecosomata
Haloptilus plumosus	*Cavolinia gibbosa*
Heterorhabdus abyssalis	*Creseis acicula*
Heterorhabdus norvegicus	*Gleba cordata*
Heterorhabdus papilliger	*Hyalocylis striata*
Heterorhabdus spinifrons	*Limacina inflata*
Lucicutia clausii	*Limacina trochiformis*
Lucicutia curta	
Lucicutia flavicornis	Chaetognatha – Sagittodea - Aphragmophora
Lucicutia gemina	*Flaccisagitta enflata* (= *Sagitta enflata*)
Lucicutia longiserrata	*Mesosagitta minima* (= *Sagitta minima*)
Lucicutia pera	*Sagitta bipunctata*
Mecynocera clausi	*Serratosagitta serratodentata* (= *Sagitta serratodentata*)
Monacilla typica	
Nannocalanus minor	Echinodermata – Echinoidea – Camarodonta (Larvae)
Neocalanus gracilis	*?Psammechinus miliaris*
Onchocalanus trigoniceps	
Paracalanus parvus	Echinodermata – Ophiuroidea – Ophiurida (Larvae)
Paracartia latisetosa	*Ophiothrix fragilis*
Paraeuchaeta acuta (= *Euchaeta acuta*)	
Paraeuchaeta hebes (= *Euchaeta hebes*)	Chordata – Actinopterygii - Clupeiformes (Larvae)
Paraeuchaeta paraacuta (= *Euchaeta paraacuta*)	*Sardina pilchardus* (= *Clupea pilchardus*)
Pareucalanus attenuatus (= *Eucalanus attenuatus*)	
Phaenna spinifera	Chordata – Appendicularia - Copelata
Pleuromamma abdominalis abdominalis	*Oikopleura (Coecaria) longicauda*
Pleuromamma gracilis	*Oikopleura (Vexillaria) albicans*
Pontella mediterranea	*Oikopleura (Vexillaria) dioica*
Pontellina plumata	*Oikopleura (Vexillaria) rufescens*
Pontellopsis regalis	
Rhincalanus nasutus	Chordata – Leptocardii
Scolecithrix bradyi	*Branchiostoma belcheri* (= *Branchiostoma lanceolatum*)
Scolecithrix danae	
Spinocalanus magnus	Chordata – Thaliacea - Doliolida
Spinocalanus spinosus	*Doliolum denticulatum*
Spinocalanus terranovae	*Doliolum nationalis*
Subeucalanus monachus (= *Eucalanus monachus*)	
Subeucalanus subtenuis	Chordata – Thaliacea – Pyrosomatida
Temora stylifera	*Pyrosoma atlanticum*
	Chordata – Thaliacea – Salpida
	Salpa maxima
	Thalia democratica

The first in-depth study is by Evans (1968) [39], who sampled zooplankton from two locations in 1966 and 1967: one location was at 4 miles from the Grand Harbour); the other location was 56 miles from the Grand Harbour, thus beyond the assessment area. This author provides both temporal (seasonal variation) and spatial (coastal vs. offshore) data on

[39] Evans, F. 1968. Le zooplankton de Malte. *Pelagos*, **9**: 5-20.

zooplankton. In the coastal location, four samples were taken on 5 May, 28 July, 13 October 1966, and February 1967. Copepods were dominant and included *Acartia (Acartia) negligens* (especially in the October sample), *Clausocalanus arcuicornis* (abundant in all seasons), *Corycaeus clausi*, *Lucicutia flavicornis* and *Nannocalanus minor* (recorded only in spring and summer samples), *Oithona plumifera* (common in October) and *Temora stylifera*. Chaetognatha, in particular *Flaccisagitta enflata (= Sagittata enflata*) and Thaliacea, particularly *Thalia democratica*, were present all year round, whereas *Doliolum nationalis* was only present in winter but still in great numbers. Crustacea (Ostracoda) and Cnidaria (Siphonophorae) were present in summer. Cladocea were also present in summer, where appendicularians were absent. The author notes only few species to be truly neritic/coastal (i.e. 19 species out of the 53 species recorded in this Study), while 15 species were truly pelagic.

In addition to the work of Evans (1968), Seguin (1968)[40] provides not only a qualitative but also a quantitative analysis of 9 samples of zooplankton collected from Malta in December 1967 and January 1968. Findings of this Study hence give an account of the winter zooplankton in Malta. Yet again, differences in zooplankton were observed between the neritic (coastal) and pelagic (offshore) stations, while in general copepods constituted the largest group (species and individuals) of which 51 species and 9 genera are reported. In addition to the 25 copepods already mentioned by Evans, Seguin adds 26 species.

Another Study is that of Lapernat & Razouls (2001)[41], which provides a review of the taxonomy and distribution of 62 species (as opposed to the 462 species in the Mediterranean Sea) of copepods off Malta on the basis of sampling of zooplankton undertaken in 1972 using horizontal hauls. Since this study was undertaken beyond the assessment area, it is only mentioned in this MSFD review and not considered further.

More recent studies include the Tara Oceans Expedition which carried out sampling of plankton in October 2009 at two offshore sites at several kilometres from the Maltese coastline (Figure 7 and Figure 8, overleaf, summarise the findings). In this study, samples were dominated by copepods, which are followed, in a rank order of abundance, for station 17, by appendicularians, protista and chaetognatha, while in the case of station 18, by ostracods, chaetognatha and protista, apart from both also comprising by representatives of taxonomic groups. Hence composition varied between the sampling stations. Zooplankton community had an overall higher abundance at station 17.

Another recent work is the initiative "Spot the Jellyfish" launched in May 2010 by the IOI-Malta Operational Centre of the University of Malta (Deidun 2010[42] and Deidun, 2011[43]) which applies citizen science to involve members of the public to report on ctenophore and cnidarian sightings in Malta.[44]

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40 Seguin, G. 1968. Contribution à l'étude quantitative du zooplancton de Malte. *Pelagos*, **10**: 109-132.

41 Lapernat P.E. & Razouls C. 2001. Taxinomie et répartition des copépodes pélagiques profonds de Méditerranée (au large de Malte). *Vie et Milieu*, **51**(3): 123-129.

42 Deidun, A. 2010. Notes on the Recent Occurrence of Uncommon Pelagic "Jellyfish" Species in Maltese Coastal Waters, *Naturalista sicil*., S. IV, XXXIV (3-4): 375-384.

43 Deidun, A. 2011. A collection of recent ctenophore sightings from the Maltese Islands; *J. Black Sea/Mediterranean Environment*; **17**(1): 4-13.

44 More information is available from: http://oceania.research.um.edu.mt/jellyfish/index.html

An assessment of spatial patterns on the basis of mesozooplankton abundance data collected in spring of the years 1984-2003 for the Mediterranean is provided by the Mazzoggi *et al*. (2010)[45] as part of the project entitled "SESAME". This study produced spatial patterns in mesozooplankton that reflect more or less the patterns of chlorophyll concentration in the Mediterranean, that is, a west-east decrease that is not clearly gradual, and a north-south decrease in some areas. The same picture was issued by the compilation of abundance data collected in summer-autumn (stratification period) as well as of biomass data collected in spring. The biomass of total mesozooplankton integrated in the 200m water column in the Mediterranean Sea was variable at both eastern and western sub-basins and seasonal scales. The late winter-early spring values were higher than the late summer-early autumn ones and showed higher spatial variability both among and within basins. In the latter period, with generally more oligotrophic conditions, the distribution was more homogeneous throughout the basins. Most biomass was concentrated in the upper 100m (sometimes 50m), with a clear step below, in both seasons. This vertical distribution of consumer communities is driven by food availability. In the epipelagic layer[46], they are dominated by copepods, which are followed, in a rank order of abundance, by appendicularians and other gelatinous groups (salps, cnidarians and ctenophores), but they are also enriched by representatives of all zoological taxa (vertebrates included, with fish eggs and larvae).

[45] Mazzocchi, M.G., Siokou-Frangou, I., Arashkevich, E., Stefanova, k., Tirelli, V., Margiotta, F., De Olazabal, A., Legovini, S. & Protopapa, M. 2010. Mesozooplankton standing stock in the open Mediterranean Sea: past and present; *SESAME* May 2010 Newsletter

[46] Shallow waters from surface to approximately 200m

Figure 7: Data on Zooplankton Community Composition and Size Structure from TARA Station 17

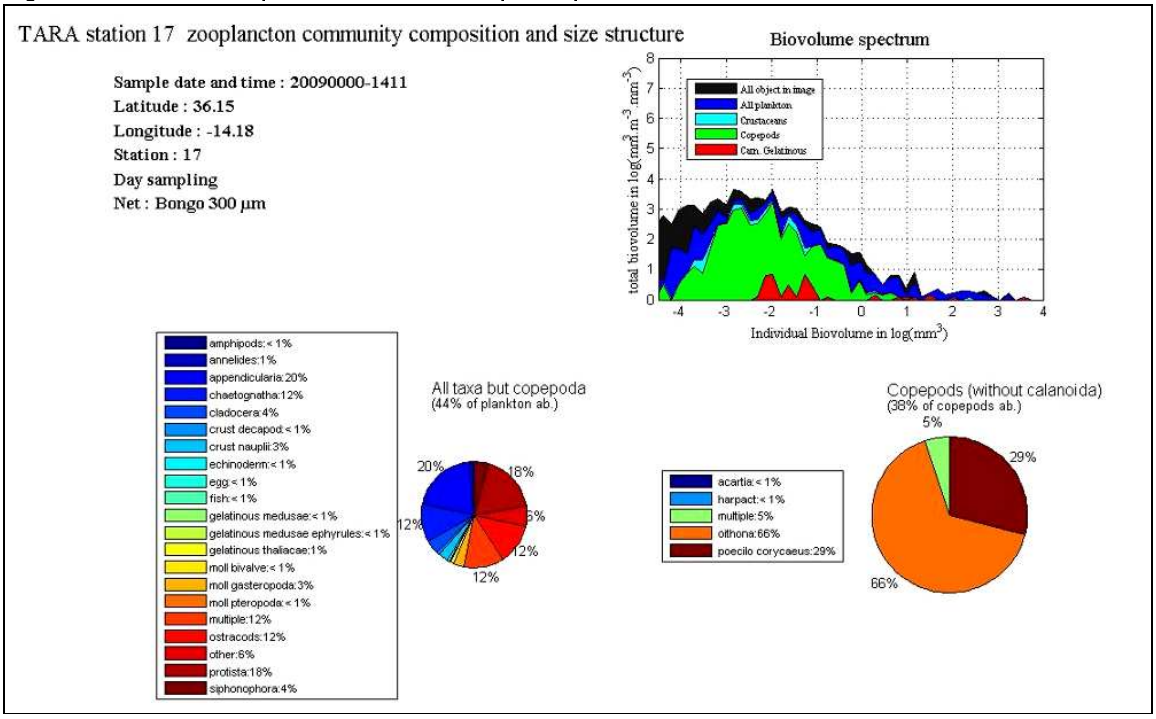
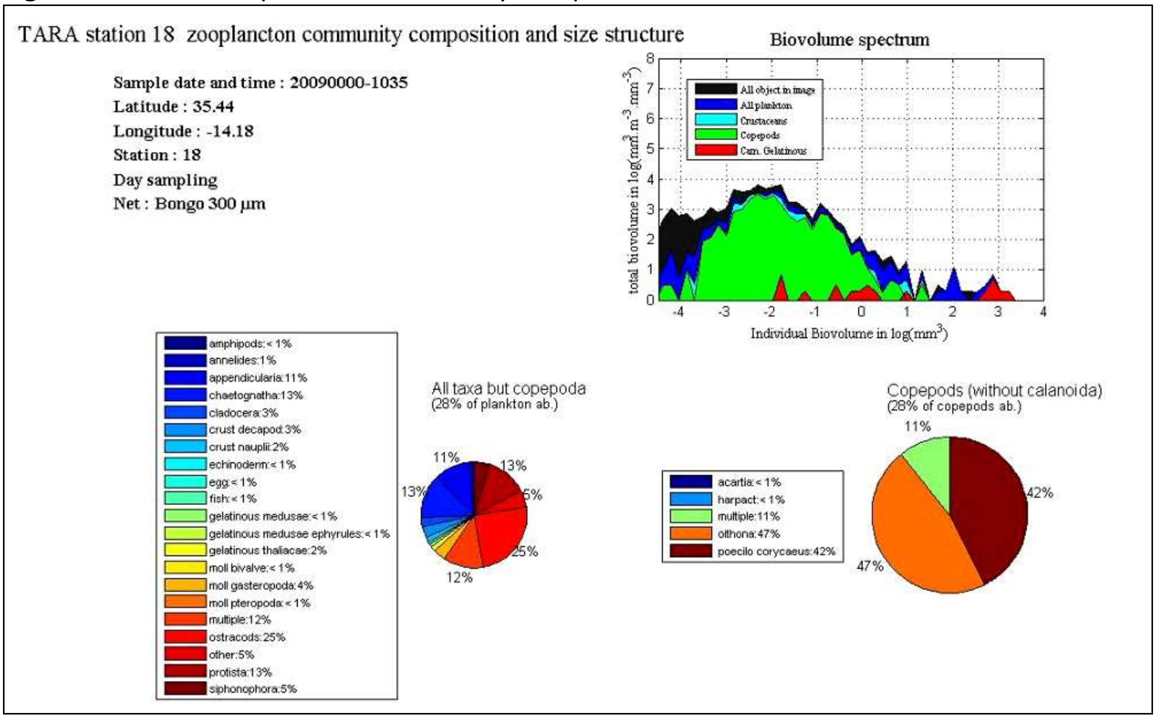


Figure 8: Data on Zooplankton Community Composition and Size Structure from TARA Station 18



1.5 Impacts on the Water Column Habitat: Marine Waters – Coastal

Nutrient and organic matter enrichment

Nutrient and organic matter enrichment is considered to be the most significant pressure affecting water column habitat types. This type of pressure in Malta is mainly associated with sewage outfalls and overflows, port operations and agricultural runoff (J.A. Borg & P.J. Schembri, personal communication).

Axiak and Chircop (1995)[47] report on the observed rapid decline of phytoplankton counts along the Southeastern coast of Malta which was until recently subject to untreated sewage effluents. Variation in species composition was observed whereby the dominance of diatoms such as *Skeletonema costatum* nearest of areas influenced the most by the waste discharge was noted, while dinoflagellates were absent. Positive and negative correlations of sewage pollution with the occurrence of different plankton species are also observed in the work of Debono (2001, see below under HABs). Within this context, it should be noted that all municipal wastewater is now being treated and second class treated wastewater is currently being discharged from wastewater treatment plants.

Water quality studies (measurement of levels of dissolved oxygen, salinity, pH, turbidity, ammonia, nitrates, phosphates, chlorophyll a and bacteriological studies) are also undertaken to detect any changes in the physico-chemical properties of the water column caused by aquaculture activities in Malta. Aquaculture activities release dissolved nutrient especially during the summer period when light availability is high and therefore it could be expected that phytoplankton blooms are likely to occur in the vicinity of fish farms, depending on various factors that affect concentrations of nutrients and particulate material in the water column such as the dispersive nature of the sites where the fish farms are located. Borg & Schembri (2006)[48] mention that for the period 2000 to 2006, lower levels of oxygen, reduced water transparency, and elevated nutrient levels were at times recorded at the tuna penning sites compared to reference sites during the penning season (July – December), however, the observed changes in the monitored attributes were sporadic and not statistically significant (see also Holmer *et al*. 2008)[49].

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[47] Axiak, V. & Chircop, P. 1995. An investigation of the major sewage outfall in Malta. *Rapp. Comm. Int. Mer. Médit.* 34:123.

[48] Borg, J.A. & Schembri, P.J. (2006) Environmental monitoring of aquaculture activities in the Maltese Islands. Presentation at seminar '*Aquaculture and the environment*' organized by the Cleaner Technology Centre, Malta and the Regional Activity Centre for Cleaner Production (UNEP Mediterranean Action Plan); Valletta, Malta, 16 November 2007.

[49] Holmer, M. Hansen, P.K., Karakassis, I., Borg, J.A. & Schembri, P.J. 2008. Chapter 2 - Monitoring of Environmental Impacts of Marine Aquaculture. In: Holmer et al. (eds) *Aquaculture in the Ecosystem.*

Interference with hydrological processes:

Given the dependence of plankton on hydrological conditions, interference with hydrological processes such as changes in thermal and salinity regimes by outfalls) is also considered to be an important pressure on water column habitats. Hydromorphological changes are expected along the NW-NE coast of Malta, in particular in the major industrial coastal harbours - Grand Harbour and Marsamxett Harbour - and Marsaxlokk Bay..

Non-Indigenous Species:

The introduction of non-indigenous species would affect the species composition of biotic communities associated with water column habitats. Streftaris *et al*. (2005) provide a list of alien phytoplankton and zooplankton from the Mediterranean Sea (Table 3). *Rhopilema nomadica*[50], first sited in 2004, is a voracious planktotrophic jellyfish species, which can form very large blooms (as seen in the easternmost parts of the Mediterranean Sea) and can decimate plankton resources. This species is not only a health concern in view of the painful stings it can inflict on bathers, but can also adversely affect tourism, fisheries (e.g. via net clogging) and coastal installations (by blocking intake pipes of cooling systems). Nationally it is thus far a casual introduction.

Table 3: List on Non-Indigenous Plankton in the Mediterranean Sea (Streftaris *et al*., 2005)

PHYTOPLANKTON	ZOOPLANKTON
Alexandrium andersoni	*Acartia centrura*
Alexandrium catenella	*Acartia grani*
Alexandrium pseudogonyaulax	*Acartia tonsa*
Alexandrium tamarense	*Calanopia elliptica*
Chaetoceros coarctatus	*Calanopia media*
Coolia monotis	*Cassiopeia andromeda*
Gonaulax grindley	*Centropagus furcatus*
Gymnodinium breve	*Coleoplana* sp.
Gymnodinium catenatum	*Gonionemus vertens (=murbachi)*
Gyrodinium aureolum	*Mnemiopsis leidyi*
Ostreopsis lenticularis	*Muggiaea atlantica*
Ostreopsis ovata	*Paramphiascella sibronica*
Prorocentrum mexicanum	*Phyllorhiza punctata*
Pseliodinium vaubanii	*Pseudocalanus elongata*
Rhizosolenia indica	*Pseudodiaptomus salinus*
	Rhopilema nomadica
	Sagitta neglecta
	Scottolana bulbosa
	Scottolana longipes
	Stenhenlia inopinata
	Stenhelnia minuta

[50] Deidun, A., Arrigo, S. & Piraino, S. 2011. The westernmost record of *Rhopilema nomadica* (Galil, 1990) in the Mediterranean – off the Maltese Islands, *Aquatic Invasions* **6**(1): 99-103.

Harmful Algal Blooms:

In eutrophic conditions due to high nutrient input, concentrations of phytoplankton can increase considerably causing what are known as blooms. When species forming the blooms are toxic to humans and other marine animals, or cause mortalities of farmed fish or benthos due to oxygen depletion during bloom die-offs, they are then termed "Harmful Algal Blooms". The occurrence of red tides in Malta was documented by Micallef & Bannister (1969)[51] and Fudge (1977)[52]. The former ascribes the blooms to the dinoflagellate *Plectodinium nucleovolvatum*, while the latter research, based on a 5-year survey of Marsamxett Harbour, documents the following:

'"Red tides" occurred usually in May but, less predictably, also during June – August. Causative organisms included the diatom *Chaetoceros* sp., and the dinoflagellate genera *Prorocentrum, Peridinium, Ptychodiscus, Gonyaulax, Ceratium* and *Cochlodinium*. Early summer red tides occurred at a time of increasing insolation, and water temperature, prevailing onshore winds and salinities in the range 34.4 to 36.6‰. A consistent feature was a quick rise in sea temperature of more than 2°C during the week preceding red water. Red tides later in the year coincided with higher temperatures and salinities and calm weather.'

More recent reports of HABs in Malta are provided by Debono (2001[53], 2004[54]). The former study was undertaken between August 2000 and January 2001, with samples taken from six fixed stations within Marsamxett and Grand Harbours: Sliema Point (reference site), Sliema Creek. Msida Creek, Pieta' Creek, Marsa (Menqa) and Dockyard Creek in Vittoriosa. A high proportion of toxic and harmful phytoplankton species were found in all locations, with higher percentage relative abundances in Marsamxett than in the Grand Harbour. Examples included:

- *Dinophysis* sp. – cause Diarrhetic Shellfish Poisoning; highest concentrations were found at Sliema Creek;
- *Gonyaulax* sp. – cause Amnesic Shellfish Poisoning; recorded at significant concentrations every month of the study period;
- *Skeletonema costatum* – formed algal blooms in both harbours; highest concentration found at Msida Creek; presence indicative of sewage pollution;
- *Pseudonitzschia* sp. – formed algal blooms in both harbours (bloomed in December); highest concentrations detected at Sliema Creek;
- *Ceratium furca* – causes physical damage to marine organism due to its long spines; formed algal blooms in both harbours; highest concentrations detected at Sliema Creek (bloomed in November);

This author concludes that "The probable causative organisms for future algal blooms in the areas investigated would be *C. furca*, *Prorocentrum* sp. or *Dinophysis* sp. for summer blooms, and *Pseudonitzschia* sp. for winter blooms." The 2004 study by the same author

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51 Micallef, H. & Bannister, W.H. 1969. On a dinoflagellate bloom (*Plectodinium nucleovolvatum* Biech) causing "red water" in Pieta' Creek (Malta). *Experentia*, **25**: 655.

52 Fudge, H. 1977. The "Red Tides" of Malta. Marine Biology, 39: 381-386.

53 Debono, S. 2001. Harmful Algal Blooms in Maltese Coastal Waters, *Xjenza*; **6/7**(1, 2): 33-34.

54 Debono, S. 2004. Harmful Marine Microalgae in Malta – Further Investigations. MSc. Biodiversity Dissertation Abstract.

undertook sampling between January and December of 2002 in the following eight sites: Mistra Bay, St Paul's Bay, Salina Bay, Sliema Creek, Marsa Creek, Dockyard Creek, Marsascala Bay and il-Magħluq ta' Marsascala. The sites mostly affected by high concentrations of phytoplankton were il-Magħluq ta' Marsascala, Salina Bay, Marsascala Bay, Marsa Creek and Dockyard Creek. In the latter three sites, the phytoplankton associations were typical of disturbed areas and eutrophic conditions. The toxin producing species found in high concentrations were: *Pseudonitzschia* spp. (found in most locations between April and August), *Gynodinium* sp (at il-Magħluq ta' Marsascala in February), *Alexandrium* sp. (at Salina Bay in September), and *Dinophysis* sp. (at Mistra Bay in May and Dockyard Creek in October). Blooms of the latter three species were attributed to increased nutrient availability and turbulent conditions disturbing seed beds from soft-bottom sediments. Species that are documented as causative organisms for large-scale fish kills were also common in this Study (e.g. *Chaetoceros* sp. and *Coscinodiscus* sp.).

Marine Acidification:

There are no local studies on the effect of acidification as a result oceanic uptake of anthropogenic carbon dioxide (CO_2) on the planktonic element. It is noteworthy however that plankton species have differing sensitivities to CO_2 concentration and have a variety of mechanisms for utilising carbon. Hence, changes in the seawater carbonate chemistry through lowering of seawater pH, carbonate ion concentration and carbonate saturation state, and, increasing dissolved CO_2 concentration will affect marine plankton in various ways. Increases in seawater CO_2 will translate into impacts at the species and ecosystem levels. At the species level, not only will the activity of individual phytoplankton species change, but will also tend to favour certain species over others (e.g. through facilitating the photosynthetic carbon fixation of some phytoplankton groups). Biogenic calcification of calcifying organisms will be repressed and this will adversely affect major planktonic calcium carbonate producers, such as coccolithophore species (Haptophyta) and euthecosomatous pteropods (Gastropoda). On the ecosystem level, responses to changes in the seawater carbonate chemistry will result in shifts in phytoplankton community structure, which will in turn influence the community structure of the higher trophic levels that are reliant upon phytoplankton as food and will also influence the cycling of elements that differ between species (e.g. carbonate by calcifying organisms and silicate by non-calcifying organisms) (see for instance Riebesell, 2004[55]; Hays *et al*. 2005[56]; Fabry *et al*., 2008[57]). The relationships between the abundance and cell viability of planktonic organisms, phosphate concentrations and temperature could serve as a basis to predict the possible responses of the planktonic community to current warming of the Mediterranean Sea (See for instance Lasternas, Agustí & Duarte, 2010[58]).

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[55] Riebesell, U. 2004. Effects of CO_2 Enrichment on Marine Phytoplankton. *Journal of Oceanography*, 60: 719-729.

[56] Hays, G.C., Richardson, A.J. & Robinson, C. 2005. Climate change and marine plankton; *Trends in Ecology and Evolution*, 20 (**6**): 337-344.

[57] Fabry, V. J., Seibel, B. A., Feely, R. A., & Orr, J. C. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science*, 65: 414–432.

[58] Lasternas, S., Agustí, S. & Duarte, C. M. 2010. Phyto- and bacterioplankton abundance and viability and their relationship with phosphorus across the Mediterranean Sea. *Aquatic Microbial Ecology*, **60**: 175–191.

Marine Litter:

There are no local studies on the effect of marine litter on the water column and associated plankton communities. Impacts of floating marine litter on the water column would however include: blockage of filter feeding mechanisms from small particulate (neustonic) plastic debris, and the potential to vector marine pests, including invasive species.

1.6 Assessment of Status for 'Marine Waters: Coastal'

Current data availability resulting from the studies reviewed in this report does not allow the application of MSFD Descriptor 1 criteria and indicators for water column habitat types, in particular criteria and indicators for habitat distribution and extent.

Nevertheless, studies undertaken thus far indicate that the water column habitat "marine waters: coastal" as interpreted in this Review seems to exhibit characteristics typical of an oligotrophic water body with exceptions at the local scale[59]. This together with the information on the phytoplankton biological quality element provided in this review, point towards an overall 'good status' of coastal waters in terms of Indicators 1.6.1 (Condition of the typical species and communities) and 1.6.2 (Relative abundance and/or biomass, as appropriate). Such status is based on the fact that the waters are deemed to harbour a plankton element consistent with an oligotrophic regime, as well as the natural seasonal variability in hydrological conditions and thermal stratification. Experts confirm that stratification of the water column in terms of physical factors in Malta is in conformity with the rest of the Mediterranean region, hence the biota associated with water column habitats is also expected to be in conformity with that of the Mediterranean region, excluding areas subject to anthropogenic disturbance (J.A. Borg & P.J. Schembri, personal communication).

Such 'good status' however would not apply to localised areas exposed to harbour activity. WFD baseline monitoring has reported eutrophic conditions in the Grand Harbour area[60] (refer to the MSFD Initial Assessment Paper report on 'Nutrient Enrichment'), which area is also subject to limited seawater circulation (plus other optimal factors such as prevailing onshore wind). HABs have also been reported from such areas.

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[59] For instance, the work by CIBM & Ambiente (2013), which attempts to classify coastal waters as represented by the stations sampled as part of the WFD baseline surveys, on the basis of chlorophyll-a concentrations (MSFD indicator 5.2.1), through the application of eutrophication classification developed by Simboura *et al.* (2005), and assuming that Malta is characterised by waters that classify as Type IIIE waters in line with 2008/915/EC, for the period between May and November only, coastal waters are deemed to be:

- oligotrophic in the Northern, Western and Southwestern waters off Malta;
- low-mesotrophic in Northeastern and Southeastern waters off Malta, which areas are more likely affected by anthropogenic activities, specifically in bays and outside harbour areas;
- high mesotrophic in the Grand Harbour and Marsascala Bay (consistently) and in Mgarr Harbour in Gozo during the summer months.

[60] CIBM and Ambiente SC (2013) Development of Environmental Monitoring Strategy and Environmental Monitoring Baseline Surveys – Water Lot 3 – Surveys of Coastal Water – August 2012. ERDF156 - Developing national environmental monitoring infrastructure and capacity

The preliminary studies undertaken so far also point to this scenario. For instance the interim conclusions from the preliminary coastal surveys as part of the WFD monitoring regime mention that although a definite ecological status for the BQE Phytoplankton could not be calculated for reasons of lack of robust time series data, the first snapshot provided in this sampling survey indicates that the situation of coastal waters is worst in the Grand Harbour area and in front of Marsaxlokk Harbour (hence WFD water bodies MTC105 and MTC107) and seems definitely better in the northern islands of the Maltese Archipelago.

Additional studies from the monitoring sites in the nine water bodies under the WFD framework will generate data that can further assist in the assessment of status for this water column habitat type. At this stage the assessment of status is hence deemed not assessed/unknown due to insufficient data.

1.7 Data Gaps

Under this review, the description of the water column habitat “marine waters: coastal” in the context of distribution and extent could not be done for two reasons: lack of delineation between water column habitat types as per reference list of the MSFD, and lack of studies that would generate data required to assess the indicators under MSFD Descriptor 1.

Although inventories on phytoplankton and zooplankton species from Malta could be formulated, albeit most taxonomic data available was generated in the late 60s and late 70s, data on trends is not available. Data that can shed light into trends of phytoplankton biomass as chlorophyll a are only becoming available now vis-à-vis WFD requirements. Impacts of marine debris and marine acidification on the water column habitat and associated communities have not been studied at a national level.