Nutrient Enrichment

1.1 Introduction

Increased levels of nutrients in the marine environment can bring about enhanced primary production or biomass production, algal blooms, and changes to the taxonomic composition of algae and plants. Enhanced primary productivity has effects on light climate, hence on biota, and increased fixation of carbon. The process of nutrient enrichment, especially compounds of nitrogen and/or phosphorous, leading to the effects described above, is termed 'Eutrophication'[1]. The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health and/or the sustainable provision of goods and services.

Increased levels of organic matter in the marine environment are also associated with negative effects on the marine environment. The decay of organic matter often leads to a stimulation of microbial decomposition and oxygen consumption, depleting bottom-water oxygen concentrations and potentially bringing about anoxic conditions especially in stratified water bodies. As a result, a reduction in benthic diversity may occur.

The extent to which nutrient loads have an effect on coastal and marine ecosystems depends largely on the physical and hydrographical characteristics of the marine environment. The presence of vertical stratification in the water column, the occurrence of areas where there is restricted water exchange and long residence times determine the extent to which the marine environment is at risk of eutrophication. Low or high tides and the degree of mixing in the water column are additional contributing factors.

The physical morphology and bottom topography of the Mediterranean Basin play an important role on the fate of nutrients. The Mediterranean Basin is divided into a Western and Eastern basin with several seas and connecting straits. This in turn influences water circulation within the Basin and contributes to the creation of a single thermo-haline cell with a dominant transportation of surface water from the west to the east of the basin. Being located towards the centre of this Basin, the Maltese Islands are to a large extent influenced by the Modified Atlantic Water jet (MAW) that flows across the Straits of Sicily, connecting the surface flow of the two basins. Marine waters can therefore generally be described as exposed waters

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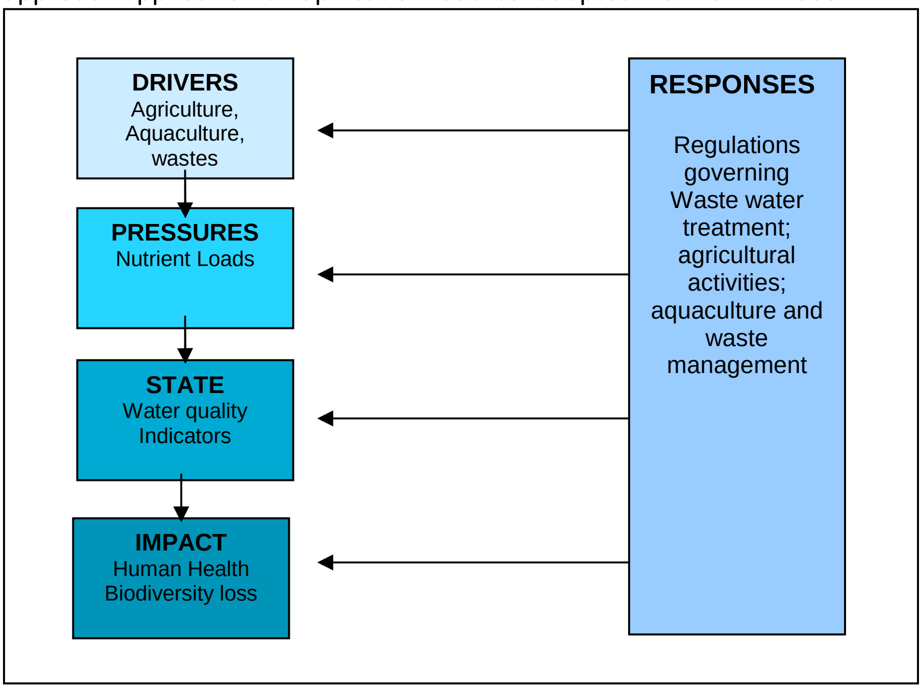
1 Definition extracted from Ferreira, J.G.; Andersen, J.H.; Borja, A.; Bricker, S.B.; Camp, J. ; Cardoso da Silva, M.; Garces, E.; Heiskanen, A.S.; Humborg, C.; Ignatiades, L.; Lancelot, C.; Menesguen, A.; Tett, P.; Hoepffner, N. & Claussen, U. Marine Strategy Framework Directive Task Group 5 report 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.

where nutrients are diluted and transported to the open sea. Despite this general view, the occurrence of eutrophication is not unknown to Malta.

This report provides a description of the levels of nutrients and the occurrence and effects of nutrient enrichment in Malta, with a view to determine status in terms of this pressure, in line with Article 8 of the EU Marine Strategy Framework Directive. As a result of the current data scenario this report will be focusing on nutrients, namely compounds of nitrogen and phosphorous, rather than organic matter.

The Driver-Pressure-State-Impact and Response framework applied to eutrophication as illustrated in Figure 1 will be followed for the purpose of this report.

Figure 1 : The Driver Pressure, State, Impact and Response Indicator approach applied to Eutrophication. Source: adapted from UNEP 2003[2].



2 UNEP. 2003. Eutrophication monitoring Strategy of MED POL. UNEP (DEC)/MED WG.231/14

1.2 Legislative and policy instruments governing eutrophication

1.2.1 Legislation controlling the level of nutrient input

Eutrophication is addressed in several EU legislative policies, on the basis of which Malta is required to monitor parameters relevant to eutrophication in coastal and marine waters and set ecologically relevant guideline values. Malta is also obliged to follow eutrophication assessment criteria and methods as developed by other regional conventions, such as the United Nations Environment Programme (UNEP) Mediterranean Action Plan (MAP).

The following text provides a brief overview of the EU and regional legislation and their contribution to controlling excessive nutrient input into the marine environment.

Urban Waste Water Treatment Directive – 91/271/EEC

This Directive aims at protecting the environment from adverse effects of urban waste water discharges and discharges from certain industrial sectors. It lays down provisions in relation to collection, treatment and discharge of domestic and industrial waste waters. In Malta, two urban wastewater treatment plants at Ras il-Ħobż (Gozo) and Iċ-Ċumnija (Malta) came into operation in November 2007 and October 2008 respectively, whereas the Malta South plant at Ta' Barkat started operating in June 2011. Prior to the construction of these plants, only a small percentage of wastewater was treated prior to disposal at sea.

The Directive calls for the identification of areas or water bodies that are eutrophic, or are at risk of becoming so if mitigation action is not taken, as 'sensitive areas'. Within these areas, higher thresholds for quality of marine discharges from urban waste water treatment plants apply. These sensitive areas have been designated for Malta through Legal Notice 120 of 2005 and include the following:

- Marsaxlokk Bay
- Marsaskala Bay
- Marsamxett and Grand Harbour
- Qammiegħ point till Ras ir-Raħeb
- Mġarr Harbour (Gozo)
- Mġarr ix-Xini (Gozo)
- Xlendi Bay (Gozo)
- Marsalforn Bay (Gozo)

The emission standards for discharges to these designated Nutrient Sensitive Protected Areas must be achieved with seven years of the designation of that area.

A revision of these areas is currently being planned in order to ensure that the areas previously designated are actually areas which are subject to eutrophication[3].

To date Malta has failed to achieve nitrogen levels as stipulated in Annex I of the Urban Waste Water Directive at the sensitive area located off Ċumnija, North of Malta. This was due to the overload of the sewerage network with farmyard waste. This waste was meant to be disconnected from the sewerage network but failure to do so has hindered the proper removal of Nitrogen. An alternative solution to handle farmyard waste is currently being investigated. An upgrading of the plant's aeration capacity is also being considered[4].

Nitrates Directive - 91/676/EEC

The Nitrates Directive deals with the diffuse nature of nitrate contamination from agricultural sources. Sites that are prone or potentially prone to nitrate contamination are designated as '**Nitrate Vulnerable Zones'** and action plans are set up to combat nitrate contamination in such areas. Monitoring for nitrate status and their eutrophic state is carried out every four years.

The Maltese Islands were designated as one whole Nitrate Vulnerable Zone, meaning that the measures outlined in the Nitrates Action Programme are mandatory for all farmers. Malta's second Nitrates Action Programme compiled in August 2011 pursuant to Article 10 and Annex 5 of the Nitrates Directive can be accessed through the following link:
http://cdr.eionet.europa.eu/mt/eu/nid/envuw2tlg

Bathing Water Directive – 2006/7/EC

Bathing water quality is governed by the EU Bathing Water Directive as transposed by Legal Notice 125 of 2008 (Management of Bathing Water Quality Regulations, 2008) and the Barcelona Convention, through the MED POL Programme[5].

While the Bathing Water Directive focuses on microbiological parameters, it also calls for the establishment of 'Bathing Water Profiles', which profiles should indicate the risk of macroalgae or marine phytoplankton proliferation within bathing areas. Adequate management measures should then be proposed accordingly.

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[3] Malta's Article 16 report for 2010 concerning the implementation of Directive 91/271/EEC concerning Urban Waste Water Treatment

[4] Malta's Article 15 report for 2010 concerning the implementation of Directive 91/271/EEC concerning Urban Waste Water Treatment

[5] The MED POL programme is the marine pollution assessment and control component of the Mediterranean Action Plan and is responsible for the follow up work related to the implementation of the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities (1980, as amended in 1996)

Water Framework Directive – 2000/60/EC

The EU Water Framework Directive (WFD) focuses on the protection of all water resources, including coastal waters. The main objective of the WFD for coastal water bodies is the achievement, by 2015, of 'good ecological status' up to one nautical mile from the coast; 'good chemical status' for all territorial waters (12 nautical miles) and 'good ecological potential'[6] for heavily modified water bodies.

Nutrient monitoring forms part of a Member State's obligations to achieve Good status in all waters by 2015. Nutrients, as part of the physicochemical quality element, must be at a level to ensure the functioning of the ecosystem and the values specified for biological quality elements. For the purposes of monitoring water bodies at risk because of nutrient enrichment, Member States must monitor parameters indicative of the Biological Quality Element (BQE)/s[7] most sensitive to the effects of nutrient enrichment as well as the nutrients that are being discharged into the water body in significant quantities.

Barcelona Convention

The Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention) was adopted in 1976 and came into force in 1978. The principal aim of the Barcelona Convention and its protocols is to reduce pollution in the Mediterranean Sea and protect and improve the marine environment in the area, thereby contributing to its sustainable development.

The Programme for the Assessment and Control of Marine Pollution in the Mediterranean region (MEDPOL) is the environmental assessment component of the Mediterranean Action Plan (MAP) of the Barcelona Convention. In recent years, the Mediterranean Action Plan has identified both a short-term and long term monitoring strategy for eutrophication[8]. The aim of the short term strategy was to monitor those parameters that support the TRIX index[9]. It is intended that in the longer term biological parameters and residence time will be introduced to the strategy.

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6 'Good Ecological Potential' is less stringent objective than good ecological status , making allowances for ecological impacts resulting from alterations to the physical environment that are necessary to either support a specific use, or must be maintained in order to avoid effects on the wider environment.

7 Biological Quality Elements for coastal waters under the WFD (2000/60/EC) are phytoplankton, macroalgae, benthic invertebrates and angiosperms.

8 UNEP. 2007. Eutrophication Monitoring Strategy for the Mediterranean Action Plan, Review meeting of MED POL monitoring activities and the use of indicators. UNEP (DEPI)/MED WG.321/Inf.5

9 The TRIX index or Trophical Index for Marine systems is an index developed by Vollenweider *et al*. 1998 based on chlorophyll-a, oxygen saturation, total nitrogen and total phosphorus to characterise the trophic state of coastal and marine waters. Such an index assesses the trophic potential of a water body but does not inform on the actual state and changes in the biological community.

1.3 Drivers and Pressures: Nutrient Input Sources

Nutrient input to the marine environment can be of two types: *anthropogenic* and *natural* (the latter type is also sometimes referred to as background levels). Background levels of nutrients are essential to marine ecosystems as they maintain adequate primary productivity, an important process that supports all other trophic levels in the ecosystem. Once nutrient levels in the marine environment depart from natural concentrations due to human input, the quality of marine water can deteriorate significantly and hinder healthy marine ecosystems to thrive.

1.3.1 Natural inputs or background levels of nutrients

Nutrient availability is generally low in the Mediterranean Basin. The hydrographic and physical dynamics of this sea partly dictate its oligotrophic nature, characterised by the nature of exchange of water through the Straits of Gibraltar. Being a concentration basin, i.e. freshwater loss exceeds freshwater input, inflowing nutrient-poor Atlantic surface water is unable to replenish the deeper nutrient–rich water flowing out of the Basin. As a result the oligotrophic nature of the Mediterranean increases along the west-east and north-south direction[10].

Furthermore, primary production by autotrophs is generally weak in the Mediterranean. Whilst usually nitrogen is the limiting factor in several oceans, in the Mediterranean the limiting factor is inorganic phosphorous. N:P ratios have in fact been reported to range from 27 to 120[11] in the Eastern Mediterranean. This limitation is however at times buffered by anthropogenic inputs from densely populated coasts, particularly in the Northern Mediterranean (refer to sections below) and from the atmosphere. Siokou-Frangou *et al.*, (2010) claim that phosphorous from the atmosphere may account up to 40% of primary production. The high N:P ratio of atmospheric inputs indicates that they are among the factors that contribute to the unbalanced ratio recorded in Mediterranean waters.

Several studies have shown that phytoplankton follow a typical temperate cycle, with biomass increase in late winter and early spring and a decrease during the summer months[12],[13]. Chlorophyll concentration in the open seas rarely exceeds 2-3mg/m^3.

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[10] Siokou-Frangou. I., Christaki, U., Mazzocchi, M.G., Montresor, M., Ribera d'Alcalà, Vaqué, D and Zingone, A. 2010, Plankton in the open Mediterranean Sea: a review. Biogeosciences, 7, 1543-1586.

[11] Krom, M.D., Kress, N., Brenner, S., and Gordon, L.I. 1991. Phosphorous Limitation of Primary Productivity in the Eastern Mediterranean Sea. Limnol. Oceanogr., 36 (3), 424 – 432.

[12] Casotti, R., Landolfi, A., Brunet, C., D'Ortenzio, F., Mangoni, O. and Ribera d'Alcala, M. 2003. Composition and dynamics of the phytoplankton of the Ionian Sea (eastern Mediterranean). Journal of Geophysical Research, VOL. 108, NO. C9, 8116.

[13] Ortenzio, D F., and Ribera d'Alcalà, M. 2009. On the trophic regimes of the Mediterranean Sea: a satellite analysis. Biogeosciences, 6, 139-148

In addition to the increasing longitudinal difference in nutrients as one moves from west to east of the Mediterranean basin, areas subject to deep convection, fronts, cyclonic and anti-cyclonic gyres also bring about differences in plankton communities. In such areas, intermittent nutrient upwelling brings about a switching of a generally small-sized microbial community with a diatom-dominated one[14].

There are also sites where coastal morphology plays a significant role, due to the intense wind stress that can generate strong vorticity, and that "leads to formation of energetic filaments"[15]. This process may significantly contribute to the dispersal of coastal inputs toward the open sea, along with plankton. Coastal input in the Mediterranean is limited to the three major rivers (Po, Rhone and the Nile). The net contribution of riverine input to overall nutrient fluxes in the Mediterranean, however, is still uncertain.

Considering these inputs to the Mediterranean Basin, it can be concluded that the Sea has a low phosphorous starved internal system[16]. The few nutrient upwelling sites and frontal regions in certain parts of the Mediterranean encourage vertical transport of nutrients from deeper waters to the photic zone in some limited areas. Inputs from the coast and atmosphere also play an important role in providing nutrients to this internal pool and help in sustaining the natural production of Mediterranean basin.

Very few studies have been carried out to date on phytoplankton communities in the Maltese Islands. The first attempt to evaluate quantitatively phytoplankton species was carried out in 1978, at three different localities in Malta (Marsaxlokk, Rinella Creek and Mistra Bay)[17]. Rinella Creek, being subject to eutrophicated conditions differed a great deal from the other two sites, which were oligotrophic in nature. Due to the fact that monitoring took place during the winter months, a period favouring diatom growth, diatoms were the most dominant group of the phytoplankton community in all sites. Dinoflagellates, coccolitophores and silicoflagellates were of relatively minor importance.

Another study concerning nutrient (nitrogen and phosphorus) enrichment effects on natural phytoplankton populations at Marsaxlokk Bay[18] found, that similar to the rest of the Mediterranean both nitrates and phosphates are scarce. The results of the study suggested that phosphate was the primary limiting factor for growth for all

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14 Siokou-Frangou. I., Christaki, U., Mazzocchi, M.G., Montresor, M., Ribera d'Alcalà, Vaqué, D and Zingone, A. 2010, Plankton in the open Mediterranean Sea: a review. Biogeosciences, 7, 1543-1586.

15 Siokou-Frangou. I., Christaki, U., Mazzocchi, M.G., Montresor, M., Ribera d'Alcalà, Vaqué, D and Zingone, A. 2010, Plankton in the open Mediterranean Sea: a review. Biogeosciences, 7, 1543-1586.

16 Krom, M.D., Woodward, E.M.S., Herut, B., Kress, N., Carbo, P., Mantoura, R.F.C., Spyres, G., Thingsted, T.F., Wassmann, P., Wexels-Riser, C., Kitidis,V., Law ,C. and Zodiatis, G. 2005. Nutrient cycling in the south east Levantine basin of the eastern Mediterranean: Results from a phosphorus starved system. Deep Sea Research II 52, 2879–2896

17 Jaccarini, V., Agius, C., and Leger, G. 1978. A preliminary survey of the phytoplankton of inshore marine waters from Malta (Central Mediterranean), Mem. Biol. Marina e Oceanogr., VIII (1) 1-12

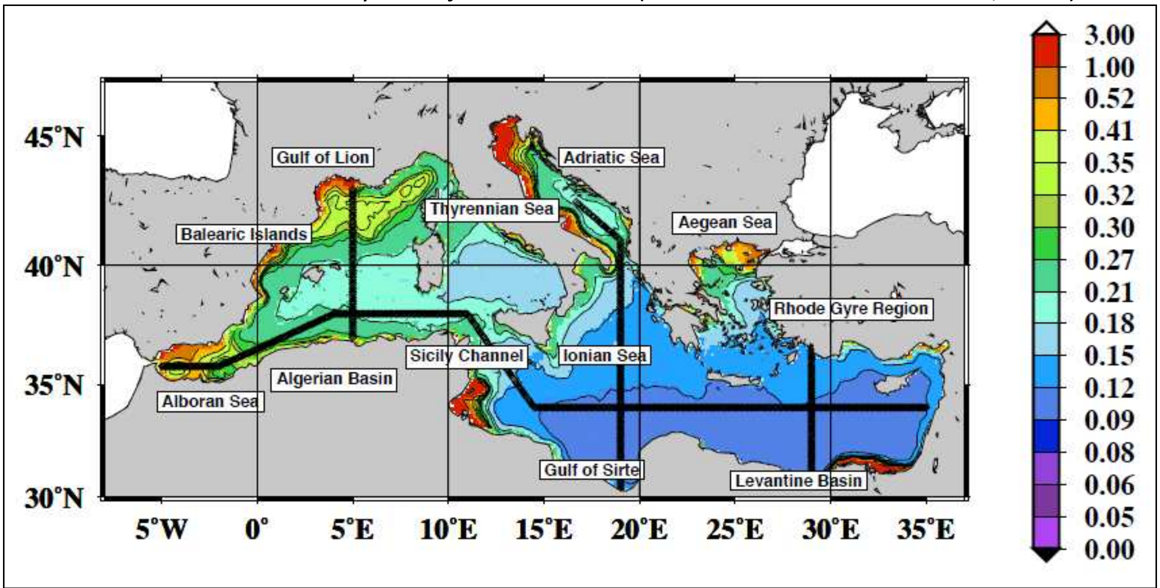
18 Agius, C., and Jaccarini, V. 1982. The effects of nitrate and phosphate enrichment on the phytoplankton from Marsaxlokk Bay, Malta in Hydrobiologia 87, 89-96

phytoplankton populations, whilst nitrogen was secondary. There also appears to be no seasonal changes in the respective roles of phosphates and nitrates as factors limiting primary productivity. Moreoever no major changes in the relative composition of the phytoplankton populations were observed. Similar to the study mentioned above[19], diatoms dominated all the culture vessels collected (mainly *Skeletonema costatum* and *Chaetoceros* spp.)

1.3.2 Anthropogenic sources

Despite being oligotrophic in nature, nutrient enrichment is not new to the Mediterranean. Anthropogenic nutrient sources, mainly related to large urban conurbations often mask this naturally limiting environment. This is best illustrated by the SeaWIFS Satellite surface Chlorophyll a data in the Mediterranean Basin over 10 years (Figure 2).

Figure 2: Ten years of SeaWIFS ocean colour observation data (1997-2007) of mean surface chlorophyll concentration in mg/m^3 Higher chlorophyll means are indicated in the vicinity of coastal cities and in the vicinity of major river deltas. (*Source: Ortenzio and d'Alcalà, 2009*).



A recent EEA report[20] confirmed that the most eutrophic waters of the Mediterranean are along the northern coastline, coinciding with common observations of dinoflagellate blooms that in some cases have also caused shellfish poisoning. The highest summer chlorophyll-a concentrations (> 5 µg/l) in the Mediterranean were in fact found in French coastal areas and along the coast of

[19] Jaccarini, V., Agius, C., and Leger, G. 1978. A preliminary survey of the phytoplankton of inshore marine waters from Malta (Central Mediterranean), Mem. Biol. Marina e Oceanogr., VIII (1) 1-12

[20] EEA. 2011. Chlorophyll in transitional, coastal and marine waters assessment. CSI 023 (http://www.eea.europa.eu/data-and-maps/indicators/chlorophyll-in-transitional-coastal-and/chlorophyll-in-transitional-coastal-and-2/) Accessed in May 2012.

Montenegro. However, eutrophication has been increasing gradually along southern Mediterranean coastlines[21],[22]. The 2011 EEA report also confirmed that significantly increasing trends are found in coastal waters of the Mediterranean Sea, whereas significantly decreasing trends are observed in the open parts of the Basin.

Likewise, high nutrient inputs also occur in Malta. The main anthropogenic sources of nutrient enrichment in Malta can be divided into two (Figure 3):

1. Land based sources mainly from sewage overflows, sewage infrastructural discharges and agricultural sources.
2. Offshore sources mainly from offshore fish farms and marine traffic generated waste directly discharged to sea.

Within the framework of the Strategic Action Plan Programme (SAP) adopted by the Contracting Parties to the Barcelona Convention, Malta has prepared National Baseline Budget reports (NBB)[23,24] for emissions/releases of the SAP targeted pollutants from land-based sources, including nutrients and organic matter. However, these national budgets were estimated prior to the operation of the major urban waste water treatment plants on the Maltese Islands and, as expected, the major sector contributing to the input of nutrients and organic matter according to these reports are public sewers[25], followed by a much lower contribution by the land-based fish farm installations[26,27](Figure 4 and Figure 5). This scenario might not be currently applicable due to the fact that sewage is now being treated prior to being discharged into the marine environment (refer to section below).

Based on the 2008 data, relatively minor contributions of nutrients to the marine environment are from desalination plants (14,458kg/yr total N; 222kg/year total P), energy generation sector (3,500kg/yr total N; 1604kg/yr total P), shipyards (266kg/yr total N; 51kg/yr total P) and Oil and Fuel Terminals (34kg/yr; 441kg/yr total P). Collectively, industries including a pig farm, food processing company and film

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21 UNEP/MAP, 2007. Approaches to the assessment of eutrophication in Mediterranean coastal waters, draft report.

22 EEA, 2013. Chlorophyll in transitional, coastal and marine waters assessment. CSI 023 (http://www.eea.europa.eu/data-and-maps/indicators/chlorophyll-in-transitional-coastal-and/chlorophyll-in-transitional-coastal-and-3/) Accessed July 2013.

23 Axiak, V. 2003. Baseline Budget of Emissions/Releases for SAP targeted pollutants for Malta. As submitted to the United Nations Environment Programme, coordinating unit for the Mediterranean Action Plan through the Environment Protection Directorate of the Malta Environment and Planning Authority. http://www.mepa.org.mt/file.aspx?f=3523

24 Axiak, 2009. Baseline Budget of Emissions/Releases for SAP targeted pollutants for Malta, 2008. As submitted to the United Nations Environment Programme, Coordinating Unit for the Mediterranean Action Plan. Environment Protection Directorate, Malta Environment and Planning Authority; 20pp.

25 2,260,669kg/year total nitrogen; 372,014kg/year total phosphorous in 2008

26 It should be noted that according to Axiak (2009), most of the wastewaters arising from tuna penning operations are ship-based sources, where tuna processing and packaging take place. The wastewater originating from ship-based operations are rich in organic contaminants and would be expected to have significantly high levels of BOD5 and nutrients. These ship-based discharges are NOT covered by the estimates provided by the National Baseline Budgets.

27 387,000kg/year total nitrogen; 102,000kg/year total phosphorous in 2008

facilities contribute an estimate of 50,800kg/yr total nitrogen and 5,588 total Phosphorous according to the National Baseline Budget (2008).

Input loads of nutrients and organic carbon from installations such as power plants, urban wastewater treatment plants, shipyards and aquaculture (offshore cages), are reported for the purposes of the European Pollutant Release and Transfer Register. Urban Waste Water Treatment Plants and aquaculture are described in specific sections below.

Figure 3: Land based and offshore sources of nutrients to marine waters of the Maltese Islands

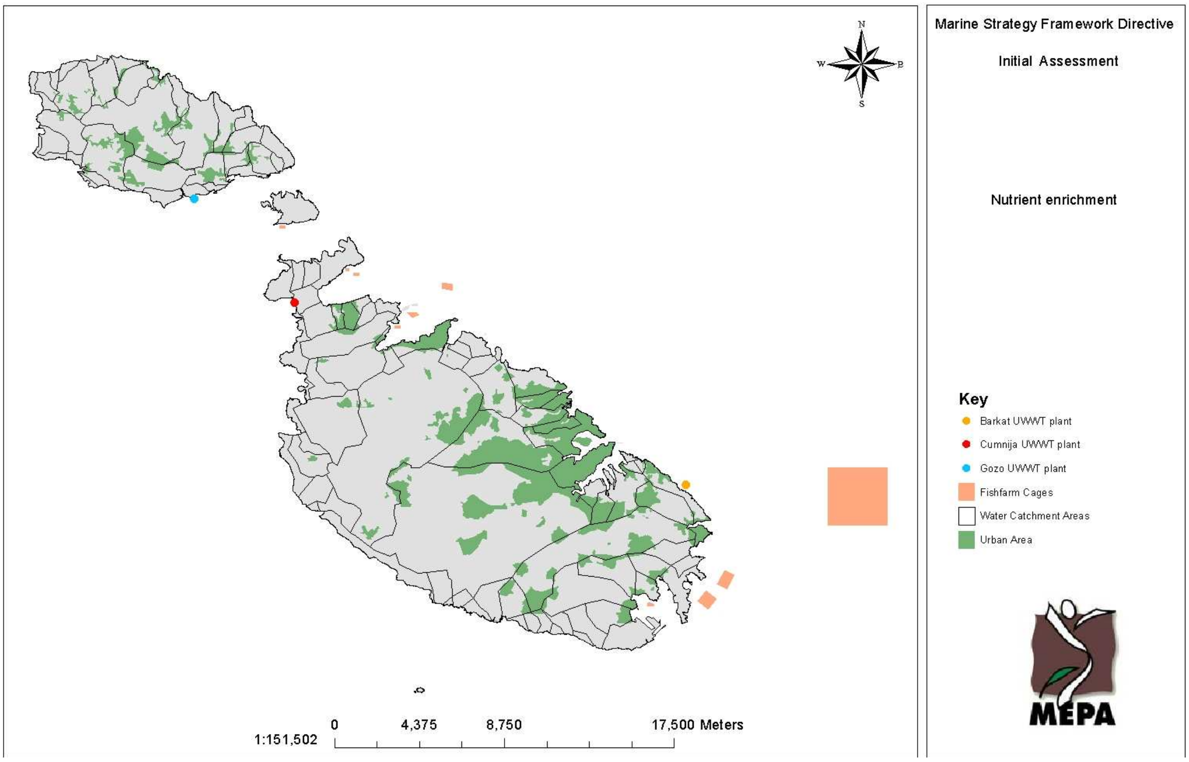


Figure 4: Past data of input of total nitrogen and total phosphorous from the different sectors as per National Baseline Budget published in 2008[28]. '

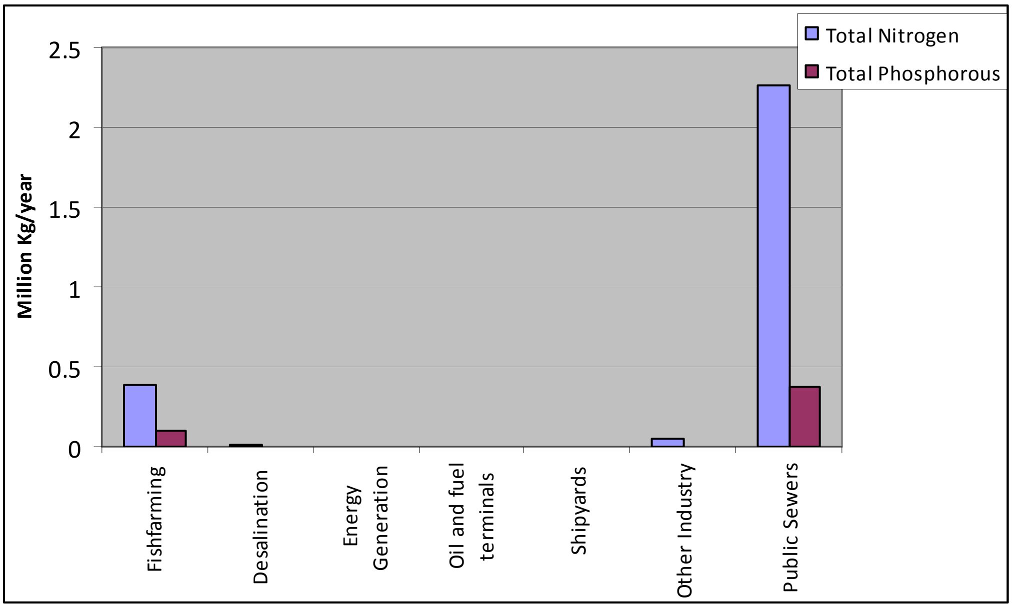
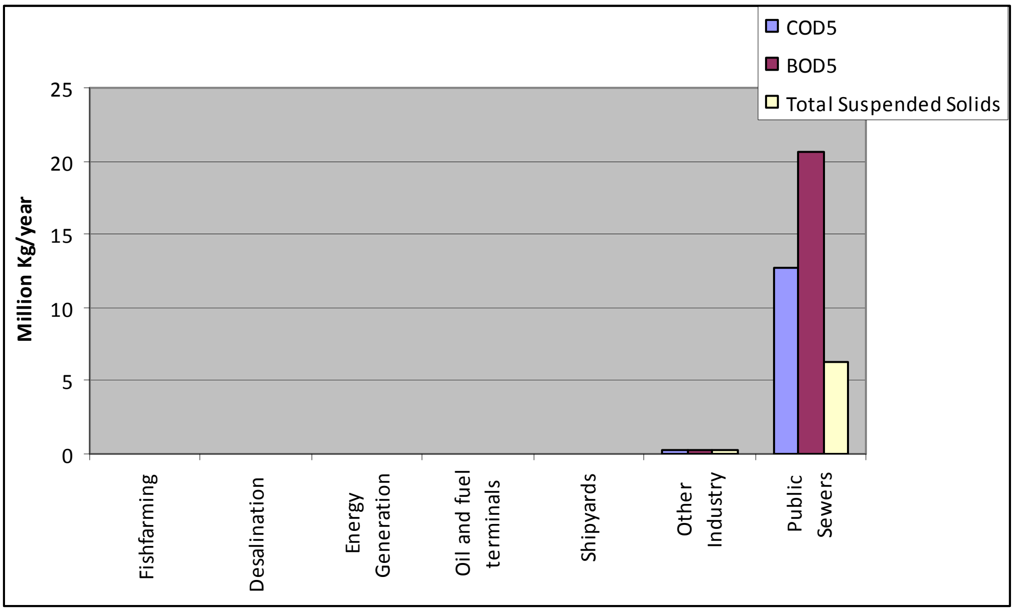


Figure 5: Past data of COD5, BOD5 and Total Suspended Solids per sector as calculated by the National Baseline Budget published in 2008[29].



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28 'Other Industry' includes a pig farm, food processing company and the location of the Malta Film Facilities.

29 ditto

1.3.2.1 Land based Sources

(i) Urban Waste Water and sewage outfalls

Prior to the operation of the largest waste water plant at ta' Barkat, Xgħajra in 2011, approximately 85% of Malta's raw sewage was released into the sea via a 716m long submarine pipeline, with a terminal diffuser at a water depth of 36m. Studies at that time[30] had indicated that the extent and effects of the resultant sewage plume are subject to different hydrographic conditions present. This was revealed by the several water parameters that were monitored at various depths over one year.

Water visibility near the outfall was low but improved significantly with distance from the outfall, nearly reaching background levels. Axiak and Chircop (1995)[31] also reported that anoxic or hypoxic conditions were never found throughout the water column in the vicinity of the outfall. Nitrate levels were generally low. Phosphates however were found to be high (4.39µg-at P/l) but again decreasing to 0.06µg-at P/l with distance from the outfall. N:P ratios exhibited nitrogen as the limiting nutrient in the immediate vicinity of the plume. However an optimum assimilatory proportion of the two nutrients was demonstrated with distance from the outfall. The study revealed that fast currents (surface currents reported to have a velocity of 0.21m/sec) together with the design and location of the outfall provided a good dilution factor for the discharged effluents.

A separate study[32], alternatively demonstrated that when the outfall was not functional the geographical extent of the impacted area of the discharged sewage at Wied Għammieq could extend up to 8km SE of the outfall, rendering the whole coastal stretch unsuitable for bathing.

Since 2011 all waste water discharged to the marine environment is treated, significantly reducing the nutrient load contribution from waste water discharge. Figure 3 above indicates the location of the three waste water treatment plants on the coast. Table 1 provides an indication of the loads of nutrients and organic matter to the marine environment through discharge of sewage effluent in 2003, 2008 and 2011. Comparison of the total input calculated by the 2003 and 2008 baseline budgets may imply that with the exception of suspended solids, there has been a general increase in the discharge of nutrients in Malta in the period 2003-2008. However the differences between the two sets of data could also be attributed to more accurate and reliable data used for the 2008 Baseline study. The data clearly indicates a significant improvement in nutrient loads to the marine environment from the sewerage network in 2011.

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30 Axiak, V. and Chircop, P. 1995. An investigation on the major sewage outfall in Malta, Rapp. Comm. Int. Mer Medit., **34**

31 Axiak, V. and Chircop, P. 1995. An investigation on the major sewage outfall in Malta, Rapp. Comm. Int. Mer Medit., **34**

32 Axiak, V., Pavlakis, P., Sieber, A.J., Tarchi, D. 2000. Extent of impact of Malta's (Central Med) Major Sewage outfall using ERS SAR, Malta in Marine Pollution Bulletin 40 (9): 734-738

Table 1: Waste water nutrient input loads in 2008 when not all sewage effluents were treated and in 2011 with all sewage effluents treated. 2011 data incorporates all effluent treated by the three sewage treatment plants on the Maltese Islands.

Nutrient Loads from waste water (kg/yr) according to the National Baseline Budgets			2011[33] Nutrient Loads from treated waste water (kg/yr)	
	2003[34]	2008[35]		
COD5	**6,642,782**	**12,716,356**	COD	**1,937,657**
BOD5	**5,645,203**	**20,639,546**	BOD5	**344,768**
Total Nitrogen	**944,993**	**2,260,669**	Nitrates[36]	**1,170,420**
Total Phosphorous	**107,851**	**372,014**	Not applicable[37]	
Total suspended solids	**6,695,434**	**6,322,209**	Total Suspended Solids	**664,341**

Untreated sewage effluents can also reach the marine environment through sewage overflows (in emergency situations, particularly during heavy rainfall events). Nevertheless, such overflows are rigorously controlled by Malta's Water Services Corporation and the influx of raw sewage into the marine environment from sewage overflows is deemed to be localized and of short duration. Therefore risks of nutrient enrichment from sporadic sewage overflows will not be considered further in this report.

(ii) Agricultural sources

Nutrient input from agricultural sources into the marine environment is mainly related to diffuse pollution from run-off. The several sub-hydrological catchments of the Maltese Islands and their individual valley systems transport nutrients from inland agricultural areas to the sea and contribute to the occasional nutrient enrichment incidences of sheltered inlets and bays around the Islands (refer to Figure 3). Due to the diffuse nature of this source, it is very difficult to quantify the contribution of this source from agricultural activity. A rough approximation of agricultural Nitrogen contribution discharged to the environment amounted to 163.7 tonnes during the first nitrate reporting cycle period (i.e. 2004-2007)[38].

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33 Data provided by the Water Services Corporation

34 Axiak, V. 2003. Baseline Budget of Emissions/Releases for SAP targeted pollutants for Malta. As submitted to the United Nations Environment Programme, coordinating unit for the Mediterranean Action Plan through the Environment Protection Directorate of the Malta Environment and Planning Authority. http://www.mepa.org.mt/file.aspx?f=3523

35 Axiak, 2009. Baseline Budget of Emissions/Releases for SAP targeted pollutants for Malta, 2008. As submitted to the United Nations Environment Programme, Coordinating Unit for the Mediterranean Action Plan. Environment Protection Directorate, Malta Environment and Planning Authority; 20pp.

36 Nitrates are being taken into consideration instead of 'Total Nitrogen', since the latter parameter is only available for the effluent discharged by the South Malta Sewage Treatment Plant. Total Nitrogen emitted from the South Malta Sewage Treatment Plant is 544,592kg in 2011 and 767,967kg in 2012 (based on E-PRTR data).

37 Data on 'Total Phosphorous' is only available for the effluent discharged by the South Malta Sewage Treatment Plant: 88,560kg in 2011 and 206, 762kg in 2012 (based on E-PRTR data).

38 MEPA. 2008. Malta 1st Annex V Report of Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources.

A key milestone in the implementation of the Nitrates Directive was the development of the Nitrate Action Programme and the Code of Good Agriculture Practice for Malta (CoGAP). The Nitrates Action Programme 2011 (hereinafter referred to as NAP 2011) was given legal effect by the Nitrates Action Programme Regulations (LN321/11). These Regulations were published in the supplement to Government Gazette Nos. 18,786 and 18,788. The aim of the Regulations is to implement the Nitrates Action Programme and to ensure compliance with Council Directive 91/676EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. Measures within this programme relate to the storage, application and discharge of both inorganic and organic fertilizers on animal holdings and agricultural fields.

1.3.2.2 Offshore Sources

(i) Aquaculture

Aquaculture activity in the Maltese Islands includes the cultivation of closed cultured species, such as sea bass and sea bream, as well as captured tuna fisheries. Being in close proximity to tuna migratory routes Malta has been the largest producer of tuna in the Mediterranean.

In total there are 9 off-shore aquaculture sites in Malta (Figure 3). Most sites are located in open, exposed waters whilst the more sheltered sites are utilized for nursery production or broodstock holding. Conditions required for the location of tuna penning vary from those of sea bass and sea bream due to their feeding habits and practices. Tuna penning cages, in fact have to be sited at least 1km offshore in exposed waters that have strong currents and away from benthic habitats that are of ecological significance[39].

Figure 6 provides an indication of the input loads of total nitrogen, total phosphorous and total organic carbon from four fish farms operating in Malta during the period 2007-2011. This data is reported for the purposes of the European Pollutant Release and Transfer Register (E-PRTR)[40]. An average of 319,038kg of total nitrogen, 53,010kg Total Phosphorous and 653,300kg Total Organic Carbon were released per year by the four offshore fishfarms.

The effects of aquaculture on water quality causes major concern due to the fact that fishfarms release large quantities of dissolved nutrients in ambient water. Moreover these nutrients are mainly released during the summer when light availability is high and thus the potential for phytoplankton blooms to occur in the

[39] Stirling Aquaculture and University of Stirling, 2012. An Aquaculture Strategy for Malta. Preparatory study and recommendations prepared for the Ministry of Resources and Rural Affairs, Government of Malta, Final Draft Report, March 2012, pp 133.

[40] http://prtr.ec.europa.eu/FacilityLevels.aspx

vicinity of these farms is highly possible. Nevertheless, numerous studies[41], both local and international, have failed to detect significant changes in chlorophyll *a* or particulate organic carbon in the water column in proximity to the fish farm cages. This phenomenon has been attributed to the dispersive nature of fishfarming sites, whereby phytoplankton cells are not around long enough to capitalize on nutrients. A study of nutrient concentrations in the water column under sea bass and sea bream cages located in the Mediterranean[42] has revealed that nutrient concentrations in the vicinity of the farms, exhibit daily cyclical changes. This strongly suggests that nutrient dispersion is a very efficient mechanism.

Environmental monitoring of aquaculture activities in the Maltese Islands has been carried out since 1991 to date. Despite the fact that the negative impact to the benthic environment found directly beneath the fish cages is well known, very little impact has been observed in terms of water quality[43]. Yearly monitoring results have shown that aquaculture activities rarely have an impact on the nutrient quality of the water column *per se*[44]. Results for nutrient contamination of the sediment matrix are less conclusive. The impacts of aquaculture on marine quality vary on the type of farm, i.e. for closed cycle species (i.e. Sea bass and sea bream) and tuna penning (refer to sections below).

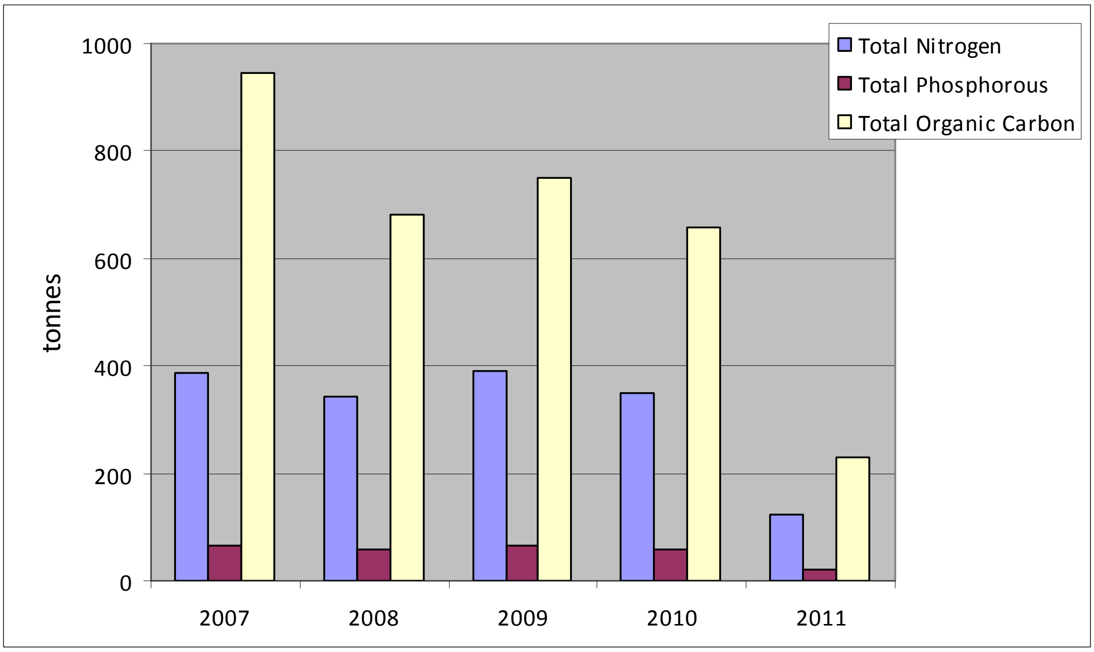
[41] Holmer, M., Kupka Hansen, P., Karakassis, I., Borg, J.A. and Schembri, P.J. 2008. Monitoring of Environmental Impacts of Marine Aquaculture in M. Holmes et al. (eds.), Aquaculture in the Ecosystem, Springer, 2 47-85.

[42] Karakassis, I., Tsapakis, M., Hatziyanni., E., and Pitta, P. 2001. Diel variation of nutrients and chlorophyll in sea bream and sea bass cages in the Mediterranean in Fresenius Environmental Bulletin 10: 278-283

[43] Borg, J.A. and 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.

[44] Ecoserv Monitoring reports Data submitted for Fish and Fish Ltd and Malta Fishfarming Limited Tuna penning monitoring data 2007-2010.

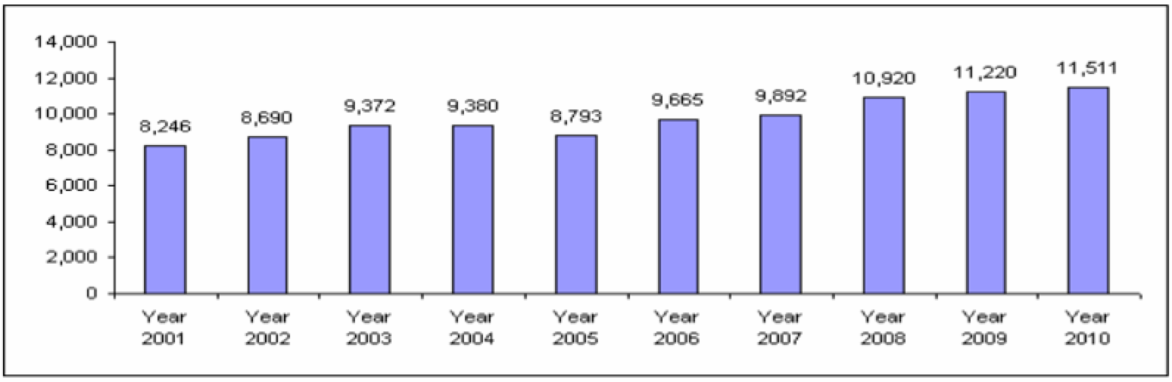
Figure 6: Loads of Total Nitrogen, Total Phosphorous and Total Organic Carbon per year as reported for the purposes of the E-PRTR by four fish farm cages operating in Malta. During 2010, one fish farm was not operating. Note that not all data used in this figure has been validated through the E-PRTR process.



(ii) Discharges from ships and pleasure craft

Given its strategic location and strong tourism sector, shipping and recreational boating activity is extensive in the Maltese Islands (Figure 7). Discharges from ships and pleasure craft are a diffuse source of nutrient input and therefore to date it has been very difficult to quantify nutrient input loads from this sector. The increase in number of vessels arriving in Malta as indicated in Figure 7, would imply an increase in discharges from ships and pleasure crafts. On the other hand, recent years have witnessed the coming into force of a number of legislative pieces with an aim to control sewage disposal and other wastes onboard the vessel and within ports and marinas.

Figure 7: Number of vessels arriving in Malta[45]



The Port Reception Facilities for Ship-generated Waste and Cargo Residues Legal Notice (legal notice S.L. 499.30 transposed from 2000/59/EC)[46] requires that adequate port reception for ship-generated waste, i.e. waste that is generated through the normal operations of the ship, be provided to vessels (size and passenger restriction applies) both calling internationally or based locally in order to deliver the latter without causing undue delay to the vessel in the main port of call.

Additionally the Recreational Crafts Directive 94/25/EC as amended by Directive 2003/44/EC on recreational craft is the centrepiece of the EU's legislation for the boating industry. It sets minimum safety and environmental requirements for boats between 2.5m and 24m, personal watercraft, engines and some components. The Directive is currently under revision in the European Parliament and the Council, with an expected adoption by the end of 2012 - early 2013. The proposal calls for the mandatory fitting of holding tanks or on-board water treatment systems to prevent the discharge of sewage at sea[47].

45 Transport Malta, Annual Report 2010

46 Subsidiary Legislation 499.30 Port Reception Facilties for Ship generated waste and Cargo Residues Regulations,2004, http://www.justiceservices.gov.mt/DownloadDocument.aspx?app=lom&itemid=11352

47 COM (2011) 456, Proposal for a Directive of the European Parliament and of the Council on recreational craft and personal watercraft. 2011. Brussels.

1.4 State: Water quality in our Marine Environment

To date the state of nutrients in Malta has, to a large extent, been monitored by means of obligations arising from the Barcelona Convention. In addition since accession to the European Union, Malta has further obligations to assess eutrophication, as described in previous sections. Attempts, therefore, to assess eutrophication are very recent and are currently ongoing at the time of compiling this report.

Data on nutrient levels in Malta exists for the period 2000-2006. However methodologies used in generating this past data differ from those used more recently, rendering comparative assessments or identification of trends difficult. Data analysis and assessment of status for the purposes of this report are thus based on the more recent data collected in 2007-2008 and the latest data collected as part of the Water Framework Directive monitoring regime[48].

Since 2011 the parameters listed in Table 2, supportive of the TRIX index[49] are being monitored monthly for a period of one year every four year cycle for coastal waters up to one nautical mile as part of the monitoring regime of the EU Water Framework Directive. No nutrient national standards or thresholds have been adopted however the TRIX value[50] indicator for Eutrophication has been specifically calculated for three inlets.

Table 2: National water monitoring parameters related to eutrophication

Parameter	Relevance to monitoring Eutrophication
Temperature	Supporting physico chemical parameter as it controls the rate of many biological parameters.
pH	When pollution results in higher algal and plant growth (e.g., from increased temperature or excess nutrients), pH levels may increase. Although small changes in pH are not likely to have a direct impact on aquatic life, they greatly influence the availability and solubility of all chemical forms in water and may aggravate nutrient problems. For example, a change in pH may increase the solubility of phosphorus, making it more available for plant growth and resulting in a greater long-term demand for dissolved oxygen.
Transparency	A decrease in water transparency (i.e. increased turbidity) is

48 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

49 The TRIX index or Trophical Index for Marine systems is an index developed by Vollenweider *et al*. 1998 based on chlorophyll-a, oxygen saturation, total nitrogen and total phosphorus to characterise the trophic state of coastal and marine waters. Such an index assesses the trophic potential of a water body but does not inform on the actual state and changes in the biological community.

50 Interpretation of TRIX Values:
TRIX Scale 0-4 corresponds to high water quality and low trophic level.
TRIX Scale 4-5 corresponds to good water quality and a medium trophic level.
TRIX Scale 5-6 corresponds to bad water quality and a high trophic level.
TRIX Scale > 6 corresponds to poor water quality and a very high trophic level.

	one of several signs that eutrophication is setting in
Salinity	There is no direct influence of salinity on eutrophication dynamics. However apart from the fact that certain plankton species are adapted to waters of a certain salinity range; more importantly salinity distribution within coastal areas can provide a tracer for studying the dispersion of freshwater from water catchments into the marine environment. It is expected that lower salinity plumes form at the mouths of major water catchments along the coastline of the Maltese Islands.
Dissolved Oxygen	A simple indicator healthy ecological environment and a highly variable parameter given that it reflects the photosynthesis and respiration processes occurring within a water body over 24 hours. A one time sample effort of DO could give a wrong assessment of the state of the water body particularly if taken at certain times of the day when aquatic flora have not been producing oxygen for long.
Nutrients - Nitrates - Nitrites - Total N - Orthophosphates - Total P - Ammonium - orthosilicates	Reflect the balance between a large number of physical and biological processes. Information is needed on both inorganic and dissolved organic forms of N and P. Si deficiency in coastal waters can favour dinoflagellates blooms
Chlorophyll *a*	Phytoplankton respond quickly to changes in nutrient concentrations and changes in biomass will in turn affect higher tropic levels of the food web.

1.4.1 Monitoring results

The following text provides a brief description of the nitrates data for 2007-2008 and the nutrient, chlorophyll and phytoplankton data collected in 2012 as part of the WFD baseline surveys.

1.4.1.1 Nutrient Concentrations and Dissolved Oxygen

Nitrate maxima and annual average concentration of nitrates measured in 2007-2008 were reported as part of Malta’s Annex V Nitrates Directive Report[51]. The annual average nitrate concentrations was between 10-25mg/l in about 10% of the coastal stations monitored, with winter averages exceeding 25mg/L in two stations located at the landward side of a relatively deep inlet/bay presumably receiving significant land run-off. Eutrophication was not assessed in this report.

[51] http://cdr.eionet.europa.eu/mt/eu/nid/envuw2tlg

Figure 8 - Figure 10 show the concentrations of nitrates, total nitrogen and total phosphorous throughout the stations sampled as part of the WFD pilot and baseline surveys carried out between May – November 2012[52].

Nitrate concentrations were generally low, with the relatively higher concentrations (between 2-10mg/L) recorded in June/July and September. In June/July such concentrations were recorded in stations located in inlets or bays and in one station along the Northeastern coastline of mainland Malta which area was until recently (2011) subject to discharge of untreated sewage. Concentrations between 2-10mg/L were recorded more frequently in September 2012. September would generally coincide with the initial episodes of heavy rainfall in Malta. The link to rainfall, hence runoff, however is only being postulated in this report. Longer term data would be able to confirm this assumption or otherwise. It should however be noted that nitrate concentrations between 2-10mg/L were not recorded in the following months (October/November), during which heavy rainfall, similar to that in September, may also be recorded. At this time nitrates in all stations were Below Detection Limits.

Total nitrogen concentrations were also relatively low ranging from <1.0 – 4.0mg/L throughout the sampling sessions between May and September 2012. The highest concentrations of total nitrogen, between 4.0 – 6.0mg/L, were only recorded in two stations in October/November 2012.

Total phosphorous concentrations are consistently low exceeding 0.3mg/L only in October/November, during which month concentrations reached approximately 1mg/L within a station off the Northeastern tip of mainland Malta.

Monthly values of dissolved oxygen measured at a depth of 5m from the stations monitored as part of the WFD pilot and baseline surveys between May and November 2012 are indicated in Figure 11. The values are quite homogenous across stations ranging between 6.09 and 7.35mg/L throughout the whole sampling period and DO percent saturation varied between 93 to 110%. Although one time DO values should be interpreted with caution due to their propensity to fluctuate depending on the time of day and depth of sampling, the resulting average values are indicative of healthy DO levels. Hypoxic conditions were not recorded.

This data is too temporally limited to be able to determine trends in nutrient concentrations or spatial and seasonal patterns. General observations from this preliminary data indicate that phosphorous is present in the lower concentrations ranging from <0.1 and 1.0mg/L, corroborating the fact that this element generally represents a limiting factor to primary production in Mediterranean waters. Overall, all nutrients are considered to be within normal ranges, with increases observed during the months of September (for nitrates), October and November (for total nitrogen and total phosphorous).

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[52] 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 8: Mean nitrate concentrations measured during the WFD pilot survey (May/June 2012) and baseline surveys carried out between August – November 2012.

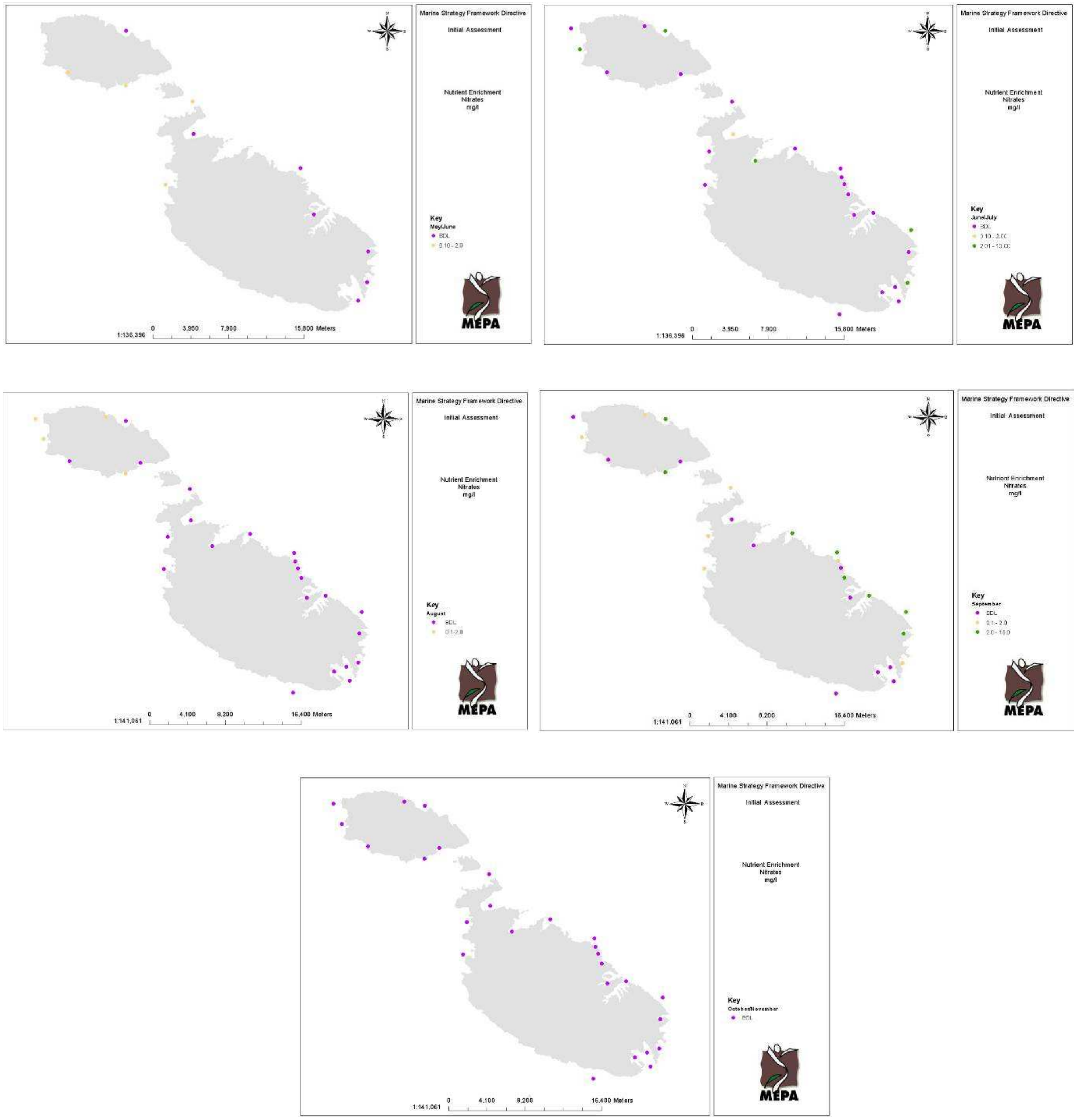


Figure 9: Mean total nitrogen concentrations measured during the WFD pilot survey (May/June 2012) and baseline surveys carried out between August – November 2012.

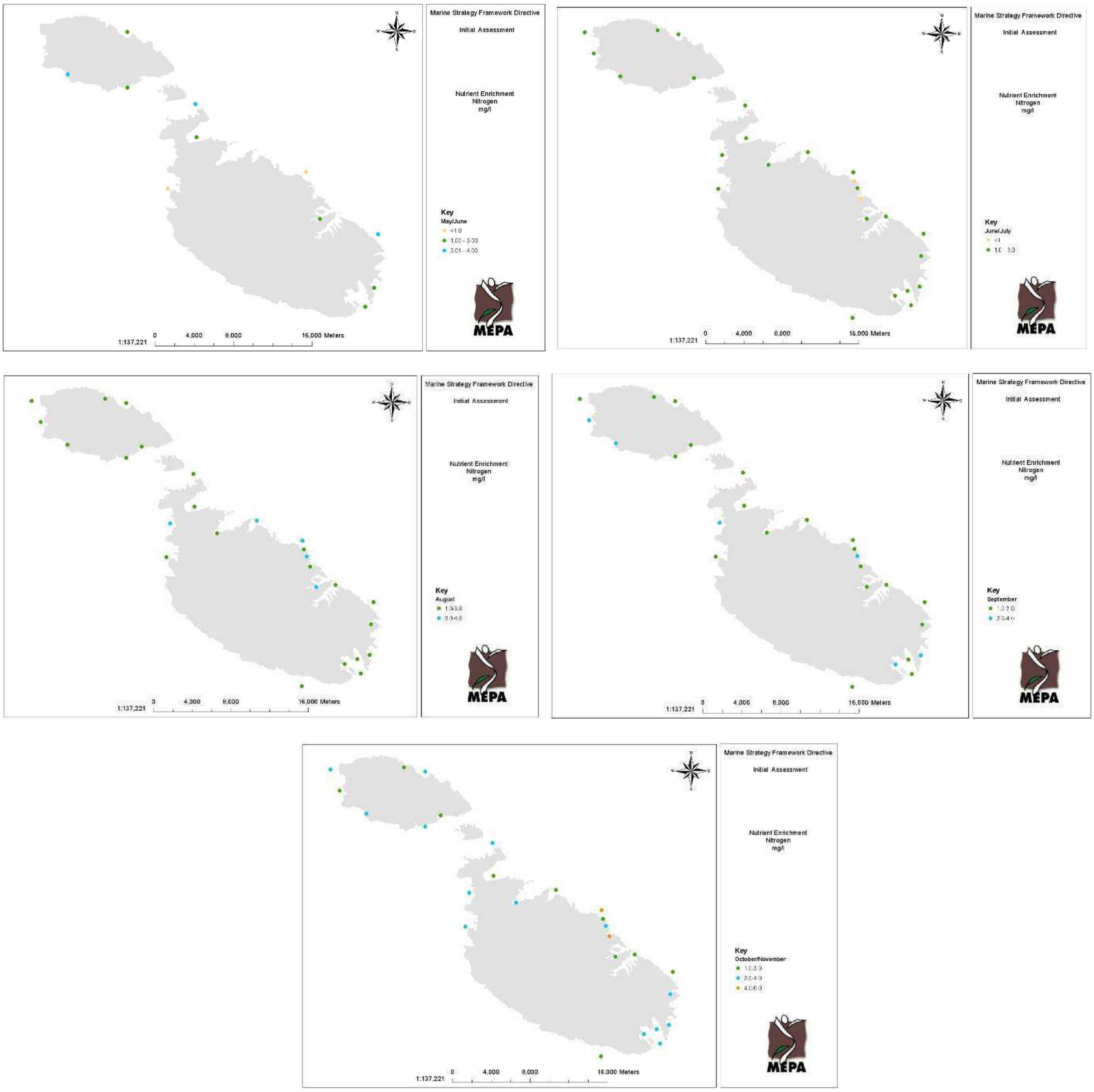


Figure 10: Mean total phosphorous concentrations measured during the WFD pilot survey (May/June 2012) and baseline surveys carried out between August – November 2012.

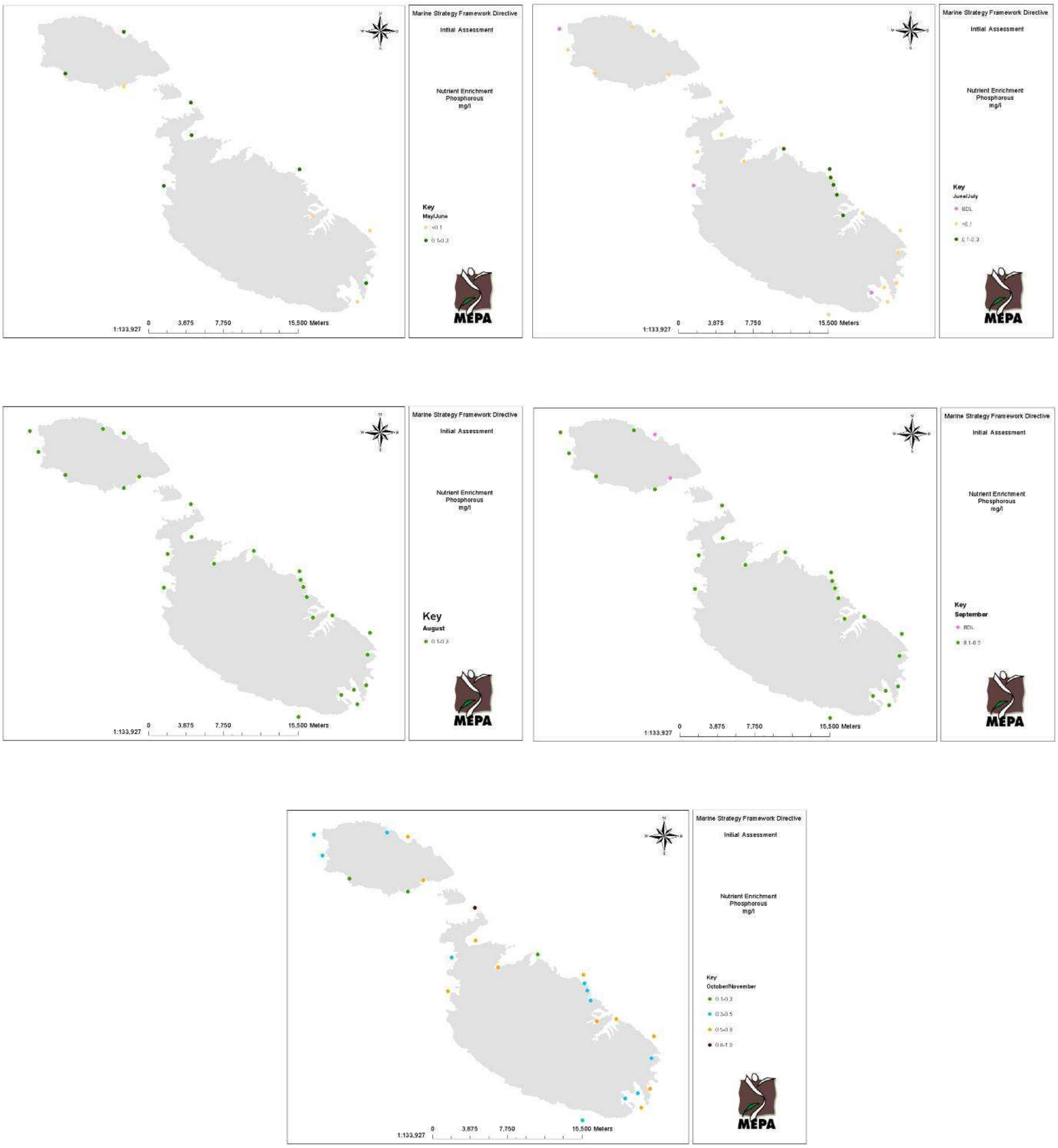
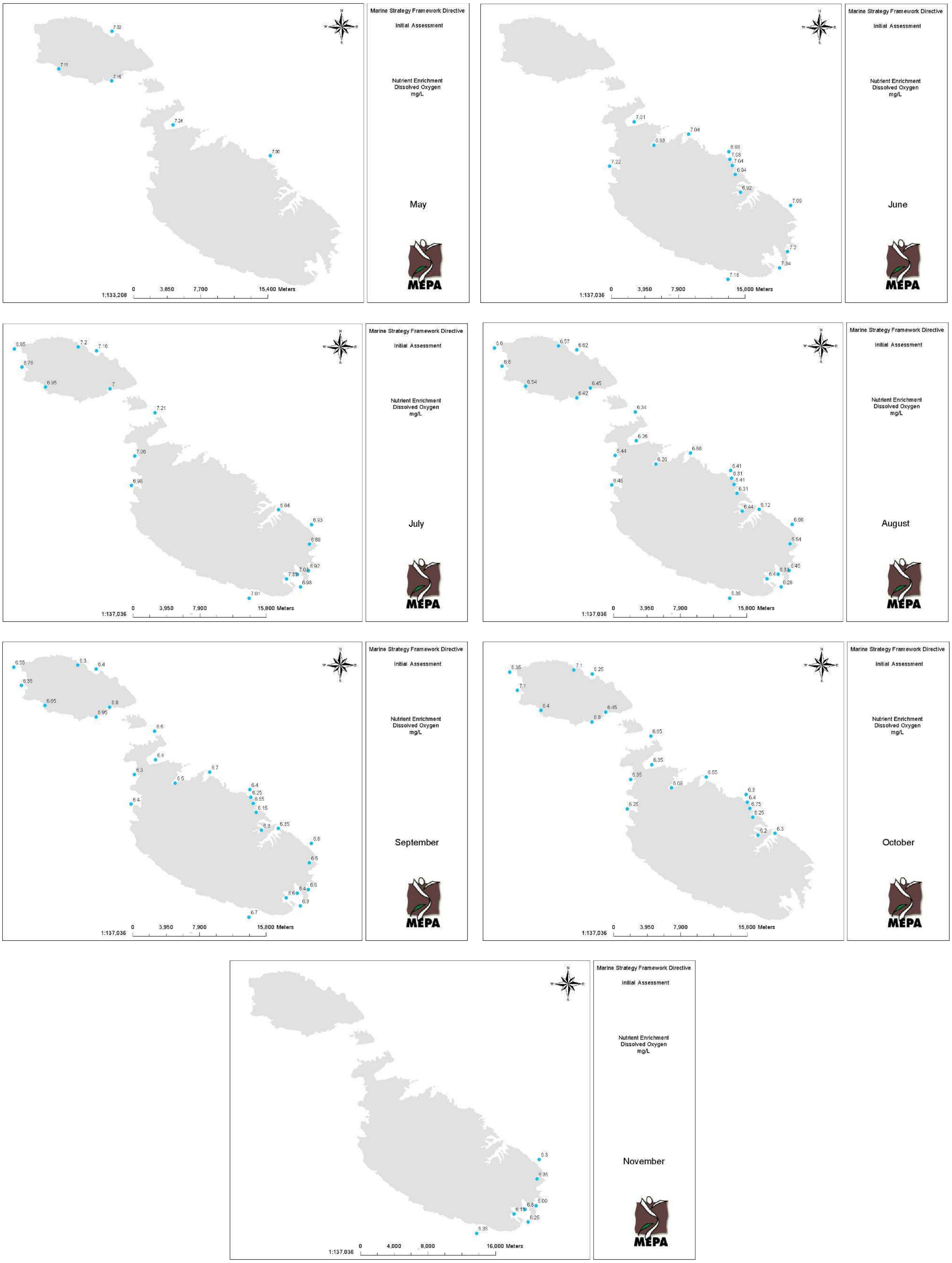


Figure 11: Dissolved oxygen measured within stations as part of the WFD baseline surveys.



1.4.1.2 Chlorophyll concentrations and phytoplankton

Biomass, composition and abundance of phytoplankton constitute key elements for assessment of the ecological quality status of coastal waters in line with the requirements of the EU Water Framework Directive. 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[53]. 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.

The distribution of chlorophyll-a concentrations and phytoplankton abundances resulting from the WFD pilot and baseline surveys are indicated in Figure 12 and Figure 13. Chlorophyll-a concentrations measured through these surveys 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. In June 2012 a bloom of *Skeletonema* cf *pseudocostatum*, which is known to be abundant in late spring, was recorded in the Grand Harbour area, however this species was quite scarce in August 2012.
- Coccolithophores are very scarce throughout all sampling stations;
- A few individuals belonging to potentially harmful taxa were observed, however their abundances were scarce.

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[53] 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

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[54]). 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.

[54] 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 12: Chlorophyll-a concentrations measured during the WFD pilot survey (May/June 2012) and baseline surveys carried out between August – November 2012.

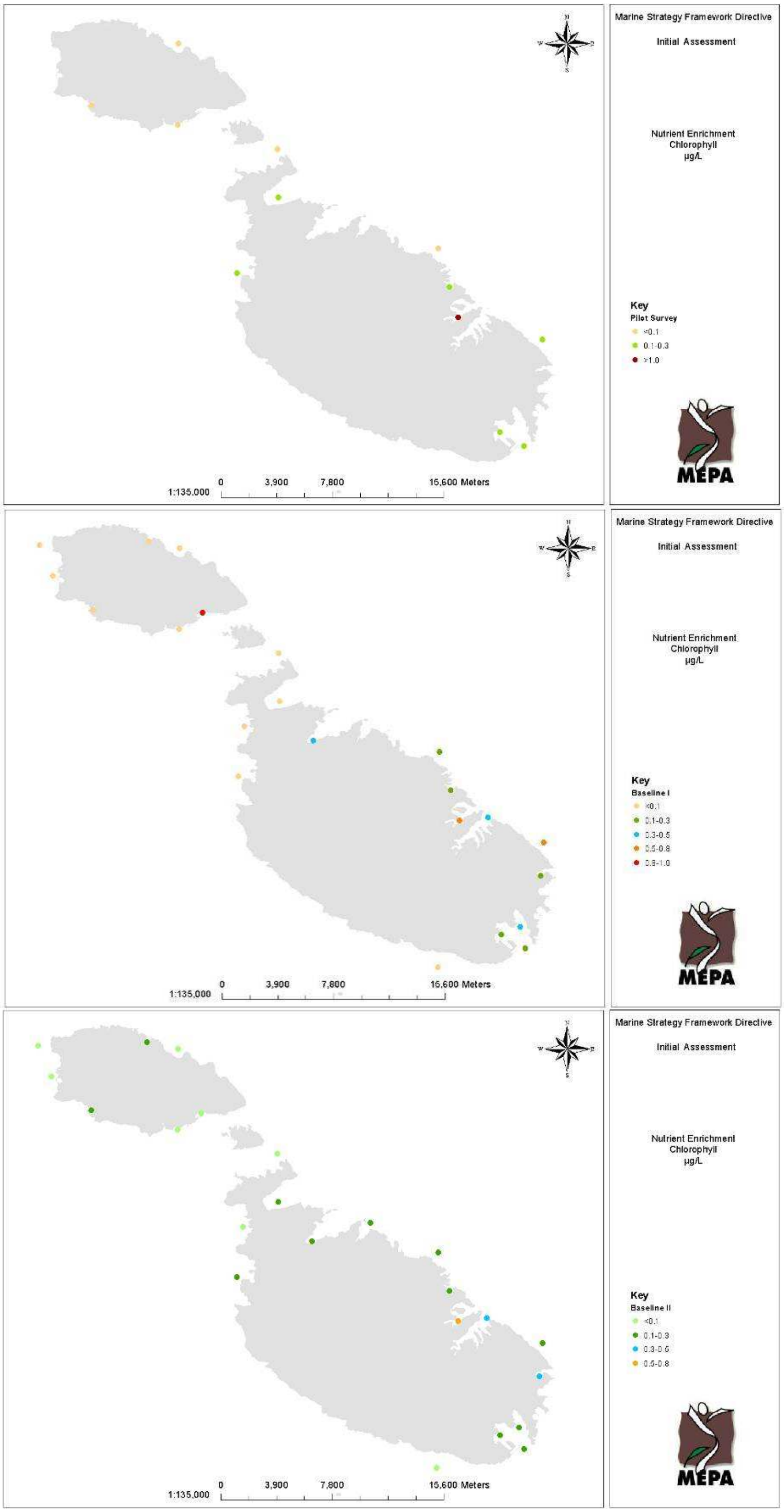


Figure 13: Phytoplankton abundance (cells per litre X 10^4) measured during the WFD pilot survey (May/June 2012) and baseline surveys carried out between August – November 2012.

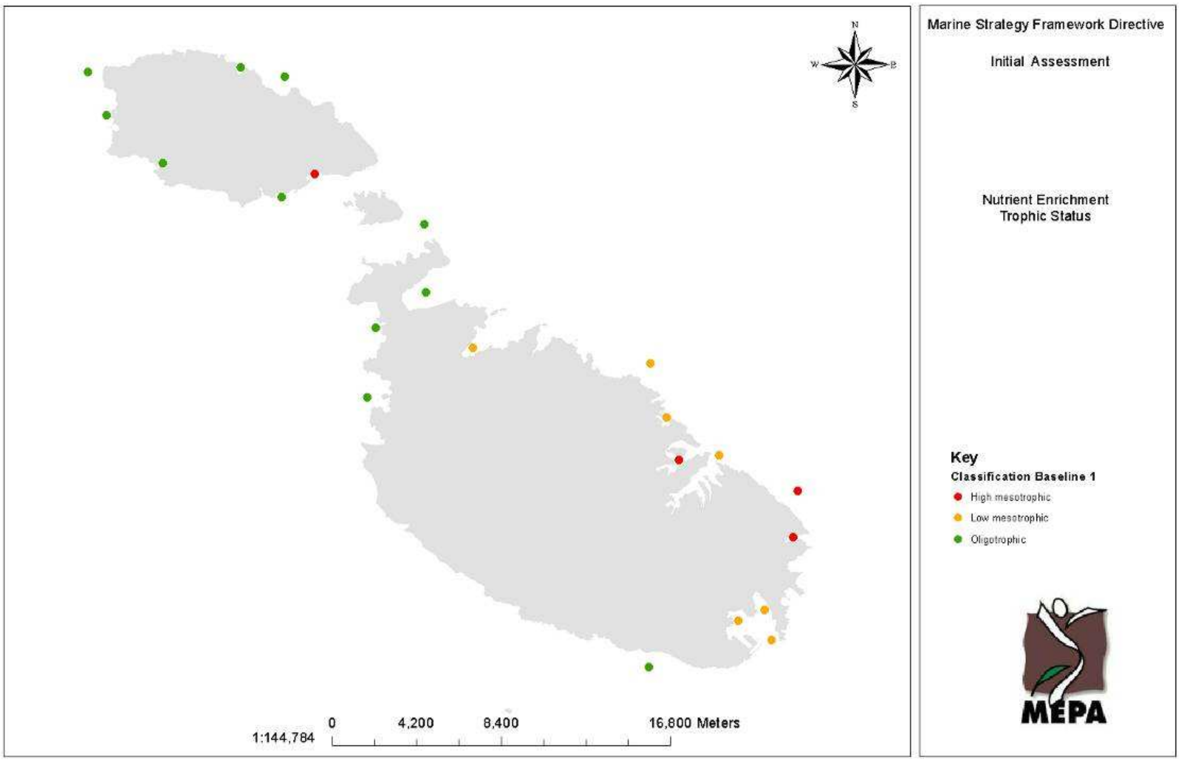
CIBM and Ambiente (2013), based on the assumption that Malta is characterized by Type IIIE waters as per 2008/915/EC[55], classified sampled stations on the basis of chlorophyll-a concentrations in accordance with the eutrophication scale developed by Simboura et al. (2005) (Figure). The following observations are noted:

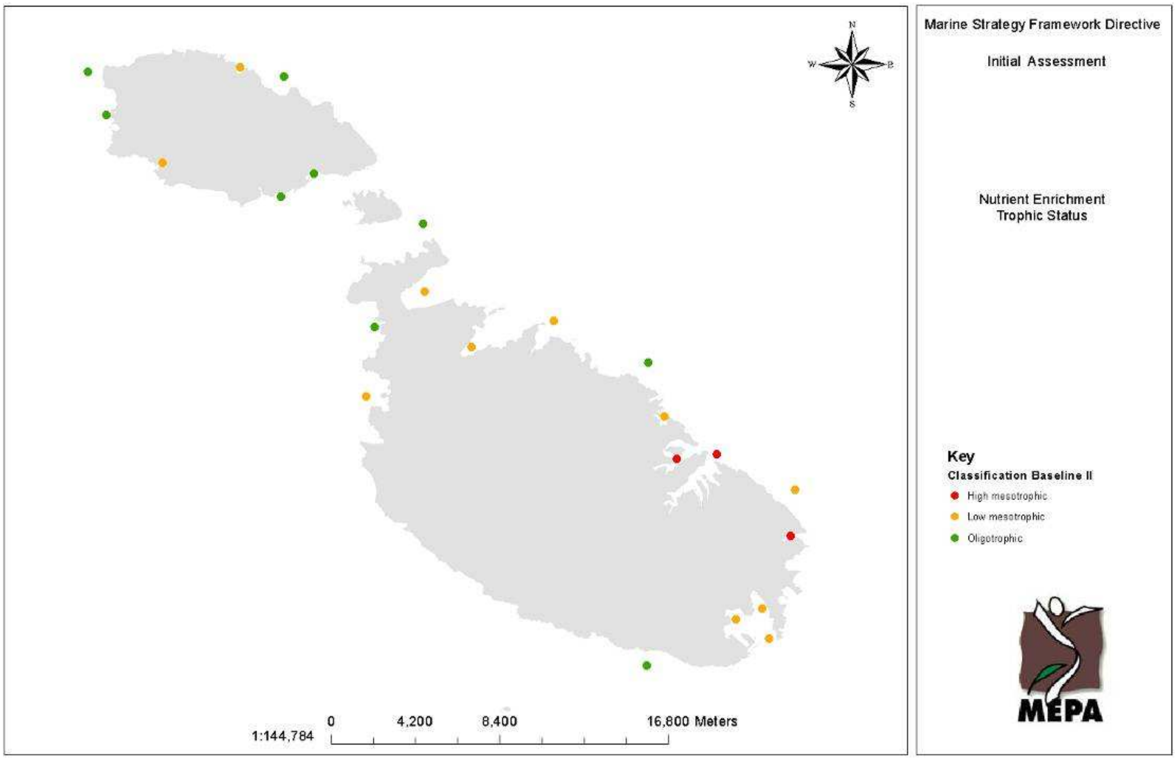
- Seven stations in Gozo, South Comino Channel and coastal waters off western Malta were constantly classified as 'oligotrophic';
- Five stations along the Northeastern and Eastern coast of Malta consistently classified as 'lower mesotrophic';
- One station within the Grand Harbour and another in Marsascala Bay consistently classifying as 'high mesotrophic'.

Abundance of phytoplankton corroborates with this classification based on chlorophyll-a concentration, with the 'oligotrophic sites' characterised by cell numbers <2.5 x10^4 cells per litre and the 'high mesotrophic sites' characterised by cell abundances >10^5 cells per litre.

[55] The Mediterranean subgroup (MEDGIG) working under the Common Implementation Strategy of the Water Framework Directive classified Mediterranean waters into three types for to differentiate between chlorophyll, differences across the Mediterranean region. These types, mainly focused on hydrological parameters characterizing water bodies' dynamics and circulation, were derived from temperature and salinity values in the water column. These types can be described as follows:
Type 1: coastal sites highly influenced by freshwater inputs (σt<25, annual mean salinity <34.5)
Type 2: coastal sites not directly affected by freshwater inputs (25<σt<27, annual mean salinity 34.5<S<37.5)
Type 3: coastal sites not affected by freshwater inputs (σt>27, annual mean salinity >37.5)
A further distinction regarding the splitting of the coastal water type 3 in two different sub basins, the Western and the Eastern Mediterranean one, according to the different trophic conditions was also suggested. Therefore the coastal waters of the Maltese Islands can be said to be of TYPE III E.

Figure 14: Stations sampled in Baseline I and Baseline II classified as 'oligotrophic', 'lower mesotrophic' and 'high mesotrophic' in accordance with Simboura *et al.* 2005 by CIBM & Ambiente (2013)





1.4.2 Ocean Colour Data

A recent attempt to correlate MODIS ocean colour data with *in situ* chlorophyll data confirmed the oligotrophic nature of national coastal waters[56]. This study attempted a statistical comparison of satellite colour data (MODIS), for a near-shore marine area off the north-east coastline of Malta, with *in situ* surface chlorophyll-a measurements. The study extracted a twelve month ocean colour data series for the same marine area. Typical to Mediterranean waters, two peaks of ocean colour values were observed in Malta during the winter months of late January/early February. However, the lowest values of surface chlorophyll were recorded during the early spring period. The mean annual ocean colour value for the total sampling stations ranged from 0.247mg/m^3 and 0.361mg/m^3, confirming the oligotrophic nature of our coastal waters.

The comparison of MODIS dataset values with in-situ surface chlorophyll a measurements resulted in the MODIS dataset providing underestimates of the surface chlorophyll a values. The match-up between satellite and in situ values was only partly consistent.

Azzopardi *et al*. (2013)[57] used multi-annual ocean colour time series to infer productivity information in Malta. The analysis carried out at WFD water body level, is as follows:

- Monthly reanalysis of OceanColour MODIS Satellite TimeSeries between 01/07/2002 and 31/12/2009;
- Monthly reanalysis of OceanColour MODIS, MERIS and SeaWIFS Satellite TimeSeries between 01/01/2010 and 31/12/2011; and
- Weekly reanalysis of OceanColour MODIS, MERIS and SeaWIFS Satellite TimeSeries between 01/01/2010 and 31/12/2011.

The WFD coastal water bodies were classified according to arbitrary indices of ocean colour chlorophyll-a values, based on seasonal values average out over the entire 2003-2011 period.

The pattern emerging from the seasonal ocean colour plots for each year is indicative of the fact that all water bodies are consistent with an oligotrophic water body, with seasonal mean values of chlorophyll-a 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

[56] Deidun, A., Drago, A., Gauci, A., Galea, A., Azzopardi, J. and 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 Remote Sensing of the Ocean, Sea Ice, Coastal Waters and Large Water Regions, Proc of SPIE 8175, 1-8.

[57] 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 12thInternational Coastal Symposium* (Plymouth, England), *Journal of Coastal Research*, Special Issue No. 65

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. Higher ocean colour values were registered for MTC 107 in spring and summer of 2010 and 2011 and for MTC 108 in autumn 2011. 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 the nature or location of these areas (MTC 107 includes the Marsaxlokk bay which might be subject to occasional eutrophication events and both MTC 107 and MTC 108 are downwind from the major treated sewage outfall at Ta' Barkat) and activities within such water bodies such as aquaculture activities (in MTC 107).

1.4.3 Case Study: eutrophication in three coastal inlets (representative of semi-enclosed marine waters)

1.4.3.1 Nutrient levels and TRIX indices

Recent nutrient monitoring in three coastal inlets, highly influenced by agricultural runoff (Marsaxlokk, Salini and Xlendi Bay) was carried out during the winter and spring months of 2012[58]. Table 3 provides the minima and maxima of the various parameters measured through this survey, while Table 4 provides an indication of the TRIX values measured for the three sites throughout the whole sampling session. Figure 11 - Figure 14 indicate the seasonal variations in surface and bottom concentrations of nitrates, total nitrogen, total phosphorous and silica at the three sites in question.

Overall, nitrate levels were most pronounced in spring (March-April), which was reflected as a high TRIX value also during these months. This high trophic status could be associated with fertilization practices of agricultural land during this period. However, TRIX values were also high when nitrate levels were not so elevated, especially for Salini. TRIX status thus cannot be ascribed to one parameter in particular. In general high TRIX values, were associated with rainfall episodes and surface runoff, but thermal stratification and water stagnation may also be contributing factors. Out of the three sites investigated, Salini is considered to be the most vulnerable to eutrophic conditions, a status that is attributed to the wide catchment area inputting surface runoff into the coastal waters in question.

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

The concentrations of dissolved inorganic phosphorous were generally very low at both surface and bottom with maxima detected in August and October. In fact mean concentrations are highest in autumn for all three sites. According to AIS (2013), the annual distribution of the ratio between total inorganic N and inorganic P, follows the temporal distribution of nitrates.

Silica concentrations vary widely between low values and 6.10mg/L. The silica content within the sampling points is highly influenced by phytoplankton activity. High silica concentrations are generally attributed to its low consumption in view of scarce growth of diatoms.

Concentration of chlorophyll-a were always below detection limit (0.03 $\mu g/m^3$) for all three sites, for all seasons.

Table 3: Minima and Maxima for parameters measured in one year (February 2012 – January 2013) at three enclosed bays: Marsaxlokk, Salini and Xlendi in 2012[59].

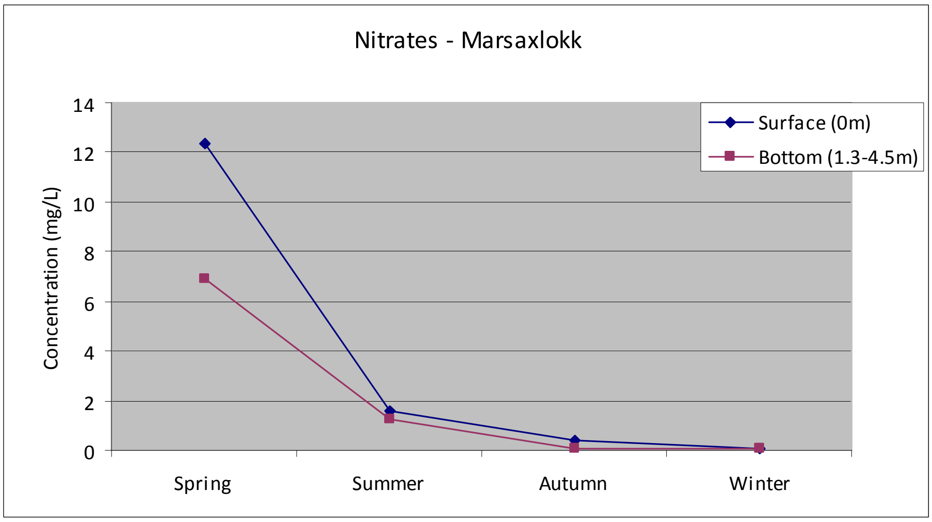
Site	Depth (m)	Nitrates (mg/L)		Total Nitrogen (mg/L)		Total Phosphorous (mg/L)		Silica (mg/L)		Chlorophyll (μg/L)		Dissolved Oxygen		Turbidity (NTU)	
		Minima	Maxima	Minima	Maxima	Minima	Maxima	Minima	Maxima	Minima	Maxima	Minima	Maxima	Minima	Maxima
MXlokk	**0m**	<0.1	29.00	1.00	9.50	<0.1	0.79	<0.05	6.10	<0.3		83.7	100.1	<0.1	0.90
	1.3-4.5	<0.1	28.00	0.75	7.50	<0.1	1.20	<0.05	4.60	<0.3		88.6	98.7	<0.1	2.80
Salini	**0m**	<0.1	42.00	1.10	12.00	<0.1	0.71	<0.05	3.30	<0.3		85.3	99.1	<0.1	0.82
	0.7-1.4	<0.1	29.00	0.75	8.00	<0.1	0.67	<0.05	2.90	<0.3		86.4	98.0	<0.1	0.67
Xlendi	**0m**	<0.1	35.00	1.20	13.00	<0.1	0.61	<0.05	6.80	<0.3		88.6	128.8	<0.1	0.60
	2.5->5	<0.1	30.00	1.10	11.00	<0.1	0.70	<0.05	2.70	<0.3		89.7	130.0	<0.1	0.40

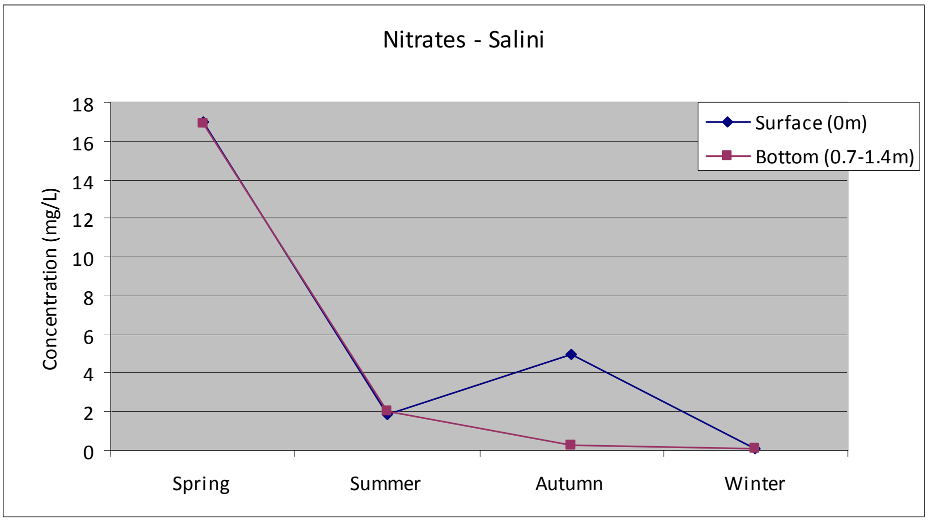
Table 4: TRIX index for the three locations[60].

Site	TRIX index		Trophic Status
	Surface waters	Bottom waters	
Marsaxlokk	4 - >6	4 - >6	Good Water Quality and medium trophic level – Poor water quality and a very high trophic level.
Salini	4 - >6	4 - >6	Good Water Quality and medium trophic level – Poor water quality and a very high trophic level.
Xlendi	4 - >6	4 - >6	Good Water Quality and medium trophic level – Poor water quality and a very high trophic level.

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

Figure 11: Seasonal mean nitrate concentrations at surface waters and waters at 0.7->5m depth for Marsaxlokk Bay, Salini Bay and Xlendi Bay





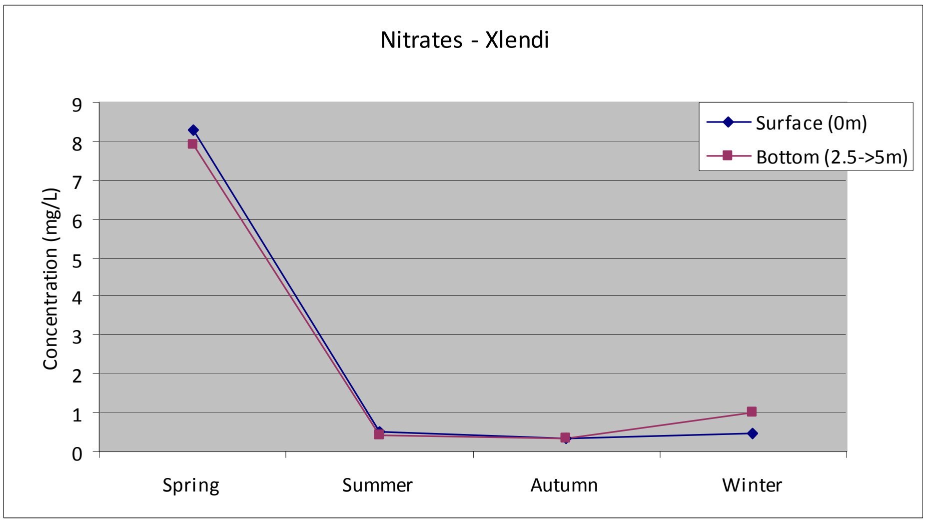
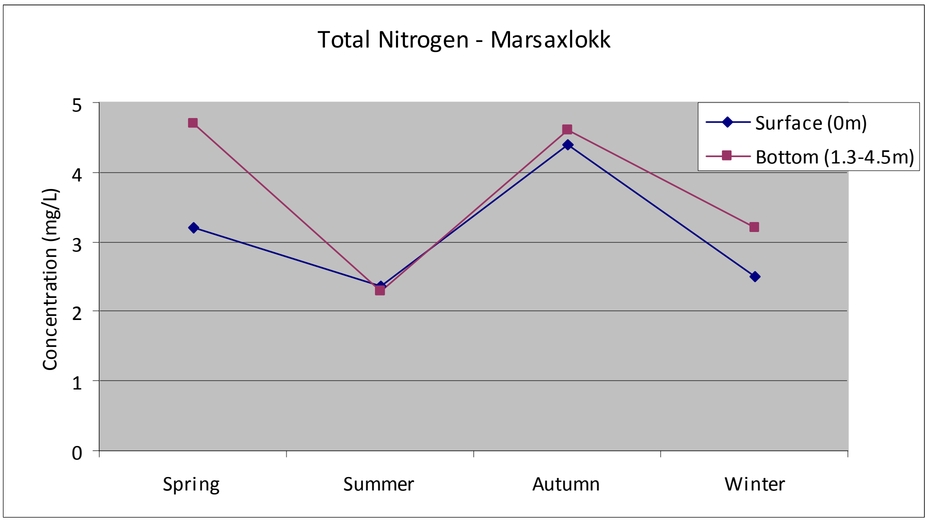
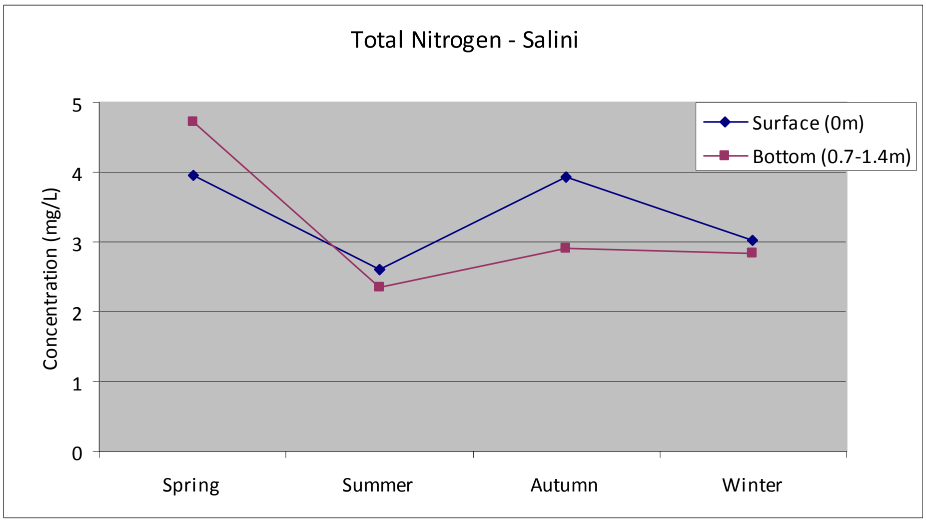


Figure 12: Seasonal mean Total Nitrogen concentrations at surface waters and waters at 0.7->5m depth for Marsaxlokk Bay, Salini Bay and Xlendi Bay





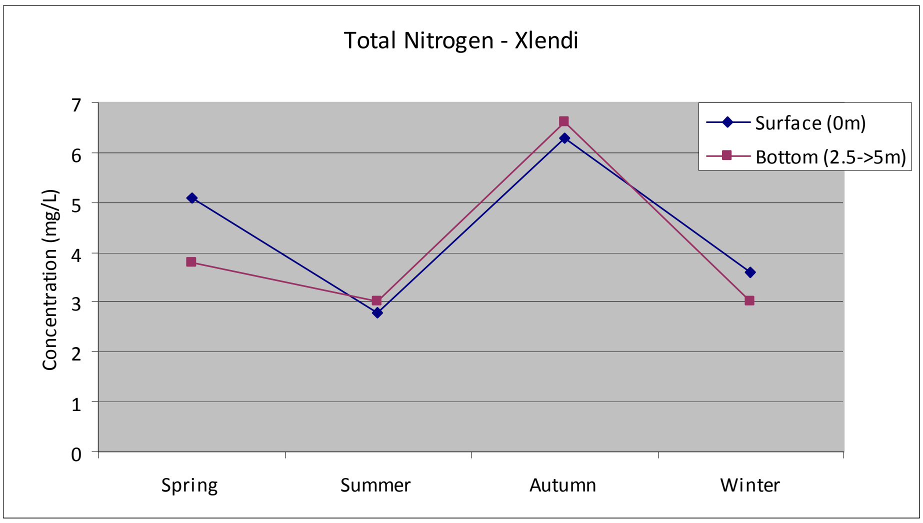
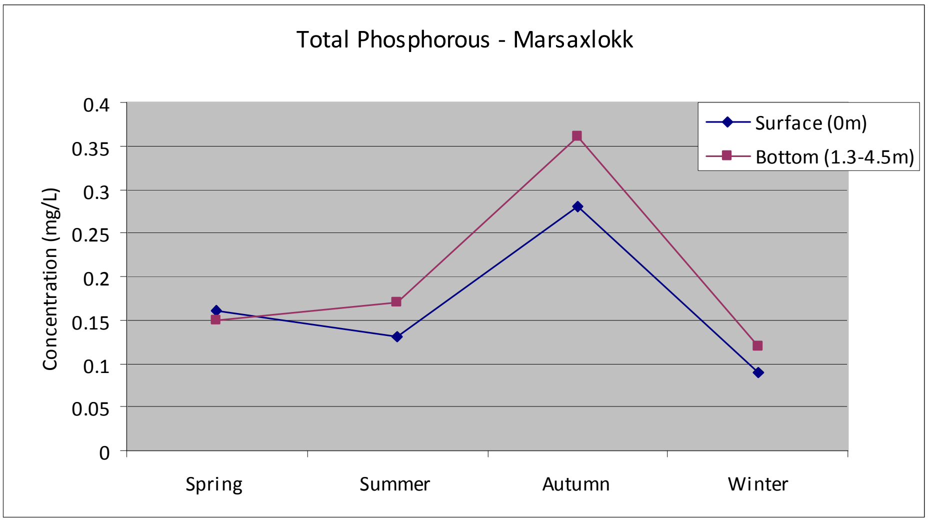
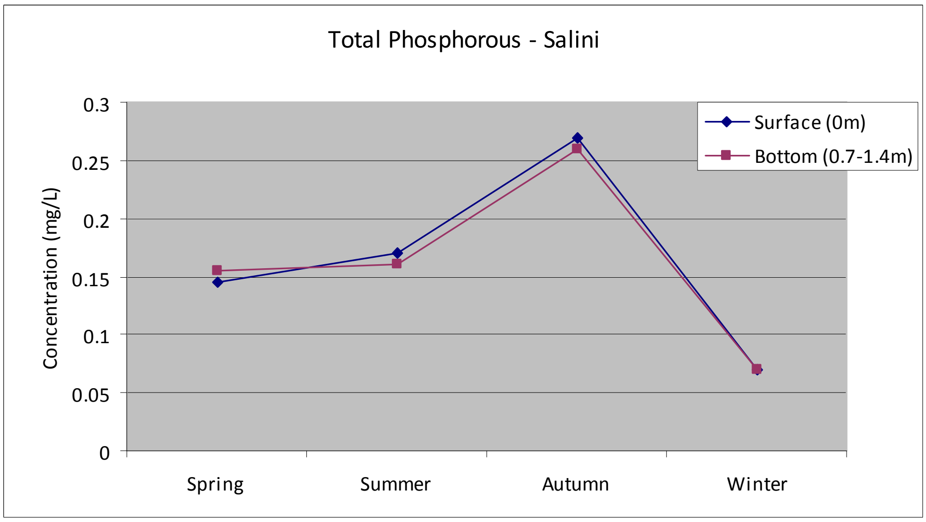


Figure 13: Seasonal mean Total Phosphorous concentrations at surface waters and waters at 0.7->5m depth for Marsaxlokk Bay, Salini Bay and Xlendi Bay





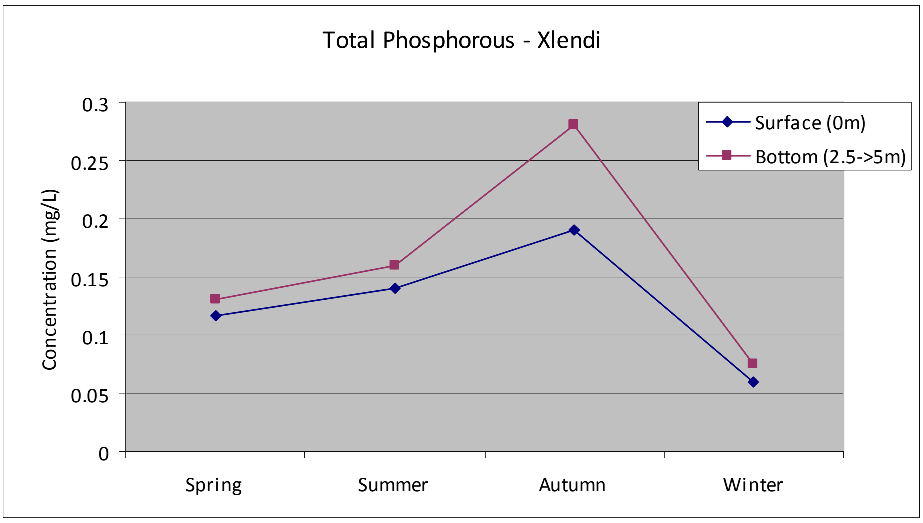
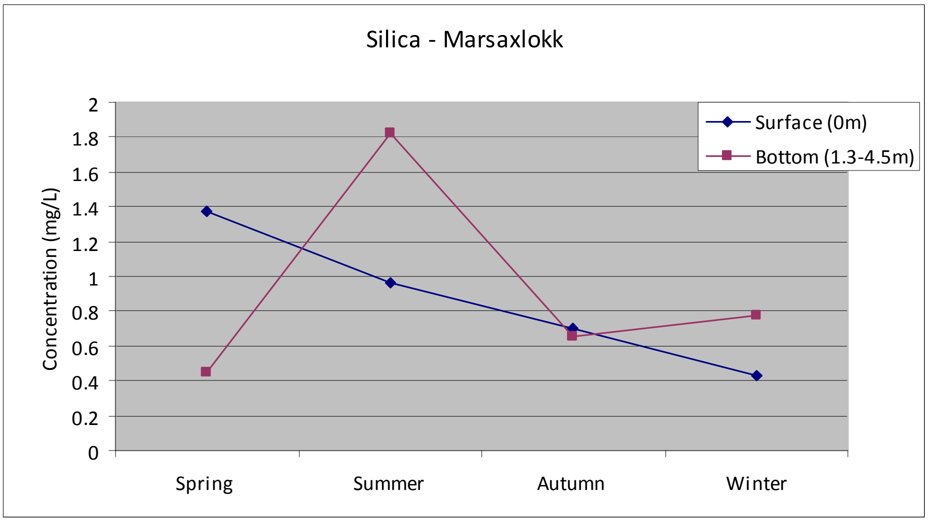
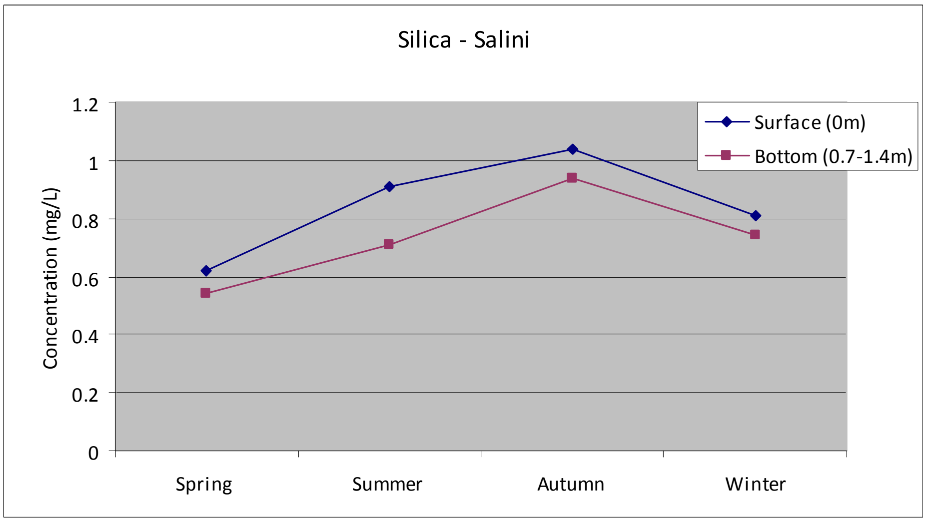
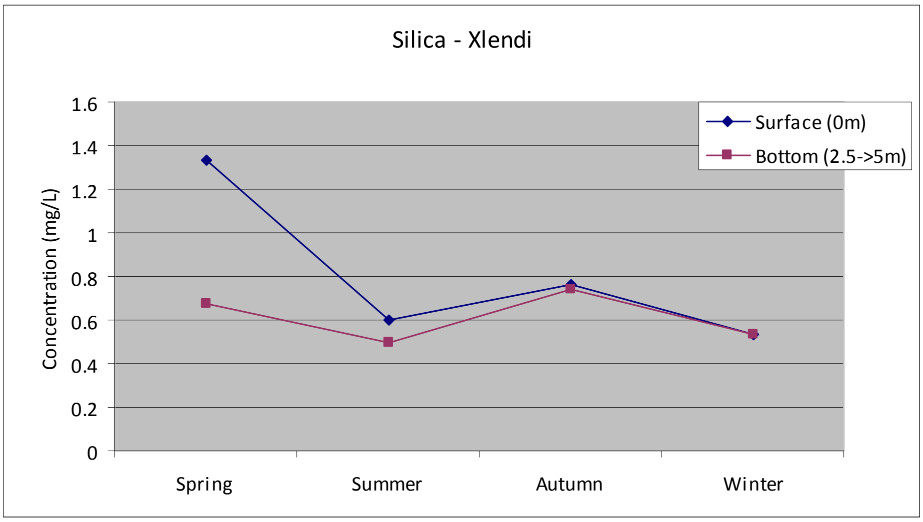


Figure 14: Seasonal mean Silica concentrations at surface waters and waters at 0.7->5m depth for Marsaxlokk Bay, Salini Bay and Xlendi Bay







1.4.3.2 Phytoplankton communities

The phytoplanktonic communities were assessed for Marsaxlokk, Salini and Xlendi during the months of February, August, November and December[61]. Table 5 lists the species identified from all three sites, while Figure 15 provides an indication of the variations in plankton abundance, differentiated into diatoms and flagellates, and compared against levels of silica reported during the months in question.

All three sites are predominantly characterized 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.

When silicates represent a limiting factor for the development of diatoms, other opportunistic algal species can grow. In this regard, it is expected that high levels of silicates would precede peaks in diatom abundance, following which silicate levels would start decreasing, coupled to a decrease in diatoms. This expected pattern is only evident for Marsaxlokk Bay.

No algal blooms were recorded and the species recorded are not associated with toxic effects on aquatic communities.

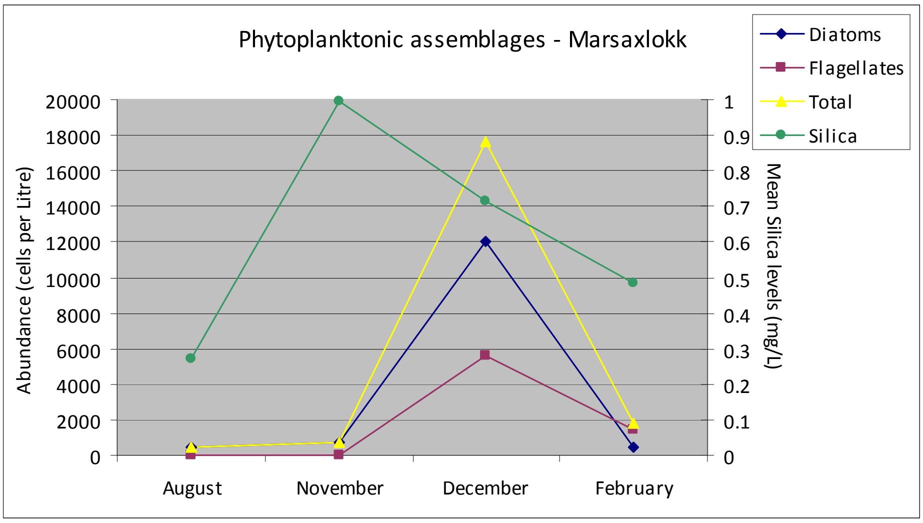
Table 5: Plankton species recorded at Salini, Marsaxlokk and Xlendi.

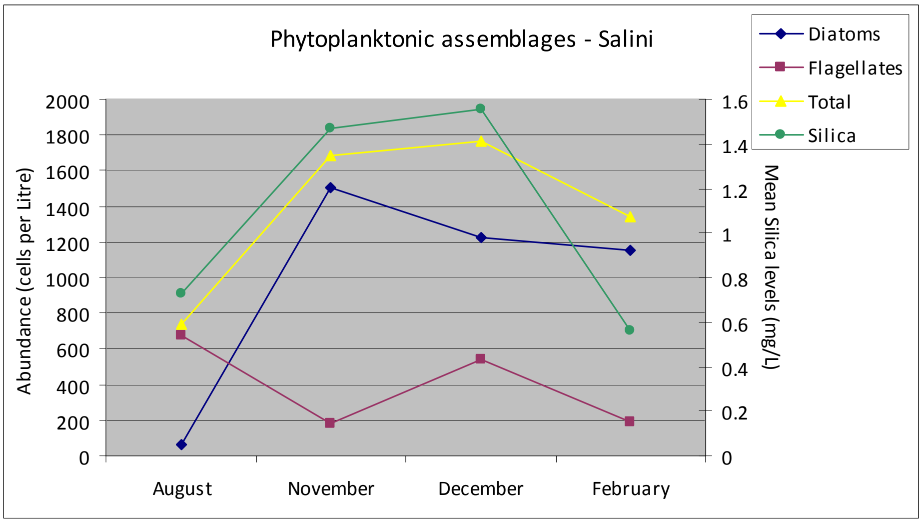
Site	Family	Species
Salini	Bacillariophyceae	*Achnanthes parvula*
		Amphora marina
		Amphora species
		Auricula species
		Cocconeis scutellum
		Cocconeis species
		Cylindrotheca closterium
		Diploneis fusca
		Diploneis species
		Fragilaria species
		Gyrosigma species
		Navicula arenaria
		Navicula crucifera
		Navicula gregaria
		Navicula transitans
		Navicula species
		Nitzschia lanceolata
		Nitzschia cf. *vermicularis*
		Nitzschia cf. *vitrea*
		Nitzschia species
		Podocystis adriatica
		Pseudonitzschia species
	Chrysophyceae	*Chromulina* species
	Chlorophyceae	*Teleaulax* species
	Dinophyceae	*Gymnodinium* species
		Prorocentrum species
Marsaxlokk	Bacillariophyceae	*Achnanthes longipes*
		Amphora obtuse
		Amphora species

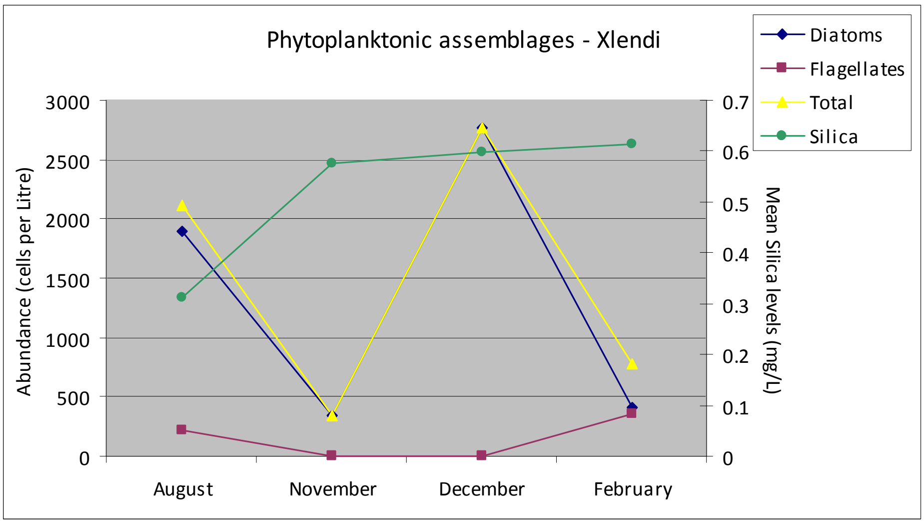
[61] AIS Environmental. 2013. Monitoring of Nutrient Status and Eutrophication Status of Selected Coastal Areas. Draft Technical Report.

		Caloneis linearis
		Caloneis species
		Chaetoceros species
		Cocconeis molesta
		Cocconeis scutellum
		Cocconeis species
		Cylindrotheca closterium
		Diploneis species
		Gyrosigma lineare
		Navicula goppertiana
		Navicula gracilis
		Navicula rhombica
		Navicula rhynchocephala
		Navicula transitans
		Nitzschia acicularis
		Nitzschia cf. *vermicularis*
		Nitzschia recta
		Nitzschia scalpelliformis
		Nitzschia species
		Opephora species
		Plagiotropsis lepidoptera
		Pseudonitzschia species
		Surirella fastuosa
		Surirella smithii
		Surirella species
		Synedra species
	Chrysophyceae	*Chromulina* species
	Chlorophyceae	*Cryptaulax* species
		Teleaulax species
	Dinophyceae	*Prorocentrum* species
		Gonyaulax species
		Gymnodinium species
	Prasinophyceae	*Cymbomonas* species
Xlendi	Bacillariophyceae	*Amphora proteus*
		Caloneis species
		Gyrosigma attenuatum
		Navicula distans
		Cocconeis scutellum
		Navicula transitans
		Navicula gregaria
		Navicula rhombica
		Synedra undulate
		Navicula distans
		Navicula species
		Nitzschia acicularis
		Nitzschia paleacea
		Amphora marina
		Auricula species
		Nitzschia species
		Nitzschia scalpelliformis
		Nitzschia sigma
		Surirella ovalis
	Chrysophyceae	*Chromulina* species
	Chlorophyceae	*Eudorina* species
		Teleaulax species
	Dinophyceae	*Gonyaulax* species
		Gymnodinium species
	Prasinophyceae	*Cymbomonas* species

Figure 15: Phytoplanktonic assemblages for Marsaxlokk Bay, Salini Bay and Xlendi Bay







1.5 Impacts on Ecosystems and Species

The various pressures described in the preceding sections all impact the coastal environment to various degrees. Local research and various monitoring reports have shed light on the extent to which some of the pressures described have impacted marine ecosystems and species, as shall be illustrated in this section. In some cases, such as aquaculture, nutrient enrichment in the water column has been found to be negligible, with impacts on benthic ecosystems being more evident through shifts in species composition. On the other hand diffuse sources from agriculture and offshore shipping could potentially contribute more significantly to nutrient-related impacts in the marine environment.

1.5.1 The occurrence of harmful algal blooms

Harmful algal blooms in coastal waters are known to occur in enclosed bays and harbours as well as areas that are frequently exposed to sewage overflows[62,63]. These harmful algal blooms consist of high concentrations of phytoplankton, some of which contain potent toxins. Their impacts vary a great deal depending on the species involved and environment in which they are found. The concentration of cells by which a particular microalgae becomes harmful varies by species.

Harmful microalgae or phytoplankton have been studied at Marsaxmett Harbour (Sliema point, Sliema Creek, Msida Creek, Pieta Creek) and the Grand Harbour (Marsa (Menqa) and Dockyard Creek in Vitorriosa[64]). Toxic and harmful phytoplankton species were found in all locations, with higher abundances in the Marsamxett harbour. The presence of particularly toxic species, such as the *Dinophysis* spp., *Gonyaulux* spp., *Gymnodinium* spp. and *Pseudontizschia* spp., are a cause of concern due to the fact that shellfish poisoning in humans has been reported to occur with concentrations as low as 1,000 cells/l. A high concentration of *Dinophysis* spp, for instance, was recorded to reach a concentration of 1.7 x 10^5 cells/l.

As indicated in the studies referred to at the start of this chapter (Jaccarini *et al*., 1978 and Aguis and Jaccarini 1982) particular harmful diatom blooms are more common in winter, coinciding with drops in salinity and sea surface temperature. Dinoflagellate blooms, on the other hand, are common during the warmer months when meteorological conditions are more stable.

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62 Debono, S. 2001. Harmful algal blooms in Maltese Coastal Waters- A preliminary Study. Unpublished B.Sc. dissertation, University of Malta.

63 Debono, S. 2004. Harmful Marine Microalgae in Malta – Further Investigations. Unpublished M.Sc. dissertation, University of Malta

64 Debono, S. 2001. Harmful algal blooms in Maltese Coastal Waters- A preliminary Study. Unpublished B.Sc. dissertation, University of Malta.

A 2004 study[65] revealed that though in the harbour areas algal growth increased with a high level of nitrates, the presence of a high concentration of nutrients did not always correlate to increased algal growths. Several instances of algal growth were accompanied by low nutrient concentrations. Often the blooming species in these cases were the opportunistic *Skeletonema costatum* and *Chaetoceros* sp. In other instances, some winter-spring blooms were reported to be affected by a high level of silicates.

1.5.2 Impacts of sewage discharges

Harmful algal blooms are not the only impact sewage discharges can have on marine waters. A study[66] on the effects of sewage discharge on coastal rocky-reef fish assemblages along the NW coast of Malta was carried out at four sites, two representative of disturbed locations, and two controlled sites. A decline in species richness was found to be significant at the two sites directly affected by sewage discharge. A decline in species richness usually reflects a severe impact on the fish community. An increase in abundance of 2 benthic species (*G. bucchichi* and *P. rouxi* species) was also detected at these disturbed sites., whilst the more sensitive species, the labrids *Simphodus spp*, *Thalassoma pavo* and scarid *Sparisoma cretense* were particularly affected by the sewage.

Moderate nutrient enrichment can influence the fish assemblage by attracting gregarious and planktivorous fishes as indicated by the increase in the *Gobius bucchichi* and *Parablennious rouxi* species in the above mentioned study. The recovery of the marine environment is expected to improve now that all waste water is being treated. The rate of this recovery, however, is yet to be indicated by the ongoing monitoring carried out under the Water Framework Directive monitoring programme.

Thibaut (2011)[67] attributes changes in biological communities on littoral rock to reduced water quality, specifically to nutrient enrichment. The MSFD Initial Assessment on benthic habitats indicates that approximately 3% of the current extent of *Cystoseira* communities on littoral rock are known to be affected by nutrient enrichment attributed to the past sewage outfall on the Northeastern coast of Malta.

Significant strides to deal with sewage discharges are at present being implemented via the operation of all three waste water treatment plants in the Maltese Islands and therefore impacts on the marine environment from this pressure are expected to diminish in the future.

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

[66] Azzurro, E., Matiddi, M., Fanelli, E., Camilleri, J., Giordano, P., Scarpato, A., Axiak, V. 2007. Effects of sewage discharges on coastal fish assemblages in Malta, Strait of Sicily in Rapp.Comm. int. mer Medit., **38**

[67] Thibaut, T. 2011. Ecological Status of the Rocky Coast of Malta, May 2008

1.5.2 Impacts of Fishfarms

Variations in the hydrographical conditions and depth of bottom substrate from farms affect the amount of organic waste found in both the water column and sediment bottoms. Changes in sediment chemistry and alterations in the benthic communities present would therefore also be variable between sites. Apart from the environmental impacts of nutrient enrichment originating from excess feed and faeces, there are also secondary potential impacts which give rise to fish stress, poor growth and even disease in the farmed fish.

Offshore sea bass and sea bream farms sited in eight localities in Malta are located in relatively shallow waters in sheltered areas (Figure 3). A case study on the impacts of fish farms in shallow waters on benthic habitats follows from the establishment of fish farm cages in 1991 at a depth of 12-16m. The fish farm in question, which has now ceased operation, pre-dated current permitting systems. This fish farm led to reduced plant growth and increased mortality in the *P. oceanica* beds located directly beneath the cages and in the vicinity[68]. These changes were attributed to the elevated nutrient levels and high sedimentation rates near the cages, which led to a high epiphytic cover of the leaves, causing a reduction in the light intensity reaching the photosynthetic tissues, possibly limiting photosynthesis and potentially causing death of the plant due to a reduced oxygen flux from the leaves to the below-ground organs[69]. These effects were noticed up to a distance of 200m. Borg *et al*. (2006) imply recovery of *P. oceanica* meadows following cessation of fish farm operation through a significant increase in shoot density[70].

Furthermore the presence of three distinct zones related to the presence and abundance of decapods, molluscs and echinoderm fauna also emerged from this study. The zone directly beneath the cages and 30m around the farm resulted in a low species richness of macrofaunal assemblages. The availability of sediment nutrients from the organic matter present permitted the succession of grazers and deposit feeders as the most dominant trophic groups present. A second zone, lying between 30-90m from the farm supported macrofaunal assemblages that had the highest species richness and abundance. The same trophic groups reported for Zone 1 were recorded here. The third zone, covering the area exceeding 90m from the farm, supported macrofaunal assemblages having a species richness and abundance value that lay between zones 1 and 2. The dominant trophic groups comprised of grazers, deposit feeders, suspension feeders and predators.

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[68] Dimech, M., Borg, J.A., and Schembri, P.J. 2002. Changes in the structure of a *Posidonia oceanica* meadow and in the diversity of associated decapods, mollusks and echinoderm assemblages resulting from inputs of waste from a marine fish farm (Malta, Central Mediterranean), Bulletin of Marine Science 71 (3): 1309-1321 in Mazik, K., Burdon, D., and Elliott, M. 2005. Seafood waste disposal at sea - a scientific review. Institute of estuarine and coastal studies, University of Hull, pp.70.

[69] Dimech, M., Borg, J.A. & Schembri, P.J. (2000): Structural changes in a *Posidonia oceanica* meadow exposed to a pollution gradient from a marine fish farm in Malta (Central Mediterranean). Biol. Mar. Medit. 7 (2): 361 - 364

[70] Borg J. A., Micallef M. A, & Schembri P. J., 2006. Spatio-temporal variation in the structure of a deep water *Posidonia oceanica* meadow assessed using non-destructive techniques. Marine Ecology 27: 320 - 327.

Current permitting processes are geared towards preventing the impacts, particularly on *Posidonia oceanica* meadows, as identified through the case study[71]. Within this context, reference is hereby being made to the aquaculture strategy for Malta (2012)[72].

Tuna Penning farms in Malta are all sited 1km offshore and in waters exposed to strong currents, distant from ecologically sensitive benthic habitats. Monitoring of the impact of these farms has been ongoing since 2000 and often carried out by SCUBA divers using observation and videography. Monitoring results of water quality[73], revealed that the adverse impacts are generally limited to the area in close proximity to the cages, with changes in monitored parameters (lower levels of oxygen, reduced water transparency and elevated nutrient levels) reported to occur during the farming season between July to December. Water quality studies, however, have not shown any consistent trend in the levels of monitored variables.

Benthic impacts on the other hand were found to be significant but localized to the area directly beneath the cages.[74] Adverse impacts were mainly related to uneaten feed fish which accumulate on the seabed towards the end of each penning season (autumn), resulting in changes to the physical and biological characteristics of the seabed. Biological alterations included the disappearance of some megafaunal species such as the sea urchin (*Spatangus purpureus*) and the crinoid (*Antedon mediterranea*); and the appearance of others including high population densities of detritus-feeding and scavenging macroinvertebrates (such as the ophiuroid *Ophiura texturata*, the crab *Inachus* sp., and fish *Gobius* sp.)[75]

The slow decomposition of uneaten feed has altered the physical characteristics of the seabed. Strong bottom currents and effects of storms cause the layer of decomposed feed to mix with the underlying mobile sediment. Once this decomposition process is complete, remaining fish bones disperse in the sediment leaving little of no trace of the original uneaten fish on the surface.

Holmer *et al*. (2008) describe these impacts as 'pulse disturbances' given that the characteristics are temporarily altered during the tuna penning season but revert back to quasi-undisturbed conditions before the next tuna penning cycle. Nevertheless monitoring results indicate that the benthic assemblages in the vicinity of the cages are not recovering completely and therefore environmental conditions, in the long run, may be permanently altered. In recent years improved fish feed

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71 http://www.mrra.gov.mt/page.aspx?id=80

72 http://www.mrra.gov.mt/loadfile.ashx?id=1bb77c1f-f3a5-43fd-974d-23b46d44f605

73 Borg, J.A. and 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.

74 Borg, J.A. and Schembri, P.J. 2006. Environmental monitoring of tuna-penning activities in Malta. Presentation at international conference on ' Offshore Mariculture 2006' organized by the Society for underwater Technology and the Greenwich Forum; Malta 11-13 October 2006 (Abstract 3pp).

75 Holmer, M., Kupka Hansen, P., Karakassis, I., Borg, J.A. and Scembri, P.J. 2008. Monitoring of Environmental Impacts of Marine Aquaculture in M. Holmes et al. (eds.), Aquaculture in the Ecosystem, Springer, **2** 47-85.

management and continuous removal of uneaten feed from the bottom has been reported in the monitoring surveys of local tuna farms[76].

1.6 Assessment of Status

1.6.1 MSFD criteria and indicators

Assessment of status in terms of nutrient enrichment for the purposes of the MSFD Initial Assessment should be based on the MSFD criteria and indicators established by the Commission Decision 2010/477/EU for MSFD Descriptor 5 (*Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters*). The whole set of criteria and indicators for this Descriptor are reproduced hereunder:

Criterion 5.1: Nutrient Levels

- Nutrients concentration in the water column (indicator 5.1.1)
- Nutrient Ratios (silica, nitrogen and phosphorous), where appropriate (5.1.2)

Criterion 5.2: Direct effects of nutrient enrichment

- Chlorophyll concentration in the water column (indicator 5.2.1)
- Water Transparency related to increase in suspended algae, where relevant (5.2.2)
- Abundance of opportunistic macroalgae (5.2.3)
- Species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms (e.g. cyanobacteria) caused by human activities (5.2.4)

Criterion 5.3: Indirect effects of nutrient enrichment

- Abundance of perennial seaweeds and seagrasses (e.g. fucoids, eelgrass, Neptune grass) adversely impacted by decrease in water transparency (5.3.1)
- Dissolved oxygen, i.e. changes due to increased organic matter decomposition and size of the area concerned (5.3.2)

Limitations in availability of long-term trend data constitutes the major impediment to the assessment of status for nutrient enrichment. Furthermore, the current data scenario does not allow the application of all MSFD criteria and indicators established for MSFD Descriptor 5 through Commission Decision 2010/477/EU. Within this context, assessment of status for the purposes of the MSFD Initial Assessment was mainly carried out on the basis of nutrient and chlorophyll concentrations in the water column (indicators 5.1.1 and 5.2.1). It should be pointed out however, that background levels or thresholds against which measured levels of these two parameters could be assessed, have not yet been established for Malta.

[76] http://www.mrra.gov.mt/loadfile.ashx?id=0bb10a3f-23f7-4724-84e8-75fede3efcc9

This, coupled to the absence of long-term trend data, limits the assessment of status even for these two parameters.

1.6.2 Assessment Area

The assessment area for the purposes of the MSFD assessment of status in terms of nutrient enrichment is considered to be equivalent to the coastal water bodies identified for the purposes of the WFD. Eutrophication events beyond these coastal water bodies are unlikely in Malta, in view of the oligotrophic nature of such waters.

On the other hand, this assessment area could be extended further in the next reporting on the basis of further knowledge with respect to the nutrient status of offshore waters.

1.6.3 Status: nutrient levels

Assessment of status on the basis of nutrient levels in the marine environment is constrained by the lack of long-term data and of established boundaries for Environmental Quality Ratios or reference conditions with respect to nutrient levels or ratios in Malta.

The results of the 2012 WFD baseline surveys are indicative of generally low nutrient (nitrates, total nitrogen and total Phosphorous) concentrations. Nutrient concentrations measured within the three inlets/bays studied specifically for the application of TRIX indices are indicative of relatively higher nutrient concentrations[77].

Therefore while the current data generated by the WFD baseline surveys carried out between May and November 2012 points towards a low nutrient scenario in coastal waters, hence 'good' status in terms of nutrient levels, this has yet to be confirmed for localised areas (such as inlets and bays) during seasons which have not yet been covered by the WFD monitoring regime. Furthermore, it should be noted that the TRIX indices[78] calculated for the three inlets/bays ranged from Good Water Quality and medium trophic level to a Poor water quality status and a very high trophic level, thus indicating that 'good' status might not apply throughout the waters all year round.

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[77] Maximum nitrate concentration recorded in inlets/bays is 42.0mg/L (nitrates measured by the WFD baseline surveys did not exceed 10mg/L); Maximum total Nitrogen concentrations recorded in inlets/bays is 13.00mg/L (Total N measured by the WFD baseline surveys did not exceed 6mg/L); Maximum total Phosphorous concentrations recorded in inlets/bays is 1.2mg/L (Total P measured by WFD baseline surveys did not exceed 1.0mg/L).

[78] Note that the TRIX index reflect various parameters and not just nutrient levels – refer to Table 2: National water monitoring parameters related to eutrophication.

Within this context, status in terms of nutrient levels is not being assessed pending the availability of longer-term trend data.

1.6.4 Status: Direct effects of nutrient enrichment

CIBM & Ambiente (2013)[79] attempted the classification of 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 the eutrophication classification developed by Simboura *et al.* (2005), assuming that Malta is characterized by waters that classify as Type IIIE waters in line with 2008/915/EC[80].

This classification for the period between May and November only, points towards a scenario where, 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.

CIBM & Ambiente (2013) conclude that on the basis of the 90th percentile values of chlorophyll-a calculated on the whole set of data collected during the period May – November 2012, lower-mesotrophic conditions can be attributed to coastal waters, hence a moderate quality status.

This scenario does not seem to be corroborated by the chlorophyll-a data collected in three inlets and bays in February, August, November and December 2012. Chlorophyll-a concentrations measured through this survey were always below detection limits (0.03µg/L) for all three sites and for all surveyed months. On the other hand, the trophic status of the inlets/bays according to the TRIX indices, which cannot be ascribed to one parameter in particular, ranged from ‘Good Water Quality and medium trophic level’ to ‘Poor Water Quality and very high trophic level’.

The analysis of ocean colour data reflecting chlorophyll-a concentrations as carried out by Azzopardi *et al*. (2013)[81] is also indicative of an oligotrophic nature of coastal waters. However, spatial variations were noted with higher ocean values recorded for areas which may be subject to occasional eutrophication events.

Collectively, the results of the surveys or analysis imply that coastal waters are of a ‘good’ to ‘moderate’ status in terms of chlorophyll-a concentrations (indicator 5.2.1),

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[79] 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

[80] Commission Decision of 30 October 2008 establishing, pursuant to Directive 2000/60/EC of the European Parliament and of the Council, the values of the Member State monitoring system classifications as a result of the intercalibration exercise.

[81] 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

which status may vary across seasons. On the other hand, such status needs to be confirmed through longer-term data.

Status on the basis of other indicators for MSFD criterion 5.2 (i.e. 5.2.2 – 5.2.4) cannot be assessed for this first reporting cycle in view of the currently limited data scenario. In particular, use of the available data on phytoplankton for the purposes of assessment of status in terms of indicator 5.2.4 (e.g. diatom to flagellate ratio) is difficult, also in view of the fact that there is very little knowledge on type-specific conditions. Longer-term data with respect to phytoplankton is necessary to characterise waters and calculate boundaries for status determination or reference conditions.

1.6.5 Status: Indirect effects of nutrient enrichment

The current data scenario does not allow assessment of status in terms of MSFD criterion 5.3 – Indirect effects of nutrient enrichment.

In line with the Commission Decision 2010/477/EU[82], these indicators should be applied, possibly in localised sites, through a risk-based approach on the basis of long-term information on nutrient levels and relevant primary effects.

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[82] Commission Decision of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters

1.7 Data Gaps

The monitoring programmes currently being carried out under the Water Framework Directive are expected to increase our understanding of the overall response of our marine environment to the various measures already being implemented to tackle nutrient enrichment. However it must be mentioned that the MSFD goes beyond the requirements of WFD in terms of analysis of eutrophication taking into account marine ecosystems. This is because the WFD evaluates nutrients, related physico-chemical elements and phytoplankton as individual quality elements. Moreover, the major difficulty encountered for the application of WFD data for the purposes of this MSFD assessment of status is related to the relatively recent implementation of the WFD monitoring programme and hence the lack of long term trend data. Furthermore, there is very little data in relation to some of the direct and indirect effects of nutrient enrichment as addressed by the MSFD criteria and indicators.

To date national nutrient standards have not been set for any of the nutrient parameters making up Malta's monitoring programme. Although ongoing work related to the development of comparable methods (known as Intercalibration) to assess the status of phytoplankton as a biological quality element (BQE) under the WFD shall partly contribute to our understanding of the direct effects of nutrient enrichment in coastal waters; there is still uncertainty with respect to the cause-effect relationship between nutrients and the value of this specific BQE.

It is expected that the long term ecosystems approach in assessing eutrophication phenomena, as advocated by both MEDPOL (Phase IV) and the MSFD working group on eutrophication would need to be developed to allow Malta to adopt a more precise means of assessing different degrees of nutrient enrichment and eutrophication. It would also enable the determination of the extent of impact on the different components making up the wider marine environment. Improved monitoring strategies developed at regional level by both MEDPOL and the European Union should also enhance regional cooperation in the field.