REPUBLIC OF CYPRUS

MINISTRY OF AGRICULTURE, NATURAL RESOURCES, AND THE ENVIRONMENT

DEPARTMENT OF FISHERIES AND MARINE RESEARCH

Initial Assessment of the Marine Environment of Cyprus

Part I – Characteristics

Nicosia, Cyprus
July 2012

Implementation of Article 8
of the Marine Strategy Framework-Directive (2008/56/EC)

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Foreward

This report was prepared by a consortium consisting of AP Marine (Cyprus), the Fisheries Research Institute of the Hellenic Agricultural Organization - Demeter (Greece), and independent experts.

The consortium undertook the authorship of three reports in the framework of the implementation of Articles 8, 9, 10 and 19 (par. 2a and 2b) of the Marine Strategy Framework Directive (2008/56/EC) on behalf of the Department of Fisheries and Marine Research (DFMR) of the Republic of Cyprus, under contract 12/2011. The three reports are: an Initial Assessment of the marine environment of Cyprus, a report on the Determination of Good Environmental Status, and a report on Environmental Targets.

This volume consists of Part I of the Initial Assessment and describes the characteristics of the marine environment of Cyprus. There are two other volumes corresponding to the other two Parts of the Initial Assessment: Part II - Pressures and Impacts, and Part III – Social and Economic Parameters.

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1. Physical and chemical features

1.1 Topography and bathymetry of the seabed

1.1.1 Seafloor morphology

The morphology of the seafloor of the eastern Mediterranean has primarily been influenced by the convergence of the African and Eurasian Plates (Benkhelil et al. 2000). The major feature of the Eastern Mediterranean sea floor is a large arcuate swell, the Mediterranean Ridge, which extends over 1500 km between the southwest of Peloponissos and southern Turkey in an area that includes Cyprus (IFREMER 2011). Figure 1.1 below illustrates the tectonic processes that shape this region. Other features of note include the Nile cone or fan (off Egypt), the Anaximander and Anaximenes seamounts (off southern Turkey and northwest of Cyprus), and the Eratosthenes Seamount, Florence Rise, and Hecateus Rise, south, west, and southeast of Cyprus respectively (MCS et al. 2008).

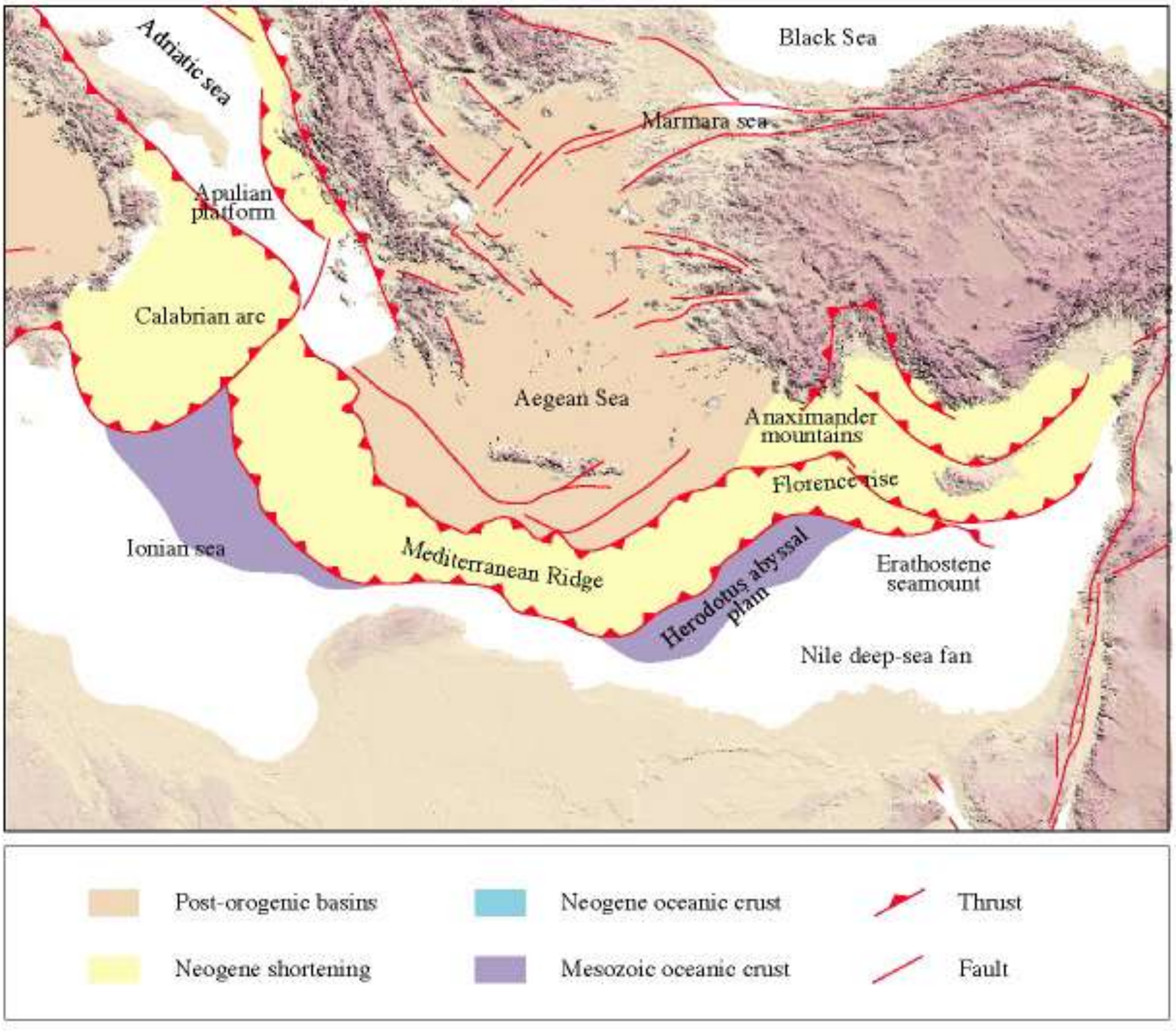


Figure 1.1 Tectonic sketch of the Eastern Mediterranean (IFREMER 2011).

1.1.2 Bathymetry

The bathymetry within the Exclusive Economic Zone of Cyprus is shown in Figure 1.2. The continental shelf, defined as the seafloor at water depths shallower than 200 m, is generally narrow in the north and wider in the south. As seen in the bathymetric map, the continental slope and rise are fairly narrow, and the vast majority of the seafloor constitutes the abyssal plain. The deepest point in the Cyprus EEZ is in excess of 3000 m below the surface, and lies on the westernmost end of the EEZ (Figure 1.2), in what is the eastern extremity of the Herodotus abyssal plain (Figure 1.1). Table 1.1 lists typical values for the sea surface and seafloor areas for the major types of water bodies as well as estimates of the volume of seawater corresponding to each region.

Beyond the continental shelf, the most prominent seafloor feature is the Eratosthenes seamount, which lies approximately 100 km south of the Limassol-Paphos coastline. It is an elliptical massif, with its major axis, which is 120 km long, oriented northwest-southwest, while its minor axis is 80 km wide. It rises from a depth of 2700 m to a maximum peak of approximately 690 m (Krasheninnikov et al. 1994).

Other important shallower platforms that rise above the abyssal plain are the Hecateus Rise and the Larnaca Ridge, which lie closer to the island and in parallel with its long axis. Due to their relatively shallow depth (104 m and 915 m from the sea surface respectively) and their distance from the coast, they may exhibit seamount or open-sea bank physicochemical characteristics and harbor corresponding communities.

Table 1.1 Sea surface areas (in km^2) of various water bodies of political/managerial and geophysical significance, calculated from the coordinates given by the Ministry of Commerce, Industry and Tourism (referenced to the UTM 36N coordinate system, USGS 84 datum). Coastal waters as defined as those within 1 nm from the shore of the Republic measured from the low-water mark at low tide (Water-Framework Directive 2000/60/EC, Law No. 13(I) of 2004). Territorial waters are defined as those within 12 nm from the shore of the Republic measured from the low-water mark at low tide (Law No. 45 of 1964). The Exclusive Economic Zone (EEZ) is defined as the zone beyond and adjacent to the territorial waters, and that extends to the boundaries shown in **Figure 1.2** (Law No. 64(I) of 2004). The nautical mile (nm) is defined as 1852 m (Law No. 64(I) of 2004). For comparison, the total land area of Cyprus is 9262 km^2, while the total coastline is 1094 km long.

Water body	**Sea surface area (km^2)**
Coastal waters ($\leq$ 1 nautical mile)	1038
Territorial waters ($\leq$ 12 nautical miles)	11880
Exclusive Economic Zone	118886
Total sea surface area under Cyprus jurisdiction	**130766**

In 2004, the Republic of Cyprus, proclaimed, by Law No. 64 (I) 2004, its Exclusive Economic Zone («EEZ»), outer limit of which does not extent beyond 200 nautical miles from the baselines from which the breadth of its territorial sea is measured. In accordance with the United Nations Convention of the Law of the Sea (UNCLOS 1982), and the relevant customary international law, the delimination between the EEZ/continental shelf of the Republic of Cyprus and the EEZ/continental shelf of other neiggbouring coastal States, is effected by an agreement on the basis of the median-line principle. Accordingly, the

Republic of Cyprus has so far concluded Agreements on the delimination of its EEZ/continental shelf with the Arab Republic of Egypt (in force), the Republic of Lebanon (raticication pending) and the State of Israel (in force), on the basis of the median-line principle. In those parts of Cyprus' maritime boundaries where no delimination Agreements have been signed and until such Agreements are signed, the Republic of Cyprus considers as the outer limit of its EEZ/continental shelf, the median-line which is measured from the baselines from which the breadth of their territorial sea is measured.

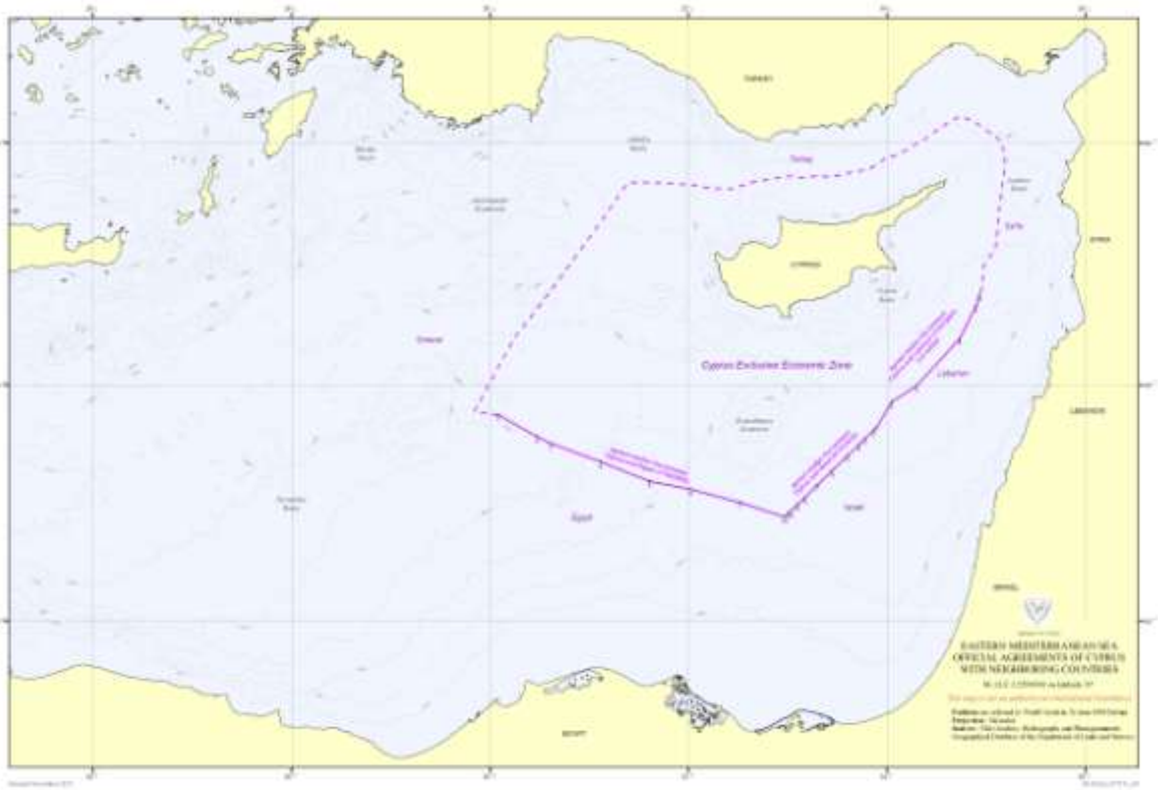


Figure 1.2 Bathymetry and boundaries of the Exclusive Economic Zone of Cyprus. Map courtesy of the Department of Lands and Surveys of the Ministry of the Interior of the Republic of Cyprus.

Annual and seasonal temperature regime and ice cover, current velocity, upwelling, wave exposure, mixing characteristics, turbidity, residence time

1.1.3 Temperature

1.1.3.1 Spatial distribution

The marine waters of Cyprus are contained in the wider Levantine Basin, defined by the Cretan Passage on the west, and the coasts of northern Africa, the Middle East, and south east Asia Minor. There are four major water masses in the Levantine Basin, and all of these are present in Cyprus waters: Levantine Surface Water (LSW), Atlantic Water (AW), Levantine Intermediate Water (LIW) and Eastern Mediterranean Deep Water (EMDW). The mean properties and main characteristics of the water masses of the southeastern Levantine are discussed in Hecht et al. (1988) and Zodiatis et al. (1998). To describe these water masses one should first examine vertical profiles of temperature and salinity and their corresponding T/S diagrams. Figure 1.3 shows profiles and T/S diagrams from the CYBO-19 cruise carried out by the Oceanography Center of the University of Cyprus in September of 2005. The LSW is shown in a thin surface layer (approx. 20 m thick) of very warm and salty water (up to 39.51 psu and 26.9 ^{o}C), a result of the extensive evaporation and intense solar radiation during the summer season. In winter (November to March), winds and convective mixing processes homogenize the water column from the surface downward to subsurface and intermediate layers, in some cases even down to 200-350 m (Zodiatis et al. 2001). Ranges in surface salinity and temperature throughout the year are approximately 39.0-39.5 psu and 17-28 ^{o}C, respectively based on in-situ and remote sensing averages of temperature over the Levantine and upper-10 m averages of temperature and salinity from cruises (Samuel-Rhoads et al. 2008).

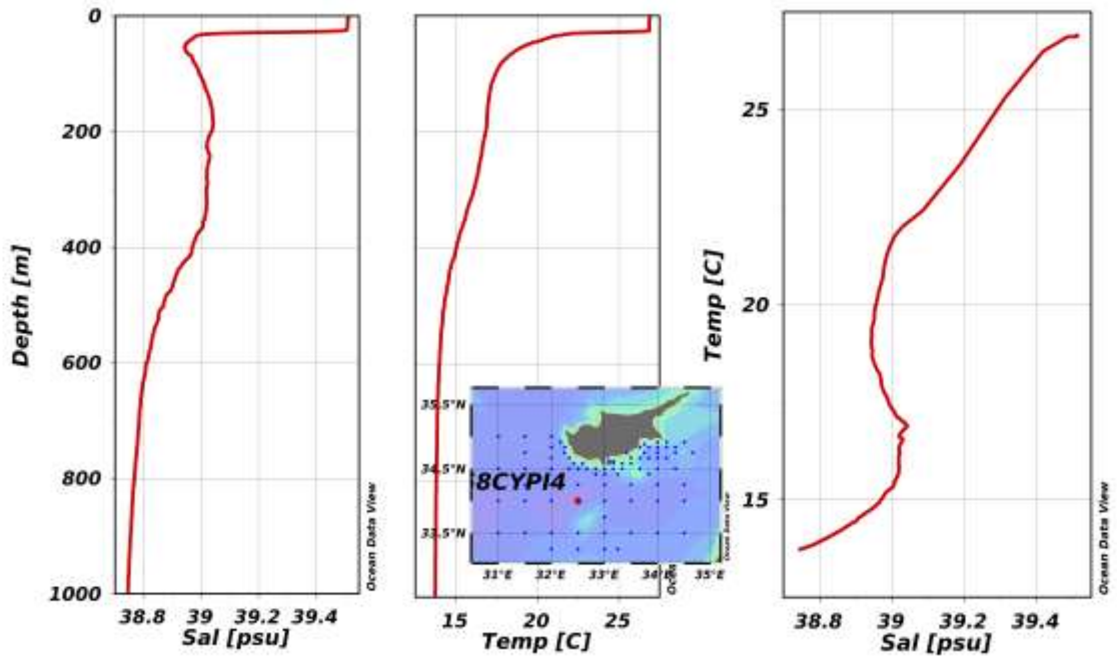


Figure 1.3 In-situ data from Cyprus Basin Oceanography cruise CYBO-19 in September 2005 (data from OC-UCY 2011a). The salinity (left) and temperature (middle) profiles are shown. In the T-S diagram (right), water masses are Levantine Surface Water (LSW), Atlantic Water (AW), Levantine Intermediate Water (LIW), and Eastern Mediterranean Deep Water (EMDW).

In some regions, a meandering jet transferring Atlantic Water can be found below the surface mixed layer, identified by a salinity minimum from the Straits of Gibraltar to the Cretan Passage and into the Levantine (Lacombe and Tchernia 1960, Oren 1971, Morcos 1972) (see section 1.2.2). AW is distributed sparsely as a jet intertwined in a field of propagating and interacting eddies, in which is found the more widespread, but patchy, LIW. The relatively warm and saline LIW is found from about 200-400 m and is the result of winter cooling and sinking of LSW at various locations, including the primary source of the Rhodes Gyre (Morcos 1972). There is currently a lack of detailed knowledge about the location and strength of sources of LIW, but most authors suggest the central northern Levantine (Nielsen 1912, Lacombe and Tchernia 1960, Wüst 1961) or the northeastern Levantine (Moskalenko and Ovchinnikov 1965, Özsoy et al. 1981). Fewer observations of LIW formation have occurred in the southeastern Levantine (Heslop 2009). LIW does seem to be formed in episodes that differ in place and time both in a given winter, and interannually, which implies it is not uniform. It has a temperature of 15-16 ^{o}C. The LIW spreads from the Levantine Basin throughout the Mediterranean.

Below depths of approximately 500 m, Eastern Mediterranean Deep Water is found. This slow-moving and relatively homogeneous water mass typically has characteristics of 13.3 - 13.38 ^{o}C and 38.66-38.80 psu. It is also formed annually, during deep convection events either in the Adriatic Sea (the typical cooler/fresher condition) or in the Aegean Sea (the more unusual and more recent warmer/saltier condition).

While the "layer view" of water masses is useful, it does not allow for the horizontal variability often seen at the mesoscales (10-100km) so prevalent in the Levantine Sea. Traditional hydrographic cruises have identified a number of such features, such as the Mersa-Matruh, the Shikmona Eddy, and the most dominant in Cyprus waters, the Cyprus Eddy (Zodiatis et al. 2005). This eddy has been extensively observed more recently (Hayes et al. 2010, 2011). It consists of a core of LIW, sandwiched by LSW above and EMDW below. Laterally, LIW of lower temperature and salinity are found, except near the upper part where AW is found (Figure 1.4). A horizontal map (Figure 1.5) shows the extent of the eddy (diameter of about 80km) and the anticyclonic currents (peaking at about 40 cm s^{-1}). Signatures from this feature have been observed almost every year since regular observations began in 1995 (Zodiatis et al. 1998, 2001, 2005, Hayes et al. 2011). Since the water mass in the center region is isolated laterally, interesting biogeochemical conditions can arise (Krom et al. 1991).

Since Cyprus has an exposed coastline with steep slopes next to a very narrow shelf region, open ocean temperature and salinity are good representatives of coastal values. Observations of surface temperature and salinity have been collected by the Department of Fisheries and Marine Research from 2005-2008, and their results indicate temperatures in the range of 17-30 ^{o}C in the top 30 m for February or March to August or September, respectively (Argyrou 2008, Argyrou et al. 2011). Also, based on the annual coastal temperature reports published by the Department of Fisheries and Marine Research (e.g. number 22, 1991), one can see the generally cooler temperatures in Limassol and Paphos in the summer months, which is a result of coastal upwelling (discussed later). For example, the coldest surface temperatures are found in February with values of 14-15 ^{o}C at Larnaca, Limassol, and Paphos. However, the warmest temperatures are found in August in the 25-26 ^{o}C range, but only in Larnaca while Paphos and especially Limassol are cooler.

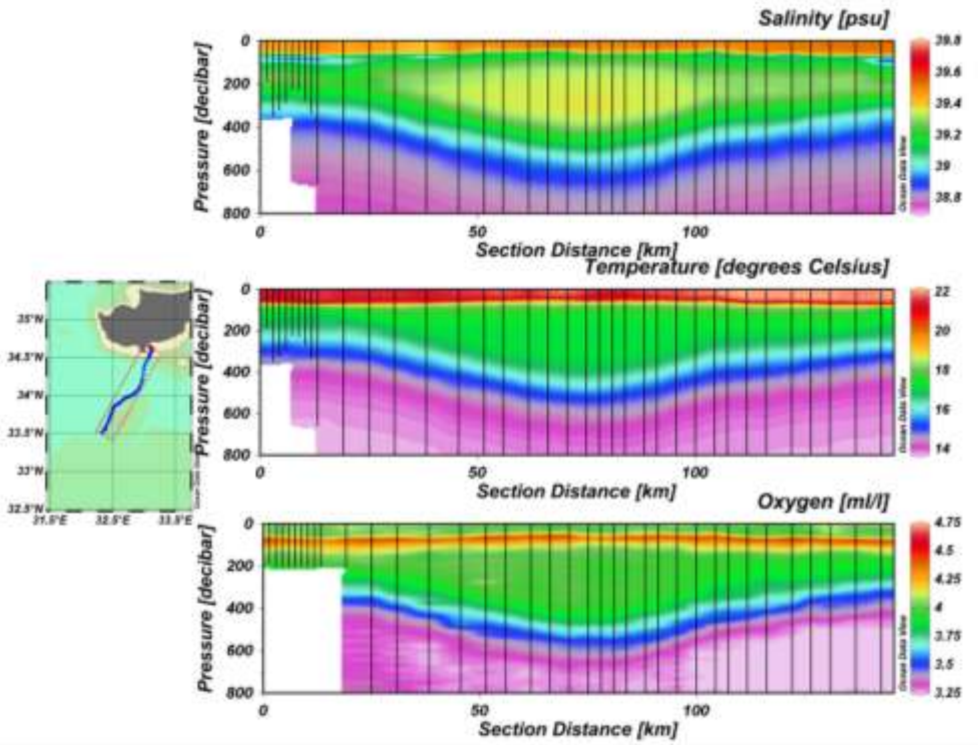


Figure 1.4 Vertical section of salinity (top), potential temperature (middle), and dissolved oxygen (bottom) from Oceanography Center, University of Cyprus glider 150 from November 23-Dec 1 2009. The section begins at the north terminus of the transect. Positions at the end of each upcast are shown with vertical black lines.

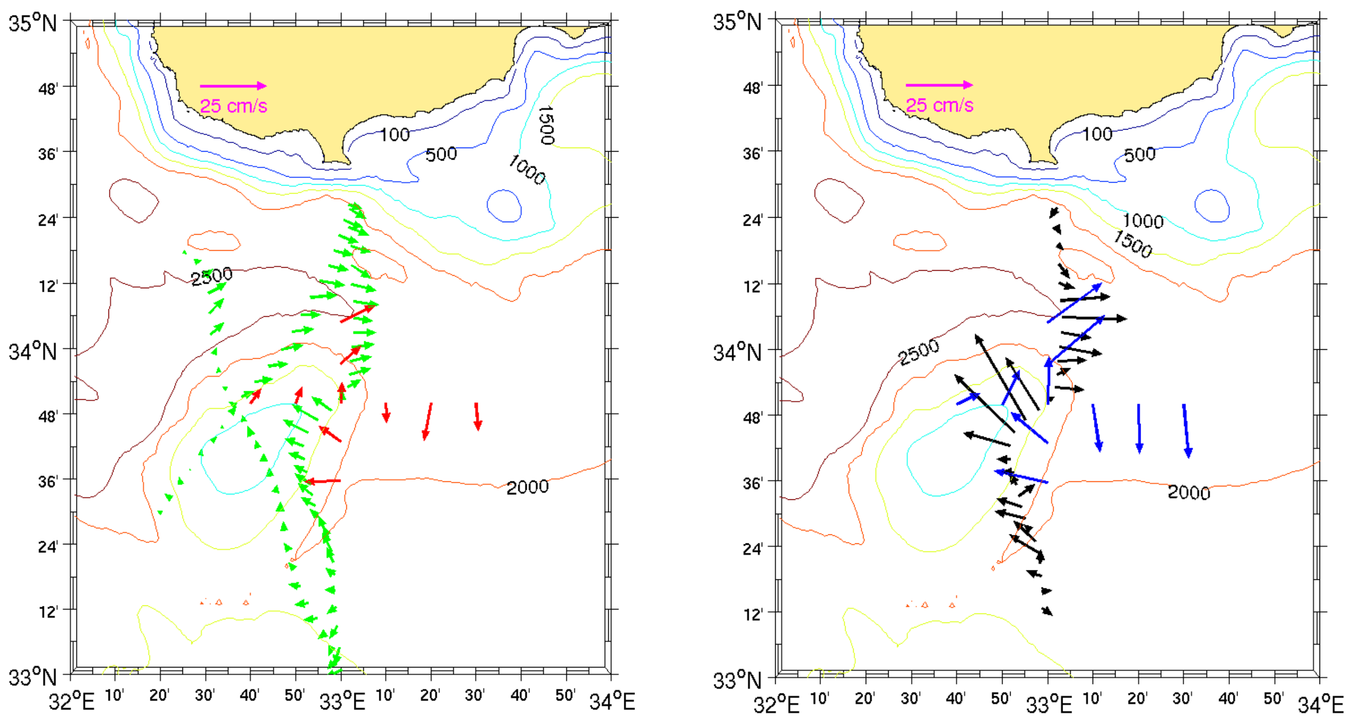


Figure 1.5 Surface map of glider-derived dive average currents (left; top 1000 m, green) and ship ADCP-derived currents vertically-averaged (top 800 m, red) overlaid on contours of bathymetry. Absolute velocity at 300 dbar computed from glider-derived geostrophic velocity and dive average currents (right; black) and ship ADCP-derived currents at 300 m (blue) during a glider mission (January 7-31, 2010) and *Maria S. Merian* Cruise 14/1 (January 4-5, 2010).

1.1.3.2 Annual and seasonal evolution

The annual cycle of the surface water properties can be seen by examining a time series of upper ocean temperature and salinity just west of the Eratosthenes Seamount (Figure 1.8). Near-surface (at the depth of 17-m) temperature peaks in late-July and has a minimum in mid-February. The deeper sensors show that from April to October, the upper 38 m are stratified (because of surface heating), while for the remainder of the year the sea is well-mixed over these depths (because of winds and surface evaporation). Because of the strong seasonal influence in this layer, an annual ventilation is expected down to at least 100 m, depending on the location and the year.

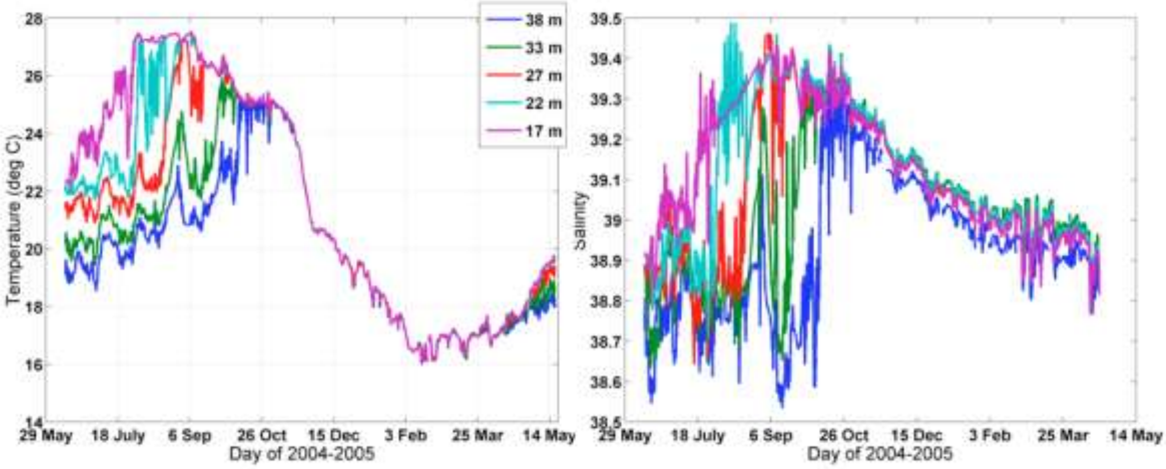


Figure 1.6 Temperature (left) and salinity (right) measured at five depths in the top 38 m at the CYCOFOS MedGOOS-3 Observatory west of the Eratosthenes Seamount. During the winter all 5 levels report nearly the same water properties, while during the summer stratification develops.

As suggested above, not only are the geographic locations of LIW formations poorly known, it is not known how the formation of LIW varies from year to year. Renewal times have been estimated to be 25 years (Ovchinnikov 1983) and between 10-20 years (Stratford and Williams 1997). The shallower layers have estimated renewal times of less than 5 years (Stratford and Williams 1997).

While most of the dynamic activity and subsequent variability of water masses occurs in the upper 500 m and data are sparser for the deeper layers, some interesting inter-annual transient changes have taken place in the deep basins recently. The Eastern Mediterranean Deep Water has formed for decades in the Adriatic Sea (Pollak 1951, Roether and Schlitzer 1991, Schlitzer et al. 1991). It does not communicate with the adjacent deep waters of the Western Mediterranean because of the shallow sill in the Straits of Sicily. Sometime between the cruises of the Meteor in 1987 (M5/6) and 1995 (M31/1), the Eastern Mediterranean thermohaline circulation experienced a switch of deep water source from the Adriatic to the Aegean, which consequently altered the EMDW from a 13.38 ^{o}C-38.66 psu water mass (Schlitzer et al. 1991) to a warmer and saltier (13.88 ^{o}C-38.8 psu) water mass (Roether et al. 1996, Klein et al. 1999). The potential density (σ_θ) of the EMDW also increased from below 29.18 to above 29.2. This change is too large to be accounted for by a change in surface evaporation or precipitation alone (Roether et al. 1996), and turns out to be related to a small change in surface buoyancy loss in combination with a number of extreme winters over the Aegean which resulted in the diversion of LIW from the Adriatic to the Aegean (Wu et al. 2000). Thus the Aegean could be more productive as a deep water formation site. The wider effects on the thermohaline circulation of the Eastern Mediterranean remain to be seen. It has been observed (Hainbucher et al. 2006) that deep water formation has returned to the

Adriatic as of 2003, but in 2006, the deep water was seen to exhibit yet another set of T-S properties never before observed (Rubino and Hainbucher 2007).

Because it is formed in winter in only a few select sites, and fills a large volume of the Levantine, it takes many years to renew this water mass. Renewal time scales have been estimated at about 100 years (Roether and Schlitzer 1991, Stratford and Williams 1997) but are probably less, as seen by the recent changes in deep water discussed above.

1.1.3.3 Decadal and inter-decadal changes

Regional changes in surface temperature have been estimated using analyses of annual mean satellite SST data (Samuel-Rhoads et al. 2008) who indicate that over the years (1996-2008) a general warming has occurred over the Levantine Basin at an average rate of approximately 0.055˚C per year, approximately twice the global average.

Changes in temperature at deeper layers have been recorded in regard to the Eastern Mediterranean Transient discussed earlier. Changes reported in the LIW properties have been limited to salinity.

1.1.4 Circulation and currents (including upwelling)

1.1.4.1 Spatial distributions

The Levantine Basin circulation was first depicted in the early 20th century by Nielsen (1912) who described a surface circulation bound to the coast and following a counter-clockwise (cyclonic) path around the basin. Later work by Ovchinnikov et al. (1966, 1976) based on hydrographic sampling suggested a system of counter-rotating gyres in the interior of the peripheral cyclonic flow. The flow was reported to be stronger in winter. A similar peripheral flow was identified by Lacombe and Tchernia (1972), with a bifurcation of one branch off the Libyan coast northeastwards towards Cyprus.

In the 1980s, knowledge of the currents of the Levantine improved after the Physical Oceanography of the Eastern Mediterranean (POEM) cruises (Özsoy et al. 1989, 1991, 1993, Robinson et al. 1991, 1992). The Shikmona gyre system was identified in the region south and east of Cyprus: a clockwise (anticyclonic) flow bounded to the north by an eastward flowing current carrying fresher, cooler Atlantic Water (AW) (Figure 1.7). In this schematic, AW enters the Levantine through the Cretan Passage, then it hugs the coast as the North African Current before detaching and flowing northward and eastward towards Cyprus as the Central Levantine Basin Current (Özsoy et al. 1989), also known as the Mid-Mediterranean Jet (MMJ; Robinson et al. 1991). On the northern side of this near-surface current was identified the Rhodes Gyre, rotating in the opposite sense. A second anticyclonic system was observed south of Cyprus, but further to the west: the Mersa-Matruh gyre. Seasonal differences between summer and winter regimes were shown to exist: the anticyclonic activity south of Cyprus generally weakened in the winter, except perhaps near the eastern coast (Özsoy et al. 1989). In these first two POEM cruises, cyclonic gyre intensity lessened with depth while anticyclonic intensity tended to increase with depth (Özsoy et al. 1989). The main conclusion is that the Levantine basin is a dynamic, evolving region, with persistent features and a rich, interacting mesoscale eddy field. Robinson et al. (1991) went one step further to classify a number of features of the dynamically active upper thermocline as permanent (MMJ, Mersa Matruh gyre), re-current (Shikmona gyre), or transient (SE Levantine jets and eddies).

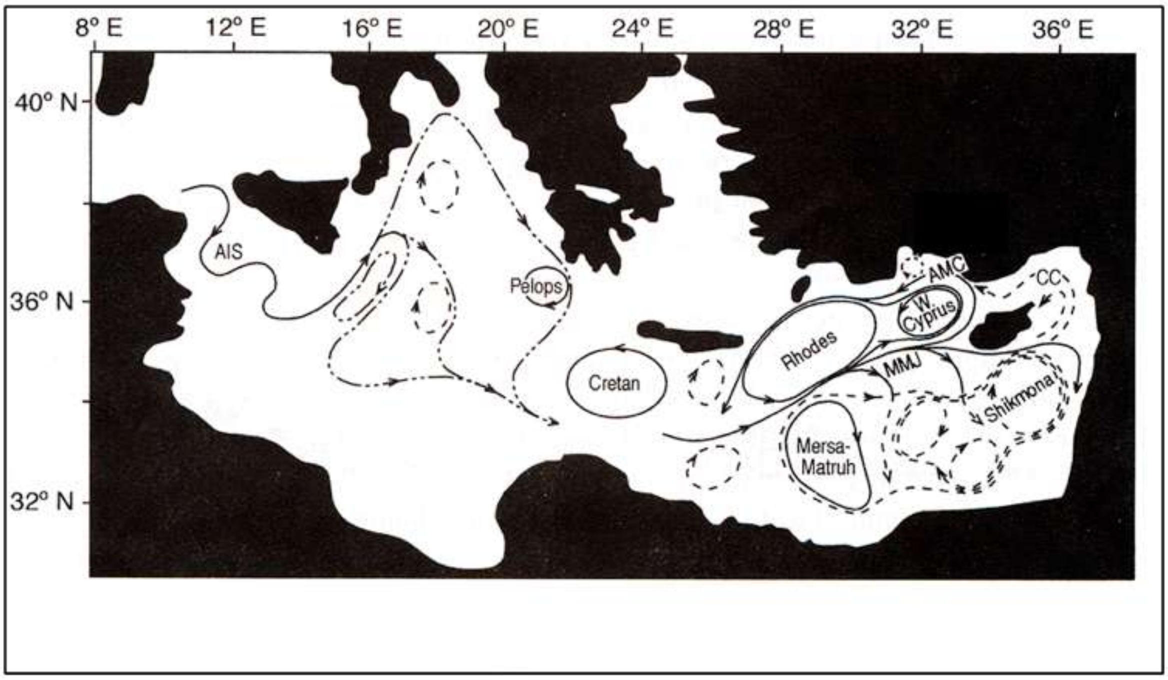


Figure 1.7 The general circulation as depicted during the 1980s (Robinson et al. 1992) consisted of a mesoscale flow structure with anticyclonic eddy activity south of Cyprus and the Mid-Mediterranean Jet (MMJ) meandering eastward transferring the Atlantic Water (AW).

Since POEM, a number of studies have elucidated more details on the structure and variability of the Levantine Basin. In general, they support the schematic structure set out by the POEM studies, even if they emphasize further the spatial variability and transient nature of the features described. Some notable exceptions exist, in which the historical view of the Atlantic Water tightly hugging the periphery of the Levantine Basin is promoted (Hamad et al. 2005, Millot 2005, Millot and Taupier-Letage 2005). These studies tend not to be based on in situ salinity measurements, which would provide direct information on the origin of the observed water mass, however, even these studies recognize the instability of such a current and the resulting field of mesoscale eddies in the basin interior. For example, expendable temperature probe (XBT) observations made during the Mediterranean Forecast System (MFS) program confirmed the persistence of the sub-basin anticyclonic gyres in the southern part of the basin, but did not find definitive evidence of the MMJ (Fusco et al. 2003). Also, AW has also been observed to continue along the African coast, based on satellite observations (Ayoub et al. 1998, Hamad et al. 2005). Remotely-sensed sea surface temperatures (SST) can aid in interpretation of coarse resolution data sets, however. For example, the main features shown in Figure 1.7 are often visible (OC-UCY 2011b, for SST averages).

It is clear that more detailed in situ observations are needed to resolve the debate of near-surface currents in the Levantine Basin. This has been addressed in the last 12 years in the Levantine basin, particularly in a broad area including the Cyprus EEZ, by more than 20 cruises carried out by the Oceanography Center of the University of Cyprus. Published results describe the approach from the southwest of the MMJ, its bifurcation into a stream diverted to the north before reaching Cyprus, and another stream that continues eastward south of Cyprus (Zodiatis et al. 2005, 2008). The MMJ meanders, encircling clockwise, warm-core eddies to its south, such as the Cyprus Eddy (Zodiatis et al. 1998, 2005, 2008). To the north of the MMJ, and near the Cyprus coast is often observed anti-clockwise eddies and westward current along the south coast of Cyprus.

1.1.4.2 Annual and seasonal evolution

The general circulation in the Levantine Basin varies from year to year and seasonally. For example, the Cyprus warm core eddy shifted westwards during the period 2000-2001 and the Shikmona gyre was re-established during the period summer 2001-2003 (Zodiatis et al. 2005). During the CYBO and CYCLOPS experiments carried out in 2001 and 2002 respectively, a significant seasonal spatial displacement of the Cyprus warm core eddy to the west of about 60-80 nautical miles from its original position was found (Zodiatis et al. 2001, 2005). This caused an even more complicated flow path for the MMJ. In particular, in April-May 2001 the northward extent of the Cyprus eddy caused for a short period the restriction of the eastward transfer of the AW. The main flow path of the MMJ became northward offshore west Cyprus, as opposed to its usual eastward direction offshore south Cyprus. In August 2001, the southern relaxation of the Cyprus warm core eddy for about 20 nm and the secondary new anticyclonic eddy, which established between southeast of Cyprus and offshore Lebanon, resulted in the re-establishment of the eastward MMJ flow, with velocities up to 45 cm s^{-1}, along the northern peripheries of these two warm core eddies. The co-existence of these two warm anticyclones until summer 2003 contributed to the re-appearance of the well-known Shikmona gyre (Zodiatis et al. 2005). During this period the AW was observed also below the secondary anticyclone, at greater depth than usual, down to 200 m. The latter suggests that the AW after its eastward advection along the Cyprus eddy was then picked up by the new (secondary) anticyclone, which was more intense at the upper surface layers comparable to the Cyprus eddy.

In accordance with the above discussions, the spatial and temporal variations of the dominating dynamic flow features of the SE Levantine are shown to be divided into three distinct periods: a) 1995-1999, b) 2000-2001, c) summer 2001-2003 (Zodiatis et al. 2004). The first period indicates the Cyprus warm core eddy was located east of the meridian of 33^{o} 00’ E, while the second period shows the significant westward shift (about 60-80 nm) of the Cyprus warm eddy. Finally, the last period shows the re-establishment of the Shikmona gyre that constituted from warm core eddies, similar as those found during the 1980s by the POEM cruises.

More recently, additional observation programs (Hayes et al. 2011) have shown the Cyprus eddy and its interaction with the MMJ to be the dominant feature of the open sea south of Cyprus. Detailed observations from May 2009 to May 2011 show the eddy to persist, but moving from west to east, with some interaction into the Shikmona eddy to the east, a meander in the northward Israeli coastal current. While the Shikmona eddy can easily be seen in images of sea surface temperature and chlorophyll concentrations, the Cyprus eddy cannot (Hayes et al. 2010).

Near the coast, smaller scale features exist, but are poorly observed, so proxies such as sea surface temperature or chlorophyll from satellites are used. Filaments of cooler water with higher concentrations of chlorophyll are seen to extend offshore from Cape Akrotiri (Figure 1.8). It is believed to be a result of upwelling caused by the off-shore transport of water during the summertime by strong, steady northwesterly winds. The tongue is advected to the south or southeast (OC-UCY 2011b, for Chl-a and SST instantaneous images). The surface temperature in the upwelling area is up to 4 ^{o}C cooler compared to the other coastal sea areas of Cyprus.

Observation programs will continue to contribute to knowledge on the general circulation. However, numerical models are also important in covering large areas and time scales simply not possible with observations. In particular, the spatial distribution of the ocean currents is difficult to observe instantaneously or in quasi - synoptic period, especially over wide-open deep-sea areas. For this reason, oceanographic teams are developing and continuously updating their numerical models, often upgrading to operational forecast centers, such as the Cyprus coastal ocean forecasting and observing system, known as CYCOFOS system (OC-UCY 2011b). In regions where no observations are available, one might fill the data gap of deep ocean currents by calculating the annual mean of near-bottom currents. This sort of analysis can be extended to include any desired region or period of interest for the Levantine basin. Many models have already been used to understand the general circulation in the Mediterranean (Malanotte-Rizzoli and Bergamasco 1991, Zavatarelli and Mellor 1995, Wu and Haines 1998, Zodiatis et al. 2002, 2008). For example, in a study focused on the Levantine seasonal circulation, Alhammoud et al. (2005) found that during summer, the cyclonic coastal circulation gets weaker and the basin interior is dominated by detached coastal current eddies and other meanders and that the eddies in the Mersa-Matruh and Shikmona areas vary greatly in extent, shape, strength and position from winter to summer. Zodiatis et al. (2008) have shown favourable comparisons between in situ and forecast fields for the Levantine Basin north of 33^{o} N. These results improve our knowledge of the relevant physical processes, especially their daily evolution over weeks, months, and years. Perhaps more useful, a statistical picture of the circulation emerges after several years of simulation.

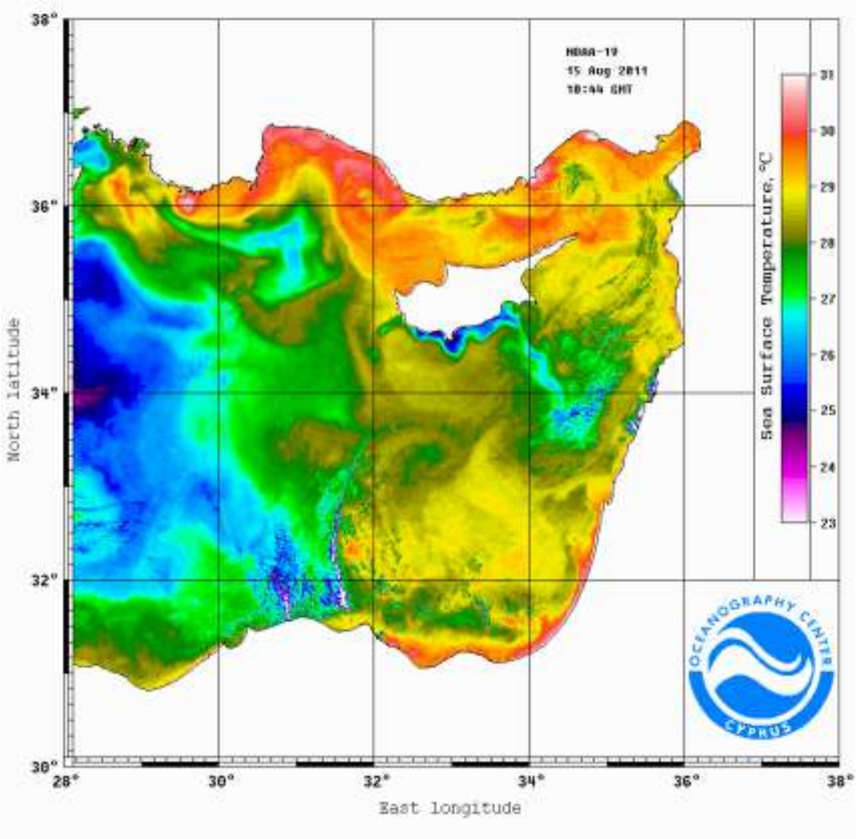


Figure 1.8 A single passage NOAA-AVHRR image on the 15 August 2011 from the CYCOFOS ground satellite receiving station at the Oceanography Center of the University of Cyprus, showing the upwelling phenomenon and its offshore extension south of Cyprus.

1.1.5 Surface gravity waves

1.1.5.1 Spatial distributions

Wave heights in Cyprus waters are generally lower than in the large ocean basins because of generally weaker storms. There are few published reports or data sets describing the wave statistics of the region. New and ongoing projects should address this lack of information in the coming years. In particular, the Oceanography Center of the University of Cyprus, within the framework of the CYCOFOS system runs an operational wave model (three-hourly output, 1/16 degree resolution, daily forecast for 96 hours), which can be used to estimate wave statistics at a point or points in the Mediterranean and the Levantine Basin (Galanis et al. 2011, OC-UCY 2011b, for wave plots), using the SKIRON wind fields. This is now being run for a 10-year period under a new project of the Oceanography Center in order to produce an atlas of wave properties (http://www.oceanography.ucy.ac.cy/ewave/). Preliminary results verify the commonly-held perception that wave energy is higher on the west and southwest costs of Cyprus (http://www.oceanography.ucy.ac.cy/ewave/wp-content/uploads/2011/08/EWAVE-%CE%9Dewsletter-1-EN.pdf).

Of course, actual wave measurements are preferred, but these require significant infrastructure to achieve in the open sea and recent data are not presently available in Cyprus waters. However, one report (Loizidou and Dekker 1994) does provide a ship-observation-based summary of open sea and near coastal wave heights from 1961-1990. The open sea conditions were estimated for three areas: north, west, and south of Cyprus. In the first area, prevailing waves come from the west/southwest and most waves are between 0.25 m and 1.25 m in significant wave height. In the west area, the prevailing waves are from the west with the same height range dominating. In the south area, prevailing waves are from the west/northwest sector with the same dominating height range. A few coastal locations were analyzed, but it was necessary to extrapolate the open sea values to the coast without detailed knowledge of bathymetry effects.

1.1.5.2 Annual and seasonal evolution

There is little information available on the annual evolution of wave energy in Cyprus waters, and only common knowledge indicating the increase of wave heights in the winter stormy season visible on wave forecasts (OC-UCY 2011b, for wave plots) and verified by most of the points analyzed for summer/winter statistics in Loizidou and Dekker (1994).

1.1.6 Sea surface tides

Tides in the Eastern Mediterranean are in the range of 0.3-0.4 m peak to peak at the coastal ports of Cyprus (OC-UCY 2011b, for tide gauges). Open ocean tides from a tidal model are of similar magnitude (OC-UCY 2011b, for tide model). One report presents results for numerical modeling of tidal constituents with data assimilation from tide gauges: for the Levantine Basin tides are purely astronomically driven (not affected by other ocean basins) and the coamplitude summed over the first 8 constituents is about 0.3 m (Kantha et al. 1994). The dominant frequency is the M2 frequency (12h 25.2 min period). The current associated with this frequency was shown by the same authors to be 0.01 m s^{-1} in a purely east-west direction for the Levantine Basin.

1.1.7 Sea level

1.1.7.1 Spatial distributions

The sea level varies spatially for a number of reasons: wind forcing, barometric air pressure, water density changes (because of density-driven currents balanced by sea level gradients or expansion/contraction due to changes in temperature or salinity), tides, and waves. The latter two have been discussed in previous sections. Very little information is available on the regional changes in sea level caused by wind forcing and air pressure, although these are critical for near coastal estimates. Density effects are more important in the open ocean, since the vertically-integrated effect of temperature and salinity changes causes changes in sea level.

In the open ocean, changes in sea level are observed using satellite altimetry, but only since the early 1990's. Typically, changes in sea level relative to some mean surface are reported. The way of calculating this mean surface is not straightforward. In fact, the mean surface itself provides information on the currents averaged over all depths and over a period of several years. In the Eastern Mediterranean, changes in sea level of several centimeters across the basin are common, and are associated with the mean currents. Deviations from this mean indicate changes in the circulation, but are very small. In the coastal region, sea level is a mix of the open ocean high and low pressure systems and local coastal phenomena, such as bathymetry and coastal morphology in concert with winds, barometric air pressure, waves and tides. At the coastal scale, sea level has been observed in Paphos since 2002, and at another 3 stations since 2010 (OC-UCY 2011b, for MedGLOSS Cyprus stations). Data from these gauges have not been analyzed to describe spatial variability.

1.1.7.2 Annual and seasonal evolution

Temporal changes in sea level relative to a long-term mean are measured by frequent satellite altimetry tracks for the open ocean or changes in density measured by profiling floats (ARGO) or expendable bathythermographs (XBT). These very small changes (on the order of a few cm) are not detectable in other ways, since waves and tides are nearly impossible to remove from direct in situ measurements in the open ocean. Since the 1990's satellite altimetry missions have indicated a global sea level rise in agreement with sea level measuring stations of about 3 mm y^{-1} (Woodworth et al. 2011). The same authors show similar values in the Mediterranean based both on satellite altimetry and in situ observations. While showing a similar basin average, a rate of sea level rise of 10 mm y^{-1} in the Levantine Basin is computed for 1992-2005 by Criado-Aldeanueva et al. (2008).

Models are often used to reconstruct and predict sea level change, because of the lack of long time series. The changes in sea level due to wind forcing and barometric pressure have been estimated using a barotropic Mediterranean Sea model to be about -0.6 mm y^{-1} from 1958-2001 (Tsimplis et al. 2005). After removing this effect from tide gauges, the eastern basin indicates a rapid sea level rise over 1993–2001 of 5–10 mm y^{-1} which is probably related to the Eastern Mediterranean Transient (EMT). Tsimplis et al. (2008) use a regional climate model forced by a high greenhouse gas emissions scenario to show that in the Levantine, the effect of air pressure is to decrease sea level by about 2 cm over the 110 year simulation, changes in circulation result in a rise of 0-2 cm, while steric effects (expansion/contraction) dominate at about 15 cm. Although not included in the model, the effect of ice melting could range from -7 to +18 cm. In the maximum scenario, this would mean a net rise of 33 cm or 3 mm yr^{-1}, which is comparable to the global average, or in the minimum scenario a rise of only 8 cm or 0.7 mm y^{-1}, low compared to the global predicted average from IPCC (2007): 19-58 cm 100 y^{-1} or 1.9 to 5.8 mm y^{-1}. One available simulation (Tsimplis et al. 2008) indicates there is no seasonal preference for the stated rate of sea level change discussed above.

At the coastal scale, sea level has been observed in Paphos since 2002, and at another 3 stations since 2010 (OC-UCY 2011b, for MedGLOSS Cyprus stations). No trend has been visible for this short series.

1.2 Spatial and temporal distribution of salinity

1.2.1 Spatial distribution

As for temperature, salinity can be identified with one of the four major water masses in the Levantine Basin: Levantine Surface Water (LSW), Atlantic Water (AW), Levantine Intermediate Water (LIW) and Eastern Mediterranean Deep Water (EMDW). Figure 1.3 shows profiles and T/S diagrams from the CYBO-19 cruise carried out by the Oceanography Center of the University of Cyprus in September of 2005. The LSW is shown in a thin surface layer (approx. 20 m thick) of very salty water (up to 39.51 psu), a result of the extensive evaporation during the summer season. In winter (November to March), winds and convective mixing processes homogenize the water column from the surface downward to subsurface and intermediate layers, in some cases even down to 200-350 m (Zodiatis et al. 2001). Ranges in surface salinity throughout the year are approximately 39.0-39.5 psu based on in-situ averages in the upper 10 m of salinity from cruises (Samuel-Rhoads et al. 2008).

In some regions, a meandering jet transferring Atlantic Water can be found below the surface mixed layer, identified by a salinity minimum from the Straits of Gibraltar to the Cretan Passage and into the Levantine (Lacombe and Tchernia 1960, Oren 1971, Morcos 1972). There, the AW is most often well-pronounced as a subsurface layer with minimum salinity, spanning 40 to 80 meters, with salinity in the range of 38.60-38.95 psu (Ovchinnikov et al. 1976, Hecht et al. 1988, Özsoy et al. 1991). However, periodically surface AW has also been found in the western part of the Levantine with similar salinity values. AW is more often found in summer, since in winter vertical mixing often homogenizes water properties to depths greater than that of the AW. The relatively warm and saline LIW is found from about 200-400 m and is the result of winter cooling and sinking of LSW at various locations, including the primary source of the Rhodes Gyre (Morcos 1972). It has a salinity of about 39.0-39.1 psu and is recognized as a subsurface salinity maximum. The LIW spreads from the Levantine Basin throughout the Mediterranean.

Below depths of approximately 500 m, Eastern Mediterranean Deep Water is found. This slow-moving and relatively homogeneous water mass typically has characteristics of 13.3 - 13.38 ^{o}C and 38.66-38.80 psu. It is also formed annually, during deep convection events either in the Adriatic Sea (the typical cooler/fresher condition) or in the Aegean Sea (the more unusual and more recent warmer/saltier condition).

As mentioned above, open ocean temperature and salinity are good representatives of coastal values. Observations of surface salinity have been collected by the Department of Fisheries and Marine Research since 2006 in the framework of the Water Framework Directive, and their results indicate salinity values in the upper 20 m of 39.0 to 39.6 psu in nearly all cases for February or March and August or September (Argyrou 2008, Argyrou et al. 2011). One can see the more saline waters in the summer, and ranges in salinity in agreement with the LSW ranges.

1.2.2 Annual and seasonal evolution

The annual cycle of salinity can be seen in the MedGOOS-3 buoy time series (Figure 1.6). Near-surface (at the depth of 17-m) salinity peaks in late-July and has a minimum between late March and early May (a gap exists in the time series during this period). Time series from model simulations show a broad minimum in salinity in the period of April and May

(INVG 2011). The deeper sensors show that from April to October, the upper 38 m are stratified, while for the remainder of the year the sea is well mixed over these depths (because of winds and surface evaporation). Because of the strong seasonal influence in this layer, an annual ventilation is expected down to at least 100 m, depending on the location and the year.

1.2.3 Decadal and inter-decadal changes

Regional changes in surface salinity calculated from hydrographic cruises in the Cyprus EEZ from 1996-2006 indicate that the surface salinity has risen, although not statistically significant (Samuel-Rhoads et al. 2008).

Regarding intermediate water, Rholing and Bryden (1992) show an increase in salinity in LIW (after it has passed into the western Mediterranean) from 38.91 to 39.043 from 1910 to 1972. These authors suggest that the damming of rivers has led to this increase and that the salinity will continue to rise until a steady state is reached, approximately 100 years after the major construction projects of the 1960’s and 1970’s.

Changes in salinity at deep water layers have been recorded in regard to the Eastern Mediterranean Transient discussed earlier. EMDW properties depend strongly on the source (Adriatic or Aegean), and it appears that the Aegean has been favored in recent years. If LIW becomes more saline, it is likely that also EMDW will become more saline, since entrained and cooled LIW is the source of EMDW.

1.3 Spatial and temporal distribution of nutrients (DIN, TN, DIP, TP, TOC) and oxygen

1.3.1 Inorganic nutrients and organic matter

1.3.1.1 Spatial distribution and temporal variations

1.3.1.1.1 Regional phenomena

The Levantine Basin is considered to be one of the most oligotrophic ocean bodies of the globe (Krom 1995). Nutrient levels in the euphotic zone are extremely low year-round. Yılmaz and Tuğrul (1998) reported average values of 0.21 ± 0.23, 0.02 ± 0.01, and 1.33 ± 0.30 μmol L^{-1} for $NO_3^- + NO_2^-$, PO_4^{3-}, and $Si(OH)_4$ respectively for the euphotic zone (0-85 m depth) of the northern Levantine Basin in October 1991. In the framework of the POEM project, Kress and Herut (2001) charted the distribution of nutrient concentrations down to 1200 m depth over different seasons between 1989 and 1995. The results are shown in Table 1.2, and they corroborate the general ranges reported by Yılmaz and Tuğrul (1998).

Table 1.2 Nutrient concentrations of various water masses in the Southern Levantine Basin at different times of the year, as recorded by Kress and Herut (2001) between the years of 1989 and 1995. Water mass abbreviations (average water depth ranges in parentheses): LSW – Levantine Surface Water (0-40 m), AW – Atlantic Water (65-95 m), LIW – Levantine Intermediate Water (200-310 m), DW – Deep Water (below 700 m). Season definitions, based on Hecht et al. (1988): Summer – July to October, Spring – April to June, Winter – February to March, Transition – March to April.

Water mass	Season	NO_3^- (μmol kg^{-1})	PO_4^{3-} (μmol kg^{-1})	$Si(OH)_4$ (μmol kg^{-1})
LSW	Summer	0.06 ± 0.11	0.02 ± 0.02	1.09 ± 0.36
	Spring	0.2 ± 0.15	0.02 ± 0.03	1.16 ± 0.41
	Transition	0.29 ± 0.18	0.02 ± 0.01	1.47 ± 0.2
	Winter	0.6 ± 0.5	0.01 ± 0.01	1.23 ± 0.48
AW	Summer	0.23 ± 0.74	0.02 ± 0.03	1.16 ± 0.69
	Spring	0.33 ± 0.45	0.02 ± 0.02	1.35 ± 0.42
	Transition	0.38 ± 0.35	0.01 ± 0.02	1.58 ± 0.27
LIW	Summer	0.55 ± 0.65	0.03 ± 0.02	1.2 ± 0.5
	Spring	1.99 ± 1.02	0.05 ± 0.03	1.81 ± 0.87
	Winter [a]	1.19 ± 1.22	0.03 ± 0.04	1.7 ± 1.17
DW	All [b]	5.57 ± 0.30	0.23 ± 0.03	10.33 ± 0.60

[a] Data from Krom et al. (1992)
[b] Data for the southeastern Levantine Basin

Distinct profiles collected during the F/S Meteor Cruise 44/4 in April 1999 (Kress et al. 2003b) illustrate the extent and intensity of the nutricline in the eastern Levantine (Figure 1.9). In the case of both NO_3^- and PO_4^{3-}, maximum concentrations of 6-6.5 and 0.21-0.23 μmol kg^{-1} respectively are encountered at a depth of approximately 500 m as compared to depleted surface waters, and decrease slightly with depth, presumably due to depletion of organic matter that fuels remineralization. In the case of $Si(OH)_4$, maximum concentrations of 10-10.5 μmol kg^{-1} are reached at a greater depth (1200-1500 m), presumably due to the slower remineralization rates of diatomaceous opal compared to soft-tissue nitrogen and phosphorus (Crombet et al. 2011).

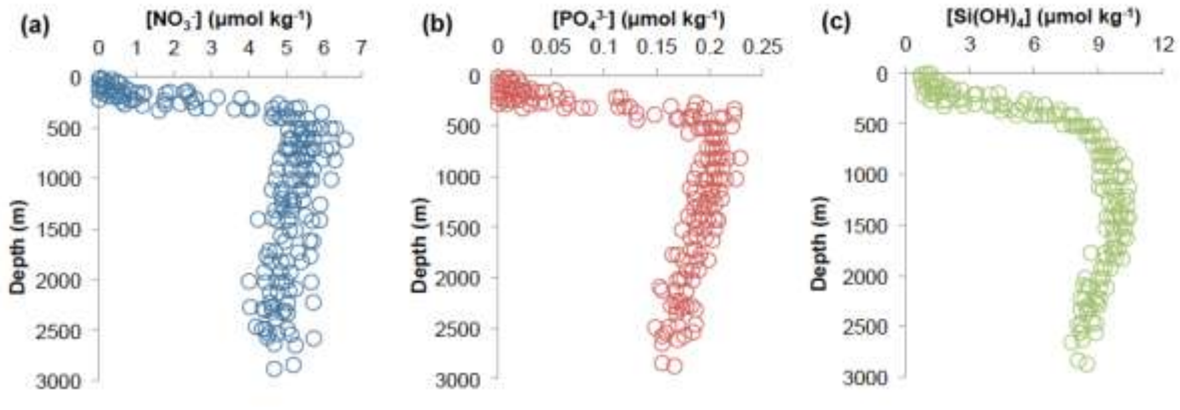


Figure 1.9 Composite profiles of (a) nitrate, (b) phosphate, and (c) silicate, collected at 11 stations in the Levantine Basin during F/S Meteor Cruise 44/4 in April 1999 (modified from Kress et al. 2003b).

Recently published data from the trans-Mediterranean cruise BOUM (Biogeochemistry from the Oligotrophic to the Ultra oligotrophic Mediterranean Sea) of 2008 (Figure 1.10) verify and enrich the previously fragmented knowledge regarding nutrient and organic matter levels in the Levantine (e.g., Crombet et al. 2011, Pujo-Pay et al. 2011). Moreover, they illustrate once more the contrast between the Western and Eastern Mediterranean basins in relative oligotrophy as it was documented in the past (e.g., Krom et al. 1991).

The oligotrophy gradient across the Mediterranean, from relatively higher nutrient levels in the west to relatively lower levels in the east, is defined by the anti-estuarine circulation of the Mediterranean Sea in combination with the important biogeochemical processes of primary production at the surface, export of biogenic material across the thermocline, and its remineralization at depth (e.g., Crombet et al. 2011). Spatial distribution patterns of the concentrations of nutrients and organic material demonstrate the net result of these processes.

Specifically, concentrations of PO_4^{3-} and NO_3^-+NO_2^- decrease steadily from west to east, and at station C (in the Cyprus EEZ) reach deep-water maxima of 0.2-0.25 μmol L^{-1} and 5.5-6 μmol L^{-1} respectively (Figure 1.11A and Figure 1.11B). More tellingly, the depth at which both nutrient classes exhibit concentration gradients, i.e., the phosphocline and nitricline respectively, increase from west to east (Figure 1.11C). However, whereas the nitracline depth increases only slightly, the phosphacline increases by nearly 200 m, a discrepancy which has been observed before in the Levantine (Ediger and Yılmaz 1996) and attributed to both methodological reasons (the calculation is influenced by the limit of detection of the analytical methods used) as well as phosphorus limitation (Krom et al. 1991, see discussion in Pujo-Pay et al. 2011).

Similarly, concentrations of $Si(OH)_4$ in the biogenic (or euphotic) layer decrease from west to east, so that at Station C (the eastern-most station) they do not exceed 1 μmol L^{-1} (Figure 1.11D), while the silicicline does not start developing until a depth greater than 200 m (Crombet et al. 2011). A deep biogenic silica maximum of 0.24 μmol L^{-1}, was observed at the same station at 100 m, suggesting that siliceous phytoplankton (e.g., diatoms) growth may be silica-limited (Crombet et al. 2011).

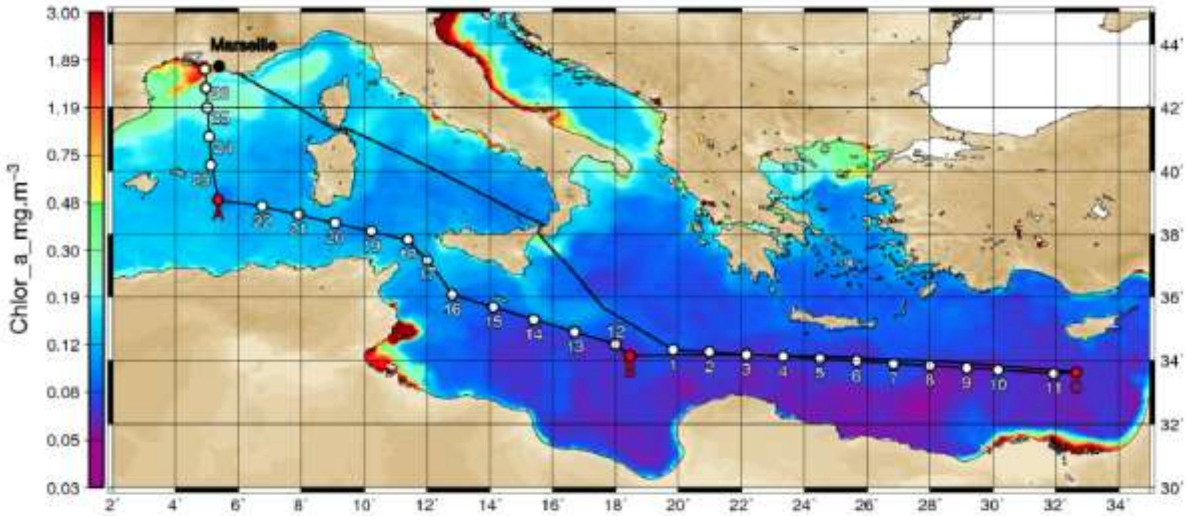


Figure 1.10 Track (black line) and stations (white circles) of the BOUM cruise, which took place in the summer of 2008, superimposed on a satellite (SeaWIFS) composite image of chlorophyll-*a* concentrations (figure from Pujo-Pay et al. 2011). Stations marked with red circles (A-C) were long-duration stations and associated with anti-cyclonic eddies.

Oligotrophy is also indicated by concentrations and inventories of organic material. Spatial distribution patterns in the concentrations of particulate organic carbon (POC), particulate nitrogen (PN) and particulate phosphorus (PP) generated from the BOUM cruise data (Figure 1.12) indicate the gradual decrease in surface concentrations of all three parameters from west to east (Pujo-Pay et al. 2011). Concentrations at station C drop to 3-3.5 μmol L^{-1}, 0.3-0.35 μmol L^{-1}, and 0.012-0.014 μmol L^{-1}, for POC, PN and PP respectively. An examination of the dissolved organic solute concentrations (Figure 1.12) yields different conclusions, and specifically overall increases from west to east, a fact which lends credence to suggestions that organic nutrients may be important for primary productivity in the more impoverished Levantine Basin (e.g., Crombet et al. 2011, Pujo-Pay et al. 2011). The concentrations at station C are 68-70 μmol L^{-1}, 4.5-4.8 μmol L^{-1}, and 0.02-0.03 μmol L^{-1}, for DOC, DON and DOP respectively (Pujo-Pay et al. 2011).

It should be briefly noted that particulate matter concentrations in the open Levantine basin are very low. Based on nephelometry data collected mainly in the north-western Levantine, and a generalized model developed by Karageorgis et al. (2008), concentrations throughout the water column and outside areas of cyclonic activity (e.g., the Rhodes gyre) are at most 0.35 mg L^{-1}, and most likely well below this value.

It should also be noted that the concentration differences between east and west in both the particulate and dissolved phases differ in that, whereas dissolved concentrations may increase by 5-10 % from west to east, particulate concentrations may decrease by as much as 50 % (Figure 1.12), despite the similarity in the extent of the depth of the nutricline for both particulate and dissolved components, clearly visible in the transect data.

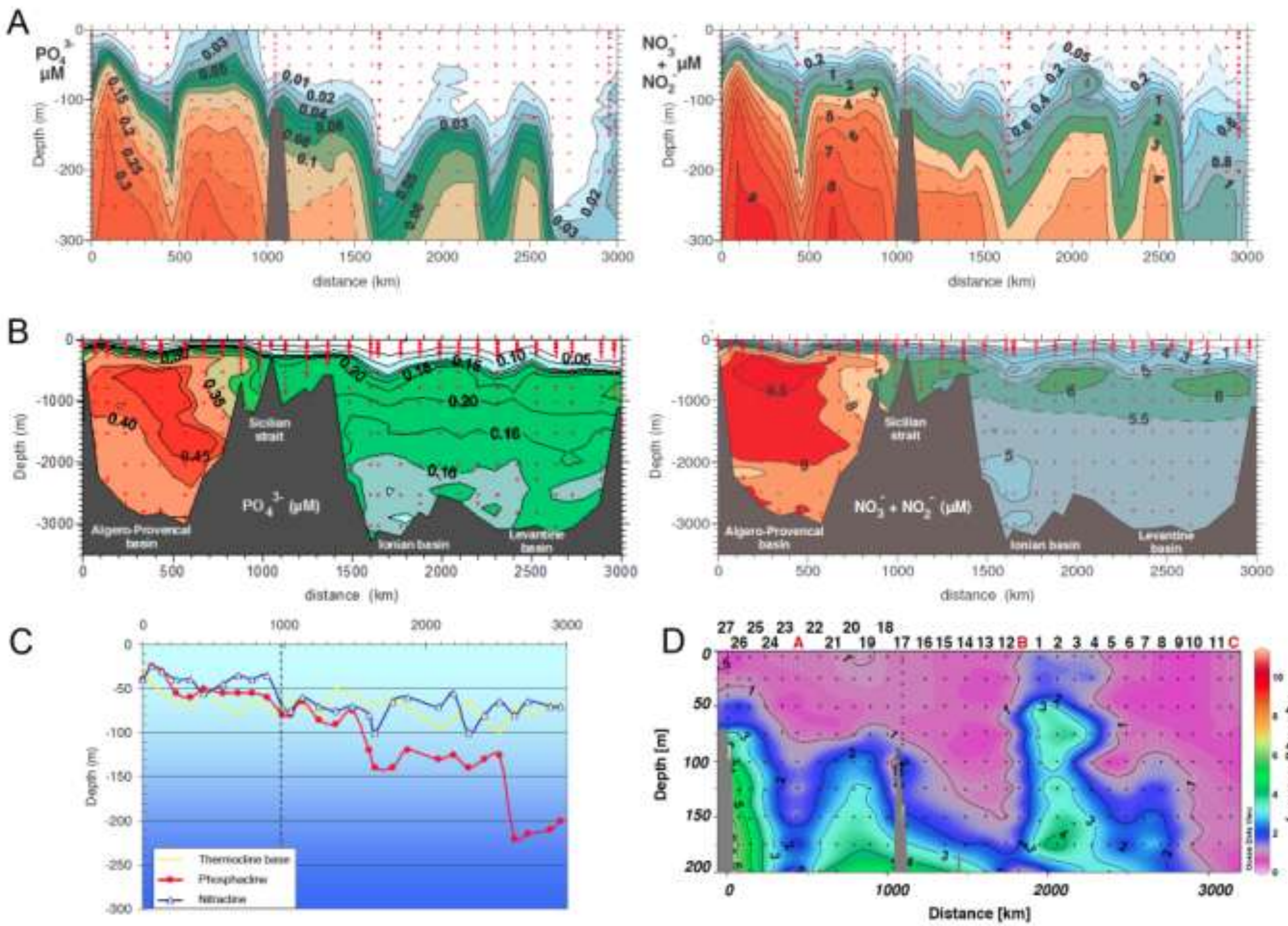


Figure 1.11 Rows A and B: Concentrations of PO_4^{3-} (left column) and NO_3^-+NO_2^- (right column) in µmol L^{-1} collected during the BOUM cruise in the summer of 2008; concentrations are shown just for the top 300 m from the surface (row A) and for the whole water column (row B). C: The depths of the base of the thermocline (yellow line), the gradient in PO_4^{3-} (phosphacline; red line) and the gradient in NO_3^-+NO_2^- (nitracline; blue line) along the same transect. The vertical dashed line indicates the Sicilian Strait. D: Concentrations of $Si(OH)_4$ in µmol L^{-1} in the top 200 m of the water column collected during the BOUM cruise transect (Crombet et al. 2011). Figures obtained and modified from Pujo-Pay et al. (2011) for A-C and Crombet et al. (2011) for D.

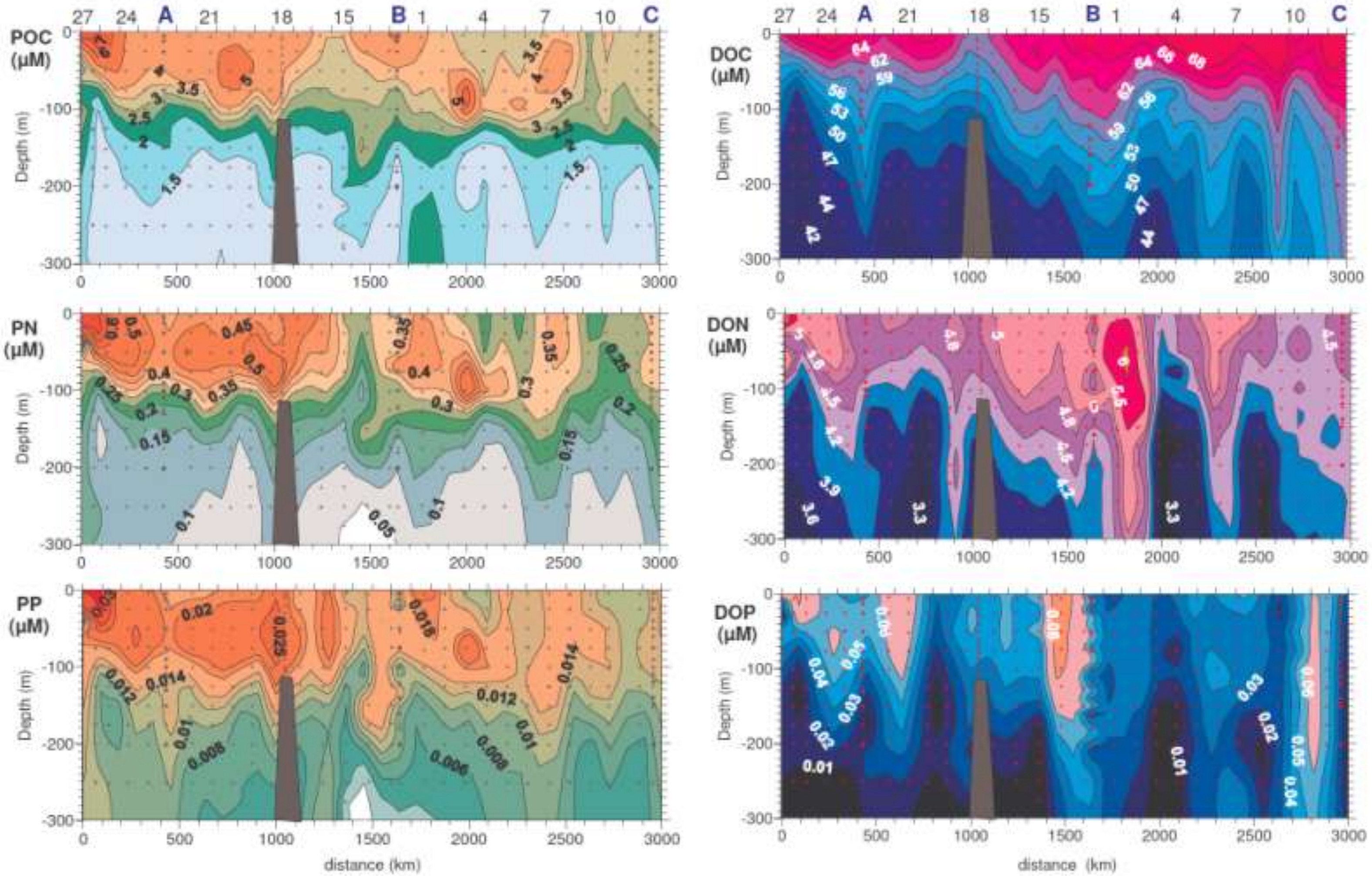


Figure 1.12 Left column: Concentrations of particulate organic carbon (POC), nitrogen (PN) and phosphorus (PP) in µmol L^{-1} in the top 300 m along the BOUM cruise transect. Right column: Concentrations of dissolved organic carbon (DOC), nitrogen (DON) and phosphorus (DOP) in µmol L^{-1} in the top 300 m along the BOUM cruise transect. Figures obtained and modified from Pujo-Pay et al. (2011).

It has long been proposed that phosphorus is likely to be the major limiting macronutrient in the Levantine basin (Krom et al. 1991, 2004, 2010, Krom 1995). The original indication of phosphorus limitation is the extraordinarily high N:P ratios in EMDW, approximately 28:1 (Krom et al. 2010), which in turn have been explained by the lack of denitrification (Krom et al. 2004), the removal of phosphorus as PO_4^{3-} by adsorption to iron in dust particles (Krom et al. 1991, Herut et al. 1999b), and the very high N:P ratios of the main external sources of nutrients (Herut et al. 1999a, Krom et al. 2010), particularly atmospheric dust input (> 120) and riverine influx (> 22; see section 1.3.1.2.1).

The effects of nutrient limitation on the abundances and growth patterns of microplankton are intense (e.g., Ediger and Yılmaz 1996, Zohary et al. 1998) and don't affect just photoautotrophs but also heterotrophs (e.g., Thingstad and Rassoulzadegan 1999). The CYCLOPS (Cycling of Phosphorus in the Mediterranean) experiment demonstrated dramatically the food-web-wide effect of the extreme nature of nutrient limitation: the zooplankton community was shown to have adapted to rapidly exploit any increase in primary productivity (stimulated by inputs of phosphorus) by rapidly investing it in reproduction, and specifically egg production (Pasternak et al. 2005, Pitta et al. 2005, Psarra et al. 2005, Thingstad et al. 2005).

The quasi-permanent Cyprus Eddy is thought to significantly affect nutrient distributions in this cyclonically intense region. Its main effect is to essentially suppress the nutricline to a much deeper layer than in its boundary: Krom et al. (1992, 1993) and Zohary et al. (1998) demonstrated that the nitracline and silicicline at the boundaries had very similar magnitude and dimensions as those at the core of the eddy but were displaced by approximately 250-350 m upwards. Another effect of the eddy which remains understudied is the evolution of its biogeochemistry which may affect (to a smaller scale than the effect above) nutrient distributions in the top 1000 m. If, for example, the eddy is net heterotrophic we would expect to see a slight accumulation of nutrients, and especially nitrogen (which is not limiting) as we indeed do see in recent data (see right panel of Figure 1.11B) for this and other eddies in the Mediterranean (Pujo-Pay et al. 2011).

Finally, it should be mentioned that the ranges reported in the text above incorporate inter-decadal variability in deep-water concentrations by phenomena such as the East Mediterranean Transient (described in section 0), which injected the deep Levantine basin with labile organic material and oxygen and pushed slightly upwards (from 2500 m to 1500 m) the nutrient maxima (Klein et al. 2003, Kress et al. 2003b). The concomitant increase in respiration of the supplied organic material and resulting nutrient regeneration are distinguished when examining profiles at specific stations (e.g., Klein et al. 2003) but in general fall within the basin-wide range of nutrient concentrations.

1.3.1.1.2 Coastal waters

The ultraoligotrophic character of the region is also reflected in the chemistry of the coastal waters of Cyprus, and this is corroborated by the up-to-date results from the monitoring programmes of the Department of Fisheries and Marine Research of the Republic of Cyprus (Loizides 2001, Argyrou and Loizides 2005, Argyrou 2006, 2008, Argyrou et al. 2011, EEA 2011). An examination of data collected at the stations identified as reference stations in these reports (Table 1.3) indicates that coastal water concentrations are comparable to those of Levantine surface waters (Table 1.2). Specifically, the averages of all the samples collected throughout the period for which data are available (2004-2010) at all depths (0-32 m) are 0.6 ± 0.7, 0.1 ± 0.3, and 0.03 ± 0.04 μmol L^{-1} for NO_3^-, NO_2^-, and PO_4^{3-} respectively. Therefore, while coastal concentrations are on average 2-3 times greater than those of open Levantine intermediate waters, they remain at the low end of the global coastal water nutrient concentration ranges.

1.3.1.2 Natural sources

The ultraoligotrophic character of the Eastern Mediterranean as well as the unusual N:P ratios in its deep waters have stimulated a discussion on the major sources of nutrients (especially N and P). A recent review by Krom et al. (2010) indicates that the major external sources of nutrients in the region are atmospheric dust input and fluvial (riverine) effluent (Table 1.4), and these are discussed briefly below. Direct anthropogenic input is not addressed in this section, but in Part II of this Report. Estimates of the impact of these external nutrient sources (including anthropogenic sources) suggest that most of the production, 70-85 %, is actually regenerated production (Carbo et al. 2005, Yogev et al. 2011). Approximately half of new production is most likely due to mixing and entrainment from deeper layers, while most of the remainder attributed to atmospheric dust inputs. A small fraction is due to riverine inputs, while nitrogen fixation is increasingly thought to be negligible in the Levantine basin (Yogev et al. 2011).

1.3.1.2.1 Atmospheric sources

A major source of limiting macronutrients and perhaps micronutrients (such as trace elements) in the region’s seas is atmospheric dust transport from the Sahara, and is believed to support a significant proportion of primary production in the Levantine Basin (Guerzoni et al. 1999, Herut et al. 1999a, 2002, 2005).

Herut (2005) summarized available data on atmospheric deposition for the southeastern Mediterranean and reported average values of total (both dry and wet deposition) of 70 and 1.3 mmol m^{-2} y^{-1} for N and P respectively. Most recently, the ADIOS project has published measurements of dry deposition inputs of macronutrients (P) and metals (including the micronutrients Fe, Zn, Cd) from Saharan dust in 9 stations across the Mediterranean during 2001-2002 (Guieu et al. 2010). One of the stations was located in Cyprus, and specifically Cavo Greco, at a distance of 800 m from the shore and an elevation of 40 m. The input of P at this location averaged 19 kg km^{-2} $month^{-1}$ or 7.4 mmol m^{-2} y^{-1}, significantly greater than the previous estimates.

To put these inputs in perspective, one may assume that the top 1 m of the water column is well mixed, resulting in input rates of 70 and 1.3 (or 7.4) µmol L^{-1} y^{-1} for N and P respectively. The annual atmospheric input is of a comparable order of magnitude to average coastal surface water concentrations of total N and P (Table 1.3). Considering water column mixing throughout the water column during the year, as well as the starved state of planktonic communities and fast removal to the sediments, atmospheric inputs do not control the rate of primary productivity on a regular broad scale, but contribute significantly (see, for example, Herut et al. 2005). Specifically, atmospheric dust inputs account for approximately 15 % of total primary production during the winter mixing months (see Table 1.2 for definition) and for as much as 30 % during the more stratified summer months (Yogev et al. 2011).

It should also be noted that the deposition values mentioned above result in an N:P ratio of 54 for the atmospheric dust that reaches the Levantine Basin surface waters, a value substantially lower than the values of 117 or 195 reported elsewhere (Table 1.4) for the eastern Mediterranean. This may reflect the substantial variability that exists across the region in both input rates and N:P ratios (and which is masked in broad-scale budget calculations), as well as the relative bioavailability of the two elements which is greater for N by approximately one order of magnitude (Carbo et al. 2005, Herut 2005).

Table 1.3 Average nutrient concentrations of coastal surface waters of Cyprus, as recorded at various reference stations during the compliance monitoring programmes of the Department of Fisheries and Marine Research between the years of 2004 and 2010 (Argyrou and Loizides 2005, Argyrou 2006, 2008, EEA 2011). The numbers in parentheses (n) represent the number of samples used in the averaging. For the purpose of calculating the averages, samples with values below the limit of detection (LD) were assigned half the value of LD, and if the calculated average was below the lowest LD for the particular dataset, it was declared as less than the particular LD.

Area	**Years**	**Sample depth (m)**	**Total N µmol L^{-1} (n)**	**NO_3^- µmol L^{-1} (n)**	**NO_2^- µmol L^{-1} (n)**	**NH_4^+ µmol L^{-1} (n)**	**Total P µmol L^{-1} (n)**	**PO_4^{3-} µmol L^{-1} (n)**
Polis Chrysochou Bay	2006, 2008	0.5	15.5±15.6 (7)	0.98±0.97 (4)	0.09±0.13 (4)	< 0.5 (7)	1.24±0.97 (7)	0.04±0.04 (4)
		10-10.5	12.6±11.3 (7)	0.94±1.02 (4)	0.08±0.05 (4)	< 0.5 (7)	1.30±0.98 (7)	0.02±0.01 (4)
		20-20.5	11.3±11.5 (7)	0.95±1.01 (4)	0.07±0.03 (4)	< 0.5 (7)	1.45±0.88 (7)	0.02±0.01 (4)
Yeronisos/Sideronisia	2008-2009	0.5	< 0.5 (1)	0.10 (1)	0.36 (1)	1.18±0.16 (2)	2.6 (1)	0.06 (1)
Lara-Toxeftra	2004-2010	0-0.5	13.8±13.4 (14)	0.53±0.67 (10)	0.05±0.06 (11)	0.41±0.65 (18)	4.30±11.7 (14)	< 0.02 (10)
		10-10.5	15.3±13.7 (5)	1.25±0.25 (2)	< 0.04 (2)	< 0.5 (5)	0.94±0.87 (5)	< 0.02 (2)
		20-20.5	21.5±27.1 (5)	1.36±0.21 (2)	0.04±0.04 (2)	< 0.5 (5)	0.88±1.00 (5)	0.02±0.01 (2)
Limassol Bay	2005-2006	0	30.0±0.00 (4)	0.16±0.13 (3)	0.05±0.04 (3)	0.23±0.21 (4)	8.23±10.7 (2)	0.05±0.03 (3)
		10	30.0±0.00 (4)	0.10±0.08 (3)	0.06±0.07 (3)	0.17±0.16 (4)	10.5±13.9 (2)	0.02±0.02 (3)
		20	50.0±23.1 (4)	0.23±0.14 (3)	0.15±0.18 (3)	0.13±0.11 (4)	12.3±15.5 (4)	0.09±0.12 (3)
		30-32	51.4±60.6 (7)	0.16±0.20 (5)	0.06±0.04 (5)	0.18±0.17 (7)	1.51±1.05 (6)	0.05±0.07 (5)
Zygi	2008-2010	0.5	5.10±1.56 (2)	0.40±0.35 (3)	0.40±0.03 (4)	0.70±0.55 (7)	2.70±0.99 (2)	< 0.02 (6)
		10.5	5.15±6.15 (2)	0.22±0.16 (2)	0.37±0.61 (3)	0.77±0.50 (8)	1.50±0.71 (2)	< 0.02 (5)
		20.5	1.55±1.48 (2)	1.23±0.69 (2)	0.63±0.78 (3)	0.79±0.46 (6)	1.90±0.14 (2)	<0.02 (5)
Cape Pyla	2008-2010	0.5	5.50±4.24 (2)	0.52±0.61 (3)	0.17±0.14 (4)	< 1.00 (6)	< 1.00 (2)	< 0.01 (1)
Average	2004-2010	0-32	20.4±25.9 (73)	0.59±0.67 (51)	0.12±0.25 (56)	< 0.5 (97)	2.80±6.61 (66)	0.03±0.04 (58)

Table 1.4 Sources and sinks of nitrogen and phosphorus for the Eastern Mediterranean (adapted from data in Krom et al. 2010). The budget includes all water bodies of the Eastern Mediterranean, including the Adriatic Sea and the Aegean Sea.

Process	**Nitrogen (10^9 moles y^{-1})**	**Phosphorus (10^9 moles y^{-1})**	**N:P**	**Reference**
Atmospheric dust input (1999-2000)	111	0.95	117	Krom et al. (2004)
Atmospheric dust input (2002-2005)	107	0.55	195	Mihalopoulos (unpublished data) in Krom et al. (2004)
Riverine input (1993)	44.8	1.4	33.6	Ludwig et al. (2009)
Riverine input (2004)	63	2.4	26	Krom et al. (2004)
Addition during exchange with the Black Sea	8	0	-	Krom et al. (2004)
Loss during exchange with the western Mediterranean	142	4.4	32	Krom et al. (2004)
Sediment deposition	27	1.0	27	Krom et al. (2004)
Sediment denitrification	10	-	-	Krom et al. (2004)
Total inputs	159 - 182	2.0 - 3.4	54 - 91	
Total sinks	179	5.4	33	

1.3.1.2.2 Fluvial sources

The term ‘fluvial’ includes both rivers and streams, which should be considered together when discussing surface inputs to the ocean. In the case of the Levantine basin inputs from both are fairly limited, so this discussion relies mainly on reviews based on data from the major rivers flowing into the Levantine basin. According to Ludwig and Meybeck (2003), the major rivers of concern in the region are the rivers of Turkey, mainly Seyhan and Ceyhan, especially since 1968 when closure of the Nile by the Aswan dam was completed. It should be noted that an unknown parameter of fluvial inputs in the Levantine basin is discharge of nutrient-rich effluents (Ludwig and Meybeck 2003), an anthropogenic source which is discussed elsewhere in this Report.

The input of nutrients by rivers is controlled by two major parameters: water discharge and nutrient concentrations in discharged water. The main rivers discharging into the northern and southern Levantine release approximately 33 km^3 y^{-1}, compared to 54 and 48 km^3 y^{-1} for the Rhône (France) and the Po (Italy) respectively, the two biggest rivers discharging in the Mediterranean (Ludwig and Meybeck 2003). The total sediment release into the margin systems and the basin is now significantly diminished after the Aswan dam construction and totals approximately 175 $\times$ 10^6 t y^{-1} (Ludwig and Meybeck 2003). Information about organic matter and nutrient discharges is very sporadic. Representative values reported by Ludwig and Meybeck (2003) for one or more of the rivers discharging in the Levantine basin are 128, 22, 0.3, 19 $\times$ 10^3, and 400 µmol L^{-1} for NO_3^-, NH_4^+, PO_4^{3-}, TN and TP respectively, and 7.9 mg L^{-1} for TOC.

Overall, the annual water discharges in combination with the nutrient concentrations summarized above result in inputs of nutrients into the marine realm comparable to those due to atmospheric dust (Krom et al. 2010), approximately half in the case of N and equal or greater in the case of P (Table 1.4). However, due to the presence of significant margin systems (deltas, estuaries, marshes) and their proximity to the shallow coastal zone, a lot of this input gets ultimately removed from the system into sediments (and the atmosphere via denitrification) and results in a contribution to the gross primary production of the Levantine of less than 2 % (Ludwig et al. 2009).

1.3.1.2.3 In situ processes

The single most-important in-situ process for nutrient generation that has been invoked for the Levantine basin is N_2 fixation by planktonic diazotrophs and it has been a hotly debated topic (for a brief review, see Bar Zeev et al. 2008, Yogev et al. 2011). Comparisons of external nutrient inputs and outputs demonstrate that, within the uncertainties of estimated rates, nitrogen fixation is not necessary to close the nutrient budget (Krom et al. 2004, 2010). On the other hand, the original suggestion by Béthoux and Copin-Montégut (1986) that N_2 fixation may contribute significantly to N input in the Mediterranean was corroborated by only one report (Rees et al. 2006), which was later dismissed for methodological reasons by Krom (2009). Work published in the last five years provides more concrete data for a more direct assessment.

While active nitrogenase (*nifH*) genes have been discovered in numerous and diverse taxa of the open Levantine basin (Man-Aharonovich et al. 2007), and while N_2 fixation does seem to take place during classically favorable conditions (i.e., the stratified summer months), the level of this activity remains very low, presumably due to P limitation (Bar Zeev et al. 2008).

Measurements of N_2 fixation across the whole of the Mediterranean during the VECTOR-TRANSMED cruise in 2007 recorded very low rates (0.018 ± 0.011 µmol N L^{-1} y^{-1} or 1.8 ± 2.1 mmol m^{-2} y^{-1}) and suggested that indeed atmospheric inputs are probably the major external source of N for primary productivity in the whole Mediterranean sea (Ibello et al. 2010). Similarly low activities (up to 0.015 µmol N L^{-1} y^{-1} or 0.95 mmol m^{-2} y^{-1}) were measured during a SESAME project cruise across the Levantine in 2008 (Yogev et al. 2011). Finally, the cross-Mediterranean BOUM cruise (2008) verified the presence of active N_2 fixers, albeit at very low abundances (Le Moal et al. 2011), with detectable activity at only one depth (0.037 µmol N L^{-1} y^{-1}) and an areal N_2 fixation rate of 0.15 ± 0.04 mmol m^{-2} y^{-1} (Bonnet et al. 2011) for station C in the Cyprus EEZ.

Based on their measurements, Bonnet et al. (2011) estimate that N_2 fixation contributes at most 0.3 % of new production or < 0.05 % of total primary production at station C, corroborating the conclusions of the most comprehensive nutrient budget calculations (Krom et al. 2004, 2010). Atmospheric dust deposition is the main external input of macro- and micronutrients, and has been shown to stimulate N_2 fixation in the Levantine basin by temporarily relieving nutrient limitation (Ridame et al. 2011).

1.3.1.3 Future trends

The previous discussion illustrates that over the past decade the available data and observations in the open Levantine have increased substantially, even though they remain sparse compared to those from the coastal ocean. Regardless, they are still insufficient to allow the quantitative prediction of future nutrient concentrations in the region's marine environment. The complexity of physical circulation, of the interplay between climatic conditions (warming and humidity) and atmospheric phenomena (dust storms and precipitation), and the response of autotrophic and heterotrophic communities necessitate the use of coupled physical-ecological models to answer most if not all questions at this point (Durrieu de Madron et al. 2011, e.g., Lelieveld et al. 2012). However, some broad conclusions may be extracted from these recently conducted broad reviews.

In Cyprus and the broader region, total precipitation will significantly decrease, along with the frequency of incidents of heavy precipitation. Warming will result in the increase of extreme heat events and, in conjunction with decreased humidity, in decrease in soil moisture. The result will be substantial increase in dust inputs (see discussion in Carbo et al. 2005) to a surface ocean that may be more stratified than before. Although the export of particulate matter may not be particularly hindered, the exchange of dissolved matter with deeper layers may be more restricted, thus resulting in accelerated recycling of nutrients in the mixed layer and the euphotic zone. The accelerated production rates both for the autotrophic and heterotrophic communities will be further enhanced by accelerated metabolic rates, as a physiological response to increased temperatures. Moreover, changes in ammonium speciation (NH_4^+:NH_3 ratios), decrease in nitrification (oxidation of ammonium species) and decrease in bioavailable PO_4^{3-} under decreasing ocean pH (see section 1.4) may result in even greater N:P ratios than at present and enhanced P-limitation (Rees et al. 2008).

Another effect of decreased precipitation is the decrease in freshwater discharges (along with dissolved and particulate matter therein) to the ocean, thus decreasing fluvial inputs. However, decreasing discharge volumes in the Levantine basin may be countered by increased nutrient concentrations due to dramatic increases in the populations inhabiting these watersheds (especially the Nile delta) and the concomitant waste generation (Ludwig et al. 2010). This topic is discussed in Part II (under Eutrophication). As far as Cyprus' coastal waters are concerned, extensive analysis of data from the last century (Pashiardis and Michaelides 2008) is reflective of the regional patterns, i.e., decrease in total rainfall and in heavy rainfall events, and is expected to continue into the future. Such conditions, combined with only slightly increasing populations suggest that fluvial nutrient inputs to the coastal waters of Cyprus will not change significantly and will remain at present levels or perhaps decrease further.

1.3.2 Oxygen

Dissolved oxygen is a master parameter of the status of aquatic ecosystems, since it is the main electron acceptor used for organic matter respiration by living organisms. Monitoring dissolved oxygen concentrations is an integral part of any pollution monitoring programme, since increased nutrient loading will result in excess productivity and aerobic respiration, and eventually oxygen depletion, i.e., hypoxia. Hypoxia is now well documented around the globe, with a recent review recording over 400 eutrophic and/or hypoxic systems worldwide (Selman et al. 2008). The following review of all existing data and information indicates that hypoxia does not occur at present in Cyprus waters and is not foreseen to arise in the near future.

1.3.2.1 Regional patterns

The Levantine Basin is characterized by high oxygen levels throughout the water column. Data collected between 1989 and 1995 in the southern Levantine in the framework of the POEM project (Kress and Herut 2001) indicate that oxygen concentrations in surface waters remain around saturation levels over different seasons, and decrease gradually to 70 % in deep waters (Table 1.5). Oxygen levels are often highest in a sub-surface layer (Figure 1.13a), often coincident with the deep chlorophyll maximum (Yacobi et al. 1995), suggesting that these high levels are due to oxygenic photosynthesis. Below the productive or biogenic layer, there is a noticeable oxygen minimum zone (OMZ) centered between 500 and 1000 m, which occurs due to microbial respiration of organic matter exported from the productive, deep-chlorophyll maximum zone.

The OMZ is clearly visible in data collected across the east Mediterranean during the F/S Meteor cruises 44/4 in April 1999 (Kress et al. 2003b) and 51/2 in November 2001 (Kress et al. 2003a), with concentrations in the OMZ below 175 μmol kg^{-1} and 185 μmol kg^{-1} respectively (see Figure 1.13b and Figure 1.14 respectively). However, it should be pointed out that these OMZ concentrations are quite high compared to typical mid-water column OMZ oxygen values below 10 μmol kg^{-1} under productive upwelling zones or monsoon-driven bloom regions (Diaz and Rosenberg 1995).

Table 1.5 Oxygen concentrations (in absolute units and % saturation) of various water masses in the Southern Levantine Basin at different times of the year, as recorded by Kress and Herut (2001) between the years of 1989 and 1995. Water mass abbreviations (average water depth ranges in parentheses): LSW – Levantine Surface Water (0-40 m), AW – Atlantic Water (65-95 m), LIW – Levantine Intermediate Water (200-310 m), DW – Deep Water (below 700 m). Season definitions, based on Hecht et al. (1988): Summer – July to October, Spring – April to June, Winter – February to March, Transition – March to April.

Water mass	Season	O_2 (μmol kg^{-1})	O_2 (% saturation)
LSW	Summer	208.6 ± 13.0	101.6 ± 3.0
	Spring	229.1 ± 3.5	100.4 ± 2.1
	Transition	232.6 ± 4.1	99.9 ± 2.3
	Winter	232.0 ± 8.7	98.4 ± 3.4
AW	Summer	231.2 ± 10. 4	101.6 ± 5.9
	Spring	229.2 ± 6.1	97.8 ± 3.2
	Transition	232.3 ± 4.3	99.2 ± 2.0
LIW	Summer	221.9 ± 8.5	95.9 ± 4.7
	Spring	210.0 ± 8.1	87.8 ± 4.0
	Winter [a]	214.1 ± 13.0	90.6 ± 6.5
DW	All [b]	175.1 ± 2.9	70.6 ± 1.2

[a] Data from Krom et al. (1992)
[b] Data for the southeastern Levantine Basin

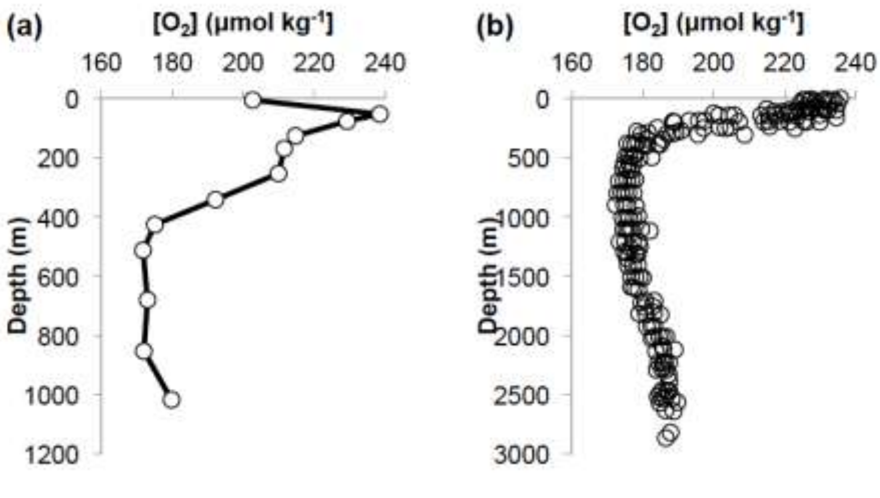


Figure 1.13 (a) Oxygen concentrations (μmol kg^{-1}) in the top 1000 m at 33° 30' N 33° 30' E of the POEM project in the Summer of 1991 (Kress and Herut 2001); (b) Oxygen concentrations (μmol kg^{-1}) in the top 3000 m at 11 stations in the Levantine Basin recorded during the F/S Meteor M44/4 cruise in April-May 1999 (Kress et al. 2003b).

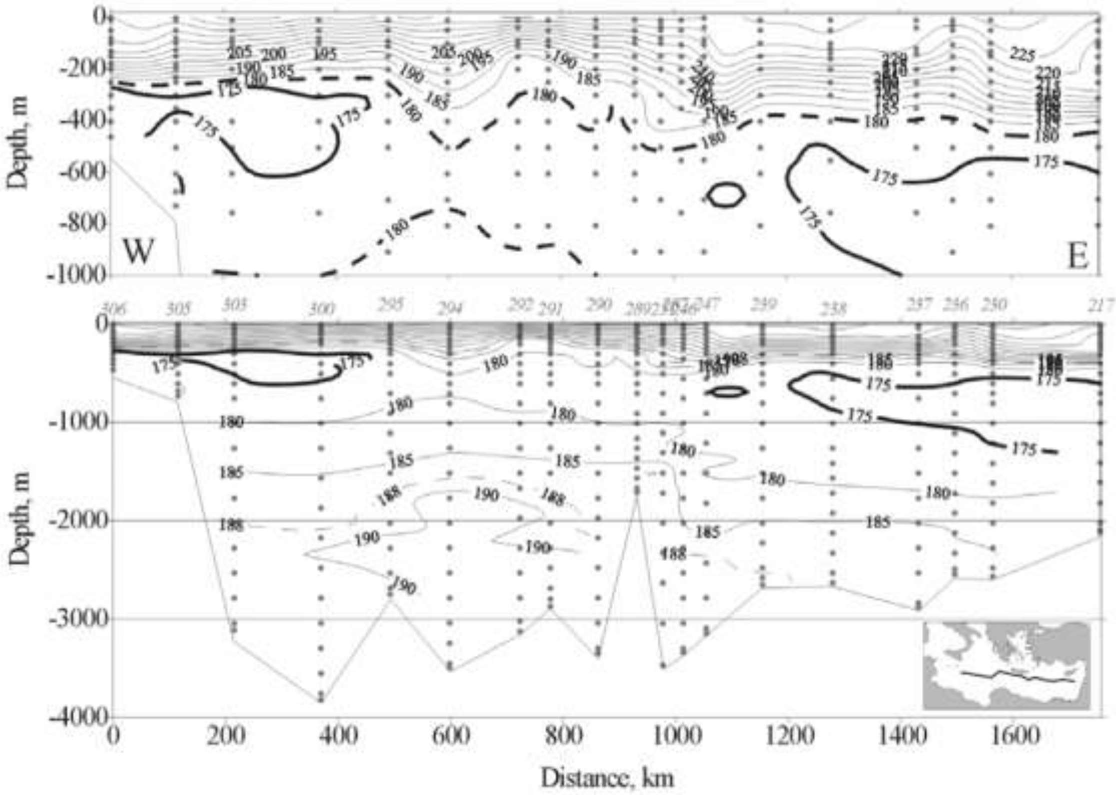


Figure 1.14 Oxygen concentrations (μmol kg^{-1}) collected during the F/S Meteor Cruise 44/4 in April 1999 (Kress et al. 2003b) along an eastern Mediterranean transect (shown at lower right inset): Top – oxygen concentrations between 0-1000 m; Bottom – Complete water column oxygen distributions. Original figures obtained and modified from Kress et al. (2003b).

The significantly higher OMZ oxygen concentrations in the eastern Mediterranean are presumably due to very low surface productivity and the consequently extremely low export of organic material to the deep layer (Krom 1995). The recently published data from the 2008 BOUM cruise corroborate the productivity-driven explanation for the distribution of the oxygen maximum and minimum layers (Pujo-Pay et al. 2011), by examining oxygen concentrations across most of the Mediterranean basin (Figure 1.15). As oxygenic photosynthesis decreases from west to east so do the maximum oxygen concentrations observed, even though, due to lower productivity, the OMZ extends deeper and is characterized by higher concentrations of oxygen in the eastern as opposed to the western Mediterranean.

The relatively straightforward vertical zonation of oxygen concentrations, which result from a balance between oxygen production and respiration of sinking organic material, can be disrupted by the presence of mesoscale features, such as the anticyclonic Cyprus Eddy (Hayes et al. 2010, 2011). The water mass trapped by the eddy is essentially isolated, resulting in low O_2 concentrations, and penetrates depths that are greater than those predicted by the gravimetric zonation model of photosynthesis-respiration balance (see bottom panel of Figure 1.4).

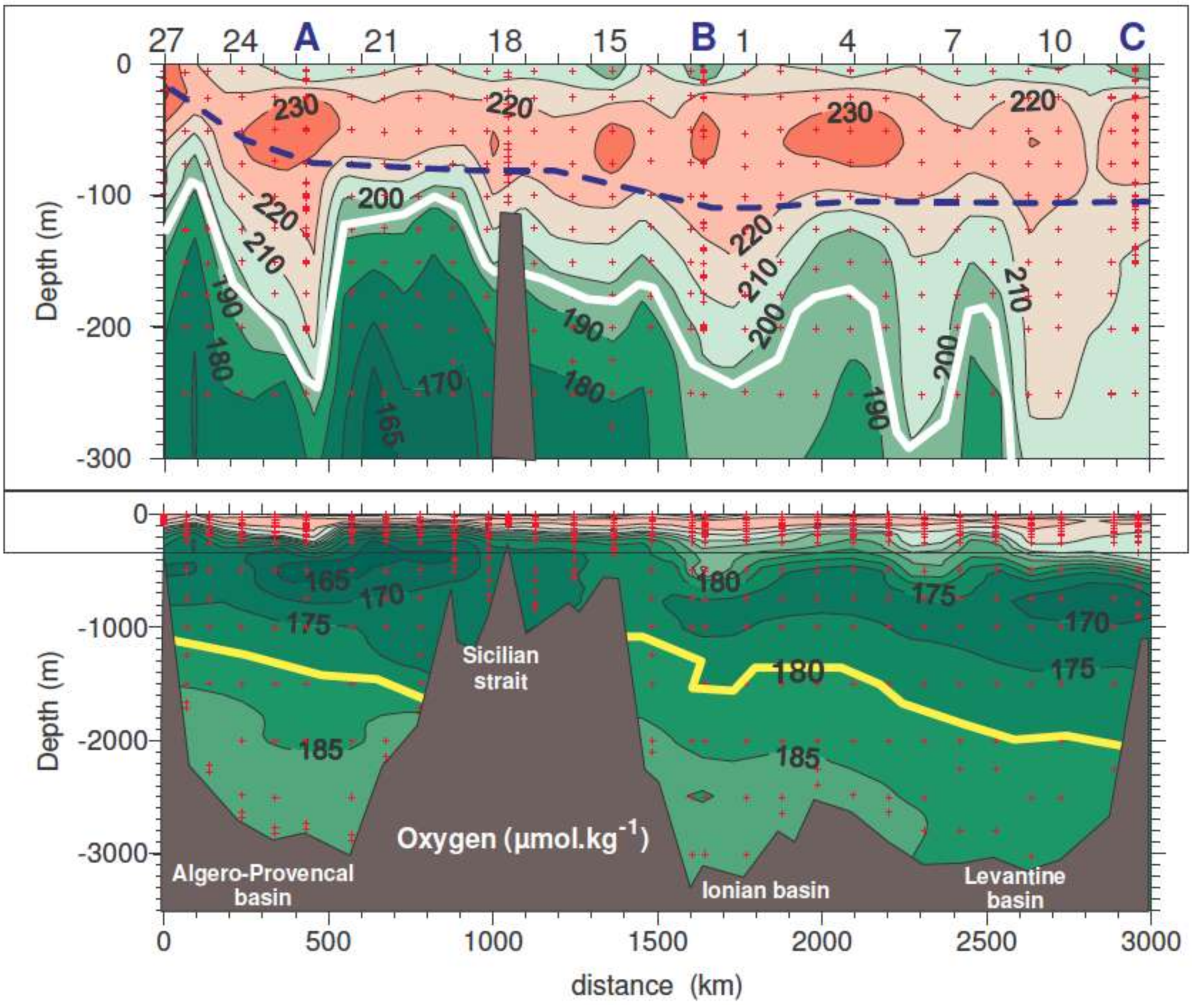


Figure 1.15 Concentrations of dissolved oxygen in µmol kg^{-1} collected during the BOUM cruise in the summer of 2008 (see **Figure 1.10** for cruise track) (Pujo-Pay et al. 2011): Top - concentrations in the top 300 m. Blue dashed line: depth of the deep-chlorophyll maximum, according to Crombet et al. (2011). White line: the 195 µmol kg^{-1} isocline; Bottom – concentrations for the whole water column. Solid yellow line: the 180 µmol kg^{-1} isocline. Figures from Pujo-Pay et al. (2011).

1.3.2.2 Coastal concentrations

Oxygen concentrations of coastal waters reflect the oligotrophic character of the broader region. An inspection of the seasonal variation in dissolved oxygen levels of a reference (control) station in Limassol Bay in 2005-2006 (Figure 1.16) indicates that, while there is some seasonal variation, dissolved oxygen concentrations remain near saturation. Coastal waters are presumably more sensitive than open basin waters to seasonal productivity patterns, where the early spring productive period is reflected in oxygen concentrations due to greater availability of organic matter which is aerobically decomposed. A characteristic indication of the high degree of oxygenation of the coastal waters of Cyprus is the average dissolved oxygen concentration of 95.8 % at all stations monitored during Water Framework Directive compliance monitoring since 2007 (Argyrou et al. 2011, EEA 2011). The main message is that these concentrations are indicative of very high near-saturation concentrations, and no hypoxia has been observed at any of the monitored locations.

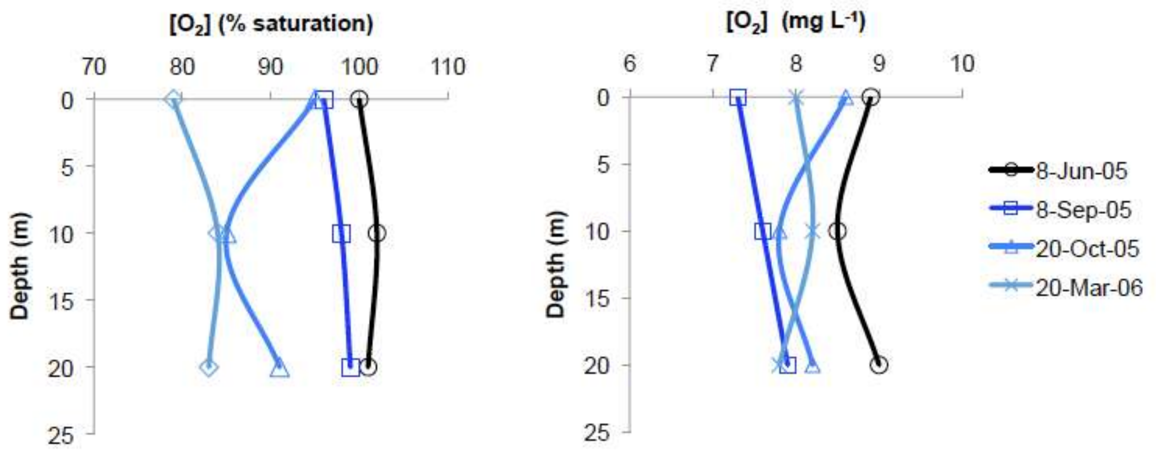


Figure 1.16 Concentrations of dissolved oxygen in % saturation (left) and mg L^{-1} (right) at station T_REF (34° 36' 3" N, 33° 2' 22" E) in Limassol Bay (or Akrotiri Bay) over a nine-month period (Argyrou 2006).

1.3.2.3 Future trends

There are currently no explicit investigations into future concentrations of O_2 in the Levantine basin and coastal ecosystems of the Mediterranean, as this would require a coupled physical-ecological modeling effort with numerous assumptions, which would broadly draw from the international literature. However, basic predictions can be made from first principles and the existing reviews (Durrieu de Madron et al. 2011, e.g., Lelieveld et al. 2012). Specifically, warming of seawater will decrease the solubility of gases in general including O_2. However, it is debatable whether this change will be detectable over and above the significant fluctuations that may result from changes in metabolic rates of both oxygenic photoautotrophs (oxygen production) and heterotrophs (oxygen consumption), a balance which is very difficult to predict explicitly. Given the near-saturation values as well as the ultraoligotrophic character of both coastal and open-ocean systems, it may be safely assumed that concentrations of O_2 will remain in high values throughout Cyprus waters, while stressing the pressing need for continuous observations for this basic ecosystem parameter.

1.4 pH, pCO_2 profiles or equivalent information used to measure marine acidification

1.4.1 Introduction

The ocean is one of the main repositories of excess carbon dioxide generated by human activities over the past two centuries (Sabine et al. 2004). Sufficient data has been collected to demonstrate, at least at ocean-basin scales (Feely et al. 2009), that any increase in atmospheric carbon dioxide is accompanied by a concomitant increase in seawater pCO_2 (Figure 1.17).

The most significant effect of pCO_2 rise in seawater is the concurrent shift of the carbonate equilibrium during CO_2 dissolution and dissociation and the release of protons (acid), a process termed "ocean acidification", and one that has now been clearly documented as a decrease in seawater pH (e.g., Figure 1.17). It is estimated that pH has dropped by 0.1-0.2 since pre-industrial times (Caldeira and Wickett 2003).

A consequence of the drop in seawater pH is an accompanying decrease in the carbonate saturation state (Ω) of marine waters (Figure 1.17), rendering the formation of carbonate shells and exoskeletons, termed "biocalcification," more energetically expensive and/or slower (Orr et al. 2005). Groups of biocalcifying organisms such as corals, coccolithophorids, calcareous algae, foraminifera, mollusks, etc., will be increasingly challenged physiologically by the carbonate saturation state decrease. Even though at present all surface waters of the oceans are supersaturated with respect to carbonate minerals, it is expected that by the end of this century polar and sub-polar waters will already be undersaturated under business-as-usual scenaria (Orr et al. 2005).

Uptake of CO_2 by oceanic surface waters, ocean acidification and carbonate saturation are affected by a suite of other factors in a non-linear fashion and with potentially complex feedback mechanisms. Increasing temperatures, which are also anticipated, reduce gas solubility but simultaneously increase metabolic rates, including respiration, which will increase the concentration of total dissolved inorganic carbon (DIC). Increasing salinities, e.g., due to increasing evaporation, also decrease gas solubility, but also increase total alkalinity (A_T, the ability of seawater to neutralize acids) which in turn enhances the ability to take up more CO_2 from the atmosphere.

Although all major ocean basins are sinks for CO_2, the seawater uptake rate varies greatly across latitudes and regions. Based on a recent compilation of global data by Takahashi et al. (2009), it is greatest in temperate and sub-polar seas, where deep mixing accelerates biological carbon fixation, and lowest in the sub-tropical gyres, where stratification of the water column is most intense.

1.4.2 Existing data and status

There is a significant gap in information on the current status of the carbonate system in Cyprus waters, and in the Eastern Mediterranean in general (Durrieu de Madron et al. 2011). Until recently, the main source of information on the carbonate system for the area was the cross-Mediterranean R/V Meteor cruise 51/2 which took place in October-November 2001 and consisted of 42 stations (Roether et al. 2003), a number of which were in Cyprus waters

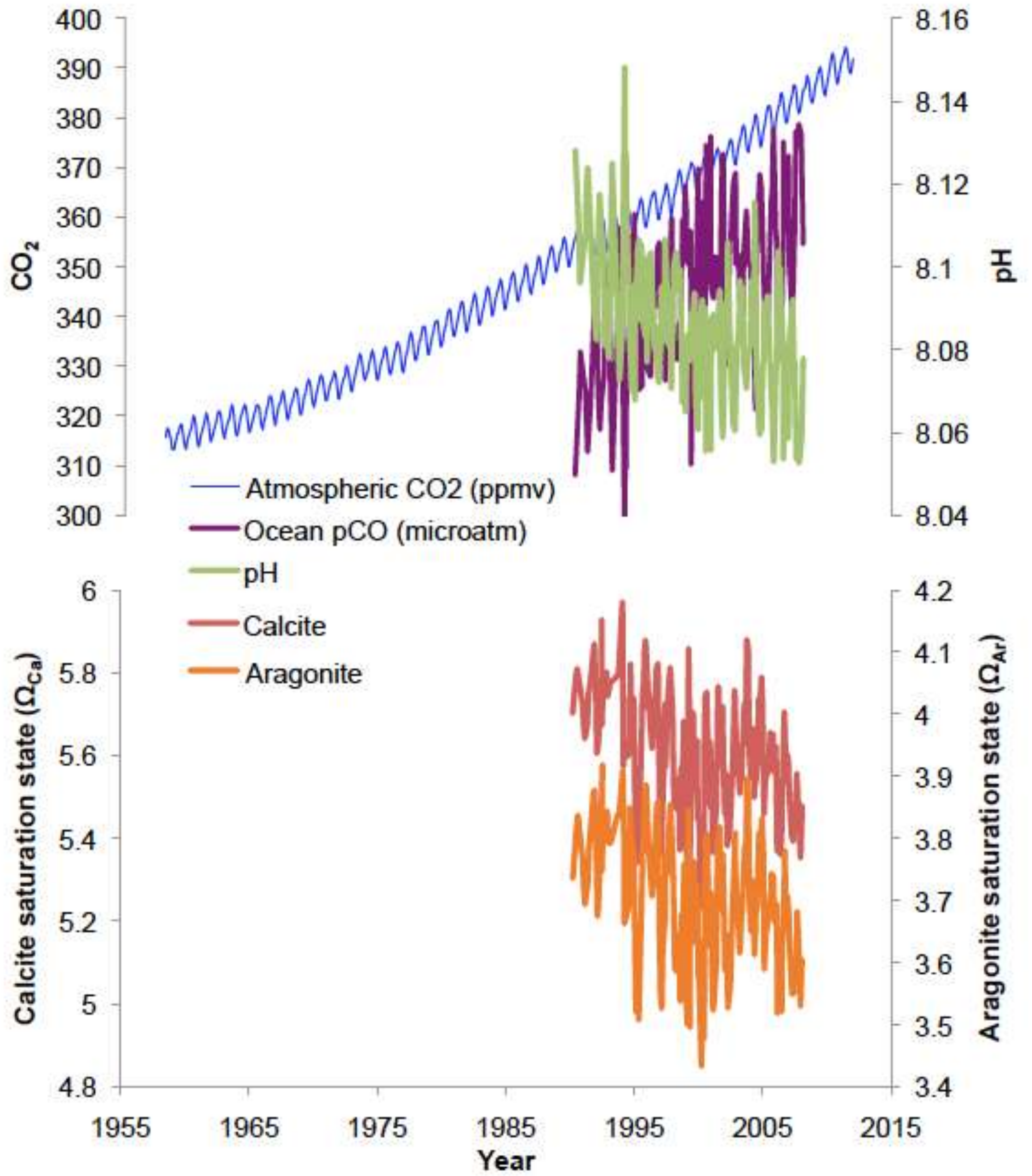


Figure 1.17 Trends in atmospheric CO_2, oceanic pCO_2, oceanic pH, and the saturation states of calcite (Ω_{ca}) and aragonite (Ω_{ar}), the two main forms of calcium carbonate, in the north sub-tropical Pacific ocean (Dore et al. 2009, Feely et al. 2009).

in the Levantine Basin (Figure 1.18). Measurements of A_T were conducted at all stations, while DIC was only measured at 14 stations in total. Based on these measurements, Ω for both calcite and aragonite was estimated by Schneider et al. (2007). The few A_T and DIC measurements made during the cruise were used by Touratier and Goyet (2011) to calibrate more extensive calculations on carbonate system parameters across the Eastern Mediterranean and allowed the calculation of the contribution of anthropogenic CO_2 to total concentrations (C_{ANT}) across the basin.

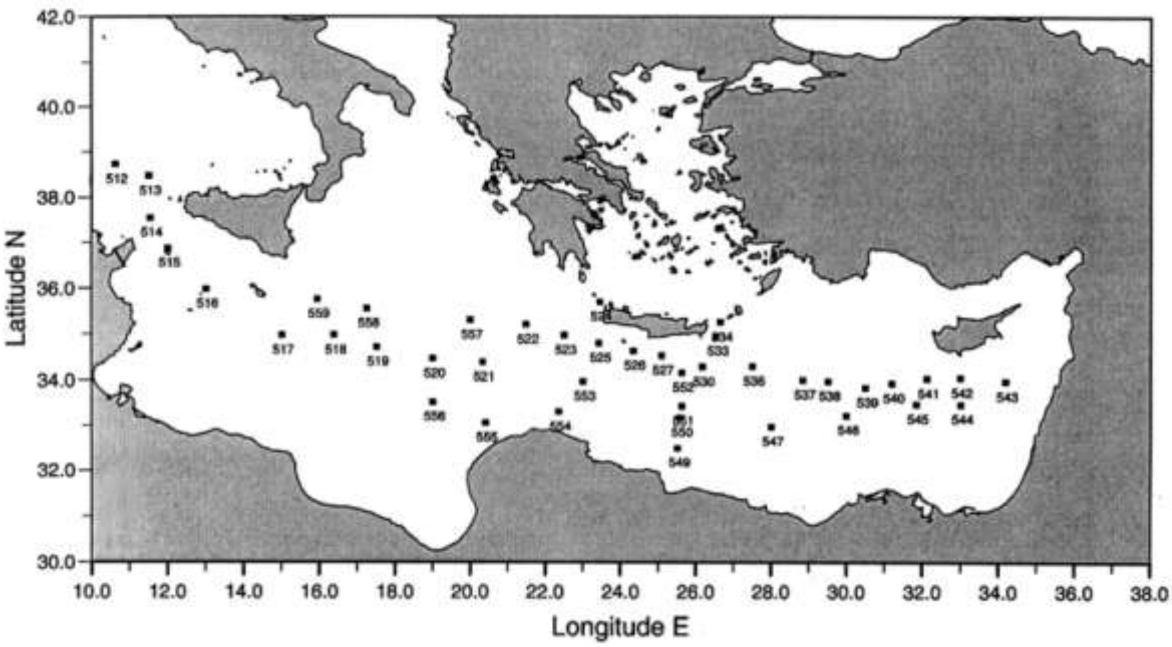


Figure 1.18 Stations occupied by the R/V Meteor during Cruise M51/2 (modified from Roether et al. 2003).

The A_T values reported by Schneider et al. (2007) are high (approximately 2.6 mmol kg^{-1}) relative to global patterns, and are indicative of the high salinities throughout the Mediterranean. The western Mediterranean waters exhibit A_T values slightly lower than eastern Mediterranean waters, as anticipated by the slightly lower salinities in the western Mediterranean (Figure 1.18a). While high salinity due to high rates of evaporation is a major factor in generating high A_T values in the eastern Mediterranean, an additional contributor is inputs from rivers as well as from the Black Sea (Schneider et al. 2007).

The DIC values are higher in the western than in the eastern Mediterranean (Figure 1.18b), presumably a result of the difference in productivity and consequently respiration between the two parts of the basin (Touratier and Goyet 2011).

Moreover, the DIC patterns recorded during the 1999 F/S Meteor cruise (Schneider et al. 2007, Touratier and Goyet 2011) are corroborated by the DIC (or C_T) data collected during the BOUM cruise (Figure 1.10) and reported by Pujo-Pay et al. (2011). Minimum values are recorded at the surface where carbon fixation by oxygenic photosynthesis drives the concentrations down, hence the delimitation of this minimum zone by the deep chlorophyll maximum. Conversely, maximum values are observed within the oxygen minimum zone where the supply rate of organic material from the biogenic, euphotic zone results in high aerobic respiration rates and consequently high oxygen consumption rates (Figure 1.15) and carbon dioxide release rates.

The calculated C_{ANT} patterns (Touratier and Goyet 2011) yield the conclusion that not only is anthropogenic carbon found throughout the Mediterranean basin, it is also stored in estimable amounts at all depths (Figure 1.18c).

Moreover, the calculated degree of acidification since pre-industrial times (approximately 1780) varies between 0.05 and 0.14 (Figure 1.18d), with eastern Mediterranean waters having acidified less than western Mediterranean waters. When compared to a global average acidification of 0.1 for surface waters, it is apparent that the Mediterranean is actually experiencing as much acidification as any other major oceanic bodies of the world (Touratier and Goyet 2011).

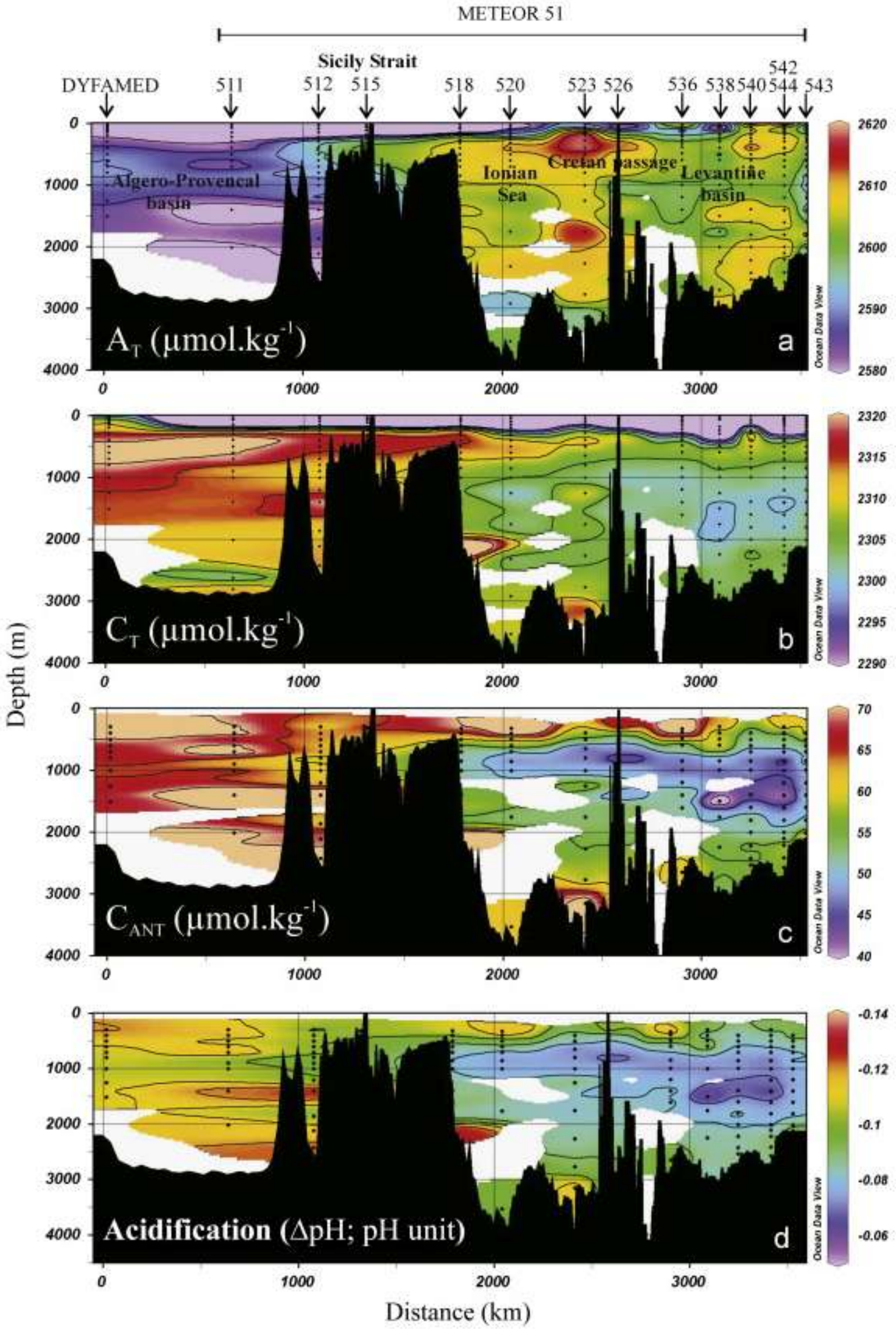


Figure 1.19 Cross-Mediterranean plots (West to East from left to right) modified from Touratier and Goyet (2011) based on the Meteor Cruise M51/2 measurements by Schneider et al. (2007), for (a) A_T, (b) DIC, (c) C_{ANT}, and (d) acidification since pre-industrial times.

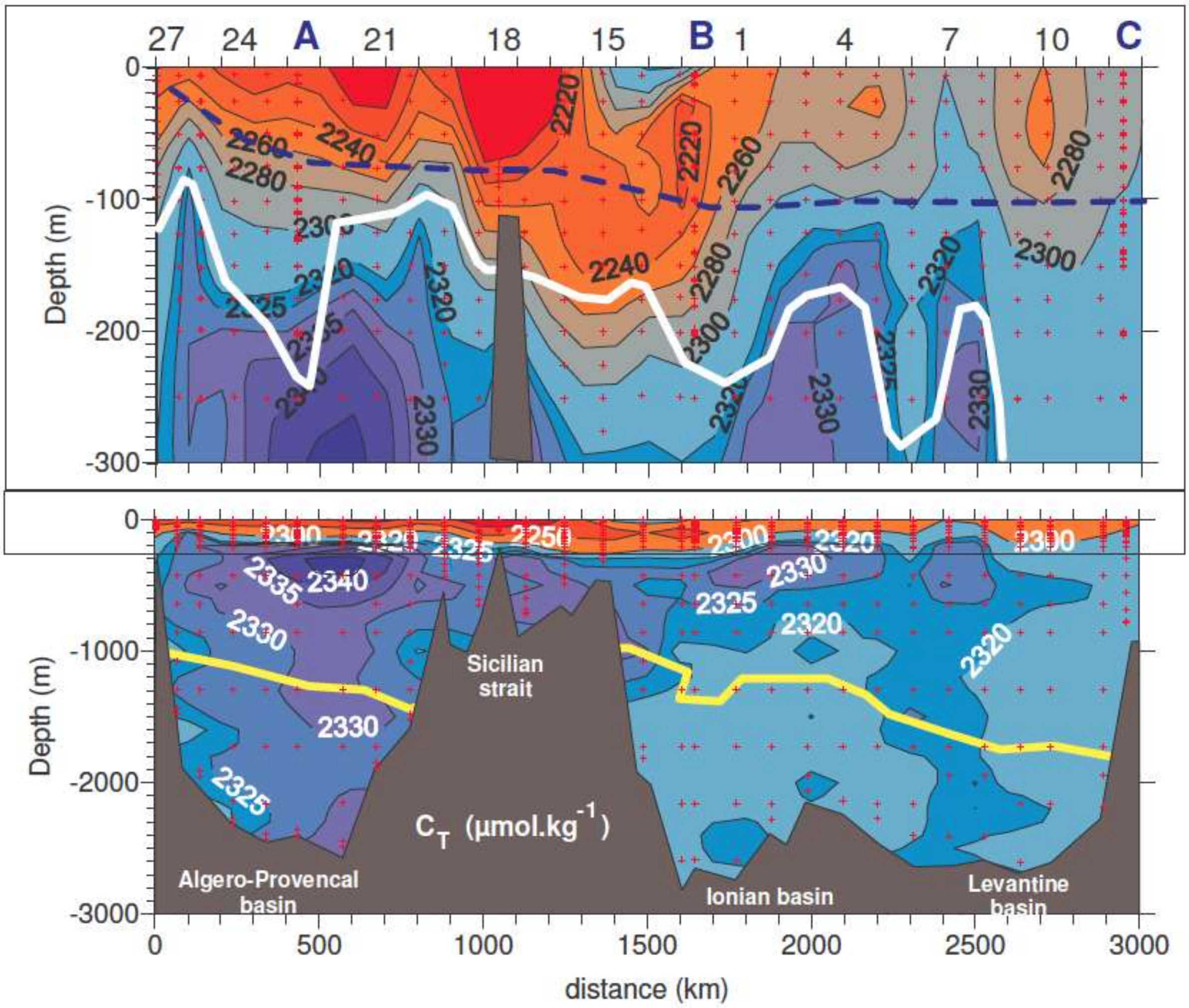


Figure 1.20 Total inorganic carbon concentrations in µmol kg^{-1} collected during the BOUM cruise in the summer of 2008 (see **Figure 1.10** for cruise track) (Pujo-Pay et al. 2011): Top - concentrations in the top 300 m. Blue dashed line: depth of the deep-chlorophyll maximum, according to Crombet et al. (2011). White line: the 195 µmol kg^{-1} isocline; Bottom – concentrations for the whole water column. Solid yellow line: the 180 µmol kg^{-1} isocline. Figures from Pujo-Pay et al. (2011).

To appropriately interpret the impacts of the relatively significant acidification, one must examine the status of the same waters in terms of carbonate saturation. Schneider et al. (2007) calculated average Ω_{ca} and Ω_{ar} profiles for the Mediterranean (Figure 1.21), which demonstrate a significant degree of supersaturation for both major (biogenic) carbonate minerals, which is not likely to be impacted by the degree and rate of acidification calculated by Touratier and Goyet (2011).

1.4.3 Future trends

The ability of calcifying organisms to produce carbonate matrices is unlikely to be affected in Cyprus waters as indicated by the degree of supersaturation, however the concerns persist in the face of uncertainty due to the lack of environmental data and the limited data which show adverse impacts of acidification on growth. The organisms of concern are calcareous algae, vermetid reefs, benthic mollusks and echinoderms as well as their larval stages, deep-sea corals, coccolithophores, foraminifera, and pteropods (Yılmaz et al. 2008).

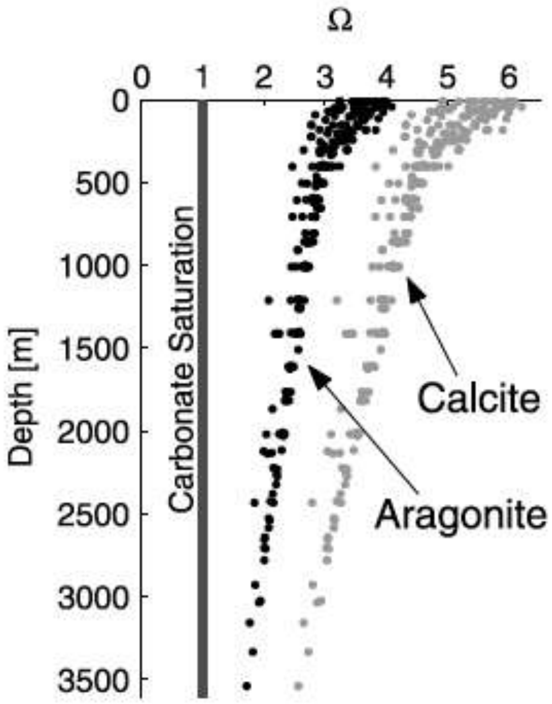


Figure 1.21 Average Ω_{ca} and Ω_{ar} profiles for the Mediterranean, calculated from data collected in 2001 (Schneider et al. 2007).

Moreover, the predicted drop in pH may possibly affect biogeochemical cycling in other ways (Yılmaz et al. 2008, Touratier and Goyet 2011).One important effect of acidification will be an increase in the solubility of metals. In some cases, e.g., iron, such an increase may be beneficial for biological productivity, since it will enhance primary productivity. In the case of many other metals, increased solubility may bring about increasing toxicity.

Another effect will be the constant shift in the state of many other complex nutrient systems, such as the nitrogen system. Soluble reduced inorganic nitrogen is currently dominated by the ammonia form (NH_3), but contribution by ammonium (NH_4^+) is increasing with a decrease in pH, and since the latter is more readily taken up by primary producers than the former, this shift, along with a decrease in nitrification (oxidation of ammonium species), will result in a decrease in bioavailable N. The simultaneous predicted decrease in bioavailable PO_4^{3-} under decreasing ocean pH will thus result in an even greater N:P ratio than at present of a decreased bioavailable nutrient pool, increased ultraoligotrophy and enhanced P-limitation (Rees et al. 2008).

The enhanced N_2 fixation rates that could occur under increased CO_2 availability, even in intense P limitation, as suggested by Yılmaz et al. (2008), now appear unlikely, given the very low abundances and activities of nitrogen fixers in the Levantine basin that have been reported over the past five years (Bar Zeev et al. 2008, Bonnet et al. 2011, Le Moal et al. 2011, Ridame et al. 2011, Yogev et al. 2011).

2. Habitat types

2.1 Introduction

The seabed is a complex environment affected by a broad range of physical, chemical, geological and biological factors. Physical variables such as topography, substratum and depth, influence, and at some scales are influenced themselves by, the variation of biological communities. These communities at the seabed are also influenced by the water column variables such as temperature, salinity and water movements.

Systems to classify the seabed in habitat types in Europe have been developed since the early 1980s, e.g. CORINE5 (Commission of the European Communities 1991), ZNIEFF-Mer (Dauvin et al. 1993). The concept was developed initially for Canadian marine habitats (Roff et al. 2003), where it was demonstrated that oceanographic and geophysical data could be utilized to predict ecologically meaningful marine features at a scale where sufficient biological data are not available. Biological data can be used to generate the rules which are then applied to classify the oceanographic and geophysical data.

The EUNIS habitat classification system was developed recently by the European Environment Agency (Davies et al. 2004) in response to the recognized shortcomings of existing pan-European systems such as the CORINE system which include the marine environment but with a limited coverage and suffered from a lack of consistent structure.

The EUNIS Habitat Classification is a complete classification system, i.e. it covers in one system all habitat types, whereas the legislative lists of habitat such as the EU Habitat Directive (92/43/EEC) cover only those habitat types which at a particular time were most in need of protection through international designation.

2.1.1 Rationale

The following key documents were taken into account:

a) Marine Strategy Framework Directive (MSFD, 2008/56/EC)
b) Implementation of Water Framework Directive (WFD, 2000/60/EC) in Cyprus (Articles 5 and 6)
c) European Nature Information System (EUNIS) (Davies et al. 2004)
d) EUSeamap (Cameron and Askew 2011)
e) Habitats Directive (92/43/EEC)
f) Guidelines for the establishment of the Natura 2000 network in the marine environment. Application of the Habitats and Birds Directives (European Commission 2007).

2.1.2 Methodology

An attempt has been made to produce a list of probable habitat types of marine underwater environment of Cyprus included with the EEZ. The approach had chosen attempts to predict the flora and fauna at certain scales, using existing geographical data (Figure 1.2) and general knowledge (Figure 2.1) concerning physical factors (such as seabed substrate, depth, and degree of wave exposure) of the sea. For this reason the basic features of Cyprus or E. Mediterranean marine environment and their impact on communities are presented briefly below.

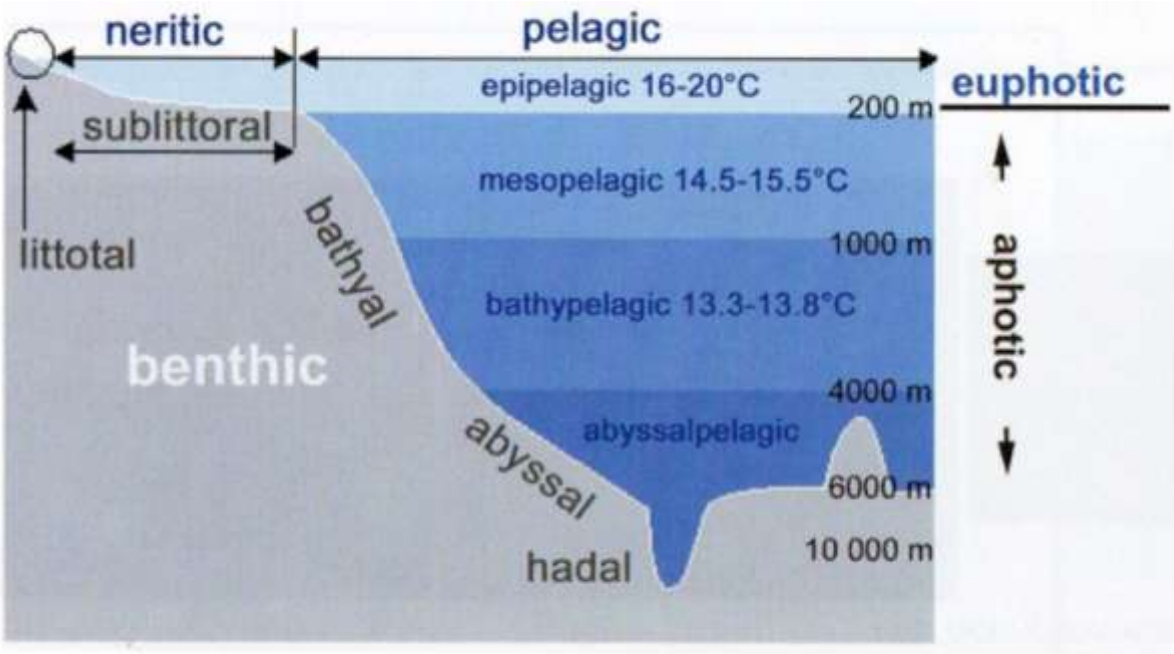


Figure 2.1 Zonation of pelagic and benthic ecosystems (Zenetos and Bellou 2005).

2.2 The predominant seabed and water column habitat type(s) with a description of the characteristic physical and chemical features, such as depth, water temperature regime, currents and other water movements, salinity, structure and substrata composition of the seabed

2.2.1 Temperature

Species biogeographical distribution and therefore biogeographical regions are mainly defined by temperature (van den Hoek 1982; Lüning 1990). Species are generally adapted to both absolute temperatures and to the fluctuations they experience on daily to annual timescales. Coastal and shelf seas are subject to seasonal variations in temperature, with these being increasingly more pronounced in shallower waters. By contrast deep sea habitats are subject to much more stable temperatures. Mean surface water temperature of Cyprus varies seasonally and ranges between 18-26 ^{o}C. During summer surface water temperatures (20–28 ^{o}C) can be higher than bottom temperatures (16–20 ^{o}C) indicating seasonal water masses stratification (Bianchi et al. 1996). Levantine Intermediate Water found from about 200-400 m has a rather constant temperature of 15-16 ^{o}C. Below depths of approximately 500 m, relatively homogeneous water mass typically characterized by 13.38 ^{o}C is found (see 1.2.1 this report).

2.2.2 Salinity

Salinity separates marine systems from freshwater systems (at 0.5 psu). It then distinguishes brackish (stable lowered salinity) and estuarine (unstable variable salinity) conditions, from fully marine conditions. Surface and deep water salinity of Cyprus marine waters shows restricted seasonal and vertical fluctuations between ca. 38.6 to 39.5 psu and is not affecting pelagic and/or benthic marine communities (see 1.2.1 this report).

2.2.3 Substrate

Benthic communities, especially species composition, are strongly influenced by the substratum type (e.g. sediment particle size) and its composition (mixtures of different particle sizes). Its structure (e.g. topography, porosity), origin (geological, biological) and mobility further influence the biology (Cameron and Askew 2011).

The Cyprus coastline is ranging from steep inaccessible cliffs and ragged rocky shorelines with sea caves to gentle sloping sandy beaches. Soft substrate of sand and gravel in shallow waters and of fine sand, muddy sand and mud in deeper waters characterize the main bays of south and east coasts. These long beaches often end into gravel beaches depending on the wave generated littoral drift. Many pocket beaches also exist. Rocky substrate dominated by hard limestone with patches of coarse sand and gravel characterizes the shallow waters of west and north coasts. Mud can be found in deeper waters (Demetropoulos 2003a). The seabed may also be composed of material of biogenic and anthropogenic origin (e.g. shells, calcareous skeletons, tree-trunks, concrete).

Seabed communities from Cyprus and elsewhere can be classified into two broad categories, those associated with hard substrata and those of soft substrata. There is, however, a complete gradation between the two, as many areas of seabed comprise mixtures of hard and soft substrata.

2.2.4 Light

Light energy is absorbed by water itself, by organic substances dissolved in the water and by particles (light attenuation). Therefore, light availability in the water column and at the seabed varies considerably by depth affecting the lower depth limit to which benthic macrophytes (seaweeds, seagrass) can grow. This attenuation tends to be higher in coastal waters, due to suspended and dissolved matter being washed down rivers, higher phytoplankton concentrations and suspension of sediment caused by wave action in shallow waters. Light attenuation is the variable used to define the infralittoral zone, where irradiance from the sun is still sufficient to allow significant photosynthetic activity of plants such as kelp and seagrass (Cameron and Askew 2011).

The lower limit of the infralittoral zone is set to the depth limit of *Posidonia oceanica* and photophilic algae in the Mediterranean. A value close to 1% of the surface light has been commonly set as the boundary value for both these habitats (Lüning 1990). Light attenuation can also be used to define the upper and lower circalittoral zones where the light reaching the bottom is estimated to range between 1% - 0.01% and less of 0.01% of the surface light, respectively (Cameron and Askew 2011).

2.2.5 Dissolved oxygen

Oxygen availability is essential for life in marine waters. The majority of marine waters are sufficiently oxygenated to support marine species at the seabed. Areas of fully or partially deoxygenated water can occur naturally (e.g. some fjordic basins with restricted water exchange) or from anthropogenic pressures (e.g. organic enrichment, eutrophication). The effects of eutrophication on benthic communities will depend on the energy conditions at the seabed and stratification of water masses. Deoxygenation has a significant effect on seabed communities, through marked reductions in species diversity as a result of partial deoxygenation, to eventual dominance of bacterial growths in fully deoxygenated water (Cameron and Askew 2011).

The Levantine Basin is characterized by high oxygen levels throughout the water column (see section1.3.2 in this report). In Cyprus dissolved oxygen levels fluctuate close to 100% saturated water (approximately 4.5-5 mg O_2 L^{-1}) in surface waters and decrease gradually to 70 % in deep waters. As a result not any affect to seabed habitats is expected.

2.2.6 Waves and tidal currents

The type of sediment is mainly determined by the dynamics or energy of water movement as a result of waves and currents (Cameron and Askew 2011). The energy levels are applied only to rocky habitats in the EUNIS classification; because sediment types typically reflect the hydrodynamic regime of an area of sediment (i.e. high energy gives coarse sediments, low energy fine sediments). The influence of waves is greatest on the shore and in the infralittoral zone. In the circalittoral zone tidal currents have a more marked influence. With increasing depth, movement of particles in the water column caused by waves decrease; the depth below which waves have a negligible influence is known as the wave base. Hence below the wave base currents have the only effect.

Bottom currents have a marked influence both on the sediment type (and hence the communities) and the communities themselves which live on rocky habitats. Wave and current exposure of Cyprus coasts can be estimated as moderate.

2.2.7 Biological zonation

Benthic communities exhibit commonly marked zonation from the top of the shore to the bottom of the deep sea. This zonation is not directly related to depth but to a range of linked factors, for example: the drying of the intertidal zone caused by low tides is greater at the top of the shore than the bottom; the amount of wave energy experienced at the seabed dissipates with depth; the degree of thermal stability increases with depth; the proportion of surface light reaching the sea floor decrease with depth (Cameron and Askew 2011). In sites where the factors determining zonation are well understood, that could be the case for Cyprus marine wagers, it may be possible to use bathymetry as a surrogate for the factor causing the zonation (Figure 1.1, Figure 2.1).

2.3 Identification and mapping of special habitat types, especially those recognised or identified under Community legislation (the Habitats Directive and the Birds Directive) or international conventions as being of special scientific or biodiversity interest

2.3.1 Classification approach

In EUNIS classification system, a ‘habitat’ is defined as: ‘a place where plants or animals normally live, characterized primarily by its physical features (topography, plant or animal physiognomy, soil characteristics, climate, water quality etc.) and secondarily by the species of plants and animals that live there’ (Davies et al. 2004).

The scale of organisms and of the environmental units in which they occur is intrinsic to the definition of habitat: it is that occupied by small vertebrates, large invertebrates and vascular plants. Samples of between 1 m^2 and 100 m^2 will generally be adequate to categorize habitats. At the smaller scale, "microhabitats" (features generally occupying less than 1 m^2 which are characteristic of certain habitat types and important for some smaller invertebrates and lower plants) can be described. At the larger scale, habitats can be grouped as "habitat complexes", which are frequently-occurring combinations or mosaics of individual habitat types, usually occupying at least 10 ha, which may be inter-dependent. This use of the term habitat to include both biotic and abiotic elements is in common with many policy mechanisms (e.g. Habitats Directive, Bern Convention lists, OSPAR Convention list), and is usually referred to in scientific terminology as a biotope (Olenin and Ducrotoy 2006). That is 'areas with particular environmental conditions that are sufficiently uniform to support a characteristic assemblage of organisms'.

For marine units the primary criteria are the ecological or biogeographical factors determining plant and animal communities (such as substratum type, exposure and water depth) leading towards the dominant plant and/or animal communities (Davies et al. 2004). It was also agreed that habitats within a particular branch of the hierarchy should be 3 ordered following a logical sequence when possible, e.g. depending on levels of a particular abiotic factor such as salinity, exposure or depth.

EUNIS classifies habitats on hierarchical scale. At level 1, habitats are separated into marine habitats (EUNIS code: A) and others (terrestrial and freshwater). At level 2, EUNIS identifies eight broad marine habitats based on depth and substrate type, permanent or non-permanent water cover, ice-cover and characteristics of the pelagic water column (EUNIS codes: A1 – A8) (Davies et al. 2004). Level 3 habitats are further classified based on criteria involving abiotic variables such as the actual substrate nature (i.e. coarse sediment, sand, sandy mud), energy levels (moderate, high, low energy), temperature, light, salinity and plant cover. Differentiations between habitats based on the components of the biological communities begin to appear at level 4 in rocky environments. However the inclusion of biological communities at level 4 is not universal across the system.

2.3.2 Determination of probable benthic and water column habitat types

EUNIS is a hierarchical classification system with several habitat levels. This study focuses on the upper three levels of the EUNIS system (levels 1–3). The first level is used to identify the marine environment of Cyprus and it is not presented in Table 2.1. The second and third levels were used to identify different combinations of physical factors that define the basic conditions for flora and fauna within the Cyprus EEZ (Figure 1.1).

Seven (7) and thirty four (34) different habitat types have been identified in total for Cyprus marine waters (Table 2.1). Although this list may also include marine habitats that do not exist, or exist but have not been already documented, it could provide the basis for further work on the conservation and management of marine environments in the county. An example is the chemosynthetic benthic communities driven by the biological oxidation of sedimentary methane (e.g., cold seeps). Although they have been documented in different sites of the Eastern Mediterranean (Cartes et al. 2004) they are unknown from the area under consideration. Recent acoustic surveys, however, have documented the widespread distribution of mud volcanoes and related mud flows, fluid seeps, and brines along the Cyprus Arc (Huguen et al. 2005) in agreement with EUNIS prognosis (Table 2.1).

Table 2.1 Possible EUNIS and Natura 2000 habitat types in Cyprus relevant for MSFD.

		EUNIS-Marine habitats (A)		Natura 2000 habitats
		Level 2	Level 3	
Pelagic habitats/ communities	Coastal water, Shelf water, Oceanic water	A7 Pelagic water column	A7.1 Neuston	
			A7.3 Completely mixed water column with full salinity	
			A7.8 Unstratified water column with full salinity	
			A7.9 Vertically stratified water column with full salinity	
			A7.A Fronts in full salinity water column	
Seabed habitats/ communities	Littoral habitats	A1 Littoral rock and other hard substrata	A1.2 Moderate energy littoral rock	1170 Reefs, 8330 Submerged or partially submerged sea caves
			A1.4 Features of littoral rock	
		A2 Littoral sediment	A2.1 Littoral coarse sediment	1110 Sandbanks which are slightly covered by sea water all the time (*Cymodocea nodosa*), 1140 Mudflats and sandflats not covered by seawater at low tide
			A2.2 Littoral sand and muddy sand	
			A3.3 Littoral mud	
			A2.4 Littoral mixed sediments	
			A2.6 Littoral sediments dominated by aquatic angiosperms	
			A2.7 Biogenic reefs	1170 Reefs
			A2.8 Features of littoral sediment	
	Shallow sublittoral habitats	A3 Infralittoral rock and other hard substrata	A3.2 Atlantic and Mediterranean moderate energy infralittoral rock	1170 Reefs, 8330 Submerged or partially submerged sea caves, 1180 Submarine structures made by leaking gases, 1120 *Posidonia* beds
			A3.7 Features of infralittoral rock	
	Shelf habitats (<200 m)	A4 Circalittoral rock and other hard substrata	A4.2 Atlantic and Mediterranean moderate energy circalittoral rock	1170 Reefs, 8330 Submerged or partially submerged sea caves, 1180 Submarine structures made by leaking gases
			A4.7 Features of circalittoral rock	
		A5 Sublittoral sediment	A5.1 Sublittoral coarse sediment	
			A5.2 Sublittoral sand	
			A5.3 Sublittoral mud	
			A5.4 Sublittoral mixed sediments	
			A5.5 Sublittoral macrophyte-dominated sediments	1120 *Posidonia* beds (Posidonion oceanicae)
			A5.6 Sublittoral biogenic reefs?	1170 Reefs
			A5.7 Features of sublittoral sediment	
	Bathyal habitats (>200 m, <4000 m)	A6 Deep-sea bed (>200 m)	A6.1 Deep-sea rock and artificial hard substrate	
			A6.2 Deep-sea mixed substrata	
			A6.3 Deep-sea sand	
			A.6.4 Deep-sea muddy sand	
			A.6.5 Deep-sea mud	
			A.6.6 Deep-sea biotherms	
			A.6. 7 Raised features of the deep-sea bed	
			A.6.8 Deep-sea trenches and canyons, channels, slope failures and slumps on the continental slope	
			A. 6.9 Vents, seeps, hypoxic and anoxic habitats of the deep sea	

2.3.3 Identification of special habitat types

According to Argyrou et al. (2002), the habitats that can be characterized as special in Cyprus marine waters are the following:

1) Littoral rocks *Spongites-Dendropoma* and *Lithophyllum* spp. formations (EUNIS codes: A1.2, A1.4; Natura 2000 codes: 1170)

Figure 2.2 Vermetids and *Lithophyllum trochanter* formations, and phaeophyta forest with *Cystoseira compressa, C. cf. humilis* and *Dictyota fasciola* (Argyrou et al. 2002).

This habitat type is characterized as sensible by Mediterranean 'Red Book' UNEP/IUCN/GIS (1990), Barcelona Convention (1995), Alghero Convention (1995), and Bern Convention (1996) and includes in Cyprus following associations/facies:

a) Association with *Tenarea undulosa* and *Lithophyllum trochanter* auct. (UNEP/MED II.4.2.3) (Figure 2.2): It is developed in exposed zones, mainly on Cape Greco and Eastern Akamas.

b) *Neogoniolithon brassica-florida* concretions (UNEP/MED II.4.2.8): With the vermetid *Dendropoma petraeum* and the calcareous algae *Neogoniolithon brassica-marina* (=*Spongites notarisii*). Also, this important concretion is present at the littoral fringe. The vermetid formations appear developed in Cape Greco and the Akamas peninsula (forming small cushion and plate structures, less developed in Moullia Rocks.

c) Facies with vermetids (UNEP/MED III.6.1.2): This facies is developed in Cape Greco and Akamas, between 0-1m depth, with the vermetid *Dendropoma petraeum* and the corallinacea algae *Neogoniolithon brassica-marina* (= *Spongites notarisii*) and *Lithophyllum trochanter*. With the erect algae *Laurencia obtusa*, *Anadyomene stellata* and *Dictyota spiralis*. Also a hydrozoan *Eudendrium* sp. is very common.

2) Upper infralittoral rocky bottoms with *Cystoseira* spp. forests (EUNIS codes: A3.2, A3.7; Natura 2000 code: 1170)

This habitat type is characterized as sensible by Mediterranean 'Red Book' UNEP/IUCN/GIS (1990), Habitat Directive European Union (1992), Barcelona Convention (1995), Alghero Convention (1995), and Bern Convention (1996) and includes in Cyprus following associations/facies:

Figure 2.3 Concretion of *Neogoniolithon brassica marina* with *Dendropoma petraeum* in midlittoral rock. *Cystoseira amentacea* belt in lower part. Agios Georgios, Akamas (Argyrou et al. 2002).

a) Association with *Cystoseira amentacea* (UNEP/MED III.6.1.2) (Figure 2.3): This association has been rare, only has been observed on some very exposed sites in Cape Greco and Akamas Peninsula (0-1m depth) and, with the macroalgae *Laurencia obtusa, L. papillosa Anadyomene stellata, Dyctiota fasciola, Corallina elongata, Jania rubens, Spongites notarisii* and *Valonia utricular.*

b) Association with shallow *Cystoseira spp.* (UNEP/MED III.6.1.16): This association correspond in Cyprus waters to the *Cystoseira crinita* one. It is well developed in Cape Greco, Moullia Rock and Akamas areas, between 1 to 14 m depth. The *Cystoseira* spp. (*C. cf. humilis, C. spinosa v. tenuior, C. compressa*) dominate the phothophilic community. It seem some bathymetric separation between *C. cf. humilis* (more superficial: 0-10m depth) and *C. spinosa v. tenuior* (7-14m depth), also the later *Cystoseira* is rare in the Akamas area.

c) Association with *Cystoseira cf. foeniculacea* (= *C. ercegovicii*). Present in the Western part of Akamas (Yeronisos Is.) at depth from 14 to 35m depth. Also the sponge *Cacospongia scalaris* is very abundant.

3) <u>Upper circalittoral rocks with *Caulerpa racemosa* and *C. prolifera*, and Fucales (EUNIS codes: A4.2, A4.7; Natura 2000 code: 1170)</u>

This habitat type is characterized as sensible by Mediterranean 'Red Book' UNEP/IUCN/GIS (1990), Habitat Directive European Union (1992), Barcelona Convention (1995), Alghero Convention (1995), and Bern Convention (1996) and includes in Cyprus following associations/facies:

a) Association with *Cystoseira* spp. (UNEP/MED IV.3.1.1) (Figure 2.4, Figure 2.5): More or less developed in Eastern cape Greco and North-eastern of Akamas area on horizontal surfaces with *C. spinosa, C. zosteroides, C. ercegovicii f. latiramosa* and *Sargassum cf. trichocarpum* from 42m depth.

b) Association with *Sargassum* spp. (UNEP/MED IV.3.1.5): This association is frequent on top of the deep rocky reefs (from 41-47m) with *Sargassum cf. trichocarpus* and *Cystoseira* spp. Observed in Cape Greco, Moullia Rocks and Eastern Akamas.

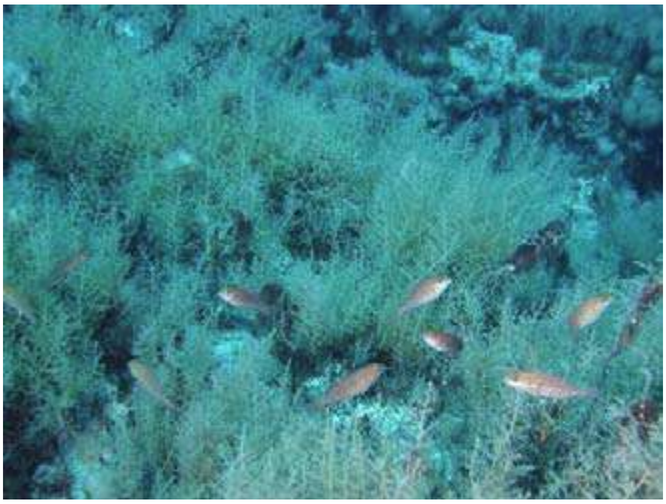


Figure 2.4 *Cystoseira cf. humilis* ‘forest’ with the scarid fish *Sparisoma cretense*. W-Cape Greco, -15m (Argyrou et al. 2002).

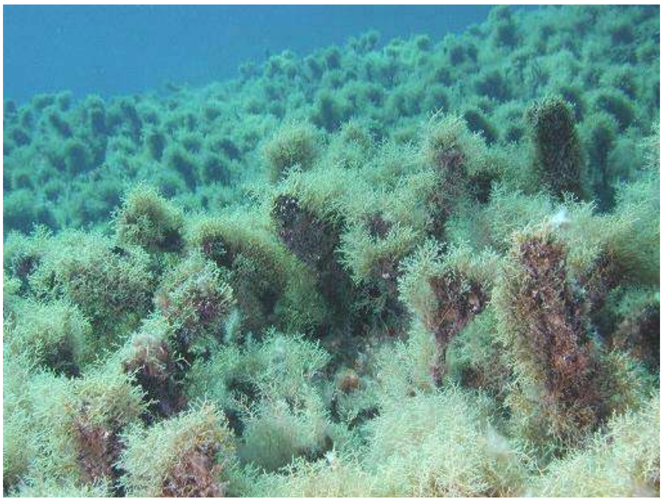


Figure 2.5 Association with *Cystoseira spinosa v. tenuior* (cylindrical thales). W-Cape Greco, -12m (Argyrou et al. 2002).

4) Seagrass meadows in rocky bottoms (*Posidonia*) and soft bottoms (*Posidonia*, *Cymodocea* and *Halophila*) (EUNIS codes: A3.2, A3.7, A.5.5, A5.6; Natura 2000 codes: 1110, 1120)

This habitat type is characterized as sensible by Mediterranean ‘Red Book’ UNEP/IUCN/GIS (1990), Habitat Directive European Union (1992), Barcelona Convention (1995), Alghero Convention (1995), and Bern Convention (1996) and includes in Cyprus following associations/facies:

a) Association with *Posidonia oceanica* meadows (UNEP/MED III.5.1) (Figure 2.6, Figure 2.7): This community is well developed around all the observed areas on coarse sand and muddy sand bottoms, as well as on rocky substratum. The shallower meadows are in the Lara area on big blocks (1m depth) and the Moullia Rocks (from 4m depth in rocky substrata), while the deeper ones in Eastern Akamas (42m depth). In depth, the *Posidonia oceanica* is dispersed (from 30-42m depth) with the chlorophytes *Caulerpa prolifera* and *C. racemosa*; from 30m depth it becomes denser.

Figure 2.6. *Posidonia oceanica* on rocky bottoms with the echinoid *Sphaerechinus granularis*. Moullia Rocks, -9m (Argyrou et al. 2002).

Figure 2.7 *Caulerpa prolifera* grass on dead matte of *Posidonia*. Moullia Rocks, -16m (Argyrou et al. 2002).

Figure 2.8 Sandy bottom with the phanerogame *Cymodocea nodosa* and *Caulerpa* spp. (*Caulerpa prolifera* and *C. racemosa*). Akamas, -41m (Argyrou et al. 2002).

b) Association with *Cymodocea nodosa* (UNEP/MED III.2.2.1) (Figure 2.8): Only present in very located stations (Eastern of Cape Greco, at 9-12 m depth, and Akamas, at 39-41 m depth) on sandy bottoms. The Akamas meadow is dense with *Caulerpa prolifera* and *C. racemosa*.

c) Association with *Halophila stipulacea* (UNEP/MED III.2.2.2): Only observed around the Cape Greco area in sandy coarse bottoms between 33-37m with *Caulerpa prolifera*; also observed in sparse *Posidonia oceanica* meadows at -23m.

d) Biocenosis of the coastal detritic bottoms (UNEP/MED IV.2.2) (Figure 2.8): Maërl facies (UNEP/MED IV.2.2.2): From 34m depth appears some sparse rhodoliths of the calcareous corallinaceae *Lithophyllum corallioides* (c), *Phymatolithon calcareum* (r) and *Mesophyllum alternans* (r) forming the 'maërl' facies of the coastal detritic bottoms. It is developed around Cape Arnauti with the chlorophyte *Dasycladus vermicularis* (c). In some places the detritic bottom is covered by the chlorophytes *Caulerpa prolifera* (cc) and *C. racemosa*, mainly in Eastern Cape Greco area, with *Flabellia petiolata* and some rhodophytes as *Osmundaria volubilis, Rhodymenia ardissonei,* and *Botryocladia botryoides*. In some places with stones the fucaceans *Cystoseira spinosa* and *Sargassum trichocarpum* are present.

Figure 2.9 Test of *Spatangus purpureus* on maërl facies. It is observed some rhodoliths (right side). Cape Greco (NE area), -54m (Argyrou et al. 2002).

e) Association with *Peyssonnelia rosa-marina* (UNEP/MED IV.2.2.3): This association has been observed by trawling samples from the front of the Cape Greco (55-65m depth) with *Peyssonnelia rosa-marina*, *Peyssonnelia* spp. and the chlorophyte *Palmophyllum crassum*.

5) Coastal detritic bottoms with Corallinaceae (*Lithothamnion*, *Phymatolithon*), Peyssonneliaceae (*Peyssonnelia* spp.) and *Palmophyllum crassum* (EUNIS codes: A3.7, 4.7; Natura 2000 codes: 1170, 8330)

This habitat type is characterized as sensible by Mediterranean 'Red Book' UNEP/IUCN/GIS (1990), Habitat Directive European Union (1992), Barcelona Convention (1995), Alghero Convention (1995), and Bern Convention (1996) and includes in Cyprus following associations/facies:

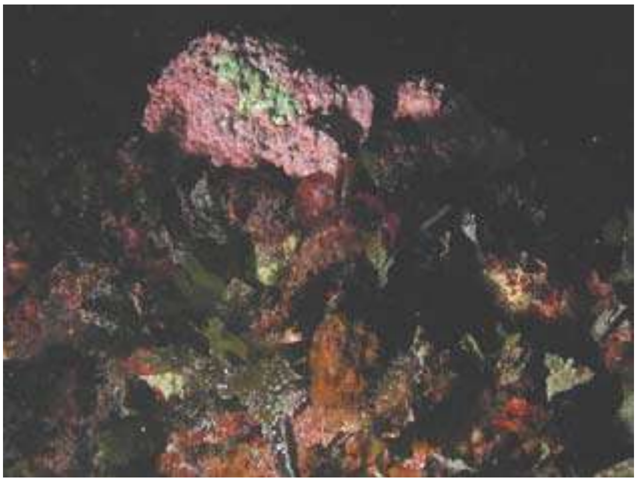


Figure 2.10 Association with the sciaphilic algae: *Peyssonnelia squamaria* (garnet spots), *Mesopyllum alternans* (rose plates), *Peyssonnelia coriacea?* (brown plates) and *Flabellia petiolata* (dark green spots). Moullia Rocks, -9m (Argyrou et al. 2002).

Figure 2.11 Coralligenous enclave in the infralittoral stage with the encrusting red algae *Mesophyllum alternans* (rose), *Palmophyllum crassum* (green) and *Peyssonnelia rosa-marina* (garnet), and the sponges *Agelas oroides* (orange) and *Crambe crambe* (red). Moullia Rocks, -13m (Argyrou et al. 2002).

Figure 2.12 Coralligenous biocenosis with incrustant rhodophytes (*Mesophyllum alternans*, *Peyssonnelia* spp.) and the sponges *Ircinia oros* (grey), *Clathrina clathrus* (yellow) and *Agelas oroides* (orange). Cape Greco, -46m (Argyrou et al. 2002).

a) Facies and association of coralligenous and semi-dark biocenosis (infralittoral enclaves) (UNEP/MED III.6.1.35) (Figure 2.10, Figure 2.11): In the infralittoral enclaves of this community (overhangs, cave entries, crevices) there is the littoral rocky coralligenous community with the calcareous algae: *Lithophyllum stictaeforme, Mesophyllum alternans, Neogoniolithon* sp. and *Peyssonnelia rosa-marina*.

b) Circalittoral encrusting algae concretions (Figure 2.12): This important community colonise horizontal surfaces from 45-49m depth, the main macroalgae are calcareous (*Lithophyllum stictaeforme*, *Mesophyllum alternans*, *Peyssonnelia* spp.) and form an encrusting substratum. The chlorophytes *Caulerpa prolifera* and *C. racemosa* (cc) colonise these horizontal surfaces between 45-55m depth (observed in Cape Greco, Moulia Rocks and Akamas).

c) Biocenosis of the semi-dark caves (UNEP/MED IV.3.2): The entry of the caves is colonised by the coralligenous community with incrusting algae *Mesophyllum alternans*, *Lithophyllum stictaeforme*, *Peyssonnelia, P. rosa-marina, P. coriacea*). In more sciaphylic surfaces the cnidarian *Madracis phaerensis*, characterise this habitat; the poriferans are abundant with *Spirastrella cunctatrix*, *Phorbas tenacior*, *Hamigera hamigera*, *Agelas oroides*, *Petrosia ficiformis*, *Chondrosia reniformis*; also the polychaete *Protula intestinum* is frequent. Although present in all of the observed parts, this community is frequent in Cape Greco due to the abundance of infralittoral submarine caves.

2.4 Habitats in areas which by virtue of their characteristics, location or strategic importance merit a particular reference, including areas subject to intense or specific pressures or areas which merit a specific protection regime

Cyprus areas with particular reference can be classified in two categories, the Marine Protected Areas (Natura 2000 sites including Lara/Toxeftra turtle reserve) and those where anthropogenic impact is evident mainly through episodic blooms of the non-periodic green alga *Cladophora* spp. (Figure 2.13).

There are currently six marine protected areas (MPAs) in Cyprus waters under the EU Habitats Directive (92/43/EEC); these MPAs are referred to as Sites of Community Importance (SCIs). An EU Decision in 2006 adopted these SCIs, updated the list of SCIs in 2008, and mandated their designation as Special Areas of Conservation (SACs [i.e., full-fledged MPAs]) by 2014 (2008/335/EC).

Figure 2.13 Areas of Cyprus with particular reference.

2.4.1 Polis-Yialia (Natura 2000 site)

a) Main habitats

- *Infralittoral* (0-40m depth): The *Posidonia oceanica* meadows are well developed and colonise the soft and rocky substrata from about 5 to 40 m depth. *Posidonia* meadows are very important for many species as feeding and breeding grounds. Green turtles feed in this area on *Posidonia* often adjacent sand banks where juveniles in particular feed on (Demetropoulos and Hadjichristophorou 1995). This site is the most important habitat for the nesting of *Caretta caretta* turtle in Cyprus falling into Annex II of the Directive and also the provisions of the Berne Convention.

b) Impact (Not reported)

2.4.2 Akamas Peninsula (Natura 2000 site)

2.4.2.1 Eastern Akamas

a) Main habitats (Argyrou et al. 2002)

- *Littoral* (0-1m depth): littoral organic concretions with *Lithophyllum trochanter*, *Neogoniolithon brassica-marina* and *Dendropoma petraeum*; and some belts of the *Cystoseira amentacea*, particularly in the Agios Giorgios Inlet and Cape Arnaoutis
- *Infralittoral* (0-40m depth): The shallow *Cystoseira* forests are not frequent, but they are abundant around the Agios Giorgios Inlet (1-19m depth). The *Posidonia oceanica* meadows are well developed and colonise the soft (10-42m depth) and rocky substrata (11-32m depth). The circalittoral enclaves (coralligenous and semi-dark caves communities) are not frequent.
- *Circalittoral* (35-55m depth): The coralligenous community is well represented at the eastern part of Agios Giorgios Inlet (40-55m depth) on vertical rocky surfaces with the organic concretions with calcareous algae (*Lithophyllum, Mesophyllum, Peyssonnelia* spp.) and sessile fauna (mainly sponges); and the subhorizontal rocky surfaces of the Fontana Amorosa area (42-46m depth) with *Cystoseira* spp., *Sargassum cf. trichocarpum* and *Axinella polypoides*. The maërl bed only has been observed in the northeastern part (north of the Fontana Amorosa).

2.4.2.2 Western Akamas

a) Main habitats (Argyrou et al. 2002)

- *Littoral* (0-1m depth): The littoral organic concretions with *Lithophyllum trochanter*, *Neogoniolithon brassica-marina* and *Dendropoma petraeum* are not frequent; some belts of the *Cystoseira amentacea*.
- *Infralittoral* (0-40m depth): The main characteristic of the infralittoral rocky bottoms of the western Akamas is the abundance of the shallow and middle *Cystoseira* forests (0-40m depth), with *Sargassum vulgare* and Spongidae at the northern part. The *Posidonia oceanica* meadows are well developed and colonise the soft (23-39m depth) and rocky substrata (11-34m depth). The circalittoral enclaves (coralligenous and semi-dark caves communities) are frequent.
- *Circalittoral* (40-55m depth): Due to the transparency of the water, the coralligenous community is well developed from 45m depth on subhorizontal rocky surfaces with the organic concretions with calcareous algae (*Lithophyllum, Mesophyllum, Peyssonnelia* spp.) and sessile fauna (mainly the sponge *Agelas oroides*). In some places the *Sargassum cf. trichocarpum* is abundant (south of the Cape Yeranisou to Yeronisos Island). The maërl bed is well develop at the northwestern sector (north of Cape

Yeranisou, 35-46m depth) with *Lithothamnion corallioides*, *Mesophyllum alternans* and *Dasycladus vermicularis* (very deep presence).

b) Impacts (Not reported)

2.4.3 Moulia Rocks (Natura 2000 site)

a) Main habitats (Argyrou et al. 2002)

- *Littora*l (0-1m depth): littoral organic concretions with *Lithophyllum trochanter*, *Neogoniolithon brassica-marina* and *Dendropoma petraeum*.
- *Infralittoral* (0-38m depth): The shallow *Cystoseira* forests are frequent (5-10m depth) with *C. humilis* and *C. spinosa var tenuior*. The *Posidonia oceanica* meadows are well developed and colonise the soft (14-38m depth) and rocky substrata (6-20m depth). The circalittoral enclaves (coralligenous community) are frequent.
- *Circalittoral* (35-43m depth): The coralligenous community is present but not well developed, with *Cystoseira spinosa* and *Sargassum cf. trichocarpum* on horizontal surfaces (35-40m depth); also, the organic concretions with calcareous algae (*Lithophyllum, Mesophyllum, Peyssonnelia* spp.) and sessile fauna (mainly sponges) are not well developed. The maërl bed has not observed.

b) Impacts (Not reported)

2.4.4 Cape Aspro – Petra tou Romiou (Natura 2000 site)

a) Main habitats

The marine habitats of the site have not been studied in detail. This site, however, has a similar typology (Implementation of WFD in Cyprus) and is located quite close to Moulia Rocks site.

- *Littora*l (0-1m depth): littoral organic concretions with *Lithophyllum trochanter*, *Neogoniolithon brassica-marina* and *Dendropoma petraeum*.
- *Infralittoral* (0-38m depth): The shallow *Cystoseira* forests are frequent (5-10m depth) with *C. humilis* and *C. spinosa var tenuior*. The *Posidonia oceanica* meadows are well developed and colonise the soft (14-38m depth) and rocky substrata (6-20m depth). The circalittoral enclaves (coralligenous community) are frequent.
- *Circalittoral* (35-43m depth): The coralligenous community is present but not well developed, with *Cystoseira spinosa* and *Sargassum cf. trichocarpum* on horizontal surfaces (35-40m depth); also, the organic concretions with calcareous algae (*Lithophyllum, Mesophyllum, Peyssonnelia* spp.) and sessile fauna (mainly sponges) are not well developed.

b) Impacts (Not reported)

2.4.5 Cape Greco (Natura 2000 site)

a) Main habitats (Argyrou et al. 2002)

- *Littoral* (0-1m depth): littoral organic concretions with *Lithophyllum trochanter*, *Neogoniolithon brassica-marina* and *Dendropoma petraeum*; some belts of the *Cystoseira amentacea*.
- *Infralittoral* (0-40m depth): The shallow *Cystoseira* forests are abundant (5-15m depth) with *Cystoseira humilis* and *C. spinosa var tenuior*. The *Posidonia oceanica* meadows

are well developed and colonise the soft (14-40m depth) and rocky substrata (10-25m depth). The circalittoral enclaves (coralligenous and semi-dark caves communities) are frequent.

- *Circalittoral* (35-80m depth): The coralligenous community is well represented with the deep Fucales forests represented by *Cystoseira spinosa*, *C. zosteroides* and *Sargassum cf. trichocarpum* on horizontal surfaces (40-50m depth). Also, the organic concretions with calcareous algae (*Lithophyllum, Mesophyllum, Peyssonnelia* spp.) and sessile fauna (mainly sponges). The semi-dark cave community is well represented with *Madracis phaerensis* and sponges. On the soft bottoms, the maërl beds are present; and the association of the Peyssonneliacea (mainly *Peyssonnelia rosa-marina*) with *Palmophyllum crassum* front Cape Greco (55-65m depth).

b) Impacts (Not reported)

2.4.6 Nisia (Natura 2000 site)

a) Main habitats

The marine habitats of the site have not been studied in detail. This site, however, has a similar typology (Implementation of WFD in Cyprus) and is located quite close to Cape Greco site.

- *Littoral* (0-1m depth): littoral organic concretions with *Lithophyllum trochanter*, *Neogoniolithon brassica-marina* and *Dendropoma petraeum*; some belts of the *Cystoseira amentacea*.
- *Infralittoral* (0-40m depth): The shallow *Cystoseira* forests are abundant (5-15m depth) with *Cystoseira humilis* and *C. spinosa var tenuior*. The *Posidonia oceanica* meadows are well developed and colonise the soft (14-40m depth) and rocky substrata (10-25m depth). The circalittoral enclaves (coralligenous and semi-dark caves communities) are frequent.
- *Circalittoral* (35-80m depth): The coralligenous community is well represented with the deep Fucales forests represented by *Cystoseira spinosa*, *C. zosteroides* and *Sargassum cf. trichocarpum* on horizontal surfaces (40-50m depth). Also, the organic concretions with calcareous algae (*Lithophyllum, Mesophyllum, Peyssonnelia* spp.) and sessile fauna (mainly sponges). The semi-dark cave community is well represented with *Madracis phaerensis* and sponges. On the soft bottoms, the maërl beds are present; and the association of the Peyssonneliacea (mainly *Peyssonnelia rosa-marina*) with *Palmophyllum crassum* front Cape Greco (55-65m depth).

b) Impacts (Not reported)

2.4.7 Lara/Toxeftra (Turtle reserve)

The Lara/Toxeftra, has been protected, since 1989, under the Fisheries Legislation as a coastal/marine reserve for turtle conservation. Both Green (*Chelonia mydas)* and Loggerhead (*Caretta caretta*) turtles nest there. The management regulations for this area are spelled out in the Fisheries Regulations (273/90). It includes the foreshore (95m) and the adjacent sea area to the 20m isobath.

a) Main habitats (similar to Western Akamas)

- *Littoral* (0-1m depth): The littoral organic concretions with *Lithophyllum trochanter*, *Neogoniolithon brassica-marina* and *Dendropoma petraeum* are not frequent; some belts of the *Cystoseira amentacea*.

- *Infralittoral* (0-40m depth): The main characteristic of the infralittoral rocky bottoms is the abundance of the shallow and middle *Cystoseira* forests (0-40m depth), with *Sargassum vulgare* and Spongidae at the northern part. The *Posidonia oceanica* meadows are well developed and colonise the soft (23-39m depth) and rocky substrata (11-34m depth). The circalittoral enclaves (coralligenous and semi-dark caves communities) are frequent.
- *Circalittoral* (40-55m depth): Due to the transparency of the water, the coralligenous community is well developed from 45m depth on subhorizontal rocky surfaces with the organic concretions with calcareous algae (*Lithophyllum, Mesophyllum, Peyssonnelia* spp.) and sessile fauna (mainly the sponge *Agelas oroides*). In some places the *Sargassum cf. trichocarpum* is abundant. The maërl bed is well developed with *Lithothamnion corallioides*, *Mesophyllum alternans* and *Dasycladus vermicularis* (very deep presence).

b) Impacts (Not reported)

2.4.8 Limassol Bay (including Vasilikos bay, Moni and Vasilicos area)

a) Main habitats

- *Infralittoral* (0-40m depth): The benthic macrophyte communities occurred in the area consists mainly of the seagrasses *Posidonia oceanica* and *Cymodocea nodosa* and the green alga *Caulerpa prolifera* (Figure 2.14). While the *Posidonia oceanica* meadows are well developed and colonise the soft from about 1 to 30 m depth (MedVeg 2005, UNEP-MAP RAC/SPA 2007) the *Cymodocea* meadows thrive in rather restricted areas from around 10 to 15 m depth (AP Marine 2009). Other macroalgal species may found in the area are the green algae *Cladophora spp., Dasycladus clavaeformis, Anadyomene stellata,* and *Udotea petiolata,* and the seagrass *Halophila stipulacea.*

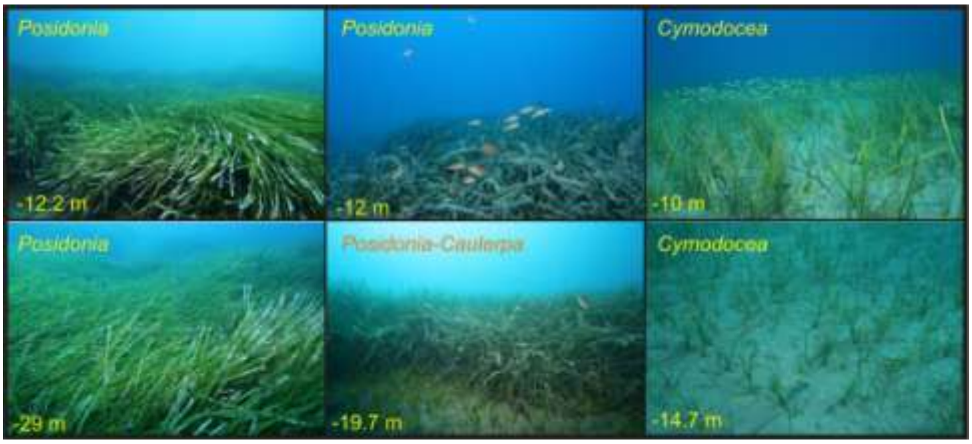


Figure 2.14 Benthic macrophyte communities at Seawave Fisheries Ltd in Limassol Bay (AP Marine 2009).

b) Impacts

Cyprus coastal waters, as a part of E. Mediterranean Sea, are naturally ultra-oligotrophic and therefore relatively small changes in the flux of nutrients as from anthropogenic sources might have disproportional effects on coastal ecosystem. An example might be the non periodic blooms of *Cladophora* spp. observed during the last 16 years (Argyrou 2000). Masses of the ephemeral filamentous macroalga *Cladophora* spp. were observed in summers of 1990-91, 1998, 2004 and 2005 in some of the coastal areas (Liopetri/ Ayia

Napa, Limassol) of Cyprus causing nuisance problems on the shore (Figure 2.13, Figure 2.15). The episodic eutrophication with *Cladophora* was associated with excess nutrients derived from several sources, such as agriculture (groundwater seepage, runoff), aquaculture and urban wastes, combined with complex interactions of other synergistic factors, such as abrupt increases of water temperature, appropriate substrate, weather conditions etc. (Argyrou 2000).

Figure 2.15 *Cladophora* spp. in Cyprus coastal waters (Argyrou and Loizides 1998).

Climate changes are expected to increase the eutrophication risk in Cyprus and in general in the Mediterranean Sea coastal ecosystems. A few degrees Celsius increase of water temperature might accelerate growth and reproduction rates of certain algae e.g. opportunistic macroalgae as *Cladophora* spp., to disrupt normal functioning of the ecosystem especially during winter-spring period when precipitations and nutrients concentrations in the seawater are maximal.

A warming of the Mediterranean Sea may also affect the marine biodiversity in shallow coastal waters, in particular the warm-temperate endemic to the Mediterranean species with specific reproduction adaptations (see Orfanidis et al. 1999) or species already stressed by other impacts such as *Posidonia oceanica* (Marbà and Duarte 2009).

The land use changes of recent decades in Cyprus coastal sites as such of Limassol due to high demands of touristic industry for land, led to fragmentation of habitats and habitat loss and placed excessive pressure on biodiversity (Demetropoulos 2003a).

Table 2.2 summarizes the main habitat types with their conservation status and impact in Cyprus areas with particular reference.

Table 2.2 Main habitat types with its conservation status and impact in areas of particular reference.

			Main habitat types		
Area	***Conservation Status***	***Main sediment type (Water body type)***	***EUNIS Level 2***	***Natura 2000***	***Impact***
Polis-Yialia	Natura 2000	Sand-gravel (C2)	A2	1110 *Cymodocea**, **	Sustainable
			A5	1120 *Posidonia* beds*	Sustainable
Akamas	Natura 2000	Hard (C1)	A1	1170***	Sustainable
			A2	1110 *Cymodocea**, **	Sustainable
			A3	1170***	Sustainable
			A4	1170***	Sustainable
			A5	1120 *Posidonia* beds*	Sustainable
Moulia	Natura 2000	Hard (C1)	A1	1170***	Sustainable
			A3	1170***	Sustainable
			A4	1170***	Sustainable
			A5	1120 *Posidonia* beds*	Sustainable
Cape Aspro – Petra tou Romiou	Natura 2000	Hard (C1)	A1	1170***	Sustainable
			A3	1170***	Sustainable
			A4	1170***	Sustainable
Cape Greco	Natura 2000	Hard (C3)	A1	1170***	Sustainable
			A2	1110 *Cymodocea**, **	Sustainable
			A3	1170***	Sustainable
			A4	1170***	Sustainable
			A5	1120 *Posidonia* beds*	Sustainable
Nisia	Natura 2000	Hard (C3)	A1	1170***	Sustainable
			A3	1170***	Sustainable
			A4	1170***	Sustainable
Lara/Toxeftra	Turtle Reserve	Hard (C1)	A1	1170***	Sustainable
			A3	1170***	Sustainable
			A4	1170***	Sustainable
			A5	1120 *Posidonia* beds*	Sustainable
Limassol Bay	At risk (according to WFD)	Sand-gravel (C2)	A2	1110 *Cymodocea**, **	Sustainable - non periodic *Cladophora* blooms
			A5	1120 *Posidonia* beds*	
			A3	1170***	
			A4	1170***	

* Priority habitat in Annex I of the Habitats Directive (92/43/EEC)
** *Cymodocea nodosa* can grow also in deeper habitats
*** Includes *Spongites-Dendropoma* and *Lithophyllum* spp. formations, *Cystoseira* forests and sciaphilic algae

3. Biological features

3.1 A description of the biological communities associated with the predominant seabed and water column habitats, including information on the phytoplankton and zooplankton communities and species and seasonal and geographical variability

3.1.1 Phytoplankton

Main habitats: A7.1, A7.3, A7.8, A7.9 (EUNIS Classification System)

Studies of the phytoplankton communities' biomass, composition, and vertical distribution in the Eastern Mediterranean Sea are relatively scarce, generally restricted to particular regions e.g. the warm-core eddy to the south of Cyprus, and limited to the fall–winter seasons of the euphotic zone.

In comparison to other biogeographical regions (Caron et al. 1995) the Eastern Mediterranean Sea is an ultra-oligotrophic sea characterized by extremely low values of chlorophyll-a (0.1 to 0.2 µg L^{-1}), primary production (60–80 g C m^{-2} y^{-1}), and cell abundance and by dominance of small-sized phytoplankton cells (Krom et al. 1991, Psarra et al. 2000, Vidussi et al. 2001). Over 85% of chlorophyll-a belongs to the <10 µm size fraction i.e. ultra-phytoplankton (Li et al. 1993) and is mainly composed of cyanobacteria, with dominance of *Synechococcus* over *Prochlorococcus* and of eukaryotes belonging to the group of chlorophyceae, prasinophyceae and prymnesiophyceae (Vidussi et al. 2001).

Older studies of Phytoplankton community (see UNEP/MAP 2010) revealed a dominance of tropical planktonic taxa due to high temperatures prevailing in the basin such as the dinoflagellates *Pyrocystis noctiluca, Ceratium carriense, C. trichoceros* and *C. massiliense*, and the diatoms, the *Chaetoceros-Rhizosoleia* complex. The presence of an increasing number of species of Indo-Pacific origin that have entered the basis through the Suez Canal and established populations in the Levant Basin is another feature.

More recent studies performed within the framework of the CYCLOPS (Cycling of Phosphorus in the Mediterranean) program (see Krom et al. 2005a, 2005b, Psarra et al. 2005, Thingstad et al. 2005, Tanaka et al. 2007) have been realized to characterize the biomass, composition, and vertical distribution of the various phytoplankton community components and to assess the production and regeneration processes throughout the euphotic layer and below it in the Levantine Basin:

- Maximum chlorophyll-a values have been measured in winter to early spring (November–March) where phytoplankton bloom occurs following the deep winter mixing. This results in complete depletion of phosphate in the surface waters but with some residual nitrate. In summer after the seasonal stratification forms, a deep chlorophyll maximum is developed, and nitrate and phosphate are at or below the conventional analytical detection limits in the surface waters.

- In the euphotic layer, heterotrophs (bacteria, heterotrophic nanoflagellates, and ciliates) dominated (60–70%) the microbial carbon biomass. Heterotrophic ciliates were much more abundant in the upper 50m of the water column, while no consistent pattern was found for bacteria and heterotrophic nanoflagellates throughout the euphotic layer. Autotrophs showed a maximum distribution at the deep chlorophyll maximum found between

100 and 130 m. Besides the importance of prymnesiophyte nanoplankton the presence of coccolithophorids and diatoms was also confirmed.

- In a phosphate addition experiment in the Cyprus Eddy was indicated that while the phytoplankton community indicated to be N- and P-co-limited in the summer, the heterotrophic community (bacteria and microbial predators) is only P-limited. This result has been recently confirmed by nutrient manipulated microcosms experiments during the BOUM experiment in the summer of 2008 (Tanaka et al. 2011).

In the Cyprus coasts phytoplankton biomass has been studied in details by Bianchi et al. (1996) in June and July 1993:

- Chlorophyll-*a* concentrations ranged between 16–90 ng L^{-1}. The highest concentrations occurred at the Pafos and Limassol sites, with the lowest measurable concentrations at Famagusta and Latsi. In June 1993, the subsurface chlorophyll-*a* maxima generally occurred between 20–30 m. In July 1993, chlorophyll-*a* concentrations were generally uniform throughout the water column with minor increases at depth at Famagusta and Latsi. Overall, the chlorophyll-*a* concentrations in July, between 0–10 m, were significantly lower than in June, except for Latsi.

- Chlorophyll *b* concentrations ranged between 0–76 ng L^{-1} in June 1993 and 2–55 ng L^{-1} in July 1993. Concentrations of the accessory pigment chlorophyll *b*, which is abundant in chlorophytes, were significantly correlated with chlorophyll-*a* concentrations at all stations in June and July. The highest concentrations of chlorophyll *b* occurred at the Limassol station.

- Concentrations of fucoxanthin, a carotenoid commonly found in diatoms, ranged between 0–10 ng L^{-1} in June 1993 and only 0–3 ng/l in July 1993; the highest concentration was found at the 50 m Pafos station. Zeaxanthin, a carotenoid found in cyanobacteria, had a concentration range of 0–14 ng L^{-1} in June 1993 and 0–16 ng L^{-1} in July 1993. Peridinin, a carotenoid marker for dinoflagellates, was generally below limits of detection in June 1993, however, it did reach detectable concentrations at stations Limassol and Pafos in July 1993 that ranged between 3–18 ng L^{-1}. Concentrations of *α*-carotene were significantly higher (3–31 ng L^{-1}) than *β*-carotene (0–5 ng L^{-1}) at all sites.

A study of chlorophyll-a change across an anthropogenic gradient in Cyprus coasts has been realized by Argyrou et al. (2011) within the WFD monitoring program the period 2007-2010. One hundred eighty one (181) samples have been sampled and analyzed from thirteen (13) different sites (Figure 3.1) from surface down to 20 m depth. In agreement with older studies (Bianchi et al. 1996) sixty one (61%) percent of the chlorophyll-a values were lower than 0.06 μg L^{-1} and seventy eight (78%) percent were lower than 0.08 μg L^{-1} (Figure 3.2).

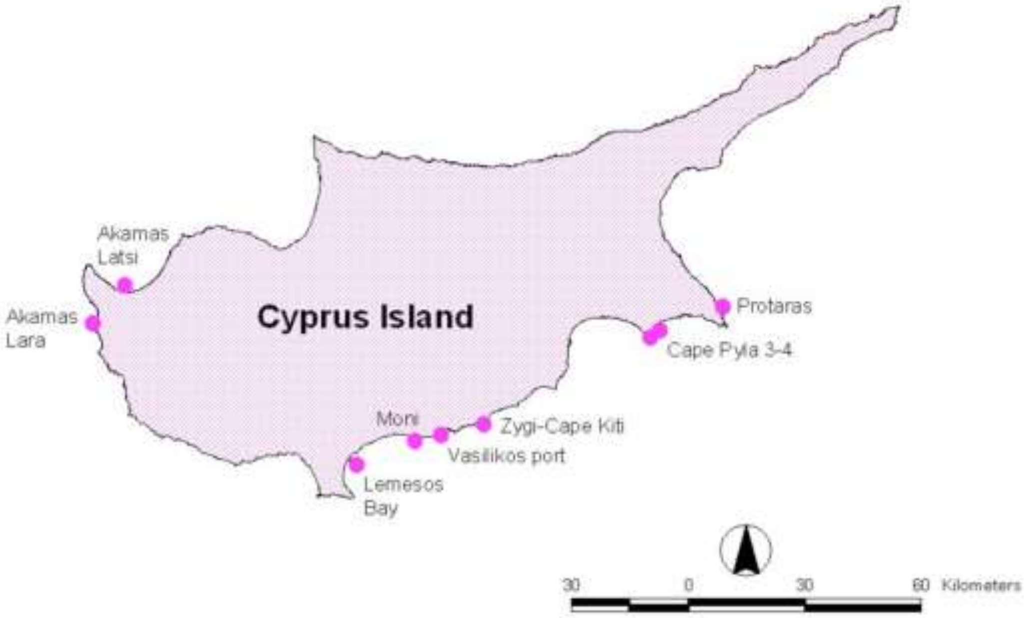


Figure 3.1 Map of the sites of the studied phytoplankton communities in Cyprus coasts within WFD monitoring program. In each indicated site one sampling station has been monitored except in Akamas Latsi, Akamas Lara and Lemesos Bay where two sampling stations have been monitored. Moreover, in Akamas peninsula the site cCY_5-C1-S1/B2 (not indicated) was monitored three times during the 2007-2009 period.

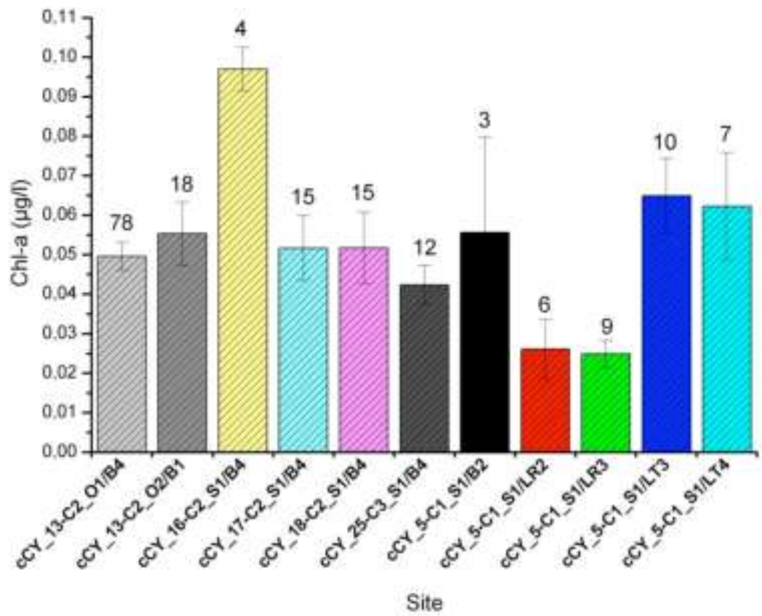


Figure 3.2 Chlorophyll-a mean values and variance across differently impacted sites of Cyprus coastal waters. Numbers indicate number of samples (only sites with >2 samples are mentioned). Site codes correspond to those in Figure 3.1 as follows: Akamas (cCY_5-C1-S1/B2), Akamas-Lara (cCY_5-C1-S1/LR2, cCY_5-C1-S1/LR3), Akamas-Latsi (cCY_5-C1-S1/LT3, cCY_5-C1-S1/LT4), Lemesos Bay (cCY_13-C2-O1/B4, cCY_13-C2_O2/B1), Moni (cCY_16-C2-S1/B4), Vasilikos Port (cCY_17-C2-S1/B4), Zigi-Cape Kiti (cCY_18-C2-S1/B4), Protaras (cCY_25-C3-S1/B4).

3.1.2 Zooplankton

The low, by global average standards, levels in primary production and phytoplankton that characterize the Mediterranean (and the Eastern Mediterranean and the Levantine in particular) are also reflected in zooplankton-related parameters. These parameters follow west-to-east trends of spatial variability in nutrients and phytoplankton (discussed elsewhere in the report), including a maximum in the depth of the deep chlorophyll layer (Siokou-Frangou et al. 2010). The smaller metazooplankton class (50-200 μm), microheterotrophs, and egg-carrying copepod species dominate zooplankton, but overall there is significant diversity over both spatial (induced by physical features, such as fronts and cyclonic activity) and temporal (induced by seasonality) scales (Siokou-Frangou et al. 2010).

Coastal zooplankton populations are dominated by copepods, which comprised approximately 80% of the total zooplankton biomass (Hannides et al. 2011). These copepods were primarily small individuals from the Families Clausocalanidae, Paracalanidae, Oithonidae, and Oncaeidae. Other taxa contributed to zooplankton communities were ostracods, cladoceran, mollusks etc. Significant seasonal patterns were noted for some groups (Hannides et al. 2011). Cyclopoid copepods were a larger component of the total zooplankton community in summer (24 - 44%) as compared to winter (13 - 26%). Cladocerans were never observed in samples collected around Cyprus in winter but were an important component of the total zooplankton in summer (0.8 - 16% of the populations). In terms of spatial variability appendicularians were observed to contribute significantly to zooplankton populations at southern stations (Agia Napa, Limassol, Larnaca: 32 - 53 individuals m^{-3}), but were less important at northern stations (Pomos, Paphos: 3-5 individuals m^{-3}) during all seasons. Zooplankton biomass and abundance in Cyprus waters were most similar to values found at oligotrophic coastal or offshore locations in the Eastern Mediterranean, as for example off the coast of Rhodes and in the southern Aegean Sea.

Open Cyprus waters are characterized by copepods, nanoflagellates, ciliates, siphonophores, ctenophores, heteropods, pteropods, ostracods, cladocerans, euphausids, isopods, chaetognaths, appendicularians, doliolids, salps, and larvae of fish, echinoderms, mollusks, polychaetes, etc. (Mazzocchi et al. 1997). Surface waters are dominated by copepods, while ciliates and autotrophic nanoflagellates are also present in significant numbers (Pitta et al. 2005, Tanaka et al. 2007). The diversity between and within these groups of zooplankton is considered to be extremely high with no species contributing more than a fifth of the total abundance (Siokou-Frangou et al. 1997)

A very comprehensive analysis of zooplankton communities in the Levantine was conducted by Lakkis (2007) and based on multidecadal oceanographic cruises in coastal and neritic Lebanese seawaters during the last four decades (1965–2005). Among the approximately 1000 identified zooplankton species were numerous introduced alien species of Indo-Pacific and Eritrean origin, the majority of which were established in stable populations. The identified macrozooplankton includes all species from Hydromedusae up to Tunicates and fish larvae. The zooplankton community shows pronounced seasonal variations in diversity and abundance, closely coupled with phytoplankton dynamics.

The above study highlights the increasingly evident similarity between the plankton (and zooplankton in particular) of the Levantine and the Red Sea. As it was highlighted in other reviews (UNEP/MAP 2010), this may be due to the Lessepsian migration as well as the higher water temperatures of the region.

3.2 Information on angiosperms, macro-algae and invertebrate bottom fauna, including species composition, biomass and annual/seasonal variability

3.2.1 Angiosperms

Main habitats: A2.6, A4.5 (EUNIS Classification System)

Most comprehensive study of Cyprus marine angiosperms has been executed by Argyrou et al. (2002) as necessary for the preparation of the protected areas Cape Greco, Moulia Rocks and Akamas Peninsula management plans.

Sub-littoral sediments of Cyprus support extensive and dense meadows of *Posidonia oceanica*, a long-lived endemic Mediterranean species, present at a depth ranging from 5 to ~40 m. In Larnaca Bay, *P. oceanica* forms dense meadows within a zone from the water depths of 4 m down to 8 m, while at greater depths (> 8 m up to 16 m) it has patchy appearance (Argyrou 2001). In the Cape Greco and Moullia Rocks areas, the *Posidonia oceanica* habitat was well developed, both in sandy bottoms and in rocky ones (5-42 m depth), with densities around 625 shoots m^{-2} (18 m depth) and 710 shoots m^{-2} (9 m depth) (Argyrou et al. 2011). Such *Posidonia* densities are very high when compared with other Mediterranean sites (Pergent-Martini et al. 1994). The deepest *Posidonia oceanica* meadow has been noticed in Eastern Akamas (42 m depth) Peninsula. This and other deep *Posidonia* meadows are dispersed and became less dense (from 30-42m depth) with the chlorophytes *Caulerpa prolifera* and *C. racemosa* (Argyrou et al. 2002).

Beside shoot density a number of *Posidonia* meadow characteristics have been also estimated in Cape Greco and Moullia Rocks sites (Argyrou et al. 2002). The number of leaves produced by vertical shoots ranged between 7 and 9. Using lepidochronological techniques different parameters of *Posidonia* productivity have been estimated. The "branching rate" of vertical shoots was low estimated between 10 and 20 years. The "rhizome production" of vertical rhizomes was around 80 mg DW sh^{-1} y^{-1} at all the localities and depths. "Rhizome production" of horizontal rhizomes was much higher, around 1.4 g DW sh^{-1} y^{-1} in most of the studied meadows, except in the shallow meadow of Cape Greco where less than half of this production was obtained. The "elongation of horizontal rhizomes" was about 6 cm per year. The lower values were obtained for the shallow meadow of Cape Greco with only 4 cm/year. The "maximum number of leaves per year" produced by horizontal rhizomes was 17.7 in the deep meadow of Cape Greco while the lowest, 13.7, was observed in the deep meadow of Pafos. The "branching rate of horizontal shoots" was very high, with more than 2 new shoots produced by year.

Posidonia shoots form a natural habitat of diverse macroalgal and faunal communities (Argyrou et al. 2002). The rhizome stratum is colonised by the sciaphilic algae association with *Flabellia petiolata*, *Peyssonnelia* spp., *Mesophyllum alternans, Caulerpa prolifera*, and *C. racemosa*. The sessile fauna is diverse, mainly the sponges as *Sarcotragus muscaria*, *Ircinia* spp., *Crambe crambe*, and the sedentary polychaete *Sabella spallanzani*. The bivalve *Pinna nobilis* has been rare. With regards of the vagile fauna, the more common species are the sea urchin *Sphaerechinus granularis* and the fishes *Spicara smaris*, *Chromis chromis*, *Coris julis*, *Sparisoma cretense*, *Siganus luridus*, *Diplodus vulgaris*, *D. annularis*, *Sarpa salpa* and *Symphodus tinca*.

All the above cited information indicates the great ecological importance of *Posidonia* in Cyprus and in general in the Mediterranean Sea (Hemminga and Duarte 2000). Since it is growing slowly having sparse reproductive episodes, it requires centuries to colonize coastal areas and it is regarded as a highly vulnerable to anthropogenic pressure species. However, in Cyprus and in other Mediterranean sites fish farms are often located close or above the *Posidonia* meadows attributed to decline of *P. oceanica* meadows and to the deterioration of sediment quality, processes and conditions detrimental for seagrass survival and growth. Additional seagrass loss may attribute to increase of epiphytic density and/or of grazing pressure in response to environmental nutrient enrichment derived from fish farm activities. The environmental effects of marine fish farming in *Posidonia* meadows of Limassol Bay, Cyprus, (39 m depth) and elsewhere within the Mediterranean Sea have been studied within the framework of MEDVEG project. Similar effects have been studied by AP Marine in several fish farms such as the Seawave Fisheries Ltd (AP Marine 2009). In accordance to these studies it is recommended that concessions for fish farms in the vicinity of seagrass (*Posidonia oceanica*) are to be avoided altogether if suitable localities away of any such seagrass meadow exist. Whenever alternative, suitable sites away from any seagrass meadow are not available, concessions must observe distances of at least 800 m from the nearest seagrass bed. Shall fish farms be established at the minimum distance referred to above; these farms should be positioned down-current, along the dominant current direction, from the seagrass meadow to further avoid materials from the fish farm from reaching the meadow (Holmer et al. 2008).

Cymodocea nodosa, a warm-temperate species and *Halophila stipulacea*, a typical Lessepsian migrant of the Eastern Mediterranean, are only present in located sedimentary sites in Cyprus. In eastern coasts of Cape Greco *Cymodocea* thrives at 9-12 m depth, and in Akamas at 39-41 m depth (Argyrou et al. 2002). While *C. nodosa*, however, predominates in shallow waters (2-10 m), *H. stipulacea* can be found in mainly in deep depths from 30 to 40 m (Hadjichristophorou et al. 1997). Beside angiosperms, sub-littoral soft sediments support the growth of the green algae *Caulerpa prolifera* and *C. racemosa*, which in most cases co-occur with *H. stipulacea*.

3.2.2 Macroalgae

Main habitats: A1.2, A1.4, A2.7, A2.8, A3.2, A.37, A4.2, A4.7, A5.6 (EUNIS Classification System)

Benthic macroalgae studies are very limited for Cyprus coastal waters and the published check-list included only a few well recognized taxa (Hadjichristophorou et al. 1997). A short check-list of macroalgae species can be also found in different studies with focus on different ecological aspects of Cyprus coastal waters (Russo 1997; Argyrou et al. 1999a, 1999b).

High water transparency of Cyprus waters, secchi disk readings can range between 21–39 m (Bianchi et al. 1996), affects seaweed communities which can grow deep and on horizontal rocky surfaces (Western Akamas) down to 50m depth. While the photophilic associations are observed until the 35m depth certain photophilic species e.g. *Padina pavonica*, can grow even deeper at 49 m depth (Argyrou et al. 2002).

In an upcoming paper (Stavrou and Orfanidis), the seaweed community changes across an anthropogenic gradient in three Cyprus rocky sites (Figure 3.3) of different typology (Akamas site: hard, intermediate depth, moderately exposed; Cape Pyla sites: hard, shallow, moderately exposed) were studied. The species composition and abundance of seventy one (71) destructive-quantitative samples (20×20 cm) from the upper sublittoral macroalgal communities were analyzed. A total 54 taxa of macroalgae (16 Chlorophyceae, 9 Phaeophyceae and 29 Rhodophyceae) were identified. According to Orfanidis et al. (2011), 18 species can be characterized as late-successional, slow-growing species and can be classified in Ecological Status Group I (1 IA, 4 IB, 13 IC) and the rest 38 species, including

Cyanobacteria and benthic diatoms, can be characterized as opportunistic, fast growing species and can be classified in ESG II (14 IIA, 24 IIB).

A cluster analysis of data (Figure 3.4) at site scale indicated two groups of sites with a higher than 50% similarity. While the site of Akamas belongs in the first group, the two sites of Cape Pyla belong in the second group. MDS analysis (Figure 3.5) along with nested ANOSIM analysis indicated statistical significant differentiation in both scales: site (R=753, p=0.001), time in site (R=274, p=0,001). A SIMPER analysis has indicated that *Cystoseira barbata* s.l. (Akamas=112.67 %; CaP3=67 %; CP4=70.17 %), *Jania rubens* (Akamas=55.25 %; CP3=3.06 %; CP4=21.25 %) and *Laurencia obtusa* (Akamas=0 %; CP3=6.4 %; CP4=2.58 %) were dominated in the studied sites. The dissimilarity of these sites was ranged between 40.93% and 45.89% (Table 3.1). These results confirm the high diversity, in terms of macroalgae communities, of Cyprus macroalgae flora as it was also hypothesized due to diverse types of hard substrate (Demetropoulos 2003a).

Over the last years, Cyprus occasionally is experiencing episodic eutrophication events with the ephemeral macroalga *Cladophora* spp*.* The cyclic outbreaks of this alga are prominent, particularly, in some coastal areas of the south and east parts of the island, resulting in mass aggregates of free-floating fragments of *Cladophora,* which in turn cause nuisance problems on the shore m (Argyrou 2000).

Caulerpa racemosa var. c*ylindracea* was reported for first time in 1991 from the Moni Bay at a depth of 30 m has been undergoing proliferative growth in the coastal waters of Cyprus. It is regarded as an invasive species to the Cyprus coasts and in general to the Mediterranean Sea (Argyrou et al. 1999a; Klein and Verlaque 2008). At present, it can be found all around the island forming extensive dense beds, in a wide range of habitats, from very shallow waters down to depth of 70 m.

In Larnaca Bay, other macroalgal species found in the area of sampling stations were the green algae *Cladophora* spp*., Dasycladus clavaeformis, Anadyomene stellata,* and *Udotea petiolata* (Argyrou 2001). The existence of marine underwater caves and scarce light conditions in Cyprus may favor the growth of sciaphilic vegetation of the genera *Flabella* and *Peyssonnelia.*

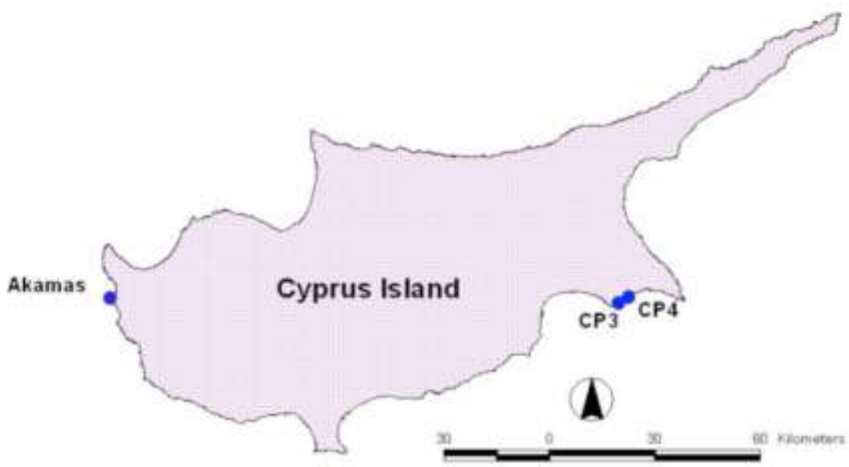


Figure 3.3 Map of the sites of the studied macroalgae communities in Cyprus coasts within WFD monitoring program.

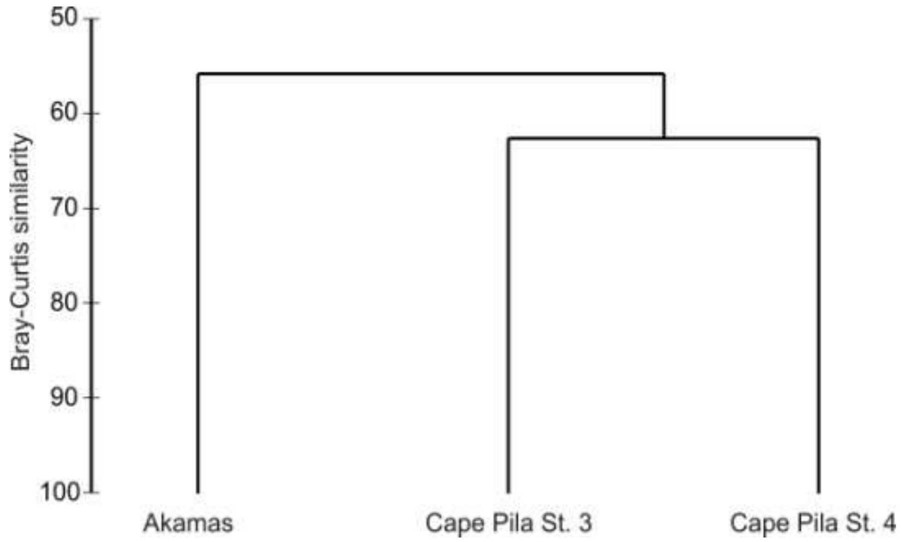


Figure 3.4 Cluster analysis at a site scale based on Bray-Curtis similarity index.

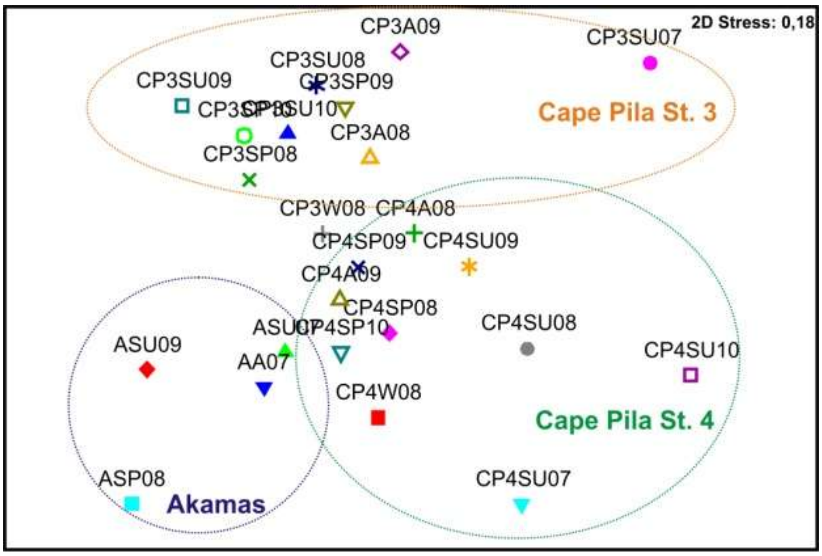


Figure 3.5 Multidimensional Scaling analysis (MDS) of sites as spatio-temporal scale (B) all based on Bray-Curtis similarity index (Stavrou and Orfanidis).

Table 3.1 Species average abundance (Av. Abund.) and contribution (Contrib%) to the Bray-Curtis dissimilarity between the groups 1 and 2 (A), 1 and 3 (B) and 2 and 3 (c). The average Bray-Curtis dissimilarity between all pairs of samples of the groups was calculated at 45.89%, 40.93%, and 43.72%, respectively %. Cut off for low contributions: 90%.

A)	***Group Akamas***	***Group Cape Pila 3***		
Species	***Av.Abund***	***Av.Abund***	***Contrib%***	***Cum.%***
Jania rubens	55.25	3,06	42.13	42.13
Cystoseira sp.	112.67	67	35.28	77.4
Laurencia obtusa	0	6,4	5.04	82.44
Cystoseira compressa	0	4,38	3	85.44
Anadyomene stellata	2	3,16	2.3	87.74
Lithophyllum sp.	3.67	3,31	2.25	89.99
Dasycladus vermicularis	1.72	2,06	2.25	92.24
B)	***Group Akamas***	***Group Cape Pila 4***		
Species	***Av.Abund***	***Av.Abund***	***Contrib%***	***Cum.%***
Cystoseira sp.	112,67	70,17	37.95	37.95
Jania rubens	55.25	21,25	27.04	64.99
Dasycladus vermicularis	1.72	14,37	10.2	75.19
Dictyota spiralis	0	10,17	7.69	82.88
Lithophyllum sp.	3.67	4,03	2.63	85.51
Laurencia obtusa	0	2,58	2.11	87.62
Anadyomene stellata	2	1,72	2.03	89.64
Dictyota dichotoma	0	2,42	1.78	91.43
C)	***Group Cape Pila 3***	***Group Cape Pila 4***		
Species	***Av.Abund***	***Av.Abund***	***Contrib%***	***Cum.%***
Cystoseira sp.	67	70.17	24.79	24.79
Jania rubens	3.06	21.25	20.76	45.55
Dasycladus vermicularis	2.06	14.37	12.08	57.64
Dictyota spiralis	2.1	10.17	10.14	67.77
Laurencia obtusa	6.4	2.58	6.51	74.29
Cystoseira compressa	4.38	2.83	5.48	79.76
Lithophyllum sp.	3.31	4.03	3.39	83.15
Laurencia papillosa	2.29	0.59	2.86	86.01
Anadyomene stellata	3.16	1.72	2.84	88.85
Dictyota dichotoma	0	2.42	2.18	91.03

3.2.3 Benthic invertebrate fauna

Main habitats: A1, A2, A3, A4, A5 (for details see Table 2.1; EUNIS Classification System)

In general, the Mediterranean littoral gravels and coarse sands support a rather impoverished invertebrate fauna due to strong physical disturbance from tidal and wave actions causing sediment mobility. In mobile sediments a range of taxa including amphipods, e.g. *Echinogammarus*, isopods, e.g. *Sphaeroma* and polychaetes, e.g. *Ophelia* can be found. Littoral and sub-littoral hard substrata support different invertebrate communities depending on the shore height and on dominant algal communities. In the upper littoral zone communities of barnacles *Chthamalus* and limpets *Patella* subject to occasional but regular emersion should dominate. Other species that may be found include the gastropod *Littorina* and the isopode *Ligia*. In the upper sub-littoral zone, where macroalgae dominate, various amphipods (*Caprella*), gastropods (*Cerithium*, *Gibbula*, *Columbella*) and crabs (*Pirimeda*, *Acanthonyx*) can be found. Sea urchins (*Paracentrotus*) and anemones (*Anemonia*) should be very common on the lower rocky shore mainly down to depths of 3 m.

The benthic invertebrate community changes across an anthropogenic gradient in eight Cyprus sedimentary sites (Figure 3.6) were studied by Aplikioti et al. (in preparation) within the WFD coastal waters monitoring program. The species composition and abundance of 35 samples (Van Veen Grabs of 0.01 m^2 surface) from the lower sublittoral zoobenthos communities were analyzed. A total 190 taxa of invertebrate fauna were identified with most of the taxa belonging to Annelida (109), Arthropoda (34) and to Mollusca (30).

Figure 3.6 Map of the sites of the studied zoobenthos communities in Cyprus coasts within WFD monitoring program.

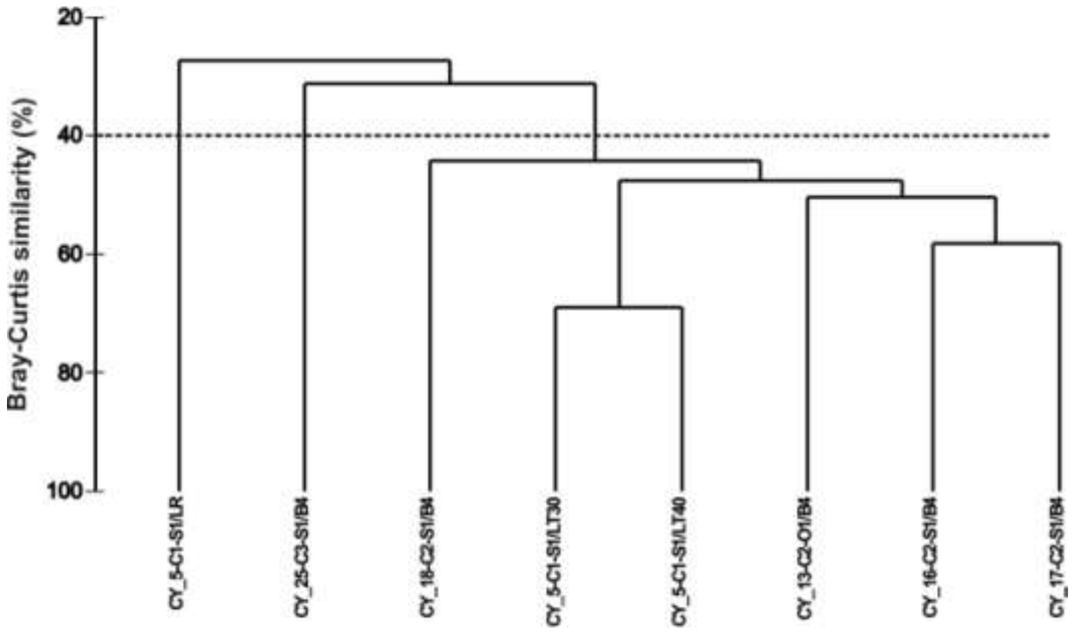


Figure 3.7 Cluster analysis at a site scale based on Bray-Curtis similarity index. Site codes are corresponded with Figure 3.4 as follows: Akamas-Lara (CY_5-C1-S1/LR), Akamas-Latsi (CY_5-C1-S1/LT30, CY_5-C1-S1/LT40), Lemesos Bay (CY_13-C2-O1/B4), Moni (CY_16-C2-S1/B4), Vasilikos Port (CY_17-C2-S1/B4), Zigi-Cape Kiti (CY_18-C2-S1/B4), Protaras (CY_25-C3-S1/B4).

A cluster analysis of data (Figure 3.7) at site scale indicated three groups of sites with a higher than 40% similarity. Within the first group belong the southern coasts sites of Cyprus (Lemesos Bay, Moni, Vasilikos and Zigi-Cape Kiti) along with two western coasts sites of Akamas-Latsi characterized by muddy sediment (68-98 % of sediment grain size less than 0.063 mm; Aplikioti et al. in preparation). Within two other groups belong the sandy sites of Akamas-Lara (Group 2) and Protaras (Group 3). Although these two groups fall into the same grain-size class, they differ in terms of sediment nature: Protaras sand is mainly composed of foraminiferans and other shell-fragments (Aplikioti et al. in preparation). A SIMPER analysis has indicated that *Paradoneis lyra* dominated in the groups 1 (123 mean abundance) and 2 (50 mean abundance) and the *Aricidea* species in the group 3 (114-173 mean abundance). The dissimilarity of these sites ranged between 83.41% and 88.41% (Table 3.2).

Table 3.2 Species average abundance (Av. Abund) and contribution (Contrib%) to the Bray-Curtis dissimilarity between the groups 1 and 2 (A), 1 and 3 (B) and 2 and 3 (C). The average Bray-Curtis dissimilarity between all pairs of sites of the groups was calculated at 86.78%, 88.41%, and 83.41%, respectively. Cut off for low contributions: 80%. Cum=Cumulative.

A)	***Group 1***	***Group 2***		
Species	***Av.Abund***	***Av.Abund***	***Contrib%***	***Cum.%***
Paradoneis lyra	123	2	8.93	8.93
Loripes lacteus	8.17	50	6.16	15.08
Nematoda	5.33	35	4.63	19.71
Turbellaria	2.33	28	3.85	23.56
Lumbrineris impatiens	2.5	26	3.6	27.15
Nematonereis unicornis	36.83	4	3.35	30.5

Lumbrineris latreilli	22.67	1	2.78	33.28
Syllis cornuta	28.33	5	2.63	35.91
Oligochaeta	0.33	18	2.55	38.46
Capitellidae	21.67	0	2.48	40.94
Lysianassidae	0	17	2.46	43.4
Protodorvillea kefersteini	5.5	22	2.34	45.75
Melinna palmata	20.17	0	2.32	48.07
Megalomma vesiculosum	0	16	2.32	50.39
Terebellides stroemi	15.83	0	2	52.39
Aricidea longobranchiata	18.33	0	1.73	54.12
Nucula sulcata	5.5	15	1.7	55.82
Laonice cirrata	9	0	1.63	57.46
Nephtys inermis	11.33	1	1.61	59.06
Glycera rouxii	9.17	0	1.46	60.52
Lanice conchilega	0	10	1.45	61.97
Spio filicornis	14.83	2	1.39	63.36
Glycera convolvuta	0	9	1.3	64.67
Branchiostoma lanceolatum	0	9	1.3	65.97
Syllis (Typosyllis) hyalina	0	8	1.16	67.13
Paguridea sp.	7	0	1.14	68.27
Anodontia (Loripinus) fragilis	6.17	0	0.98	69.25
Armandia polyopthalma	6.33	5	0.88	70.13
Nepthys caeca	0	6	0.87	71
Marphysa bellii	11.67	1	0.86	71.86
Rhodine loveni	9	0	0.85	72.71
Ampelisca pseudosarsi	0.33	6	0.85	73.56
Lumbrineris gracilis	7.67	0	0.81	74.36
Cirrophorus branchiatus	6	0	0.78	75.14
Syllis ferrugina	7.33	0	0.77	75.9
Schistomeringos rudolphii	7.67	0	0.74	76.65
Syllis amica	0	5	0.72	77.37
Cirratulus filiformis	8.33	1	0.72	78.1
Euclymene lumbricoides	0.17	5	0.69	78.79
Nereis fucata	0.67	5	0.68	79.47
Magelona sp.	6.67	0	0.66	80.13

B)	***Group 1***	***Group 3***		
Species	***Av.Abund***	***Av.Abund***	***Contrib%***	***Cum.%***
Aricidea sp2	0	173	13.92	13.92
Aricidea sp1	0	136	10.94	24.86
Aricidea sp3	0	114	9.17	34.03
Paradoneis lyra	123	0	6.4	40.43
Nematoda	5,33	57	4.29	44.72
Exogone verugera	0,33	35	2.79	47.51
Keffersteinia cirrata	2,5	34	2.55	50.06
Caulleriella bioculata	0	31	2.49	52.55
Nematonereis unicornis	36,83	1	2.35	54.9
Apseudes latreillei	4,5	33	2.32	57.22
Jasmineira caudata	0	27	2.17	59.39
Polyopthalmus pictus	4,17	29	2.12	61.52
Syllis cornuta	28,33	1	1.75	63.27
Lumbrineris latreilli	22,67	0	1.7	64.97
Goniada norvegica	0,17	19	1.51	66.48
Melinna palmata	20,17	0	1.4	67.88
Terebellides stroemi	15,83	0	1.16	69.03
Aricidea longobranchiata	18,33	0	1.15	70.19
Protodorvillea kefersteini	5,5	19	1.07	71.26
Capitellidae	21,67	14	1.07	72.32
Syllidae	0	13	1.05	73.37
Spio filicornis	14,83	0	0.93	74.3
Nephtys inermis	11,33	10	0.92	75.22
Orbiniidae	0	11	0.88	76.11
Laonice cirrata	9	9	0.73	76.84
Cumacea sp	3,83	11	0.67	77.51
Dorvilleidae	0	8	0.64	78.15
Branchiostoma lanceolatum	0	8	0.64	78.79
Iphinoe serrata	0,33	8	0.61	79.41
Marphysa bellii	11,67	0	0.61	80.02

C)	***Group 2***	***Group 3***		
Species	***Av.Abund***	***Av.Abund***	***Contrib%***	***Cum.%***
Aricidea sp2	0	173	15.78	15.78
Aricidea sp1	0	136	12.41	28.19
Aricidea sp3	0	114	10.4	38.59
Loripes lacteus	50	2	4.38	42.97
Exogone verugera	0	35	3.19	46.17
Keffersteinia cirrata	0	34	3.1	49.27
Caulleriella bioculata	0	31	2.83	52.1
Polyopthalmus pictus	0	29	2.65	54.74
Jasmineira caudata	0	27	2.46	57.21
Lumbrineris impatiens	26	0	2.37	59.58
Apseudes latreillei	8	33	2.28	61.86
Nematoda	35	57	2.01	63.87
Turbellaria	28	8	1.82	65.69
Goniada norvegica	1	19	1.64	67.34
Oligochaeta	18	1	1.55	68.89
Lysianassidae	17	0	1.55	70.44
Nucula sulcata	15	0	1.37	71.81
Capitellidae	0	14	1.28	73.08
Megalomma vesiculosum	16	3	1.19	74.27
Syllidae	0	13	1.19	75.46
Orbiniidae	0	11	1	76.46
Lanice conchilega	10	0	0.91	77.37
Glycera convolvuta	9	0	0.82	78.19
Nephtys inermis	1	10	0.82	79.01
Laonice cirrata	0	9	0.82	79.84
Dorvilleidae	0	8	0.73	80.57

The benthic invertebrate community changes as response to organic loadings from three (3) fish farms in Cyprus coastal waters (Figure 3.8) has been monitored for three years (2008-2010) by AP Marine. The species composition and abundance of 225 samples (3 fish farms x 5 sites x 5 samples x 3 years; Van Veen Grab of 0.01 m^2 surface) on a transect of five sites away from the fish cages, downstream in the dominant current direction were analyzed. A total 366 taxa of invertebrate fauna were identified.

Cluster analyses of data at site scale at three different fish farms have indicated not a consistent pattern of benthic invertebrate community with distance from organic load source (cages) (Figure 3.9). Statistical significant differences have been estimated at 0.01% level using ANOSIM between years 2008 and 2009-2010 (for Kimagro R=0.78, for Blue Island R=0.923, for Telia Liopetri R=0.952). A SIMPER analysis at fish farm level has indicated that Cirratulidae and Capitellidae were dominated in the Kimagro (average abundance 50.95 and 25.91, respectively), in Blue Island (average abundance 12.59 and 9.05, respectively) and in Telia Liopetri (average abundance 18.99 and 8.19, respectively) fish farms.

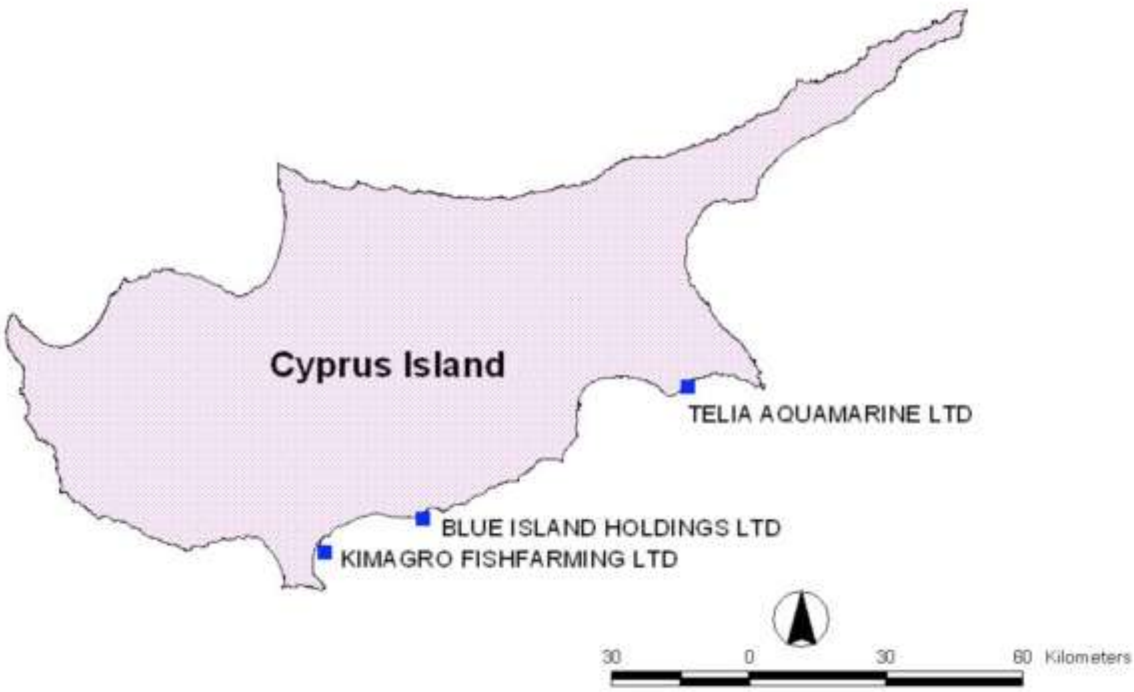


Figure 3.8 Map of the sites of the studied zoobenthos communities in three aquaculture farms in Cyprus.

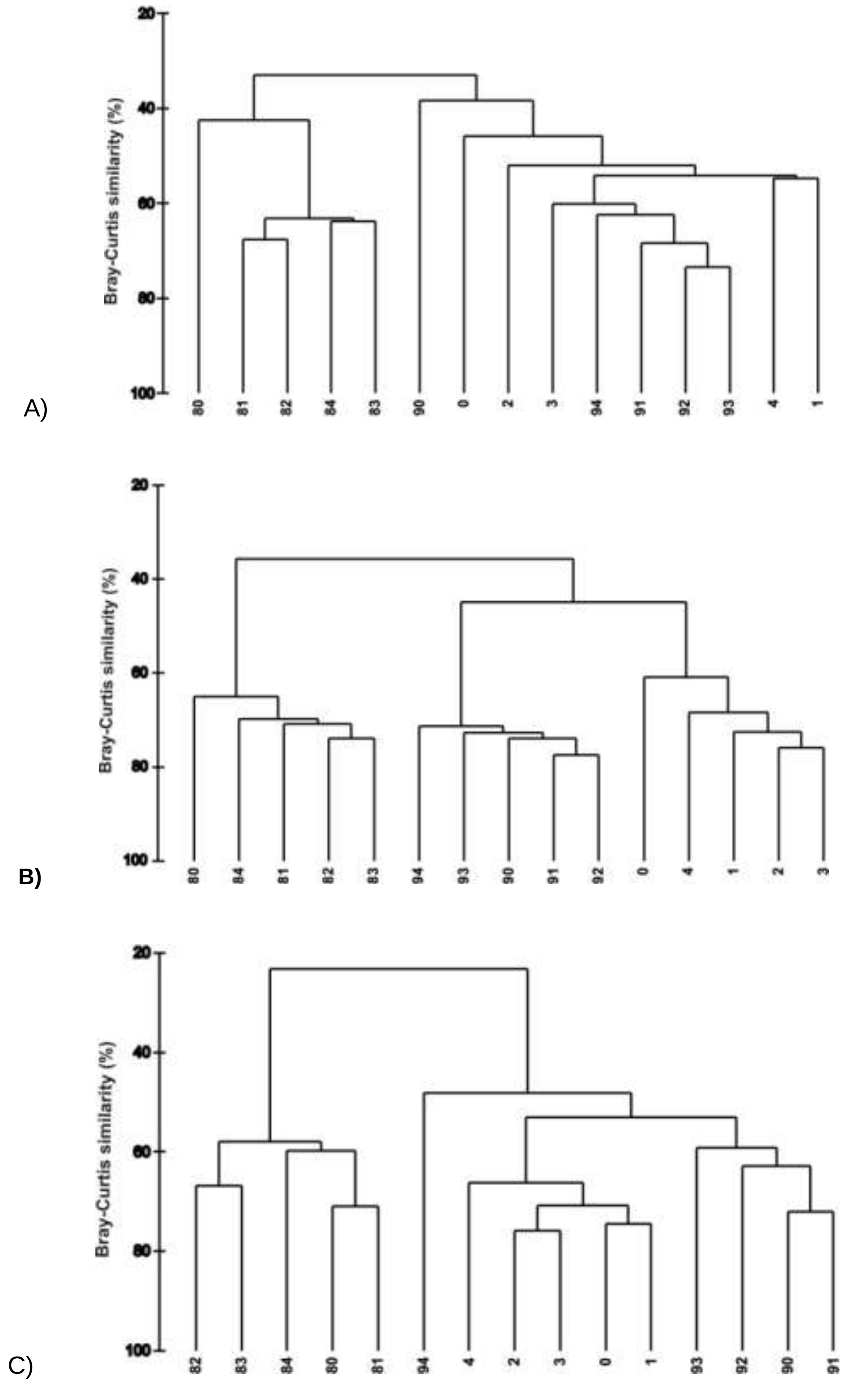


Figure 3.9 Cluster analysis at a site scale of three fish farms (A=Kimagro; B=Blue Island, C=Telia Liopetri) based on Bray-Curtis similarity index. Site codes are corresponded with Figure 3.4. 8=2008, 9=2009, without number=2010; 0=under cage, 1=50 m distance from cages, 2=200 m distance, 3=500 m distance, 4=reference.

Table 3.3 Taxon average abundance (Av. Abund) and contribution (Contrib%) to the Bray-Curtis similarity in three fish farms (A=Kimagro; B=Blue Island, C=Telia Liopetri) of Cyprus coastal waters. The average Bray-Curtis similarity within the sites of different farms ranged between 18.12 and 29.64. Cut off for low contributions: 80%. Cum=Cumulative.

A)			
Species	***Av.Abund***	***Contrib%***	***Cum.%***
Cirratulidae	50.95	18.7	18.7
Capitellidae	25.91	15.39	34.09
Paraonidae	17.43	7.41	41.5
Ampharetidae	18.16	7.34	48.84
Nematonereis hebes	10	5.43	54.27
Anodontia (Loripinus) fragilis	14.89	5.13	59.4
Phascolosoma sp.	12.96	4.7	64.1
Abra alba	6.68	3.67	67.77
Loripes lacteus	9.8	2.71	70.48
Nereis sp.	34.03	2.57	73.05
Lumbrineris impatiens	6.27	2.36	75.41
Phascolosoma granulatum	6.29	2.21	77.62
Anthuridea	4.09	2.11	79.73
B)			
Species	***Av.Abund***	***Contrib%***	***Cum.%***
Capitellidae	12.59	9.91	9.91
Cirratulidae	9.05	6.9	16.81
Paraonidae	8.89	6.41	23.22
Nematonereis hebes	7.03	5.93	29.14
Anodontia (Loripinus) fragilis	9.08	5.47	34.61
Gammaridea	8.13	4.61	39.23
Ampharetidae	6.16	4.36	43.59
Goniadidae	3.96	3.6	47.19
Lumbrineris impatiens	5.01	3.29	50.47
Maldanidae	3.92	2.75	53.22
Syllis sp.	8.12	2.62	55.85
Spionidae	3.99	1.93	57.78
Thyasira flexuosa	4.87	1.82	59.6
Lumbrineridae	4.03	1.78	61.38
Nemertini	6.95	1.76	63.15
Abra alba	2.93	1.63	64.77
Nereis sp.	3.95	1.52	66.29
Leptochelia savignyi	3.79	1.39	67.68
Eunice sp.	2.68	1.3	68.98
Terebellidae	2.95	1.25	70.23

Syllinae	2.76	1.05	71.28
Gouldia minima	1.83	1.01	72.3
Dorvilleidae	3.37	0.97	73.26
Sabellidae	2.61	0.94	74.2
Polynoidae	1.59	0.88	75.08
Anthura gracilis	1.64	0.86	75.94
Paguridea	2.47	0.86	76.8
Nereididae	2.8	0.81	77.61
Exogoninae	3.79	0.79	78.4
Eusyllinae sp.	4.16	0.7	79.1
Amphiura chiajei	1.87	0.7	79.8
C)			
Species	***Av.Abund***	***Contrib%***	***Cum.%***
Leptochelia savigny	4.47	9.4	9.4
Syllinae	7.45	7.43	16.83
Cirratulidae	18.99	6.17	22.99
Gammaridae	5.21	5.87	28.86
Unknown sp1.	5.11	4.66	33.52
Unknown sp2.	4.4	3.99	37.51
Copepoda spp.	1.68	3.89	41.4
Capitellidae	8.19	3.55	44.96
Syllis hyalina	3.71	3.22	48.17
Phtisica marina	3.12	3.04	51.22
Orbiniidae	2.48	2.84	54.06
Exogone gemmifera	2.21	2.6	56.67
Nereis sp.	5.27	2.28	58.95
Tanais dulongii	2.01	2.03	60.98
Lumbrinereis impatiens	1.87	1.88	62.87
Syllis gracilis	2.25	1.88	64.75
Nematonereis hebes	1.37	1.76	66.51
Protodorvillea kefersteini	3.72	1.66	68.17
Eunice spp.	1.41	1.44	69.61
Gammaridea	2.65	1.38	70.99
Echinocyamus pusillus	1.13	1.3	72.29
Dexamine spiniventris	1.89	1.22	73.51
Nereididae	3	1.18	74.69
Sabella sp.	2.83	1.07	75.76
Hesionidae	1.4	1.07	76.83
Caprella acanthifera	1.97	1.01	77.84
Syllis sp.	2.12	0.95	78.79
Ophellidae	1.09	0.9	79.69

Regarding deep sea benthos, the eastern Mediterranean is known as one of the most oligotrophic seas on earth, mainly because of the limited phosphorus, the particulate lipid, protein and carbohydrate low concentrations, and the dominance of pico-particles through all seasons (Tselepides and Eleftheriou 1992, Ignatiades et al. 1995, Danovaro et al. 2000). According to several studies (Tselepides and Eleftheriou 1992, Karakassis and Eleftheriou 1997, 1998, Danovaro et al. 2000, Tselepides et al. 2000a, 2000b), biomass, abundance and diversity at depths down to 1600 m are substantially reduced in the Mediterranean sea relative to the Atlantic (Tselepides et al. 2000a). Therefore, the deep Mediterranean is generally considered to be a biological desert (Ramirez-Llodra et al. 2010). This comes from the low number of megabenthic species. Few reports (Company et al. 2004, D'Onghia et al. 2004, Ramirez-Llodra et al. 2010, Tecchio et al. 2011) study the oligotrophic regions of the Mediterranean, such as the Levantine Sea (Jones et al. 2003, Galil 2004) at depths between 400 m and 4264 m.

The low diversity and species richness is caused by many factors such as: the temperature (water temperatures at 4000 m in excess of 14°C, rather than <4°C for other deep oceanic basins), the salinity, and the supply of food (principle regulating factor). The high temperature of the water, even in greater depths, results in intensive bacterial degradation of sinking organic matter (Legendre and Le Fèvre 1995). For this reason, the organic matter reaching the seafloor is highly refractory. This might also reduce seasonal variability in the deep sea.

Due to the above mentioned reasons and the dominated species that were found in the deep sea waters, Galil (2004) characterized them as "autochthonous, self-sustained population of opportunistic and eurybathic''. In Tselepides and Lampadariou (2004), the meiofaunal communities mainly consisted by nematodes, harpacticoid copepods, and polychaetes. In the eastern basin, 20 species of decapod crustaceans have been encountered, including the endemic Geryonid crab (*Chaceon mediterraneus*), which was photographed southwest of Cyprus at 2900 m. *Polycheles typhlops, Acanthephyra eximia, Aristeus antennatus*, and *Geryon longipes* were also included in the common decapod species. Amphipod crustaceans, cumaceans and molluscs were found in Cyprus. Four of the 22 deep-sea amphipod species collected were Mediterranean endemics, two of the most common were *Ileraustro ilergetes* and *Pseudotiron bouvieri*. The next most common ware *Rhachotropis rostrata* and *Stegophaloides christianiensis*. From the 12 collected species of cumaceans the most frequent were *Procampylaspis bonnieri* followed by *Campylaspis glabra*, *Makrokylindrus longipes*, *Platysympus typicus, and Procampylaspis armata*. In depths greater than 1000 m, 42 species were found. The most common benthic mollusks were *Yoldia micrometrica*, *Kelliella abyssicola*, *Cardyomia costellata*, *Entalina tetragona*, *Benthonella tenella*, *Bathyarca pectunculoides*.

3.3 Information on the structure of fish populations, including the abundance, distribution and age/size structure of the populations

3.3.1 Analyses of MEDITS data

3.3.1.1 Fish community structure and depth distribution

The analysis of fish community structure was based on data which have been collected during the project "Biological sampling with experimental bottom trawling in the Cyprus Republic coastal area, 2005-2010". The density and biomass indices of species have been calculated for five depth zones, 10-50 m, 50-100 m, 100-200 m, 200-500 m and 500-800 m. According to a stratified sampling strategy, 5, 9, 5, 3 and 4 hauls were made in the depth zones, 10-50m, 50-100 m, 100-200 m, 200-500 m and 500-800 m respectively. Also, the length frequency distribution was calculated for each caught species for each depth zone and year.

3.3.1.2 Species assemblages by depth zone

The similarity between two samples (each sample indicates specific depth zone and sampling period) was calculated using the Bray-Curtis similarity coefficient (Table 3.4). Based on the Bray-Curtis similarity matrix (Table 3.4), a dendrogram (Figure 3.10) for hierarchical clustering of samples was calculated, using the group-average linking method.

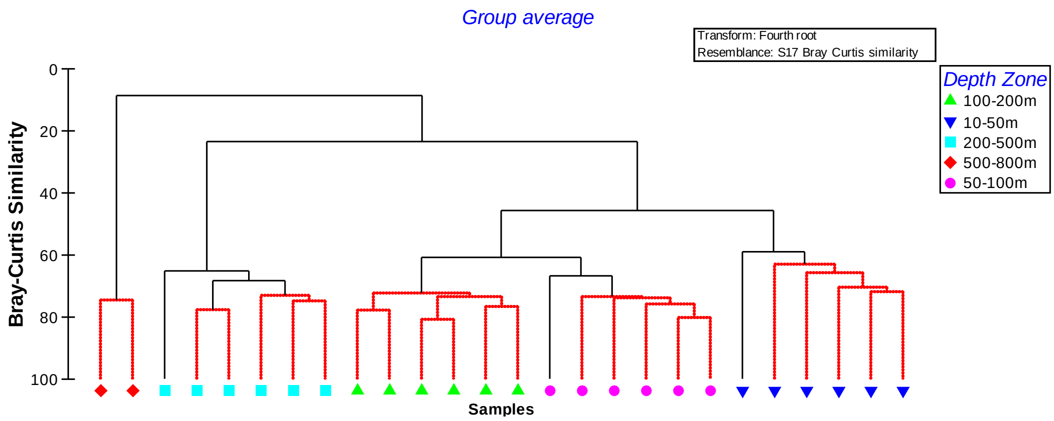


Figure 3.10 Dendrogram for hierarchical clustering (using group-average linking) of 5 depth zones from each of the 6 years 2005-2010.

Furthermore, the method of non-metric Multi-Dimensional Scaling (MDS) was used to project the information of samples on two dimensions (**Figure 3.11**). The average Bray-Curtis similarity between all pairs of samples of the group in the zone of 10-50 m was calculated 63.8, in the zone of 50-100 m was 72.1, in the zone of 100-200 m was 73.8, in the zone of 200-500 m was 69 and in the zone of 500-800 m was 74.6. The cumulative contribution of about 70% of these similarities was made up of 22 species for the zone 10-50 m (Table 3.5), 24 species for the zone 50-100 m (Table 3.6), 18 species for the zone 100-200 m (Table 3.7), 14 species for the zone 200-500 m (Table 3.8) and 22 species for the zone 500-800 m (Table 3.9).

The cumulative distribution of length frequencies of species by depth zone is given in Figure 3.12 (a)-(q).

Table 3.4 Similarity matrix, where the Bray-Curtis similarity coefficient between two samples is indicated. The similarity coefficient ranges from 0 (if the two samples have no species in common) to 100 (if two samples are identical). The 5 different depth zones 10-50m, 50-100m, 100-200m, 200-500m and 500-800m and the 6 sampling periods 2005, 2006, 2007, 2008, 2009 and 2010 are indicated. The Bray-Curtis similarity coefficients were calculated after the 4th root transformation of species' densities of the initial data.

		2005				2006				2007				2008				2009					2010				
		100-200m	10-50m	200-500m	50-100m	100-200m	10-50m	200-500m	50-100m	100-200m	10-50m	200-500m	50-100m	100-200m	10-50m	200-500m	50-100m	100-200m	10-50m	200-500m	500-800m	50-100m	100-200m	10-50m	200-500m	500-800m	50-100m
2005	100-200m																										
	10-50m	40,9																									
	200-500m	37,6	9,8																								
	50-100m	63,5	55,7	22,4																							
2006	100-200m	76,7	35,5	36,1	57,2																						
	10-50m	34,5	65,5	6,6	48,5	29,8																					
	200-500m	39,3	9,2	63,3	22,3	45,5	8,1																				
	50-100m	66,2	54,1	20,8	74,3	60,2	53,2	25,4																			
2007	100-200m	73,2	37,1	35,9	62,2	79,0	33,6	41,0	64,5																		
	10-50m	44,9	63,7	10,7	59,5	38,8	67,6	14,1	63,1	43,3																	
	200-500m	34,9	11,9	66,2	21,4	40,0	10,3	73,3	21,6	42,4	16,1																
	50-100m	68,4	53,9	19,3	74,3	58,7	49,4	24,7	80,2	65,6	60,9	23,3															
2008	100-200m	69,6	37,3	30,1	61,4	72,1	30,8	35,4	64,8	80,8	42,7	34,1	65,9														
	10-50m	36,6	62,3	3,9	48,7	33,8	67,7	9,8	50,7	35,9	70,1	9,6	50,3	37,0													
	200-500m	36,8	9,0	62,0	19,2	40,3	6,4	72,8	23,6	42,8	15,7	74,8	24,7	37,1	7,4												
	50-100m	62,0	57,0	18,8	71,7	55,5	51,4	20,4	76,1	57,8	63,4	19,9	75,5	62,2	56,2	18,2											
2009	100-200m	73,3	34,6	31,8	59,9	71,6	29,7	38,5	64,9	70,9	41,7	32,7	64,3	73,2	33,8	36,9	61,5										
	10-50m	42,5	60,5	6,6	57,7	38,8	62,0	10,2	58,7	42,7	70,8	10,8	59,1	46,5	71,9	9,4	63,4	42,1									
	200-500m	39,7	10,6	66,0	26,9	45,9	8,0	77,3	27,8	43,5	13,6	68,8	28,0	38,4	6,7	69,6	24,5	41,8	10,6								
	500-800m	9,1	0,7	21,4	3,9	9,1	1,7	22,9	2,4	10,0	3,2	21,7	5,6	8,5	1,1	22,7	0,8	8,6	0,0	26,5							
	50-100m	54,5	54,7	18,7	73,5	50,0	51,6	19,8	73,8	56,5	60,3	18,4	72,9	58,4	50,8	18,4	74,8	62,5	63,8	23,3	2,9						
2010	100-200m	71,2	34,0	31,2	59,2	73,5	28,1	39,1	63,2	71,6	40,3	34,6	62,7	72,9	36,4	38,4	58,8	77,8	43,1	42,0	7,9	55,9					
	10-50m	31,7	54,1	5,5	51,2	27,3	56,8	9,2	53,6	33,9	61,6	7,2	47,5	36,8	56,4	7,4	51,5	34,6	66,1	7,0	0,7	59,9	29,9				
	200-500m	36,2	11,1	68,3	22,8	42,3	10,2	67,9	23,6	38,9	15,0	65,3	22,8	34,6	6,9	60,9	21,5	39,1	9,8	77,7	23,7	22,2	37,9	7,6			
	500-800m	7,6	0,8	20,9	2,5	7,2	0,9	19,1	1,8	8,5	2,8	21,3	4,4	7,2	0,0	21,4	0,0	6,7	0,0	23,0	74,6	2,1	7,0	0,8	22,4		
	50-100m	57,1	46,6	23,5	65,3	55,0	46,8	23,2	68,3	59,9	52,2	25,2	63,8	63,6	47,8	24,3	65,7	63,4	57,7	28,1	4,1	70,8	60,9	56,7	27,2	3,5	

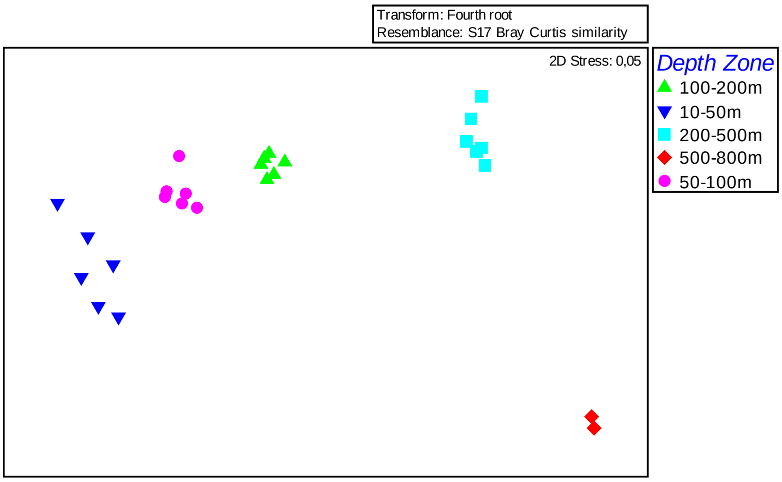


Figure 3.11 MDS ordination of samples (5 depth zones from each of the 6 years 2005-2010) based on the 4th transformed densities of species of the initial data. The stress value of 0.05 indicates that there is no difficulty in displaying the relationships between the samples in two dimensions.

Table 3.5 Contribution (Contrib%) of each species to the Bray-Curtis similarity within the group of samples of the depth zone 10-50m for the period 2005-2010. The average similarity (Av.Sim) of each species within the samples and the cumulative contribution (Cum.%) of species were calculated. The average Bray-Curtis similarity between all pairs of samples of the group in the zone of 10-50 m was calculated at 63.8%.

Species	**Av.Sim**	**Contrib%**	**Cum.%**
Serranus hepatus	4,72	7,4	7,4
Spicara smaris	3,92	6,14	13,54
Serranus cabrilla	3,19	5	18,54
Sparisoma cretense	2,51	3,93	22,47
Mullus barbatus	2,5	3,92	26,39
Scorpaena scrofa	2,47	3,88	30,27
Pagellus erythrinus	2,2	3,44	33,72
Scorpaena notata	2,19	3,43	37,15
Synodus saurus	2	3,14	40,29
Diplodus annularis	1,99	3,11	43,41
Scorpaena porcus	1,92	3	46,41
Trigloporus lastoviza	1,83	2,87	49,28
Bothus podas	1,75	2,75	52,03
Sepia officinalis	1,55	2,42	54,45
Zeus faber	1,54	2,42	56,87
Syngnathus acus	1,52	2,38	59,25
Coris julis	1,5	2,36	61,61
Octopus vulgaris	1,42	2,22	63,83
Loligo vulgaris	1,23	1,93	65,76
Mullus surmuletus	1,17	1,84	67,6
Symphodus mediterraneus	1,15	1,81	69,41
Gobius niger	1,13	1,77	71,17

Table 3.6 Contribution (Contrib%) of each species to the Bray-Curtis similarity within the group of samples of the depth zone 50-100m for the period 2005-2010. The average similarity (Av.Sim) of each species within the samples and the cumulative contribution (Cum.%) of species were calculated. The average Bray-Curtis similarity between all pairs of samples of the group in the zone of 50-100 m was calculated at 72.1%.

Species	Av.Sim	Contrib%	Cum.%
Spicara smaris	4,68	6,5	6,5
Serranus hepatus	4,51	6,26	12,75
Lepidotrigla cavillone	2,66	3,69	16,44
Macrorhamphosus scolopax	2,63	3,65	20,1
Centracanthus cirrus	2,54	3,53	23,63
Pagellus acarne	2,38	3,31	26,94
Mullus barbatus	2,38	3,31	30,24
Sardina pilchardus	2,15	2,99	33,23
Pagellus erythrinus	2,09	2,9	36,13
Alloteuthis media	2,03	2,82	38,94
Diplodus annularis	1,96	2,72	41,67
Serranus cabrilla	1,95	2,7	44,37
Trachurus mediterraneus	1,92	2,67	47,04
Bothus podas	1,91	2,65	49,69
Spicara flexuosa	1,67	2,32	52,02
Synodus saurus	1,67	2,32	54,34
Trigloporus lastoviza	1,67	2,32	56,66
Sepia elegans	1,66	2,31	58,96
Citharus linguatula	1,64	2,27	61,24
Loligo vulgaris	1,57	2,18	63,42
Arnoglossus laterna	1,46	2,02	65,43
Zeus faber	1,38	1,92	67,35
Blennius ocellaris	1,35	1,87	69,22
Boops boops	1,27	1,76	70,98

Table 3.7 Contribution (Contrib%) of each species to the Bray-Curtis similarity within the group of samples of the depth zone 100-200m for the period 2005-2010. The average similarity (Av.Sim) of each species within the samples and the cumulative contribution (Cum.%) of species were calculated. The average Bray-Curtis similarity between all pairs of samples of the group in the zone of 100-200m was calculated at 73.8%.

Species	**Av.Sim**	**Contrib%**	**Cum.%**
Macrorhamphosus scolopax	8,36	11,33	11,33
Spicara smaris	5,84	7,91	19,24
Centracanthus cirrus	5,11	6,93	26,16
Serranus hepatus	3,77	5,1	31,27
Lepidotrigla cavillone	3,27	4,42	35,69
Trachurus mediterraneus	2,48	3,36	39,06
Argentina sphyraena	2,35	3,18	42,24
Sepia elegans	2,3	3,12	45,36
Mullus barbatus	2,29	3,11	48,46
Pagellus acarne	2,27	3,08	51,54
Alloteuthis media	2,24	3,04	54,57
Trachurus trachurus	1,95	2,63	57,21
Serranus cabrilla	1,9	2,58	59,79
Pagellus erythrinus	1,87	2,53	62,32
Spicara flexuosa	1,84	2,5	64,82
Parapenaeus longirostris	1,76	2,38	67,2
Loligo vulgaris	1,59	2,15	69,34
Citharus linguatula	1,58	2,14	71,48

Table 3.8 Contribution (Contrib%) of each species to the Bray-Curtis similarity within the group of samples of the depth zone 200-500m for the period 2005-2010. The average similarity (Av.Sim) of each species within the samples and the cumulative contribution (Cum.%) of species were calculated. The average Bray-Curtis similarity between all pairs of samples of the group in the zone of 200-500m was calculated at 69%.

Species	**Av.Sim**	**Contrib%**	**Cum.%**
Argentina sphyraena	7,75	11,24	11,24
Capros aper	6,31	9,16	20,4
Macrorhamphosus scolopax	5,52	8,01	28,4
Aspitrigla cuculus	4,68	6,79	35,2
Parapenaeus longirostris	3,3	4,79	39,98
Helicolenus dactylopterus	2,95	4,27	44,25
Alloteuthis media	2,91	4,22	48,47
Scyliorhinus canicula	2,84	4,12	52,59
Chlorophthalmus agassizii	2,35	3,4	56
Merluccius merluccius	2,2	3,18	59,18
Illex coindetti	2,13	3,08	62,26
Sepia elegans	1,85	2,69	64,95
Lophius budegassa	1,85	2,68	67,63
Scaergus unicirrhus	1,77	2,57	70,2

Table 3.9 Contribution (Contrib%) of each species to the Bray-Curtis similarity within the group of samples of the depth zone 500-800m for the period 2005-2010. The average similarity (Av.Sim) of each species within the samples and the cumulative contribution (Cum.%) of species were calculated. The average Bray-Curtis similarity between all pairs of samples of the group in the zone of 500-800m was calculated at 74.6%.

Species	**Av.Sim**	**Contrib%**	**Cum.%**
Chlorophthalmus agassizii	6,02	8,07	8,07
Plesionika martia	4,23	5,67	13,75
Plesionika edwardsii	4,11	5,51	19,26
Hymenocephalus italicus	3,18	4,26	23,52
Hoplostethus mediterraneus mediterraneus	3,15	4,22	27,74
Nezumia sclerorhynchus	3,03	4,07	31,8
Etmopterus spinax	2,56	3,43	35,24
Parapenaeus longirostris	2,47	3,31	38,54
Argentina sphyraena	2,34	3,14	41,69
Galeus melastomus	2,27	3,04	44,72
Helicolenus dactylopterus	2,02	2,71	47,43
Plesionika heterocarpus	1,73	2,33	49,76
Peristedion cataphractum	1,7	2,28	52,03
Argyropelecus hemigymnus	1,68	2,25	54,28
Abralia veranyi	1,66	2,22	56,5
Squalus acanthias	1,52	2,03	58,54
Plesionika acanthonotus	1,51	2,03	60,57
Epigonus constanciae	1,46	1,96	62,52
Diaphus holti	1,45	1,94	64,46
Plesionika giglioli	1,39	1,87	66,33
Processa sp.	1,37	1,83	68,17
Lepidorhombus whiffiagonis	1,32	1,77	69,93

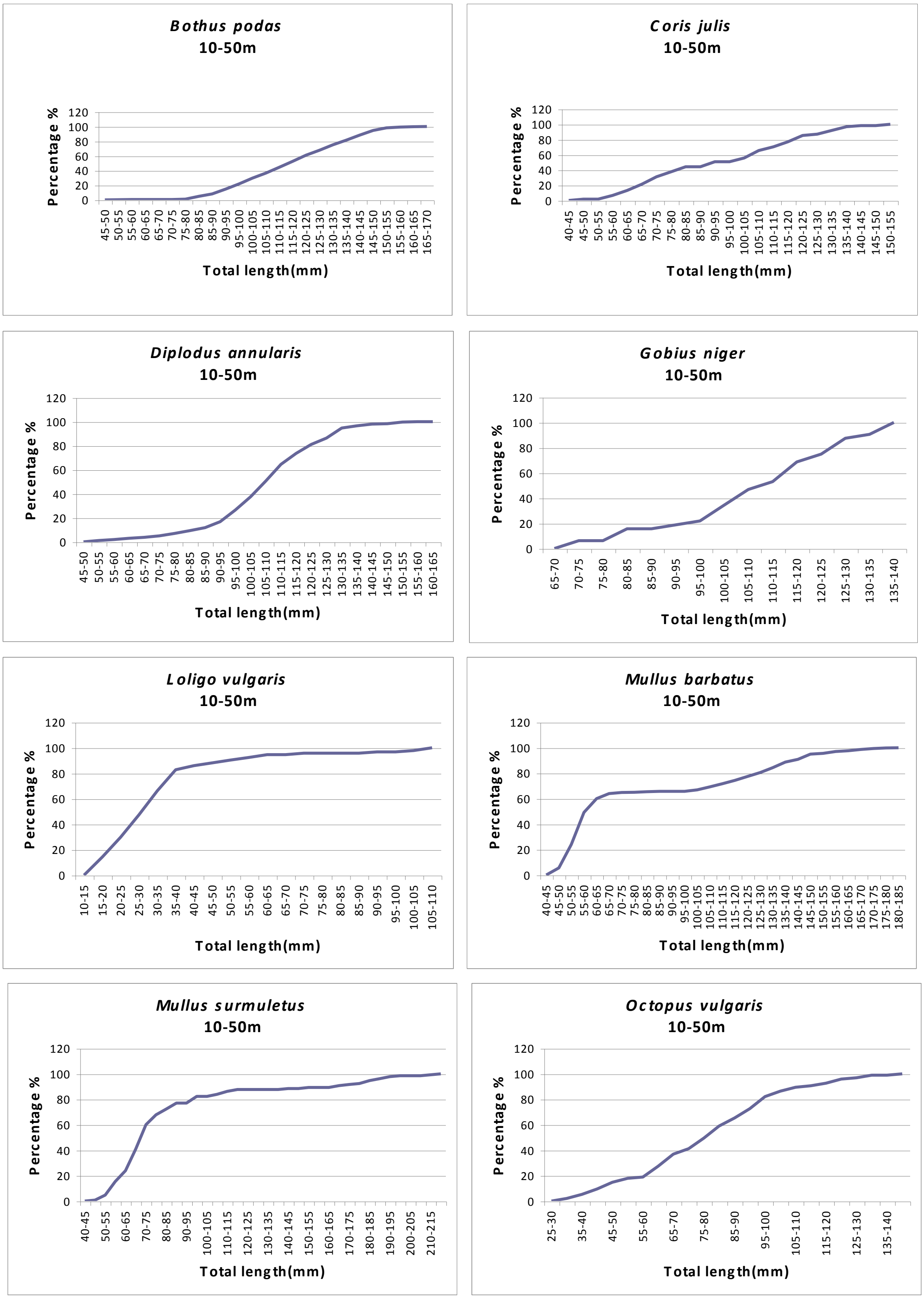


Figure 3.12 (a) Cumulative distribution of length frequencies of species in the 10-50 m zone.

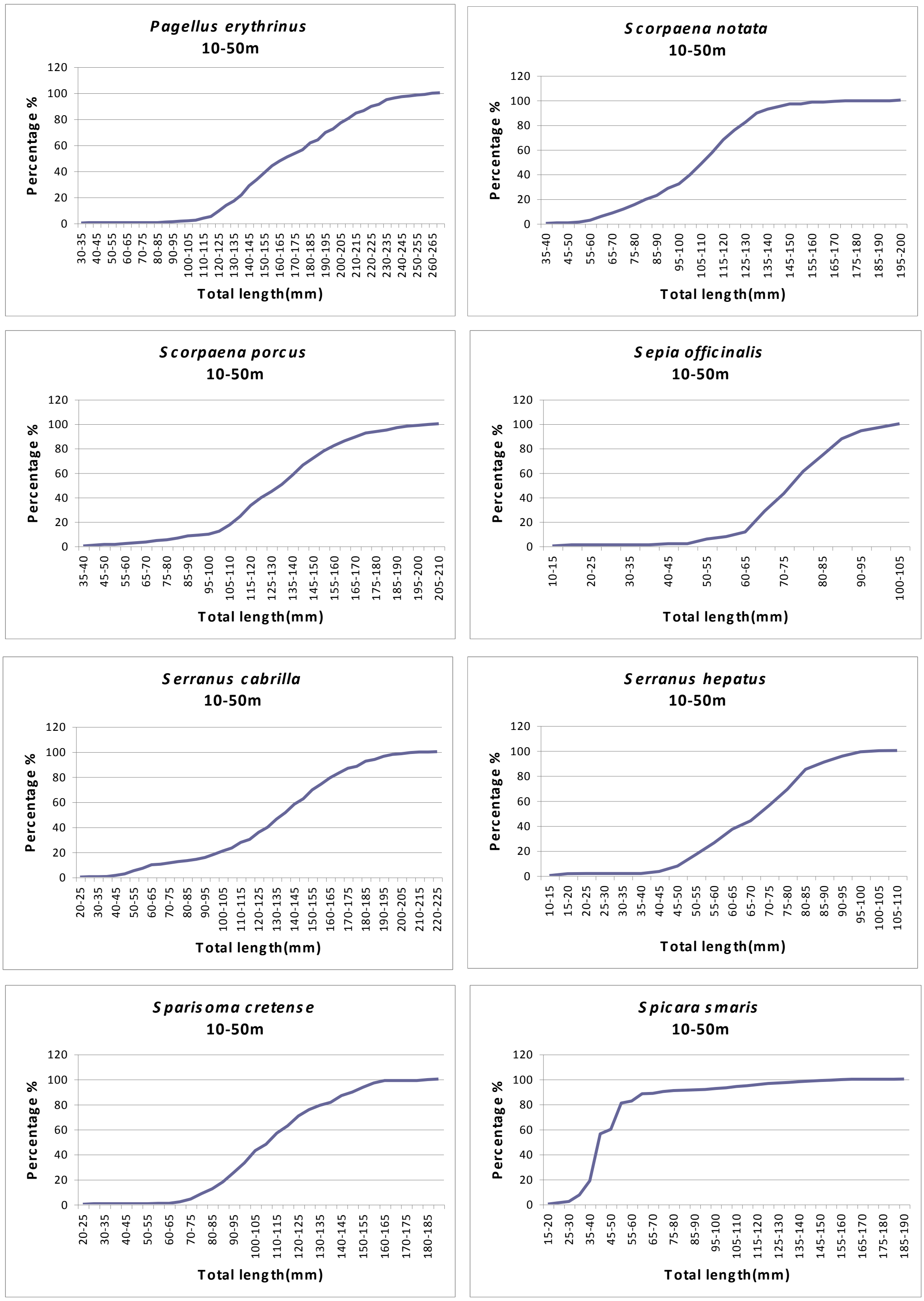


Figure 3.12 (b) Cumulative distribution of length frequencies of species in the 10-50 m zone.

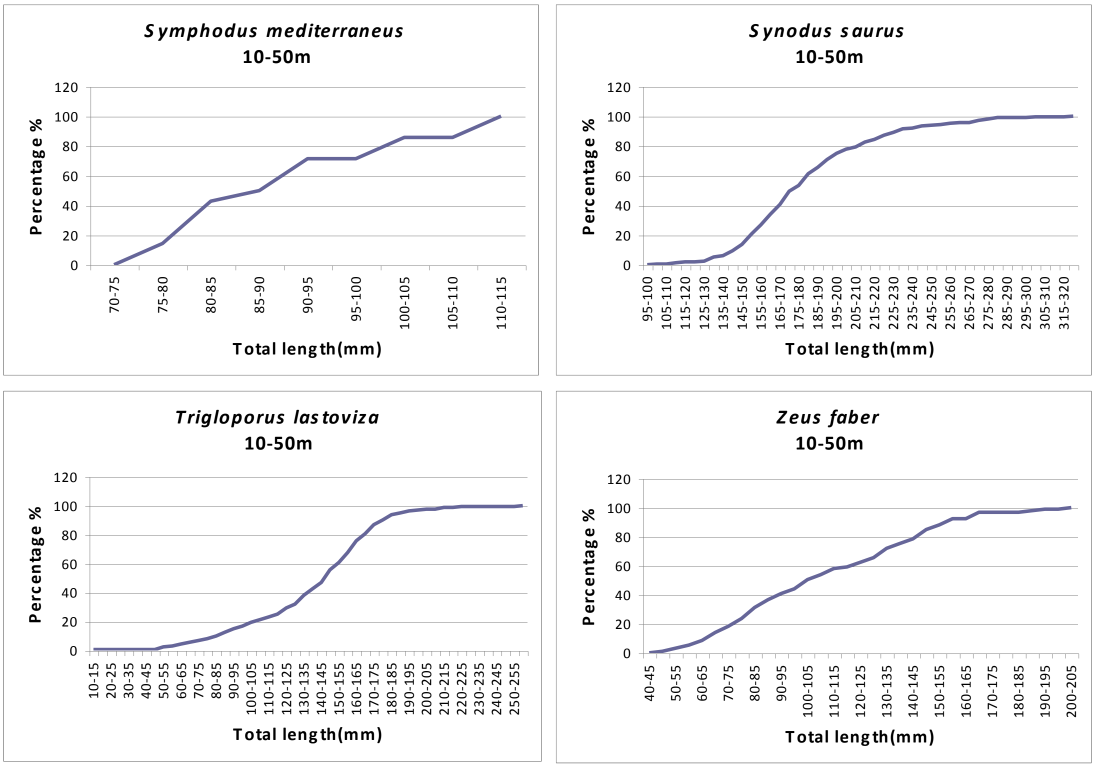


Figure 3.12 (c) Cumulative distribution of length frequencies of species in the 10-50 m zone.

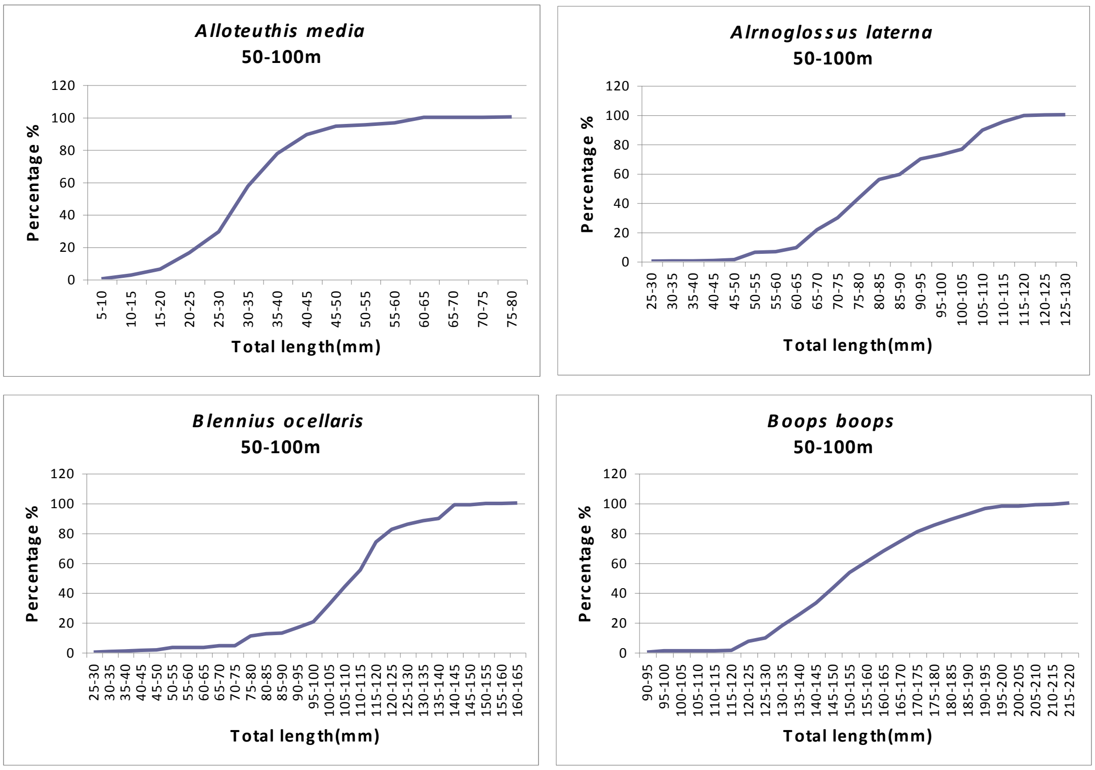


Figure 3.12 (d) Cumulative distribution of length frequencies of species in the 50-100 m zone.

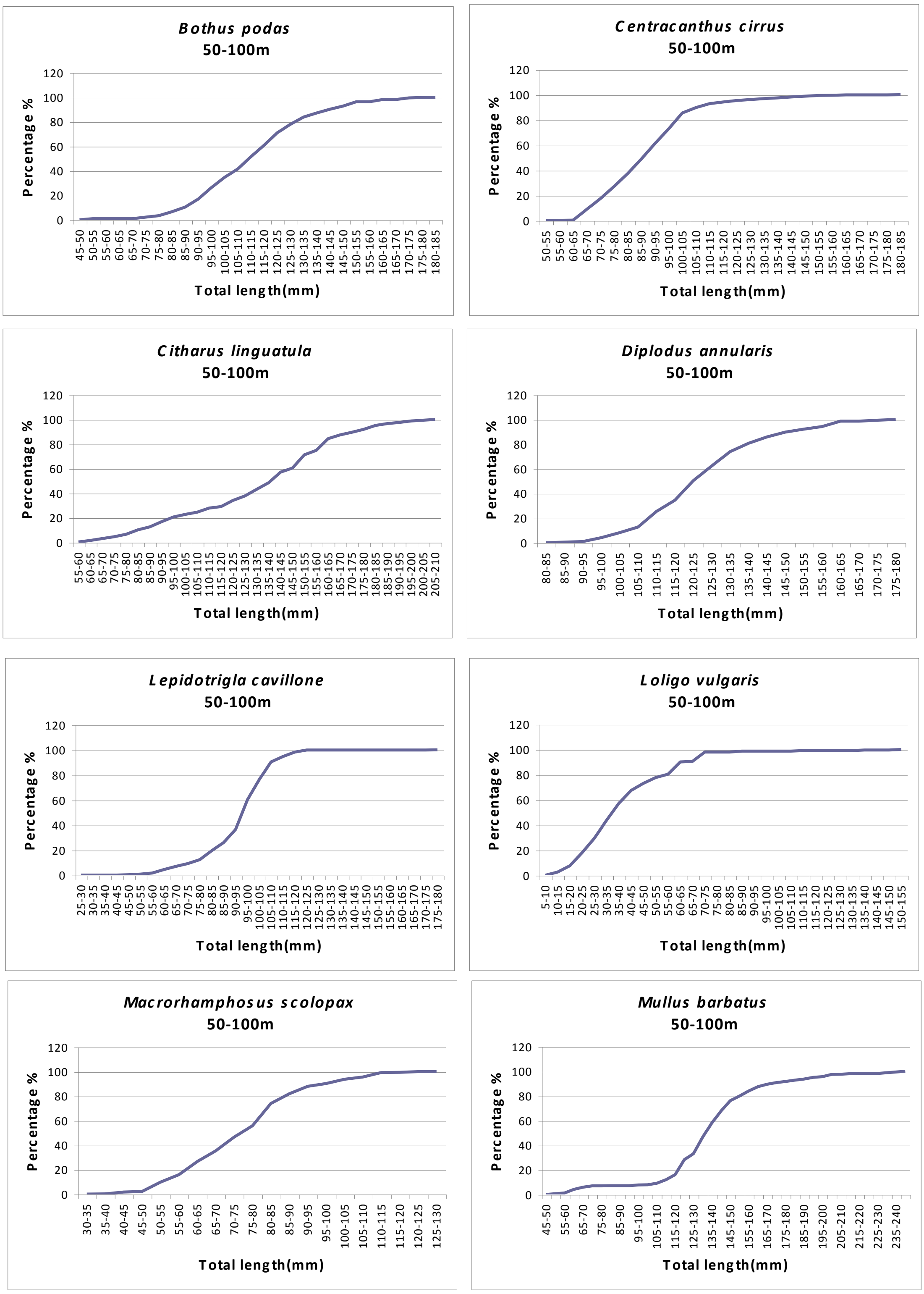


Figure 3.12 (e) Cumulative distribution of length frequencies of species in the 50-100 m zone.

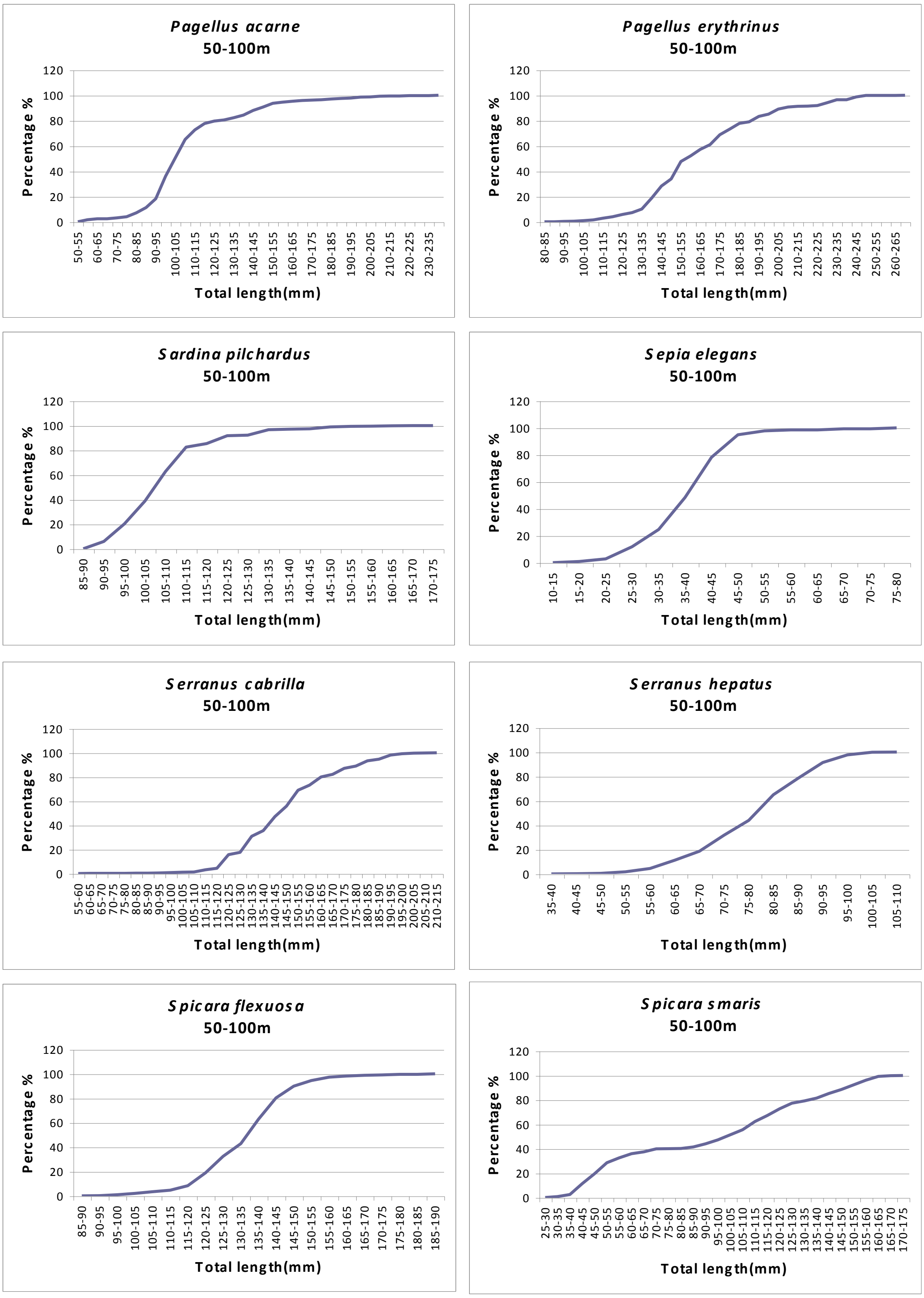


Figure 3.12 (f) Cumulative distribution of length frequencies of species in the 50-100 m zone.

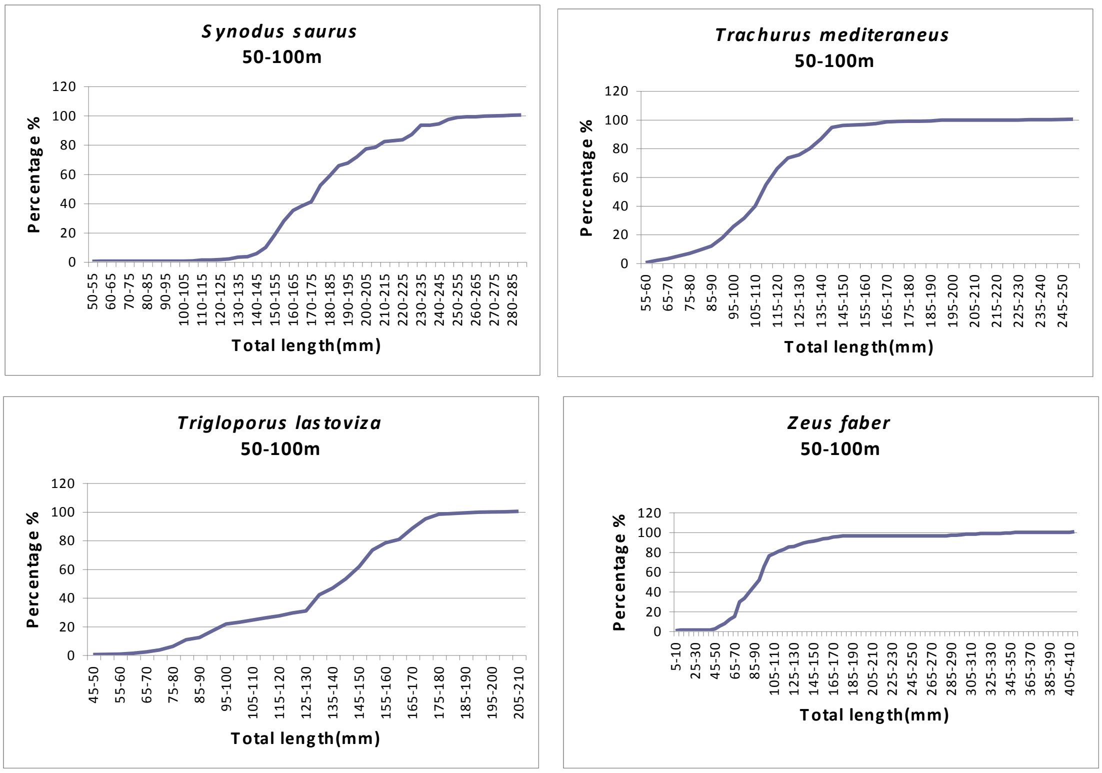


Figure 3.12 (g) Cumulative distribution of length frequencies of species in the 50-100 m zone.

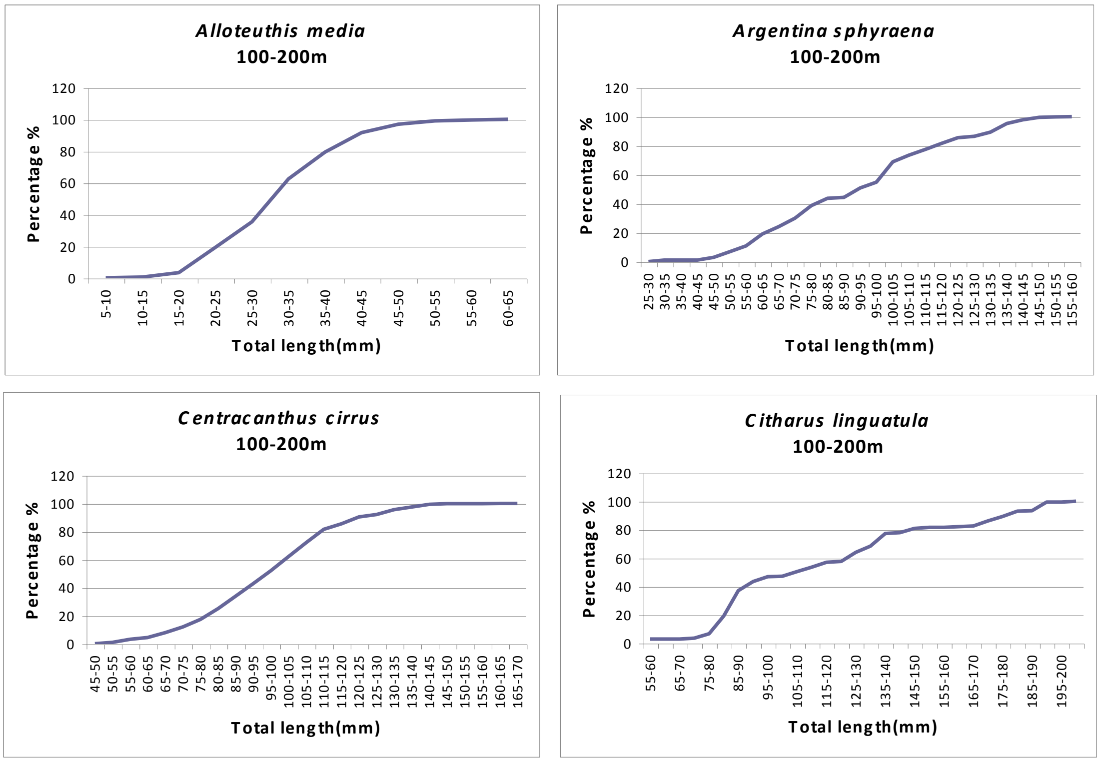


Figure 3.12 (h) Cumulative distribution of length frequencies of species in the 100-200 m zone.

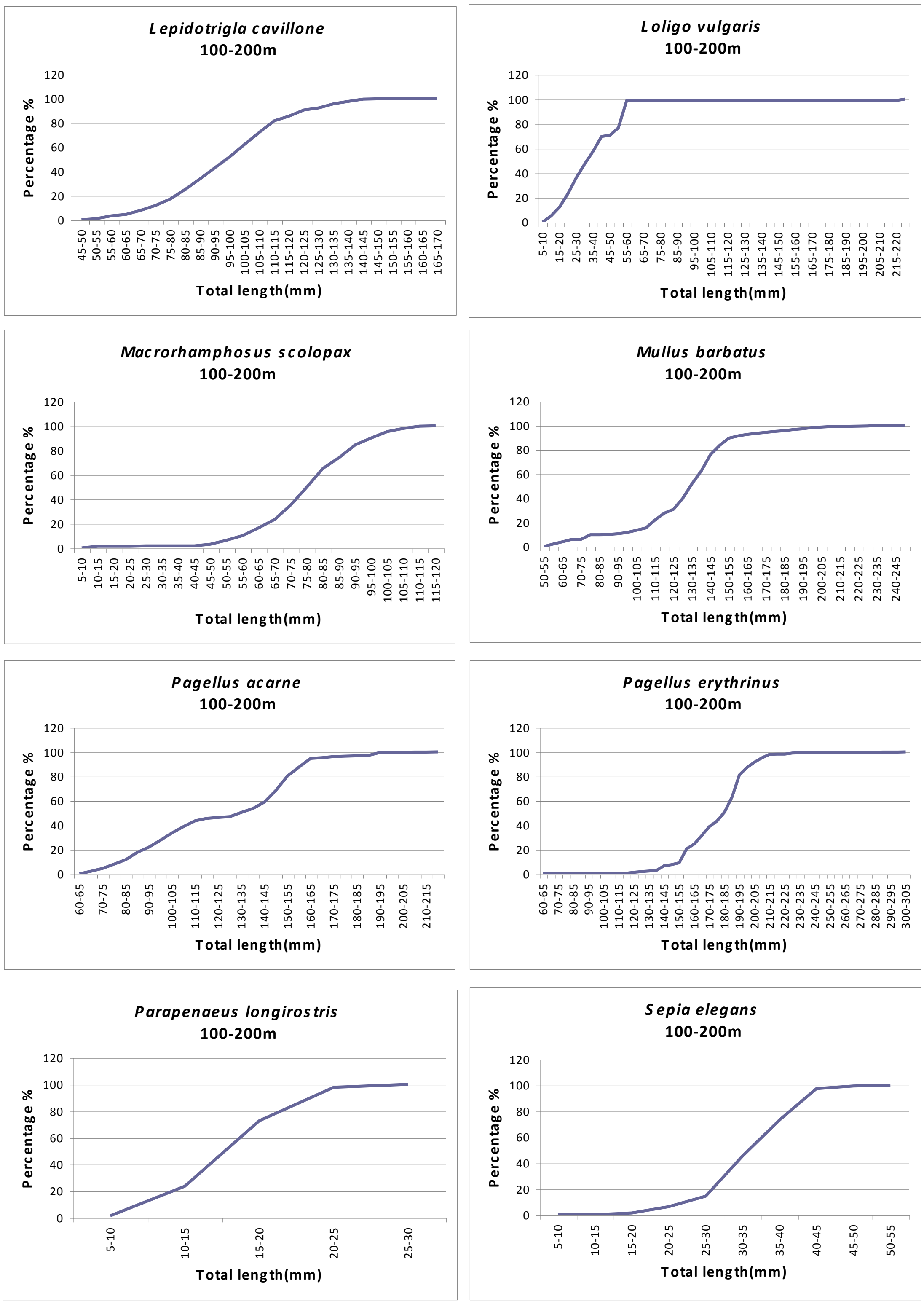


Figure 3.12 (i) Cumulative distribution of length frequencies of species in the 100-200 m zone.

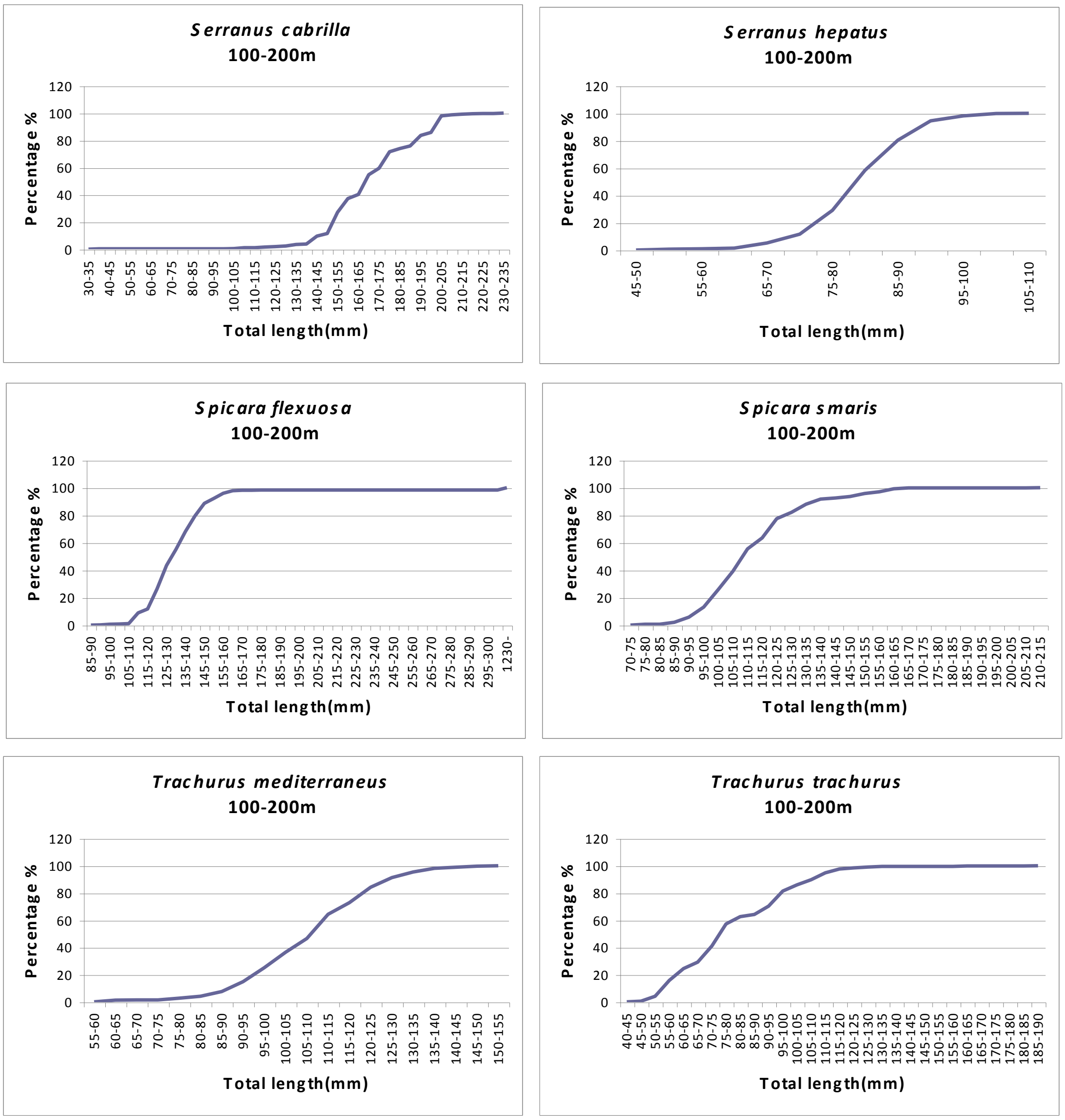


Figure 3.12 (j) Cumulative distribution of length frequencies of species in the 100-200 m zone.

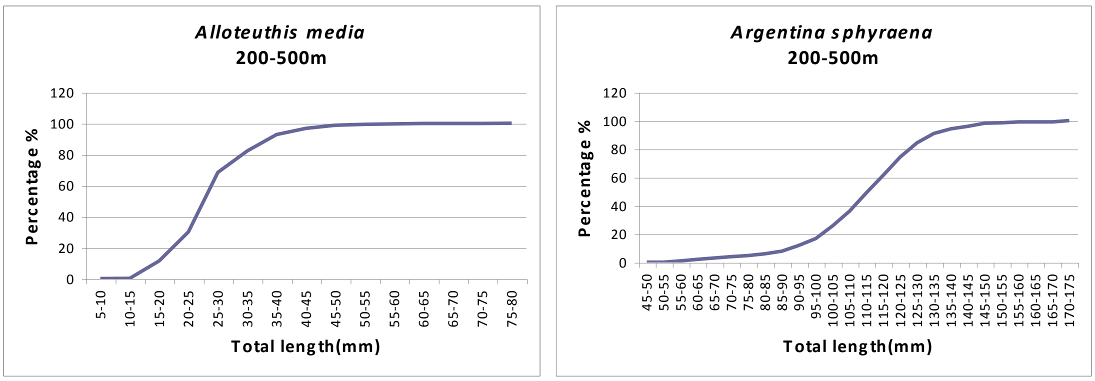


Figure 3.12 (k) Cumulative distribution of length frequencies of species in the 200-500 m zone.

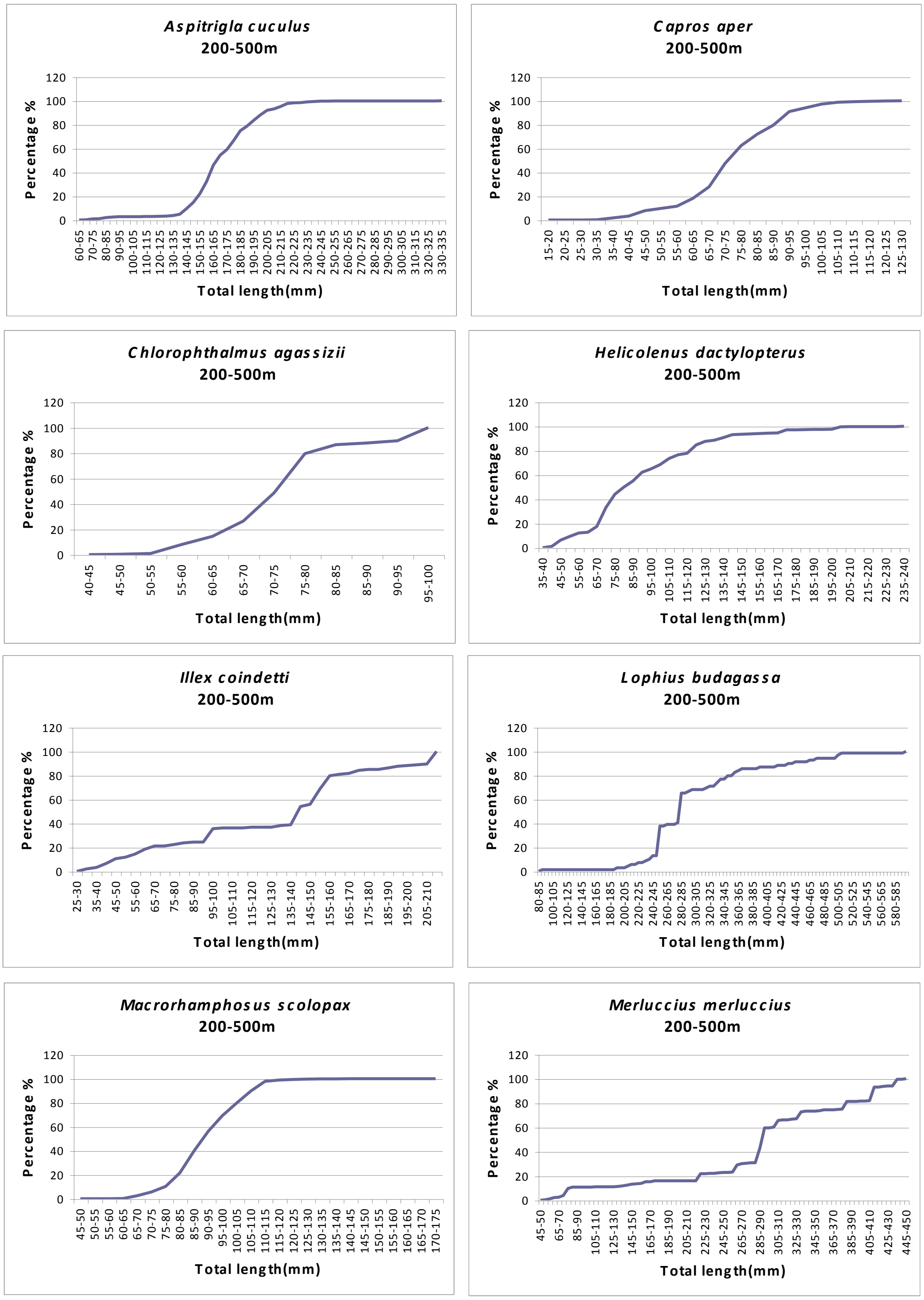


Figure 3.12 (l) Cumulative distribution of length frequencies of species in the 200-500 m zone.

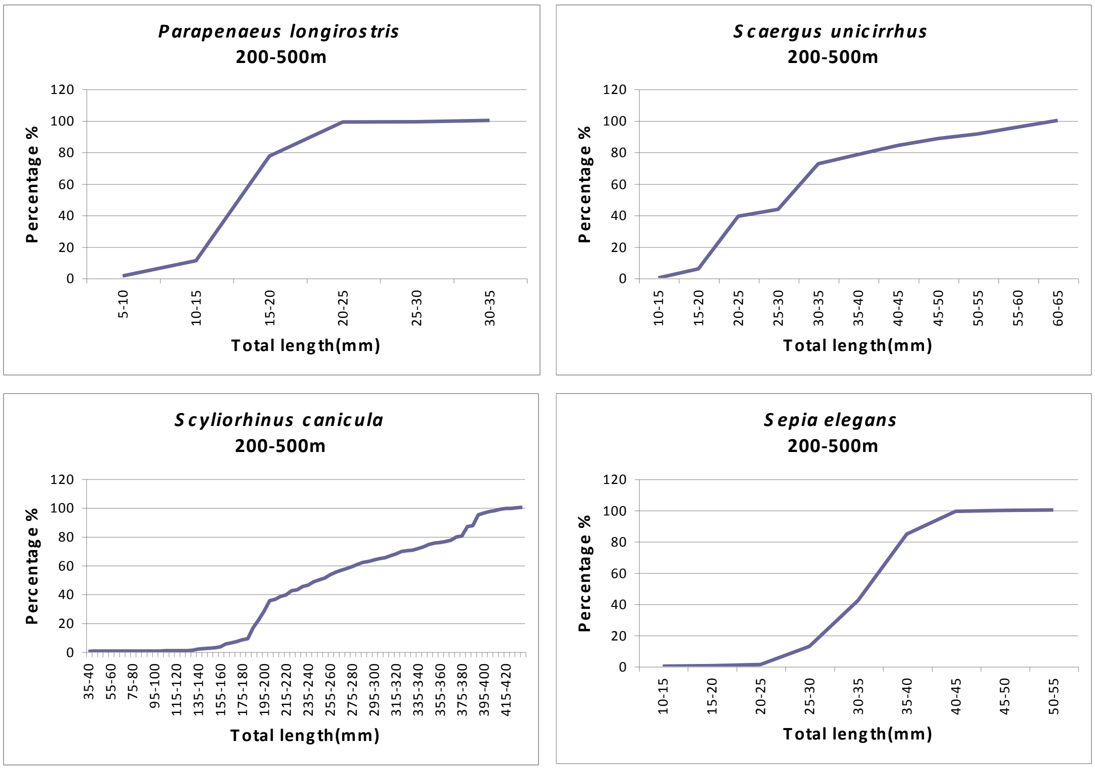


Figure 3.12 (m) Cumulative distribution of length frequencies of species in the 200-500 m zone.

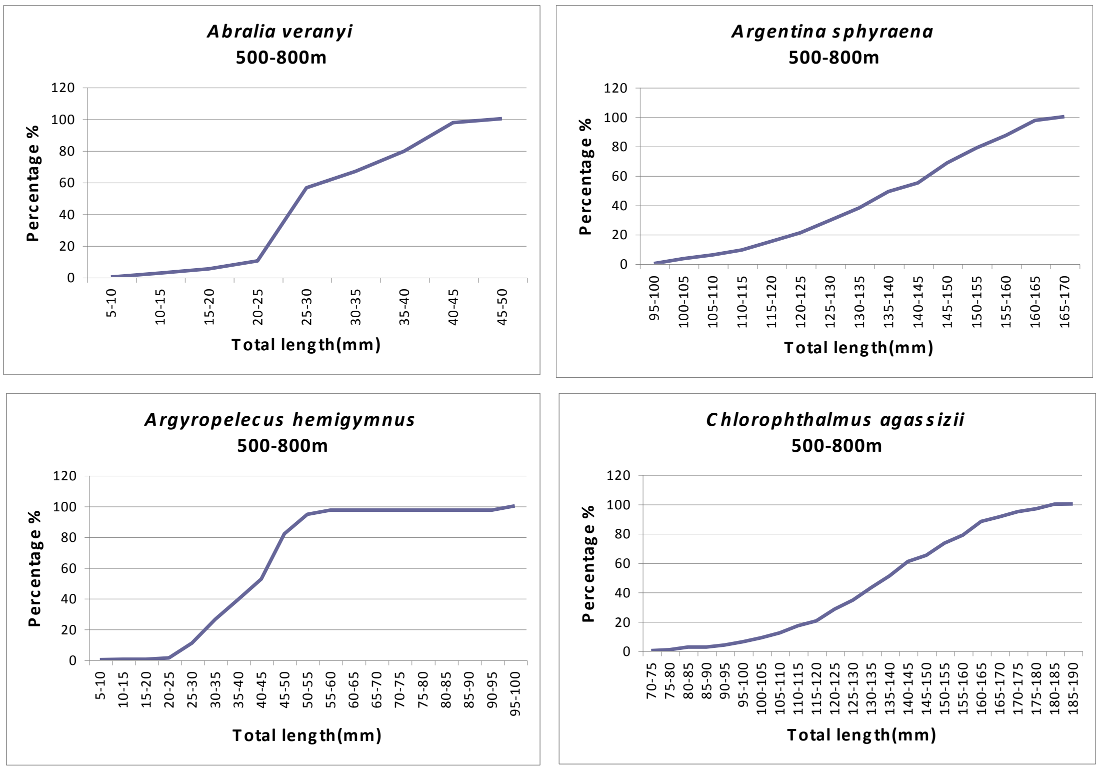


Figure 3.12 (n) Cumulative distribution of length frequencies of species in the 500-800 m zone.

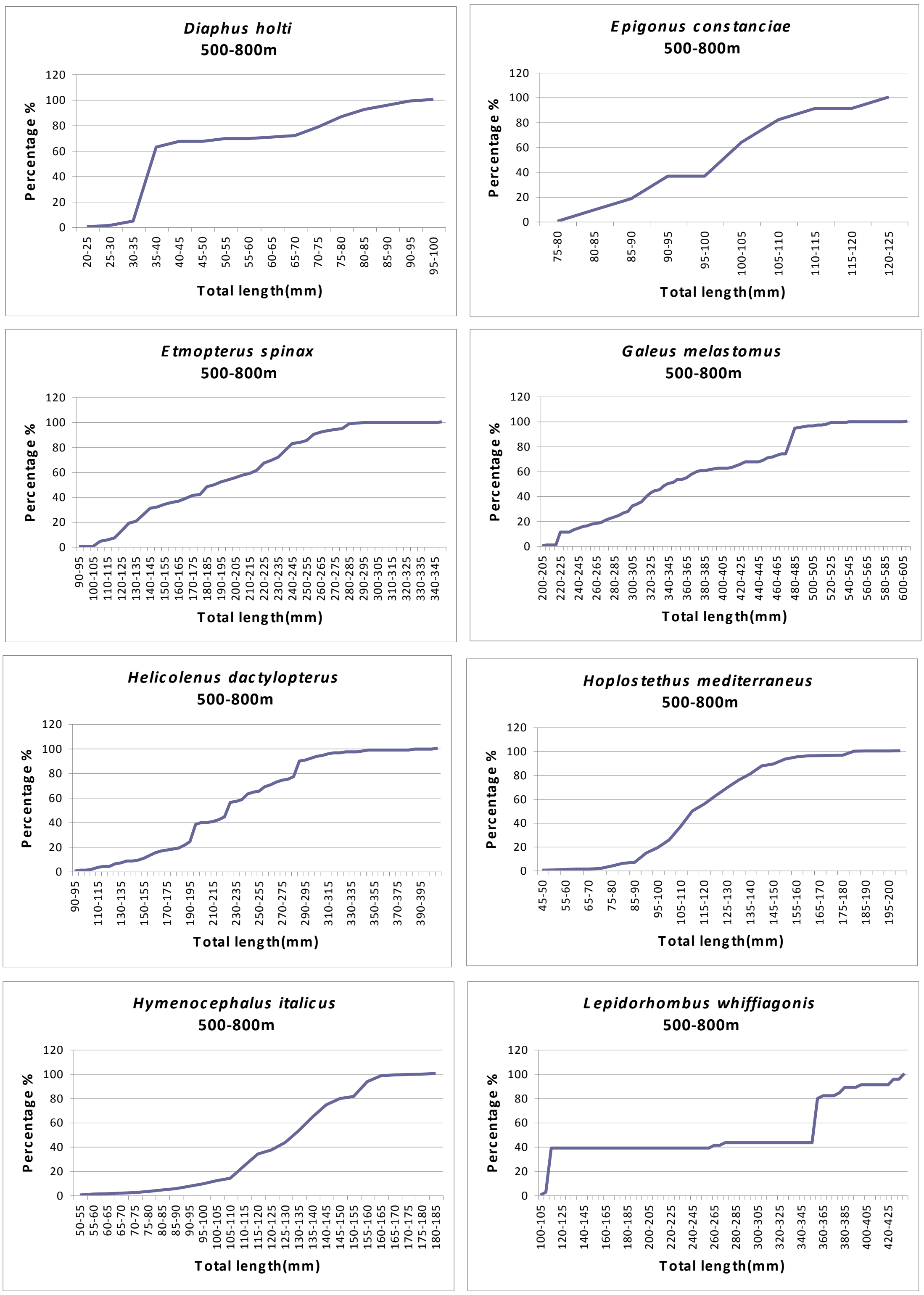


Figure 3.12 (o) Cumulative distribution of length frequencies of species in the 500-800 m zone.

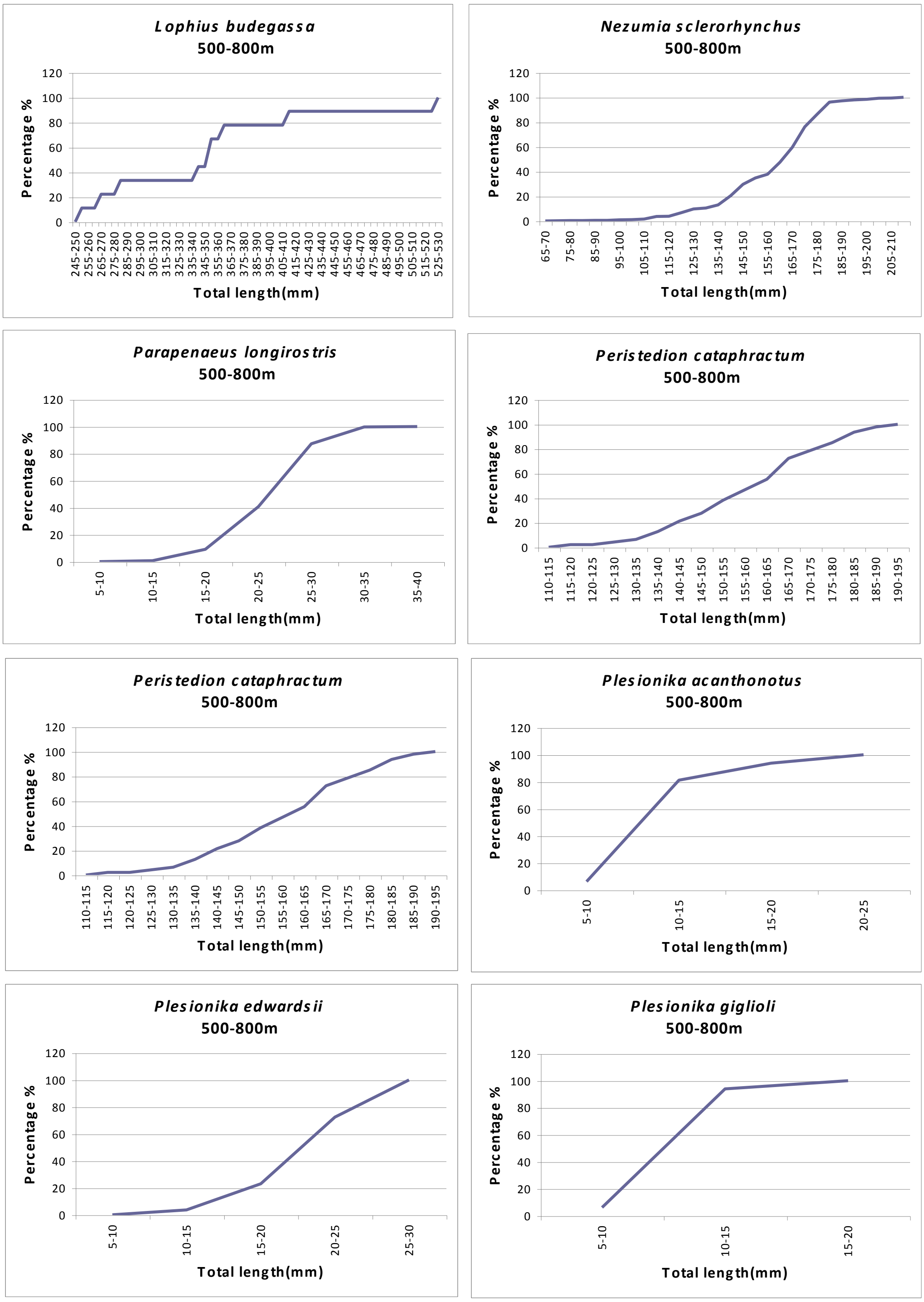


Figure 3.12 (p) Cumulative distribution of length frequencies of species in the 500-800 m zone.

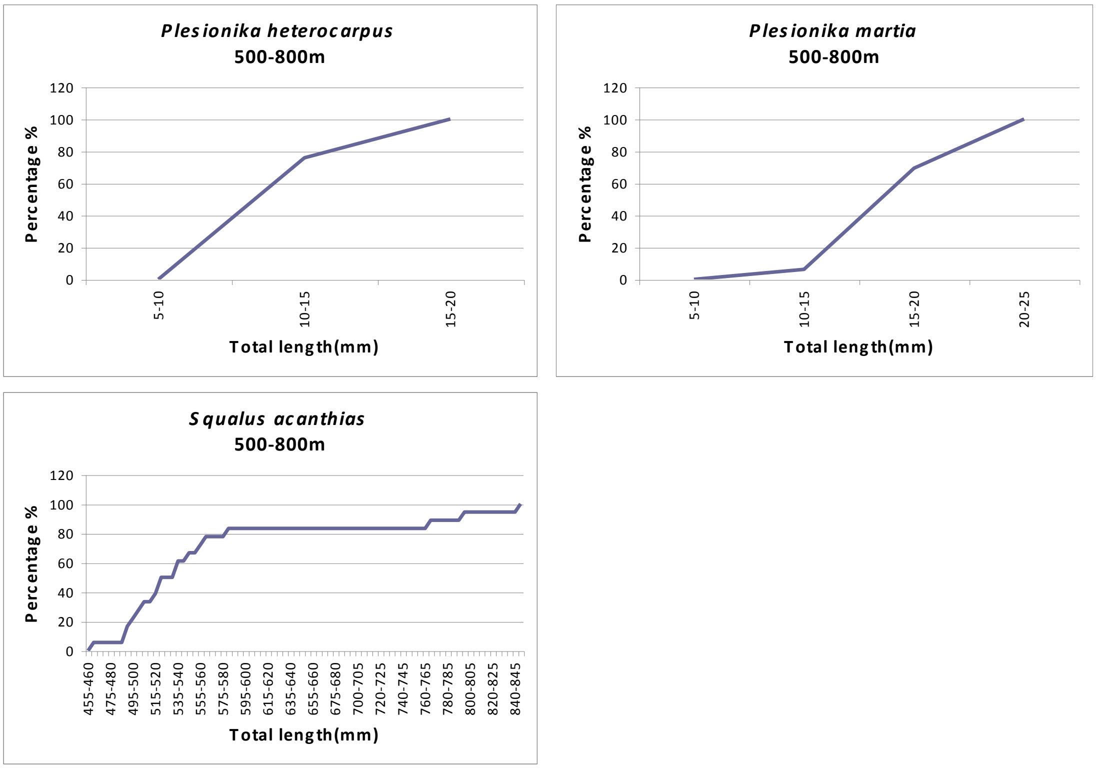


Figure 3.12 (q) Cumulative distribution of length frequencies of species in the 500-800 m zone.

3.3.1.3 Diversity measures

A variety of indices were used as measures of community structure:

(1) Total species: S - the number of species in each sample

(2) Species richness (Margalef): $d = (S-1)/Log(N)$ - Margalef's species richness for each sample. It is a measure of the number of species present, making some allowance for the number of individuals N.

(3) Shannon-Wiener diversity index, H´: $H' = -\Sigma_i p_i \ln(p_i)$, where p_i is the proportion of the total count arising from the *i*th species.

(4) Pielou's evenness, J´: $J' = H'/H'_{max} = H'/\log S$ - this is a measure of equitability, a measure of how evenly the individuals are distributed among the different species.

(5) Brillouin, HB : $HB = [\ln(N!) - S \ln(n_i!)/N]$; where

a. N = total number of individuals

b. n_i = number of individuals in the ith species

c. N! = factorial of N

d. $n_i!$ = factorial of n_i

The differences between Brillouin index and Shannon index is that the (i) Shannon index does not change with abundance, as long as the proportional abundance remains constant, (ii) Brillouin index does change Brillouin index uses factorials, which quickly produces huge numbers that are unwieldy. Shannon index is often chosen for its computational simplicity.

(6) Fisher's alpha: $S=\alpha*\ln(1+n/\alpha)$ where S is number of taxa, n is number of individuals and α is the Fisher's alpha. This is a parametric index of diversity that assumes that the abundance of species follows the log series distribution. This is a useful index that has been widely used.

(7) Simpson index, (1-λ´): $1-\lambda' = 1 - \{\Sigma_i N_i(N_i-1)\}/\{N(N-1)\}$; where N_i is the number of individuals of species *i*. The λ´ index it is a dominance index, in the sense that its largest values correspond to assemblages whose total abundance is dominated by one, or a very few, of the species present. Thus, the complement index, 1-λ´, is an evenness index, taking its largest value when all species have the same abundance.

The above 7 diversity indices were calculated for each of the 5 depth zones, 10-50 m, 50-100 m, 100-200 m, 200-500 m and 500-800 m, for all the 6 sampling periods, 2005, 2006, 2007, 2008, 2009 and 2010 (Table 3.10).

A multivariate procedure, principal component analysis (PCA) was used to identify statistically close relationships between depth zones and diversity indices. PCA was made on the normalized data of the 27 samples. Principal axes were produced by working with the 27 samples by the 7 indices matrix (Table 3.10) after the normalization of the initial data. According to Kaiser criterion (StatSoft, Inc. 1996), only PCs with eigenvalues > 1 were retained (Table 3.11).

The 27 samples were projected on the space of 2 dimensions (Figure 3.13), where the 1st axis, PC1 and the 2nd axis PC2, explain 76.4% and 21.7% of the initial total variance respectively (Table 3.11). The coefficients in the linear combinations of indices (eigenvectors) that are making up the PCs, were calculated for the three first PCs (Table 3.11).

The coefficients (eigenvectors) show that the simple left to right gradient in the main axis, PC1, of the PCA plot is a roughly equally weighted combination of all indices (both richness and evenness), whereas the PC2 is a contrast of richness and evenness (Table 3.12 and Figure 3.13).

Table 3.10 Community indices for 5 depth zones, 10-50m, 50-100m, 100-200m, 200-500m and 500-800m and 6 sampling periods, 2005, 2006, 2007, 2008, 2009 and 2010.Community species richness indices: Total number of species (S), Margalef (d), Fisher's *α*. Community evenness indices: Shannon-Wiener (H´), Pielou's (J´), Brillouin (H_B) and Simpson (1-λ´).

Depth zone	Year	S	d	J´	Brillouin	Fisher' α	H´(loge)	1-λ´
10-50m	2005	64	5,739	0,279	1,159	7,097	1,162	0,442
50-100m	2005	69	6,222	0,415	1,756	7,771	1,759	0,714
100-200m	2005	52	4,563	0,322	1,269	5,489	1,271	0,555
200-500m	2005	34	3,572	0,561	1,969	4,38	1,979	0,775
10-50m	2006	61	6,548	0,61	2,49	8,716	2,508	0,82
50-100m	2006	65	5,934	0,449	1,872	7,4	1,876	0,743
100-200m	2006	49	3,859	0,251	0,976	4,48	0,976	0,408
200-500m	2006	39	3,519	0,347	1,268	4,16	1,27	0,605
10-50m	2007	73	7,335	0,537	2,296	9,673	2,305	0,812
50-100m	2007	68	6,02	0,404	1,701	7,456	1,703	0,692
100-200m	2007	55	4,624	0,371	1,485	5,517	1,486	0,639
10-50m	2008	44	4,738	0,596	2,244	6,047	2,256	0,829
50-100m	2008	57	5,674	0,514	2,071	7,221	2,079	0,771
100-200m	2008	43	3,6	0,361	1,358	4,203	1,36	0,606
200-500m	2008	32	3,028	0,436	1,508	3,569	1,511	0,664
10-50m	2009	53	5,292	0,47	1,858	6,686	1,865	0,71
50-100m	2009	73	6,986	0,514	2,198	9,002	2,204	0,817
100-200m	2009	52	4,668	0,431	1,702	5,657	1,704	0,671
200-500m	2009	45	4,013	0,257	0,976	4,789	0,978	0,385
500-800m	2009	61	5,985	0,39	1,599	7,632	1,604	0,642
10-50m	2010	62	5,607	0,535	2,206	6,932	2,209	0,827
50-100m	2010	68	6,685	0,542	2,279	8,646	2,286	0,836
100-200m	2010	51	4,43	0,377	1,479	5,301	1,481	0,683
200-500m	2010	43	4,371	0,345	1,292	5,432	1,299	0,503
500-800m	2010	47	5,237	0,488	1,862	6,852	1,879	0,713

Table 3.11 The eigenvalues of the first three principal axes (PCs). PC1 and PC2 explain 76.4% and 21.7% of the initial total variation (% Variation) respectively. These to axes cumulatively explain 98.1% (Cum. 5 Variation) of the total initial variation.

PC	Eigenvalues	% Variation	Cum. % Variation
1	5,35	76,4	76,4
2	1,52	21,7	98,1
3	0,107	1,5	99,6

Table 3.12 Eigenvectors of community indices - coefficients in the linear combinations of indices making up PCs: Total number of species (S), Margalef (d), Fisher's α, Shannon-Wiener (H´), Pielou's (J´), Brillouin (H_B) and Simpson (1-λ´).

Index	PC1	PC2	PC3
S	-0,303	-0,557	0,546
d	-0,369	-0,419	-0,223
J'	-0,373	0,404	-0,236
Brillouin	-0,413	0,233	-0,095
Fisher' α	-0,378	-0,377	-0,409
H'(loge)	-0,413	0,234	-0,115
1-λ'	-0,386	0,315	0,638

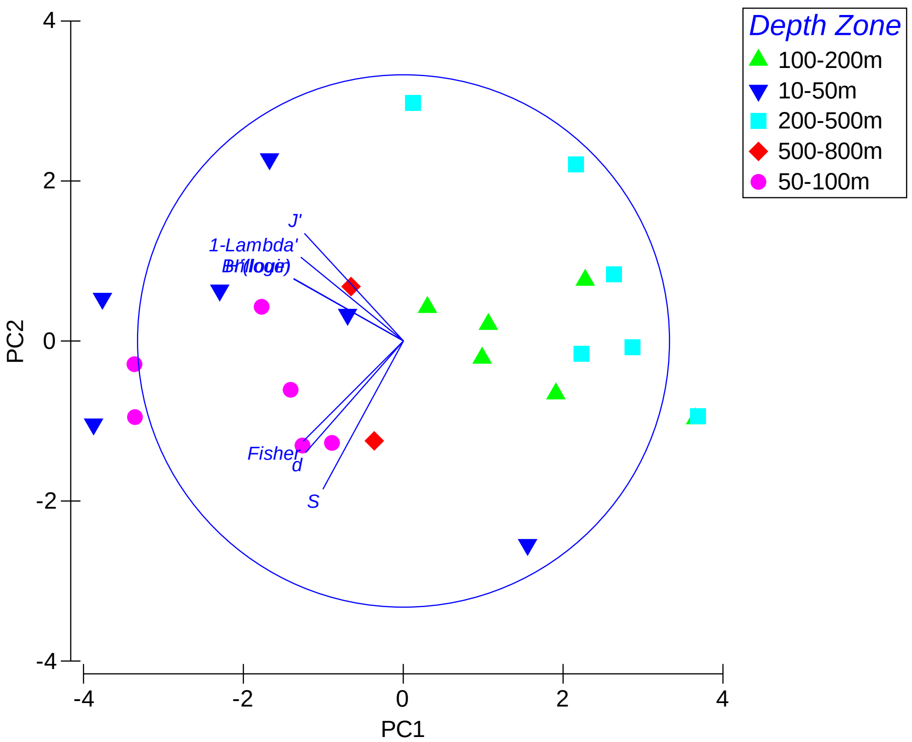


Figure 3.13 PCA plot - Ordination of 27 samples on 2-dimensions. The PC1 and PC2, explain 76.4% and 21.7% of the initial total variance respectively. The length of eigenvector of each index reflects the importance of that index's contribution to these particular two PCs, in relation to all possible PCs (if the line reaches the circle then none of that index's other coefficient in the *eigenvectors* table will differ from 0.

3.3.2 Analyses of commercial data

Species/stocks were selected on the base of landings statistics from National official statistics from 2004 to 2008. The cumulative percentage composition has been calculated excluding the mixed categories and the species contributing for more than 1% of the total landings in the selected area have been selected for catch and effort analyses (Table 3.13). The mixed categories will be analyzed successively on the base of the information provided by the DFMR.

Table 3.13 List of species contributing for more than 1% of the total landings

Species	Total landing 2004 - 2008 (kg)	Percentage
Spicara smaris	1098	30.7
Boops boops	1086	30.4
Mullus surmuletus	325	9.1
Mullus barbatus	210	5.9
Sparisoma cretense	192	5.4
Spicara maena	156	4.4
Pagrus pagrus	78	2.2
Pagellus erythrinus	68	1.9
Pagellus acarne	51	1.4
Serranus cabrilla	49	1.4
Dentex dentex	48	1.3

3.3.2.1 Stocks for which stock assessments are conducted

For the following species (*Spicara smaris*, *Mullus barbatus*, *Boops boops* and *Mullus surmuletus*) summaries of the assessments carried out in the framework of the 2011 FAO – GFCM working group on demersal are presented. Moreover for *Spicara smaris* also a summary of the assessment carried out in the framework of the STECF-EWG 11-12 is presented.

3.3.2.1.1 Picarel, Spicara smaris *(FAO – GFCM 2011)*

Picarel (*Spicara smaris*) in GSA25 is exploited mainly by the bottom trawl fleet comprising 4 vessels OAL 12-24m since 2006 operating in the territorial waters. The main species caught with picarel in bottom trawl are: *Mullus barbatus*, *Pagellus erythrinus*, *Serranus cabrilla* and cephalopods (*Octopus vulgaris*, *Loligo vulgaris* and Sepia officinalis) while in gill nets are: *Boops boops*, *Spicara maena* and *Sardina pilchardus*. The percentage of bogue in the overall landings for bottom trawl fishery for the period 2005-2010 has a range of 44.8 - 65.9% while for artisanal fishery is 3.2-10%. Bottom trawl fishery exploits mostly age classes 2 and 3 while artisanal fishery exploits 3 and 4 age classes. Catch-at-age data from two three year periods (2005-2007 and 2008-2010) derived from landings for each fishing gear exploiting the stock (bottom trawl and gillnet), and discards data from bottom trawl are used. A combined ALK for 2006-2008 and annual length distributions from 2005-2010 were used.

M- Vector for each age class was used, estimated by PROBIOM (Abella et al. 1997). The biological parameters used are growth parameters and L-W relationship. Assessment method utilized is a Standard VPA in VIT software.

Stock status

2005-2007: Fcur= 0.19, Fmax= 0.38 and F0.1=0.19; 2008-2010: Fcur= 0.37, Fmax= 0.40 and F0.1=0.24.

2005-2007: in fully-exploitation status (Fcur= F0.1) and intermediate abundance; 2008-2010: in overfishing status and intermediate abundance.

3.3.2.1.2 Picarel, Spicara smaris *(STECF-EWG 11-12)*

XSA based assessment and ASPIC based production model were carried out during EWG 11-12. DCF 2011 official data were used to perform XSA using two sets of tuning fleets: MedITS data and CPUE data from commercial OTB. ASPIC based production model has been performed using OTB effort data series provided by official statistics of the Department of Fishery and Marine Research of Ministry of Agriculture, Natural Resources and Environment from 1970 to 2004 (Department of Fisheries and Marine Research 2003, 2004, Hadjistephanou 2003). For the same period total landing of picarel were provided by the GFCM FishStat database. For the period 2005-2010 OTB effort data and landings statistics were provided by the 2011 official data call. Picarel landings decreased from 2003 to 2010, for the application of the use of the 40 mm mesh size for the trawl net. Moreover in the same period the number of trawler operating in Cypriot waters decreased from 8 to 4. For this reason another run of the ASPIC model using the data series from 1970 to 2003 has been used to estimate the reference points.

Stock status

A stable trend of SSB has been observed from XSA. An increasing trend of biomass at sea, although below the BMSY, has been shown by ASPIC model. Recruitment varied without any trend in the years 2005-2010. Consistent estimate of current F has been estimated by production model and XSA, respectively 0.05 and 0.08, with and FMSY = 0.31 the stock is considered sustainable exploited.

3.3.2.1.3 Red mullet, Mullus barbatus

Red mullet in GSA25 is exploited by the artisanal fleet using trammel nets and by the bottom otter trawlers. The species is exploited with a number of other demersal species for both fisheries. For the assessment period (2005-2010) the average landings by each fleet was around 15-16 tons. The most exploited age classes by both fleets are the age classes 1 and 2. Catch-at age data derived from landings of each fishing gear exploiting the stock (trammel net and bottom trawl) and discards data from bottom trawl are used. The assignment of catches in ages was based on Age Length Keys. M vector for each age class was used, estimated by PRODBIOM (Abella et al. 1997). The L-W relationship and the maturity at age used were estimated within the framework of the Cyprus National Data Collection Programme. The growth parameters used were the ones adopted by the STECF SGMED-08-03 meeting for slow growth (estimated from otolith reading). The assessment methods utilized are Separable VPA for the period 2005-2010, VPA-pseudocohort and Y/R analysis for 2009 and 2010 separately.

Stock status

The recruitment can be considered constant for the period 2005-2010. Average F for ages 1-3 shows a decreasing trend from 2007, while for the last years of the studied period (2009-2010) F seems to be constant. There is a decreasing trend in the SSB, although in the last two years the SSB remains constant. Based on the Y/R analysis for 2010 the current fishing mortality (0.434) is 24% higher than the F0.1 reference point (0.33), but smaller than Fmax (0.51). Based on the Y/R analysis for 2009 the current F (0.461) is 28% higher than the F0.1 reference point (0.33), but smaller than Fmax (0.51).

The stock is in overfishing state, considering that the current F should be reduced by 24% (based on 2010 Y/R analysis) or by 28% (based on 2009 Y/R analysis) for reaching the F0.1 reference point. The stock abundance seems to be in low levels, on the basis of available data and considering the decrease in official landings and the LPUE of the stock throughout the years.

3.3.2.1.4 Bogue, Boops boops

Bogue (*Boops boops*) in GSA25 is exploited mainly by the artisanal fleet comprising 500 vessels OAL 6-12 m using gillnets and secondly by the bottom otter trawlers that comprise 4 vessels OAL 12-24 m. The main species caught with bogue in gillnets are: *Spicara smaris*, *Spicara maena* and *Sardina pilchardus*, while in bottom trawl are: *Spicara smaris*, *Mullus barbatus*, *Mullus surmuletus*, *Pagellus erythrinus* and cephalopods (*Octopus vulgaris*, *Loligo vulgaris* and *Sepia officinalis*). The percentage of bogue in the overall landings for artisanal fishery for the period 2005-2010, has a range of 20-28.7% while for bottom trawl fishery is 5.7-9.4%. Both gears exploit mostly age classes 3 and 4 years. Catch-at-age data from two three year periods (2005-2007 and 2008-2010) derived from landings for each fishing gear exploiting the stock (gillnet and bottom trawl), and discards data from bottom trawl are used. A combined ALK for 2006-2008 and annual length distributions from 2005-2010 were used. M- Vector for each age class was used, estimated by PROBIOM (Abella et al. 1997). The biological parameters used are growth parameters and L-W relationships. Assessment method utilized is a Standard VPA in VIT software.

Stock status

2005-2007: Fcur= 0.57, Fmax= 0.38 and F0.1=0.24; 2008-2010: Fcur= 0.37, Fmax= 0.39 and F0.1=0.24.

2005-2007: overfishing status and intermediate abundance; 2008-2010: overfishing status and intermediate abundance.

3.3.2.1.5 Stripped red mullet, Mullus surmuletus

Stripped red mullet in GSA25 is exploited mainly by the artisanal fleet using trammel nets and also by the bottom otter trawlers in a minor extent. The species is exploited with a number of other demersal species for both fisheries. For the assessment period (2009-2010) the average landings were less than 40 tons, of which the 96% was caught by the artisanal fleet. The most exploited age classes by the artisanal fleet are the ages 1and 2, while the bottom trawl fishery exploits mainly the age classes 2 and 3. Catch-at age data derived from landings for each fishing gear exploiting the stock (trammel net and bottom trawl), using Age Length Keys. M vector for each age class was used, estimated by PRODBIOM (Abella et al. 1997). The L-W relationship, the maturity at age and the growth parameters used were estimated within the framework of the Cyprus National Fisheries Data Collection Programme. Assessment methods utilized are VPA-pseudocohort and Y/R analysis for the years 2009 and 2010 separately.

Stock status

Based on the Y/R analysis of 2010 the current F (0.492) is 53% higher than the F0.1 reference point (0.23). Based on the Y/R analysis of 2009 the current F (0.422) is 48% higher than the F0.1 reference point (0.22). The stock is in overfishing state, considering that the current F should be reduced by 53% (2010 results) or 48% (2009 results) for reaching the F0.1 reference point. The stock abundance seems to be in low levels, on the basis of available data and considering the decrease in official landings and the LPUE of the stock throughout the years.

3.3.2.2 Stocks for which stock assessments are not conducted

For those species that are relevant from a commercial perspective but for which no stock assessments are available a production model has been carried out using catch and effort data from 1980 to 2010. The analysis was performed using the ASPIC.5.4 (A Stock-Production model Incorporating Covariates) software (Prager 1994, 2005) assuming a Schaefer (1954) model. This program implements a non-equilibrium, continuous-time, observation-error estimator for the dynamic production model (Schnute 1977, Prager 1994). The model was used to estimate K, MSY, the ratios of both current biomass or F to the biomass or F at which MSY can be attained, and q (the catchability coefficient, the proportion of total stock removed by one unit of fishing effort).

3.3.2.2.1 Common Pandora, Pagellus erythrinus

Common Pandora in GSA25 is exploited mainly by the artisanal fleet using trammel nets and hooks and also by the bottom otter trawlers. The species is exploited with a number of other demersal species for both fisheries. The average landings for the period 1980 – 2010 were around 16 tons, of which the 65% was caught by the artisanal fleet. The most exploited age classes by the artisanal fleet and bottom trawl fishery are the ages 2 and 3. ASPIC based production model has been performed using artisanal fleet and bottom trawl fishing effort data series from 1980 to 2010. For the same period total landing from each fishery of common pandora were utilized in the model.

Stock status

A stable trend of the CPUE of the two fishery is observed since 1993. The calculation of the ratios F/F_{MSY} and B/B_{MSY} shows for the last years a situation of sustainable exploitation ($F_{current} < F_{MSY}$) and low biomass ($B_{current} < B_{MSY}$; Figure 3.14).

3.3.2.2.2 Parrotfish, Sparisoma cretense

Parrotfish in GSA25 is exploited mainly by the artisanal fleet using trammel nets and hooks. ASPIC based production model has been performed using artisanal fleet landings and effort data series from 1980 to 2008.

Stock status

An increasing trend of the CPUE is observed from 1980 to 1998, followed by a negative trend. The calculation of the ratios F/F_{MSY} and B/B_{MSY} shows for the last years a situation of high exploitation ($F_{current} > F_{MSY}$) and low biomass ($B_{current} < B_{MSY}$; Figure 3.15).

Figure 3.14 CPUE trends and F/F_{MSY} and B< B_{MSY} ratios calculated for *Pagellus erythrinus* in GSA25.

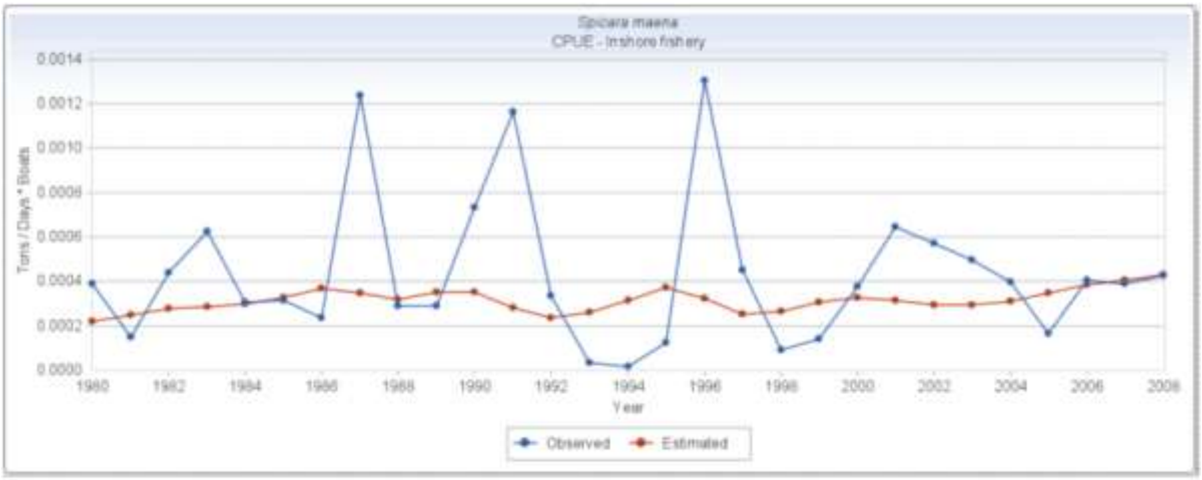
Figure 3.15 CPUE trends and F/F_{MSY} and B< B_{MSY} ratios calculated for *Sparisoma cretensis* in GSA25.

3.3.2.2.3 Blotched picarel, Spicara maena

Blotched picarel in GSA25 is exploited mainly by the artisanal fleet using trammel nets and hooks. ASPIC based production model has been performed using artisanal fleet landings and effort data series from 1980 to 2008.

Stock status

A stable trend of the CPUE is observed from 1980 to 2008. The calculation of the ratios F/F_{MSY} and B/B_{MSY} shows for the last years a situation of sustainable exploitation ($F_{current} < F_{MSY}$) and high biomass ($B_{current} > B_{MSY}$; Figure 3.16).



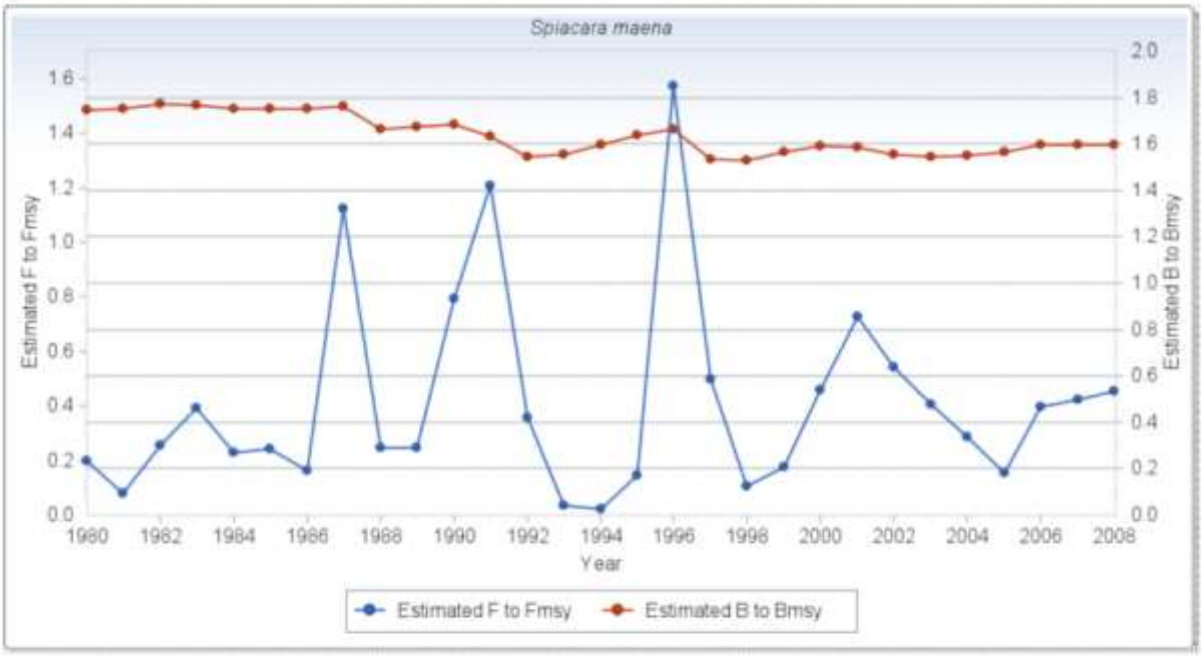


Figure 3.16 CPUE trends and F/F_{MSY} and B< B_{MSY} ratios calculated for *Spicara maena* in GSA25.

3.3.2.2.4 Red porgy, Pagrus pagrus

Red porgy in GSA25 is exploited mainly by the artisanal fleet using trammel nets and hooks and also by the bottom otter trawlers. The species is exploited with a number of other demersal species for both fisheries. The average landings for the period 1980 – 20008 were around 28 tons, of which the 95% was caught by the artisanal fleet. ASPIC based production model has been performed using artisanal fleet and bottom trawl fishing effort data series from 1980 to 2010. For the same period total landing from each fishery of common pandora were utilized in the model.

Stock status

An increasing trend of the CPUE of the two fishery is observed since from 1980 to 1992, followed by a decrease until 2001 and a subsequent increase in the following years. The calculation of the ratios F/F_{MSY} and B/B_{MSY} shows for the last years a situation of sustainable exploitation ($F_{current} \approx F_{MSY}$) and low biomass ($B_{current} < B_{MSY}$; Figure 3.17).

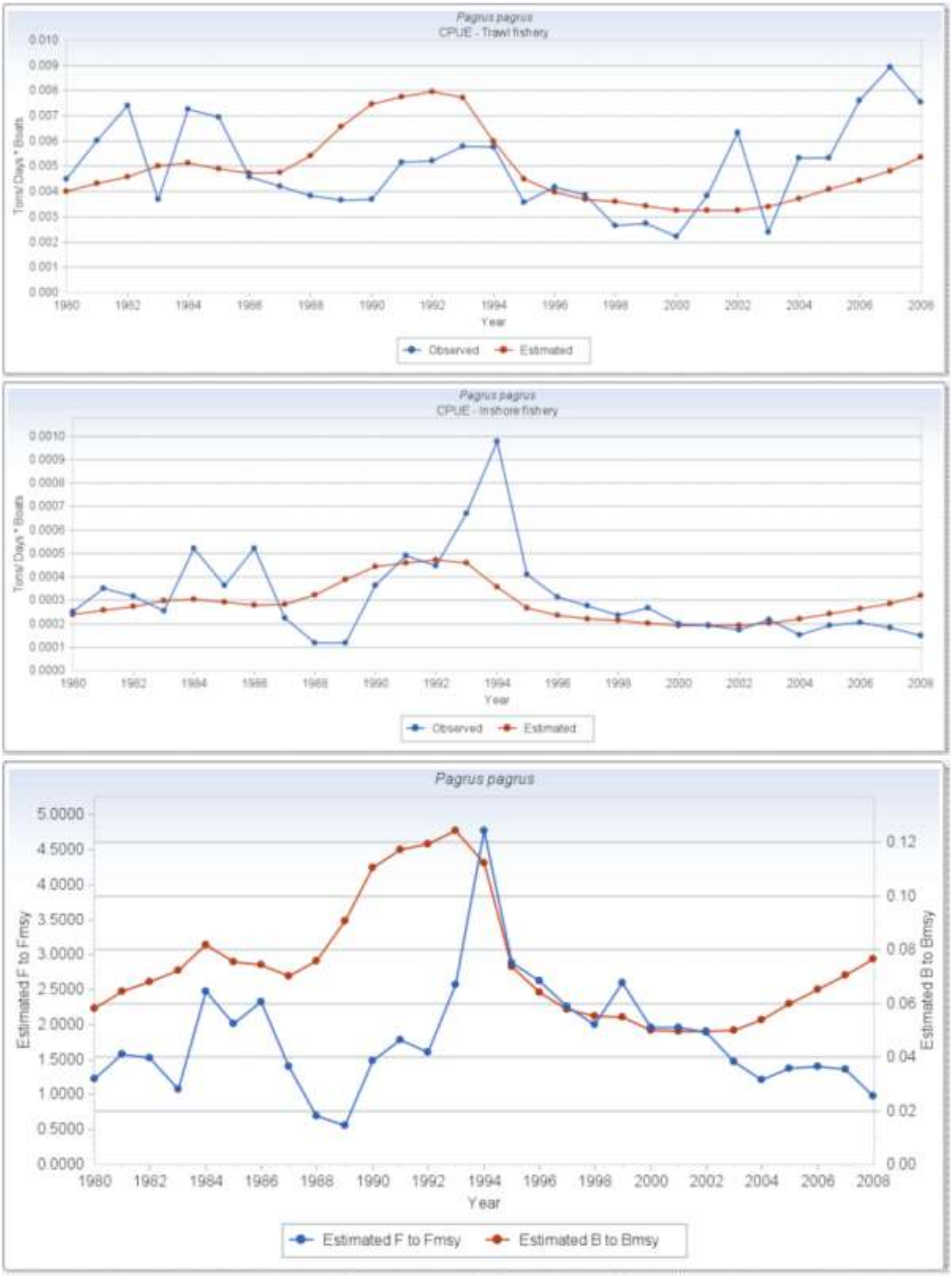


Figure 3.17 CPUE trends and F/F_{MSY} and $B< B_{MSY}$ ratios calculated for *Pagrus pagrus* in GSA25.

3.3.2.2.5 *Axillary seabream,* Pagellus acarne

Axillary seabream in GSA25 is exploited mainly by the artisanal fleet using trammel nets and hooks. ASPIC based production model has been performed using artisanal fleet landings and effort data series from 1980 to 2008.

Stock status

A general decreasing trend of the CPUE is observed from 1980 to 2008. The calculation of the ratios F/F_{MSY} and B/B_{MSY} shows for the last years a situation of high exploitation ($F_{current} > F_{MSY}$) and low biomass ($B_{current} > B_{MSY}$; Figure 3.18).

Figure 3.18 CPUE trends and F/F_{MSY} and $B< B_{MSY}$ ratios calculated for *Pagellus acarne* in GSA25.

3.3.2.2.6 Comber, Serranus cabrilla

Comber in GSA25 is exploited mainly by the artisanal fleet using trammel nets and hooks. ASPIC based production model has been performed using artisanal fleet landings and effort data series from 1980 to 2008.

Stock status

A decreasing trend of the CPUE is observed from 1980 to 2008. The calculation of the ratios F/F_{MSY} and B/B_{MSY} shows for the last years a situation of low exploitation ($F_{current} < F_{MSY}$) and high biomass ($B_{current} > B_{MSY}$; Figure 3.19).

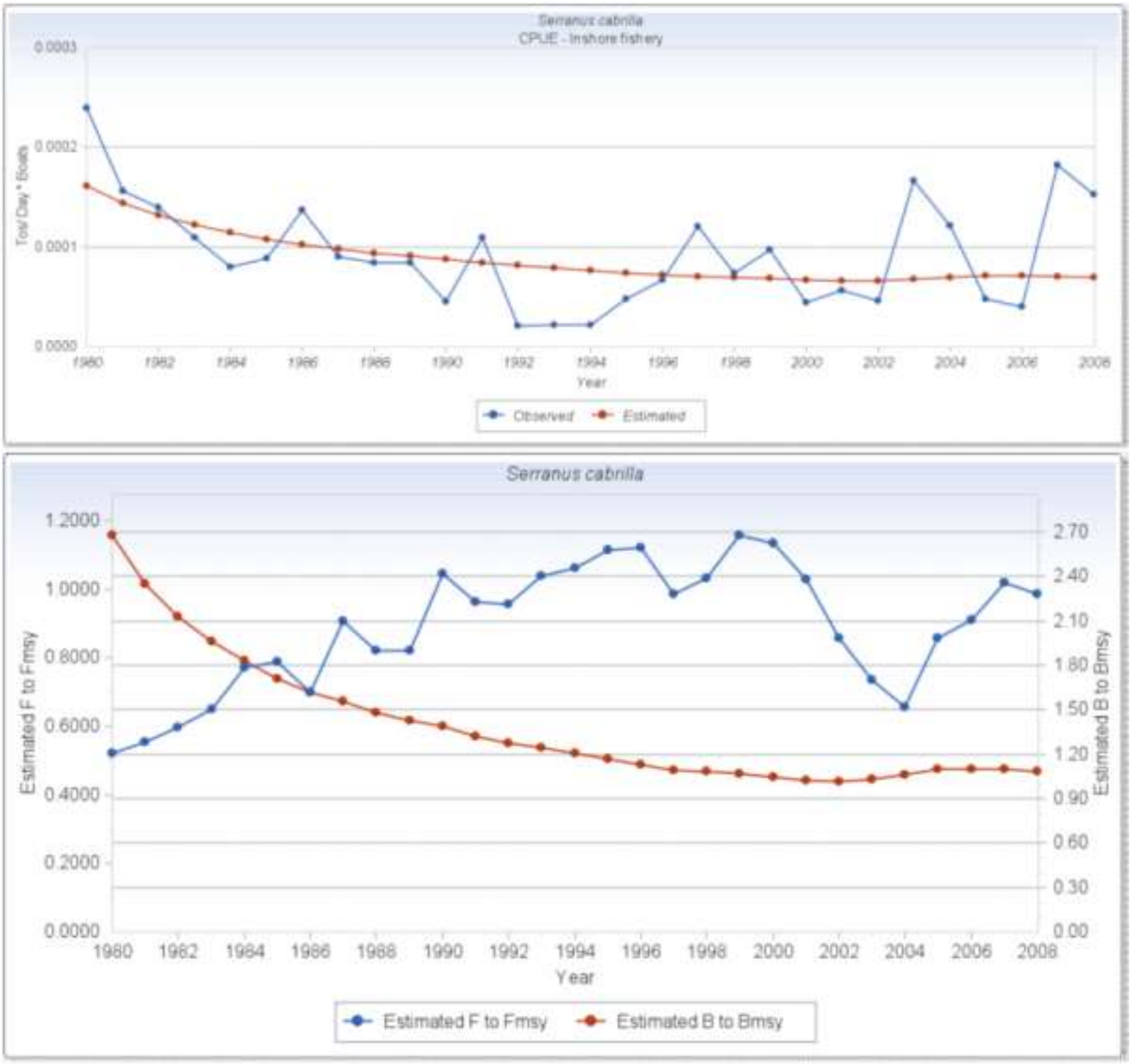


Figure 3.19 CPUE trends and F/F_{MSY} and $B< B_{MSY}$ ratios calculated for *Serranus cabrilla* in GSA25.

3.3.2.2.7 *Common dentex,* Dentex dentex

Common dentex in GSA25 is exploited mainly by the artisanal fleet using trammel nets and hooks. ASPIC based production model has been performed using artisanal fleet landings and effort data series from 1980 to 2008.

Stock status

A decreasing trend of the CPUE is observed from 1980 to 2008. The calculation of the ratios F/F_{MSY} and B/B_{MSY} shows for the last years a situation of high exploitation ($F_{current} < F_{MSY}$) and low biomass ($B_{current} > B_{MSY}$; Figure 3.20).

Figure 3.20 CPUE trends and F/F_{MSY} and $B< B_{MSY}$ ratios calculated for *Dentex dentex* in GSA25.

3.4 A description of the population dynamics, natural and actual range and status of species of marine mammals and reptiles occurring in the marine region or subregion

3.4.1 Marine mammals

3.4.1.1 List of species

3.4.1.1.1 Cetaceans – Dolphins and whales

Tursiops truncatus	Bottlenose dolphin. Vulnerable (VU A2c,d,e)
Delphinus delphis	Short-beaked Common dolphin
Stenella coeruleoalba	Striped Common dolphin
Grampus griseus	Risso’s Dolphin
Steno bredanensis	Rough-toothed dolphin
Ziphius cavirostris	Cuviers Beaked whale
Physeter macrocephalus	Sperm whale
Balaenoptera physalus	Fin whale

3.4.1.1.2 Pinnipedia – Seals and sea lions

Monachus monachus	Mediterranean Monk Seal

3.4.1.2 Population dynamics

3.4.1.2.1 Cetaceans

The main species of dolphin found in Cyprus is the Bottlenose dolphin (*Tursiops truncatus*) that is found both in coastal waters in small groups (5-10 individuals) and in offshore waters in larger groups. There is no thorough assessment of populations. Very tentatively the coastal population is estimated at 30 -100 animals. There probably is an interchange of individuals between open water groups and coastal ones making assessments more complex. Bottlenose dolphins are causing problems to fishermen as the dolphins find food in nets and cause damage to them, hence the conflict between dolphins and fishermen. This is a Mediterranean-wide problem probably caused to a large degree by overfishing (Notarbartolo di Sciara et al. 2012).

It is listed by IUCN in its Red List as a species of Least Concern. It is also listed in ANNEX II of Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora of the EU (The Habitats Directive) and is covered also by ANNEX IV (which covers all Cetaceans).

The Striped Common dolphin and Short-beaked dolphins are basically open sea species. They were once common in the Mediterranean. The population of *Delphinus delphis* in this sea, has dwindled in recent years. The Mediterranean sub-population of *Delphinus delphis*, presently listed as Endangered in the IUCN Red List, may need to be reviewed (reassessed) as it is evidently now verging on being critically endangered (Bearzi 2011). In Cyprus it is known mainly from strandings of dead specimens (A. Demetropoulos and DFMR, unpublished information). Evidently no Mediterranean sub-population of the *Stenella coeruleoalba* is recognized by IUCN and it is listed as being of Least Concern.

The other species listed above are evidently occasional visitors to the coastal or offshore waters of the island but more research and observations are needed. The presence of the Fin Whale and Cuvier's Whale in particular need attention as both may pay regular visits (migrations?) to the island's waters (edge of the continental shelf and more open waters). As is to be expected there are no estimates of populations.

Steno bredanensis was recorded in March 2010 when 14 animals stranded on Lady's Mile beach near Limassol out of a group of about 20 animals. They were stranded alive and were after several attempts returned to the sea (A. Demetropoulos, unpublished information communicated to ACCOBAMS and the DFMR).

3.4.1.2.2 Mediterranean monk seal

The Mediterranean monk seal is one of the world's most endangered mammalian species. It is listed as Critically Endangered in the IUCN Red List, based on criteria A2abc5, C2a(i)6, and E7 (Aguilar and Lowry 2010).

It is classed as a Priority species in the Habitats Directive (Annex II and IV); it is listed as a protected species in the Bern Convention Annex II (1996-98) and the Barcelona Convention Annex II of the SPA/BD Protocol (1995).

The countries in the Mediterranean now hosting the main breeding populations are Greece and Turkey.

There are still a few monk seals found around Cyprus. Monk seals migrate and there may be connections between the Cyprus individuals and the populations in nearby coasts (Turkey, Syria). They breed in caves on the coast. Two surveys were undertaken, in 1997 and 2005/6, to assess the status of the monk seals in Cyprus and identify their breeding and resting caves (Dendrinos and Demetropoulos 1998, Demetropoulos et al. 2006, Demetropoulos 2011). The surveys were undertaken by the Cyprus Wildlife Society in cooperation with the Department of Fisheries and Marine Research. It has been estimated that about 6-10 seals are still found in Cyprus, though migrations around the island and between the island and the nearby mainland make it difficult to make such estimations. Work is ongoing in this field by the CWS and the DFMR. Breeding in the caves of the island was confirmed in 2009 and 2011 (CWS and DFMR monitoring programme).

3.4.1.3 Habitats

3.4.1.3.1 Cetaceans

The bottlenose dolphin is present in coastal waters particularly off the south coast (Limassol Bay to Cape Greco) but there are also records in other coastal areas. Very little or no detailed information is available for the open sea off Cyprus, except for occasional reports of sightings of large groups in such areas.

Both the Stripped and the Common dolphins are found in more open waters, seldom approaching coastal waters. In the Mediterranean, the Striped Common dolphins are associated with highly productive, oceanic waters beyond the continental shelf (Bearzi 2011).

Strandings of some other species of cetaceans denote the presence of these species in the area. These include Risso's dolphin and the Cuvier's toothed whale, with the occasional stranding both of adults (2 specimens) and several juveniles of the latter species, mainly on the west coast of the island.

There is little information on the other whales apart from a stranding of a Sperm whale stranded on the northwest coast in Akamas and a set of sightings of a group of Fin whales in the same area at the edge of the continental shelf, in 2004. This species feeds mainly on cephalopod species, which are often found in such areas. There is however a great scarcity of information on them.

3.4.1.3.2 Monk seals

Historically there was information apparently of about 7-8 small colonies at which breeding took place. In 1959, Davidson mentioned that "... seals of the Eastern Mediterranean variety breed in the island in seven or eight places, one of which was at Cape Andreas area. Members of the expedition to the islands (authors note: i.e. Klidhes Islands off Cape Andreas) may see them. The seals breed on the south coast of Turkey and at Yalousa, and Paphos among other places" (Davidson 1959).

The data concerning the monk seals in Cyprus have been synthesized by Hadjichristophorou and Demetropoulos (1994).

Breeding/Resting areas at that time were listed as:

- Thalassines Spilies near Ayios Georgios, Peyia, on the west coast - north of Paphos
- Akamas coast (two areas - one on the west coast and one on the north coast)
- Cape Gata at Akrotiri Peninsula (in effect the area stretches halfway to Cape Zevgari)
- Dhekelia - Cape Pyla (the caves are at Cape Pyla)
- Cape Andreas and Klidhes islands on the north-eastern tip of the Island
- North coast, east of Yialousa.

The last confirmed breeding (until the recent records) was in the period between 1955 and1958.

There is now a list of the breeding and resting caves that came about from the surveys carried out in 1997 and 2005/6 (Dendrinos and Demetropoulos 1998, Demetropoulos et al. 2006). Within the study area 18 different suitable monk seal habitats (sea caves) were identified, explored and charted:

- Eight of the caves were recorded in the part of coastline north of Paphos up to Yeronisos Point.
- Two were recorded in the area of Chrysochou Bay.
- Six caves were recorded in the area of Cape Gata (Akrotiri).
- One cave was recorded in the area of Cape Pyla and one in the area of Ayia Napa.
- At least four of the above caves/seal shelters were evaluated to be suitable for breeding.

For obvious reasons the exact locations of the caves are not given here.

3.4.1.4 Protection measures

3.4.1.4.1 Cetaceans

The main legislation involved is the Fisheries Law and Regulations and the Law on the Protection and Management of Nature and Wildlife (Habitats Directive), Law 153(I)/2003 which transposed the Directive into National Law.

Monk Seals along with dolphins and turtles have been protected in Cyprus since 1971. The relevant regulations were made under the Fisheries Law (CAP 135). The various Fisheries Regulations passed up to 1990 were consolidated into the 1990 Fisheries Regulations (Reg.273/90). The relevant regulation, 13(1), foresees that:

"Without a special written permit from the Director of the Department of Fisheries and Marine Research, it is prohibited:-

(a) to kill, pursue, take, buy, sell or possess any aquatic turtle, seal, **dolphin**, freshwater crab or sand crab of the species *Ocypode cursor*;

(b) to attempt to kill, pursue, take, buy or sell any of the **above species**; or

(c) to buy, sell or possess turtle eggs or any part of a turtle, seal, or **dolphin**."

The basic law provides for a fine of up to about €8,500 (£5000) or for imprisonment for up to 6 months or both penalties, for any contravention of the regulations.

The Bottlenose dolphin is listed by IUCN in its Red List as a species of Least Concern. It is also listed in ANNEX II of Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora of the EU (The Habitats Directive) and is covered also by ANNEX IV (which covers all Cetaceans). Work on the implementation of the Directive is ongoing.

Relevant Conventions and Supranational Legislation ratified by Cyprus

(Note: R – Ratified)

- Barcelona Convention (R – 1979) Amendments (Acc. 2001)
  - SPA Protocol (R - 1988)
  - Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (R - 2001)
- Bern Convention (R - 1988)
- Bonn Convention - Convention on Migratory Species (R - 2001)
  - ACCOBAMS Agreement (Bonn Convention) – Applicable to all cetacean species
- CBD - Convention on Biological Diversity (Biodiversity Convention) (R - 1996)
- CITES (R - 1974)
- GFCM Agreement (FAO)

European Legislation

- DIRECTIVE 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (Habitats Directive 1992)
- Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 (the "Marine Strategy Framework Directive")

3.4.1.4.2 Monk seals

Legislation

The main legislation involved is the Fisheries Law and Regulations and the Law on the Protection and Management of Nature and Wildlife (Habitats Directive).

Monk Seals along with dolphins and turtles have been protected in Cyprus since 1971. The relevant regulations were made under the Fisheries Law (CAP 135). The various Fisheries Regulations passed up to 1990 were consolidated into the 1990 Fisheries Regulations (Reg.273/90). The relevant regulation, 13 (1) foresees that:

“Without a special written permit from the Director of the Department of Fisheries and Marine Research, it is prohibited:-

(a) to kill, pursue, take, buy, sell or possess any aquatic turtle, **seal**, dolphin, freshwater crab or sand crab of the species Ocypode cursor;

(b) to attempt to kill, pursue, take, buy or sell any of the **above species**; or

(c) to buy, sell or possess turtle eggs or any part of a turtle, **seal**, or dolphin.”

The basic law provides for a fine of up to about €8,500 (£5000) or for imprisonment for up to 6 months or both penalties, for any contravention of the regulations.

At present there is no specific Regulation or Order protecting monk seal habitats as such. There are provisions for this in the Habitats Directive and in the Fisheries Legislation. What is prescribed in Law 153(I) 2003 (Law on the Protection and Management of Nature and Wildlife), for setting up and managing Natura 2000 sites is in place. In 2010 the Akamas area was proposed to the EC for inclusion in the Natura 2000 network, as an addition to the areas which had already been proposed to the EC by the Government and which have been accepted by the Commission. This was recently accepted by the EC. Monk seals are a Priority Species in the Habitats Directive and Cyprus needs to protect Monk Seal sites (as habitats listed in Annex I – Habitat 8330 “Submerged or partially submerged sea caves” and as habitats of a species listed in Annex II). The Akamas site is extensive and includes several caves and cave areas, including Halavron and Thalassines Spilies which are on the border of the Akamas area in the north and the south respectively. It also includes the other caves on the North and West coast of Akamas. The Ayia Napa caves are also covered by the Cape Greco Natura 2000 site, in part at least.

There is a number of other provisions in the fisheries legislation that are indirectly relevant. Interalia these are the prohibitions to the use of explosives, fish resource management measures, especially those concerning the limitations to fishing effort, closed seasons for trawling, depth limitations to trawling (protection of *Posidonia* meadows etc.).

Other legislation that is in part relevant is:

- The Foreshore Protection Law which controls the use of the foreshore.
- The Town and Country Planning Law which provides for zoning in the use of land. The Countryside Policy is also relevant for areas which are not covered by Local Plans.
- The Forest Law and Regulations. This is relevant in areas in which forest areas extend to the sea, as in Akamas, in which case the powers of the local authorities, for the use of the foreshore, have no effect.

Relevant Conventions and Supranational Legislation ratified by Cyprus

- Barcelona Convention (R – 1979) Amendments (Acc. 2001)
  - SPA Protocol (R - 1988)
  - Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (R - 2001)
- Bern Convention (R - 1988) Appendix II lists inter alia the Common and the Bottlenose dolphins
- Bonn Convention - Convention on Migratory Species (R - 2001)
- CBD - Convention on Biological Diversity (Biodiversity Convention) (R - 1996)
- CITES (R - 1974)
- GFCM Agreement (FAO)

European legislation

- Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (Habitats Directive 1992)

- Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 (the “Marine Strategy Framework Directive”)

National Action Plan for the Conservation of the Mediterranean Monk Seal in Cyprus

A National Action Plan for the Conservation of the Mediterranean Monk Seal in Cyprus has been prepared with assistance from RAC/SPA (UNEP/MAP) and has been approved by the DFMR (Demetropoulos 2011). It is expected that it will guide the formulation of the necessary management and legislative measures for monk seal conservation.

3.4.2 Marine reptiles

3.4.2.1 List of species

1. *Caretta caretta* – Loggerhead turtle
2. *Chelonia mydas* – Green turtle
3. *Dermochelys coriacea* – Leatherback

3.4.2.2 Population dynamics

The estimation of the population sizes and trends of both *Caretta caretta* and *Chelonia mydas* is based on the number of nests made. Nesting in both species takes place three times in a season. Turtles do not nest every year but are estimated to nest every two to three years.

1. *Caretta caretta* – See Figure 3.21 and Table 3.14. There is a significant increasing trend in the number of nests made each year since 2007.

2. *Chelonia mydas* – See Figure 3.22 and Table 3.14. There are wide fluctuations in nesting which appear to be wider in recent years. No trend is noticeable. Wide fluctuations are characteristic of the Green turtle.

3. *Dermochelys coriacea* – This species does not reproduce in the Mediterranean. It has been recorded on a few occasions in the sea around Cyprus, usually when it is incidentally caught in fishing gear.

There is a stranding network for the collection of data on stranded dead or injured turtles. (number, size, species etc). This is maintained by the Department of Fisheries and the Cyprus Wildlife Society.

Table 3.14 Nesting in 2011 – 2010 (Demetropoulos and Hadjichristophorou, unpublished data)

Area	**Number of Nests**					
	Loggerhead turtle		**Green turtle**		**Total**	
	2011	**2010**	**2011**	**2010**	**2011**	**2010**
West Coast	240	177	43	63	283	240
Chrysochou Bay	562	435	10	6	572	441
Other areas	22	21	1	1	23	22
New beaches monitored since 2011	27	-	0	-	27	-
Total	851	633	54	70	905	703

3.4.2.3 Habitats

3.4.2.3.1 Caretta caretta

Nesting beaches

The main nesting beaches of this species are in Chrysochou Bay (about 12km of beach) and on the West Coast (mainly in the Lara/Toxeftra Reserve and south of it. There are also significant nesting beaches to the east of the Polis – Giallia Natura 2000 site in Chrysochou Bay, stretching as far as Pyrgos.

Foraging areas

There are no known foraging areas for Loggerheads. This species feeds on benthic animals as an adult and generally travels west of the island, to the richer foraging areas of the central and possibly the western basins of the Mediterranean. Small numbers forage around Cyprus. All migrate back to their natal nesting beaches to lay their own eggs.

3.4.2.3.1 Chelonia mydas

Nesting beaches

The main nesting beaches of this species, in the area under Government control, are in the Akamas area, in the Lara/Toxeftra Reserve. A small number of nests (about 10% of the total number of nests) are found on certain beaches in Chrysochou Bay and on the West Coast.

Foraging areas

The known foraging areas of this species are mainly in Chrysochou Bay, though investigations are ongoing for any significant additional areas. Green turtles graze on the seagrass *Cymodocea nodosa* that is apparently the main food of both juveniles and adults in our area. Adults also graze, though to lesser degree, on the seagrass *Posidonia oceanica* in the extensive meadows this species form (Demetropoulos and Hadjichristophorou 1995).

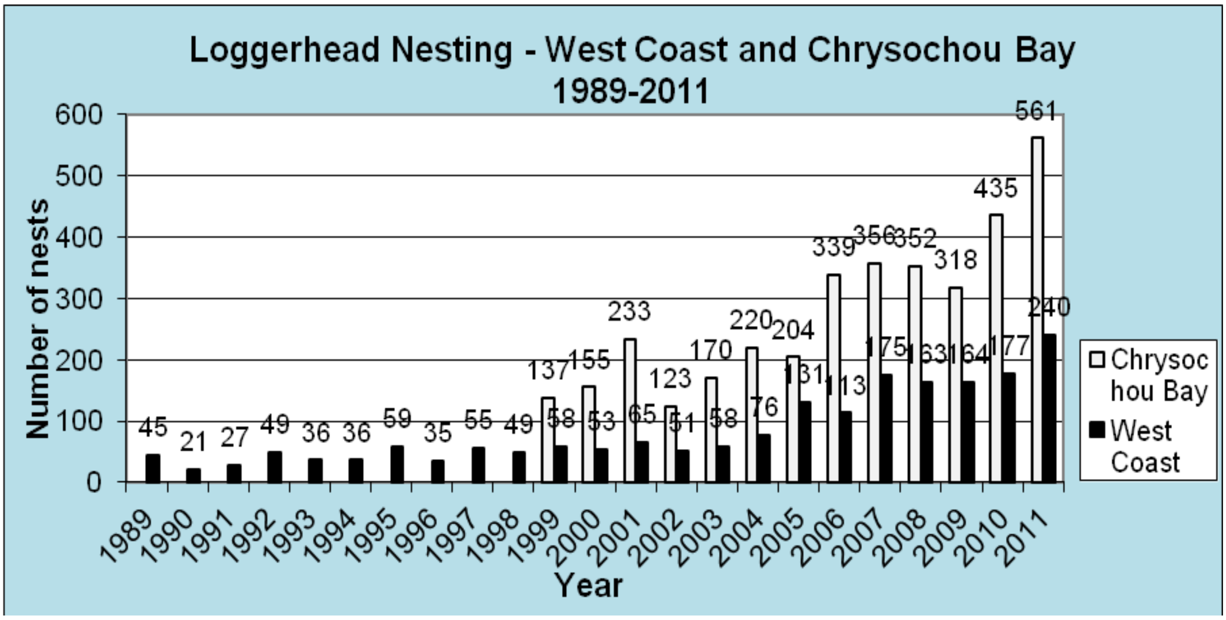


Figure 3.21 Loggerhead nesting on the West Coast and Chrysochou Bay, 1989 – 2011 (Demetropoulos and Hadjichristophorou 2010, Demetropoulos and Hadjichristophorou, unpublished data for 2009-2011). The nesting data for Chrysochou Bay prior to 1999 are not compatible with the data for 1999-2011 and are not included.

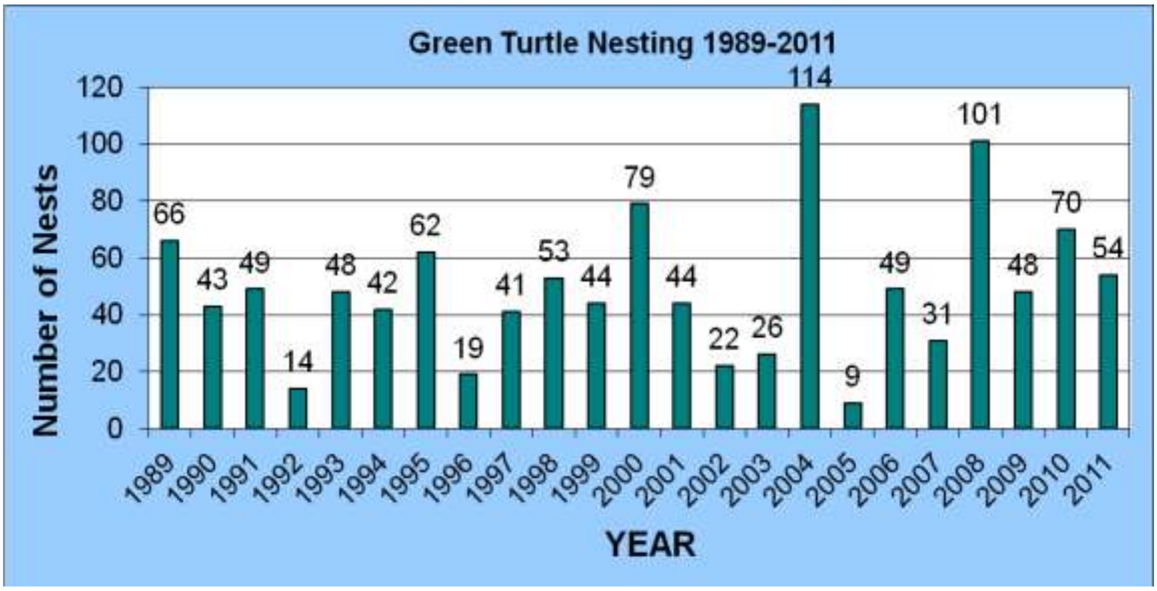


Figure 3.22 Green turtle nesting 1989-2011 (Demetropoulos and Hadjichristophorou 2010, Demetropoulos and Hadjichristophorou, unpublished data for 2009-2011).

Conservation measures

Turtles in Cyprus are protected mainly by the provisions of the fisheries legislation. Since joining the European Union turtles are also protected under the provisions of the EU Habitats Directive and Law 153(I)/2003 for the Conservation and Management of Nature and Wildlife which transposes this Directive into national law. This law has provisions for the conservation of species and habitats listed in the annexes. Both turtle species are included inter alia in Annex II and Annex IV of the Directive, as Priority Species.

Cyprus has ratified inter alia the Barcelona Convention and its Biodiversity Protocol, the Bern and Bonn Conventions and CITES, all of which have provisions for turtle conservation.

The legal protection of turtles in Cyprus is analyzed below in greater detail.

3.4.2.3.2 Species conservation

Turtles and their eggs have been protected under the fisheries legislation since 1971 (Fisheries Law, CAP135 and amendments and the Fisheries Regulations enacted on the basis of this law). The killing, pursuing, catching, buying, selling or possessing of a turtle or attempting to do any of these is prohibited, as is the buying or selling or possession of any turtle egg or turtle part or derivative.

3.4.2.3.3 Habitat conservation

West coast – In 1989 habitat protection was given to the main nesting area on the west coast of the island on the basis of the Fisheries Law and Regulations. A 10 km stretch of coastline was declared, on the basis of the above legislation, as a turtle reserve. This was the Lara/Toxeftra Turtle Reserve. It includes the coastline and the adjacent sea area, down to the 20 m isobath (about 1-1.5 km distance from the coast). The Reserve includes the 5 main Green turtle nesting beaches, which also support loggerhead nesting. The management regulations are in the Law. These foresee that the public is not allowed to:

- Stay on the beaches or the coastal area at night
- Drive any vehicle on a beach or tolerate such action
- Place any umbrella, caravan, tent etc., in the Protected Area
- Use or anchor a boat or tolerate such action (to the 20m isobath)
- Fish, except with a rod and line (to the 20m isobath)

Chrysochou Bay – In 2002 the Polis/Limni was declared on the basis of the Town and Country Planning legislation as a “Shore for Ecological Protection”. Its provisions include: no permits for the commercial use of beach; no breakwaters or marinas and restrictions for the adjacent area regarding lights.

In 2005, the Polis/Limni area was extended to include the Yialia area and the whole area was proposed to the European Commission as “Natura 2000” site. It was accepted in 2008. The site includes an 11 km stretch of coastline (65-200 m wide) and the adjoining sea area down to the 50m isobath. The management regulations are at their final stage of adoption at the time of writing.

3.4.2.3.4 Enforcement

The Fisheries legislation is implemented by the Department of Fisheries and Marine Research (DFMR) and its Inspectorate Service, which has offices and patrol boats in all the coastal towns. The management plans for all “Natura 2000” sites are being elaborated and law implementation and enforcement is partly in place already. Licensing and law enforcement on the basis of this law is the responsibility of the Environment Department of the Ministry of Agriculture Natural Resources and Environment, in cooperation with the DFMR in the marine/coastal sites. Licensing and law enforcement on the basis of the Fisheries legislation remains the responsibility of the DFMR.

3.4.2.3.5 Conservation efforts

Conservation activities started in 1978, after earlier surveys, with the setting up of the Lara Turtle station. They continued without interruption since then. The main initial aim was to protect nests and hatchlings from predation by foxes. The turtle conservation project is a government project and is implemented by the Department of Fisheries and Marine Research (DFMR). The Cyprus Wildlife Society has undertaken the implementation of the Cyprus Turtle Conservation Project since 2009. It used to help implement the project prior to that. The project covers all the nesting beaches that are in the part of the island that is under government control. Law enforcement remains the responsibility of the DFMR.

The main aims of the project now are:

- Protecting and managing the nesting beaches and the adjacent sea
- Protecting nesting females on the nesting beaches and adjacent sea during nesting
- Protecting eggs and hatchlings from predation - and from human activities
- Protecting turtles at sea
- Monitoring the turtle population and nesting activity in Cyprus
- Raising public awareness in turtle conservation

A rescue centre now operates as needed at Meneou, where DFMR has its mariculture research station.

3.4.2.3.6 Conservation methods used

In the Lara-Toxeftra Reserve and on the Polis/Limni/Yialia beaches as well as on practically all other beaches that have any nesting, all nests are protected in situ, i.e., where the eggs are laid, by placing open, self releasing, aluminium (non magnetic) cages over them. These cages have been used in the Cyprus Turtle Conservation Project since 1995. The cages used allow hatchlings to escape to the sea, as soon as they emerge from the sand, but prevent foxes from getting at the nest.

The minimum of intervention is aimed for, at all stages of conservation. A “hatchery” is used for a small number of nests (ca. 20) that cannot be adequately protected where they were laid. Loggerhead nests are relocated there mainly from two tourist beaches on the west coast (Coral Bay). The hatchery is a fenced off part of the beach. No green nests are relocated to the hatchery at Lara, as there is no green turtle nesting on the Coral Bay beaches.

The conservation practices used are the ones described in the Manual for Marine Turtle Conservation in the Mediterranean (Demetropoulos and Hadjichristophorou 1995) and its 2008 Addendum 1 (Demetropoulos and Hadjichristophorou 2008). The conservation practices used have evolved during the life of the project with the experience and knowledge gained. Part of the work carried out in the project is focused on the mitigation of the impact of tourism development on turtle nesting beaches. The recommended strategies and actions are outlined in Demetropoulos (2003b).

3.5 A description of the population dynamics, natural and actual range and status of species of seabirds occurring in the marine region or subregion

3.5.1 Introduction

More than 390 bird species have been recorded in Cyprus. Out of these, two species and four subspecies are endemic. As a result, Cyprus is the only country in Europe included in the list of Endemic Bird Areas of the World (Stattersfield et al. 1998). In addition, due to Cyprus' geographical location relative to the western Palaearctic and Africa, it is one of the most important staging posts in the South-East Mediterranean for millions of migrating and wintering birds travelling between Europe, Africa and the Middle East. Almost 200 species occur as regular passage migrants while another 20 or so occur irregularly. In general, the migrants are species which breed in Europe, pass south through the island in autumn to winter in Africa or the Middle East, and return northward in spring (Flint and Stewart 1992).

The migrants include among others seabirds, waterbirds and raptors which are found offshore, or in terrestrial coastal areas and wetlands (Flint and Stewart 1992, Gordon 2004, Richardson 2005, 2006, 2007, 2008, 2009). Systematic monitoring of these birds, as well as resident species which are found on the island all year round, takes place on a monthly basis at wetlands (Charalambidou et al. 2008, Kassinis et al. 2010). In coastal areas, only two species are monitored regularly, on an annual basis (Wilson 2005), while birds that occur offshore tend to be overlooked (Flint and Stewart 1992).

Importantly, Cyprus supports internationally important populations of the Greater Flamingo (*Phoenicopterus ruber roseus*), Demoiselle Crane (*Grus virgo*), Eurasian Thick-knee (*Burhinus oedicnemus*) and Common Shelduck (*Tadorna tadorna*) (Charalambidou et al. 2008, Kassinis et al. 2010). It also regularly hosts endangered species such as the Greater Sandplover (*Charadrius leschenaultii*), Audouin's Gull (*Larus audouinii*) and Mediterranean Shag (*Phalacrocorax aristotelis desmarestii*). It is of European importance for the Spur-winged Lapwing (*Vanellus spinosus*) that has a predominantly African distribution and in Europe breeds only in Cyprus (Charalambidou et al. 2012), Greece and Turkey (BirdLife International 2004). Cyprus' wetlands also support important breeding populations of the Black-winged Stilt (*Himantopus himantopus*) and Kentish Plover (*Charadrius alexandrinus*) (Kassinis 2007, 2008).

3.5.2 Existing data and status

3.5.2.1 Birds at wetlands

Data on birds that frequent the wetlands of Cyprus is abundant as a result of systematic, monthly waterbird counts carried out since 2003 by the Research Unit of the Cyprus Game Fund, Ministry of Interior of the Republic of Cyprus. Additional data is published by birdwatchers (Flint and Stewart 1992, Gordon 2004, Richardson 2005, 2006, 2007, 2008, 2009) and the non-governmental organisation BirdLife Cyprus (BirdLife Cyprus 2003, 2004, 2005, 2006, 2007, 2008, 2009, Iezekiel et al. 2004). Furthermore, since 2007, monthly waterbird counts are being carried in the whole of Cyprus as a result of two bi-communal projects (Charalambidou et al. 2008, Kassinis et al. 2010). All these data have contributed to the evaluation of distribution ranges and calculation of population sizes of birds that utilize wetland areas.

3.5.2.2 Birds at coastal areas

On the other hand, birds that frequent coastal areas are not monitored systematically, with the exception of an annual 'Survey of Eleonora's Falcon (*Falco eleonorae*) Breeding Colonies' on the coastal cliffs between Limassol and Paphos conducted since 2002 (Wilson 2005), and regular surveys of breeding Griffon Vultures (*Gyps fulvus*) in the same area, by the Forestry Department (Ministry of Agriculture) and Game Fund Service (Ministry of Interior), of the Republic of Cyprus. Moreover, few studies have focused on population sizes of other coastal birds, i.e. breeding population size and breeding success of Audouin's Gull (*Larus audouinii*) colonies at Kleidhes Islands (Charalambidou and Gücel 2008), and population sizes of migrating birds in autumn at the Southeastern Peninsula and Cape Greco (Roth and Corso 2007, Roth 2008). Additional data is published by birdwatchers and the non-governmental organisation BirdLife Cyprus (Flint and Stewart 1992, BirdLife Cyprus 2003, 2004, 2005, 2006, 2007, 2008, 2009, Gordon 2004, Richardson 2006, 2007, 2008, 2009, 2005).

Overall, few estimates of population sizes of coastal birds exist based on systematic data collection, and these focus on breeding but not on wintering populations. Data from coastal areas is generally sufficient for defining the distribution ranges of birds that utilize these areas, but does not cover the whole coastline and is more abundant in locations favoured by birdwatchers.

3.5.2.3 Birds that occur offshore

Furthermore, data on the following four seabird species that are pelagic and only occur offshore is scarce, as these species tend to be overlooked: Cory's Shearwater (*Calonectris diomedea*), Yelkouan Shearwater (*Puffinus yelkouan*), European Storm Petrel (*Hydrobates pelagicus*), and Northern Gannet (*Morus bassanus*) (Flint and Stewart 1992).

The majority of bird species that frequent wetlands, coastal and offshore areas are protected by Cypriot legislation under the Barcelona Convention (UNEP 2005), the EU Birds (79/409/EEC) and Habitats (92/43/EEC) Directives, and the Cyprus Law 152 (I) of 2003.

3.5.2.4 The Barcelona Convention list of protected species

The Mediterranean is a small but important sea in the context of global biodiversity (UNEP-MAP RAC/SPA 2010). The Protocol concerning 'Specially Protected Areas and Biological Diversity in the Mediterranean' (SPA/BD Protocol) of the Barcelona Convention, was established in order to safeguard the areas and species that best represent the conservation value of Mediterranean ecosystems. Seabirds are a good example of the region's richness in which eight of the nine breeding taxa of exclusively marine birds are either endemic species or subspecies (Zotier et al. 1999). Annex II lists seabird species of the highest conservation concern (see Table 3.15).

3.5.2.4.1 Scopoli's (Cory's) Shearwater

Breeds on rocky coasts and islands in the Mediterranean and the Atlantic. Evaluated in Europe as Vulnerable (BirdLife International 2004). According to Flint and Stewart (1992), this species is a scarce passage migrant in Cyprus but is probably greatly overlooked offshore. During spring passage, from late March to mid-May, it has been observed mainly off the south and east coasts; and during autumn passage, from July to October, mainly off the north coast (Cape Kormakitis, Karpasia peninsula, Polis Chrysochou Bay).

3.5.2.4.2 Yelkouan Shearwater

Breeds almost exclusively within Europe and nests mostly on offshore islands in the northeast Atlantic. Evaluated in Europe as Localised (BirdLife International 2004). According to Flint and Stewart (1992), in Cyprus this species is fairly common offshore from August to September, and scarce from December to March. There are records from Cape Andreas, Cape Kormakitis, Cape Greco and Paphos.

Table 3.15 Status in Cyprus of birds previously (UNEP 2005, marked with an asterisk) and currently (UNEP-MAP-RAC/SPA 2010) listed in Annex II (List of Endangered or Threatened Species), of the 'Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean', of the Barcelona Convention.

Common Name	**Scientific name**	**Status in Cyprus**	**Status in Mediterranean**
Scopoli's (Cory's) Shearwater	*Calonectris diomedea diomedea*	Scarce passage migrant	Mediterranean subspecies
Yelkouan Shearwater	*Puffinus yelkouan*	Fairly common offshore	Endemic
Balearic Shearwater	*Puffinus mauretanicus*	One unconfirmed record	Endemic
European Storm Petrel	*Hydrobates pelagicus melitensis*	Accidental visitor	Mediterranean subspecies
Mediterranean Shag	*Phalacrocorax aristotelis desmarestii*	Resident breeder	Mediterranean subspecies
Audouin's Gull	*Larus audouinii*	Resident breeder	Endemic
Mediterranean Gull	*Larus melanocephalus*	Passage migrant Winter visitor	Near endemic
Slender-billed Gull	*Larus genei*	Passage migrant Winter visitor	
Sandwich Tern	*Sterna sandvicensis*	Scarce passage migrant Winter visitor	
Little Tern	*Sternula albifrons*	Scarce passage migrant Migrant breeder	
Lesser Crested Tern	*Sterna bengalensis*	One unconfirmed record	
Caspian Tern	*Hydroprogne (Sterna) caspia*	Scarce passage migrant	
Gull-billed Tern	*Gelochelidon (Sterna) nilotica*	Passage migrant	
Pygmy Cormorant*	*Phalacrocorax pygmeus*	Irregular and scarce passage migrant	
White Pelican*	*Pelecanus onocrotalus*	Scarce passage migrant	
Dalmatian Pelican*	*Pelecanus crispus*	Rare passage migrant	

Greater Flamingo*	*Phoenicopterus ruber roseus*	Abundant winter visitor	
Osprey*	*Pandion haliaetus*	Scarce passage migrant	
Eleonora's Falcon*	*Falco eleonorae*	Migrant breeder	
Slender-billed Curlew*	*Numenius tenuirostris*	Accidental visitor in 50s, 60s and 70s	

3.5.2.4.3 Balearic Shearwater

This is a globally threatened species. The Balearic Shearwater was formerly treated as a subspecies of the Yelkouan Shearwater. Its global breeding range is confined to the Balearic Islands (Spain) and it has a breeding population of about 1,650 pairs. It is evaluated as Critically Endangered (BirdLife International 2004). In Cyprus, there is one potential first record of two individuals sighted at Mandria on 9 April 2011 (Pelagic Birds of the Eastern Mediterranean 2011).

3.5.2.4.4 European Storm Petrel

Breeds almost exclusively within Europe and nests on offshore islands in the northeast Atlantic and western Mediterranean. Evaluated in Europe as Secure (BirdLife International 2004). According to Flint and Stewart (1992), this species is and accidental visitor in Cyprus, with records from Larnaca and Cape Andreas.

3.5.2.4.5 European Shag

The Mediterranean Shag (*Phalacrocorax aristotelis desmarestii*) is a subspecies of the European Shag and a resident species in Cyprus. It is endemic to the Mediterranean and usually found in coastal areas with cliffs, small islets and rocks. In 1999, its global population was estimated at less than 10,000 pairs (BirdLife International 2004). In Cyprus, it is distributed in small colonies on rocky islets around the island (Flint and Stewart 1992). Estimates based on anecdotal data have put its breeding population in Cyprus at 50 pairs and 8 colonies (Aguilar and Fernández 1999), and 80-120 pairs from 1994 to 2002 (BirdLife International 2004). Nevertheless, the actual size of the breeding and wintering populations is unknown since its major colony is at Kleidhes islands.

3.5.2.4.6 Pygmy Cormorant

Breeds in south and southeastern Europe and has a relatively small European breeding population. Evaluated as Secure in Europe and globally as a Near Threatened Species (BirdLife International 2004). In Cyprus it is a scarce and irregular visitor with records from Akrotiri, and Polemidhia, Yermasoyia, Asprokremmos and Achna Dams (Flint and Stewart 1992).

3.5.2.4.7 Great White Pelican

Evaluated as rare in Europe (BirdLife International 2004). In Cyprus, it is a scarce passage migrant, mainly recorded in autumn on the south coast, and at the salt lakes or dams, with about 3 to 5 records per year (Flint and Stewart 1992, BirdLife Cyprus 2003, 2004, 2005, 2006, 2007, 2008, 2009, Charalambidou et al. 2008). Birds usually overfly or remain for 1 to 2 days, but some occasionally remain for several weeks at the salt lakes or dams. Birds are usually observed singly or less than 10 together, but sometimes in large flocks (Flint and Stewart 1992).

3.5.2.4.8 Dalmatian Pelican

Breeds locally in southeastern Europe and has a small European breeding population. It is a globally threatened species and is evaluated as rare in Europe (BirdLife International 2004). In Cyprus, it is a scarce and irregular passage migrant with records from Akrotiri and Larnaca Salt Lakes (Flint and Stewart 1992).

3.5.2.4.9 Greater Flamingo

This species requires large undisturbed expanses of shallow brackish and saline lagoons, salt lakes, salt pans and tidal flats, with seasonal access to fresh drinking water. In Europe it is evaluated as Localised (BirdLife International 2004). In Cyprus it is a regular winter visitor to Larnaca and Akrotiri Salt Lakes, with internationally important numbers of up to 10,000 individuals observed in some years. The birds arrive in autumn as the salt lakes fill with water, to feed upon the invertebrate biomass that rapidly colonises the water. Birds move opportunistically between the two salt lakes, depending on water levels in the lakes. Greater Flamingos attempted to breed unsuccessfully in 2003 and 2005 at Akrotiri salt lake.

3.5.2.4.10 Osprey

This is a widespread summer visitor to much of northern Europe, occurring patchily further south. Its European breeding population is small and it is evaluated as Rare (BirdLife International 2004). In Cyprus it is a passage migrant, more common in autumn than spring. Most birds overfly, while some individuals stop to fish at wetlands, e.g. Kouris Dam and Oroklini Lake (Charalambidou et al. 2008) where they sometimes remain for days and exceptionally up to three weeks (Flint and Stewart 1992).

3.5.2.4.11 Eleonora's Falcon

The Eleonora's Falcon is a summer visitor to rocky coasts and islands in the Mediterranean, where it arrives from its wintering grounds in Madagascar. About 95% of its global population breeds in Europe with more than 70% in Greece. In Europe it has an unfavourable conservation status and is evaluated as Declining (BirdLife International 2004). In Cyprus, this bird is present from April to October. Before the breeding season, birds have a wide feeding range and can be seen hunting insects far from the coast at areas with high insect concentrations, such as wetlands and Troodos, Pafos and Madari forests (Flint and Stewart 1992, Gordon 2004, Richardson 2005, 2006, 2007, 2008, 2009).

The end of July and August, birds breed along the coastal cliffs between Limassol and Pissouri and feed their young on migrating passerine birds. During this time, they hunt in the coastal airspace that extends a few km seaward and inland. Based on annual surveys of this species, breeding populations of 169 pairs in 2002, 75 pairs in 2003, 191 pairs in 2004, and 104 pairs in 2005 have been counted, with 50% of the pairs located at Akrotiri Aspro–Petra tou Romiou SPA (Wilson 2005).

3.5.2.4.12 Slender-billed Curlew

This is a globally threatened species. It occurs in Europe as an extremely rare passage migrant, occasionally as a winter visitor, and is poorly known with unknown breeding areas. Therefore, its European status is Not Evaluated (BirdLife International 2004). In Cyprus it has been recoded as an accidental visitor, with one record from Famagusta in 1958, Nicosia in 1964, and Cape Andreas in 1972 (Flint and Stewart 1992).

3.5.2.4.13 Audouin's Gull

This is a globally threatened species. From March to August, it breeds in scattered and small colonies in the Mediterranean on rocky coasts and islands, and spends winter mainly along the coast of North Africa. Europe holds more than 75% of its global breeding population, and it is evaluated as Localised (BirdLife International 2004). In Cyprus, it breeds on Kleidhes Islands (Charalambidou and Gücel 2008) and overwinters in coastal areas around Cyprus (Flint and Stewart 1992, Gordon 2004, Richardson 2005, 2006, 2007, 2008, 2009). While the breeding population has been counted at between 40-50 pairs, the size of the wintering population is unknown.

3.5.2.4.14 Mediterranean Gull

This species has a widespread but patchy breeding distribution in Europe, which contains its entire global breeding range. Its breeding population is large and stable, therefore the species is evaluated as Secure (BirdLife International 2004). In Cyprus, it is a passage migrant and winter visitor to coasts, harbours and salt lakes (Flint and Stewart 1992).

3.5.2.4.15 Slender-billed Gull

This species breeds locally in coastal areas of the Mediterranean and Black Seas, and in Turkey, with Europe accounting for less than half of its global breeding range. Its European breeding population is relatively small (<56,000 pairs) but stable. As more than 90% of its European breeding population occurs at 10 sites, it is evaluated as Localised (BirdLife International 2004). In Cyprus it is a common passage migrant, while some birds overwinter in coastal and wetland areas (Flint and Stewart 1992).

3.5.2.4.16 Sandwich Tern

This species is widespread in coastal areas of Europe, with a relatively small European breeding population. It is evaluated as Depleted (BirdLife International 2004). In Cyprus, it is a scarce winter visitor and passage migrant to inshore waters, mainly from November to April, with most records at Larnaca Bay, also in harbours at Famagusta, Limassol and Paphos (Flint and Stewart 1992).

3.5.2.4.17 Little Tern

This is a widespread and patchily distributed summer visitor to much of Europe, where it is evaluated as Declining (BirdLife International 2004). In Cyprus, it is a scarce passage migrant in spring, mainly at coastal wetlands or offshore, and occasionally at inland waters (Flint and Stewart 1992). Breeding populations of between 2 to 5 pairs have been recorded in Larnaca, Achna Dam and Oroklini Lake (Charalambidou et al. 2008, Kassinis et al. 2010).

3.5.2.4.18 Lesser Crested Tern

This species has a predominantly tropical and subtropical breeding distribution, with only 2 or 3 pairs breeding in Spain (BirdLife International 2004). There is one unconfirmed record from Larnaca in 1963 (Flint and Stewart 1992).

3.5.2.4.19 Caspian Tern

This species breeds patchily along the Baltic Sea coast and in south-east Europe, which accounts for less than a quarter of its global breeding range. Its European breeding population is small (as few as 4,700 pairs). Its population size renders it susceptible to the risks affecting small populations and it is evaluated as Rare (BirdLife International 2004). In Cyprus it is a scarce passage migrant, mainly offshore or at coastal wetlands, and occasionally at inland waters (Flint and Stewart 1992).

3.5.2.4.20 Gull-billed Tern

This species is a patchily distributed breeder in southern and eastern Europe, which accounts for less than a quarter of its global breeding range. Its European breeding population is relatively small (<22,000 pairs). Due to an overall decline in its breeding population, it is evaluated as Vulnerable (BirdLife International 2004). In Cyprus, it is a scarce to fairly common passage migrant, at coastal wetlands or offshore, occasionally at inland waters (Flint and Stewart 1992).

3.5.2.5 Special Protection Areas (SPAs) for the conservation of coastal and wetland birds

Six designated SPAs in Cyprus include coastal areas in part of their territory, for the protection of bird species listed in Annex I of the EU Birds Directive (79/409/EEC), and protected under Cyprus law 152 (I) of 2003.

3.5.2.5.1 Cape Greco

This area constitutes the easternmost edge of Cyprus, serves as the first station for migratory birds and is considered one of the most important stop-over sites on the island (Flint and Stewart 1992, Roth and Corso 2007, Roth 2008). About 90% of the site is terrestrial with heath, scrub, maquis, and garrigue, phrygana habitat cover, while 10% of the site is marine including shingle, sea cliffs and islets (LIFE 1998). The avifauna includes at least 77 species. Among these, 23 are listed in Annex I of the EU Birds Directive (79/409/EEC) or are new additions to the Annex, and 54 are regularly occurring migratory species (Table 3.16 and Table 3.17) (Game Fund 2008a). The area is used for nesting by the endemics Cyprus Warbler (*Sylvia melanothorax*) and Cyprus Wheatear (*Oenanthe cypriaca*) while thousands of passerines and other migratory species stop-over during migration. Irregular bird species for Cyprus, and sometimes for Europe, are recorded here, such as the Bateleur Eagle (*Terathopius ecaudatus*; first record for Europe), Short-toed Snake Eagle (*Circaetus gallicus*), Booted Eagle (*Aquila pennata*) and Corn Crake (*Crex crex*) (LIFE 1998).

Table 3.16 Birds at Cape Greco SPA listed on Annex I of the EU Birds Directive (79/409/EEC) (Game Fund 2008a). Abbreviations: P = Present; C = Common; R = Rare; V = Vagrant.

Common name	Scientific name	Resident	Migratory		
			Breed	**Winter**	**Stage**
Common Kingfisher	*Alcedo atthis*			R	
Tawny Pipit	*Anthus campestris*			R	
Purple Heron	*Ardea purpurea*				C
Squacco Heron	*Ardeola ralloides*				C
Kentish Plover	*Charadrius alexandrinus*				R
Western Marsh Harrier	*Circus aeruginosus*				C
Northern Harrier	*Circus cyaneus*			R	
Pallid Harrier	*Circus macrourus*				C
European Roller	*Coracias garrulus*		R		
Lesser kestrel	*Falco naumanii*				C

Red-footed falcon	*Falco vespertinus*				C
Little Egret	*Egretta garzetta*				C
Cretzschmar's Bunting	*Emberiza caesia*		C		
Ortolan Bunting	*Emberiza hortulana*				R
Gull-billed Turn	*Gelochelidon nilotica*				R
Red-backed Shrike	*Lanius collurio*				R
Lesser Grey Shrike	*Lanius minor*				R
Audouin's Gull	*Larus audouinii*	P			V
Slender-billed Gull	*Larus genei*				C
Black Kite	*Milvus migrans*				V
Cyprus Wheatear	*Oenanthe cypriaca*		P		
Osprey	*Pandion haliaetus*				V
Cyprus Warbler	*Sylvia melanothorax*	P			
Barred Warbler	*Sylvia nisoria*				R
Rüppell's Warbler	*Sylvia rueppelli*				R

Table 3.17 Regularly occurring Migratory Birds at Cape Greco SPA not listed on Annex I of the EU Birds Directive (79/409/EEC) (Game Fund 2008a). Abbreviations: P = Present; C = Common; R = Rare; V = Vagrant.

			Migratory		
Common name	**Scientific name**	**Resident**	**Breed**	**Winter**	**Stage**
Skylark	*Alauda arvensis*	C			
Red-throated Pipit	*Anthus cervinus*			C	
Meadow Pipit	*Anthus pratensis*			C	
Tree Pipit	*Anthus trivialis*				C
Common Swift	*Apus apus*				C
Alpine Swift	*Apus melba*				C
Lesser Short-toed Lark	*Calandrella rufescens*				R
Siskin	*Carduelis spinus*				
Rufous Bush Robin	*Cercotrichas galactotes*				V
Great Spotted Cuckoo	*Clamator glandarius*		V		C
Common Quail	*Coturnix coturnix*				C
Common Cuckoo	*Cuculus canorus*				C
Common House Martin	*Delichon urbica*		C		C

Yellowhammer	*Emberiza citrinella*				V
Black-headed Bunting	*Emberiza melanocephala*		C		
Red-rumped Swallow	*Hirundo daurica*		R		C
Barn Swallow	*Hirundo rustica*		C		C
Woodchat Shrike	*Lanius senator*				R
Lesser Black-backed Gull	*Larus fuscus*				C
Little Gull	*Larus minutus*				C
Black-headed Gull	*Larus ridibundus*			C	
Nightingale	*Luscinia megarhynchos*				C
European Bee-eater	*Merops apiaster*				C
Common Rock Thrush	*Monticola saxatilis*				R
Blue Rock Thrush	*Monticola solitarius*			C	
Spotted Flycatcher	*Muscicapa striata*				C
Black-eared Wheatear	*Oenanthe hispanica*				C
Isabelline Wheatear	*Oenanthe isabellina*				C
Northern Wheatear	*Oenanthe oenanthe*				C
Spanish Sparrow	*Passer hispaniolensis*				C
Black Redstart	*Phoenicurus ochruros*			C	
Common Redstart	*Phoenicurus phoenicurus*				C
Wood Warbler	*Phylloscopus sibilatrix*				C
Willow Warbler	*Phylloscopus trochilus*				C
Sand Martin	*Riparia riparia*				C
Whinchat	*Saxicola rubetra*				C
Stonechat	*Saxicola torquata*			C	
Common Starling	*Sturnus vulgaris*				C
Blackcap	*Sylvia atricapilla*				C
Garden Warbler	*Sylvia borin*				R
Common Whitethroat	*Sylvia communis*				C
Lesser Whitethroat	*Sylvia curruca*				C
Orphean Warbler	*Sylvia hortensis*				C
Sardinian Warbler	*Sylvia melanocephala*				C
Redwing	*Turdus iliacus*			C	
Common Blackbird	*Turdus merula*			C	
Song Thrush	*Turdus philomelos*			C	

Fieldfare	*Turdus pilaris*			R	
Mistle Thrush	*Turdus viscivorus*			R	
Barn Owl	*Tyto alba*	P			
Hoopoe	*Upupa epops*		R		C
Northern Lapwing	*Vanellus vanellus*				C
Spectacled Warbler	*Sylvia conspicillata*	C			
Bateleur	*Terathopius ecaudatus* (reported once)				

3.5.2.5.2 Agia Thekla

Agia Thekla SPA is linear and ribbon-like, stretching along the coastal belt, west of Ayia Napa town. The avifauna of the site includes at least 30 bird species. Among these, 20 are listed in Annex I of the EU Birds Directive, and 10 are regularly occurring migratory species (Table 3.18 and Table 3.19) (Game Fund 2008b). Moreover, the site has been classified by BirdLife Cyprus as an 'Important Bird Area' as it is considered among the three most important migration staging points and wintering sites in Cyprus for the Greater Sandplover (*Charadrius leschenaultii*), and regularly holds 1% of the European flyway of this species (Table 3.20) (Iezekiel et al. 2004). Turkey is the European breeding stronghold for this species, with a breeding population of between 800–1,200 individuals.

Table 3.18 Birds at Agia Thekla SPA listed on Annex I of the EU Birds Directive (79/409/EEC) (Game Fund 2008b) Abbreviations: P = Present; C = Common; R = Rare; V = Vagrant.

			Migratory		
Common name	**Scientific name**	**Resident**	**Breed**	**Winter**	**Stage**
Kentish Plover	*Charadrius alexandrinus*		R	R	R
Black-crowned Night Heron	*Nycticorax nycticorax*				C
Little Egret	*Egretta garzetta*				C
Purple Heron	*Ardea purpurea*				R
Cattle Egret	*Bubulcus ibis*				C
Western Marsh Harrier	*Circus aeruginosus*				R
Eurasian Thick-knee	*Burhinus oedicnemus*			R	
Pied Avocet	*Recurvirostra avosetta*				R
Black-winged Stilt	*Himantopus himantopus*				R
Cream-colored Courser	*Cursorius cursor*				R
European Golden Plover	*Pluvialis apricaria*				C
Ruff	*Philomachus pugnax*				C
Wood Sandpiper	*Tringa glareola*				C
Audouin's Gull	*Larus audouinnii*	R			
Common Kingfisher	*Alcedo atthis*			C	C

Greater Short-toed Lark	*Calandrella brachydactyla*				C
Woodlark	*Lullula arborea*			R	
Tawny Pipit	*Anthus campestris*				C
Ortolan Bunting	*Emberiza hortulana*				R
Cretzschmar's Bunting	*Emberiza caesia*				C

Agia Thekla SPA is also used for breeding by the Kentish Plover (*Charadrius alexandrinus*) and is one of the most important migration stop-over sites in Cyprus for the Great Ringed Plover (*Charadrius hiaticula*) and the Kingfisher (*Alcedo atthis*). Most importantly it is one of the few sites in Cyprus where the Audouin's Gull is regularly observed (Iezekiel et al. 2004, Game Fund 2008b).

Table 3.19 Regularly occurring Migratory Birds at Agia Thekla SPA not listed on Annex I of the EU Birds Directive (79/409/EEC) (Game Fund 2008b) Abbreviations: P = Present; C = Common; R = Rare; V = Vagrant.

			Migratory		
Common name	**Scientific name**	**Resident**	**Breed**	**Winter**	**Stage**
Greater Sandplover	*Charadrius leschenaultii*			5-10i	5-10i
Common Quail	*Coturnix coturnix*				C
Common Ringed Plover	*Charadrius hiaticula*				C
Common Sandpiper	*Actitis hypoleucos*				C
Black-headed Gull	*Larus ridibundus*			C	
Hoopoe	*Upupa epops*				C
Red-rumped Swallow	*Hirundo daurica*				C
Whinchat	*Saxicola rubetra*				C
Stonechat	*Saxicola torquata*			C	
Grey Heron	*Ardea cinerea*				C

Table 3.20 Qualifying species for the classification of Agia Thekla - Liopetri as an Important Bird Area (Iezekiel et al. 2004)

Common name	**Scientific name**	**Estimated Population**	**Status**
Greater Sandplover	*Charadrius leschenaultii*	3-10 pairs	Passage migrant Winter visitor

3.5.2.5.3 Larnaca Salt Lake

Larnaca Salt Lake, which constitutes a network of four salt lakes, is considered one of the most important wetlands for birds in Cyprus and was designated a Ramsar site in 2001 and Natura 2000 SCI and SPA sites in 2004 (Larnaca Natura 2000 Standard Data Form). The avifauna of the site includes at least 100 bird species. Among these, 31 are listed in Annex I of the EU Birds Directive (79/409/EEC). The site regularly supports internationally important numbers of overwintering Greater Flamingo, reaching populations of up to 10,000 birds. Other important bird species are also observed here and the area has been classified by BirdLife Cyprus as an 'Important Bird Area' according to the qualifying species shown in Table 3.21 (Iezekiel et al. 2004).

Table 3.21 Qualifying species for the classification of Larnaca Salt Lake as an Important Bird Area (Iezekiel et al. 2004)

Common name	**Scientific name**	**Estimated Population**	**Status**
Greater flamingo	*Phoenicopterus ruber*	3000-12000	Winter visitor Passage migrant
Common crane	*Grus grus*	500-1000	Passage migrant
Kentish plover	*Charadrius alexandrinus*	250-350	Resident, passage migrant
Black-headed gull	*Larus ridibundus*	5000-6000	Passage Migrant Winter visitor
Black-winged stilt	*Himantopus himantopus*	5-70p	Passage migrant Occasional breeder
Eurasian thick-knee	*Burhinus oedicnemus*	5-10p	Resident, Migrant breeder Passage migrant
Spur-winged Lapwing	*Vanellus spinosus*	0-3p	Migrant breeder
85 species of waterbirds		20,000-38,000	

3.5.2.5.4 Akrotiri Peninsula - Episkopi Cliffs

Akrotiri Peninsula, together with Larnaca Salt Lake, is considered one of the most important wetlands for birds in Cyprus. Large parts of the wetlands were designated in 2003 as the Akrotiri Ramsar Site, for which they qualified due to the wintering populations of Greater Flamingo. In 2011, Akrotiri Wetlands and Akrotiri Cliffs were designated as Natura 2000 SPAs. The avifauna of the site includes at least 308 bird species. Among these, 28 are listed in Annex I of the EU Birds Directive (79/409/EEC) or are new additions to the Annex (Table 3.22).

This site is of major importance as a staging area during spring and autumn passage for hundreds to thousands of waterbirds. Among these, flocks numbering internationally important numbers of the Demoiselle Crane (*Grus virgo*) roost at the lake from mid-August to early September (Charalambidou et al. 2008, Kassinis et al. 2010). The area is also important for raptor migration, with large numbers of the Red-footed Falcon (*Falco* *vespertinus*), European Honey Buzzard (*Pernis apivorus*), and Harriers (*Circus* spp.) using the site (Iezekiel et al. 2004).

Moreover, it is an important wintering site for many duck (*Anas)*, Shelduck, and wader species, as well as the Greater Flamingo (Charalambidou et al. 2008, Kassinis et al. 2010). During spring and summer, Akrotiri and Episkopi sea cliffs are important breeding sites for the Eleonora's and Peregrine Falcons and the Mediterranean Shag, while Episkopi cliffs is the most important breeding site for the Griffon Vulture in Cyprus (Iezekiel et al. 2004). The area has been classified by BirdLife Cyprus as an 'Important Bird Area' according to the qualifying species shown in Table 3.23 (Iezekiel et al. 2004).

Table 3.22 Qualifying species, listed in Schedule 1 of the Game and Wild Birds Ordinance, for the SPA designation of Akrotiri Wetlands and Akrotiri Cliffs. Species marked with an asterisk (*) are important breeding species in the SPAs, some also in the general area of the Peninsula. Species not marked with an asterisk, are important non-breeding species in the SPAs and the general area of the Peninsula. These use Akrotiri Peninsula for wintering and migration, including roosting, resting, staging and thermalling to gain lift before flying offshore.

Common name	**Scientific name**
Demoiselle Crane	*Grus virgo*
Purple Heron	*Ardea purpurea*
Squacco Heron	*Ardeola ralloides*
Ferruginous Duck *	*Aythya nyroca*
Little Stint	*Calidris minuta*
Kentish Plover *	*Charadrius alexandrinus*
Greater Sandplover	*Charadrius leschenaultia*
White-winged (Black) Tern	*Chlidonias leucopterus*
Western Marsh-harrier	*Circus aeruginosus*
Pallid Harrier	*Circus macrourus*
Saker Falcon	*Falco cherrug*
Eleonora's Falcon *	*Falco eleonorae*
Peregrine Falcon *	*Falco peregrinus*
Red-footed Falcon	*Falco vespertinus*
Collared Pratincole	*Glareola pratincola*
Common Crane	*Grus grus*
Black-winged Stilt *	*Himantopus himantopus*
Slender-billed Gull	*Larus genei*
European Bee-eater	*Merops apiaster*
Great White Pelican	*Pelecanus onocrotalus*
European Honey Buzzard	*Pernis apivorus*

European Shag *	*Phalacrocorax aristotelis desmarestii*
Ruff	*Philomachus pugnax*
Greater Flamingo	*Phoenicopterus ruber roseus*
Glossy Ibis	*Plegadis falcinellus*
Gull-billed Tern	*Sterna nilotica*
Shelduck	*Tadorna tadorna*
Spur-winged Lapwing *	*Vanellus spinosus*

Table 3.23 Qualifying species for the classification of Akrotiri Peninsula – Episkopi Cliffs (Iezekiel et al. 2004).

Common name	**Scientific name**	**Estimated population**	**Status**
Squacco heron	*Ardeola ralloides*	100-250	Passage migrant
Glossy ibis	*Plegadis falcinellus*	250-500	Passage migrant
Greater flamingo	*Phoenicopterus ruber*	4000-10000	Winter visitor Passage migrant
Eleonora's falcon	*Falco eleonorae*	50-65p	Migrant breeder
Red-footed falcon	*Falco vespertinus*	1100-1500	Passage migrant
Common crane	*Grus grus*	3000-5000	Passage migrant
Black-winged stilt	*Himantopus himantopus*	300-350ind 5-10p	Passage migrant Occasional breeder
Collared pratincole	*Glareola pratincola*	100-200	Passage migrant
Kentish plover	*Charadrius alexandrinus*	300-500ind 20-40p	Resident breeder Passage migrant Winter visitor
Slender-billed gull	*Larus genei*	1200-1500	Passage migrant Winter visitor
Gull-billed tern	*Gelochelidon nilotica*	80-100	Passage migrant
Demoiselle crane	*Grus virgo*	400-560	Passage migrant
Shelduck	*Tadorna tadorna*	800-2000	Passage migrant Winter visitor
Greater Sandplover	*Charadrius leschenaultii*	5-10	Passage migrant Winter visitor
Bee-eater	*Merops apiaster*	20,000-30,000	Passage migrant
Peregrine Falcon	*Falco peregrinus*	4-6p	Resident breeder
Black-headed gull	*Larus ridibundus*	5000-6000	Passage Migrant Winter visitor

Shag	*Phalacrocorax aristotelis*	35-40p	Resident breeder
Griffon vulture	*Gyps fulvus*	5-8p	Resident breeder
Eurasian thick-knee	*Burhinus oedicnemus*	5-10p	Passage breeder Passage migrant
Spur-winged Lapwing	*Vanellus spinosus*	5-10p	Migrant breeder
86 species of waterbirds		30,000-70,000	Passage migrant
13 species of raptors		3900-7300	Passage migrant

3.5.2.5.5 Akrotiri Aspro - Petra tou Romiou SPA

This site includes a terrestrial and a marine part. The highest point is 250 m above sea level and the lowest is at sea level, spanning 10 km of coastline. Along the coast there are gravelly beaches and steep, un-vegetated sea cliffs extending at 70 % of the coastline. The avifauna includes at least 95 species. Among these, 25 are listed in Annex I of the EU Birds Directive or are new additions to the Annex, and 53 are regularly occurring migratory species (Game Fund 2005a).

The site is one of the few on the island that provides nesting habitats on sea cliffs for threatened and important birds of prey such as the Eleonora's and Peregrine (*Falco peregrinus*) Falcons. About 50% of the breeding population of Eleonora's Falcon in Cyprus nests here. The site is also used for nesting by the Alpine Swift (*Apus melba*), and the endemic Cyprus Warbler and Cyprus Wheatear. Importantly, the site is a feeding area for the threatened Griffon Vulture (*Gyps fulvus*), which nests about 10 km from the site. Finally, due to its location and morphology the site is an important resting station for migratory birds (LIFE 1998, Iezekiel et al. 2004, Wilson 2005).

Furthermore, the Mediterranean Shag is considered common in this area and the site has been classified by BirdLife Cyprus as an 'Important Bird Area' according to the qualifying species shown in Table 3.24 (Iezekiel et al. 2004).

Table 3.24 Qualifying species for the classification of Cape Aspro as an Important Bird Area (Iezekiel et al. 2004).

Common name	**Scientific name**	**Estimated Population**	**Status**
Eleonora's falcon	*Falco eleonorae*	65-75 pairs	Migrant breeder
Peregrine Falcon	*Falco peregrinus*	2 pairs	Resident breeder
Shag	*Phalacrocorax aristotelis*	5-10 pairs	Resident breeder

3.5.2.5.6 Kato Pafos Lighthouse

Kato Pafo Lighthouse SPA consists of Pafos Headland immediately to the west of Kato Pafos town, and Pafos castle and marina. About 95% of the site is a fenced-in area that is an archaeological site. This area is dominated by open grassland with remnant patches of scrub and planted species. Beyond and to the seaward side of the fenced-in archaeological area, and consisting 5% of the site, is a narrow coastal stretch with mostly rocky and some sandy shores. The avifauna of the site includes 23 bird species listed in Annex I of the EU Birds Directive, and 23 regularly occurring migratory species (Game Fund 2005b).

Additionally, the site has been classified by BirdLife Cyprus as an 'Important Bird Area' as is considered among the three most important migration staging points and wintering sites in Cyprus for the Greater Sandplover and regularly holds 1% of the European flyway of this species (Table 3.25) (Iezekiel et al. 2004). The coastal strip is an important migration stop-over point for waders while the open grassland and low scrub on the headland is important for migrating passerines.

Table 3.25 Qualifying species for the classification of Kato Paphos Lighthouse Area as an Important Bird Area (Iezekiel et al. 2004).

Common name	Scientific name	Estimated Population	Status
Greater Sandplover	*Charadrius leschenaultii*	3-15 pairs	Passage migrant Winter visitor

3.5.2.5.7 Akamas Peninsula

Akamas Peninsula constitutes the westernmost edge of Cyprus, and is one of the most important areas for migratory birds (Flint and Stewart 1992, Iezekiel et al. 2004). The avifauna of the site includes at least 170 species. Among these, 55 are listed in Annex I of EU Birds Directive and 99 are regularly occurring migratory species. In addition there are another 16 important species, among them the endemic Cyprus Scops Owl (*Otus scops cyprius*). Importantly, the site is a breeding area for the largest population of Woodchat Shrike (*Lanius senator*) in Cyprus, also for the Bonelli's Eagle (*Hieraaetus fasciatus*), the Peregrine Falcon, and until 1990 the Griffon Vulture. Large populations of the endemic Cyprus warbler and Cyprus wheatear are also found here (LIFE 1998, Iezekiel et al. 2004).

According to Iezekiel et al. (2004), non-breeding populations of Eleonora's Falcon, the Mediterranean Shag and Audouin's Gull are present around Akamas Peninsula. However, there is no estimate of the populations of these species in this area. The coastal part of Akamas Peninsula is dotted with small islands, such as Geronisos Island, and rockly islets that may be used as breeding and/or roosting areas for the Mediterranean Shag and Audouin's Gull, and wintering areas for the Mediterranean Shag. However, a survey on Geronisos island has revealed only three common bird species nesting there: the Yellow-legged Gull (*Larus michahellis michahellis*), Eurasian Jackdaw (*Corvus monedula*) and Rock Dove (*Columbia livia)* (Blanchard 1992).

The north tip of Akamas (offshore) is the gathering point for a large number of raptors and egrets during autumn migration and may well be one of the best areas on the island where most of the heron and egret species of Cyprus can be seen (Gordon 2004, Richardson 2005, 2006, 2007, 2008, 2009). As a result, Akamas Peninsula has been classified by BirdLife Cyprus as an 'Important Bird Area' according to the qualifying species shown in Table 3.26 (Iezekiel et al. 2004).

Table 3.26 Qualifying species for the classification of Akamas Peninsula as an Important Bird Area (Iezekiel et al. 2004).

Common name	Scientific name	Estimated Population	Status

Squacco heron	*Ardeola ralloides*	100-250	Passage migrant
Little egret	*Egretta garzetta*	1000-1500	Passage migrant
Glossy ibis	*Plegadis falcinellus*	250-300	Passage migrant
Bee-eater	*Merops apiaster*	20,000-30,000	Passage migrant
Bonelli's Eagle	*Hieraaetus fasciatus*	1 pair	Resident breeder
Peregrine Falcon	*Falco peregrinus*	4-7 pairs	Resident breeder
Roller	*Coracias garrulus*	70 pairs	Migrant breeder
Cyprus warbler	*Sylvia melanothorax*	3,000-5,000 pairs	Resident breeder
13 species of raptors		3000-5800	Passage migrant

3.5.3 Future trends

Overall, there is sufficient data to define the distribution ranges of most species on the island. Some of the data is sufficient for the calculation of trends in some bird populations, e.g., data collected at wetland areas, and for two coastal species (Eleonora's Falcon, Griffon Vulture). However, few published records or studies exist presenting population sizes and trends.

While it is not possible to calculate future trends for the majority of bird populations, it is well known that many species, e.g. the Great White Pelican, Greater Flamingo and Eleonora's Falcon, are vulnerable to human disturbance. These species do not readily tolerate human proximity and favour areas guarded against disturbance by natural barriers, such as extensive reedbeds and water, or steep inaccessible cliffs. The Great White Pelican and Greater Flamingo are also intolerant of low-flying aircrafts and are known to collide with power lines and fences (Iezekiel et al. 2004). Flamingos collided with commercial aircraft at Larnaca airport after its expansion in 2008 and 2009.

Future building and tourism development in terrestrial coastal areas, which are already extensive in and around some of the SPAs, will pose a serious threat to the sites' integrity and will lead to further loss of habitat and increased disturbance to birds if they are unregulated. Domestic pets such as dogs and cats pose a serious predation risk for birds. In particular, potential wind farms, golf courses and marinas will pose unrecoverable negative impact as the site's quality and characteristics will be affected (LIFE 1998, Iezekiel et al. 2004). Moreover, some species are also threatened by illegal hunting, such as the Eleonora's Falcon, and bird trapping with lime-sticks and nets at Cape Greco (BirdLife Cyprus 2003, 2004, 2005, 2006, 2007, 2008, 2009).

Some issues also relate to particular species. The use of sandy beaches in areas frequented by the Greater Sandplover, for example, is not an issue when human activities take place in summer. A serious disturbance risk is posed by the uncontrolled use of the area by walkers in autumn, winter and spring, which is when the birds are present in the area, especially as many have dogs with them (Iezekiel et al. 2004). Another example is the Mediterranean Shag, which is generally threatened by competition with the Great Cormorant (*Phalacrocorax carbo*), which is larger, more numerous and widely distributed. It is also often mistaken for this particular species and accidentally persecuted, since the Great Cormorant is considered as a pest for fishing, particularly near fish farms (LIFE 1998, Iezekiel et al. 2004).

3.6 An inventory of the temporal occurrence, abundance and spatial distribution of nonindigenous, exotic species or, where relevant, genetically distinct forms of native species, which are present in the marine region or subregion

3.6.1 Introduction

Non-indigenous species (NIS) as defined by the EU funded project DAISIE (Stattersfield et al. 1998) are “species, subspecies or lower taxa introduced outside their natural range (past or present) and outside their natural dispersal potential. This includes any part, gamete or propagule of such species that might survive and subsequently reproduce. Their presence in the given region is due to intentional or unintentional introduction resulting from human activities, or they have arrived there without the help of people from an area in which they are alien”.

Additionally terms such as “exotic”, “alien”, “non-native” and “allocthonous” are synonyms of non-indigenous species (Zenetos et al. 2010) and are commonly utilized to describe NIS. Invasive alien species (IAS) “are a subset of established NIS and/or cryptogenic species (species of unknown origin which cannot be ascribed as being native or alien) which have spread, are spreading or have demonstrated their potential to spread elsewhere, and have an adverse effect on biological diversity, ecosystem functioning, socio-economic values and/or human health in invaded regions” (Olenin et al. 2010).

The Mediterranean and the Eastern Mediterranean Basin (EMB) in particular are one of the world’s most affected areas in terms of the numbers of NIS species detected (Costello et al. 2010) and the rate of introduction of new NIS (Zenetos 2010). An 82% of the biota introduced into the Eastern Mediterranean are of Indo-Pacific origin entering through the Suez Canal (EastMed 2010). The level of knowledge is deemed as substantial in the sub-region of the eastern Mediterranean although this does not apply equally to all regions and countries. The lack of research in Cyprus particularly in this area may have a direct effect on the numbers of recorded NIS.

The Mediterranean like other parts of the world is affected by alien marine invasions, brought about by the opening of the Suez Canal, fouling and ballast transportation along shipping lines, aquaculture and the aquarium trade (Streftaris et al. 2005, Galil 2009).

In Zenetos et al. (2010) a complete list (up to the time of publication) is given for all NIS in the Mediterranean. Furthermore, the Mediterranean is split into sub-regions as defined by EU Marine Strategy Framework Directive.

3.6.2 NIS in the Eastern Mediterranean

Based on this division, Cyprus lies in the Eastern Mediterranean Sea, which is made up of two water bodies: the Aegean Sea and the Levant Sea (and also the smaller Sea of Marmara). Eastern Mediterranean, due to its location to the crossroads of the Ponto-Caspian and the Indo-Pacific Ocean/Red Sea, is particularly influenced by a substantial and continual flow of marine NIS. Especially in the Levantine, the most important pathway of NIS introduction is the Suez Canal (a manmade corridor of unintentional introduction). The Suez Canal has been connecting the Mediterranean with the Red Sea and the Indo-Pacific Ocean since 1869, allowing the entrance of marine flora and fauna (vertebrates and invertebrates) species in the Mediterranean. Although at a global scale, shipping is considered as the most important vector for the transfer of NIS, in the case of the Eastern Mediterranean, shipping and intentional/unintentional mariculture transfers are far less important pathways compared to manmade corridors like the Suez Canal regarding the number of NIS introduced. It has been reported that more than 80% of marine exotics in the Eastern Mediterranean (fishes, decapod crustaceans and mollusks) have been introduced via the Suez Canal (e.g., Galil and Zenetos 2002). Lessepsian migrants (species passing through the Suez Canal into the Mediterranean) are particularly prevalent in the Eastern Mediterranean. The comprehensive report by Zenetos et al. (2010), gives an in depth view of the dynamics and the hydrological conditions that may attract NIS and allow settlement. Apart from the proximity to the Suez Canal, the dense shipping patterns in this area assist in particular the spread of macrophytes and bivalves.

3.6.3 NIS in Cyprus

Cyprus, due to its proximity to the Suez Canal, is highly susceptible to NIS and in particular Lessepsian immigrants. Katsanevakis et al. (2009) in collaboration with the Department of Fisheries and Marine Research of the Government of Cyprus carried out an inventory of alien marine species of Cyprus. In total, 126 alien marine species have been reported in Cyprus up to July 2009, 42 of which were molluscs, 28 fish, 19 polychaetes, 15 phytobenthic species, 12 crustaceans and 10 species from other taxa. Among these 80 are established (12 invasive), 31 are casual, 9 are cryptogenic and 6 are questionable (Katsanevakis et al. 2009).

3.6.3.1 Species Present

Table 3.27 lists all known alien marine species present in Cyprus waters, based on reports in Katsanevakis et al. (2009) and Zenetos et al. (2010).

Table 3.27 Alien marine species present in Cyprus waters.

SPECIES	YEAR OF FIRST RECORD	ESTABLISMENT SUCCESS	ORIGINAL REFERENCE
PHYTOBENTHOS/CHLOROPHYTA			
Caulerpa racemosa var. cylindracea (Sonder) Verlaque, Huisman & Boudouresque	1991	Invasive	Hadjichristophorou et al. (1997)
Caulerpa racemosa var. lamourouxii f. requienii (Montagne) Weber-van Bosse	1997	Casual	Verlaque et al. (2000)
Caulerpa racemosa var. turbinata/uvifera (J. Agardh) Eubank / (C. Agardh) J. Agardh	1992	Cryptogenic	Verlaque et al. (2000)
Cladophora cf patentiramea (Montagne) Kützing	1991	Casual	Argyrou (2000)
PHYTOBENTHOS/PHAEOPHYTA			
Stypopodium schimperi (Buchinger ex Kützing) Verlaque & Boudouresque	1990	Established	Verlaque and Boudouresque (1991)
PHYTOBENTHOS/RHODOPHYTA			
Acanthophora nayadiformis (Delile) Papenfuss	1997	Cryptogenic	Cirik et al. (2000)

Asparagopsis armata Harvey	1998	Casual	Cirik et al. (2000)
Chondria coerulescens (J. Agardh) Falkenberg	2008	Cryptogenic	Tsiamis (pers. obs.) in Katsanevakis et al. (2009)
Ganonema farinosum (J.V. Lamouroux) K.C. Fan & Yung C. Wang	1997	Cryptogenic	Cirik et al. (2000)
Lophocladia lallemandii (Montagne) F. Schmitz	1997	Established	Cirik et al. (2000)
Neosiphonia sphaerocarpa (B. rgesen) M.S. Kim & I.K. Lee	2008	Cryptogenic	Tsiamis (pers. obs.) in Katsanevakis et al. (2009)
Polysiphonia atlantica Kapraun & J.N. Norris	2008	Questionable	Taşkin et al. (2008)
Polysiphonia fucoides (Hudson) Greville	2008	Cryptogenic	Taşkin et al. (2008)
Womersleyella setacea (Hollenberg)	2008	Casual	Taşkin et al. (2008)
PHYTOBENTHOS/SPERMATOPHYTA			
Halophila stipulacea (Forsskal) Ascherson	1967	Established	Lipkin (1975)
PHYTOPLANKTON/ BACILLARIOPHYTA (DIATOMES)			
Pseudosolenia calvar-avis (Schultze, 1858)	1964	Established	Kimor and Berdugo (1967)
FORAMINIFERA			
Amphistegina lobifera (Larsen, 1976)	1976	Cryptogenic	Langer and Hottinger (2000)
CNIDARIA/SCYPHOZOA			
Cassiopeia andromeda (Forsski, 1775)	1903	Established	Maas (1903)
Rhopilema nomadica (Galil, 1990)	1995	Established	Galil (2006)
CNIDARIA/HYDROZOA			
Laodicea fijiana (Agassiz & Mayer, 1899)	1972	Questionable	Schmidt (1973) in Por (1978)
ANNELIDA			
Branchiomma bairdi (McIntsosh, 1885)	1998	Established	Çinar (2009)
Branchiomma luctuosum (Grube, 1869)	1998	Established	Çinar (2005)
Ceratonereis mirabilis (Kinberg, 1866)	1997	Established	Çinar (2005)
Eusyllis kupfferi (Langerhans, 1879)	1998	Established	Çinar and Ergen (2003)
Exogone (Parexogone) wolfi (San Martín, 1991)	2003	?	Çinar et al. (2003)
Hydroides dianthus (Verrill, 1873)	1997	Questionable	Ben-Eliahu and Payiatas (1999)
Hydroides elegans (Haswell, 1883)	1996	Established	Ben-Eliahu and Payiatas (1999)
Hydroides heterocerus (Grube, 1868)	1998	Established	Ben-Eliahu and Payiatas (1999)
Linopherus canariensis (Langerhans, 1881)	1997	Established	Çinar (2009)
Lysidice collaris (Grube, 1870)	1968	Questionable	Ben-Eliahu (1972)

Metasychis gotoi (Izuka, 1902)	1997	Established	Çinar (2005)
Neopseudocapitella brasiliensis (Rullier & Amoureux, 1979)	?	?	Zenetos et al. (2010)
Notomastus aberans (Day, 1957)	1997	Established	Çinar (2005)
Notomastus mossambicus (Thomassin, 1970)	1997	Established	Çinar (2005)
Oenone cf. fulgida (Savigny, 1818)	1997	Casual	Çinar (2005)
Pista unibranchia (Day, 1963)	1997	Established	Çinar (2005)
Pseudonereis anomala (Gravier, 1900)	1969	Invasive	Ben-Eliahu (1972)
Prosphaerosyllis longipapillata (Hartmann-Schröder, 1979)	1997	Casual	Çinar et al. (2003)
Spirobranchus tetraceros (Schmarda, 1861)	1996	Established	Ben-Eliahu and Payiatas (1999)
Spirorbis marioni (Caullery and Mesnil, 1997)	1998	Casual	Zibrowius (2002)
Terebella ehrenbergi (Grube, 1870)	1969	Questionable	Ben-Eliahu (1972)
CRUSTACEA/ISOPODA			
Apanthura sandalensis (Stebbing, 1900)	1998	Established	Zibrowius (pers. obs.) in Katsanevakis et al. (2009)
CRUSTACEA/ AMPHIPODA			
Linguimaera caesaris (Krapp-Schickel, 2003)	1997	Established	Kocatas et al. (2001)
CRUSTACEA/ DECAPODA			
Callinectes sapidus (Rathbun, 1896)	1964	Established	Demetropoulos and Neocleous (1969)
Charybdis helleri (A. Milne-Edwards, 1867)	1998	Invasive	Galil et al. (2002)
Charybdis longicollis (Leene, 1938)	1986	Established	Lewinsohn and Holthuis (1986)
Marsupenaeus japonicus (Bate, 1888)	1961	Established	Demetropoulos and Neocleous (1969)
Metapenaeopsis aegyptia (Galil & Golani, 1990)	2004	Established	Kirmitzoglou et al. (2006)
Metapenaeus monoceros (Fabricius, 1798)	1961	Established	Demetropoulos and Neocleous (1969)
Percnon gibbesi (H. Milne-Edwards, 1853)	?	?	Katsanevakis et al. (2011)
Pilumnopeus vauquelini (Audouin, 1826)	1963	Established	Galil (2006)
Portunus segnis (Forsskal, 1775)	1958	Established	Elton (1958)
Thalamita poissonii (Audouin, 1826)	1969	Cryptogenic	Gilate in Por (2007); Gitarakos et al. (2007)
CRUSTACEA/STOMATOPODA			
Erugosquilla massavensis (Kossmann, 1880)	1963	Established	Ingle (1963)
MOLLUSCS/GASTROPODA			
Acteocina mucronata (Philippi, 1849)	1992	Established	Cecalupo and Quadri (1996)
Alvania dorbignyi (Audouin, 1826)	1985	Cryptogenic	Bogi et al. (1989)

Aplysia dactylomela (Rang, 1828)	2004	Established	Yokes (2008)
Bulla arabica (Malaquias & Reid, 2008)	2000	Casual	Zenetos et al. (2004)
Cerithidium perparvulum (Watson, 1886)	1995	Casual	Cecalupo and Quadri (1995)
Cerithiopsis pulvis (Issel, 1869)	1985	Casual	Bogi et al. (1989); Cecalupo and Quadri (1996)
Cerithiopsis tenthrenois (Melvill, 1896)	1985	Established	Tornaritis (1987); Buzzuro and Greppi (1997)
Cerithium nesioticum (Pilsbry and Vanatta, 1906)	1985	Casual	Bogi et al. (1989); Buzzuro and Greppi (1997)
Cerithium scabridum (Philippi, 1848)	1983	Invasive	Fischer (1993); Cecalupo and Quadri (1996)
Chrysallida maia (Hornung & Mermod, 1924)	1995	Casual	Buzzuro and Greppi (1997)
Cingulina isseli (Tryon, 1886)	1998	Casual	Zenetos et al. (2004)
Conomurex persicus (Swainson, 1821)	1985	Invasive	Bazzocchi (1985)
Cycloscala hyalina (Sowerby, 1844)	1992	Casual	Cecalupo and Quadri (1994)
Cylichnina girardi (Audouin, 1826)	1996	Casual	Cecalupo and Quadri (1996)
Ergalatax junionae (Houart, 2008)	1993	Established	Buzzuro and Greppi (1997)
Finella pupoides (A. Adams, 1860)	1996	Established	Cecalupo and Quadri (1996)
Infundibulops erythraeus (Brocchi, 1821)	1985	Invasive	Tornaritis (1987)
Leucotina natalensis (Smith, 1910)	1996	Casual	Cecalupo and Quadri (1996); Buzzuro and Greppi (1997)
Melibe viridis (Kelaart, 1858)	2007	Casual	Sanchez Villarejo (2007)
Metaxia bacillum (Issel, 1869)	< 1995	Casual	Cecalupo and Quadri (1995)
Purpuradusta gracilis notata (Gill, 1858)	2000	Established	Zenetos et al. (2004)
Pyrunculus fourierii (Audouin, 1826)	1995	Casual	Buzzuro and Greppi (1997)
Rhinoclavis kochi (Philippi, 1848)	1976	Established	Demetropoulos and Hadjichristophorou (1976)
Rissoina bertholleti (Issel, 1985)	1869	Casual	Bogi et al. (1989)
Smaragdia souverbiana (Montrouzier, 1863)	1995	Casual	Buzzuro and Greppi (1997)
Sticteulima cf. lentiginosa (A. Adams, 1861)	1995	Casual	Buzzuro and Greppi (1997)
Syrnola fasciata (Jickeli, 1882)	1995	Casual	Nofroni and Tringali (1995)
Thais lacera (von Born, 1778)	1988	Casual	Houart (2001)
Turbonilla edgarii (Melvil, 1896)	1996	Casual	Cecalupo and Quadri

			(1996); Buzzuro and Greppi (1997)
Zafra savignyi (Moazzo, 1939)	1995	Established	Buzzuro and Greppi (1997)
Zafra selasphora (Melvill & Standen, 1901)	1995	Casual	Buzzuro and Greppi (1997)
MOLLUSCS /BIVALVIA			
Brachidontes pharaonis (Fischer P., 1870)	1960	Invasive	Mienis (pers. comm.) in Katsanevakis et al. (2009); Tornaritis (1987); Cecalupo and Quadri (1996)
Chama pacifica (Broderip, 1834)	1998	Established	Zenetos et al. (2004)
Dendostrea frons (Linnaeus, 1758)	2008	Established	Zenetos et al. (2009)
Fulvia fragilis (Forsskal in Niebuhr, 1775)	1983	Established	Fischer (1993)
Gafrarium pectinatum (Linnaeus, 1758)	2005	Established	Zenetos et al. (2009)
Malvufundus regula (Forsskal, 1775)	1970	Established	Demetropoulos (1971)
Paphia textile (Gmelin, 1791)	2004	Established	Zenetos et al. (2009)
Pinctada imbricata radiata (Leach, 1814)	1899	Invasive	Monterosato (1899)
Psammotreta praerupta (Salisbury, 1934)	2009	Casual	Zenetos et al. (2009)
Septifer forskali (Dunker, 1855)	2005	Established	Zenetos et al. (2009)
Spondylus spinosus (Schreibers, 1793)	2001	Established	Zenetos et al. (2009)
ECHINODERMATA/HOLOTHUROIDEA			
Synaptula reciprocans (Forssk l, 1775)	1986	Established	Cherbonnier (1986)
ECHINODERMATA/OPHIUROIDEA			
Ophiactis macrolepidota (Marktanner-Turneretscher, 1887)	<2002	Established	Zibrowius (2002)
SIPUNCULA			
Ophiactis savignyi (Müller & Troschel, 1842)	<2002	Established	Zibrowius (2002)
Phascolosoma scolops (Selenka & de Man, 1883)	1998	Established	Acik et al. (2005)
CHORDATA/ASCIDACEA			
Herdmania momus (Savigny 1816)	1998	Established	Nishikawa (2002)
FISH/OSTEICHTHYES			
Alepes djedaba (Forsskål, 177)	1964	Established	Demetropoulos and Neocleous (1969)
Atherinomorus forskalii (Róppell, 1838)	1929	Established	Norman (1929); Demetropoulos and Neocleous (1969)
Dussumieria elopsoides (Bleeker, 1849)	1985	Established	Whitehead (1985); Gitarakos et al. (2007)
Enchelycore anatina (Lowe, 1838)	2008	Casual	Ioannou and Michailidis, (pers. obs.) in Katsanevakis et al. (2009)

Equulites klunzingeri (Steindachner, 1898)	1961	Established	Fodera (1961)
Etrumeus teres (DeKay, 1848)	1999	Established	Golani (2000)
Fistularia commersonii (Rüppell, 1835)	1999	Invasive	Wirtz and Debelius (2003)
Hemiramphus far (Forsskal, 1775)	1964	Establish	Demetropoulos and Neocleous (1969)
Herklotsichthys punctatus (Rüppell, 1837)	1985	Casual	Whitehead (1985)
Himantura uarnak (Forsskal, 1775)	1994	Questionable	Last and Stevents (1994)
Lagocephalus sceleratus (Gmelin 1789)	2004 or 2006	Invasive	DFMR (2010); Katsanevakis et al. (2009); EastMed (2010)
Lagocephalus spadiceus (Richardson, 1844)	2006	Established	Ioannou and Michailidis, (pers. obs.) in Katsanevakis et al. (2009)
Lagocephalus suezensis (Richardson, 1844)	2007	Established	Ioannou and Michailidis, (pers. obs.) in Katsanevakis et al. (2009)
Parexocoetus mento (Richardson, 1844)	< 2002	Established	Golani (2000)
*Pempheris vanicolensis (*Cuvier 1831)	1995	Established	Torcu et al. (2001)
Pteragogus pelycus (Randall, 1981)	1997	Established	Kaya et al. (2000)
Sargocentron rubrum (Forsskål, 1775)	1961	Established	Fodera (1961)
Saurida undosquamis (Richardson, 1848)	1960	Established	Ben Tuvia (1961)
Scarus ghobban (Forsskål, 1775)	2010	Established	Ioannou et al. (2010)
Siganus luridus (Rüppell, 1829)	1964	Casual	Demetropoulos and Neocleous (1969)
Siganus rivulatus (Forsskal, 1775)	1928	Established	Norman (1929)
Sillago sihama (Forsskal, 1775)	2009	Invasive	Ioannou et al. (2010)
Sphoeroides pachygaster (Müller & Troschel, 1848)	2005	Invasive	Ioannou and Michailidis, (pers. obs.) in Katsanevakis et al. (2009)
Sphyraena chrysotaenia (Klunzinger, 1884)	1964	Casual	Demetropoulos and Neocleous (1969)
Stephanolepis diaspros (Fraser-Brunner, 1940)	1935	Established	Hornel (1935); Gitarakos et al. (2007)
Torquigener flavimaculosus (Hardy & Randall, 1983)	2009 / 2010	Established	Michailidis (2010)
Upeneus moluccensis (Bleeker, 1855)	1964	Casual	Demetropoulos and Neocleous (1969)
Upeneus pori (Ben-Tuvia & Golani, 1989)	2004	Established	Tzomos et al. (2007)

3.6.3.2 Commercially important NIS Species

For the last two decades in particular the fish population of the NIS *Siganus luridus* and *Siganus rivulatus* (DFMR Fisheries Statistical Reports 1995-2008) which are also deemed invasive (Katsanevakis et al. 2009), have been particularly highly exploited by the local coastal fishing fleet. Siganids appear to be invasive and compete with species such as *Salpa salpa*, which in some areas of Cyprus have become rare, and to a lesser extent species such as *Sparisoma cretense* (Bariche et al. 2004). These highly valued fish form the exception in Cyprus fisheries and have created a selective fishery by themselves.

3.6.3.3 Invasive Alien Species

Invasive alien species as defined by Olenin et al. (2010), are prevalent in Cyprus. Invasive species are considered to be the second most important cause for global biodiversity change (McNeely et al. 2001). Twelve invasive species are already considered established in Cyprus (Katsanevakis et al. 2009). Apart from *Trochus erithreus*, the other eleven species (*Caulerpa racemosa var. cylindracea*, *Cerithium scabridum*, *Strombus persicus*, *Brachidontes pharaonis*, *Pinctada radiata*, *Pseudonereis anomala*, *Charybdis helleri*, *Fistularia commersonii*, *Lagocephalus sceleratus*, *Siganus luridus*, and *Siganus rivulatus*) are included in the list of the 100 “Worst Invasives” in the Mediterranean (Streftaris and Zenetos 2006).

3.6.3.3.1 Lagocephalus sceleratus

This NIS is without question the most recent invasive species with substantial economic impacts on the artisanal fishery in Cyprus. According to the Department of Fisheries and Marine Research of Cyprus, *L. sceleratus* accounted for 4% of the landings (by weight) of the artisanal fishery in 2010 (EastMed 2010). The species is caught as by-catch mainly on set trammelnets, gillnets and longlines and is known to cause considerable damage to the gear and the catch of fishermen (EastMed 2010).

L. sceleratus is a relatively recent species which has managed to acclimatize and become established in a short period with remarkable success. First recorded in 2006, and although it has spread throughout the island, it is particularly prevalent in three areas of the island where areas of *Posidonia oceanica* seagrass meadows occur in high abundance. Most catches occur in depths less than 50 m, which is a major activity area for the coastal fishery. The species has no known predators and is highly adaptable regarding feeding preferences although it does tend to prefer fish and cephalopods thus having an even greater impact on the commercial artisanal fishing sector.

3.6.3.3.2 Fistularia commersonii

F. commersonii is also a relatively recent arrival to Cyprus waters, first detected in 1999 (Wirtz and Debelius 2003). This species is an avid piscivore with a appetite for commercially important fish (Kalogirou et al. 2007). Although this species has not been specifically studied in Cyprus, it is become highly abundant in artisanal catches and does not have an important commercial value. The impact of *F. commersonii* is not directly apparent and therefore is probably underestimated since it is deemed to have a significant effect on native ichthyofauna (Katsanevakis et al. 2009).

3.6.3.3.3 Caulerpa racemosa

The alga develops on various types of substrata, both soft and hard bottom, both in polluted and unpolluted areas, down to 60 m depth in Cyprus (Argyrou et al. 1999a, Argyrou and Hadjichristophorou 2000). Furthermore, it has been thought to cause changes to the vegetation system as well as changes in macrofaunal assemblages (Argyrou et al. 1999a). It additionally has colonized “empty niches” where there is no surface algal or other growth in deep and shallow waters. The low nutrient environment of deeper, stable substrate environments around Cyprus appears to be available to colonization by *C. racemosa*. According to Argyrou et al. (1999a), it was suggested that the alga may compete with native algal species, but this remains to be researched further. Possible consequences of the *C. racemosa* invasion event include modifications of physical and chemical conditions (water movement, sediment deposition, substrate characteristics) and the underwater landscape, as well as profound modifications of benthic assemblages (Klein and Verlaque 2008).

3.6.3.4 Pest NIS

Cladophora cf *patentiramea*

Since 1990, sporadic eutrophication events involving *Cladophora* spp. have occurred resulting in mass aggregates of free – floating filaments in coastal areas of the island causing ‘nuisance blooms’ and affecting the tourism industry (Argyrou 2000). These have been related to nutrient inputs from anthropogenic sources (Argyrou 2000).

3.6.3.5 Spatial distribution

The distribution of most NIS is island wide and no information is available on particular areas of aggregation. Fisheries activities regarding the *Siganus* fishery tend to concentrate in the southeast and northwest of the island. These are areas with extensive *Posidonia oceanica* meadows as well as very transparent, oligotrophic and higher-temperature water masses.

3.6.4 Future trends

It is expected that the numbers of NIS will increase, as there are already indications of this trend although this may be masked by more intense scientific interest (Zenetos et al. 2010). The commercialization of more NIS especially of Lessepsian origin is a trend that is already visibly taking place in the Levantine basin and is expected to take place in Cyprus to a greater extent in the near future. Impacts at both ecosystem level as well as on the commercial and tourist sectors of the island are expected to increase with the future arrival and establishment of NIS.

4. References

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REPUBLIC OF CYPRUS

MINISTRY OF AGRICULTURE, NATURAL RESOURCES, AND THE ENVIRONMENT

DEPARTMENT OF FISHERIES AND MARINE RESEARCH

Initial Assessment of the Marine Environment of Cyprus

Part II – Pressures and Impacts

Nicosia, Cyprus
July 2012

Implementation of Article 8
of the Marine Strategy Framework-Directive (2008/56/EC)

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Foreward

This report was prepared by a consortium consisting of AP Marine (Cyprus), the Fisheries Research Institute of the Hellenic Agricultural Organization - Demeter (Greece), and independent experts.

The consortium undertook the authorship of three reports in the framework of the implementation of Articles 8, 9, 10 and 19 (par. 2a and 2b) of the Marine Strategy Framework Directive (2008/56/EC) on behalf of the Department of Fisheries and Marine Research (DFMR) of the Republic of Cyprus, under contract 12/2011. The three reports are: an Initial Assessment of the marine environment of Cyprus, a report on the Determination of Good Environmental Status, and a report on Environmental Targets.

This volume consists of Part II of the Initial Assessment and describes the Pressures and Impacts on the marine environment of Cyprus. There are two other volumes corresponding to the other two Parts of the Initial Assessment: Part I - Characteristics, and Part III – Social and Economic Parameters.

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The following Project Team members contributed to the present report as follows:

Petrou	Introduction of non-indigenous species
Kallianiotis	Selective species extraction
Hannides	Physical damage, interference with hydrological processes, nutrient and organic matter input, introduction of microbial pathogens
Loizidou	Physical loss, physical damage
Scarcella	Selective species extraction
Stamatis	Underwater noise, marine litter, contamination by hazardous substances
Vidoris	Selective species extraction

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Marina Argyrou	DFMR, Head of Marine Environment Division
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1. Physical loss

1.1 Introduction

1.1.1 Coastal pressures and impacts

In order to estimate the real pressure that the coastal areas of Cyprus accept by coastal structures, Cyprus was divided in12 littoral cells (Figure 1.1), as per the suggestions and methodology that was implemented throughout the study "Coastal Zone Management for Cyprus" (1993-1996, Delft Hydraulics – Public Works Department; Delft Hydraulics 1996).

Figure 1.1 The boundaries of the 12 littoral cells used in the estimation of pressures in coastal areas.

The pressure can be estimated in two ways, that serves the needs of the implementation of the MSFD:

a) As the percentage of coastal length that has infrastructure. This is the method that is mainly used by coastal experts e.g. by EUROSION project (2004) and by the UNEP/MAP 2006 report on the state of Mediterranean coasts.

b) The area covered by coastal structures: this is the area within a port, a marina or a fishing shelter and the area under coastal structures such breakwaters, groyns etc. This numbers give us the sealing of coastal area by coastal structures.

These data and computations are described below per littoral cell. Google maps from the most important spots of each littoral cell are also shown.

1.1.1.1 Coastal section 1: Tilliria

Coastal length: 18 km

Number/kind of structures:
- 5 groyns: total length 250 m, covered area 375 m^2
- 2 Fishing shelters: total length 530 m, covered area 27000 m^2

Density of structures: The density of coastal structures in this area is app. 4%. However, all coastal structures in Tilliria area are concentrated in Kato Pyrgos Bay (Figure 1.2, Figure 1.3), apart from the fishing shelter in Pomos. The bay has a total coastline length of 2940 m and accommodates 600 meters of coastal structures, i.e. the density of coastal structures within Kato Pyrgos Bay is approximately 20,40%. A new project is under construction in Kato Pyrgos Bay: the existing groyns are going to be replaced with a series of offshore breakwaters. So, the situation in this coastal area is expected to change within the next months.

Sealing: 780 meters of coastal structures exist in this coastal area. 27375 m^2 of seabed is covered by coastal structures.

1.1.1.2 Coastal section 2: Chrysochou Bay

Coastal length: 41,1 km

Number/ kind of structures:
- 4 offshore, detached breakwaters: total length 400 m, cover area 7200 m^2
- Fishing shelter: total length 660 m, covered area 61500 m^2
- Revetment: 200 m, covered area 2000 m^2

Density: Total density of coastal structures in Chrysohou Bay is app. 3%. However, 850 m of structures are concentrated within 2870 m of coastline, in the coastal area of Latsi (Figure 1.4), so local density is approximately 29,61%. The plan is to proceed with the construction of 16 more offshore breakwaters. So, the data will change soon.

Sealing: 1260 meters of coastal structures exist in this area. 70700 m^2 are covered by coastal structures.

1.1.1.3 Coastal section 3: Akamas

Coastal length: 35,7 km

Number/ kind of structures:
- Fishing shelter (St Georgios of Peyia): total length 200 m, covered area 17500 m^2

Density: The total length of coastal structures is 200 m (Figure 1.5), which refers only to the breakwaters of the fishing shelter. The density of coastal structures in this entire area is near 0.

Sealing: the fishing shelter covers an area of app. 17500 m^2.

1.1.1.4 Coastal section 4: Pafos North

Coastal length: 25,4 km

Number/ kind of structures:

- Seven offshore, detached breakwaters: total length 700 m, covered area 12600 m^2
- Fishing shelter (Laourou/ Coral Beach Hotel, Figure 1.6): total length 190 m, cover area 10350 m^2

Density: The length of coastal structures is 890 m. The new Pafos Marina is located at Potima Bay. The negotiations for the construction of this Marina are not yet completed, so it is not confirmed if the Marina is going to be constructed at all. The density of coastal structures in this area is 3,5% (890 m of structures in 25,4 km).

Sealing: 22950 m^2.

1.1.1.5 Coastal section 5: Pafos South

Coastal length: 34,9 km

Number/ kind of structures:

- Nine offshore, detached breakwaters: total length 1100 m, covered area 19800 m^2
- Eight groyns: total length 400 m, 600 m^2
- Coastal walls: 1,5 km
- One harbour: total length 700 m, 51600 m^2

Density: The length of coastal structures is 3700 m, i.e., the density in 34,9 km is app. 10,6% (Figure 1.7, Figure 1.8). However 90% of those structures are concentrated within a distance of 5,23 km. The density of coastal structures in this section is 2200 m of structures in 5229 m of coastline, i.e., 42,07%.

Sealing: app. 72000 m^2.

1.1.1.6 Coastal section 6: Episkopi Bay

Coastal length: 31,2 km

Number/ kind of structures:

- Fishing shelter (Happy Valley): total length 130 m, cover area 3000 m
- A sand trap infrastructure (no more in operation) near Apollo Helates temple, that had a length of 1,44 km, 121000 m^2.

Density: The density of coastal structures in this section is 1570 m of structures in 4300 m of coastline, i.e., 34,8% (Figure 1.9).

1.1.1.7 Coastal section 7: Cape Gata

Coastal length: 10,4 km

Number/ kind of structures:

No coastal structures

1.1.1.8 Coastal section 8: Limassol

Coastal length: 36,5 km

Number/ kind of structures:

- Seventy (70) offshore, detached breakwaters: total length 7000 m, covered area 12600 m^2
- Thirty one (31) groynes: total length 1550 m, covered area 2325 m^2
- Two (2) marinas (New Marina Figure 1.11, St Rafael Figure 1.13): total length 2,448 km, 279050 m^2 .
- Harbour (Figure 1.10): total length 3760 m. Harbor covered area/surface:1053400 m^2.
- 3 Fishing shelters (Moni, Akrotiri harbor and old harbor): total length 970 m, cover area 51350 m^2

Density: The length of coastal structures is 15728 m. However the 10000 m of those structures are concentrated within an area of 13 km (Figure 1.12). The density of coastal structures in this area is 10,02 km of structures in 19,960 km of coastline (approx. 50,2%).

Sealing: 1,512,125 m^2.

1.1.1.9 Coastal section 9: Zygi-Kiti

Coastal length: 36 km

Number/ kind of structures:
- Seventeen (17) offshore, detached breakwaters: total length 1700 m, covered area 30600 m^2
- Four (4) groynes: total length 400 m, covered area 600 m^2
- Four (4) shelters (Vasiliko harbor and 3 smaller shelters): 2,52 km. Covered area/ surface 218600 m^2 (113850, 67150, 9100 and 28500 m^2).
- 2 Fishing shelters (Vasiliko, Alaminos): total length 680 m, cover area 9750 m^2
- Marina (Zygi): total length 0,760 km, 47300 m^2.

Density: Total length of coastal structures 6060 m. The density of coastal structures in this area is 19% (Figure 1.14).

Sealing: 306850 m^2

1.1.1.10 Coastal section 10: Larnaka

Coastal length: 39,1 km

Number/ kind of structures:
- Twentyfour (24) offshore, detached breakwaters: total length 2400 m, covered area 43200 m^2
- Nineteen (19) groynes: total length 950 m, covered area 1425 m^2
- One (1) marina: 650 m, covered area 102900 m^2
- One (1) harbour: total length 1810 m, covered area 235000 m^2
- Five (5) shelters: 1,1 m, covered area 43700 m^2

Density: Total length of coastal structures:6,910 km. The density of coastal structures in this area is appr. 15%. Most of the structures are concentrated in an area of 22,6 km length, starting from the town of Larnaka towards Pyla- Oroklini beach. i.e. the density of coastal structures in this area is approximately 23 % (Figure 1.15, Figure 1.16, Figure 1.17).

Sealing: Total area covered by coastal structures 426225 m^2.

1.1.1.11 Coastal section 11: Dekelia – Ayia Napa

Coastal length: 33,7 km

Number/ kind of structures:

- Two (2) shelters: total length 600 m

Density: There are no coastal structures in this area apart from the two shelters (Ayia Napa, Figure 1.18, and Ayia Thekla). The density of the structures for the protection of the shelters in this area is app 2%.

Sealing: Area/ surface covered in shelters: 16250 m^2.

1.1.1.12 Coastal section 12: Protaras

Coastal length: 20,3 km

Number/ kind of structures:
- Five (5) offshore, detached breakwaters: total length 500 m, covered area 9000 m^2
- Two (2) shelters: total length 340 m, covered area 12450 m^2

Density: Total coast length 840 m. The density of coastal structures in this area is approximately 5% Figure 1.19.

Sealing: 21450 m^2.

1.1.2 Open sea pressures and impacts

The two activities of interest in terms of physical losses and damages are bottom trawling, which is partly regulated, and the exploration and exploitation of marine hydrocarbon reserves. These two activities are discussed in section 2.3 (Selective extraction).

1.2 Smothering

Smothering is defined as *covering the natural seabed habitat with a layer of material which, under some circumstances, might be expected to disperse*. This pressure is not one expected to occur due to coastal structures. Damping of sediments is the major reason for smothering.

1.3 Sealing

Sealing is defined as the permanent structures fixed on the seabed. The sealing due to the coastal structures is estimated for each of the littoral cells. **Total area of sealing in the 12 littoral cells caused by coastal structures is 2617425 m^2.** This is the area covered by the coastal structures (breakwaters, groyns, revetments etc), the harbours and the fishing shelters.

For reasons of having an estimate of the percentage of the coastal area that is subject to sealing, we deliberately defined a zone of 100 meters width, starting from the coastline and seawards (this is very obvious in photograph 1.17). For the entire coastal length of the 12 littoral cells (362,33 km), the surface of this strip of 100 meters width is 36,23 km^2.

Thus, 7,2 % of the coastal area of Cyprus is subject to sealing due to coastal structures and harbors/shelters, for a coastal strip of 100 metered width (seawards).

It is interesting to see that 1,51 km^2 of sealed seabed, i.e. the 57,6% of total coastal surface that is under sealing, are located in Limassol area. The big harbor, the new Marina, the old Marina of St Raphael and the series of coastal structures make Limassol coastal area an area of high density and highly sealed seabed.

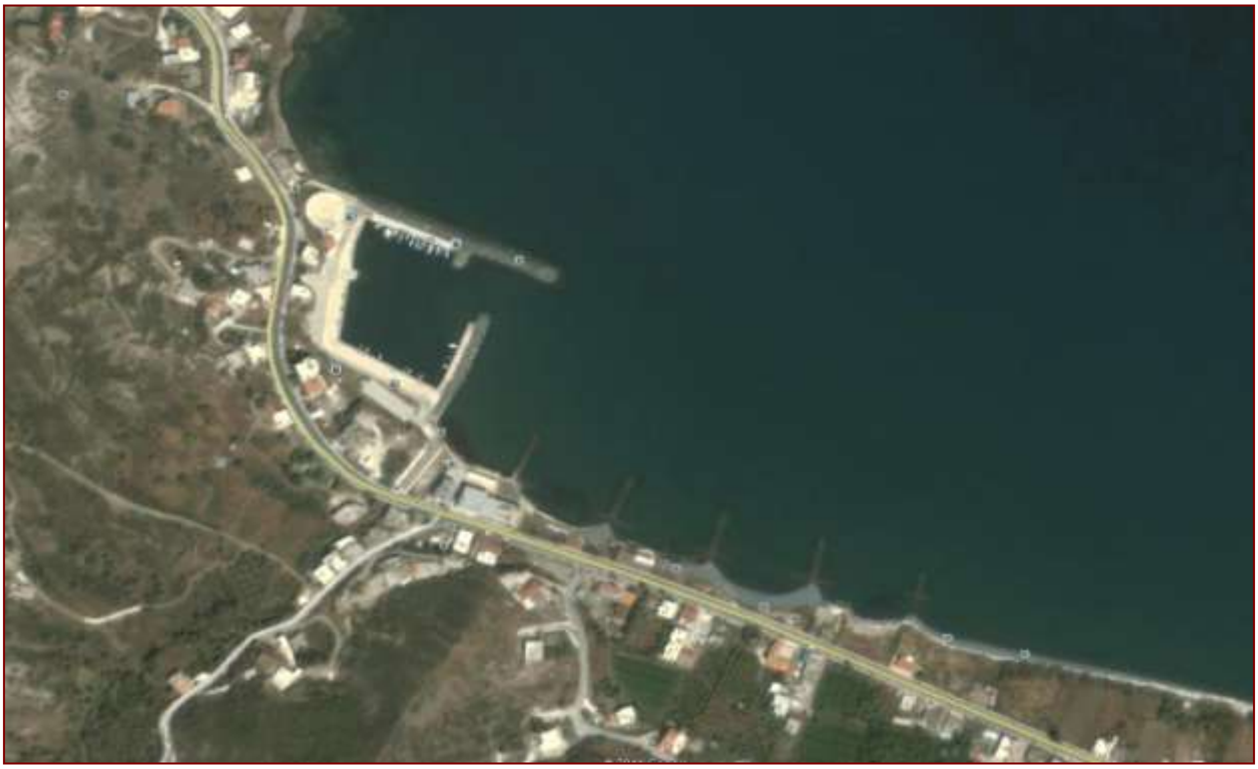


Figure 1.2 Kato Pyrgos Bay, coastal area 1: Tilliria.

Figure 1.3 Pomos, coastal area 1: Tilliria.

Figure 1.4 Latsi Fishing shelter, coastal area 2: Chrysochou Bay

Figure 1.5 St George fishing shelter, coastal area 3: Akamas

Figure 1.6 Laourou Bay, coastal area 4: Pafos N

Figure 1.7 Kato Pafos, coastal area 5: Pafos S

Figure 1.8 Part of Geroskipou coastal area coastal area 5: Pafos S

Figure 1.9 British Military Bases, coastal area 6: Episkopi Bay

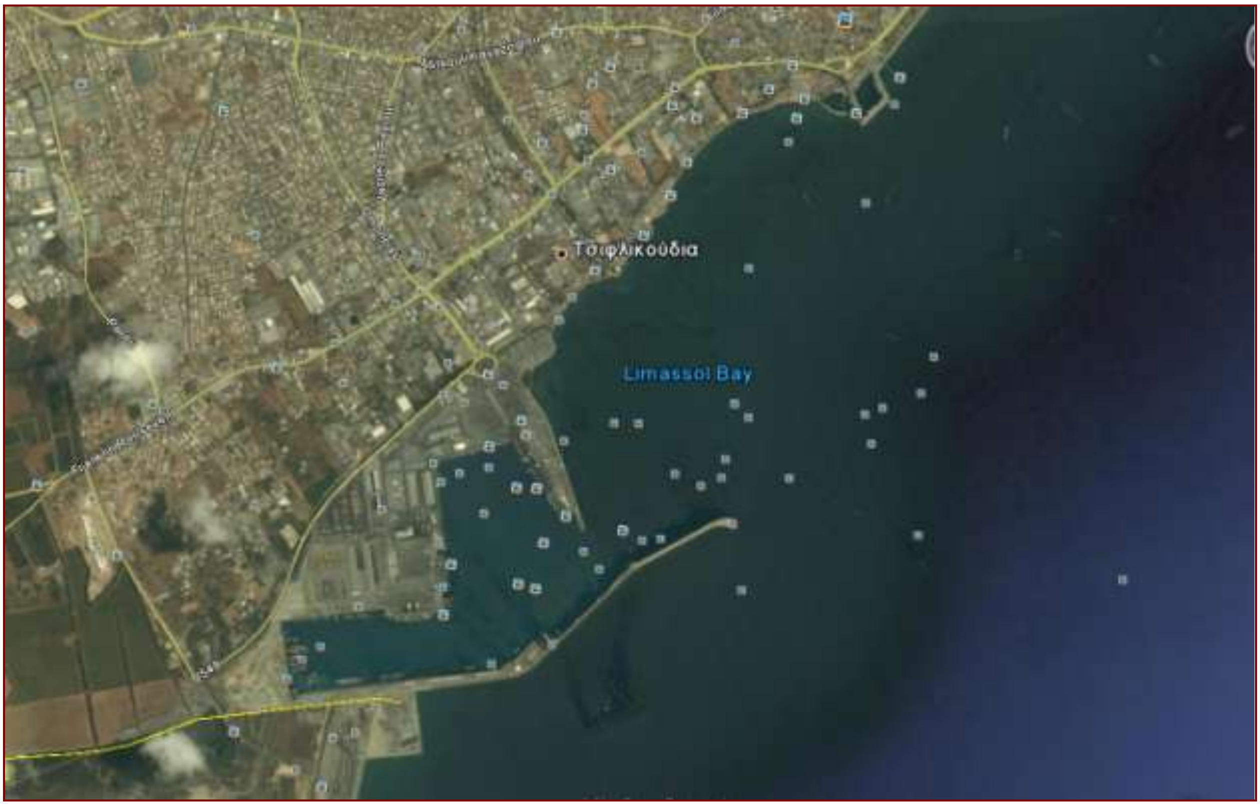


Figure 1.10 New and Old harbors, coastal area 8: Limassol

Figure 1.11 The New Limassol Marina (this is a prediction, the Marina is still under construction), coastal area 8: Limassol

Figure 1.12 Part of the coast of Limassol, coastal area 8: Limassol

Figure 1.13 St Raphael Marina, coastal area 8: Limassol

Figure 1.14 Alaminos area, coastal area 9: Zygi-Kiti

Figure 1.15 Mackenzie beach, coastal area 10: Larnaka

Figure 1.16 Larnaka marina and harbor, coastal area 10: Larnaka

Figure 1.17 Pyla – Oroklini beach, coastal area 10: Larnaka

Figure 1.18 Ayia Napa harbor, coastal area 11: Dekelia – Ayia Napa

Figure 1.19 Golden Coast area, coastal area 12: Protaras

2. Physical damage

2.1 Changes in siltation

Siltation is the deposition or accumulation of unconsolidated or loose sedimentary material whose constituent rock particles are finer than grains of sand and larger than clay particles. In coastal areas, siltation exists in the areas in front of the offshore breakwaters (from the offshore structures to the coast) and upstream/ downstream of groyns: these are areas of accumulation of sediments. Also, the areas covered by harbors and fishing shelters are areas of high siltation.

The siltation areas have been estimated as follows:

1. The total length of coastal structures (minus the length of harbors) is 19,05 km. Most of these structures are constructed within a distance of 100 from the coastline.
    a. assume that there is siltation in the entire area in front of the breakwaters
    b. assume there is siltation in an area equal to their length upstream/ downstream of the groyns,

    then the total area under siltation around Cyprus due to coastal structures is 1,905 km^2.

2. The total are of siltation due to harbors, marinas, fishing shelters and sand traps is 1,143 km^2, which coincides with the area that is sealed due to these structures.

So, the total area under siltation around Cyprus is 3,093 km^2.

In order to have an estimate of the percentage of the coastal area that is subject to siltation, a zone of 100 m width, starting from the coastline and seawards has been deliberately defined, as already described in section 1.3 (Sealing). The surface of this coastal strip of 100 meters width is 36,23 km^2.

Thus, 8,54% of the coastal strip of 100 m width is under siltation due to coastal structures and harbors/shelters.

2.2 Abrasion

Abrasion is defined as *the scouring and ploughing of the seabed.* Coastal structures do not have this impact on the seabed, so this is a pressure not responding to coastal structures impacts.

2.3 Selective extraction

Currently, legislation prohibits the use of any bottom trawling gear to depths shallower than 50 m (Fisheries Laws and Regulations). Moreover, EU Council Regulation No. 734/2008 prohibits bottom-fishing activities in areas harboring vulnerable habitats, such as the Eratosthenes seamount. Bottom trawling is perhaps the single most-likely-to-occur activity of exploitation of living seafloor resources, and the above protection measures contain the range over which it occurs in Cyprus waters. At this point, the extent to which bottom trawling takes place in Cyprus waters is unknown.

The single most important activity of exploration and exploitation of geological (i.e., non-living) seafloor resources in the Cyprus sea involves marine hydrocarbon reserves. After a Strategic Environmental Assessment of what such activities would entail in terms of risks involved (MCS et al. 2008), exploration drilling has recently begun in Block 12, on the southeast margin of the Cyprus EEZ, on the boundary with the Israeli EEZ, at a distance of 160 km from Cyprus' shores and 30 km from Eratosthenes seamount, at an approximate depth of 1700 m (CSA International 2011).

It is not possible to give a quantitative estimate of the physical damage of hydrocarbon exploration and extraction, since the numbers of drilling platforms established and wells drilled is not known. However, in terms of physical damage to the seafloor, two aspects of exploratory and exploitative drilling merit discussion in this section: anchoring/mooring of drilling rigs, and the discharge of drill cuttings (i.e., rock fragments removed during drilling).

Anchoring/mooring a drilling rig may bring about abrasion due to setting and dragging of weights and chains, siltation and smothering due to suspension of sediments, and ultimately sealing of sediments under the anchoring/mooring gear. Typical coverage of the all the area affected by the anchoring/mooring operation will depend on the drilling rig and consequently the mooring system used and is therefore currently unknown. Based on the information available regarding ongoing exploratory drilling, the area impacted by anchors and chains will be approximately 0.5 km^2 (CSA International 2011).

According to available information regarding exploratory drilling occurring at present, drill holes at the seafloor surface are 36 inches in diameter, and it is anticipated that during the drilling of a single exploratory well 870 m^3 of cuttings will be discharged: initially 350 m^3 will be released directly at the seabed, and another 520 m^3 will be released at a later stage from sea surface level (CSA International 2011). While it is not possible to estimate the area over which these cuttings will disperse, empirical observations from other areas of similar drilling activity suggest that distances up to 500 m away from the drilling point (or areas of 0.8 km^2) exhibit patchiness in epibiotic cover, and seafloor texture (MCS et al. 2008).

Specifically, abrasion will cause the removal of existing epifauna and bring about the reorganization of benthic communities on the newly exposed seafloor. Increased siltation caused by the deposition of the cuttings will cause smothering of existing epifauna, a shift from aerobic or suboxic microbiota to anoxic and perhaps chemosynthetic microbiota, and colonization by opportunistic species. Sealing will prevent the oxygenation of underlying sediments resulting in the exclusion of aerobic organisms, including microbiota. Currently, there are only plans to drill in soft sediments away from Eratosthenes seamount, which could possibly be hosting important hard-substrate deep-sea coral and sponge communities (Galil and Zibrowius 1998, Mayer et al. 2011).

3. Other physical disturbance

3.1 Underwater noise

3.1.1 Introduction

According to Hildebrand (2004), sources of anthropogenic noise are becoming more pervasive increasing both sea background sound and peak intensity levels (Figure 3.1). In general, ambient noise in the sea has increased over the past 50 years. Main contributors to anthropogenic ambient noise are commercial shipping, defense-related activities, petroleum and natural gas exploration and development, research activities and recreational activities. Sound is an extremely efficient way to propagate energy through the sea, and marine mammals have evolved to exploit its potential.

3.1.1.1 Natural sound in the marine environment

The natural sound in the marine environment is caused mainly from the sources such as: wind, sea state and swell patterns, bubble distributions, currents and turbulence, seismic activity, precipitation and marine life.

3.1.1.2 Anthropogenic sound in the marine environment

Anthropogenic sound in the sea is an important component of the total sea sound background and may vary in space and time, but may be grouped into the following categories: (a) large commercial ships, (b) seismic exploration devices, (c) sonars, (d) acoustic harassment devices and pingers, (e) offshore drilling implements, (f) research sound sources, and (g) small ships.

<u>Commercial Shipping</u>: Commercial shipping is the major contributor to noise in the seas. Ships generate noise primarily by (a) propeller action, (b) propulsion machinery, and (c) hydraulic flow over the hull. Furthermore, ship noise results from diesel engines and generators or gears. Small vessels do not contribute significantly to the eastern Mediterranean acoustic environment, but may be important local sound sources. Major ports of Cyprus handle the majority of the traffic, but in addition many of small harbors and ports host smaller volumes of traffic. Vessels found in areas outside major shipping lanes include fishing vessels, military ships, scientific research ships, and recreational craft – the last typically found near shore.

<u>Seismic Exploration</u>: Seismic reflection is the primary technique used by the energy industry for finding and monitoring reserves of petroleum and natural gas. Airguns release a specified volume of air under high pressure, creating a sound pressure wave from the expansion and contraction of the released air bubble. Offshore petroleum and gas exploration and construction activities occur along continental margins. Currently active areas include also Cyprus offshore gas exploration installations.

<u>Sonar:</u> Sonar creates sound to probe the sea, seeking information about objects within the water column, bottom, or sediment. Active sonar emits acoustic energy and receives reflected and/or scattered energy. A wide range of sonar systems are in use for both civilian and military applications. Commercial sonars are designed for fish finding, depth sounding,

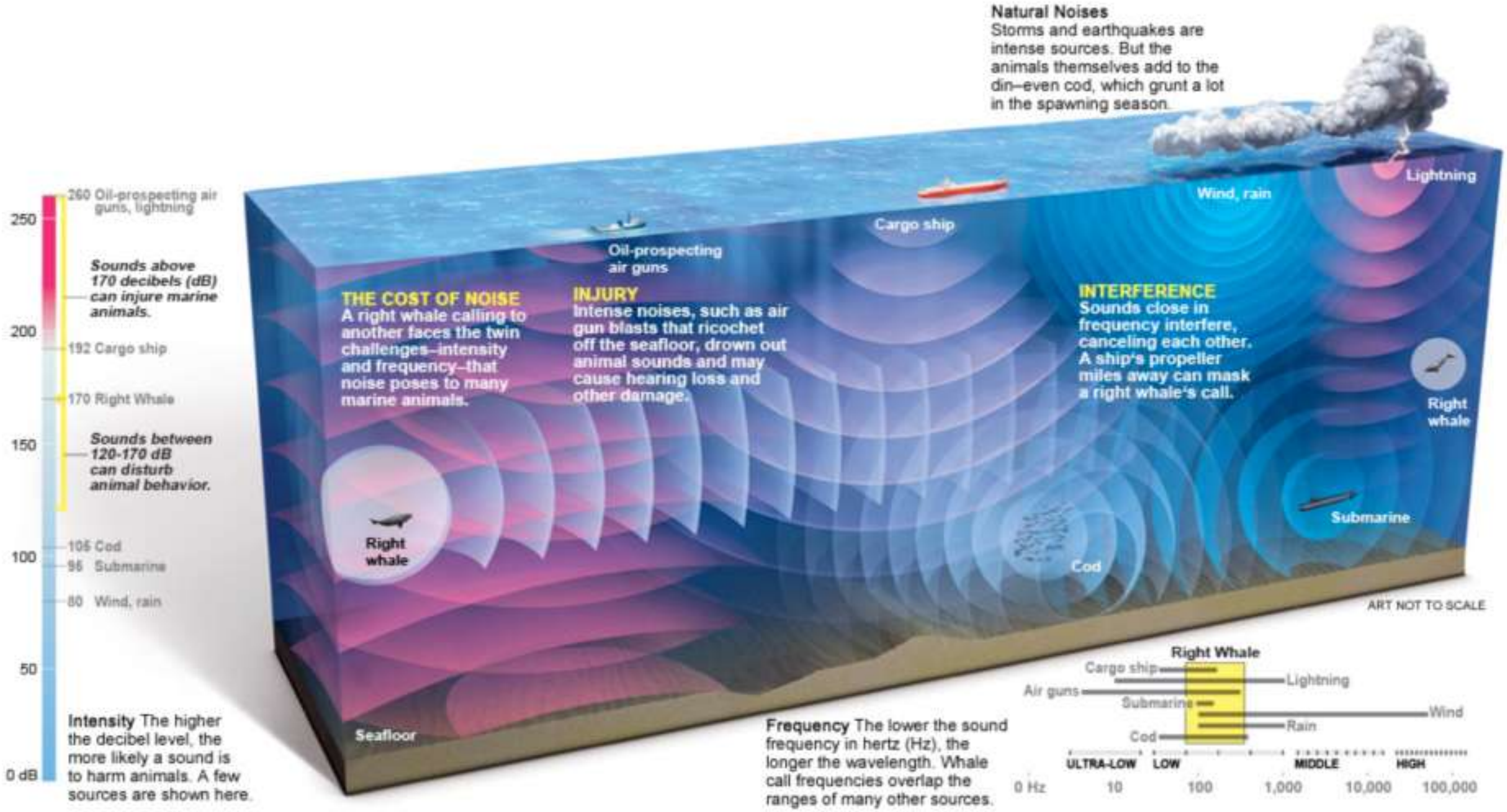


Figure 3.1 A rising tide of anthropogenic sound is disrupting the lives of marine mammals (adapted from: http://ngm.nationalgeographic.com/2011/01/big-idea/noisy-ocean).

and sub-bottom profiling. Commercial depth sounders and fish finders are typically designed to focus sound into a downward beam. Depth sounders and sub-bottom profilers are operated primarily in near shore and shallow environments, however, fish finders are operated in both deep and shallow areas.

<u>Acoustic Deterrent Devices</u>: Acoustic deterrent devices use sound in an effort to repel marine mammals from fisheries activities. Pingers are used in some fisheries also to reduce the by-catch of marine mammals.

<u>Explosions:</u> Chemical explosions are portable and easily conducted in a sea setting. They have been used for sea research, for construction, and for military testing. In the past, chemical explosions were commonly used for marine seismic exploration, but they have been replaced by airgun arrays that provide a more reliable source signature. Chemical explosions continue to be used in the construction and removal of undersea structures, primarily by the oil industry.

<u>Industrial Activities and Construction:</u> Industrial activities and construction both in the open sea and along the shoreline can contribute to underwater noise. Examples include coastal power plants, pile driving, dredging, tunnel boring, power-generating windmills, and canal lock operations (Green and Moore 1995). Petroleum and gas activities that generate marine noise include drilling, offshore structure emplacement - removal and production.

3.1.2 Existing data, status and further trends

Based on data drown from the study with the title “Strategic Environmental Assessment (SEA) Concerning Hydrocarbon Activities within the Exclusive Economic Zone of the Republic of Cyprus” (MCS et al. 2008), the most likely sources of ambient noise across the Cyprus marine waters are (1) local shipping, (2) distant shipping and (3) industrial noise. Cyprus marine environment comprises deep offshore waters in which the dominant noise source will be distant shipping in the absence of wind and precipitation. It is also anticipated that under the right conditions, industrial noise (from existing and future offshore natural gas production installations) could increase in the region. Due to the fact that in Cyprus data on sea noise trends are no publicly and informed estimates suggest noise has increased significantly during the past few decades (for example the expanding use of the sea for commercial shipping, the offshore natural gas production installations and the advanced warfare have resulted in noise levels are at least 10 times higher today than they were a few decades ago), without some effort to monitor, reduce or at least cap these noise levels, they are likely to increase and further degrade the acoustic environment of marine mammals.

3.2 Marine litter

3.2.1 Introduction

According to the U.S. National Oceanic and Atmospheric Administration (2008) but also in general, marine litter can injure and kill marine wildlife, degrade sea habitats, interfere with navigation safety, cause economic loss to shipping, fishing, and coastal communities, and pose a threat to human health. These adverse impacts have been documented all over the Mediterranean Sea. From fishing nets to medical equipment and to food packaging, many man-made persistent objects play key roles in supporting the economy and protecting human health. As consumption and use of these objects increases globally, the challenge of containing and properly managing them becomes even greater, regardless of whether these materials enter the marine environment directly from activities on the water or indirectly from activities on land.

3.2.1.1 Sources of marine litter

People and their actions are the source of most marine litter, which originates from two sources:

(1) actions in the marine environment, for example: merchant shipping, ferries and cruise liners, fishing-, public- or private vessels; offshore petroleum or/and gas platforms, drilling rigs, aquaculture installations, natural events, and

(2) land-based actions, for example: municipal landfills, litter and waste transport, storm water discharge, industrial and manufacturing litter and waste, natural events.

The growth in coastal population has also required expansion of waste repositories such as landfills and transfer stations. Overused and poorly managed landfill can result in increased marine litter. Industrial facilities and by-products from production, particularly persistent synthetic materials such as plastics are another source of land-based marine litter. Natural events such as floods and storms can create large amounts of litter washed from near-shore areas that may end up in the marine environment. Fishing vessels may introduce marine litter into the sea environment when items such as nets, traps, monofilament, lines, light sticks, and floats are lost or discarded at sea (Figure 3.2). Derelict fishing gear either lost at sea or improperly disposed of by fishing vessels is of particular concern. Furthermore, recreational vessels are also a potential source of open sea-based marine litter. Petroleum and gas platforms are another sea-based source of marine litter.

Land-based sources of marine litter may originate from coastal areas or farther inland. Waterfront areas, including beaches, piers, harbors, riverbanks, marinas, and docks, are common land-based sources of marine litter.

Figure 3.2 Plastic litter 'killing Adriatic loggerhead turtles' (adapted from: http://www.globalgarbage.org/blog/index.php/)

3.2.1.2 Impacts of marine litter

Regardless of origin, litter entering the aquatic environment can have significant impacts on ecology, human health and safety, and the economy.

3.2.1.2.1 Ecological Impacts

Marine litter can cause adverse impacts on aquatic ecosystems, such as wetlands, fish habitats, beaches, coral reefs, and migratory species breeding grounds and pathways. Marine litter can impact species directly, such as through entanglement or smothering of species, or indirectly, such as through changes to habitat. Ecological impacts can also vary depending on the type of marine litter. Derelict fishing gear can cause numerous impacts on habitats and fisheries. When marine species become entangled within litter, their mobility is limited. Constricted movement may inhibit the animal's ability to collect food or breath and can lead to starvation, suffocation, exhaustion, and increased predation. Ingestion of marine litter can lead to starvation or malnutrition because the ingested items may collect in the animal's stomach and lessen the desire to feed.

3.2.1.2.2 Human Impacts

Marine litter can also endanger human health and safety. Certain types of marine litter such as fishing nets and lines can impact vessel movement and navigation by wrapping around boat propellers, disabling the vessel, and ultimately endangering human lives. Human impacts from marine litter also may occur from direct contact with sharp litter objects, such as broken glass, rusted metal, or medical litter, on beaches or the sea floor.

3.2.1.2.3 Economic Impacts

Marine litter can have substantial economic impacts. Marine litter can be detrimental to the tourism industry by creating unsightly, dangerous beaches. In addition, the costs associated with cleanups and proper disposal of litter can be significant. Cleanup-related costs may include the cost of restoring the habitat impacted by marine litter, beach cleanup costs, the costs to clean piers, harbors, marinas, docks, and other waterfront areas, and the costs associated with at-sea cleanups.

3.2.1.3 Existing data, status and further trends

Recent existing literature for European marine waters is summarized in the Task Group report on marine litter (Galgani et al. 2010). Furthermore, the reports that cover the Mediterranean Sea do not cover the Cyprus area. Only scant information about marine litter pollution in the Cyprus marine environment is available through the work by Gabrielides et al. (1991) that was conducted in the years 1988-1989 in 13 Mediterranean beaches including also the "Lara" and "Makronisos" beaches of Cyprus (Gabrielides et al 1991). According to these results, the distance of a beach from a city is one of the main factors, which control the quantity of marine litter on the beach. Moreover, and in contrast to the above factor, "Lara" site, which is located on an isolated beach is found to be twice more littered as "Makronissos" site, which is located on a beach near to a population center. This fact can be explained due to the exposure of "Lara" site to the predominantly westerly winds, which cause marine-based litter to accumulate on this particular beach. Therefore, one factor that causes marine litter pollution on the marine environment of Cyprus is the population living on coastline cities and the other crucial factor, difficult to control, is clearly the international merchant shipping. The European Union recommends that the member states (until the year 2020) the following criteria and methodologies for the evaluation of the state of good environmental status in the total amount of marine litter: (1) Amount, distribution and composition of litter washed ashore and/or deposited on coastlines, (2) Amount, distribution and composition of litter at sea and on the sea floor, (3) Amount, distribution and composition of litter impacting marine animals, and (4) Amount, distribution and composition of microparticles. Monitoring results combined with research on social, economic and ecological harm will lead to improved knowledge of critical thresholds.

4. Interference with hydrological processes

Abstraction of seawater in Cyprus and its return to the sea in an altered form is restricted to three main purposes:

- Use in power-plant cooling water systems,
- Desalination for residential and tourist use,
- Aquaculture in hatcheries on the coast for the production of fry.

For the purposes of this chapter, only the first two uses will be examined since they may interfere with hydrological processes, whereas in the third case the returned water is not significantly different from a hydrological stand-point.

4.1 Significant changes in thermal regime

The main hydrological impacts of concern due to the discharge of heated water include stratification of the water column, decrease in exchange rate between coastal and offshore waters and changes in circulation patterns. Moreover, the abstraction process at the intake has also been considered as a cause for changes in circulation patterns.

According to Fisheries Law and Regulations, the returned water must not have a temperature 10 ^{o}C higher than that of the seawater in which it is returned. The regulation mainly concerns the discharge of cooling water used at the Electricity Authority of Cyprus power plants, which operate in the Limassol and Larnaca districts of Cyprus (Figure 4.1, Table 4.1). Indicative estimates of the seawater abstracted for cooling and returned to the sea after use were calculated using a relationship developed from data relating to cooling water usage in steam power generating plants in the U.S. (Nieder 2010). The estimates suggest a significant volume of cooling water returned to the sea every year. However, no data exists on the impacts of this cooling water on circulation in the area. Stratification of the water column is likely to have greater impacts during the winter when abstracted water temperatures are lower, thus making the differential temperature of returned cooling water more effective than in the summer time. At the same time, calmer conditions in the summer time render the likelihood of stratification greater.

Table 4.1 Power generation capacity and indicative estimates of cooling water usage for the main power plants of Cyprus. Generation capacity statistics were obtained from the Electricity Authority of Cyprus (2011). Cooling water usage was based on a relationship calculated from data in Nieder (2010).

	Electricity generating capacity (MW)		**Cooling water usage (10^6 m^3 y^{-1})**	
Power plant	**2009**	**2010**	**2009**	**2010**
Vasilikos	648	648	723	723
Moni	330	330	390	390
Dhekelia	410	460	474	526

Figure 4.1 The inshore cooling-water outfall of the Vasilikos power plant (Turnpenny et al. 2010).

Apart from impacts on local circulation, warmer waters will establish enclaves of average warmer temperatures and may change the local community structure in two ways: (a) Eliminating species that are less tolerant to higher temperatures and relatively more psychrophilic than others (see examples in UKMMAS 2010); (b) Harboring more thermophilic species that replace them (Taylor 2006). In terms of impacts due to the abstraction process itself, impingement and intake of living organisms during abstraction is of great concern to the fisheries and environment sectors (Turnpenny and Bamber 2006), and requires appropriate remediation systems (Taft 2000, UKMMAS 2010). Finally, it should be pointed out that intakes and outfalls of cooling-water systems also permanently alter the shoreline and thus impact marine ecosystem function, as well as other human activities.

4.2 Significant changes in salinity regime

The use of desalination to satisfy the needs for potable water in Cyprus has become a matter of national policy (WDD 2011), and its impacts have been analyzed in a strategic environmental assessment (I.A.CO Ltd and Enveco S.A. 2010). Current freshwater generation by desalination is at 142.000 m^3 d^{-1}, while it is planned to rise to 262.000 m^3 d^{-1} by the year 2020. Based on brine salinity values of 60-75 ‰ (Argyrou and Loizides 2005, Argyrou 2006, 2008), conversion efficiencies of the employed Reverse Osmosis process employed at Cyprus desalination units may range roughly between 35-48 % (see also Lattemann et al. 2008), resulting in current brine discharges which could exceed 200.000 m^3 d^{-1}, and projected to rise to almost 400.000 m^3 d^{-1} in 2020 (Table 4.2).

Table 4.2 Desalination plant freshwater output and brine generation values for 2010 and projected for 2020. Freshwater output values were obtained from I.A.CO Ltd. and Enveco S.A. (2010). Brine generation was calculated based on the range of salinities of the Dhekelia and Larnaca desalination plant brine, which ranged between 60 and 75 ‰ (Argyrou and Loizides 2005, Argyrou 2006, 2008), resulting in conversion/extraction efficiencies of 35-48%.

	2010		2020	
	Daily output	**Annual output**	**Daily output**	**Annual output**
Plant	10^3 m^3 d^{-1}	10^6 m^3	10^3 m^3 d^{-1}	10^6 m^3
Dhekelia	60	21,90	60	21,90
Larnaca	62	22,63	62	22,63
Limassol	-	-	40	14,60
Paphos	-	-	40	14,60
Moni	20	7,30	-	-
Vasilikos	-	-	60	21,90
Total	142	51,83	262	95,63
Brine release 35%	264	96,26	487	177,60
Brine release 48%	154	56,16	284	103,60

Argyrou (1999) described the hydrological and ecological effects of brine discharge at the then-newly operating Dhekelia desalination plant. Both stratification as well as elevated salinities were observed in the vicinity of the Dhekelia outflow diffuser, which is at relatively shallow depth (5 m) in the vicinity of hard substrate. Salinities at the discharge points were elevated by more than 10 ‰ on certain occasions, relative to the salinities at the intake vent. However, Argyrou (1999) notes that, depending on the whether conditions these effects are restricted to a radius of 200 m (or an area approximately 0.125 km^2) from the discharge points. Regardless of the small size of the impacted area, the increase in salinity therein was reasonably connected to adverse effects on forests of the macroalga *Cystoseira*, as well as significant shifts in macrofaunal community composition (Argyrou 1999).

Based on this report, it is apparent that impacts of the discharge of desalination brine depend on the depth of the water column, the form of discharge (preferably multiple diffusers at various distances along the outflow vent), the communities present, and the hydrology of the area. The Dhekelia desalination plant employs multiple diffusers, which discharge at a relatively shallow depth. The Larnaca desalination plant discharges at greater depths (12 m) using a single vent, while most new desalination plants under construction will be employing multiple diffusers discharging at relatively great depths (I.A.CO Ltd and Enveco S.A. 2010). This strategy may prevent the stratification and salinity accumulation problems observed in the Dhekelia desalination plant.

5. Contamination by hazardous substances

Marine pollution, in contrast with marine contamination, can be of natural and anthropogenic origin. Various forms of marine pollution could be caused for example by volcano explosions, where a large quantity of pollutants goes on the air environment and so wide territories are surcharged with a big range of toxic chemical compounds. Marine pollution of anthropogenic origin is caused by humans and is categorized as follows:

- Urban, usually associated with wastes from cities or settlements on the coastal zone,
- Industrial, usually associated with industrial wastes in coastal zones or shipping and transportation,
- Agricultural, usually coming from extensive use of fertilizers or pesticides,
- Energy, usually associated with different radiations, vibrations, temperatures, radioactivity, etc.,
- Acoustics, caused often from sea transports, geological researches and military exercises.

From the chemical point of view, the main reasons for the pollution and the quality degradation of the marine, and in particular of the coastal, environment are: (1) drainages, (2) organic substances with high half-life, (3) radioactive compounds, (4) heavy metals, (5) petroleum hydrocarbons, (6) nutrients, (7) sediment mobilities and (8) wastes.

Cyprus is the easternmost Mediterranean island located in the Levantine basin of the eastern Mediterranean. The eastern Mediterranean comprises the Ionian and Levantine basins and the Adriatic and Aegean Seas. Compared with other regions of the Mediterranean, this is the most poorly studied in relation to physical, chemical, biological and geological oceanography, particularly the Levantine basin. The Levantine water formed in the basin, consists of dense salty water that is highly oligotrophic (Hecht et al. 1988). Other studies carried out in the deep waters of the Levantine basin have shown that primary productivity is limited by phosphorus (Krom et al. 1992). Concerning the chemical pollution of the coastal zone of Cyprus (for example heavy metals, organochlorines, petroleum hydrocarbons, radioactive compounds in seawater, sediment or biota) research publications are fragmentary and very specific (Yemenicioğlu et al. 1997, Storelli et al. 2005, Fatta et al. 2007, Lysandrou and Pashalidis 2008, Thébault et al. 2008, Guieu et al. 2010).

The aim of the present study is to investigate the current good status of the marine environment in Cyprus, with the recording of potential marine pollution spots. It is well known that pollution studies in marine environments are a relative new research topic, that had began late in the 1950s, when the first radioactive wastes were buried on the seafloor. The study of pollution in the Cyprus marine environment consists of verification, analysis and study of existing research data, namely (1) chemical oceanography data (heavy metals, nutrients, petroleum and chlorinated hydrocarbons, radioactive isotopes etc.) but also (2) underwater noise pollution data at coastal and offshore areas in Cyprus.

5.1 Introduction of synthetic compounds

5.1.1 Introduction

Electricity supply transformer liquid coolants, for example polychlorinated biphenyls (PCBs), and insecticides or other agrochemicals, as exemplified by the hydrocarbon insecticide DDT, (Smith 1991) are two main categories of organochlorine compounds present as contaminants in the environment (IPCS 1993, 1997). Furthermore the technological use of the organochlorine compounds consists of:

- Raw products for synthesis of very usable polymer compound (for example chloroprene, PVC etc.),
- Organic solvents in usages of the chemical industry (methylene chloride, dichloropropane, dichloroethylene, chloroform etc.),
- Substances for chemical purification (trichloroethylene, tetrachloroethylene, tetrachloromethane),
- Conservatives in wood industry, for example pentachlorophenol.

The main reasons for the increasing presence of these compounds in the environment are the following:

- First, the cheap and ready availability of chlorine gas on an industrial scale led to the production of a plethora of chlorinated compounds of technological importance,
- Secondly, many of these polychlorinated organic compounds, cyclic in structure, and highly thermostable in character, are resistant to biodegradation, and
- Thirdly, the uncontrolled use and discharge of these chemicals resulted in their accumulation and persistence in the environment.

PCBs, which have been in industrial use for a much longer time than for example the organochlorine pesticides, were found to be the major source of organochlorine residues in some environments (Albaiges et al. 1987, Vigano et al. 2000, Fox et al. 2001). Commercial disposal of PCBs and other organochlorines for example in Greece was banned before the mid-1970s (Albanis 1997), none the less these pollutants still persist in the Greek environment (Albanis et al. 1994, 1995, 1996, Fytianos et al. 1997, Konstantinou et al. 2000, 2004, Golfinopoulos et al. 2003, Christoforidis et al. 2008).

The aim of the present work is to study if in the past (mainly in the 60s and 70s) organochlorines used in Cyprus (organochlorine pesticides and polychlorinated diphenyls, PCB’s) are detectable in marine water, sediment or biota samples (for example fish species such as *Mullus barbatus* or shell fish species such as *Mytilus galloprovincialis*) until today.

5.1.2 Existing data and status

Water, sediment and biota samplings were conducted by the Department of Fisheries and Marine Research in the years 2005 and 2009 at ten sampling stations in the wide coastal areas of the cities Larnaka, Lemesos and Pafos. Biota samplings were carried out in the frame of the monitoring programs MED POL (UNEP/MAP) and MYTIOR (IFREMER), while water and sediment samplings were conducted in the framework of the Cyprus coastal waters monitoring program (Water Framework Directive, 2000/60/EC). Analyses of the samples were carried out by the State General Laboratory of Cyprus for the following parameters: a-HCH; b-HCH; c-HCH (lindane); HCB; p,p’-DDE; p,p’-DDD; p,p’-DDT; aldrin; Heptachor epoxide; Diedrin; Endrin; cis-chlordane; trans-chlordane and trans-nonachlor; Anthracene; Benzo(a)anthracene; Benzo(a)pyrene; Benzo(b)fluoranthene; Chrysene; Fluoranthene; Fluorene; Naphtalene and 10 PCB congeners: IUPAC-101, 105,118, 138, 153, 156, 180, 28, 31 and 52. The results of the above analyses show concentrations of pesticides and polychlorinated diphenyls at low levels (mainly traces). Some times the above examined concentrations were very close to the detection limit of the Gas Chromatography – Mass Spectrometry Analyzer.

5.1.3 Future trends

Organochlorine determinations from this work show that organochlorine pesticides and polychlorinated biphenyls were only present at trace levels at the wider coastal areas of the cities Larnaka, Lemesos and Pafos in water, sediment and biota samples. The maintenance of this excellent coastal environmental status in Cyprus concerning the investigated organochlorine compounds is regarded as a fact, since these very toxic compounds were prohibited for further use since the 1960s or 1970s.

5.2 Introduction of non-synthetic substances and compounds

5.2.1 Heavy metals

5.2.1.1 Introduction

The plethora of toxicological and environmental studies aiming at the determination of the toxic heavy metal levels, in particular lead (Pb), cadmium (Cd) and mercury (Hg) in water, sediment and biota samples of marine environments prove the interest of the world scientific community in such valuations of environmental upgrade of coastal environments (Stamatis et al. 2002, Christophoridis et al. 2007, Storelli 2008). Furthermore, the toxicity of the above metals and their hazardous consequences for the marine ecosystem, as well as for human health are also very well investigated (for example, Zheng et al. 2007). In a great number of papers the measurement of such pollutants in the wide ecosystem (water, sediment) as well as in the biota (for example marine fish) was used for studying the ecosystem degradation consequences in the whole food chain (Argyrou et al., Tragantzopoulos et al. 2010).

In the framework of these studies, water, sediment and fish samples from Cyprus were analyzed for the concentrations of the following heavy metals: copper (Cu), zinc (Zn), lead (Pb), nickel (Ni), chromium (Cr), cadmium (Cd), mercury (Hg) and iron (Fe). The aim was to determine the metal concentrations and whether these examined concentrations are able to degrade the environmental status of the Cyprus marine ecosystem. Furthermore, the recording of the most toxic metals, namely Pb, Cd and Hg in fish tissues aimed at confirming if the species *M. barbatus* (koutsomoura) constitutes suitable food for human consumption. For that reason, the measured concentrations of these three selected heavy metals must not overcome the limit values, as these values were enacted from the EU, namely 0,2, 0,05 and 0,5 mg kg^{-1} wet weight for the metals Pb, Cd and Hg respectively (Official Journal of the European Union 2005).

5.2.1.2 Existing data and environmental status

Marine water samplings were conducted by the Department of Fisheries and Marine Research at four sampling stations (Vasilikos E-power plant, Vasilikos Harbor, Lemesos City and Lemesos Karnagio, Figure 5.1) in the years 2010 and 2011 according to the sampling protocol ELOT EN ISO 15586/3500 for the metals Cu, Zn, Pb, Ni, Cr, Cd, Fe and according to the sampling protocol ELOT EN ISO 1484 for Hg. These samplings were carried out in the framework of the Cyprus coastal waters monitoring program (Water Framework Directive, 2000/60/EC). One (1) liter of the water sample was first filtered (Millipore 0.45 μm) and then acidified with diluted HNO_3 until pH<1, for Hg and until pH<2 for the rest of the metals determination. All samples were stored at 4 ^{o}C until the day of analysis (maximum storage time was15 days).

Sediment samplings were conducted by the Department of Fisheries and Marine Research at two sampling stations (Vasilikos E-power plant and Lemesos Karnagio) in the years 2007 and 2008, in the framework of the Cyprus coastal waters monitoring program (Water Framework Directive, 2000/60/EC). The sediment samples were taken using a stainless steel Van Veen sampling instrument and then were stored at 4 ^{o}C in airproofed plastic bottles of PVC, until their drying process. Afterwards, the samples were dried at 50 ^{o}C for 24 hours and after their homogenization in a porcelain mortar with pestle, 0.5 g from the homogenate were handled with 10 mL of the following acid mixture ($HCl:HNO_3$ 3:1), first at 24 hours at room temperature and afterwards 5 hours at the boiling temperature of the solution, on a hot plate. After their filtration (Whatman 1 filters) and their following dilution, the samples were analyzed for their Cu, Zn, Pb, Ni, Cr, Cd, Fe and Hg metal content. The dried sample was fully dissolved in the above acid mixture, so that the total concentration of each metal was determined.

Figure 5.1 Map of Cyprus and the sampling sites (cycle: water and sediment sampling sites, quadrangle: water sampling sites, green symbol: fish sampling sites, red line: scale of 10 km).

M. barbatus specimens were sampled by the Department of Fisheries and Marine Research at three sampling stations (Lemesos, Larnaka and Pafos) in the years from 2004 to 2010 in the framework of the program MED POL (UNEP/MAP). The fish were sampled by boat using nets. The samples were placed in aluminium foil after their separation (each sample was composed from 6 different fish species of similar size), and placed in the refrigerator at -20 ^{o}C. Following this, 0.5 g of the dried fish filets after their homogenization were digested at 90 ^{o}C, under pressure in the presence of a H_2O_2 and HNO_3 mixture in appropriate aluminium vessels.

The concentration results (mean values and standard deviation) of the metals in water samples are presented in Figure 5.2. Metal concentrations of Cu, Zn, Pb, Ni, Cr, Cd, Hg and Fe were detected at low levels without significant differences (ANOVA, $p>0.05$) in their concentrations during the whole sampling period. The mean concentration range of 0.06-3.77 μg L-1 for the metals Cu, Zn, Pb, Ni, Cr, Cd, Hg and Fe in the four coastal sites is comparable with concentration values from other inshore “low pollution risk” ecosystems or offshore Mediterranean ecosystems. Anthropogenic polluted coastal Mediterranean ecosystems (caused, for example, by mining operations in the coastal zone, inflow of riverine waters, water discharges from areas with intensive agricultural activities, industrial activities on coastal zone, biological treatments etc.) as for example are the inshore Saronikos, Thermaikos and Ierissos Gulfs, the Venice or south France lagoons, demonstrate metal concentrations 100- or 200-fold higher in comparison to the concentrations from this work in the Cyprus ecosystem.

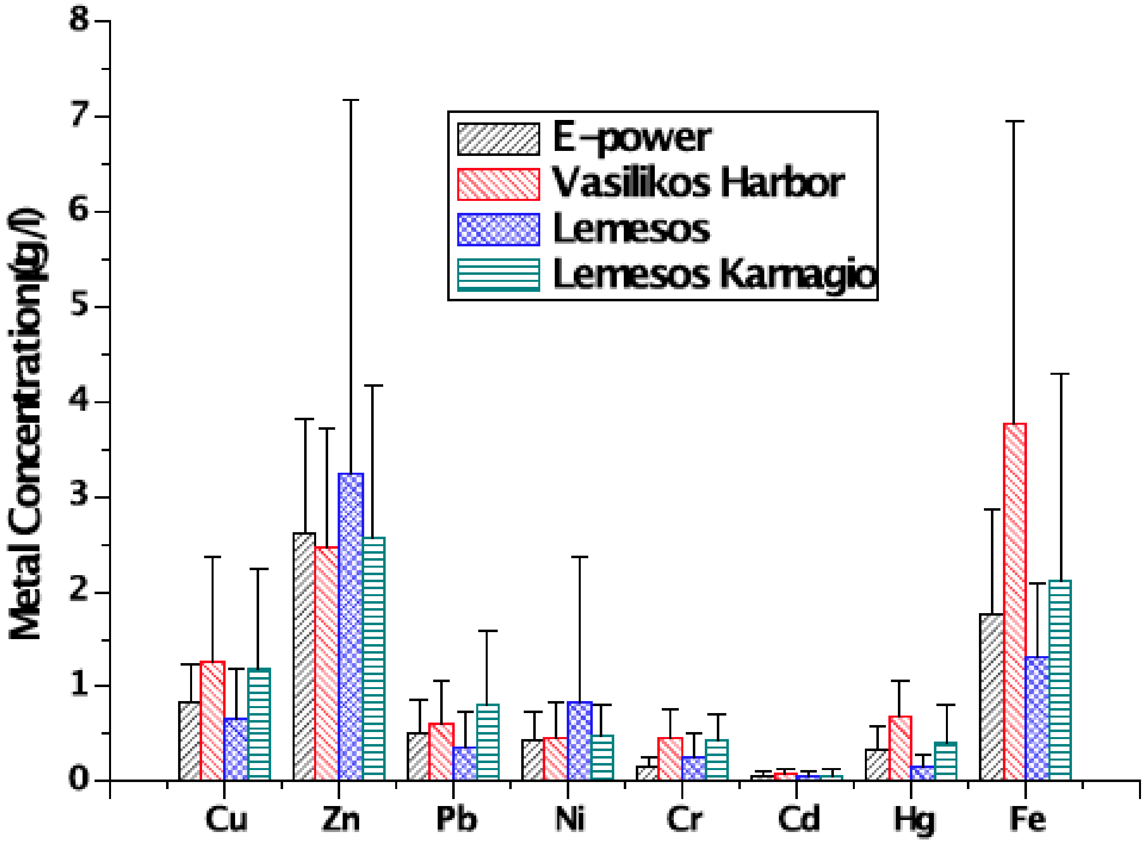


Figure 5.2 Mean metal concentrations (± standard deviation) in water samples from four sampling sites in Cyprus.

Metal concentration results (mean values and standard deviation) in sediment samples are shown in Figure 5.3. Copper, Zn, Pb, Ni, Cr, Cd και Hg concentrations were measured at low levels compared with values detected in offshore or oceanic waters (Turekian and Wedepohl 1961). The high correlation coefficients between Cr and Ni ($r = 0.78$; mean concentrations between 75 and 100 mg kg^{-1}) but also between Cu, Zn and Pb ($r = 0.67$; mean concentrations between 20 and 50 mg kg^{-1}), but also the relatively high concentrations of the metal Fe (until to 25000 mg kg^{-1}) as the only exception in Cyprus sediments, prove their natural origin, coming mainly from ores or minerals from the investigated area. Moreover, the application of the statistical analysis ANOVA showed no significant differences of the metal concentrations in the samples collected during the whole sampling period. Similarly low sediment concentrations of heavy metals were also measured at other, low anthropogenic polluted coastal Mediterranean areas such as is the Kerkyra strait and the gulfs of Amvrakikos, Pagasitikos and Navarino in the Ionian and the Aegean Sea (Voutsinou-Taliadouri 1984, 1998).

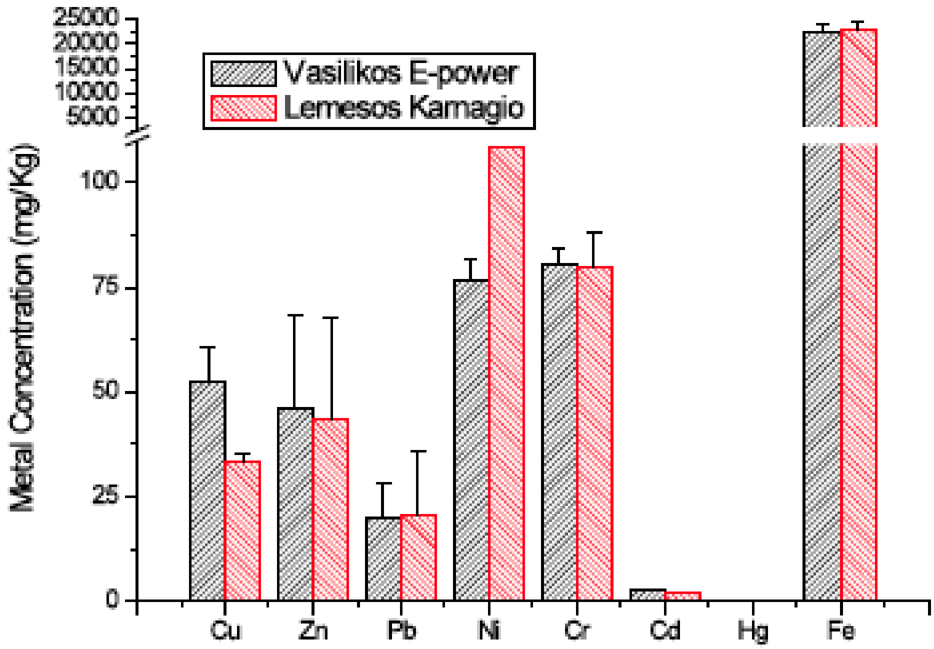


Figure 5.3 Mean metal concentrations (mg kg^{-1} of dry weight ± standard deviation) in sediment samples from two sampling sites in Cyprus.

Concentration results (mean values and standard deviation) for the metals Pb, Cd and Hg in fish samples (*M. barbatus*) from three sampling stations are shown in Figure 5.4. In the majority of these samples and in the whole sampling period mercury was detectable, it was, however, in low concentrations, lower than the limits enacted by the EU for fish tissues (namely 0.5 mg kg^{-1} wet weight, or approx. 2-2.5 mg kg^{-1} dry weight). Only in 6 samples (4 from the site in Pafos, 1 from the site in Lemesos and 1 from the site in Larnaka) were mercury concentrations measured over 0,25 mg kg^{-1} wet weight but in any case lower than the limit, and this for a small fraction, approximately 6,7 % of the total sample of fish. Maximum Hg values in fish filets analyzed during this work (0.25 mg kg^{-1}) yield 0.375 mg Hg for a 60-kg person when that person consumes 1500 g of fish in one sitting. In general, Hg values for koutsomoura from this work are lower in comparison to the values measured for the same species caught in other Mediterranean regions, for example in Tyrenian or Adriatic seas (Sapunar et al. 1989, Rossi et al. 1993). From the 90 investigated samples only in 14 and 12 were Cd and Pb detected respectively, always in lower concentrations (up to 0.0025 or 0.04 mg kg^{-1} wet weight for Cd and Pb respectively) in comparison to their EU-mandated limits and often very close to the upper detection limit of the atomic absorption analyser instrument. Concentrations of the above two metals examined in this work are lower than the concentrations in other Mediterranean ecosystems (Bei et al. 1992, Storelli et al. 1998). The provisional tolerable weekly intakes (PTWI) for Cd and Hg for a 60-kg person are 0,007 (JECFA 2006) and 0,025 mg kg^{-1} (EFSA 2004) respectively. Thus, taking into consideration the maximum higher values for Cd and Hg from this work, a person in Cyprus can consume up to 168 or 96 meals of koutsomoura per week for Cd or for Pb respectively.

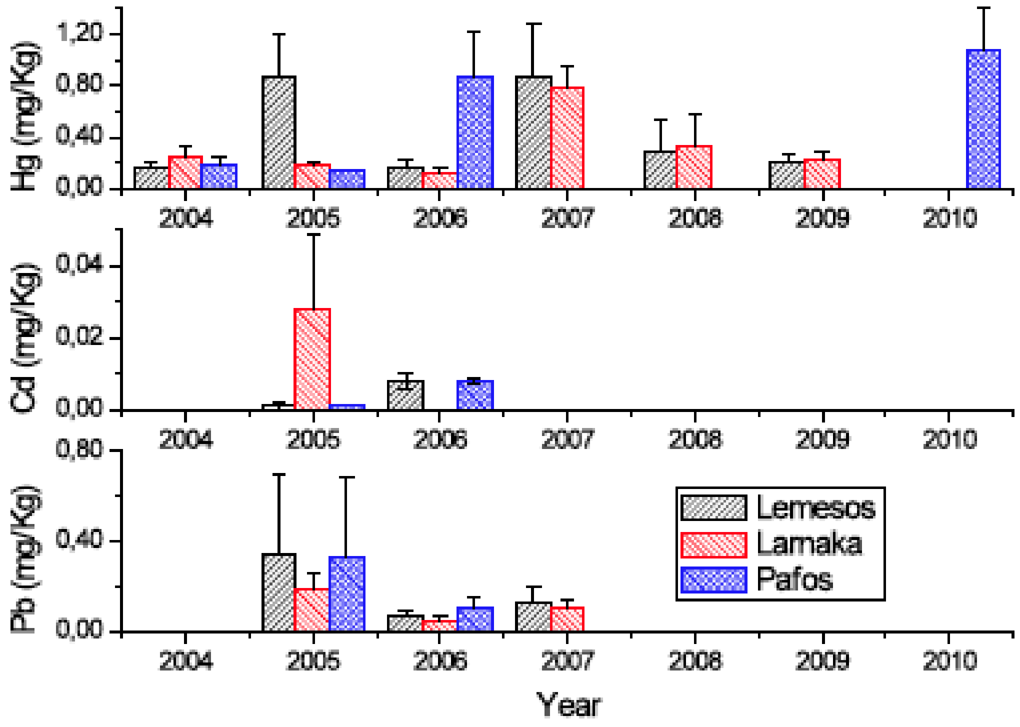


Figure 5.4 Mean metal concentrations (mg kg^{-1} of dry weight ± standard deviation) in fish samples (*M. barbatus*) from three sampling sites in Cyprus (1 mg kg^{-1} dry weight equals approximately 0,2-0.25 mg kg^{-1} wet weight).

5.2.1.3 Future trends

In conclusion, from the existing data for toxic metal concentrations in water, sediment and fish samples from the Cyprus marine ecosystem it is clear that the findings are not able to provoke any apprehension regarding ecosystem degradation caused by heavy metals. The high Fe concentrations in the sediment samples were probably of natural origin caused by local mineralogy. The decline order of the heavy metals in koutsomoura samples was Hg>Pb>Cd, however the concentrations were detected at low levels, under the limit values which are enacted by the EU for fish filets.

For the maintenance of this excellent status in the Cyprus coastal ecosystem aiming at the quality of water, sediment and biota samples concerning heavy metals, the slogan “Not a Drop of water to the Sea” which is the water policy of the Cyprus Government, helps.

5.2.2 Petroleum hydrocarbons

5.2.2.1 Introduction

The biggest contribution to marine pollution from petroleum hydrocarbons is a result of the loading and unloading procedures in tankers, namely the rejected petroleum at sea during the cleaning works of the decks in the oil tankers. According to the results of the European Commission Programme with title "Monitoring Illicit Discharges from Vessels (MIDIV)", that was conducted in the years from 1999 to 2004, satellite photos of the Mediterranean Sea show small-scale oil pollution for its eastern part, that occur during mooring, loading and unloading operations (UNEP/MAP 2009). At the global scale, these procedures correspond approximately to the quantities of petroleum spilled to the environment after a major oil tanker accident. The Mediterranean Sea, in particular its eastern part after the reopening of the Suez Canal for marine transport at the 70s is considered to be one of the most petroleum polluted seas in the world. Considering that Mediterranean Sea covers only 0.8% of the world sea area, more than 20% of the world petroleum transport takes place there and the measurement of pelagic tar particularly in the Eastern Mediterranean Sea was one of the most popular quality parameter for recording marine petroleum pollution in the region. The last two decades of 1990 and 2000, the adoption of the conventions against petroleum pollution, their enforcement and the new technologies which were developed to reduce intentional or accidental petroleum spillages to the sea have caused a significant reduction in tar pollution in the Levantine basin and therefore in Cyprus.

5.2.2.2 Existing data and environmental status

Information about the levels of petroleum pollution in the sea environment of Cyprus and particularly in the area of the western Levantine is reduced to the scanty published results of pelagic tar measurements during the decades 1970 and 1980. For example, from the samplings between August and September 1987 at 101 sites in the Mediterranean, most of them were located in the Levantine basin, the values for pelagic tar were higher in marine areas north and western of Cyprus in comparison to the rest of the Mediterranean locations. A comparison of mean values for pelagic tar from all Mediterranean stations (ConcPT) in the years 1969, 1974 and 1987 (ConcPT 1969 = 37000 μg m^{-2}; ConcPT 1974 = 9700 μg m^{-2}; ConcPT 1987 = 1175 μg m^{-2}) shows a significant decline of starting concentrations (Morris et al. n.d., Horn et al. 1970, Golik et al. 1988). In addition to the decrease in pelagic tar, a decrease in quantity of beach-stranded tar was reported from some eastern Mediterranean coasts. Thus, for example in the years 1976-78 the mean tar quantity of the beach in Paphos was calculated at 268 g m^{-2} (UNEP 1980), whereas in the year 1983 tar quantity was measured at 67 g m^{-2} in the same beach (Demetropoulos 1985). A general decrease of pelagic and beach-stranded tar in Cyprus marine waters has taken place.

5.2.2.3 Future trends

In conclusion taken into account the existed literature information, which is from the 80s, water, sediment or seaside sand samples from the marine ecosystem of Cyprus were not polluted with pelagic or beach-stranded tar. The new conventions in force and the developing of the new techniques and procedures of petroleum handling, such as equipping all new tankers with segregated ballast and developing a crude oil washing system which allows collection of the washed oil had lead in excellent reduced values of pelagic tar in the marine environment in general and therefore in the marine environment of Cyprus.

Furthermore, potential impacts on offshore marine environment in Cyprus after the natural gas exploration in the block 12 are presented in the Environmental Impact Assessment for Exploratory Drilling in that block (CSA International 2011). Eventual marine ecological impacts from accidents or upsets are minimized from the facts that: (1) no a large diesel or crude oil release could happen, from the fact that natural gas is the target hydrocarbon for exploration, (2) natural weathering processes could rapidly remove diesel and crude oil from the water column (offshore deep waters) with diluting of the rest concentrations to background levels, (3) marine biota such as marine mammals, sea turtles and marine birds is expected to have only low impact due to the expected low density of these resources and (4) marine biota such as plankton, fish and benthic communities could be affected from a diesel or crude oil release but relatively small and for a duration of only a few days.

5.3 Introduction of radionuclides

5.3.1 Introduction

Radioactive radiation in the marine environment could originate from space, from marine sediments, from the atmosphere, from the water and from other natural sources. Furthermore, radioactive radiation could originate from radioactive effluents, nuclear weapon tests and other sources of anthropogenic origin. Two anthropogenic radioisotopes strontium (^{90}Sr) and caesium (^{137}Cs), can originate from release of radioisotopes in the atmosphere after nuclear weapon tests or from leaks in nuclear power plants, like for example after the accident in the nuclear power plant of Tschernobyl, Ukraine, in 1986. Both radioisotopes were monitored (in combination to natural radioisotopes) quite often in the framework of monitoring programs for radioactivity measurements in marine environment.

5.3.2 Existing data and environmental status

The existing information for the radioactivity levels in Cyprus marine environment is limited to the following:

(a) Results from the year 2002 for ^{137}Cs which were made in the framework of the programs entitled “Global Inventory of Radioactivity in the Mediterranean Sea” (GIRMED) and “Mediterranean Mussel Watch” (MMW) for the detection of radioisotope traces after the Tschernobyl explosion, and

(b) Results of systematic determinations for anthropogenic ^{137}Cs and ^{40}K but also for some natural isotopes such as ^{241}Am, ^{109}Cd, ^{60}Co, 54Mn, ^{65}Zn were carried out in the radioactivity laboratory of the State General Laboratory in samples from the coastal marine environment of Cyprus (time interval from 2004 to 2009). The samplings of marine water, beach sand, sediment, algae and fish were conducted by the Department of Fisheries and Marine Research and they were included in the final report by the Radiation Inspection and Control Service (2010) entitled “Radioactivity measurements in Cyprus environment 2004-2009”.

According to the results of the determination of radioactivity pollution in mussel samples (200-300 individuals, 3-5 kg) from the species *Mytilus galloprovincialis* that have been used as bioindicator from one sampling site in Cyprus (in the program GIRMED - MMW were sampled individuals from 60 sampling sites in the whole Mediterranean and the Black Sea), mean values fluctuated around 0.11 ± 0.06 Bq kg^{-1} wet weight for ^{137}Cs. This value is considered as a low level value and does not cause concern. Furthermore, this level for ^{137}Cs is comparable with levels detected in other Mediterranean areas which were not affected from the Tschernobyl explosion (Catsiki and Florou 2006).

According to the results shown in the final report of the Radiation Inspection and Control Service (2010) for radioactivity in Cyprus, it is concluded that civilians in Cyprus are not exposed to ionizing radiations and environmental radioactivity is staying at normal, very low levels. Values for ^{137}Cs were on the one hand high in water (up to 2,46 Bq m^{-3} in Lemesos harbor sampling site) and sediment samples (up to 2,86 Bq kg^{-1} in Larnaka sampling site), in comparison to the values detected in beach sand (up to 0,64 Bq kg^{-1} in Paralimni sampling site) and marine biota of animal origin (for example *Spicara smaris*, up to 0,18 Bq kg-1) or marine algae (*Cystoseira* sp., up to 0,07 Bq kg^{-1}), but on the other hand (and in general), it is evident that radioactivity levels in the marine environment of Cyprus are detected at normal, very low levels. The above observation could possibly be caused by the Cyprus mineralogy, by the absence of a nuclear plant in the wider region and finally in the fact that the Tschernobyl nuclear power plant explosion did not influence Cyprus environment.

5.3.3 Future trends

In conclusion, and from the existing data for radioactivity levels in water, sediment, beach sand or biota samples in Cyprus it is clear that the above findings do not cause concern for radioactivity exposure for the Cyprus ecosystems. Some relatively highly detected levels in water and sediment samples, in relation always to the detected levels in beachside sand and biota samples in Cyprus are considered physiological, since it is known that radioactive elements have the tendency to accumulate easier in suspended matter in the coastal zone followed by high values in water and sediment samples at the coastal region. Similar high values for radioactive elements have been measured for water and sediment samples also at other coastal Mediterranean ecosystems (e.g., Gascó et al. 2002).

5.4 Other compounds

Growth of aquatic organisms on vessel hulls creates roughness which gives rise to reduced vessel speed per unit energy consumption. Primary marine antifouling paints were based on Cu_2O. But these coatings became ineffective within 1 year and so more effective biocides were needed. A wider-spead use of TBT-based antifouling paints, which meet this demand, began in the early 1970s. Only in the year 1987 in the U.S.A., the annual consumption of TBT in antifouling paints was reported to be about 450 tons (Champ and Bleil 1988). But it is very well known that surfaces treated with TBT-based copolymer paints are designed to reach a constant TBT leach rate of approximately 1.6 μg (Sn) cm^{-2} per day (Batley 1996). For example, during a 3-day stay in a harbour a commercial ship, leaching TBT at the constant leach rate, can release more than 200 g TBT into water. This fact results in TBT: (a) combined with its strong lipophilic character, to bioaccumulate in marine organisms, in particular in the marine bivalves (> 5 μg g^{-1}) (Laughlin 1996) but also (b) to be detected in water, and later in the marine sediments.

The results of a pilot survey of tributyltin (TBT) and its derivates in Mediterranean areas within the framework of the MEDPOL activities conducted in 1988 showed that only at one station near the southern coastal area of Turkey TBT concentrations were between 1 and 10 ng L^{-1} (Gabrielides et al. 1990). These concentrations are harmful to a number of sensitive marine organisms, some of which appear to be affected by concentrations as low as 1 ng L^{-1} (Bryan et al. 1986). These findings concern mainly potential impacts to the sampling site caused by the activities in Turkey and not by activities in Cyprus. But these are the only research results concerning TBT in the wide area and from this point of view they are included in the present study.

6. Nutrient and organic matter enrichment

Anthropogenic inputs of nutrients into the marine environment of Cyprus could result from terrestrial or marine activities. The potential that these activities result in significant inputs of nutrients into the marine environment is tempered by the relatively well-documented ease with which the oligotrophic marine environment of Cyprus absorbs any added organic and inorganic nutrients. This capacity accounts for the relatively rare cases of detectable impacts due to nutrient and organic matter inputs.

Regarding terrestrial inputs, and according to the official water balance of Cyprus (Water Development Department 2012), 48×10^6 m^3 of surface water and 70×10^6 m^3 of groundwater are lost to the sea every year. Even though these figures are to a large extent a result of closing the budget and don't necessarily reflect actual measurements and/or observations, they necessitate pause for thought because of their sheer size. The water lost to the sea acts as a conduit for nutrients and organic material from land, where the majority of human activities takes place.

Coastal waters, which are the front line of this interaction between land and sea, are in good ecological and chemical condition at present, as documented by the Cyprus River Basin Management Plan (Water Development Department 2011). With this in mind, this section examines various sources of potential pressures in terms of inorganic and organic nutrient inputs to the Cyprus sea as well as any impacts they may have at present or in the future.

6.1 Inputs of fertilisers and other nitrogen- and phosphorus-rich substances

6.1.1 Urban wastewater

In terms of nutrient and organic matter inputs, urban pollution is primarily the result of the discharge of wastewater, which includes domestic wastewater or the mixture of domestic wastewater with industrial wastewater and/or run-off rain water. An estimate of the current loads in oxygen demand, total nitrogen and phosphorus generated by urban wastewater in Cyprus is shown in Table 6.1.

As noted repeatedly in the past, Cyprus is a relatively rare case in the Mediterranean, since almost all of the produced wastewater is treated and reused (WL | Delft Hydraulics et al. 2004a, 2004b, UNEP/MAP 2009, 2010). However, a small fraction of treated water, 10-20 % (Table 6.2), has been routinely released into the sea in the winter months due to lack of demand (e.g., Larcou Yiannakou 2008).

Calculations of the maximum possible amounts of nutrient and organic matter loading being released into the sea, based on maximum concentrations permissible by law for such discharges (Table 6.2) indicate that only a very small fraction (< 1 %) of the total load generated each year as urban wastewater is released into the sea. Concentrations of nutrients from the point of discharge of the Sewerage Board of Limassol-Amathounta (Table 6.3) indicate elevated concentrations for all monitored nutrients, compared to typical values from coastal reference stations (see Part I, Section 1.4), ranging from $\times$ 3 (TN) to $\times$ 170 (PO_4^{3-}).

Table 6.1 Estimates of biochemical oxygen demand (BOD_5), total nitrogen (TN) and total phosphorus (TP) loads that will be generated from urban waste in 2012. Per capita equivalent loads and load reduction factors were obtained by past analysis in the framework of the implementation of the Water Framework Directive in Cyprus (WL | Delft Hydraulics et al. 2004a). The per capita equivalent loads were multiplied by a population of 838,837, based on the 2011 census (Statistical Service 2011) for 365 days. It was assumed that by the end of 2012 and in the framework of the National Implementation Programme of the Directive Concerning Urban Waste Water Treatment (91/271/EEC), 50 % of the generated load will be subjected to tertiary treatment (Eliades 2010).

Parameter	**BOD_5**	**TN**	**TP**
Per capita equivalent load (g capita^{-1} day^{-1})	60	12	2.5
Whole-population generated load (t y^{-1})	18372	3674	765
Load to be treated (50 % of total) (t y^{-1})	9186	1837	383
Tertiary treatment reduction factors (%)	96	80	80
Post-treatment load (t y^{-1})	735	735	153
Load remaining untreated (50 % total) (t y^{-1})	9186	1837	383
Total load (t y^{-1})	9921	2572	536

Table 6.2 Estimates of biochemical oxygen demand (BOD_5), total nitrogen (TN) and total phosphorus (TP) loads released into the sea between 2004 and 2009. Volumes of the generated treated water and treated water discharged into the sea were obtained from Larcou Yiannakou (2008) and Eliades (2010). Maximum loads were calculated by assuming that levels in the discharged water did not exceed the maximum legal permissible levels of 10 mg L^{-1}, 10 mg L^{-1} and 2 mg L^{-1} for BOD_5, TN and TP respectively (e.g., Larcou Yiannakou 2008).

Year	2004	2005	2006	2007	2009
Volume of treated water discharged (10^6 m^3)	2,47	2,58	2,02	0,97	1,30
Volume of total treated water (10^6 m^3)	13,6	14,3	15,2	20,8	13,0
Fraction of treated water discharged (%)	18,2	18,1	13,3	4,7	10,0
Maximum BOD_5 discharged (t)	24,6	25,8	20,2	9,7	13,0
Maximum TN discharged (t)	24,6	25,8	20,2	9,7	13,0
Maximum TP discharged (t)	4,9	5,2	4,0	1,9	2,6

However, it should be pointed out that these concentrations are well below (< 10 %) the maximum legal permissible levels of the discharged treated water, which are 10 mg L^{-1} (714 μmol L^{-1}) and 2 mg L^{-1} (65 μmol L^{-1}) for TN and TP respectively, perhaps indicative of sufficient mixing with seawater even at the point of discharge. Indeed, a study on the impact of sewage discharge on benthic communities in the case of the Larnaca outfall documented a diverse community of low abundances and biomass, "typical of an area poor in nutrients and largely unaffected by pollution" (Hadjichristophorou 1988). It is expected that as the efficiency of both water use and treated effluent reuse improve in the near future, so will the amount of both generated treated water as well as discharged treated water, along with any unforeseen impacts.

Table 6.3 Average nutrient concentrations recorded at the point of discharge of the Sewerage Board of Limassol-Amathounta (SALA) at surface (0-0,5 m) and at depth (5 m) for the years 2004-2007 (Argyrou and Loizides 2005, Argyrou 2006, 2008). The numbers in parentheses (n) represent the number of samples used in the averaging.

Depth	Year	TN µmol L^{-1} (n)	NO_3^- µmol L^{-1} (n)	NO_2^- µmol L^{-1} (n)	NH_4^+ µmol L^{-1} (n)	TP µmol L^{-1} (n)	PO_4^{3-} µmol L^{-1} (n)
Surface	2004	-	0,08±0,10 (3)	0,02±0,00 (3)	0,05±0,00 (3)	-	0,01±0,01 (3)
	2005	16,8±15,0 (3)	0,39±0,53 (3)	0,06±0,05 (3)	0,36±0,25 (3)	43,9±66,3 (6)	0,02±0,01 (3)
	2006	25,0±21,2 (2)	1,07 (1)	0,02 (1)	0,71±0,61 (3)	1,29±1,68 (3)	0,16 (1)
	2007	58,7±76,6 (2)	0,64 (1)	0,07 (1)	0,16±0,15 (2)	4,27±5,82 (2)	0,07 (1)
5 m	2004	-	0,13±0,02 (2)	0,06±0,00 (2)	0,05±0,00 (2)	-	0,02±0,01 (2)
	2005	66,8±58,3 (3)	4,93±6,11 (3)	4,06±3,84 (3)	10,6±0,51 (2)	-	5,14±4,95 (3)
	2006	34,7±8,08 (3)	1,07 (1)	0,04 (1)	2,80±4,16 (3)	29,1±48,6 (3)	0,02 (1)
	2007	12,8±9,32 (4)	6,57±8,89 (2)	2,36±3,53 (3)	3,37±6,27 (4)	61,7±120 (4)	4,95±6,68 (2)

6.1.2 Industrial discharges

The sources of industrial discharges into the marine environment are relatively well-constrained. They include alcoholic beverage-producing industries in the city of Limassol, and desalination units in Larnaca and Limassol districts.

The alcoholic-beverage producing industries, consisting of four wineries and a brewery, operate along the coast near the main Limassol harbor and discharge their cooling waters into Limassol (Akrotiri) Bay (Argyrou 2008). The cooling waters are obtained through boreholes and not through seawater abstraction, therefore they are likely to be enriched in nutrients at the source. The industries previously used to discharge all of their effluents, untreated, into the sea but that practice ceased in 2004 when they were connected to the sewerage system (Argyrou 2008).

The chemical characteristics of the discharges (Table 6.4) indicate that levels of BOD_5 and COD_4 have significantly improved since 2004, however they still may exceed the legally mandated levels of 30 mg L^{-1}, which may suggest a recurrent problem. Nutrient levels are also high, by orders of magnitude above those at coastal reference stations (see Part I, Section 1.4), but still under permissible levels for the disposal of other waste, such as treated urban wastewater (see previous section, 6.1.1).

The currently operating desalination units, consisting of two permanent units, the Dhekelia and Larnaca desalination units, operating in Larnaca Bay, and a soon-to-become-permanent desalination unit in Moni, near the city of Limassol, produce 60,000, 60,000 and 20,000 m^3 d^{-1} of desalinated water. Based on actual conversion efficiencies of 32-48 % (see section 4.2 for calculations), these three units discharge to the sea 154.000-264.000 m^3 d^{-1} of brine.

The average NO_3^- and NO_2^- concentrations of the brine discharged by the two permanent desalination plants (Table 6.5) are at levels similar to those at coastal reference stations (see Part I, Section 1.4). The average PO_4^{3-} concentrations can be as high as × 20 those at coastal reference stations, however it is anticipated that at those levels such inputs are rapidly and thoroughly mixed upon discharge into the sea.

Table 6.4 Average values for biochemical oxygen demand (BOD_5), chemical oxygen demand (COD_4), total suspended solids (TSS) and nutrients, of the discharges of the alcoholic beverage industries of Limassol for the years 2004-2007 (Argyrou and Loizides 2005, Argyrou 2006, 2008). The numbers in parentheses (n) represent the number of samples used in the averaging.

Year	2004	2005	2006	2007
BOD_5 (mg L^{-1})	1683±3423 (10)	524±551 (11)	113±118 (6)	211±498 (8)
COD_4 (mg L^{-1})	3210±7001 (10)	801±1276 (12)	199±193 (7)	312±738 (8)
TSS (mg L^{-1})	17,8±11,8 (5)	222,0±367,7 (12)	57,2±80,0 (7)	21,6±34,0 (8)
TN (μmol L^{-1})	-	561±920 (8)	218±245 (6)	152±157 (8)
NO_3^- (μmol L^{-1})	1080±809 (9)	1539±985 (11)	1820±1402 (7)	-
NO_2^- (μmol L^{-1})	15,5±8,8 (9)	39,5±56,3 (11)	34,0±53,1 (7)	-
TP (μmol L^{-1})	0,2±0,3 (9)	69,9±99,4 (8)	45,7±52,5 (6)	10,9±15,7 (8)
PO_4^{3-} (μmol L^{-1})	223,1±434,6 (9)	71,3±107,0 (13)	23,1±46,6 (7)	-

Table 6.5 Average values for total suspended solids (TSS) and nutrients, of the discharges of the Dhekelia and Larnaca desalination plants for the years 2004-2007 (Argyrou and Loizides 2005, Argyrou 2006, 2008). The numbers in parentheses (n) represent the number of samples used in the averaging.

Year	2004	2005	2006
TSS (mg L^{-1})	5,8 ± 4,3 (6)	1,5 ± 0,0 (4)	5.3 ± 3,2 (3)
NO_3^- (μmol L^{-1})	0,16 ± 0,03 (2)	0,07 ± 0,10 (4)	0,02 (1)
NO_2^- (μmol L^{-1})	0,16 ± 0,07 (2)	0,22 ± 0,10 (4)	0,25 (1)
PO_4^{3-} (μmol L^{-1})	0,73 ± 0,11 (2)	0,60 ± 0,47 (4)	0,61 (1)

6.1.3 Groundwater discharges

According to the official water balance of Cyprus (Water Development Department 2012), 70 $\times 10^6$ m^3 y^{-1} of water are lost to the sea via (presumably submarine) groundwater discharge. Groundwater is laden with nutrients, not only because of natural processes but also due to anthropogenic inputs, e.g., enrichment of the aquifer with treated water, excess fertilizer dissolution and transport, surface run-off from industrial, urban and other waste sources, storm runoff etc., as well as regeneration in situ via organic matter breakdown (WL | Delft Hydraulics et al. 2004a, Water Development Department 2011).

As a result of groundwater monitoring in the framework of the implementation of the Water Framework Directive, a large portion (42 %) were found in bad chemical condition, suggesting above-threshold-levels in many parameters (Water Development Department 2011). An indication of how big a source of nutrients can groundwater be to the marine ecosystem can be obtained by a simple calculation shown in Table 6.6. Due to the magnitude of the amount of water involved, it could be surmised that groundwater discharges are a significant diffuse (non-point) source of nutrients along the coast and shelf of Cyprus.

Table 6.6 Estimates of nitrogen inputs into the sea from groundwater discharge, obtained by multiplying minimum, maximum and average groundwater concentrations by the volume of groundwater discharge. Concentrations in groundwater were obtained from publicly available data for all the water bodies in coastal areas in 2010 (EEA 2011). In total, 86 and 96 values were used for NH_4^+ and NO_3^- respectively. The volume of groundwater discharge to the sea is 70×10^6 m^3 y^{-1} of water based on the current official water balance (Water Development Department 2012).

Parameter	**NH_4^+**			**NO_3^-**		
	Minimum	**Maximum**	**Average**	**Minimum**	**Maximum**	**Average**
Concentration (mg L^{-1})	0,019	6,05	0,26	0,18	476	48,7
Concentration (μmol L^{-1})	1,360	431,9	18,23	12,85	33980	3479
Discharge (t y^{-1})	1,33	423,5	17,87	12,6	33320	3411
Discharge ($\times 10^6$ mol y^{-1})	0,095	30,24	1,276	0,90	2379	243,6

6.1.4 Aquaculture

Marine aquaculture activities, as a potential source of anthropogenic nutrient and organic matter inputs in the marine environment, are probably the best-studied in Cyprus. Aquaculture activities that release nutrients and organic material into the environment include fry production in shore-based hatcheries and fattening operations in sea cage farms. As of 2011, four hatcheries and seven sea cage farms were in operation, dealing almost exclusively with the rearing of sea bream (*Sparus auratus*) and sea bass (*Dicentrarchus labrax*), and these numbers are roughly representative of the activity over the past decade (Department of Fisheries and Marine Research 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011). Even though two permits for sea cage farms for the fattening of wild-caught bluefin tuna (*Thunnus thynnus*) were issued for 2010, such farms did not operate in 2010 (Department of Fisheries and Marine Research 2011), and have only operated between 2004 and 2008. In similar vein, a shore-based shrimp farm had been granted permit for 2010, but no production figures were reported by the Department of Fisheries and Marine Research (2011).

Estimates of the magnitude of potential loads of nutrients and organic material from the operation of sea cage farms can be obtained based on production values and empirical waste generation related to production from the bibliography (Table 6.7 and Table 6.8). Production figures and load generation estimates for the past decade are shown in Table 6.9 and Table 6.10.

Table 6.7 Empirical conversion factors which, when multiplied by sea bream (*Sparus auratus*) and sea bass (*Dicentrarchus labrax*) production values, yield estimates of dissolved and particulate inorganic and organic nutrients as well as organic matter generated as waste during the same time period reflected in the production figures (Lupatsch and Kissil 1998, Holmer et al. 2008). PN: Particulate Nitrogen, PP: Particulate Phosphorus, POM: Particulate Organic Matter.

	NH_4^+	PO_4^{3-}	PN	PP	POM
Minimum	4.17 %	0.30 %	0.77 %	-	-
Maximum	4.47 %	0.37 %	1.07 %	-	-
Average	-	-	-	0.97 %	32.2 %

Table 6.8 Empirical conversion factors which, when multiplied by bluefin tuna (*Thunnus thynnus*) production values, yield estimates of total dissolved and particulate nitrogen and phosphorus generated as waste during the same time period reflected in the production figures. Average waste production rates in mg kg^{-1} fish d^{-1} of fattening (Aguado-Giménez et al. 2006) were converted to t t^{-1} fish produced for two scenaria: a 90-day fattening period (minimum), and a 180 day fattening period (extreme maximum).

Nutrient	Phase	90 d (minimum)	180 d (maximum)
Total Nitrogen (t t^{-1} fish)	Particulate	0.004451	0.008901
	Dissolved	0.06248	0.1250
Total Phosphorus (t t^{-1} fish)	Particulate	0.006301	0.01260
	Dissolved	0.004652	0.009304

Table 6.9 Minimum, maximum and/or average estimates of loading of inorganic and organic nutrients from sea cage farming of sea bream (*Sparus auratus*) and sea bass (*Dicentrarchus labrax*), for the past decade. Production values were obtained from the annual reports of the Department of Fisheries and Marine Research (2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011). Conversion factors and abbreviations are shown in **Table 6.7**.

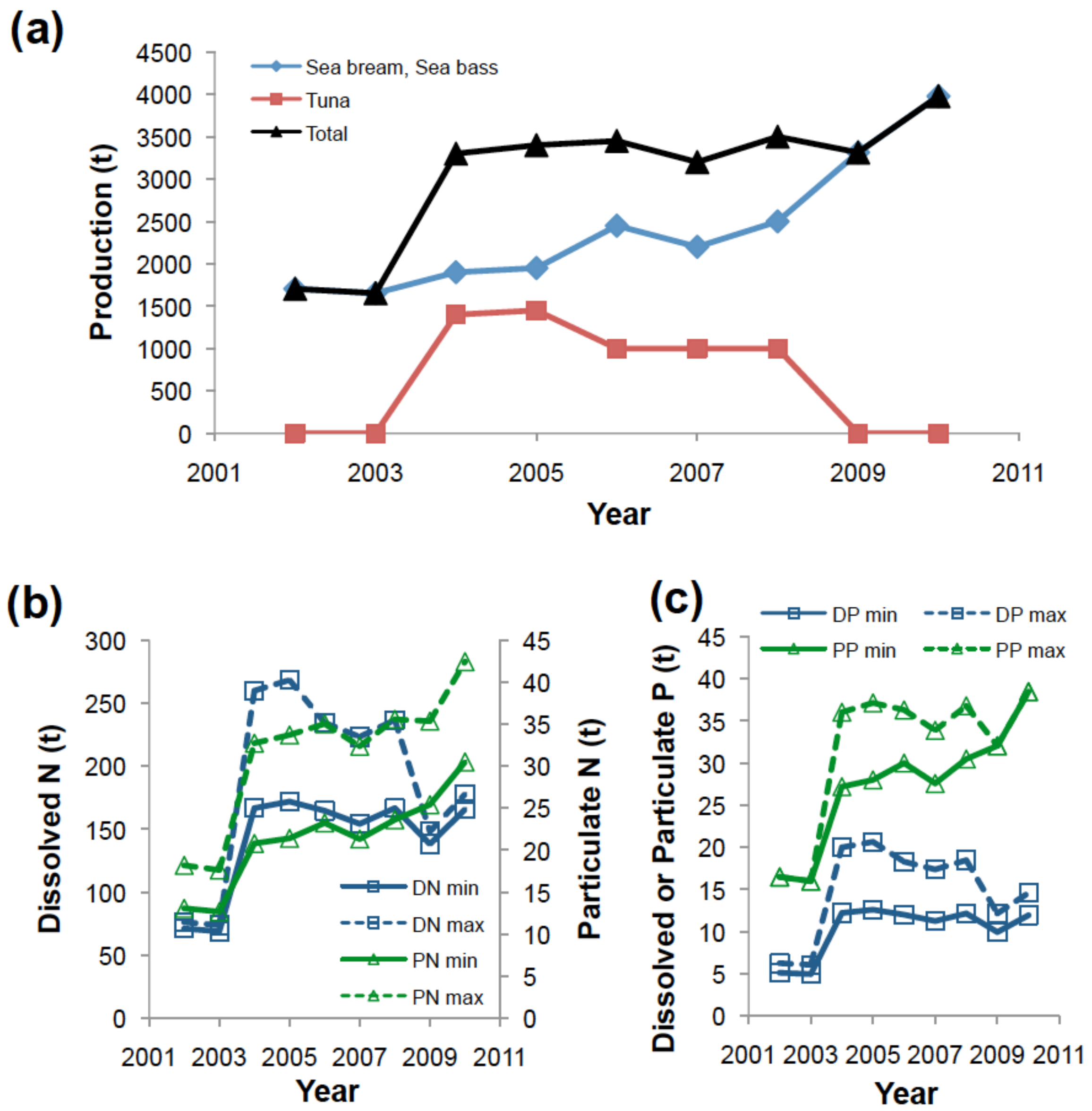
Year		**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Production (t)		1705	1653	1900	1950	2450	2200	2500	3314	3978
NH_4^+ (t)	min	71,04	68,88	79,17	81,25	102,1	91,67	104,2	138,1	165,8
	max	76,16	73,83	84,87	87,10	109,4	98,27	111,7	148,0	177,7
PO_4^{3-} (t)	min	5,12	4,96	5,70	5,85	7,35	6,60	7,50	9.94	11,93
	max	6,25	6,06	6,97	7,15	8,98	8,07	9,17	12.15	14,59
PN (t)	min	13,07	12,67	14,57	14,95	18,78	16,87	19,17	25.41	30,50
	max	18,19	17,63	20,27	20,80	26,13	23,47	26,67	35.35	42,43
PP (t)	aver	16,48	15,98	18,37	18,85	23,68	21,27	24,17	32.04	38,45
POM (t)	aver	549,0	532,3	611,8	627,9	788,9	708,4	805,0	1067	1281

Table 6.10 Indicative estimates of potential nutrient releases (TN: total nitrogen, and TP: phosphorus, in dissolved and particulate phase) from blue-fin tuna (*Thunnus thynnus*) farming for two fattening scenaria: a 90 d fattening period and a 180 d fattening period. Production values were obtained from the annual reports of the Department of Fisheries and Marine Research (2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011). Conversion factors and more details on the methodology are shown in **Table 6.8**.

Year			**2004**	**2005**	**2006**	**2007**	**2008**
Production (t)			1400	1450	1000	1000	1000
TN (t)	**Particulate**	90 d	6,2	6,5	4,5	4,5	4,5
		180 d	12,5	12,9	8,9	8,9	8,9
	Dissolved	90 d	87,5	90,6	62,5	62,5	62,5
		180 d	175,0	181,2	125,0	125,0	125,0
TP (t)	**Particulate**	90 d	8,8	9,1	6,3	6,3	6,3
		180 d	17,6	18,3	12,6	12,6	12,6
	Dissolved	90 d	6,5	6,7	4,7	4,7	4,7
		180 d	13,0	13,5	9,3	9,3	9,3

Combined production and load estimate time-series for both types of sea cage farming types are shown in Figure 6.1, and provide a general indication of the order of magnitude of nutrient release rates from sea cage aquaculture over the past decade. It should be pointed out that, while sea bream and sea bass farming takes place throughout the year, tuna fattening takes place over usually over a three-four-month period (at most half the year), presumably resulting in higher loading episodes than at sea-bream/sea-bass farms (Piedecausa et al. 2010). Therefore, the calculated metric of t y^{-1} is not as representative of loading rates due to tuna farming as it is for the other type. On the other hand, the complete absence of nutrient loading from a tuna farming site for at least six months, removes the pressure, and consequently any temporary impacts, for that period in the surrounding environment (see elsewhere in this section), allowing the surrounding ecosystem to recover (Piedecausa et al. 2010).

Figure 6.1 Time-series of: (a) production, (b) nitrogen load estimates, and (c) phosphorus load estimates, for the two types of sea cage farming, based on the data in presented in **Table 6.9** and **Table 6.10**.



Estimates of the potential loads not withstanding, the ability of the marine ecosystem to absorb anthropogenic inputs may temper their effect on ambient concentrations. Water at and away from sea cages and the outfalls of hatcheries has been sampled over the past several years for nutrient concentrations and chlorophyll. Comparisons of the nutrient concentrations at increasing distances away from sea cage farms rearing sea bream/sea bass (Table 6.11) and tuna (Table 6.13), indicate that any effects on nutrient concentrations, if any, are restricted at the sea cages. Similarly, the effluent of hatcheries which is rich in nutrients is barely detectable at the points of discharge in the sea (Table 6.12).

Table 6.11 Average annual nutrient concentrations at and 50 m away from a sea bream/sea bass sea cage farm for the years 2004-2007 (Argyrou and Loizides 2005, Argyrou 2006, 2008). The numbers in parentheses (n) represent the number of samples used in the averaging.

Year	Distance (m)	TN µmol L^{-1} (n)	NO_3^- µmol L^{-1} (n)	NO_2^- µmol L^{-1} (n)	NH_4^+ µmol L^{-1} (n)	TP µmol L^{-1} (n)	PO_4^{3-} µmol L^{-1} (n)
2004	**0**	-	0,09±0,11 (3)	0,02±0,00 (3)	0,25±0,35 (3)	-	0,09±0,05 (3)
	50	-	0,12±0,12 (3)	0,03±0,04 (3)	0,27±0,38 (3)	-	0,08±0,07 (3)
2005	**0**	30,3±25,6 (4)	0,27±0,57 (6)	0,03±0,02 (6)	0,92±1,21 (6)	0,89±0,55 (4)	0,03±0,06 (6)
	50	25,1±25,0 (4)	0,17±0,18 (4)	0,04±0,03 (3)	0,33±0,40 (4)	0,69±0,46 (4)	0,05±0,08 (4)
2006	**0**	53,3±15,3 (3)	1,14 (1)	0,04 (1)	1,10±1,33 (3)	3,01±1,97 (3)	0,01 (1)
	50	46,7±11,5 (3)	0,71 (1)	0,07 (1)	0,66±0,54 (3)	1,99±1,62 (3)	0,03 (1)
2007	**0**	22,6±16,3 (3)	0,18±0,10 (2)	0,11±0,05 (2)	0,66±0,64 (3)	1,13±1,28 (3)	0,02±0,02 (2)
	50	30,1±32,7 (3)	0,11±0,00 (2)	0,09±0,03 (2)	0,60±0,59 (3)	1,13±1,28 (3)	0,02±0,01 (2)

Table 6.12 Average nutrient concentrations at the outfall and in the sea at the discharge point in two hatcheries (denoted H1 and H2) for the year 2005 (Argyrou 2006). The numbers in parentheses (n) represent the number of samples used in the averaging.

Hatchery	Location	TN µmol L^{-1} (n)	NO_3^- µmol L^{-1} (n)	NO_2^- µmol L^{-1} (n)	NH_4^+ µmol L^{-1} (n)	TP µmol L^{-1} (n)	PO_4^{3-} µmol L^{-1} (n)
H1	**Outfall**	26,8±24,9 (3)	4,12±0,33 (3)	0,26±0,07 (3)	4,81±1,50 (3)	6,94±5,19 (3)	0,62±0,13 (3)
	Sea	16,8±15,0 (3)	4,20±1,03 (3)	0,13±0,02 (3)	2,00±2,50 (3)	2,42±1,16 (3)	0,24±0,12 (3)
H2	**Outfall**	37,8±51,6 (4)	30,9±35,7 (4)	0,45±0,58 (4)	7,87±7,83 (3)	11,7±22,3 (4)	0,51±0,59 (4)
	Sea	13,7±22,8 (3)	4,91±7,23 (3)	0,43±0,56 (3)	0,13 (1)	0,54±0,19 (3)	0,02±0,02 (3)

Table 6.13 Concentrations of major nutrients along two transects at increasing distances from a tuna farming operation in Limassol (Akrotiri) Bay in 2005-2006 (Argyrou 2006). The concentrations were averaged throughout the water column, which ranged in depth between 21-40 m.

Distance (m)	**0**	**50**	**100**	**150**	**200**	**400**	**500**	**4700**
Date	***June 2005***							
PO_4^{3-} (µmol L^{-1})	0.02 ± 0.01	0.11 ± 0.03	-	-	-	-	-	0.08 ± 0.10
TP (µmol L^{-1})	-	-	-	-	-	-	-	-
NH_4^+ (µmol L^{-1})	< 0.1	< 0.1	-	-	-	-	-	< 0.1
NO_2^- (µmol L^{-1})	< 0.036	0.05 ± 0.02	-	-	-	-	-	< 0.036
NO_3^- (µmol L^{-1})	0.24 ± 0.02	0.11 ± 0.08	-	-	-	-	-	0.21 ± 0.08
TN (µmol L^{-1})	117 ± 81	85.0 ± 65.5	-	-	-	-	-	77.5 ± 70.9
Date	***September 2005***							
PO_4^{3-} (µmol L^{-1})	< 0.016	< 0.016	0.04 ± 0.04	0.02	0.08 ± 0.07	0.02 ± 0.02	0.03 ± 0.03	0.04 ± 0.04
TP (µmol L^{-1})	19.3 ± 10.3	13.5 ± 17.3	30.5 ± 25.2	< 3.23	93.95	< 3.23	< 3.23	19.8 ± 3.74
NH_4^+ (µmol L^{-1})	0.34 ± 0.11	0.52 ± 0.42	0.27 ± 0.2	0.16 ± 0.14	0.25 ± 0.28	0.32 ± 0.39	0.16 ± 0.16	0.37 ± 0.09
NO_2^- (µmol L^{-1})	< 0.036	< 0.036	< 0.036	< 0.036	0.04 ± 0.15	< 0.036	0.07 ± 0.00	0.04 ± 0.04
NO_3^- (µmol L^{-1})	0.17 ± 0.17	0.25 ± 0.13	0.23 ± 0.11	0.23 ± 0.11	0.11 ± 0.15	0.40 ± 0.54	0.18 ± 0.15	0.15 ± 0.12
TN (µmol L^{-1})	30.0 ± 0.00	11.7 ± 4.08	21.7 ± 7.5	36.7 ± 12.1	25.0 ± 0.15	25.0 ± 7.07	15.0 ± 7.07	30.0
Date	***October 2005***							
PO_4^{3-} (µmol L^{-1})	-	0.15 ± 0.08	0.06 ± 0.06	0.02 ± 0.02	0.03 ± 0	< 0.016	0.07 ± 0.03	0.03 ± 0.02
TP (µmol L^{-1})	-	-	-	-	-	-	-	-
NH_4^+ (µmol L^{-1})	-	0.08 ± 0.05	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
NO_2^- (µmol L^{-1})	-	0.08 ± 0.04	0.10 ± 0.13	0.08 ± 0.04	0.02 ± 0	0.07 ± 0.00	0.06 ± 0.01	0.18 ± 0.16
NO_3^- (µmol L^{-1})	-	0.13 ± 0.07	0.15 ± 0.08	0.12 ± 0.10	< 0.036	0.21	0.11 ± 0.05	0.11 ± 0.15
TN (µmol L^{-1})	-	56.6 ± 46.2	61.6 ± 59.1	45.0 ± 24.3	25.0 ± 7.07	45.0 ± 28.3	30.0 ± 0.00	43.3 ± 23.1
Date	***March 2006***							
PO_4^{3-} (µmol L^{-1})	< 0.016	< 0.016	< 0.016	< 0.016	< 0.016	< 0.016	< 0.016	-
TP (µmol L^{-1})	1.29 ± 0.65	1.08 ± 0.53	1.51 ± 0.53	2.48 ± 2.90	1.61 ± 0.46	1.61 ± 0.46	2.26 ± 0.46	0.86 ± 0.37
NH_4^+ (µmol L^{-1})	0.16 ± 0.07	0.19 ± 0.08	0.16 ± 0.10	0.17 ± 0.10	0.22 ± 0.09	0.11 ± 0.00	0.13 ± 0.01	0.25 ± 0.12
NO_2^- (µmol L^{-1})	0.02 ± 0.01	0.01 ± 0.01	0.01 ± 0.001	0.004 ± 0.00	0.01	0.01	0.01	-
NO_3^- (µmol L^{-1})	-	-	-	-	-	-	-	-
TN (µmol L^{-1})	33.3 ± 15.3	43.3 ± 8.16	23.9 ± 15.3	2.38 ± 9.83	45.0 ± 7.07	30.0 ± 0.00	45.0 ± 7.07	30.0 ± 0.00

As mentioned in the first part of this Initial Assessment (section 1.4), the occasional relief of nutrient limitation in open Cyprus waters has dramatic effect on both photoautotrophs and heterotrophs (e.g., Ediger and Yılmaz 1996, Zohary et al. 1998, Thingstad and Rassoulzadegan 1999). The CYCLOPS experiment demonstrated how zooplankton has adapted to rapidly exploit any increase in primary production by rapidly investing in reproduction (Pasternak et al. 2005, Pitta et al. 2005, Psarra et al. 2005, Thingstad et al. 2005). An analogous situation is likely in coastal waters, since water column chlorophyll concentrations at sea cages or outfalls are rarely observed to exceed values at reference stations. However, when micro- and macroalgae bioassays were used during the MedVeg project field experiments in Limassol (Akrotiri) Bay, they demonstrated significant enhancement of primary productivity up to 150 m downstream from the sea cages, demonstrating the rapid sequestration of released nutrients by microbiota (Holmer et al. 2008).

However, more definite and evident signs of enrichment are visible in the case of benthic macroalgae. Various macroalgal species, such as *Cladophora*, *Enteromorpha* and *Ulva* spp. occur in significantly higher abundances tens of meters away from the outfall point of the Liopetri hatchery (WL | Delft Hydraulics et al. 2004b, and references therein). Moreover, epiphytes on *Posidonia oceanica* near sea cages elsewhere in the Mediterranean demonstrated increased N and P content as well as a higher $\delta^{15}N$ signature (indicative of fish feed input) closer to the sea cages than at reference sites (Pérez et al. 2008).

The assessment of aquaculture impacts on the marine environment is concluded in the next section (6.2) on organic matter inputs.

6.1.5 Regional change

Based on analyses of the rainfall patterns of the twentieth century, Cyprus is experiencing a drop of 125 mm of rainfall per 100 years, overlain with high variability in interannual rainfall (Michaelides and Pashiardis 2008, Pashiardis and Michaelides 2008). This past trend is consistent with regional analyses that project drier and warmer conditions for the future (Durrieu de Madron et al. 2011, Lelieveld et al. 2012). Reduced rainfall will likely be accompanied by decreased natural replenishment of the aquifer and reduced surface flows and storm run-off, and consequently may reduce their contribution to groundwater and surface water losses from land to sea. No estimates of the degree of reduction are available at this point.

Based on their past comprehensive reviews on fluvial supply and changes in that supply in the Mediterranean during the twentieth century (Ludwig and Meybeck 2003, Ludwig et al. 2009), Ludwig et al. (2010) attempted to predict the impact of population growth in the watersheds of the major rivers emptying into the Mediterranean over the first half of the twenty-first century. Their results (Table 6.14) project that population growth will most likely account for a significant increase in nutrient input in the Levantine, slightly off-setting the effects of mitigating measures to contain such discharges into fluvial supply. It should be pointed out that these inputs, especially in the case of the Nile, may be significantly reduced prior to reaching open waters by uptake by and removal in to the sediments of extensive margin systems, such as deltas, estuaries, and marshes (Ludwig et al. 2010).

Table 6.14 Population density (inhabitants km^{-2}) and predictions of riverine NO_3^- and PO_4^{3-} inputs (10^3 $t\ y^{-1}$) in the northern and southern Levantine (NLE and SLE respectively) based on models of four different scenarios developed by the Millenium Ecosystem Assessment (Ludwig et al. 2010). Ranges indicate minimum and maximum values obtained collectively by the four models.

	Basin	**Basin area (10^3 km^2)**		**Current river discharge (km^3 y^{-1})**	
	NLE	131		26.69	
	SLE	3010		6.06	
Year		**1970**	**2000**	**2030**	**2050**
Population density (inhabitants km^{-2})	**NLE**	4	39	144 - 159	152 - 177
	SLE	16	63	97 - 116	114 - 156
Riverine NO_3^- input (10^3 $t\ y^{-1}$)	**NLE**	4	39	46 - 51	27 - 72
	SLE	16	63	73 - 112	53 - 113
Riverine PO_4^{3-} input (10^3 $t\ y^{-1}$)	**NLE**	2	4	5 - 5	5 - 6
	SLE	1	6	14 - 23	20 - 31

6.2 Inputs of organic matter

6.2.1 Urban wastewater

It is estimated that urban waste in 2012 will contain 9921 t of BOD_5 (Table 6.1). Almost all of the produced wastewater will be treated and reused, however, as in the past (Table 6.2), a small fraction may be released into the sea in the winter due to lack of demand. Even though a metric of organic matter content is not measured in marine samples, some conclusions on the effects of loading on marine concentrations can be drawn from patterns for nutrients of N and P (Table 6.3): sufficient mixing results in greatly diminished concentrations, well below permissible levels, even at the point of discharge at sea. A study on the impact of sewage discharge on benthic communities around a sewage outfall documented a community high in diversity and low in abundance and biomass (Hadjichristophorou 1988).

6.2.2 Industrial discharges

The alcoholic-beverage producing industries of Limassol discharge their cooling waters into Limassol (Akrotiri) Bay (Argyrou 2008). The cooling waters, which are obtained through boreholes and not through seawater abstraction, are likely to be enriched in nutrients at the source. The levels of BOD_5 and COD_4 in the discharges have significantly improved since 2004 ($\times$ 8-10, Table 6.4), however they do remain mostly above the legally mandated levels of 30 mg L-1 (averages of 211 and 312 mg L^{-1} respectively) necessitating a reexamination with more recent data.

The desalination units have been shown (Table 6.5) to release brine with nutrient levels either similar (N) or in relatively slight excess (P) compared to concentrations at coastal reference stations. Organic matter content indicators are not routinely monitored, and it is not known what the concentration of organic matter is in particulate material removed during the pre-filtration process and released by back-wash into the discharge stream (e.g., Koutsakos and Moxey 2008). The reported TSS concentrations (< 10 mg L^{-1}, Table 6.5) are certainly well below the legally mandated 30 ppm limit. Finally, the adverse impacts reported by Argyrou (1999) on forests of the macroalga *Cystoseira*, as well as significant shifts in macrofaunal community composition, have been attributed to the brine and not to organic matter enrichment.

6.2.3 Aquaculture

Indicative estimates of organic matter load generation from sea cage farming of sea bream/sea bass and tuna is shown in Table 6.9 and Table 6.10 respectively, and discussed further in that section.

The sedimentation of the generated particulate (organic) material in the vicinity of sea cages was studied, among other processes, during the MedVeg study (Holmer et al. 2008). It was shown that sedimentation of particulate matter was significantly greater under the cages than at reference sites, diminishing gradually with distance away from the farm sites. It was also shown, corroborating previous studies, that at the depths the sea cages are placed (typically greater than 20 m), a significant portion of the particulate matter escaping the cages is consumed by aggregating populations of wild fish, which on the one hand decrease the rate of deposition of particulate material and on the other hand spread its distribution over a wider area by fragmentation and defecation (Sarà et al. 2004, Holmer et al. 2007).

The impact of sea cage farming on meadows of the angiosperm *Posidonia oceanica* has been of particular focus during the MedVeg study (Díaz-Almela et al. 2008, Holmer et al. 2008). The main finding was that various indicators of meadow health, such as shoot density, were negatively correlated with particulate sedimentation rates and nutrient supply, and were reflected in plant physiology as well as epiphyte growth.

Even this brief and cursory biogeochemical and ecological analysis of the effects of aquaculture operations on the surrounding ecosystem indicates that the present measures regarding their permitting are justified and adequate, and this is expected since discharge sources are concentrated over a relatively small geographic area (Holmer et al. 2008). On a broader geographic scale, their effects could be detectable with frequent and targeted monitoring in locations that are not exposed and are characterized by slow turnover times (e.g., Sarà et al. 2011) , while at basin scales they appear to play a small role relative to other inputs (Karakassis et al. 2005).

7. Biological disturbance

7.1 Introduction of microbial pathogens

The previous section (6 Nutrient and organic matter enrichment) has discussed various inputs, both natural and anthropogenic, into the marine environment of Cyprus, including treated urban wastewater, cooling waters from alcoholic beverage industries, groundwater seepage, and aquaculture effluents and waste. While the potential for introduction of microbial pathogens along with nutrient and organic matter inputs is possible in principle, such an effect has not been observed.

All the inputs previously discussed remain at levels that do not overwhelm the ecosystem. Even if low numbers of pathogens are introduced, the naturally-occurring microbial populations may effectively compete with them. Since the development of simple and effective epifluorescence microscopy techniques for the enumeration of microbes in the aquatic environment (Hobbie et al. 1977), it has become common knowledge that typical non-pathogenic microbial abundances in marine waters and sediments are 10^4-10^5 mL^{-1} and 10^6-10^9 cm^{-3} respectively for bacteria and archaea, while viruses occur in 10^7 mL^{-1} (e.g., Suttle 2007).

Data collected in the framework of the Directive concerning the management of bathing water quality (2006/7/EC) support the argument that even if microbial pathogens are introduced they either are not introduced in large numbers or they are outcompeted and eliminated by natural non-pathogenic populations and cannot establish themselves. The monitoring of bathing waters involves measuring the abundances of two groups of microbial pathogens, intestinal enterococci and *Escherichia coli*, in more than 110 coastal locations around Cyprus (Figure 7.1), designated as bathing waters (MANRE and MOH 2010). Since the implementation of this Directive as part of the harmonization process with EU legislation began, the level of compliance with guide and mandatory values has markedly improved (Table 7.1), to the point where all the monitored coastal waters (112 for 2010) complied with both guide values and mandatory values. Cyprus was the only EU member-state to post such a record in 2010 (European Environment Agency 2011).

Figure 7.1 Monitoring locations for microbial pathogens in the framework of the implementation of the Bathing Waters Directive (2006/7/EC) in Cyprus (European Environment Agency 2012).

Table 7.1 Record of compliance with the Bathing Waters Directive for the years 2004-2010 (MANRE and MOH 2010).

Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total number of bathing areas	100	100	100	100	111	111	112
% Sufficiently sampled and complying with guide values and mandatory values (C(I))	86	100	99	99	100	100	100
% Sufficiently sampled and complying with guide values (C(G))	81	100	99	99	98.2	99.1	100
% Not sufficiently sampled (NF)	9	0	0	0	0	0	0
% Not complying with mandatory values (NC)	5	0	1	1	0	0	0
% Prohibited for bathing (NB)	0	0	0	0	0	0	0

7.2 Introduction of non-indigenous species and translocations

The Mediterranean and particularly the Levantine Sea is one of the worst effected places in the world in terms of the numbers of non-indigenous species (NIS) present (Costello et al. 2010). The man-made route through which NIS enter the Mediterranean is the principal cause of biological disturbance that takes place in the Eastern Mediterranean. Shallow water species are more likely to be established and are made up of littoral or sublittoral benthic or demersal species since they are also more likely to be introduced by the predominant method of introduction via the Suez Canal (Galil 2009).

With the exception of documented intentional introductions only rarely do we known of the way that NIS arrive in the Mediterranean (Galil 2009). Regarding Cyprus no intentional introductions are known to have taken place.

Aquaculture in Cyprus deals primarily with Mediterranean species and aquarium facilities on the island are limited and well regulated. Accidental release of organisms is not thought to have taken place but cannot be ruled out via these routes. It is not known how many or indeed if any organisms have been introduced by ballast waters in the area but the possibility of this occurring due to the proximity with the Red Sea in particular is highly likely and is a more than likely an ongoing process. Cyprus ports are a hub for container transportation and this causes the likelihood of ballast water release to be increased. Additionally fouling organisms transported on vessels are also unknown and rarely documented although the incidence of this has become more common due to increased scientific interest (Zenetos et al. 2010). Introduction is likelier to take place in Cyprus water due to the shorter periods of time organisms are held in ballast tanks and the similarity of abiotic factors between the eastern Mediterranean and the Red Sea (EastMed 2010).

7.3 Selective extraction of species, including incidental non-target catches

The World Summit on Sustainable Development (United Nations 2002), held in Johannesburg in August 2002, laid the foundation for a radical shift about how marine ecosystems and fisheries are to be managed in the future. The Plan of Implementation adopted during WSSD encouraged the application by 2010 of the ecosystem approach to fisheries management (EAF, Garcia and Cochrane 2005), the elimination of destructive fishing practices and the establishment of marine protected areas consistent with international laws and based on scientific information. WSSD also agreed to restore the world's depleted fish stocks to levels that can produce the maximum sustainable yield (MSY) on an urgent basis where possible no later than 2015. After 10 years from the adoption of WSSD, Europe is still far from achieving these objectives (Froese and Proelß 2010). The Common Fisheries Policy (CFP) was inefficient in terms of reducing fishing capacity (Villasante and Sumaila 2010) as well as in rebuilding marine ecosystems (Worm et al. 2006). The fishery sector is still suffering from overfishing, fleet over-capacity, heavy subsidies, low economic resilience and decline in the volume and size of fish caught (European Commission 2009). Most of the stocks in European waters (88%) are estimated as being overfished and 30% of them are outside safe biological limits, which mean that they may not be able to replenish (European Commission 2009). In the Mediterranean, the achievements of WSSD targets risks to be further delayed by the assessment and management systems currently enforced at the national and EU level. A general condition of overfishing emerged for most of the Mediterranean stocks, confirming results of assessments carried out in the past (Lleonart 2005). According to Casey and Dörner (2010), 32 of 38 stocks assessed in Mediterranean European countries are overfished (about 84%), while only 4 stocks are considered sustainably exploited compared to the fishing mortality (F) level able to provide MSY. In the case of Cyprus, the last assessment carried out in the framework of FAO-GFCM show a similar situation with the stocks of the most important target species in overfishing (GFCM 2011).

Moving beyond the single species scale, fisheries also interact with a number of nonharvested species and with mankind's other uses of the natural environment at an ecosystem scale. Although some fisheries operate far offshore and away from other human activities, most of the world's fisheries are in coastal waters where interactions with other users are an important consideration and frequently a constraint. Other uses of the aquatic environment can include transport, tourism, conservation, oil and gas extraction, offshore mining and shipping, and aquaculture (Cochrane 2002). Fisheries management should take account of the effects that these other sectors can have on fishing and also of the converse effects that fishing may have upon them. The "Ecosystem Approach" aims to consider all significant interactions between species, sectors and the wider environment. The challenge is in turning all these principles and guidelines into operational objectives and ecosystem management plans that incorporate fisheries. Broadly speaking, the ecosystem approach implies a more holistic approach to management aiming to ensure that flora and fauna are maintained at viable levels in their native habitats and that the integrity of ecosystems is maintained as far as possible while supporting sustainable levels of human use. A FAO Technical Consultation (FAO 2003) has adopted the term "Ecosystem Approach to Fisheries" and defined its purpose as "to plan, develop and manage fisheries in a manner that addresses the multiplicity of societal needs and desires, without jeopardizing the options for future generations to benefit from a full range of goods and services provided by marine ecosystems". Garcia et al. (2003) explain the multiple elements of the approach and emphasizes its compatibility with the FAO Code of Conduct. It promotes maintaining the reproductive capacity of target resources; maintaining biological diversity (limiting introduction of alien species and protecting endangered species); using networks of MPAs; protecting and enhancing habitats (reducing both fisheries impacts and pollution); reducing bycatch, discarding and ghost fishing. From this new EAF perspective, discarding is currently one of the most important topics in fisheries management, both from economic and environmental points of view (Catchpole and Gray 2010). The FAO Fisheries Glossary describes discards as ‘that proportion of the total organic material of animal origin in the catch, which is thrown away or dumped at sea, for whatever reason. In Cyprus a pilot study on the evaluation of discards of the Cyprus fishery has been conducted in 2006 (Catchpole and Gray 2010). The study involved the on board sampling of two fisheries, the bottom otter trawl fishery around Cyprus waters and the large pelagic longline fishery in the Eastern Mediterranean. Results from the bottom otter trawl fishery show that catches are composed by a large number of species (~80), with one species dominating the catches (*Spicara smaris*). Total quantities discarded, including noncommercial species, represented 13% of the total catch. The commercial species with relatively high ratio of discards were *Pagellus erythrinus* and *S. smaris*, the latter exhibiting seasonal discard variation. The sampled catches of the large pelagic longline fishery were dominated by two species, *Thunnus alalunga* and *Xiphias gladius*. Discards were composed by species of low/no commercial value, including the marine turtle *Caretta caretta*. In both fisheries, sporadic occurrence of high value of discards created difficulties in raising discards to the population levels.

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REPUBLIC OF CYPRUS

MINISTRY OF AGRICULTURE, NATURAL RESOURCES, AND THE ENVIRONMENT

DEPARTMENT OF FISHERIES AND MARINE RESEARCH

Initial Assessment of the Marine Environment of Cyprus

Part III – Economic and Social Parameters

Nicosia, Cyprus
July 2012

Implementation of Article 8
of the Marine Strategy Framework-Directive (2008/56/EC)

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Foreward

This report was prepared by a consortium consisting of AP Marine (Cyprus), the Fisheries Research Institute of the Hellenic Agricultural Organization - Demeter (Greece), and independent experts.

The consortium undertook the authorship of three reports in the framework of the implementation of Articles 8, 9, 10 and 19 (par. 2a and 2b) of the Marine Strategy Framework Directive (2008/56/EC) on behalf of the Department of Fisheries and Marine Research (DFMR) of the Republic of Cyprus, under contract 12/2011. The three reports are: an Initial Assessment of the marine environment of Cyprus, a report on the Determination of Good Environmental Status, and a report on Environmental Targets.

This volume consists of Part III of the Initial Assessment and includes an economic and social assessment of the marine environment of Cyprus. There are two other volumes corresponding to the first two Parts of the Initial Assessment: Part I – Characteristics, and Part II - Pressures and Impacts.

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1. Economic and Social Assessment of the use of marine waters

1.1 Introduction- Marine Waters a source of national wealth

The contribution and importance of marine waters to the food provision, income and social wellbeing of human beings is well known. Specially, island states like Cyprus, devote their historical, economic and social evolution to this irreplaceable natural source.

1.2 Method

For the Assessment of the value of marine waters the second option proposed by DG Environment (final report 2010) was adopted. According to this approach in the Initial Assessment the Value of marine waters is assessed by calculating the financial benefits of the sectors/economic activities which are direct users of marine waters in the base line of 2010.

Similarly, the Cost of Degradation is the cost accrued to these sectors (losses of financial benefits) due to the degradation of the environmental status of marine waters. This approach corresponds to the Marine Waters Accounts presented by the Working Group on ESA (DG Environment December 2010).

The main advantage of this method is that it focuses on financial results generated through the market therefore directly quantifiable through market prices from official statistical sources and meaning full to everyone. Furthermore, the indicators and codes are common in the European System of National Accounts and thus comparable among member states.

The main disadvantage of this approach compared with the alternative of Ecosystem Services Approach is that the latter presents a more holistic view of the total value of marine waters as it includes non-profiting users and non users as well. But, as these values are not marketed there are immense difficulties in quantifying and putting them in monetary terms. This was the main reason for adopting the first approach.

The basic economic indicators used are: The Production Value, the Value Added and the Employment.

1.3 Sectors depended or related to the marine waters

All economic activities related directly to the marine waters can be classified in three main categories:

- The field of *goods extracted* from the sea like food provision. This field includes sectors like fisheries, marine aquaculture, fish products manufacturing, and the desalination for potable water.
- The field of *leisure and recreation* which includes mainly Tourism sector, restaurants and other recreational activities related to the sea.
- The field of *transportation* including activities related to the Shipping sector, ports and other supporting activities.

All three fields generate pressures (and they are not the only ones) on the environmental status of marine waters leading to their degradation in a bigger or lesser degree. The first two are those that in turn will suffer the negative impacts from water degradation through for example the decrease in fish stocks, the devaluation of the sea waters as an attraction factor for tourism and as a source for other recreational activities both by Cypriots and visitors.

It must be mentioned that the third field's dominant sector, Shipping, bears also additional cost related to water degradation, such as insurance, anti-fouling, ballast water treatment, air emissions, and marine litter(LEI, Wageningen UR, January 2011). But these are costs of measures to avoid degradation and not costs of degradation.

1.3.1 Field of goods extracted from the sea

1.3.1.1 Fisheries

Fishing is one of the most traditional sectors of Cypriot economy. The Cypriot fishing fleet consists of three main segments: The passive gear 0-12m segment, the polyvalent vessels and the bottom trawlers. The most important segment both in economic and social terms, is the passive gear 0-12m segment. There are 1,039 active vessels in the Fishing fleet Register of which the 96.8% (1,006 vessels) operates in inshore waters.

The most common species targeted are octopuses, red mullets, picarel and bogue which count for the 40% of total catches (2008).

In Table 1.1 the total catches show variations from year to year. Values are expressed in current prices.

Table 1.1 The total fisheries catches and value for years 2005-2008.

	2005		2006		2007		2008	
	Quantity (in tons)	Value (000 Euros)	Quantity (in tons)	Value (000 Euros)	Quantity (in tons)	Value (000 Euros)	Quantity (in tons)	Value (000 Euros)
Inshore Fishing	947	6.372	1.007	7.796	1.054	8.507	1.147	7.420
Fishing with trawlers	922	3.048	1.120	4.376	1.387	6.412	825	3.930
Total	**1.869**	**9.420**	**2.126**	**12.172**	**2.441**	**14.918**	**1.972**	**11.349**

Landings during the years 2009 and 2010 remain constant at 1,396 tons (DFMR, 2010).

Landings during 2009 reached 1900 tons of which 1000 tons from inshore fishing (€ 8 million value) of which 10 tons from polyvalent fleet, trawlers in territorial waters 169 tons (€ 578.671 value), trawlers in international waters 269 tons (€ 1,9 million value) and large pelagics (bluefin tuna tuna, albacore, swordfish) 253 tons of total value € 1,25 million. Likewise in 2010, landings reached 1,396 tons (DFMR, 2010). See box 1 for vessel fleet description.

In fisheries 1,238 persons are employed in a professional basis (DFMR, 2010) and their distribution by fishing type and territory is shown in Table 1.2.

Box 1. Fishing fleet description

In Cyprus, each vessel must declare the main gear that it is using plus one additional gear. Licenses are valid for one year and must be renewed after that period. Applications have to pass through an approval process. When a vessel owner wants to change something on his vessel, he has to submit a request to the DFMR. The request is analyzed, and if the change is authorized, a letter of approval is sent back to the vessel owner. There are different types of permits depending on fleet major categories:

A. small scale inshore fishing vessels that mainly use nets and are under 12 metres in length. The small scale inshore fishing vessels segment consists of the majority of the fleet in terms of the total number of the vessels. There are three different types of licenses for small fishing vessels, according to the length of net that can be used during a fishing operation: Vessels with license A' or B' and Vessels with license C'.

The vessels in the first category (license A' or B') can use nets every day all year round with minor restrictions (A up to 5 000 m nets and B up to 3 500 m nets). The licenses A and B category cannot exceed 500 per year. When renewing the license, the holders of A' and B' category of license have to prove that they have been active during at least 120 days and that their catches exceed 1 200 kg during the previous year. The primary gear used by the vessels with license A' or B' is a trammel net (GTN) and the secondary gear type used is set-anchored gillnets (GNS). For 2011 there are 500 licenses A' and B'.

The C' category has increased restrictions, such as a 600 m maximum length of nets and maximum of 70 working days (set at pre-defined days in a calendar at the beginning of each year). The licenses of category C' cannot exceed 1 200 per year. There are 375 licenses Category C' with vessel at present. This number might reach 450 this year. The primary gear type of the vessels with license C' is set-anchored gillnets (GNS) and the secondary gear type is either handlines or pole lines (LHP).

The small scale inshore fishery corresponds to 96.2 % of the total number of active vessels in the Cypriot Fishing Vessel Register.

B. polyvalent or longliners which are vessels above 12 metres

The fishing vessels in this category target mainly large pelagic species such as swordfish, albacore, bluefin tuna and other tuna like species. All polyvalent vessels must be above 12 metres according to National Law. The polyvalent fleet consists of 22 vessels (May 2011), corresponding to 2.1 % of the fleet. These vessels are authorized to use the following fishing gears:

1. Drifting longlines,

2. Set longlines,

3. Trammel nets or set-anchored gillnets and pots/traps.

C. bottom trawlers which operate inside and outside the national waters of Cyprus (12 nautical miles),

This category is subdivided into the trawlers that operate inside or outside the national territorial waters (12 nautical miles) and the ones that operate exclusively outside the national waters. Three trawlers were authorized to fish inside the national waters in 2011 and eight operate exclusively outside the national waters, in the Mediterranean Sea (north Cyprus, south Cyprus and around Malta).

D. purse seiners.

There is only one (1) purse seine in operation in Cyprus now.

Table 1.2 Employment in Fisheries (2008 DFMR Data). Values refer to individual persons engaged in fisheries activities. Abbreviations: Own. – Owners; Assist. – Assistants.

CLASS/ GENDER	Inshore fishing (licenses A,B,T)		Inshore Fishing (C)		Polyvalent		Trawlers in Territorial Waters		Trawlers in International Waters		Total
	Own.	Assist.	Own.	Assist.	Own.	Assist.	Own.	Assist.	Own.	Assist.	
FEMALE	8	18	3		2	6					37
MALE	490	295	248		28	56	4	24	8	48	1201
TOTAL	498	313	251		30	62	4	24	8	48	1238

1.3.1.2 Marine aquaculture

In Cyprus there are three marine fish hatcheries and one shrimp hatchery, seven cage farms for sea beam and sea-bass and two farms for blue fin tuna fattening (there are no production figures for tuna in recent years)[1].

A slight decline is noted after 2005 but the production recovers and in 2008 reached again the levels of 2005. According to the data released by the Department of Fisheries and Marine Research the production of table size fishes in 2009 and 2010 has reached 3,390 tons and 4,077.4tons respectively (4,007.8 excluding the fresh water production). In other words an increase of 20.3% is recorded in 2010 in quantity. The relevant value of production for 2010 was 20.1 million Euros (19.5mEuros if only marine aquaculture is considered). The production of fry reached 11.8 millions of small fishes and a value of 1.9 million Euros in 2010 (DFMR report 2010).

Table 1.3 Production of marine aquaculture in quantity and value by product.

	2005		2006		2007		2008	
	Quantity in tons	Value In 000 Euros	Quantity in tons	Value In 000 Euros	Quantity in tons	Value In 000 Euros	Quantity in tons	Value In 000 Euros
Fishes	3,530	30,026	3,522	30,131	3,110	26,300	3,507	29,461
Fry	14000*	3,259	13000*	3,204	15000*	4,832	11,17*	3,571
Shrimps	5	69	23	320	30	413	35	478
Total	3,535	33,354	3,545	33,655	3,140	31,545	3,542	33,510

* Millions of fingerlings

Employment in the sector reaches the 250 persons in 2010 while according to DFMR a much greater number is employed in related occupations.The sector is characterized as extrovert since 55% of the production is exported.

The basic indicators relevant for the Economic and Social Analysis of the Initial Assessment are presented in Table 1.5 jointly for Fisheries and Marine Aquaculture.

[1] Apart of these farms there are also nine farms for trout culturing and two farms for ornamental fishes but their figures are not included in the Table of production because they are fresh water farms. They are though included in the table of Value Added as the data is offered jointly and could not be separated. Due to their small quantity their inclusion in data will not affect the reliability of the figures.

Table 1.4 Exports of marine aquaculture by type of fish and fry 2010

Type	Culturing/fattening farms (table size)					
	For Domestic Consumption		Exports		Total	
	Quantity (tons)	Value (€)	Quantity (tons)	Value (€)	Quantity (tons)	Value (€)
Sea-beam	1,068	5,264,000	1,705	8,012,000	2,773	13,277,000
Sea-bass	650	3,291,000	555	2,824,000	1,205	6,115,000
Japanese red sea bream	14	83	0	0	22	85
Marbled spinefoot (*Siganus rivulatus)*	5	41	0	0	5	41
Meagre (*Argyrosomus regius*)	2.8	27	0	0	2.8	27
Total	**1,809.4**	**9,291,500**	**2,26**	**10,836,000**	**4,077.4**	**20,130,500**

Type	Hatcheries (fry)					
	For Domestic Consumption		Exports		Total	
	Quantity (number)	Value (€)	Quantity (number)	Value (€)	Quantity (number)	Value(€)
Sea-beam	9,101,000	1,483,000	0	0	9,101,000	1,483,000
Sea-bass	2,695,000	420	0	0	2,695,000	420
Japanese red sea bream	7,5	1,2	0	0	7,5	1,2
Total	**12,203,500**	**1,947,200**	**29**	**46**	**12,232,500**	**1,993,200**

Total Value of Cypriot marine Aquaculture	**22,123,700**

Table 1.5 Basic Economic indicators for Fisheries and Marine Aquaculture

	2004	2005	2006	2007	2008
Value of Production (000 Euros)	41,273	41,408	40,709	44,328	43,267
Value Added (000 Euros) in current market prices	28,528	27,758	27,578	30,790	30,626
Value Added (000 Euros) in constant prices 1995	32,155	30,959	33,404	31,935	32,516
Employment[2] (number of persons in equivalent of full employment)	1.300	1.200	1.150	1.200	1.441

[2] The number strictly employed in aquaculture is 250.

1.3.1.3 Processing and trade of fish products

In this sector, 24 firms are recorded (2010 data) with the majority of them (64%) operating in "repackaging of frozen fishes and other fishing products". Three firms are engaged in "packaging of aquaculture products", two in "fish manufacturing and other products". There is one enterprise for cultured shrimp packaging, and three more that serve more than one category.

The basic economic indicators of the sector appear in Table 1.6.

Table 1.6 Basic Economic Indicators for Processing and Trade of fish products sector

	2009	**2010**[3]
Value of Production(000 Euros)	38,826	38,116
Value Added(000 Euros)	8,518	7,970
Employment (number of persons)	221	215

According to the annual report 2010 of DFMR this sector is a new economic activity in Cyprus which with the evolution of time opened the range of its activities and products. Much of recent sector's development is owed to financial aid opportunities through European Funds and to the increased demand of fishing products with high value added. The manufactured fish products are almost exclusively traded in the domestic market. Only a small number of firms operate in the segment of high value added products (ready meals) due to the high capital investment requirements. Most part of raw materials are imported as the domestic fishing production is sold fresh, profiting from higher prices.[4]There are only three firms with vertical integrated production as they have their own trout farms[5].

In any case the sector is characterized by the good quality of its products and the increased demand of the domestic market which cannot be satisfied by the actual domestic production.

1.3.1.4 Desalination Units

A central problem that affects the quality of life of Cypriot citizens is that of lack of potable water. The situation deteriorates due to climate changes with temperature increases and long periods of drought. The problem is extremely intense in urban areas where the 69% of the population[6] lives, and it is characterized by seasonality due both to climate conditions and (and perhaps mainly) due to tourist arrivals. It is worthwhile mentioning that while Cypriot population is around 845 thousands inhabitants (Central Bank Bulletin 2011) tourists arrivals in recent years are up to 2.5 millions. Repeated stops of water supply are the result of the lack of adequate water resources.

In order to deal with this problem the Cypriot Government a) Elaborated a plan for managing and monitoring the demand for fresh water according to COM(2007)414 of the European

[3] *Provisional Estimates*

[4] There is a point of controversy here, as this sector depends on imported raw materials it is not actually related to the Cypriot marine waters and it is not affected by the environmental status of these waters. Therefore it may not be included in the calculation of Value of marine waters.

[5] This in fact support the argument of the previous footnote as trout is a product of fresh waters not related with marine waters.

[6] Census 2001

Union and b)proceeded with the establishment of desalination units while additional ones are in the planning phase, aiming to the increase of availability of potable fresh water.

The existing desalination units and their capacity are:
- The permanent unit of Dekeleia with a daily capacity of 60,000m^3
- The permanent unit of Larnaca with a daily capacity of 63,000m^3

In parallel, some mobile units are under operation, those of:
- Moni with daily capacity of 20,000m3
- Garrili (it is actually a river water treatment unit) with a daily capacity of 10,000m^3

Three additional permanent units are under completion (2010), those of:
- Episkopi (Limassol) with a daily capacity of 40,000m^3
- Pafos with a daily capacity of 40,000m^3
- Vasiliko with a daily capacity of 60,000m^3

Two more units are in the initial phase of planning:
- A movable unit in Pafos of 20,000m^3capacity per day
- A movable unit in Vasiliko of 20,000m^3 per day

The operating units produce (2009) 55.5millionsm^3 annually of fresh potable water (Ministry of Agriculture, Natural Resources and Environment 2010) as it is shown in Table 1.7.

Table 1.7 Annual capacity of fresh water per year.

Desalination Unit	Capacity in millionsm^3/year
Larnaca	22,63
Dekeleia	21,90
Moni movable	7,30
Garrili	3,65
Total	**55,48**

The value and quantity of water coming from the operating desalination units for the years 2008 and 2009 appear in Table 1.8

Table 1.8 Value and Quantity of water from desalination units.

	2008	2009
Value (000 Euros)	36,300	49,400
Quantity (millions m^3)	33.2	49.7

1.3.2 Field of Leisure and recreation

1.3.2.1 Tourism

Tourism in Cyprus, tied unbreakably with the marine surrounding of the island, is one of the most important sectors of the Cypriot economy. Despite the recent downturn in its basic statistics, it continues to contribute a lot to the GDP of the country. In 2001 tourism revenues were the 23% of GDP while in 2009 dropped to 10%.

2009 was a bad year for Cypriot Tourism mainly due to world recession. But from the statistics of the Table 1.9 it is evident that this sector faces a general stagnation.

Table 1.9 Tourism statistical data

	2006	**2007**	**2008**	**2009**
Arrivals(in 000)	2,401	2,416	2,404	2,141
Nights spent (000)	14,439	14,378	14,380	13,004
Revenues(millions Euros)	1,755.3	1,858.1	1,792.8	1,493.2

In 2009 tourists arrivals decreased by 10.9% compared to those of 2008. Accordingly nights spent dropped by 9.6% and revenues decreased by 16.7%.

Statistics of the two other categories of visitors, namely the cruise-ship visitors and the same-day tourists present the same picture.

Table 1.10 Movement of same-day visitors

	2006	**2007**	**2008**	**2009**
Cruise-ship visitors[7]	221,107	246,917	221,544	225,129
Same-day tourists	7,145	8,335	5,251	3,658

Regarding the origin of tourists, United Kingdom remained the major source of tourists' movement with a share of 49.9% of total arrivals, while eight countries contribute to the 80% of arrivals.

Tourism in Cyprus is clearly of leisure character with the 80% of tourists declare leisure as their purpose of visit. For business trip came only the 7.3% and visiting friends and family the 13.7% (2009).

The spatial distribution of nights spent indicates that Famagusta and Pafos are the most attractive resorts with a share of 43.1% and 33.9% of total nights spent respectively.

[7] The data includes also some movement transit at ports but the relevant figures in recent years are insignificant.

Table 1.11 Arrivals by country of origin (in 000).

	2006	2007	2008	2009
United Kingdom	1,360.1	1,282.9	1,242.7	1,069.2
Germany	152.8	138.5	132.1	131.2
Greece	126.8	139.8	133.0	131.9
Switzerland	41.3	41.4	38.6	38.7
Norway	50.7	53.4	63.5	60.2
Russia	114.8	145.9	180.9	148.7
Sweden	94.0	121.0	124.9	108.3
France	37.8	41.4	36.1	26.2
% of Total	**82.39%**	**81.30%**	**81.19%**	**80.06%**

Table 1.12 Spatial distribution of nights spent (in 000)

	2006	2007	2008	2009
Nicosia	252	269	277	254
Limassol	2.129	2.012	2.005	1.656
Larnaca	1.102	1.054	1.042	896
Famagusta	5.717	6.043	6.166	5.603
Pafos	5.089	4.842	4.736	4.413
Hill resorts	150	158	154	182

The small share of Hill resorts justifies the argument that the main attraction pole for Tourism in Cyprus is the marine waters.

1.3.2.2 Touristic infrastructure

<u>Accommodation</u>

Hotels and other types of tourists' accommodation follow a decline as well, during the same period. Due to impressive economic results in years 2000-2001 the construction of new hotels showed an increase in the following years. This trend was reversed the next period following the decrease in touristic movement. As a result some hotels were shut down.

Data in Table 1.13 shows a decrease in the number of accommodation units of 5.9% during the period 2006-2009, while the relevant decrease in beds was 5.5%.

The spatial distribution of accommodation units is a verification that Pafos and Famagusta (Ag. Napa, Paralimni) are the areas with the most developed touristic infrastructure. From the total number of accommodation units Pafos has over the one third with Famagusta possessing the other one third. Regarding the beds the relevant percentages are 31.9% and 40.3% respectively.

The 40.1% of total hotel beds belongs to the category of luxury hotels (4 and 5 stars), an element that shows the high quality of touristic capital in Cyprus. Analytical tables of accommodation are in Annex A.

Table 1.13 Number of Accommodation units and beds.

	2006	2007	2008	2009
Accommodation units	909	902	869	855
Beds	93.957	92.569	90.398	88.803

Organized Beaches

The beaches of Cyprus are a main attraction both for tourists and residents. Most of them are located in Famagusta area. A big number of them are awarded with the blue flag for their excellent status.

Table 1.14 Number of organized beaches and blue flag award

	Organized beaches	Of whom blue flag
Famagusta	28	22
Larnaca	7	5
Limassol	16	16
Pafos	8	8
Total	**59**	**51**

Apart from the organized beaches Cyprus has many other coastal locations designated as bathing waters. As mentioned in 7.3 of Part II of this report all of the monitored areas (112) comply with guide and mandatory values.

Fishing shelters and Marinas

Marinas and in a lesser extend fishing shelters are a necessary part of infrastructure for a competitive touristic product. Motivate the development of yachting and of organized marine tours enriching thus the touristic product.

Table 1.15 Fishing shelters and Marinas.

Famagusta	Limassol	Larnaca	Pafos
F.S. Paralimni	F.S. Old Port Limassol	Marina Larnaca	F.S.Pomou
F.S. Potamou Liopetriou	F.S. Pissouri	F.S. Vassiliko	F.S.Ag. Georgios Pegeia
F.S. Ag. Napa	Port Limasol	F,S. Larnaca	F.S. Lakkiou
F.S. Ag. Triada	Marina Ag. Raphael	F.S. Ormideia	F.S. Pafos
	F.S. Melounda		

Economic and social indicators of both Accommodation and Food and Beverage services activities are presented here reflecting the contribution of Tourism and more general of leisure in the calculation of the Value of Marine waters. This can lead in overestimated results as, while for accommodation the dependence with marine waters is quite clear, in the case of food and beverage services this is not so obvious, as there are no figures for the spatial distribution of these activities in coastal areas or not. Additionally there are no figures of the percentage of the turnover of this sector generated by tourists. But the alternative solution of not being included could lead in an even bigger error of underestimated results.

The basic indicators appeared in the following tables.

Table 1.16 Basic Economic indicators of Accommodation.

	2007	**2008**	**2009**
Value of Production (000 Euros)	861,613	886,316	780,084
Value Added (000 Euros) in current market prices	512,515	524,398	451,112
Value Added (000 Euros) in production factors prices	500,780	512,725	445,575
Employment	17,066	16,985	15,517

Table 1.17 Basic Economic indicators of Food and beverage service activities.

	2007	**2008**	**2009**
Value of Production (000 Euros)	1,004,786	1,052,866	1,075,328
Value Added (000 Euros) in current market prices	498,154	501,319	510,596
Value Added (000 Euros) in production factors prices	495,154	498,450	507,435
Employment	**21,357**	**22,152**	**22,964**

1.3.2.3 Building of pleasure and sporting boats

The sector is quite small, only three firms are involved (Industrial Statistics,2010). Small as well, is its contribution to the Value of marine waters. As it is definitely a sector related with the sea it is presented here for the analysis completion. The relevant indicators presented in the following table.

Table 1.18 Basic economic indicators of pleasure boats.

	2009	**2010**
Value of Production (000 Euros)	1,740	2,160
Value Added (000 Euros) in current market prices	540	710
Employment	29	34

1.3.3 Field of marine transportation

1.3.3.1 Shipping

The strategic importance of Cyprus geographical positioning, as well as the targeted policies of the State have elevated Cyprus as an important international shipping center. The contribution of shipping sector to the economy is well above most of the other European countries. According to the Central Bank the sector contributes to the GDP by 5.5%.

Employment of the shipping sector and the adjacent activities, counts 4,500 persons working in land (the 2.2 % of total employment) while the number of sailors is 40,000, with only 5,000 of them being Europeans.

An identification of all activities related to shipping is attempted below

<u>Ports</u>

Cyprus Port Authority manages the three main ports of the island and the oil terminals of Larnaca, Dekeleia and Vassiliko.

Port of Larnaca

It is the second in size port of Cyprus and it is located 2 km from the city center and 6 km from the International airport. It is a multipurpose port, its surface is of 0.445 km^2 and handles almost every type of cargo.

Port of Lemesos

It is the main port of Cyprus, a multipurpose one handling cargo and passengers traffic activity. Its inland surface covers 1.3 km^2 with sea surface of 1 km^2. It started operation in 1974, replacing the old port of Lemesos. The latter is under redesign and reforming plans.

Port of Vassiliko

It is located between Lemesos and Larnaka and it is an industrial port handling mainly bulk cargo. Cement, animal foodstuffs, scrap etc.

There are two additional small ports, of Pafos and Latsi serving fishing and recreational boats.

Labor services are supplied at the ports by Port workers. Employment in the two main ports consists of 134 such workers at Lemesos port (109 port workers, 15 Tally clerks and 10 overseers) while at Larnaka 33 such workers are employed (26 Port workers, 4 Tally clerks and 3 overseers). Licensed porters carry on the horizontal transport work of cargo and their number is 54 (who in turn employ 68 workers) at Lemesos port and 33 at Larnaca. To these numbers 9 more must be added for transporting passengers' luggage.

<u>Cypriot fleet</u>

The Cypriot fleet is ranked 10th internationally and 3rd among European countries (Port Authority of Cyprus 2010). Cypriot fleet generates state revenues of about 9mn Euros per year.

Table 1.19 Cypriot fleet

	Number of vessels	Registered tonnage
2005	1,802	21,094,415
2006	1,845	21,994,770
2007	1,789	20,196,441
2008	1,869	21,626,432
2009	1.856	21.715.158
2010	1.862	22.057.524

Table 1.20 State revenues from Cypriot fleet vessels

	2006	2007	2008	2009	2010
Registration fees	1.039.331	1.385.072	1.508.052	1.453.522	1.319.829
Sales of ship documents	1.195.322	1.261.594	1.513.012	1.307.804	1.244.848
Tonnage tax	4.314.391	4.224.608	4.066.836	4.092.339	3.451.799
Wireless licenses	70.770	99.774	98.316	99.488	109.477
Tax for ship- management companies	1.306.725	1.458.377	1.556.660	1.789.395	1.838.872
Miscellaneous	494.442	955.615	593.541	878.084	1.270.269
Total	**8.420.981**	**9.385.040**	**9.336.417**	**9.620.632**	**9.235.085**

Ship-management

Cyprus is among the five countries with the highest number of ship-management companies in the world. More than 60 companies among which are some of the international “big names” are established in Cyprus. Most of them are located in Lemesos which has become one of the most important third party ship-administration centers. According to estimations the 20% of the global ship-administration fleet is operated by Cyprus. The majority of these companies are of Cypriot and other European Interests.

Shipping Activity

Annex A includes analytical tables presenting the shipping activity served by the three main Cypriot ports and oil terminals, referring to the number of vessels, the volume of cargo traffic, as well as, the passengers movement.

Summarizing the figures from these analytical tables the total cargo and passengers’ traffic to the ports of Cyprus in 2009 showed a decrease as a result of the economic crisis of 2008. The number of vessels which called Cypriot ports was 4,811 compared with 5,008 of 2008. The total tonnage of cargo carried amounted to 7.8mn metric tons showing a decrease of 15% from the 8.9mn metric tons of the preceding year. The same drop was reported in containers handling and passengers’ traffic. As expected, this trend affected, among others, the revenues of the Port Authority of Cyprus who face a decrease of 8.2 % in the period 2008-2009 (Port Authority of Cyprus, Annual report 2009).

Table 1.21 Port Authority of Cyprus Revenues

	2008	2009
Administrative	52.638.045	44.924.116
Warehousing	2.554.488	2.888.415
Licenses and rights	9.160.945	8.417.704
Investments	7.978.926	9.944.337
Other sources	694.180	995.711
Total	**73.026.584**	**67.170.283**

As already mentioned the trend in shipping activity, both freight and passengers, reflect the negative impacts of the recent economic crisis. Despite these results shipping sector is one of the most important for the Cypriot economy. The basic indicators are shown in Table 1.22.

Table 1.22 Basic Indicators of Sea Transportation

Economic Activity	Gross Output	Value Added	Employment
Passengers sea transportation	206,937	99,427	2,554
Short excursion trips by small vessels	6,115	2,967	75
Freight sea transportation	67,931	30,759	340

1.3.3.2 Services supporting Shipping Activity

Shipping sector calls for a wide range of other services necessary for currying on business. Such services are custom clearing services, refrigerated storage and warehouses, shipping agencies, packing and forwarding services etc. Their basic economic indicators appear in Table 1.23.

Table 1.23 Basic Indicators of Supporting Activities

Economic Activity	Gross Production value(000s Euros)	Value Added (000s Euros)	Employment
Cold storage services	1.062	547	40
Bonded warehouses	4.435	2.270	67
Ports Authority	56.713	50.647	372
Navigation, pilotage and ship salvage	4.307	2.123	42
Loading and unloading of cargo and passengers luggage	25.956	20.054	380
Stevedoring	7.779	4.538	133
Shipping agencies	333.865	241.490	3.803
Custom agents	29.237	20.260	588
Government revenues from ships	9.235		

1.4 Total Value of Marine Waters

The identification of the sectors dependent on marine waters and profiting from the use of them, and the relative easiness of finding reliable monetary values through the National Statistical Systems is the key advantage of this method. Bearing in mind some precautions regarding the possibility of some overestimation or double-counting errors, the figures of the concise Table 1.24 may added up to give the Total Value o Marine Waters in terms of Value Added.

Table 1.24 Total Value of Marine Waters

Economic Activity	Gross Production Value (000 Euros)	Value Added (000Euros)	Employment
A Field			
Fisheries[8] and Aquaculture	43.267	30.626	1.441
Processing and Trade of fish products	38.826	8.518	221
Desalination	49.600[9]		
B Field			
Accommodation	780.084	451.112	15.517
Food and Beverage services	1.075.328	510.596	22.964
Building of pleasure boats	1.740	540	34
C Field			
Water Transportation			
Passengers sea transportation	206.937	99.427	2.554
Short excursion trips by small vessels	6.115	2.967	75
Freight sea transportation	67.931	30.759	340
Supporting Activities			
Cold storage	1.062	547	40
Bonded warehouses	4.435	2.270	67
Port Authority	56.713	50.647	372
Navigation, pilotage and ship salvage	4.307	2.123	42
Loading and unloading	25.956	20.054	380
Stevedoring	7.779	4.538	133
Shipping agencies	333.865	241.490	3.803
Custom agents	29.237	20.260	588
Government revenues from ships	9.235		

The total Value of Marine Waters of Cyprus amounts to 1.47 billions Euros. In order to reduce the risk of an overestimation, the Total Value was recalculated eliminating some factors that lead to overestimation. Specifically, a) the sector of "processing and trading fish products" was excluded because its dependence on the country's marine waters is not

[8] Figures 2008
[9] Cost of buying water

justified as the total of raw materials used are imported, and b) only 50% of the value added of the sector "food and beverages" was included in calculations. The new Total Value of Marine Waters is 1.2bn Euros.

The actual Total Economic Value of Marine Waters is though a much higher figure than that calculated on the market benefits of the profiting sectors. Because marine environment creates additional values to both, users and non-users, that cannot be quantified through the market mechanism.

1.5 Other values

Except the above mentioned market oriented benefits, there are many other benefits that are linked with the marine waters. Marine waters create values that are not profit-generating, but nevertheless are extremely significant to the human well-being. Due to this significance- though the Marine Water Accounts Method adopted does not include such values- it is worthwhile referring to these non-profit generating values. These values can be subdivided into three groups: Values of direct use of marine waters, values of indirect use of marine waters, and non-use values.

1.5.1 Direct use values

In this category fall recreational activities as well as educational and research activities.

Recreational activities: Includes activities such as bathing, angle fishing, scuba diving. In Cyprus, as in all island states, bathing is an essential part of everyday life of inhabitants. Though data on the actual number of bathers is not available, it is worthwhile mentioning that Cypriot bathing areas have a total length of 59,700 m. Cyprus is ranked 3rd among European countries in the number of bathing areas per million of population[10] and 6th in the number of bathing areas per thousand kilometers of coastline. Both these indicators are good proxies of the importance of bathing as recreational value of marine waters. License is not required for sea angling, therefore it is not possible to estimate the number of sea anglers. The availability of fishing boats rental, the excellent climate conditions and the over 80 salt water fish species[11] in the surrounding sea, as well as the long tradition in such an activity are factors in favor of sport fishing in Cyprus. Scuba diving is a comparative new recreational activity (at least as a mass recreational activity). Water temperature varies from 18^{0}C in January to 27^0 C in July, and the visibility ranges from 10-40 meters. There are more than 12 Dive centers and the dive sites include wrecks, caves and ancient settlements. Though Cyprus is not considered as the top priority of scuba divers it has one of the best wreck dives of the world, Zenobia, and at the same time it enriches the touristic product.

Educational and research activities: In Cyprus there is an important number of institutions, public, private and non-profit organizations who work on research and training for marine environment or specific marine species. These organizations have established cooperation with other European and International bodies, forming a network for Mediterranean research and marine education. As it was not possible to compile data on marine research funding, we just introduce the value added number computed by Pugh and Skinner for UK in 2002[12] which was 24.8miilion pounds for education and training, and 292million pounds for marine research funding.

[10] Παπαναστασίου Α. «Διαχείριση της ποιότητας των νερών κολύμβησης στην Κύπρο». Μάιος 2011, Τμήμα Περιβάλλοντος, Υπουργείο Γεωργίας, Φυσικών Πόρων και Περιβάλλοντος. http://www.moa.gov.cy/moa/environment/environment.nsf/5B3F5BD32AA6B336C2257951003F3D62/$file/Bathig%20Water%20Quality%20Management%201905111.pdf

[11] http://www.and-world.com/cyprus-fishing.htm

[12] http://www.oceannet.org/library/publications/documents/marine_related_activities.pdf

Cultural identity: Cypriot cultural identity is in fact shaped by its marine surroundings. Though this cannot be valued it cannot be denied as of great importance to Cypriot citizens.

1.5.2 Indirect use values

These are values that people derived from marine waters without direct using them but through their (regulatory) impact on other ecosystem services.

Carbon removal: In planet level, marine waters are the primary long term sink for CO2, generated by human activities. This natural process reduces the amount of CO2 in the atmosphere with obvious benefits the reduction in some degree of global warming due to the increase of CO2. An estimation of global ocean uptake of carbon through phytoplankton primary productivity (PP) gives an amount of 52 to 55 Gt C per year[13]. This amount reflects the immense indirect use value of marine waters[14], as a regulator of global climate conditions. Lower carbon storage would have global climate impacts[15].

Resilience: Resilience refers to the capacity (degree, rate) of an ecosystem to overcome an ecological disturbance. It is therefore a key factor for the stability of the Ecosystem and it is critical for the provision of all other goods and services, especially in this period of increased environmental perturbation. It is worthwhile mentioning that this value of the marine ecosystem depends on the level of biodiversity.

1.5.3 Non-use values

Existence value and bequest value: In practice it is very difficult to separate these two value types (Beaumont et al., 2008), the first meaning the satisfaction to humans knowing that ecosystems continue to exist and the latter the satisfaction from passing on ecosystem services in tact to future generations. Some studies use the average household's willingness to pay to ensure the survival of various sea mammals, as a measure of these values. Using the benefit transfer technique, the Contingent Valuation Method study for Mediterranean monk seal in Greece[16] (Langford et al.) was adopted. According to this study an annual payment of $72 per household ($2006) was the WTP amount estimated by the survey. Calculating for total Cyprus households and keeping the amount constant and converting for euro, the non-use value of marine waters for Cyprus is roughly 13 million per year.

1.5.4 Option values

Option values may also exist (potential use of marine species for future new pharmaceutical applications or for new food provision), but it is impossible to be valued. In any case there is common agreement in the relevant literature, that the marine genetic diversity may provide the necessary resources for future developments in medicines.

[13] Smyth. T.J., Tilstone, G.H., Groom, S.B., 2005. Integration of radiative transfer into satellite models of ocean primary production. Journal of Geophysical Research 110, C10014.
[14] With the continuously increasing CO2 emissions, on the other hand, carbon sequestration by marine waters causes increasing acidity of seas with severe potential negative impacts in marine ecosystems.
[15] http://ec.europa.eu/environment/nature/biodiversity/comm2006/pdf/2020/1_EN_impact_assesment_part1_v4.pdf
[16] Langford, I.H., Kontogianni, A., Skourtos, M.S., Georgiou, S., Bateman, I.J., 1998. Multivariate mixed models for open-ended contingent valuation data: willingness to pay for conservation of monk seals. Environmental and Resource Economics 12, 443–456

1.6 Social Aspects

The basic indicator of social aspect is the employment generated by the sectors that are directly linked with marine waters, in other words their contribution on creating jobs. The

1.6.1 Stakeholders

Field A- Fishermen, aquaculture farmers

This social group constitute only a small part of the overall employment, their contribution on total employment is only 0.44%

Field B- Employed in Tourism and Recreation

These sectors are an important source of employment. The total number of persons employed in this field is 38,515 and it covers the 10.26% of the total employment. It is indicative of the importance of this field in total employment the fact that in 2009 out of a total of 2,900 losses in jobs, the 2,200 were in the sectors “Hotels and Food and Beverage services”.

Field C- Employed in Water transportation and supporting services

According to official statistical data the persons employed in these sectors are 8,394 and the percentage of contribution to the employment is 2.24%.

Summarizing, the participation of these three fields in employment is by 13% as the figures of Table 1.25 show. Or, 1 out of 8 Cypriots is employed in a sector directly linked with marine waters.

Table 1.25 Contribution of marine waters sectors to the employment

	No of Employees	Percentage of contribution to the employment
Field A	1.662	0,44%
Field B	38.515	10,26%
Field C	8.394	2,24%
Total	**48.571**	**12,94%**

Another point worthwhile to be mentioned is the contribution of these sectors to a special group of working force, namely the immigrants.

During the last years employed immigrants show a continuous and sharp increase. In 2009 alone this group increased by 10.2%, and reached the number of 106,110. A substantial percentage of 16% of immigrants is employed in “Accommodation and Food and Beverage” sector, while very significant is the number of immigrants employed in Cypriot Ship Register. In this sense the marine water sectors help to ease social pressures generated by the increasing coming of immigrants.

1.6.2 Spatial Aspect

Studying the data presented in the following two tables gives an insight on the spatial aspect of the social assessment. Figures refer to 2010.

As it is shown in Table 1.26 the area of Famagusta and the area of Pafos owe a very significant share of the local employment to these two broad sectors. The 23.4% of the local employment in Famagusta and the 17.7% of employment in Pafos are absorbed by these sectors. Any future benefit loss on these sectors will have immense negative impacts especially in these two areas. The high unemployment rate of Famagusta, well above the national average, intensifies the problem of a potential future decline of these sectors.

Table 1.26 Population, Employment and Unemployed by Geographic area

	Population	Working force	Employment	Unemployed
National Total	771.135	410.465	385.093	25.372 (6,2%)
Nicosia	300.633	166.105	157.981	8.124 (4,9%)
Famagusta	40.187	21.294	18.962	2.332 (11,0%)
Larnaka	125.906	66.524	62.374	4.151 (6,2%)
Lemesos	229.113	119.349	111.928	7.421 (6,2%)
Pafos	75.295	37.192	33.849	1.940 (5,2%)

Table 1.27 Contribution of marine sectors to local Employment

	Employment	In Transportation[17] and warehousing	In Accommodation and Food and Beverage	Joint contribution of the sectors
Nicosia	157.981	4.094	6.938	6,64%
Famagusta	18.962	769	3.659	23,35%
Larnaka	62.374	3.556	5.307	14,20%
Lemesos	111.928	6.513	7.458	12,48%
Pafos	33.849	834	5.158	17,70%

2. Cost of Degradation

Cost of degradation refers to the assessment of the welfare loss due to the degradation of the marine environment (European Commission DG Environment, June 2010, p.23). In this study a more accessible (and therefore more narrow) option is used, namely the focus on

[17] To be treated with caution, as it refers to the total transportation and not to the sea transportation. There are no analytical figures in local level. It is used as a proxy

the impacts in the sectors “directly benefitting from the use of the marine waters and the goods and services they provide”(same citation as above).

2.1 Pressures and impacts

Summarizing the impacts of environmental pressures from Part II of the Initial Assessment it is evident that during the next decade Cyprus is not probable to face severe impacts on marine waters degradation. The amount of pressures does not constitute a critical mass altering the environmental status of marine waters in such a degree as to lower the benefits of the sectors profiting from marine waters.

There are three areas though that could produce such results.

a) Planned works in Larnaca’s port and marina expansion, Limassol marina, the new port in Pissourri and the potential natural gas terminal to Vassiliko may degrade the status of bathing waters.

b) The overfishing mentioned is going to have at the end benefit losses for fisheries either due to fish stock collapse or due to deliberate reduction of catches by fisheries in order to avoid fish stocks collapse.

c) The Lessepsian migration (up to now more than 300 species from Red Sea were identified in East Mediterranean) may lead to severe impacts both in Tourism and Fishing sector.

2.2 Economic Sectors considered for benefit losses

In the previous section sectors benefitting from the use of marine waters are identified (Section 1.3). As it is suggested by DG Environment (Working group on Economic and Social Assessment, December 2010, Annex A) assessment may not include all sectors, may focus instead on the main sectors affected by the impacts.

In order to select the main sectors to focus upon, a number of parameters were used and each sector was marked with a score ranging from 3 to1 according to its performance on each parameter. The set of parameters was:

- Importance of the sector to the Cypriot Economy
- The vulnerability of the sector to marine waters degradation
- Affect to small local communities

From these parameters the “vulnerability to marine waters degradation” is weighed double.

The results of this approach appear in Table 2.1, according to which two economic sectors are chosen, namely Tourism and Fishing[18].

Table 2.1 Scoring of the three main sectors on three main parameters.

Sectors	Importance to the Cypriot Economy	Vulnerability to marine water degradation(*2)	Affect to small local communities	SUM

[18] In reality it is fishing and acquaculture, because financial data is offered jointly. In fact Cyprus (as well as Greece) shows a relative low indicator of production over coastline length (3-10 tons/km) compared to other countries in Mediterranean like Italy, Spain, France and Turkey.(http://www.eea.europa.eu/data-and-maps/indicators/acquaculture-production-1/acquaculture-production-assessment-published-feb-2009

Tourism	3	6	1	10
Shipping	3	1	1	5
Fishing	1	6	3	10

There is an increasing concern that the negative effects of Tourism in natural environment can ultimately hurt the tourism industry itself. There is now plenty of evidence of the "life-cycle" of tourist destinations –discovery, development, decline- due to overuse and deterioration of key attractions. The so called *Tourism Death Spiral* appears in the relevant literature in early 70s. It is true that mainly this interdependence refers more to inland environmental distractions, but the good status of marine waters is a key attraction as well, especially for island states such as Cyprus.

Overexploitation of fisheries been mentioned in section 7.3 of Part II of the Initial Assessment which may lead to fish stock collapse, has serious consequences not only to biodiversity and more generally to natural ecosystems, but also to the revenues of the fishing sector. Given the structure of this sector this will have serious impacts in local communities. In order to comply with WSSD targets steps must be taken to reduce fish catches tonnage.

2.3 Calculation of Cost of Degradation

As mentioned above there are no quantifiable impacts on those economic sectors. Therefore the calculation of Cost of Degradation will be a construction of a scenario based on well defined working hypotheses assuming benefit losses for each of the two sectors. The Cost of degradation will equal the Present Value of lost Gross Value Added. The calculated Cost of degradation, though based in working hypotheses, can be used as a tool by policy makers – as a worst case scenario – to see what means for the Cypriot economy the environmental degradation of marine waters based on the pressures identified above.

2.3.1 Time horizon

The baseline situation is that of the year 2010. The time horizon for carrying out the cost of degradation analysis is the period 2010-2020, as it is suggested by the most of EC working papers. This is partly due to the fact that 2020 is the year to maintain good environmental status (MSFD article1, no. 1).It is also directly comparable with the analysis of "Programme of measures" of article 13.

2.3.2 Discount Rate

There is a lot of debate about the appropriate discount rate among scientists. In this report's calculations a discount rate of 3% is used. This choice is based on the European Commission's base rates for 1/1/2012 which is 2.07% and a margin of 100 basis points are add up to this. For reasons of simplicity 3% is used instead of 3.07%. The fact that the time horizon is quite limited no serious impacts are expected because of the rounding(http://ec.europa.eu/competition/state_aid/legislation/reference_rates.html)

2.3.3 Impacts on Tourism

A basic scenario was constructed assuming an annual loss in Gross Value Added of 3%. The calculation of losses starts from year 2014 allowing for the deterioration of waters quality from the present status of excellent condition.

The Gross Value Added upon which losses are counted is that of the year 2010 and it is taken constant throughout the whole period. Though this assumption may seem unreasonable, it is adopted in order to isolate the clear effect of water degradation from other factors affecting Tourism revenues. Furthermore there is no clear trend in Tourism revenues as since 2008 the sector faces a down turn, while the slight recovery of 2011 is attributed to exogenous factors such as the political instability in Middle East destinations.

Calculations of the basic scenario appears in Annex B.

The Present Value (PV) of potential losses is 146.55 million Euros, which corresponds to 0.8% of GDP.

Dealing with the risk. In order to deal with the risk two alternative scenarios are used allowing for a more optimistic and less optimistic outcome. These two alternative scenarios are based in the assumption that the actual loss is 1% and 5% respectively.

In the first case the PV of losses have a Present Value of 51.73 million Euros or 0.3% of GDP, and in the second case the resulting PV is 230.80 million Euros or 1.3% of GDP.

2.3.4 Impacts on Fisheries

Rebuilding the fish stocks requires short-term sacrifices. All fisheries that require stock rebuilding must undergo reductions on exploitation rates and fishermen must therefore make short-term sacrifices in the form of reduced catches (Garrity, 2011). The difficulties of succeeding reduced catches are well known but out of the scope of this assessment. The point here is to calculate the losses in fishing revenues regardless of the cause (in other words either being the result of monitoring implementation or reduced catches due to reduced stocks). Whatever the cause, loss of revenues is a result of marine water degradation and therefore it constitutes Cost of degradation.

Again a basic scenario is constructed assuming an annual Gross Value Added loss of 5%. Data for the baseline GVA is jointly available for fisheries and marine aquaculture. In order to get GVA separately for fisheries the relative contribution of each sector to Value of Production is used, for which the data appears separately. So 25% of joint GVA is considered to be the share of fisheries. Though this calculation may not be completely accurate, it is a well proxy.

The basic assumptions of the Tourism calculations are used, that is that the starting point accruing losses is again the year 2014, and the base line GVA is remaining constant through the whole time period.

Calculations of the Present Value appear in Annex C.

The Present Value of benefit losses for fisheries is 1.8 million Euros, which corresponds to an insignificant percentage of GDP.

Two alternative scenarios are constructed to deal with risk. The optimistic one is based on a 3% reduction and the pessimistic one is based on a 7% reduction.

In the first case the Present Value of losses is 0.411 million Euros, while for the second one the Present Value is 2.4 million Euros.

2.4 An alternative approach to Cost of Degradation for Tourism

A published report of World Bank regarding the Cost of Environmental Degradation in Middle East and North Africa uses the Willingness to Pay approach to estimate the cost of marine water degradation for tourism sector in Tunisia. Tunisia is a Mediterranean country as Cyprus with similar dependence on Tourism and the same more or less origin of international tourists. Furthermore the case study was published recently, in2010, therefore it is justifiable to argue that overall conditions are not changed.

The above mentioned traits of the World Bank report permit the adaptation of the Tunisian report core findings in this report with the necessary adjustments[19].

The basic approach of the report is that the Cost of seawater degradation is best reflected through the amount of money the tourists are willing to pay in order to improve seawaters quality.

The key findings of the survey were the following:

--4% of European and American Tourist are willing to pay an additional amount of money in order to improve seawater quality.

--The amount that they are willing to pay is US$ 13 per person per night.

Applying these two findings in Cyprus case will lead to the following.

Number of bed nights In Cyprus resorts	13,000,000
Number of bed nights adjusted for the tourists' origin[20](80%)	10,400,000
Percentage of tourists willing to pay	4%
Amount they are willing to pay	10 Euros[21]
Total amount	4,160,000
% to GDP	0.02

[19] The conduction of an analogous survey in international tourists of Cyprus was not possible due to the fact that during winter months the response of tourists is not the same
[20] Only Europeans and Americans in order to be compatible with Tunisian survey
[21] Exchange rate used for the conversion 1$=0.759936 Euros

2.5 Other Costs due to Water Degradation

2.5.1 Fall in the price of coastal land

In recent years, since the mid-2008, the market of coastal land properties has faced a down-turn due to various reasons. This down-turn came due to global recession and economic uncertainty that influence potential foreign investors and made them very cautious. Especially those from UK as the British Sterling lost value against euro making investments in Euro zone more expensive for British nationals. This drop in demand led to a decrease in real estate prices by 4.1% in 2009 and a further 1.8% in first months of 2010(Central Bank of Cyprus, December 2010 p.65), while experts of the Central Bank estimate that the average annual decrease in 2010 will be 3%. The decrease in price index was sharper in coastal areas, a drop of 4% was recorded in Paphos, and 3.3% in Famagusta- Paralimni.(CBC, December 2010, p.113). According to Central Bank's officials both the increase in real estate up to 2008 and the decrease thereafter are primary caused by foreigners.

If this was the impact of "exogenous" economic reasons it is obvious that marine water degradation will reinforce this trend leading to a further decrease. If the comparative advantage of excellent water is lost the impact will not only be restricted to Tourism but also to the demand for coastal apartments and houses mainly expressed by foreigners. They are going to look in other antagonistic destinations for their investments.

2.5.2 Decrease in the value of recreational activities related with the marine waters

Bathing, scuba diving, recreational fishing etc. are all recreational activities that depend on marine waters, and the environmental status of sea is one of the most important factors affecting their demand.

As it was reported in PART II potential degradation of marine waters due to expansion works for marinas and ports would be locally generated. Therefore the most probable result is that residents of the affected beaches will not abandon their marine recreational activities, but they are going to move to other more distant beaches.

This movement generates a cost of transportation due to the local degradation. As these works are not yet accomplished there is no data again for such transportations. In order to give an idea of the cost generated the following assumptions are used

Price of oil	1.30 Euros
lt/100 km	10lt
Average length of round trip	40
Average trips per year	30
% of population that make such trips	10%
Total annual cost of transportation	13.3 million Euros

This annual degradation cost is underestimated as it includes only fuel cost. The amount could be doubled if operating costs (maintenance, depreciation) and value of time were included.

3. ANNEXES

3.1 Annex A – Analytical tables

Collective Accommodation Establishments by type and locality, 2009

Category	Total	NICOSIA	LEMESOS	LARNAKA	Ag. NAPA	PARALIMNI	PAFOS	HILL RESORTS
TOTAL	**855**	**20**	**82**	**110**	**171**	**95**	**303**	**74**
I. HOTELS AND SIMILAR ESTABLISHMENTS	**699**	**20**	**77**	**107**	**165**	**94**	**162**	**74**
HOTELS	**578**	**20**	**59**	**98**	**105**	**90**	**142**	**64**
Hotels with Stars	***224***	***15***	***33***	***25***	***45***	***27***	***58***	***21***
5 stars	22	1	6	1	4	2	8	0
4 stars	58	3	8	7	9	11	19	1
3 stars	79	4	12	4	24	12	15	8
2 stars	43	6	5	12	7	1	7	5
1 star	22	1	2	1	1	1	9	7
Hotel Apartments	***193***	***2***	***19***	***22***	***53***	***60***	***37***	***0***
Tourist Villages	***23***	***0***	***2***	***0***	***7***	***2***	***12***	***0***
Traditional Buildings	***138***	***3***	***5***	***51***	***0***	***1***	***35***	***43***
II. SIMILAR ESTABLISHMENTS	**121**	**0**	**18**	**9**	**60**	**4**	**20**	**10**
Hotels without star	***8***	***0***	***0***	***0***	***0***	***0***	***0***	***8***
Guest Houses	***6***	***0***	***3***	***0***	***0***	***0***	***1***	***2***
Tourist Apartments	***107***	***0***	***15***	***9***	***60***	***4***	***19***	***0***
III. OTHER COLLECTIVE ACCOMMODATION ESTABLISHMENTS	**156**	**0**	**5**	**3**	**6**	**1**	**141**	**0**
Holiday Dwellings	***152***	***0***	***4***	***3***	***6***	***1***	***138***	***0***
Tourist Villas	141	0	0	1	5	0	135	0
Furnished Apartments	11	0	4	2	1	1	3	0
Tourist Campsites	***4***	***0***	***1***	***0***	***0***	***0***	***3***	***0***

Beds in Collective Accommodation Establishments by Type and by Locality, 2009

Category	Total	NICOSIA	LEMESOS	LARNAKA	Ag. NAPA	PARALIMNI	PAFOS	HILL RESORTS
TOTAL	**88.803**	**2.329**	**13.051**	**6.949**	**20.456**	**15.338**	**28.345**	**2.335**
I. HOTELS AND SIMILAR ESTABLISHMENTS	**84.327**	**2.329**	**11.507**	**6.829**	**19.998**	**15.334**	**25.995**	**2.335**
HOTELS	**79.239**	**2.329**	**10.879**	**6.469**	**17.654**	**15.256**	**24.562**	**2.090**
Hotels with Stars	***52.020***	***2.173***	***9.453***	***4.558***	***10.336***	***7.136***	***16.577***	***1.757***
5 stars	10.662	596	3.202	386	1.700	788	3.990	0
4 stars	21.137	823	2.734	2.454	3.009	3.554	8.283	280
3 stars	15.604	356	2.789	753	4.852	2.615	3.331	908
2 stars	3.560	347	647	976	730	145	458	257
1 star	1.057	51	81	19	45	34	515	312
Hotel Apartments	***18.692***	***130***	***1.024***	***1.416***	***5.142***	***7.418***	***3.562***	***0***
Tourist Villages	***7.338***	***0***	***320***	***0***	***2.176***	***690***	***4.152***	***0***
Traditional Buildings	***1.189***	***26***	***82***	***465***	***0***	***12***	***271***	***333***
II. SIMILAR ESTABLISHMENTS	**5.088**	**0**	**628**	**360**	**2.344**	**78**	**1.433**	**245**
Hotels without star	***192***	***0***	***0***	***0***	***0***	***0***	***0***	***192***
Guest Houses	***138***	***0***	***64***	***0***	***0***	***0***	***21***	***53***
Tourist Apartments	***4.758***	***0***	***564***	***360***	***2.344***	***78***	***1.412***	***0***
III. OTHER COLLECTIVE ACCOMMODATION ESTABLISHMENTS	**4.476**	**0**	**1.544**	**120**	**458**	**4**	**2.350**	**0**
Holiday Dwellings	***1.668***	***0***	***104***	***120***	***458***	***4***	***982***	***0***
Tourist Villas	1.450	0	0	60	442	0	948	0
Furnished Apartments	218	0	104	60	16	4	34	0
Tourist Campsites	***2.808***	***0***	***1.440***	***0***	***0***	***0***	***1.368***	***0***

Number of Ships by Category and Port

	2008					2009				
	Lemesos	Larnaka	Vassiliko	Oil Terminals	Total	Lemesos	Larnaka	Vassiliko	Oil Terminals	Total
Passenger Ships	368	8	0	0	376	291	34	0	0	325
Cargo Ships	2.607	510	266	302	3685	2638	427	213	312	3.590
Others	859	83	5	0	947	812	61	22	1	896
Total	3.834	601	271	302	5.008	3.741	522	235	313	4.811

Cargo Handled 2008 (in 000 metric tons)

	IMPORTS			EXPORTS			
	Cypriot	**In Transit**	**Total**	**Cypriot**	**In Transit**	**Total**	**Grand Total**
Lemesos	3.089	309	3.398	658	599	1.257	4.655
Larnaka	770	8	778	291	8	299	1.077
Vassiliko	1.257	1	1.258	177	0	177	1.435
Oil Terminals	1.785	0	1.785	0	0	0	1.785
Total	**6.901**	**318**	**7.219**	**1.126**	**607**	**1.733**	**8.952**

Cargo Handled 2009 (in 000 metric tons)

	IMPORTS			EXPORTS			
	Cypriot	**Transit**	**Total**	**Cypriot**	**Transit**	**Total**	**GRAND TOTAL**
Lemesos	2.569	92	2.661	598	364	962	3.623
Larnaka	607	1	608	251	0	251	859
Vassiliko	1.141	0	1.141	196	0	196	1.337
Oil Terminals	1.792	0	1.792	0	0	0	1.792
TOTAL	**6.109**	**93**	**6.202**	**1.045**	**364**	**1.409**	**7.611**

Containers Handled (TEUs)

	2008			2009		
	Unloading	**Loading**	**Total**	**Unloading**	**Loading**	**Total**
Lemesos						
Full						
Cypriot	179.681	35.906	215.587	160.135	33.515	193.650
Transit	16.711	16.161	32.872	4.708	4.143	8.851
Subtotal	**196.392**	**52.067**	**248.459**	**164.843**	**37.658**	**202.501**
Empty	15.861	152.650	168.511	10.246	140.934	151.180
TOTAL	**212.253**	**204.717**	**416.970**	**175.089**	**178.592**	**353.681**
Larnaka						
Full						
Cypriot	0	0	0	193	0	193
Transit	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**193**	**0**	**193**
Empty	0	0	0	39	0	39
Total	**0**	**0**	**0**	**232**	**0**	**232**
Lemesos & Larnaka						
Full						
Cypriot	179.681	35.906	215.587	160.328	33.515	193.843
Transit	16.711	16.161	32.872	4.708	4.143	8.851
Subtotal	**196.392**	**52.067**	**248.459**	**165.036**	**37.658**	**202.694**
Empty	15.861	152.650	168.511	10.285	140.934	151.219
Total	**212.253**	**204.717**	**416.970**	**175.321**	**178.592**	**353.913**

Containers Handled (in metric tons- net weight)

	2008			2009		
	Unloading	**Loading**	**Total**	**Unloading**	**Loading**	**Total**
Lemesos						
Cypriot	1.682.733	435.470	2.118.203	1.448.287	411.850	1.860.137
Transit	225.152	222.504	447.656	53.821	49.825	103.646
TOTAL	**1.907.885**	**657.974**	**2.565.859**	**1.502.108**	**461.675**	**1.963.783**
Larnaka						
Cypriot	0	0	0	1.950	0	1.950
Transit	0	0	0	0	0	0
Total	**0**	**0**	**0**	**1.950**	**0**	**1.950**
Lemesos &Larnaka						
Cypriot	1.682.733	435.470	2.118.203	1.450.237	411.850	1.862.087
Transit	225.152	222.504	447.656	53.821	49.825	103.646
TOTAL	**1.907.885**	**657.974**	**2.565.859**	**1.504.058**	**461.675**	**1.965.733**

Passengers Traffic

	2008				2009			
	Arrivals	Departures	In Transit	**Total**	Arrivals	Departures	In Transit	**Total**
LEMESOS	73.980		222.839	371.615	48.542	48.069	202.662	299.273
LARNAKA	376	377	4.338	5.091	24	27	22.710	22.761
TOTAL	**74.356**	**75.173**	**227.177**	**376.706**	**48.566**	**48.096**	**225.372**	**322.034**

3.2 Annex B – Tourism

Basic Scenario (decrease by 3% annually, starting from 2014)

Year	**Gross Value Added Loss In millions of EURO**
2010	0
2011	0
2012	0
2013	0
2014	28,851.24
2015	27,985.70
2016	27,146.13
2017	26,331.74
2018	25,541.79
2019	24,775.54
2020	24,032.27
Present Value	146,550.00

Scenario I (decrease by 1% annually, starting from 2014)

Year	**Gross Value Added Loss In millions of EURO**
2010	0
2011	0
2012	0
2013	0
2014	9,617
2015	9,520
2016	9,426
2017	9,331
2018	9,238
2019	9,146
2020	9,054
Present Value	51,734.37

Scenario II (decrease by 5% annually, starting from 2014)

Year	Gross Value Added Loss In millions of EURO
2010	0
2011	0
2012	0
2013	0
2014	48,085.4
2015	45,681.13
2016	43,397.07
2017	41,227.22
2018	39,165.85
2019	37,207.56
2020	35,347.18
Present Value	230,804.01

3.3 Annex C – Fisheries

Basic Scenario(decrease by 5% annually, starting from 2014)

Year	Gross Value Added Loss In millions of EURO
2010	0
2011	0
2012	0
2013	0
2014	382.82
2015	363.68
2016	345.49
2017	328.22
2018	311.81
2019	296.22
2020	281.41
Present Value	1,837.31

Scenario I(decrease by 1% annually, starting from 2014)

Year	Gross Value Added Loss In millions of EURO
2010	0
2011	0
2012	0
2013	0
2014	76.56
2015	75.79
2016	75.04
2017	74.29
2018	73.54
2019	72.81
2020	72.08
Present Value	411.27

Scenario II (decrease by 7% annually, starting from 2014)

Year	Gross Value Added Loss In millions of EURO
2010	0
2011	0
2012	0
2013	0
2014	535.95
2015	498.43
2016	463.54
2017	431.09
2018	400.91
2019	372.85
2020	346.75
Present Value	2,432.45

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