Deliverable D2.4

"PILOT ACTIONS ON THE INTEGRATION OF AUTOMATED CONTINUOUS MONITORING SYSTEMS (MOORINGS) AND OFFSHORE PLANKTON PELAGIC SAMPLING ADDRESSING DESCRIPTORS 1, 4 AND 10 WITHIN ROUTINE MESOSCALE HYDROGRAPHIC SURVEYS"

Date: April 2017

Action Plans for Integrated Regional Monitoring Programmes, Coordinated Programmes of Measures and Addressing Data and Knowledge Gaps in Mediterranean Sea

ActionMed

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Coordinator

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EXECUTIVE SUMMARY

Background and Rationale

One of the agreed key principles regarding the Marine Strategy Framework Directive (MSFD) (DIRECTIVE 2008/56/EC), as stated in its Article 11, is the need of integrating existing monitoring programs. More specifically, the MSFD monitoring programs (as listed in the Annex V) requires the “Need to ensure, as far as possible, compatibility with existing programs developed at regional and international level with a view to fostering consistency between these programs and avoiding duplication of effort, making use of those monitoring guidelines that are the most relevant for the marine region or sub-region concerned”. Within the MSFD Common Implementation Strategy (CIS) program, the Marine Strategy Coordination Group (MSCG) stressed this necessity, recommending, in its 2013 document on “Monitoring under MSFD - Recommendations for implementation and reporting”, to “build upon and integrate, as much as possible, existing well-established monitoring programs and relevant guidance under Habitats and Birds Directives, the Water Framework Directive and other relevant EU legislation, as well as under Regional Sea Conventions and other international agreements”. As Zampoukas *et al.* (2014) pointed out regarding this recommendation, “it is obvious that, in order to minimize additional costs, Member States should define the MSFD monitoring requirements relevant for their marine areas and check them against existing monitoring efforts (i.e. programs aiming to fulfill the requirements of other EU legislation, of RSCs agreements and recommendations and of national initiatives). This would allow them to identify the additional requirements of the MSFD and develop monitoring programs only for those additional requirements” and also that “… existing programs may need to be adjusted, in order to be more coherent with neighboring countries as well as in the subregional and regional level. Adjustments should be balanced against the need for continuity of current monitoring, in particular with a view to long time series, which are required for trend assessments…. In reviewing, existing monitoring, Member States should seek opportunities for cooperation on monitoring activities with neighbors and through joint regional data products from other observation platforms to enhance coherence and reduce costs”.

The potential of engaging existing oceanographic surveys carried out on regular basis under marine monitoring programs related to other EU policies, such as the Common Fisheries Policy (CFP), international conventions or even under national programs, to contribute to the monitoring programs envisaged under MSFD has been widely recognized. Moreover, it has been proposed not only to incorporate the data currently provided by these surveys to the MSFD monitoring scheme, but mainly to use their spare capacity to incorporate new sampling activities addressing MSFD indicators not covered by the ongoing sampling strategies. By doing so, they could aim at a more multidisciplinary approach in line with the MSFD holistic and integrative view, and /or widen their spatial scope, in order to match MSFD requirement of covering all the waters under jurisdiction of MSs. Moreover, with the enormous amount of monitoring undertaken in the previous decades and the addition of further requirements through the MSFD, it is important to investigate the possibility for synergies between monitoring schemes for different purposes. Also, different MSFD Descriptors require the same or similar data, thus allowing a considerable reduction in effort through integration. Considering the high daily operational costs of research vessels, this would be a good way for optimizing the cost efficiency of MSFD monitoring programs. However, in any case, there will always be some extra cost derived from the 'new' sampling activities and, in addition, there are logistic limitations that can impede or pose difficulties to the proposed new/ extra sampling activities. Because of that it is recommended to carry out pilot feasibility studies, in order to: (a) guarantee that the changes in the ongoing sampling strategies will not compromise the original scope of the surveys; (b) to confirm that these new activities can be carried out effectively within the framework of such surveys and (c) to estimate more precisely the additional costs. On the other hand, for some of the MSFD descriptors, such as marine litter, there are not yet mature sampling protocols available, or the existing knowledge is not yet enough for designing properly sampling strategies. Therefore, pilot actions could provide guidance towards better design of future monitoring, and thus be cost-efficient in the long run. Some of these pilot feasibility studies have been already carried out within EU funded projects in support of MSFD implementation, as IRIS-SES (Alemany *et al*, 2015)

In any case, MSFD implementation will require large scale, continuous and intensive sampling programs, able to account for the high spatial and temporal variability characterizing marine ecosystems, mainly those in the Southern European Seas. Undoubtedly, such programs will be costly, both in terms of human and economic resources, and because of that it is imperative to look for the most cost-effective sampling strategies and methodologies, to minimize such costs. This can be achieved not only by taking advantage of the available spare capacity of existing surveys, but also from new technological developments, since technologies are evolving and can help to improve the overall monitoring process. Therefore, monitoring systems able to register data in a continuous way from the temporal point of view, or covering synoptically large areas, as well as those analytical techniques providing more precise data at lower cost, should be taken into account when developing the MSFD monitoring programs. Such technologies and their potential application have been reviewed by the Expert Group on Marine Research Infrastructures (Anonymous, 2013) and in Barbera *et al*. (2015). Moreover, the Marine Strategy Coordination Group pointed out that for every MSFD criterion/target/indicator used, there should be data and information collection program which may involve, among others, continuous recording of parameters (e.g. for physical parameters such as temperature or pH).

Physical oceanography is the field in which new technologies, such as remote sensing, autonomous devices and models, are already routinely applied for marine environment monitoring, but there is still a considerable potential for using them to address MSFD needs. Because of that all the existing hydrological monitoring systems and networks constitute an indispensable reference and should be incorporated in the MSFD monitoring programs. MSFD Descriptor 7 (hydrological conditions) focuses explicitly on permanent alterations and it is understood that it concerns mainly future activities with potential hydrological impact at a larger scale than the scale of impacts addressed in the WFD. The MSFD hydrographical data requirements include the WFD requirements and some additional ones such as, topography and bathymetry of the seabed, habitat types, ice cover, upwelling, pH and

pCO_2. Therefore, it is agreed that hydrographical monitoring should cover not only the data to assess D7 related indicators, but also to gather data for describing the overall hydrographic scenario and reflecting long-term changes in ecosystems, in order to interpret properly other indicators' results. This becomes obvious since the study of the 11 GES descriptors will depend greatly on the information on the hydrographic and hydrodynamic conditions of the sampled area. Therefore, both the hydrographic data registered within the framework of MSFD monitoring programs, designed for addressing descriptors other than D7 and the information generated by the various existing more global and permanent platforms for hydrographic monitoring, should be taken into account within the framework of the future MSFD monitoring system in a given region. Moreover, even though climate change is considered to be part of the prevailing environmental conditions and therefore not explicitly addressed through the MSFD, for the interpretation of monitoring outputs, the effects of climate change need also to be taken into account. For this reason, monitoring programs, able to describe these background large-scale changes is an implicit requirement for D7 and for the MSFD as a whole (Zampoukas *et al*., 2014). In this line, the MSCG pointed out that in spite the fact that the assessments of the marine environment state (characteristics, pressures/impacts) should be based on the monitoring of the elements listed in the MSFD Annex III, which are directly related to the indicators, additional monitoring is necessary to put indicators and their message into context (e.g. oceanographic parameters relating to changes in the ecosystem) and assess whether there are major changes in the environment, their natural variability and any new and emerging issues. This MSCG group also highlighted the necessity of filling the gaps detected during the initial evaluations of the MSFD 2012 Reporting process, in order to enable Member States to adapt their monitoring programs accordingly.

Scope and Context of the Pilot Studies within the ACTIONMED Project

The initial assessments regarding the state of EU marine waters detected some knowledge gaps affecting several MSFD descriptors. Similarly, the recent reviews of the MSFD national monitoring plans carried out by the Commission to the European Parliament and the Council (Report 16/01/2017) COM final), as well the work of the ActionMed project regarding specifically Mediterranean region, highlighted important gaps affecting the spatial scope of monitoring plans, pointing out a lack of monitoring in offshore areas. Consequently, one of the biggest challenges is to extend monitoring off-shore (Zampoukas *et al.*, 2012). Also , some Descriptors (and their related indicators), such as D10 on Marine Litter and D11 about Noise/Energy were not mature yet when Decision 477 defining MSFD proposed indicators was adopted; in consequence, as a follow up of the Commission Decision 477, technical subgroups for the further development of these descriptors were established in 2011. These gaps affect also the monitoring of some of the elements listed in the Annex III of MSFD, as CO_2 measurements, or some specific items within these elements, as microplastics in water column, in spite of their important potential impact on marine ecosystems.

Considering all the aforementioned issues, ActionMed project conceived and carried out a series of pilot actions. These actions act both as feasibility studies on the logistic possibilities of integrating sampling activities addressing new MSFD monitoring requirements, within existing routine seasonal hydrographical surveys in the Western

Mediterranean; and as pioneer studies addressing knowledge gaps detected in relation to MSFD needs, useful for defining current state and threshold levels for the application of indicators. Specifically, these pilot actions deal with atmosphere/ocean CO_2 exchange, the flux of carbon to deep ecosystems and the abundance and distribution of microplastics in neuston.

Due to their importance for determining the GES of marine ecosystems, both pH, pCO_2 profiles or equivalent information used to measure marine acidification and marine litter, were included among the elements to be monitored under MSFD. In the case of microplastics, they are addressed specifically by one of the Descriptor 10 indicators (10.1.3. Trends in the amount, distribution and, where possible, composition of micro-particles (in particular micro-plastics)).

The CO_2 exchange between ocean and atmosphere and the transfer of carbon to deep marine ecosystems, which controls the long-term sequestration of atmospheric CO_2, are among the most important processes to be considered within the actual context of climate change, since the oceans regulate the concentrations of carbon dioxide, one of the main greenhouse effect gasses, in the atmosphere. Moreover, the ocean acidification derived from the absorption by the oceans of the excess of the atmospheric CO_2 (resulting from human kind's industrial and agricultural activities) affects key biological processes for marine organisms, such as calcification of body structures**.** Thus, studying CO_2 dynamics in the oceans is of outmost importance for understanding climate change, as well their impacts on marine ecosystems, and hence to interpret properly the evolution in the mid-long term of several MSFD indicators.

On the other hand, the current period of human history has been referred as the Plastic Age. Plastic pollution reaches the most remote areas of the planet, including the surface waters of the open ocean. The models predict that large-scale vortices act as conveyor belts, collecting the floating plastic debris released from the continents and accumulating it into central convergence zones (Cózar *et al.*, 2014). The impacts of marine litter on marine biota are variable and potentially harmful, from entanglement and ingestion to their function as vectors of introduction of toxics in the food webs or introduction of allochthonous species (Katsanevakis *et al.*, 2010; Kühn *et al*., 2015).

Thus within the ActioMed project was decided to carry out pilot studies on the above issues.

1. INTRODUCTION

The Spanish Institute of Oceanography (IEO) scientists and administration, being aware of the need to integrate, adapt and improve the marine monitoring programs for better addressing the numerous and increasing compromises derived from EU directives, Regional Conventions or other international agreements, as well as the necessity of implementing multidisciplinary sampling strategy, in line with the Ecosystem Approach, carried out during the last decades several related monitoring actions. More recently, the Spanish Ministry of Agriculture, Fisheries and Environment, assigned to IEO the design and implementation of the future national MSFD monitoring programs, therefore a great effort was undertaken for adapting IEO's ongoing monitoring programs to MSFD needs and requirements. In addition, within the framework of EU co-funded projects aiming at supporting MSFD implementation, such as PERSEUS, IRIS-SES and ACTIONMED, IEO has carried out several pilot actions focusing on filling monitoring gaps detected during MSFD initial evaluation and on taking advantage of spare capacity of existing regular surveys, in order to include new additional sampling activities, addressing MSFD indicators other than those covered by the routine sampling (Iglesias & Alemany, 2015; Massutí *et al*., 2015; Lopez-Jurado *et al*., 2015).

One of the IEO's existing monitoring programs relevant to MSFD is the IEO's Observing System, IEOOS, which incorporates different marine environment observing systems, including deep moorings and surface-meteorological moorings, tide gauge networks, a satellite reception station, regional oceanographic observatories, continuous R/V sampling systems, periodic R/V surveys and modelling facilities, contributing also to the Argo-Spain network. Among the most relevant IEOOS subprograms, it is worth to mention the Oceanographic Sections Monitoring System. This subprogram dates back to the late 80's, and it is based on the systematic sampling (hydrographical and biological), monthly or seasonally, of a series of stations along transects, since despite recent advances in hydrodynamic modeling and satellite imagery, "*in situ*" monitoring is still needed. The position of these fixed stations is shown in Figure 1.

The Mediterranean component of this subprogram is RADMED (Amengual *et al*., 2010). Its sampling scheme consist of transects according to the bathymetry, from the coast to the bottom of the slope, alongside the Spanish Mediterranean coast, from Barcelona to the neighborhoods of the Gibraltar Strait and around the Balearic Islands. It includes productive areas as Alboran Sea, oligotrophic waters as to the north of Cape Palos and around the Balearic archipelagos, or areas of special interest, as those surrounding the Ebro River, which are visited every 3 months. It maintains also two hydrographic moorings, included in the HYDROCHANGES CIESM network (Commission Internationale pour l'Exploration Scientifique de la Méditerranée, http://www.ciesm.org/marine/programs/hydrochanges.htm). More specifically, at each station temperature, salinity, dissolved oxygen, photosynthetically active radiation, fluorescence and turbidity are recorded with CTD probe (Conductivity-Temperature-Depth), whereas pH, total alkalinity, Chlorophyll-a and inorganic nutrients are determined from water samples taken with a carousel water sampler at standard depths. Phytoplankton and zooplankton are sampled both by Niskin bottles and BONGO nets, to determine their biomass and taxonomic composition.

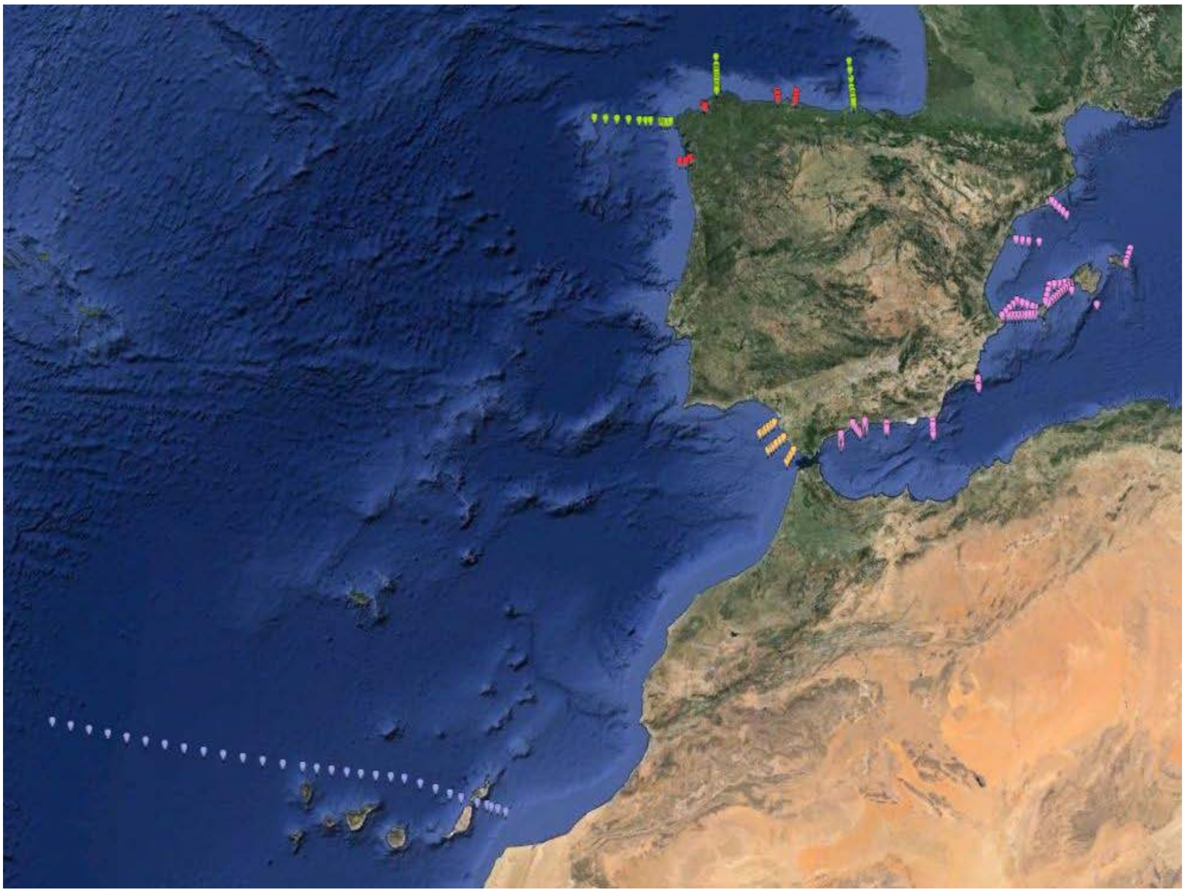


Figure 1. Location of regularly monitored hydrographic stations within the framework of IEO Oceanographic Section Monitoring System.

Regarding data management, all CTD and biogeochemical data are integrated into the IEO Data Centre, following standard procedures and consequently are incorporated into SeaDataNet, being fully accessible through it. In parallel, all the RADMED CTD data, nutrients and chlorophyll-a are included into the IBAMar database, which at standard levels is freely available for exploration and download from http://www.ba.ieo.es/ibamar/. Biological data (biovolume, zooplankton biomass, phytoplankton abundance and composition, nutrients, chlorophyll-a) and some meteorological parameters are included in the IEO SIRENO (Seguimiento Integrado de los REcursos Naturales Oceánicos) database. Integration within EMODNet-Biology is under development.

The RADMED historical series were used for elaborating the MSFD report on Initial Assessment of the Current Environmental Status in the Spanish waters. Mean values, seasonal oscillations and long term trends together with spatial distribution of the different oceanographic environmental variables were included on that reports. Recently, RADMED have been included in the Spanish national proposal of MSFD Monitoring Programs, as a multipurpose platform for providing information for

MSFD descriptors D1 (Biological diversity is maintained) in Pelagic Habitats, D4 (All elements of the marine food webs occur at normal abundance), D5 (Human-induced eutrophication is minimized) and D7 (Permanent alteration of hydrographical conditions).

In addition, taking advantage of the MSFD related EU projects namely PERSEUS, IRIS-SES and ACTION MED, and following the recommendations from different groups of experts assessing MSFD implementation process (Zampoukas *et al*., 2012, 2014), several pilot actions aiming at optimizing the use of this existing platform to address more MSFD indicators/descriptors or improve data collection including as well in some cases new technologies and automated and continuous monitoring systems, have been carried out in the recent years. Those carried out within the, ACTION MED project, are those reported here, specifically:

-Study of atmosphere/ocean CO_2 exchange

-Study of particulate mass fluxes

-Study of microplastics in upper layers of water column

-Study of atmosphere/ocean CO_2 exchange

The necessity of monitoring the atmosphere/ocean CO_2 exchange, in order to understand the fate of the excess CO_2 released in the atmosphere from human activities has been already pointed out, since the mid of last century (Revelle and Suess, 1957) and, as mentioned in previous paragraphs, the MSFD confirmed the CO_2 as one of the elements to be measured. The CO_2 system in the Mediterranean Sea and its monitoring have been recently reviewed (Alvarez, 2012; Alvarez *et al*., 2014) and it can be concluded that the regular monitoring of atmosphere/ocean CO_2 exchange in the regions is still scarce. Because of that, within the framework of the EU IRIS-SES project, the IEO implemented, for the first time, a plan for CO_2 atmosphere/ocean exchange in the Western Mediterranean, based on continuous measurements by means of a SUNDANS system (Balbín *et al*., 2015). However, in spite the new equipment was successfully installed and used, when demonstrating the feasibility to incorporate this new sampling activity within routine RADMED surveys, a technical problem prevented the gathering of reliable data. Thus, a new pilot action for getting correct measurements all over the study area, useful for establishing the baseline for future MSFD monitoring, have been developed under ACTIONMED project. The incorporation of CO_2 to trophic webs is addressed also within RADMED through phytoplankton sampling and the relations with the next trophic level can be estimated from the zooplankton studies. The higher trophic relations with zooplanktivourous and tertiary consumers are not being considered. On the other hand, the heterotrophic bacteria, essential for the decay of the organic matter to complete the cycle, are also being sampled regularly.

-Study of particulate mass fluxes

Within IRIS-SES project, the complementarity between continuous monitoring systems, as moorings and the more traditional surveys based on seasonal monitoring of a grid of stations, in order to complement the temporal gaps between visits to decrease the signal-to-noise ratio in "the seasonal and interannual evolution of temperature, salinity, turbidity and currents on the whole water column" (Table 1, Annex III Directive 2008/56/CE), were also analyzed. Takin advantage of these moorings and to complement all the information on CO_2 exchange and planktonic communities within ACTIONMED (data compiled under the IBAMar database, Aparicio *et al.* 2012), it was proposed to analyze the transfer of organic matter to the benthos and also the CO_2 content of the sediment. Thus, a pilot action in this direction has been carried out using the mooring deployed in one of the RADMED stations in the Ibiza channel. Specifically, two sediment traps were installed in 2015 to characterize separately the sediment dynamics (cascading, resuspended matter, etc.) and the biogeochemical effects, which have been recovered and their samples analyzed within ACTIONMED pilot action. This mooring is actually included in the CIESM HYDROCHANGES program.

The aim of the particle flux studies was to quantify the amount of carbon and other components, such as anthropogenic pollutants that are exported into Deep Ocean, which controls the long-term sequestration of atmospheric CO_2 and the inputs of organic matter to deep ecosystems. A sediment trap collects material that is settling through the water column. These particles can be examined to measure the total mass flux, and their characteristics with chemical and microscopic analyses. (Honjo, 1996). This represents a keystone for the prediction of deep ecosystems functioning and response to climate change and increasing anthropogenic pressures to ensure the sustainability of marine living resources.

This pilot action aimed to determine the organic matter origin, quality and quantity and the natural and anthropogenic factors that control their cycle, in order to establish a solid basis for a comprehensive ecosystem based approach management of deep sea ecosystems around the Balearic Islands. A better understanding of the quantity and quality of particulate organic matter export to deep-sea ecosystems is of upmost importance to understand ocean carbon cycling, the determination of the factors driving the inputs of particulate organic matter and, thus determinate the sedimentation patterns of the Balearic deep-sea. This work is relevant for scientific, political and socio economic stakeholders, aiming in achieving sustainable management of fishery resources as address the "Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy" EU societal challenges of Horizon 2020 program and the EC's Marine Strategy Directive to save Europe's seas and oceans (Directive 2008/56/EC). This kind of projects represents a high-impact multidisciplinary and integrated research on the study of deep-sea ecosystem.

-Study of microplastics in upper layers of water column

The issue of microplastics (fragments less than 5 mm), a ubiquitous and persistent debris, which requires centuries to completely degrade (Collignon *et al*., 2012) has attracted increasing attention worldwide in recent years. Microplastics are accumulating at the sea surface, especially within the neustonic habitat (Ryan *et al*., 2009). Concentrations of microplastics at sea surface have been reported worldwide; the Northeast Pacific Ocean (Doyle *et al*., 2011), the central Northern Pacific Ocean (Moore *et al*., 2001), the Sargassum Sea (Law *et al*., 2010) and the waters off California (Lattin *et al*., 2004). Microplastics are obviously hideous. Moreover, it is probable that a wide range of marine organisms are affected by plastic wastes in the sea. Unfortunately, despite of their potential impact on marine biota, there are currently no regular monitoring programs for microparticles in the Mediterranean region. Some studies on microplastics, in neustonic layers, have been carried out in the neighborhoods of Mediterranean Spanish marine demarcations, such as the one carried out in the northern areas of Northwestern Mediterranean by Collignon *et al*. (2012), pioneer in Western Mediterranean, and that recently published by Suaria *et al*. (2016), covering central-western Mediterranean and southern Adriatic. However, no offshore surveys of plastic microfragments in the Spanish Mediterranean Sea have been conducted, and in general the information is still scarce (see Suaria *et al*., 2016 and references therein: http://www.nature.com/articles/srep37551#t1).

Moreover, sampling protocols of microparticles still need harmonization (Piha and Zampoukas, 2011). In order, to fill this gap, a pilot action for microplastics sampling in water column was proposed to be implemented within the frame of RADMED monitoring under ACTIONMED project. It was conceived primarily as a feasibility study to test the logistic possibilities for adding this new sampling operation within RADMED program, following the same standard methodologies already put in place in Atlantic Spanish waters (Gago *et al*., 2015).

2. MATERIAL AND METHODS

2.1 Atmosphere/ocean CO_2 exchange

Field work

The mole fraction of carbon dioxide (xCO_2) in surface waters of the western Mediterranean and in the atmosphere was measured within the framework of the RADMED_0216, in February 2016 covering all the Mediterranean waters under Spanish jurisdiction, from Mar de Alborán (4.4°W 36.2°N) to Barcelona (2.1° E 41.2°N) and North of Menorca (4.4°E 40.1°N). This study area shows a clear latitudinal gradient in the thermohaline properties of water in the upper layer of the water column. Each one of the campaigns lasted around 25 days and was performed on board the R/V F.P. Navarro (Fig. 2) - length of 30.46 m and a capacity for 17 people, including scientist and the crew. Seawater-atmosphere CO_2 flux (FCO_2) was calculated by means of a SUNDANS device and other relevant parameters (e.g. wind speed and direction, surface salinity, temperature and chlorophyll-a) using the meteorological station of the R/V and a CTD probe.

Figure 2. Oceanographic Research Vessel F.P. Navarro.

The SUNDANS device was installed inside a 10 feet cargo container, which includes a laboratory with the necessary electricity and salty water connections required by the system (Fig. 3).

Figure 3. Laboratory in the 10 feet cargo container.

The route followed by the R/V F.P. Navarro in the RADMED_0216 campaign and the covered oceanographic stations can be seen in Figure 4.

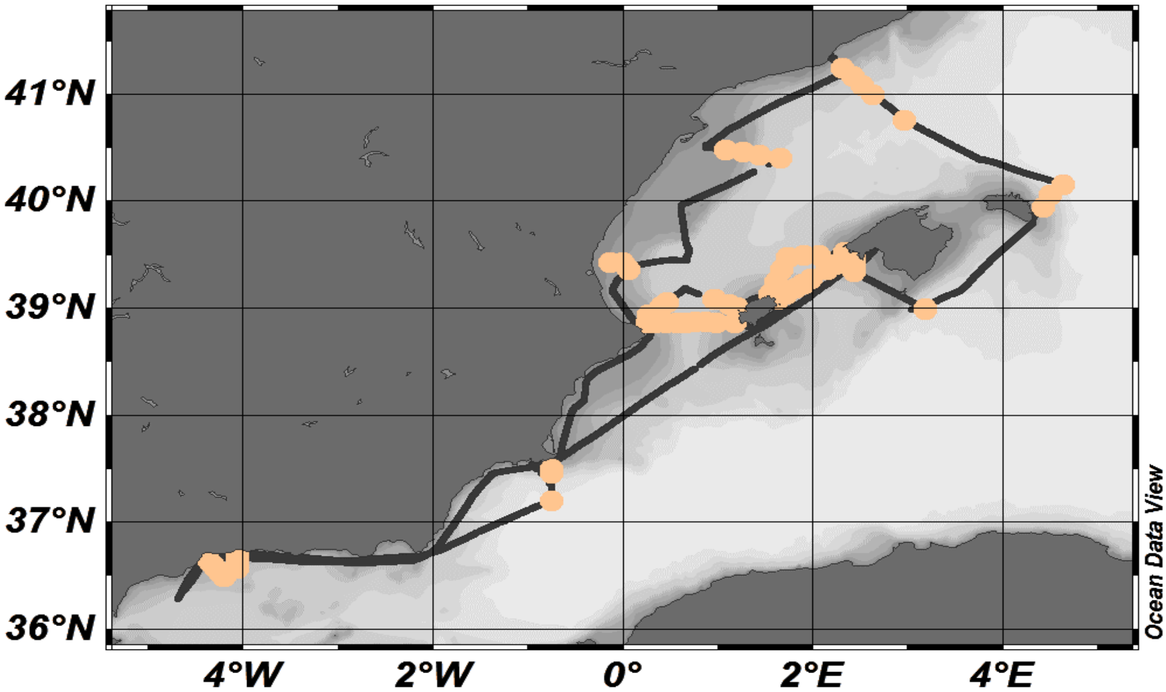


Figure 4. R/V F.P. Navarro route (black line) & Oceanographic stations (pink dots) in RADMED_0216.

SUNDANS parts

The components of SUNDANS (UNderway carbon Dioxide partial pressure ANalySer) system are shown in Figure 5. This device has been designed and built by MARIANDA company, Kiel, Germany.

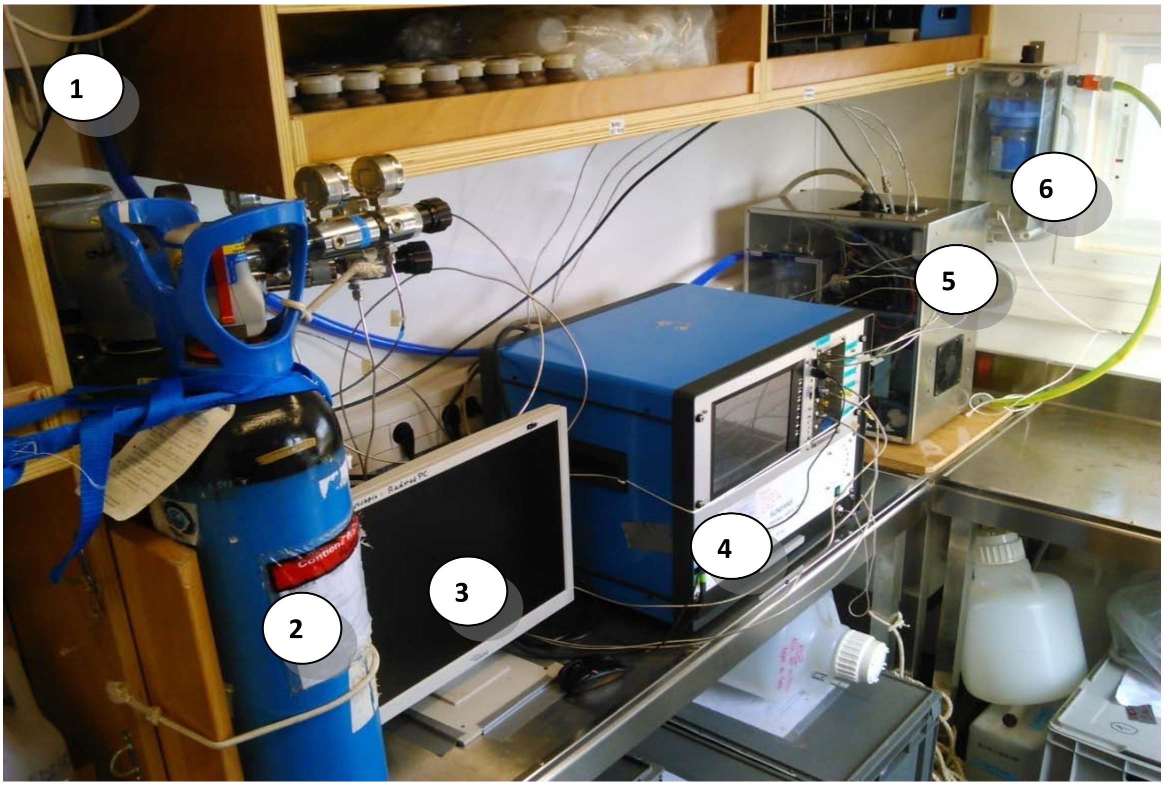


Figure 5. SUNDANS device parts.

1. GPS and atmospheric pressure sensor;
2. Calibration gas bottles;
3. Screen;
4. Dry box;
5. Wet box;
6. Sea water filtering system.

An IRGA (LICOR LI-7000 infrared gas analysis detector) is installed in the SUNDANS dry box, which measures CO_2 and H_2O vapor in the air stream from the wet box. The SUNDANS measurements are realized in continuous flow and not in discrete samples, as the gases pass through the IRGA at a constant speed provided by a pump. The system provides measurement data every 6 seconds. The LI-7000 LICOR is equipped with internal algorithms for the calculation of CO_2 and H_2O concentrations with high precision and takes into account the effects of temperature, pressure and water vapor.

During the analysis water from the sea surface was continuously pumped from a socket located at the bottom of the ship's hull; a pipeline to sample atmospheric air was also installed above the bridge of the ship. This zone was chosen because it is an area away from the possible CO_2 pollution produced by the ship's engines. The equipment was manually calibrated with two standard gases: synthetic air without CO_2 and H_2O (ALPHAGAZ NITROGEN N_2 purity greater than 99.999 %) and another gas with a known concentration of CO_2 (491.4 ppm of CO_2) (DIAMOND mixture with 491.4 ppm CO_2 and the rest N_2). In addition, another gas was used for intermediate calibrations (DIAMOND mixture with 345.3 ppm CO_2 and the rest N_2). These gases were prepared and supplied by the company Air Liquide.

With xCO_2 measured at atmospheric pressure and assuming 100% saturation of water vapor and the partial pressure of CO_2 in the atmosphere (measured every three hours), CO_2 flow can be calculated on the basis of wind speed provided by the ship's weather station.

Auxiliary equipment in the vessel

For calculations of pCO_2 and CO_2 flows between the atmosphere and sea water it was necessary to use additional information, recorded continuously by the other equipment carried by the R/V F.P. Navarro:

- **Thermosalinograph:**
  The sea surface temperature (° C) and salinity (PSU) were measured by a SeaBird SBE21 Thermosalinograph.
- **Fluorescence:**
  The fluorescence of chlorophyll-a was continuously recorded by a fluorometer TURNER DESIGNS 10-AU.
- **Weather Station:**
  The R/V had a weather station "AIRMAR PB200 Weather Station" that facilitates the collection of data as atmospheric temperature, the atmospheric pressure, the speed and the direction of the wind.
- **GPS:**
  The position data of the boat was provided by a GPS SIMRAD GN33.
- **Echo sounder:**
  The boat had a depth probe SIMRAD ES70.
- **Remote Temperature Sensor:**
  The surface sea water temperature was measured directly with a remote temperature sensor installed in the water intake of the B/O F.P. Navarro.

Integration of ship data

All these data were integrated in a daily text file made using the software "Marine data management system (MDM)", which produce a data line every minute.

CTD probe

A CTD SBE911plus equipped with redundant salinity (SBE4) and temperature sensors (SBE3) was used, as well as an oxymeter (SBE43), a fluorometer (WETLABS ECO FL) and a turbidimeter (WETLABS ECO NTU), a PAR detector and SPAR (LI-COR Biospherical), sonar altimeter and a pressure gauge (to know exactly the working depth). This CTD was associated with an oceanographic rosette (SEBE32) equipped with twelve 5 liter Niskin bottles, as shown in Figure 6.

Figure 6. Rosette & CTD

Data Processing Protocol

In the land laboratory, most of the work with SUNDANS data involved the cleaning of erroneous data and the calculation of pCO_2 and CO_2 flow. For CO_2 flow calculations, data from SUNDANS and the rest of the equipment carried by the B / O F.P. Navarro was needed. The data of the thermosalinograph, continuous fluorometer, meteorological station, GPS and echo sounder from the boat have different temporal resolution than the SUNDANS data. The weather station offers data whenever it is on, independent if the ship is sailing or not, whereas the data of the thermosalinograph, fluorometer, echo sounder, GPS and the SUNDANS data are only provided when the boat is sailing and out of harbour. All these data were integrated with reference to the frequency at which SUNDANS works (every 6 seconds).

2.2 Sediment traps

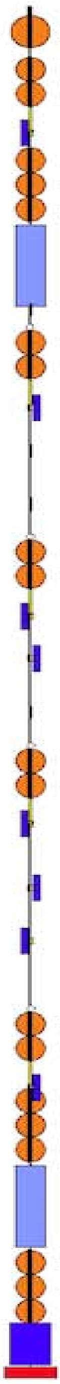
Experimental design and data recovery

The aim of incorporating sediment traps to the RADMED permanent mooring line was to investigate the environmental factors that control the particulate matter fluxes in the northern part of Menorca Island, through the samples recorded from two sediment traps PPS3 Technicap sequential sampling sediment trap (12 collecting cups, 0.125 m2 opening and 2.5 height/diameter aspect ratio for the cylindrical part) at 300 m and 2473 m water depth from September 2015 to March 2016. The mooring line was equipped also with Nortek current meters (200, 400, 1000, 1600 and 2450 m water depth), SBE37 CTDs (200, 400, 1000, 1300, 1600, 1900, 2200 m) and SBE56 thermistors (150, 300, 500, 600, 700, 850, 1150 and 1450 m). The scheme of mooring line is shown in Figure 7.

Sample treatment and analytical procedures

Sample treatment and analytical procedures are described by Heussner *et al*. (1990). Briefly, in the sediment trap bottles a poisoning solution is used to prevent the physical-chemical processes, such as the dissolution of biominerals or organic aggregates. Since the intrusion of swimmers may affect the particle flux, sediment trap samples were wet-sieved through a 1mm nylon mesh, in order to retain the largest organisms. Swimmers smaller than 1 mm were manually removed under a dissecting microscope using fine tweezers. After recovering, samples were stored in dark at 2-4 ºC until they were processed in the laboratory. Depending on the quantity of material collected, several different analyses can be done for the determination of the main constituent content (organic matter, opal, calcium carbonate, and siliciclastics), which provide the necessary information of the quantity of organic matter settling and its origin.

Deciphering the different components of the mass flux (e.g., horizontal vs. lateral fluxes) is also challenging and tracing the specific origin of the OM inputs (e.g, autochthonous vs. allocthonous) is difficult, due to the wide range of possible sources, degradation and selective transport processes in canyons (Hedges *et al*., 1997). Specific organic biomarkers, including pigments, amino acids and lignin phenols and stable isotopic analyses can also be analyzed to obtain information on the specific origin, quality or degradation processes of the organic matter. Micro plastics analyses of sediment traps samples can also provide information on their sources and transfer into the marine environment.



Mooring Element	Length[m]	Height[m]
[illegible]	[illegible]	[illegible]
30in float	0.76	2335.23
Sbe-56	0.29	2330.00
17 in glass	0.57	2291.47
17 in glass	0.57	2290.90
Nortek	0.58	2285.33
Sbe-37 SMP	0.61	2280.00
17 in glass	0.57	2209.75
17 in glass	0.57	2209.18
17 in glass	0.57	2208.61
PPS3 SedTr	1.90	2197.99
Sbe-56	0.29	2190.00
17 in glass	0.57	2120.91
17 in glass	0.57	2120.34
Nortek	0.58	2114.77
Sbe-37 SMP	0.61	2100.00
Sbe-56	0.29	2000.00
Sbe-56	0.29	1900.00
Sbe-56	0.29	1800.00
Sbe-56	0.29	1650.00
17 in glass	0.57	1514.05
17 in glass	0.57	1513.48
Nortek	0.58	1507.91
Sbe-37 SMP	0.61	1500.00
Sbe-56	0.29	1350.00
Sbe-37 SMP	0.61	1300.00
Sbe-56	0.29	1050.00
17 in glass	0.57	907.20
17 in glass	0.57	906.63
Nortek	0.58	901.06
Sbe-37 SMP	0.61	900.00
Sbe-37 SMP	0.61	600.00
Sbe-37 SMP	0.61	350.00
17 in glass	0.57	50.33
17 in glass	0.57	49.76
Nortek	0.58	44.19
Sbe-37 SMP	0.61	40.00
17 in glass	0.57	33.61
17 in glass	0.57	33.04
17 in glass	0.57	32.47
PPS3 SedTr	1.90	21.86
17 in glass	0.57	12.93
17 in glass	0.57	12.36
17 in glass	0.57	11.79
Double Benthos 6	0.96	11.21
2 ruedas de tren	0.25	0.25

Figure 7. Mooring design.

2.3 Microplastics in sea surface

Field work

A grid of 25 RADMED coastal and open sea stations were selected for sampling, located on 5 sections, orthogonal to the coast along bathymetric gradient, from Catalonia to Alboran Sea. At each station, ten minutes neuston tows were performed at 2 knots using a neuston net (Figure 8) fitted with a 333 microns mesh, equipped with a General Oceanics flowmeter for measuring track distance.

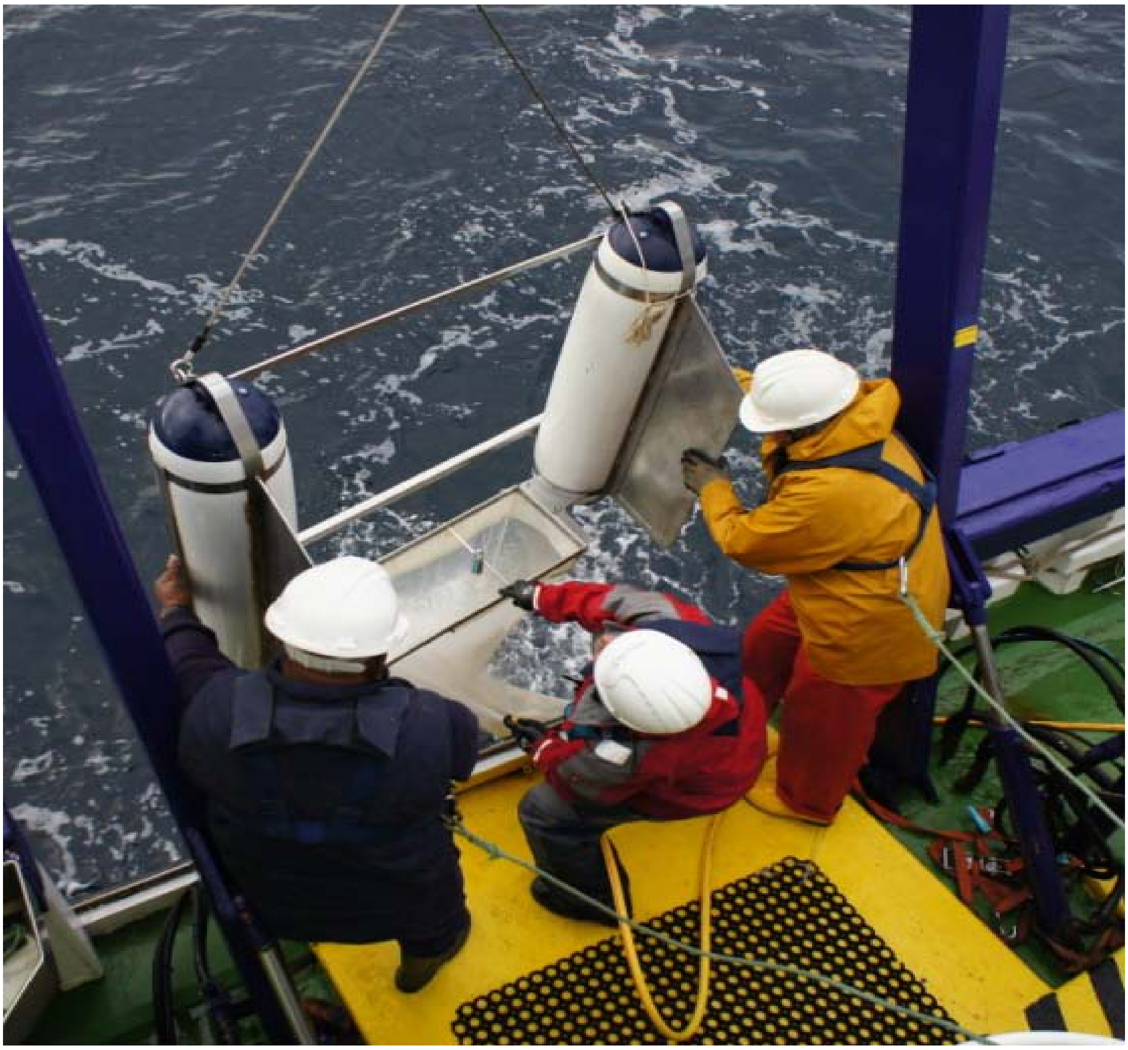


Figure 8. Neuston net.

Sampling strategies and methodologies, as well samples analysis followed the recommendations from JRC Scientific and Policy Reports Report EUR 26113 “A guidance document within the Common Implementation Strategy for the Marine Strategy Framework Directive MSFD Technical Subgroup on Marine Litter” (2013).

Finally, 23 of 25 selected stations were effectively sampled. Details of sampling operations are summarized in Table I.

Table I. Location of neuston sampling stations.

ESTADILLO PESCAS NEUSTON		RADMED_0216													
Orden Estación	Malla RADMED	Nombre Estación	Fecha	Hora GMT inicio	Hora GMT final	Tiempo arrastre	Posición inicial		Posición 7,5'		Posición final		Flujómetro inicial	Flujómetro final	Nº vueltas
							Latitud	Longitud	Latitud	Longitud	Latitud	Longitud			
1	101	B1	05/02/2016	10:03	10:18	15'05''	39º28,229	2º26,454 E	39º28,374	2º26,193	39º28,519	2º25,936	466	3812	3346
2	102	B2	05/02/2016	12:03	12:24		39º23,997	2º26,196 E	39º24,084	2º25,888	39º24,189	2º25,594	3812	6805	2993
3	103	B3	05/02/2016	13:41	13:54	15'15''	39º20,461	2º26,139 E	39º20,494	2º25,856	39º20,527	2º25,520	6805	9899	3094
4	115	BNA5	08/02/2016	10:37	10:52	14'58''	41º00,280	2º38,182 E	41º00,211	2º37,829	41º00,130	2º37,588	9899	12892	2993
5	111	BNA1	10/02/2016	14:22	14:37	15'05''	41º19,619	2º13,126 E	41º19,384	2º13,112 E	41º19,099	2º12,980 E	12805	16620	3815
6	112	BNA2	10/02/2016	15:42	15:57	15'09''	41º15,265	2º18,478 E	41º15,090	2º18,250 E	41º14,896	2º18,005 E	16620	19182	2562
7	113	BNA3	10/02/2016	17:39	17:54	15'08''	41º10,009	2º24,672 E	41º09,831	2º24,465 E	41º09,640	2º24,248 E	19182	21340	2158
8	121	T1	11/02/2016	6:59	7:14	15'00''	40º30,666	0º52,256 E	40º30,426	0º52,232 E	40º30,199	0º52,218 E	21340	24730	3390
9	122	T2	11/02/2016	8:34	8:49	14'58''	40º29,230	1º08,880 E	40º28,963	1º08,924 E	40º28,728	1º08,982 E	24730	28000	3270
10	123	T3	11/02/2016	10:33	10:48	14'59''	40º27,873	1º15,849 E	40º27,654	1º15,638 E	40º27,454	1º15,441 E	28000	31332	3332
11	125	T5	11/02/2016	14:03	14:18	15'06''	40º24,003	1º38,489 E	40º23,983	1º38,810 E	40º23,986	1º39,147 E	31332	34975	3148
12	44	44	12/02/2016	12:38	12:53	15'02''	39º25,666	0º00,291 E	39º25,757	0º00,015 w	39º25,866	0º00,328 w	34975	38682	3707
13	43	43	12/02/2016	14:05	14:20	15'00''	39º25,550	0º08,467 W	39º25,587	0º08,146 W	39º25,625	0º07,815 W	38682	41300	2618
14	42	42	12/02/2016	15:26	15:41	15'00''	39º21,815	0º04,154 E	39º21,847	0º03,856 E	39º21,855	0º03,562 E	41300	44226	2926
15	20	20	17/02/2016	7:54	8:09	15'05''	38º52,240	0º14,704 E	38º52,405	0º14,905 E	38º52,593	0º15,146 E	44226	47201	2975
16	18	18	17/02/2016	10:11	10:26	14'58''	38º51,718	0º27,185 E	38º51,948	0º22,148 E	38º52,190	0º27,091 E	47201	50204	3003
17	15	15	17/02/2016	14:21	14:36	15'01''	38º52,738	0º45,462 E	38º52,583	0º45,173 E	38º52,466	0º48,959 E	50204	53008	2804
18	6	6	18/02/2016	12:16	12:31	15'05''	38º16,594	1º59,491 E	38º16,629	1º59,173 E	38º16,678	1º58,862 E	53008	55421	2413
19	145	CP5	22/02/2016	15:33	15:48	15'05''	37º12,950	0º45,518 W	37º12,719	0º45,566 W	37º12,472	0º45,628 W	55421	58287	2866
20	185	M5	23/02/2016	15:11	15:26	15'01''	36º29,797	4º12,401 W	36º29,564	4º12,637 W	36º29,391	4º12,854 W	58288	60182	1894
21	188	M8	23/02/2016	17:37	17:52	14'57''	36º35,487	4º18,768 W	36º35,358	4º19,016 W	36º35,208	4º19,259 W	60182	62972	2790
22	182	M2	23/02/2016	18:40	18:55	15'02''	36º38,274	4º21,249 W	36º38,100	4º21,456 W	36º37,941	4º21,686 W	62972	65436	2464
23	181	M1	23/02/2016	20:07	20:22	15'00''	36º41,583	4º23,856 W	36º41,629	4º23,518 W	36º41,636	4º23,195 W	65436	66468	1032

Analysis of samples at laboratory

The contents of each sample was firstly filtered through a 200 microns mesh and placed in a beaker. Both the 200 microns mesh and the jars were carefully cleaned with distilled wáter, to ensure that all the sample was transferred to the beaker. Then the samples were analyzed under a stereomicroscope (Nikon SMZ 10). For doing that small amounts of sample were sequentially placed on crystal Petri dishes. Microplastic particles were extracted with fine tweezers, counted and placed in vials with Ethanol. Microfibers were not included, except those that judging according to their shape and colour originated from the sea (Foekema *et al*., 2013).

Contamination control

Contamination control is a key issue in the studies on microplastics. These particles are found both in the air and in the water, and hence can easily contaminate the samples both onboard and in the lab. Because of that, it is imperative to establish preventive measures. In our case, during sampling operations at sea, the crew involved in the operations, used clothes made 100% with natural fibers and wet suit clothes than do not produce easily microfibers. Moreover, during the operations the crew was located leeward. During navigation, the net was covered with a plastic bag.

Once in the lab, the working station was frequently cleaned, and all the used equipment was cleaned with distilled water. The analysis process was carried out under an extraction tube. Both the beaker and the Petri dishes remained covered, as much time as possible. Moreover, a Petri dish with distilled water was placed besides the work station during analysis, as a blank, in order to measure any potential contamination. Once finished the extraction of microplastics, the samples were replaced in the original jars and fixed with 2% formalin.

3. RESULTS

3.1 Atmosphere/ocean CO_2 exchange

SUNDANS pCO_2 measures in the RADMED_0216 campaign are shown in Figure 9 (values over time) and Figure 10 (spatial distribution).

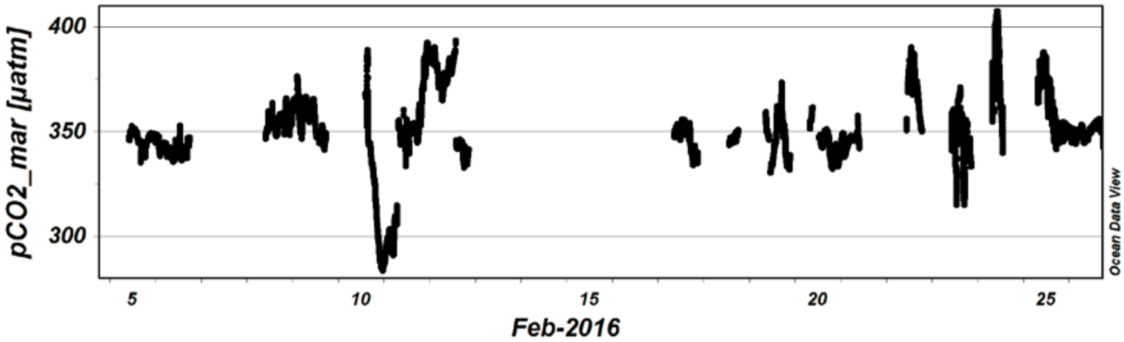


Figure 9. pCO_2 measures throughout the campaign.

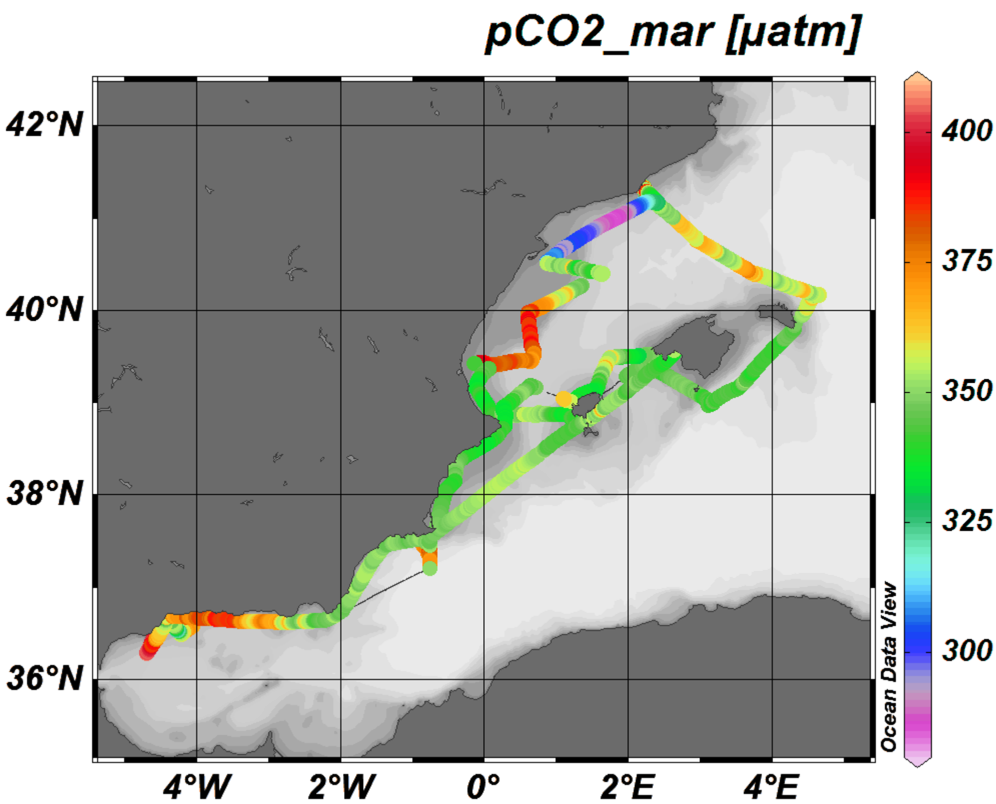


Figure 10. Spatial distribution of pCO_2 in seawater surface.

Along RADMED_0216 a total of 102,215 valid FCO_2 values were obtained after the cleaning, integration and data processing procedure. Calculated flows are shown in Figures 11 (over time) and 12 (over space). Negative flows were found throughout the campaign, which means a net input of CO_2 from the atmosphere to the sea. The minimum values were of -50 mmol m^{-2} d^{-1}. The mean FCO_2 for the whole survey was -7.33 mmol m^{-2} d^{-1}.

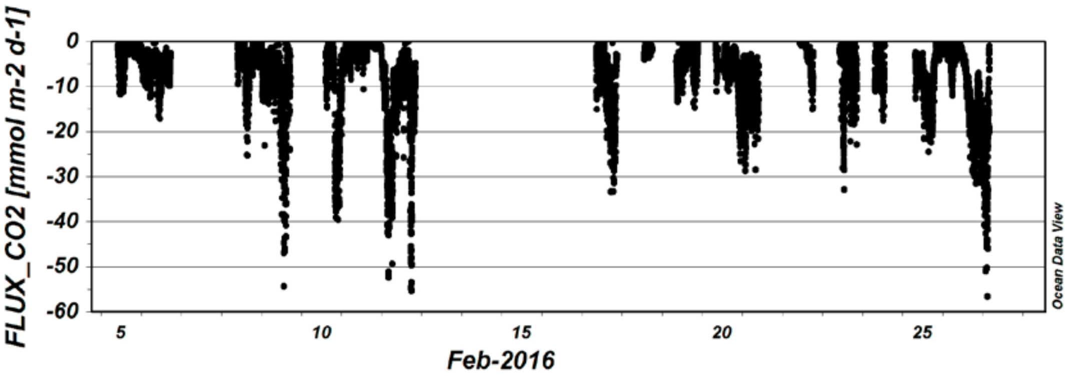


Figure 11. FCO_2 in the equilibrator throughout the campaign

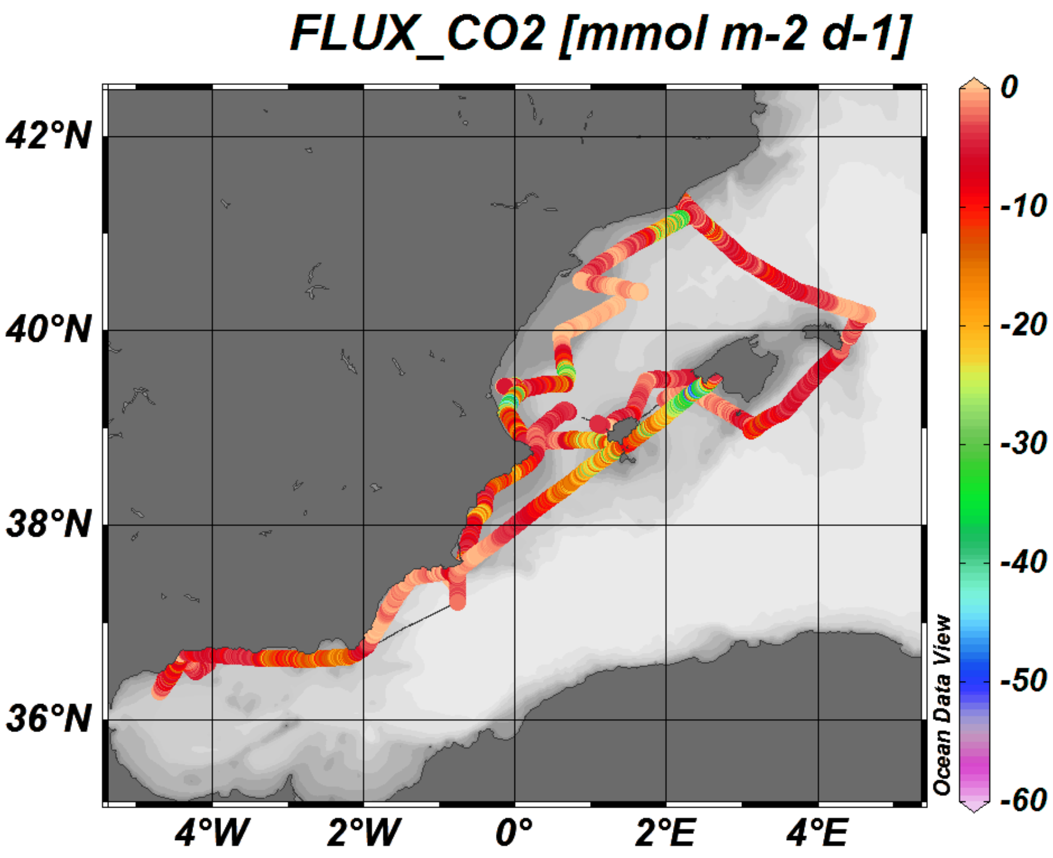


Figure 12. Spatial distribution of FCO_2 in seawater surface.

As can be seen in the previous figures, the calculated FCO_2 distribution do not match the pCO_2 in seawater, because for estimating flows besides pCO_2 in seawater and in the atmosphere, other parameters, such as seawater temperature and wind speed, are also considered.

These preliminary results were presented as a poster entitled “Seawater-atmosphere CO_2 Flux during RADMED_0216 campaign” (Aparicio *et al.*, 2016) during the Congress “SEMINARIOS IBÉRICOS DE QUÍMICA MARINA, V SIMPOSIO INTERNACIONAL DE CIENCIAS DEL MAR, Alicante, Spain, (2016)”. After the “fine tuning” of this sampling methodology within this pilot action, these CO_2 measurements were incorporated in the routine monitoring scheme of RADMED program, and similar data sets were obtained within the following three campaigns (RADMED_0416, RADMED_0716, and RADMED_1016), covering an annual cycle. These data will be complemented with those on nutrients and phyto- and picoplankton counts and a scientific paper on CO_2 atmosphere/ocean exchange in Spanish Western Mediterranean will be elaborated shortly, whose results will be useful as a first reference in the region for defining the baselines for future MSFD monitoring results. However, it will be necessary to monitor these processes along several years, to get a sound idea about the spatio-temporal variability in the measurements of these parameters and their causes, in order to agree on reference values for defining GES. Moreover, it is expected that global warming and evolution of CO_2 concentrations in the atmosphere, driven in a high percentage directly or indirectly by human activities, affect directly these processes. Thus, warmer and saltier waters in Mediterranean, as a consequence of climatic changes will complicate the dissolution of CO_2 in seawater, but increases of CO_2 concentrations will favor such process. On the other hand, higher T and CO_2 levels in seawater will enhance phytoplankton fixation of CO_2, but its higher metabolic rates also increase its CO_2 production. Changes in the structure and taxonomic composition of planktonic communities associated to climatic variation, and to the changes in seawater pH derived from those in carbon dioxide levels, will also play a role in the dynamics of atmospheric CO_2 sequestration by oceans.

Economic considerations

Performing this additional monitoring within the SUNDANS, generated further expenses, but very limited, since the RADMED campaign can be performed within the same time range as usual. Therefore, the extra expenses for getting CO_2 exchange data include only:

- boat technician: 1.5 h day^{-1} · 23 days · (155+105) € 7.5^{-1} h^{-1} = 1196 €
- technician for data filtering procedure: 75 h · 155 € 7.5^{-1} h^{-1} = 1550 €
- Standard gases: 400 €

Thus, total amount is around 3146 € per campaing. This does not include the cost of the acquisition of the equipment, but this is a cost that has to be occurred irrespective of the monitoring scheme it will be incorporated into and the scope of this work is to examine the additional cost of running the scheme.

3.2 Sediment traps

Preliminary results indicate that different processes affected the material flux at the study station. Total mass fluxes were higher at 2400 m than at 200m, as shown in Table II, suggesting that periodic lateral advection of material or *in situ* resuspension of sediment, is taking place. Since the mooring line was well equipped with physical monitoring instruments, posterior analysis will allow to determinate the processes that cause such increases in deep sedimentation.

The distribution over time of these fluxes is shown in Figure 14.

Ongoing biogeochemical analyses include the determination of organic matter and lithogenic fractions that will allow elucidating on organic matter fluxes to the deep Menorca ecosystem, the environmental drivers and the degradation rates of the organic matter through the water column. Once these results will be available and further statistical analysis completed, the results of this action are expected to be shortly published in a peer-review journal.

Table II. Mass flux estimated from sediment traps in RADMED mooring.

	UPPER SEDIMENT TRAP 200 m	BOTTOM SEDIMENT TRAP 2400 m
TOTAL MASS FLUX (mg / 180 days)	2.946,40	13.320,88
MEAN FLUX (mg/m^{-2}/d)	16,37	74,00
MAX FLUX (mg/m^{-2}/d)	76,84	141,59
MIN FLUX (mg/m^{-2}/d)	0,01	11,47

These total Mass Fluxes are in the range of values found at Mediterranean Sea open sea and slope sediment trap experiments, as can be seen in the next figure 13.

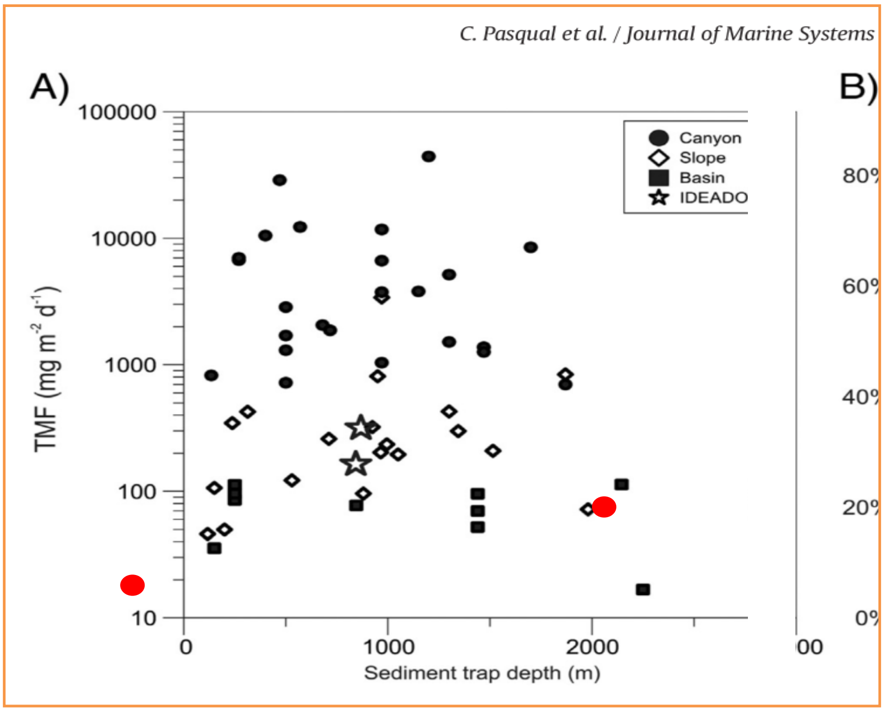


Figure 13. Total mass fluxes recorded in different areas of Mediterranean.

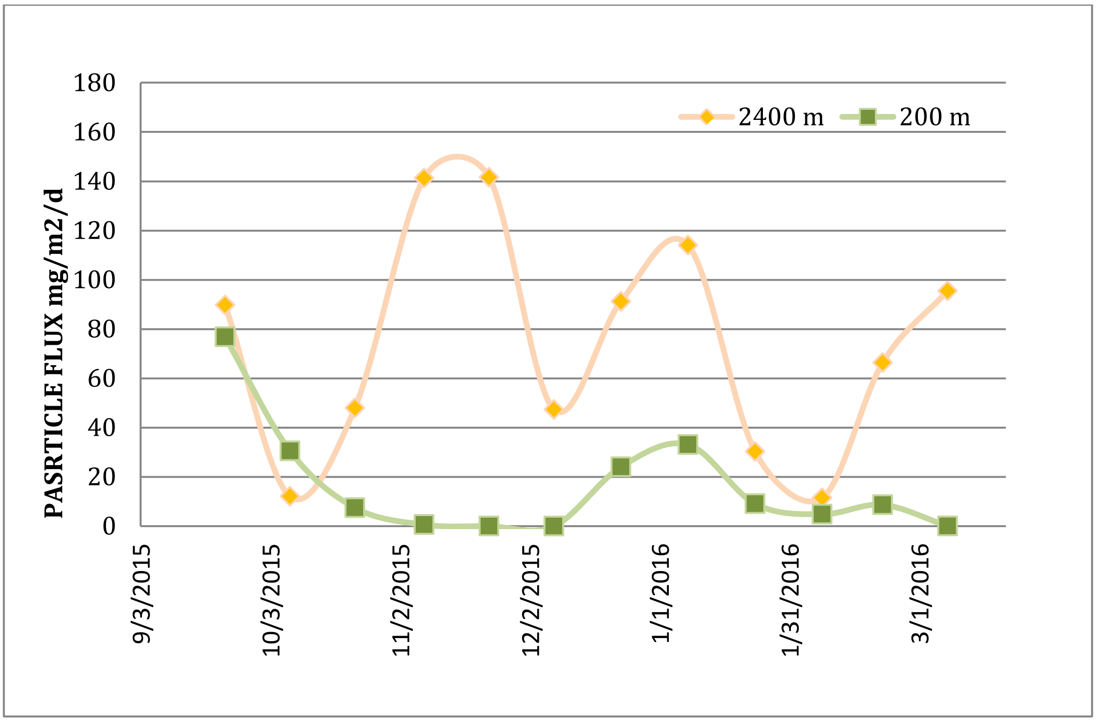


Figure 14. Particle flux recorded by sediment traps along sampling period (March 2015-February 2016).

Economic considerations

The acquisition of the equipment may cost about 20000€ / Sediment traps, with long depreciation / amortization period (>10 years). However, for this first pilot action they were borrowed from the University of Barcelona, at zero cost, and in any case the cost of the equipment is not in the scope of the additional monitoring cost.

The deployment and maintenance of sediment traps within the RADMED mooring line does not implicate any significant extra cost, only the preparation of the buffering solution with current lab solution and clean sampling bottles that are reused.

The samples processing requires around 1 hour per sample. Thus, the cost of processing the 24 samples from each 6-month sampling period, considering a daily cost for technicians work of 155€ and about 4 working days, would be 620€.

Sample treatment analyses may require experienced technicians. The costs of the analyses are different for each technique:

- ☐ Organic Carbon: x 24 samples / mooring period = 240€
- ☐ Inorganic Carbon: x 24 samples / mooring period = 240€
- ☐ C-13 stable isotopes: x 24 samples / mooring period = 408€.

3.3 Microplastics in sea surface

The number of microplastic items (excluding microfibers) per station, is shown in Table III.

Table III. Number of microplastics per station.

N station	N plastics
1	252
2	297
3	215
4	104
5	161
6	192
7	N.A.
8	248
9	189
10	515
11	441
12	70
13	133
14	65
15	164
16	140
17	118
18	80
19	185
20	84
21	154
22	133
23	55
Total	3995

The general appearance of analyzed microplastics is shown in Figure 15

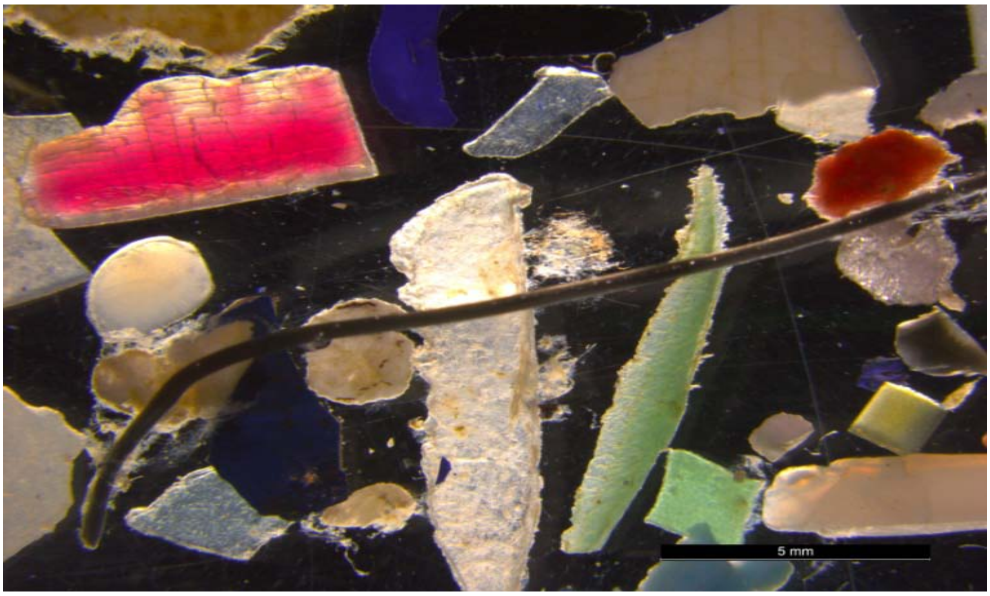


Figure 15. Example of microplastics found in neustonic layer of Spanish Western Mediterranean.

The spatial distribution and abundance of microplastics in neuston (microfibers excluded), standardized to items per square meter, is shown in the next Figure 16.

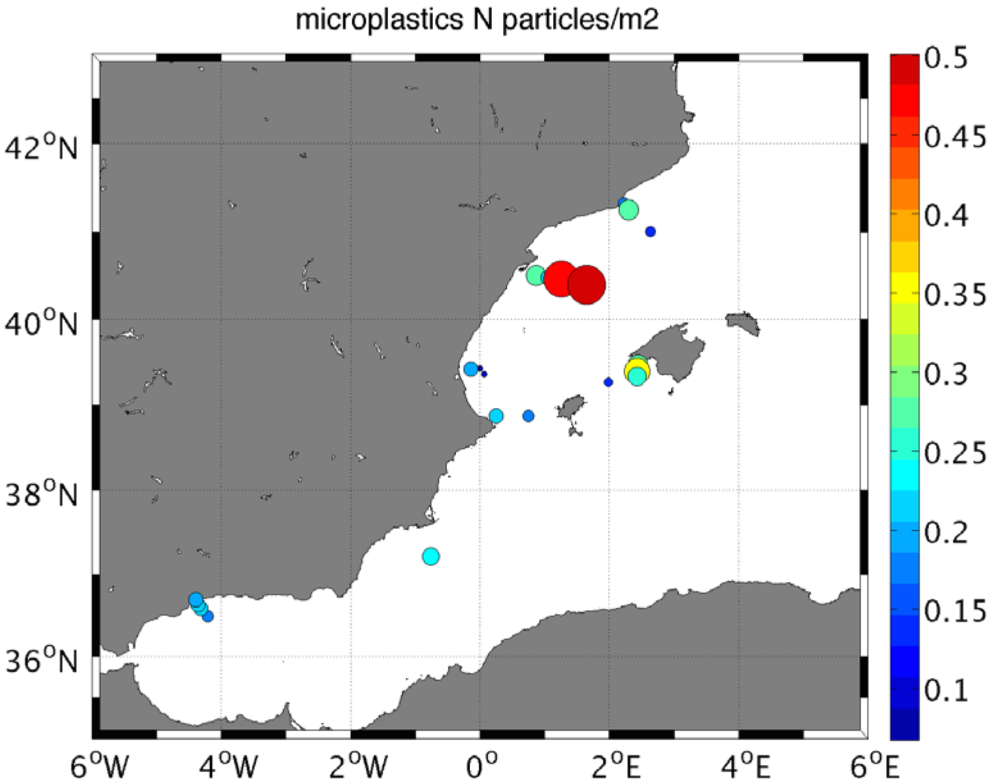


Figure 16. Density of microplastics (except microfibers) in Spanish Western Mediterranean, during RADMED February 2016 survey.

The observed abundances, between 0,1 and 0,5 items per square meter, are in line with those previously recorded in other areas of Mediterranean, as can be seen in the following table taken from Suaria *et al.* (2016).

Table IV. Comparison of floating microplastic concentrations obtained in all previous studies performed in the Mediterranean Sea.

Study area	Sampling period	Net mesh	#	Mean abundance ± SD (Max)	Ref.
Cretan Sea	July 1997	500 µm	25	119 ± 250 (1160) g/km^2	63
NW Mediterranean	July–Aug 2010	333 µm	40	0.116 (0.892) $items/m^2$ 2020 (2280) g/km^2	64
Ligurian/Sardinian Sea	Jun–Jul 2011	200 µm	23	0.31 ± 1.0 (4.83) $items/m^2$	65
Bay of Calvi (Corsica)	Aug 2011–Aug 2012	200 µm	38	0.062 (0.688) $items/m^2$	66
W Mediterranean	Sept 2011–Aug 2012	333 µm	41	0.135 (0.42) $items/m^2$ 187 (216) g/km^2	55
W Sardinia	July 2012–July 2013	500 µm	30	0.15 (0.35) $items/m^3$	67
Ligurian Sea	July–Aug 2013	333 µm	35	0.103 (0.36) $items/m^2$	68
NW Sardinia	July 2012–July 2013	200 µm	27	0.17 ± 0.32 (1.69) $items/m^3$	69
Ligurian Sea	Summer 2011/2012/2013	200 µm	70	0.31 ± 1.17 (9.67) $items/m^3$	70
Mediterranean	May 2013	200 µm	39	0.243 $items/m^2$ 423 (1934) g/km^2	19
Central W Mediterranean	May 2011–June 2013	333 µm	71	0.147 (1.16) $items/m^2$ 579.3 (9298) g/km^2	53
W Med/Adriatic	May–June 2013	200 µm	74	0.40 ± 0.74 (4.52) $items/m^2$ 1.00 ± 1.84 (11.30) $items/m^3$ 671.91 ± 1544.16 (10432.36) g/km^2	This study

The next step of this study will consist in the chemical characterization of these microplastics, in order to compare these results with those obtained in other areas of Western Mediterranean.

Economic considerations

The additional cost of this sampling and data analysis, apart of the initial investment that represents the purchase of a neuston net, if not already available (less than 3000€), is mainly associated to the analysis of samples once in the lab, since most of the field work was integrated within a RADMED regular survey. Thus, the neuston tows carried out during the survey, up to three or four operations by day lasting each one around 20 minutes and only in some selected transects, did not imply an increase of the total duration of the survey, and hence the cost of field operations is limited to around 6 extra working hours of two members of the crew plus two technicians of the scientific staff. The sampling analysis requires around 1 technician working day by sample, that is 155€/day.

4. CONCLUSSIONS AND RECOMMENDATIONS

General conclusions

- Hydrographic surveys designed initially for monitoring the seasonal evolution of the mesoscale hydrodynamic dynamics, based on the coverage of a regular grid of stations, constitute suitable platforms for monitoring planktonic pelagic communities, from bacterioplankton to mesozooplankton, as well for microplastics in the water column. This is true, since these additional sampling activities can be realized at a relatively low cost by the same staff in charge of hydrographic casts, without any significant increase in the total duration of the surveys. On the other hand, the spatial and temporal match between hydrological and biological data and samples collection allows a more precise interpretation of results on biological communities' structure.

- The continuous data recording systems, like hydrographic moorings at fixed points or equipments that collect data continuously along the R/V routes, such as termosalinographers or SUNDANS systems, do not only provide direct information on environmental parameters required under MSFD, but they also increase the spatial and/or temporal coverage of sampling, diminishing the "signal to noise" ratio. Hence, they contribute to a better definition of the environmental status and in consequence a better interpretation of the results from other monitoring activities. Moreover, the cost of acquiring these additional data, apart of initial investment in the equipments, is very low, if these activities are integrated within multidisciplinary regular research surveys (e.g. deploying, maintenance and recovery of moorings during other surveys or use of continuous on board data recording systems in parallel with other sampling activities).

Specific conclusions

SUNDANS

- Automated CO_2 measurement systems as SUNDANS can be incorporated at a reasonably low cost and without important changes in the routine sampling schemes (only requires occasional surveillance by a technician on board), within hydrographic surveys.

- In the surveyed area and period, the Mediterranean Sea acted mainly as a sink of atmospheric CO_2. However, more surveys are required to define the dynamics of this atmosphere-ocean CO_2 exchange, along annual and multiannual cycles, and hence to determine what could be considered the baseline for GES evaluation.

Sediment traps

- Sediments' traps can be incorporated to hydrographic moorings at a very low operational cost.

- Sediments' traps contribute significantly to the study of the marine ecosystems material/energy fluxes.

- Specific organic biomarkers and tracers can be analysed to obtain information on the specific origin, quality or degradation processes of the organic matter.

- Micro-plastics analyses of sediment traps samples can also provide information on their sources and transfer into the marine environment.

- Information of sediments' traps samples represents a keystone for the prediction of deep ecosystems functioning and response to climate change and increasing anthropogenic pressures, to ensure the sustainability of marine living resources.

Microplastics

- Sampling for microplastics (neuston tows) can be integrated within a RADMED regular survey at a very low operational cost.

- Microplastics abundance in neuston is not negatively correlated to distance to the coastline (sources), indicating their long time of residence and subsequent widespread distribution. Thus, a proper sampling design for getting a global view of their potential impact in a given marine demarcation should include both coastal and offshore stations.

- Detected neustonic microplastics abundances are in the order of 0.5 particles per square meter of sea surface, in line with predictions from models and results from previous samplings in the Western Mediterranean. Thus, relatively short tons of 10' carried out with standard neuston nets are enough for sampling effectively microplastic in the Spanish Western Mediterranean region.

Recommendations

- In order to fill some of the monitoring gaps detected during the revision of the MSFD Mediterranean MSs monitoring plans, both in terms of elements monitored and spatial coverage (lack of monitoring in offshore areas), the administrations and organisations in charge of MSFD monitoring programs implementation should make the most of the spare capacity of research vessels, carrying out regular surveys under existing programs for incorporating new sampling activities, especially in the case hydrographic surveys covering offshore areas.

- Ad hoc meetings among the different responsible of existing regular monitoring surveys in the Mediterranean, including non-EU countries, should be set up and supported by EU. The aim should be to identify and discuss from a practical point of view, the logistic feasibility and cost of different additional sampling activities within such surveys, in order to maximize the monitoring capacity and efficacy in an integrated and cost effective manner.

- The use of continuous *in situ* data recording systems, as moorings or any on board device (thermosalinographers, equipments for measuring CO_2…), within the framework of regular existing monitoring programs should be recommended and supported by EU, for example considering grant facilities for such equipment acquisition.

5. REFERENCES

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