SUPPLEMENTARY MATERIAL

Plastic debris occurrence, convergence areas and fin whales feeding ground in the Mediterranean Marine Protected Area Pelagos Sanctuary: a modelling approach

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Plastic Pelagos survey and sampling

The Plastic Pelagos survey has been carried out for ten days (8-18 September 2014) with the Research Vessel ASTREA (ISPRA) across the whole Pelagos Sanctuary. During the “Plastic Pelagos” survey a total of 967 nautical miles were travelled, 21 zooplankton/microplastic samples were collected (Fig 1 SM) and monitored for marine litter.

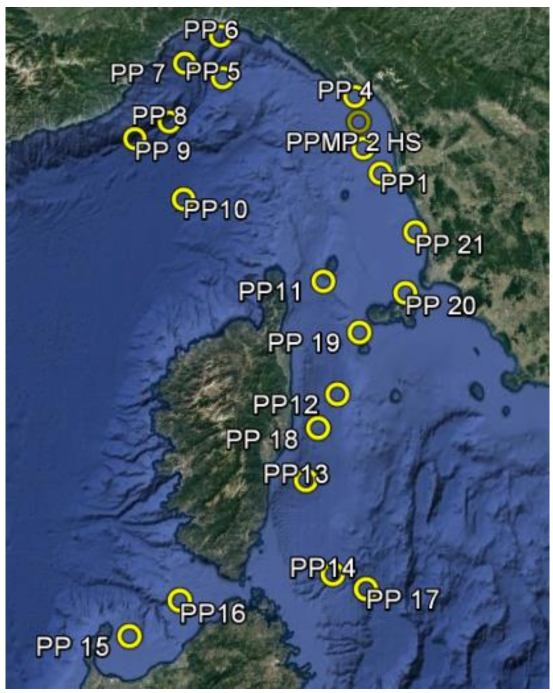

Figure 1SM. Plastic Pelagos Survey: microplastic and macroplastic sampling site in the Pelagos Sanctuary (north-western Mediterranean Sea); map produced using the open source software Google Earth version 7.1.5.1557.

Cetaceans sightings

Four different cetaceans species were identified during the sampling cruise (Bp=*Balaenoptera physalus,* Sc=*Stenella coeruleolba*, Tt=*Tursiops truncatus*, Gg=*Grampus griseus*) in the Pelagos

Sanctuary for a total of 14 sightings and 44 specimens. The respective sightings site and numbers of individuals (Bp=8, Sc=14, Tt=19, Gg=9) were reported in Fig 2 in SI.

The species of interest in the project was the largest filter feeders in the Mediterranean sea: the fin whale *(Balaenoptera physalus*). The *Balaenoptera physalus* habitat preference are mainly associated with pelagic areas in the Central and Western part of the Sanctuary at depths of 2000 m or higher (Azzellino et al., 2012; Notarbartolo-Di-Sciara et al., 2003; Panigada et al., 2008). This species is present in the Sanctuary throughout the year, but seem to be more abundant from May to October (Clark et al., 2002; Laran and Drouot-Dulau, 2007; Notarbartolo-Di-Sciara et al., 2003). His distribution in the western Ligurian Sea may change in response to climate variability and the SST features are a key factor for the habitat selection of fin whales (Azzellino et al., 2008), with the tendency to prefer colder waters (Sea Surface Temperature 21-24°C) (Panigada et al., 2008). Surface chlorophyll content, considered a good proxy for fin whales prey availability, seems to be another parameter affecting their distribution (Druon et al., 2012; Littaye et al., 2004; Panigada et al., 2008). In the Sanctuary area fin whales feed mainly on *Meganychtiphanes norvegica*, a small euphasiid found at great densities in association with areas of divergence of the Ligurian–Provencal front (Notarbartolo-Di-Sciara et al., 2003; Panigada et al., 2005).

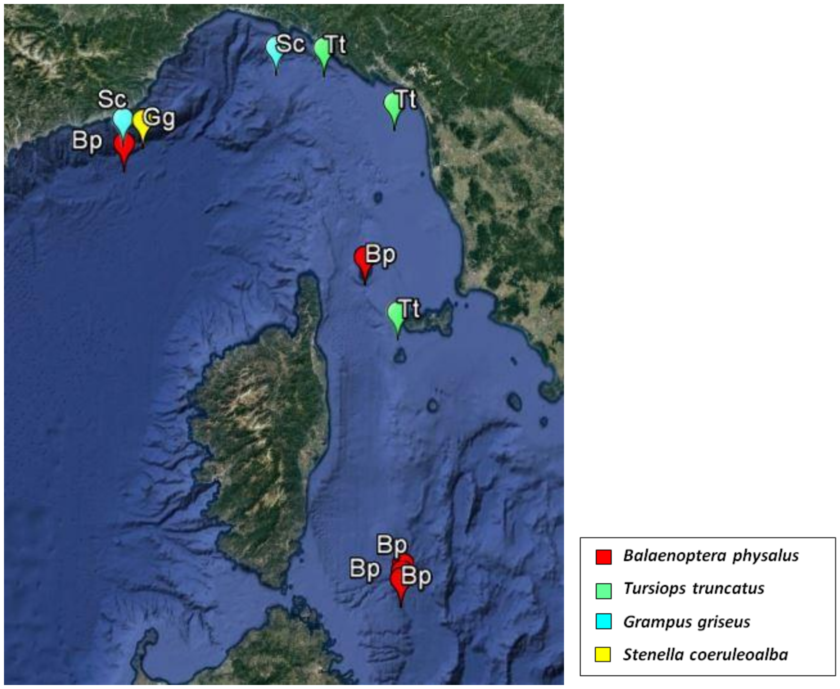

Figure 2 SM Sightings of cetaceans, in the Pelagos Sanctuary during the survey Plastic Pelagos (Bp=*Balaenoptera physalus,* Sc=*Stenella coeruleolba*, Tt=*Tursiops truncatus*,Gg=*Grampus griseus*); map produced using the open source software Google Earth version 7.1.5.1557 (https://www.google.com/earth/) .

Satellite data

The chosen satellite data for this work are sea level anomaly (SLA), absolute dynamic topography (ADT), sea surface temperature (SST) and chlorophyll a. We selected weekly updated delayed maps of sea level anomaly (SLA), which result from an offline elaboration of the tracks of all the available satellite sensors: two of them until 1999 and at least three in the following 11 years, with a peak of four between October 2002 and September 2005. The Ssalto/Duacs altimeter products were produced and distributed by the Copernicus Marine and Environment Monitoring Service (CMEMS) (http://www.marine.copernicus.eu). These data have a horizontal resolution of

1/8°, comparable to the typical Rossby radius of deformation (10–15 km for the Mediterranean Sea). SLA—the time varying signal extracted from the satellite measurements— is not always sufficient to draw a correct picture of the main flow patterns. Sometimes, structures appearing in the SLA maps cannot be univocally associated with specific circulation features, and to remove the ambiguity it is necessary to know information on the height change associated with the mean circulation present in the area, the so-called mean dynamic topography (MDT). Adding the MDT to the SLA yields the absolute dynamic topography (ADT), maps (Iacono et al., 2013). Seasonal variability of the Tyrrhenian Sea surface geostrophic circulation as assessed by altimeter data. The altimeter products were produced by Ssalto/Duacs and distributed by Aviso with support from CNES (http://www.aviso.altimetry.fr/duacs/). ADT are multi-mission surface heights above geoid, *along-track* or gridded (1/8°x1/8°) with a reference calculatedover a twenty-year period. Daily maps were extracted.

As for SST, this study was conducted using the Copernicus Marine Service Products: Copernicus (http://marine.copernicus.eu/) sea surface temperature nominal operational product for the Mediterranean Sea, daily gap-free maps (L4) at 1 km horizontal resolution.

For the Mediterranean Sea- The CNR MED Sea Surface Temperature provides daily gap-free maps (L4) at 0.0625deg. x 0.0625deg. horizontal resolution over the Mediterranean Sea. The data are obtained from infra-red measurements collected by satellite radiometers and statistical interpolation(Buongiorno Nardelli et al., 2013). Both AVISO SLA and Copernicus SST were acquired for August and September 2014. Chlorophyll-a concentration data are 8 day composites centered on the day of interest. Satellite-derived chlorophyll a concentrations (Chl *a*) were estimated using the OC5 algorithm, an empirical ocean color algorithm provided by IFREMER

(Gohin et al., 2002) which aims at correcting CHl-a values from the overestimation effect generated by particulate inorganic matter.The OC5 algorithm was initially developed in the Bay of Biscay and the English Channel oceanic and coastal areas. This algorithm, which was recently updated by data from the French Mediterranean area, presents intrinsic robustness for both oceanic and coastal waters when compared with other regional and global algorithms used in offshore waters of the Ligurian and North Tyrrhenian sea (Lapucci et al., 2012) and also in other seas such as the Bay of Bengal (India) (Tilstone et al., 2011). All the MODIS-AquaLevel-2 files that contain all or part of the study area in August and September 2014 were acquired from the online OBPG (Ocean Biology Processing Group http://oceancolor.gsfc.nasa.gov/cms/) Data Processing System. This data have a spatial resolution of about 1 km^2 at nadir and were corrected from the atmospheric effects. All the SLA, ADT, SST and Chl *a* data that contain the study area were also acquired for August and September 2014.

Details on modelling marine litter abundance

To obtain the best available estimate of ocean surface currents is necessary to determine the spatial distribution of floating debris. The reduction of the spatial and temporal scale of interest is particularly challenging for numerical models as many factors are involved in the dynamical processes at mesoscale and notably when strong interactions with the coastline and bathymetry occur, as in the north western Mediterranean area.

In the absence of assimilation of observations, the outputs of ocean hydrodynamic models suffers from high uncertainty. It is thus quite difficult to represent accurately mesoscale features, to reasonably determine the intensity, position and extension of real currents and also to identify a possible time lag between the structures represented by models and reality. These model uncertainties have different origins and magnitudes, e.g. errors in the ocean density estimation or in the atmospheric forcing, nonlinear dynamical effects affecting forecast to several days, numerical representation problems due to the multi-scale and nonlinear nature of oceanographic processes.

In order to reduce such uncertainties, operational hydrodynamic modelling are based on data assimilation concepts developed by the several oceanographic centers simultaneusly. When used to process hind cast data, these procedures are aimed to give the best possible estimate of oceanographic covariates (e.g. currents, temperature and salinity) by combining model results and observed data (in-situ and satellite data) through specific assimilation techniques. The hydrodynamic analysis of reference used for the purpose of this study in the Mediterranean Sea was extracted from the COPERNICUS Marine Environment Monitoring Service (CMEMS). The horizontal resolution of the products currently provided in the Mediterranean is 1/16˚ (ca. 6-7 km). The hydrodynamic reanalysis is supplied by the NEMO model and the system uses a variational data assimilation based on a 3DVARscheme (Adani et al., 2011).

The quality of these products was widely documented over the years with substantial improvements of the representation of the mesoscale currents. Residual bias however affects this data as resulting from the characteristics of the models themselves (i.e. the physical representation of some processes) as well as from the lack of relevant observation data.

Oceans are "chronically under sampled" and the assimilation process in the hydrodynamic models suffers from this lack of data even in the Mediterranean Area. Ocean dynamics is also affected by high density gradients determined by the concomitant presence of Atlantic and Mediterranean-origin waters. The North-Western Mediterranean is moreover characterized by a marked variability of the atmospheric circulation, such as of the wind Mistral episodes in the Gulf of Lions, the prevailing southern winds (SE and SW), and the cyclogenesis phenomena in the Ligurian Sea.

Because the present work required having a accurate circulation estimates at a regional level, we used an "eddy resolving" high resolution ocean model to improve the circulation in the North-Western Mediterranean Sea: the regional hydrodynamic circulation model Tyrreno ROMS, which is operational at LaMMA (http://www.lamma.rete.toscana.it/en/currents-lamma-roms-model) for ocean forecast. Such regional model is an implementation of ROMS (Shchepetkin and McWilliams, 2005)in an area which includes the Tyrrhenian sea, the Ligurian sea, and the western portion of the Mediterranean Sea with a western boundary at the east of Toulon. It has a horizontal resolution of 2 km and a vertical discretization of 30 sigma-levels. The bathymetry was extracted from the EMODNET dataset. It has a resolution of 500 m. The model is configured with a third-order upstream horizontal advection where the horizontal mixing parameters, similarly to other regional high resolution models, are intentionally taken as zero, since an internal numerical diffusivity of the advection scheme can hide that due to the horizontal turbulence. The closure scheme is the General Length Scale turbulence closure. Air-sea interactions are imposed using fluxes derived from an implementation of the WRF-ARW model over the central Mediterranean area at 3 km resolution, which is implemented at LaMMA. ECMWF analysis data were used as initial and boundary conditions for air-sea forcing. Turbulent fluxes on the ocean/atmosphere interface were estimated using bulk flux formulation (Fairall et al., 1996). Turbulent momentum, heat and mass exchange processes were realistically reproduced in the model taking into account latent/sensible heat fluxes, radiative heat flux (including the effect of cloud cover), evaporation and precipitation.

Boundary and initial conditions for the regional hydrodynamic model were taken from the Mediterranean Forecasting System (MFS) model at 6-7 km resolution available derived by CMEMS.

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