SEDIMENT TRAPS: A TOOL FOR MONITORING THE PELAGIC ENVIRONMENT

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Sediment traps

Sediment traps are made of an open funnel and a set of collecting vials, which are alternated under the funnel lower opening by a stepping motor (Fig. 1). They are fixed along a mooring line anchored to the bottom, so as to passively collect the material sinking through the water column (Fig. 2). This material, composed mainly by biogenic and lithogenic particles, constitutes the so-called biogeochemical flux.

Potential of sediment trap study

- Sediment traps located at shallow depth (300-500 m). Depending on the sampling interval (which is set prior to deployment), they can allow detection of significant events such as massive dust deposition, phytoplankton blooms or sporadic occurrence of some phytoplankton species. As regards the biogenic component, shallow water sediment traps record the export production, i.e. that part of primary production that escapes the photic zone. This signal is directly linked to the productivity in the photic zone, so that it can give information on seasonal variations in primary production and phytoplankton assemblage composition and dynamics, in relation to measured oceanographic parameters.

- Sediment traps located at depth collect the fluxes resulting from sinking through different mechanisms, and affected by modifications which occur during their transport through the water column, with potential loss due to degradation/dissolution or lateral currents, and potential input again due to lateral currents. Therefore, although the sampling interval is nominally the same as for the trap deployed at shallow depth, the time scale can be thought as mediated over a longer time period (weeks-month), depending on particle sinking speed.

- Comparison between surface and deep sediment trap fluxes allows to observe the extent of modification in particle flux, due to the mechanisms above, to infer these dismentation mechanisms (i.e. free particle sinking vs. particle aggregation) and, by detecting significant peaks, to estimate the particle sinking speed.

Fig. 1 Sediment trap recovering in the Ionian Sea, eastern Mediterranean.

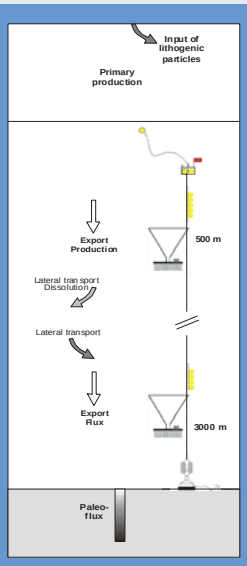


Fig. 2 scheme of sediment trap deployment

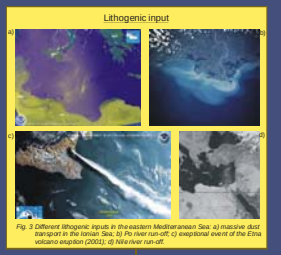
- Long time series of sediment traps allow to observe interannual variations of biogenic fluxes, which can be linked to surface oceanographic conditions: sediment traps are therefore an important tool to monitor the short-scale biological response to changing oceanographic conditions.

- Finally, sediment traps provide average annual fluxes, which represent the response of the pelagic environment to present-day climatic and oceanographic conditions, and can be used to interpret past records from paleofluxes, as recorded in bottom sediments (monitoring of long term oceanographic changes).

Problems

Although their great potential in oceanographic studies, sediment traps are affected by limitations. It is in fact often observed that sediment traps have low trapping efficiency, resulting in sensible underestimation of the actual fluxes. This can be due to various possible mechanisms, related to the pattern of flux itself (e.g. strong lateral currents) or to biases of the method itself (e.g. sticking of the particles on the trap cone). The actual flux can however be recalculated by estimating the trapping efficiency through radiogenic analyses (^{230}Th flux).

Biogeochemical fluxes in the Ionian Sea



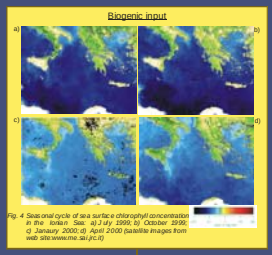


Fig. 3 Different lithogenic inputs in the eastern Mediterranean Sea: a) massive dust transport in the Ionian Sea; b) Po river run-off; c) exeptional event of the Etna volcano eruption (2001); d) Nile river run-off.

Fig. 4 Seasonal cycle of sea surface chlorophyll concentration in the Ionian Sea: a) July 1998; b) October 1998; c) January 2000; d) April 2000 (satellite images from web site www.rsc.jrc.it)

The Ionian Sea is an oligotrophic sea, characterised by a generally low primary productivity. The phytoplankton community is mainly represented by coccolithophorids, nanoflagellates and naked dinoflagellates. Diatoms and silicoflagellates secondarily contribute to present-day primary production. Several studies revealed that in recent years the whole eastern Mediterranean experienced severe changes in its circulation pattern. Such changes, involving both surface and deep water masses, have a potential strong impact on the primary production regime, as they modify the nutrient distribution in the water column, and were shown to be particularly important in the Ionian Sea.

Here we present sediment trap data on the biogeochemical flux registered in the Ionian Sea region during 1999/2000 (Anoxic Basins Area, West of Crete). Results of analysed samples from two sediment traps located at different depths (500m and 2800m) are reported. Particular emphasis will be devoted to biogenic carbonate and silicious contribution to the total biogeochemical flux (see the lower part). Additional information on total radiolarian and pollen grains interannual flux variations will be also provided.

The main contribution to the flux in the pelagic eastern Mediterranean is given by lithogenic and biogenic particles, which are alternatively important in driving the downward flux.
The lithogenic component is mainly due to the eolic input, deriving from episodic dust pulses from the North Africa (Fig. 3a). Other important lithogenic contribution results from the river run-off which directly flows into the basin. An example from Po and Nile rivers delta is represented in Figs. 3b and 3d. Finally, extraordinary events related to volcanic eruptions can transport finer volcaniclastic products into the basin (Fig 3c).
The biogenic component is mainly constituted by carbonate, which is derived from coccoliths - the skeletal remains of coccolithophorids, with a minor contribution from siliceous phyto- and zooplankton constituents. The resulting export fluxes change accordingly and can be monitored through sediment traps.

Total mass flux

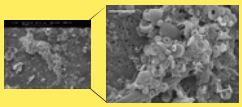


Fig. 5 Sinking aggregate containing several biogenic particles

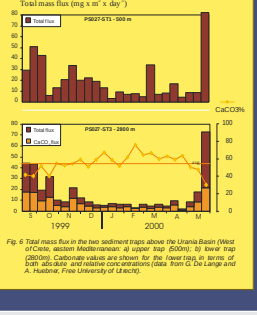


Fig. 6 Total mass flux in the two sediment traps above the Urania Basin (West of Crete, eastern Mediterranean: a) upper trap (500m); b) lower trap (2800m). Carbonate values are shown for the lower trap, in terms of both absolute and relative concentrations (data from G. De Lange and A. Huebner, Free University of Utrecht).

Phytoplankton productivity follows seasonal variations, as shown by satellite images of sea surface chlorophyll concentrations (Fig.4), with changes in the overall total production and in assemblage composition: interannual variations can also be observed, due to changing oceanographic conditions. The resulting export fluxes change accordingly and can be monitored through sediment traps.

Here we present an example of total mass flux in the Ionian basin from the two studied sediment traps (Fig.6).
The **total mass flux** is in the same range for both traps, even through the upper trap displays at times slightly higher values. The flux pattern is much more complicated in the upper trap, with peaks during September-October, November-December, March and the highest peak in May-June, while the lower trap displays a more regular pattern, with values decreasing gradually from September to December and increasing again starting from May. It appears therefore that the flux recorded in the lower trap is more smoothed, cutting out the short-scale variations / the mesoscale events but displaying the main overall seasonal fluctuations.
Comparison with **previous records** can be done only for the Bannock Basin area, where a complete series is available from late 1991 to middle 1994 (Rutten et al., 2000). Also here, the total mass flux appears to be highly seasonal, (0.28 to 446 mg x m^{-2} x day^{-1}). Maximum peaks occur in April and June-July '92, April-June '93, June-August '94, while small maxima are present between November '93 and April '94.
Therefore large variations are present not only on a seasonal scale, but also from year to year, both in the flux entity and in the timing of the maxima.
The **carbonate composition** of the sediments recovered in the traps displays strong variations (data from PS027-ST3 show a mean value of 85.1 %, ranging from 40 % to 67 %, with a minimum peak of 29 % in the last sample, due to a large input of dust particles), reflecting the variable contribution from biogenic and lithogenic particles.

Carbonate fluxes

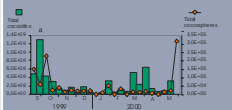
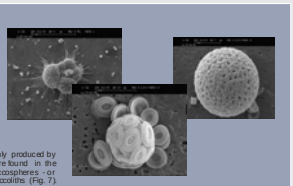


Fig. 7 Coccolith and coccosphere flux in the two traps: a) 500m; b) 2800m.



Biogenic carbonate is mainly produced by coccolithophorids which are found in the traps as intact shells - coccospheres - or as separated platelets - coccoliths (Fig. 7). Their flux displays a well defined seasonal pattern, in both studied traps, with a decreasing trend from late summer to winter and a sudden increase in spring. Coccospheres and coccoliths show a similar pattern, possibly indicating a common sinking mechanism.

Minor amounts of biogenic carbonate are due to calcareous dinoflagellates, which apparently display the same seasonal trend in export production and flux. They are present as both intact shells and fragments, as shown in Fig. 8. The higher amounts of fragments recovered in the lower trap may be due to lateral transport or to slower sinking of older material.

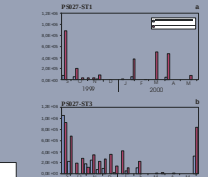


Fig. 8 Flux of calcareous dinoflagellates and related fragments in the two traps: a) 500m; b) 2800m.

Both the coccolith and coccosphere flux assemblage is dominated by *E. huxleyi*, which is the most abundant species throughout the year; the second most abundant species is then *F. profunda*: its fluxes reach maximum values during September-October, decrease during fall and remain low in winter, with a small increase in March-April. Many other major and minor species are present, showing a similar seasonal pattern, with the highest fluxes during early fall and generally low fluxes during winter. However, the assemblage composition shows a clear seasonal pattern, when looking at the relative abundance of all species (fig. 9), in particular from the upper trap:
a) late summer-fall: high relative abundance *F. profunda* and of the other deep species, high relative abundance of the other minor species;
b) Fall-winter-begin of spring: lower values of *F. profunda* and of all other species, clear dominance of *E. huxleyi* (excluding the exceptionally high relative abundance of reworked species in one sample);
c) Spring: high relative abundance of *E. huxleyi*, low *F. profunda* (14 to 25 %) slight increase of minor species.

The lower trap display a similar pattern, but its record is more smoothed, possibly due to the longer sinking period, with consequent homogenisation of the seasonal signal.

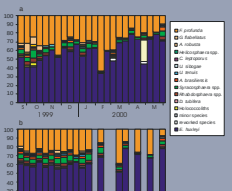
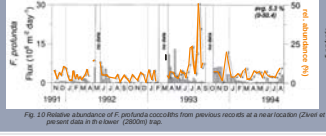


Fig. 9 Relative abundance of major and minor coccolith species in the two traps: a) 500m; b) 2800m.

Finally, comparison with previous coccolith records at a near location showed a similar seasonal pattern for all species. However, a significant difference is observed in the relative abundance of *F. profunda* coccoliths.
F. profunda is long known to be a key species to investigate the dynamics of the deep photic zone, as its relative abundance with respect to the other coccolithophorid species is strictly related to the depth of the nutricline: high nutrient concentrations in the deep photic zone induce the development of a Deep Chlorophyll Maximum (DCM), to which *F. profunda* significantly contributes.
Its high relative abundance, which is a well defined pattern in our data (Fig. 10), but also appears sporadically at the end of the previous record, could represent the biological response to the recent circulation changes observed in the Ionian Sea.



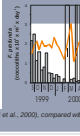


Fig. 10 Relative abundance of F. profunda coccoliths from previous records at a near location (Ziveri et al., 2000), compared with the present data in th e lower (2800m) trap.

Siliceous fluxes

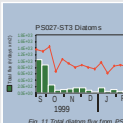
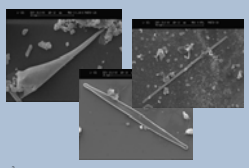


Fig. 11 Total diatom flux from PS027-ST3 trap at 2800 water depth (green) and specific diversity (red).

Biogenic silica present in the water column is mainly constituted by diatom, silicoflagellate and radiolarian skeletons. Here we present data from a sediment trap (PS027-ST3) located at 2800m water depth, collected during 1999-2000. Particular attention will be devoted to diatoms interannual flux and additional results on silicoflagellates, radiolarians and pollen grains pattern will be shown. In spite of the eastern Mediterranean oligotrophic regime, diatoms can be found in the traps, although not so abundant as coccolithoforids. In particular, they can be present as intact shells (frustules) or disarticulated (epivalves and ipovalves), if girdle bands separate during frustules sinking. This trap diatom assemblage shows a very high specific diversity (a total of 156 different taxa observed) with a continuos record all through the study period but sample from 14 to 23 May 2000, when diatoms weren't observed. The total diatom flux displays a well defined seasonal modulated pattern with major concentrations in late summer-fall and late spring periods (Fig. 11). From an ecological point of view the total diatom assemblage is mostly constituted by tropical-subtropical pelagic species, even if a clear occurrence of brackish to fresh-water species (i.e., *Amphora* sp., *Aulacoseira* sp., *Cyclotella* sp., *Diatomella* sp., *Eunotia* sp., *Luticola* sp., *Rhopalodia* sp., *Staurosirella* sp., *Stephanodiscus* sp. and *Surirella* sp.) is also detected during spring time (Figs. 12 and 13). This signal could be possibly linked to the major saharian-dust input registered in the same period. Another interesting feature is represented by the occasional occurrence of some subpolar-polar species (*Fragilariopsis kerguelensis* and *Thalassiosira lentiginosa*) during late winter and spring seasons. This presence could be possibly related to some changes in the oceanographic setting of the basin resulting from the inflow of Atlantic waters (Fig. 14).



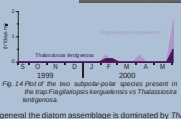


Fig. 14 Plot of the two subpolar-polar species present in the trap:Fragilariopsis kerguelensis vs Thalassiosira lentiginosa.

In general the diatom assemblage is dominated by *Thalassionema bacillare* (max value 811.387 valves/days m2) and *Nitzschia interruptestriata* (max value 215.875 valves/days m2), two species present all through the study period and reaching maximum values during September-October 1999 and May 2000 (Fig. 15).

Fig. 15 Thalassionema bacillare plotted against Nitzschia interruptestriata.

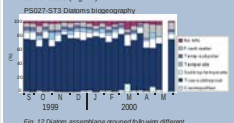


Fig. 12 Diatom assemblage grouped following different species tolerance to temperature.

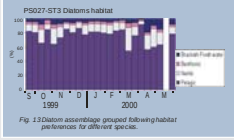


Fig. 13 Diatom assemblage grouped following habitat preferences for different species.

Alveus marinus, *Asterolampra marylandica*, *Pseudonitzschia seriata* var. *obtusa* and *Thalassionema nitzschioides* group strongly contribute to the total diatom association with maximum concentrations ranging from 41 to 58 valves/days m2. All these species well tolerate the oligotrophic regime which characterises the basin for the most part of the year.

In particular some diatom species display a strictly seasonal-related occurrence as summarised below.
A) late summer-fall: *Amphora* cf. *costata*, *Asteromphalus arachne*, *A. heptactis*, *Bacteriastrum hyalinum*, *Biremis* sp., *Calonеis* sp., *Campylonеis* sp., *Chaetoceros* sp., *Cocconeis britannica*, *C. pseudomarginata*, *Coscinodiscus* sp., *Diploneis* sp., *Hemiaulus hauckii*, *Mastogloia* sp., *Nitzschia bicapitata*, *N. sicula*, *Planktoniella sol*, *Psammodyction panduliforme*, *Rhizosolenia* sp., *Stellarima stellaris*, *Thalassionema frauenfeldii*, *Thalassiosira angulata*, *T.fereilineata* and *T. leptopus*;
C) winter: *Amphora commutata*, *A. holsatica*, *Bacteriastrum furcatum* and *Coconeis placentula*;
D) spring: *Actinoptychus* sp., *Amphora* sp., *Bacillaria paxillifera*, *Bacteriastrum delicatulum*, *B. elongatum*, *Climacosphenia* sp., *Cyclotella* sp., *Diatomella* sp., *Luticola* sp., *Proboscia alata*, *Stephanodiscus astrea*, *Thalassiosira* sp. and *Thalassothrix* sp..

Among other biogenic siliceous components here are shown seasonal trends of total silicoflagellate and radiolarian assemblages (Figs. 16 and 17). Even if less abundant with respect to diatoms, they apparently display the same seasonal pattern. In particular their strong increase in concentration coincides with late summer and spring periods, with the highest values reached in coincidence of the major saharian-dust input registered during May. Finally, additional information are also provided for pollen grains (Fig. 18). Again, their interannual flux seems to be easily correlable with the other studied proxies.

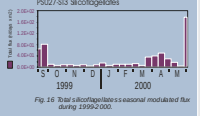


Fig. 16 Total silicoflagellates seasonal modulated flux during 1999-2000.

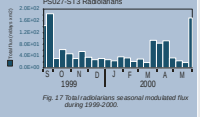


Fig. 17 Total radiolarians seasonal modulated flux during 1999-2000.

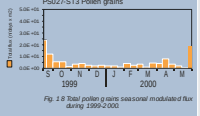


Fig. 18 Total pollen grains seasonal modulated flux during 1999-2000

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Ziveri P., Rutten A., De Lange G. J., Thomson J. and Corselli C. (2000). *Present-day coccolith fluxes recorded in central eastern Mediterranean sediment traps and surface sediments.* Palaeoceanogr. Palaeoclimatol. Palaeoecol., 158, 175-195.