Short-term dynamics of vertical flux of biogenic matter during upwelling and relaxation on and off the Iberian shelf, north-west Spain

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Work Package I "**Temporal evolution of surface production and fate of organic matter**"

Mainly responsible for:

I.5 Suspended matter, aggregation potential, faecal pellet production and vertical flux

Objectives:
(a) Estimate the short-term vertical flux of organic matter and phytoplankton during the Lagrangian experiments and compare these with the suspended standing stock of organic matter and phytoplankton.
(b) Describe and quantify the spatial and temporal distribution of the zooplankton faecal pellets production with the goal to determine their role in material cycling. Evaluate the role of zooplankton grazing and flux mediation (coprophagy etc.). These are to be interpreted in terms of the influence of zooplankton communities on horizontal and vertical fluxes of material.
(c) Estimate the amount of transparent exopolymeric particles (TEP) in the water column and the sediment traps; compare TEP concentrations with diatom distribution and vertical flux of phytoplankton cells and POC.
(d) To evaluate the role of the short-time phytoplankton species succession and the corresponding suspended organic matter concentrations on primary production and on vertical flux of carbon
(e) Validate the physical and biological model of the Iberian margin on the basis of available and new data of nutrients, phyto- and zooplankton and vertical flux of organic matter.

Introduction
The physical environment determines nutrient availability, influences the aggregation of sticky particles and hence the particles potentially available for sedimentation. Thus there is a strong impact of "bottom-up" regulation of vertical flux. However, there is also an obvious, but in marine ecosystems so far less considered, "top-down" regulation. For example, top-down regulation is reflected in the relationship between phyto- and zooplankton. This relationship governs vertical flux seasonally and zooplankters with different life cycles and feeding strategies further modify the principle patterns of export production.

Also the role of different zooplankton functional groups to promote (*e.g.*, grazing and production of large faecal pellets) or remove sinking matter (*e.g.*, grazing on aggregates and processes such as coprophagy) influence the export and retention efficiency of various pelagic ecosystems. Zooplankton can thus remove biomass which otherwise would sink or contribute with exported biomass (*e.g.*, faecal pellets and repackaging) which other wise would be recycled. Obviously, studies of export of phytoplankton and biogenic matter should be accompanied by work focusing on the role of the zooplankton community on retention and export.

Diatoms are known to aggregate and sink rapidly out of the euphotic zone. During periods of upwelling aggregation of diatoms, in addition to zooplankton grazing is supposed to be the most important mechanism regulating the vertical export of organic matter from the upper layers. Thus, we expected a dominance of ungrazed phytoplankton cell export, in particular diatoms, in concert with a limited number of faecal pellets.

Material and methods

WP1 Task I.5 a. Vertical export of pigments, particulate organic carbon and nitrogen (POC, PON), pico-, nano- and microplankton carbon (PNMC) and faecal pellet carbon (FPC) was studied during upwelling and relaxation on the shelf (*CD114* leg *a*) and off the shelf (*CD114* leg *b*) during short term exposure (24 hours) of drifting sediment traps. On *CD114* leg *a* vertical export was measured at 3 depths in the upper layer (30, 40 and 50 m) while during *CD114* leg *b* sediment traps were exposed at 8 depths (30, 40, 50, 60, 90, 120, 150 and 200 m). POC/PON was analysed with a CHN analyser. The abundance of all recognisable pico-, nano- and microplankton was estimated. PPC was calculated from the biovolume of pico-, nano- and microplankton applying volume:carbon conversion factors. Similarly the abundance of various categories of faecal pellets was estimated and their biovolume and the FPC were calculated.

WP1 Task I.5 b. The suspended biovolume of various categories faecal pellets (FP) was estimated at 3-8 depths on both legs. The FP production rate for the larger and dominating mesozooplankton species was quantified in specific defecation chambers on *CD114* Leg *b*.

WP1 Task I.5 c. Transparent Exopolymer Particles (TEP) in the water column and the sediment traps were quantified on both *CD114* leg *a* and *b*. A study of the composition, size and configuration of sedimented aggregates inside sediment traps by exposure of acrylamid dishes was not carried out due to the limited number of berths on board of *CD114*.

Results

WP1 Task I.5 a. Vertical POC export was moderately high and ranged between 140 - 260 and 60 - 230 mg C m^{-2} d^{-1} on and off the shelf, respectively (Fig. 1). These rates are similar to vertical export estimates from boreal shelves. There was a general decline of POC export with depth, reflecting the mineralisation of biogenic matter, in particular below the upper layers. The POC/PON ratios (a:a) were on average around 8 and ranged between 6-9, indicating that vertical export is derived from reasonably fresh and marine sources and not particularly influenced by resuspension.

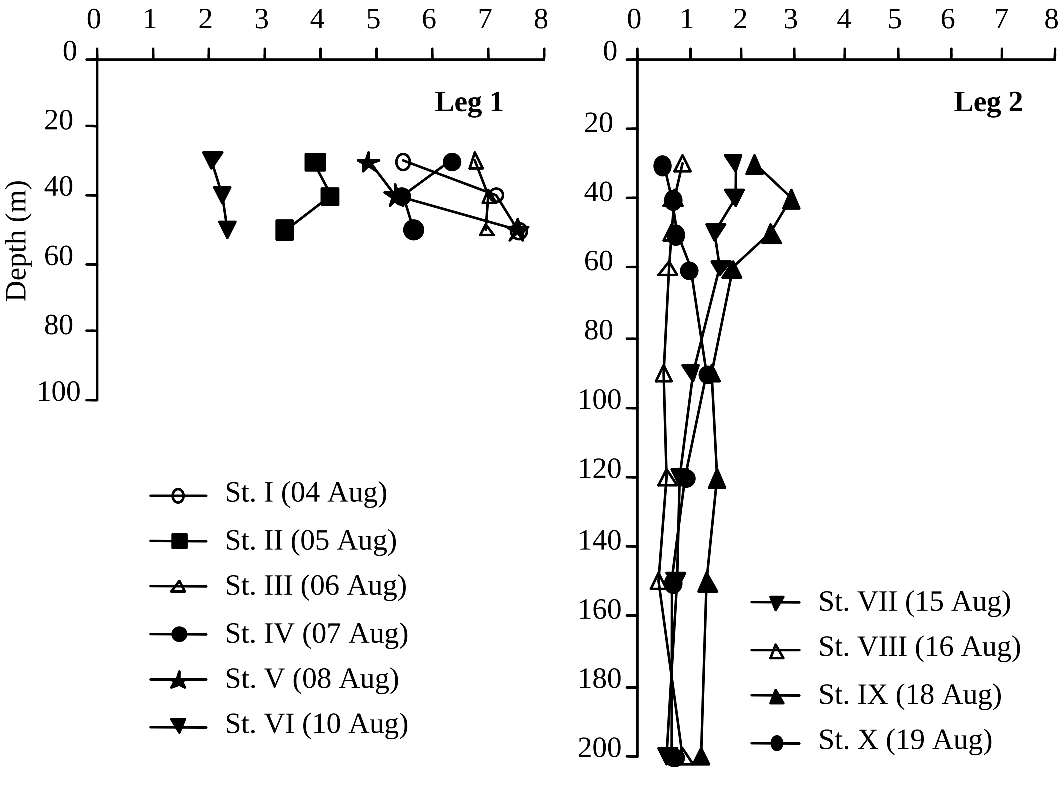

Fig. 1. Vertical flux of POC at various stations of *CD114* leg *a* and *CD114* leg *b* (mg m^{-2} d^{-1}).

The vertical export of chlorophyll a equivalents was significant during both legs, but lower on *CD114* leg *b* (Fig. 2). The export of chlorophyll a on the shelf was about 1 mg m^{-2} d^{-1}), but an order of magnitude lower off-shelf. However, the vertical export of phaeopigments and chlorophyll equivalents was in the same order of magnitude in both areas, indicating that degradation of phytoplankton off the shelf is considerable.

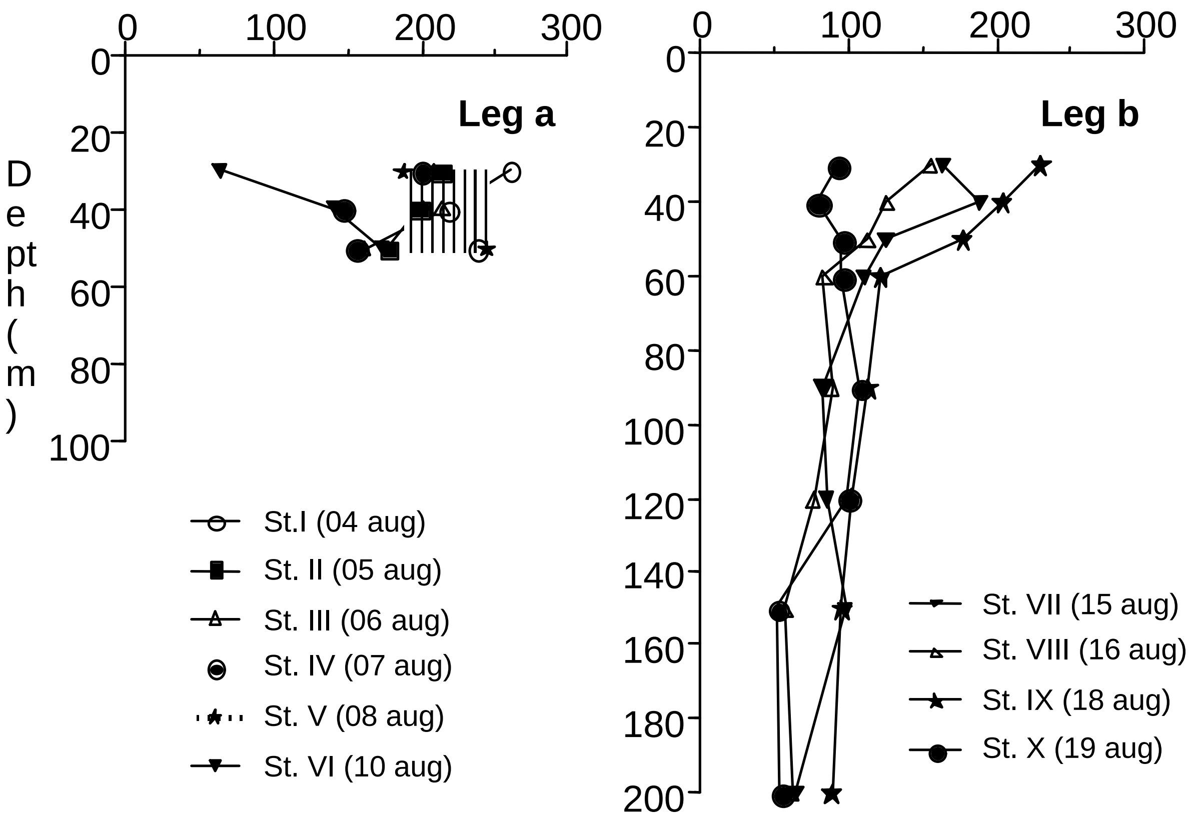

Fig. 2. Vertical flux of Chl a equivalents at various stations of *CD114* leg *a* and *CD114* leg *b* (mg m^{-2} d^{-1}).

Vertical export of pico-, nano- and microplankton reflected similar differences between the on- and offshore region, *i.e.*, higher phytoplankton export on the shelf compared to off-shelf. Fig. 3 shows examples of PNMC export for August 4 and 5 on *CD114* leg *a* and August 18 and 19 on *CD114* leg *b*. Flagellates dominated among the exported PPC (55-90 % of POC export). Of less significance were diatoms and dinoflagellates.

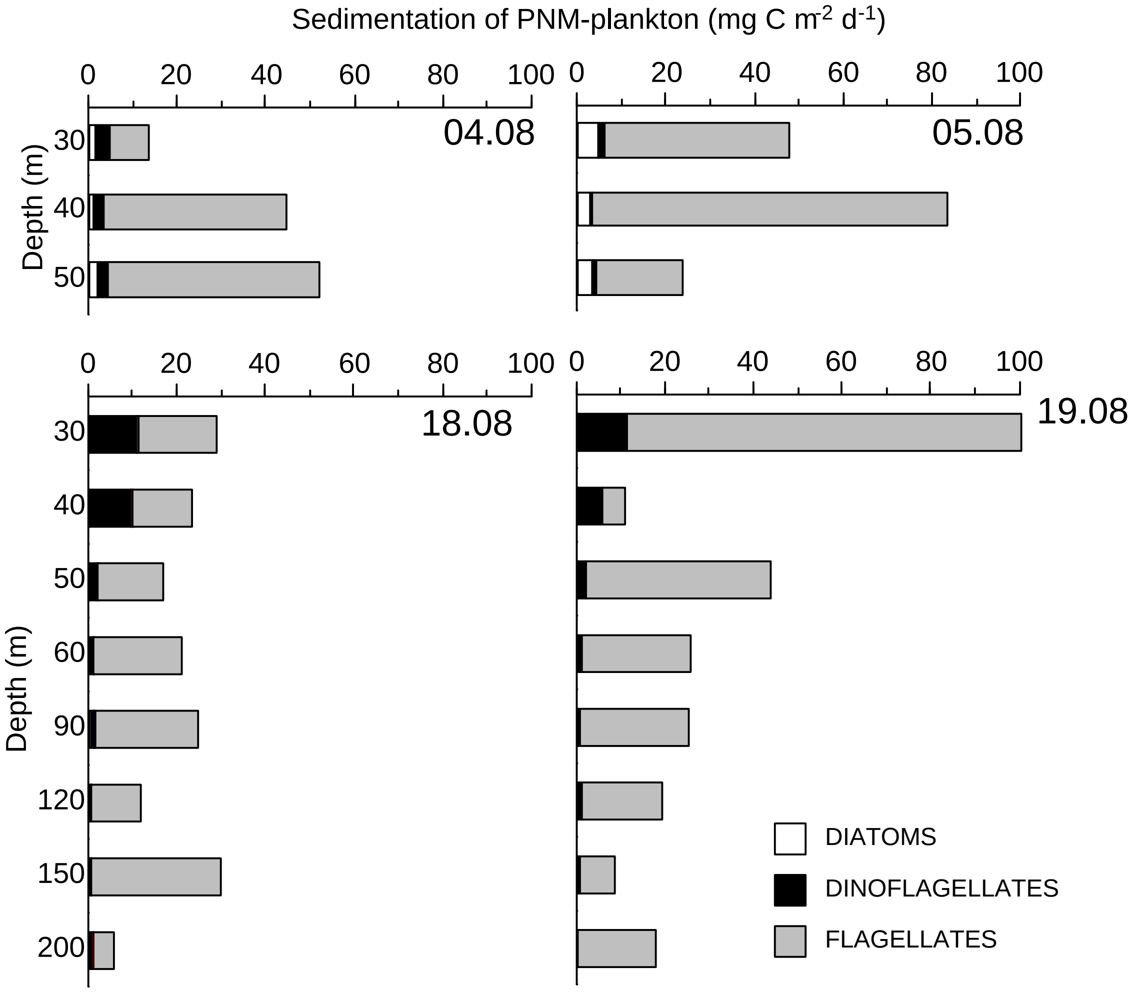

Fig. 3. Vertical flux of PNMC of diatoms, dinoflagellates and flagellates at the stations 4/8 and 5/8 on *CD114* leg *a* and 18/8 and 19/8 on *CD114* leg *b* (mg m^{-2} d^{-1}).

Cylindrical faecal pellets with a diameter between 40 and 100 µm, produced by reasonably small copepods and krill, contributed the most to the vertical export of faecal pellets, but there was much less export of faecal pellets off-shore compared to on-shore. Fig. 4 shows examples of FPC export for August 4 and 5 on *CD114* leg *a* and August 18 and 19 on *CD114* leg *b*. Obviously, coprophagy and related processes were of great significance off the shelf. Please observe that the FPC flux on *CD114* leg *b* is an order of magnitude smaller compared to that on *CD114* leg *a* (Fig. 4)

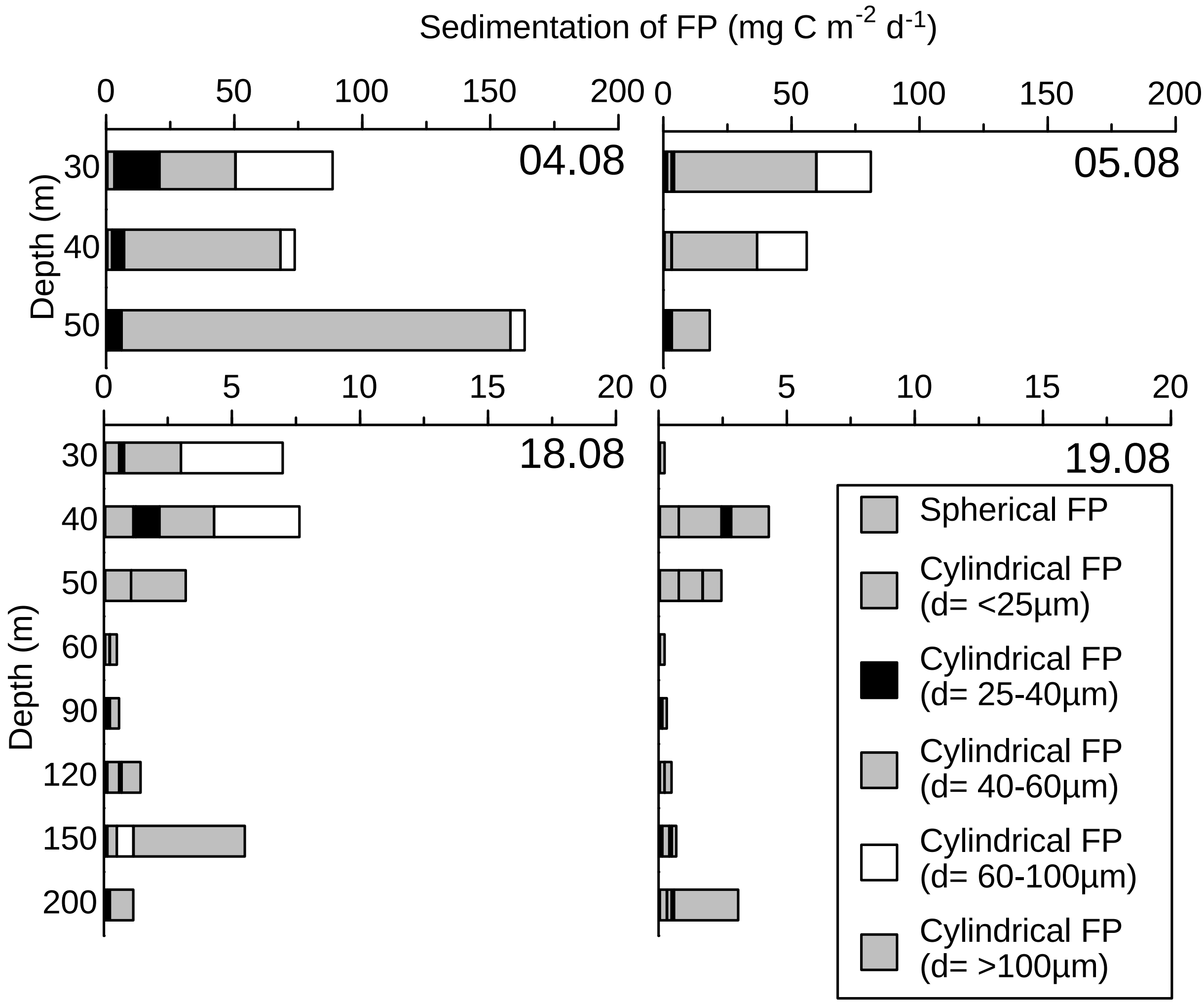

Fig. 4. Vertical flux of different fractions of FPC at the stations 4/8 and 5/8 on *CD114* leg *a* and 18/8 and 19/8 on *CD114* leg *b* (mg m^{-2} d^{-1}). Please observe the differences in scales.

WP1 Task I.5 b. The suspended biovolume of various categories faecal pellets (FP) varied greatly between *CD114* Leg *a* and *CD114* Leg *b*. The FPC concentration on *CD114* leg *b* was far smaller compared to *CD114* leg *a*. This does first of all not reflect lack of producers, but is interpreted as a results of increased coprophagy etc. off the shelf. Most of the samples from the FP production experiments for the larger and dominating mesozooplankton species from *CD114* Leg *b* were quantified, but the rates are still not calculated. The rates will be available very soon.

The vertical loss rates of suspended FPC is difficult to estimate as there appears to exist a significant difference in suspended FPC during day and night (Fig. 5), implying greater grazing activity in surface water at night of species producing the largest cylindrical faecal pellets. The specific vertical sinking rates on both legs varied between 25 - 50 d^{-1}, which reflects the rather small size of copepods. Also, the appearance of large FP at night indicates that there are different in diurnal feeding. These large FP indicate that there are large zooplankton taxa, probably krill, off the shelf, which have not been quantified by applied sampling procedures.

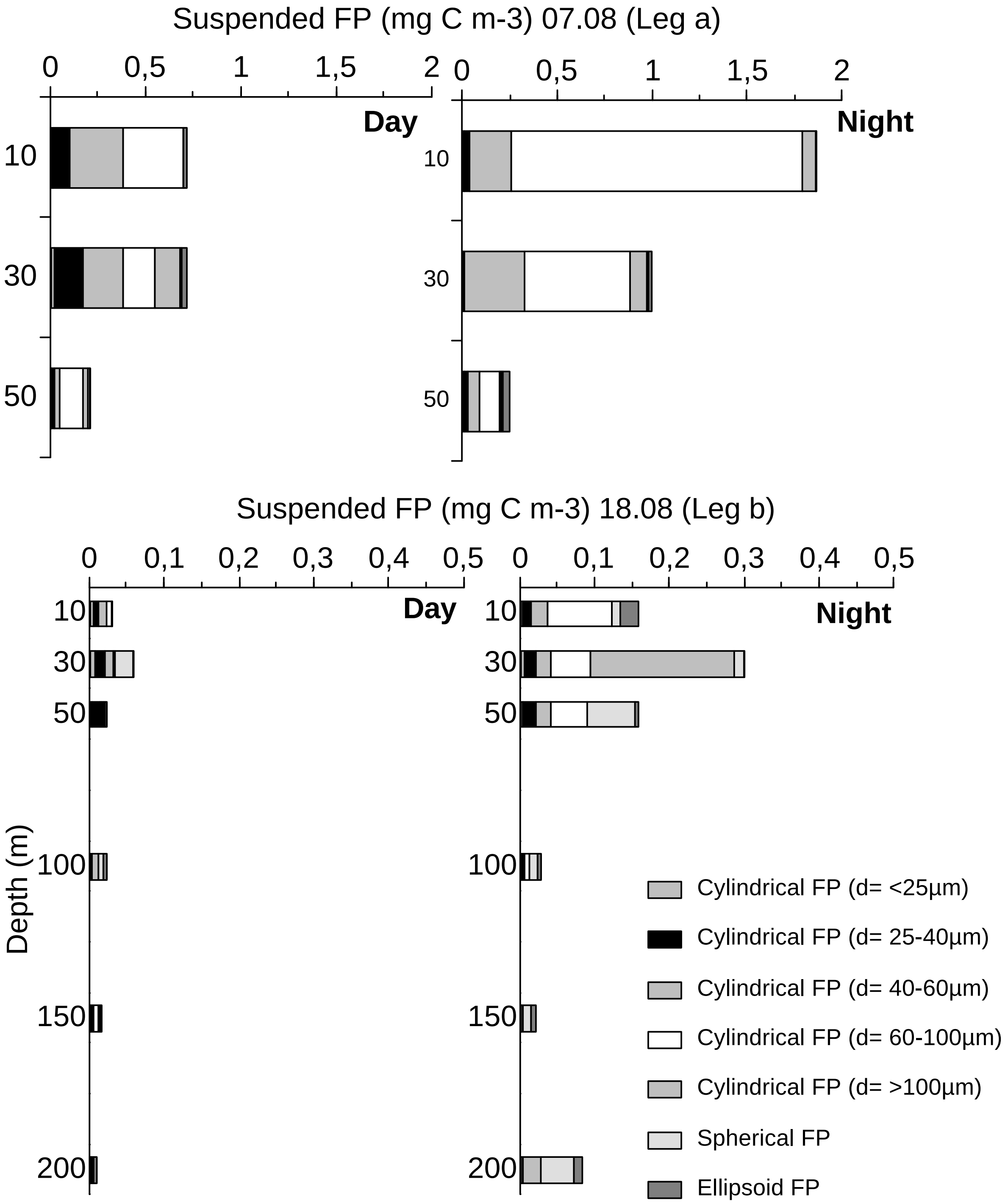

Fig. 5. Different size fractions of suspended FPC during day and night 07/8 on *CD114* leg *a* and 18/8 on *CD114* leg *b*.

WP1 Task I.5. (c).
TEP samples were analysed, but are not calculated and plotted as yet.

WP1 Task I.5 (a-c). Attempts were made to calculate the residence times and specific sinking rates of pigments, POC/PON, phytoplankton and FPC in the upper 60 or 100 m by comparing the standing stock and vertical export (combining tasks a and b). The vertical export of cells and detritus will be compared with TEP (combining task a with c). This work depends on the availability of all suspended data and will be continued in the forthcoming period.

Conclusions

The export of biogenic matter during upwelling and relaxation is moderately high and more dominated by phytoplankton cells and faecal pellets on the shelf than off the shelf where detritus prevailed.

In contrast to our assumption diatoms do not represent a dominant part of the export of biogenic matter. Flagellates prevailed and they cannot have sedimented as single cells. Mechanisms for the vertical export of flagellates are not known, but they could represent a part of the microbial community colonising detrital aggregates (Fig. 6).

Faecal pellets channel a substantial portion of the available biomass into vertical export, but zooplankton mediate fluxes such as coprophagy etc. minimise vertical loss rates, in particular off the shelf. The detrital fraction was higher off the shelf compared to on-shelf (Fig. 6) and reflects most probably increased coprorhexy.

The diurnal differences in FP distribution in the water column indicate higher grazing activity at night. The zooplankton size classes which produce these FP are different from those quantified by netting techniques.

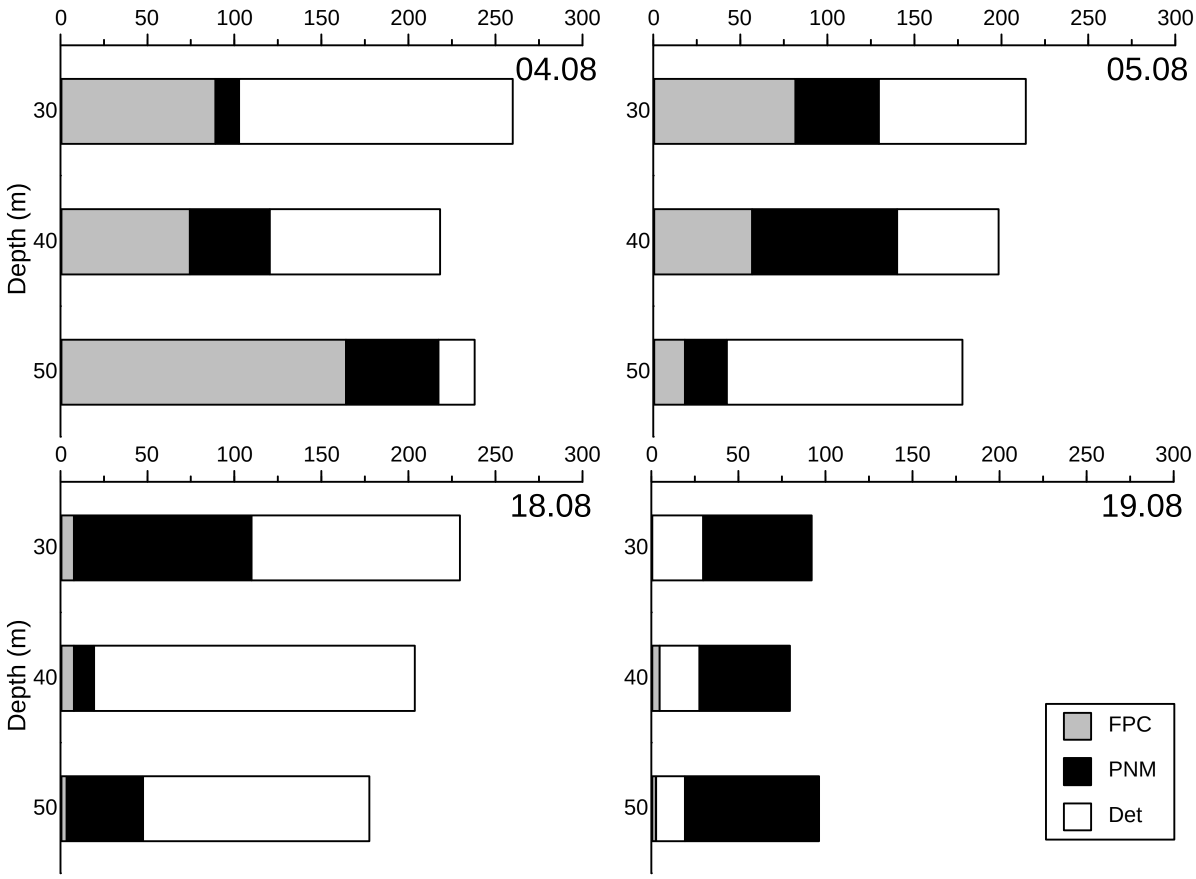

Fig. 6. A summary of the vertical export of POC (entire bar), FPC, PNMC and detritus (Det = POC - (PNMC + FPC)) in the upper 50 m of stations 4/8 and 5/8 on *CD114* leg *a* and stations 18/8 and 19/8 on *CD114* leg *b*.