Analysis of biological properties on the continental shelf off the north NSW coast

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Abstract

Key words: Coral Sea, East Australian Current, phytoplankton, zooplankton, biomass size spectra, isotopic ratio

1 Introduction

The link between physical and biological processes in the world's oceans is well known (Denman and Gargett, 1995).

The has been visited on previous cruises (Roughan and Middleton, 2002, 2004).

2 Methods

2.1 Study site

The cruise took place at the beginning of the austral spring, in September 2004. At this time, the EAC had separated from the coast at approximately

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31^0S, and formed a large pool of water at 33^0S, 155^0E, creating a counter-clockwise rotating warm core eddy (Fig. 1).

2.2 Sampling strategy

Five sections were sampled along constant latitude transects roughly perpendicular to the north NSW coast over a 6 day period in September 2004 using a CTD and a towed device called the Bunyip (a highly modified SeaSoar). During the CTD transects, fluorescence, temperature, salinity and oxygen were electronically measured, and nutrients (NO_3, PO_4, Si) and bottle oxygen taken at the surface, and, total depth of water allowing, at depths of 25, 50, 75, 100, 150, 200, 250, 400 and 500 m. Filtered particulate matter samples were taken at the surface of each of the CTD stations. The Bunyip varied between the surface and 120 m, and sampled temperature, salinity, and, using an optical plankton counter, the size distribution of particulate matter. Further sampling during this period using towed plankton nets will be reported in later publications.

The shelf sampling was interupted on the 8-10th September to undertake a wake study around North Solitary Island ($29^0$55'S $153^0$23'E) which will be reported elsewhere. All times reported are local (Sydney) eastern Standard Time.

Diamond Head Section (31º45'S). The Bunyip undertook a transect between 1953-2201 on the 6th September in an easterly direction, followed by net tows in a westward direction. A CTD transect was then undertaken in a easterly direction on the 7th September from 0437-0838.

North Solitary Island Section (30º00'S). The Bunyip undertook a transect between 2134 on the 7th September and 0013 on the 8th in an easterly direction, followed by net tows in a westward direction. A CTD transect was then undertaken in a easterly direction on the 8th September from 1340 -2314.

Wooli Section (29º40'S). A CTD transect was undertaken in an eastward direction from 2003 on the 9th September to 0136 on the 10th and followed net tows. No Bunyip transect was attempted at this section.

Evans Head Section (29º00'S). A Bunyip transect was undertaken in an easterly direction from 1048-1243 on the 11th September. A CTD transect followed in an westward direction from 1317-2044 on the 11th September, and finally net tows.

Cape Byron Section (28º38'S). A Bunyip transect was undertaken in an easterly direction from 0805-1006 on the 12th September. No other sampling was

undertaken at Cape Byron.

2.3 Surface Particulate Organic Matter (POM)

Samples of particulate matter were taken to determine concentrations of particulate organic carbon (POC) and particulate organic nitrogen (PON), and the $\delta^{13}C_{POM}$ and $\delta^{15}N_{POM}$ isotopic signatures. Four litres of water were sampled from just below the surface using the CTD bottles and filtered on 47 mm diameter, 1.2 μm precombusted (450^0C for 1.5 h) glass fibre filters under low vacuum within 30 minutes of collection, frozen within a further 30 minutes, and kept frozen until analysis at the Griffith University, NSW, Australia.

2.4 Chlorophyll analysis

Water sampled for Chl *a* analysis was filtered through a 47 mm diameter, 1.2 μm glass fibre filter under low vacuum within 30 minutes of collection. Filters were then folded, blotted dry, wrapped in aluminium foil and stored at -20^0C until analysis. Chl *a* concentration was calculated using the method of Jeffery and Humphrey (1975). The calibration curve of the CTD fluorometers is shown in Fig. 2 of Baird et al. (in prep.), where Fl = 4.66 [Chl *a*] +52.66, r^2 = 0.73. Chl *a* is converted to phytoplankton biomass using 1 mmol N = 1.59 mg Chl *a* (Fasham et al., 1990).

2.5 Optical plankton counter

The optical plankton counter was mounted on the Bunyip, a CSIRO customised towed device. The optical plankton counter (OPC) is a Focal Technologies Corporation Model OPC-2T with a sampling aperture of 2 x 10 cm. The OPC records equivalent spherical diameters of particles that pass through the instrument in a 0.5 s interval. The particle sizes are recorded digitally into 4096 bins, corresponding within the operating range of the instrument to bins with a 5 and 15 μm width.

Particle volumes are converted to carbon content using 0.126 $\times 10^6$ g C cell^{-1} = 1 m^3 cell^{-1} (Hansen et al. (1997), Table 1), and to nitrogen content using the Redfield C:N ratio of 6.625 mol mol^{-1}. To convert from biomass in nitrogen (mmol N m^{-3}) to biovolume (m^3 m^{-3}) multiply by 5.26 $\times 10^{-5}$ m^3 mmol N^{-1}.

The calculations of the total biomass and the size distribution of biomass are based on a running average of the counts in a particular size-class over six

seconds. The volume of flow through the sample region is based on distance measured, average over a 6 s interval. The choice of time interval is a trade-off between a larger time period to obtain a higher particle count to accurately obtain the estimate of the size distribution, and a shorter time period to provide better spatial resolution. The spatial averaging is along the instrument trajectory. As the instrument moves vertically at approximately 1 m s^{-1}, a long period averaging most affects vertical resolution. A 6 s interval provides the best resolution of spatial distribution of size distribution of the Tasman Sea waters with a biomass of $\approx$ 1-10 mmol N m^{-3}. The biomass in the Coral Sea waters is so low that no sensible size-distribution data can be spatially-resolved. Instead, size-distribution is averaged for the all Coral Sea water in a particular transect.

Following Platt and Denman (1977), the normalised biomass, $\beta(w)$ is the total biomass $b(w)$ in the size-class characterised by weight w, divided by the width of the size-class Δw:

$$\beta(w) = \frac{b(w)}{\Delta w} \tag{1}$$

The slope of the NBSS is given by:

$$S = \overline{\left(\frac{\partial \ln \beta}{\partial \ln w}\right)} \tag{2}$$

where the bar represents a linear fit of the difference for sizes $\geq$ 420 μm. To calculate the NBSS, the raw binning by the instrument is further binned into sizes centred at equivalent spherical diameters of 106, 208, 312, 420, 531, 645, 761, 880, 1001, 1123, 1247, 1373, 1501, 1630, 1760, 1891, 2024, 2158, 2292, 2248, 2565, 2703, 2842, 2981, 3122, 3263 μm. The lowest three size ranges showed low values, and are probably below the detection limit of the instrument. Bins are included only up to, but not including, the first bin to record a zero count.

3 Results

3.1 Fluorescence, Oxygen and Nutrients

3.2 Particulate matter (PM)

3.3 Surface elemental and isotopic ratios

4 Discussion

References

Baird, M. E., Timko, P. G., Suthers, I. M., Middleton, J. H., Mullaney, T. J., in prep. Analysis of biological properties across the Tasman Front off south east Australia. Deep-Sea Res. .

Denman, K. L., Gargett, A. E., 1995. Biological-physical interactions in the upper ocean: the role of vertical and small-scale transport processes. Annu. Rev. Fluid Mech. 27, 225–255.

Fasham, M. J. R., Ducklow, H. W., McKelvie, S. M., 1990. A nitrogen-based model of plankton dynamics in the oceanic mixed layer. J. Mar. Res. 48, 591–639.

Hansen, P. J., Bjornsen, P. K., Hansen, B. W., 1997. Zooplankton grazing and growth: Scaling within the 2-2,000 μm body size range. Limnol. Oceanogr. 42, 687–704.

Jeffery, S. W., Humphrey, G. F., 1975. New spectrophotometric equations for determining chlorophylls a, b, c_1 and c_2 in higher plants, algae and natural phytoplankton. Biochem. Physiol. Pflanz. 167, 191194.

Platt, T., Denman, K., 1977. Organisation in the pelagic ecosystem. Helgoländer wiss. Meeresunters 30, 575–581.

Roughan, M., Middleton, J. H., 2002. A comparison of observed upwelling mechanisms off the east coast of Australia. Cont. Shelf Res. 22, 2551–2572.

Roughan, M., Middleton, J. H., 2004. On the East Australia Current: variability, encroachment, and upwelling. J. Geophys. Res. 109, C07003.

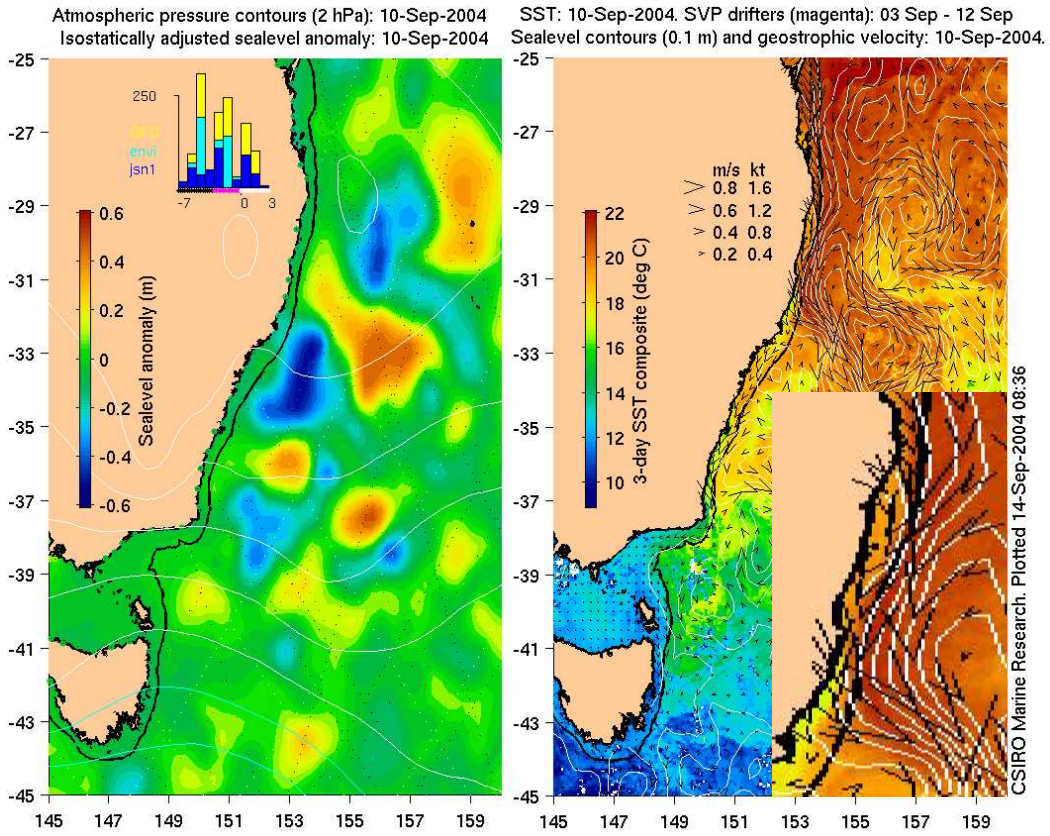

Fig. 1. Synoptic ocean properties on the 10th September 2004. *Left* - Sea level anomaly (surface colour) and atmospheric pressure (white contours). *Right* - Sea surface temperature (SST) averaged over a 9 day period (surface colour), geostrophic velocity (black arrows) and sea level contours (white contours). The locations of the Sections are shown in the bottom right of the right panel. Courtesy of David Griffin at CSIRO.

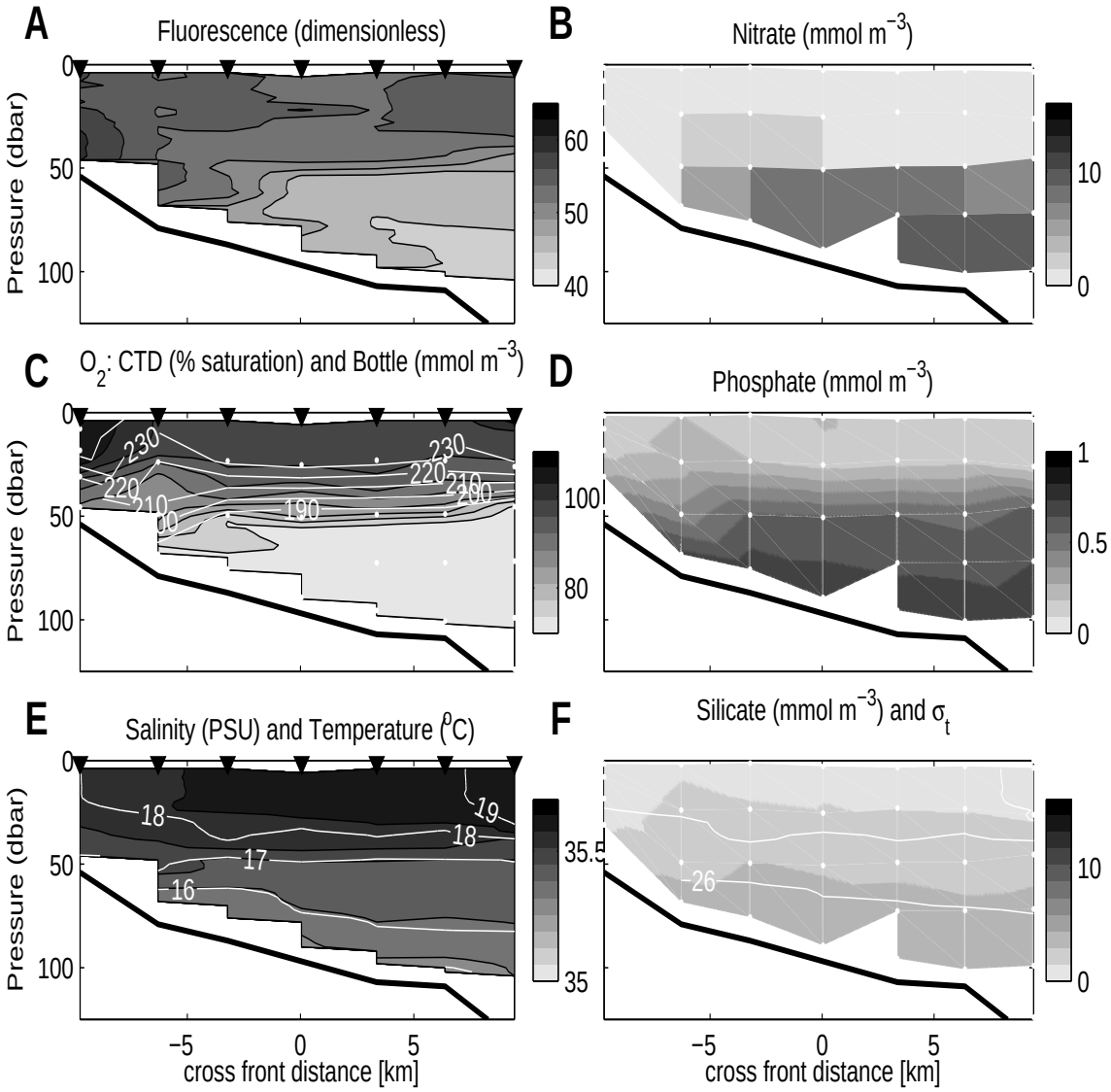

Fig. 2. CTD transect at Diamond Head (31^o45'S). Panels show (A) Fluorescence, (B) Nitrate, (C) Oxygen from the CTD (greyscale) and bottle oxygen (contours), (D) Phosphate, (E) Salinity (greyscale) and temperature (contours), (F) Silicate (greyscale) and σ_t (contours). Fluorescence and CTD oxygen are 2 m depth averages from a dropping CTD instrument. Black triangles indicate the locations in the along front direction of the CTD stations. The bottle oxygen, nitrate, phosphate and silicate are obtained from bottle samples from location indicated by a white dot. The transect was undertaken in an easterly direction from 0437-0838 on the 7th September eastern Standard Time.

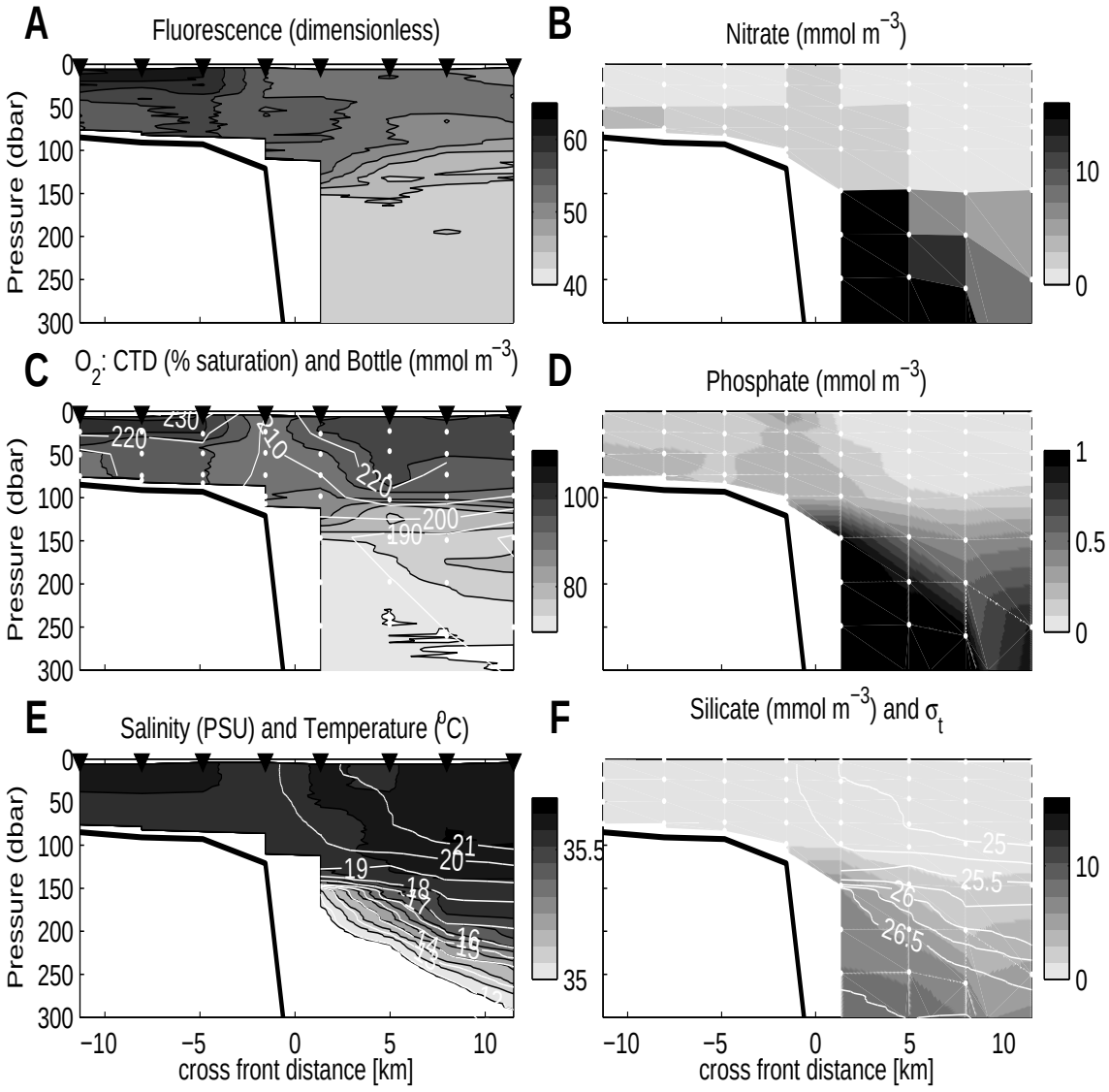

Fig. 3. CTD transect at North Solitary Island (30^{o}00'S). The transect was then undertaken in an easterly direction on the 8th September from 1340-2314. For further details see Fig. 2.

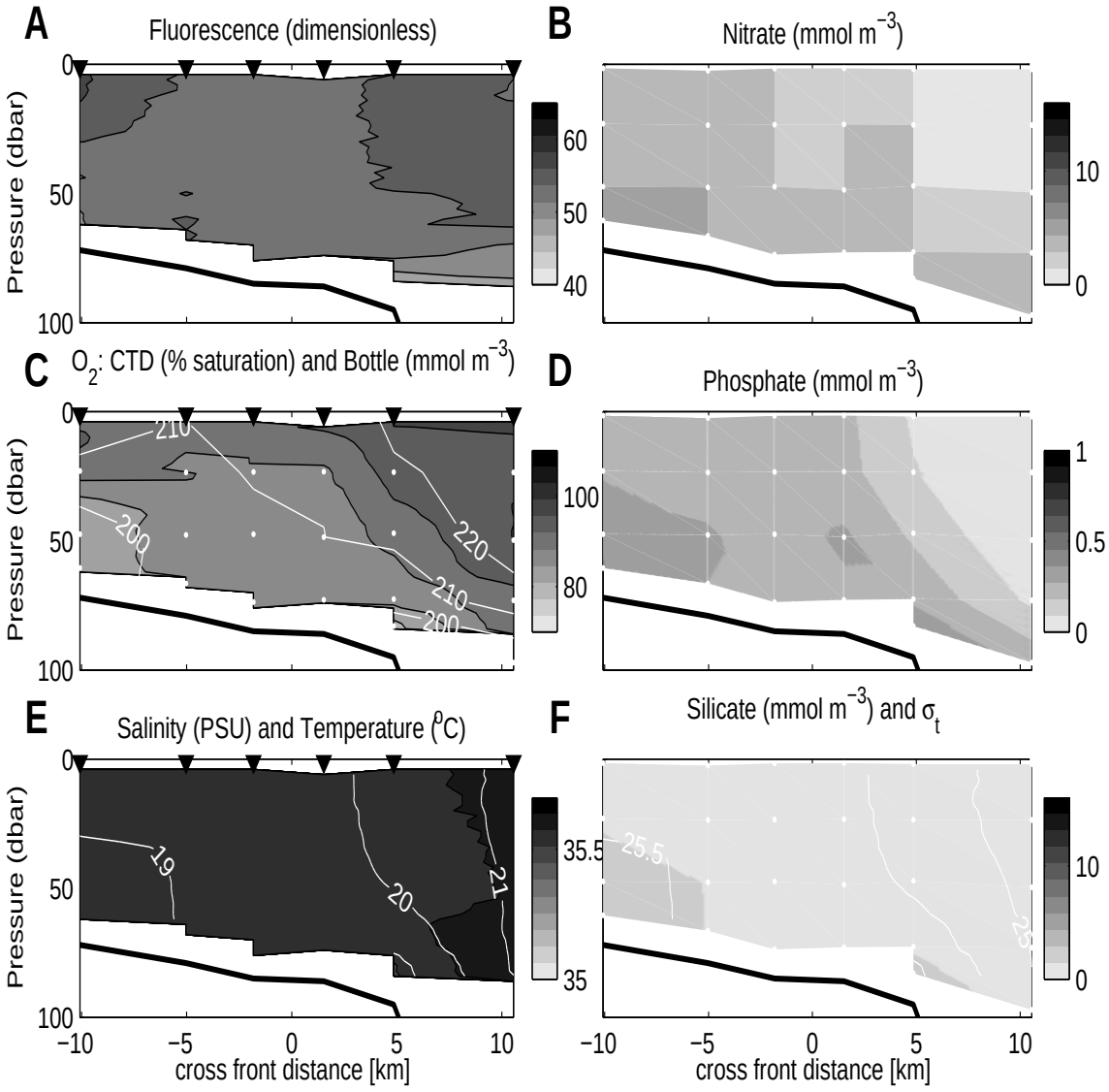

Fig. 4. CTD transect at Wooli (29^o40'S). The transect was then undertaken in an easterly direction from 2003 on the 9th September to 0136 on the 10th. For further details see Fig. 2.

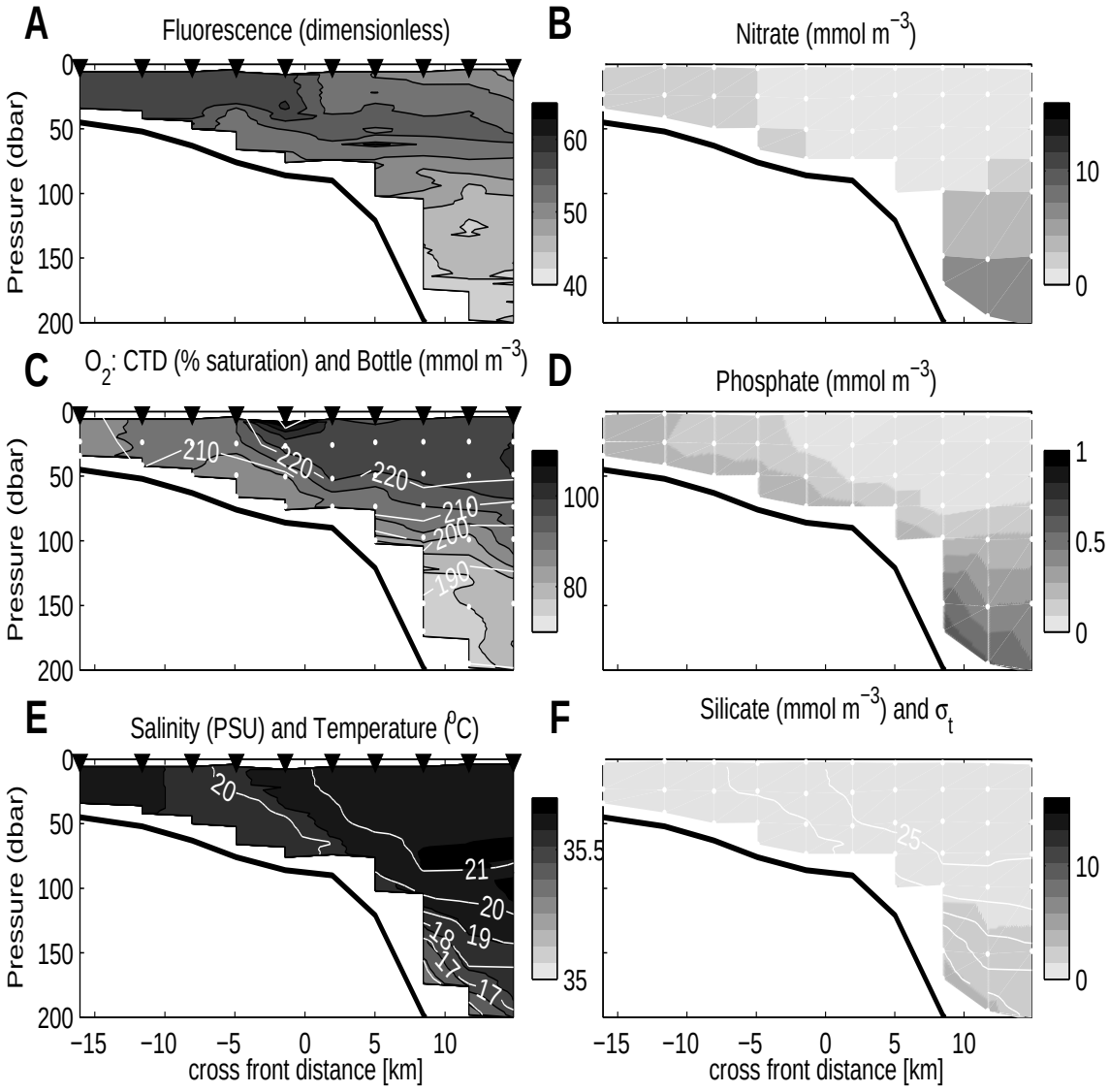

Fig. 5. CTD transect at Evans Head (29^{o}00'S). The transect was undertaken in an westward direction from 1317-2044 on the 11th September eastern Standard Time. For further details see Fig. 2.

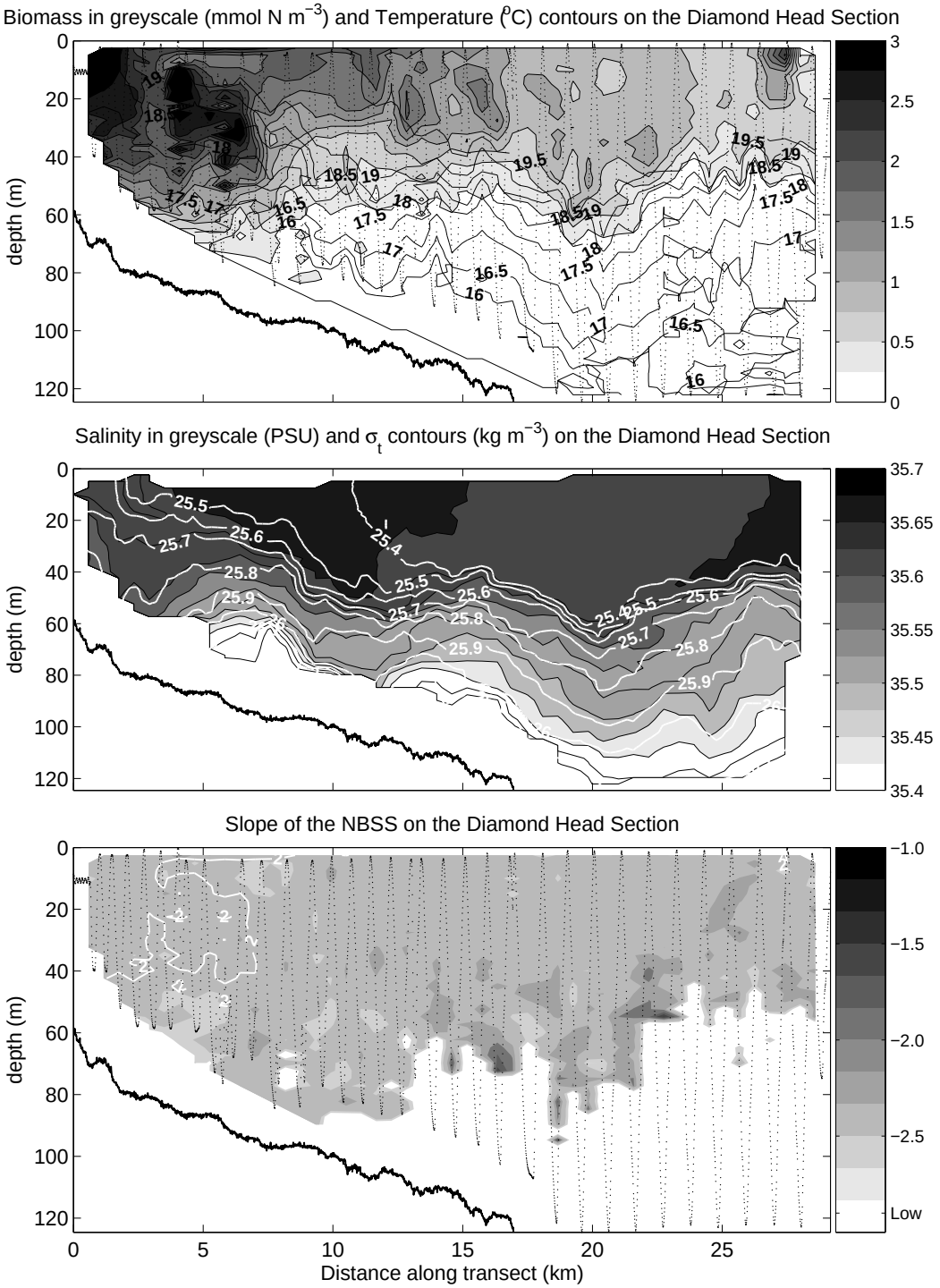

Fig. 6. Diamond Head Section (31^{o}45'S). The biomass of particular matter in greyscale with temperature contours (top) and the salinity in greyscale with potential density contours (centre) and the points at which measurements were averaged, and the slope of the normalised biomass size spectra (bottom). The small dotted black lines in the top panel shows the path of the Bunyip. The transect was undertaken in an easterly direction from 1953-2201 on the 6th September eastern Standard Time.

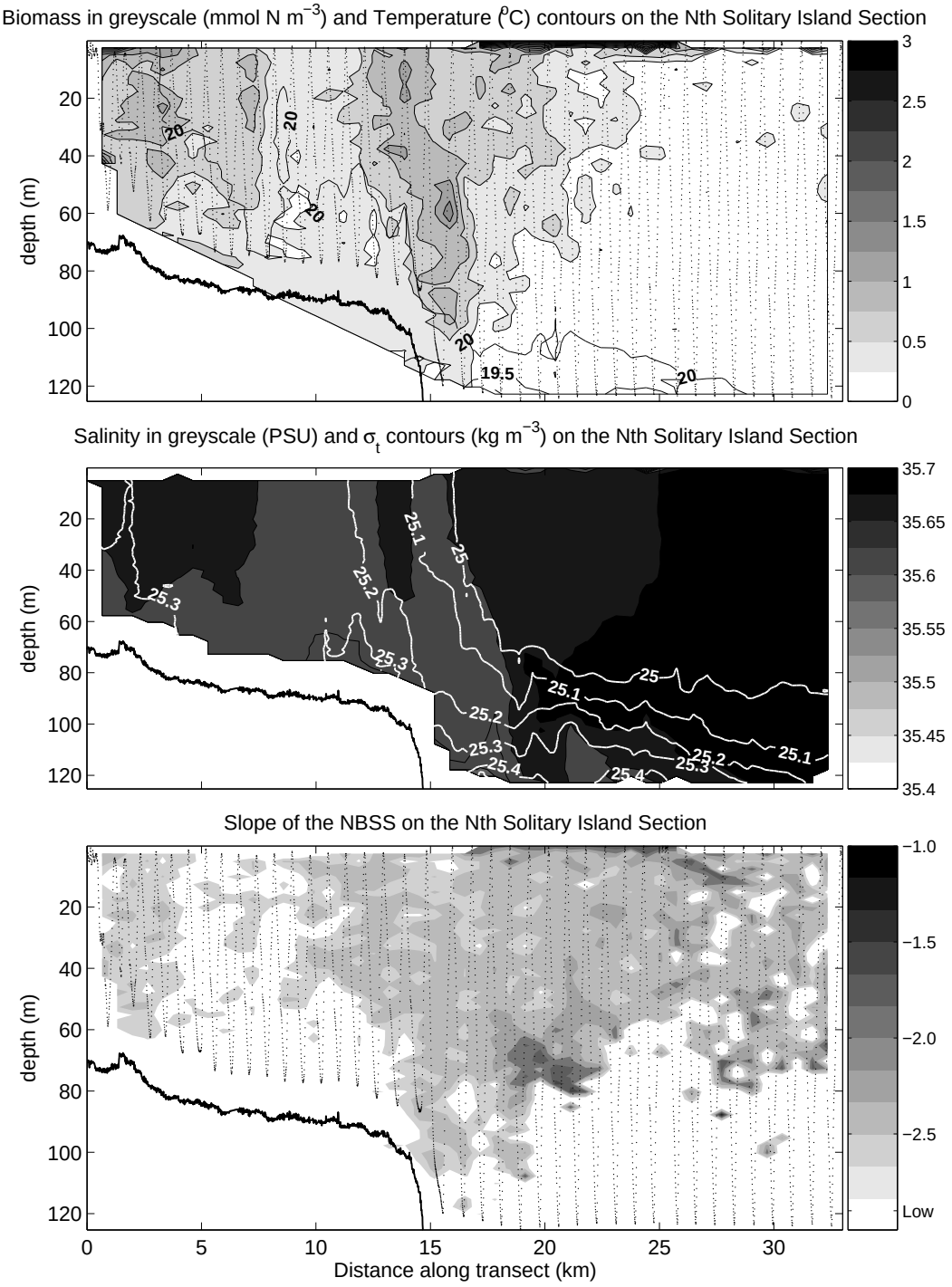

Fig. 7. North Solitary Island Section (30^{o}00'S). The transect was undertaken between 2134 on the 7th September and 0013 on the 8th in an easterly direction. See Fig. 6 for more details.

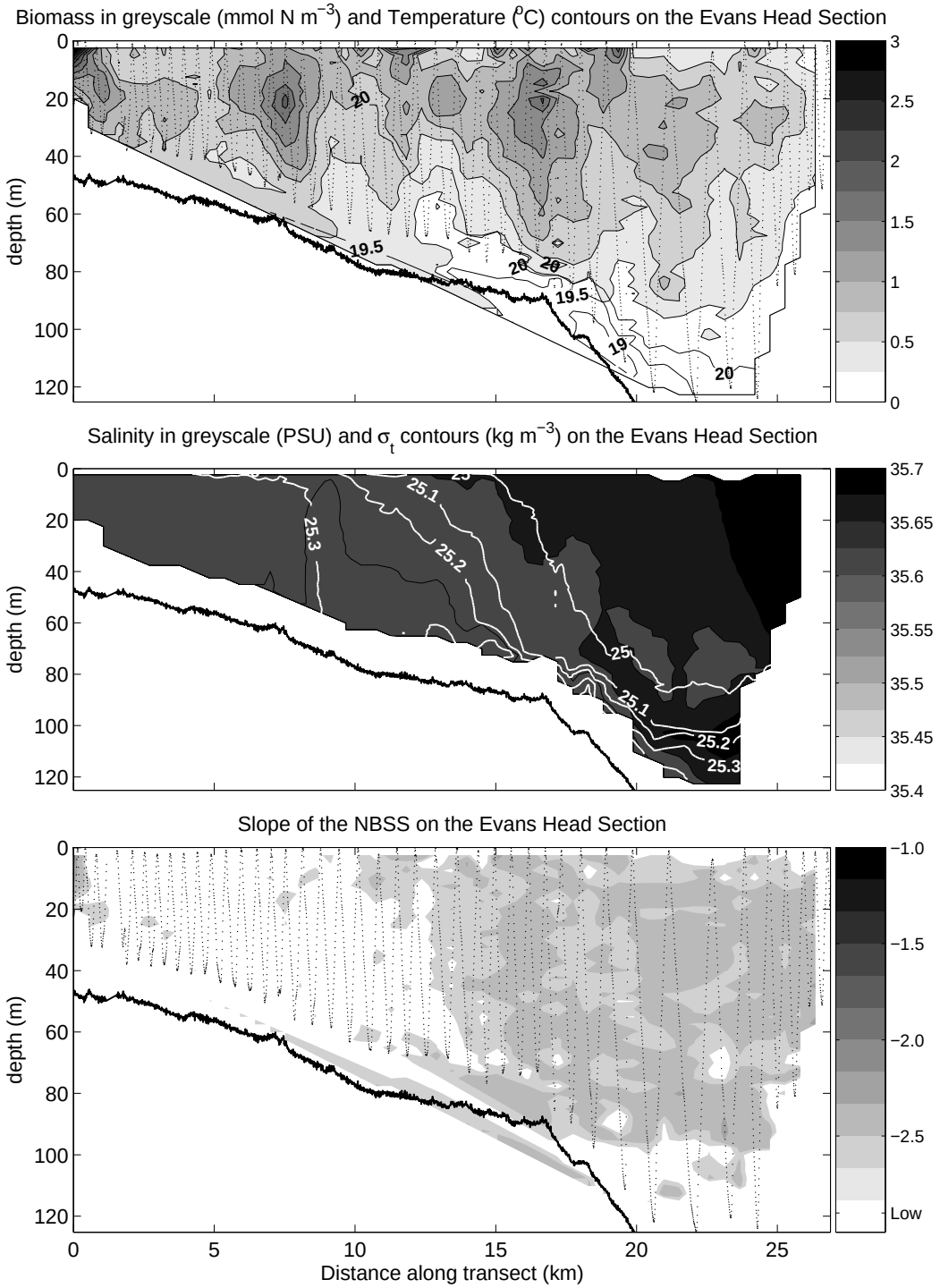

Fig. 8. The Evans Head Section (29^{o}00'S). The transect was undertaken in an easterly direction from 1048-1243 on the 11th September eastern Standard Time. See Fig. 6 for more details.

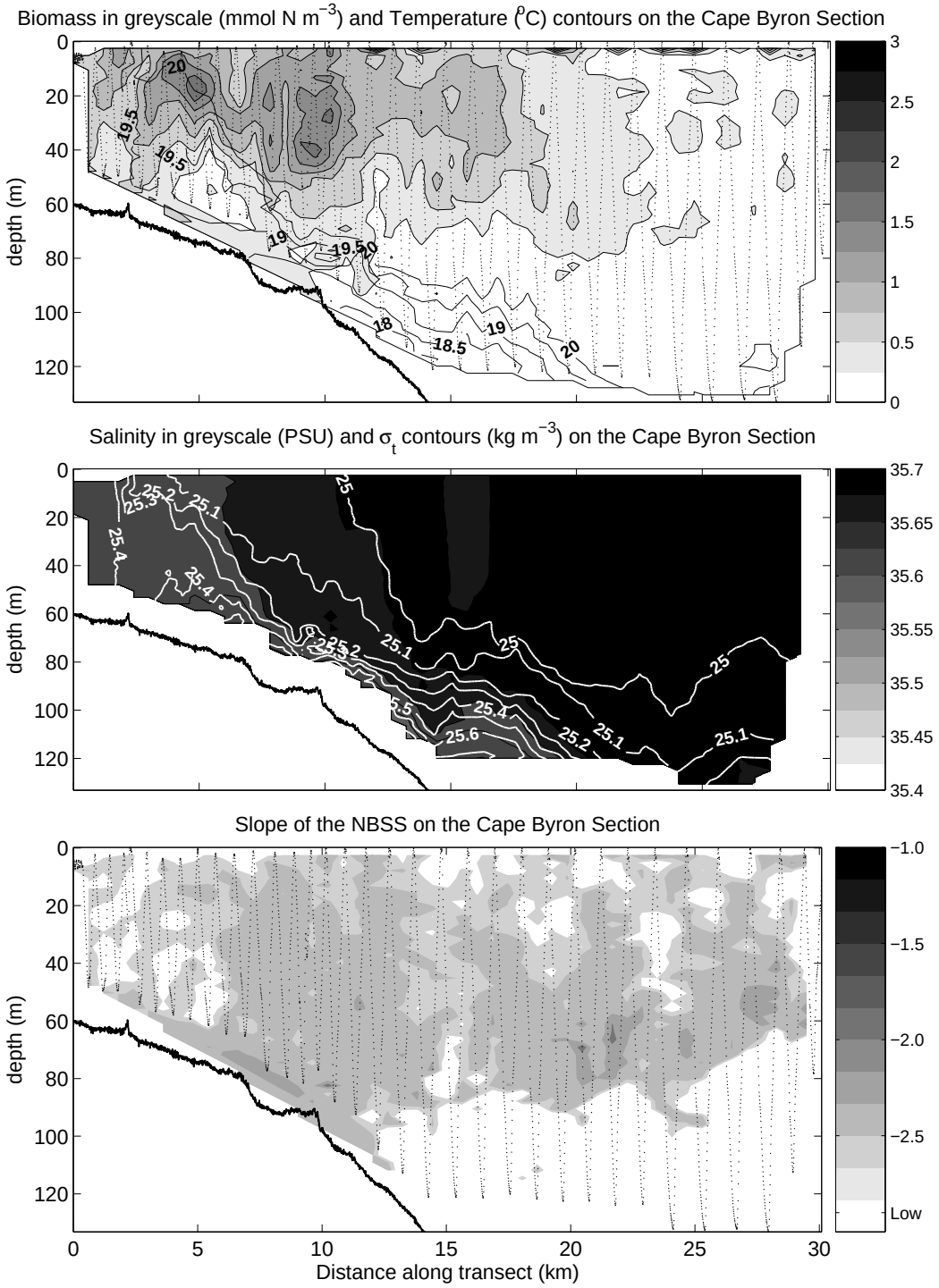

Fig. 9. The Cape Byron Section (28^{o}38'S). The transect was undertaken in an easterly direction from 0805-1006 on the 12th September. See Fig. 6 for more details.

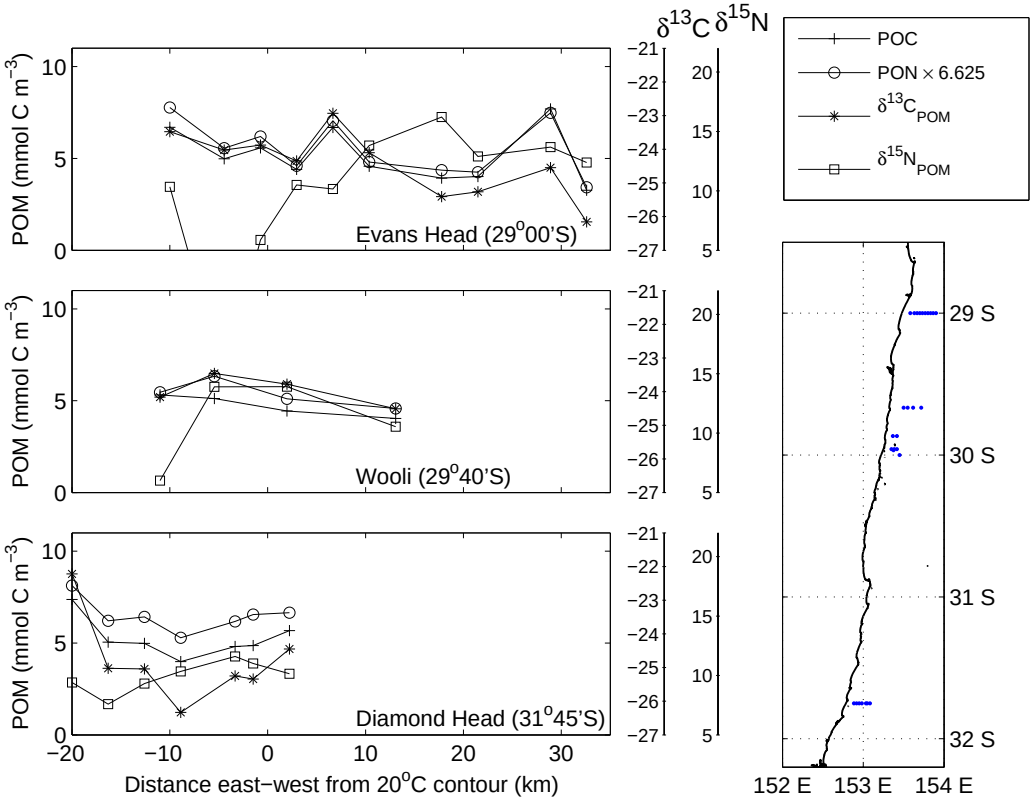

Fig. 10. Surface measurements of particulate organic matter (POM). Map shows the position of the samples. The left bottom panels plot the particulate organic carbon (POC), particulate organic nitrogen (PON), and isotopic signatures of the POM. The distance in the lower panels is positive into the East Australian Current, and is measured along the transect which lies approximately perpendicular to the coast.

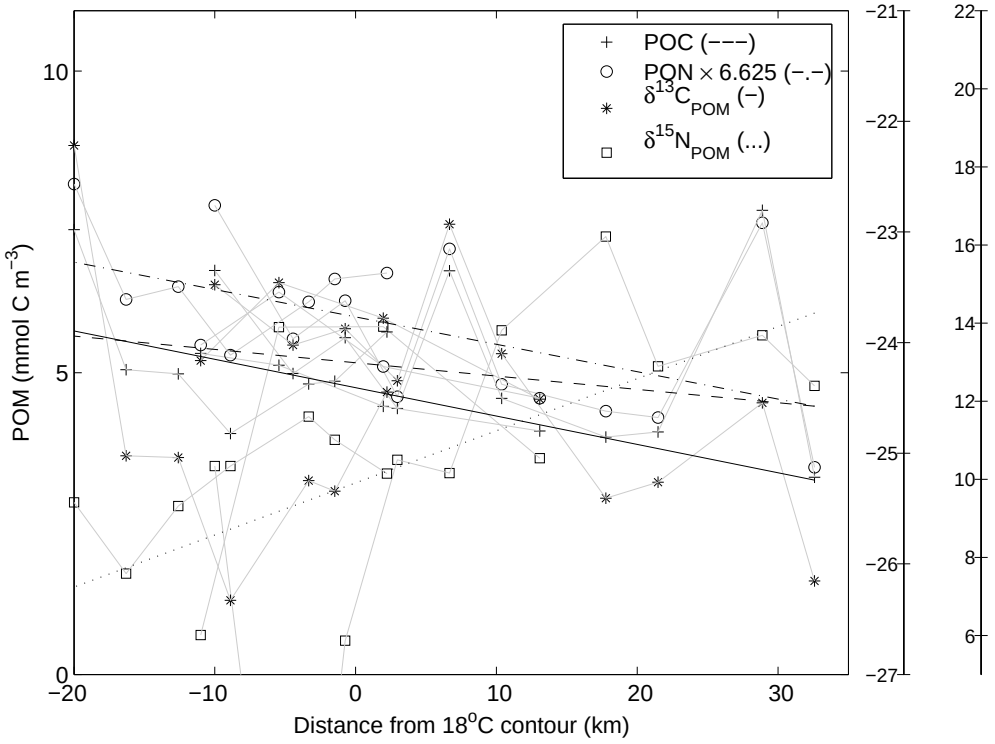

Fig. 11. Surface measurements of particulate organic matter (POM) for Sections combined, and a linear best fit. The distance is positive into the East Australian waters, and is measured along the transect which lies approximately perpendicular to the coast. Individual transects are joined by light gray lines.