INSTITUTO ESPAÑOL DE OCEANOGRAFÍA

IEO

CRUISE REPORT

CRUISE: OMEX-0898

Ship: R/V Professor Shtokman

Chief Scientist: Antonio Bode (IEO-La Coruña)

Start date: 1/08/98 **End date:** 11/08/98

Call Port: La Coruña **End Port:** La Coruña

Objectives:

The main objective of the cruise is the study of physical, chemical and biological properties in the continental shelf and shelf-break zone of the Galician coast near the Rias Baixas (NW Spain) during summer. The results obtained will be used as input data to models and biogeochemical budgets to determine the exchange of matter between the continental shelf and the ocean. This cruise is part of Workpackage 2 of the project OMEX-II, Phase II. The study area is located between Cape Finisterre (43°00' N) and Ría de Vigo (42°09' N).

The specific objectives are:

1.- Physical and chemical oceanography:

1.1.- Measurement of vertical profiles of temperature, salinity and fuorescence in OMEX-II reference stations.

1.2.- Measurement of dissolved inorganic nutrient concentration in coastal upwelling stations and oligotrophic oceanic stations.

1.3.- Measurement of dissolved organic carbon (DOC) and total disoolved nitrogen (TDN).

2.- Phytoplankton:

2.1.- Study of distribution patterns of different size-classes of phytoplankton in the area.

2.2.- Comparative study of carbon and oxygen fluxes through phyto and microplankton in coastal upwelling stations and oligotrophyc oceanic stations.

2.3.- Study of the photosyntheticaly derived carbon frsaction that fuels the microbial food-web in selected stations.

2.4.- Characterization of the dissolved organic matter (DOM) by chemical and optical methods.

3.- Microplankton:

3.1.- Measurement of the abundance of taxonomic and trophic groups of microplankton (bacteria, flagellates and ciliates).

3.2.- Measurement of bacterial production rates in selected stations.

3.3.- Measurement of bacterial DOC consumption rates in selected stations.

3.4.- Measurement of bacterial respiration rates in selected stations.

3.5.- Measurement of ammonium and dissolved organic nitrogen (DON) excretion rates of microplankton in selected stations.

3.6.- Measurement of production and respiraion rates of the microplankton community in selected stations.

4.- Zooplankton

4.1.- Measurement of mesozooplankton abundance and biomass.

4.2.- Measurement of herbivory rates of copepods in selected stations.

4.3.- Measurement of copepod respiration rates in selected stations.

4.4.- Measurement of ammonium excretion rates of copepods in selected stations.

4.5.- Measurement of DOC and DON production rates in presence of copepods in selected stations.

4.6.- Determination of egg and feces production rates of copepods in selected stations.

Participant Scientists:

Name	First Name	Institut
Bode Riestra	Antonio	IEO- A Coruña (IEO)
Lorenzo Salamanca	Jorge	IEO- A Coruña
Spyres	Georgina	Plymouth Marine Laboratory (PML)
Cariño Álvarez	Carlos	Universidade de Vigo (UV)
Fernández Suárez	Emilio	Universidade de Vigo
Panete Couto	Cristina	Universidade de Vigo
Serret Ituarte	Pablo	Universidade de Vigo
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Cabrera Gómez	Sergio	Universidad de Oviedo
Alvarez-Sostres	Jorge	Universidad de Oviedo
Cabal Diaz	Esteban	Universidad de Oviedo

Technical crew:

Name	First Name	Institut
Kuleshov	Alexej F.	Shirshov Institute of Oceanology, Russian Academy of Sciences, Atlantic Branch, Kaliningrad
Bulanov	Vladimir	Russian Institute of Fisheries and Oceanography, Laboratory of Oceanological Measuring Systems, Moscow
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Distribution of tasks:

#	Objective	Institut
1.1	CTD measurements	Technical crew, IEO, (UO)
1.2	Inorganic nutrients	IEO, (PML)
1.3	DOC, TDN	PML
2.1	Photosynthetic pigments	UV
2.1	Phytoplankton species	IEO
2.2	Primary production	UV
2.3	DOC poduction	UV
2.4	DOM characterization	UV
3.1	Bacteria, flagellates and ciliates abundance	UA, UAH, IEO, (PML)
3.2	Bacterial production	UA
3.3	DOC consumption	UA
3.4	Bacterial respiration	UA
3.5	Ammonium and DON excretion	IEO
3.6	Community production and respiration	UV
4.1	Mesozooplankton abundance and biomass	UO
4.2	Copepod herbivory	UO
4.3	Copepod respiration	UO
4.4	Ammonium excretion of copepods	UO
4.5	DOC and DON production with copepods	UO, UV, IEO
4.6	Egg and feces production of copepods	UO

Methods:

Sampling:

Sampling was made using CTD-Rossette casts and plankton hauls using nets. Stations were distributed in three transects normal to the coast (Figure 1), following the strategy adopted in OMEX-II Workpackage 2 cruises. Transect N was located in the vicinity of Cape Finisterre. Transect P was located near Ria de Muros, and Transect S was at the latitude of Ria de Vigo. In all stations a CTD cast to the bottom was made, and water samples were collected by the Rossette bottles at standard depths to analyse inorganic nutrients. Zooplankton was also collected in all stations by vertical net hauls (WP_2) from 200 m (or near the bottom at coastal stations) to the surface. Irradiance vertical profiles and additional water samples for dissolved carbon and nitrogen determination, photosynthetic pigment analysis and plankton for on board experimentation were obtained in selected stations (Biological Stations). Each Biological Station was occuppied between 00:00 and 12:00 h (local time = GMT + 2) and there were made experimental measurements of primary production and DOC excretion, ammonium and DON regeneration, bacterial production and respiration, oxygen production and consumption by microplankton, and herbivory, ammonium excretion, egg and fecal pellet production rates of zooplankton.

During this cruise it was not possible to contact with the R/V Charles Darwin (cruise CD114), working in a nearby area for OMEX-II project. However, parallel nutrient and plankton samples were collected for intercalibration.

Oceanographic stations:

Transect	Station	Latitude N	Longitude W	Biological Station	Depth (m)
N	19	43°00'	09°18.0'	*	30
	20	43°00'	09°24.0'		100
	16	43°00'	09°31.0'	*	220
	18	43°00'	09°39.0'		1600
	17	43°00'	09°43.0'		2300
	15	43°00'	10°01.0'		3100
	14	43°00'	10°18.0'		3300
P	8	42°40'	09°12.6'	*	100
	9	42°40'	09°30.0'		200
	10	42°40'	09°36.3'	*	1000
	11	42°40'	09°50.7'		2000
	12	42°40'	10°00.0'		2250
	13	42°40'	10°18.0'	*	2800
S	2	42°09'	08°57.5'		90
	1	42°09'	09°08.4'	*	150
	3	42°09'	09°19.0'		300
	4	42°09'	09°28.0'	*	1000
	5	42°09'	09°39.2'		2000
	6	42°09'	10°00.0'		2550
	7	42°09'	10°18.0'		2600

Specific methods

1.- Descriptive variables (IEO, PML):

Water samples were collected with 12 l Niskin bottles attached to a 24-position Rossette (General Oceanics). The rossette was coupled to a CTD Mark-III with temperature, conductivity, presure and fluorescence sensors. The CTD was calibrated in March 1998. At least one vertical profile from the surface to the bottom was made with the CTD in all stations. Water samples were collected in two stations for salinity determinations in the laboratory and post-cruise calibration.

In some transects, detailed measurements of conductivity, temperature, pressure, fluorescence and photosynthetically active irradiance (PAR) were obtained using a Chelsea Instruments UOR.

Irradiance and fluorescence vertical profiles were also measured at Biological Stations using a CTD Seabird SBE-25 (date of last calibration: May 1998). Crosscalibration of CTD probes was made after coupling all CTD to the rossette in one of the stations.

Water samples for the determination of dissolved inorganic nutrients (nitrate, nitrite, phosphate, silicate and ammonium) were collected at standard depths (5, 10, 20, 30, 40, 50, 60, 75, 100, 125, 150, 200, 300, 400, 500, 600, 700, 1000, 1500, 2000, 2500 and 3000 m). These samples were drwan directly from the Niskin bottles in polyethylene tubes and were immediately frozen until later analysis in the laboratory of IEO. Nutrient analysis were made using an Autoanalyser Technicon AA-II and the procedures described in Grasshoff et al. (1984). Parallel nutrient samples were collected in two stations for intercallibration with PML. These samples were drawn directly from the Niskin bottles using acid cleaned syringes, filtered through Millipore (0.45 μm) membrane filters, and collected in 50 ml polycrabonate bottles in which were frozen until later analysis. All collection and processing material was acid cleaned before use.

Samples for the determination of DOC and TDN were collected directly from the Nisking bottles and filtered through glass fiber filters (GF/F) in a pure oxygen atmosphere using a closed filtering device to exclude particulate matter. These samples were thereafter acidified with 30 μl of ortophosphoric acid, introduced in 10 ml pre-ashed glass ampoules and sealed for transport to PML and subsequent analysis. Later, the samples will be analysed by the high temperature combustion technique (HTCO) using a Shimadzu TOC 5000 analyser. In this technique, water samples were transported by a current of ultrapure oxygen through a Al-Pt 0.5% catalyser at high temperature (680 – 900 °C) and converted in CO_2 gas, that was measured in an infrarred analyser (IRGA). Total dissolved nitrogen (TDN) will be determined in the same samples using a nitrogen specific chemilumiscence analyser (Antek 705D). Dissolved organic nitrogen (DON) concentrations will be obtained by difference between TDN and dissolved inorganic nitrogen values. Some of the DOC-TDN samples will be intercalibrated with the research group of the Instituto de Investigaciones Marinas de Vigo (CSIC).

Total samples collected by PML for DOC-TDN and dissolved nutrients were:

Station	DOC – TDN	Nutrients
19	7	-
20	10	10
16	8	-
18	10	-
17	11	-
15	9	-
14	12	-
8	6	-
9	10	-
10	11	-
11	10	-
12	12	12
13	8	-
2	4	-
1	2	-
3	2	-
4	6	-
5	11	-
6	8	-

2. Phytoplankton (UV, IEO):

The following table list stations where dissolved oxygen (Dis. O_2), size-fractionated chlorophyll a, b and c (SF Chla) and primary production (SF Prod), DOC production rate (DOC Prod), oxygen production and respiration rate (O_2 Prod), free and combined dissolved carbohydrates (Dis. Carbo) and fluorescence characteristics of DOM (DOM fluor), was measured in 3 to 5 depths within the euphotic zone.

Station	Dis. O_2	SF Chla	SF Prod	DOC Prod	O_2 Prod	Dis. Carbo	DOM Fluor
1	X	X	X	X	X	X	X
4	X	X	X	X	X	X	X
8	X	X	X	X		X	X
9		X				X	X
10	X	X	X	X		X	X
11		X				X	X
12		X				X	X
13	X	X	X	X	X	X	X
14		X				X	X
15		X				X	X
16	X	X	X	X	X	X	X
17		X				X	X
18		X				X	X
19	X	X	X	X		X	X
20		X				X	X

Samples for the determination of phytoplankton species were collected at the same depth as primary production determinations. These samples were preserved with Lugol's solution until later observation in the laboratory.

Chlorophyll concentration was analysed after subsequent filtration of 150 ml of sample through 5 and 2 µm polycarbonate and glass fiber (APFF) Millipore filters. The extraction of pigments was made in 90 % cold acetone during 10 h. Fluorescence due to chlorophylls a, b and c was measured using a SAFAS FLX spectrofluorimeter calibrated with pure pigments extracts obtained by HPLC. Calculations were made using the following equations:

$$F\ (432/667) = 2.53\ Ca + 20.207\ Cb + 18.329\ Cc$$
$$F\ (463/652) = 644.2\ Ca + 3.546\ Cb + 11.61\ Cc$$
$$F\ (451/633) = 1408.3\ Ca + 58.47\ Cb + 2.516\ Cc$$

where F is fluorescence at the corresponding excitation/emission wavelenghts and Ca, Cb and Cc are the concentrations (mg m^{-3}) of chlorophylls *a, b,* and *c,* respectively. In addition, parallel measurements of chlorophyll *a* concentration were made with a Turner-Designs fluorometer and the results were used to calibrate the 'in situ' fluorescence measurements obtained with the fluorometer of the Mark-III CTD.

Size-fractionated primary production rates were measured using four (1 dark) 80 ml seawater samples drawn from the Niskin bottles and innoculated with 370 KBq (10 µCi) of $NaH_{14}CO_3$. Samples were kept in an on-deck incubator simulating the irradiance experienced by the cells at their original depth. Bottles were incubated for 4 h at noon and then filtered subsequently through 5 µm, 2 µm polycarbonate filters and Millipore APFF glass fiber filters which were exposed to concentrated HCl fuming for 12 h. Four ml of scintillation cocktail were added to each vial and the radiactivity determined with a LKB ß-scintillation counter.

Dissolved organic carbon production rates were determined using four 30 ml seawater samples collected from selected depths, innoculated with 1295 KBq (35 µCi) of $NaH^{14}CO_3$ and incubated in an on-deck incubator for 2 h. Two 8 ml subsamples were drawn from each bottle and filtered through Millipore APFF glass fiber filters. Filtrates were acidified with 40 µl of HCl 50% and bubbled with CO_2 free air for 12 h. Filters were decontaminated as described above. Scintillation cocktail was then added to both filters and filtrates. Duplicate blank tests were run in parallel by innoculating, incubating and processing 0.2 µm filtered seawater in the same way as mentioned before.

Oxygen production and respiration rates were measured in twelve 125 ml seawater samples collected from the Niskin bottles into individually calibrated borosilicate glass bottles. Four samples were immediately fixed, four were kept in the dark for 24 h and the four remaining were kept under a light-dark diel cycle in an on-deck incubator. Dissolved oxygen concentration was meassured through automated precision Winkler titration performed with a Metrohm 716 DMS Titrino, using a potentiometric end point.

Dissolved mono and polysaccharides and DOM fluorescence were determined in 30 ml seawater samples, filtered through pre-combusted Millipore APFF glass fiber filters using acid-washed Teflon syringes. The filtrate was disposed into pre-combusted glass ampoules which were sealed inmediately after sampling and subsequently kept frozen (-20 °C) until further analysis ashore. Dissolved carbohydrates were determined according to Myklestad et al. (1997). DOM fluorescence was measured with a Safas flx spectrofluorometer at excitation/emission wavelenghts corresponding to tyrosine-like substances (230/290), tryptophane-like substances (270/320) and humic compounds

(254/440 and 308/440). Raman correction was performed following Determan et al. (1994).

3. Bacteria and Microplankton:

3.1. Bacteria (UA):

At every station, samples were collected at six different depths for Acridine Orange (AO) staining. Filtration and slide preparation was done on board. At the home lab, TBN (Total Bacterial Number), MCV (Mean Cell Volume) and FDC (Frequency of Dividing Cells) will be obtained from the collected samples.

At selected intensive stations (Stations 1, 6, 8, 10 and 14), samples at all depths, and, at every other station, bottom and surface samples were collected for bacterial production measurements. These were taken with two replicates and a blank for each depth. Bacterial respiration was measured by ^{14}C-Leucine incorporation. Dark incubation of samples took place for four hours (saturation curves drawn from results of the R/V "Belgica" cruise in June 1998) at the temperature of the water column, and then was blocked by the addition of formaldehyde. Within 48 hours, fixed incubated samples were filtered for scintillation counting. At two selected stations (Station 1 and 6) leucine saturation curves were drawn, for future reference on the local bacterial Leucine uptake rates. These curves were obtained with surface water samples. Different quantities of ^{14}C-Leucine were added to replicate samples and blanks, in order to establish the saturation concentration.

Four incubation experiments were carried out, in order to study essentially DOC uptake rate and bacterial growth efficiency, but also to compare direct (biomass increment) and indirect (^{14}C-leucine incorporation) techniques for measurements of bacterial production. DOC uptake was carried out in close cooperation with PML that will analyse DOC and TDN on the collected samples. The four experiments were carried out in replicate, at four stations: Station 1, 4, 6 and 8. Samples were incubated in polycarbonate flasks, at an average temperature of 19 ºC. The experimental design for the DOC uptake experiments (on-board) was as follows:

Treatment*	**Strategy**	**Collected samples** (every 6th hour in a 36 hour incubation period)
A **(9 litre flask)**	6.4 l of water sample filtered through 0.1 µm cartridges + 1.6 l filtered through 0.8 µm cellulose nitrate	• Acridine Orange staining • Bacterial Production • Nutrients • DOC + TDN
B **(2 litre flask)**	2 l of sample, filtered through 0.8 µm cellulose nitrate	• Acridine Orange staining
C **(2 litre flask)**	2 l of sample, filtered through a 10 µm nylon mesh	• Acridine Orange staining • Proflavin staining

* At station 1, A,B,C in replicate; at station 4 A, B, C single; at stations 6 and 8, A in replicate;

The experimental objectives for the DOC uptake experiments were:

Treatment	**Variables**	**Objectives**
A **(<0.8 µm + <0.2 µm)**	**1.** DOC **2.** TBN (Bacterial Abundance) **3.** MCV **4.** Bacterial Biomass **5.** FDC **6.** ^{14}C-Leucine incorporation rate	• DOC uptake rate (**1**) • Bacterial growth efficiency (**1,2,3**) • ^{14}C Leucine conversion factor (**2,3,6**) • FDC calibration for BP (**2,5**) • Comp. of direct and indirect techniques for PB (**2,3,4,6**)
B **(< 0.8 µm)**	**7.** TBN (Bacterial Abundance) **8.** MCV **9.** Bacterial Biomass **10.** FDC	• Protist predation rate (**7,11**)

C **(< 10 µm)**	**11.** TBN (Bacterial Abundance) **12.** MCV **13.** Bacterial Biomass **14.** FDC **15.** Nano-protist abundancy **16.** MCV of nanoprotists **17.** Nano-protist Biomass	• FDC calibration for BP (**7**,**10**) • Importance of bact. size on the predation rate (**8**,**10**,**12**,**14**) • Growth and production rate of fagotrophic protists • Relative importance of "bottom-up" vs. "top-down" control

Bacterial respiration was measured at biological stations using a method ("bubbling") for determining the respired fraction of ^{14}C-Leucine, which is being developed in conjunction with Dr. Jorma Kupparinen, of the FIMR (Finnish Institute for Marine Research). Bacterial respiration is then followed in water samples that were incubated following the general protocol for bacterial production measurements. Once the pre-set incubation time is up, the sample is then purged with 200 cm^3 of air, in the presence of a minute volume of concentrated TCA (Tri-Chloroacetic Acid), and the free $^{14}CO_2$ is then captured in a trapping solution, for scintillation counting.

Results of the UA group will be compared with those obtained by members of the same team that were in the R/V Charles Darwin CD114 cruise during the same period.

3.2. Microplancton (PML, UAH):

Water samples were collected from the Rossette bottles by PML (for E. Fileman) and UAH participants to determine species abundance of microplankton. These samples were preserved in Lugol's solution until observation in the laboratory. The following table list samples collected:

Station	Sampling depths (PML)	Sampling depths (UAH)
1	6	-
2	3	-
3	6	-
4	6	-
5	6	-
6	6	-
7	-	-
8	6	6
9	6	-
10	6	6
11	6	-
12	6	-
13	6	6
14	6	-
15	-	-
16	6	6
17	-	-
18	-	-
19	3	6
20	5	-

In addition to these samples, one liter from each depth sampled by UAH was stained with proflavin and fixed with glutaraldehyde, subsequently filtered through membrane 0.8 µm filters, mounted on

slides and frozen until later observation of flagellates and ciliates in the laboratory using epifluorescence microscopy (Haas, 1982, Sherr et al., 1993). Some samples of large ciliates were obtained using vertical hauls of plankton 200 µm nets from 200 m to the surface. These ciliates were kept alive and transported to the UAH laboratory for further isolation and culture.

3.3. Ammonium and DON excretion (IEO):

Experimental determination of ammonium and DON excretion rates by the microplanktonic community were made at three depths within the euphotic layer of biological stations. Duplicate water samples from the Niskin bottles were placed in polycarbonate bottles, inoculated with trace concentrations of $(^{15}NH_4)_2\ SO_4$ and incubated in an on-deck incubator simulating irradiance levels of the sampling depths with filters. Incubations were terminated by filtration through glass-fiber filters (Millipore AF) and both the particulate material and the filtrate were kept for further determination of particulate and dissolved nitrogen concentrations and ^{15}N enrichment. Two replicates were inoculated and immediately filtered to determine initial nitrogen concentrations. All samples were frozen until further processing in the laboratory using the method of Slawyk and Raimbault (1995). Inorganic nitrogen concentrations will be analysed using the methods of Grasshoff et al. (1983) and a Technicon AAII autoanalyser. Particulate nitrogen concentration and ^{15}N enrichment will be determined using an isotope-ratio mass spectrometer (Integra-N).

The stations and depths studied are listed below.

Station	Depth (m)	Irradiance relative to surface (I_o) (%)
1	1, 29, 54	100, 7, 1
4	5, 20, 50	100, 7, 1
8	4, 20, 40	100, 7, 1
10	5, 20, 49	100, 14, 1
13	5, 20, 48	100, 14, 3
16	4, 19, 50	100, 14, 1
19	4, 15, 19	100, 14, 7

In addition, an experiment was performed at station 16 in collaboration with UV and UO to determine the effect of herbivorous copepods in DON and DOC production rates (see section 4 Zooplankton).

3.4. Respiration of the microplanktonic community: (see section 2. Phytoplankton)

4. Zooplankton (UO):

Mesozooplankton samples to determine abundance and biomass were collected at all stations by means of vertical hauls (0-200 m) of a WP_2 triple net of 40 cm diameter and 200 µm mesh size. In order to study diel patterns, night (1 h aprox.) and day (11 h aprox.) samples were collected at biological stations. All samples were fractionated in three size classes using meshes of 200, 500 and 1000 µm. Samples for systematic analysis were fixed in 4% formalin, and those for biomass measurement were filtered on preweighted GF/A glass-fiber filters and frozen until dry-weight determiantions and analysis of carbon and nitrogen content using a CNH elemental analyser.

Mesozooplankton grazing was estimated by the gut pigment method (Mackas and Bohrer, 1976) at

all stations, using both night and day samples at biological stations. Vertical tows from 200 m depth to the surface were fractionated in three size classes as those for biomass. After fractionation animals were filtered on skin filtres and inmediately frozen in dark. Also, unfractionated samples were preconcentrated in 30 ml of filtered seawater and inmediately frozen in liquid nitrogen, to estimate the gut content of gelatinous organisms, principally appendicularians and doliolids. In order to capture living animals for experiments, vertical tows using an RF net were performed. Evacuation rates were obtained from experiments during the night in intensive stations to obtain the gut passage time. The animals were fractionated and inmediately placed on filtered (0.2 µm) sea water. Some individuals were filtered as for the gut content method at consecutive time intervals.

Experiments to determine the influence of the phytoplankton size on the ingestion of the mesozooplankton size classes were performed at the intensive stations. Size fractionated animals were maintained during 7 h in filtered seawater to empty their gut. Water samples from the deth of the chlorophyll maximum were prefiltered by different mesh sizes, and animals of different size fractions were incubated for 3 or 4 hours. At the beginning and the end of the experiments, water subsamples were taken to measure chlorophyll a concentration, C, N and Si. Subsamples of the fecal pellets produced were preserved either in Lugol's solution for qualitative analysis or frozen for the determination of C and N content. All animals used in the experiments were preserved for counting and determination.

Fecal pellet production rate by copepods of three size classes was determined in experiments at biological stations where the animals were fed for 24 hours with water of the chlorophyll maximum. The obtained fecal pellets were preserved frozen for C, N and chlorophyll analysis. Chlorophyll concentrations of the incubation water were determined at the start and at the end of the experiments.

Experiments to determine the specific ratios of respiration and excretion of the mesozooplankton were performed at biological stations in the same size fractions as those for biomass. The individuals were collected by net tows and maintained in filtered seawater for acclimatization for two hours. Unselected animals of the whole community were introduced in one liter oxygen bottles, and maintained at the temperature of surface water for 20 to 24 hours. Subsamples for initial and final oxygen, ammonia and phosphate were taken. The organisms were filtered on Whatman GF/A filters and frozen until analysis of C and N content at the laboratory.

The role of herbivorous mesozooplankton on DOC and DON production was estimated at station 16, in collaboration with UV and IEO, by incubation of three replicated samples of prefiltered (200 µm mesh size) seawater in 125 ml polycarbonate bottles, as for DOC and DON production determinations (see sections 2. Phytoplankton and 3.3 Ammonium and DON excretion). In addition, three aditional replicates were incubated with 4 adult specimens of *Calanus helgolandicus* and similar experimental bottles were incubated to analyse copepod grazing, collecting subsamples of water at the beginning and the end of the incubations for chlorophyll, C, N and dissolved carbohydrates analysis.

Secondary production was estimated by the egg production method (Hay, 1995) in the most abundant species of the different size classes. The species used were *Calanus helgolandicus, Calanus tenuicornis, Calanoides carinatus, Centropages typicus, Acartia clausi.* Mature females were selected from vertical net hauls (200 m depth to surface) and incubated in water from the chlorophyll maximum for 24 to 48 hours. The eggs produced in the two 24 hours intervals as well as the incubated females were filtered and preserved until laboratory analysis of C and N.

Samples collected and the different measurements are summarized below:

Station	Abundance and biomass	Gut content (Copepods and gelatinous plankton)	Evacuation (Copepods)	Evacuation (gelatinous plankton)	Grazing and fecal pellet production	Respiration and excretion	DOC and DON production	Egg production
1	x	x			x	x		x
2	x	x						
3	x	x						
4	x	x	x		x	x		x
5	x	x						
6	x	x						x
7	x	x	x		x			
8	x	x	x		x	x		x
9	x	x						
10	x	x	x		x			
11	x	x						
12	x	x						
13	x	x	x		x	x		x
14	x	x						
15	x	x						
16	x	x	x		x		x	x
17	x	x						
18	x	x						
19	x	x	x		x			x
20	x	x		x			x	

Activity report:

Day	Local time	Operations
01/08/98	09:00	La Coruña. Equipment mounting. Scientific personnel embarks.
02/08/98	08:00	Departure to Transect S.
	11:00	UOR towed from 200 m isobath
	15:30	UOR on board for data retrieval. Data only available for a single depth.
	17:30	UOR towed at 10 knots until the 200 m isobath near Ría de Vigo (Transect S).
03/08/98	05:30	UOR on board for data retrieval. Again, data only available for a single depth. Technicians study possible causes and solutions.
	07:00	Arrival to Station 1 (Transect S).
	07:30	Rossette sampling (Cast 1) to the bottom.
	10:30	Plankto sampling with nets and Van Dohrn bottles.
	11:00	Irradiance profile (CTD SBE-25).
	11:40	Rossette sampling (Cast 2) to the bottom. Samples for incubations and production measurements.
	12:00	Departure to Station 2.
	13:45	Arrival to Station 2. Rossette sampling (Cast 3) to the bottom.
	14:15	Plankton sampling with nets.
	14:35	Departure to Station 3.
	16:15	Arrival to Station 3. Rossette sampling (Cast 4) to the bottom.
	17:00	Plankton sampling with nets.
	17:35	Departure to Station 4.
	18:30	Arrival to Station 4. Rossette sampling (Cast 5) to the bottom.
	20:00	Plankton sampling with nets.
	21:00	Ship at Station 4 but no sampling possible (4 – 5 m swells)
04/08/98	00:00	Fluorescence profile to 100 m depth (CTD SBE-25).
	00:30	Plankton sampling with nets.
	03:00	End of plankton sampling.
	09:00	Irradiance profile (CTD SBE-25).
	10:00	Rossette sampling to 500 m depth. Some bottles failed to close.
	11:00	Rossette sampling to 200 m depth (Cast 6). Samples for incubations and production measurements.
	11:30	Plankton sampling with nets and Van Dohrn bottles.
	13:00	Departure to Station 5.
	14:00	Arrival to Station 5. Rossette sampling to 2000 m depth (Cast 7).
	17:00	Plankton sampling with nets.
	17:30	Departure to Station 6.
	19:00	Arrival to Station 6. Rossette sampling to 2000 m depth (Cast 8). Sampling difficult because large swells (up to 4 m).
	22:30	Departure to Station 7.
05/08/98	00:00	Arrival to Station 7.
05/08/98	01:30	Fluorescence profile to 100 m depth (CTD SBE-25).
	02:00	Plankton sampling with nets.
	03:00	End of plankton sampling.
	05:30	Wind and swell increase. Operations suspended and instruments and equipment are secured.
	08:00	Operations at Station 7 cancelled due to sea state. Departure to Station 8 (Transect P).

Day	Local time	Operations
	19:00	Arrival to Station 8. Good meteorological conditions.
	19:15	Fluorescence and irradiance profiles (CTD SBE-25).
06/08/98	01:00	Plankton sampling with nets.
	03:00	End of plankton sampling.
	09:00	Irradiance profile (CTD SBE-25).
	10:00	Joint deployment of Rossette, CTD SBE-25 for intercalibration (Cast 9). Samples for incubations and production measurements.
	11:00	Plankton sampling with nets and Van Dohrn bottles.
	12:45	Departure to Station 9.
	13:45	Arrival to Station 9. Rossette sampling to the bottom (Cast 10).
	14:30	Plankton sampling with nets.
	15:00	Departure to Station 10.
	15:45	Arrival to Station 10. Rossette sampling to the bottom (Cast 11).
	17:00	Plankton sampling with nets.
	18:00	Departure to Station 11.
	19:00	Arrival to Station 11. Rossette sampling to the bottom (Cast 12).
	21:15	Plankton sampling with nets.
	22:00	Departure to Station 10.
07/08/98	00:00	Arrival to Station 10. Plankton sampling with nets and Van Dohrn bottles.
	03:00	End of plankton sampling.
	11:00	Rossette sampling to the bottom (Cast 13). Samples for incubations and production measurements.
	13:30	Plankton sampling with nets.
	15:00	Departure to Station 12.
	16:00	Arrival to Station 12. Rossette sampling to 2000 m depth (Cast 14).
	18:15	Plankton sampling with nets.
	18:50	Departure to Station 13.
	20:00	Arrival to Station 13. Rossette sampling to 2000 m depth (Cast 15).
08/08/98	00:00	Plankton sampling with nets.
	02:00	End of plankton sampling.
	09:00	Irradiance profile (CTD SBE25).
	09:30	Rossette sampling to 200 m depth (Cast 16). Samples for incubations and production measurements.
	09:45	Plankton sampling with nets and Van Dohrn bottles.
	12:00	Departure to Station 14 towing UOR
	15:00	UOR on board. Arrival to Station 14.
	15:15	Rossette sampling to 3000 m depth (Cast 17).
	17:45	Plankton sampling with nets.
08/08/98	18:30	Departure to Station 15.
	19:45	Rossette sampling to 2000 m depth (Cast 18).
	21:00	Plankton sampling with nets.
	22:00	Departure to Station 16 towing UOR.
09/08/98	00:00	Arrival to Station 16. UOR on board.
	00:30	Fluorescence profile to 100 m depth (CTD SBE-25).
	01:00	Plankton sampling with nets.
	03:00	End of plankton sampling.
	09:00	Irradiance profile to 100 m depth (CTD SBE-25).
	09:30	Rossette sampling to 200 m depth (Cast 19). Samples for incubations and production measurements.

Day	Local time	Operations
	10:00	Plankton sampling with nets and Van Dohrn bottles.
	11:30	Departure to Station 17.
	13:00	Arrival to Station 17.
	13:15	Rossette sampling to 2000 m depth (Cast 20).
	15:10	Plankton sampling with nets.
	15:30	Departure to Station 18.
	16:00	Arrival to Station 18.
	16:15	Rossette sampling to 1500 m depth (Cast 21).
	17:15	Plankton sampling with nets.
	18:10	Departure to Station 19.
	20:00	Arrival to Station 19.
10/08/98	00:00	Fluorescence profile to 100 m depth (CTD SBE-25).
	00:30	Plankton sampling with nets.
	03:00	End of plankton sampling.
	09:00	Irradiance profile to 100 m depth (CTD SBE-25).
	09:30	Rossette sampling to 40 m depth (Cast 22). Samples for incubations and production measurements.
	10:15	Plankton sampling with nets.
	10:34	Departure to Station 20.
	11:20	Arrival to Station 20.
	11:30	Rossette sampling to 125 m depth (Cast 23).
	11:45	Plankton sampling with nets.
	12:45	End of sampling at Station 20. Departure to La Coruña.
	15:30	UOR towed in waters deeper than 200 m.
	16:30	UOR on board.
	18:00	Arrival to La Coruña
11/08/98	08:00	Equipment downloaded. Change of scientific personnel.

Results:

The cruise was made during general upwelling conditions (Figure 2). Surface shelf waters were clearly colder than oceanic surface waters, and minimum temperatures occurred near Cape Finisterre. The main mesoscale features observed from satellite images of sea surface temperature were two cold water filaments extending from the coast to the ocean in the northern and southern limits of the study area. The longest of such filaments was located south of Ria de Vigo (42°N) and with the filament located near Cape Finisterre surrounded an area of relatively warm surface water off the shelf. These general conditions were maintained during the cruise, with little variations in the location of the coldest surface waters (Figure 2).

The distribution of water mases reflects upwelling dynamics in the surface layer, especially above 500 m. Surface isotherms in transect S display an upward trend from the ocean to the coast, where salinity values higher than 35.7 psu are found. Such observations indicate upwelling of cold and saline waters, with characteristics of Eastern North Atlantic Waters (ENAW, Rios et al., 1992), and little influence of coastal freshwater (Figure 3). The layer of Mediterranean Water (MW), indicated approximately by salinity values higher than 36 psu and the 11.5 °C isotherm, shows a variable vertical distribution in this transect, having the nucleus at 1000 m at the oceanic station 6 and at 1700 m at the shelf-break (Figure 3). The situation found in transect P also reflects surface upwelling near the coast, but in this case there is a clear influence of freshwater in stations close to the coast (Figure 4). In this transect, the layer of MW is located between 700 and 1300 m depth in all off-shelf stations, with little variations in thickness. Upwelling is detected also in transect N as an upward trend in the isotherms towards the coast and the relatively high salinity of the subsurface coastal water, with little influence of freshwater (Figure 5). The layer of MW in this transect has the nucleus near 1000 m in all stations but having maximum salinity values and thickness near the shelf-break (Figure 5). The large variability in the distribution and morfology of deep water layers among transects, especially near 1000 m, are indicative of a significant dynamic activity.

Even when the structure of the surface layer has common characteristics there are also variations among transects, particularly in the distribution of isohalines and isopycnals. An increase of salinity from the coast to the ocean is observed in transect S (Figure 6), where a layer of surface water (above 60 m) with density lower than shelf waters is located off the shelf-break (between stations 3 and 6). The layer of surface oceanic water has marked pycnocline and halocline below 60 m, and is clearly different from the upwelled coastal water because the latter is vertically mixed in the upper 100 m. The separation between upwelling and oceanic water in transect P is accompanied by a deepening of the isotherms and isopycnals below 50 m in stations 10 and 11, located off the shelf-break and charcterised by the presence of a nucleus of subsurface water with a lower salinity than nearby stations (Figure 7). Salinity values in this transect were lower than those of the oceanic station in transect S. The distribution of isopycnals in central stations of transect P suggests the existence of a zone of active downwelling of subsurface water off the shelf-break, probablu as a consequence of upwelling dynamics near the coast (Figure 7). In contrast, the structure of surface water layer in transect N is similar to that of transect S, but with lower salinity values in subsurface layers and in the oceanic station (Figure 8). There is a nucleus of saline water between 60 and 100 m depth in central station of transect N, however such heterogeneity do not affect to the general pattern shown by isopycnals.

The structure of the surface layer causes a differential distribution of phytoplankton biomass, as indicated by the ‘in situ’ fluorescence values (Figure 9). The general trend in all transects is an increase of biomass from the ocean towards the coast, where maximum values appear closer to the surface (near 20 m depth) than in ocean waters (approximately at 80 m depth). Phytoplankton

biomass distribution in transect P is more discontinuous than in other transects. On one hand, a marked nucleus of high biomass appears in the coastal station of this transect. This biomass maximum is located at a higher depth than in other transects. On the other hand, maximum biomass values occur at depths between 50 and 70 m in oceanic stations (Figure 9). Such horizontal discontinuity in phytoplankton biomass distribution of transect P is found in the same stations where donwelling of subsurface water occurs (Figure 7).

Maximum biomass values measured as chlorophyll *a* concentrations can be estimated using the calibration of the fluorescence sensor of the CTD with the acetonic extracts (Figure 10). Coastal stations in all transect reach values near 3 mg Chl*a* m^{-3}, with some values near 5 mg Chl*a* m^{-3} in transect N.

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APPENDIX:

Position and timing of Rossette cast. (GMT = local time + 2 h). Lat.: N Latitude, Lon.: W Longitude.

Station	Cast	Date	Start time	End time	Start Lat.	Start Lon.	End Lat.	End Lon.	cast depth
1	1	03/08/98	05:39	06:06	42°08.93’	09°08.43’	42°08.08’	09°08.30’	145
1	2	03/08/98	10:58	11:23	42°09.00’	09°08.20’	42°09.00’	09°08.30’	145
2	3	03/08/98	11:58	12:14	42°08.90’	08°57.38’	42°08.78’	08°57.50’	90
3	4	03/08/98	14:20	14:50	42°09.00’	09°19.00’	42°08.68’	09°19.23’	200
4	5	03/08/98	16:40	17:50	42°08.95’	09°28.07’	42°08.98’	09°28.11’	1000
4	6	04/08/98	08:53	09:23	42°09.00’	09°28.05’	42°09.00’	09°28.10’	200
5	7	04/08/98	12:26	14:18	42°09.00’	09°39.20’	42°08.97’	09°40.13’	2000
6	8	04/08/98	17:08	20:14	42°08.92’	09°59.99’	42°09.01’	09°59.91’	2000
8	9	06/08/98	08:22	08:40	42°40.00’	09°12.60	42°40.00’	09°12.60’	90
9	10	06/08/98	11:46	12:00	42°40.00’	09°29.90’	42°40.00’	09°29.90’	190
10	11	06/08/98	13:44	14:32	42°40.00’	09°36.30’	42°40.02’	09°36.18’	950
11	12	06/08/98	16:29	18:14	42°40.02’	09°50.69’	42°39.75’	09°50.78’	2000
11	13	07/08/98	08:48	09:13	42°40.00’	09°36.07’	42°40.02’	09°35.95’	200
12	14	07/08/98	14:17	16:07	42°39.97’	10°00.04’	42°39.95’	09°59.92’	2000
13	15	07/08/98	18:16	20:55	42°40.00’	10°17.86’	42°39.95’	10°18.01’	2700
13	16	08/08/98	07:18	07:37	42°39.94’	10°17.94’	42°39.82’	10°17.85’	150
14	17	08/08/98	13:00	15:43	43°00.00’	10°18.00’	42°59.86’	10°17.77’	3000
15	18	08/08/98	17:42	19:16	42°59.98’	10°01.05’	42°59.97’	10°01.06’	2000
16	19	09/08/98	07:15	07:39	42°59.97’	09°30.97’	42°59.99’	09°30.87’	200
17	20	09/08/98	11:00	12:40	43°00.00’	09°43.00’	43°00.02’	09°43.03’	2000
18	21	09/08/98	14:16	15:28	43°00.01’	09°38.98’	42°53.92’	09°38.99’	1500
19	22	10/08/98	07:34	07:47	42°59.91’	09°18.07’	42°59.89’	09°18.14’	40
20	23	10/08/98	09:28	09:42	42°59.94’	09°24.05’	42°59.93’	09°24.14’	125

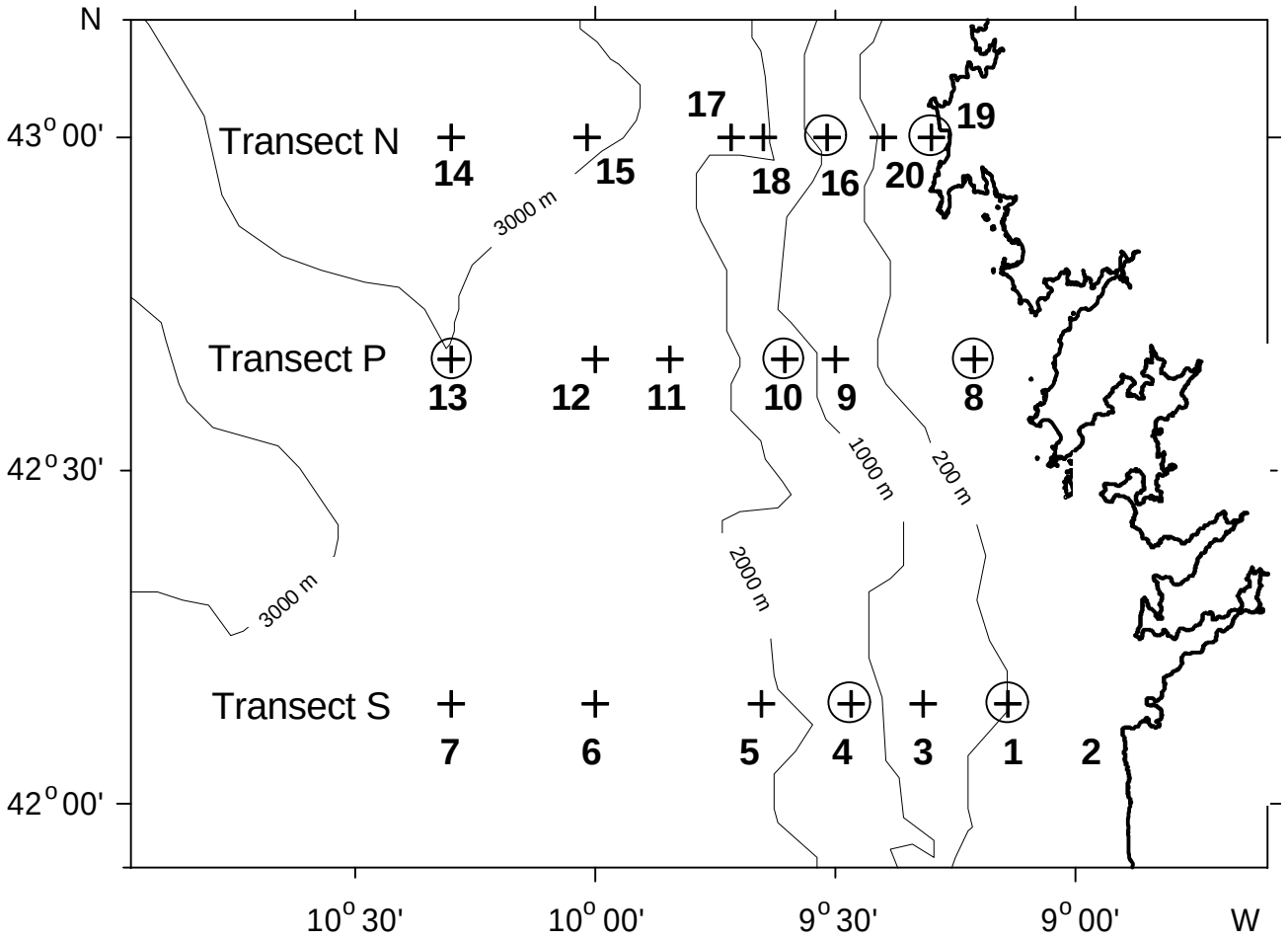

Figure 1. Map of sampling stations. Biological Stations are encircled.

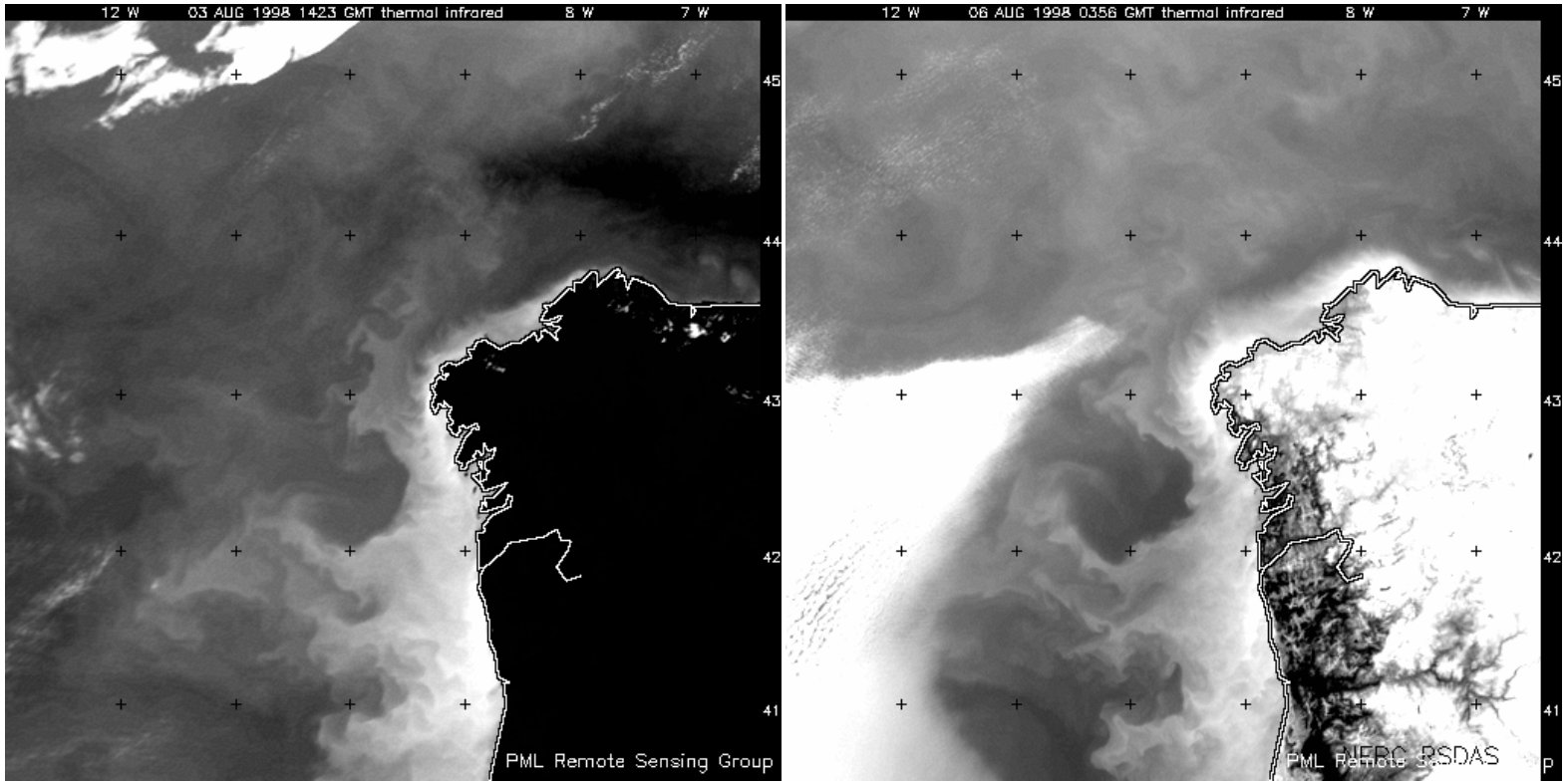

Figure 2. Sea surfa temperature distribution in the study area obtained by infrarred thermography. Coldest areas are indicated by lighter tones.

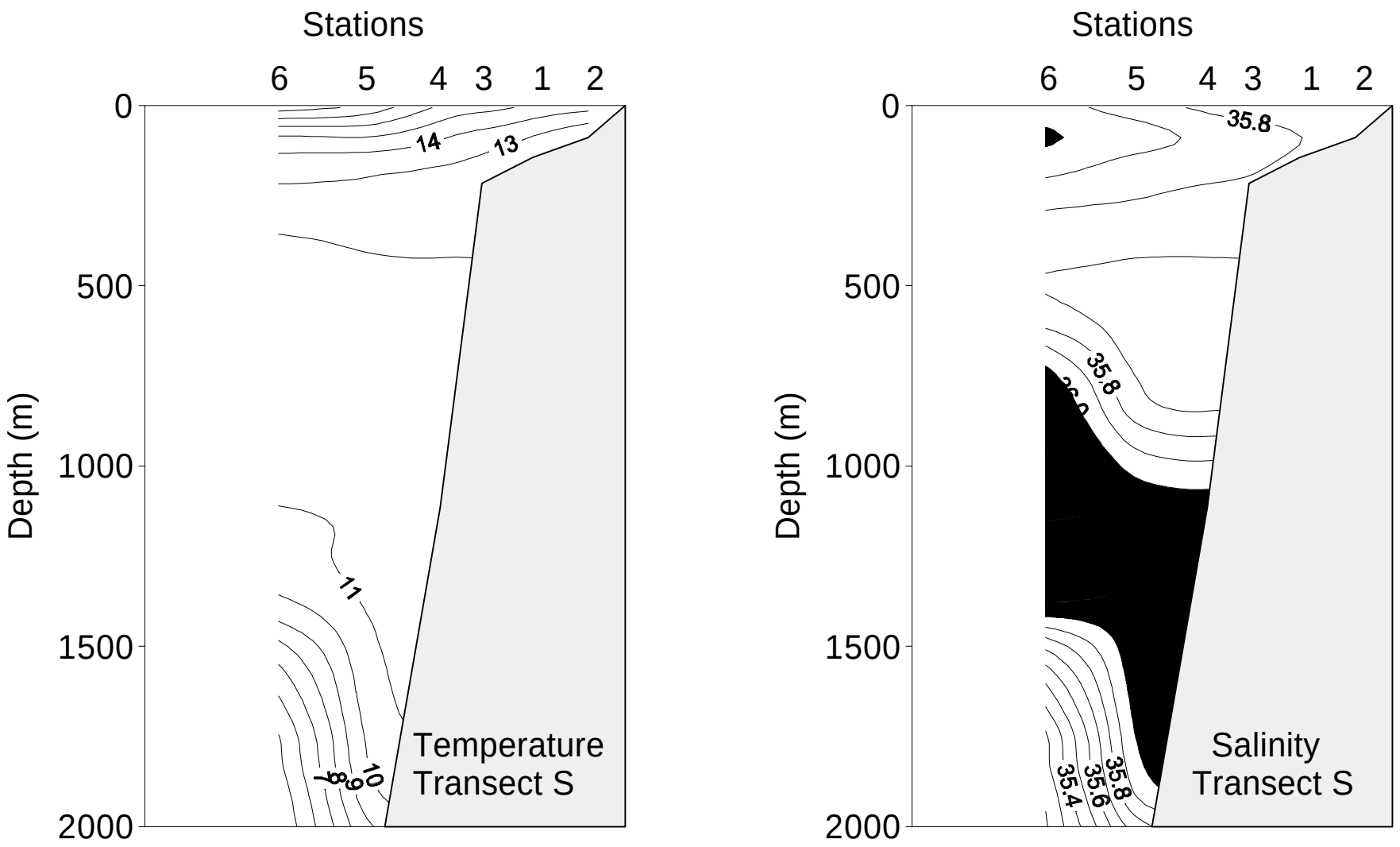

Figure 3. Temperature and salinity distributions down to 2000 m depth in Transect S

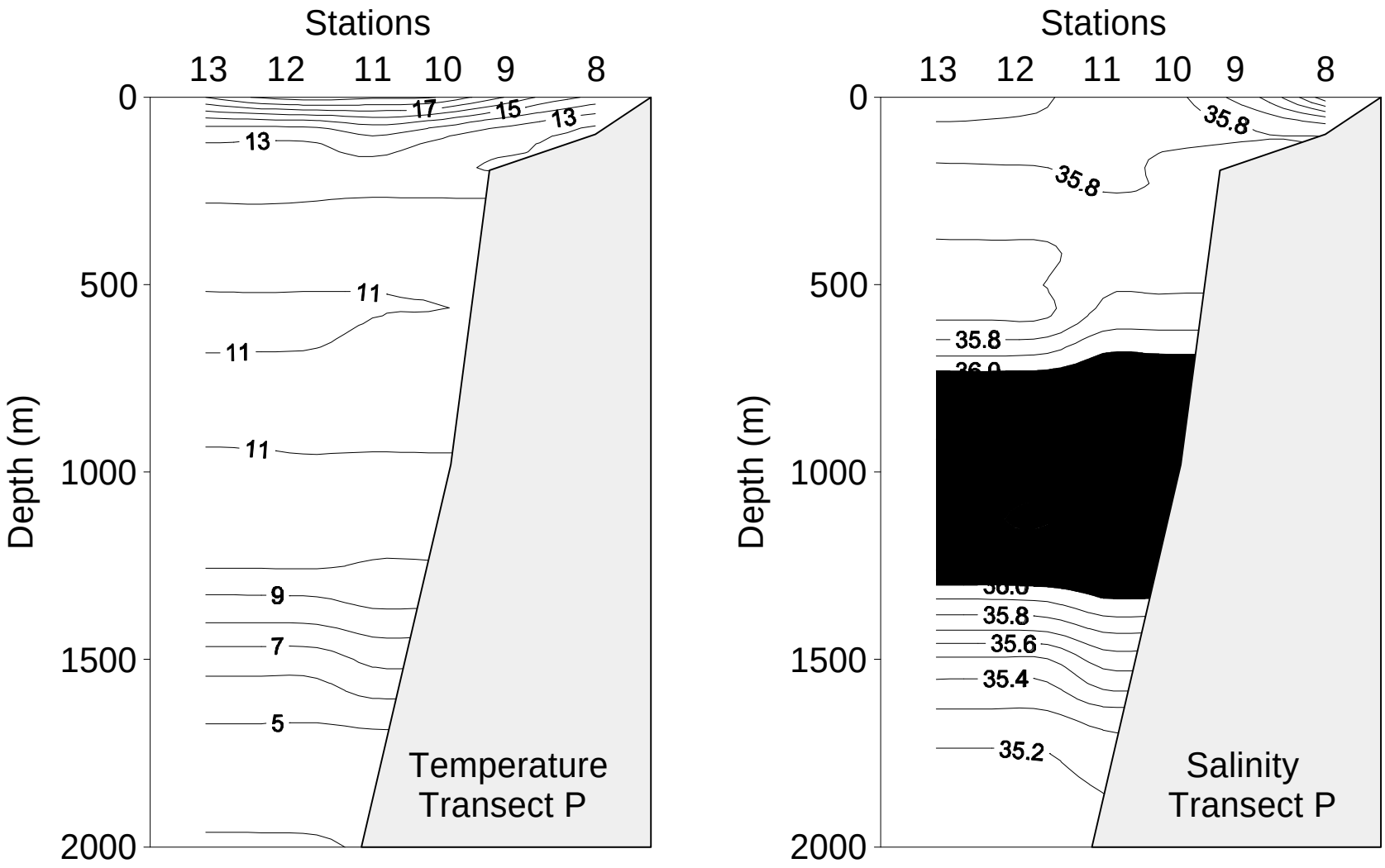

Figure 4. Temperature and salinity distribution down to 2000 m in Transect P.

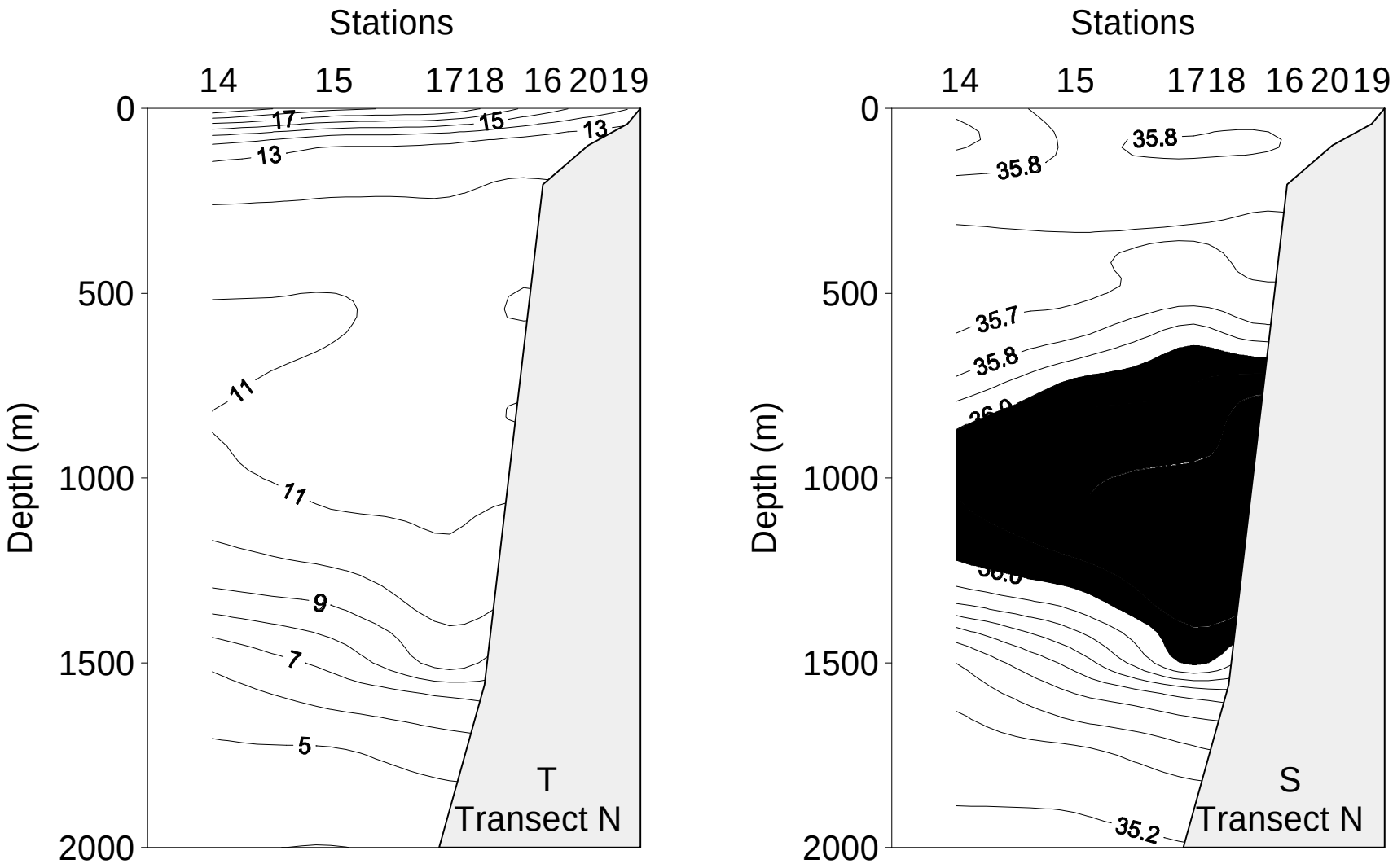

Figure 5.Distributions of temperature and salinity down to 2000 m in Transect N.

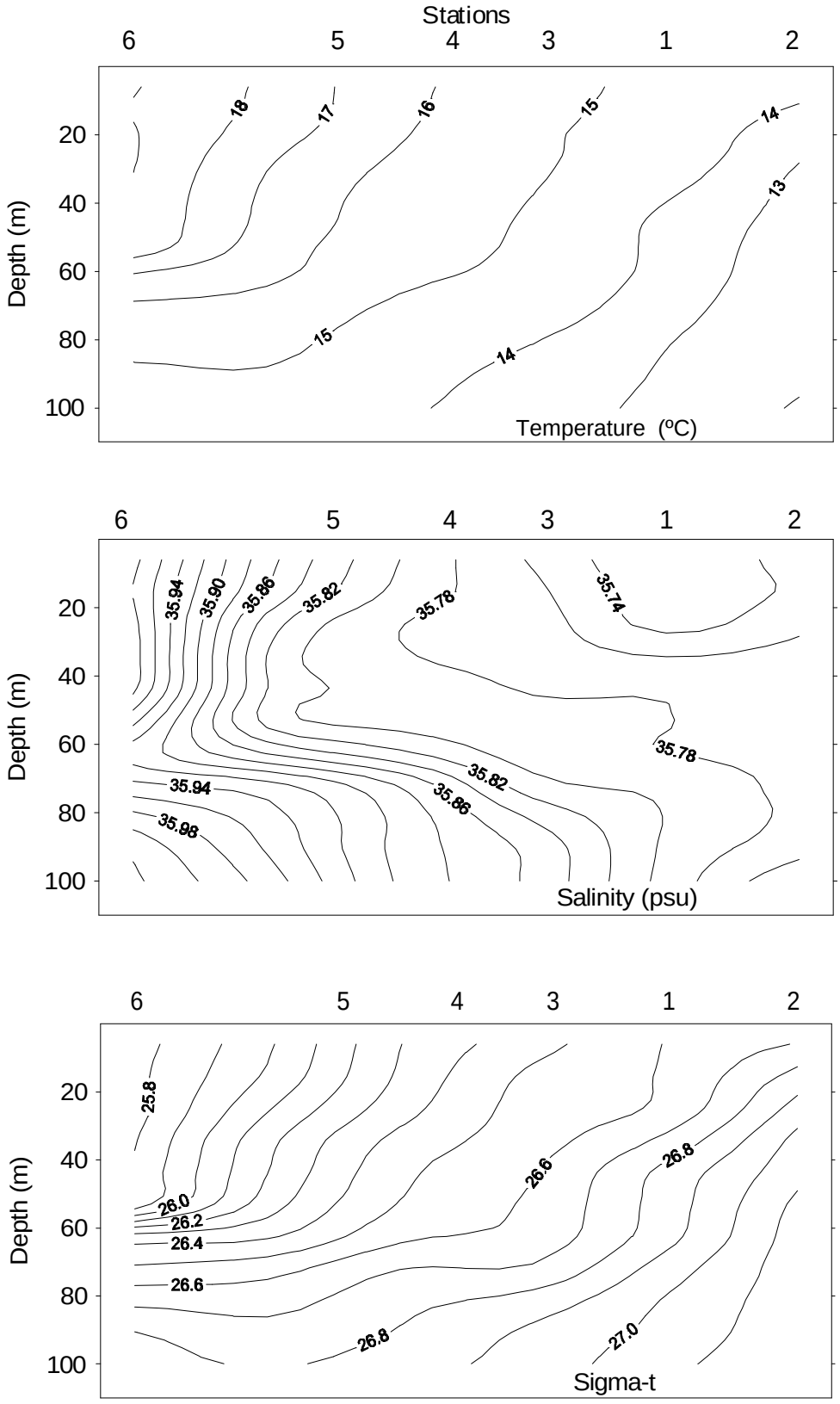

Figure 6. Distribution of temperature, salinity and sigma-t in the upper 100 m of Transect S.

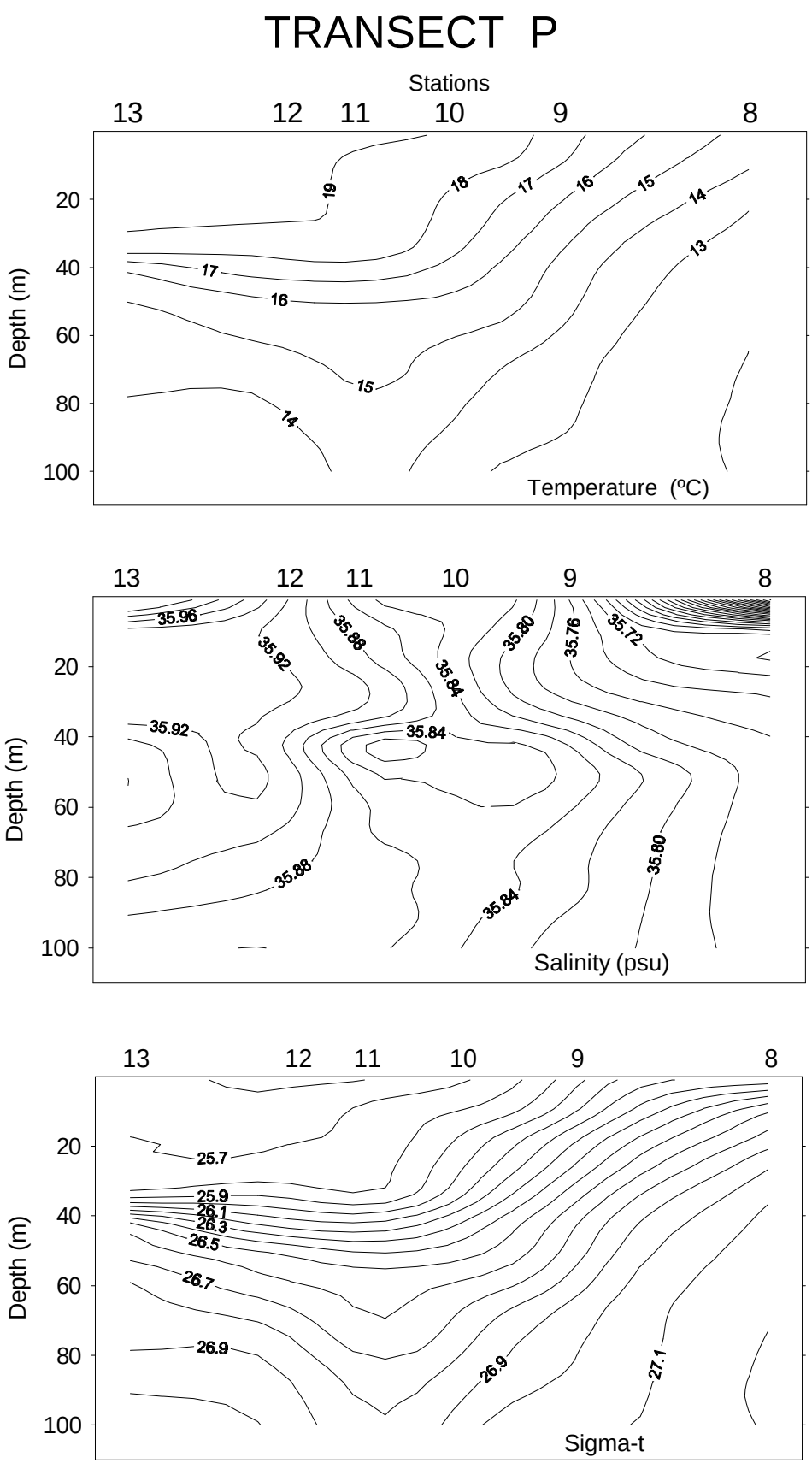

Figure 7. Distributions of temperature, salinity and sigma-t in the upper 100 m of Transect P.

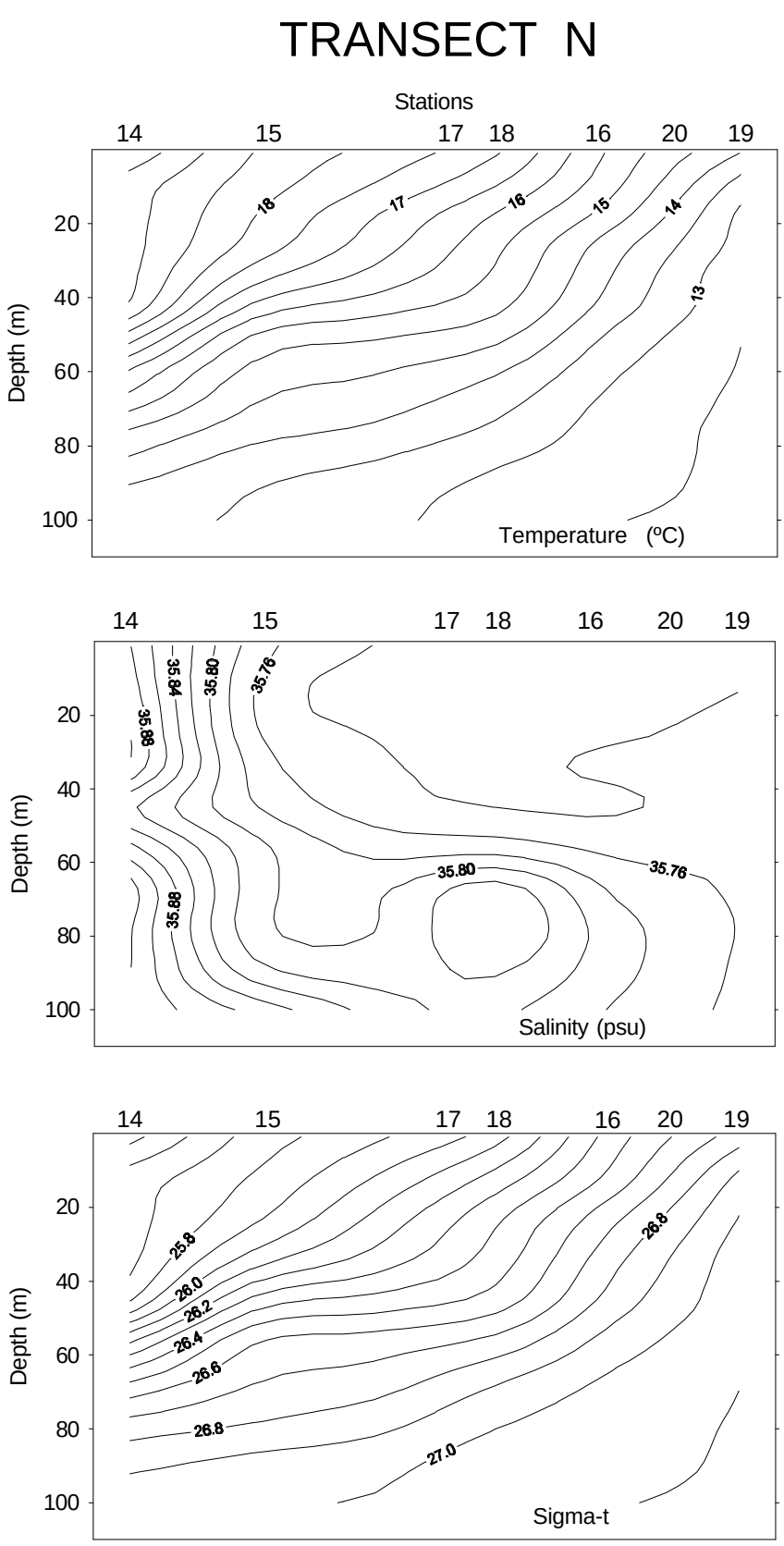

Figure 8. Distributions of temperature, salinity and sigma-t in the upper 100 m of Transect N.

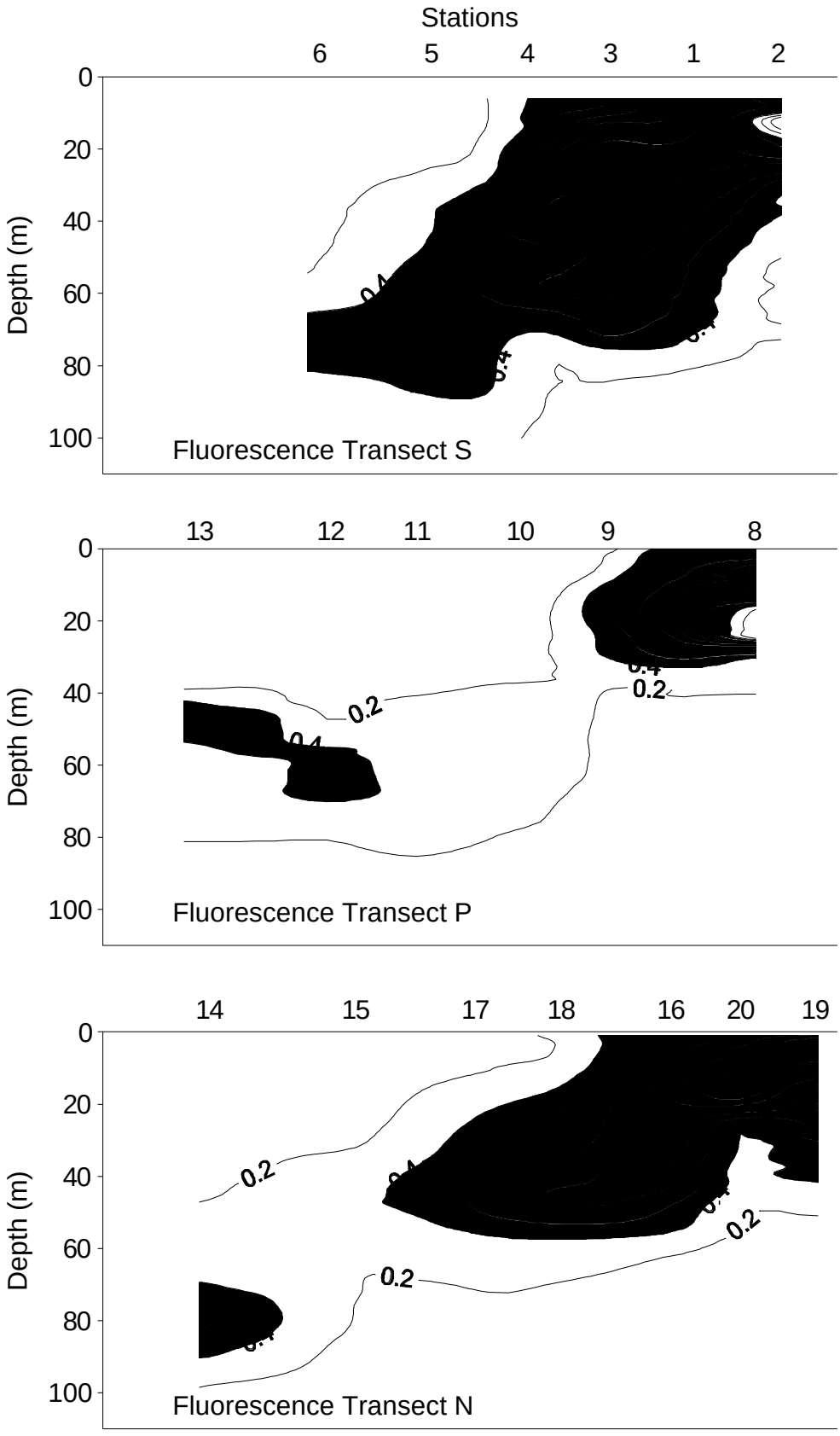

Figure 9. Distribution of 'in situ' fluorescence in the upper 100 m.

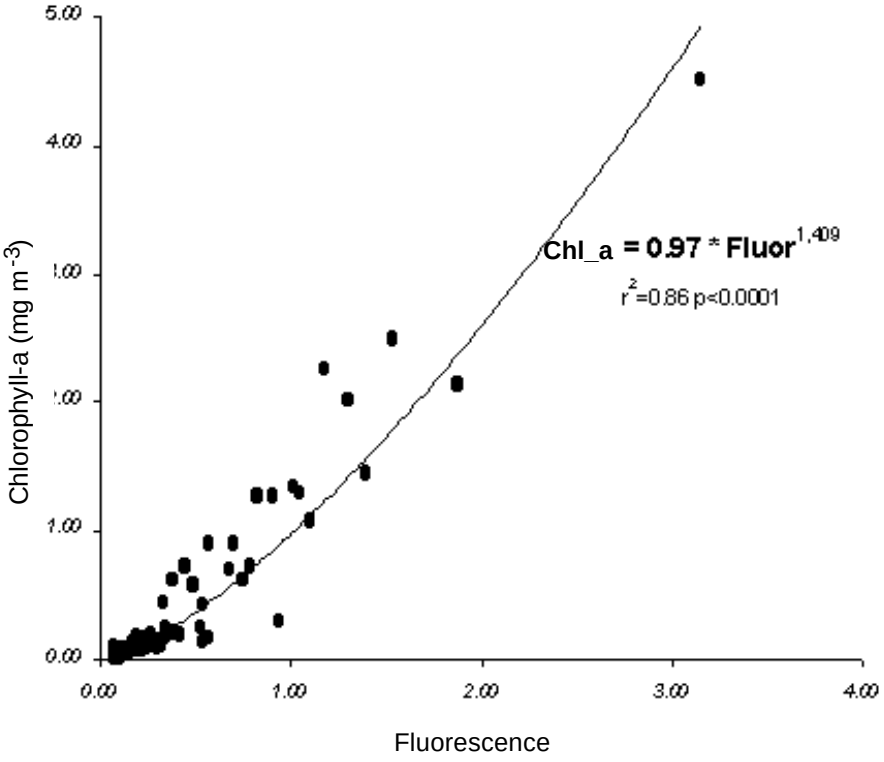

Figure 10. Calibration of CTD Mark-III fluorescence sensor.