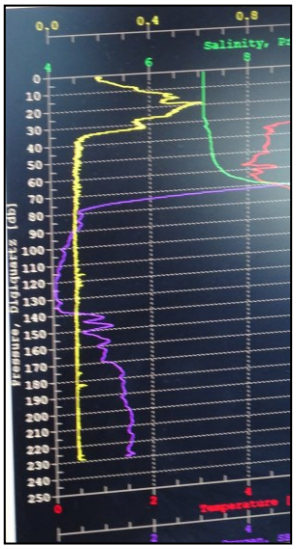
CRUISE REPORT

R/V Aranda

COMBINE 2 / 2015

25 May - 9 June, 2015



This report is based on preliminary data and is subject to changes.

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R/V Aranda Cruise Report

COMBINE 2 / 2015

Period: 25.5. – 9.6. 2015

Chief scientist: Kari K. Lehtonen (Finnish Environment Institute, Marine Research Centre)

Photos in the report by KKL.

1. General description of the cruise

The r/v *Aranda* COMBINE 2 expedition headed first to the Gulf of Bothnia wherefrom it continued via the Åland Sea towards the southern parts of the Gotland Basin. The main purpose of the expedition was to take samples for the monitoring of macrozoobenthos, bottom water oxygen levels and general hydrography in Baltic Sea open-sea areas. Sampling carried out onboard contributes to the HELCOM Baltic Sea monitoring programme and also to the long-term monitoring study on macrozoobenthic communities of SYKE Marine Research Centre. Monitoring samples were also collected for phyto- and zooplankton. In addition, water and sediment samples were collected for the monitoring of radioactive substances (HELCOM-MORS and Finnish Radiation and Nuclear Safety Authority). Also other studies were carried out during the cruise, including observations on the progress and effects of the major saltwater inflow that occurred in the southern Baltic Sea in December 2014.

2. Participants

The scientific staff of COMBINE 2 consisted of employees of the Marine Research Centre (MRC) of the Finnish Environment Institute (SYKE), Finnish Meteorological Institute (FMI), and University of Helsinki (HU).

Scientific staff:

Chief scientist:	Kari Lehtonen	SYKE	25.05. - 09.06.2015
CTD/ICT chiefs:	Panu Hänninen	SYKE	25.05. - 09.06.2015
	Heini Jalli	FMI	25.05. - 29.05.2015
Chief chemists:	Jere Riikonen	SYKE	01.06. - 09.06.2015
	Tanja Kinnunen	SYKE	01.06. - 09.06.2015
	Kirsi Hyvärinen	SYKE	25.05. - 29.05.2015

Susanna Hyvärinen	SYKE	25.05. - 09.06.2015
Marko Jaale	SYKE	25.05. - 09.06.2015
Markku Jansson	FMI	25.05. - 09.06.2015
Harri Kankaanpää	SYKE	01.06. - 09.06.2015
Samuli Korpinen	SYKE	25.05. - 29.05.2015
Pekka Kosloff	FMI	25.05. - 29.05.2015
Ilkka Lastumäki	SYKE	25.05. - 29.05.2015
Simo Siiriä	FMI	01.06. - 09.06.2015
Eetu Savilahti	FMI	25.05. - 09.06.2015
Riku Mesiniemi	SYKE	25.05. - 09.06.2015
Mikko Jalo	SYKE	25.05. - 09.06.2015
Gunnar Jakobs	UH	01.06. - 09.06.2015
Jukka-Pekka Myllykangas	UH	01.06. - 09.06.2015

3. Cruise route

The COMBINE 2 cruise departed from Helsinki (Jätkäsaari Harbour) on Monday, May 25, 2015 at 18:00 hours. The first areas visited for sampling and observations were located in the Bothnian Sea and the Bothnian Bay. After a weekend break in Vaasa the expedition continued southwards towards the Åland Sea, continuing to the Baltic Proper and Eastern Gotland Basin. Completing the cruise with observations in the western Gulf of Finland, *Aranda* returned to its home harbour on Tuesday morning of June 9, 2015 at 07:00 hours. The cruise route (in two maps showing the two legs of the cruise) with all the stations is presented in Fig. 1. Station data with coordinates, depth and arrival time is given in Table 1.

4. Sampling information

A synopsis of the samples collected and observations made is given in Tables 2 and 3. CTD data was obtained from all study sites while all other sampling activities were carried out according to the pre-agreed sampling programme. In Fig. 11, examples of CTD profiles are given from selected stations visited during the cruise. In addition, a more detailed examination was carried out in the Eastern Gotland Basin on the status and impacts of the major saltwater inflow recorded in December 2014 (*Saltwater inflow monitoring report*).

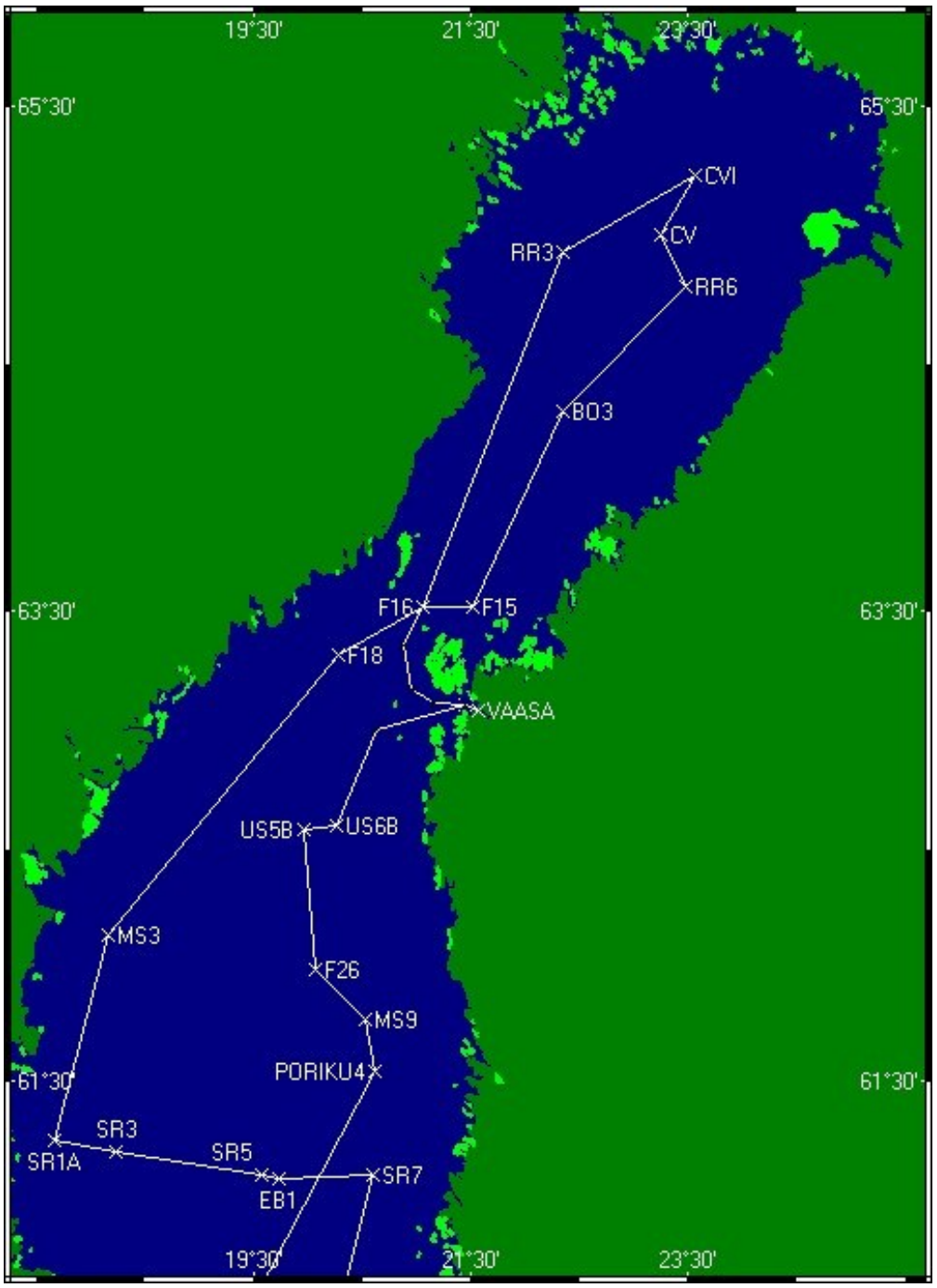


Fig. 1. COMBINE 2 2015 expedition. Sampling stations in the Gulf of Bothnia.

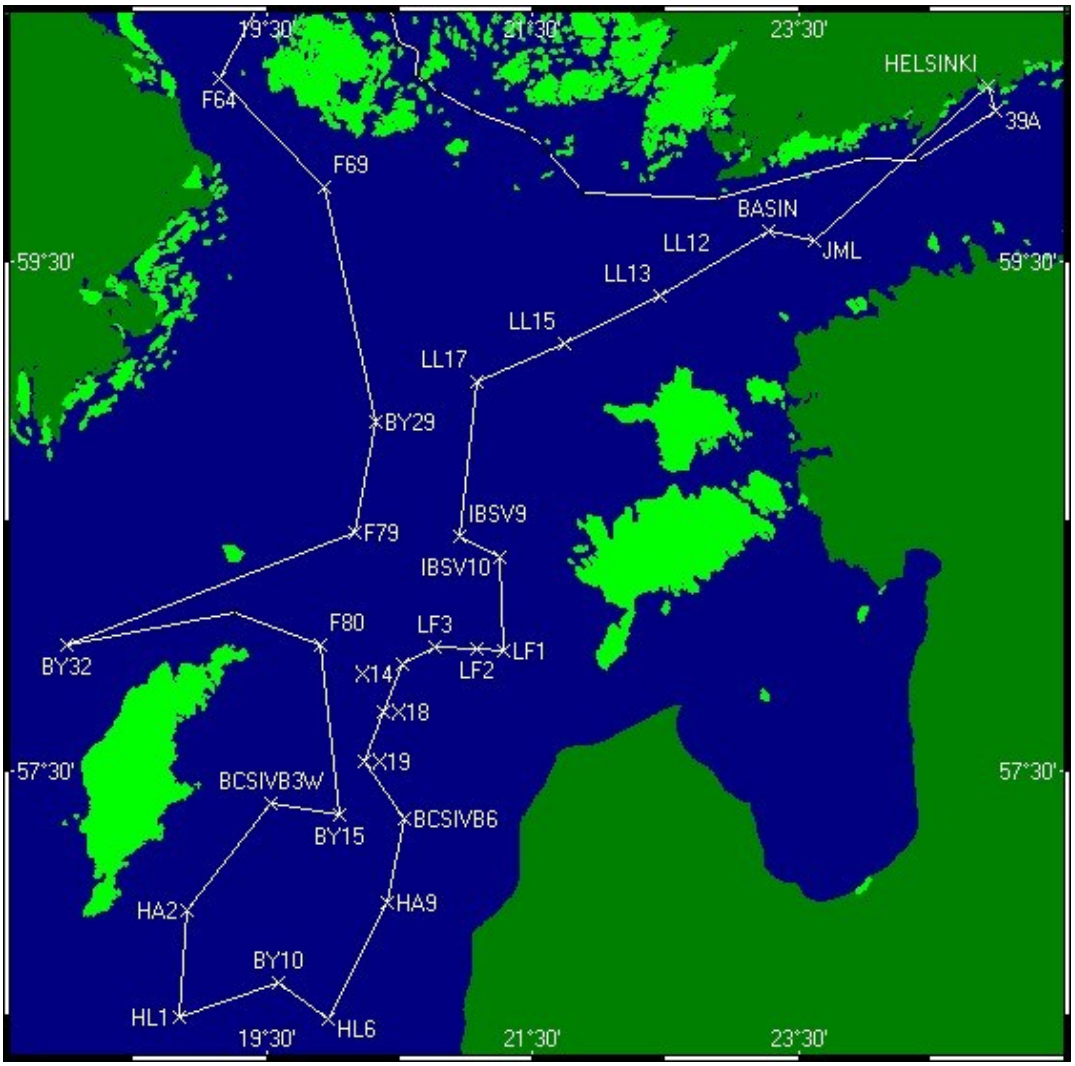


Fig. 1 (Cont'd). COMBINE 2 2015 expedition. Sampling stations in the Baltic Proper and Eastern Gotland Basin.

Table 1. Station data from the COMBINE 2 2015 expedition.

INDEX	STATION	LAT.	LON.	DEPTH [m}	DATE	TIME [UTC]
0273	39A	N60.0401	E024.5881	43	20150525	1446
0274	SR7	N61.0501	E020.3579	81	20150526	0726
0275	EB1	N61.0400	E019.4379	131	20150526	1049
0276	SR5	N61.0500	E019.3478	126	20150526	1214
0277	SR3	N61.1100	E018.1380	75	20150526	1900
0278	SR1A	N61.1400	E017.3979	61	20150526	2125
0279	MS3	N62.0807	E018.0979	88	20150527	0307
0280	F18	N63.1886	E020.1636	103	20150527	1145
0281	F16	N63.3101	E021.0377	50	20150527	1547
0282	F15	N63.3101	E021.3078	50	20150527	1831
0283	BO3	N64.1812	E022.2059	110	20150527	2330
0284	RR6	N64.4802	E023.2877	90	20150528	0450
0285	CV	N65.0002	E023.1477	91	20150528	0745
0286	CVI	N65.1402	E023.3377	69	20150528	1051
0287	RR3	N64.5602	E022.2076	98	20150528	1605
0288	F9	N64.4202	E022.0377	128	20150528	1916
0289	US6B	N62.3601	E020.1578	85	20150602	0012
0290	US5B	N62.3517	E019.5813	230	20150602	0307
0291	F26	N61.5901	E020.0378	143	20150602	1016
0292	MS9	N61.4601	E020.3183	104	20150602	1422
0293	PORIKU4	N61.3241	E020.3719	100	20150602	1729
0294	F64	N60.1134	E019.0855	297	20150603	0301
0295	F69	N59.4700	E019.5580	199	20150603	1105
0296	BY29	N58.5300	E020.1900	168	20150604	0308
0297	BY29	N58.5300	E020.1900	169	20150604	0551
0298	BY29	N58.5300	E020.1900	169	20150604	0739
0299	F79	N58.2700	E020.1000	106	20150604	1058
0300	BY32	N57.5999	E017.5981	176	20150604	1918
0301	F80	N58.0000	E019.5381	200	20150605	0444
0302	BY15	N57.1920	E020.0300	245	20150605	1036
9303	BY15	N57.1920	E020.0300	245	20150605	1330
0304	BY15	N57.1920	E020.0300	245	20150605	1401
0305	BCSIVB3W	N57.2200	E019.3175	120	20150605	2115
0306	HA2	N56.5590	E018.5390	127	20150606	0155
0307	HL1	N56.2950	E018.5000	103	20150606	0543
0308	BY10	N56.3800	E019.3500	147	20150606	1044
0309	HL6	N56.2900	E019.5800	105	20150606	1430
0310	HA9	N56.5750	E020.2460	89	20150606	1905

Table 1. (Cont'd)

0311	BCSIVB6	N57.1801	E020.3200	119	20150606	2203
0312	X19	N57.3200	E020.1400	177	20150607	0038
0313	X18	N57.4400	E020.2300	145	20150607	0310
0314	X14	N57.5540	E020.3140	101	20150607	0504
0315	LF3	N57.5950	E020.4600	98	20150607	0706
0316	LF2	N57.5900	E021.0500	83	20150607	1045
0317	LF1	N57.5895	E021.1684	69	20150607	1326
0318	IBSV10	N58.2100	E021.1481	81	20150607	1719
0319	IBSV9	N58.2600	E020.5681	91	20150607	1946
0320	LL17	N59.0200	E021.0477	177	20150608	0302
0321	LL15	N59.1100	E021.4481	135	20150608	1041
0322	LL13	N59.2200	E022.2781	107	20150608	1435
0323	BASIN	N59.3672	E023.1695	77	20150608	2019
0324	JML	N59.3491	E023.3761	83	20150609	0020

Table 2. Sampling during the COMBINE 2 2015 expedition: parameters and equipment used, and institutes responsible for the analyses.

Code	**Purpose**	**Sampling device**	**Analysis**
O2_BOTTOM	Near-bottom oxygen concentration/H2S	Water bottle	SYKE
CTD + ROSETTE	Salinity, temperature, depth, conductivity, fluorescence, alkalinity, and nutrients (NO2, NO3, SiO2, PO4, NH4)	CTD + water bottles	IL/SYKE
"PULSE" WATER	Chemistry and microbiology of seawater (inflow studies)	CTD + water bottles	SYKE/UH
PHYTO	Phytoplankton community	Water bottle	SYKE
ZPL	Zooplankton community	WP2 net	SYKE
DOC/N/M	Dissolved organic carbon, nitrogen and matter	CTD + water bottles	SYKE
H2S/O2 PROBE	Hydrogen sulphide and oxygen boundary layer in the water column	RIPA sensor	SYKE
WATER_STUK	Radioactivity in seawater	Water bottle 30 l	SYKE
BENTHOS	Benthos community	van Veen / Box corer	SYKE
SED_STUK	Radioactivity in sediments	GEMAX dual corer	STUK
SED_MHS	TBT profiles in bottom sediments	GEMAX dual corer	SYKE
SED_CONTEST	Sediments for CONTEST project	van Veen	SYKE

Table 3. Sampling during the COMBINE 2 2015 expedition. Codes as in Table 2.

	WATER PHASE								SEA BOTTOM			
	O2_BOTTOM	CTD + ROSETTE	"PULSE" WATER	PHYTO	ZPL	DOC/N/M	H2S/O2 PROBE	WATER_STUK	BENTHOS	SED_STUK	SED_MHS	SED_CONTEST
HELSINKI												
SR7	x	x				x			x			
SR5	x	x		x	x	x+5L			x		x	x
EB1								x		x		
SR3	x	CTD							x			
SR1A	x	x				x			x			
MS3	x	x				x			x			
F18	x	x				x			x			
F16	x	x		x	x	x+5L			x			
F15	x	CTD							x			
BO3	x	x		x	x	x			x			
RR6	x	x							x			
CV	x	x							x			
CVI	x	x				x+5L		x	x	x		
RR3	x	x							x			
F9	x	x							x			
VAASA												
US6B	x	x							x			
US5B	x	x		x	x	x		x	x			
F26	x	x							x			
MS9	x	x				x			x			
PORIKU4	x	CTD							x			
F64	x	x		x	x	x+5L			x			
F69	x	x							x			
BY29	x	x	+ 2 Rosette				x		x			
F79	x	x	(x)				x		x			
BY32	x	x	x						x			
F80	x	x	x				x		x			
BY15	x	x	+ 2 Rosette				x	x	x	x		
BCSIVB3W	x	x							x			
HA2	x	x					x		x			
HL1	x	CTD		x	x	x+5L			x			
BY10	x	x	x						x			
HL6	x	x							x			
HA9	x	CTD							x			
BCSIVB6	x	x							x			
X19	x	CTD										
X18	x	CTD										
X14	x	CTD										
LF3	x	CTD	(x)				x		x			
LF2	x	x							x			
LF1	x	CTD							x			
IBSV10	x	x							x			
IBSV9	x	CTD	(x)						x			
LL17	x	x	(x)	x	x		x	x		x		
LL15	x	x										
LL13	x	CTD					x					
BASIN	x						x					
JML	x										x	
HELSINKI												
Additional measurements: seafloor integrity (echosounding close to Helsinki); 12 kHz overall echosounding ~300 NM												

Fig. 2. Yippie-yo-yay, we've caught the pulse! Joy has no limits when **Harri Kankaanpää** (left), **Panu Hänninen** and **Marko Jaale** celebrate catching the greatest saltwater pulse in 60 at the Eastern Gotland Basin station BY15. **Gunnar Jakobs** (right) is still wondering if it really is true… it is! Champagne must wait, the work only begins here…

5. Observations

SPECIAL: Saltwater inflow monitoring report

1. General information

Observations in the northern Baltic Proper (BP) and Eastern Gotland Basin (EGB) related to the monitoring of the major saltwater inflow of December 2014 were made during the COMBINE 2 expedition of r/v *Aranda* during June 4-7 2015 as follows:

- hydrography (temperature, salinity, O_2, fluorescence)
- chemistry (inorganic N, P and Si, pH, H_2S)
- benthos

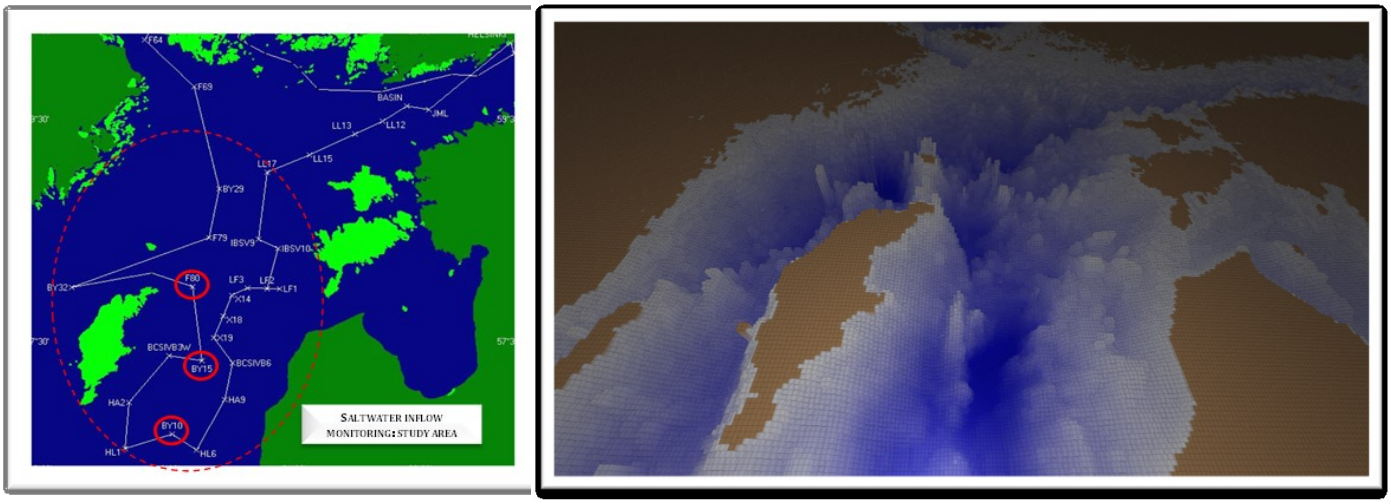


Fig. 3. Left: route of COMBINE 2 cruise in the Baltic Proper. The specific area for studies on the saltwater inflow and its effects (*dashed line*) marked with the stations described in detail in this report (*circles*). Right: a bathymetric overview of the Baltic Proper region. Depth is exaggerated in the illustration.

2. Summary of main observations

Oxygen conditions

- The saltwater inflow is currently proceeding and increases oxygen conditions within two main depth sections of the water column;
- the inflow has reached at least stations F80 and LF3 in the northern edges of the Gotland Basin area;
- the inflow, where observed, appeared to have oxygenated two vertical layers (A: ca. 80-105 m and B: ca. 130 m downwards) within the water column;
- at several locations the intermediate water between sections A and B was still in or almost in anoxic state (O_2 < 0.5 ml/l; occasionally with H_2S);
- at the shallower stations flanking the main Gotland Deep basin the inflow layer B had not reached the near-bottom layer, but, instead, layer A had clearly (e.g., at F80) or with some uncertainty (at BY32) ventilated the water column;
- the inflow-induced oxygenation appeared to continue improving conditions as oxygen concentrations increased within section A at BY15 in ca. four hours;
- the ADCP system was tested alongside the physical observations for monitoring water velocities; some correlations with velocities and stratifications were noted;
- at the northern BP (BY29) no signs of the saltwater intrusion could be recorded;

- at the northern end of the western GB (BY32) (checking the possible spreading of the pulse around Gotland) no absolutely clear signs of the saltwater intrusion could be recorded (but cannot be fully excluded);
- similar to BY32, in the BP (F79), a possible slight anomaly in midwater O_2 concentration possibly indicating pulse effects (uncertain);
- at the northern end of the EGB (F80) a minor indication of intrusion of oxygenated water was detected at the midwater depth (section A, ca. 80-105 m);
- in the centre of the EGB (BY15) there was oxygenated water from ca. 130 m until the bottom (ca. 240 m) (ca. 0.5 to 1.75 mg/l);
- in shallower southwestern parts of the EGB no oxygen was found near the bottom;
- central southern part of the EGB (at BY10) was oxidized from 120 m until the bottom (almost anoxic water however between 100-110 m);
- in the northern EGB oxygenated bottoms without H_2S were found up to station X14 (but H_2S at bottom of X18 and LF3).

Nutrient concentrations

- Clear effects on nutrient concentrations in oxygenated areas.

Benthos

- Apparent slow recolonization of seabottoms in newly oxygenated areas in the southern EGB by the most tolerant species (polychaete *Harmothoë sarsi*) (Table 4).

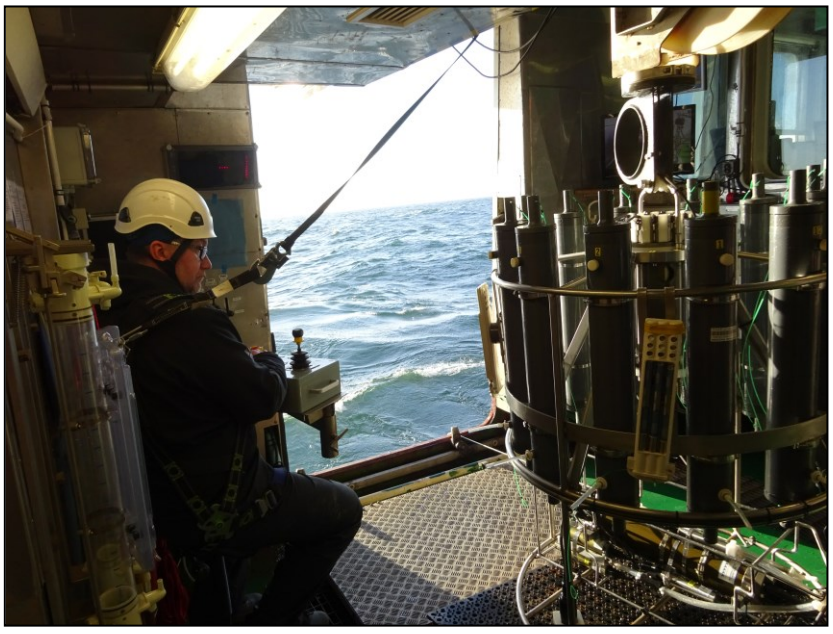
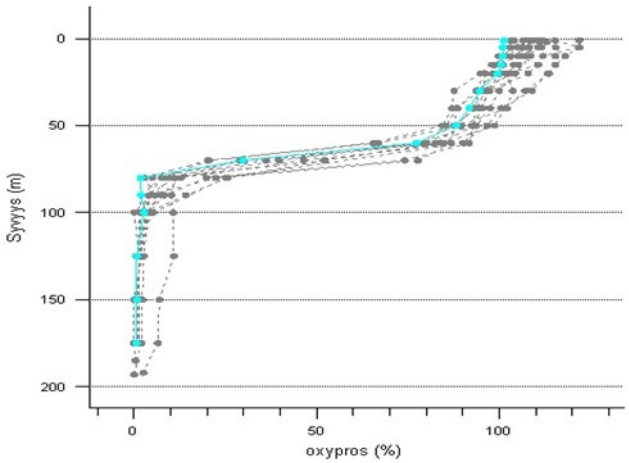
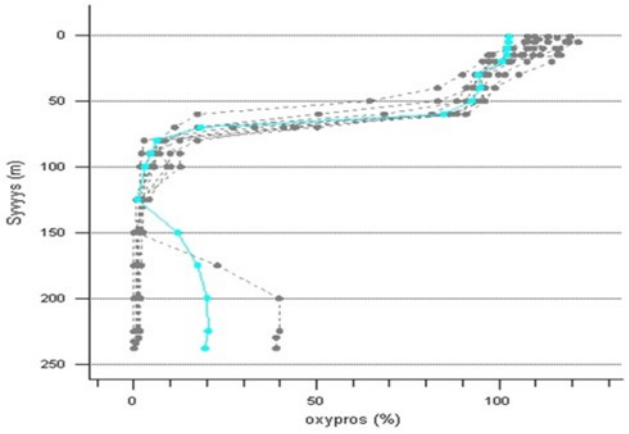


Fig. 4. In the driving seat. **Markku Jansson** operating our precious Sea-Bird CTD equipped with Rosette bottle sampler, guiding the gear safely through the depths. The occasionally more-or-less inclined horizon did not pose any problems for this crew.

F80



BY15



BY10

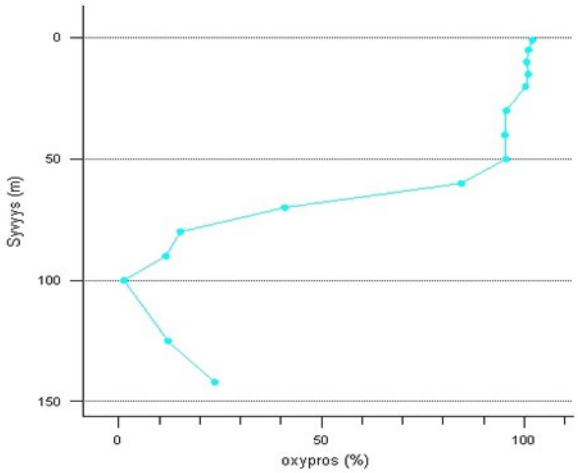
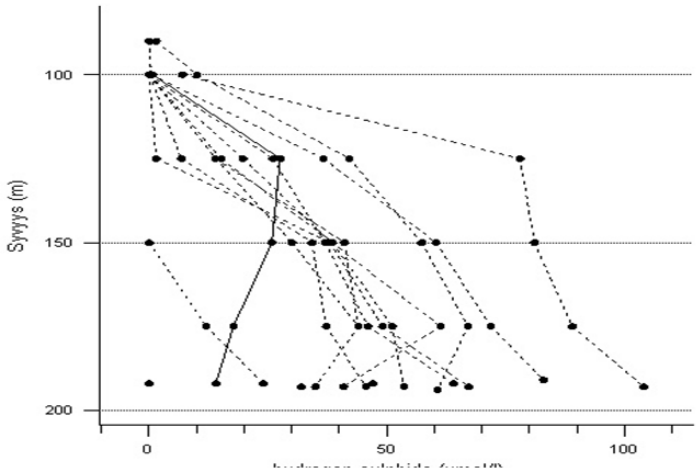


Fig. 5. O_2 profiles at stations F80 and BY15 in June 2015 (*blue line*) and May-June 2000-2014, and at station B10 in June 2015. NOTE: The other differering profile is from year 2003. The deepwater O_2 ventilated zone B (downwards ca. 125 m) caused by the inflow is clearly visible at BY15 and BY10.

F80



BY15

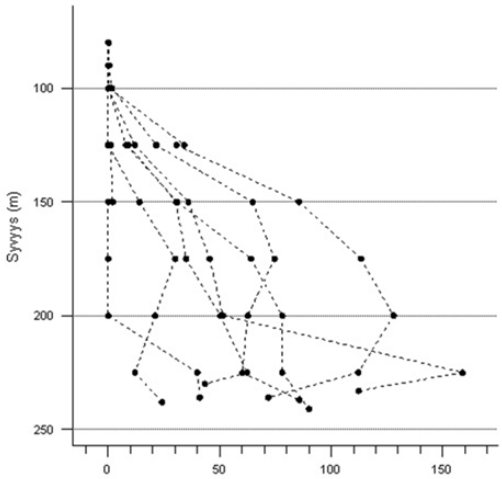
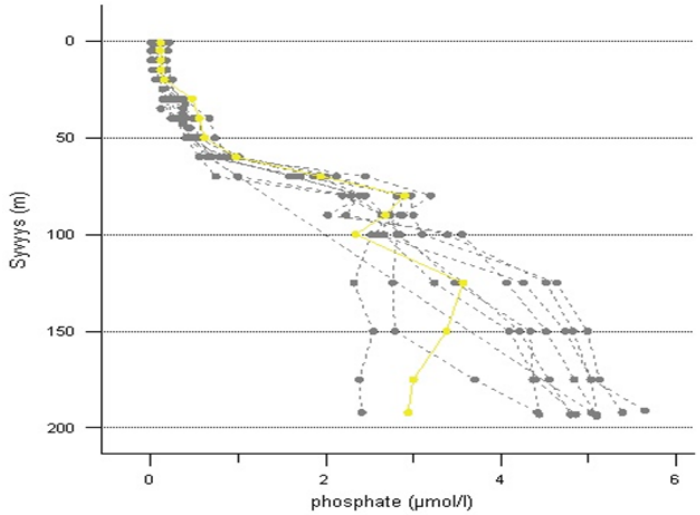
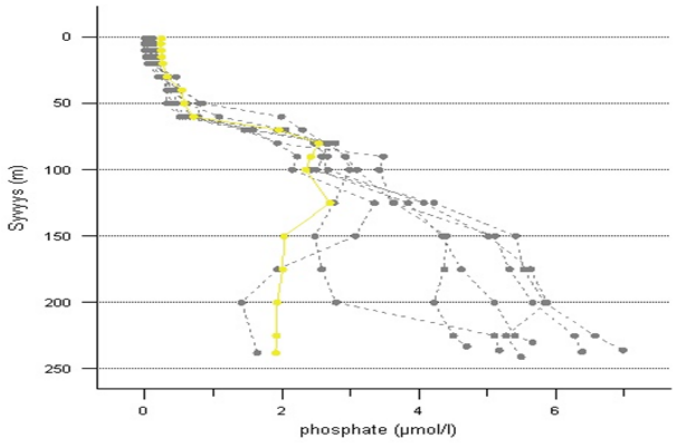


Fig. 6. H_2S profiles at stations F80 and BY15 in June 2015 (*solid line*) and May-June 2000-2014. NOTE: No H_2S was observed at BY15 at any depth in June 2015. At station BY10 H2S at 0.29 µmol/l was observed at midwater depth (100 m) in June 2015 (no image as only one sample was analysed). This reflects that the deepest oxygenated water layer occurred is yet to reach this anoxic "old water" layer.

F80



BY15



BY10

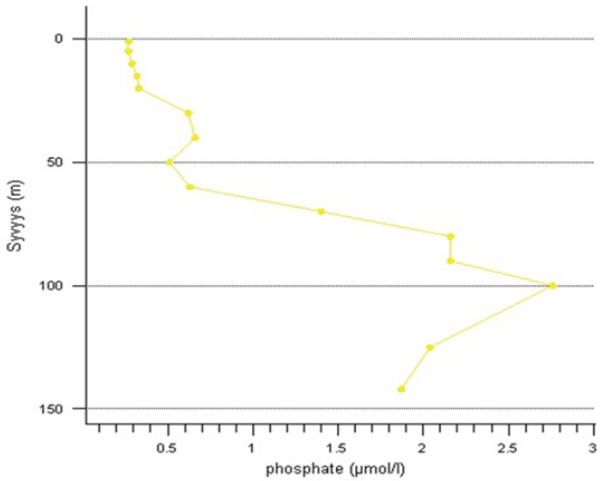
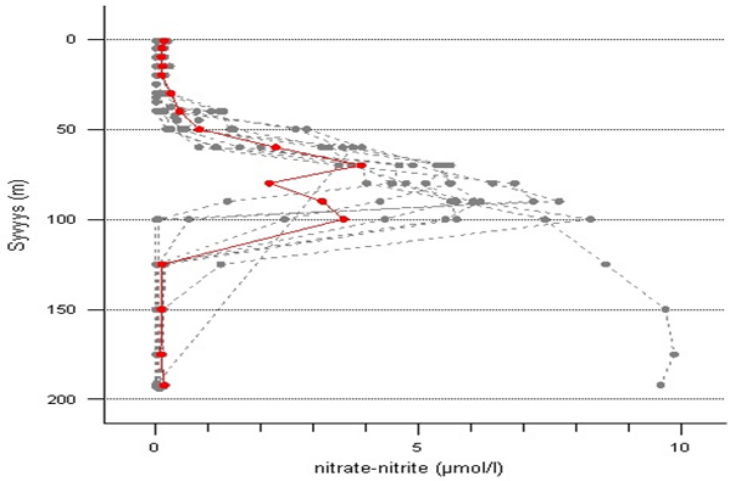
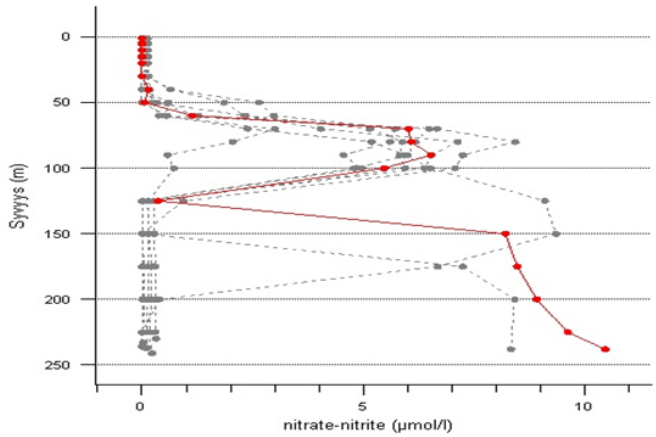


Fig. 7. PO_4-P profiles at stations F80 and BY15 in June 2015 (*yellow line*) and May-June 2000-2014, and at station B10 in June 2015 indicating declining trend in phosphates. NOTE: The other differering profile is from year 2003.

F80



BY15



BY10

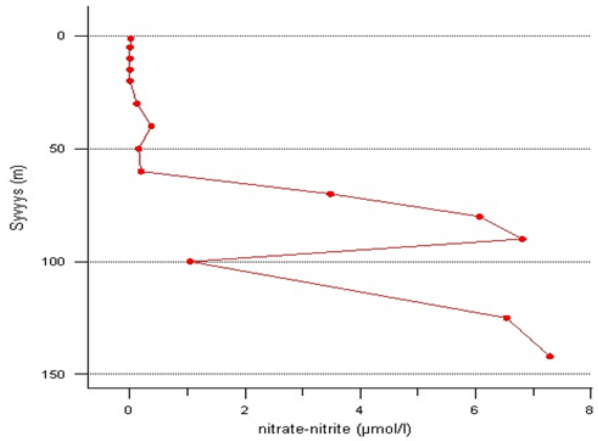


Fig. 8. NO_2-N + NO_3-N profiles at stations F80 and BY15 in June 2015 (*yellow line*) and May-June 2000-2014, and at station B10 in June 2015. The effects of the upper (A) and lower (B) inflow layer (A) on NH_3/NH_4+ → NO_3- turnover is clear. Remnants of the old anoxic seawater keep nitrate concentrations low at ca. 100-125 m (BY15 and BY10) and at > 125 m (F80).

Table 4. First estimation of the abundance of benthic organisms at selected stations compared with obseravations from most recent previous samplings at the study stations.

Station	Depth m	June 2015	Last observation/year
F80	192	no life	no life/2014
BY15	240	no life	no life/2014
BCSIVB3W	117	no life	no life/2010
HA2	123	no life	no life/2010
HL1	103	*Harmothoë sarsi* 6 ind/m^2	no life/2010
BY10	143	*Harmothoë sarsi* 11 ind/m^2	no life/1970
HL6	103	*Harmothoë sarsi* 39 ind/ m^2	*Harmothoë sarsi* 9 ind/ m^2/2009
HA9	86	*Harmothoë sarsi* 48 ind/m^2 *Pontoporeia femorata* 3/m^2	no life/2010
BCSIVB6	116	no life	no life
X19	171	no life	no previous data
LF3	96	no life	*Harmothoë sarsi* 9 ind/ m^2/2011
LF2	81	no life	no life/2014

Fig. 9. Early worm… with no birds around. The polychaete **Harmothoë sarsi** knows when its time to move in and grab a seat in the front row. Still only a few per square metre in the southern part of the Eastern Gotland basin, but the rapidly improving oxygen conditions over vast areas promise company for the toughest of the Baltic toughsters. What will the situation look like a year from now?

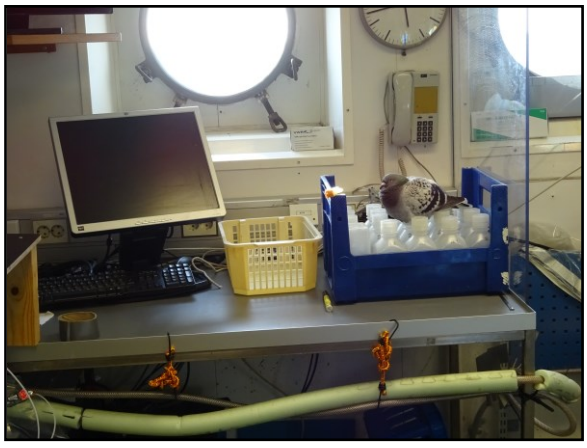
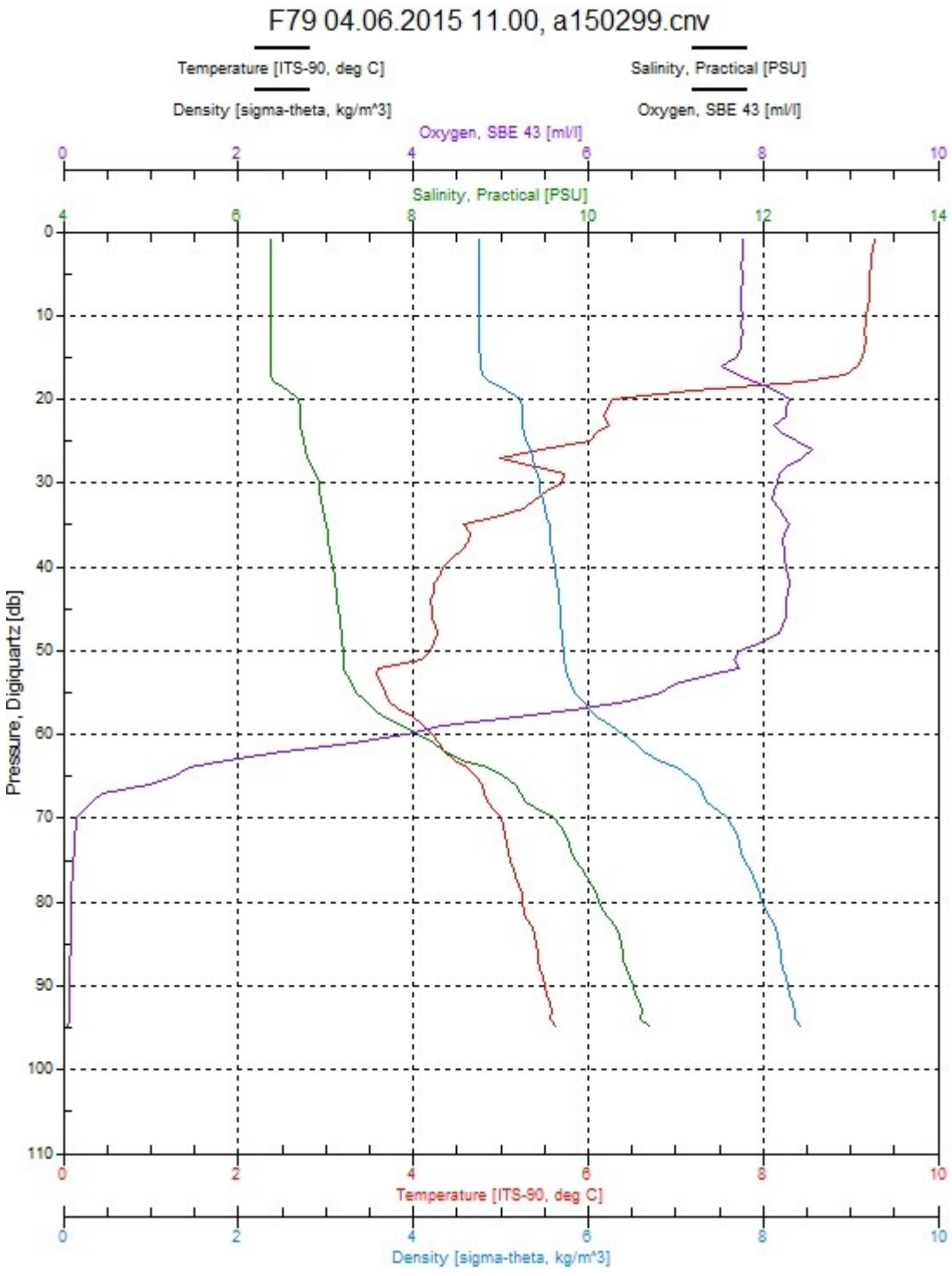
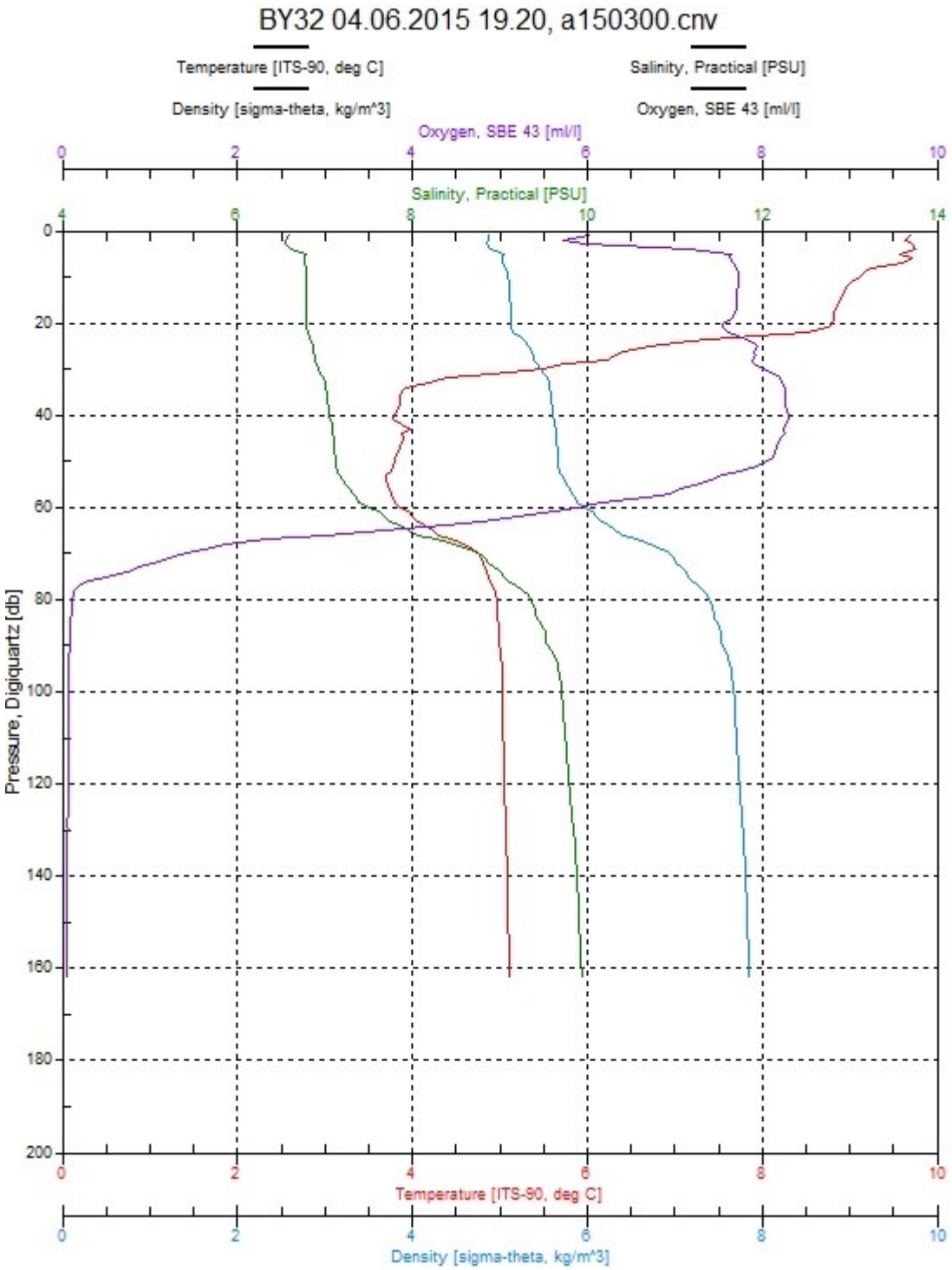


Fig. 10. Now the birds are around, and everywhere! *Main:* **Panu Hänninen** holds a little one lost at sea that had two ugly ticks removed from her head and set to new freedom. *Down left:* an exhausted pigeon taking a rest in the most comfortable place she could find aboard the vessel… and the sun warmed her sooo nicely. *Down right:* The Nutrient Bird **Tanja Kinnunen** attending the CTD lab to put the guys on track again… and then enjoys a well-earned refreshing yerba mate on the deck.



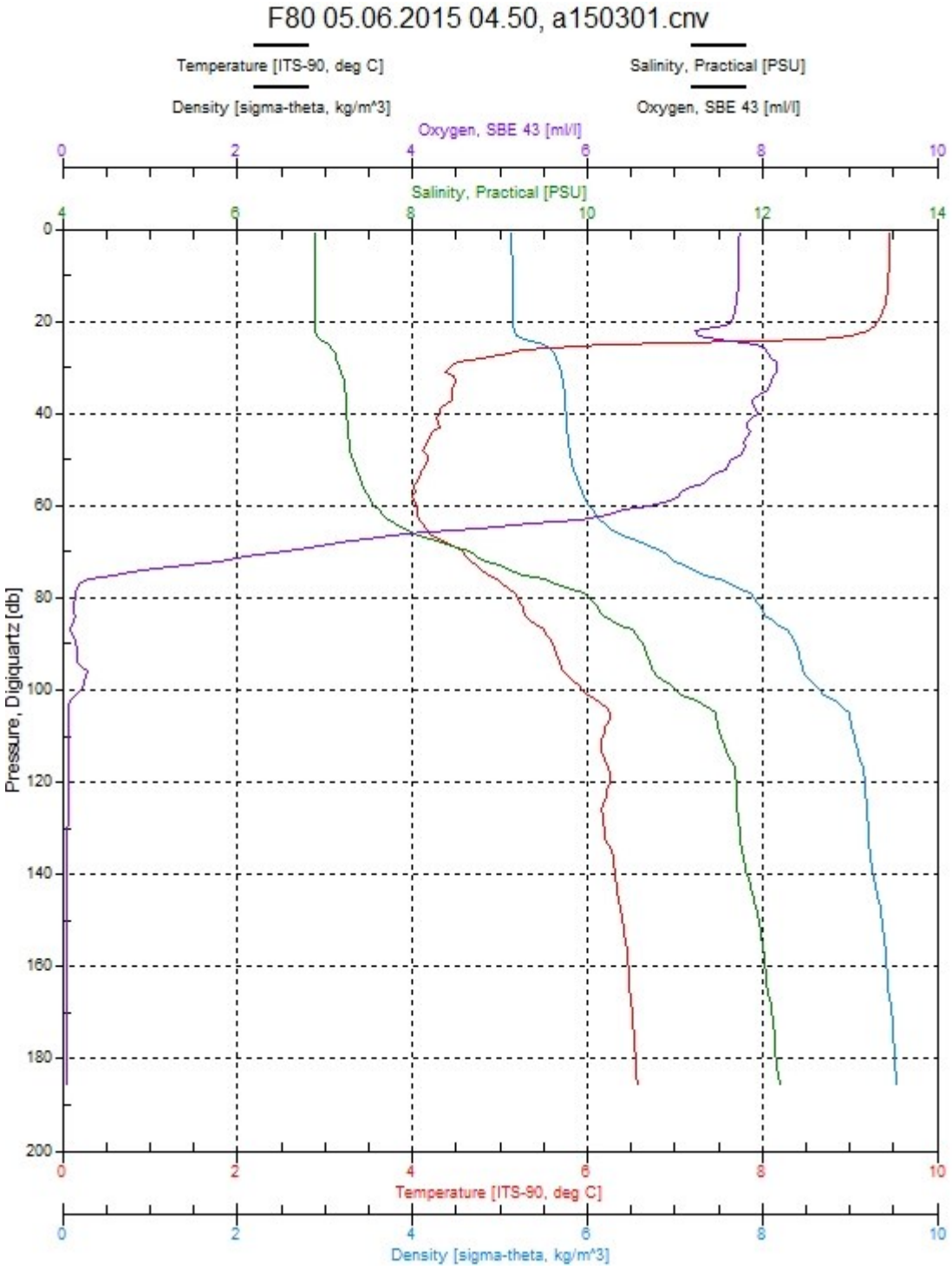
A trace of inflow layer A at 65 m?

Fig. 11. Vertical profiles of temperature, salinity, oxygen concentration and fluorescence at selected stations of the COMBINE 2 2015 cruise.



A trace of inflow layer A at 70-75 m?

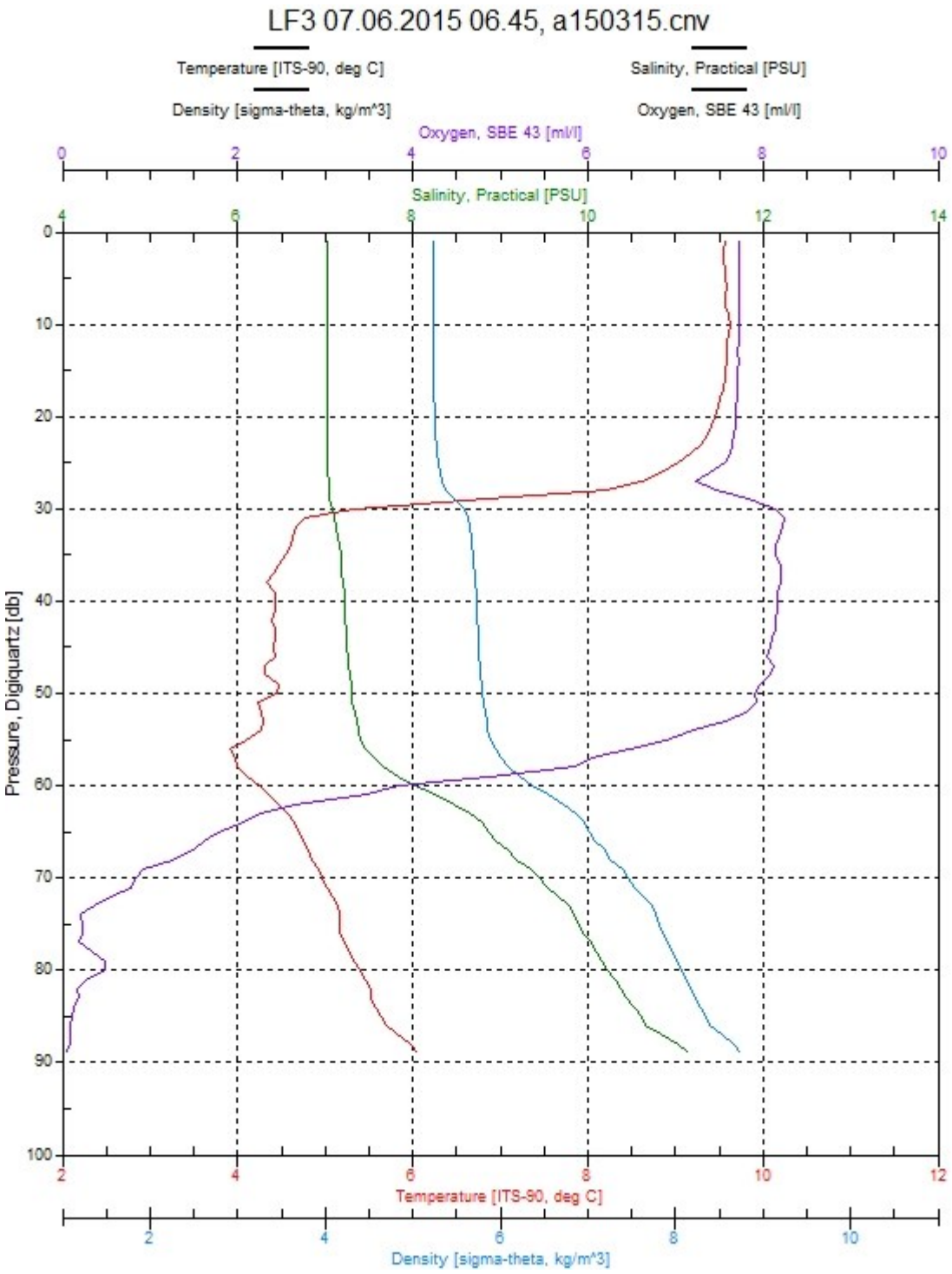
Fig. 11 (Cont'd).



A

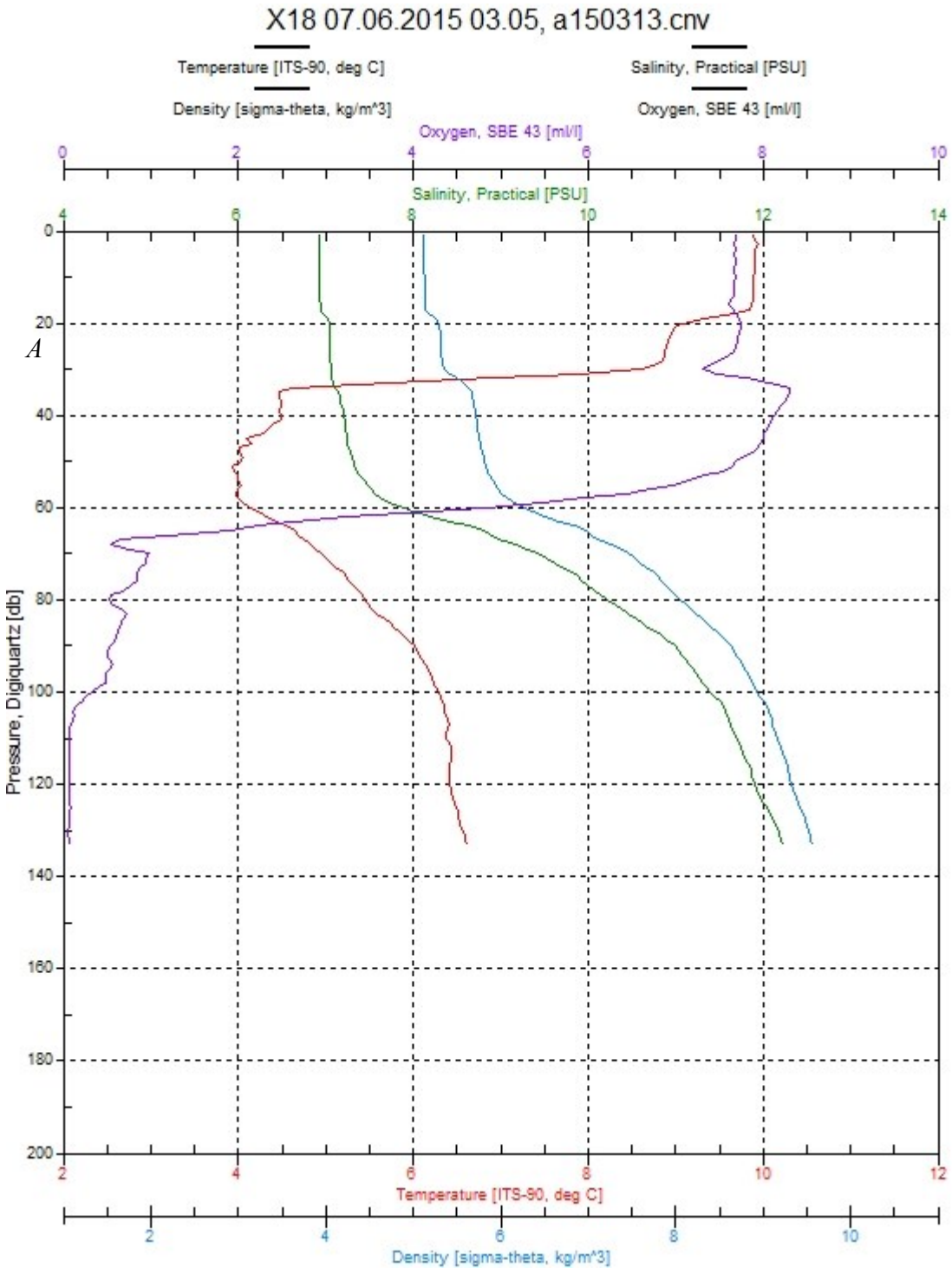
A rather clear inflow layer A at F80.

Fig. 11 (Cont'd).



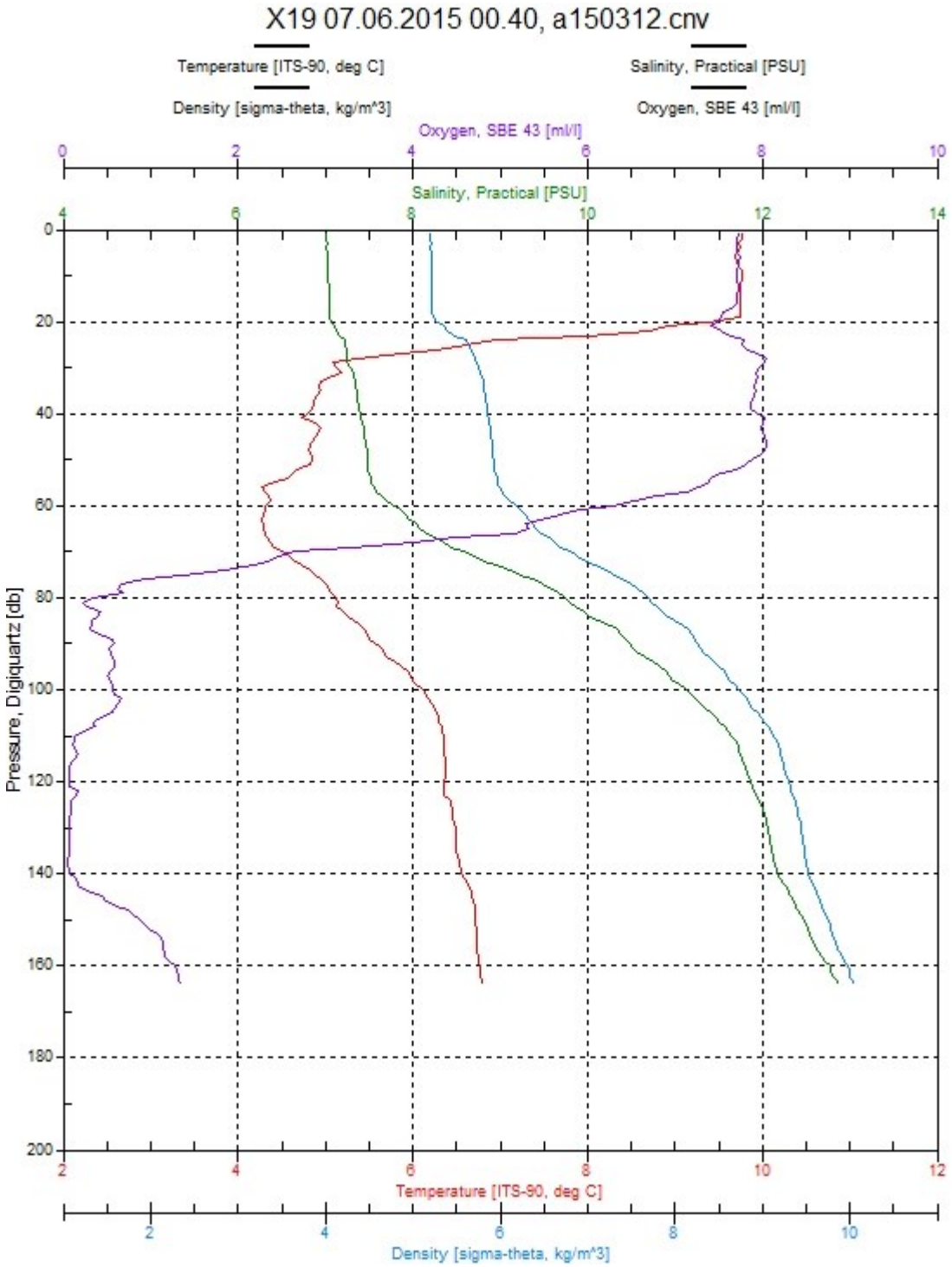
A rather clear inflow layer A at LF3.

Fig. 11 (Cont'd).



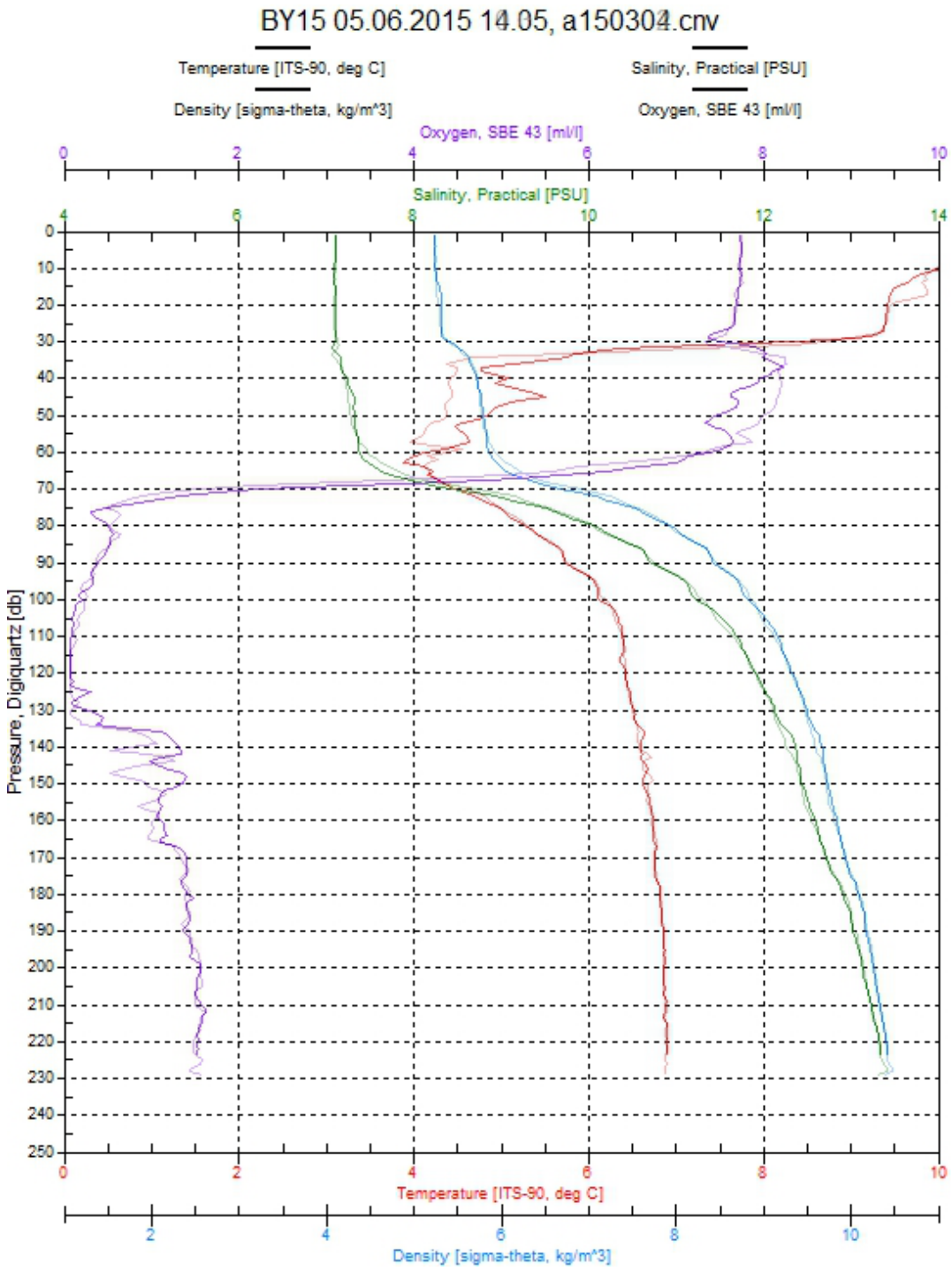
A clear inflow layer A at X18.

Fig. 11 (Cont'd).



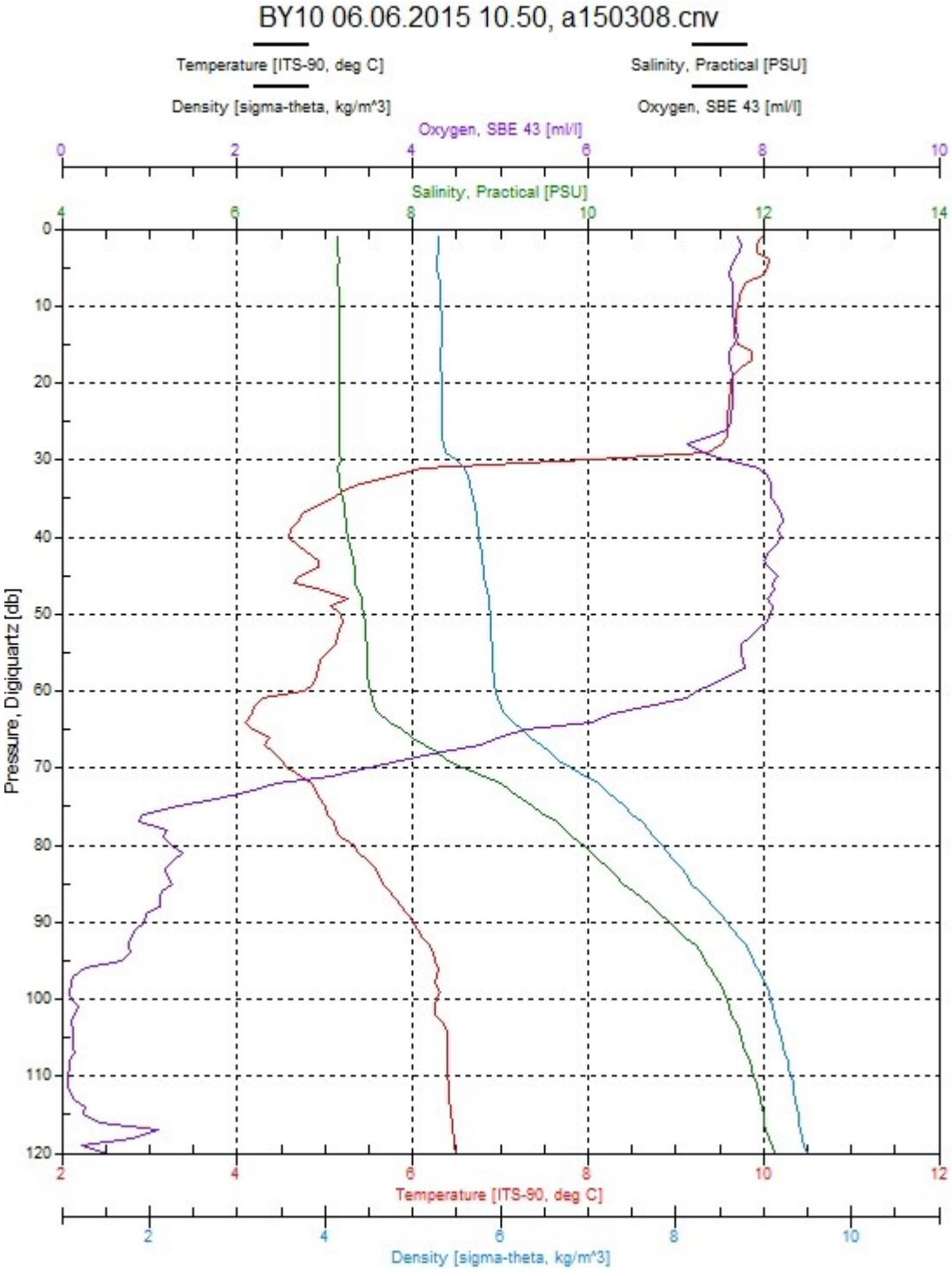
Clear inflow layers A and B at X19.

Fig. 11 (Cont'd).



Evolution in oxygenated zone B (130-230 m) between zero hours (faint coloured lines) and four hours (darker coloured lines) at station BY15 (Gotland Deep) on June 6, 2015.

Fig. 11 (Cont'd).



Clear inflow layers A and B (narrow) at BY10.

Fig. 11 (Cont'd).