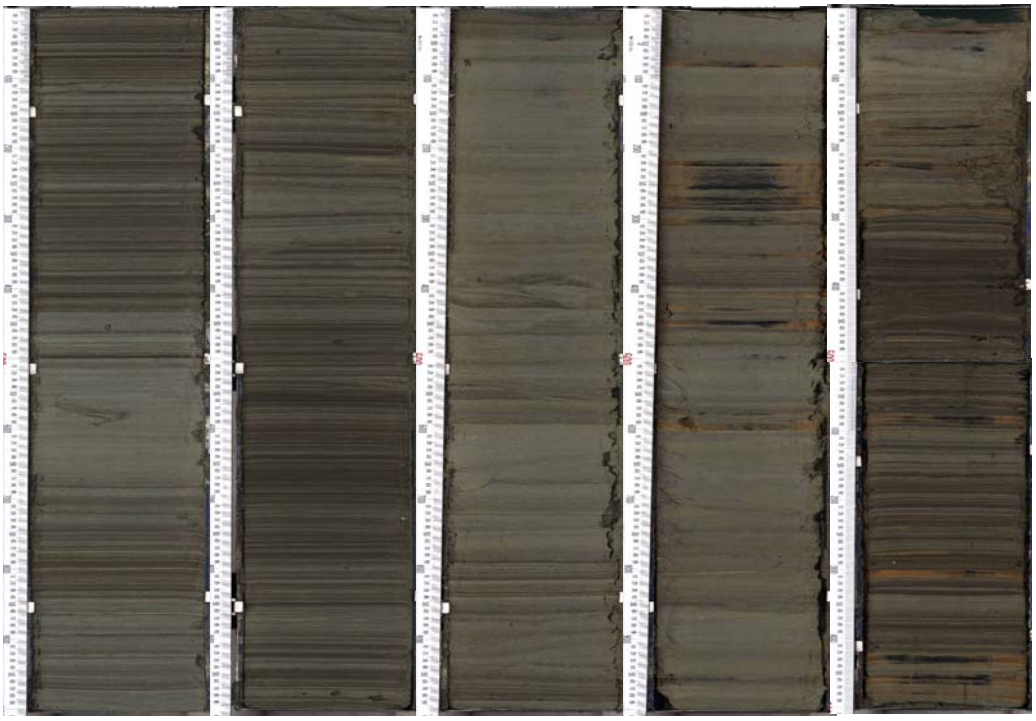
INFLOW Interim Report No. 4

High-resolution sediment cores covering the past 6000 years



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BONUS INFLOW

Title **High-resolution sediment cores covering the past 6000 years**	INFLOW Interim Report No. **4**		
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IOW = Leibniz Institute for Baltic Sea Research Warnemünde, Germany
VSEGEI = A. P. Karpinsky Russian Geological Research Institute, St. Petersburg, Russia

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CONTENTS

0 PREFACE

Precondition for high quality sediment proxy studies is well planned and successfully executed sediment coring.

This report will present a short concise description of the field work activities conducted (and the sediment cores collected) by the INFLOW project Partners in the Baltic Sea in 2009. INFLOW (Holocene saline water inflow changes into the Baltic Sea, ecosystem responses and future scenarios) (2009-2011) is one of the BONUS research programme (http://www.bonusportal.org/) projects and it is funded by national funding agencies (e.g. Academy of Finland), participating institutes and the EU Commission.

The INFLOW field expeditions were organized by the Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Germany (*RV Maria S. Merian*, *RV Professor Albrecht Penck*), A.P Karpinsky Russian Geological Research Institute (VSEGEI), Russia (*RV Ladoga*) and The Finnish Environment Institute (SYKE) (*RV Aranda*). The INFLOW scientists want to thank the organizing institutes IOW, VSEGEI and SYKE for the possibility to participate in the cruises and to finance (plus German Science Foundation DFG) most of them.

In addition the INFLOW partners want to thank the personnel of research vessels for the help, co-operation, maintenance and pleasant company during the cruises.

For more information on the INFLOW project, please look at INFLOW website (http://projects.gtk.fi/inflow/index.html).
More detailed Cruise Reports are available at the website or at IOW.

Aarno Kotilainen

The Geological Survey of Finland

1 INTRODUCTION

INFLOW (Holocene saline water inflow changes into the Baltic Sea, ecosystem responses and future scenarios) (2009-2011) is one of the BONUS research programme (http://www.bonusportal.org/) projects and it is funded by national funding agencies, participating institutes and the EU Commission. Geologian tutkimuskeskus (GTK) coordinates the INFLOW project that has 9 partners in 7 countries of the Baltic Sea Region: Finland, Russia, Poland, Germany, Denmark, Sweden and Norway.

The INFLOW –project investigates natural variability of the Baltic Sea ecosystem and the linkage to the large-scale atmospheric forcing using sediment proxy studies on a transect from the western to the northern Baltic Sea combined with state-of-the-art modelling approaches. Focus of the project will be the Late Holocene. The validated ecosystem models can provide simulated data for extreme natural climatic conditions over the last 6000 years (e.g. Medieval Warm Period, Little Ice Age) and selected future scenarios. Comparing hind casts with simulations of modern and future scenarios will be used to investigate the relationship between natural variability and human impact. Selected scenarios of the future development of the Baltic Sea produced by the INFLOW –project can form the scientific basis for political strategies adapting to future climate change. INFLOW will provide policy makers with valuable information on how humans have been affected in the past 6000 years. This may shed some light on the possible impacts of future climate change.

The field investigations of the INFLOW project in 2009 concentrated on the whole INFLOW project study area: on a transect from the marine Skagerrak to the freshwater dominated northern Baltic Sea (Figure 1). The purpose of the field investigations were to take (all) sediment samples from the study area to sediment proxy studies.

2 CRUISES

Altogether five cruises onboard four research vessels (*RV Maria S. Merian, RV Professor Albrecht Penck, RV Ladoga, RV Aranda)* were carried out during year 2009 (Table 1). The INFLOW field expeditions were organized by the Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Germany (*RV Maria S. Merian, RV Professor Albrecht Penck*), A.P Karpinsky Russian Geological Research Institute (VSEGEI), Russia (*RV Ladoga*) and The Finnish Environment Institute (SYKE) (*RV Aranda*).

Figure 1. Bathymetric map of the Baltic Sea with the coring locations indicated. Bathymetric map is a product of BALANCE "Baltic Sea Management – Nature Conservation and Sustainable Development of the Ecosystem through Spatial Planning" Interreg IIIB EU-project. Working areas (A, B and C) are also shown in figure.

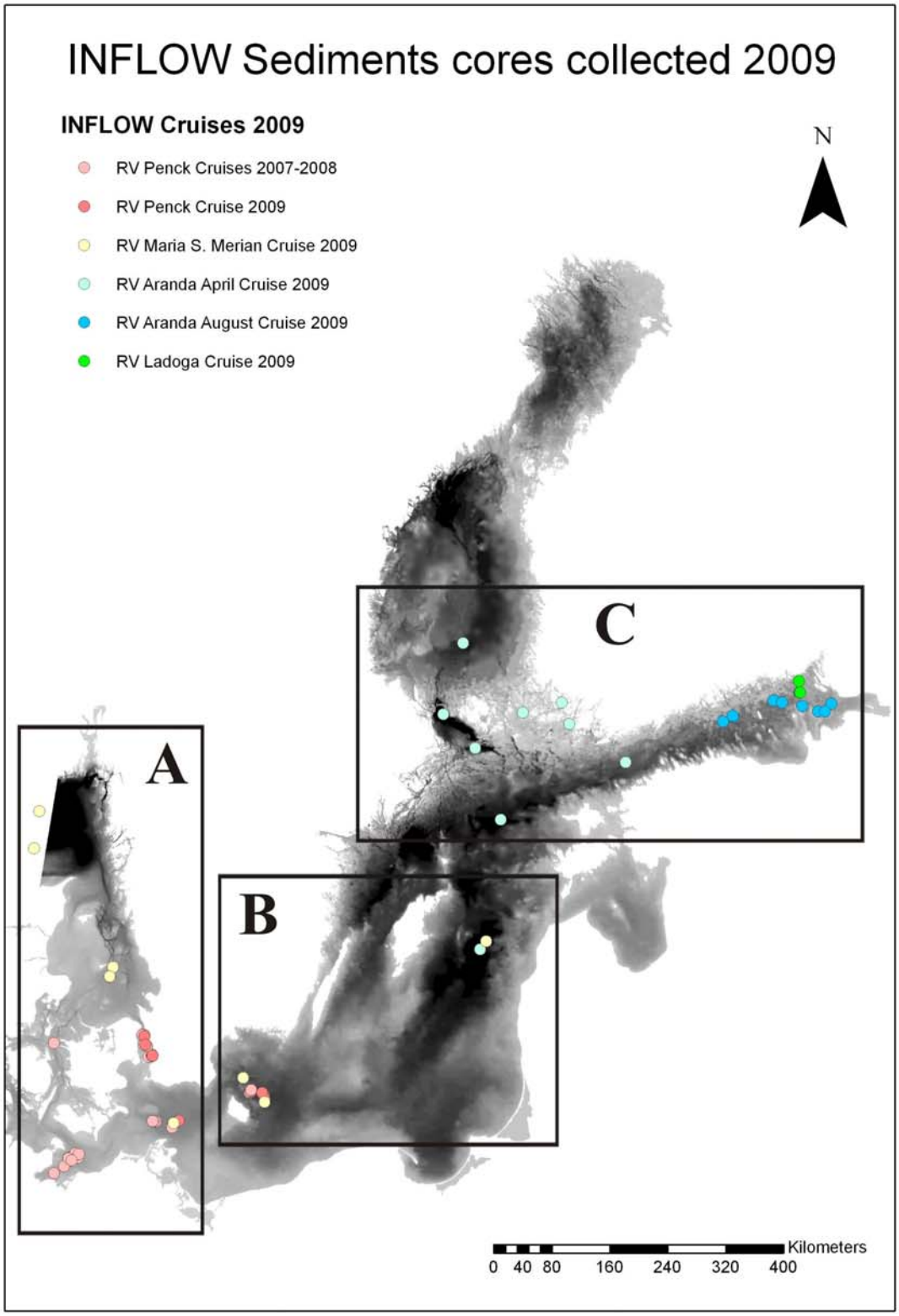

Table 1. Cruises of the BONUS INFLOW project. Cruise material available to INFLOW.

Research Vessel	Date	Chief Scientist	Cruise Report
Albrecht Penck	May–June 2007	Thomas Leipe (IOW)	#
Albrecht Penck	April 2008	Matthias Moros (IOW)	#
Aranda	April 2009	Harri Kankaanpää (SYKE)	*Available
Albrecht Penck	June 2009	Matthias Moros (IOW)	#
Ladoga	June 2009	Daria Ryabchuk (VSEGEI)	*Available
Maria S. Merian	September 2009	Falk Pollehne (IOW)	#
Aranda	August 2009	Harri Kankaanpää (SYKE)	*Available

* Cruise Report available in the INFLOW website; # cruise report available at IOW

3 SITE SELECTION

The selection of key-coring sites for proxy studies is essential. Site selection of the INFLOW project key-coring sites (Fig. 1) was based on new high-resolution (multibeam) topographic information, shallow seismic, ecosystem modelling and other relevant data (from former projects) available at the participating institutes. As well as on the consortiums long-term experience in working with Baltic Sea sediments.

Sites were selected from the spatially very different hydrographic conditions in the Baltic Sea. The high sedimentation rates (approximately 1-2 mm/year) at all selected sites provide an excellent opportunity to reconstruct ecosystem variability through time at decadal to centennial time scales. Records obtained in the western Baltic will contain clear signals of saline water inflow and the Baltic Sea outflow changes. Sites from the central and northern part of the Baltic Sea are to lesser degree directly influenced by saline water inflow changes and are influenced by feedback mechanisms (e.g. redox stage). However, these sites provide records of precipitation and terrestrial input changes, and of past variability in sea-ice cover. Sea-ice cover is a critical parameter for ecosystem modelling.

4 COLLECTED SEDIMENT MATERIAL

Altogether, more than 50 sediment cores (including gravity cores, piston cores and different type of surface sediment cores) were successfully recovered from the INFLOW project study areas of the Baltic Sea (Fig. 1; Tables 2–8). The recovered sites cover all the study areas planned for the project (Fig.1).

The sediment cores were digitally imaged, and first detailed lithologic descriptions were prepared onboard. In addition, bulk magnetic susceptibility measurements along with other mineral magnetic parameters, X-ray imaging, colour- and XRF scanning, and microfossil studies have been, and are, in part, still being carried out in order to pinpoint key-sites for the planned high resolution studies. Surface samples are currently analysed for microfossils.

On the basis of the scanning data, first AMS^{14}C results, most suitable and representative "key cores" from all study areas will be selected in December 2009 for detailed high-resolution studies.

Figure 2 shows an example of recovered Gotland Basin material: Alternating intervals of intensely bioturbated and thinly-laminated sediments characterize the lithology. Detailed inspection reveals burrows and biodeformational structures (Fig. 3A) in the bioturbated intervals, and rare deformational and erosional features, as well as occasional lamination-discontinuity horizons overlain by inclined downlapping laminae (Fig. 3B) in the laminated intervals. The inclined downlapping lamination indicates mud accumulation from bedload transport (Virtasalo *et al.*, submitted).

Table 2. Sediment cores and coring locations. Cruise onboard R/V Albrecht Penck, May-June 2007.

Station	Latitude (WGS84)	Longitude (WGS84)	Water Depth (m)	Gear
342760	54°50.32	13°32.06	45	MUC, 3-m GC
342780	54°53.69	13°10.25	44	MUC, 3-m GC
342790	54°53.70	13°07.53	43	MUC, 3-m GC
342810	54°53.74	13°06.44	44	MUC, 3-m GC
342850	54°05.99	11°09.94	23	MUC, 3-m GC
342860	54°12.01	11°21.00	22	MUC, 3-m GC
342870	54°18.64	11°25.55	23	MUC, 3-m GC
342890	54°19.56	11°37.24	25	MUC, 3-m GC
342910	54°22.58	11°33.03	25	MUC, 3-m GC
342920	54°22.51	11°37.94	25	MUC, 3-m GC

MUC = multicorer, GC = gravity corer.

Table 3. Sediment cores and coring locations. Cruise onboard R/V Albrecht Penck, April 2008.

Station	Latitude (WGS84)	Longitude (WGS84)	Water Depth (m)	Gear
348120	54°54.465	13°34.52	48	MUC, 4-m GC
348130	55°17.88	15°27.96	92	MUC, 4-m GC
348140	55°21.93	15°07.40	89	MUC, 4-m GC
348150	55°22.75	15°08.30	84	MUC, 4-m GC
348160	55°23.12	15°08.67	84	MUC, 4-m GC
348170	55°23.97	15°09.65	81	MUC, 4-m GC
348180	55°40.88	12°51.41	12	MUC, 4-m GC
348190	55°41.73	12°55.46	15	MUC, 4-m GC
348200	55°41.90	12°56.23	15	MUC, 4-m GC
348210	55°42.45	12°55.77	16	MUC, 4-m GC
348220	55°48.65	12°47.53	25	MUC, 4-m GC
348230	55°49.51	12°45.19	25	MUC, 4-m GC
348240	55°49.40	12°42.98	22	MUC, 4-m GC
348250	55°56.54	12°42.85	26	MUC, 4-m GC
348260	55°56.32	12°40.02	25	MUC, 4-m GC
348270	56°43.64	11°49.09	40	MUC, 4-m GC
348280	56°36.11	11°46.67	37	MUC, 4-m GC
348290	56°35.88	11°47.16	37	MUC, 4-m GC
348300	55°41.64	10°45.62	33	MUC, 4-m GC
348310	54°18.57	11°25.56	23	MUC, 4-m GC
348320	54°17.36	11°29.72	25	MUC, 4-m GC

MUC = multicorer, GC = gravity corer.

Table 4. Sediment cores and coring locations. Cruise onboard R/V Aranda, April 2009. For more detailed information see Cruise Report (Kotilainen et al. 2009b).

Station	IOW core ID (GTK core ID)	Latitude (WGS84)	Longitude (WGS84)	Water depth (m)	Gear
370510 JML	370510-2	59º34.908	23º37.572	80	MUC
JML	370510-3 (MGGN-2009-1)	59º34.908	23º37.572	80	GEMAX
JML	370510-4	59º34.908	23º37.572	80	GC (foil)
JML	370510-5	59º34.907	23º37.572	80	GC (liner)
JML	370510-6*	59º34.949	23º37.909	80	GC (liner)
NCB_IN	370520-2	58º53.660	20º34.427	182	MUC
NCB_IN	370520-3 (MGGN-2009-2)	58º53.660	20º34.427	182	GEMAX-1
NCB_IN	370520-4	58º53.662	20º34.428	182	GEMAX-2
NCB_IN	370520-5	58º53.657	20º34.419	182	GC-1 (foil)
NCB_IN	370520-6	58º53.657	20º34.419	182	GC-2 (liner)
NCB_IN	370520-7	58º53.657	20º34.419	182	GC-3 (liner)
GB1	370530-2	57º23.123	20º15.489	230	MUC
GB1	370530-3 (MGGN-2009-3)	57º23.123	20º15.490	230	GEMAX
GB1	370530-4	57º23.123	20º15.490	230	GC-1 (foil)
GB1	370530-5	57º23.123	20º15.489	230	GC-2 (liner)
GB2	370540-2	57º17.025	20º07.269	243	MUC
GB2	370540-3 (MGGN-2009-4)	57º17.025	20º07.269	243	GEMAX
GB2	370540-4	57º17.025	20º07.271	243	GC-1 (foil)
GB2	370540-5	57º17.011	20º07.246	243	GC-2 (liner)

GB2	370540-6	57º17.011	20º07.248	243	GC-3 (liner)
F69	370550-2	59º47.000	19º55.801	200	MUC
F69	370550-3 (MGGN-2009-5)	59º47.000	19º55.800	200	GEMAX
F69	370550-4	59º46.998	19º55.796	200	GC-1 (foil)
F69	370550-5*	59º46.996	19º55.784	200	GC-2 (liner)
ÅD	370560-2	60º11.653	19º07.213	264	MUC
ÅD	370560-3 (MGGN-2009-6)	60º11.653	19º07.214	264	GEMAX
ÅD	370560-4	60º11.652	19º07.213	264	GC-1 (foil)
ÅD	370560-5	60º11.650	19º07.211	264	GC-2 (liner)
ÅD	370560-6	60º11.650	19º07.211	264	VV
SR5	370570-2	61º05.115	19º34.703	125	MUC
SR5	370570-3 (MGGN-2009-7)	61º05.115	19º34.703	125	GEMAX
SR5	370570-4	61º05.115	19º34.703	125	GC-1 (foil)
SR5	370570-5	61º05.115	19º34.703	125	GC-2 (liner)
SMA_sed	MGGN-2009-8	60º13.729	21º04.214	28	GEMAX
SMA_gra	MGGC-2009-1	60º13.674	21º06.556	28.5	GC-1 (foil)
SMA_gra	MGGC-2009-2	60º13.671	21º06.564	28.5	GC-2 (liner)
AIRISTO2	370580-2 (MGGN-2009-9)	60º20.790	22º05.207	60	GEMAX
AIRISTO2	370580-3	60º20.789	22º05.207	60	MUC
AS2	370590-2	60º04.881	22º15.879	47	MUC
AS2	370590-3 (MGGN-2009-10)	60º04.880	22º15.882	47	GEMAX

LL11	59º35.010	23º17.809	67	Water sample (bottle)
LL11	59º35.010	23º17.809	67	VV

MUC = multicorer, GC = gravity corer, GEMAX = GEMAX corer for surface sediment sampling, ÅD = Åland Deep, VV = vanVeen grab sampler.

* sediment core for the BONUS Baltic Gas project.

Table 5. Sediment cores and coring locations. Cruise onboard R/V Albrecht Penck, June 2009.

Station	Latitude (WGS84)	Longitude (WGS84)	Water Depth (m)	Gear
371050	54°55.95	13°40.12	47	MUC, 4-m GC
371080	55°20.37	15°26.76	93	MUC, 4-m GC
371090	55°22.50	15°23.98	93	MUC, 4-m GC
371110	55°55.51	12°42.77	44	MUC, 4-m GC
371120	55°49.34	12°45.42	25	MUC, 4-m GC
371140	55°41.90	12°56.27	15	MUC, 4-m GC

MUC = multicorer, GC = gravity corer.

Table 6. Sediment cores and coring locations. Cruise onboard R/V Ladoga, June 2009.

Station	Latitude (WGS84)	Longitude (WGS84)	Water Depth (m)	Gear
09-BI-1-T-1	60°26.004	28°03.211	36.5	GC
09-BI-1-T-2	60°26.002	28°03.200	37	GC
09-BI-1-T-3	60°26.003	28°03.220	37	GC
09-BI-1-N-1	60°26.003	28°03.233	36.5	Niemistö
09-BI-1-N-2	60°26.002	28°03.227	36.5	Niemistö
09-BI-1-N-3	60°25.993	28°03.231	36.5	Niemistö
09-BI-2-T-1	60°17.498	28°02.998	40	GC
09-BI-2-T-2	60°17.499	28°02.995	40	GC
09-BI-3-T-1	60°17.503	28°03.406	40	GC
09-BI-3-T-2	60°17.506	28°03.405	40	GC
09-BI-4-T-1	60°17.505	28°03.405	40	GC

GC = gravity corer, Niemistö = Niemistö-type short gravity corer.

Table 7. Sediment cores and coring locations. Cruise onboard R/V Maria S. Merian, September 2009.

Station	Latitude (WGS84)	Longitude (WGS84)	Water Depth (m)	Gear
372600	54°06.73	08°02.92	28	MUC, 9-m GC
372610	57°41.05	06°41.00	320	MUC, 9-m GC
372630	57°40.55	07°09.97	330	MUC, 9-m GC
372650	58°29.76	09°35.91	550	MUC, 9-m GC
372640	58°01.98	09°37.30	298	MUC, 9-m GC
372670	56°43.66	11°49.13	42	MUC, 9-m GC
372680	56°36.26	11°46.54	38	MUC, 9-m GC
372700	54°53.73	13°33.55	49	MUC, 9-m GC
372710	55°32.31	14°57.90	83	MUC, 9-m GC
372720	55°15.67	15°28.21	96	MUC, 9-m GC
372740	57°23.10	20°15.50	232	MUC, 9-m GC

MUC = multicorer, GC = gravity corer.

Table 8. Sediment cores and coring locations. Cruise onboard R/V Aranda, August 2009. For more detailed information see Cruise Report (Kotilainen et al. 2009a).

Station	GTK core ID	Latitude (WGS84)	Longitude (WGS84)	Water depth (m)	Gear
KILPI2	MGGN-2009-18	60º13.543	27º22.368	62	GEMAX
KILPI2	MGML-2009-1	60º13.543	27º22.368	62	Piston corer
SECTOR3	MGGN-2009-19	60º11.225	27º34.727	61	GEMAX
SECTOR3	MGML-2009-2	60º11.225	27º34.721	61	Piston corer
SECTOR3	MGML-2009-3	60º11.226	27º34.719	61	Piston corer
F41b	MGGN-2009-20	60º06.999	28º03.929	51	GEMAX
F40	MGGN-2009-21	60º06.408	28º47.521	38	GEMAX
F40	MGML-2009-4	60º06.408	28º47.521	38	Piston corer
F40	MGML-2009-5	60º06.409	28º47.518	38	Piston corer
F40	MGML-2009-6	60º06.402	28º47.481	38	Piston corer
SeskarE	MGVV-2009-1	60º01.921	28º26.783	25	vanVeen
SeskarE	MGVV-2009-2	60º01.921	28º26.783	25	vanVeen
SeskarE	MGVV-2009-3	60º01.921	28º26.783	25	vanVeen
SeskarE_b	MGVV-2009-4	60º01.915	28º26.793	25.5	vanVeen
SeskarE3	MGGN-2009-22	60º01.420	28º36.774	35	GEMAX
LL3a	MGGN-2009-23	60º04.020	26º20.794	69	GEMAX
LL3a_sed	MGGL-2009-7	60º04.680	26º19.734	63.5	Piston corer
LL4a	MGGN-2009-24	60º01.011	26º04.811	58	GEMAX

GEMAX = GEMAX corer for surface sediment sampling, VV = vanVeen grab sampler.

Fig. 2. Colour scan of core 370530-6. The depth scale is relative; the core base is at the lower left corner, and the core top is at the upper right corner.

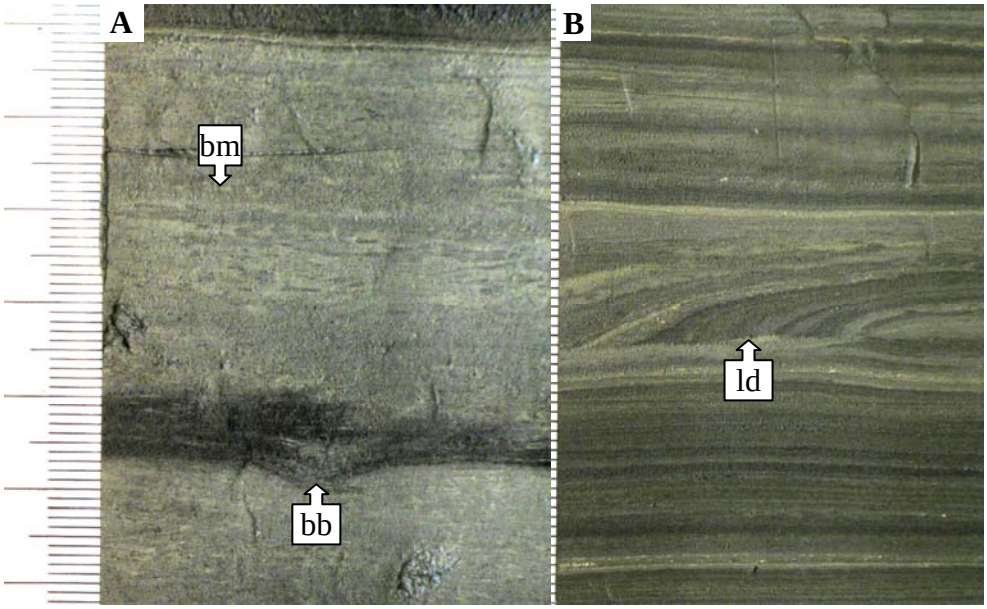

Fig. 3. Close-ups for the core 370530-6. (A) Bioturbated sediment with burrow mottling (bm) and bivalve biodeformation (bb). (B) Laminated sediment with an erosional lamination-discontinuity horizon overlain by steeply-inclined downlapping laminae (ld) indicative of mud accumulation from bedload transport. For background for the interpretation, see Virtasalo *et al*. (submitted).

5 CONCLUSIONS

INFLOW –project partners participated in seven cruises onboard four research vessels (RV Maria S. Merian, RV Professor Albrecht Penck, RV Ladoga, RV Aranda) during 2007-2009 that collected material for the INFLOW project purposes.

Altogether, more than 50 sediment cores (including gravity cores, piston cores and different type of surface sediment cores) were successfully recovered from the different INFLOW project study areas (Fig. 1; Tables 2–8). The quality of the recovered material is currently being checked and key-sites for high-resolution studies will be selected in December at an INFLOW workshop to be held at IOW.

We can summarize that BONUS Research Programme INFLOW -project participation in the cruises was successful. All the planned locations/sites (and sediment cores) have been recovered.

The most suitable and representative “key cores” will be selected in December 2009 for detailed high-resolution studies on the basis of available data (results from analyses).

6 REFERENCES

Kotilainen, A., Hämäläinen, J., Ryabchuk, D., Spiridonov, M, Tuhkanen, M., Vallius, H., Zhamoida, V., 2009a. INFLOW Cruise Report, FYTO 2009, the RV Aranda 3.-10.8.2009. INFLOW Interim Report No 3. Espoo: GTK. 14 p. Electronic publication. Available at http://projects.gtk.fi/inflow/index.html .

Kotilainen, A., Ryabchuk, D., Kotilainen, M., Arppe, L., Dobosz, S., Hämäläinen, J., Karhu, J., Kabel, K., Kaskela, A., Lougheed, B., Moros, M., Neumann, T., Porsche, C., Pötzsch, M., Sergeev, A., Snowball, I., Virtasalo, J. 2009b. INFLOW Cruise Report, SEDU 2009, the RV Aranda 22.-29.4.2009. INFLOW Interim Report No 1. Espoo: GTK. 19p. Electronic publication. Available at http://projects.gtk.fi/inflow/index.html .

Virtasalo, J.J., Leipe, T., Moros, M., Kotilainen, A.T., submitted: Physicochemical and biological influences on sedimentary-fabric formation in a salinity and oxygen-restricted semi-enclosed sea: Gotland Deep, Baltic Sea. *Sedimentology* .

This report is a product of the ”INFLOW” project.

INFLOW (Holocene saline water inflow changes into the Baltic Sea, ecosystem responses and future scenarios) –project studies ongoing and past changes in both surface and deep water conditions and their timing by means of multi - proxy studies combined with state-of-the-art modelling approaches. INFLOW uses sediment proxy data on a transect from the marine Skagerrak to the freshwater dominated northern Baltic Sea. The validated ecosystem models can provide simulated data for extreme natural climatic conditions over the past thousands of years (e.g. Medieval Warm Period, Little Ice Age). Proxy reconstructions will be compared to results from model simulations. These evaluated models will be used to provide predictions of the Baltic Sea ecosystem state at the end of the 21st century for selected IPCC climate change scenarios. Those scenarios of the future development of the Baltic Sea can form the scientific basis for political strategies adapting to future climate change.

INFLOW (2009-2011) is one of the BONUS research programme (http://www.bonusportal.org/) projects and it is funded by national funding agencies (e.g. Academy of Finland) and the EU Commission. Geologian tutkimuskeskus (GTK) coordinates the INFLOW project that has 9 partners in 7 countries of the Baltic Sea Region: Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Germany; Geological Survey of Denmark and Greenland (GEUS), Denmark; Lund University, Sweden; Swedish Meteorological and Hydrological Institute, Sweden; University of Szczecin, Poland; Unifob AS, Bjerknes Centre for Climate Research, Norway; A.P Karpinsky Russian Geological Research Institute (VSEGEI), Russia; Department of Geology, University of Helsinki, Finland.

The INFLOW Report Series included following reports on 30th of October 2009:

INFLOW Interim Report No. 1 “INFLOW Cruise Report, SEDU 2009, the RV Aranda 22.-29.4.2009”.

INFLOW Interim Report No. 2 “Floating University Report, the RV Aranda 22.-29.4.2009”.

INFLOW Interim Report No. 3 “INFLOW Cruise Report, FYTO 2009, the RV Aranda 3.-10.8.2009”.

INFLOW Interim Report No. 4 “High-resolution sediment cores covering the past 6000 years”.

For more information on INFLOW –project see (http://projects.gtk.fi/inflow/index.html).