



# SCOR Annual Meeting

4 - 7 September 2016, Sopot, Poland

Session - Polish Oceanic Science

**Institute of Oceanology Polish Academy of Sciences**

5<sup>th</sup> September 2016, 14.00 - 17.45



**Book of Abstracts**

# **SCOR Annual Meeting**

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**Session schedule**

- 14.00-14.15 W. Surosz (Gdańsk University)  
**Polish marine research capacity mapping.**
- 14.15-14.30 R. Kotliński (Szczecin University)  
**Geology of the Clarion Clipperton Fracture Zone in the Pacific.**
- 14.30-14.45 T. Radziejewska, B. Wawrzyniak-Wydrowska (Szczecin University)  
**Research on benthic communities in a Pacific deep-sea area targeted for mineral resource development.**
- 14.45-15.00 P. Kowalczyk (Institute of Oceanology PAN)  
**CDOM distribution as derived from Atlantic Meridional Transect cruises.**
- 15.00-15.15 K. Blachowiak-Samolyk et al. (Institute of Oceanology PAN)  
**Exploration of bathymetric and latitudinal distribution patterns of pelagic ostracods in Atlantic Ocean.**
- 15.15-15.30 W. Walczowski, A. Beszczyńska (Institute of Oceanology PAN)  
**Large-scale oceanographic observations in the subpolar North Atlantic and Nordic Seas.**
- 15.30–16.00 Coffee**
- 16.00-16.15 M. Głuchowska et al. (Institute of Oceanology PAN)  
**Spatial and inter-annual zooplankton variability within Atlantic water flow to the Arctic.**
- 16.15-16.30 M. Węstawski (Institute of Oceanology PAN)  
**Recent change in Arctic fjords ecosystem function.**
- 16.30-16.45 T. Zieliński, T. Petelski (Institute of Oceanology PAN)  
**Polish Activities within the SOLAS Initiative.**
- 16.45-17.00 H. Mazur-Marzec (Gdańsk University)  
**Linkage between Harmful Algal Blooms and other environmental problems.**
- 17.00-17.15 A. Sokołowski (Gdańsk University)  
**Current issues in the Baltic biological research.**
- 17.15-17.30 M. Witak (Gdańsk University)  
**Polish experience in marine geology.**
- 17.30-17.45 M. Ostrowska (Institute of Oceanology PAN)  
**Physical and chemical investigations in the Baltic.**

## Polish Marine Research Capacity Mapping

**Waldemar Surosz**

Faculty of Oceanography and Geography, University of Gdańsk

Al. Piłsudskiego 46, 81-378 Gdynia, Poland

[surosz@ug.edu.pl](mailto:surosz@ug.edu.pl)

Marine research in Poland is rather well established with over 100 years' history of scientific excellence. The oceanographic research is conducted by several Institutions subdivided into the three organizational categories: (i) Universities, (ii) Institutes of Polish Academy of Sciences as well as (iii) State and Ministerial Institutes.

From the listed categories there are some leading bodies such as Institute of Oceanography of the University of Gdansk (IO UG), Institute of Oceanology – Polish Academy of Science (IO PAS), National Marine Fisheries Research Institute (NMFRI) and the Maritime Institute in Gdańsk (MI). Overall, there are several Institutions dealing with oceanographic research. They are geographically unevenly distributed in the Polish coast of the Baltic Sea – mainly located in the area of the Gulf of Gdańsk. The latter have their headquarters in other parts of Poland (Warszawa, Toruń, Łódź, Kraków, etc.).

While research focuses primarily on the southern Baltic Sea and the Gulf of Gdańsk, the polar regions (Arctica and Antarctica) are also investigated. Polish oceanographic research Institutes operate field stations around the world, such as: "ARCTOWSKI" Polish Antarctic Station (Institute of Biochemistry and Biophysics PAS), Polish Polar Station Hornsund at Svalbard (Department of Polar and Marine Research, Institute of Geophysics PAS), Nicolaus Copernicus University Polar Station on Spitsbergen, and Marine Station in Hel, Poland (University of Gdańsk) among others.

For the excellence and quality assurance in the Polish oceanographic research in the fields of marine biology, chemistry, geology, physics and environmental protection, Institutions are equipped with a high quality infrastructure – laboratories and research vessels. There are four major vessels operating in the areas of scientific interests: OCEANIA (IO PAS), IMOR (MI), BALTICA (NMFRI) and newly built OCEANOGRAF (IO UG).

One of the indicators of a high oceanographic research capacity is the number of scientific peer-review journals edited by major Institutions. The most recognized quarterly journals are as follows: *Oceanologia* – edited by Polish Scientific Committee on Oceanic Research and IO PAS; *Oceanological and Hydrobiological Studies* edited by IO UG, *Polish Polar Research* edited by the Committee on Polar Research of the PAS and *Acta Ichthyologica et Piscatoria* edited by the Faculty of Food Sciences and Fisheries, West Pomeranian University of Technology in Szczecin and the Polish Zoological Society and its Ichthyology Section in association with FishBase. All abovementioned journals are indexed in ISI Science Citation Index Expanded.

## Geology of the Clarion-Clipperton Fracture Zone

**Ryszard Kotliński**

University of Szczecin

ul. Mickiewicza 16a, 70-383 Szczecin, Poland

[ryszard.kotlinski@univ.szczecin.pl](mailto:ryszard.kotlinski@univ.szczecin.pl)

Global geological data collected so far, including those supplied by DSDP and ODP, allowed to conclude that the lithosphere consists of 35 plates. The most distinct of them is the Pacific plate, prominent by being composed of the oceanic crust. It occupies the central part of the present Pacific Ocean's seafloor and has been subjected to geodynamic structural transformations since the disintegration of the supercontinent Pangaea. The central part of the Pacific plate features a prominent fracture zone, the Clarion-Clipperton Fracture Zone (CCFZ) which is characterised by its rich mineral deposits and is therefore important for the future deep-sea mining. A synthesis of results obtained during comprehensive geological and geophysical research carried out by the Interoceanmetal Joint Organization (IOM) in 1988-2011 in a 550 thou. km<sup>2</sup> area (20 cruises) of the CCFZ is presented.

The CCFZ is located in the southern part of the North-Eastern abyssal basin (NEAB). It covers about 5.5 million km<sup>2</sup> (ca. 5200 km in length and ca. 1000 km in width) and shows diverse bathymetry. It extends latitudinally from the western slope of the Mathematicians Palaeo-East Pacific Rise in the east (108°-110° W) to a volcano-tectonic Line Chain in the west (160° W). The data show the seafloor bottom to gradually descend from 3800–4200 m depth in the east (110°-115° W) to 4800-5200 m (130° W) at the average slope of 0.57°, to 5400–5600 m in the west (145°-160° W) at the average slope below 0.5°. The seafloor features a number of parallel volcano-tectonic rises (the Cooper, Central, and East Rise), volcanoes and seamounts. The seabed topography is undulating, showing longitudinal hills 100-200 m and slopes locally exceeding 3°. The oceanic crust thickness averages ca. 10.6-10.8 km. The upper part of the crust features the sedimentary cover (the so-called layer 1) ca. 100-300 m thick, overlying the crystalline fundament (layer 2) consisting of MORB-type toleitic basalts. Their age gradually decreases from west to east, from 90 x 10<sup>6</sup> years (C34 anomaly) at 153° W to 20 x 10<sup>6</sup> years (C5 anomaly) at 118° W. The basalts overlay a gabbro complex belonging to the crystalline layer 3. The step- and block-like fragmentation of the fundament resulted from tectonic activity and transformations of the zone proceeding since the Miocene, as indicated by the presence of criss-crossing fault and escarpment zones and the Mahi-Mahi Fracture Zone, hills and volcanic massifs of seamounts, and the Mathematicians palaeorift. The high geodynamic activity of the zone is confirmed by the presence of basalts and metallogenic clays found in nodes of fracture criss-crossing.

The nature of crystalline fundament determines the seafloor topography and directly affects the spatio-temporal lithological variability of the sediments. The varying thickness of sediment sequences reflects changes in sedimentation conditions and sediment accumulation rate. The lithology of Upper-Cretaceous-Eocene sediment complexes was shaped by a low sediment accumulation rate (0.15 - 0.18 cm/10<sup>3</sup> years), the Oligo-Holocene sediments accumulating at a rate of 0.45cm/10<sup>3</sup> years. From west to east, the sedimentary cover shows a sequence of sediments from the late Cretaceous to recent, accompanied by thickness reduction and outcropping of older calcareous and younger siliceous, siliceous-clayey, pelagic and zeolitic clay complexes. The vertical and horizontal variability of sediments in the area is

associated with a decline of individual segments of the seafloor and their distance from the East Pacific Rise (EPR) and the Pacific Plate rotation, which resulted in a relative change in the Carbonate Compensation Depth (CCD) and the formation of a zone with elevated biological productivity. Those conditions shaped the amount and type of bioclasts (calcareous above the CCD and siliceous beneath it) in the sediments. A change in sedimentation conditions of the recent sediment is reflected in the zonal facial gradation from carbonate to siliceous silts. A distinct increase in siliceous components of the sediment has been going on since the Miocene. The seafloor areas featuring a low sediment accumulation rate and a low supply of bioclasts, clayey, and colloid components, the basic role is played by hydrogenous processes leading to the formation of polymetallic nodules.

The Clarion-Clipperton nodule field is unique among the known oceanic fields by virtue of its high nodule abundance, averaging 6.72 kg/m<sup>2</sup> and a high concentration of the critical metals h (Mn, Ni, Cu, Co, Ti, V, Mo and REE). The field covers an area of 3.83 million km<sup>2</sup>, the nodule resources being estimated at 21.1x 10<sup>9</sup> mt. The spatial distribution of various genetic types of the nodules (H, D, HD) since the Miocene is governed by the depth of deposition relative to the CCD as well as by the environmental conditions of nodule formation. The nodule types differ in morphology as well as in mineral and chemical composition, including the metal contents. High contents of Mn, Cu, and Ni are typical of diagenetic nodules (D), hydrogenic nodules (H) showing elevated contents of Co, Mn, and Pt (H).

Acknowledgements: The Interoceanmetal Joint Organization (IOM) and the International Seabed Authority (ISA) are acknowledged, with gratitude, for making their data available.

## **Research on benthic communities in a Pacific deep-sea area targeted for mineral resource development**

**Teresa Radziejewska, Brygida Wawrzyniak-Wydrowska**

University of Szczecin

ul. Mickiewicza 16a, 70-383 Szczecin, Poland

[tera@univ.szczecin.pl](mailto:tera@univ.szczecin.pl)

Deep-sea mining, i.e. extraction of raw materials from the deep seafloor, will involve a serious human intervention into the natural environment of the deep sea. Considering the seriousness and costs involved, this intervention should be successful (i.e., should provide the benefits intended) and sustainable (i.e., should provide the benefits on a long-term basis), but – first and foremost – it should be responsible (i.e., should cause as little disruption of the deep-sea environment and its communities as possible). The success, sustainability and responsibility of mining operations require knowledge of conditions under which the intervention is to be carried out. Mandatory for this knowledge are the appropriate environmental baseline datasets pertinent to the area(s) targeted for mining operations. The knowledge on the status and natural variability of benthic communities (meio-, macro-, and megabenthos) is particularly important in this context. Polymetallic nodule deposits in the Pacific's Clarion-Clipperton Fracture Zone (CCFZ) belong to the deep-sea mineral resources which have been drawing particularly avid international attention as the CCFZ supports the highest known concentration of polymetallic nodules worldwide at depths between 4500 m and 5500 m. The imminence of mining, and the uncertainties as to the impact of mining activities and their aftermath on the highly diverse benthic communities in the CCFZ, make it imperative both to collect baseline data and to attempt prediction of the severity of mining effects and the extent and rate of recovery from them.

In July 1995, an experiment (IOM BIE) aimed at producing disturbance of the seafloor sediment imitating that generated during nodule mining was carried out in the CCFZ by the Interoceanmetal Joint Organization (IOM), a 6-nation consortium with a mission to prepare future nodule development. An 1.5 x 2 km area of the seafloor, at ca. 4300 m depth, was impacted by a series of tows of a device known as the Benthic Disturber. The programme relied on examining changes in metrics describing the meio- and megabenthic assemblage structure as the major proxies with which to assess the magnitude and intensity of the disturbance. An attempt was also made, by resampling the test site during follow-up cruises undertaken at various time intervals (22 months and 5 years) post-disturbance, to assess the degree of recovery in the disturbed area and its recolonization by the benthos. The meiobenthos did respond to habitat disturbance, the major response being seen in the reduction of abundance immediately after the disturbance. Effects observed during the follow-up studies involved some degree of recovery, accompanied by alteration in the taxonomic composition of meiobenthic taxocoenes. It is not known, however, how persistent those effects are, and how the recovery proceeds in the long-term. These are some of the issues tackled by the European Joint Programming Initiative (JPI) Oceans Pilot Action project "Ecological Aspects of Deep-Sea Mining".

The project involves, i.a., a cruise on board RV SONNE (SO 239, EcoResponse: Assessing the Ecology, Connectivity and Resilience of Polymetallic Nodule Field Systems) effected in March-April 2015, i.e. 20 years after the original disturbance, during which the IOM BIE site was resampled to supply data on the benthic assemblage structure for comparison with the

community status from before and just after the experimental disturbance. Processing of the cruise materials is in progress.

Acknowledgements: the study was made possible by support to the cruise participants from the JPI Oceans Pilot Action “Ecological Effects of Deep-Sea Mining” and by the Polish National Science Centre grant No. 2014/13/B/ST10/02996.

## CDOM distribution as derived from Atlantic Meridional Transect cruises

**Piotr Kowalczyk**

Institute of Oceanology Polish Academy of Sciences  
ul. Powstańców Warszawy 55, 81-712 Sopot, Poland  
[piotr@iopan.gda.pl](mailto:piotr@iopan.gda.pl)

Absorption spectra and induced fluorescence excitation emission matrices of colored dissolved organic matter were measured in water samples collected along the Atlantic Meridional Transect in different bio-geographic provinces of the Atlantic Ocean from October–November 2010. The highest values of CDOM absorption coefficient at 305 nm ( $a_{\text{CDOM}(305)}$ ), were recorded at the continental margins of the English Channel and Patagonian Shelf. The lowest values of  $a_{\text{CDOM}(305)}$  were observed in the mixed layer of both North and South Atlantic subtropical oligotrophic gyres. The DOM composition was assessed using fluorescence spectroscopy, Excitation Emission Matrix spectra (EEMs) and the Parallel Factor Analysis (PARAFAC) model in addition to spectral indices calculated from CDOM absorption spectrum and EEMs spectra. Six different components were identified in the EEMs by PARAFAC: Two components were similar to the humic-like fraction of DOM, associated with basin scale microbial mineralization processes. These components represent allochthonous DOM in the biogeographic provinces studied. One component of marine humic-like material of autochthonous origin, associated with DOM production from marine phytoplankton. Three components were associated with protein-like DOM. Two protein-like components had the spectral characteristics of pure tryptophan and tyrosine. There was a significant difference in DOM composition both between bio-geographical provinces and above and below the mixed layer. In the mixed layer in all provinces, except the waters of the Western European Shelf, the DOM was dominated by protein-like components. At the Western European Shelf, it was dominated by humic-like components. Fluorescence intensities of humic-like components were high at the Patagonian Shelf, but were up to 40% lower compared to Northern Hemisphere shelf waters. Humic-like components made a significant contribution to the DOM composition of the upper mesopelagic layer in all provinces, with the highest values at the Equatorial Upwelling zone. There was a significant inverse relationship between humic-like components and salinity and temperature and a positive relationship with Apparent Oxygen Utilization. The humification index (HIX) was linearly correlated with the intensity of the humic-like DOM components. These trends suggest that the humic-like components are in dynamic equilibrium between likely microbial production in the deep ocean and photochemical degradation in the mixed layer.

## Exploration of bathymetric and latitudinal distributions patterns of pelagic ostracods in Atlantic Ocean

Blachowiak-Samolyk K. <sup>1\*</sup>, Wichorowski M. <sup>1</sup>, Vanden Berghe E. <sup>2</sup>, Baczewska A. <sup>1</sup>,  
Angel M.V. <sup>3</sup>

<sup>1</sup> Institute of Oceanology of Polish Academy of Sciences  
ul. Powstańców Warszawy 55, 81-712 Sopot, Poland

\* [kasiab@iopan.gda.pl](mailto:kasiab@iopan.gda.pl)

<sup>2</sup> Free University of Brussels, Belgium

<sup>3</sup> National Oceanography Centre, Southampton, United Kingdom

The distribution of zooplankton is influenced by a range of abiotic factors varying in time and space. Factors driving bathymetric distributions have been extensively studied, but those influencing horizontal distributions, particularly within the body of deep ocean have received significantly less attention. In the upper layers, the boundaries to the horizontal distributions of both individual species and their assemblages are associated with discontinuities at ocean fronts. However within the deep layers these boundaries are not well defined or understood, but they are often assumed to coincide with different water masses. The mixing processes that occur across frontal zones blur the boundaries so they have very subtle expressions in the hydrographic parameters that are routinely monitored during oceanographic surveys.

Planktonic organisms are very sensitive to these changes; so they have the potential to be used as indicators of even the subtlest changes in the hydrographical structure within the water column. So not only are detailed descriptions of the three-dimensional patterns of zooplankton assemblages invaluable in understanding their ecology, but they can provide powerful alternative tools for tracking the changes that are occurring in pelagic oceanic communities.

The current study is basing on pelagic ostracods, mainly halocyprids, which are ubiquitous in the World's oceans, occurring at all depths and in all oceans. In zooplankton samples planktonic ostracods are often second in abundance only to copepods. There are at least 150 species occurring in the Atlantic. Their species richness shows a systematic increase at all depths from high to low latitude. Thus some ostracod species have the potential to be indicators, because: 1. They are numerous, but not as overwhelmingly abundant as are copepods; 2. They are sufficiently diverse; 3. They are ubiquitous throughout the water column. Despite their abundance and important role in various ecosystems, they are rarely studied, so their potential value as indicators remains unrealised.

Our dataset comprises two main planktonic ostracods collections. The first one includes British *Discovery* expeditions where zooplankton was taken by RMT1 sampler towed horizontally for a minimum of an hour within each 100 m depth layer along the Northeast Atlantic between 1968 and 1974. The second dataset covers ostracods sampled during *Polarstern* cruise (under the aegis of the Census of Marine Zooplankton, CMarZ) to the Southeast Atlantic in 2007. During the last expedition two MOCNESS samplers: MOC1 and MOC10 were used by fishing obliquely over a constant depth ranges: the upper 1000 m and 1000-5000 m depth range, respectively.

This investigation is based on the datasets, which are uniquely comprehensive globally for a single planktonic taxon. All the ostracod samples were identified and/or revised by an authority on this group - Dr Martin Angel. Our datasets contain detailed information about

spatial occurrence (both horizontal and vertical), age structure (juveniles and adults divided into males and females) with morphometric descriptions, which facilitate identification to the species level. This extensive set of biological data is supplemented by complete hydrographical background from British Oceanographic Data Centre (BODC). Furthermore the taxonomic ostracods Atlases with bio-geographical and taxonomic information on each Antarctic and Atlantic species have been published on Internet during the past few years. Raw data related to these particular ostracods' research have been enriched with standardised meta-information on cruise, dataset identifier, collating datacentre, but also aims of the research, equipment, collecting techniques, details of conservation and identification, names of researchers, who possess precise information about material. Data originating from archives and variety of sources are transformed and loaded by ETL tools to data mart and provided for further data mining, OLAP analyses and visualisation.

Completing data originating from different sources is still one of the most emerging trends in ecological and biological sciences. Interdisciplinary analyses, carried out on extensive sets of data, can lead to promising progress in oceanology. Very good example of robust databases providing multiple data from many disparate disciplines (i.e. taxonomy, ecology) in temporal scales is Ocean Biogeographic Information System (OBIS), which collects huge faunal and environmental databases in a standardized form. Furthermore it preserves data for studies of long-term temporal changes and offers easy access to raw data. The current study joins this worldwide trend by expanding the idea from data repository through analyses of the relationship between pelagic marine Ostracoda diversity and natural barriers (e.g., temperature, salinity, bottom topography and depth, etc.) for dispersion of planktonic species in the Atlantic Ocean. Using innovative technologies of data processing and visualization we are going to expose geographic distribution of planktonic ostracods, reveal biodiversity patterns, develop indicators, estimate faunistic variation driven by environmental and climate changes, define ecosystem units and describe relationships of hydrographical conditions within those units. Mining of physical and biological data run by optimised OLAP tools will allow to track global distribution of pelagic species, as an important step towards discovering natural isolation barriers, which created the present plankton diversity. Our ambition is to provide tools for prediction and exploring the biological implications for hydrographical models of the Atlantic Ocean.

## Large-scale oceanographic observations in the subpolar North Atlantic and Nordic Seas

**Waldemar Walczowski, Agnieszka Beszczynska-Möller**

Institute of Oceanology Polish Academy of Sciences  
ul. Powstańców Warszawy 55, 81-712 Sopot, Poland  
[walczows@iopan.gda.pl](mailto:walczows@iopan.gda.pl) ; [abesz@iopan.gda.pl](mailto:abesz@iopan.gda.pl)

A linkage between the Atlantic and Arctic Ocean circulation constitutes a crucial component of the Earth's climate system: the Atlantic Meridional Overturning Circulation. This circulation system transports a huge amount of heat from the South Atlantic and tropical North Atlantic to the subpolar and polar North Atlantic, where that heat is released to the atmosphere with substantial impacts on climate. In the upper layers of the North Atlantic warm and salty waters move poleward to far northerly latitudes where they undergo buoyancy loss, sink, and return southward at depth. Since the mid-80s the northward flow of Atlantic Water in the subpolar North Atlantic and Nordic Seas has been investigated by the Institute of Oceanology PAS under the long-term monitoring program ARES. Large-scale oceanographic measurements are carried on during the annual summer expeditions of the IO PAN research vessel *Oceania* with the main focus on the northernmost extension of the Gulf Stream system - the Norwegian Atlantic Current (NwAC) and the West Spitsbergen Current (WSC).

The region of interest has shifted over time. While in the 80s and early 90s IOPAN observations covered mostly the Faroe-Shetland Channel and the continental slopes of the Norwegian and Barents seas, the station grid have been significantly extended to the north and west in the following years. Since 2000 the standard sections have been established, crossing the Atlantic water flow along the eastern rim of the Nordic Seas and farther through Fram Strait. Two meridional sections between the northern Norway and southern Svalbard cover the Atlantic inflow to the Barents Sea. During each summer campaign the full-depth profiles of temperature, salinity, dissolved oxygen, and speed and direction of ocean currents are measured at more than 200 stations. Optical and aerosol measurements as well as water samples for chemical and biological analyses are collected at selected stations. The standard sections are visited at the same time every year to account for seasonal variability. The valuable time series accumulated during nearly 30 years of observations allow to address the interannual variability of Atlantic water properties and its pathways and spatial transformation in the Nordic Seas.

Based on the long-term observations, the complex, multi-branch structure of the Atlantic water flow towards the Arctic Ocean has been described. The outer branch of the West Spitsbergen Current and its role for recirculation of the Atlantic water towards the North Atlantic has been studied in details. A dedicated study has been devoted to the exchange processes across the Arctic Front, separating the Atlantic and Arctic domains in the Nordic Seas, and the Polar Front between shelf and Atlantic waters west of Svalbard. At all sections crossing the Atlantic inflow a positive trend has been found in temperature and salinity of Atlantic water. However, Atlantic water temperature and salinity do not increase steadily but time periods with anomalously warm and saline Atlantic inflow are followed by years when its temperature and salinity drop significantly. The 5-6 year periodic variability can be recognized in the Atlantic water properties and the strongest warm and salty anomaly was found in the northern Nordic Seas and Fram Strait in 2006. High temperature and salinity of Atlantic water

are usually observed in parallel with intensified northward flow while a stronger eastward flow to the Barents Sea can be associated with a colder and less saline Atlantic inflow. Anomalously warm Atlantic inflow through Fram Strait influences the local climate and ice conditions north of Svalbard.

IO PAN has participated in numerous international projects focused on the subpolar North Atlantic, the Nordic Seas and the Arctic Ocean. IO PAN activities in the northern regions, started in the early projects GSP (Greenland Sea Project) and VEINS (Variability and Exchanges in the Nordic Seas), took on a new dimension under the EU ASOF-N (Arctic and Sub-Arctic Oceanic Fluxes) and IP DAMOCLES (Developing Arctic Modeling and Observing Capabilities for Long-term Environmental Studies) projects. The Polish-Norwegian projects PAVE (Atlantic Water Pathways to the Arctic: Variability and Effects on Climate and Ecosystems) and AWAKE-2 (Arctic Climate System Study of Ocean, Sea Ice and Glaciers Interactions in Svalbard Area) address the specific research questions, related to the Atlantic water impact on climate and ecosystem in the European Arctic. Argo floats deployed by IOPAN under the Euro-Argo program contribute to better understanding of circulation and variability in the North Atlantic and Nordic Seas. Under the H2020 project INTAROS (starting in December 2016) IO PAN will take an active part in developing an Integrated Arctic Observing System. IO PAN also participates in the H2020 project AtlantOS.

## **Spatial and interannual zooplankton variability within Atlantic water flow to the Arctic**

**Gluchowska M.<sup>1\*</sup>, Dalpadado P.<sup>2</sup>, Beszczynska-Möller A.<sup>1</sup>, Olszewska A.<sup>1</sup>, Trudnowska E.<sup>1</sup>,  
Goszczo I.<sup>1</sup>, Kubiszyn A.M.<sup>1</sup>, Blachowiak-Samolyk K.<sup>1</sup>, Walczowski W.<sup>1</sup>, Ormanczyk M.<sup>1</sup>,  
Ingvaldsen R.B.<sup>2</sup> and Kwasniewski S.<sup>1</sup>**

<sup>1</sup> Institute of Oceanology Polish Academy of Sciences  
ul. Powstańców Warszawy 55, 81-712 Sopot, Poland

\* [mgluchowska@iopan.gda.pl](mailto:mgluchowska@iopan.gda.pl)

<sup>2</sup> Institute of Marine Research, P.O. Box 1870 Nordnes, 5817 Bergen, Norway

The inflow of Atlantic water (AW) into the Arctic Ocean has complex two-branched structure via Fram Strait and the Barents Sea, and the impact of AW on the Arctic ecosystem depends on the entrance route. Although the AW is carrying the largest amount of salt, sensible heat and marine biota into the Arctic Ocean, the information on zooplankton transported with this waters are still scarce and fragmented. Zooplankton form important links between pelagic primary producers and consumers, and play essential roles in biogeochemical cycles, including carbon cycle. Changes in zooplankton distribution and abundance can influence ecosystem structures and functions and have economic consequences.

Here we present results of study on the distribution of zooplankton along the main pathways of the AW flow into the Arctic Ocean, via Fram Strait and the Barents Sea branches. The main data for the study was collected in summers of 2001-2014, during research cruises of Institute of Oceanology Polish Academy of Sciences and Institute of Marine Research in Norway. The study focused on determining patterns of zooplankton distribution within the two branches, in relation to hydrography, and evaluating the impact of variability of the AW flow on zooplankton distribution, composition, abundance and development of main zooplankton species. The results suggest that the pathway of transport has no considerable effect on the total zooplankton standing stock but the interannual variability of AW advection influences species distributions, composition and development. The role of local and regional oceanographic factors in controlling the zooplankton dynamics is discussed.

Additionally, in 2012, stratified vertical zooplankton samples were collected down to 1 000 meters, across the West Spitsbergen Current (WSC) flow, to assess more in depth patterns of vertical and horizontal zooplankton distribution on route to the Arctic Ocean through Fram Strait. The results indicate that in a given instance of time, there were large differences in zooplankton distribution with depth, and less ones horizontally. Analysis using multivariate methods revealed, however, significant interactions between vertical and horizontal distribution patterns, related to along and across WSC environmental gradients. This suggest that in order to improve our understanding of the zooplankton distribution patterns and to gain knowledge about processes that shape zooplankton communities structure, diversity and function, one needs to focus on studying the distribution over horizontal scale separately for different water layers.

The findings can be used in foreseeing impact of the Atlantic water biota on the pelagic and benthic ecosystem of Arctic Ocean in the era of climate warming, and in constructing and tuning plankton components of ecosystem models.

## **Recent change in Arctic fjords ecosystem function**

**Jan Marcin Węśławski**

Institute of Oceanology Polish Academy of Sciences  
ul. Powstańców Warszawy 55, 81-712 Sopot, Poland  
[weslaw@iopan.gda.pl](mailto:weslaw@iopan.gda.pl)

Regular multidisciplinary surveys of two Spitsbergen fjords, are completed by r/v OCEANIA every summer since 1996 and are still going on. Long time of those observations, permits for comparative studies and synthesis. The overarching concept, was that Kongsfjorden (79°N) is warmer, exposed for Atlantic water inflow from the shelf, while Hornsund (77°N) is a cold fjord, dominated with local, coastal, cold waters. Hence, Kongsfjorden represents Arctic fjord after warming, while Hornsund remains in original, cold state. Oceanographic parameters, like temperature and salinity confirm above concept, while biogeochemical studies show more complicated picture. It turns out, that Kongsfjorden contains mainly marine carbon in sediments, while Hornsund have higher carbon content, largely due to the terrestrial input. Bacterial activity, oxygen consumption and chemical analyses show all, that carbon in Kongsfjorden is used in high percent, while in Hornsund lower quality carbon is not utilized. Plankton and benthos are more diverse (species count) and richer in biomass in Kongsfjorden compared to Hornsund, and the food web is more complex and efficient there. We assume, that observed differences meet the criterion of “ecosystem maturation” and warming of the coastal Arctic waters is likely to follow this scenario. On the other hand it is not the temperature increase per se as a decisive factor, but the stronger and more frequent advection of shelf waters in Kongsfjorden, that creates most important functional differences between two sites.

## Polish activities within the SOLAS Initiative

**Tymon Zieliński\*, Tomasz Petelski**

Institute of Oceanology Polish Academy of Sciences  
ul. Powstańców Warszawy 55, 81-712 Sopot, Poland

\* [tymon@iopan.gda.pl](mailto:tymon@iopan.gda.pl)

In comparison to open seas such regions as coastal zones or marginal seas are generally studied in a more comprehensive manner. However, the question is, how comparable are physical and bio-geochemical processes for different types of regions. Therefore, Polish efforts related to the SOLAS activities have recently been devoted to two very different regions, the Baltic Sea and the Svalbard area. The Baltic Sea is a relatively well monitored (an important source of SOLAS data) brackish reservoir with a salinity changing from values close to the ocean levels in the Danish Straits to almost fresh water in the Gulf of Bothnia. On the other hand, the Svalbard region features an Arctic climate, although with significantly higher temperatures than other areas at the same latitude.

In order to obtain the full picture of aerosol situation over the Baltic region we launched a research campaign dedicated to the studies of aerosol optical properties in different regions of both the open Baltic Sea and its coastal areas. During the campaign the research team carried out simultaneous measurements of aerosol optical properties at 4 stations with the use of the hand-held Microtops II sun photometers. The studies were complemented with aerosol data provided by the MODIS and air mass back-trajectories at various altitudes as well as wind fields. Such complex information facilitated reasoning regarding aerosol optical depth and Ångström exponent for the region and discussion of the changes of aerosol properties with distance and with changes of meteorological factors.

In case of Svalbard we analyzed data series (1992-2013) of wind measurements from meteorological stations in Ny-Ålesund and Hornsund in Svalbard and compared them to surface layer winds from the NCEP/NCAR reanalysis. They showed large discrepancies between the local wind directions and directions of wind compatible with analyses of the pressure fields. One of the most important factors controlling wind directions in the Svalbard fjords is the temperature difference between the neighboring glaciers and surface sea temperatures of open waters warmed by the West Spitsbergen current. This creates atmospheric circulation patterns similar to night breeze in temperate climates.

As a result of our studies we have proposed to SOLAS a special session for the SOLAS conference in 2015. We organized Session 3: Differences between marginal areas and open ocean - Baltic Sea example. The Session was jointly convened by Jacek Piskozub and Anna Rutgersson.

The following issues were discussed during the Session:

- In the context of air-sea interaction, can the Baltic be treated as a typical coastal shelf sea?
- Can Baltic data sets be used as part of global sets for process studies?
- Can universal air-sea flux parameterizations be used in the Baltic with no reservations?
- If the Baltic is different, what is the main reason (salinity, fetch, surfactants, something else)?

The discussion started on the differences between the Baltic Sea and typical shelf sea and possibility of comparison of these two cases. It was pointed out that no experiment with

tracers has been carried out in the Baltic Sea. The meaningfulness of applying the oceanic gas transfer velocity parameters for the Baltic Sea was also discussed, especially the possible causes for different parameterizations, especially the role of surfactants. Participants drew attention to high variability of salinity of the Baltic Sea connected with big drainage from the rivers. The question about uncertainties of biological models was raised.

In summary, the discussion indicated the importance of further studies of air-sea fluxes in this very specific basin. The main conclusion of the discussion was that despite the good coverage of the Baltic Sea with measurements performed by several Baltic countries, there are still no simultaneous high quality datasets of all the relevant parameters. The discussion showed that there is a strong need and motivation, to conduct new international experiments in the Baltic Sea using eddy correlation, tracers and surfactant measurements.

## Linkages between harmful algal blooms and other environmental problems

Hanna Mazur-Marzec

Faculty of Oceanography and Geography, University of Gdańsk

Al. Piłsudskiego 46, 81-378 Gdynia, Poland

[biohm@ug.edu.pl](mailto:biohm@ug.edu.pl)

Half of organic compounds produced on Earth derives from marine phytoplankton. This figure indicates a key role of these photosynthesising microorganisms in functioning of marine ecosystems. However, mass occurrence of microalgae, and especially the development of harmful species, can generate health problem and lead to serious economic losses (approx. 10 billion USD annually) due to fish kills, aquaculture closures and beach closures. At international level, several organisations and projects, such as GEOHAB or the new GlobalHab and IOC-ICES WGHABD were established. Their task is to promote the development of monitoring systems, data collection and harmful algal blooms (HABs) modelling. These activities lead to better understanding of the principal factors that have an effect on initiation and development of (HABs). Based on this knowledge, HAB trends and responses to the changing environmental factors can be deduced. Some of the factors are of global importance, e.g. eutrophication or climate change. But in different marine ecosystems, some specific problems can occur.

In the Baltic Sea, the annual blooms of N-fixing filamentous cyanobacteria, including the toxin-producing species *Nodularia spumigena*, is a nuisance phenomenon. There is a common opinion that the blooms started to occur and developed in response to human induced eutrophication, and especially to phosphorous surplus. As nitrogen-fixers, the filamentous cyanobacteria are independent of N level and during bloom events, introduce significant pool of the element to the sea, stimulating further development of phytoplankton organisms. However, analysis of sediment cores from the Baltic Sea and adjacent basins provided new insight into the factors that favoured the blooms of cyanobacteria. It was proved that climate warming is the main prerequisite for the blooms to occur. The climate conditions in the Baltic Sea are thought to be controlled by NOA (North Atlantic Oscillation).

High biomass of cyanobacteria and other phytoplankton organisms generated during bloom events increases the oxygen demand in bottom waters and contributes to the development of dead zones in the Baltic Sea. Under anoxic conditions, the enhanced release of phosphorous from sediment stimulate further development of phytoplankton. These processes constitute a part of so called "vicious circle", which inhibits the improvement of the Baltic ecosystem, even if nutrient loads were significantly reduced.

The distribution of the main components of cyanobacteria community in the Baltic Sea is also determined by water salinity. It was recently suggested that expected increase in freshwater inflow to the sea will lower its water salinity and can have significant effect on phytoplankton structure in the Baltic. As a consequence, the development of other toxin-producing species can be expected.

Although long-term data show a decline in phytoplankton biomass, it was postulated that under changing environmental conditions, the occurrence of toxin-producing species, and the synthesis of harmful compounds can be enhanced.

## Current issues in the Baltic biological research

**Adam Sokołowski**

Faculty of Oceanography and Geography, University of Gdańsk

Al. Piłsudskiego 46, 81-378 Gdynia, Poland

[oceas@univ.gda.pl](mailto:oceas@univ.gda.pl)

The Baltic is the second largest brackish habitat in the world (salinity 7-8 in the central part) differing from other continental inland seas additionally by restricted water exchange with oceanic system, strong thermo-haline stratification of the water column, syncline topography in many coastal areas (decantation basins) and large freshwater input. The Baltic is also a relatively young ecosystem, continuously undergoing post-glacial successional changes since the last glaciation 8000 yr ago, which is driven by strong physical and chemical environmental gradients (e.g. temperature, salinity and carbon) and ecological diversity. Together with a high anthropogenic pressure (including eutrophication, pollution, fishery and tourism) this has created locally harsh ecological conditions affecting the composition and structure of the Baltic fauna and flora. The resident biota consists mainly of euryhaline species that have extended their natural range from the North Atlantic, relicts from previous periods of sea history, and brackish and freshwater species with obviously opportunistic ways of life traits. These specific inherent properties of the Baltic Sea present for many years now a challenging research issue to marine biologists and ecologists, and more recently also to ecophysicists and geneticists whose scientific efforts are related to potential effects of Global Climate Changes. Based on regionalized global general circulation model (GCM) data, the future Baltic Sea ecosystem may unprecedentedly change compared to the past 150 yr. Assuming the IPCC greenhouse gas emission scenarios (A1B or A2), water temperatures at the end of 21<sup>st</sup> century is projected to increase and salinities and oxygen concentrations may be lower than ever measured.

Recent biological research in the Baltic Sea are in line with worldwide investigations of the effects of global phenomena (e.g. warming, acidification, biodiversity shifts) which affects inevitably also the Baltic and reflect specifically distinctive features of this water-basin. The studies address primarily functioning of the biocenoses in areas of different geochemical and ecological conditions and at various levels of biological organization (from genes to ecosystems). Special attention is focused upon responses and acclimatisation and/or adaptation potential of organisms to natural environmental gradients (salinity, temperature, carbon load) and disturbances, and to major threats caused by eutrophication (e.g., high sedimentation rate, cyanobacteria blooms) and pollution (e.g. trace metals, organic derivatives of phenol, endocrine-disrupting chemicals (EDC), pharmaceutical and weapons deposited on the sea floor after the II WW). A particular environmental research issue is formation of hypoxia and anoxia on the deep and shallow sea floor and effect of an expansion of anoxic dead bottoms on marine benthic fauna. In addition, long-term and multiscale monitoring data from observatory systems on the structure and distribution of different ecological formations (benthos, zooplankton, and fish) are combined to describe their multiannual variation patterns and to provide a baseline against which future changes in their structure can be assessed. Significant research efforts are also made to detect and describe marine bioinvasions in the Baltic which is sometimes called „Sea of Invaders”. Until now, introduction of 132 Non-indigenous species (NIS) representing different taxa have been observed of which app. 90 established new populations. Compared to other Baltic regions the

number of NIS established in the Polish coastal waters is relatively high. Due to dynamically developing marine infrastructure related to increasing offshore and coastal human activities (windmills, harbours, and piers), the importance of artificial hard substrates for colonisation and ecological succession of benthic fauna becomes an important study area. In contrast, mariculture is a sector which in the Baltic (only Sweden, Denmark and Germany) has lagged behind those in other coastal regions. Recent transfer and implementation of innovative and sustainable aquaculture technologies across the Baltic countries (e.g. through South Baltic Programme) has actuated, however, new research interests towards development of integrated aquaculture systems (algae, invertebrates and fish) and their impact on the marine environment.

## Physical and chemical investigations in the Baltic

**Mirosława Ostrowska**

Institute of Oceanology Polish Academy of Sciences  
ul. Powstańców Warszawy 55, 81-712 Sopot, Poland  
[ostra@iopan.gda.pl](mailto:ostra@iopan.gda.pl)

The physical and chemical properties of seas change as a consequence of both natural processes and human activities. The Baltic is a semi-enclosed, shelf sea, surrounded by economically developed countries, which means that it is subjected to strong human pressure and that its ecosystem differs substantially from those of open oceans. Because of the immense importance of the Baltic to Poland, it is the water body on which Polish oceanologists have primarily focused their research ever since the 1920s. Current studies on natural and anthropogenic variability of the Baltic Sea environment are usually carried out in cooperation with scientific institutions from other Baltic Sea states often within the framework of international research programmes. The results of this research, examples of which will be given below, have made a significant contribution to the expansion of our knowledge of how the Baltic Sea is functioning.

One of the most urgent issue raised also by society is contamination by chemical compounds. Many organic and inorganic substances of anthropogenic origin have been detected in different Baltic ecosystems, for example, heavy metals, , radionuclides, and man-made organic substances. The risk assessments of the presence of these compounds in the ecosystem, what includes identification of their sources, concentration levels determination, pathways of transmission, effects on organisms and the presence in sea food are all topics explored by Polish research institutions. These investigations have made it possible, for example, to assess the state of the remains of chemical weapons in the Baltic Sea sediments and the risk of the substances they contain seeping into the surrounding water. The results of these studies also include the first reports of the presence of emerging biologically active contaminants (like pharmaceuticals residues, nonylphenols etc.), estimating the fluxes of mercury between the atmosphere, the water column and the sediment, to mention but a few.

A characteristic property of the Baltic environment is its high level of eutrophication, due to the large concentrations of nutrients flowing into the sea from surrounding catchment area. Polish institutions analyse the short-term changes in the concentrations of their various forms in selected regions and the levels of these substances in different compartments of the environment. Since the 1970s, the trophic state of the southern Baltic has been investigated. These studies have shown an improvement in the trophic situation in these waters, including the coastal zones. It was also estimated that the Polish unit loads of nitrogen in the last years were among the lowest of all the Baltic Sea countries.

The eutrophication of the Baltic Sea contributes to the absorption of atmospheric CO<sub>2</sub> and the effective deposition of carbon in the bottom sediments, so it has a direct influence on the direction and value of CO<sub>2</sub> flow between the sea and the atmosphere. An important contribution to understanding the part played by the Baltic Sea in the global CO<sub>2</sub> cycle was made by the *qualitative and quantitative descriptions of the main carbon flows in the Baltic Sea as well as their possible shifts induced by climatic and global change*, presented in the monograph *Carbon Cycling in the Baltic Sea* (J. Pempkowiak & K. Kuliński, Springer 2012). It

was established that, among other things, the Baltic is a weak source of CO<sub>2</sub> for the atmosphere.

The circulation and transport of gases, nutrients and also organisms in the sea depend on water mixing processes, in which internal waves play an important part. A comprehensive analysis of their interaction with the variable topography of the Baltic Sea bed, a mathematical description of them and practical methods for recording and determining the parameters of such waves will be found in the monograph *Internal Gravity Waves in the Shallow Seas* (S. Massel, Springer 2015).

Polish research teams are also carrying out regular observations of the water circulation and saline inflows through the Danish Straits. Yielding the largest database on inflows into the southern Baltic and their transport through the Słupsk Furrow, these investigations have made a significant contribution to the assessment of water exchange in the Baltic. Among other things, they have shown that a full exchange of waters in the deep, near-bottom zones is possible only when the inflows are large in volume and consist of highly saline waters (PSU > 17).

Analysing the physical phenomena affecting the whole Baltic Sea requires not only empirical studies but also advanced mathematical modelling techniques. Hydrodynamic models, based on the standard oceanological numerical codes and adapted to the specific conditions of the Baltic Sea, have been started up in several Polish institutions (see e.g.

<http://model.ocean.univ.gda.pl/>; <http://proza.ocean.ug.edu.pl/doku.php?id=model>; [http://deep.iopan.gda.pl/CEMBaltic/new\\_lay/pl/index.php](http://deep.iopan.gda.pl/CEMBaltic/new_lay/pl/index.php)). Expanding these models to include modules combining aspects of physics, geochemistry and biology and has enabled a wide range of physical and chemical processes occurring in this sea to be simulated at different spatial and temporal scales.

For many years now, a large inter-institutional team of scientists in Poland has been carrying out empirical and theoretical studies of the optical and bio-optical properties of the sea. Some of the results of this work can be found, for example, in the books *Marine Physics* (J. Dera, Elsevier 1992) and *Light absorption in sea water* (B. Woźniak & J. Dera, Springer 2007). These studies have resulted *inter alia* in models describing the links between the concentrations of the various constituents of Baltic Sea waters and their optical properties. Accounting for the specific properties of Baltic waters, these models have become the foundation for algorithms enabling the comprehensive and systematic remote sensing of the Baltic environment with the aid of the operational SatBałtyk System ([www.satbaltyk.pl](http://www.satbaltyk.pl)).

This system came into existence as a result of the long-term cooperation among scientists from the Institute of Oceanology (Polish Academy of Sciences) in Sopot (coordinator), the Institute of Oceanography at the University of Gdańsk, the Institute of Physics at the Pomeranian Academy in Słupsk, and the Institute of Marine Sciences at the University of Szczecin. The system enables several parameters distribution maps to be drawn on the basis of integrated satellite observations, *in situ* measurements, as well as diagnostic and prognostic mathematical models. More than 70 physical, chemical and biological characteristics, describing the whole Baltic Sea area, along with its coastal zone and the atmosphere above it, are available. These maps show historical and current values of environmental parameters, determined with an accuracy not much less than or comparable with that of empirical measurements. Short-term forecasts of these characteristics are also available in the SatBałtyk System. A comprehensive quantitative analysis of the natural processes taking place in Baltic ecosystems is thus possible. For example, photosynthesis can be tracked all the way from the

parameters associated with sunlight and heat radiation to the amounts of organic matter and free oxygen produced in the sea.

Polish scientific institutions also have important achievements to their name as regards acoustic investigations of the Baltic ecosystem. They include the identification of the basic properties of noise in the Baltic Sea and its dependence on hydro-meteorological conditions, assessments of anthropogenic noise pollution, new techniques for the identification of marine sediments using SONAR, and estimating the energy dissipated during the breaking of wind waves.

Sustainable use of marine areas and environmental protection of the Baltic Sea is of great importance. The status and the changes of the marine environment have been monitored and analyzed by all the Baltic countries for many years in accordance to recommendations of international organizations and groups of experts such as HELCOM. Polish research institutions have made significant contributions to the monitoring.

To present the entire range of research carried on in Polish scientific institutions, even just those related to marine chemistry and physics, would go far beyond the scope of this text. All this work has, however, been documented in scientific publications, the details of which can be found on the websites of the institutions involved in Baltic Sea research.



INSTITUTE OF OCEANOLOGY  
POLISH ACADEMY OF SCIENCES

81-712 SOPOT, POLAND  
POWSTAŃCÓW WARSZAWY 55  
P.O. BOX 148  
TEL.: (+48) 58 73 11 600 (+48) 58 551 72 81  
FAX.: (+48) 58 551 21 30  
E-MAIL: [office@iopan.gda.pl](mailto:office@iopan.gda.pl)

[www.iopan.gda.pl](http://www.iopan.gda.pl)

**KNO** | Krajowy Naukowy  
Ośrodek Wiedzący

