Recent important publications from Institute of Oceanology PAS

in the four main fields of our research 2017- 2019

1) Physical Oceanography

High proportion of phytoplankton biomass remained undetected by satellite observations in the Arctic Ocean.

Bio-optical properties within the Atlantic Water (AW) inflow region off Spitsbergen are mainly driven by phytoplankton. Winds affect advection of sea ice and melt waters, influencing stratification and thus occurrence of subsurface chlorophyll maxima. Phytoplankton pigments line height absorption at 676 nm is the best optical proxy for estimating chlorophyll a concentration in the area

Arctic is rapidly changing due to anthropogenic climate change. One of the manifestations of that change is a northward advancement of warm Atlantic Water in the European Sector of the Arctic Ocean. This has important implications for marine ecosystem, including phytoplankton at its base. Ocean color remote sensing from space is a common tool to monitor phytoplankton in surface waters of the ocean. However, in situ optical and biological observations are needed for correct estimates of phytoplankton biomass from space. In this study we provide a comprehensive description of bio-optical properties of surface waters within the Atlantic Water inflow region near Svalbard based on three years of observations. We found that phytoplankton itself is the most important factor influencing the underwater light field and therefore the signal that is detected from space. We established key bio-optical relationships that are needed for validation of remote sensing products. Three different optical ways to estimate chlorophyll a concentration, which is a proxy for phytoplankton abundance, have been tested. We found that year to year variability in optical properties in central Fram Strait is linked to wind patterns in the area, which affect the interaction between Atlantic Water and sea ice, and therefore stratification. The increased stratification stimulates occurrence of subsurface chlorophyll a maximum, that is located below the depth of satellite remote sensing detection limit. As a result, a high proportion of phytoplankton biomass remained undetected by satellite observations in the Arctic Ocean , what should be considered in many research related to climate change in the region.

Kowalczuk, P., S. Sagan, A. Makarewicz, J. Meler, K. Borzycka, M. Zabłocka, A. Zdun, M. Konik, M. Darecki, M. A. Granskog, and A. K. Pavlov,. 2019. Bio-optical properties of surface waters in the Atlantic Water inflow region off Spitsbergen (Arctic Ocean). Journal of Geophysical Research: Oceans, 124, 1964–1987. https://doi.org/10.1029/2018JC014529

Is wintertime climate variability over Eurasia predictable a few months ahead?

The day-to-day weather and several aspects of surface climate depend profoundly on synoptic-scale, short-lived eddies that form, propagate and decay along their preferred pathways through the earth's atmosphere known as storm tracks. Major wintertime storm track displacements and associated surface climate variations over Eurasia have been shown to be largely predictable from Arctic sea ice cover anomalies in the preceding autumn.

Numerous studies have shown more or less significant relations of wintertime climate variability over Eurasia to prewinter Arctic sea ice cover. Many of them recognised the importance of storm tracks in shaping these relations, but none treated explicitly the storm track predictability provided by Arctic sea ice variations. On the other hand, there is increasingly more evidence for considerable seasonal predictability of the most prominent regional mode of wintertime variability of atmospheric circulation in the Northern Hemisphere extratropics - the North Atlantic Oscillation (NAO). The NAO is related to storm track changes and strongly impacts the Eurasian climate. Statistical analyses of observationally-based atmospheric data and observed Arctic sea ice concentrations in the period 1979-2017 carried out at the Institute of Oceanology, Sopot, show that a dominant mode of year-to-year variations in the winter mean storm track activity over Eurasia explains an exceptionally large fraction (about 70% of the variability) of the NAO and of a dominant mode of Eurasian surface air temperature variations. Results from statistical forecast experiments demonstrate that all these modes are largely predictable from the sea ice cover anomalies in the Barents/Kara Sea during the preceding October and indicate that this predictability might have increased after an acceleration of the sea ice decline in the mid-2000s.

Schlichtholz, P., Climate impacts and Arctic precursors of changing storm track activity in the Atlantic-Eurasian region, Scientific Reports, vol. 8, Article number: 17786 (2018), https://www.nature.com/articles/s41598-018-35900-8

2) Biological Oceanography

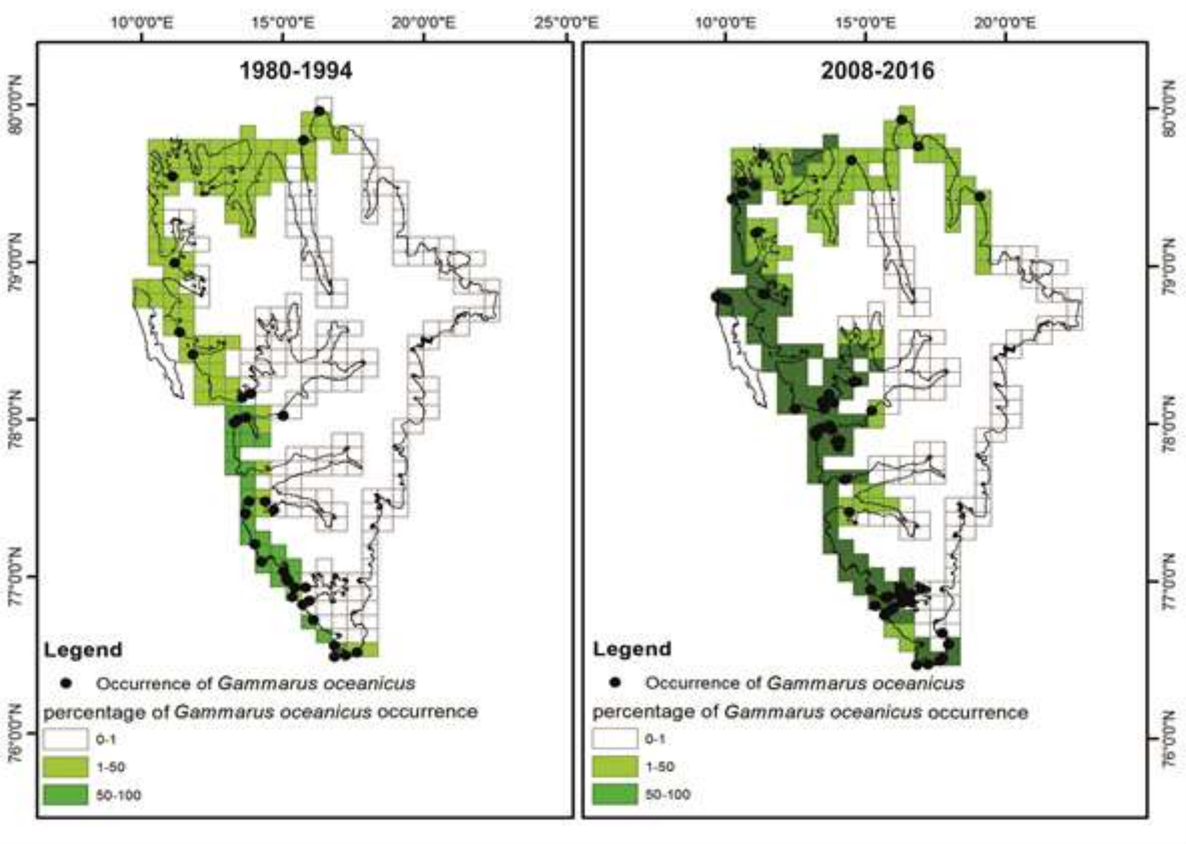
Boreal species follow the Atlantic waters advance and temperature rise in the Arctic

European Arctic coasts are rapidly loosing its ice cover. Deglaciation with increased advance of Atlantic waters brings new species from the south and changes the functioning of coastal ecosystem.

Comparison of satellite ice maps of Spitsbergen from 1990-ties with such collected after 2010, shows the fast disappearance of winter (fast) ice from fjords and open coasts. The sea surface temperature on Spitsbergen is rising continuously over the last years, and intrusions of Atlantic shelf waters are noted more frequently in previously isolated, cold fjords. The occurrence of two sibling, competing coastal crustacean species along Spitsbergen shores have been compared between 1988-1992 and 2010-2017. There is a marked increase of the area of occurrence, density and frequency of the boreal, warm water crustacean species, associated with the retreat of local, cold water sibling species towards innermost fjord basins. Observed process is a sign of biodiversity increase in the warming Arctic, and change in ecosystem functioning, with more dispersed energy flow and distribution of resources.

Ecology and Evolution vol.8/15 2018 09 July 2018, https://doi.org/10.1002/ece3.4281

Fig. 1 Expansion of boreal litoral species along Spitsbergen coast during last 40 years



Progressing warming can alter characteristic of plankton and particles in Svalbard waters

Crossing the zones of the Arctic plankton studies: innovative high-resolution survey enhanced by multi-fraction approach bring a new knowledge on the polar pelagic system functionality.

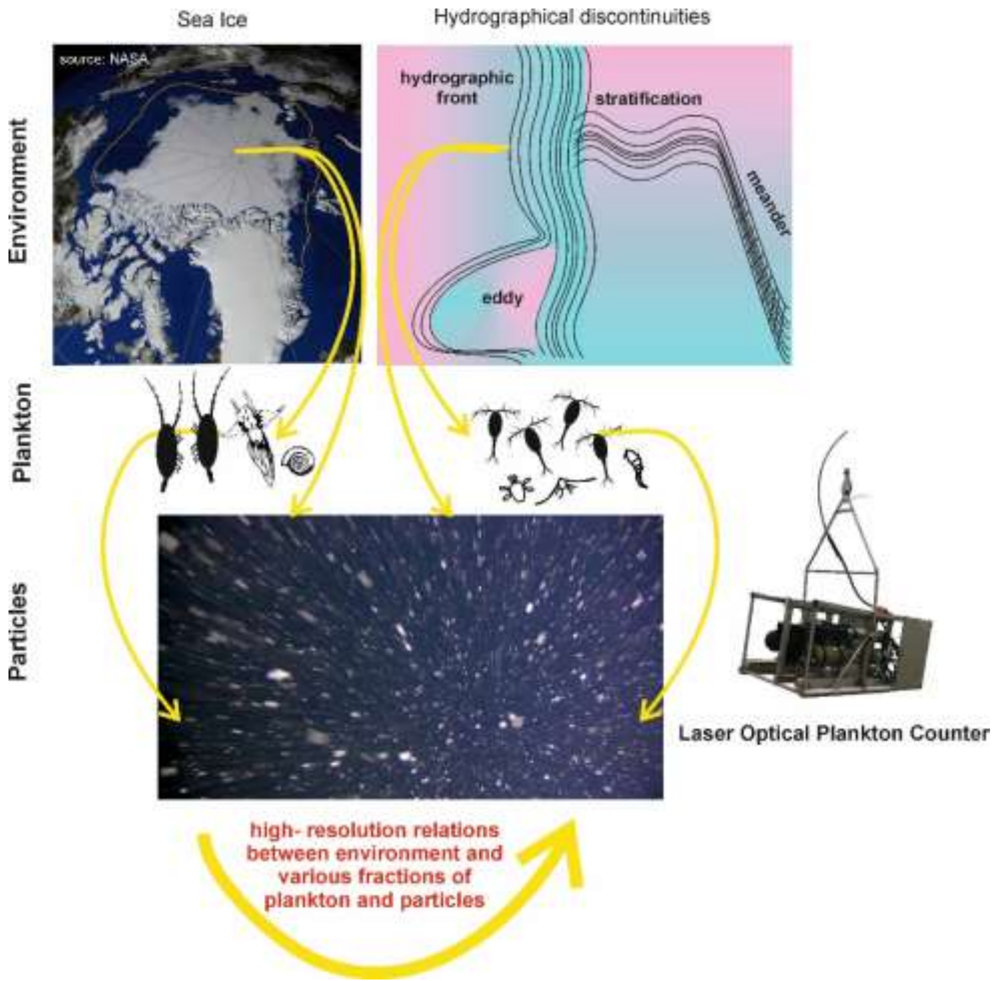
Climate change results in substantial alteration of abundance, distribution, species composition and size structure of plankton, which can have drastic effects on the whole Arctic ecosystem. Advanced equipment, such as laser optical plankton counters allowed to continuous high-resolution observations of poorly studied so far phenomenon of plankton and particles patchiness in polar frontal Svalbard waters, difficult to provide by traditional sampling (at stations)[1]. This novel investigation clearly demonstrated that patches occupied only a minor portion of the studied ocean (2−17%), but contained plankton concentrations that were 3−17 times higher than in the background waters were associated with increased primary production and/or hydrographic structures (e.g., discontinuities in the density field and/or the presence of meanders/eddies)[1]. Furthermore, it was shown that the patch formation and related processes are strictly size-specific, with much higher impact of the hydrography on the small[2] and medium plankton fractions than on the large zooplankton[1,2]. This phenomenon was also tested and proved by the multi-year observations[2]. Then our study area was extended to the Fram Strait and the scope of the research was broaden to various functional groups – including very small particles, phytoplankton, detritus[3], which reduced the substantial knowledge gap regarding so far neglected seawater components, such as non-living particles and marine snow aggregates, occurring in this vulnerable Arctic region[3]. Such multi-specific, innovative approach has widened our perception on increasing influence of the Atlantic water inflow on the structure and dynamics of particles and plankton, which has definite effects not only on the Arctic but potentially also on the global biogeochemical cycles.

Polar Research 2018, 37/1/1427409, 1-12

https://www.tandfonline.com/doi/full/10.1080/17518369.2018.1427409

Progress in Oceanography 2018, vol. 168, pages 1-12

https://www.sciencedirect.com/science/article/pii/S0079661117302446


Sea Ice
Hydrographical discontinuities
source: NASA
hydrographic front
stratification
meander
eddy
Environment
Plankton
Particles
Laser Optical Plankton Counter
high- resolution relations between environment and various fractions of plankton and particles

Small changes do not mean no changes at all. Summer mesozooplankton distribution in the West Spitsbergen Current in 2001-2014.

Long term zooplankton observations in the European Arctic show doubling of boreal plankton species biomass with minor changes in the species geographical occurence

Mesozooplankton, such as copepods *Calanus finmarchicus* or *Oithona similis* and arrow worms such as *Eukrohnia hamata*, play a central, mediating role in the food webs in the northern and Arctic seas, as phytoplankton grazers, lower trophic level consumers and food for fish, birds, whales or benthic communities. Marine ecosystems in Arctic regions are expected to undergo large changes, driven by sea ice retreat and increasing impact of warmer and saline waters of Atlantic origin, transported predominantly via Fram Strait with the flow of the West Spitsbergen Current (WSC). The impact of Atlantic waters will be associated not only with influence of physical factors but also with introduction of external biota, first of all plankton with often different functional roles, which will affect productivity and carbon cycling in the Arctic ecosystems. Observations from the WSC area conducted in 2001-2014 period could not confirm overall drastic trends in mesozooplankton, expected as a consequence of anomalous warming episodes of 2005-2007, but showed subtle changes over time overlaid by considerable interannual variability. Along with significant positive temporal trend in salinity in the main flow of the WSC, *Calanus finmarchicus*, the key element of the Atlantic origin plankton, became increasingly important over time, almost doubling its biomass and contributing more than 50% of the total biomass at the end of the study period. In the light of the conducted research, with the continued pressure on ecosystems associated with climate change, the increase in the share of Atlantic species in Arctic communities seems inevitable. The question remains whether Atlantic plankton will play only the role of an extra food source, in an existing trophic network, or whether it will start a slow acclimation and adaptation in the new environment, finding its niche and changing the structure and functioning of the original Arctic ecosystems.

Based on :Carstensen J, Olszewska A and Kwasniewski S (2019) Summer Mesozooplankton Biomass Distribution in the West Spitsbergen Current (2001–2014). Front. Mar. Sci. 6:202. doi: 10.3389/fmars.2019.00202

Glacial disturbance reshapes benthic size structure in Arctic fjords

Food availability and disturbance effects on the size structure of zoobenthic communities were studied in Arctic glacial fjords. Glacial disturbance causes reduction of the biggest organisms, and the benthic system shifts from larger organisms (macrofauna) to smaller organisms (meiofauna) dominated.

Warming climate in Arctic will change food supply and glacier related disturbance pressures for benthic organisms. We explored the effects of both factors on the size structure of benthic communities dwelling in Arctic fjordic sediments. Decreasing food availability suppresses biomass across all community (from meiofauna to macrofauna), but size structure (the distribution of the biomass among the sizes classes) remains unchanged. When low food conditions are coupled with physical disturbance, the biggest organisms are eliminated and the biomass in selected macrofaunal taxa strongly reduced. In contrast, biomass of smaller animals (meiofauna) increases. Functioning (productivity) of the benthic communities switches from larger animals (macrofauna) dominated in stable sediments to smaller taxa (meiofauna) dominated in disturbed conditions.

Progress in Oceanography, 2017, 152: 50-61, https://doi.org/10.1016/j.pocean.2017.02.005

3) Chemical Oceanography

Heavy metals in the Svalbard area: distribution, origin and transport pathways

By the global warming, the glaciers and permafrost that accumulated different contaminants for decades have started to melt. Thus the recent and historical loads of eg. heavy metals to the Arctic coastal areas should be monitored. Study have shown that although heavy metal concentrations in Svalbard fjord sediments are not particularly elevated yet, up to 85% of eg. lead originated from global anthropogenic sources mainly from atmosphere.

Spatial and historical variations in heavy metal concentrations, deposition rates and sources in the context of different metal transport pathways in bottom sediments of 7 Svalbard fjords were studied. Some fjords were unpolluted by heavy metals while in others a clear signal of metal enrichment was found (outer Kongsfjorden, Hornsund, Adventfjorden). It was calculated that from 3% (Rijpfjorden) to 85% (Hornsund) of lead originated from anthropogenic sources. Large-scale processes such as atmospheric and oceanic transport were found to be important drivers of heavy metal contaminant distribution. The significance of global drivers varied among the fjords, due to coupling with local processes. The air transport from Europe and Asia is the major transport pathway. Northern Svalbard fjord sediments can receive Pb also from North American sources. Marine currents can be important metal source for outer parts of the fjords. It was found that fluxes of heavy metals are two folds higher than recent atmospheric loads particularly at the glaciers front suggesting that melting glaciers can be important source of heavy metals. This phenomena is caused by the fact that glaciers accumulated heavy metals over centuries and nowadays the contaminants are introduced to the seawater by the glaciers melting.

Zaborska A., Beszczyńska-Möller A., Włodarska-Kowalczuk M., 2017, History of heavy metal accumulation in the Svalbard area: distribution, origin and transport pathways. Environmental Pollution 231 (1), 437-450.

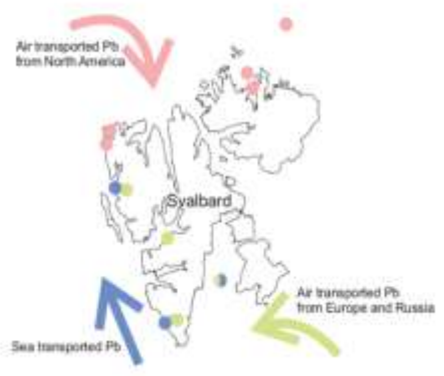


Fig. 1 Based on measurement of lead (Pb) isotopic ratios it was found that southern and central Svalbard fjords receive Pb transported by air and water masses originating mainly from Europe and Russia, while northern Svalbard fjords additionally receive Pb transported by air masses from Northern America.

A new indicator of oxygen deficiency in near-bottom water

The ratio of $13^2,17^3$-cyclopheophorbide-a enol to the sum of other chloropigments-a (CPPB-aE/ΣChlns-a) is proposed as a new paleoredox proxy.

CPPB-aE ($13^2,17^3$-cyclopheophorbide-a enol) – a derivative of chlorophyll-a, has been discovered in recent sediments of the Gulf of Gdańsk and Oslofjord as well as in old (formed during 5,500 years) sediments of the Deep of Gdańsk. Environmental studies and laboratory tests indicated that the presence of this labile compound in sediments, owing to its instability under oxic conditions, may be a biomarker of oxygen deficiency in near-bottom water during formation of sediment and afterwards. The ratio of CPPB-aE to the sum of other chloropigments-a (i.e. chlorophyll-a and its derivatives) is proposed as a new paleoredox proxy (geological indicator of oxygen conditions) that can be used to reconstruct not only oxygen deficiency but also the presence of hydrogen sulphide (euxinia) during sediment formation, in a basin. This proxy may be very useful for tracking eutrophication in the past.

1. Szymczak-Żyła M., 2018. CPPB-aE ($13^2,17^3$-cyclopheophorbide-a enol) in sediments – A potential proxy of oxygen deficiency in near-bottom water. *Organic Geochemistry*, 115, 166–173. https://doi.org/10.1016/j.orggeochem.2017.10.011
IF(2017): 2,810; pkt MNiSW (2013-2016): 35

2. Szymczak-Żyła M., Krajewska M., Witak M., Ciesielski T. M., Ardelan M. V., Jenssen B. M., Goslar T., Winogradow A., Filipkowska A., Lubecki L., Zamojska A., Kowalewska G., 2019. Present and Past-Millennial Eutrophication in the Gulf of Gdańsk (southern Baltic Sea). *Paleoceanography and Paleoclimatology,* 34, 136-152. https://doi.org/10.1029/2018PA003474
IF(2017): 2,718; pkt MNiSW (2013-2016): 45

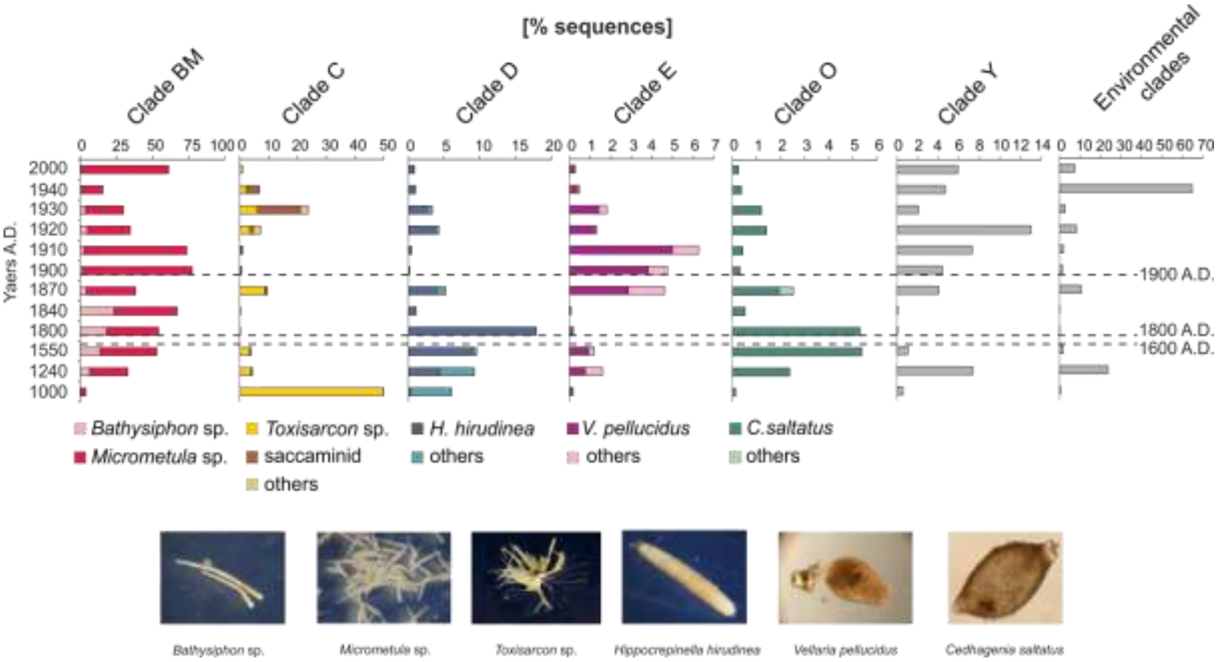
4) Paleooceanography

What ancient DNA reveals about climate?

Ancient environmental DNA approach is an effective tool in investigating past and modern Arctic foraminifera communities, including poorly studied non-fossilized taxa. Molecular record revealed event small environmental changes that were not indicated by fossil record.

Foraminifera are widely used for reconstructing past and present environmental changes in all types of marine environments. Common use of foraminifera as ecological proxies is based on excellent preservation of hard-shelled foraminifera in fossil material. However, in some marine habitats, such as polar regions, the foraminiferal fauna is dominated by soft-walled non-fossilized species that are rarely encountered in fossil assemblages. To include this overlooked group into paleoceanographic studies, scientists applied ancient environmental DNA approach for reconstruction of climatic and environmental changes in Hornsund fjord (Svalbard) during the last millennium. Molecular data revealed extraordinary richness of foraminiferal communities, mainly due to the detection of non-fossilized monothalamous taxa. Ancient DNA record correlated well with environmental changes and revealed even small changes that were not clearly indicated by fossil record. The paleogenetic approach offers a complementary source of material for paleoenvironemntal studies and a powerful tool to refine or validate paleoecological information obtained with traditional proxies.

Pawłowska et al. 2016, Climate of the Past, 12, 1459-1472. https://doi.org/10.5194/cp-12-1459-2016



The percentage of nono-fossilized monotalamous foraminifera sequences in Hornsund fjord over the last millennium (after Pawłowska et al., 2016; modified). Photo credit: forambarcoding.unige.ch

5)Interdisciplinary

Sea Dumped ammunition affects the marine ecosystem. Both corroding munitions and contaminated sediments create a diffuse pollution source for benthic ecosystem.

After World War II, as part of Germany's demilitarization, up to 385,000 tonnes of munitions were sunk in the Baltic Sea. Objects containing various dangerous substances—chemical warfare agents (CWA)—and explosives that can affect a marine environment were dumped on the sea-floor. Some of those objects contain also mercury either as elemental mercury or mercury compounds (e.g. mercury fulminate, a popular explosive primer) and thus could be a specific local source of mercury in the dumping areas.. This study aimed to answer the question of how the munitions are distributed on the Baltic Sea bottom, whether those munitions can be regarded as point-sources of contamination to marine environment, can the pollution be transported by nearbottom currents, and does it affect benthic life and fish. Hydroacoustic surveys were performed in major chemical and conventional munition dumpsites, transport of contaminated sediments was estimated using hydrodynamic models, chemical analyses were performed, and biodiversity and health of marine organisms were examined. Results show, that munitions are loosely scattered in an area much greater than designated dumpsites. Some of them are either partially or fully corroded, and sediments are contaminated in radius of several dozen meters around objects. Organisms show bolth decreased health and bioaccumulation of pollutants in tissues, although at the moment levels are not yet harmful for fish consumers.

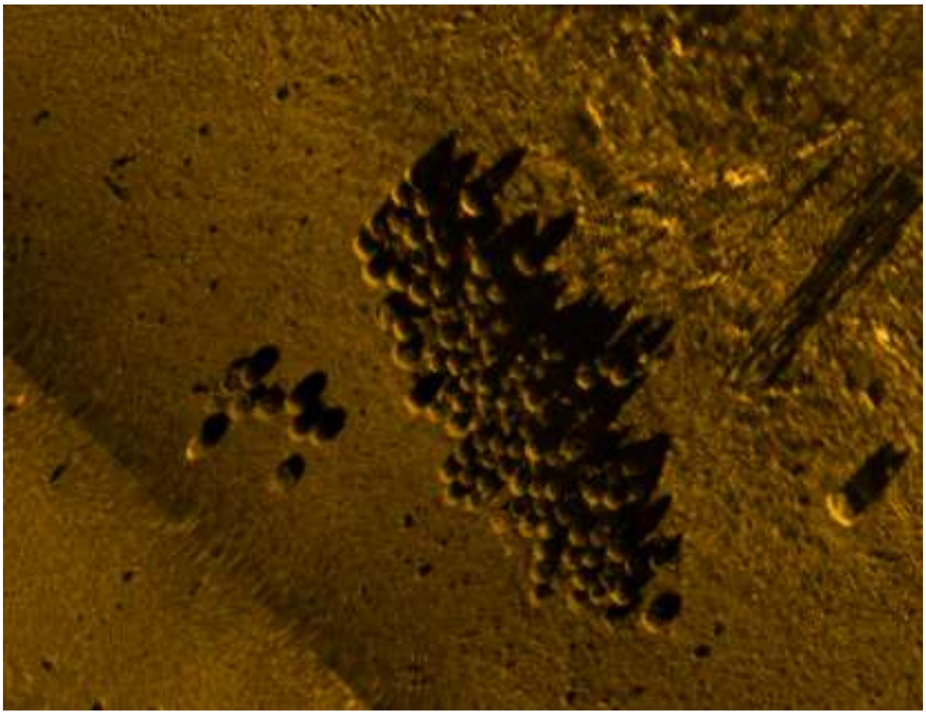


Figure 1 Dumped Sea mines in Kiel Bight

- Bełdowski J, Been R, Turmus EK (2017) Towards the Monitoring of Dumped Munitions Threat (MODUM): A Study of Chemical Munitions Dumpsites in the Baltic Sea. Springer Netherlands
- Carniel S, Beldowski J, Cumming A. (2017) Munitions in the Sea: Time for Global Action. Sea Technol 58 (1):37-39
- Czub, M., Kotwicki, L., Lang, T., Sanderson, H., Klusek, Z., Grabowski, M., Szubska, M., Jakacki, J., Andrzejewski, J., Rak, D., Beldowski, J., 2018. Deep sea habitats in the chemical warfare dumping areas of the Baltic Sea. Sci Total Environ 616, 1485-1497.
- Bełdowski J, Szubska M., Siedlewicz G., Korejwo E., Grabowski M., Bełdowska M., Kwasigroch U., Fabisiak J., Łońska E., Szala M., Pempkowiak J. 2019. Sea-dumped ammunition as a possible source of mercury to the Baltic Sea sediments. Sci. Tot. Environ., 674, 363-373

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