[Journal of Conventional Weapons Destruction](https://commons.lib.jmu.edu/cisr-journal)

Volume 23
Issue 3 *The Journal of Conventional Weapons Destruction Issue 23.3*

Article 11

January 2020

Explosive Ordnance in the Baltic Sea: New Tools for Decision Makers

Torsten Frey
Leipzig University

Jacek Beldowski
Polish Academy of Sciences

Edmund Maser
Kiel University

Recommended Citation

Frey, Torsten; Beldowski, Jacek; and Maser, Edmund (2020) "Explosive Ordnance in the Baltic Sea: New Tools for Decision Makers," *Journal of Conventional Weapons Destruction*: Vol. 23 : Iss. 3 , Article 11.
Available at: https://commons.lib.jmu.edu/cisr-journal/vol23/iss3/11

Explosive Ordnance in the BALTIC SEA

NEW TOOLS FOR DECISION MAKERS

by Torsten Frey [Leipzig University], Jacek Bełdowski, Ph.D. [Polish Academy of Sciences], and Edmund Maser, Ph.D. [Kiel University]

The global ocean economy is predicted to grow by more than 100 percent between 2010 and 2030. By then, more than 40 million people are going to be employed by the maritime industry.[1] Recognizing this potential, the European Union (EU) devised a "Blue Growth" strategy that seeks to reap the anticipated economic benefits.[2] While technological advancements allow for an increased utilization of marine resources, the newly gained access to untapped opportunities forces coastal nations to simultaneously face the challenge of explosive remnants of war (ERW) and chemical warfare agents (CWAs) in the sea.

FACING EXPLOSIVE REMNANTS OF WAR IN THE BALTIC SEA

Like all European seas, the Baltic Sea is still heavily affected by ERW and CWAs from the world wars. One estimate suggests that around 300,000 metric tons (t) of conventional munitions are still present in German Baltic waters alone.[3] Here, explosive ordnance was in part introduced due to naval and air battles and mine laying activities. During both world wars, between 100,000 and 150,000 naval mines were laid in the Baltic.[4] An additional mode of entry of ERW and CWAs into the Baltic Sea were post-war dumping activities. Up to 65,000 t of chemical ordnance were dumped in the Baltic Sea.[3]

Against this backdrop, the EU seeks to organize the efficient, safe, and sustainable use of its waters. A framework for maritime spatial planning has been established to take advantage of the economic potential of the European seas and to increase transboundary cooperation while simultaneously protecting the environment.[5] The main goal of the EU's Marine Strategy Framework Directive is to "achieve a good environmental status of European seas by 2020.[6]" The presence of ERW and CWAs impedes ambitions to make use of the Baltic's economic potential as well as with the aim of doing so in a sustainable and ecosystem-friendly fashion.

Image 1. A corroded German KC-250 mustard bomb, found at the Bornholm dumpsite was first recognized on a sonogram, then investigated by an ROV, while final identification was done by classifying the bursting charge with the help of the munitions database.
Image courtesy of DAIMON project.

In recent years, research groups in Europe have focused on the development of new tools that provide guidance on how to treat submerged ERW and CWAs. Some of these tools are discussed in this article, which is the first publication wherein their potential integration is described. The DAIMON (Decision Aid for Marine Munitions) decision-support system (DSS) suggests management options for ERW and CWAs at different geographic locations at a strategic level. One of these management options is site-specific monitoring, which may be performed with the help of a new biomonitoring approach. Another management option is the execution of an explosive ordnance disposal (EOD) campaign. For the implementation of this option, a comprehensive quality guideline was published.

THE NEW DECISION SUPPORT SYSTEM

The presence of ERW and CWAs at any given location constitutes an inherent risk. The DSS bases its decision-making process on the categorization of this risk, which is a function of a multitude of

Published by JMU Scholarly Commons, 2020

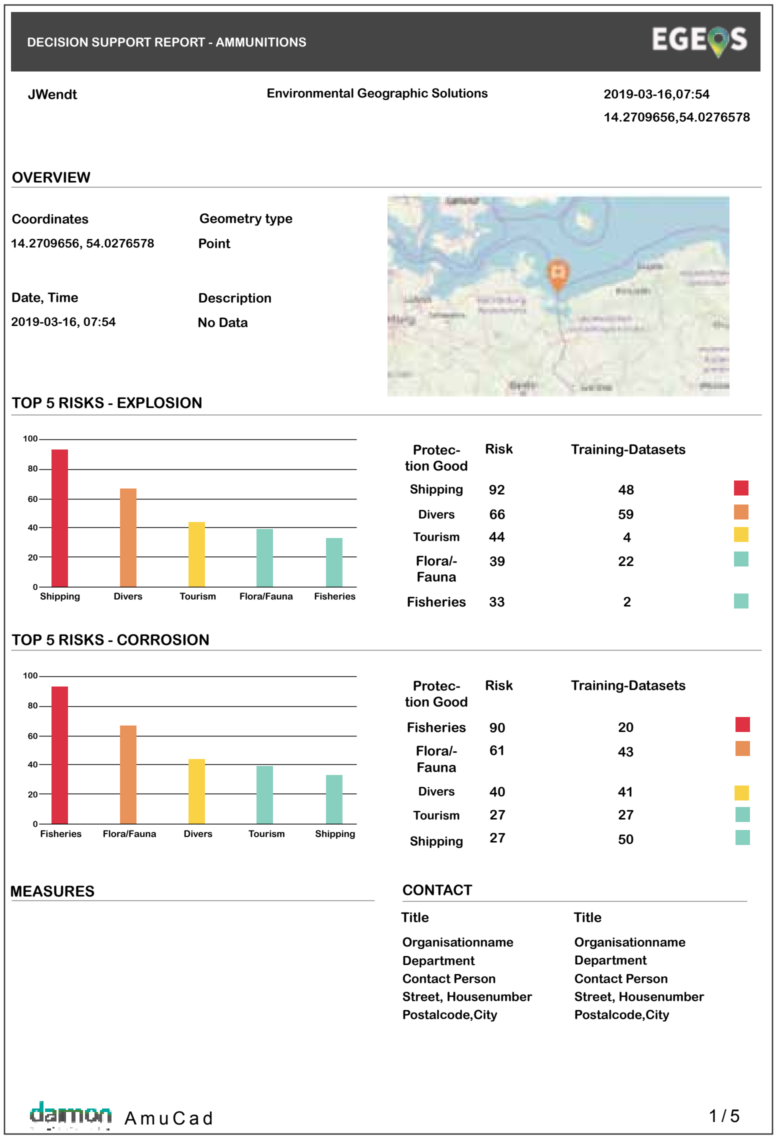


Figure 1. An example report of an ERW site located at the border between German and Polish territorial waters. The report was generated with the Decision Support System in the web-based software AMUCAD.org.
Figure courtesy of EGEOS GmbH, 2019.

aspects. Some ERW items may be buried under sediment, or their munitions compounds (MCs) may have already leached into the environment. Such circumstances limit the imminent threat these items pose for the ecosystem. On the other hand, some ERW emit toxic effluents to nearby sediments or constitute a hazard for fishing vessels and workers employed in the offshore industry.[7] In order to support decision makers with the management of ERW and CWA sites, it is required to assess their risk level. The DAIMON project responded to this requirement by creating a user-friendly web-based tool.[8] This system is able to evaluate available local and regional data and to suggest management options to decision makers in Baltic Sea states. It utilizes data on object properties, site-specific environmental conditions, and impact on biota.

Object properties include the type and current state of ERW and CWAs. Information on the object type is derived from technical surveys and object recognition with the help of hydroacoustic imaging, visual inspection, and an online munitions database (Image 1).[9] Corrosion assessment for present condition and corrosion modelling for future condition provide information on object integrity. Environmental properties that are processed by the DSS include oceanographic data (which are integrated from public HELCOM and SEDNET databases), modelled spread of contamination by bottom currents by a high-resolution hydrodynamic model,[10] and concentration measurements of degradation products from MCs in nearby sediments. The impact on biota is included in a dedicated database, containing biomarker data of ca. 20,000 fish specimens, which were collected in munitions dumpsite areas.

All of this information is processed by neural networks, which were trained on data from the dumpsites and contain weighting factors for each parameter. Experts used all of the parameters entered into the DSS for risk assessment calculations during case studies, and calibrated neural nets to produce comparable outputs. The data interpretation is based on toxicity thresholds obtained during the DAIMON project, and a full list of references is available in the DSS documentation.[9] It furthermore uses specialized algorithms, which involve, inter alia, the number of ERW items in close proximity to one another and health stressors for marine biota. The result is subsequently judged by another neural network, which considers the potentially-affected subjects of protection such as fishery, shipping, offshore structures, and tourists.

The DSS presents users with a comprehensive risk-assessment report, which includes color-scale coding for both the risk level and the confidence level, allowing them to decide either how to manage the site or to collect additional relevant data to aspire for more informed decision making (Figure 1). If not considered a threat, the DSS may advise the decision maker to omit action for some ERW and CWA items. For other items it may propose a number of management options. These include monitoring, if the system is warning for delayed consequences; establishing restrictions for maritime sectors, in case the items present a latent safety hazard or could become more dangerous if disturbed; or EOD, if items present an immediate threat for a given subject of protection.

The DSS is currently under development. It is exclusively concerned with the Baltic Sea but could be extrapolated to other geographic areas. It uses data that were collected during research projects and by maritime protection agencies in a comprehensive way, thereby allowing for informed decision making.

BIOMONITORING OF SUBMERGED ERW

The informed decision to necessitate site monitoring requires a plan on how to perform the monitoring. A holistic, environmental monitoring program for conventional ERW in the sea has thus been developed as part of the joint scientific project UDEMM (environmental monitoring for the delaboration of munitions on the seabed) by partners GEOMAR Helmholtz-Centre for Ocean Research Kiel, Institute of Toxicology and Pharmacology of the Christian-Albrechts-University in Kiel, and Leibnitz Institute for Baltic Sea Research Warnemünde. The concept includes the use of hydroacoustic and optical means such as towed cameras, autonomous underwater vehicles (AUVs), and divers, as well as sediment and water sampling, with subsequent chemical analyses of munition contaminants. It also integrates biomonitoring, which is a long-term possibility to classify ERW.[11]

Monitoring is a collective term for all types of systematic recordings, measurements, or observations of an operation or process by means of technical aids or other observation systems. The term biomonitoring is used, inter alia, in ecology and describes the periodic measuring of the stock and state of health of plants and animals as well as their communities with the aim of determining the quality of environmental conditions. Modern analytical methods enable experts to record many pollutants in very low, environmentally-relevant concentrations. The goal of biomonitoring is the protection of the ecosphere and of human health.

A main hazard of ERW in the marine environment is the chronic contamination of the marine ecosystem and marine organisms with toxic explosives continuously leaching from corroding ERW. In the worst cases, this may lead to toxic substances entering into marine and human food chains, so that seafood consumers may be heavily exposed. It is universally accepted that explosive MCs pose a threat to marine organisms and the marine ecosphere. In addition, health risks for humans that are exposed to trinitrotoluene (TNT) have been determined. Notable toxic manifestations have included aplastic anemia, toxic hepatitis, cataracts, hepatomegaly, and liver cancer.

For a number of reasons, mussels (bivalves) are particularly suitable for the detection and recording of explosive compounds that leach from corroding ERW in the marine environment.[12] They are widespread representatives of the marine fauna and are benthic and sedentary organisms—meaning that they live a mostly stationary life on the seabed—and constitute a main source of food for fish, birds, crustaceans, and starfish. In addition, their filter feeding lifestyle and slower metabolic rate favor the absorption and bioaccumulation of explosives. Further, they are a resistant species which can thrive in unfavorable conditions. Finally, bivalves are an important seafood species and can be used as indicators for the entry of toxic substances into the marine food chain, even at low concentrations.[13] While conditions in the sea that change in the short-term (temperature, salinity, and currents) make it difficult to continuously assess the ecological hazards of ERW by other means, biomonitoring with mussels offers the opportunity for long-term studies to predict potential risks for the ecosphere and for seafood consumers.

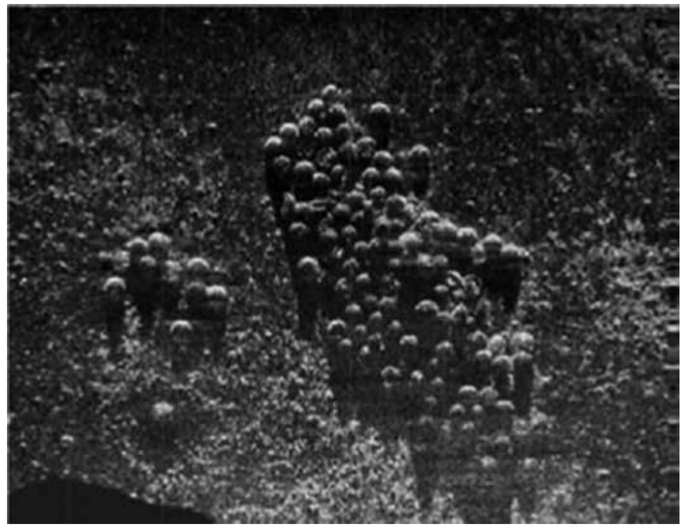


Image 2. A synthetic aperture sonar image of around seventy moored mines at Kolberger Heide in German territorial waters. The location's distance to the closest German beach is 2 km. *Image courtesy of German Navy, 2012.*

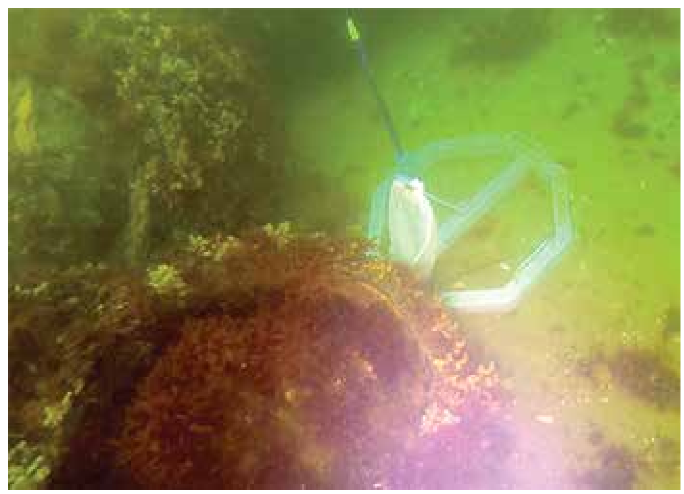
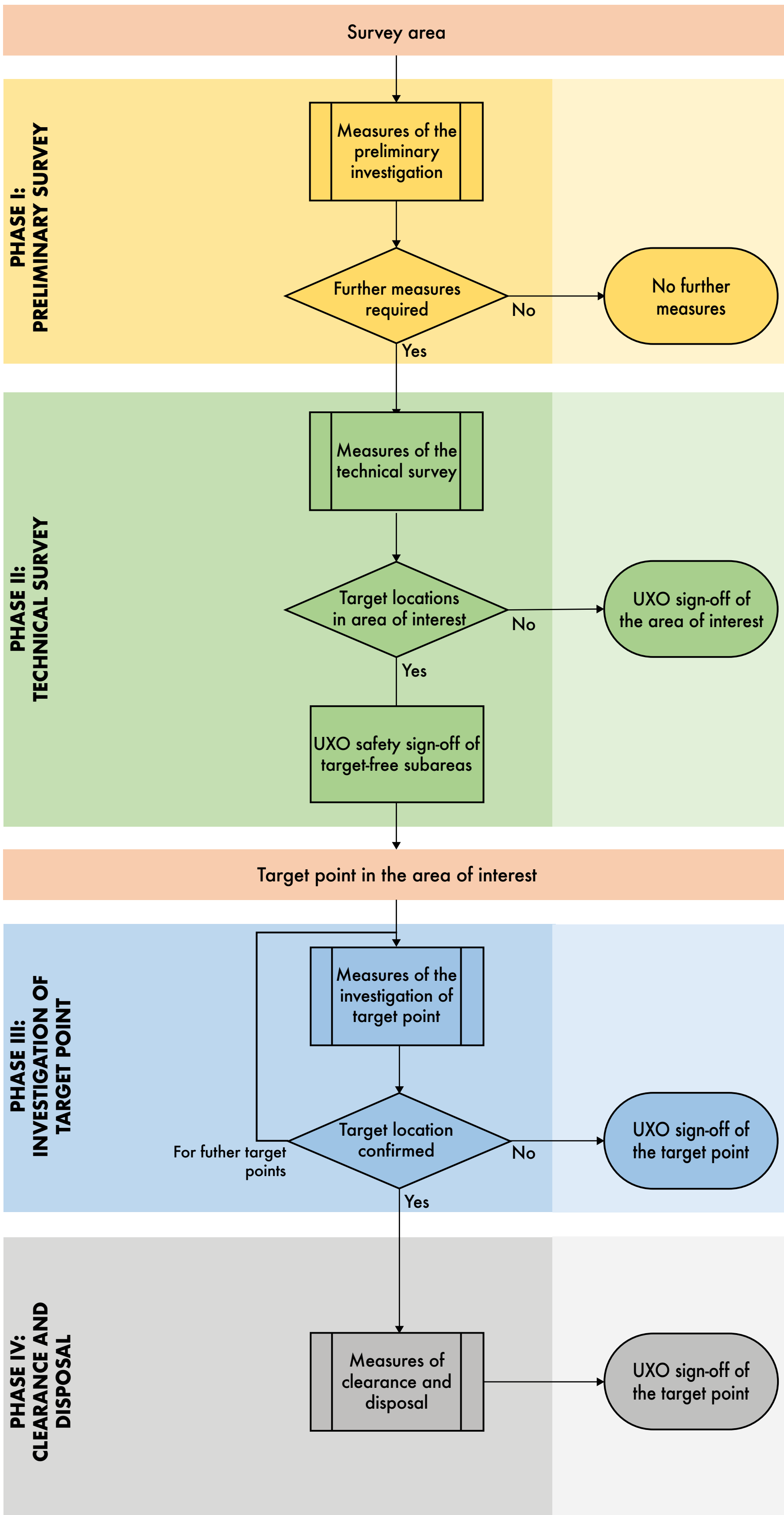


Image 3. A mooring with a net containing mussels that was placed adjacent to a corroding moored mine. *Image courtesy of Diving Center of Kiel University.*

Mussel monitoring was used in the German dumpsite of Kolberger Heide (Image 2). The area served as a test site to develop new methods and workflows for detection, monitoring, and assessment of ERW in the marine environment.[12] Divers placed moorings with mussel bags (Image 3) at various positions near a pile of about seventy moored mines distributed over an area of approximately 70 × 30 sq m. After recovery, the bioconcentration levels of 2,4,6-TNT and its main metabolites 2-amino-4,6-dinitrotoluene (2ADNT), and 4-amino-2,6-dinitrotoluene (4ADNT) were measured in mussel tissue by means of two gas chromatography-mass spectrometry/mass spectrometry (GC-MS/MS) analytical methods.[14] The result of such mussel monitoring may then be entered into the DSS, which will increase the system's capacity to suggest management options for a specific area.



One of the most important results was that comparatively higher total concentrations of the different TNT metabolites were usually detected in mussels placed directly on a free-lying piece of hexanite,[15] a widely used military explosive that was used by the German Navy during both world wars. Lower concentrations were found in mussels placed in the immediate vicinity of dumped mines in different states of corrosion.[16] This unexpected result is a strong case against the common practice of blasting dumped munitions for clearing purposes. As a consequence of low-order deflagrations, large areas might be contaminated with unexploded materials, such as hexanite, thereby increasing the availability of the chemicals to the surrounding biota.

GUIDANCE ON PERFORMING OFFSHORE EOD

If an ERW item or a dumpsite presents an immediate hazard to human life or offshore assets, an EOD campaign is imperative. Every offshore construction and exploration project in the Baltic renders the execution of at least the survey phases of an EOD campaign essential. However, numerous challenges in connection with offshore EOD exist, and the process is often performed in the absence of universally-accepted standards. There was no recognized industry-wide method of assessing the suitability of organizational procedures, deployed personnel, devices used, and the handling of these devices during EOD. This situation was mainly owed to the fact that a

Figure 2. Flow chart illustrating the phases of offshore explosive ordnance disposal representing the top layer of organization in the quality guideline.
Figure courtesy of Leipzig University, IIRM, 2019.

framework for formal recognition of any of these aspects was absent. In response, Leipzig University's Institute for Infrastructure and Resources Management (IIRM) developed a "Quality Guideline for Offshore Explosive Ordnance Disposal."[17] This effort was part of the RoBEMM project (Robotic Underwater Salvage and Disposal Process with the Technology to Remove Explosive Ordnance in the Sea, in Particular in Coastal and Shallow Waters).

The development of the quality guideline was initiated with a comprehensive literature review, with the aim of identifying the basic actors and processes of offshore EOD. The International Mine Action Standard (IMAS) for Underwater Survey and Clearance of Explosive Ordnance (EO)[18], served as an input of this initial step. Of great importance for the future recognition of the quality guideline was the involvement of representatives of all those stakeholders who would ultimately be affected by the finished document. Accordingly, stakeholder workshops were organized during which the findings of the literature review were verified, clarified, and expanded upon. Next, a preliminary version of the quality guideline was drafted and experts were given the opportunity to annotate. As these comments were processed, it became apparent that some expert opinions were conflicting, and thus expert groups were held to moderate these differing views and prepare the final document.

The resulting quality guideline covers the entire procedure of offshore EOD. A general section at the beginning of the document includes a glossary and a register of relevant normative and legal documents. It contains sections that define the overall competence requirements and mandatory qualification verification of the actors and their personnel. The subsequent chapters each describe one of the four phases, which have been divided as follows (Figure 2):

- Phase I: Preliminary Survey (five processes)
- Phase II: Technical Survey (eight processes)
- Phase III: Investigation of Target Points (nine processes)
- Phase IV: Clearance and Disposal (eight processes)

The document outlines these phases and subsequently subdivides them into their processes. For each process it provides a general description as well as potential deviations from the standard procedure. Furthermore, it details the functions and responsibilities of actors relevant to the process. Where necessary, it describes suitable technologies and their way of application. Finally, it supplements processes requiring documentation and reporting with lists of necessary content items. The ultimate section of the quality guideline is a reference section for technical and environmental quality drivers, which influence the quality of offshore EOD work. The quality drivers are defined, their interrelations are identified, and where possible, threshold values for minimum operational requirements are suggested.

The "Quality Guideline for Offshore Explosive Treatment" is available in German and English, and focuses on the execution of EOD in German waters. The principles and practices it suggests, however, can be applied to any location in the Baltic Sea.

THE TOOLS ARE READY FOR APPLICATION

The tools described in this article demonstrate the eagerness of the European scientific community to actively contribute to the development of approaches, which are meant to respond to the challenge of offshore ERW and CWAs. While all of the presented instruments and concepts are beneficial on their own, their benefits further increase when combined. They may be picked up by national and state authorities, militaries, offshore construction companies, and EOD specialists to tackle the ERW and CWA challenge in the field.

As economic and ecologic pressure on the Baltic Sea increase, ERW and CWAs constitute one of a myriad of challenges that need to be addressed. The DSS, the monitoring concept, and the quality guideline are aids that will help fulfill the vision of maritime spatial planning, thereby achieving sustainable and cooperative Blue Growth. The tools are ready for application.

See endnotes page 60

Torsten Frey
Researcher
Institute for Infrastructure and Resources Management
Leipzig University

Torsten Frey is a researcher at Leipzig University's Institute for Infrastructure and Resources Management, Germany. As a team member of the research project RoBEMM, Frey is the lead author of the "Quality Guideline for Offshore Explosive Ordnance Disposal." In his current research, he focuses on risk-based decision making during UXO clearance operations.

Jacek Bełdowski, Ph.D.
Professor; Researcher
Department of Marine Chemistry and Biochemistry
Institute of Oceanology of the Polish Academy of Sciences

Jacek Bełdowski is a professor and researcher at the Department of Marine Chemistry and Biochemistry, Institute of Oceanology of the Polish Academy of Sciences, Sopot, Poland. As a coordinator of EU projects CHEMSEA, DAIMON, and DAIMON2, and NATO SPS project MODUM, he has been active in submerged munition studies for the last decade. In his current research he focuses on risk categorization of CWAs and ERW.

Edmund Maser, Ph.D.
Professor; Director
Institute of Toxicology and Pharmacology for Natural Scientists
University Medical School, Kiel University

Edmund Maser is a professor and director of the Institute of Toxicology and Pharmacology for Natural Scientists, University Medical School, Kiel University, Germany. Maser focuses on researching reductive drug metabolism where he established the field of pluripotent steroid oxidoreductases. More recently, he and his colleagues established the blue mussel (M. edulis) as bioindicator and biomonitoring system for explosive chemicals that leak from corroding sea-dumped munitions. He has authored more than 180 original publications and reviews.