



Factsheet #1 Marine Dumped Munitions – Problems and Solutions

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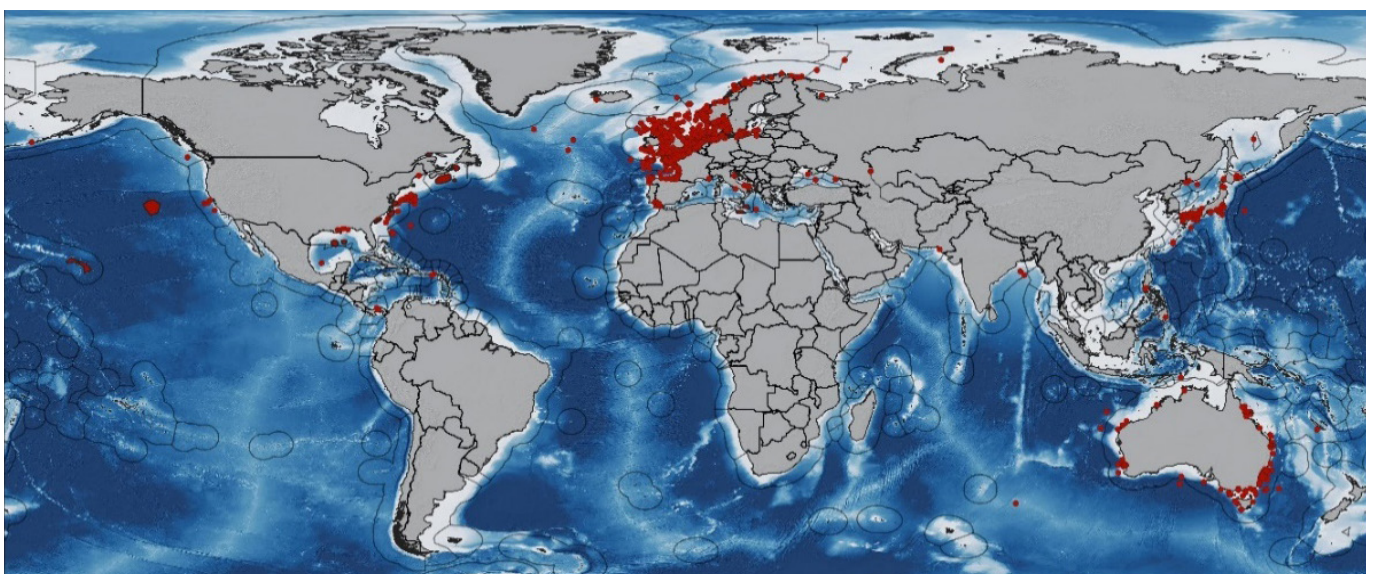
Introduction

Dumped marine munitions, also referred to as unexploded ordnance (UXO), poses multiple risks: it endangers shipping, bottom trawling, and offshore infrastructure projects such as cable routes, pipelines or wind farms. It also presents a threat to the public when munition remnants are washed ashore, and it remains a serious security concern.

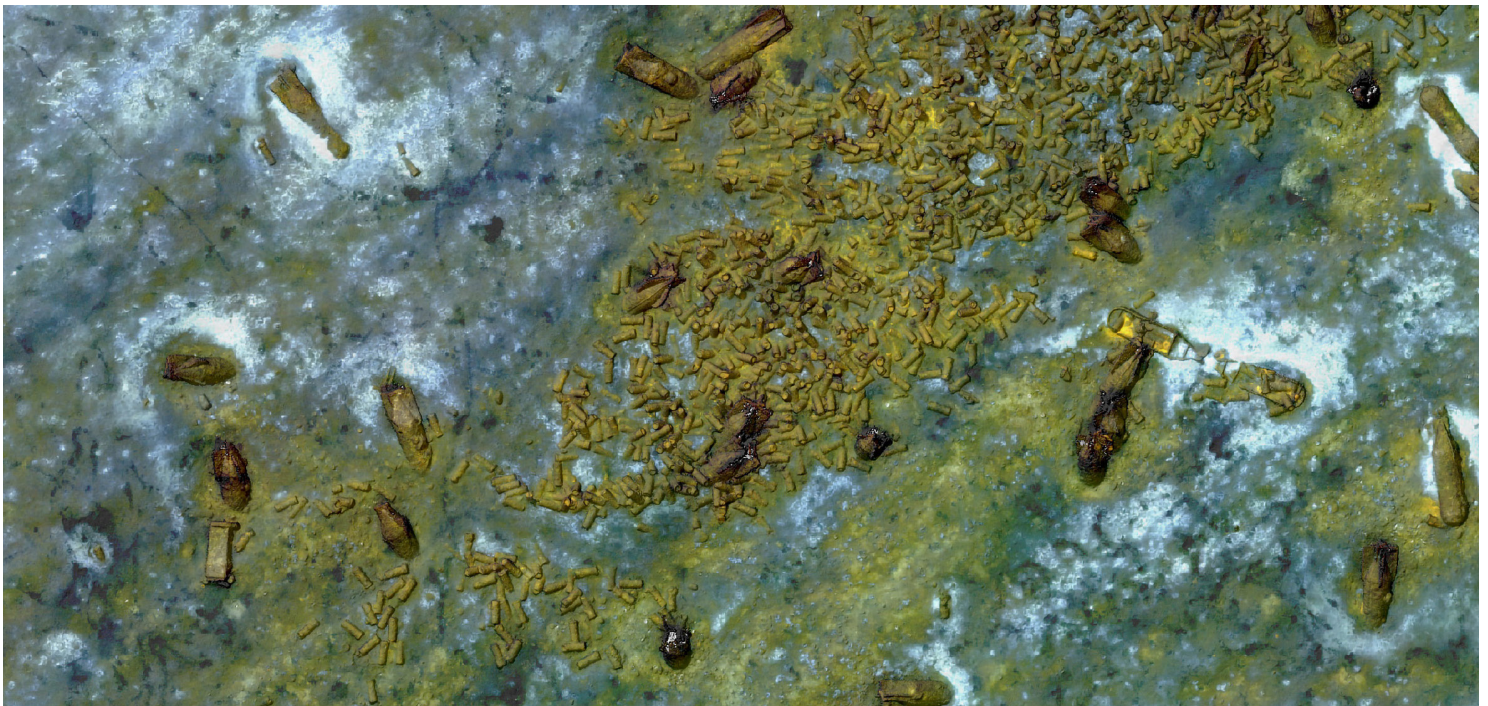
Explosive devices include both conventional munitions and those loaded with chemical warfare agents. While chemical weapons have long been recognized as toxic and dangerous, conventional munitions have only been acknowledged as environmental pollutants within the last 20 years. Scientists have since shown that toxic substances, such as TNT – which is carcino-

genic and mutagenic – can be absorbed by marine organisms, with harmful effects on ecosystems. The extent and nature of this impact have only recently come into sharper focus.

This growing awareness, combined with more open public discussion and improved understanding of the scale and distribution of dumped munitions – often close to shore – has led to increased research at national and international levels. Areas where dumping occurred on a large-scale face particularly significant ecological and economic consequences. The threat is compounded by the fact that both explosive and chemical munitions can remain functional even after more than 80 years underwater.



Global overview of marine dumped munitions. (Data compiled from EMODnet, HELCOM and AMUCAD; Illustration: GEOMAR)



The photomosaic shows a munitions pile at a depth of 20 metres in the Baltic Sea. It is composed of cluster bomb casings and more than 5,000 bomblets. (Photo: GEOMAR)

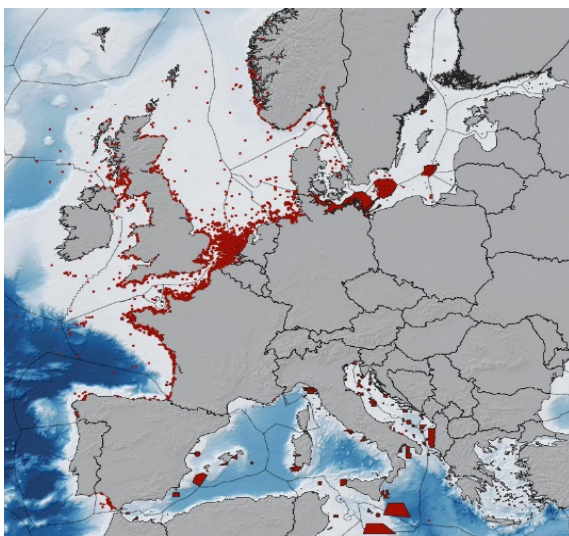


Large quantities of surplus ammunition were dumped at sea during the demilitarisation efforts following the war. This resulted in large piles of munition on the seafloor. (Photo: Imperial War Museums)

Why Is There Dumped Munition in the Ocean?

Munitions were introduced into the ocean during wartime activities – for example, through coastal artillery, aerial bombing, naval mines, and shipwrecks. In addition to munitions lost in combat or accidents, large quantities were dumped after the end of wars during demilitarisation efforts and the disposal of surplus or captured arms.

Dumped marine munitions include a wide range of ordnance – from small-calibre ammunition and grenades of all sizes to large aerial bombs, sea mines, and chemical weapons. These materials were often jettisoned from ships and barges at designated sites, but sometimes also dumped en route due to navigational errors or the lack of accurate positioning systems in the post-war years. As a result, munitions can be found outside officially marked dumping grounds – especially in coastal waters.



Where Is Dumped Munition Found?

Dump sites were designated shortly after the wars, usually near ports with good transport infrastructure. Offshore sites in deeper waters were chosen particularly for chemical munitions, but practical considerations often led to the dumping of conventional munitions within just 12 nautical miles off the coast.

For instance, chemical weapons were dumped in the Bornholm and Gotland Basins in the Baltic Sea, and entire ships were scuttled in the Skagerrak at depths of around 600 metres. In the Bay of Biscay, munitions were dumped at a depth of almost 5,000 metres. Although many dumping sites are known, detailed information on their actual size and contents is lacking. This information must be gathered to enable proper risk assessments and mitigation planning.

Map showing munition dumping grounds and known finds in European waters (Data: EMODnet, HELCOM, AMUCAD, Illustration: GEOMAR).



Military 'Blast-in-Place' operation in shallow waters. Detonations like this eliminate immediate risks but pose serious risks to marine mammals due to intense shockwaves (Photo: Uwe Wichert).

What Are the Options for Remediation?

Various approaches exist for dealing with munition. The method used depends on the urgency and reason for removal.

In-place disposal: When immediate threats to human safety or infrastructure exists, munitions can be neutralized where they lie. This can be done via:

- **Low-order detonation (LOD): The casing is breached without triggering a full explosion.**
- **High-order detonation (HOD): The explosive charge is intentionally detonated.**

LOD can spread explosives over a wide area, while HOD creates powerful shockwaves that can harm marine life – especially mammals. To mitigate these effects, bubble curtains are often deployed to reduce pressure waves, and acoustic deterrents are used to scare animals away.

In general, if no immediate safety threat exists, munition is often left in place. However, long-term environmental monitoring is necessary to assess the release of toxic substances and their accumulation in marine ecosystems.

Who is Responsible?

Responsibility for dealing with marine munition usually lies with the coastal state where it is found. In most countries, the military is responsible for dealing with marine munition in case of immediate threats or planned removal. In the context of offshore constructions, private companies are contracted to detect and remove munitions, particularly in connection with the growing offshore wind sector. This has led to increased expertise within the commercial sector for handling individual UXO.

However, there is still little clarity around who is responsible for large-scale clearance of entire dumping sites, both from a technical and legal standpoint. National regulations vary, and different agencies may be in charge of safety and environmental assessments.

In Germany, for instance, the Federal Ministry for the Environment has recently launched a pilot project to clear munitions piles in the German Baltic Sea. Meanwhile, international discussions are under way to explore how joint efforts can be coordinated to prevent further environmental damage and address this legacy.

What Is the European Science Community Doing?

For more than a decade, researchers have been investigating the ecological impact of marine munitions, both in designated sites and around wrecks. Studies focus on the presence of toxic substances from explosives and chemical weapons, and evaluate the environmental consequences of disposal techniques such as LOD and HOD.

Scientists are also actively engaging in dialogue with stakeholders and developing tools to support decision-making – often using methods from the social sciences. Numerous national and international research projects have been established, particularly in the North and Baltic Seas, often in collaboration with intergovernmental organisations like HELCOM and CBSS.

Where Can I Find More Information?

Several national and international research projects have generated substantial knowledge, which is published in scientific journals and public reports. Project websites are a good starting point for information on goals and findings.

A key resource is the “Munitions in the Sea” action under JPI Oceans:
<https://www.jpi-oceans.eu/en/munition-sea>





Factsheet #2

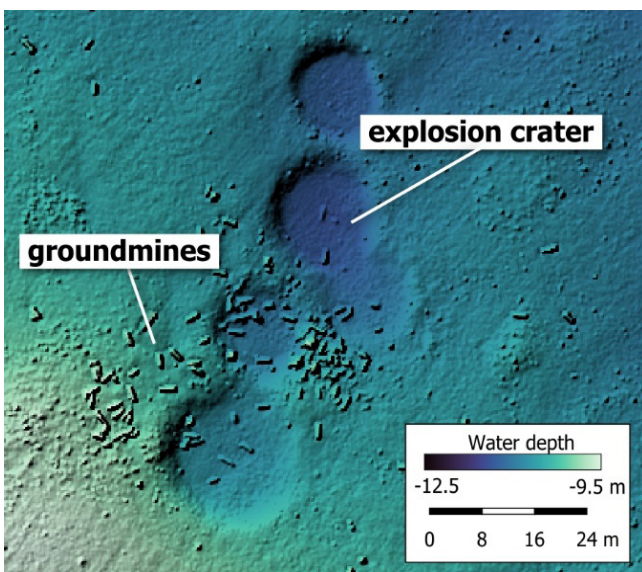
Detection of Marine Dumped Munition and Clearance Options

#2

Background – Marine Munition Surveys

Historical documents and reports highlight significant quantities of marine-dumped munitions in European seas. While the approximate locations of dumpsites are generally known, their exact contents and the conditions of the munitions are often not fully understood. Technical surveys are therefore essential – both to detect and identify objects and to develop clearance strategies that include prioritization and the selection of appropriate remediation methods.

The suitability of survey methods depends on oceanographic and seafloor properties, as well as on whether the munition is buried or not. For instance, highly dynamic current regimes may result in object burial and migration, necessitating ground-penetrating and non-optical survey methods.



Bathymetric map of explosion craters and ground mines. (Image: GEOMAR)

Hydroacoustic Surveys

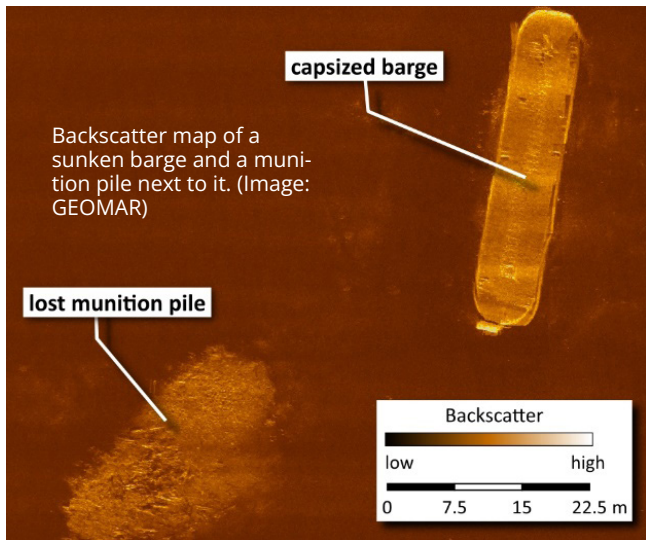
Hydroacoustic methods are a type of non-optical geophysical method that enables seafloor mapping based on sound propagation through the water. These methods differ in terms of deployment and therefore have different operational spectra.

Multibeam Echosounder (MBES): MBES are state-of-the-art hydroacoustic sensors used for precise seafloor mapping. They emit multiple sound beams across a wide swath beneath a survey vessel, enabling detailed capture of the seafloor's topography and the detection of objects. MBES is particularly effective in identifying underwater obstructions and variations in sediment composition thanks to its high resolution and accuracy. The results are georeferenced maps. These can be analysed and correlated with other spatial data. The munition detection capability is linked to data resolution, which depends on the water depth and the technical properties of the hardware.

Advantages: High-resolution seafloor bathymetry and object detection with high positional precision.

Limitations: Only objects on the surface can be detected. The detection capability depends on the size of the object and the data resolution. The footprint (and therefore survey efficiency) decreases with water depth.

Sidescan Sonar: Sidescan Sonar is a hydroacoustic survey method that also uses sound waves but to create detailed backscatter images of the seafloor. It emits sound pulses to the side and captures the return signals reflected from seafloor objects. The resulting high-resolution data can reveal the texture and composition of the seafloor, aiding comprehensive undersea exploration. It is typically operated either by being towed from a vessel or by being based on an AUV, in order to achieve high data resolution due to the low altitude and very narrow beam opening angle.



Optical Validation

In order to identify suspicious contacts, optical ground truth is essential. It also gives important information about corrosion conditions, fouling and the degree of burial. Data quality depends on the underwater visibility. Apart from divers, two main methods exist: Remotely operated and autonomous operations.

Remotely Operated Vehicle (ROV): due to their maneuverability and ability to capture high-resolution images, Remotely Operated Vehicles (ROVs) are highly effective for underwater object identification. They can be equipped with cameras and sensors to provide real-time visual data and detailed inspections, even in challenging underwater environments.

Advantages: High-resolution underwater footage and detailed observation of target objects.

Limits: Only surface-level objects are detectable. Detection capability depends on visibility. High-quality positioning is required.

Autonomous Underwater Vehicles (AUVs) equipped with advanced imaging systems are invaluable for underwater photo mapping. These vehicles can autonomously navigate pre-defined areas, capturing high-resolution images of the seabed and submerged objects. Their ability to operate independently allows for efficient and comparable mapping, which is crucial for identifying, documenting and monitoring underwater munitions.



AUV for high-resolution photo surveys. (Photo: Köser, et al. 2024)

Advantages: High-resolution underwater images and georeferenced photo mosaics for munition identification and monitoring. AUVs can be equipped with magnetic sensors as well.

Limitations: Only surface-level objects are detectable unless magnetic sensors or sediment penetrating hydroacoustic sensors are used.

Advantages: High-resolution seafloor backscatter imagery for object detection. Constant altitude ensures consistent data resolution.

Limitations: Only surface-level objects are detectable. The detection capability depends on the size of the object. Towed systems may be affected by weather conditions, and precise data positioning may be difficult.



AUV with attached magnetometer. (Photo: Marc Seidel / GEOMAR)

Magnetic Surveys

Magnetic surveys are essential for detecting ferrous objects underwater, including munitions. These instruments measure variations in the Earth's magnetic field caused by ferromagnetic objects, enabling potential hazards to be located precisely. Magnetometers are sensitive enough to detect buried munitions. Magnetometers or magnetic gradiometer arrays can be towed from a vessel or operated by an AUV.

Advantages: Enables the distinction between stones and munitions. Buried objects can be detected.

Limitations: Further information is required for object identification. The small footprint makes surveys time-consuming. Precise data positioning can be an issue.

Data Analysis

Hydroacoustic data forms the basis for optical confirmation operations. Magnetic methods can be used for contact detection and validation. In order to identify suspicious targets, the hydroacoustic data must first be annotated to determine locations for follow up investigations. Annotation can be done manually by experts or via automated detection using trained machine learning models. Bathymetric data allow the generation of morphological derivatives like slope or surface area, which improve the visibility of objects within the dataset and assist with annotation. Annotation software such as Validity (<https://validity-project.eu/>) or various GIS (Geographic Information System) tools can streamline the annotation process further. All datasets can be integrated into GIS software to assess the number and condition of munitions and to facilitate further spatial planning, monitoring and clearance actions.

Methods of Marine Munition Clearance

Options for underwater munition clearance include retrieval by divers, who can locate and secure items manually for removal, and the use of ROVs or crawlers – remotely operated vehicles that manoeuvre on the seabed – to recover objects. Another option is to neutralise the munitions by detonating them on site (Blast in Place), which is often the preferred method when clearance is too dangerous. Each method has its own specific challenges and advantages, depending on the conditions and the type of munitions involved.

Clearance Options at a Glance

	Advantages	Drawbacks
Diver recovery	<ul style="list-style-type: none">+ Targeted operation+ Expert identification on site+ controlled handling	<ul style="list-style-type: none">- Limited bottom time- Highest risk to humans
ROV / crawler recovery	<ul style="list-style-type: none">+ Targeted operation+ Low risk to humans+ Cost- and time-efficient	<ul style="list-style-type: none">- High technical effort
In-situ detonation	<ul style="list-style-type: none">+ Works for almost any object+ No transport required	<ul style="list-style-type: none">- Costly and time-consuming- Environmental stress due to noise and contamination

Future Clearance Vision

Marine munition dumpsites pose a significant threat of toxic contamination and security risk in national waters. Existing clearance methods are tailored to small areas and individual unexploded ordnance (UXOs) rather than large and complex munition dumpsites. On-site detonation requires extensive infrastructure – such as bubble curtains – to protect the environment from noise and contamination. Manual or remote munitions retrieval still involves transporting munitions to land-based disposal facilities, which are already operating at full capacity. The goal is to develop secure, efficient, and scalable solutions. Ideally, delaboration and disposal will take place near the dumpsites on a remotely operated platform at sea.



In 2024, Germany launched its first clearance trials in the Baltic Sea targeting complex munition piles and initiated the development of a mobile clearance platform

<https://www.bundesumweltministerium.de/themen/meeresschutz/munitionsaltlasten-im-meer>



Factsheet #3

Environmental risks of sea-dumped munitions: What we know so far

#3



English ground mine found in Kiel Bight in the dumping site Kolberger Heide. (Photo: Jana Ulrich)

Millions of tons of munition have entered our seas during and after the two World Wars. Many coastal regions in Europe, North America, Australia, and Asia are still affected by these legacies of war today.

Explosives in water and sediment

Most munitions in our seas were either dumped deliberately after the wars or remained due to wartime activities. They have now been lying on the seabed for over 75 to 80 years. Even if some of the casings still appear intact, corrosion has often progressed to a point where explosive substances are leaking into the environment.

This is particularly evident in the Baltic Sea, where large quantities of dumped munitions rest uncov-

ered on the seabed, in direct contact with oxygen-rich saltwater – conditions that accelerate corrosion. As a result, traces of explosive compounds are detected in water samples across the southern Baltic Sea, from Kiel Bight to the German-Polish border. Nearby sediments also show contamination. A similar, though less pronounced, situation exists in the German North Sea, where munitions are often buried under thick sediment layers, limiting leakage into the overlying water.

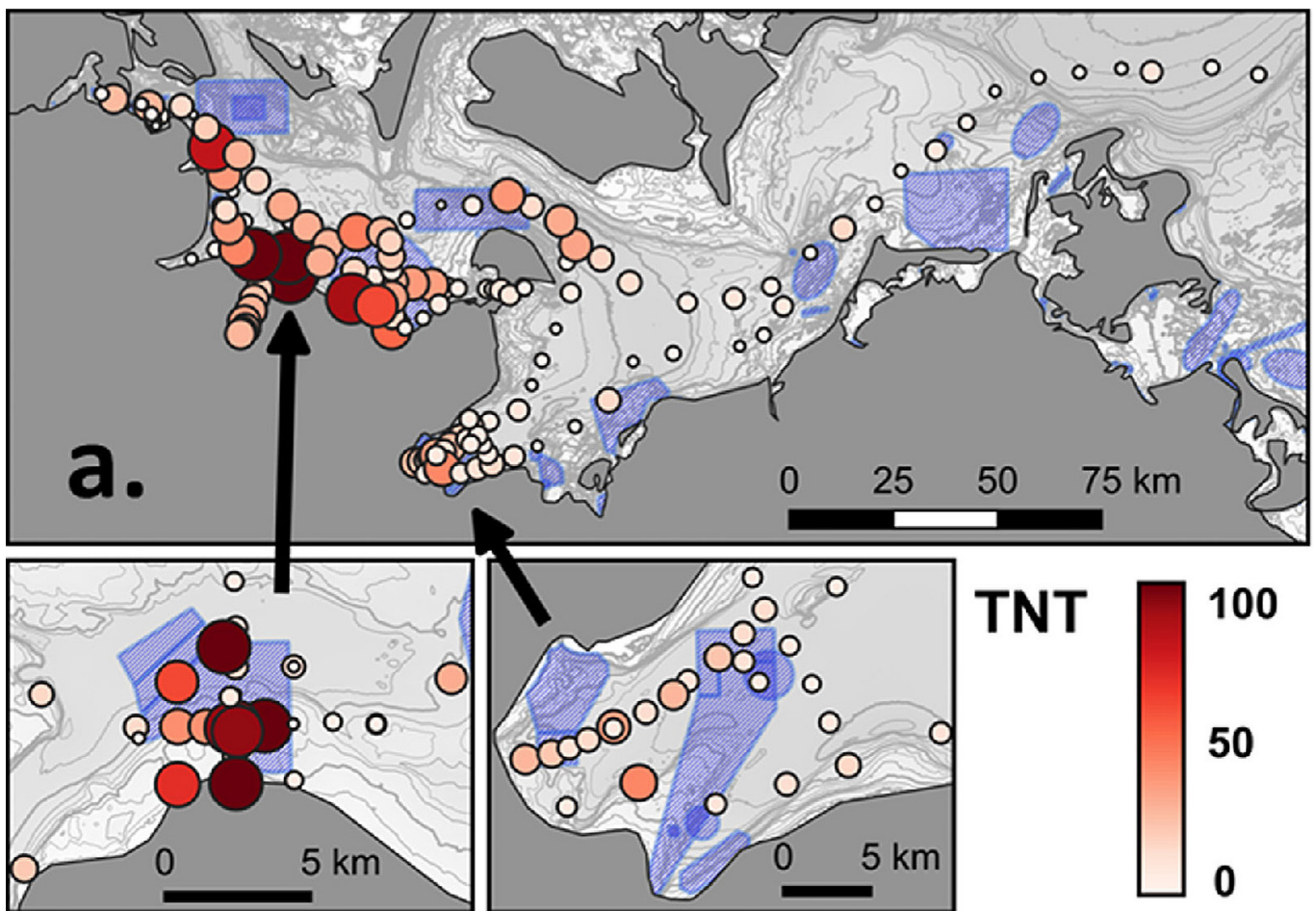
Explosives in marine organisms

Once dissolved, explosive compounds become bioavailable and are taken up by marine organisms — especially by those living near the seabed, such as mussels, worms, and flatfish. Laboratory studies show that uptake and concentration levels in tissues depend directly on ambient concentrations.

For example, TNT absorbed via gills or food is metabolised by mussels and fish into breakdown products like ADNT. While ADNT is less reactive than TNT, it is still toxic — and potentially mutagenic and carcinogenic. Fortunately, marine organisms can eliminate these substances fairly quickly. Mussels exposed to TNT, for instance, were shown to depurate the chemicals within a few hours after being transferred to clean seawater.

Background levels of dissolved munition compounds

In both the Baltic and North Seas, background concentrations of TNT and its breakdown products (ADNT, DANT, DNB) typically range in the nanograms per litre. However, near wrecks or dump sites, these levels can rise significantly — up to micrograms or even milligrams per litre.

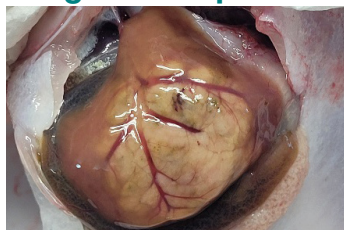


Distribution of TNT in the southern Baltic Sea (Illustration: Beck et al., 2025; Chemosphere, <https://doi.org/10.1016/j.chemosphere.2025.144115>)

Acute and chronic toxicity

From human medicine, we know that direct contact with solid TNT can cause eye, skin, liver, and bladder diseases. Marine organisms exposed to dissolved TNT exhibit similar signs of stress. Lab experiments have demonstrated lethal effects at concentrations in the milligram-per-litre range after only a few days of exposure. While such high levels are rarely found in the open environment, the more relevant concern is chronic exposure to lower levels over extended periods.

Long-term impacts on marine life



Tumour visible in a dab liver caught at a wreck site in the southern German Bight (Photo: R. Schuster)

Long-term field studies with mussels and fish near munitions sites have shown measurable biological effects even at low concentrations. Mussels exposed for several weeks to dissolved TNT show signs of metabolic disturbance, oxidative stress, and increased activity of detoxification enzymes. Flatfish such as dab (*Limanda limanda*), which are non-migratory and may spend their entire lives near contaminated wrecks, accumulate TNT metabolites in the liver and muscle tissue. These chemical residues are significantly associated with liver damage, including lesions, nodules, and tumours — suggesting a possible link to disease development.

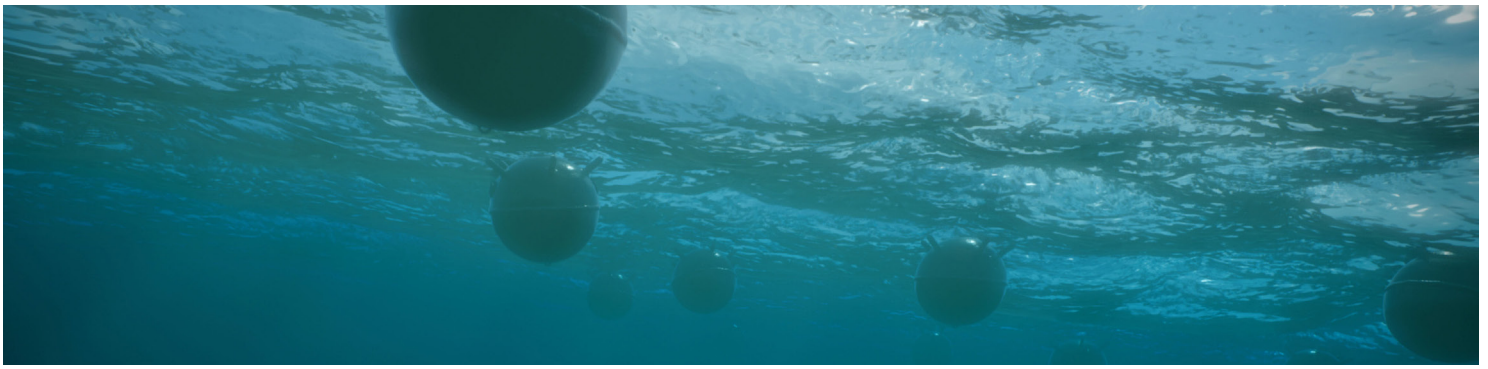
TNT in the food web

Leaked explosives from munitions are taken up by marine organisms and may enter the food web. Organisms living close to the seabed are more strongly affected than pelagic fish passing through the area. Feeding habits also play a role: if prey is contaminated, predators may ingest the substances indirectly.

Although marine organisms can eliminate TNT and its byproducts relatively quickly, trace amounts are still detectable in fish fillets and mussel tissue. These levels currently pose no health risk to humans, but because corrosion continues and more explosives become exposed, concentrations in seafood are expected to increase—especially in coastal areas of the North and Baltic Seas. This could bring levels closer to thresholds of concern over time.

Potential impact on fish reproduction

The observed liver damage in adult fish suggests a likely reduction in lifespan. Since affected individuals belong to the reproductive portion of the population, a decline in reproductive success and overall population health cannot be ruled out.



Factsheet #4 Threats of Munitions in the Sea to the Blue Economy

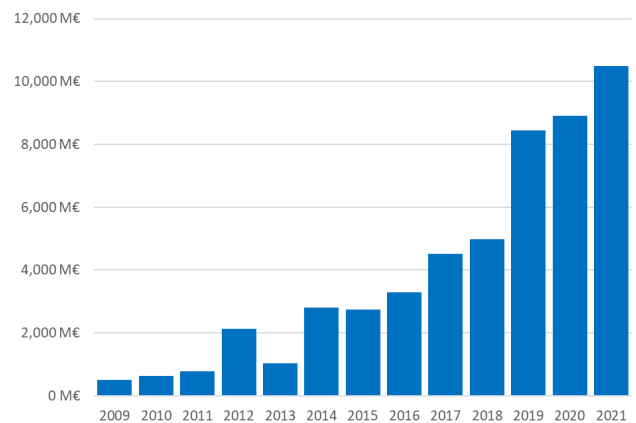
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Munitions in the sea constitute a threat to the blue economy. Raising awareness is the first and most important step towards understanding the associated risks and addressing them effectively.

Although recent projections do not predict significant growth in the blue economy's GDP, spatial demands are expected to rise – especially due to the expansion of offshore wind energy and aquaculture. As a result, key sectors must be prepared to deal with the issue of submerged munitions.

There are two primary patterns of munitions distribution in the ocean. One is the presence of concentrated contamination hotspots, such as former dump sites. In these areas, risks can often be managed through spatial planning and avoidance. The second—and arguably more challenging—pattern is the random distribution of munitions across the sea-floor, especially in coastal and nearshore areas. This widespread legacy of past military activities requires sector-specific risk mitigation measures. Addressing the issue proactively entails costs in terms of personnel and funding, but helps prevent accidents that could result in injury, loss of life, or material damage.

A projected ninefold increase in spatial ocean use between 2018 and 2050 will lead to a higher frequency of munition encounters. The way these threats materialise depends on multiple factors. Sectors most at risk are those that interact directly with the seabed. This fact sheet focuses on offshore construction and development (including wind farms, cable laying, shipping lane extension and other dredging activities), fishing, and tourism. Other industries, such as aquaculture and port operations may also be affected. Shipping, although a major sector economically, is generally only marginally exposed – except in the unlikely case of a freak accident.



Annual net investment in offshore energy in the European Union. Growth is primarily driven by Germany, the Netherlands, Denmark, and Belgium. (Data: EU Blue Economy Observatory)

Three Threat Pathways

1. Explosion Risk: Munitions contain explosive compounds intended to detonate. While dumped munitions are usually not equipped with a functioning fuze, unexploded ordnance (UXO) from combat zones may still function as originally intended. Their various fuzes – some triggered by pressure, magnetic field changes, impact or even sound – make them unpredictable. A detonation underwater generates rapidly rising gas bubbles, shock waves and intense sound, all of which can cause serious harm to people, vessels, and other equipment. This represents the most immediate and severe threat to the blue economy.

2. Toxic exposure: Even without detonation, contact with toxic materials – such as chemical warfare agents (CWAs), incendiaries, or toxic explosive compounds – can be dangerous. CWAs like sulfur mustard (mustard gas) are highly toxic and can cause injury or death with minimal exposure. In seawater, mustard gas forms lumps with a liquid core that can break

open when moved or handled without care. Accidental contact with munitions or its compounds poses an ongoing risk, particularly for the fisheries and beachgoers.

3. Environmental Contamination: Over time, toxic compounds from corroding munitions can leach into the marine environment and accumulate in seafood species. While current concentrations are not considered hazardous to human health, contamination monitoring is important.



Various munitions that were cleared during a shipping line extension in the German North Sea are prepared for detonation at low tide (Photo: SeaTerra).

Sector Specific Impacts

Offshore construction and development projects are commonly avoided in dump sites or other contamination hotspots. In areas where munitions may be randomly distributed, interactions with the seabed are inherently hazardous. Activities like dredging, pile driving, and cable ploughing carry inherent risks without prior explosive ordnance disposal (EOD). The four EOD phases - (I) a desk-based preliminary survey, (II) technical site survey, (III) investigation of potential objects, and (IV) clearance and disposal of munitions – must be performed by trained professionals.

One notable example: construction of the Nord Stream 1 pipeline involved the removal of over 100 munitions in Russian, Finnish, Swedish, and German waters. This demonstrates that EOD is the way of risk management that is accepted throughout the construction and development sector. While EOD processes entail additional costs, they are a small fraction of total budgets and significantly reduce the risk of delays or catastrophic incidents.

Fishing: The fishing sector is especially vulnerable. Hauling up munitions or CWAs can cause explosions or toxic exposure—both with potentially fatal outcomes. In the Baltic Sea, fishers have repeatedly been exposed to all kinds of munitions. Bottom trawling poses the highest risk, but any gear that contacts the seabed may result in unintended recoveries, as shown by the near-fatal incident aboard the crab potting vessel Galwad-Y-Mor.

Marked exclusion zones and areas labeled as “foul ground” in nautical charts offer some protection. Yet, encounters are not limited to official dump sites. In the Bornholm Basin, of 327 encounters with chemical warfare agents (CWA) that were reported to Danish authorities from 1961 to 2012, only 26 occurred inside the boundaries of the dumpsite as it is shown on officially issued maps. Guidance documents have been issued, e.g., by HELCOM, Poland, and Denmark,

to instruct fishing personnel on how to act, when munitions are encountered.

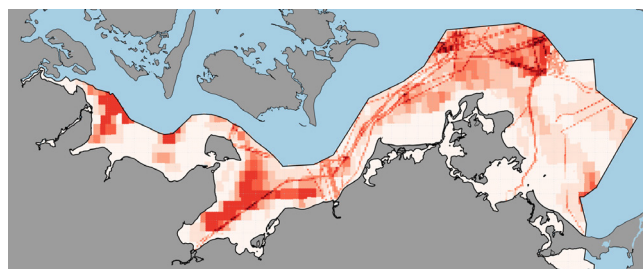
Tourism: Although tourists are unlikely to interact with large-scale seabed munitions, small objects—including explosive lumps or incendiary materials—can wash ashore, particularly after storms. White phosphorus, for instance, resembles amber but can spontaneously ignite when dry, burning at temperatures up to 1,300°C. Children are especially at risk.

Such incidents may negatively impact tourism in affected areas. Regular beach patrols by EOD experts and clear signage can help prevent accidents and reassure the public.

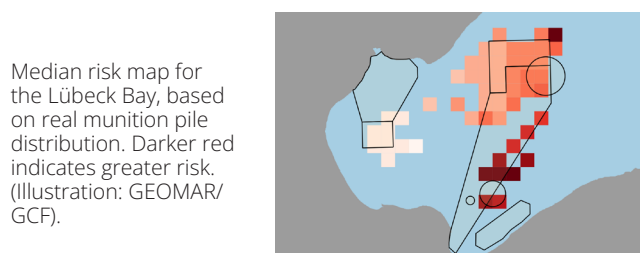
Threat and Risk Assessment

To assess risks, data on munition type, location, and condition must be combined with information on maritime use. Since detailed data is often unavailable, area-wide threat assessments can be carried out using hypothetical munition objects. These models help identify zones where preventive surveys are warranted.

For areas where munition information and blue economy data are both equally available, a risk assessment can be performed. In this case, a high risk should be followed by a recommendation for clearance in the respective area.



Potential threat map for the German Baltic Sea assuming uniform munition distribution. Darker red indicates high threat levels, correlating with fishing intensity and shipping routes. (Illustration: GEOMAR/GCF).



Median risk map for the Lübeck Bay, based on real munition pile distribution. Darker red indicates greater risk. (Illustration: GEOMAR/GCF).

Conclusion

The threat posed by munitions in the sea increases with a sector's interaction with the seabed. The offshore construction industry has developed comprehensive safety protocols. The fishing sector, by contrast, remains the most accident-prone. Coastal tourism, while employing the most people within the blue economy, is comparatively less affected, though not entirely risk-free.

For further information on security issues please contact: mmine-sweeper@geomar.de



Factsheet #5 Security Concerns Related to Marine Dumped Munitions

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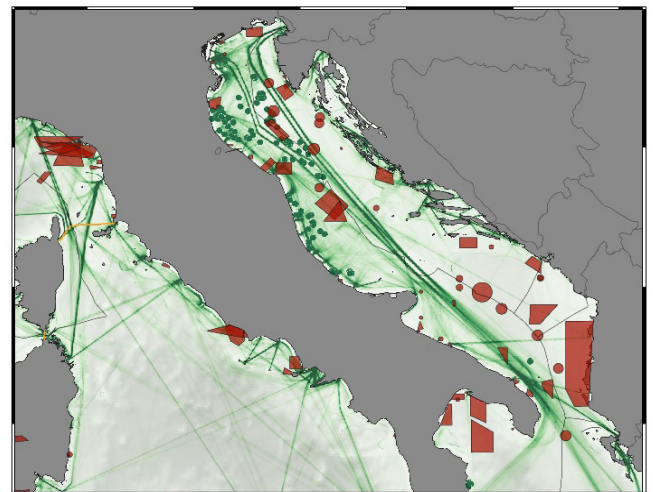
Direct threats to human safety

Marine dumped munitions pose a range of concerns. These primarily relate to the safety of shipping lanes and harbors, fishing activities, and the encounter of munitions or their components on beaches – for example, chunks of explosives or phosphorous from tracer ammunition or incendiary bombs. Additional risks arise during clearance operations, which endanger personnel, equipment and the environment. Beyond these immediate safety hazards, there are broader security-related issues that warrant closer attention.

Risk of misuse and intentional detonation

One critical concern is the potential misuse of old munitions for criminal or terrorist purposes. Likewise, deliberately triggering explosions at munition dumpsites to damage critical infrastructure could cause significant harm, while leaving uncertainty as to whether the blast was accidental or intentional. Such events would likely cause concern among the public, especially in tourist regions.

For in-situ detonation of munition piles, it is essential to determine both the net explosive mass and the overall explosive potential, along with the corresponding safety distances. A further concern arises with the prospect of industrial-scale munition clearance and on-site disposal operations in the coming years. These efforts will require the installation of substantial infrastructure for extended periods – necessitating a comprehensive and effective security strategy.



Ship traffic density (green lines) offshore infrastructure (green dots) and munition dump sites (red) in the Adriatic Sea. (Data and Illustration: GEOMAR)

Knowing what lies on the seafloor

Before any meaningful risk mitigation can occur, munitions must first be detected and identified. Nautical charts typically mark historic dump sites based on national archival records, but these areas are often only rough estimates. Munitions are frequently found outside of the map-indicated areas. While the charted areas do indicate regions where munitions can be encountered, munitions itself cover less than one per cent of the total area – meaning that locating munitions still requires extensive mapping efforts (e.g. with multibeam echo sounders or side-scan sonar) followed by targeted identification.

In some cases, circular exclusion zones are drawn around a single known object, usually positioned at the circle center. Such isolated and typically large items may be located relatively easily by divers without the need for prior mapping.

Accurate, high-resolution data – sometimes down to decimeter scale or better – are already available for certain areas. These data have been gathered through hydrographic surveys, offshore infrastructure planning, the military and scientific research into the ecological impacts of dumped munitions.

This raises several important questions:

1. Who needs to know the exact locations of individual objects or dump sites – and to what level of detail?
2. With whom can location data of certain accuracy be shared?
3. And how can this information be exchanged securely within a protected IT environment?

Ultimately, it must be determined who can and should access what type of information and in which level of resolution. For instance: How imprecise should coordinates be in scientific publications? Is it acceptable to publish polygon-coordinates indicating the density or type of munitions within an area? At a certain threshold, such information is deemed security-relevant and becomes subject to classification.



Half-buried bombs in a water depth easily reachable by recreational scuba divers. (Photo: ROV-Team, GEOMAR)

Misuse of old munition

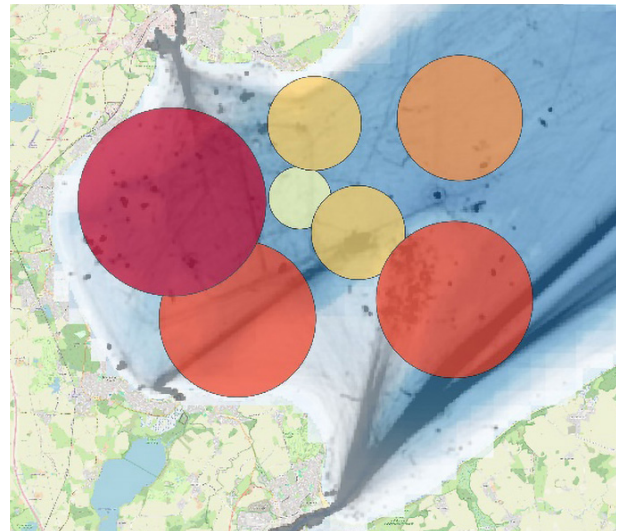
Even after decades underwater, many munitions still contain usable explosives. While their chemical properties may have changed, some materials remain viable for detonation. With sufficient local knowledge, it is theoretically possible to retrieve military explosives and reuse them for criminal or terrorist activities. That said, modern explosives are relatively accessible via legal or illegal channels — retrieving munitions from the seafloor is complex and resource-intensive, which may reduce the attractiveness of such methods. Still, the possibility must be considered.

Terrorism via intentional detonation

Another hypothetical threat is the deliberate detonation of entire munition piles. Estimates suggest that a single pile can contain several tons of explosives, for instance:

- 18 tonnes in a box pile of 2cm-grenades
- 5.6 tonnes from seven F103 war heads with each 800 kg explosives
- 3.9 tonnes in 78 sea mines

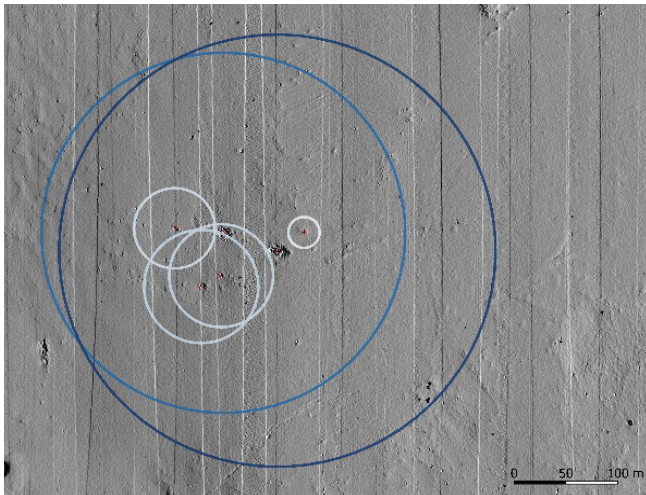
When multiple piles are located in close proximity (less than a few hundred metres apart), sympathetic detonations become a possibility, though still considered unlikely. Nonetheless, even a single event – whether accidental or deliberate – could trigger widespread fear. Such incidents would demand urgent political and security responses, even without immediate human casualties or infrastructure damage.



Safety radii of potential munition piles with a high net explosive mass. These interfere with the shipping lanes (presented as grey bands). (Hypothetic data for Lübeck Bay, Germany/ Illustration: GEOMAR)

Mass explosive danger and required safety zones

The impact radius of an underwater explosion depends on the net explosive mass and detonation dynamics. For example, using Dutch Explosive Ordnance Disposal (EOD) guidelines, a detonation of 5.6 tonnes of explosives would result in an “insignificant damage radius” of about 175 metres – but would require a safety zone for civilian shipping of up to 1800 metres. However, whether a true mass explosion of unfused underwater munition is technically feasible remains unclear, given the damping effect of water on pressure waves compared to air. Mass explosions of underwater munition piles may thus be harder to initiate than on land.



Shock radii of six neighbouring munition piles overlapping each other may cause the spreading of munition objects if not mass detonation. (Real data from the Baltic Sea / Illustration: GEOMAR)

Risk to critical infrastructure and marine traffic

Even if large-scale mass detonations are unlikely, smaller explosions can still pose a serious threat to critical infrastructure at sea. If old munitions are located near such infrastructure, a small amount of additional explosives might be enough to trigger significant damage. Therefore, sufficient distance between known munitions and key installations is essential – ideally, all munitions should have been cleared before construction began.



A jack-up barge in Lübeck Bay, Germany, during munition clearance operations in summer 2024 (Photo: GEOMAR).

Surveillance of disposal platforms at sea

In summer 2024, clearance operations began in German waters to test available technologies for the removal of munitions of varying sizes and types. In this context, an offshore disposal platform is planned. As with land-based facilities, these platforms will require stringent surveillance and security protocols.

Secure data exchange and coordination

All clearance activities depend on a robust and secure knowledge base:

- potential risks for the encounter of munitions from naval archives
- high resolution mapping
- object-specific identification, including condition and layering.

An ongoing debate concerns the level of detail at which munition-related data should be shared with different stakeholders, and how such data can be exchanged and stored securely. The challenge lies in balancing transparency and risk awareness with the need to protect security-relevant information.

Conclusion

All of the above security risks are valid and represent serious concerns for national governments and European security frameworks. Several research projects are currently working together to quantify these risks, develop shared security strategies, and define data protocols that enable secure yet effective cooperation among trusted partners. Their joint goal is to ensure the best possible knowledge base for informed decision-making.

For further information on security-related aspects, please contact: mmine-sweeper@geomar.de



Factsheet #6 Legal Framework for Marine Munition Remediation

#6

Responsibilities, regulatory gaps and options for action in European marine waters

Conventional and chemical munitions dumped into the ocean pose significant risks to human safety and a sustainable blue economy. Although several international and regional conventions and treaties acknowledge the urgency of addressing these risks, the fragmented legal landscape currently prevents most European countries from taking coordinated remediation action.

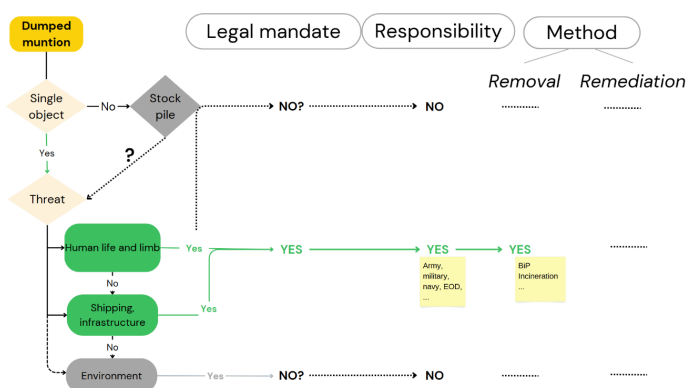
The Baltic States have recently committed to tackling this issue (Our Baltic Conference, Palanga, 2023), including closing legal gaps to assure remediation of marine munitions and their derived environmental impacts.

Activating Removal Mechanisms

In cases of acute security threats – such as risks to human life, maritime traffic, or critical infrastructure – national security units (e.g. armed forces, defence ministries, or specialized security agencies) are authorised to remove sea-dumped munitions. However, environmental risks or long-term threats to economic development do not trigger similar mandates.

Currently, most regulations focus on the removal of individual objects on a case-by-case basis, rather than mandating the large-scale clearance of stock-piled chemical or conventional munitions. There is no direct institutional obligation to remove sea-dumped munitions solely due to the environmental threat they pose, nor are environmental authorities involved in the munition removal process to minimise the environmental impact of these activities.

A common clearance practise is “blow-in-place” (BiP), where munitions are detonated underwater at their current location. While cost-effective, BiP causes severe environmental damage – such as sediment

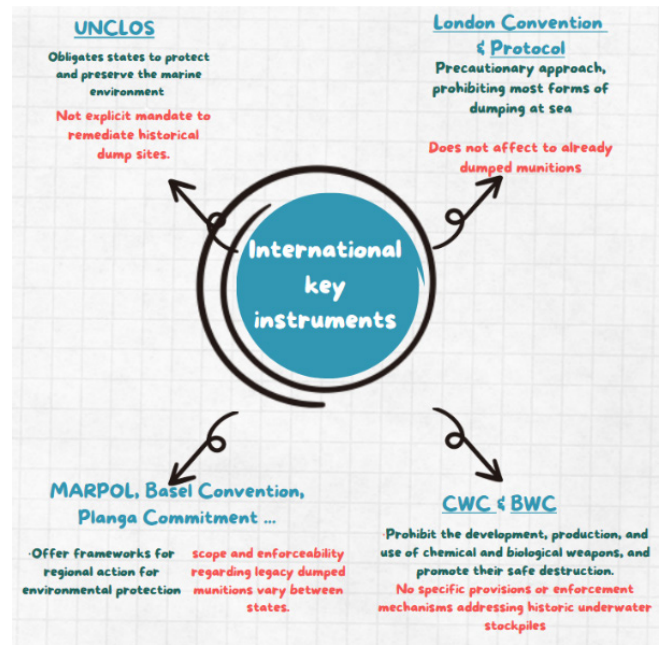
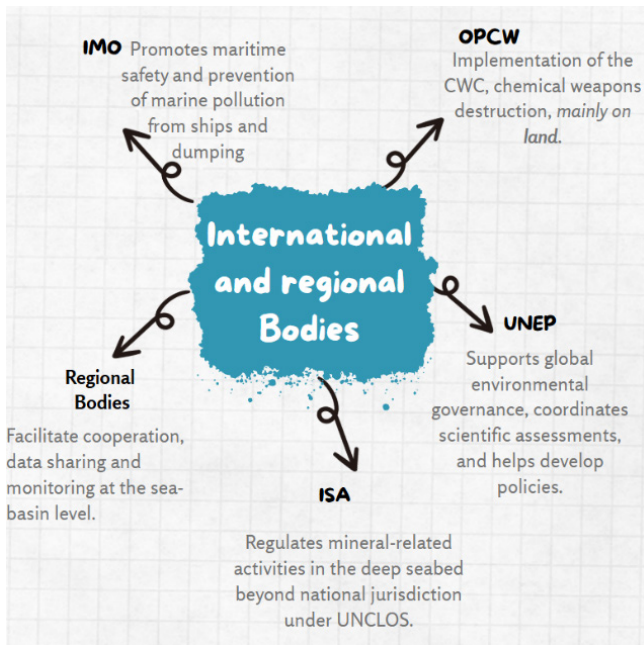


resuspension and injuries to marine life from shock-waves and explosions.

Fragmented Legal Landscape

Key shortcomings include:

- No single comprehensive treaty governs sea-dumped munitions.
- Legal responsibilities are distributed across international environmental law, the law of the sea, disarmament treaties, and regional agreements.
- No mandatory clearance unless there is an immediate threat to humans or infrastructure.
- Key environmental law principles – like precautionary action or the polluter-pays principle – are not applied.
- Coordination between national agencies is weak or unclear.
- Beyond the 12 nautical mile zone (i.e. in the Exclusive Economic Zone, EEZ), environmental oversight is often absent.
- There is no permitting process for environmentally harmful practices like BiP.



- Lack of coordination between authorities of the same country and unclear mandates slow the national response.
- Transport restrictions further complicate the safe recovery and disposal of munitions.

Political and Economic Barriers

Legal complexity is not the only challenge. The remediation of marine munitions is a historically sensitive topic – linked to wartime legacies and unresolved liability questions. Additionally, actions have high costs: for instance, constructing and operating a mobile offshore disposal platform can cost over €100M annually.

Even though technologies are available, there is still no consensus on who should finance large-scale remediation or how to prioritise sites for clearance.

Options for a Future Legal Framework

1. Enhancing existing laws

- Amending waste legislation to classify munitions as hazardous waste is one possible route, but comes with legal and practical challenges.

2. Tailored legal solutions

- National laws can be more quickly adopted and adapted to context, but have limited effect in cross-border marine areas.
- A new international treaty could harmonise current regulations, clarify accountability, and define funding structures. However, negotiation and ratification would take years.
- An EU-wide regulation offers the advantage of stronger enforcement and coordinated action – though limited to member states and potentially contentious in terms of national sovereignty.

3. A phased, hybrid approach:

- Short-term: Strengthen national and regional legislation, improve inter-agency coordination, and imple-

ment existing EU strategies.

- Long-term: Develop a binding international framework, informed by consultations, feasibility studies and funding mechanisms.

EU-Funded Projects Working Towards Holistic Strategies

Several EU co-founded projects – including MMinE-SWEEPER, MUNIMAP, and MUNI-RISK – are collaborating to improve the legal framework and to develop a coordinated strategy for the remediation of chemical and conventional dumped munitions in European waters. Their joint legal work focuses on three core steps:

1. Mapping existing legal, methodological, and responsibility frameworks of the European countries.
2. Identifying legal or practical barriers that prevent national action on remediation.
3. Facilitating dialogue between relevant sectors and countries via workshops and consultations.

These projects aim to spark industrial innovation and attract both public and private investment in marine remediation – ultimately contributing to the restoration of ocean health.

Explore further

The German Environment Agency has launched a two-part publication, “Legal Aspects of Marine Munitions Management in the Baltic Sea Region”. The first volume is already available:





Factsheet #7 How to Engage, Share Knowledge and Boost Solutions

#7

Munitions dumped at sea continue to pose serious environmental, safety and socio-economic risks across Europe's seas. Over the past 15 years, more than 30 research projects have generated valuable insights into the scale and nature of this challenge.

Now, the field is entering a new phase: information is being centralised, coordination between initiatives is strengthening, and momentum is growing. This creates an unprecedented opportunity for collaborative, efficient, and impactful action.

Further progress depends on engaging new stakeholders and integrating fresh perspectives. This factsheet provides guidance on how you can get involved, access shared resources, raise awareness and contribute to real solutions.

Why act now? A Turning Point for Visibility and Coordination

European efforts are gaining momentum: in its **European Oceans Pact** the EU announces UXO removal strategies for the North, Baltic, and Black Seas, signaling strong political will. **Germany's Immediate Action Programme** provides a practical blueprint for systematic remediation. These initiatives have the potential to align closely with global processes and inspire action beyond Europe. At the same time, **maritime security is rising on the UN agenda**, with a Security Council high-level debate and UNIDIR designating it as a new research area. Furthermore, the UN Decade of **Ocean Science for Sustainable Development** provides a unifying framework for science-based solutions.

This unique convergence of regional leadership, global visibility, and growing policy engagement presents a critical opportunity. Now is the time for actors

worldwide to connect, contribute, and drive lasting change.

1. Get informed and contribute knowledge to the Munitions Portal

The European research community, working under the umbrella of Munitions in the Sea, stands ready to transfer knowledge and collaborate on the growing threat of underwater munitions. While scientists remain the driving force, the community now includes strong ties with industry, Explosive Ordnance Disposal (EOD) services, coast and border guards, the military, and policymakers. These stakeholders address all types of submerged munitions, both conventional and chemical, as well as sunken wrecks.

To provide an authoritative overview of this field, **JPI Oceans has developed the JPI Oceans Knowledge Portal Munitions in the Sea** (briefly, the 'JPI Oceans Munitions Portal' at munitionsinthesea.eu). This central hub consolidates studies, stakeholders, and projects, offering structured insights into mapping, risk assessment, and remediation to support informed decision-making.

Coordinated by JPI Oceans, hosted by Fraunhofer ICT, and authored by experts, the portal is central to advancing joint mitigation efforts. To showcase the various aspects of marine munition management and further develop the portal, content contributions are warmly welcomed. A central repository for publications on munitions in the sea is currently being established, and suggestions for relevant entries are likewise encouraged.

Get in touch with:
knowledge-munition@jpi-oceans.eu
Link: www.munitionsinthesea.eu



JPI OCEANS



2. Join the discourse on social media

To encourage broad community engagement and keep stakeholders informed about project developments and the wider discourse, communication efforts are becoming more streamlined, including the launch of a unified social media presence.

Join the discourse by:

- Sharing knowledge with the LinkedIn group “Forum: Munitions in the Sea” – a space for collaboration, exchange, and discussion among all interested in the topic
- Following #MunitionsInTheSea and the LinkedIn page “Munitions in the Sea” – for news, events, and key updates

3. Connect with Munitions in the Sea Projects

BaltWreck: Preventing massive marine waters chemical pollution from the leaking wrecks and munition / weapon dumps in the south Baltic

Funding: Interreg South Baltic Programme 2021-2027

Duration: 7/2024 - 6/2027

<https://www.imp.gda.pl/en/projects/interreg-programmes/baltwreck/>

BorDEx: Development and construction of a mobile demonstrator for the thermal disposal of explosives from coastal dumped munitions

Funding: former German Federal Ministry for Economic Affairs and Climate Action

Duration: 2024 - 06/2027

<https://bordex.de/>

CAMMera: Clearance Activities for Marine Munition through Efficient Remediation Approaches

Funding: Horizon Europe

Duration: 07/2025- 06/2028

<https://cammera-munition.eu/>

Conmar II: Concept for conventional Marine munition Remediation in the German North and Baltic Sea

Funding: sustainMare “Protection and sustainable use of marine areas”, funded by the former German Federal Ministry of Education and Research

Duration: 12/2024 - 11/2027

<https://conmar-munition.eu/>

IRAV2: Industrial Clearance of Contaminated Sites in Dumping Areas

Funding: Federal Ministry for Economic Affairs and Energy

Duration: 03/2026 - 02/2029

MMinE-SwEEPER: Marine Munition in Europe - Solutions with Economic and Ecological Profits for Efficient Remediation

Funding: Horizon Europe

Duration: 10/2024 - 03/2028

<https://mminesweeper-munition.eu/>

MUNIMAP: Baltic Sea Munitions Remediation Roadmap

Funding: Interreg Baltic Sea Region Programme

2021-2027

Duration: 3/2024-2/2027

<https://interreg-baltic.eu/project/munimap/>

MUNI-RISK: Mitigation of Risks due to submerged munitions for a sustainable development of the Baltic Sea

Funding: European Maritime, Fisheries and Aquaculture Fund (EMFAF)

Duration: 11/2024 - 10/2027

<https://muni-risk.eu/>

REMARCO: Remediation, Management, Monitoring and Cooperation addressing North Sea UXO

Funding: Interreg North Sea Region Programme 2021-2027

Duration: 07/2023 - 06/2027

www.interregnorthsea.eu/remarco/about-us

SAFE-BS2BKS: Safe Actions for Environment - Baltic Solutions to the Black Sea

Funding: CBSS Project Support Facility

Duration: 09/2025 - 02/2027

<https://safe-bs2bks.vercel.app/>

WATERSIDE: Removing ammunition remnants from the sea

Funding: German Aerospace Center e.V. (self-funded)

Duration: 01/2025 - 12/2027

<https://www.dlr.de/en/ki/research-transfer/projects/waterside>

4. Get involved

See here possibilities listed to actively contribute to ongoing research efforts by the Munitions in the Sea research projects:



Representatives of the projects BaltWreck, MMinE-SwEEPER, MUNIMAP, MUNI-RISK, CONMAR II, and EROVMUS at the BlueMission BANOS Arena in Sopot, Poland in April 2025