Study on underwater unexploded munition

Final Report

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EUROPEAN COMMISSION

European Climate, Infrastructure and Environment Executive Agency

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Executive summary

In January 2021, ICF Consulting Services Ltd. (ICF), in collaboration with Ventura Associates, was commissioned by the European Climate, Infrastructure and Environment Executive Agency (CINEA) to conduct a 'Study on Underwater Unexploded Munitions'. The Study's general objectives are to: i) identify the scope for improving cooperation between Member States' authorities, private bodies and regional organisations in dealing with accidental recovery, or any encounter with unexploded ordnances and chemical munitions dumped at sea; ii) contribute to improving coordination in the monitoring and systematic removal of these munitions so as to minimise the challenge to marine environment and maritime security; iii) increase Member States authorities' awareness of the issues related to underwater unexploded munitions.

What is the context of the Study?

The European Union Maritime Security Strategy and the Communication on the Sustainable Blue Economy[1] have highlighted the sea as a valuable source of growth and prosperity for the European Union (EU) and its citizens[2]. The security of seas and oceans is vital for 'economic development, free trade, transport, energy security, tourism and good status of the marine environment'.

Despite actions at supra-national and national level, the issue of unrecovered underwater unexploded munition may benefit from stronger coordination between EU Member States, at both legislative and operational level. The unexploded ordnance (UXO) depots represent an inherited burden that often lack ownership or a clear chain of responsibility. To date, Member States' national authorities have simply reacted to the problem whenever UXOs are found by fishers, or when laying cables, pipes or offshore structures.

What are the key objectives of the Study?

Using a mixed-method approach (primary and secondary data collection and analysis), the Study develops guidance to enhance cooperation between Member States' authorities, private bodies and regional organisations dealing with accidental recovery or any encounter with UXO and chemical munitions dumped at sea. It provides information on:

- Current situation of existing unexploded munitions in each European sea basin, as well as mechanisms (e.g. through mapping) and approaches used to monitor, evaluate and remove these ordnances;
- Available capabilities to deal with the disposal of sea-dumped unexploded weapons;
- Best practice in dealing with accidental encounters with dumped munitions at sea in different maritime communities (e.g. engineering/construction entities, fisheries, transport and tourism entities, other relevant stakeholders);
- Best practice in removal that limits impacts on the marine environment; and
- Current common procedures and response models for such incidents that could be promoted across maritime communities.

How was the Study carried out and what was the methodological approach?

The Study used mixed-methods, with primary and secondary data collection and analysis:

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:240:FIN

[2] European Union Maritime Security Strategy as adopted by the Council (General Affairs) on 24 June 2014. See: https://data.consilium.europa.eu/doc/document/ST%2011205%202014%20INIT/EN/pdf

- A substantial body of documentation was reviewed and analysed from a variety of EU, international/regional, Member State, third country, industry, academic and grey sources. The data provided an understanding of the location of existing UXOs in each European Sea basin, as well as the mechanisms/approaches adopted to identify, monitor and remove them. Early insights into existing national capabilities were discussed with the Directorates-General for the Environment (DG ENV), Maritime Affairs and Fisheries (DG MARE) and Mobility and Transport (DG MOVE) via scoping interviews.
- In-depth interviews were carried out with key stakeholders from seven EU maritime Member States (BE, BG, DE, FR, IT, NL, LT, SE) in order to gather systematic information on the current situation of existing unexploded munitions at sea, mechanisms/approaches for their monitoring and disposal, relevant capabilities, and any operative constraints. The following stakeholder groups were consulted: i) EU/international organisations and transnational research projects; ii) national/military authorities; iii) local/port authorities (including coast guards); iv) maritime communities; and v) non-governmental organisations (NGOs) and academia.
- A survey of 22 EU Member States + Norway broadened the scope of the consultation to the whole EU, with a specific focus on maritime Member States.
- A workshop focused on common EU procedures and best practice in dealing with accidental recovery of dumped munitions at sea. The following stakeholder groups were invited: i) EU/international organisations and transnational research projects; ii) national/military authorities; iii) local/port authorities (including coast guards); iv) maritime communities; and v) NGOs and academics. The workshop went beyond its initial scope, facilitating an open discussion of current problems with dumped munitions at sea and potential solutions at EU level.

How is the report structured?

The Draft Final Report is structured as follows:

- Section 1: Introduction;
- Section 2: Methodological approach, including data issues and limitations;
- Section 3: Main findings (covering all Study tasks); and
- Section 4: Overall conclusions and recommendations.

The following documents are annexed to the Draft Final Report:

- Annex 1: Sources;
- Annex 2: Stakeholder engagement;
- Annex 3: Survey and interview questionnaires;
- Annex 4: Survey report;
- Annex 5: Relevant capabilities employed for identification, monitoring and disposal of sea-dumped unexploded weapons: definitions;
- Annex 6: Responsible authorities involved in the management of UXO; and
- Annex 7: Technologies/Scientific approaches employed for identification, monitoring and disposal of sea-dumped unexploded weapons.

Summary of key-findings

Based on the information and analysis, the key findings of this report are:

Mapping of existing unexploded munition at sea in each European Sea basin

- The presence of UXOs in the **Atlantic Ocean** appears relatively uneven. Most of the UXOs can be found in the Brest Harbour and around Brittany and Normandy, where bombing raids took place during WWII. There are very few identified dumps along the rest of the French coastline and along the Spanish coastline. Encounters of UXOs are extremely rare in those areas. Generally speaking, UXOs are considered mainly a risk for the environment (rather than a human safety risk), even in Brest Harbour, because those who regularly encounter these devices (i.e. fishers) are well-trained on what to do and accidents are extremely rare.
- The **Baltic Sea** was, by contrast, heavily mined during World War I (WWI) and World War II (WWII), and was also the dumping site for many aborted or accomplished missions. Historical data has been of significant help in identifying the main sites and enabling national and regional effort to clear the path for key maritime routes. However, such data is hindered by the lack of precision that characterised georeferencing tools in the mid-20th century. A complicating factor is the presence of underwater currents which means that UXOs may move and areas of interest tend to be large rather than precise. On the plus side, regional cooperation is very good.
- The **Black Sea** is far more difficult to map due to the lack of historical archives and the inability to access dedicated archives. Limited means and a lack of immediate risks (the main maritime trade routes have been cleared) means reduced opportunities to carry out regular monitoring and clearing activities.
- The situation in the **Mediterranean Sea** is uneven, both in terms of UXO presence and ways to address the issue. As accidents and encounters are infrequent, the situation is largely addressed on an ad hoc basis. In Italy, the Adriatic part of the Mediterranean Sea reveals the presence of far more UXOs than anywhere else in the Sea due to the existence of several depots. However, regular encounters are also infrequent.
- The **North Sea** was heavily bombed and mined during WWII. No particular regional mechanism for regular monitoring has been identified, but each country appears to have established different systems to ensure the safety of citizens and maritime trading routes. Currents and tides in the North Sea make it difficult to be certain of UXO positions, thus encounters at sea (unlike those along beaches) are dealt with in a reactive manner.

Mechanisms/approaches adopted to identify, monitor, and remove UXOs:

- In all Member States, **navies** are involved in the process of identifying, monitoring and/or disposing of UXOs. The nature and stage of their involvement varies significantly between Member States. For example, while the Spanish, Polish, Swedish and Bulgarian navies are systematically involved in all steps, a number of other countries (FR, IT, DE, NL), adopt an ad hoc approach. Generally, the approach depends on who found the UXO and where (some areas are under exclusive responsibility of the navy and others are not), as well as whether it was an accidental encounter or part of a monitoring exercise.
- **Private companies** are often involved in identifying UXOs, particularly in the context of infrastructure works such as port extensions. This is the case in Germany and France, although the disposal of UXOs remains the prerogative of national authorities.
- **UXO monitoring** is not a systematic practice across the different sea basins. The North and Baltic Seas are regularly monitored, primarily because frequent encounters with UXOs trigger searches in the surrounding area. In the Atlantic and the Mediterranean, it is much less systematic (except Brest Harbour, where

encounters are also frequent). There is no regular monitoring in the Black Sea. Monitoring is far more systematic where there is regular regional cooperation, such as the Baltic Marine Environment Protection Commission (HELCOM), with annual exercises organised by Lithuania, Latvia and Estonia in the Baltic Sea, or Belgian-Dutch bilateral cooperation in the North Sea.

- With a few exceptions generally involving fishers (e.g. IT, LT), there are no **rules or guidelines** in case of UXO recovery. Interviewees highlighted the important role of maritime rescue coordination centres (MRCCs) and, in some cases, port authorities (e.g. IT).
- **Environmental** risks are not considered a priority in addressing UXOs. At the **monitoring** stage, there is little evidence that countries regularly assess the environmental risks associated with the presence of UXOs in their waters. Most projects have been the result of short-term regional and international projects. At the **disposal** stage, the majority of stakeholders noted that safety was the priority, ahead of environmental concerns (although in FR, for instance, acoustic devices to scare off mammals are regularly used).

Member States' capabilities for identification, monitoring and disposal of sea-dumped unexploded weapons:

- EU Member States **mine countermeasures (MCM)** clearance capabilities are world-class, as are their cooperation, joint exercises, and common training sessions. All Member States in scope have response mechanisms for accidental UXO recovery. This includes protocols/procedures, reactive chain of intervention, operational assets mobilisation and explosive ordnance disposal (EOD) diver qualifications.
- **Responsible authority(ies)** involve both public authorities and private actors, although the disposal of UXOs remains the prerogative of national authorities. In all Member States, **Navies** are involved in the process of identifying, monitoring and/or disposing of underwater unexploded munitions (UXOs). The nature of their involvement is subject to significant differences across Member States. For example, while ES, PL, SE and BG navies are systematically involved in all the steps of the UXO management cycle, other countries (FR, IT, DE, NL) adopt an ad-hoc approach which depends on the particular circumstances and environmental settings. Generally, this depends on whether it was an accidental encounter or whether it was part of a monitoring exercise. Furthermore, private contractors are increasingly involved in the identification and monitoring of underwater munitions. In this sense, a common operative framework is needed for all types of private entities (training, methods and procedures) undertaking these activities.
- **Capability gaps:**
    - Even if Member States' **MCM clearance capabilities** and cooperation are world-class, UXO identification and clearance capability nevertheless faces **a number of challenges**. While accidental discoveries are very efficiently addressed in all affected Member States and accidents are rare, underwater UXOs in EU seabeds remain an important and long-lasting risk to users and the environment;
    - Underwater UXO clearance is more challenging than terrestrial explosive clearance, which itself faces difficulties, hazards, and high costs. Currently, only naval forces have the capability to approach, identify, handle and neutralise underwater UXOs. The development of offshore infrastructure along the EU coastline (wind farms, communication cables, pipelines) has enabled the development of civilian capabilities to survey the seabed; However, the private sector is not authorised to intervene and neutralise UXOs detected. As the primary mission of armed forces is demining in the context of current military operations, the resources available for the activities

of UXO identification and disposal remain largely limited to accidental recoveries;

- Climate change-induced coastal erosion is a new aggravating factor. Since WWII, UXOs have typically been exposed by fishing activity, in particular when using sea floor trawlers and dredges. As UXOs encounters are common, the fishing community appears well-aware of the threat and applies the appropriate risk mitigation procedures when UXOs are tangled in their fishing gear. Increased coastal erosion might expose the general public, who are unaware of UXO risk culture and may ignore precautions and alert procedures. This risk is difficult to avoid, as the preventive clearance capability of buried UXOs remains limited (it requires complex magnetic detectors);
- Chemical monitoring of UXO leaks remains an unsolved capability challenge and is still at research and development (R&D) stage. Sensors must be developed, along with sufficient knowledge on the extent of the pollution, its evolution over time, and its impact on marine life and - ultimately - on the food chain and/or human health;
- There is a need to develop, adapt and validate procedures and techniques to mitigate environmental impacts, as well as to train operators across the different UXO threats and contexts. It is important to develop open UXO detection systems featuring unified taxonomies and data-models) to be used for artificial intelligence (AI)-based UXO identification algorithms from sonar and magnetic anomaly data.

Response protocols/procedures in UXO accidental recovery

- Immediate interventions in the Member States are generally **harmonised under international maritime regulations**. This is also true of the deminers' training programme, which is based on North Atlantic Treaty Organization (NATO) standards.
- **Immediate management** of the reported munition is based on the existing alert systems provided by international maritime regulations. For instance, in the event of danger, the MRCC is alerted on **VHF channel 16** or through the **European emergency phone number, 112**. **Treatment** is generally carried out by the alert teams (24/7) of the Member States or regional demining services. They usually operate under the authority of the navy, sometimes the police, and are trained according to NATO standards.
- The **risk of accidental discovery** of chemically loaded (sometimes leaking) munitions persists, especially in the Baltic Sea. However, demining teams receive only limited training on the use of environmentally safe methods and procedures;
- **Climate change** may increase the accidental discovery of ammunition by individuals on the foreshore.
- **Loss of knowledge** should be considered, with older fishers replaced by new generations. These new fishers are less experienced in UXO encounters and thus less aware of risk areas and safe procedures.
- **Information exchange** continues to be insufficient. It is crucial to enable the circulation of information between professionals, civilians, and Member States' authorities in order to mitigate the risks posed by UXOs and facilitate the sharing of best practice.

Set of recommendations f to support Member States in dealing with accidental recovery of dumped munitions at sea

The current analysis highlighted the importance of developing policies that go beyond emergency responses, including structured and proactive measures. This requires a multi-level and cross-border approach, including harmonised legislation, development of new and possibly shared detection and clearance capabilities, and UXO-specific training systems. An EU-wide assessment of UXO chemical risks (including current pollution maps, agreed safety thresholds and common monitoring policies) is thus

recommended. As the UXO depots conditions depend on currents, sea water oxygen content, possible burying in sediments etc., detailed mapping of these risks would facilitate the establishment of risk scales valid for all known historic depots.

This Study identifies **8 specific actions** across **four key areas.** Depending on their scope, these actions can be divided into **National, Regional, and/or EU level**:

Action A1 - Environmental protection

- Regional and EU level
  - Action A1.1 - Promote cross-border cooperative projects for systematic surveys and EU wide detection of UXO chemical pollution; and
  - Action A1.2 – Facilitate the creation of an EU-wide UXO knowledge hub.
- National level
  - Action A1.3 - Map the seafloors through risk parameters to assess depot-related risks.

Action A2 - UXO dedicated capability building

- All levels
  - Action A2.1 – Scaling up UXO clearance capabilities
  - Action A2.2 – Increase the detection and identification capabilities of UXOs; and
  - Action A2.3 - Improve the impact reduction technologies for underwater UXO disposal.

Action A3 - UXO management capabilities of private operators

- National level
  - Action A3.1 - Increase the UXO management capabilities of private operators

Action A4 - Response models

- Regional and EU level
  - Action A4.1 Common procedures and response models.

Abstract

The issue of underwater unexploded munitions is a large-scale problem in European sea basins, posing a threat to the marine environment and the security of all maritime activities. Various European Union coast guard cooperation initiatives have been consolidated through the years, as well as several legislative and operational initiatives to improve the focus on underwater unexploded munition and promote cooperation. Nevertheless, the issue continues to require stronger coordination between Member States. The purpose of this Study is to: i) develop guidance to enhance cooperation between Member States' authorities, private bodies and regional organizations dealing with accidental recovery or any encounter with unexploded ordnances and chemical munitions dumped at sea; and ii) contribute to improving coordination on the overall monitoring and systematic removal of these munitions. By using a mixed-method approach of primary and secondary data collection and analysis, this Study developed guidance to enhance cooperation between Member States' authorities, private bodies and regional organisations in dealing with accidental recovery or any encounter with unexploded ordnances and chemical munitions dumped at sea by developing relating guidance.

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Concepts and definitions

Term	Description
Ammunition	Generic term related mainly to articles of military application consisting of all kinds of bombs, grenades, rockets, mines, projectiles, and other similar devices or contrivances.
Biota	Animal or plant life in a specific area, habitat or geological period.
Bomb	Explosive weapon that uses explosive material to provide a sudden and violent release of energy. Usually dropped from aircraft with or without a fuse.
Classification	Steps to classify an object as an UXO, and then according to the level of danger posed by the UXO.
Chemical warfare material (CWM)	Items configured as a munition containing a chemical compound that is intended to kill, seriously injure, or incapacitate a person through its physiological effects. Chemical warfare materials include V- and G-series nerve agents or H-series (mustard) and L-series (lewisite) blister agents in other-than-munition configurations; and certain industrial chemicals (e.g., hydrogen cyanide (AC), cyanogen chloride (CK), or carbonyl dichloride (called phosgene or CG)) configured as a military munition.
Conventional munition	Munitions that create damage from kinetic, explosive or incendiary energy. They include small arms, sea and land mines, bombs, rockets, missiles and cluster munitions that do not have a nuclear or chemical load.
Demining	Activities which lead to the removal of mine and UXO hazards, including technical survey, mapping, clearance, marking, post-clearance documentation, community mine action liaison and the handover of cleared land. Demining may be carried out by different types of organizations, such as NGOs, commercial companies, national mine action teams or military units. Demining may be emergency-based or developmental.
Detection	Process of scanning seabeds (or water columns for mines) up to the point of detecting traces of the presence of a (possible) UXO, leading up to identification.
Depth charge	Anti-submarine explosive weapons, usually canisters loaded with explosives and occasionally with sensor devices, designed to explode at an appropriate depth to damage or sink submarines.
Disposal	Includes any form of neutralisation to lower the risk created by an UXO.
Dumping (at sea)	Deliberate disposal of waste and other matter from aircraft, vessels or other man-made structures at sea, as well as any disposal at sea of any of these structures.
Dumpsite	Geographical point or area where munitions have been dumped at sea.
Dredging	Excavation of material from an aquatic environment, usually rock, sand or other sediments.

Explosives	A substance or mixture of substances which, under external influences, is capable of rapidly releasing energy in the form of gases and heat.
Explosive ordnance disposal (EOD)	The detection, identification, onsite evaluation, rendering safe, recovery, and final disposal of unexploded ordnance and of other munitions that have become an imposing danger, for example by damage or deterioration.
Explosive Ordnance Disposal (EOD) personnel	Military personnel assigned to perform EOD duties. EOD personnel have received specialized training to address explosive and certain chemical agent hazards during both peacetime and wartime. EOD personnel are trained and equipped to perform "render safe procedures" (RSP) on nuclear, biological, chemical, and conventional munitions, and on improvised explosive devices.
Explosive Ordnance Disposal (EOD) unit	A military organization constituted by proper authority; manned with EOD personnel; outfitted with equipment required to perform EOD functions; and assigned an EOD mission.
Explosion	A chemical reaction of any chemical compound or mechanical mixture that, when initiated, undergoes a very rapid combustion or decomposition, releasing large volumes of highly heated gases that exert pressure on the surrounding medium. Also, a mechanical reaction in which failure of the container causes sudden release of pressure from within a pressure vessel. Depending on the rate of energy release, an explosion can be categorized as a deflagration, a detonation, or pressure rupture.
Hazardous wrecks	Shipwrecks on the seabed containing or being surrounded by hazardous substances such as explosive, biological or chemical substances, and that present a risk to human and animal life.
Identification	Steps taken to positively identify an object as an UXO, and to further identify more specific characteristics such as type of munition, size, contents, triggering status and condition.
Influence mines	Mines triggered by the influence of a vessel or submarine, rather than direct contact. Such mines incorporate electronic sensors designed to detect the presence of a vessel and detonate when it comes within the blast range of the warhead.
Maritime community	Type of users of the marine environment, grouped as follows: engineering / construction entities, fisheries, transport and tourism entities, and any other relevant stakeholders in this area (e.g. environmental organisations or UXO specialists).
Maritime Mine Warfare (MMW)	Activities relating to the military use of naval mines (under all angles). MCM is part of MMW.
Mine	Munition designed to be placed under, on or near the ground, or other surface area and to be exploded by the presence, proximity or contact of a person or a vehicle. Terrestrial mines found as UXOs relate to the loss of cargo or overboard disposal. Naval mines can as well have such origin but most commonly were laid during wartime coastal and port defence, and missed by the post-war demining effort.

Mine Countermeasures (MCM)	Activities related to the detection, monitoring and removal of naval mines, including minesweeping.
Military munitions	All ammunition products and components produced for or used by the armed forces for national defence and security. Ordnance is part of munitions.
Missile	Guided airborne ranged explosive weapon propelled through the atmosphere by a jet engine or rocket motor.
Monitoring	Regular assessment of known UXO depots through geo-location, sampling, tests of corrosion and environmental pollution.
Munitions response	Response actions, including investigation, removal actions, and remedial actions to address the explosives safety, human health, or environmental risks presented by unexploded ordnance (UXO), discarded military munitions (DMM), or munitions constituents, or to support a determination that no removal or remedial action is required.
NOMBO	Non-Mine, Mine-Like Bottom Object.
Ordnance	Explosives, chemicals, pyrotechnics, and similar stores (e.g., bombs, guns and ammunition, flares, smoke, or napalm). (See military munitions.)
Propellant	An agent such as an explosive powder or fuel that can be made to provide the necessary energy for propelling a munition.
Risk	Combination of the probability of occurrence of harm and the severity of that harm.
Remotely Operated Vehicle (ROV)	Land or sea-based vehicle operated remotely for the purpose of UXO detection, monitoring and disposal.
Scuttling (ship)	Deliberate act of sinking a ship by allowing water to enter its hull. This can be done by perforating the hull with tools or explosives.
Shell	Large-calibre explosive projectile fired by land artillery, armoured fighting vehicles and naval artillery.
TNT	Trinitrotoluene (TNT) (118-96-7) is used as a high explosive for military and industrial applications. The explosive yield of TNT is considered the standard comparative convention of bombs impacts.
Torpedo	Primarily naval warfare weapons launched by air, surface or sub-surface towards military or civilian targets at sea. Include various types of propulsion devices to travel through water.
Unexploded ordnance (UXO)	Military munitions that: have been primed, fused, armed, or otherwise prepared for action; have been fired, dropped, launched, projected or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material; lost or deliberately disposed; remain unexploded whether by malfunction, inappropriate design, or any other cause.

List of abbreviations

Term	Description
ASW	Anti-Submarine Warfare
AUV	Autonomous Underwater Vehicle
BOSB	Baltic Ordnance Safety Board
CDP	Capability Development Plan
CMRE	Centre of Maritime Research and Experimentation
CONOPS	Concept of Operations
CW	Chemical Weapon
CWA	Chemical Weapon Agent
CWM	Chemical Warfare Material
DMM	Discarded Military Munitions
EDA	European Defence Agency
EOD	Explosive Ordnance Disposal
FRA	Fisheries Restricted Areas
HP	Harbour Protection
IMO	International Maritime Organisation
LMB	Luftmine B
MCM	Mine Countermeasures
MRCC	Maritime Rescue Coordination Centre
NMW	Naval Mine Warfare
ROV	Remotely Operated Vehicle
USV	Unmanned Surface Vehicle
UXO	Unexploded Ordnance
WWI & II	World War I & II

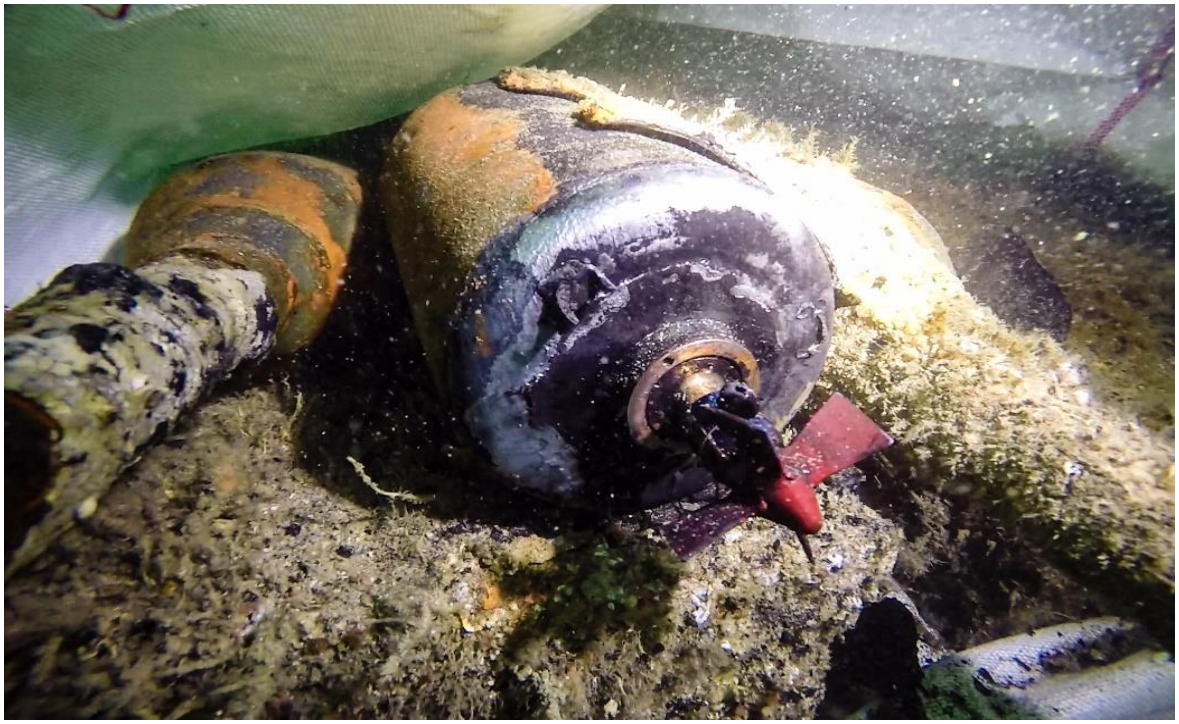
1 Introduction

The issue of underwater unexploded munitions (UXOs) is a matter of serious concern across European sea basins and poses a significant threat to civilians and the environment.

The European Union Maritime Security Strategy (EUMSS)[3] and the Communication on the Sustainable Blue Economy[4] highlight the importance of the sea as a valuable source of growth and prosperity for the European Union (EU) and its citizens. The security of seas and oceans is therefore vital for the 'economic development, free trade, transport, energy security, tourism and good status of the marine environment'. The issue of UXOs affects the security of all maritime activities, preventing the construction of new infrastructure, and hindering coastal tourism and fishing.

Underwater depots were originally seen as the most quick and secure way to dismantle stockpiles of unused ammunitions at the end of World War I (WWI) and World War II (WWII) Now, however, they threaten human and marine life, the environment, and economic activities at sea.

Figure 1. Underwater UXO found in the English Channel



Source: Marine Nationale

Dumped hastily and unpreparedly, some ordnances have spread via currents and the use of fishing gear, some have rusted to the point of leakage, and some could potentially be recovered to assemble powerful improvised explosive devices (IEDs) that combine war-grade explosives and toxic chemicals. UXOs are found during routine fishing activities, construction work, or other marine activities[5].

[3] European Union Maritime Security Strategy (EUMSS) as adopted by the Council (General Affairs) on 24 June 2014. Available at: https://data.consilium.europa.eu/doc/document/ST%2011205%202014%20INIT/EN/pdf

[4] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:240:FIN

[5] For example, in 2005, three Dutch fishers were killed by a bomb that was caught in their net and exploded on deck. OSPAR Commission (2010a). *Quality status report: Assessment of the impact of dumped conventional and chemical munitions*. London: OSPAR Commission.

Underwater detonation is standard practice to dispose of UXOs. As a key source of anthropogenic noise in the marine environment, however, it poses a threat to marine biota (e.g. fish, mammals)[6]. In addition, ammunition shells may release toxic substances into the sea water, as the inevitable corrosion of the shells and drums can increase leaks and contamination of the seabed. To date, the potential short-term and long-term impacts of such leakage has been analysed to only a limited extent. Some of these warfare chemicals may also degrade into a broader variety of molecules, which can contaminate local marine life and end up in the human food chain.

Recent estimates suggest 'at least 500,000 tonnes of ammunition from World Wars I and II plus an unknown amount of modern ammunition still lie in German waters of the North and Baltic Seas'[7]. Over the last 50 years, many accidents related to unexploded munitions have been reported in the Baltic Sea, Black Sea, Mediterranean Sea, North Sea, and the Atlantic. The challenge of accurately locating munitions is even more relevant, as such encounters are not restricted to areas surrounding dumpsites and are widespread in some locations, such as the Channel and southern North Sea[8]. According to the Oslo-Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR), 'more than 4,600 encounters with munitions have been reported between 1999 and the end of 2013' and 'nearly 2,500 of these since the last assessment was reported in 2009'[9].

As part of their security strategies, Member States conduct operations to identify, monitor and dispose of sea-dumped unexploded ordnances, either on a regular or an ad hoc basis. Member States recently agreed to undertake specific cooperation activities[10] to improve the procedures of disposal, removal, and elimination of sea-dumped munitions. These activities aim to improve EU-level mechanisms/procedures and emergency responses in cases of accidental recovery of UXOs and/or chemical munitions. This includes measures such as contingency plans, unified response models

[6] Richardson, W. J. et al. (1995). *Marine mammals and noise*. Academic Press. San Diego, pp. 576.

[7] Nehring, S. (2008). 'Kriegsaltlasten im Meer - Aus den Augen aus dem Sinn?' *WirtschaftBild Spezial,* 2008, pp. 40-44. Koschinski, S. and Kock, K.-H. (2015). Underwater unexploded ordnance – Methods for a Cetacean-friendly removal of explosives as alternatives to blasting. 22nd ASCOBANS Advisory Committee Meeting, Document Inf.4.6.e, p. 2. According to a Baltic Marine Environment Protection Commission (HELCOM) report, 'the increasing use of seafloor for economic purposes increases the risk of encountering sea-dumped munitions' and chemicals originating from these materials can spread from the disposal sites of the containers due to natural and/or anthropogenic reasons (HELCOM (2018). State of the Baltic Sea – Second HELCOM holistic assessment 2011-2016. Baltic Sea Environment Proceedings 155); Beldowski, J. et al. (2014). CHEMSEA findings. Results from the CHEMSEA project (chemical munitions search and assessment). Institute of Oceanology, Polish Academy of Sciences.

[8] See https://www.ospar.org/work-areas/eiha/munitions.

[9] OSPAR (2013). Encounters with chemical and conventional munitions. Available at: https://www.ospar.org/site/assets/files/7413/assessment_sheet_munitions_2015.pdf; Sanderson, H. et al. (2007). 'PBT screening of chemical warfare agents (CWAs)'. *J Haz. Mat.,* 148, pp. 210-215; OSPAR Commission (2003). *OSPAR framework for reporting encounters with marine dumped conventional and chemical munitions*. OSPAR Commission, London. Recommendation 2003/2; OSPAR Commission (2004). *A framework for developing national guidelines for fishers on how to deal with encountered conventional and chemical munitions*. OSPAR Commission, London. Agreement 2004-09; OSPAR Commission (2010b). *Framework for Reporting Encounters with conventional and chemical munitions in the OSPAR maritime area*. OSPAR Recommendation 2010/20; OSPAR Commission (2010a). *Quality Status Report 2010*. OSPAR Commission, London, pp. 176. OSPAR (2010c). *Overview of past dumping at sea of weapons and munitions in the OSPAR Maritime Area* – 2010 update.

[10] See EUMSS Action Plan, as adopted by the General Affairs Council on 26 June 2018.

and guidelines. The Commission has organised several initiatives to raise awareness of the current situation, as well as promoting cooperation activities[11].

These initiatives highlighted the need of EU-level instruments to monitor the risks associated with these underwater threats and the need for improved 'cooperation and coordination between EU and Member States, public and private bodies'[12]. This need is also reflected in the objective set out by the European Commission for 'a strong sustainable, resilient and climate-neutral model blue economy'. In particular, the new EU Action Plan on Zero Pollution calls for concrete actions to tackle sea pollution from chemicals and underwater noise[13].

Addressing the issues created by UXO depots will also help to protect marine biodiversity by contributing to climate mitigation and resilience, with a direct effect on the marine food chain and sustainable aquaculture. In this sense, maritime spatial planning (MSP) can emerge as a supporting tool for the operations of UXO removal, identifying the zones which may overlap with maritime activities.

Despite efforts and actions at supra-national and national level, the issue of as-yet unrecovered UXOs continues to require stronger coordination between Member States at both legislative and operational level. The UXO depots represent an inherited burden that often lacks recognised ownership or a clear chain of responsibility. To date, Member States' national authorities have addressed the problem of UXOs through a reactive approach whenever UXOs are found by fishers, or when laying cables, pipes or offshore structures. Data collection systems vary between Member States where UXO detection and classification processes may be subject to false alarms and limited detection probability. There is a lack of scientific knowledge of the environmental impact of sea-dumped unexploded munitions, together with a corresponding lack of sufficient investment in developing capabilities for their safe neutralisation.

There is a need for reliable instruments that are able to collect information about UXOs in each European sea basin and about the mechanisms implemented by Member States to monitor and remove these ordnances[14]. The development of these instruments, together with a systematic assessment of best practice in dealing with these munitions, would enhance future cooperation between Member States, private bodies, and regional stakeholders.

[11] Challenges of Unexploded Munitions in the Sea event was organised by the Commission in February of 2019 to bring together representatives of EU institutions, Member States' public and private authorities, industry and the research community.

[12] European Parliament (2021). Notice to Members: Petition No 1328/2019 by Jānis Kuzins (Latvian), on behalf of SDK Dzimtene, on purging the Baltic Sea from chemical weapons; Petition No 0406/2020 by Nélia Pinto (Portuguese) on chemical residues from ancient World War shells in the Baltic Sea, p. 2.

[13] See: https://ec.europa.eu/environment/strategy/zero-pollution-action-plan_en

[14] HELCOM CHEMU (2013). *Chemical Munitions Dumped in the Baltic Sea*. Report of the ad hoc Expert Group to Update and Review the Existing Information on Dumped Chemical Munitions in the Baltic Sea. Available at: https://helcom.fi/media/documents/Dumped-chemical-munitions-in-the-Baltic-Sea.pdf; Bełdowski, J. et al. (2014). *CHEMSEA findings*. Gdańsk, Instytut Oceanologii Polskiej Akademii Nauk, Poland; OCPW (2020). *Eliminating Chemical Weapons. Committed to complete and verifiable destruction*. Available at: https://www.opcw.org/work/eliminating-chemical-weapons; Pomarico, L. G. and De Moor, W. (Eds.) (2020). *JPI Oceans Annual Activities 2019*. JPI Oceans, Brussels, Belgium; De Moor, W. (Eds.) (2019). *JPI Oceans Annual Activities 2018*. JPI Oceans, Brussels, Belgium; OSPAR (2009). *Assessment of the impact of dumped conventional and chemical munitions*; OSPAR Commission (2005). *Overview of Past Dumping at Sea of Chemical Weapons and Munitions in the OSPAR Maritime Area*.

1.1 Study objectives and scope

The purpose of the Study is to: i) enhance cooperation between Member States' authorities, private bodies, and regional organizations in dealing with accidental recovery or any encounter with unexploded ordnances and chemical munitions dumped at sea by developing relating guidance; and ii) contribute to improving coordination in the overall monitoring and systematic removal of these munitions, hence minimising this important challenge to maritime security. The specific objectives can be summarised as follows:

- Map existing unexploded munition at sea and mechanisms or approaches to monitor and remove these ordnances;
- Map relevant capabilities employed for identification, monitoring and disposal of sea-dumped unexploded weapons;
- Identify and assess best practices in (1) dealing with accidental recovery of dumped munitions at sea in different maritime communities and (2) in removals with limited impacts to marine environment; and
- Propose a set of common procedures and response models in dealing with accidental recovery of dumped munitions at sea.

The scope of the Study is summarised in Figure 2.

Figure 2. Scope of the Study

Source: ICF elaboration

1.1.1 Geographic scope

All EU maritime Member States + Norway have been considered through the administration of a survey. Furthermore, targeted semi-structured interviews to relevant stakeholders have been administrated in 7 EU MS (Belgium, Bulgaria, France, Italy, Netherlands, Lithuania, Sweden). These Member States were selected to cover all the European Sea basins (Atlantic Ocean; Baltic Sea; Black Sea; Mediterranean Sea; North Sea).

1.1.2 Stakeholders' engagement

A selection of stakeholders was consulted at different stages of the Study. The consultations took place between February and December 2021. Most of the stakeholders were consulted at interim and final stage to ensure that among others the interviews covered the gaps identified at earlier stages. All the feedback and recommendations received were further analysed and, where relevant, incorporated in the Draft Final Report.

The following stakeholders groups were consulted:

- EU/International organisations and transnational research projects;
- NGOs/Academia;

- National/Military authorities;
- Local/Port authorities (including coast guards); and
- Maritime communities, covering engineering / construction entities, fisheries, transport and tourism entities, and any other relevant stakeholders in this area (e.g. environmental organisations or UXO specialists).

The consultation entailed the following:

- **Scoping interviews:** Four scoping interviews were conducted with DG ENV, DG MARE, and DG MOVE. The objective was to discuss early insights into existing national capabilities, as well as the main areas of concern regarding yet to recover underwater unexploded munitions.
- **In depth interviews**: 44 In-depth interviews in 7 EU maritime Member States were conducted to gather systematic information the current situation of existing unexploded munitions at sea, mechanisms/approaches used for their monitoring and disposal, relevant capabilities, as well as potential operative constraints. This also helped to identify gaps in the draft survey questionnaire and further fine tuning the interview questions to ensure all gaps were covered.
- **Survey**: one survey in 22 EU Member States + Norway was conducted to broaden the scope of the consultation to the maritime MS with the aim to: i) map underwater unexploded munitions in all the European sea basins (task 2); ii) identify relevant capabilities employed for identification, monitoring and disposal of sea-dumped unexploded weapons (task 3); iii) identify and assess best practices in dealing with accidental recovery of dumped munitions at sea in different maritime communities (task 4).
- **Workshop** on common procedures and best practices in dealing with accidental recovery of dumped munitions at sea in the EU. The following stakeholder groups were invited: i) EU/International organisations; ii) National/Military authorities; iii) Local/Port authorities (including coast guards); iv) Maritime Communities; and v) NGO/Academia. The workshop went beyond its initial scope, allowing an open and creative discussion on the existing problems with current dumped munitions at sea and to identify potential solutions.

Table 1 presents an overview of the stakeholder consultations. Annex 2 provides detailed information on the overall process.

Table 1. Overview of the stakeholder consultations

Stakeholder	Engagement	No. of stakeholders consulted
EU institutions (DG MARE, DG ENV, DG MOVE)	Scoping interviews	4
Other EU institutions and entities, as well as international organisations and transnational research projects	In-depth interviews	10
	Workshop	3
NGOs/Academia	In-depth interviews	3
	Workshop	6
National/Military authorities	In-depth interviews	17
	Survey	7
	Workshop	10

Local/Port authorities	In-depth interviews	1
	Survey	2
	Workshop	1
Maritime communities	In-depth interviews	9
	Survey	13
	Workshop	5
Total		**91**

Source: ICF elaboration

1.2 Structure of the report

The Draft Final Report is structured as follows:

- Section 1: Introduction;
- Section 2: Methodological approach, including data issues and limitations;
- Section 3: Main findings (covering all the tasks of the Study); and
- Section 4: Overall conclusions and recommendations.

The following documents have been annexed to the Draft Final Report:

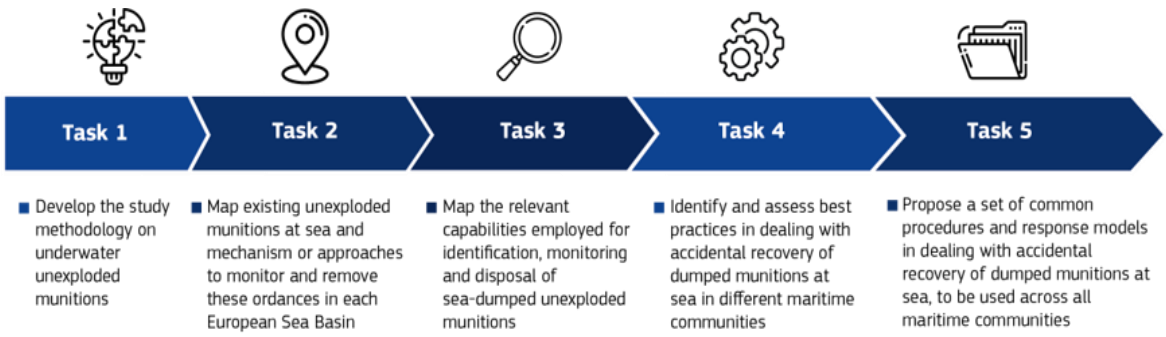
- Annex 1: Sources;
- Annex 2: Stakeholder engagement;
- Annex 3: Survey and interview questionnaires;
- Annex 4: Survey report;
- Annex 5: Relevant capabilities employed for identification, monitoring and disposal of sea-dumped unexploded weapons: definitions;
- Annex 6: Responsible authorities involved in the management of UXO; and
- Annex 7: Technologies/Scientific approaches employed for identification, monitoring and disposal of sea-dumped unexploded weapons.

2 Methodological approach

This section presents the methodology of the Study and describes in detail the specific tasks and activities carried out by the Study team to meet the objectives.

2.1 Methodology

Figure 3. Methodological approach



Source: ICF elaboration

Task 1: We developed **an integrated methodology** to carry out the Study on underwater unexploded munition. This included in particular: i) the instruments for data collection and the protocols and carry out data mapping; ii) the interaction and validation strategy with the national and EU stakeholders. Several scoping interviews to representatives of the EU Commission have been conducted to further fine tune the methodology as well as to collect further information on the areas of interest.

Task 2: We carried out a **mapping analysis of existing unexploded munition at sea and mechanisms or approaches to monitor and remove these ordnances, in each European Sea basin**. This mapping included sea-dumped unexploded munition (including chemical), covering in particular the types of munition, geographical locations, and risks related to the presence/explosion/removal of unexploded munitions. Mechanisms or approaches to monitor and remove UXOs were also examined. The mapping has been further completed with targeted interviews with relevant stakeholders such as representatives of the EU Commission, EU Agencies, national/militaries authorities, local and port authorities, relevant NGOs, as well as the research community. These interviews have also been used to fine-tune the data collection methodology for the following tasks. Finally, a survey with military authorities and local/port authorities has been administered to complement the information collected as well as broadening the scope to 22 European Member States + Norway.

Task 3: We carried out a **mapping analysis of relevant capabilities employed for identification, monitoring and disposal of sea-dumped unexploded weapons**. This mapping identified and assessed the current capabilities (i.e.: preparation and planning; training of personnel; equipment and resources) used by EU Member States for the identification, monitoring and disposal of sea-dumped unexploded weapons and their environmental impact, as well as the needs in terms of capabilities to improve these activities.

A mixed data collection method including surveys with military authorities and local/port authorities, as well as targeted interviews with key experts has been used to this extent.

Task 4: We identified and assessed the best practices in accidental recovery of dumped munitions at sea in different maritime communities (i.e. engineering and construction entities, fisheries, transport and tourism entities, and any other relevant stakeholder in this area). This included the conduction of targeted interviews followed by a survey of maritime communities, national/military authorities and local/port authorities, NGO/Academic experts to identify, as a minimum:

- Best practices in removals with limited impacts to marine environment;
- Authorities/ actors that report more often such cases and where these cases mostly occur;
- Evolution of the findings (by type), reporting actor and disposal; and
- Relevant cooperation achievements at national and regional levels.

A mixed data collection method including surveys with military authorities and local/port authorities, as well as targeted interviews with key experts has been used to this extent.

Task 5: We proposed a set of recommendations to support Member States in dealing with accidental recovery of dumped munitions at sea. Using the results of the activities carried out in the previous tasks, as well as the workshop held on the 29th of November 2021, we gathered information on best practices and possible policy options to support Member States in dealing with accidental recovery of dumped munitions at sea.

Table 2 presents an overview of the methodological approach.

Table 2. Methodological approach

Task	Objectives	Approach
Task 1: Develop the study methodology on underwater unexploded munition	• Set up a data collection plan and protocols and carry out data mapping • Enhance, refine and finalise the methodological approach, including the stakeholders' engagement plan and analytical framework • Draft a project management plan (PMP) • Set the common toolbox (shared document repository, GIS tool, co-editing tools, interview plan, interview questionnaire and reporting sheet, reports templates...)	• Data collection strategy and design • Stakeholder engagement strategy
Task 2: Map existing unexploded munition at sea and mechanisms or approaches to monitor and remove these ordnances in each European Sea basin	• Map existing unexploded munitions at sea • Identify the relevant capabilities for the disposal of sea-dumped unexploded weapons	• Define capabilities via desk review and interviews • Survey of civil and military stakeholders • Analyses of capabilities, stage of these capabilities, capability gaps / needs or opportunities for improvement
Task 3: Map the relevant capabilities employed for identification, monitoring and disposal of sea-dumped unexploded weapons	• Identify and assess the current capabilities used for identification, monitoring and disposal of sea-dumped unexploded weapons and their environmental impact, as well as the needs in terms of capabilities that would contribute to improve these activities	• Define capabilities via desk review and interviews • Survey of civil and military stakeholders • Analyses of capabilities, stage of these capabilities, capability gaps / needs or

Task	Objectives	Approach
		opportunities for improvement
Task 4: Identify and assess best practices in dealing with accidental recovery of dumped munitions at sea in different maritime communities	• Identify and assess best practices in dealing with accidental recovery of dumped munitions at sea in different maritime communities	• Identify and categorise practices via desk review and interviews • Survey of civil and military stakeholders • Assess practices in dealing with accidental recovery of dumped munitions at sea in different maritime communities (a section shall be dedicated to removal with limited impact to marine environment)
Task 5: Recommendations to support Member States in dealing with accidental recovery of dumped munitions at sea	• Analyse the main risks posed by underwater unexploded munitions and to provide recommendations to contribute supporting MS in better addressing the UXO threats.	• Survey of civil and military stakeholders • Workshops with maritime communities: - EU institutions (DG MARE, DG ENV, DG MOVE) - Other EU institutions and entities, as well as international organisations and transnational research projects - NGOs/Academia - National/Military authorities - Local/Port authorities - Maritime communities

Source: ICF elaboration

2.2 Data issues and limitations

The main limitations of the Study are:

- **Lack of available literature** on underwater unexploded munition, with specific reference to: i) existing unexploded munition at sea (i.e. type of ordnances and their characteristics, location of the ordnances); ii) capabilities employed for UXO identification/monitoring/disposal; iii) disposal techniques with limited impact to the environment; iv) environmental impact of chemical/conventional ammunitions. To overcome this issue, we synthesised and triangulated the desk research findings with the data collected during the stakeholder consultation. The

team also conducted additional tests or hypotheses on evidence interpretation, including further combinations of elements for the evidence base;

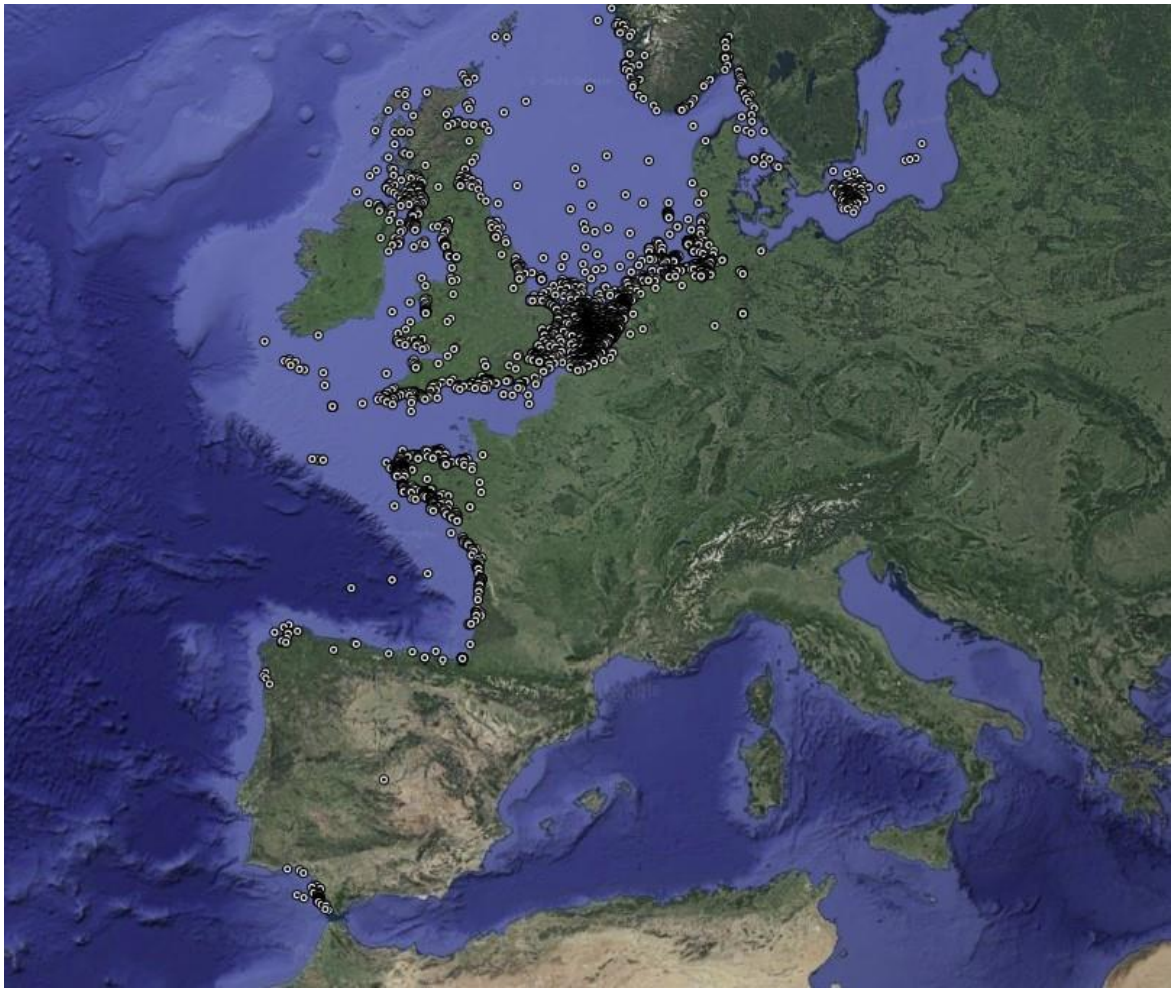
- **Difficulty to access national data on ammunitions depots due to national sensitivity on the matter**. For this reason, a flexible approach to data gathering has been used, triangulating findings according to readily available information and analytical requirements across the previous mapping exercises;
- Reluctance of public authorities and companies to share **confidential information** amid security concerns. This includes, among others, policy documents and guidelines for civilians in case of UXO recovery, capabilities employed for identification, monitoring and disposal of UXOs, technical documents. To overcome this issue, ICF has provided the necessary guarantees by ensuring that only a small number of team members had access to those documents, and each team member signed a confidentiality declaration. Furthermore, all information was exchanged and stored using the appropriate tools and protocols to ensure its safety;
- **Limited availability** of the national stakeholders to respond to the survey and/or provide information about their security programmes due to lack of resources or restrictions related to the COVID-19 pandemic. The survey response period was extended twice to give Member States more time to respond;
- **Limited availability of private companies** to be consulted, and/or provide information about their situation due to lack of resources or restrictions related to the COVID-19 pandemic. We extended the period of consultations and adopted a flexible approach to accommodate the restrictions of the companies related to timelines and approach;
- **Difficulty in engaging** maritime communities due to lack of time, resources and/or limited knowledge of the topic;
- **Lack of data on encounters and risk areas:** There is limited data for some sea basins (e.g., Mediterranean) and on dumping sites, either because data has not been recorded consistently or because it is not publicly available. For example, certain adversarial or belligerent authorities such as the Soviet Union or Nazi Germany were responsible of many UXO dumping operations, but their disappearance and that of their archives leaves some of their dumping sites unaccounted for (this is most notably the case in the Black Sea);
- **Level of detail of the available data**: Specific information is missing from most records such as depth, ordnance type and/or subtype. In a few cases the latitude and longitude were also not available. Therefore, the study team has worked to extract this information from associated descriptions, often in corrupted data or foreign languages, to try and complete each record to the best possible extent.

3 Main findings

3.1 Mapping existing unexploded munitions at sea and mechanisms or approaches to identify, monitor and dispose of them, by European Sea basin

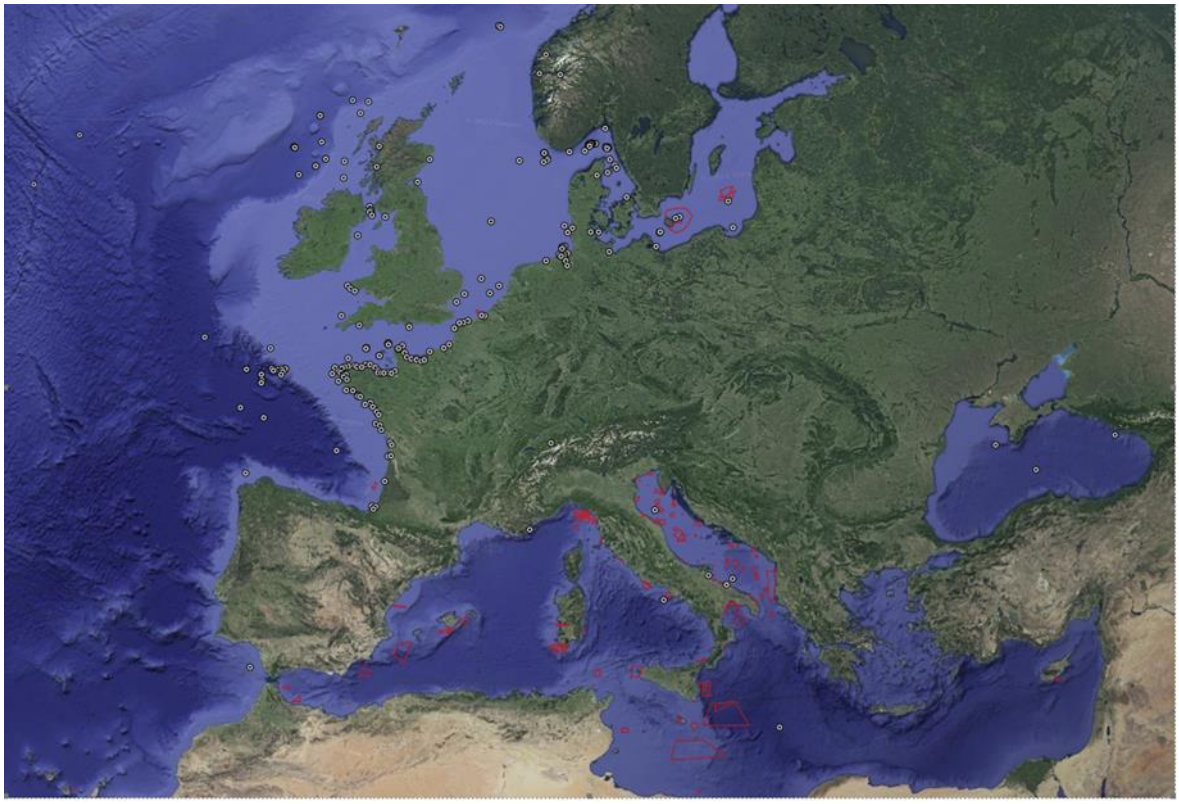
This section presents an overview of existing UXOs in each European sea basin, as well as the mechanisms/approaches adopted to identify, monitor and remove them. It also provides information on the main deposits and risks entailed for each sea basin.

Figure 4. Distribution of underwater munitions encounters in the EU sea basin (1999-2018)



Source: ICF elaboration

Figure 5. Known conventional and chemical munition risk areas in EU sea basins, represented by point data (black) and polygon data (red)



Source: ICF elaboration

Figure 4 shows underwater munitions encounters in the EU sea basins, while Figure 5 provides information on the known chemical and conventional munition risk areas in the same region. The lack of data on UXO dumping sites does not indicate an absence of this type of munitions at these locations. There is limited information in the Black Sea because World War I (WWI) and World War II (WWII) records were poorly kept, are incomplete, lost or maintained as military secrets[15]. It is commonly assumed that more than one-third of the munitions were placed in Bulgarian territorial waters, with only half yet found and neutralised[16]. Every year sees news reports of the Bulgarian and Romanian Navies locating and neutralising mines near their coasts[17].

While dumpsites and other areas of concern are well-documented in the North Sea and Baltic Sea, the Mediterranean remains rather more ambiguous. Recent evidence suggests that 'due to a failure to maintain appropriate recordings, sites remained uncharted and charted sites remained unspecified in terms of UXO type and quantity'[18].

[15] Historical evidence suggests that the Axis forces and their allies (Bulgaria and Romania) installed approximately 5,000 anchor mines and 2,795 mine defenders in the Western Black Sea coast and the south coast of Crimea up to 1943. See: Panayotov, A. (2016). Mining barriers in the territorial waters of Bulgaria in the context of the coalition relations with Germany and Romania (1941-1944) (Минните заграждения в териториалните води на България в контекста на коалиционните взаимоотношения с Германия и Румъния (1941–1944 г.)). Available at: http://morskivestnik.com/compass/news/2016/072016/images/doklad2007MZagr.pdf

[16] Desant (2011). Russian mining barriers along the Black Sea coast (Руските минни заграждения по Българското Черноморие). Available at: http://www.desant.net/show-news/22364.

[17] Reports available on Bulgarian Navy website. Available at: http://www.navy.mod.bg/?page_id=291; Romanian Navy website is available at: https://www.navy.ro/comunicate.php.

[18] Frey, T.,Hollaender, R, and Ortleb, Mathias. (2019). *A comprehensive quality guideline for the treatment of unexploded ordnance encountered during offshore construction projects*, p.2.

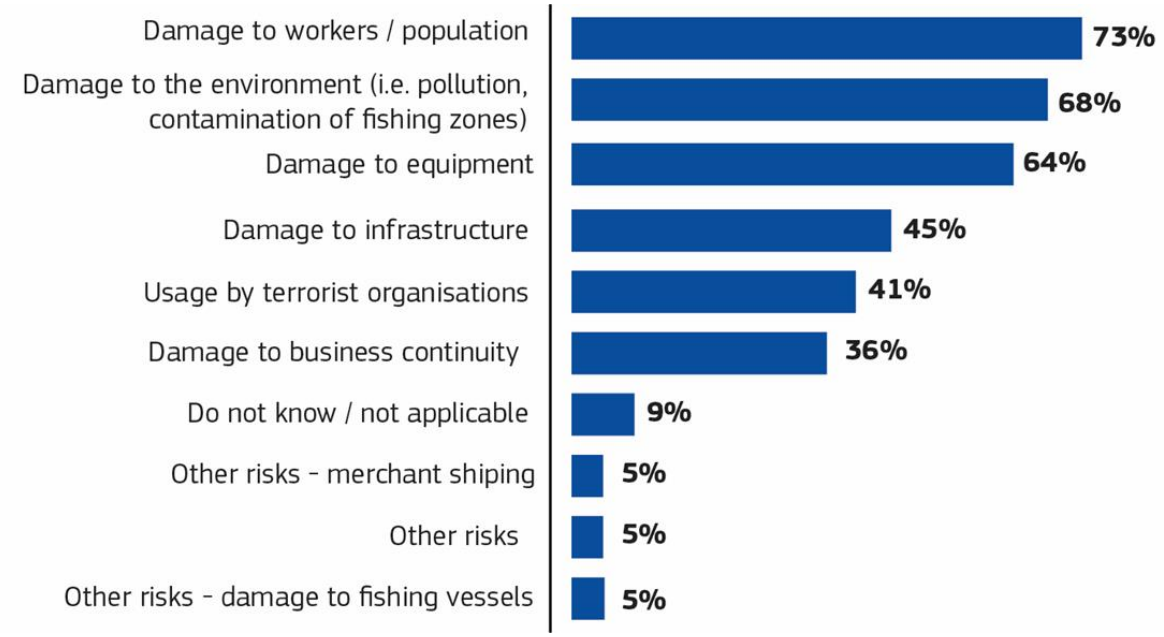
The tonnage of dumped munitions in the Adriatic Sea, for example, suggest many more UXOs in these regions than the available data show.

Table 3. Reported location and tonnage of chemical weapons dumping sites in the Adriatic, Mediterranean, Black and Baltic Sea regions

Region	Reported munition dumping sites
Adriatic Sea	*Total: 4*
	1 site reporting 90 tons/2000 UXO's
	3 sites with no data
Mediterranean Sea	*Total: 3*
	3 sites with no data
Black Sea	*Total: 3*
	3 sites with no data

Source: James Martin Institute for Non-Proliferation Studies[19]

Figure 6. Main risks posed by underwater munition[20]



Source: ICF elaboration (Survey on underwater unexploded munition, B2)

Figure 6 provides information on the **risks posed by unexploded munitions**. According to the survey respondents[21], 73% highlighted the risks of UXOs to workers and the overall population, while 68% stressed the risks posed by the release of toxic warfare agents into the sea. These could pollute the water, harm marine life and have negative effects on fish and other biota. Other risks mentioned included damage to equipment and infrastructures (64% and 45%). Half of the respondents believe that weather conditions, currents, changes in the seabed and the different seasons have a *moderate impact* **on the risks posed by UXOs**. By contrast, 18% (4 respondents)

[19] See https://www.nonproliferation.org/chemical-weapon-munitions-dumped-at-sea/.
[20] N= 22.
[21] Survey of civil and military stakeholders administered in 22 Member States + Norway.

believe that these factors have low or no impact and 5% (1 respondent) indicated that they have a high impact.[22]

3.1.1 Atlantic Ocean

Four European countries border the Atlantic Ocean: Ireland, France, Spain and Portugal.

3.1.1.1 Main deposits and status

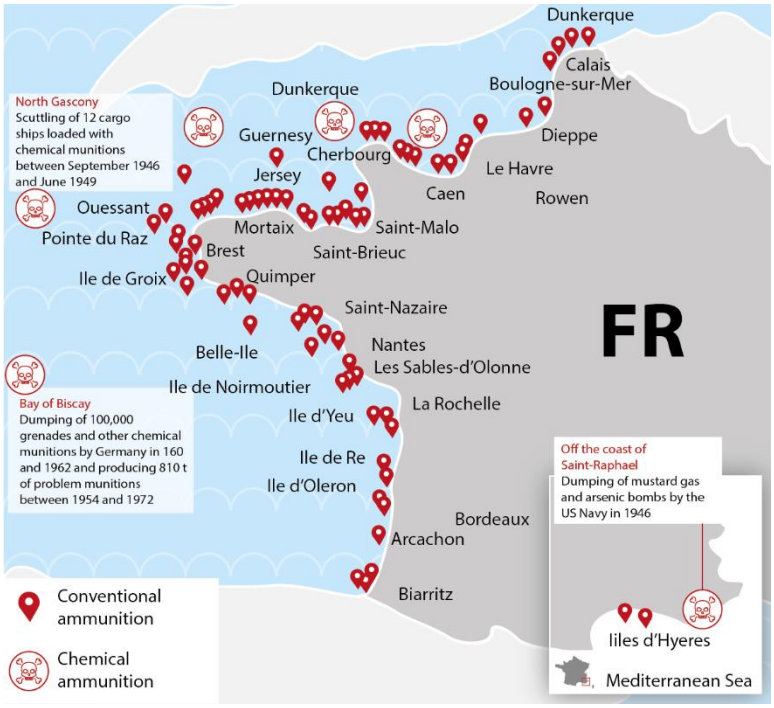
Main deposits

The Atlantic Ocean played an important role during WWI and WWII, with United States (US) allied ships approaching Brittany during WWI to then deploy throughout **France**, for example[23]. During WWII, Brittany was also at the forefront of fighting, resulting in a vast variety of explosive UXOs in French Atlantic harbours (especially Brest), including: mines, bombs, torpedoes, depth charges and shells.

Figure 7 provides an approximate overview of the remaining sunken munitions in French waters[24]. It shows only very limited amounts of chemical munitions in French coastal waters and estuaries[25]. However, dumping areas can be found in French Atlantic waters, at the outer limit of the continental shelf in the Bay of Biscay. Munitions in the Bay of Biscay were dumped between February 1940 and November 1980 [26] and include mustard gas and other unknown chemical substances[27].

[22] 27% indicated 'Do not know / not applicable'.
[23] 13 interviews in total. Interviews with FR national authorities – FR 01, 02, 04, 06, 08. Interview with FR military authorities – FR 05. Interview with FR local authorities – FR 03. Interview with FR NGO/academia – FR 11. Interviews with FR (Maritime Communities (MC) – Fisheries – FR 09, 10 and 13; Engineering/construction entities – FR 12; UXO specialists – FR 07.
[24] Robin des Bois (NGO). (2016). *Atlas de la France toxique*. Editions ARTHAUD.
[25] Map caveats: the NGO, *Robins des Bois,* considers any site where munitions were found to be a 'dumpsite' whereas they are not necessarily locations for voluntary disposal of munitions. Similarly, they take an approach of 'waste treatment', considering any site with munitions as 'waste areas'. On the map, an estimated 50% of the marked areas are dumpsites in the sense of this Study, the other half being zones with simply found munitions.
[26] In the 1980s (1982 Montego Bay agreements, ratified by France in 1996), these waters came within the 200 nautical mile limit defined by the EEZ and 'became French'. Previously, they were free for navigation and exploitation.
[27] *See dynamic map:* https://www.google.com/maps/d/viewer?ll=45.726937319118925%2C-2.4530913787822635&z=7&mid=1ALnyOrN5JQ8H50znwJqI_Sj8IwE

Figure 7. Approximate UXO locations along French coast



Source: ICF elaboration of Robin des Bois 'Atlas de la France toxique' *(2016).*

Note: precise locations may vary

Available evidence suggests that, compared to France, **Spanish** waters in the Atlantic do not contain many known dumpsites for chemical or conventional dumped munitions. In Spain, the two main reported dumpsites are in North-Western Spain near A Coruña, and near the entrance to the Strait of Gibraltar. Both contain only conventional munitions[28,29].

Status

Historically, in **France**, systematic post-conflict mine clearance operations were undertaken at the end of WWII by the Ministry of Reconstruction and Urbanisation (MRU). These operations aimed to remove all munitions lying on the seabed and those known to be buried, in order to reduce the danger to the extent possible[30].

However, UXOs may still be encountered in French Atlantic waters, either because they were buried in cliffs and have since been revealed by erosion, or because sand movements revealed ammunition that was neutralised and buried. Similarly, the retreat of the coastline may regularly reveal ammunitions buried after bombardments or shelling.

3.1.1.2 Main risks and challenges

Main risks

French Atlantic waters play a significant role in a number of key sectors in **France**.

[28] OSPAR Commission (2010). Overview of past dumping at sea of weapons and munitions in the OSPAR Maritime Area – 2010 update.
[29] View Data | EMODnet Human Activities (emodnet-humanactivities.eu).
[30] Interview with FR MC – UXO specialist – FR 07.

The North-Eastern part of the Atlantic, in particular, was the key area of activity for over half of French fishers in 2019[31]. In certain areas, such as the Brest harbour, the risk is well-known to fishers, and accidental recovery of artillery shells is a frequent occurrence during scallop fishing season. Fishers are well acquainted with the appropriate procedure and there have been no accidents for many years. Outside of the Brest harbour, recovery of UXOs is extremely rare and is not considered a risk.

The area around Groix is the location of one of four important French offshore wind projects (*Eoliennes flottantes de Groix*), slated to go online in 2022 and produce up to 28.5MW of renewable energy[32]. Such projects will likely increase in the coming years and move further away from shore as floating offshore wind picks up. This will require further focus on sunken munitions dumping sites.

Risks related to chemical warfare agents appear minimal along the French Atlantic coast and there are no reported incidents of encounters with such UXOs[33].

Main challenges

Regular monitoring and clearing takes place in Brest harbour, which was heavily bombed during WWII. Where there is no threat to maritime trade or tourism, or where the potential presence of UXOs is not considered a risk (e.g. no encounters or accidents for a long time), there is far less interest to organise regular monitoring and clearing exercises, however, with UXOs typically dealt with in a reactive manner.

Interviews[34] revealed that part of the issue lies in the costs of carrying out these activities and, to a certain extent, the administrative burden of coordinating different authorities. Only major infrastructure projects can afford the services of UXO survey operators.

3.1.2 Baltic Sea

Seven European countries border the Baltic Sea: Denmark, Estonia, Germany, Lithuania, Latvia, Poland, and Sweden.

3.1.2.1 Main deposits and status

Main deposits

Generally speaking, there are several main types of UXOs in the Baltic Sea: hazardous wrecks[35]; dumped munitions; mines; bombs (including tank bombs and incendiary bombs); missiles; rockets; grenades (hand/rifle); small calibre ammunition (including rifles and handguns); submunitions; torpedoes; artillery and mortar shells; fireworks; depth charges; white phosphorus munitions[36].

Historical data suggest that a large number of UXOs were dropped and dumped in the Baltic Sea during and after WWI and WWII. The majority were laid in the Gulf of Finland, largely reflecting allied maritime strategies to prevent the exit of Russian fleets. A large quantity of mines can also be found in the area of Skagerrak (between Denmark, Norway and Sweden) and Kattegat (between Germany and Sweden). The latter correspond to

[31] INSEE (2019). *Tableaux de l'Economie Française*. Collection INSEE Références. Available at: https://www.insee.fr/fr/statistiques/3676825?sommaire=3696937.
[32] Wind Europe (2019). *Offshore Wind in Europe – Key trends and statistics 2019*. Available at: https://windeurope.org/about-wind/statistics/offshore/european-offshore-wind-industry-key-trends-statistics-2019/.
[33] Interview with FR MC - UXO specialist – FR 07.
[34] Ibid.
[35] Known to contain explosives and/or have significant quantities of oil onboard.
[36] Incendiary bombs are particularly thin-walled and rust quickly. The white phosphorus contained is then released and, after drifting, can be mistaken for washed-up amber, causing severe burns. White phosphorous is considered a severe risk for beach-goers, in particular in the Usedom area (Germany), where it amounts to between two and five cases a year.

English air bombing campaigns during WWII (so called 'vegetable gardens', after the code names given to the mines by the British).

Interviews and background research highlighted two key findings:

- There appears to be a much greater awareness of the dumping sites in this area than in many other European sea basins. This is undoubtedly due to the accessibility of historical archives and to improved reporting mechanisms and record-keeping in the different countries and through HELCOM (see section below).
- Data on the area are nevertheless disparate. Despite extensive efforts at regional level (primarily through HELCOM), there is no single database aggregating records on accidental encounters from different countries (see Table 4).

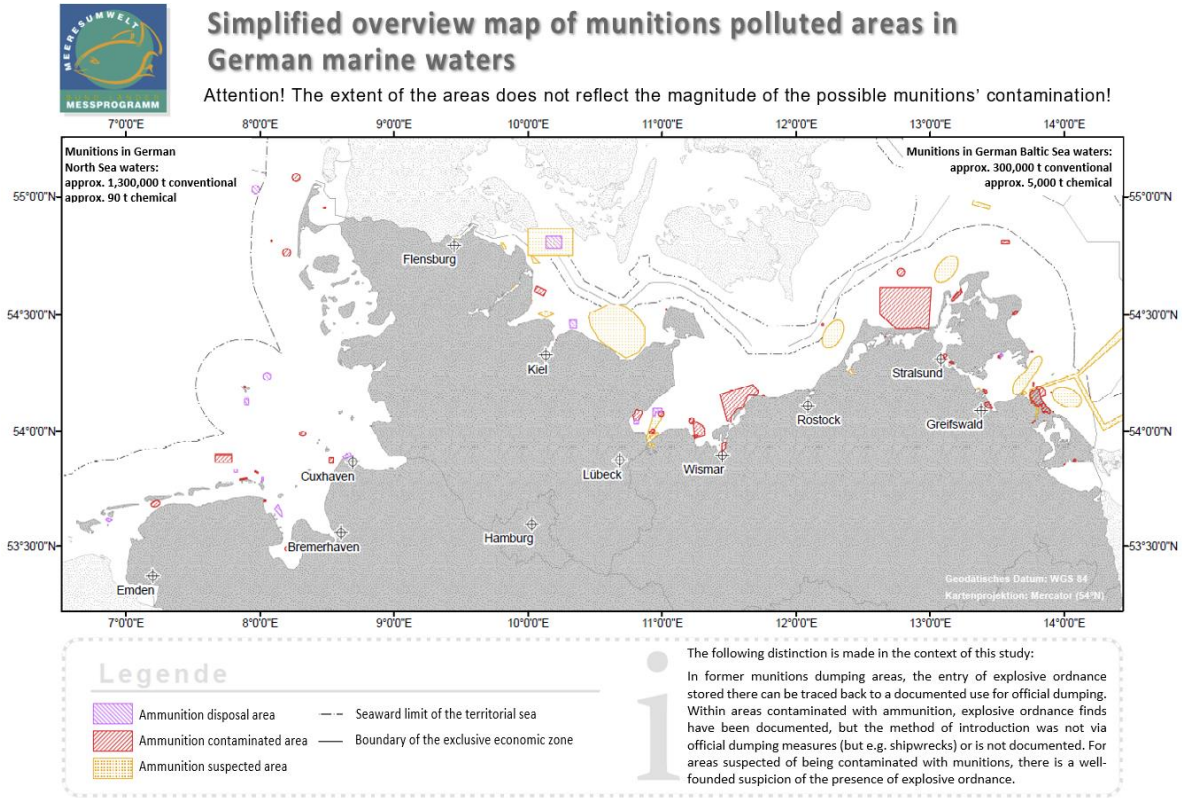
Table 4. Summary of research findings on Baltic Sea UXOs

Data origin	Type	Quantity	Area
Sweden[37]	Naval mines	60,000 during WWI	Baltic Sea, with a majority in the Gulf of Finland
		100,000 during WWII	
Lithuania[38]	Mines and explosives	1642	Lithuanian territorial waters
	Mines and explosives	Known dump site – unknown quantities	Around the Gotland Island
	Chemical weapons	Known dump site – unknown quantities	Eastern Baltic
Germany[39]	Munition contaminated areas – specific type unknown	21	Baltic Sea
	Conventional munitions	300,000 tonnes	Baltic Sea
Denmark	Chemical munitions	Varying estimates[40]	Skagerrak, the Little Belt and the Bornholm Basin are the main known dumping sites in Denmark Gotland Deep in Swedish waters

[37] Interview with SE military authorities – SE 01.
[38] Interview with LT military authorities – LT 01. Most mapping products are incorporated with international frameworks: HELCOM, Baltic Ordnance Safety Board (BOSB) for military; DAIMON, MODUM and CHEMSEA in environmental impact-focused projects.
[39] Böttcher, C. et al. (2011). Munitionsbelastung der deutschen Meeresgewässer - Bestandsaufnahme und Empfehlungen. Available at: https://www.schleswig-holstein.de/DE/UXO/Berichte/PDF/Berichte/aa_blmp_langbericht.html.
[40] Skagerrak (130,000 tonnes), the Little Belt (5,000 tonnes) and the Bornholm Basin (32,000 tonnes) are the main known dumping sites for chemical munitions in Denmark, while the Gotland Deep (2,000 tonnes) is the main known chemical munitions dumping site in Swedish waters. The numbers in the 2011 German Report differ somewhat: 170,000 tonnes in the Skagerrak, the German Bight (North Sea) and the Norwegian Sea; 42,000-65,000 tonnes in the Baltic Sea (Bornholm Basin, Gotland Basin, Little Belt).

Data origin	Type	Quantity	Area
Baltic Ordnance Safety Board (BOSB) [41]	Unspecified	Approximately 2,200 historical minefields – approximately 180,000 objects	Baltic Sea ports and shipping lanes

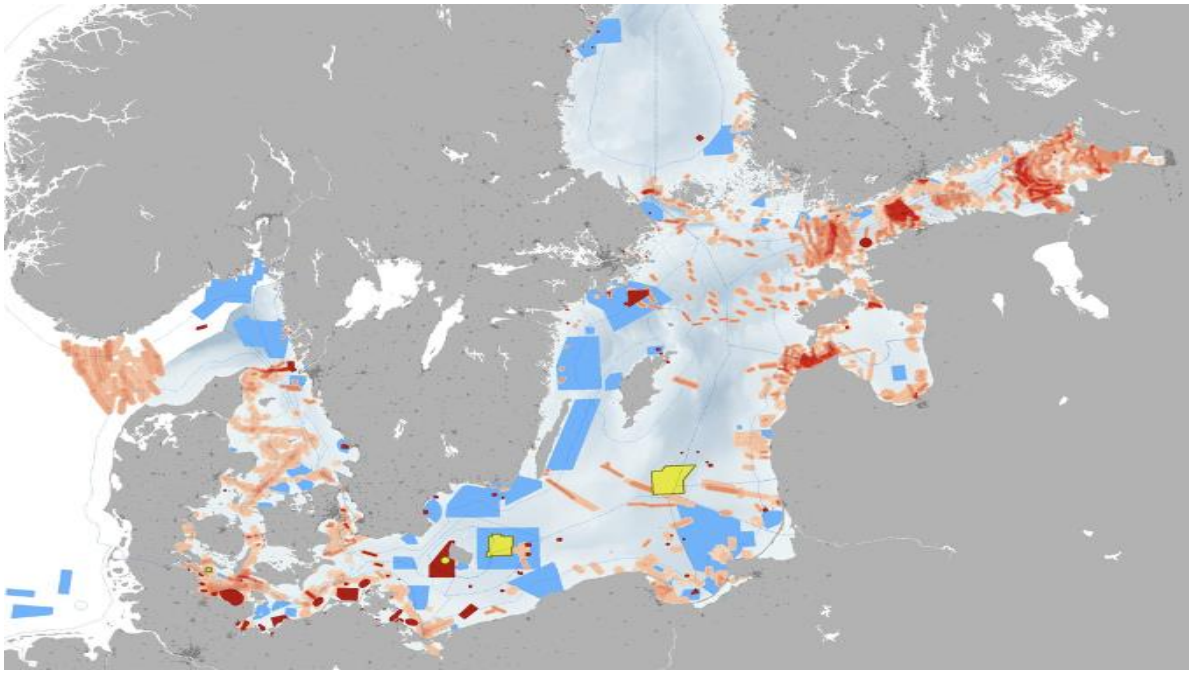
Figure 8. General overview of German marine waters



Source: Böttcher, C. et al. (2011). Munitionsbelastung der deutschen Meeresgewässer - Bestandsaufnahme und Empfehlungen, Hamburg: Bundesamt für Seeschiffahrt und Hydrographie.

[41] Interview with SE military authorities – SE 01.

Figure 9. Overview of UXOs in the Baltic Sea



Source: Swedish Navy Maritime Warfare Data Centre

Status

There have been a number of clearing campaigns in the Baltic Sea because it was a well-known dumping site for different types of munitions from WWI and WWII and because of the high level of maritime traffic. However, the Swedish Navy Maritime Warfare Data Centre (MWDC) estimates that **approximately 20 to 30% of the sunken mines are still active and lying on the seabed**[42]. Efforts continue today and take place at national and international cooperation level through HELCOM and the BOSB[43].

Table 5 presents the clearance exercise information gathered in the framework of this Study.

Table 5. Clearance exercises

Country	Type	Quantity recovered	Area	Date
Lithuania[44]	Naval mines, torpedoes, missiles, depth bombs	194	1600 miles^2 in Lithuanian waters	Since 1997
Germany[45]	Unspecified	Estimated 250,000 tonnes	German Baltic waters	Between 1952 and 1958
	Unspecified	21,546 objects	German Baltic waters	Since 2013
Sweden [46]	Influence mines	70%	Baltic Sea	Post WWII

3.1.2.2 Main risks and challenges

Main risks

Risks are extremely uneven across the Baltic Sea. As Figure 9 and Figure 11 highlight, **Sweden** has a very low density of UXOs and chemical munitions, and none are deemed a priority. In fact, accidental recovery of UXOs is often not considered an issue in Swedish waters[47]. The situation in **Poland** and **Lithuania** also appears to be of little immediate concern to population and maritime activities, although one area where chemical dumping sites have been identified sits close to these two countries. Seafloor activities such as cable-laying, offshore wind farms and sand mining are the most exposed to risks and are expected to increase in the coming years[48].

[42] Interview with SE military authorities – SE 01.
[43] All eight Baltic Sea Member States are members of the BOSB and HELCOM.
[44] Interview with LT military authorities – LT 01. Most mapping products are incorporated with international frameworks: HELCOM, BOSB for military; DAIMON, MODUM and CHEMSEA in terms of environmental impact-focused projects.
[45] Böttcher, C. et al. (2018). Ammunition pollution in German marine waters - developments and progress, page: 6. Available at: https://www.schleswig-holstein.de/DE/UXO/Berichte/PDF/Berichte/ag_blano_fortschritt2018.html. Complemented by interview with DE NGO/Academia – DE 01.
[46] Interview with SE military authorities – SE 01.
[47] Interview with SE military authorities – SE 01.
[48] Interview with LT military authorities – LT 01; Only recorded incident: company dragging sand from seafloor picked up some exploded ammunition (from sea exercises) which resulted in one light incident. Industrial undertakings require communicating with authorities, including the Lithuanian Navy, e.g. 2020 offshore wind farm study (for Ministry of Energy); Harmony Link connection; NordBalt project.

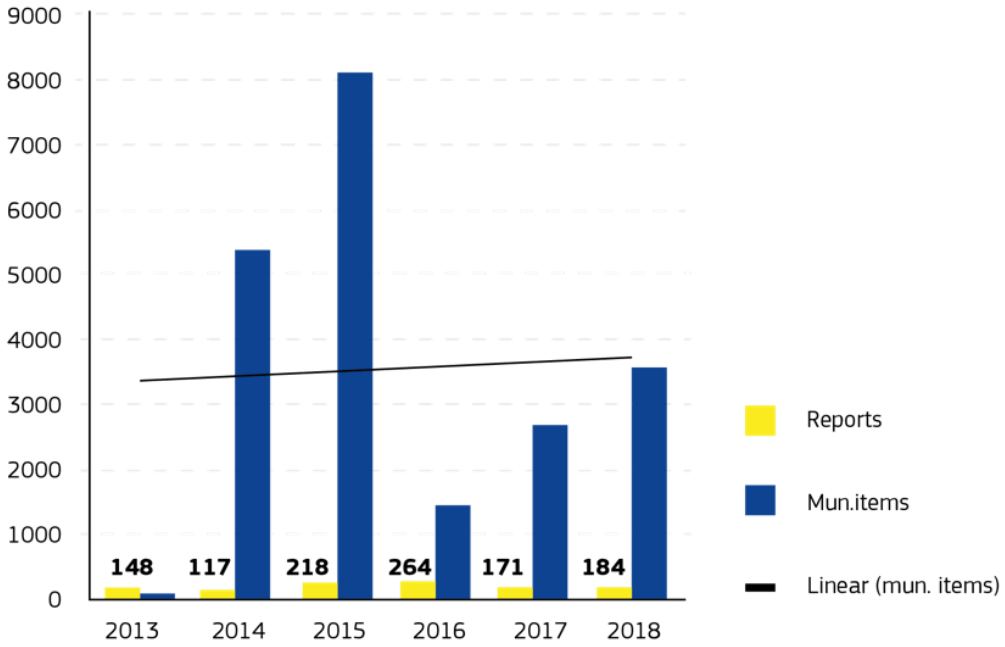
UXO presence in Germany, **Latvia** and **Estonia** present far bigger risks to fishing, trade and tourism activities. The proximity of the planned Nord Stream II to the dumpsite area further increases the risk of incidents.

Environmental risk is now a major concern, as evidenced in the multiple research projects in the area – CHEMSEA, MODUM, DAIMON 1 and 2[49]. In **Lithuania**, a notable impact has been observed on biota in Lithuanian waters, with the number of the *macrozoobenthic* species (molluscs) significantly decreased in studied areas (from 10 in the years between 1981 and 1993 to 3 in 2013) and many damaged shells found. Whether there is a correlation or causation link with underwater munitions remains to be determined and the risk levels remain difficult to assess from current data[50].

According to the German Programme on Underwater Munitions, the main risks for ships in **German marine water** relates to underwater mines. However, the measures taken by the federal and state governments have already led to the recovery of a large volume of objects from the main shipping lanes, principally in the 1950s and 1960s, and main dumping sites are well-identified and known by maritime communities. Risk is well recognised and mitigated, although there is a reduced risk for activities on the seafloor, despite well-established procedures involving private, specialised companies and public authorities[51].

Figure 10 shows that reported encounters with UXOs are quite frequent in German waters.

Figure 10. Reported encounters in German Marine Waters 2013-2018



Source: ICF elaboration on BLANO presentation at the 2019 Brussels Colloquium on Status, Challenges and Solutions of Unexploded Munitions

[49] Op. cit., Beldowski, J, et al. (2014). MODUM NATO webpage: http://www.iopan.gda.pl/MODUM/; DAIMON project webpage: https://www.daimonproject.com/. See also Lithuanian Environmental Protection Agency presentation at the 2019 colloquium on Challenges of UXOs: https://webgate.ec.europa.eu/maritimeforum/sites/default/files/presentation_g.garnaga-budre.pdf.

[50] Interview with LT national authorities – LT 02.

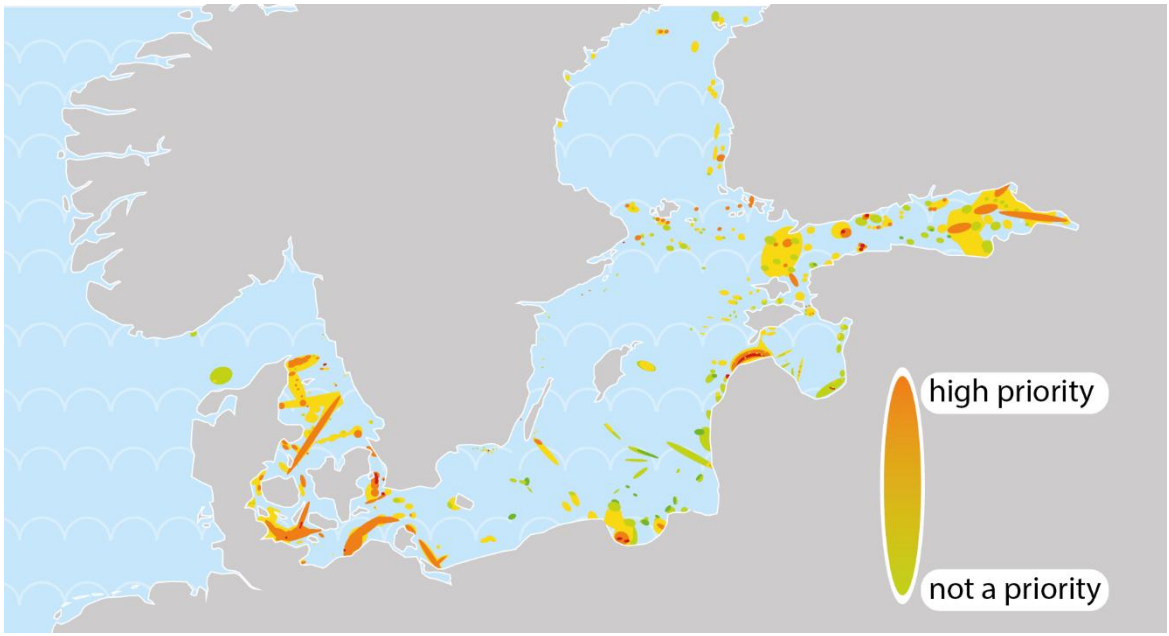
[51] Interview with DE NGO/academia – DE 01.

Since its creation in 2006, the BOSB has carried out significant work to map UXOs in the Baltic Sea and to determine the level of risk. It has developed a list of criteria to determine priority areas for UXO clearance:

- *Activity,* including sea traffic, anchorage areas, fisheries and underwater installations – the higher the activity the higher the risk;
- *Depth* - risks also depend on the level of depth of the UXO. The shallower the UXO the higher the risk;
- *Precision* – the more precise the information on UXOs, the more likely they are to be included in a mine clearance campaign. This is to avoid losing time when there is too much uncertainty;
- *Density* – the higher the density of mines in a given area the higher the risk;
- *Clearance* – if there has already been a mine-clearance campaign in the area, the priority level decreases.

Figure 11 shows the priority areas for mine clearance based on the five criteria, from green (not a priority) to red (high priority).

Figure 11. BOSB priority areas for mine clearance in the Baltic Sea



Source: ICF elaboration on presentation provided through interview with SE Military authorities – SE 01

Offshore wind is expected to pick up in the Baltic Sea. According to WindEurope, 'the Baltic Sea holds an incredible potential for offshore wind in Europe and could host as much as 93MW by 2050'[52]. UXOs could present a risk for these activities and the priority list established by the BOSB might need to be revised.

[52] WindEurope (2021). *Significant developments on offshore wind in the Baltic Sea*. Available at: https://windeurope.org/newsroom/significant-developments-on-offshore-wind-in-the-baltic-sea/.

Main challenges

The UXO situation in the Baltic Sea varies across the basin but is generally agreed to be one of the European seas with the highest number of UXOs. As such, it benefits from high levels of regional cooperation, such as HELCOM, and international cooperation, such as the yearly clearance exercise organised by Lithuania, Latvia and Estonia (which also includes other NATO members).

Several key difficulties in mapping the area remain, in particular the fact that the Baltic Sea, much like the North Sea, is subject to a number of marine currents that can move UXOs around and/or change their burial status. Combined with the fact that geo-referencing tools used during WWI and WWII to geolocate bomb-dropping/mine-laying activities, there is always a degree of uncertainty about the location of a UXO over time. Historical references are more akin to large areas of concern than accurate locations.

3.1.3 Black Sea

The Black Sea is surrounded by six countries: Russia, Ukraine, Romania, Bulgaria, Turkey and Georgia. For the purposes of this Study, interviews were carried out only in Bulgaria[53].

3.1.3.1 Main deposits and status

Main deposits

Information on UXO dumping zones in the Black Sea is scarce because records of such activities in the area during WWI and WWII were poorly kept, incomplete, lost or held as a military secret[54]. As such, most of the available information comes from research papers and research for project investments.

Figure 12. Summary of research findings on Black Sea UXO

Location	Type	Quantity	Source
Burgas Bay	Shells of different calibres	Over 400,000	Dimitriu, R.G. et al. (2017) [55]
Western Black Sea and Southern Coast of Crimea	Anchor mines	Approx. 5000	Panayotov, A. (2016) [56]
Western Black Sea and Southern Coast of Crimea	Mine	2795	Panayotov, A. (2016) [57]

[53] 5 interviews in total. Interviews with BG military authorities – BG 01-03. Interviews with BG MC – Transport and tourism entities – BG 04 and BG 05.
[54] Barbu, M-B. and Dimitriu, R.G. (2020). An assessment of UXO dumpsites in the Black Sea. Available at: http://appliedgeophysics.ro/wp-content/uploads/2020/08/16_GEOSCIENCE-2019_BarbuDimitriu.pdf; See also op. cit., Panayotov, A. (2016).
[55] Dimitriu, R.G. et al. (2017). UXO search off Burgas: a high resolution marine magnetic survey prior to the start of the second phase harbor's expansion. 17th International Multidisciplinary Scientific GeoConference SGEM 2017, Conference Proceedings, Volume 17, Issue 14, pages: 475 – 482. Available at: https://doi.org/10.5593/sgem2017/14.
[56] Op. cit. Panayotov, A. (2016).
[57] Ibid.

Midia Gas Development (RO)	Anomalies or UXOs	Over 700	Fellows (2019) [58]
Burgas port (BG)	Artillery shells	Over 2000	Dimitriu R.G., Shtirkov I., Barbu M.B. (2017)[59]
Northern Bulgarian and Southern Romanian coasts	Russian shipwrecks carrying weapons and ammunition	1 destroyer 4 submarines	Dimitriu R.G., Barbu M.B. (2020)[60]
Eastern Black Sea (Russia)	Mustard gas, Zaikov lewisite, mixtures, viscous solutions of gas and hydrocyanic acid, phosgene, adamsite, diphenylchlorarcine	N/A	Federov, A. (1995)[61]

The following map has been developed from several sources of information.

Figure 13. Suspected dumpsites based on historical research

Source: AmuCad.org (2021): the International Ammunition Cadastre Sea

Status

Given the UXO threat, the first task of the Bulgarian Navy after 1945 was to remove the ordnances from the sea lanes to ensure the safety of commercial and military ships[62]. The Naval Mine Division carried out 26 inspections of the fairways, disarming 50 and blasting 38 Bulgarian, German and Soviet mines[63]. The efforts of the Bulgarian Navy to clear the sea lanes of any UXO continued in later decades and in the 1960s the sea lanes

[58] Fellows (2019). *Fellows International Limited win Black Sea marine UXO survey contract.* Available at: https://www.fellowsint.com/case-studies/fellows-international-limited-win-black-sea-marine-uxo-survey-contract.
[59] Op. cit., Dimitriu R.G. et al. (2017).
[60] Op cit., Barbu, M-B. & Dimitriu, R.G. (2020).
[61] Federov, A (1995). The undeclared chemical war in Russia: Politics versus ecology. Centre for Russian Ecological Policy, Moscow (Source: AmuCad).
[62] Bulletin of the Military Museum – Varna.
[63] Ibid.

were declared clear of UXOs[64]. Periodic inspections performed more recently did not identify any UXOs[65].

Historical information suggests that more than one-third of Black Sea munitions were placed in Bulgarian territorial waters during WWII by Russia, only half of which have been found and neutralised[66].

3.1.3.2 Main risks and challenges

Main risks

Interviews[67] revealed minimal risks related to **UXOs (mines, shells, etc)** in the Black Sea.

The sea lanes have been cleared by the Navy and there are no risks to maritime trade (most maritime trade runs between the Kersh Strait and Istanbul through the Chornomorsk-Derince[68]).

There have been no incidents in the past decades: the risks posed to tourists, divers, and fishers can therefore be considered as minimal. Overall, the number of accidental encounters with UXOs have averaged one to two each year, and none have result in any accident or harm. No risk assessments have been carried out in Bulgaria on UXOs in general or **chemical warfare agents** specifically[69].

Main challenges

Although there are no specific rules or guidelines for reporting accidental encounters with UXOs, interviews revealed that both fishers and transport vessels 'normally' dutifully report any such encounter. There is no information on reporting by divers or tourists, thus no way of knowing if they follow the procedures correctly.

The Bulgarian Navy follows their protocol for disposing of the mines by exploding them. An interview revealed that corrosion is considered as the main issue for the identification and disposal of UXOs, as it makes almost impossible to locate the fuses[70].

More generally, a key issue in mapping the presence of UXOs in the Black Sea is the lack of historical archives. Russia does not permit access to its archives, and information on allied activities during the wars does not include data on the Black Sea. This means that any mapping in the areas has had to rely heavily on monitoring capabilities and activities, as well as reporting.

3.1.4 Mediterranean Sea

The Mediterranean Sea is subdivided into different sea basins, from the Strait of Gibraltar to the Gulf of Iskenderun. This Study focuses on: the Mediterranean along the coast of **France;** the Tyrrhenian Sea along the West coast of Italy; the Adriatic Sea along the East Coast of **Italy** and **Slovenia;** the Balearic Sea along the Eastern coast of **Spain,** around the Balearic Islands; and, the Alboran Sea along the Southern coast of **Spain**.

This research focused on three countries: **France**, **Italy** and **Slovenia**.

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[64] Interview with BG military authorities – BG 01.
[65] Bulgarian Navy (2015). *The naval mine division is defending the slogan 'For clear fairways'* (отряда противоминни кораби отстоява своя девиз „за родината чисти и безопасни фарватери"). Available at: http://www.navy.mod.bg/?p=7463.
[66] Op. cit., Desant (2011).
[67] Interview with BG military authorities – BG 01-03; with BG MC - transport and tourism entities – BG 05.
[68] Ship Traffic Net website: http://www.shiptraffic.net/2001/04/black-sea-ship-traffic.html?map=dual (accessed 22 October 2021).
[69] Ibid.
[70] Interviews with BG military authorities – BG 01 and 02.

3.1.4.1 Main deposits and status

Main deposits

Both the Mediterranean Sea and the Tyrrhenian Sea (mostly the Southern part, where allied forces made their landings during WWII) present a wide variety of sunken munitions, in particular moored mines, bombs, shells, torpedoes, depth charges and ground mines.

According to two stakeholders[71], these sunken munitions are usually found around harbours. There is a particular concentration around St Raphaël, the site of the second most important allied forces landing during WWII. Chemical munitions were also reported here, as a result of US forces dumping 3,400 bombs filled with lewisite and mustard gas between July and October 1946 (size and exact type unknown)[72].

Desk research reveals that sunken munitions are a constant concern in **Italy's Tyrrhenian** waters. This typically followed allied troop landings during WWII[73]. Similarly, sunken munitions still appear to be lying on the seabed of the Southern part of the **Adriatic** Sea. This is largely the result of dumping activities, in particular chemical munitions, at the end of WWII, when ports were cleared and ammunition factories decommissioned. Documents consulted suggest that at least 20,000 chemical weapons were dumped in the Southern Adriatic Sea after WWII[74].

Figure 14. Ammunition dumping sites into the Mediterranean Sea - AmuCad

Source: AmuCad.org (2021): the International Ammunition Cadastre Sea

In the **Spanish** waters of the Mediterranean (Balearic and Alboran Seas), knowledge of UXO presence is limited to a list of risk areas off the Spanish coast, mostly beside the cities of Murcia and Valencia, and around the Balearic island of Mallorca. The events linked to these risk areas are two known ordnance dumping in Gibraltar and Murcia, as

[71] Interviews with FR MC - UXO specialists - FR 07; Interviews with national authorities – FR 08.
[72] See https://nonproliferation.org/chemical-weapon-munitions-dumped-at-sea/.
[73] The allied strategy was to first take over Sicily and then move from South to North, therefore waters around Sicily but also all along the Southern coast of Italy saw a significant amount of fighting.
[74] Alcaro, L. et al. (2012). *Studies on Environmental Effects of Underwater Chemical Munitions in the Southern Adriatic Sea (Mediterranean Sea).*

well as a number of recorded firing practice around Mallorca, Valencia and the Moroccan Coast (see above)[75].

Status

Historically, remediation activities for chemical munitions were carried out in **Italy** between 1947 and 1953, mainly in the port of Bari and, for a few weeks, in other Apulian ports affected by dumped chemical weapons, such as the Molfetta Harbour. Between 1946 and 1996, more than 200 fishers were hospitalised as a result of exposure to chemical weapon agents (CWAs) leaking from rusting bombshells or bomb fragments caught in their trawl nets[76]. Additionally, between the end of WWII and the 1970s, the removal of UXOs (not including chemical munitions) was mainly done through sinking[77]. However, it is important to note that military archives on the region are vague and incomplete, making it difficult to gather a complete picture of the situation[78].

Similarly, while the Italian Navy regularly carries out detection, identification and removal of sunken munitions at sea, the exact frequency of these exercises remains unclear[79,80].

There are no known actions to regularly monitor and dispose of UXOs in French or Spanish Mediterranean waters. One stakeholder[81] noted that the threat of underwater munitions along the coast of the Cote d'Azur might become a concern for local authorities as it could disrupt tourism (albeit to a minor extent), a key economic sector for the area. These could potentially be a trigger for more concerted action and create some room for private contractors.

3.1.4.2 Main risks and challenges

Main risks

It is possible for fishing vessels in the Mediterranean Sea to recover UXOs. While trawling has been significantly reduced in the French Mediterranean EEZ, with Fisheries Restricted Areas (FRA) near Marseille and Sète[82], it does still take place. With dumping sites located along the coast off Nice and Montpellier, there is a risk that fishers who still practice trawling may catch a UXO in their net.

For offshore wind, the risk is very limited, for two main reasons:

- **France** is currently developing three important offshore wind projects in the Mediterranean (**EolMed**, near Gruissan; Provence Grand Large, West of Marseille; Eoliennes flottantes du Golfe du Lion, also on the Western side of the

[75] United Nations Environmental Programme Mediterranean Action Plan (UNEPMAP) (2009). *Ammunitions dumping sites in the Mediterranean Sea*.
[76] Op. cit., Alcaro, L. et al. (2012).
[77] ICRAM (2001). *Manuale illustrativo delle misure precauzionali da adottare in caso di salpamento di residuati bellici mediante reti di traino*. Available at: https://www.isprambiente.gov.it/files/pubblicazioni/manuali-lineeguida/ACABmanual.pdf
[78] Op. cit., Alcaro, L. et al. (2012).
[79] The latest reported by the Navy was in November 2020 off the coast of Cagliari. See: https://www.marina.difesa.it/media-cultura/press-room/comunicati/Pagine/2020_CS_58_CONTINUA-OPERA-DEI-PALOMBARI.aspx
[80] A number of these operations also took place in 2015, for instance off the coasts of Naples, Salerno and Latina. See: https://www.marina.difesa.it/media-cultura/Notiziario-online/Pagine/20150327_ordigni.aspx
[81] Interview with French MC – UXO specialists – FR 07.
[82] France 3 Regions (2020). *Mer Méditerranée: au lieu de réduire les jours de pêche, il faut interdire le chalutage de fond pour l'ONG MedReAct*. Available at: https://france3-regions.francetvinfo.fr/occitanie/herault/sete/mer-mediterranee-au-lieu-reduire-jours-peche-il-faut-interdire-chalutage-fond-ong-medreact-1905806.html.

French Mediterranean Sea) and none of these are located in areas where there are known sunken munitions;

- **Italy** has yet to develop a strong offshore wind policy. Given the relatively low mean wind speed in the Tyrrhenian and Adriatic Seas compared to other areas of the world, it is unlikely to become a concern in the foreseeable future[83].

In terms of tourism, Scuba diving is an important activity throughout the Mediterranean and sunken munitions are likely to be much more of a concern for divers in those areas.

In the context of the **Joint Programming Initiative Healthy and Productive Seas and Oceans** (JPI Oceans), Italy is leading a joint effort[84] to coordinate research and innovation to assess risks, define priorities and suggest intervention options in respect of munitions in the marine environment[85]. Project objectives include scientific support, technology transfer, and exchange of knowledge to improve mapping and mitigating effects of disposal.

Main challenges

One of the key challenges in this area[86] is the lack of reporting. The new project initiated by the Italian Ministry of Defence to map out UXOs through geo-referencing depends on coordination with the authorities responsible for carrying out risk assessments for 'systematic disposal'. Reporting from fishers and citizens remains sporadic -with fishers often simply dumping the munition back where it was picked up[87]- with the exception of France, where reporting seems more common.[88]

3.1.5 North Sea

The following countries have territorial waters in the North Sea: France, Belgium, the Netherlands and Germany.

3.1.5.1 Main deposits and status

Main deposits

The North Sea, off the coasts of Belgium, France, Germany, and the Netherlands was a heavy bombing route during WWI and WWII. As a result, there are large amounts of unexploded conventional air bombs either around the targeted ports and anchorage areas, or further out to sea (aborted mission releases). As the North Sea is connected to the Atlantic by the **English Channel**, it also saw significant activity during the WWII D-day landing and the bombarding campaigns that followed. As such, areas around the Baie de Somme and Baie de Seine off the coasts of Normandy contain a large number of UXOs.

Interviews and background research revealed two key findings:

- There appears to be considerable awareness of dumping sites in this area compared to other European sea basins, such as the Mediterranean Sea, Black Sea, or parts of the Atlantic Ocean. This is primarily due to the accessibility of historical archives, as well as better reporting mechanisms and record-keeping, especially in Germany.

[83] See: https://globalwindatlas.info/.
[84] Participating countries: BE, DE (co-lead), EL, IE, IT (lead), NL, PL, PT, SE and NO (co-lead), United Kingdom (UK).
[85] JPI Oceans (2019). Factsheet Joint Action – Munition in the sea. Available at: https://www.jpi-oceans.eu/sites/jpi-oceans.eu/files/public/Munition/Action%20info%20munition%20in%20the%20sea%20July%2019%20web%20V3.pdf
[86] Internal waterways, territorial sea, contiguous zone and Exclusive Economic Zone (EEZ).
[87] Interview with IT MC – UXO specialist – IT 01.
[88] Interviews with FR MC – Fisheries – FR 13.

- Data on the area are disparate, with no single database aggregating records on accidental encounters from different countries (see Table 6).

Table 6. Summary of research findings on North Sea UXOs

Data origin	Type	Quantity	Area
Netherlands	Naval mines, mine-clearing charges, aerial bombs, grenades and shells, mortars, torpedoes, depth charges, landmines, and hand grenades[89]	1,952 reported (of which 1,441 disposed)	North Sea[90]
		Tens of thousands estimated - unreported	North Sea[91]
	Metals from casings and munition boxes, raw materials for powder and explosives, and materials from smoke and light grenades[92]	Known dump site – unknown quantities	30km from the coast of IJmuiden[93], covered by sand[94] 30km from the coast of the Hook of Holland[95], covered by sand[96]
	Mostly powder, explosives, pyrotechnics, and metals (casings)[97]	Known dump site – unknown quantities	Eastern Scheldt[98], in a 'well' of 50 metres depth, spread over an area of 800 metres by 1.5km[99]
	Mostly grenades[100]	Known dump site – unknown quantities	Wadden Sea[101], covered by sand[102]
France, Belgium and Germany	One-third chemical weapons and/or chemical agents. The rest: bombs (including tank bombs and incendiary	An estimated 35,000 tons of munitions	Northwest of Zeebrugge, in Belgium, 'Paardenmarkt'

[89] Dutch Coast Guard (2021). Coast Guard UXO Card (*Kustwacht Explosievenkaart*).
[90] Dutch Coast Guard (March 2021). UXO's: state of play (*Explosievenstand*).
[91] Dutch Ministry of Defence (2021). UXO disposal (*Explosieven ruimen*).
[92] Dutch Provincial Executive (2019). Response from the Provincial Executive to questions from J.H. Haasnoot (50Plus) (*Antwoord van Gedeputeerde Staten op vragen van J.H. Haasnoot (50Plus)*). Number 3514. Topic: Munition dump in North Sea.
[93] Trouw (2019). *The bottom of the North Sea is full of ticking time bombs* (*De bodem van de Noordzee ligt vol met tikkende tijdbommen*).
[94] Dutch Ministry of Defence (2020a). Answers to questions from Members, Schonis, Belhaj and De Groot (D66), to the Ministers of Infrastructure and Water Management, Agriculture, Nature and Food Quality and Defence about munition dumps in the Delta waters and North Sea coast (*Antwoorden op vragen van de leden Schonis, Belhaj en De Groot (D66) aan de ministers van Infrastructuur en Waterstaat, van Landbouw, Natuur en Voedselkwaliteit en van Defensie over munitiedumps in de Deltawateren en Noordzeekust*).
[95] Op. cit., Trouw (2019).
[96] Op. cit., Ministry of Defence (2020a).
[97] Van Eck, G.T.M. et al. (2001). Risk assessment munition dump Eastern Scheldt (*Risicobeoordeling Munitiestort Oosterschelde*).
[98] Op. cit., Trouw (2019).
[99] Ministry of Defence (2020b). *Defence researches munition dump* (*Defensie onderzoekt munitiedump*).
[100] Eenvandaag (2013). *Munition dump with 500 tonnes of German grenades in Wadden Sea* (*Munitiestort met 500 ton Duitse granaten in Waddenzee*).
[101] Op. cit., Trouw (2019).
[102] Op. cit., Ministry of Defence (2020a).

Data origin	Type	Quantity	Area
	bombs with phosphorous), missiles, rockets, grenades (hand/rifle), small calibre ammunitions (including rifles and handguns), fireworks, mines (including naval/moored mines, landmines, anchor mines, torpedo mines), submunitions, mortar and artillery shells, torpedoes, depth charges[103]		
Germany[104]	Conventional weapons	1.3 million tonnes	21 munitions-contaminated areas (including 7 munitions dumping areas) in German marine waters of the North Sea
	CWA	Unknown	• West of the Bailiwick of Guernsey[105] • Just off the coast of Caen[106]
Sweden[107]	Mines	Unknown	• Skagerrak (between DK, SE and NO) • Kattegat areas (between Denmark and Sweden)

Figure 15 and Figure 16 show two maps developed from the various sources of information for the Study.

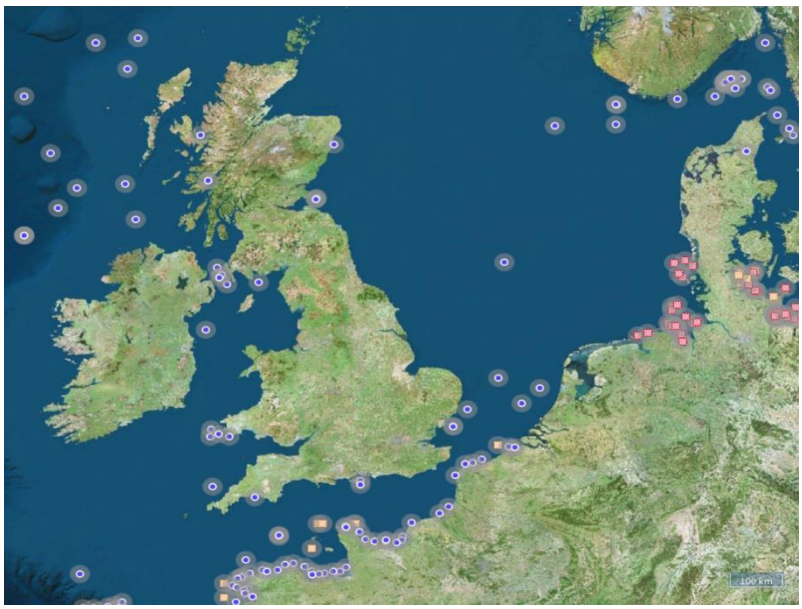
[103] Böttcher, C. et al. (2011). German report on Munition in German Marine Waters (*Munitionsbelastung der deutschen Meeresgewässer - Bestandsaufnahme und Empfehlungen*). See also interview with DE NGO/academia – DE 01.
[104] Op. cit., Böttcher, C. et al. (2011). Section 1.3.
[105] A chemical munition disposal site was reported by the Oslo-Paris Commission.
[106] The Royal Navy ship 'William L. Marcy' was scuttled on 7 August 1944 with an alleged unknown quantity of chemical weapons on board.
[107] Interview with SE military authorities – SE 01.

Figure 15. Approximate locations of munition dumps in the Netherlands

Note: precise locations may vary

Source: ICF elaboration

Figure 16. Ammunition dumping sites into the North Sea – AmuCad



Source: AmuCad.org (2021): the International Ammunition Cadastre Sea

Status

After WWII, the French MRU carried out systematic post-conflict mine clearance operations[108]. Additionally, Dutch data reported indicates that 1,952 UXOs were reported in the North Sea, of which 1,441 have been disposed (see Table 6). Whether these numbers correspond to some of the UXOs removed under the responsibility of the French MRU is unknown.

Neither desk research nor interviews revealed any further information on the status of UXOs in the North Sea.

[108] Interview with FR MC – UXO specialist – FR 07.

3.1.5.2 Main risks & challenges

Main risks

Data gathered through desk research and interviews revealed that encounters with UXOs are very frequent – weekly - for all countries bordering the North Sea. Accidents are quite rare and while historical archives can be imprecise and do not account for the movement of UXOs as a result of currents and tides, they nevertheless provide a good indication of areas that should be avoided.

The North Sea is one of the most important fishing grounds in the world[109]. The United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage lists the Wadden Sea as a biosphere reserve, one of the few undisturbed large-scale intertidal ecosystems in the world[110]. Additionally, the Eastern Scheldt is part of National Park Oosterschelde (International Union for Conservation of Nature protected area category II). Consequently, the presence of unaddressed UXOs and their potential impact on the marine environment could be a significant risk for these areas.

The following risks have also been identified in the Netherlands:

- Corrosion and release of toxic chemicals into ecosystems and food chains, as well as munitions movement due to unpredictable wind, sea and sandstorms (environmental and safety risks) (in particular risky for the munition dumps, though also in general)[111];
- Marine activities, including fishing and wind farms (safety risks)[112].

More generally, North Sea coastlines are intensively fished by trawls and dredges (for pelagic species of high value, such as soles and scallops) and are densely developed (many submarine cables and large offshore wind farms) resulting in very frequent accidental encounters.

Main challenges

Desk research in the Netherlands revealed that trawling activities mean there is frequently 'no clear relation between the positions of encountered mines and the locations of historical minefields'[113].

Historical data can indicate where dump sites can be found. However, geo-referencing tools were much less precise during and following WWII, and many of the coordinates are more akin to general area indications than precise locations. This uncertainty is exacerbated by the fact that the North Sea is prone to a number of different currents that move UXOs across the seafloor.

3.1.6 Authorities involved in the UXO management

Table 7 provides an overview of the authorities involved in the management of recovered – voluntary or accidental – underwater UXOs. These authorities are described in detail in Annex 6.

[109] European Environment Agency (2017). *The North Sea*. Available at: https://www.eea.europa.eu/publications/report_2002_0524_154909/regional-seas-around-europe/page131.html/

[110] See https://whc.unesco.org/en/list/1314/, UNESCO – Wadden Sea.

[111] Op. cit., Trouw (2019); Op. cit., Ministry of Defence (2020a); Dutch Ministry of Defence (2014). Answers to questions about the munition dump in the Wadden Sea (*Antwoorden op vragen over de munitiestort in de Waddenzee*).

[112] Netherlands Enterprise Agency (2018). UXO desk study, unexploded ordnance, Hollandse Kust (west) Wind Farm Zone (HKWWFZ). See also Netherlands Enterprise Agency (2020). Hollandse Kust (west) Wind Farm Zone: project and site description.

[113] Op. cit., Netherlands Enterprise Agency (2018).

Table 7. Authorities involved in the detection, monitoring, and disposal of underwater unexploded munition

	Responsible authority		
Member State	*Identification*	*Monitoring*	*Disposal*
BE	At sea, joint 24/7 team BE+NL belonging to Naval MCM forces, possibility to mutualize assets if most efficient (Beneficial Cooperation) Ashore, SEDEE / DOVO, 24/7 team BE	Regional Government: for regular beaches monitoring provided by a contractor. Private sector for wind farms, etc. The Natural Environment Operational Directorate (ODnature) and Directorate General of the Environment organise regular samplings at the Paardenmarkt chemical UXO depot.	At sea, joint 24/7 team BE+NL belonging to Naval MCM forces, possibility to mutualize assets if most efficient Ashore, SEDEE / DOVO, 24/7 team BE
BG	Bulgarian Navy In case of investment projects in the Black sea – private contractors (e.g. contractors of Burgas port, South Stream Development Project, Midia Gas Development Project)	Bulgarian Navy	Bulgarian Navy (When needed, the maritime authorities support the navy by prohibiting the traffic in the area.)
DE	For EEZ: **Federal authorities*** *NB: in the EEZ, private companies performing seafloor activity usually manage the survey for and disposal of UXOs via contractors, only informing the relevant authority (+ WPCC)* Centralised, 24/7 reporting + cataloguing: **Joint Waterways Police Command Centre (WPCC)**, within the Maritime Safety and Security Centre in Cuxhaven (Lower Saxony) For territorial waters: **Coastal States (Landers)** Schleswig-Holstein: State police Bremen: State police Hamburg: Metropolitan fire department Lower Saxony: Land survey administration Mecklenburg-Western Pomerania: Civil Protection *NB: in case of insufficient means, federal or other States' capabilities provide support or private contractors (e.g.: for chemical warfare agents)* * Armed forces, Federal Police, Customs, Waterways Administration, Federal Maritime and Hydrographic Agency	For EEZ: **Federal authorities** *NB: in the EEZ, private companies performing seafloor activity usually manage the survey for and disposal of UXOs via contractors, only informing the relevant authority (+ WPCC)* Centralised, 24/7 reporting + cataloguing: **Joint Waterways Police Command Centre (WPCC)**, within the Maritime Safety and Security Centre in Cuxhaven (Lower Saxony) For territorial waters: **Coastal States (Landers)** Schleswig-Holstein: State police Bremen: State police Hamburg: Metropolitan fire department Lower Saxony: Land survey administration Mecklenburg-Western Pomerania: Civil Protection *NB: in case of insufficient means, federal or other States' capabilities provide support or private contractors (e.g.: for chemical warfare agents)*	For EEZ: **Federal authorities** **For munitions from German Armed Forces, NATO forces and foreign nations (post 1945): German Navy** *Private companies performing seafloor activity usually manage the survey for and disposal of UXOs via contractors, only informing the relevant authority (+ WPCC)* For territorial waters: **Coastal States (Landers)** Schleswig-Holstein: State police Bremen: State police Hamburg: Metropolitan fire department Lower Saxony: Land survey administration Mecklenburg-Western Pomerania: Civil Protection *NB: in case of insufficient means, federal or other States' capabilities provide support or private contractors (e.g.: for chemical warfare agents)*
DK	Royal Danish Navy In the past: Nordstream Nordstream technical contractors	Royal Danish Navy	Royal Danish Navy (also as of 2019, on behalf of NATO)
ES	Spanish Navy Maritime Surveillance and Operations Center (COVAM) Commercial diving companies	Spanish Navy/Guardia Civil	Spanish Navy/Guardia Civil

	Responsible authority		
FR	French Navy (Mine Warfare) – 24/7 team Private companies, in the framework of maritime engineering Bomb squads of interior ministry (civilian ports only)	French Navy (Mine Warfare) Bomb squads of interior ministry (civilian ports only)	French Navy (Mine Warfare) – 24/7 team Bomb squads of interior ministry (civilian ports only)
IT	Italian Navy	Italian Navy	Italian Navy (in coordination with port authorities where relevant)
LT	Maritime Rescue Coordination Centre (MRCC, Navy, 24/7 dispatch and operating ship) Ministry of environment – Environmental Protection Agency (AAA) for environmental impact	Navy, MRCC + Mine Warfare Data Centre (MWDC) for data collecting Ministry of environment – Environmental Protection Agency (AAA) for environmental impact	Navy, MRCC Klaipeda State Sea Port Authority State Border Guard Service (Ministry of Interior) Fire and Rescue Department (Ministry of Interior) Municipal administration (washed up ordnance)
NL	In practice, certified companies hired to survey e.g. future construction or infrastructure sites (though this works differently with accidental discovery)	The Ministry of Defence and the Directorate-General for Public Works and Water Management, part of the Ministry of Infrastructure and Water Management (*munition dumps*)	Netherlands Explosive Ordnance Disposal (EOD) Authority, part of the Ministry of Defence
PL	Polish Navy	Not to seem relevant for Poland, as no significant deposits are known.	Polish Navy
SE	Royal Swedish Navy	Royal Swedish Navy	Royal Swedish Navy

3.1.7 Summary of the key findings

This section explored understandings of the locations of existing UXOs in each European Sea basin, as well as the mechanisms/approaches adopted to identify, monitor and remove them.

For **mechanisms/approaches** adopted to identify, monitor and remove UXOs:

- In all Member States, **navies** are involved in identifying, monitoring and/or disposing of UXOs. The nature and stage of their involvement varies significantly between Member States. For example, while the Spanish, Polish, Swedish and Bulgarian Navies are systematically involved in all steps, a number of other countries (FR, IT, DE, NL) instead adopt an ad hoc approach according to the particular circumstances. Generally, this depends on who found the UXO and where, as some areas are under exclusive responsibility of the navy and others are not. It also depends on whether it was an accidental encounter or part of a monitoring exercise;
- **Private companies** are often involved in identifying UXOs, particularly in the context of infrastructure works such as port extensions. This is the case in Germany and France, although the disposal of UXOs remains the prerogative of national authorities;
- **UXO monitoring** is not a systematic practice across the different sea basins. The North Sea and Baltic Sea are regularly monitored, primarily because encounters with UXOs are frequent and therefore trigger searches in the surrounding areas. In the Atlantic and the Mediterranean Sea, it is far less systematic (except perhaps in Brest Harbour where encounters are frequent). There is no regular monitoring in the Black Sea. Monitoring appears to be far more systematic where there is regular regional cooperation, such as HELCOM, annual exercises (e.g. organised by Lithuania, Latvia and Estonia in the Baltic Sea), or specific bilateral cooperation (e.g. Belgian-Dutch bilateral cooperation in the North Sea);
- With some exceptions, which generally involve fishers (e.g. IT, LT), there are no **rules or guidelines** on UXO recovery. Interviewees for most countries highlighted the important role of MRCCs and, in some cases, port authorities (e.g. IT);
- **Environmental** risks are not considered a priority when it comes to addressing UXOs. At the **monitoring** stage, little evidence exists that countries regularly assess the environmental risks associated with the presence of UXOs in their waters. Most projects have been the result of short-term regional and international projects. At **disposal** stage, the majority of stakeholders noted that safety came first, then environmental concerns (although in FR, for instance, acoustic devices to scare off mammals are regularly used).

Several key findings were identified for **sea basins**:

- The presence of UXOs in the **Atlantic Ocean** appears relatively uneven. Most of the UXOs can be found in the Brest Harbour and around Brittany and Normandy, where bombing raids took place during WWII. There are very few identified dumps along the rest of the French coastline and along the Spanish coastline. Encounters of UXOs are extremely rare in those areas. Generally speaking, UXOs are not considered a risk, even in Brest Harbour, because those who regularly encounter these devices (i.e. fishers) are well-trained on what to do and accidents are extremely rare;
- The **Baltic Sea** was, by contrast, heavily mined during World War I (WWI) and World War II (WWII). Historical data has been of significant help in identifying the main sites and enabling national and regional effort to clear the path for key maritime routes. However, such data is hindered by the lack of precision that characterised georeferencing tools in the mid-20th century, while the complicating

factor of a number of different currents means that UXOs can move and areas of interest remain large rather than precise. Regional cooperation is very good.

- The **Black Sea** is far more difficult to map due to the lack of historical archives and the inability to access Russian archives. Limited means and a lack of immediate risk (the main maritime trade routes have been cleared) means little political will and/or ability to carry out regular monitoring and clearing activities;
- The situation in the **Mediterranean Sea** is uneven, both in terms of UXO presence and ways to address the issue. In France, the as accidents and encounters are infrequent, the situation is typically addressed on an ad hoc basis. There is little interest in carrying out regular monitoring activities. In Italy, the Adriatic part of the Mediterranean Sea reveals the presence of far more UXOs than anywhere else in the Sea, but regular monitoring is also lacking.
- The **North Sea** was heavily bombed and mined during WWII. Although no particular regional mechanism for regular monitoring was highlighted, each country has established different systems to ensure the safety of their citizens and maritime trading routes. Currents and tides in the North Sea also make it particularly difficult to be certain of UXO positions, and encounters at sea (as opposed to along beaches) are thus dealt with in a reactive manner.

Overall, **mapping exercises** appear to happen at too many different levels (national, regional, international) and there is no single database that appears to draw them all together. Many valuable efforts are happening separately and relying on different (often complementary) sources of data. There needs to be an effort to bring together all these databases.

Projects seeking to understand the **environmental risks** of UXOs for marine life are sporadic and short-term. There needs to be a more concerted effort across the EU to build a monitoring mechanism that regularly tracks the evolution of known dumpsites.

Finally, across interviews and countries, it was evident that there was little to no awareness of the applicable EU, national health and environmental law in respect of monitoring, preserving and remediating ecosystems affected by such substances. The few studies available on the impact of such substances on the marine environment (and, indirectly, human health) are limited to scientific academic research or short-term regional projects. This suggests limited national awareness of the potential consequences of these substances and a related lack of appropriate laws or regulations.

3.2 Mapping of relevant capabilities employed for identification, monitoring and disposal of sea-dumped unexploded weapons

3.2.1 Detection, classification and identification capability

3.2.1.1 Operational approaches

The process of organising UXO surveys – chiefly, organisation, equipment, risk management - is well described in the available sources[114].

While some private actors have emerged in the context of large offshore projects (NordStream2 pipeline, wind farms, etc.), the main actor for UXO detection, classification and identification remains the naval mine warfare forces responsible for mine countermeasures (MCMs).

International naval cooperation is common in MCM detection and classification campaigns under the NATO framework, with NATO Explosive Ordnance Disposal (EOD) procedures also considered fundamental. International cooperation is also evident in the development of MCM capabilities (i.e. multipartite vessel design and procurement, equipment benchmarking trials, cooperation on sea trials, etc.), resulting in a solid sharing of best practice.

Overall, mine warfare domain features a wide array of technologies, allowing for a certain degree of creativity in the design of innovative equipment[115] . The pace of new technology introduction is therefore very rapid.

3.2.1.2 Main operational challenges

The main operational challenges for UXO surveys can be summarised as follows:

- Lack of data on UXO localisation, even in detailed inventories.
- Limited visual detection of UXOs in unconsolidated seabeds: water can quickly turn muddy and murky when seabed is disturbed.
- Technical challenges for underwater geolocalisation (with regard to the universal geo-referencing standard): there is no generalised underwater GPS equivalent (the electromagnetic waves of GPS systems cannot penetrate water)[116]. Natural seafloor markers (e.g. prominent rocks) can be used as permanent local geo-references to ease relocalisation and combine maps/images from surveys performed with different equipment and/or at different times.
- Natural or involuntary dragging: UXOs on the seabed may be dragged away from their original location by fishing gear (e.g. bottom trawlers) or currents and tides, thus widening the area to be searched[117]. Those UXOs already mapped may still need to be relocated if the classification survey is not performed immediately.

[114] Geneva International Centre For Humanitarian Demining (2016). *A guide to survey and clearance of underwater explosive ordnance*.
[115] Unlike anti-submarine warfare domain, featuring very similar equipment worldwide and a limited number of suppliers.
[116] A device that transmits short high-pitched signals at brief intervals.
[117] UXOs trapped in nets can then be dropped off from the fishing vessel without being properly geo-referenced, marked and declared.

- Intermittent burial: such event further complicates the detection and relocation of UXOs in unconsolidated sediment, often shifting due to tidal currents and even within a single tide cycle.
- Positioning of Autonomous Underwater Vehicles (AUV) which are more and more used for surveying: these platforms are subject to the electro-optic shift of their inertial sensors (autonomous absolute localisation degrades in line with duration of submerging). They are also subject to drifting caused by currents (planned survey routes are increasingly distorted during the mission duration). Here again, the use of natural seafloor markers (e.g. prominent rocks) can correct the AUV's precise position and course.

Figure 17. A9 AUV

Source: Frédéric Lucas/Marine Nationale/Défense

- Environment-related challenges: depending on the local oxygen content, marine bio-fouling and marine growths (along with the 'dust' of sediment) can make the remote collection of data on UXOs difficult. Complete classification is therefore unlikely without diver intervention (e.g. dusting-off, cleaning, concretion removal). Fortunately, deeper UXO depots (beyond diver reach) are generally less prone to fouling (due to low oxygen/light conditions) and sediment accumulation (larger distance to estuaries). These are likely to provide clearer visual evidence.

UXO survey operations are also subject to further operational challenges:

- Reliance on weather conditions, especially sea conditions and currents (WMO SS scale 0-9), as UXO surveys require off-board operations (e.g. recovery of tethered remotely operated vehicles is challenging above SS3, the recovery of AUVs above SS2 or a 2kn current etc.);
- Reliance on complex/cutting-edge technologies, sometimes offering limited endurance and reliability;
- Reliance on specific skills (UXO identification experts, EOD qualified divers, remotely operated vehicle (ROV) operators); and
- Due to the limited detection ranges of the high frequency sonar required for UXO detection, survey vessels might often operate within the danger zone of large bombs (e.g. the 500kg WWII aerial bombs or unexploded heavyweight

Figure 18. ROV PAP 104

Source: Lumir Lugué/Marine Nationale/Défense

torpedoes). This is a key driver for using unmanned surface vehicles as a master platform for the ROVs and AUVs[118].

3.2.1.3 Technologies/scientific approaches

This section summarises the main technologies/scientific approaches used in identification, monitoring and disposal of sea-dumped unexploded weapons (a comprehensive overview is included in Annex 7).

Acoustics

- Forward-looking sonar (FLS*);*
- Variable depth sonar (VDS);
- Propelled variable depth sonar (PVDS);
- Side scan sonar (SSS); and
- Synthetic aperture sonar (SAS).

Magnetic

- Passive magnetic sensing; and
- Active magnetic sensing.

Chemical

- In-situ water sampling and remote analysis;
- Material *in-situ* filtering mechanisms;
- Biological *in-situ* filtering organisms; and
- Selective detection of explosives.

Specific skills and qualifications

- **Sonar operators –** detect and classify echoes and pilot MCM equipment (ROV, PVDS, etc.);
- **Underwater EOD** divers – search, identify, move and destroy *in situ* or neutralise the devices; and
- **Boatswains/bosuns -** launch and recover devices such as PVDS, ROVs, AUVs, sweeping system or towed vehicle, etc.

3.2.2 Periodic inspection and monitoring capability

3.2.2.1 Operational approaches/constraints

Some specific environments/areas (sea lanes, harbour entrances) require periodic UXO inspection. Some critical UXO depots might require specific periodic monitoring or readjustment of protection perimeters.

The capability is the same as for detection, classification and identification (methods, sensors and assets). Specific capability elements aim to:

- Reproduce a similar inspection pattern at each iteration in order to enable data overlay; and
- Refine geolocalisation reference to enable data overlay, e.g. by using stable geo-referenced markers such as characteristic rocks.

[118] This has yet to reach full operational capability, resulting in persistent exposure of human operators.

3.2.3 On-site neutralisation and destruction capability

3.2.3.1 Operational approaches/constraints

'Human safety first' is the motto of the EOD community. Most historic UXOs entail several hazards that further complicate the assessment of their explosive power. Small changes of depth can trigger unexploded anti-submarine depth charges, while old mines can be triggered by a mere variation in the magnetic field when approaching with metallic equipment, etc.

Figure 19. Detonation of a bottom naval mine

Source: Benjamin Papin/Marine Nationale/Défense

The safest way to neutralise an UXO is to explode it, while trying to maintain its original position. Even so, the persisting danger of triggering the simultaneous explosion of undetected adjacent UXOs may result in strong shockwaves[119,120].

On-site destruction remains the safest option to limit risk for humans. This implies bringing an appropriately sized explosive charge in contact with the UXO casing to create a shockwave sufficient to initialise explosion. This charge might be deposited by a small underwater robot or by a diver. Shaped charges form a jet of plasma that is able to penetrate the casing while creating a thermal front sufficient to generate a detonation. The timer must be long enough to move back to the required safety distance (hardwearing robots can withstand significant shockwaves). Typical charges range from 500 grammes to 100 kilogrammes of equivalent TNT and can only be prepared and handled by certified personnel. The safety distance ranges for swimmers and divers are

[119] In October 1999, French EOD divers neutralising a heavy WWII mine in the British Channel inadvertently triggered the simultaneous detonation of about 20 tonnes of adjacent undetected buried mines (uncharted depot). The resulting massive explosion induced an earthquake of 4.4 magnitude and harmed (not seriously) some of the sailors of the marine warfare RHIB vessel conducting the neutralisation operation.

[120] The worst-case scenario when neutralising historic UXOs is leaving some still-live explosive material in the debris, due to its incomplete combustion. To prevent this, the destruction charge must be augmented compared to recent UXOs: it must overcome the possible degradation of the explosive's ignition threshold due to the ageing of the chemical compound and seawater contamination.

between 1',500 and 3,000 metres (the largest very common UXOs exceed 500kg TNT-equivalent: naval mines, aerial bombs and depth charges).

In general, the design of UXOs ensures that ordnances do not suffer any major consequences from thermal and chemical impact. Examples of this include fragmentation or bullet impact.[121] High-velocity projectiles can thus pierce UXOs whilst avoiding a (first) reaction. To overcome this issue, UXOs can be disposed of through a **'low-order' explosion procedure.** In this scenario, the case is burst by a neutralisation charge that imparts just the right amount of reaction energy to the explosive charge. The neutralisation charge does not impart too much reaction energy to the explosive charge, which would generate a complete detonative chain reaction from the over-pressure. Instead, in the absence of detonation due to insufficient shock, the explosive material possibly responds with a rapid burn, the 'deflagration' process ('essentially vigorous burning with the reaction occurring at sub-sonic speeds'[122])[123].

To reduce the risk of uncontrolled explosions while protecting the environment, further research should be conducted on possible alternatives, using the specific chemistry and thermodynamics of explosive compounds to find ways to neutralise – or at least mitigate – their explosive potential in the first step of the process. This remains an open question for the research community.

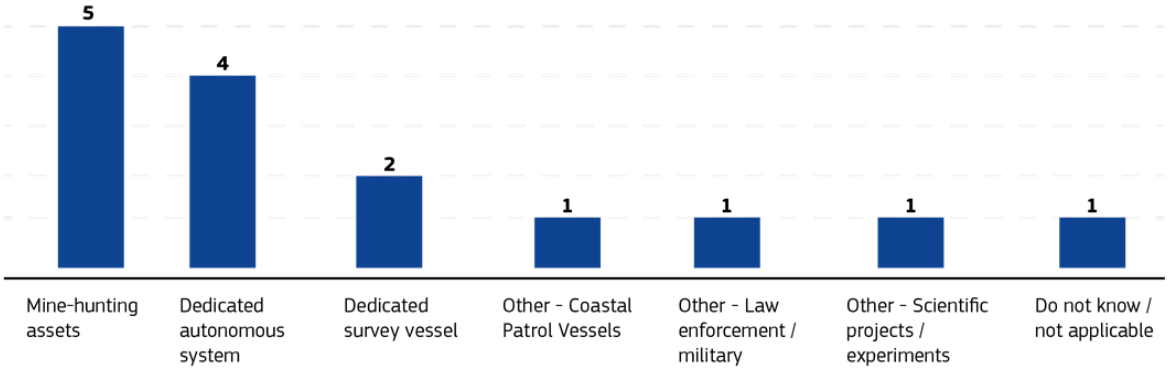
Bubble curtains are commonly quoted as an efficient mitigation measure for the environmental impact of sunken UXO detonation. They consist of using a powerful air compressor and a network of pipes fitted with small nozzles. By expanding during their ascent, the air bubbles create a double barrier:

- A physical barrier to contain contaminated water; and
- An acoustic barrier, as the high acoustic impedance contrast (the air bubbles are far more compressible than the water) attenuates the propagation of sound[124] and shockwaves[125].

Future developments may require the **specific reengineering of bubble curtain technology** to significantly increase its concrete applicability and to contain the environmental impact of on-site disposal of UXOs across a range of diverse operational contexts. Optimising the layout, nozzle details, etc. is important to minimise the size and power of the required air compressors.

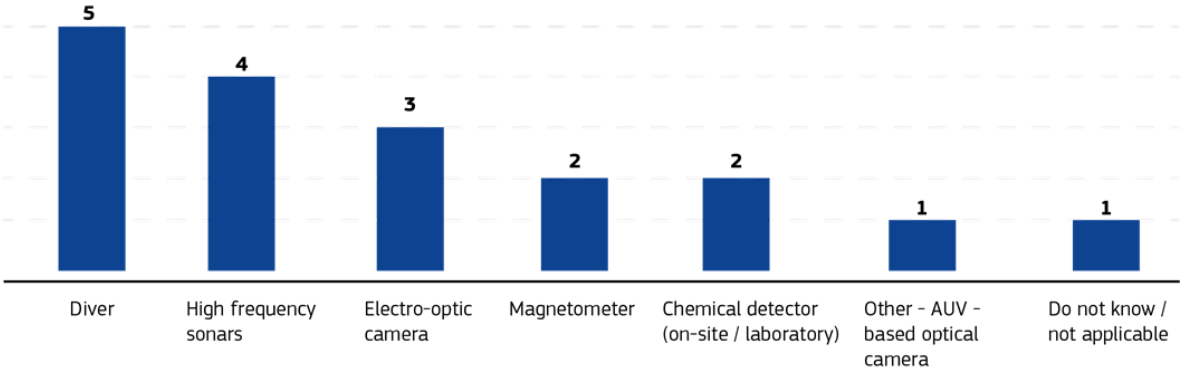
[121] Cheong, S-H. et al. (2020). Final report: characterisation of acoustic fields generated by UXO removal – Phase 2. Page 24.
[122] Op. cit., Cheong, S-H. et al. (2020).
[123] Again, it is only safe to apply this approach to UXOs in good condition and even then there is always a risk of detonating the totality of its explosive charge, failing to minimise collateral damages. A failed attempt of low-order detonation of a German WWII terrestrial 1000kg-UXO in Exeter (UK) on 27 April 2021 turned into a spectacular blow, with debris up to 250 metres away.
[124] Bubble curtains are used to reduce the underwater noise signature of large naval vessels, such as anti-submarine frigates in tactical operations.
[125] These devices are rarely used in practice due to: i) the acoustic barrier effect is only effective at a sufficient distance of the exploding UXO, while polluted water containment needs to be closer: the trade-off does not guarantee optimal efficiency for either containment issue; ii) the nozzles must be cleaned very frequently; iii) the whole set is bulky, heavy and time-consuming to deploy and retrieve.

Figure 20. Main assets/equipment used for the in-situ identification of underwater unexploded munitions[126]



Source: ICF elaboration (Survey on underwater unexploded munition, C3)

Figure 21. Main sensors used for the in-situ identification of underwater unexploded munitions[127]



Source: ICF elaboration (Survey on underwater unexploded munition, C3)

According to Figure 20, the **main assets used by Member States for on-site identification** of UXOs are mine-hunting assets (5 of 7 respondents), followed by dedicated autonomous system (4 respondents), and dedicated survey vessels (2 respondents). The **main sensors used for on-site identification** (Figure 21) are EODs (5 respondents), high-frequency sonars (4 respondents), and electro-optic cameras (3 respondents). For **periodicity**, five respondents carry out on-demand surveys related to specific off-shore projects, while three do not conduct regular surveys and identification is limited to accidental recovery tracing.

3.2.4 Underwater handling and removal capability

3.2.4.1 Operational approaches/constraints

Excluding situations where UXOs are brought to the surface by external factors such as severe storms, fishing gear or dredging equipment, the current standard UXO clearance processes exclude the possibility of bringing them to shore. On-site disposal is not achievable in inner harbours (risk of damage to infrastructure and ships), in lagoons and shallow protected marine areas, or in areas with direct proximity to existing cables or pipes.

The main operational approach involves the displacement of the UXO:

[126] N= 7.
[127] N= 7.

- Exploding in deeper waters reduces the intensity and distance of propagation of both seismic and acoustic shock waves;
- Exploding closer to the surface reduces the impact on the seabed;
- Possibly deploying bubble curtains to contain the effects of the explosion; and
- If the place of discovery is close to an underwater canyon[128], the UXO might simply be sunk to a depth out of reach for anchors, fishing gear, etc.

Figure 22. UXO removal operation

Source: Marine Nationale/Défense

3.2.4.2 Technologies/assets/equipment and applicability

The use of armoured casings to mitigate the risk of explosion is common practice in the removal of terrestrial UXOs. However, it is only applicable to homogeneous depots (reduced number of types and models) of UXOs of limited calibre and perfect preservation. This technique is therefore unlikely to be of use for underwater UXOs.

Liquid gas is used to deep freeze UXOs on-site (at least for terrestrial UXOs), reducing the chemical instability and enabling safer handling and transport in a block of ice at very low temperature. Using liquid gas underwater is challenging, given the high thermal conductivity of water.

Calls for innovative proposals have not been identified but nevertheless seem a valuable future work area.

3.2.4.3 Risk management, specific skills and qualifications

UXO risk management requires the previously described EOD qualifications, together with robust procedures and permanent training.

Although the general trend towards increasing use of robotisation to minimise human exposure should apply to underwater handling and removal of UXOs, no dedicated development programme was identified during the desk review or the stakeholder consultation. Compared to MCM threats, marine growth, fouling and corrosion of historic ammunitions, and their frequent partial burying create an additional layer of complexity for full robotisation.

What seems to be missing is a clear business case, likely stemming from the lack of ownership of the UXO clearance challenge, which remains a side task for MCM forces and has not been yet transferred to the private sector (generally tasked only with detection surveys).

Some of the experts interviewed[129] recommended that Member States develop systematic UXO clearance and removal capability. Should UXO-related pollution become a major political and societal issue (e.g. health and food security), the lack of technological means to remove and clean major depots would become more evident.

[128] Commonly found in the Mediterranean Sea, for example.
[129] Interview with DE NGO/academics – DE 02.

3.2.5 Onshore neutralisation, disposal and recycling capability

3.2.5.1 Operational approaches/constraints

Onshore neutralisation, disposal and recycling is a capability quoted only in principle. It is not considered currently applicable in the European sunken UXO context.

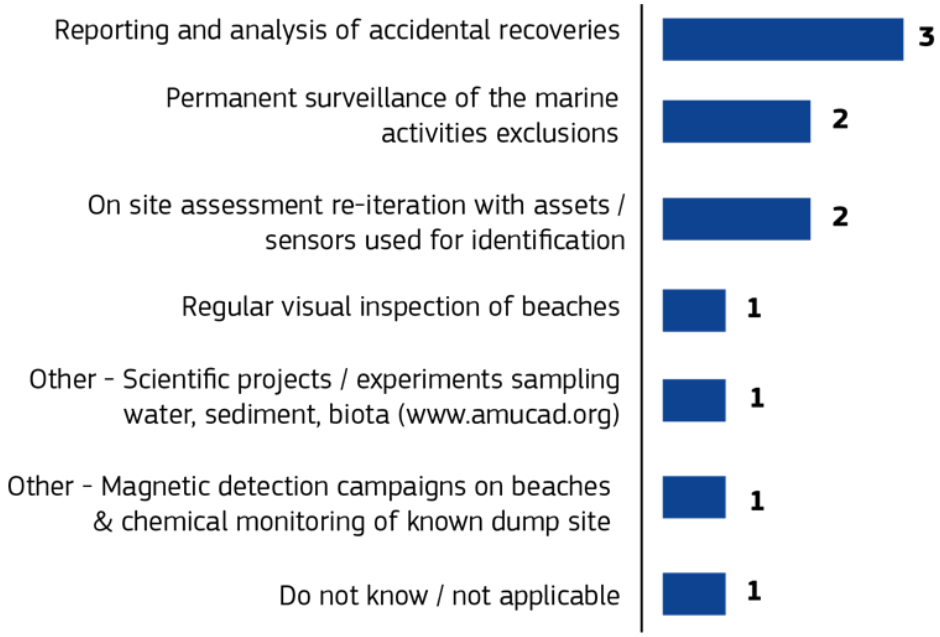
3.2.5.2 Technologies/Assets/Equipment

Armoured water tanks have been developed to safely detonate terrestrial UXOs, as a controlled alternative to underwater explosion[130]. For small ammunitions, they can be mounted on a truck that operates on the discovery site. The contaminated water can be processed.

A number of sites have been established to specifically handle and decompose/neutralise war chemicals (e.g. Poalkappelle in Belgium).

France is currently commissioning a fully robotised facility (SECOIA project) to handle war explosives, but this was confirmed to be both complex and lengthy. Its current scope is limited to dismantling the unused ammunition stockpile and terrestrial UXOs neutralisation.

Figure 23. Main assets/equipment used for the monitoring of underwater unexploded munitions[131]

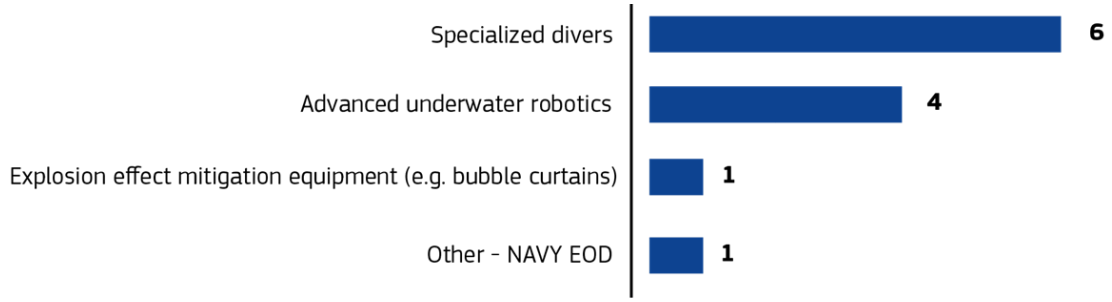


Source: ICF elaboration (Survey on underwater unexploded munition, C4)

According to Figure 23, the main assets/equipment used to **monitor underwater unexploded munitions** is reporting and analysis of accidental recoveries (3 of 7 respondents), followed by permanent surveillance of marine activities' exclusions (2 respondents), on-site assessment reiteration with assets/sensors used for identification (2 respondents), and regular visual inspection of beaches (1 respondent).

[130] For many years, it has been common practice to destroy terrestrial UXO stockpiles by detonating them underwater at high tide, as the water acts as a security blanket to stop debris and dampen sound waves.
[131] N= 7.

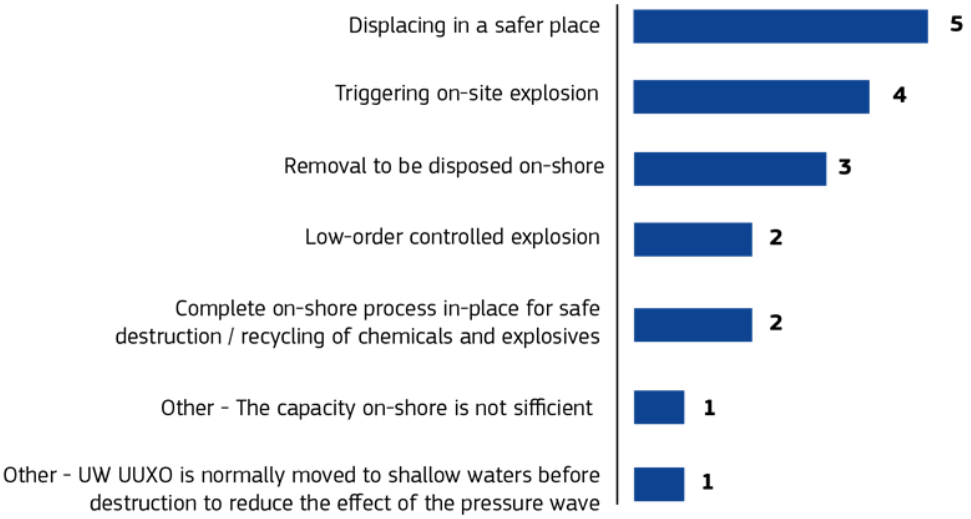
Figure 24. Main assets/equipment used for the disposal of underwater unexploded munitions[132]



Source: ICF elaboration (Survey on underwater unexploded munition, C5)

In the **disposal of underwater unexploded munitions**, the main equipment used are specialised divers, followed by advanced underwater robotics (4 respondents).

Figure 25. UXO disposal strategy[133]

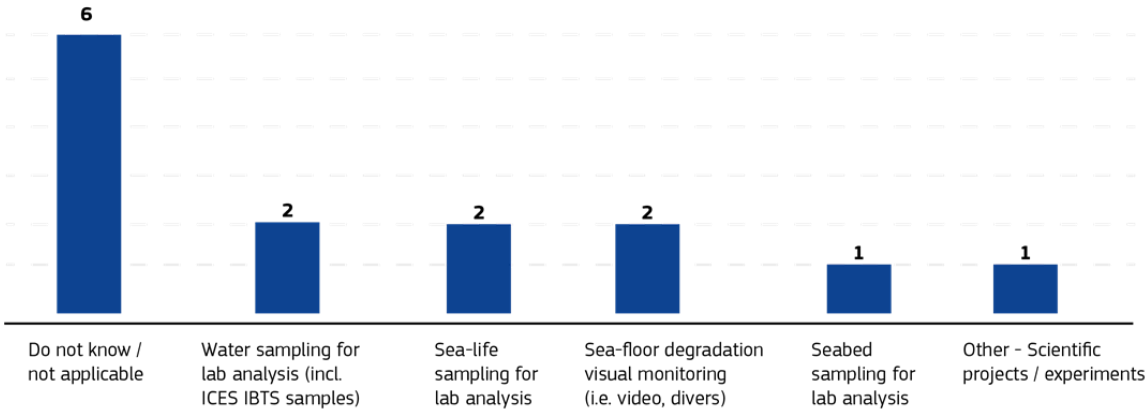


Source: ICF elaboration (Survey on underwater unexploded munition, C5)

As regards to the **UXO disposal strategy**, d*isplacement in a safer place* is the strategy mentioned by most respondents (5 respondents, out of 7), followed by *triggering on-site explosion* (4 respondents) and *removal to be disposed onshore* (3 respondents) are the most used strategies for the disposal of UXO. One respondent also highlighted that UXOs are normally moved to shallow waters before destruction to reduce the effect of the pressure wave.

[132] N= 7.
[133] N= 7.

Figure 26. Protocols used for the monitoring of marine pollution in the vicinity of UXO depots[134]



Source: ICF elaboration (Survey on underwater unexploded munition, C6)

Figure 26 illustrates the main **protocols used to monitor marine pollution in the vicinity of UXO depots**. However, a large proportion of the respondents (5 of 9 respondents) did not know these protocols. According to the other respondents, the main protocols are water sampling for lab analysis (including ICES IBTS samples) (2 respondents) and sea-floor degradation visual monitoring (e.g. video, drivers) (2 respondents).

3.2.6 Availability and operation of capabilities

3.2.6.1 Public authorities

All of the Member States consulted have EOD teams available 24/7, which can intervene at any time to secure and manage accidental discoveries of UXOs. They are typically provided by naval MCM forces. Some are also qualified and trained to be deployed from helicopters, e.g. to the deck of a fishing vessel[135].

A common challenge is sufficient recruitment to EOD diver schools, as it remains among the most demanding and stressful military speciality training (only half of the candidates eventually achieve full certification). According to a recent estimate, about 60 divers are trained every year in EU to clearance diver level and no more than 40 to full EOD diver certification[136]. Normally, their service does not exceed 15-20 years, due to the physical demands of this activity.

While divers are trained to deal with UXOs 'bare-handed', dedicated hand-held lightweight/(reasonably) low-cost equipment for facilitating UXO detection and classification can be used to augment their capability, such as the Sonadive system. Helmet-drysuit EOD divers do spot dives, generally with an umbilical link to the diving support vessel. Conversely, scuba-wetsuit divers can perform extended surveys in the diving time allowed by the depth.

Extended seabed inspection surveys require the use of vessels able to operate with high-frequency sonar systems. Dedicated tools to specifically identify UXOs could be

[134] N= 9.

[135] Some Member States (e.g. FR) have EOD diver teams within their civil protection forces, with a differentiated intervention area. This capability is built through former military EOD divers and erodes as these specialists retire.

[136] Council of the European Union (2021). Training Requirements Analysis Report on Maritime Security. EEAS. Available at: https://data.consilium.europa.eu/doc/document/ST-9790-2021-INIT/en/pdf.

developed (see Section 5 Recommendations) to improve the reliability and productivity of surveys and facilitate systematic inspection of large areas of the seabed.

The measurement of chemical pollution in the vicinity of UXO depots remains a challenge, as there is no standard protocol nor are sensing devices currently available commercially. As a result, the few published studies sometimes provide contradictory conclusions on the risk level and scale of the problem.

Ownership of this heavy heritage remains a highly political issue, with questions raised as to whether the burden accrues to the nation or solely to the defence forces, possible application of the polluter pays principle, and a disposal process that conformed to historic international agreements but is now recognised as unsustainable.

3.2.6.2 Private actors

Several EOD survey companies are currently operating for UXO clearance operations on offshore construction sites. However, the disposal of UXOs remains the prerogative of national authorities, even where private actors have qualified personnel.

Considering the development of offshore infrastructures, with naval mine warfare forces tending to modernise and decrease, private actors are likely to be increasingly involved in UXO clearance operations. An area of possible improvement is public-private cooperation, which could usefully involve clear predefined protocols, certification convergence, regulations (e.g. to define and implement security perimeters), and subsequent responsibility sharing.

3.2.7 Capability gaps and emerging technologies

3.2.7.1 Ongoing UXO-specific capability procurement plans

A large part of the current capability procurement plans relates to global MCM capability. By contrast, the plans relating to UXOs generally aim to improve the destruction of terrestrial UXOs from an environmental perspective.

The only ongoing capability procurement plan identified in the survey is the dedicated underwater UXO testbed launched by NATO-CMRE.

3.2.7.2 Ongoing initiatives on common procedures, assets pooling and joint experimentation and training

A full standard for EOD diver certification is not available in the EU. It remains instead defined at Member State level, except for the few bi-national frameworks (e.g. BE-NL EGUERMIN curricula).

A number of initiatives are being developed to network diving training schools and progress toward common certification and diving procedures in the framework of PESCO. The European Union Network of Diving Centres (EUNDC) was established by Romania, Bulgaria and France. It coordinates and enhances the operation of EU diving centres to better support common security and defence policy operations by providing a full spectrum of authorised training courses for divers and rescue swimmers in accordance with common standards and procedures.

The NATO-CMRE UXO testbed aims to support joint experimentation and open trials to benchmark innovative solutions in a controlled environment. Workshops will focus on fostering international collaboration: the first seeks to understand lessons from the implementation and use of the CMRE UXO test site, while the second will take the form of a conference featuring presentations and discussions on the results of UXO detection, classification monitoring, identification and disposal. CMRE will publish the proceedings and disseminate the results broadly across the NATO and military community.

3.2.8 Summary of the key findings

Examining existing capabilities for identification, monitoring and disposal of chemical and unexploded ordnances, this section provided a multi-angle assessment of:

- Capabilities used for identification, monitoring and disposal of chemical and unexploded ordnances;
- Authority(ies) using those capabilities; and
- Gaps in specific capabilities (including knowledge) reported by stakeholders.

The report draws several conclusions:

- **Capabilities**: EU Member States' MCM (clearance) capabilities are world-class, as are their cooperation, joint exercises, and common training. All Member States in scope have response mechanisms for accidental UXO recovery. This includes protocols/procedures, reactive chain of intervention, operational assets mobilisation and EOD diver qualifications.
- **Authority(ies)**: both public authorities and private actors are involved, although the disposal of UXOs remains the prerogative of national authorities.
- **Gaps**:
  - UXO identification and clearance capability faces a number of challenges. While accidental discoveries are very efficiently addressed in all affected Member States and accidents are rare, UXOs in the EU seabed remain an important and long-lasting risk for the environment and for seabed users.
  - Underwater UXO clearance is challenging compared to terrestrial explosive clearance (which itself faces several hazards and high costs). Currently, only naval forces have the capability to approach, identify, handle, and neutralise UXOs underwater. The development of offshore infrastructure along the EU coastline (wind farms, communication cables, pipelines) has enabled the development of civilian capabilities to survey the seabed but the private sector is not authorised to intervene or neutralise detected UXOs. As the primary mission of armed forces is demining in the context of current military operations, the resources available for UXO identification and disposal are typically limited to accidental recovery.
  - Climate change-induced coastal erosion is a new aggravating factor. Previously exposure of UXOs was largely due to fishing activities – in particular when using sea floor trawlers and dredges, with fishers well-aware of the UXO threat and risk mitigation procedures. In future, coastal erosion might increasingly expose the general public, which has low awareness of both UXO risk, precautions and alert procedures. This risk is difficult to avoid, as the preventive clearance capability of buried UXOs remains limited.
  - Chemical monitoring of UXO leaks remains at the R&D stage, requiring the development of both sensors and relevant knowledge on the extent, evolution and impact of this type of pollution.
- There is a need to develop, adapt and validate procedures and techniques for the mitigation of environmental impacts, as well as the training of operators to allow their deployment for different UXO threats and contexts. Open UXO detection systems would be valuable, featuring unified taxonomies and data-models to be used for AI-based UXO identification algorithms from sonar and magnetic anomaly data.

3.3 Best practices in dealing with accidental recovery of dumped munitions at sea in different maritime communities

This section looks at best practice in dealing with accidental recovery of dumped munitions at sea in different maritime communities. The information is drawn from interviews conducted with various EU maritime communities[137] and the analysis of secondary sources.

[137] Fisheries, engineering/construction, transport and tourism entities, as well as others (environment, UXO specialists, etc.).

These practices are designed for the local and professional context and this section starts by examining the **response** of authorities to the discovery through to the **implementation** of measures at national and international level.

Overall, policies for managing underwater munitions in cases of accidental discovery systematically address:

- Location of the discovery (sea basin);
- Type of munition encountered (chemical or conventional);
- Context of the discovery (industrial site, offshore or dredging, professional fishing, individual);
- Action to be taken and alerting of the authorities;
- Reaction capacity of the demining services; and
- Initiatives aimed to improve:
  - Knowledge of the impact of UXOs on the environment;
  - Quality of authorities' intervention (speed, efficiency, environmental consideration); and
  - Prevention of physical and natural hazards in the event of accidental discovery and treatment of munitions.

The first part of this section analyses the principles common to all European maritime basins, as well as specific initiatives in managing accidental discoveries of munitions. The second part proposes a number of recommendations to improve Member States' responses to accidental discovery and subsequent treatment of underwater munitions.

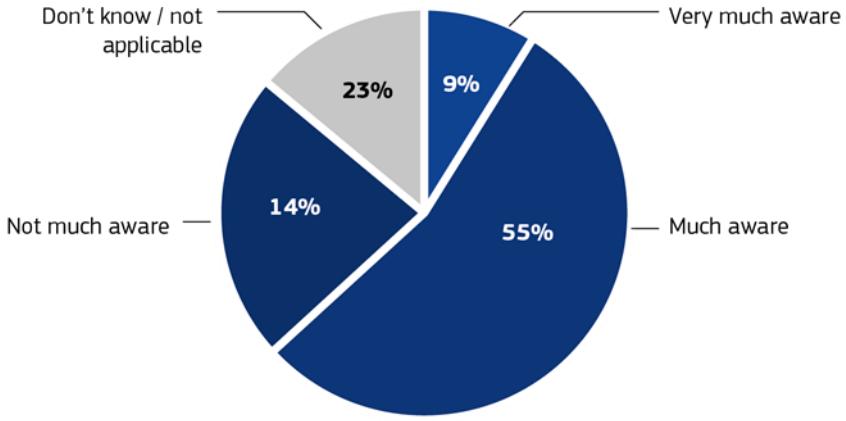
There is little information available on the practices of seafarers in the event of accidental discovery of submerged or washed-ashore munitions. Much of the information presented here comes instead from primary sources, such as interviews with professionals working with the sea, or organizations and services in charge of dealing with this issue.

Guidelines or flyers exist for fishers, summer visitors and EOD operators and were referenced during the interviews, but these are rarely made available to the wider public and/or published online[138]. Nevertheless, the Study identified and analysed several documents of practical use and value, including:

- **Almanach du marin breton pour la Manche et l'Atlantique** (Breton sailors' almanac for the Channel and the Atlantic)[139] for pleasure boaters and fishers. One chapter provides technical information on how to identify munitions[140], including charts and photographs to guide identification. It also sets out the discharge zones (200 metre radius) for fishers from Hendaye to Dunkirk for munitions encountered accidentally;
- **Technical reference framework for national defence activities for the management of Natura 2000 sites at sea, Volume 1**[141] - for the Ministry of Defence. This document is supplemented with practical sheets compiled locally by state and non-governmental stakeholders (environmental protection associations) for EOD mission leaders in charge of handling accidentally discovered munitions.

[138] Interviews with national authorities – FR 01, BG 01; Interviews with FR MC – Fisheries – FR 09, 10 and 13; Interview with FR MC – UXO specialist – FR 07.
[139] Oeuvre du Marin Breton (1984).
[140] Ibid., 'Activities to conduct in the event of discovery of a war device up to the high-water mark'.
[141] Marine Protected Areas Agency (2014).

Figure 27. Sea environment users' awareness of which authority to contact for UXO[142]



Source: ICF elaboration (Survey on underwater unexploded munition, C2)

Figure 27 shows that, out of 22 respondents, 12 (55%) believe that the users of the sea environment are generally well aware of who to contact in case of accidental encounters with UXOs. By contrast, 5 respondents (23%) believe that sea environment users are generally not aware, while only 2 respondents (9%) believe that they are very much aware.

3.3.1 Underwater unexploded munitions management priorities, by sea basin

The procedures followed in the event of an accidental discovery of underwater munitions, as well as the methods for the identification and disposal of those munitions, **are technically similar in all EU sea basins**. These procedures are based on alerting the MRCC, followed by the rapid intervention of State authorities, whether civilian or military.

A large proportion of the chemical munitions in EU sea basins have been discovered in the Baltic Sea and the northern part of the North Sea. However, **fishing professionals** and maritime authorities report that the numbers of accidental discoveries of conventional munitions at sea has dropped significantly since the 1990s. Underwater munitions no longer represent a problem for their activity, with the exception of a few geographical areas (e.g. Brest Harbour), where specific procedures are in place for cases of accidental discovery of munitions.

Other maritime professionals (**dredging, offshore, marine renewable energy industries, transport**, etc.) may also be affected. The risk of accidental discovery of underwater munitions is usually integrated in related impact studies and prevention plans. Available data suggest that industry has no difficulty in managing this problem as part of worksite contingencies once it receives administrative authorisation to begin the work[143].

Coastal populations or beachgoers seem to be the most affected by accidental discoveries. Indeed, these largely occur on the foreshore, where the coastline has been eroded by the consequences of climate change.

Member States' measures to deal with accidental recoveries of UXOs range from **targeted information campaigns** to **systematic clean-up operations** in at-risk areas. The approach depends on the frequency of discoveries, which can range from

[142] N= 22.

[143] For example, the Courseulles sur Mer wind farm, where, as part of the preliminary work for the installation of the wind turbine, underwater munitions are regularly discovered and treated by the French Navy under special agreements. See also interviews with MC – Engineering/Construction, FR 12 and LU 01.

several encounters per week (e.g. in the North Sea) to very few, for example along the Bulgarian coast, where around one or two discoveries are made each year[144].

3.3.1.1 Common responses to accidental discovery of UXOs

Immediate response

All maritime Member States have sea rescue systems in place, with public or sometimes associate/voluntary means of intervention to save lives.

In the event of accidental discoveries, **sea marine VHF channel 16**, the international distress frequency, is used to contact the rescue services (generally the nearest MRCC[145]) and to immediately obtain individual and collective instructions, even an intervention within a few hours of onboarding their vessel.

Longer-term responses to avoid future accidental discoveries:

- Prevention of accidents in the event of accidental discovery of dumped munitions requires specific protocols to clear hazardous areas and policies to inform the population about the dangers posed by UXOs. The demining activities carried out from the end of WWII until the 1970s proved effective despite the limited technologies available (mainly mechanical dredging and influence). Most of the ammunition has since become inactive, with the threat now largely limited to handling UXOs (fishers or careless individuals). Overall, **long-term responses** in the EU Member States are driven by:
  - Quality of the **demining work** already carried out after the end of WWI and WWII;
  - **Incident rate**, combined with the ability to provide an immediate response; and
  - Direct and indirect **impact of UXOs** on professional and tourist activities.

Some Member States remain particularly affected by the problem of UXOs[146]. Recommendations for future action in this respect include:

- Implementation of **awareness campaigns** on the risk of accidentally encountering ammunition, through seasonal means (tourist flyers) or specialised media (nautical documents for boaters and sea professionals);
- Analysis of **coastline erosion** linked to climate change;
- Regular **updates on UXO discoveries**, including a specific focus on areas that are less fished, dredged or surveyed for UXOs, where accidental encounters are most likely;
- **Incentive/compensation systems** in case of accidental encounters (e.g. DK, FR) to encourage systematic reporting of recovered UXOs;
- Systematic **clean-up operations** in areas identified as at-risk (e.g. after several accidental discoveries in the same place); and
- Development of **best practice guidelines** in collaboration with local actors (authorities, professionals, and associations).

3.3.2 Regional adaptations of the response model

This section provides specific information on the response models at regional level, based on the specific characteristics of the various EU sea basins.

3.3.2.1 Baltic Sea

The countries bordering the Baltic Sea are the most **historically involved** in the long-term response to UXO threats. The **BOSB** initiative brings together the Baltic Sea states,

[144] Interview with Military authorities, BG 01.
[145] List of world RCCs: https://sarcontacts.info/
[146] For a detailed analysis, see Task 2, Report on the current situation of unexploded munitions in each European sea basin.

in cooperation with HELCOM, and coordinates the activities of UXOs long-term disposal. BOSB has recorded around 2,200 historical minefields, i.e. about 180,000 objects in front of ports, their approaches and along shipping lanes.

Under the NATO operative umbrella, BOSB has collected data on the demining operations conducted in the Baltic Sea from 1995 to 2008. This initiative allowed new exercise planners to follow the proposed order of priority among UXO sites (old minefields) when planning their annual demining exercises off the Baltic States.

In terms of **chemical munitions**, the Baltic Sea is undoubtedly the most polluted sea in Europe, especially its shallow waters. Accidental discoveries are regular but decreasing, in particular on the seabed near the Danish coast[147].

Over the past 20 years, a total of 115 incidents involving submerged chemical war agents (CWA) were reported by Baltic countries to HELCOM. As BOSB operations focus primarily on listed naval minefields, they do not search for dispersed chemical munitions, whose size makes them more difficult to detect and which also pose a processing problem if found.

Denmark is the only Member State in the Baltic Sea with a compensation programme in place for fishers and other professionals who report UXO encounters. They are compensated for each shell recovered and brought onshore, as well as for damaged nets and destroyed or contaminated catches[148]. According to HELCOM, this has resulted in a significant increase in munitions encounters reported and brought to shore by fishers: 450 or more in the period 1976 to 2002, compared to significantly smaller (unspecified) numbers in neighbouring Sweden[149].

The practice was established to encourage fishers to report UXOs to competent authorities instead of re-dumping them at sea and its effectiveness is evident in the far larger number of reported encounters between Danish fishers and their neighbours. If adopted at a larger scale, this practice may have the effect of **gradually reducing the number of UXOs** (at least those within range of fishing equipment) in this sea basin, a process which may accelerate over time as fishers become acquainted with the procedures.

3.3.2.2 North Sea, British Channel

Compared to the Baltic Sea, the North Sea and the Channel share **similar risks of accidental discovery of munitions**. The environmental conditions are also similar, characterised by moderate depths (continental shelf), strong currents, significant bottom movements (dunes), burial in front of estuaries and very turbulent areas. These conditions represent a major challenge for mine-hunting operations, as a discovered munition can be covered by sediment in less than 24 hours.

The **risks** entailed by UXOs are substantial, with North Sea Member States developing a unique expertise in their management since the end of WWII. Operations to eliminate old minefields or to remove ammunition from wrecks are conducted annually, when environmental conditions and tidal coefficients allow (e.g. HOD - Baie de Somme). Like Denmark in the Baltic Sea, France has a compensation programme for civilians (fishers,

[147] DK average number of discoveries in fishing areas: 1976-2002: between 17 and 18 per year; 2003-2012: between 4 and 5 per year; Interview with SE military authorities – SE 01, Sweden/HELCOM/BOSB.

[148] Missiaen, T. and Henriet, J.P. (2002). *Chemical munition dump sites in coastal environments*. Renard Centre of Marine Geology, University of Ghent, Belgium Federal Office for Scientific, Technical and Cultural Affairs (OSTC), p. 5.

[149] This figure reflects the intense fishing activity (mostly bottom-trawling) in the Baltic Sea, particularly around Denmark. Many fishers have disregarded warnings to avoid known dumping sites in their activities. See: Project DAIMON (Decision Aid for Marine Munitions), Management Strategies And Technological Availabilities, p. 77.

individuals, etc.) reporting UXOs accidental findings[150]. This system facilitates systematic rapid informing and reaction in case of an encounter, especially along the Channel coast. Since 2005, the Royal Netherlands Navy has intensified its cooperation with the Belgian Navy, mutualising the standing intervention teams with the objective of 'keeping the sea, coastal waters, ports and maritime approaches free of mines and explosives'".[151]

3.3.2.3 Atlantic Ocean

The environmental setting in the Atlantic is similar to those in the North Sea and Baltic Sea. However, available data suggests that the diffusion of UXOs is **comparatively less significant** and problems related to bottom movements (dunes) are not very frequent. Exposure of the coast to bad weather significantly limits the search for underwater UXOs.

While the Atlantic coastline is not affected by the risk of accidental discovery of chemical munitions, a large proportion of those are identified in front of **ports, their approaches, and beaches**.

Economic activities (e.g. fishing with trawls or dredges) are involved in the majority of discoveries, in particular in the Brest Harbour, where special measures to assist fishers have been implemented by the Maritime Prefecture[152]. These include a hotline to quickly communicate information on the characteristics of recovered UXOs (including image exchange), as well a system of financial compensation for fishers reporting UXO encounters.

In terms of **risks**, accidental discoveries are somewhat regular and mainly occur on the foreshore where the coastline has been eroding for several years. To date, these discoveries have not had any major consequences for civilians. However, the recent implementation of wind farms could lead to the discovery of new ammunition in previously unexplored areas.

Member States in this sea basin have efficient procedures/protocols enabling the authorities to intervene within a few hours of an accidental discovery being reported. Considering the vast areas affected by UXOs, coastal Member States rely on prevention policies that provide information to sea professionals and tourists (poster campaigns, warnings in nautical documents for the use of boaters and fishers.

3.3.2.4 Mediterranean Sea

Available data suggest that the Mediterranean Sea is the **least affected** by accidental discoveries of UXOs, given its great depths and the narrowness of the continental shelf. Nevertheless, areas near ports require particular caution. The environmental conditions are favourable for detection, even if the seagrass beds (*posidonia*) can create problems for echo-based detection systems.

Trawling activities are limited to certain areas, but summer tourism and scuba diving activities are frequent. Mine warfare exercises are regularly organised in the areas of former minefields, which were treated by dredging at the end of WWII.

3.3.2.5 Black Sea

The risks linked to underwater munitions are **poorly documented** in the Black Sea[153]. Like the Baltic Sea, the Black Sea is sensitive to pollution, albeit with deeper sea floors. At least three chemical UXO depots from the former Soviet Union are known, but these

[150] This programme is also valid for the French Exclusive Economic Zones (EEZ) of the Atlantic and the Mediterranean.
[151] See https://english.defensie.nl/topics/international-cooperation/other-countries/mine-clearance-operation-%E2%80%98beneficial-cooperation%E2%80%99.
[152] Tourism is important in the summer and diving is also frequent.
[153] See Task 2, *Report on the current situation of unexploded munition in each European sea basin*.

are outside Bulgarian and Romanian coastal waters. The continental shelf of Bulgaria and Romania is not extensive and is comparable to that of the Mediterranean countries, thus conditions for detecting **submerged devices are similar**.

Overall, the chemical UXO challenge is not raising as much interest here as in the Baltic Sea, but nevertheless remains real. Document research has not identified any major problem related to the accidental discovery of dumped munitions, with only one or two pieces of ammunition discovered each year.

3.3.3 Review of current UXO management practices

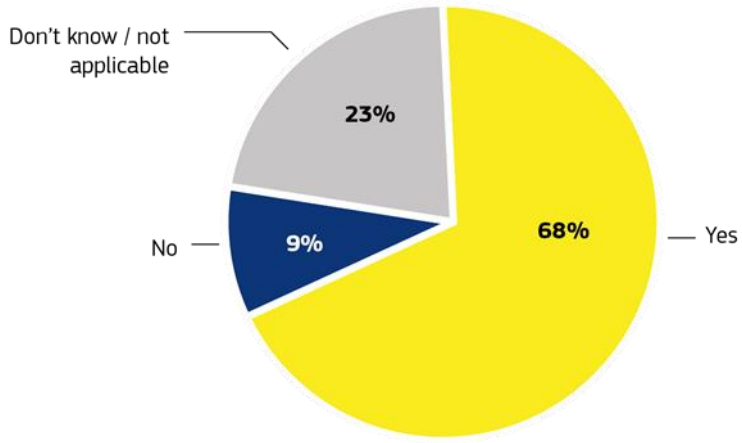
In all scenarios and circumstances, **safeguarding the finder** is a priority. In the event of accidental recovery of munitions, the following general rules should be followed by any type of finder:

- Do not touch the device;
- If possible, take a photograph of the device;
- Move away and alert people nearby (on the ground, within 100 metres);
- Alert the authorities, describe the device and (if possible) send the photograph; and
- Be available to the authorities to inform the security and demining services.

Specific actions taken by the finder will also depend on:

- The maritime community to which they belong;
- Their knowledge of the type of threat entailed by the recovered munition; and
- Their experience of this type of discovery or, in some cases, the application of an existing prevention plan (marine/offshore engineering, dredging).

Figure 28. Existence of formal reporting procedures/protocols in case of accidental discovery[154]



Source: ICF elaboration (Survey on underwater unexploded munition, D1*)*

When it comes to **formal reporting protocols/procedures for accidental discoveries,** 15 of 22 respondents (68%) reported having protocols/procedures in place, while 2 respondents (9%) reported no protocols/procedures in place.

The **main types of protocols/procedure used** is general guidelines (i.e. limited to a standard incident declaration form) (10 of 15 respondents). This is followed by detailed guidelines (i.e. identifying UXO type and associated risks; taking immediate risk reduction measures) (6 respondents), Standard Operating Procedures (SOPs) for meeting baseline technical and operational security measures (6 respondents), SOPs for meeting more stringent and additional technical and operational measures in case of

[154] N= 22.

higher level of threats (6 respondents), and SOPs and methods for deciding which measures to implement (6 respondents).

The following sections will present a number of **specific recommendations**, as well as **specific safeguard protocols** that can be implemented based on the type of finder.

3.3.3.1 Fishing

Regardless of their country of origin, **fishers** share a common professional culture and an overall need for efficiency due to the time pressure that characterises their job. The accidental discovery of ammunition is mainly linked to the type of technique used, which is itself closely related to the specificity of the environment and the species fished.

The **fishing techniques** most affected by the accidental discovery of munitions are: i) coastal trawling; and; ii) dredging (shellfish). Other fishing activities such as trolling, trapping, long-lining or netting are not typically associated with the discovery of munitions.

Given these considerations, the main issue related to fishers' activities is that they can **throw recovered UXOs back into the sea**. Fishers are often concerned of wasting time (and money) by reporting accidental discoveries. In the best case, the position of the mooring (GPS coordinates or near a navigation buoy) and the nature of the ammunition is recorded by the fishers and later transmitted to MRCC.

Overall, fishers are aware of the areas where the risk of catching munitions is high (particularly chemical UXOs) and tend to avoid them. Exceptions are those fishing activities where the financial gain is considered 'worth the risk' (e.g. scallop fishing in the Brest Harbour). Unless the accidental discovery of an UXO becomes a problem that requires specialised intervention (e.g. UXO stuck in scallop dredge knives), most only apply two of the five safeguarding rules: i) **recording the ammunition's location** and ii) **alerting the authorities**. Current legislation in all Member States does not allow fishers to return with ammunition on board, with breaches subject to various sanctions, ranging from a first reminder of common sense (e.g. BE), a fine or imprisonment (e.g. FR).

Interviews with fishers from the North of France or the Mediterranean highlighted their substantial knowledge of the areas at risk, which allowed them to deal with part of the danger without recourse to the local authorities[155]. Nevertheless, they also noted that decreasing numbers of discoveries and retirement of older fishers will hinder the transmission of such knowledge and, combined with the degradation of the ammunition casing, could entail more risk of future accidents.

Extract from interview with MC – Fisheries, FR 09 (ship owner and fisher in the Channel and North Sea for 40 years)

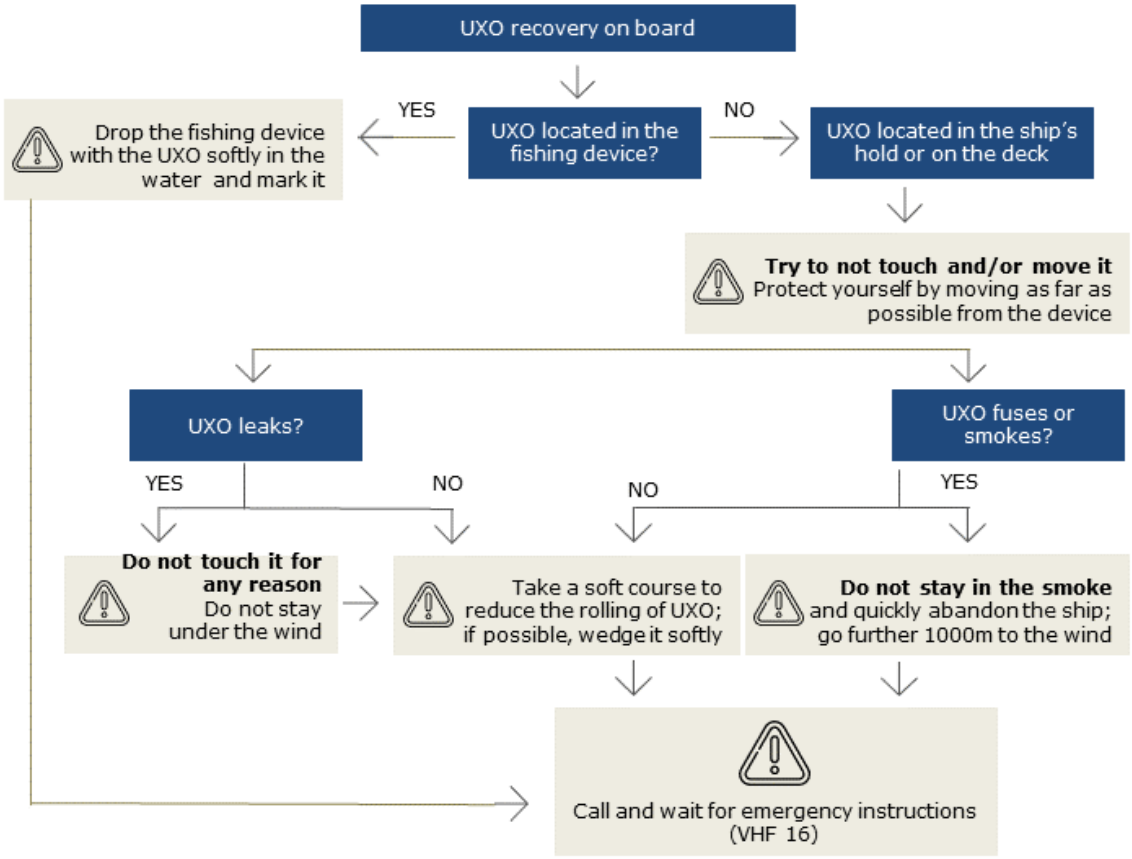
Given the rarity of ammunition finds, the interviewee noted that the new generation of fishers, unfamiliar with these accidental encounters, may have accidents when handling ammunition, in particular shells, whose warheads at the fuse are increasingly corroded and often crumble.

In fact, in the event of the discovery of a shell, the fishers in this area used to avoid calling the MRCC and to treat the shell themselves by unscrewing the fuse and rewetting them on rocky outcrops where there is no trawl fishing.

[155] Interviews with FR MC – Fisheries – FR 09 and FR 13.

Figure 29 shows a safeguarding protocol for fisheries.

Figure 29. Safeguarding protocol for fisheries



Source: ICF elaboration

3.3.3.2 Industrial activities - engineering and maritime/ports

The activities of engineering and maritime/port operations are regulated by business organisations as well as labour law. Specific measures are available to safeguard operators. A **threat assessment** to identify/consider the presence of UXOs is carried out in the operation areas before works start[156], with possible follow-up actions including:

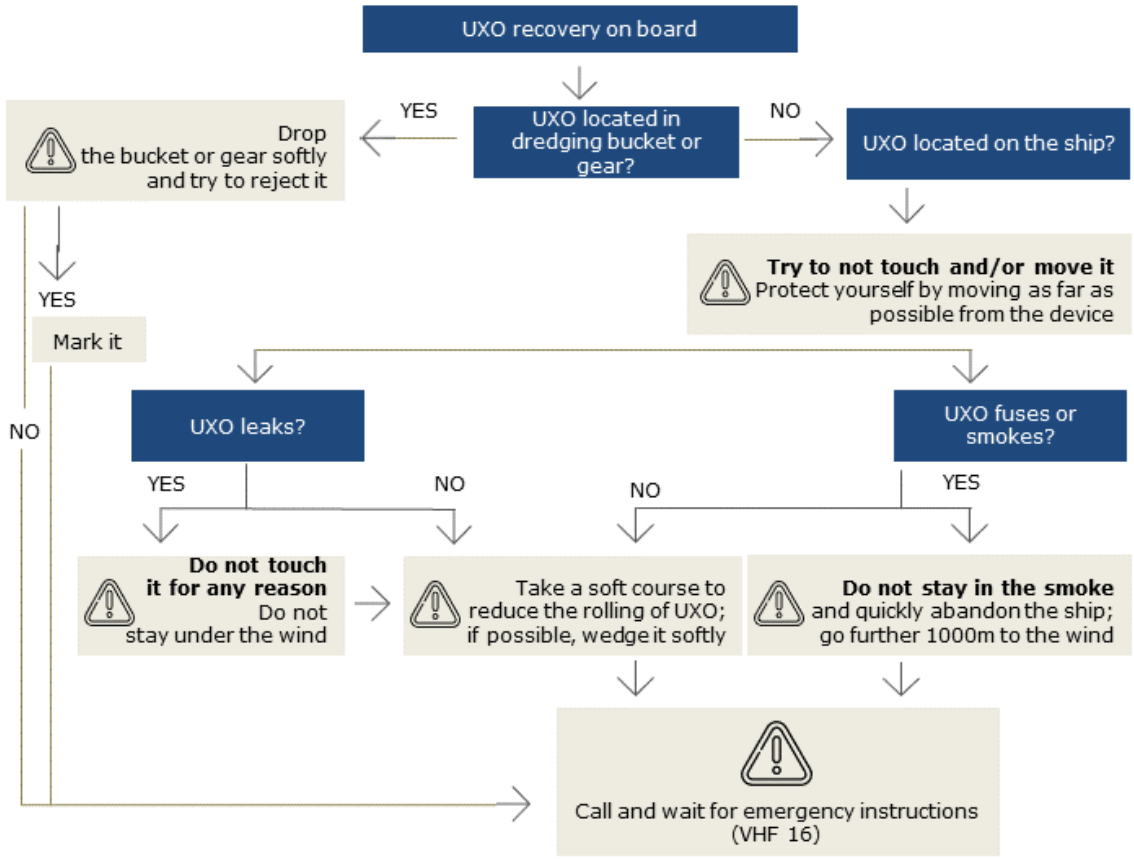
- Relocation of the worksite;
- Clean-up of the site by a private company/in coordination with State services;
- Application of specific instructions and employee training on the discovery of munitions;
- Establishment of a demining team which will be on alert 24 hours a day for the duration of the operation considered at risk[157];
- Use of unmanned systems to carry out the phases of work assessed as at-risk; and
- Cancellation of the operation if the area is considered saturated (e.g. ports).

[156] Even on sites where the risk of encountering dumped munitions is higher, accidental recoveries of underwater munitions are rare.
[157] Usually dredging or excavation.

Overall, evidence suggests that the employees of maritime and underwater engineering companies are insufficiently trained on the dangers entailed by UXOs, increasing the risk associated with any accidental discovery of an explosive device outside of a planned worksite [158].

Safeguarding protocols for industry are proposed in Figure 30 and Figure 31 (the latter focuses on accidental discoveries of UXOs ashore or in a harbour).

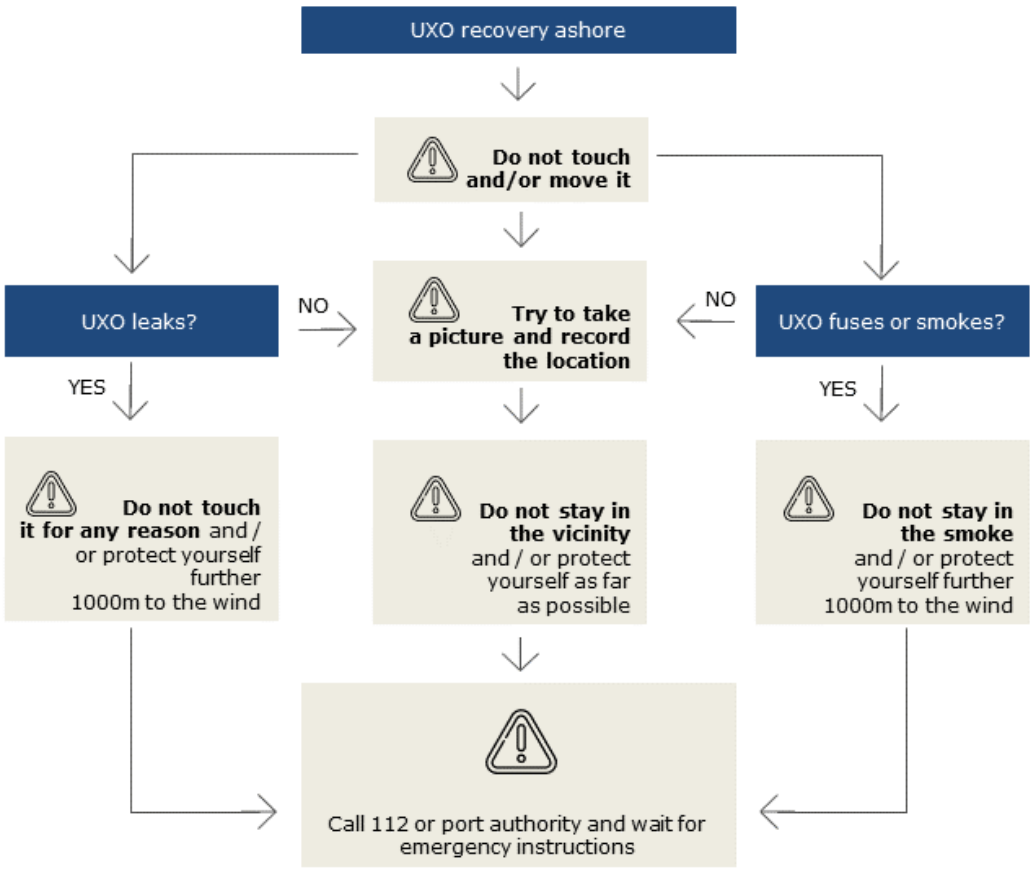
Figure 30. Safeguarding protocol for engineering/industry



Source: ICF elaboration

[158] Interviews with MC – Engineering/Construction, FR 12 and LU 01.

Figure 31. Safeguarding protocol for accidental discovery of UXOs ashore or in a harbour



Source: ICF elaboration

3.3.3.3 Transport and tourism

Available data suggest that transport and tourism are by far the least involved activities in accidental recovery of UXOs and can thus also be considered the least-prepared to deal with any such accidental discovery.

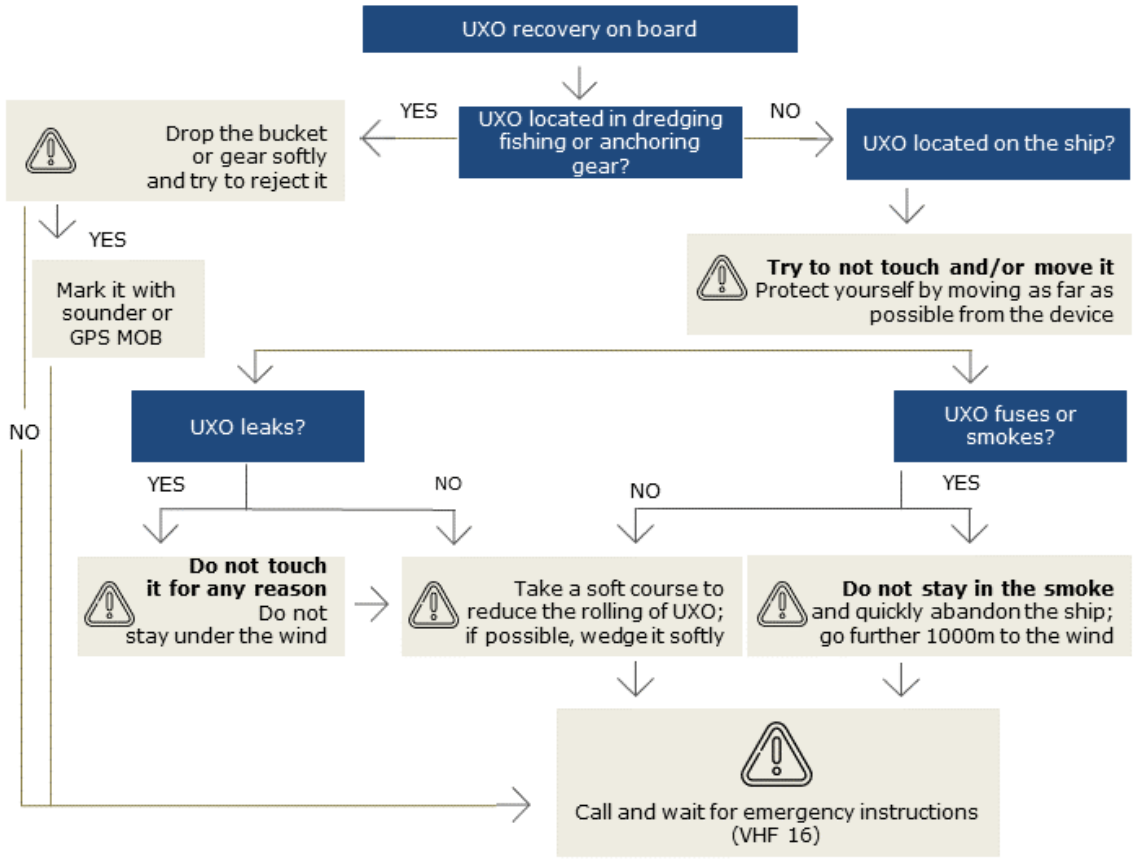
Maritime transport is usually not concerned with the discovery of dumped or drifting munitions, except in exceptional events, such as terrorist attacks or conflict zones. Today, WWII munitions (bottom mines and moored mines) that were placed to destroy merchant ships have either been removed and destroyed or deactivated.

As far as the **tourism** sector is concerned, the risk of discovering dumped munitions can be assessed as fairly low. Indeed, most munitions are discovered by tourists in contexts such as:

- Natural events, such as storms, that move large quantities of sand from beaches or heavy rainfalls eroding cliffs and releasing shells buried since the end of WWII; and
- Development of outdoor activities, which leads tourists to places previously not accessible and where UXOs were perfectly integrated in the landscape for a long time and therefore not visible;
- Scuba diving activities.

A safeguarding protocol for transport/tourism is presented in Figure 32.

Figure 32. Safeguarding protocol for transport/tourism



Source: ICF elaboration

3.3.4 Towards harmonised mechanisms and procedures

The harmonisation of best practice mechanisms and procedures in dealing with accidental recovery of dumped munitions at sea in different maritime communities follows a two-folded strategy based on **prevention** and **intervention**.

The prevention of risks linked to underwater munition – whether targeting private individuals or professionals – first requires a thorough and transparent **historical study of the areas at risk**[159] in order to:

- Determine the type and condition of UXO that may be encountered;
- Take specific measures to protect the relevant population (individuals and professionals). These can include information campaigns on recognising a corroded UXO or a UXO encrusted with marine growth;
- Implement specific protocols/procedures to react in case of danger (protect, alert, etc.); and
- Systematic clean-up of areas where UXOs are identified.

A number of international standards are in place for procedures/protocols of intervention in dealing with accidental recovery of dumped munitions:

- International maritime rules in case of danger (accidental discovery of ammunition) with a call to the MRCC;

[159] Interview with FR NGO/academia, FR 11.

- Training of responders in the maritime environment (most of the interventions are carried out by government services, military or civilian), according to NATO[160] standards, even for the former Warsaw Pact countries;
- Labour laws must be adapted and harmonised in respect of the involvement of private contractors, who are increasingly involved in the identification and monitoring of underwater munitions. A common operative framework is needed for all types of private entities (training, methods and procedures) undertaking these activities; and
- Harmonisation of methods and procedures could be extended to environmental protection, which has not yet been considered in the training standards required by NATO.

3.3.5 Involvement of authorities, actors and organisations

This section provides an overview of the key actors involved in the UXO management cycle. It is possible to divide these actors into three categories, based on their type of responsibility/activity:

- **Problem owners** – Final users of the seabed (fishers, industry, transport, etc.), who may be involved in an accidental recovery of UXOs during their daily activities;
- **Problem managers** – Authorities in charge of UXO identification, monitoring, and disposal; and
- **Action owners** – In case of discovery, the local or regional authority receiving the alert from the finder and the demining team.

3.3.5.1 Problem owners

Final users of the seabed may be involved in accidental recovery of UXOs during their daily activities. They may generally be unaware of the danger of submerged ammunition.

Human safety is the priority in the UXO management cycle. Key problems in respect of the stakeholders involved in accidental recoveries are their ability to:

- **Recognise** a corroded or marine-growth encrusted UXO;
- **Protect** workers/population in the vicinity of the UXO (sometimes, fishers also dispose of and mark the UXO);

Alert the competent authorities; Experience shows that the finder of the ammunition is generally cautious and uses his common sense to protect himself and give the alert.

3.3.5.2 Problem managers

Member States **manage** accidental discovery of ammunition through effective alert and immediate reaction chains[161]. For problem managers, however, the difficulty is broader than the spectrum of technical intervention, as they must also:

- Organise **public awareness campaigns** about the danger represented by munitions;
- Use feedback to develop **prevention** and **training** capacity of UXO teams, in particular to take into account the limitation of the impact of interventions on the environment;
- Identify **areas at risk**, possibly forbidding access or organising systematic clearance;
- Promotion of the **demining profession** and potential careers among a wider audience (particularly in the maritime environment); and

[160] NATO (2020). AEODP 10: Explosive Ordnance Disposal (EOD) Publication: principles and minimum standards of proficiency.
[161] Interviews with FR national authorities, FR 06.

- Provide updated **tools** and **training** to deal with submerged chemical munitions.

3.3.5.3 Action owners

Action owners fall into two categories:

First responder

This is usually the local or regional authority that receives the alert from the finder. It can be located at the MRCC, the police station, city hall, etc. The first responder's action is essential, as it needs to undertake the following activities:

- Confirm the suspect object;
- Take precautionary measures;
- Request the intervention of the competent authorities (mine clearance service); and
- Maintain or reinforce security measures until the deminers arrive.

Intervener (demining team)

In Europe, the intervention time (elimination of the ammunition) of demining teams is generally less than two hours (24/7), or under an hour in the most urgent cases.

Within the framework of this type of mission, the deminers preserve their own safety and also try to take into account the protection of the marine environment.

3.3.5.4 Other stakeholders

Other stakeholders involved in the UXO management cycle include:

Environmental organisations[162]

These are the main channels for exchanging information on environmental problems related to underwater explosions, pollution by degradation of UXOs, and the presence of marine life to be protected in zones of intervention. They play a key role in providing an external and independent insight into the management of accidental discovery of ammunition, especially its treatment.

Fisheries committees

These committees act as an information exchange platform for problems encountered by fishers in relation to UXOs (e.g. accidental discoveries, financial compensation).

International ship owner organisation[163]

Through dedicated working groups, these organisations may issue prevention sheets (e.g. on the danger of ammunition) to their employees and subcontractors.

3.3.6 Cooperation achievements and best practices

Cooperation between Member States on incidents of accidental discovery of submerged munitions is regulated through international maritime practices (International Maritime Organization (IMO)). The overarching rules remain the same as those described in section 2.2:

- Do not touch the device;
- If possible, take a photograph of the device;
- Move away and alert people nearby (on the ground, within 100 metres);
- Alert the authorities, describe the device and (if possible) send the photograph; and
- Be available to the authorities to inform the security and demining services.

[162] For example, a French NGO was interviewed for this study.
[163] For example: European Community Shipowners' Association (ECSA), Baltic and International Maritime Council (BIMCO).

Beyond these basic and common-sense actions that mainly concern non-professional sea users, other specific practices related to the different contexts are also shared among sea professionals. These are summarised in the following subsections.

3.3.6.1 Fishing

Fishers in all countries may decide to throw back the found ammunition into the sea, usually to avoid wasting time notifying the authorities, unless they consider the danger to be critical or there is financial compensation for the reporting. Accidents are rare, with accidental discoveries in fishing areas significantly decreasing over the last 15 to 20 years.

This situation deserves particular attention, however, as young fishers may lack knowledge of the likely locations and risks posed by underwater ammunition. It is advisable to make them aware of this danger through dedicated sensibilisation and risk maps. The local expertise developed by older fishers on risk areas and safe procedures has been progressively lost with the decreasing trend of UXO encounters and the generation change. It is therefore important to develop standardised systems for the collection of data on known depots.

3.3.6.2 Marine/offshore engineering

Protocols/procedures in case of discovery of submerged munitions during offshore works can be considered largely harmonised, as marine/offshore engineering works are usually carried out by **international companies**. These generally apply the principles of labour law, in particular those regarding the prevention of accidents[164].

For each project, where preliminary studies show a risk of munitions present, procedures are put in place with the demining agencies of the State(s) to deal with any accidental discovery of submerged munitions as quickly as possible[165]. Offshore wind projects, in particular, may be subject of significant delays due to the presence of underwater UXOs. The costs entailed by their removal are more expensive to manage once projects are underway, as compared to before the installation. For example, the costs of turbine installations can touch the £200,000 per day, and long periods of inactivity due to UXO removal have a clear impact on the overall expenses[166].

3.3.6.3 Dredging

Good practices are similar to those among fishers when it comes to regular port dredging (e.g. port of Dunkirk) or to those of the offshore industry in respect of large-scale dredging operations.

Box 1. Opportunities for improved cooperation

France and the **Baltic States** already cooperate to reduce the risk related to accidental discoveries of dumped munitions by conducting naval operations under NATO – Partnership for Peace cooperation in areas known to contain WWII minefields. Two operations - OPEN SPIRIT (Baltic Sea) and COD (Channel and North Sea) - are conducted jointly with other EU Member States. They remain a good training opportunity for mine warfare and allow the gradual clearance of these areas.

In the North Sea, 'beneficial cooperation' between Belgium and the Netherlands has been established with the objective of keeping 'the sea, coastal waters, ports and

[164] Interviews with MC – Engineering/Construction, FR 12 and LU 01.
[165] Currently the case in France at Courseulles sur Mer, or in the context of the implementation of wind turbines at sea: munitions are regularly found and treated by the deminers of the French Navy. Interview with FR local authorities, FR 03.
[166] Cooke, S. (2014). Managing the offshore UXO threat. Available at: https://www.hazardexonthenet.net/article/88413/Managing-the-offshore-UXO-threat.aspx

maritime approaches free of mines and explosives', as well as mutualising the standing intervention teams.

The BOSB initiative, of which Operation OPEN SPIRIT is part, could be extended to other basins in order to further dispose of dumped munitions in the longer term.

However, these initiatives only target the treatment of conventional munitions. Indeed, the discovery of chemical munitions systematically raises the problem of their safe treatment.

3.3.7 Current capability gaps and technical and operational challenges

While the capabilities for identification, monitoring and disposal of dumped munitions at sea have been subject to continuous improvement, a number of gaps and technical/operational challenges persist. These include:

- **Technical limitation** in the methods used to prevent accidental discoveries;
- **Mitigation of the environmental impact** of UXO disposal; and
- Treatment of underwater **chemical munitions**.

Small or buried UXO detection capability

Key technical difficulties in the detection and prevention of accidental discoveries include:

- Ability to **detect and identify buried objects**, either in muddy areas/unconsolidated seafloors or in sandy areas regularly reshaped by currents (seabed dunes and ripples)[167]; and
- Ability to **detect munitions spread over large areas**, as in the Channel and the Atlantic. These are difficult to detect because of their **small size** (e.g. shells) and the **nature of the seabed**. This explains why, in spite of important and permanent demining campaigns (e.g. Brest Harbour every week for the protection of nuclear submarines), fishers continue to accidentally discover such types of munition.

Given the current technical capacity, it does not seem feasible to develop a common procedure on systematic cleaning of the EU sea basins.

Cost-effective solutions thus remain limited to the identification of 'dense' UXO presence areas (depots, air discharges, naval battle sites) in order to circumscribe, treat, survey or even declare them as exclusion zones for any marine activity (anchoring, dredging, foundation-laying, etc.).

Mitigation of the effects of an underwater explosion on wildlife or infrastructure

Future operational challenges are primarily related to **environmental protection**. At this stage, the safety of the operators is a priority and limited techniques are available to protect the environment during UXO disposal. This consideration would have dual effects, as it is also relevant to naval operations. Indeed, the ability of EOD operators to mitigate the effects of underwater explosions on wildlife is also useful in dealing with munitions located in the confined waters of a port.

The implementation of SOPs such as **the treatment of munitions by low-order effect**, the implementation of mitigation systems such as **bubble curtains,** or the consideration of the seabed soil coefficient remain **insufficiently explored**, although the results of early studies are promising[168]. Further evidence suggests that bubble

[167] Interview with FR military authorities, FR 05.

[168] For example: POSA study (https://anr.fr/Project-ANR-15-ASTR-0001) or SIRES project (https://cordis.europa.eu/project/id/227887). See also Rude, G. and Lee, J. (2007). Performance evaluation of the Roach Cove bubble screen apparatus. *Report of the Defence Research and*

curtains can effectively reduce the noise levels of explosions[169], and recent trials demonstrated that the use of advanced techniques such as **double bubble curtains** may significantly reduce the impact area. However, according to Cheong et al., further testing is necessary for these types of sound sources. Furthermore, bubble curtains are still an expensive technology which may be ineffective in deep waters and/or areas characterised by strong water currents[170].

Treatment of submerged chemical munitions

In the event of the accidental discovery of submerged chemical munitions, there are **no standard procedures** for its treatment, apart from the adaptation of land-based principles, combined with those of intervention by divers in polluted waters.

Eliminating these munitions remains a major challenge, as the existing treatment facilities are primarily land-based[171], making it necessary to transport munitions whose condition is uncertain from the sea to existing sites. An alternative is to treat these munitions directly on-site by setting up an offshore site (depending on feasibility: depth of the deposit, ability to locate the munitions, etc.). This complex field of intervention will require more attention in the coming years.

Box 2. Capability upgrade and R&D opportunities

The detection of buried objects is deserving of further analysis, although work has been conducted for many years using sediment sounders and magnetometers towed from the surface.

Surface towing can induce navigation errors and does not allow the towed train to navigate at a fixed altitude relative to the bottom.

Nevertheless, the development of submarine drones that can be equipped with this type of sensor facilitates operation as close as possible to the seabed, obtaining accurate results (position and depth of burial) without being affected by the state of the sea.

The Buried Objects Detection by Acoustic & Magnetic Methods (BODAMM project) carried out by RTSYS (a French company specialising in acoustics and underwater drones) has recently been developed with the guidance of the Ministry of French Armies, a demonstrator capable of operating on buried UXO and underwater cables.

Development Canada. Croci, K. et al. (2014). Mitigation of underwater explosion effects by bubble curtains: experiments and modelling. In *23rd MABS (Military Aspects of Blast and Shock), Oxford, UK, 7-12 September 2014* (p. 14). Kölbel, J. and Rose, D. (2016). 'Offshore unexploded ordnance recovery and disposal'. *Hydrographische Nachrichten* 105. Rostock: Deutsche Hydrographische Gesellschaft e.V..S, pp. 40-42. https://doi.org/10.23784/HN105-08. Kunde, T. et al. (2018). Ammunition detection using high frequency multibeam snippet backscatter information. *Marine pollution bulletin*, *133*, pp. 481-490. Speedie, C. (2019). Harbour Porpoise (*Phocoena phocoena*) Special Area of Conservation: Southern North Sea. Robinson, S.P. et al. (2020). 'Underwater acoustic characterisation of unexploded ordnance disposal using deflagration'. *Marine Pollution Bulletin* 160: 111646. Salomons, E. M. et al. (2021). 'Noise of underwater explosions in the North Sea. A comparison of experimental data and model predictions'. *Journal of the Acoustical Society of America*, *149*(3), pp. 1878-1888.

[169] Nützel, B. (2008). "Untersuchungen zum Schutz von Schweinswalen vor Schockwellen". Rep Technischer Bericht TB 2008-7, 18 pp., Kiel, Germany: Forschungsanstalt der Bundeswehr für Wasserschall und Geophysik (FWG); Schmidtke, E B. Nützel and Ludwig, S. (2009). "Risk mitigation for sea mammals- The use of air bubbles against shock waves," Proceedings of NAG/DAG 2009 – Rotterdam, 269 – 270. http://pub.degaakustik.de/NAG_DAGA_2009/data/articles/000311.pdf.

[170] Cheong, S. H., Wang, L., Lepper, P. A., & Robinson, S. P. (2020). Characterization of Acoustic Fields Generated by UXO Removal-Phase 2. *NPL REPORT AC*, *19*. BEIS OFFSHORE ENERGY SEA SUB-CONTRACT OESEA-19-107.

[171] See SECOIA (FR) and BE site in operation at Poalkapelle.

3.3.8 Key findings

Immediate interventions are **largely harmonised under international maritime regulations**. This is also true of the deminers' training programme, which is based on NATO standards.

The **immediate management** of reported munitions is based on the existing alert systems provided by international maritime regulations. For instance, in the event of danger, the MRCC is alerted on **VHF channel 16** or through the **European emergency phone number 112**. **Treatment** is generally carried out by Member States' 24/7 alert teams or regional demining services. They usually operate under the authority of the navy, sometimes the police, and are trained according to NATO standards.

The **risk of accidental discovery** of chemically loaded (sometimes leaking) munitions persists, especially in the Baltic Sea. However, demining teams are trained only to a limited extent in the use of environmentally safe methods and procedures for handling this type of ammunition.

Climate change has impacted the erosion of the coastline and may play a role in increasing accidental discovery of ammunition by individuals on the foreshore.

Loss of knowledge is another factor to be considered, as older fishers retire and are replaced by new generations whose lower exposure to UXOs means they are less aware of risk areas and safety procedures in cases of accidental recovery.

Exchange of information remains insufficient. It is crucial to enable the circulation of information among professionals, civilian, and Member States authorities in order to mitigate the risks posed by UXOs and facilitate the sharing of best practice[172].

Overall, three key areas of improvement can be highlighted with respect to risk prevention policy (human and environmental):

1. Type and quality of **information** on the threats represented by dumped munitions (including Chemical Warfare agents) made available to public and maritime professionals;
2. Capacity to treat **chemical munitions**; and
3. **Protection** of the **environment**.

A number of recommendations can be made in respect of each of these areas.
Information and protection for the public and maritime professionals on the threats represented by dumped munitions (including CW)

- Focus on **threat prevention** through the development of localised seasonal media campaigns and by including information on UXO threats in documentation for sea users;
- Systematically **clean up** (or ban) the areas where discoveries are frequent, especially when they pose a threat to civilians (e.g. beaches, wrecks); and
- Carry out a **European awareness campaign** for young fishers on the dangers of underwater munitions, including through fisheries committees, depending on the areas concerned.

Capacity to treat chemical munitions

- Establish common systems, methods, and procedures to deal with accidentally discovered chemical munitions. Thorough monitoring of the status of submerged stockpiles and their possible disposal is also essential.

[172] For example, although the number of accidental discoveries at sea - in the more frequently fished areas - has significantly decreased over the last 15 years, it is expected to increase after Brexit, partly due to the reduction of fishing licences in British waters. Younger fishers, who until now have had little or no exposure to the risks of reeling in ammunition, could become exposed to such risks while seeking new fishing grounds.

Protection of the environment

Encourage Member States to increase their efforts to fund studies and develop training methods/facilities:

- Accurately and comparatively **map the presence of UXOs** based on official data and an independent historical study;
- Improve the techniques aimed at **reducing the environmental impact** of explosions (e.g. develop/improve techniques such as bubble curtain and low order effects);
- Agree on **common methodologies** and indicators to measure the **level of pollution** generated by submerged munitions (corrosion, leakage, dissolution) and underwater explosions; and
- Develop and harmonise techniques and procedures for **EOD operators** to dispose of UXOs with limited environmental impact.

4 Overall conclusions and recommendations

By using a mixed-method approach of primary and secondary data collection and analysis, this Study developed guidance to enhance cooperation between Member States' authorities, private bodies and regional organisations in dealing with accidental recovery or any encounter with unexploded ordnances and chemical munitions dumped at sea by developing relating guidance.

Based on the data analysed, the key findings of this report can be summarised as follows:

Mapping of existing unexploded munition at sea in each European Sea basin

- The presence of UXOs in the **Atlantic Ocean** appears relatively uneven. Most of the UXOs can be found in the Brest Harbour and around Brittany and Normandy, where bombing raids took place during WWII. There are very few identified dumps along the rest of the French coastline and along the Spanish coastline. Encounters of UXOs are extremely rare in those areas. Generally speaking, UXOs are not considered a risk, even in Brest, because those who regularly encounter these devices are well trained on what to do (i.e. fishers) and accidents are extremely rare.
- The **Baltic Sea** was, by contrast, heavily mined during the two wars, and was also the dumping site for many aborted or accomplished missions. Historical data has been of significant help in attempting to identify the main sites and, through national and regional efforts, clear the path for key maritime routes. The issue with such data, however, is the lack of precision that characterised georeferencing tools in the mid-20th century. The presence of different currents had the effect of displacing many UXOs, enlarging therefore the areas of interest. Regional cooperation in the basin is very good.
- The **Black Sea** is far more difficult to map due to the lack of historical archives and the inability to access dedicated archives. Limited capabilities as well as a lack of immediate risks (especially since the main maritime trade routes have been cleared) seem to have negatively affected the regular monitoring and mine clearing activities.
- The situation in the **Mediterranean Sea** is uneven, both in terms of UXO presence and in terms of ways to address the issue. Since accidents and encounters are not frequent, the situation is mostly addressed on an ad hoc basis. The Adriatic Sea reveals the presence of far more UXOs than anywhere else in the Mediterranean Sea, but regular monitoring activities seems to be lacking.
- The **North Sea**, much like the Baltic Sea, was also heavily bombed and mined during WWII. No regional mechanism for regular monitoring was highlighted, however each country appears to have established different systems in place for ensuring the safety of their citizens and of maritime trading routes. Currents and tides in the Sea also make it particularly difficult to be certain of UXO positions, so encounters at sea (as opposed to along beaches) are dealt with in a much more reactive manner.

Mechanisms/approaches adopted to identify, monitor, and remove UXOs:

- In all Member States, **Navies** are involved in the process of identifying, monitoring and/or disposing of underwater unexploded munitions (UXOs). The nature of their involvement, and the stages of such involvement, is subject to significant differences across Member States. For example, while ES, PL, SE and BG navies are systematically involved in all the steps of the UXO management cycle, other countries (FR, IT, DE, NL) adopt an ad-hoc approach which depends on the particular circumstances and environmental settings. Generally, this depends on whether it was an accidental encounter or whether it was part of a monitoring exercise.
- **Private companies** are often involved in the activities of UXO identification, particularly in the context of infrastructure works such as port extensions. This is

the case of DE and FR, although the disposal of UXOs remains a prerogative of national authorities.

- **UXO Monitoring** is not a systematic practice across the different Sea basins. The North and Baltic Seas are regularly monitored, primarily because encounters with UXOs are frequent leading to further searches around the areas of these encounters. In the Atlantic and the Mediterranean, this is much less systematic (except Brest harbour where, again, encounters are frequent). In the Black Sea, there is no such regular monitoring. It also appeared that monitoring was far more systematic when there is regular regional cooperation, such as HELCOM and exercises organised yearly by LT, LV and EE in the Baltic Sea, or such as the Belgian-Dutch bilateral cooperation in the North Sea.
- With a few exceptions, which generally involve fishers (e.g. IT and LT), there are no **rules or guidelines** for civilians in case of UXO recovery. Interviewees for most countries did, however, highlight the important role of MRCCs and, in some cases, port authorities (e.g. IT).
- **Environmental** risks are not considered as a priority when it comes to removing UXOs. At the **monitoring** stage, little evidence exists that countries regularly assess the environmental risks associated with the presence of UXOs in their waters. In the **disposal** stage, the majority of stakeholders interviewed observed that human safety is a priority over environmental protection (though in FR, for instance, acoustic devices to scare off mammals are regularly used).

Member States' relevant capabilities employed for identification, monitoring and disposal of sea-dumped unexploded weapons:

- EU Member States MCM (clearance) capabilities are world-class, as are their cooperation, joint exercises, and common training sessions in this context. All the Member States in scope have response mechanisms in place for accidental UXO recoveries. This includes protocols/procedures, reactive chain of intervention, operational assets mobilization and EOD diver qualifications.
- As regards **responsible authority(ies)**: both public authorities and private actors are involved, although the disposal of UXOs remains a prerogative of national authorities.
- As regards **capability gaps**:
  - The UXO identification and clearance capability still faces a number of challenges in resolving this inherited problem. While accidental discoveries are very efficiently addressed in all affected EU Member States, underwater unexploded munitions in the EU seabeds remain an important and long-lasting risk for the environment and seabed users.
  - Underwater UXO clearance is a challenging task as compared to terrestrial explosive clearance, which already faces several difficulties, hazards, and high costs. Currently, only Naval Forces have the capability to approach, identify, handle, and neutralize underwater UXOs. The development of offshore infrastructure along the EU coastline (wind farms, communication cables, pipelines) has enabled the development of civilian capabilities to survey the seabed. However, today the private sector is not authorised to intervene and neutralize the detected UXOs. As the primary mission of armed forces is de-mining in the context of current military operations, the resources available for the activities of UXO identification and disposal remain mostly limited to accidental recoveries.
  - Climate change-induced coastal erosion is a new aggravating factor: since WW2, exposure of UXO has mostly been due to fishing activities - in particular when using sea floor trawlers and dredges -. As UXOs encounters are common, the fishing community appears well aware of the UXO threat and rightly applies the risk mitigation procedures when UXOs appear tangled in their fishing gear. In future, coastal erosion might increasingly expose the general population, which is at risk of ignoring precautions and alert

procedures. This risk is difficult to avoid, as the preventive clearance capability of buried UXOs remains limited.

- The chemical monitoring of UXO leaks is also a yet unsolved capability challenge, still at RT&D stage. It is not only an issue of sensors development, but also a question of insufficient knowledge on the extent of this pollution and its evolution in time and its impact on marine life, food chain, and possibly human health.
- In terms of training capabilities, there is a need for developing, adapting, and validating procedures and techniques for the mitigation of environmental impacts, as well as the training of operators to allow for their use across the different UXO threats and contexts. Furthermore, it is important to develop open UXO detection systems featuring unified taxonomies and data-models to be used for AI-based UXO identification algorithms from sonar and magnetic anomaly data.

Response protocols/procedures in case of UXO accidental recovery

- Immediate interventions in the EU MS are for large part **harmonised under international maritime regulations**. This is also the case of the deminers' training programme, which is based on NATO standards.
- In particular, the **immediate management** of the reported munition is based on the existing alert systems provided by international maritime regulations. For instance, in the event of danger, the Maritime Rescue Coordination Centre is alerted on **VHF channel 16** or through the **European emergency phone number 112**. As regards to the **treatment**, this is generally carried out by the alert teams (24/7) of the Member States or regional demining services. They usually operate under the authority of the Navy, sometimes the Police, and are trained according to NATO standards.
- The **risk of accidental discovery** of chemically loaded (and sometimes leaking) munitions is still persistent, especially in the Baltic Sea. However, demining teams are trained only to a limited extent in the use of environmentally safe methods and procedures for handling this type of ammunition.
- **Climate change**, with its impact on the erosion of the coastline, may also play a role in increasing accidental discoveries of ammunition on the foreshore.
- **Loss of knowledge** is another factor to be considered as older fishers retire while being replaced by new generations. Thus, new generations (due to less frequent UXO encounters) seem to be less aware of both risk areas and safe procedures in case of accidental recovery.
- As regards to the **exchange of information**, this seems to be still insufficient. It is therefore crucial to enable the circulation of information among professionals, civilians, and Member States authorities, to mitigate the risks posed by underwater unexploded munition, as well as to facilitate the sharing of best practices.

4.1 Recommendations to support Member States in dealing with accidental recovery of dumped munitions at sea

The analysis outlined in the first part of the report showed that the management of different and complex types of risk depends on the specific environmental conditions, as well as a common understanding of the legal aspects concerning the UXO management cycle. However, it is crucial to develop policies and measures that go beyond emergency situations, including structured and proactive measures to continually improve multiple sites at the right time and in the right order of priority. This requires a multilevel cross-border approach, including shared analytical methodologies, capabilities and training systems.

Based on the results of the desk research, interviews, survey, and the workshop on 29 November 2021, this Study identified **four key areas** of intervention:

- Environmental protection;
- Dedicated capability-building;
- Capabilities for private actors; and
- Response models.

For each area, the recommendations will be divided according to three levels:

- EU level;
- Regional level; and
- National level.

During the workshop, Member States provided feedback on possible actions at EU and national level. Overall, Member States agreed on the need for more cooperation on a common categorisation of the risks posed by UXOs to humans, environment, the food chain and industry. They highlighted the need to further develop cross-border initiatives and policy exchanges between national, regional and local actors from maritime countries. These should include the organisation of common training, knowledge-sharing, and capability-building initiatives.

Member States generally disagreed on the usefulness of centralising capability at EU level (i.e. pooling equipment) or establishing an EU centre to coordinate monitoring and intervention activities.

4.1.1 Environmental protection

While several studies provided evidence on the threats posed by the presence of UXOs in the underwater environment (and on aspects such as the food chain, or industrial activities, as well as risks of injury or death to marine mammals and other fauna due to the high sound levels produced)[173], other findings highlighted the limited diffusion of this pollution into EU waters.

The reasons for this lack of consensus are threefold. Firstly, the available data is limited and/or difficult to obtain/collect. Secondly, there is a lack of shared methodologies for the collection and analysis of results. Thirdly, leakage of chemicals may not be the same as corrosion and local conditions differ.

Furthermore, traditional disposal techniques (such as high-order detonation) can pose a number of risks of injury or death to marine mammals and other fauna due to the high sound levels produced. Common standards should therefore be developed for the analysis of the effects of UXOs on the marine environment and humans. At the same time, it is important to provide Member States with substantial instruments to assess the current UXO chemical threat, and to identify the most problematic depots, with a systematic, robust, and generalisable approach across the whole EU.

[173] See table 2 and Annex 1.

Several specific actions can be recommended:

Regional and EU level

Action A1.1 - Promote cross-border cooperative projects for systematic surveys and EU-wide detection of UXO chemical pollution

While some research facilities[174] already conduct on-site surveys to map the type and concentration of chemicals (particularly TNT) released by leaking UXOs, their activity remains limited, given the relevance of the UXO threat.

Guidelines exist at international level on the environmental monitoring of UXOs[175], but have yet to be translated into effective implementation. A key challenge is the development of technologies capable of detecting pollutant concentrations on the parts-per-million (ppm) scale, on-site and in real-time. Although some prototypes have been developed, they are far from widespread implementation[176].

It is essential to promote cross-border cooperative project(s) to:

- Develop a framework for the mapping of **chemical pollution 'hotspots'** in the EU sea basins, in an open, accessible format[177];
- Develop shared methodologies to define **UXO chemical pollution markers**, as well as the associated risk scales (for local sea life, marine food chain, and human seafood consumption). Such methodologies should also be developed for sampling, analysis, and data publishing;
- **Develop technologies** such as sensors for deployment on towed bodies, ROVs and AUVs. This will include the development of common operating procedures/protocols for the use of these technologies; and
- Improve cooperation between **civilian and military stakeholders** on sharing updated information. Industry and, more broadly, private companies can gather important information (during risk assessments) on UXO location and potential risks.

Action A1.2 – Build an EU-wide UXO database

The evidence gathered throughout this Study showed that information on the effects of underwater UXOs on the marine environment is limited and difficult to access. This is due to scarcity of data, confidentiality, and a lack of historical archives recording information on UXO location, encounters, or successful removal. This data gap presents a major obstacle to the creation of common standards and approaches to mitigate the environmental risks entailed by underwater munitions. To ensure the organised collection of structured data and information, this Study recommends the development of an **EU-wide UXO database,** including:

- A **common taxonomy** and **data models library** (from text to interoperable XML strings for e-repositories), and (possibly) standardised reporting templates for UXO locations, encounters, or successful removal;

[174] For example, the German GEOMAR in Kiel, the Maritime Research Institute of the Helmholtz R&D network.
[175] Practical Guide for Environmental Monitoring of Conventional Munitions in the Seas. Available at: http://oceanrep.geomar.de/48842/1/geomar_rep_ns_54_2019.pdf.
[176] The EU has recently co-funded the E*xPloTect* project, which aims to develop, optimise and test a prototype sea-going device for detection of chemicals associated with unexploded ordnance in the marine environment. See: https://www.explotect.eu/
[177] Since 1992, HELCOM has developed a list of significant pollution sites around the Baltic Sea. Although UXOs are not covered, the updated Baltic Sea Action Plan (BSAP) asks HELCOM to widen the scope and include additional criteria for the identification of hot spots. See: https://helcom.fi/action-areas/industrial-municipal-releases/helcom-hot-spots

- A **georeferenced UXO information database**, covering type, specific risks, condition, eventual markers, managing authority, neutralisation plan, possible causes of concern, images (visual or sonar 'vignettes'); and
- A **virtual library** linked to each known depot, including archives from the original disposal process, earlier surveys, relevant studies, accidental recovery reports, neutralisation reports, etc.

National level

Action A1.3 - Map the seafloors through risk parameters

UXOs pose low risk of releasing chemical agents into the marine environment as long as they remain buried and protected from corrosion. The risk is increased by their presence on unconsolidated seafloors, which sees UXOs buried, re-exposed and drifted by currents, or even washed on-shore by storms. UXOs may be subjected to corrosion (e.g. from relatively high oxygen content or acidic sea water) or to accelerated erosion in the surf zone due to rising sea levels. These factors increase the risk of chemical leaks and accidental human exposure.

In rocky areas (generally avoided by fishers), the detection of UXOs is complicated by their possible similarity with the surrounding rocks, aggravated by corrosion and marine growth on the UXOs. This complicates the detection and classification process, with greater false alarms and limited detection probability.

It is therefore important to develop an EU-wide system for geophysical data collection and mapping activity. This system should include a map of priorities based on risk assessment, aiming to:

- Map the **UXO corrosion risk factors** (oxygen content, other corrosion enablers), i.e. to identify the areas where UXOs will degrade faster, for each casing material (steel, bronze, aluminum, etc.)
- Map **seabed stability,** with reference to UXO dragging, burying and re-exposure mechanisms; and
- Map UXO risks related to **coastal erosion and the effects of sea level increase** (climate change impact) from the angle of re-exposure of UXOs in the surf zone.

4.1.2 UXO dedicated capability-building

The main **capabilities** to deal with underwater UXOs in the Member States are **naval mine countermeasures** (MCM), with disposal and removal operations routinely used to train minehunter crews and EOD divers.

Recent developments have seen an increasing number of technologies to facilitate the process of UXO disposal, limiting the human and environmental risk[178]. These technologies need to be fully developed, however, and also require a systematic assessment of best practices in dealing with these munitions.

The current design of MCM equipment (high frequency sonar, robots, shaped charges etc.) is not driven by UXOs but, rather, by modern mines. The priority of MCM is human safety and rapid clearing of possibly mined areas in order to reopen seaways. Most explosive ordnance clearance protocols/processes currently consider environmental protection only to a limited extent.

Member States should develop an **UXO clearance strategy,** including the development of specialised equipment and building dedicated clearance capabilities. This would

[178] This includes the use of bubble curtains and/or alternative techniques for on-site neutralisation and decontamination (e.g. injection of chemical solvents or mechanical dismantling). A detailed analysis of these capabilities is provided in Annex 7 of this report.

facilitate future cooperation in monitoring initiatives between Member States, private bodies, and regional stakeholders.

Several specific actions are recommended.

All levels

Action A2.1 – Scale-up UXO clearance capability

Underwater UXOs are a large-scale problem in European sea basins and require an adequate response at EU level. However, there is an overall lack of resources to foster Member State cooperation and current capabilities appear insufficient.

This issue can be resolved by enabling the **private sector** to operate throughout the whole UXO management cycle, including disposal and removal. This would require the development of legal and regulatory frameworks to enable private contractors to neutralise UXOs.

Cross-border initiatives and policy exchanges should be promoted between national, regional, and local actors from the different maritime Member States and European third countries. These initiatives could include the organisation of common training and knowledge-sharing/capacity-building programmes[179].

Action A2.2 – Increase the area detection and identification capability of UXOs

The range of current high-frequency mine detection and identification sonar is significantly reduced in sea water and rarely exceeds 300m. The use of synthetic aperture array processing requires a stable navigation of towed bodies, giving a very low survey speed (3 to 5 km) and a long stabilisation time when manoeuvering[180]. Taken together, this means a daily survey capability of very few square kilometres.

UXO depots already located may be displaced by dredging fishing gear and move far from their original location. This represents a major challenge for systematic UXO detection operations, such as periodic seabed inspections to monitor depots that have yet to be cleared.

Resources dedicated to funding technological RT&D programmes[181] should be increased in order to:

- Develop/adapt **specific MCM equipment for UXO detection and identification**, using advanced sonar and magnetic joint signal processing options and/or long range/more penetrating buried UXO detection solutions, such as low-frequency sonar alternatives coupled with shell resonance detection;
- Further develop **AI-based UXO identification algorithms**, with the prerequisite of building shared learning databases of various types of UXOs on a variety of seabed textures and geological nature[182]; and

[179] France and the Baltic States already cooperate to reduce risk related to accidental discoveries of dumped munitions, conducting naval operations under NATO cover in areas known to contain WWII minefields. These operations, called OPEN SPIRIT (Baltic Sea) and COD (Channel and North Sea), are conducted jointly with other Member States. The BOSB initiative, of which Operation OPEN SPIRIT is part, could be extended to other basins in the longer term, to further dispose of dumped munitions. However, these initiatives only target conventional munitions and the discovery of chemical munitions routinely raises the question of their safe disposal.
[180] Sonar is increasingly used on UAVs and ROVs, but has yet to reach full operational capability, resulting in persistent exposure of human operators.
[181] See BASTA (Boost Applied munition detection through Smart data integration and AI workflows) and ExPloTect (Ex-situ, near-real-time explosive compound detection in seawater), which aim to advance the approach for munition detection at local and larger scales. The recently launched MIRICLE (Mine Risk Clearance for Europe) project is a military MCM project that does not focus on UXOs.
[182] Ibidem.

- Develop **training facilities** with underwater UXO testbeds that combine various environments (sand, mud, rocks, currents, etc.) to support joint testing, training and benchmarking of innovative solutions in a controlled environment. The NATO CMRE UXO testbed near La Spezia (Italy) is paving the way for future initiatives.

Action A2.3 - Improve impact reduction technologies for underwater UXO disposal

Underwater detonation is a standard practice for UXOs disposal. However, as a source of anthropogenic noise in the marine environment, it can pose a threat to marine biota (e.g. fish, mammals)[183]. Despite increasing awareness of the environmental impact of non-safe neutralisation techniques, on-site blowing remains the most frequent disposal option[184]. Safer techniques (e.g. low order explosion or bubble curtains) are increasingly considered, but not always suitable. Low order explosion may turn to a full blow, or may not entirely consume the explosive charge, releasing debris and creating new environmental risks. Bubble curtains have proved effective in damping the shock wave (and debris) but remain difficult to deploy. The EU could play a role in promoting initiatives dedicated to the development of environmentally safe UXO neutralisation operations[185], such as:

- Develop **bubble curtains** technologies that are easy to deploy, as well as other options to control the environmental effects of UXO neutralisation;
- Improving the current **alternative techniques for on-site neutralisation** and decontamination (e.g. injection of chemical solvents or mechanical dismantling);
- Improve the effectiveness of **mammal-frightening techniques/devices**. This could include optimised range and frequencies and user-friendly interfaces; and
- Develop **standard protocols/procedures** for minimising the environmental impact of undersea UXO destruction in a diversity of contexts, and associated training.

4.1.3 UXO management capabilities of private operators:

National level

Action A3.1 - Increase the UXO management capability of private operators

While NATO has already contributed to standardising the qualification process for MCM procedures/protocols and EOD diver training, the private sector is regulated only through national provisions, which vary across the Member States.

An increasing number of private companies are now specialised in UXO survey and detection activities. These were initially contracted ahead of oil exploration, dredging operations and underwater pipeline construction, but are increasingly contracted by national authorities. The current involvement of private companies in the UXO management cycle is limited by national legislation and restricted access to appropriate training (they generally need to hire former naval EOD divers, limiting the pool of candidates for recruitment). This creates a bottleneck effect that contrasts with the growing demand for UXO clearance.

[183] Richardson, W. J. et al. (1995). *Marine mammals and noise*. Academic Press. San Diego, pp. 576.

[184] However, the thresholds on noise pollution set by the Marine Strategy Framework Directive might make this practice more difficult. See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0056

[185] The EU has recently funded projects to reduce underwater noise from maritime transport, including through the use of specific technologies such as bubble curtains. See AQUO (Achieve quieter oceans by shipping noise footprint reduction) and SONIC (Suppression of underwater noise induced by cavitation) projects. Available at: http://www.aquo.eu/ and http://www.sonic-project.eu

Two specific actions are proposed:

- Develop specific provisions, qualifications, and statutes; and
- Allow private actors to access **training and certification**.

4.1.4 Response models

Member States' current response models have proved effective and sufficient to tackle accidental discoveries of UXOs. The EU's Maritime Security Strategy and the related Action Plan aim to tackle the challenge of environmental security by setting out a cooperative response based on the exchange of information and common operative approaches[186].

Several specific actions are recommended:

Regional and EU level

Action A4.1 - Common procedures and response models

- Few Member States have an effective system of **financial compensation in place** for the reporting of UXOs by civil stakeholders. A common system of financial compensation would incentivise reporting among fishers, who may otherwise decide to throw the ammunition back into the sea to avoid wasting time notifying the authorities; and
- UXO detection capability varies substantially across the Member States. This is valid not only for an effective UXO management cycle, but also for the quality of the data collected. **Common training** programmes (in synergy with Action A3-1) as well as MCM programmes (such as the former tripartite minehunter design, development, and modernisation plans) have already demonstrated their benefit to the overall community.

[186] Aker, J., Howard, B., and Reid, M. (2012). 'Risk Management for Unexploded Ordinance (UXO) in the Marine Environment'. *Dalhousie Journal of Interdisciplinary Management,* 8 – Fall.

Annexes

Annex 1: Sources

Bibliography

Table 8 overleaf provides an overview of the sources used for this study.

Table 8. Bibliography (by type of source)

Type	Title	Author	Year
EU	COM(2015) 185 final, The European Agenda on Security	European Commission	2015
EU	Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)	European Commission	2008
EU	European Union Maritime Security Strategy	Council of the European Union	2014
EU	European Union Maritime Security Strategy (EUMSS) Action Plan	Council of the European Union	2018
EU	Guidance on Monitoring of Marine Litter in European Seas	European Commission (JRC)	2013
EU	Identification of marine chemical contaminants released from sea-based sources	European Commission (JRC)	2016
EU	Notice to Members: Petition No 1328/2019 by Jānis Kuzins (Latvian), on behalf of SDK Dzimtene, on purging the Baltic Sea from chemical weapons; Petition No 0406/2020 by Nélia Pinto (Portuguese) on chemical residues from ancient World War shells in the Baltic Sea	European Parliament	2021
EU	Regulation (EU) 2016/1624 of the European Parliament and of the Council of 14 September 2016 on the European Border and Coast Guard and amending Regulation (EU) 2016/399 of the European Parliament and of the Council and repealing Regulation (EC) No 863/2007 of the European Parliament and of the Council, Council Regulation (EC) No 2007/2004 and Council Decision 2005/267/EC	European Parliament & Council of the European Union	2016
EU	Regulation (EU) 2016/1625 of the European Parliament and of the Council of 14 September 2016 amending Regulation (EC) No 1406/2002 establishing a European Maritime Safety Agency (Text with EEA relevance)	European Parliament & Council of the European Union	2016

EU	Regulation (EU) 2016/1626 of the European Parliament and of the Council of 14 September 2016 amending Council Regulation (EC) No 768/2005 establishing a Community Fisheries Control Agency	European Parliament & Council of the European Union	2016
EU	The North Sea	EEA	2017
EU	Training Requirements Analysis Report on Maritime Security	Council of the European Union	2021
International/ regional	A framework for developing national guidelines for fishers on how to deal with encountered conventional and chemical munitions	OSPAR Commission	2004
International/ regional	AEODP 10: Explosive Ordnance Disposal (EOD) Publication: principles and minimum standards of proficiency	NATO	2020
International/ regional	AMMUNITIONS DUMPING SITES IN THE MEDITERRANEAN SEA	UNEPMAP	2009
International/ regional	Assessment of the impact of dumped conventional and chemical munitions	OSPAR Commission	2009
International/ regional	Cooperative measures to assess and increase awareness of environmental effects related to waste originating from chemical munitions dumped at sea	UN	2013
International/ regional	Danish report on dumped chemical munitions in the Baltic Sea	HELCOM	2011
International/ regional	Draft HELCOM Thematic Assessment on Hazardous Submerged Objects	HELCOM	2018
International/ regional	Eliminating Chemical Weapons. Committed to complete and verifiable destruction	OPCW	2020
International/ regional	Encounters with Chemical and Conventional Munitions	OSPAR Commission	2013
International/ regional	Environmental Impact of Munition and Propellant Disposal	NATO	2010
International/ regional	Framework for Reporting Encounters with conventional and chemical munitions in the OSPAR maritime area	OSPAR Commission	2010
International/ regional	Interim report on sea-dumped munitions for the 29th BSPC	Baltic Sea Parliamentary Conference (BSPC)	2020
International/ regional	OSPAR framework for reporting encounters with marine dumped conventional and chemical munitions	OSPAR Commission	2003

International/ regional	Overview of Past Dumping at Sea of Chemical Weapons and Munitions in the OSPAR Maritime Area	OSPAR Commission	2005
International/ regional	Overview of Past Dumping at Sea of Chemical Weapons and Munitions in the OSPAR Maritime Area 2010 update	OSPAR Commission	2010
International/ regional	Quality status report: Assessment of the impact of dumped conventional and chemical munitions	OSPAR Commission	2010
International/ regional	Report on Chemical Munitions Dumped in the Baltic Sea. Report of the ad hoc Expert Group to Update and Review the Existing Information on Dumped Chemical Munitions in the Baltic Sea (HELCOM MUNI)	HELCOM CHEMU	2013
International/ regional	Report on Chemical Munitions Dumped in the Baltic Sea. Report to the 16th Meeting of Helsinki Commission from the ad hoc Working Group on Dumped Chemical Munitions	HELCOM CHEMU	1994
International/ regional	Response Manual 2002, Volume 2	HELCOM	2002
International/ regional	Risk Management for Unexploded Ordnance (UXO) in the Marine Environment	ASCOBANS	2015
International/ regional	State of the Baltic Sea – Second HELCOM holistic assessment 2011-2016	HELCOM	2018
International/ regional	Trois pays rejoignent l'initiative MUSI, pour l'avancée des drones UMS	NATO	Unclear
International/ regional	Underwater unexploded ordnance in the ASCOBANS area	ASCOBANS	2015
International/ regional	Updating of the report on dumped chemical munitions in the Baltic Sea, submitted by Denmark	HELCOM	2011
Member State	Advies afwegingskader en kenniscentrum conventionele explosieven	Dutch Ministry of the Interior and Kingdom Relations	2018
Member State	Annual Report	Dutch Coast Guard	2016
Member State	Antwoord van Gedeputeerde Staten op vragen van J.H. Haasnoot (50Plus)	Dutch Provincial Executive	2019
Member State	Antwoorden op vragen over de munitiestort in de Waddenzee	Dutch Ministry of Defence	2014
Member State	Antwoorden op vragen van de leden Schonis, Belhaj en De Groot (D66) aan de ministers van Infrastructuur en Waterstaat, van Landbouw, Natuur en	Dutch Ministry of Defence	2020a

	Voedselkwaliteit en van Defensie over munitiedumps in de Deltawateren en Noordzeekust		
Member State	Beleidsnota Omgaan met niet-gesprongen explosieven uit de Tweede Wereldoorlog	Municipality of Goirle	2020
Member State	Bommenkaart	Dutch Association for UXO Detection	2021
Member State	Dataverzoek niet gesprongen explosieven	Dutch government	2017
Member State	Defensie onderzoekt munitiedump	Dutch Ministry of Defence	2020b
Member State	Explosieven ruimen	Dutch Ministry of Defence	2021
Member State	Explosievenstand	Dutch Coast Guard	2021
Member State	Handleiding opsporing en ruiming explosieven Tweede Wereldoorlog	Municipality of Dordrecht	2010
Member State	Hollandse Kust (west) Wind Farm Zone: project and site description.	Netherlands Enterprise Agency	2020
Member State	Kustwacht Explosievenkaart	Dutch Coast Guard	2021
Member State	Manuale illustrativo delle misure precauzionali da adottare in caso di salpamento di residuati bellici mediante reti di traino	ICRAM	2001
Member State	Status, Challenges and Solutions of Unexploded Munitions	BLANO	2019
Member State	The naval mine division is defending the slogan "For clear fairways"	Bulgarian Navy	2015
Member State	UXO Desk Study, Unexploded Ordnance, Hollandse Kust (west) Wind Farm Zone (HKWWFZ)	Netherlands Enterprise Agency	2018
Member State	Vragen gesteld door de leden der Kamer, met de daarop door de regering gegeven antwoorden	Dutch Ministry of Defence	2019
Third country	Dredging Equipment Modifications for Detection and Removal of Ordnance	Environmental Security Technology Certification Program	2006
Third country	Dredging in Sediments Containing Munitions and Explosives of Concern (MEC)	U.S. Army Engineer Research and Development Centre	2008
Third country	ESTCP Project MM-0321: Dredging Equipment Modifications for Detection and Removal of Ordnance	ESTCP	2006

Third country	Field Manual No. 4-30.51 (21-16): Unexploded Ordnance (UCO) Procedures	US Army	2006
Third country	Final Unexploded Ordnance 16 (Uxo 16) Underwater Wide Area Assessment Report Atlantic Fleet Weapons Training Area, Former Naval Ammunition Support Detachment And Former Vieques Naval Training Range Vieques Puerto Rico	US Naval Facilities Engineering Command	2018
Third country	Handbook on the Management of Munitions Response Actions	EPA	2005
Third country	Handbook on the Management of Ordnance and Explosives at Closed, Transferring, and Transferred Ranges and Other Sites	EPA	2001
Third country	Management of US Legacy Underwater Military Munitions Sites: States' Perspective	EPA	Unclear
Third country	Protocol for In-Situ Underwater Measurement of Explosive Ordnance Disposal for UXO	National Physical Laboratory (NPL)	2020
Third country	Scoring Underwater Demonstrations for Detection and Classification of Unexploded Ordnance (UXO)	Institute for Defense Analyses	2020
Third country	SERDP Workshop on Acoustic Detection and Classification of Munitions in the Underwater Environment	SERDP	2018
Third country	SERDP/ESTCP Munitions Response Program: Underwater Remediation Of Unexploded Ordnance (UXO)	Richardson, M.D. et al.	2019
Third country	SERDP/ESTCP Office of Naval Research Workshop on Acoustic detection and classification of UXO in the underwater environment	SERDP/ESTCP	2013
Third country	Underwater UXO Standardized Demonstration Sites (Test Beds) Workshop Report	SERDP	2018
Third country	Unexploded Ordnance (UXO) procedures	Headquarters, Department of the US Army	2006
Industry	2205 Sonar System Options / Choices	EdgeTech	Unclear
Industry	Clearance Map	Barink Explosieven Opsporing	2021
Industry	Dealing with munitions in marine aggregates	Quarry Products Association (QPA)	2006
Industry	Dealing with munitions in marine sediments	Mineral Products Association (MPA)	2010

		and British Marine Aggregate Producers Association (BMAPA)	
Industry	Fellows International Limited win Black Sea marine UXO survey contract	Fellows	2019
Industry	Munitions dumped at sea: a literature review	Imperial College London Consultants	2005
Industry	Seeing with Sound	Kraken Robotics	Unclear
Industry	Significant developments on offshore wind in the Baltic Sea	WindEurope	2021
Industry	Unexploded ordnance: a critical review of risk assessment methods	RAND for the US Army	2004
Industry	UXO below: mitigating marine UXO Risk	RPS Energy Ltd Explosives Engineering Services	Unclear
Industry	UXO Clearance Cetacean Risk Assessment Moray East Offshore Wind Farm	Royal HaskoningDHV	2018
Academic / grey	A case study in modeling dispersion of yperite and CLARK I and II from munitions at Paardenmarkt, Belgium	Francken, F. & Hafez, A.	2009
Academic / grey	Acoustic colour-based convolutional neural networks for UXO classification with low frequency sonar	Williams, D.P.	2019
Academic / grey	A Comprehensive Quality Guideline for the Treatment of Unexploded Ordnance Encountered During Offshore Construction Projects."	Frey, T. et al.	2019
Academic / grey	A Guide to Survey and Clearance of Underwater Explosive Ordnance	Geneva International Center For Humanitarian Demining	2016
Academic / grey	Ammunition detection using high frequency multibeam snippet backscatter information	Kunde, T. et al.	2018
Academic / grey	Ammunition pollution in German marine waters - developments and progress	Böttcher, C. et al.	2018
Academic / grey	An assessment of UXO dumpsites in the Black Sea	Barbu, M-B. & Dimitriu, R.G.	2020
Academic / grey	Assessing the impact of underwater clearance of unexploded ordnance on harbour porpoises (Phocoena phocoena) in the Southern North Sea.	von Benda-Beckmann, A. M. et al.	2015

Academic / grey	Atlas de la France toxique	Robin des Bois	2016
Academic / grey	Atomic magnetometers detect underwater objects	Wogan, T.	2018
Academic / grey	Chemical contaminants entering the marine environment from sea-based sources: A review with a focus on European seas	Tornero, V. & Hanke, G.	2016
Academic / grey	Chemical munition dump sites in coastal environments	Missiaen, T. & Henriet, J.P.	2002
Academic / grey	Chemical Munitions Search & Assessment-An evaluation of the dumped munitions problem in the Baltic Sea	Beldowski, J., Z. et al.	2016
Academic / grey	Chemical sensing of unexploded ordnance with the mobile underwater survey system (MUDSS)	Darrach, M.R. & Chutjian, A.	Unclear
Academic / grey	Chemical Weapon Munitions Dumped at Sea: An Interactive Map	Wilkinson, I. et Al. J., Brewer P.G.	2017
Academic / grey	Chemical Weapons in Russia: History, Ecology, Politics	Fedorov, L.A.	1994
Academic / grey	Cleanup of Chemical and Explosive Munitions (Second Edition) Location, Identification and Environmental Remediation	Albright, R.D.	2012
Academic / grey	Coordination action in support of the implementation of the Joint Programming Initiative on Healthy and Productive Seas and Oceans	CSA OCEANS	2019
Academic / grey	Corrosion of Unexploded Ordnance in Soil– Field Results	Chendorain, M.D. et al.	2005
Academic / grey	De bodem van de Noordzee ligt vol met tikkende tijdbommen	Trouw	2019
Academic / grey	Dealing with UXO (Unexploded Ordnance): Detection, Identification, Disposal and Awareness	Kölbel, J. & Seubring, F.	2015
Academic / grey	Decontamination of chemical warfare agents	Yang, Y.C. et al.	1992
Academic / grey	Detection of landmines and UXO using advanced synthetic aperture radar technology	Schreiber, E. et al.	2016
Academic / grey	Development of an underwater instrument for advanced geophysical classification of UXO	Odlum, N. & Bell, T.	2019
Academic / grey	Dispersion of Passive Tracers in the Baltic Sea Deep Water as Applied to Dumped Chemical Weapons	Zhurbas, V. & Paka, V.	2012

Academic / grey	Distribution of chemical warfare agent, energetics, and metals in sediments at a deep-water discarded military munitions site	Briggs, C. et al.	2016
Academic / grey	Dix mois ferme pour avoir ramené une bombe au port de Boulogne	Le Marin	2020
Academic / grey	Dumped conventional warfare (munition) catalog of the Baltic Sea	Miętkiewicz, R.	2020
Academic / grey	Effect of diurnal and seasonal weather variations on the chemical signatures from buried land mines/UXO	Webb, S.W. & Phelan, J.M.	2000
Academic / grey	Electromagnetic methods for UXO discrimination	O'Neill, K. & Fernández, J.P.	2009
Academic / grey	Emerging technologies in underwater munitions mapping	Jans, W. et al.	2017
Academic / grey	EMI modeling for UXO detection and discrimination underwater	Shubitidze, F.	2011
Academic / grey	Estimation of Potential Leakage from Dumped Chemical Munitions in the Baltic Sea Based on Two Different Modelling Approaches	Jakacki, J., Golenko, M. and Zhurbas, V.	2018
Academic / grey	Exploration of the munition dumpsite Kolberger Heide in Kiel Bay, Germany: Example for a standardised hydroacoustic and optic monitoring approach	Kampmeier, M. et al.	2020
Academic / grey	Exposure status of sea-dumped chemical warfare agents in the Baltic Sea	Vanninen, P. et al.	2020
Academic / grey	Exposure status of sea-dumped chemical warfare agents in the Baltic Sea	SAGEEP	2019
Academic / grey	Final report: characterisation of acoustic fields generated by UXO removal – Phase 2.	Cheong, S-H. et al.	2020
Academic / grey	Generation of a Quality Guideline for the Treatment of Unexploded Ordnance Faced During Offshore Wind Park Construction	Frey, T.	2018
Academic / grey	Harbour Porpoise (Phocoena phocoena) Special Area of Conservation: Southern North Sea	Speedie, C.	2019
Academic / grey	In Situ Measurements of Explosive Compound Dissolution Fluxes from Exposed Munition Material in the Baltic Sea	Beck, A. et al.	2019
Academic / grey	Joint Action Munition in the Sea	JPI Oceans	2019

Academic / grey	JPI Oceans Annual Activities 2018	De Moor, W.	2019
Academic / grey	JPI Oceans Annual Activities 2019	Pomarico, L. G. & De Moor, W.	2020
Academic / grey	Management Strategies and Technological Abilities	DAIMON project	Unclear
Academic / grey	Managing land mine and UXO contamination in exploration projects	Chirgwin, C.	2005
Academic / grey	Marine mammals and noise	Richardson, W. J. et al.	1995
Academic / grey	Marine Robots for Underwater Surveillance	Terracciano, D. et al.	2020
Academic / grey	Mer Méditerranée: au lieu de réduire les jours de pêche, il faut interdire le chalutage de fond pour l'ONG MedReAct	France 3 Regions	2020
Academic / grey	Minimum requirements for munitions detection at sea: submerged munitions, no hazard left undetected	Hydro International	Unclear
Academic / grey	Mining barriers in the territorial waters of Bulgaria in the context of the coalition relations with Germany and Romania (1941 - 1944)	Panayotov, A.	2016
Academic / grey	Mitigation of underwater explosion effects by bubble curtains: experiments and modelling	Croci, K. et al.	2014
Academic / grey	Modelling of Ecological Risks Related to Sea-Dumped Chemical Weapons	Missiaen, T., Paka, V. and Emalyanov, E.	2006
Academic / grey	Munitiestort met 500 ton Duitse granaten in Waddenzee	Eenvandaag	2013
Academic / grey	Munitionsbelastung der deutschen Meeresgewässer - Bestandsaufnahme und Empfehlungen	Böttcher, C. et al.	2011
Academic / grey	New Capabilities for Marine UXO Detection, Classification and Information Management: Case Studies from the U.S. Military Munitions Response Program	The Hydrographic Society UK	2015
Academic / grey	Noise of underwater explosions in the North Sea. A comparison of experimental data and model predictions.	Salomons, E. M. et al.	2021
Academic / grey	Offshore unexploded ordnance recovery and disposal	Kölbel, J. & Rose, D.	2016
Academic / grey	Overview on underwater munitions technology and mythology for military	International Dialogue on Water Munitions	2013

	munitions response programs (MMRP's)		
Academic / grey	Pathways of Suspended Particles Released in the Bottom Boundary Layer of the Bornholm Deep, Baltic Sea (Numerical Simulations)	Zhurbas, V., Elken, J. and Vali, G.	2008
Academic / grey	Passive Sampling of Munitions Constituents	Lotufo, G. & Rosen, G.	2020
Academic / grey	PBT screening of chemical warfare agents (CWAs)	Sanderson, H. et al.	2007
Academic / grey	Performance evaluation of the Roach Cove bubble screen apparatus	Rude, G., & Lee, J.	2007
Academic / grey	Practical Guide for Environmental Monitoring of Conventional Munitions in the Seas	GEOMAR	2019
Academic / grey	Prediction of the initial Movement of Objects on the Sea Floor	Menzel, P. et al.	2017
Academic / grey	Regional Cooperation in Mine Action: The Case of South-Eastern Europe	Geneva International Centre for Humanitarian Demining (GICHD)	2005
Academic / grey	Remote operated non-destructive removal of unexploded ordnance from the sea floor	Barton, J.	2006
Academic / grey	Report on a workshop on electromagnetic induction methods for UXO detection and discrimination	Butler, D.K.	2004
Academic / grey	Research handbook on international environmental law	Fitzmaurice, M. et al.	2010
Academic / grey	Results from the Chemsea Project – Chemical Munitions Search and Assessment	Beldowski, J, et al.	2014
Academic / grey	Risicobeoordeling Munitiestort Oosterschelde	Van Eck, G.T.M. et al.	2001
Academic / grey	Risk management for unexploded ordinance (UXO) in the marine environment	Howard, B. et al.	2012
Academic / grey	Risk management for unexploded ordinance (UXO) in the marine environment	Howard, B. et al.	2012
Academic / grey	Russian mining barriers along the Black sea coast	Desant	2011
Academic / grey	Sea-dumped chemical weapons: environmental risk, occupational hazard	Greenberg, M.I. et al.	2016

Academic / grey	Site Assessment and Risk Management Framework for Underwater Munitions	Sayle, S. et al.	2009
Academic / grey	Some Specific Features in the Logistic System of ISAF Regional Command North	Pohl, Á.	2003
Academic / grey	Spread, Behaviour, and Ecosystem Consequences of Conventional Munitions Compounds in Coastal Marine Waters. Frontiers in Marine Science	Beck, A.J. et Al. Achterberg E.P.	2018
Academic / grey	Stop blowing up bombs on sea floor, say whale campaigners	Carrington, D.	2020
Academic / grey	Studies on Environmental Effects of Underwater Chemical Munitions in the Southern Adriatic Sea (Mediterranean Sea)	Alcaro, L. et al.	2012
Academic / grey	Support to the JPIO action Munitions in the Sea: Report from Oslo and Rome workshops - The way forward	CSA OCEANS 2 project (JPI Oceans)	2019
Academic / grey	The ocean is a giant dump for chemical weapons. Can we clean it up before it's too late?	Rubiano, M.P.A.	2021
Academic / grey	The Regional Center for Divers Training and Underwater Demining	Mijajlovic, V.	2013
Academic / grey	The undeclared chemical war in Russia: Politics versus ecology	Federov, A.	1995
Academic / grey	Towards a general prediction-model for the current-induced mobilisation of objects on the sea floor	Menzel, P. et al.	2018
Academic / grey	Trace explosives signatures from World War II unexploded undersea ordnance	Darrach, M. R. et al.	1998
Academic / grey	Underwater acoustic characterisation of unexploded ordnance disposal using deflagration	Robinson, S.P. et al.	2020
Academic / grey	Underwater Unexploded Ordnance - Methods for a Cetacean-friendly Removal of Explosives as Alternatives to Blasting	Koschinski, S. & Kock, K.H.	2015
Academic / grey	Underwater Unexploded Ordnance (UXO) Classification Using a Matched Subspace Classifier With Adaptive Dictionaries	Hall, J. et al.	2018
Academic / grey	Unexploded ordnance cleanup costs: implications of alternative protocols	MacDonald, J. & Mendez, C.	2005
Academic / grey	UXO search off Burgas: a high resolution marine magnetic survey prior to the start of the second phase harbor's expansion	Dimitriu, R.G. et al.	2017

Statistics	AMUCAD	EGEOS	2019
Statistics	Chemical Weapon Munitions Dumped at Sea: An Interactive Map	Centre for Non-proliferation Studies (CNS)	2017
Statistics	EMODnet Human activities Dumped Munitions dataset	EMODnet Human Activities	2020
Statistics	HELCOM Dumped chemical munitions	HELCOM Map and Data Service	2020
Statistics	ORDTEK	ORDTEK	2019
Statistics	OSPAR Dumped Munitions	Odims.ospar.net	2020

Note: excluding web page links provided throughout the report.

Recent and ongoing technological RT&D projects

A number of ad-hoc organizations and cooperative RT&D projects on the clearance of sunken UXO has been identified. An overview of these is provided in Table 9 overleaf.

Table 9. Recent and ongoing technological RT&D projects

Project name	Description	Weblink
AMMOTRACe	MMOTRACe is a transdisciplinary project, involving science, engineering, and companies across a range of disciplines to develop new solutions beyond disciplinary perspectives. The project aims to design, develop, prototype, and demonstrate complete technology solutions for new real-time ship-board and in-situ analyzers for conventional and chemical MCs in coastal systems. For this, new laser photoionization mass spectrometers (PIMS), including latest laser developments as well as state of the art ion mobility spectrometers (IMS), will be combined with innovative membrane inlet (MI) sampling to provide highly selective and sensitive detection of MCs in marine systems. The key objectives of the project are as follows: • Design and development of ship-board as well as a submersible PIMS/IMS prototypes for rapid and direct analysis of MCs in seawater • Design and develop Nd:YAG-laser – optical parametric oscillator (OPO) systems with tuneable wavelengths as sources for photoionization, for ship-board and in situ submersible use • Design and develop components and interfaces for the underwater deployment of the submersible PIMS/IMS device • Demonstration of the prototypes alongside traditional chemical and geophysical measurements at munition	https://www.zimmermann.chemie.uni-rostock.de/en/projekte/ammotrace/

Project name	Description	Weblink
	dumping sites and regions with the presence of munitions.	
CONMAR	The DAM (Deutsche Allianz Meeresforschung) project CONMAR aims to advance our understanding of the role, fate and impact of marine munition in the environment, and provide policy solutions for monitoring and remediation actions in consultation with stakeholders. CONMAR will provide detailed information on the distribution and condition of munitions in German waters and deliver mechanistic and quantitative understanding on the release, spread, attenuation and transfer in the food chain of munition compounds, including assessments of their ecological and toxicological impacts.	https://www.geomar.de/en/research/fb2/fb2-ch/working-groups/team-water-column-biogeochemistry-1/translate-to-english-water-column-biogeochemistry-projekte
JPI Oceans	Ordnance in the Sea (participants: BE, DE, EL, IR, NL, NO, PL, PT, SP, SW, UK): coordinates research and innovation to assess risks, define priorities and suggest intervention options with regard to ordnance in the marine environment by: • Introducing and structuring a European scientific interdisciplinary and cross-sector cooperation; • Providing an interface between scientific expertise and operators; • Contributing to cost- and time-efficient solutions.	http://www.jpi-oceans.eu/munitions-sea
IDUM	International Dialogue on Underwater Munitions (IDUM) is an NGO founded in Canada in 2004, and established as a Dutch Foundation in The Hague, the Netherlands. IDUM was founded by retired demining experts from all over the world to ensure: The creation of a global treaty on all underwater weapons; The development of a global database of underwater weapons sites; The creation of a repository of information for underwater weapons; The eradication of the "Point-Source Emitters of Pollution" from the seas and oceans. IDUM has contributed to CHEMSEA, NATO Science for Peace and Security (SPS) MODUM; DAIMON	https://underwatermunitions.org/
BASTA project	BASTA (Boost Applied munition detection through Smart data integration and AI	https://www.basta-munition.eu/

Project name	Description	Weblink
	workflows) aims at advancing the approach for munition detection both at local and larger scales. The project seeks to advance data acquisition through ultra-high-resolution 3D sub-bottom profiling (SBP) and intelligent autonomous underwater vehicle (AUV) based magnetic mapping as part of an adaptive and iterative survey approach. In addition, it will foster sustainable use of survey and historical data within a multi-sensor database. Conducting data analysis of big data by means of artificial intelligence will lead to new approaches in detection and identification of UXOs.	
ExPloTect project	ExPloTect (Ex-situ, near-real-time explosive compound detection in seawater) will develop a prototype system for shipboard, near-real-time detection of dissolved explosive compounds and chemical warfare agents in seawater. The underlying concept of ExPloTect is a flexible platform that is adaptable to explosive compounds such as TNT, as well as chemical warfare agents. The technology will be based on an analytical methodology extensively demonstrated by GEOMAR in the Baltic Sea during the German Science Ministry (BMBF) funded UDEMM project ("Environmental monitoring for the *delaboration* of munitions in the sea").	https://www.explotect.eu/
ProBaNNt	The project ProBaNNt analyses the currently available AI techniques for supporting the handling process of world war munitions found at the seafloor. A core part of this project lies in detailed 3D reconstruction of UXOs from super high-resolution acoustic and optical data to assist identification, state estimation and planning of treatment.	https://www.geomar.de/en/omv-research
UDEMM project (completed)	In the framework of UDEMM (Environmental monitoring for the *delaboration* of munitions on the seabed) project, scientists of different partner institutions investigated four relevant aspects concerning the effects of underwater munitions. This project was conducted in close collaboration with the *Projektträger Jülich* (PtJ) and the technology project RoBEMM ("Robotic underwater salvage and disposal process with the technology to remove explosive ordnance in the sea, in particular in coastal and shallow waters") to achieve the best possible result to develop a both economically viable and autonomous (without divers) as well as environmental friendly (without detonating) method to in-situ (underwater) neutralize	https://udemm.geomar.de/home

Project name	Description	Weblink
	potentially dangerous mines and other explosives.	
DAIMON project (completed)	DAIMON (Decision Aid for Marine Munitions: Practical Application) is an international applied-science project consisting of partners from Poland, Germany, Sweden, Finland and Norway collaborating with experts worldwide, united by the goal of solving the problem of underwater munitions. It is part-financed by the EU INTERREG Baltic Sea Region Programme 2014-2020.	https://www.daimonproject.com/
DAIMON 2 project	The goal of the extension project DAIMON 2 (2019-2021) is to popularise those decision-aid tools and train their administrative end-users around the Baltic Sea.	https://www.daimonproject.com/
Munitect	The Munitect network is an association of companies and research institutions driving the development of economically effective munitions detection systems for underwater use. By means of the cooperation, the competences and variety of experiences from the network partners' different industries are bundled and experiences are shared. Within the scope of the network, the members initiate and develop application-oriented research and development projects together with national and international project partners. They need to make a sustainable contribution to the goal of solving the problem of the old military munitions.	https://www.munitect.de/en/home
NATO CMRE	The NATO research centre undertakes studies on advanced acoustic processing allowing specific detection of the UXOs illuminated by low frequency sonar and "colourising" the echo by the structural response of the UXO casing to the sonar sound wave. While remaining complex, this technique would considerably augment the survey speed and range while minimizing false alarms. The centre has also the plan to establish a dedicated underwater UXO test bed in the harbour of La Spezia under the sponsorship of the Environmental Security Technology Certification Program (ESTCP) of the US Department of Defence. This will allow conducting open controlled UXO detection and classification trials to validate and benchmark equipment and processes	https://www.cmre.nato.int/ https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwj-9ta57sHwAhWG2BQKHTJAB0sQFjABegQIBBAD&url=http%3A%2F%2Fwww.davidwilliamsphd.com%2Fpublications%2FDPW_UAC19_UXO.pdf&usg=AOvVaw34p0YzXpS8pBmzC_hTnURC
RoBEMM "Robotic	The technology project RoBEMM ("Robotic underwater salvage and disposal process with	https://www.ict.fraunhofer.de/content/dam/ic

Project name	Description	Weblink
underwater salvage and disposal process with the technology to remove explosive ordnance in the sea, in particular in coastal and shallow waters"	the technology to remove explosive ordnance in the sea, in particular in coastal and shallow waters") aims to develop a both economically viable and autonomous (without divers) as well as environmental friendly (without detonating) method to in-situ (underwater) dispose potentially dangerous mines and other explosives.	t/en/documents/media/es/ES_Robotisches_Unterwasser_Bergungs-_und_Entsorgungsverfahren_V02_en.pdf
CHEMSEA project (completed)	Some 50 000 tonnes of chemical munitions have been dumped in the Baltic Sea since the end of World War II, posing a threat to the environment. The CHEMSEA project seeks to learn more about the locations of dumping areas, the content and state of the munitions and how they react to Baltic conditions. A possible follow-up project has been suggested by EU parliamentarians in March 2021.	http://underwatermunitions.org/wp-content/uploads/2016/08/CHEMSEA_Findings_24.01.pdf

Annex 2: Stakeholder engagement

Table 10 overleaf provides an overview of the stakeholder consultations. Table 11 and Table 12 overleaf indicate how the interviews were anonymised.

Table 10. Overview of stakeholder consultations

Type	Results
Survey National/Military authorities, Local/Port authorities and Maritime communities	Received: • National/Military authorities: 7 (BE, DE, ES, LV, LT, MT, NO) • Local/Port authorities: 2 (BE, RO) • Maritime communities: 13; 2 engineering / construction entities (FR), 2 fisheries (LV, SE), 9 others (transport, environment, tourism, NGOs, etc.) (5 DE, LT, NO, PT, NL)
Scoping interviews EU institutions (DG MARE, DG ENV, DG MOVE)	Two scoping interviews conducted with DG MARE (Maritime Policy and Blue Economy, Fisheries Policy, Implementation), one with DG ENV (Marine environment, Waste Management & Secondary Materials), and one with DG MOVE
In-depth interviews National/Military authorities; Local/Port authorities; Maritime communities; NGOs/Academia; other EU institutions and entities, as well as international organisations and transnational research projects	• National/Military authorities: 17 (3 BE, 3 BG, 6 FR, 2 LT, 2 NL, SE) • Local/Port authorities: 1 (FR) • Maritime communities: 9 (2 BG, 5 FR, LU, IT) • NGOs/Academia: 3 (2 DE, FR) • Other EU institutions and entities, as well as international organisations and transnational research projects: 10 (European Defence Agency, NATO, OPCW, OSPAR, Barcelona Convention/UNEPMAP, London Convention, CMRE, NMW CoE Eguermin (Ostend), AMUCAD, IDUM)
Workshop National/Military authorities; Local/Port authorities; Maritime communities; NGOs/Academia; other EU institutions and entities, as well as international organisations and transnational research projects	• National/Military authorities: 10 (BE, BG, FR, IT, LT, NL, 3 NO, SE) • Local/Port authorities: 1 (DE) • Maritime communities: 5 (3 DE, 2 FR) • NGOs/Academia: 6 (3 DE, 2 FR, PT) • Other EU institutions and entities, as well as international organisations and transnational research projects: 3 (NATO, OPCW, CBSS Secretariat)

Table 11. Anonymous stakeholder list – scoping interviews + EU/international/regional/transnational in-depth interviews

Institution category	Institution name	REFERENCE
EU institution / agency	DG MARE (Maritime Policy and Blue Economy, Fisheries Policy, Implementation)	Scoping interview 01
EU institution / agency	DG MARE (Maritime Policy and Blue Economy, Fisheries Policy, Implementation)	Scoping interview 02
EU institution / agency	DG MOVE	Scoping interview 03
EU institution / agency	DG ENV (Marine environment, Waste Management & Secondary Materials)	Scoping interview 04
EU institution / agency	European Defence Agency	EU / int. / reg. / trans. 01
Intergovernmental institution	NATO	EU / int. / reg. / trans. 02
Intergovernmental institution	OPWC	EU / int. / reg. / trans. 03
Regional conventions	OSPAR	EU / int. / reg. / trans. 04
Regional conventions	Barcelona Convention/UNEPMAP	EU / int. / reg. / trans. 05
Intergovernmental organisations	London Convention	EU / int. / reg. / trans. 06
Transnational project	CMRE	EU / int. / reg. / trans. 07
Research	NMW CoE Eguermin (Ostend)	EU / int. / reg. / trans. 08
Transnational project	AMUCAD	EU / int. / reg. / trans. 09
Research	IDUM	EU / int. / reg. / trans. 10

Table 12. Anonymous stakeholder list – national in-depth interviews

MS	USER CATEGORY	USER SUBCATEGORY	REFERENCE PART A	REFERENCE PART B
BE	National_authorities	Military authorities	Military authorities	BE 01
BE	National_authorities	Military authorities	Military authorities	BE 01
BE	National_authorities	National authorities (ministries, etc.)	National authorities	BE 02
NL	National_authorities	Military authorities	Military authorities	NL 01
BG	National_authorities	Military authorities	Military authorities	BG 01
BG	National_authorities	Military authorities	Military authorities	BG 02
BG	National_authorities	Military authorities	Military authorities	BG 03
BG	Maritime_community	Transport and tourism	MC - Transport and tourism	BG 04
BG	Maritime_community	Transport and tourism	MC - Transport and tourism	BG 05
DE	NGO_Academia	Research centres	NGO / Academia	DE 01
DE	NGO_Academia	GEOMAR	NGO / Academia	DE 02
FR	National_authorities	national authorities (ministries, etc.)	National authorities	FR 01
FR	National_authorities	Law enforcement	National authorities	FR 02
FR	Local_authorities	Local administration	Local authorities	FR 03

FR	National_authorities	national authorities (ministries, etc.)	National authorities	FR 04
FR	National_authorities	Military authorities	Military authorities	FR 05
FR	National_authorities	national authorities (ministries, etc.)	National authorities	FR 06
FR	Maritime_community	UXO Specialists (private)	MC - UXO specialist	FR 07
LU	Maritime_community	Engineering / construction	MC - Engineering / construction	LU 01
FR	National_authorities	National authorities (ministries, etc.)	National authorities	FR 08
FR	Maritime_community	Fisheries	MC - Fisheries	FR 09
FR	Maritime_community	Fisheries	MC - Fisheries	FR 10
FR	NGO_Academia	Association, NGO	NGO / Academia	FR 11
FR	Maritime_community	Engineering / construction	MC - Engineering / construction	FR 12
FR	Maritime_community	Fisheries	MC - Fisheries	FR 13
IT	Maritime_community	UXO Specialists (private)	MC - UXO specialist	IT 01
LT	National_authorities	Military authorities	Military authorities	LT 01
LT	National_authorities	National authorities (ministries, etc.)	National authorities	LT 02

NL	National_authorities	Military authorities	Military authorities	NL 02
SE	National_authorities	Military authorities	Military authorities	SE 01

Annex 3: Survey and interview questionnaires

Survey questionnaire

Info

Survey on underwater unexploded munition

The Commission has contracted ICF to conduct a study on underwater exploded munition. In the context of this contract, ICF is performing the following survey.

Purpose of the consultation

The main objective of the study is to enhance cooperation between Member States' authorities, private bodies and regional organisations in dealing with accidental recovery or any encounter with unexploded munitions and chemical munitions dumped at sea by developing relating guidance. The study will also contribute to improving coordination in the monitoring and systematic removal of these munitions, hence minimising this important challenge to maritime security. The specific objectives of the study are:

- To map existing unexploded munition at sea and mechanisms or approaches to monitor and remove these munitions;
- To map relevant capabilities employed for identification, monitoring and disposal of sea-dumped unexploded munitions;
- To identify and assess best practices in (1) dealing with accidental recovery of dumped munitions at sea in different maritime communities and (2) removals with limited impacts to the marine environment and
- To propose a set of common procedures and response models in dealing with accidental recovery of dumped munitions at sea.

How to complete the survey?

Please complete the survey in English.

Fields marked with * are mandatory.

Please note that for some questions, depending on the answer provided, you may either be asked to answer sub-questions, or be redirected to another question. It is therefore possible that the numbering of questions does not always follow in sequential order.

Your data will be used for the purpose of the survey only. All information will be stored incompliance with the Privacy Statement.

Treatment of information

This survey focuses on generic information (i.e. non-specific or sensitive information) about underwater unexploded munition. Hence, you have the possibility to submit an "edited down" /"redacted" version of the relevant parts of any supporting guidelines, tools and templates. You can send such information directly with the survey (i.e. for non-classified documents) or by secure file transfer (should you consent to use this transfer method).

Non-disclosure of information is a clear obligation as per the contract signed between ICF and the European Commission. Furthermore, ICF:

- has experts in possession of a security clearance;
- is a long-term and trusted partner of the EC (e.g., CINEA, DG MARE, DG MOVE);
- has strict procedures in place to ensure that their staff maintains confidentiality and that information is securely transferred, stored and deleted.

For any questions/clarification please contact the Project Manager, Fabrizio Costantino, at the following email address: [REDACTED].

Do you agree to take part in the survey and for your data to be used?*

[YES/NO]

Section A: Information about you and your organisation

A1. Please indicate your Member State

A2. Please select the type of organisation(s) you represent or work for* [SINGLE CHOICE]

- National/military authorities (NM)
- Local/port authorities/coastguards (LP)
- Fisheries (FI)
- Engineering (marine engineering/construction) (ME)
- Others (transport, environment, tourism, NGOS, etc)

Section B: Information on (1) existing unexploded munition at sea and (2) mechanisms or approaches to monitor and remove these munitions

B1. (NM) What types of unexploded munition, conventional or chemical, are already identified or mapped in your territorial waters? (You may choose more than one answer)

Munition types:

- Bombs
- Missiles
- Rockets
- Artillery shells
- Mortar shells
- Hand grenade
- Rifle grenade
- Small calibre ammunitions
- Fireworks (detcord, blasting caps, ignitors)
- AP / AV mines (anti-personnel/vehicle)
- AT mines (antitank)
- Submunitions (include cluster shells and cluster bombs)
- Naval mines (include bottom mines and moored mines)
- Torpedoes
- Depth charges (mortars or drums)
- Limpet mines
- Do not know/not applicable

Associated chemicals:

- Explosive materials (nitroaromatic explosives/nitramine explosives e.g. TNT, DNT, RDX)
- Chemical ammunitions (warfare chemical agents)

- Do not know/not applicable

Please indicate the most concerning chemical hazards in the UXOs found in your territorial waters: (You may choose more than one answer)

- Blistering agents (e.g. sulphur mustard gas and arsenic-containing compounds)
- Nerve agent (organophosphates, e.g. Tabun)
- Choking agents (e.g. phosgene)
- Lachrymatory agents (e.g. α-chloroacetophenone)
- Aromatic and chlorinated solvents (e.g., benzene, chlorobenzene, tetrachloromethane)
- Other

B2. What are the main risks posed by underwater unexploded munition? (You may choose more than one answer)

- Damage to infrastructure
- Damage to equipment
- Damage to workers/population
- Damage to business continuity
- Damage to the environment (i.e. pollution, contamination of fishing zones)
- Usage by terrorist organisations
- Other risks (please specify)
- Do not know/not applicable

B2.1 Could you please provide an example of the main risks posed by underwater unexploded munition?

B3. What is the extent of the impact and evolution of weather conditions, currents, changes in the seabed and the different seasons on the risks posed by underwater unexploded munitions?

- High impact
- Moderate impact
- Low or no impact
- Do not know/not applicable

B4. Could you please reorder the following risks in order of importance (where "1" is the most concerning in your opinion and "4" the least concerning):

Exposure of UXOs on accessible shores (beaches)

Alternance of exposure and burial of UXOs on the seabed making it impossible to declare a sector fully cleared

Accelerated corrosion of the UXO shells

Increased diffusion of the UXO pollutants

Other issues (please specify)

B5. What is the extent of the impact and evolution of weather conditions, currents, changes in the seabed and the different seasons on the characteristics and location of underwater unexploded munitions? [SINGLE CHOICE]

- High impact
- Moderate impact
- Low or no impact
- Do not know/not applicable

B6. Could you please reorder (by dragging each statement) the following challenges in order of importance (where "1" is the most concerning in your opinion and "4" the least concerning):

Alternance of exposure and burial of UXOs on the seabed, making their identification more complicated

Limited time to proceed to the neutralization

Lack of adequate technologies (seabed penetrating sonar, dedicated dredging equipment…)

Other issues (please specify)

Section C: Capabilities employed for identification, monitoring and disposal of sea-dumped unexploded munitions

C1. In your Member State, which authorities are responsible for the following activities?

a) Identification (i.e. seafloor surveys, in-situ visual inspection) of underwater unexploded munitions

- Civil protection authorities
- Law enforcement and military authorities
- Local/Port authorities
- Other (please specify)

b) Monitoring (i.e. periodic re-location and condition assessment) of underwater unexploded munitions

- Civil protection authorities
- Law enforcement and military authorities
- Local/Port authorities
- Other (please specify)

c) Disposal (i.e. in-situ neutralization and/or destruction, displacement in a safer disposal location, recovery and destruction on-shore…) of underwater unexploded munitions

- Civil protection authorities
- Law enforcement and military authorities
- Local/Port authorities
- Other (please specify)

C2. In your Member State, how aware are the users of the sea environment of who to contact for UXO? [SINGLE CHOICE]

- Very much aware
- Much aware
- Not much aware
- Not at all aware

- Do not know/not applicable

C3. What are the main assets/equipment used for the in-situ identification of underwater unexploded munitions in your Member State? (You may choose more than one answer)

Assets:

- Mine-hunting assets
- Dedicated survey vessel
- Dedicated towed system
- Dedicated autonomous system
- Other (please specify
- Do not know/not applicable

Sensors:

- Diver
- High frequency sonars
- Lidar
- Electro-optic camera
- Magnetometer
- Chemical detector (on-site/laboratory)
- Other (please specify)
- Do not know/not applicable

Periodicity:

- On-demand surveys related to specific off-shore projects
- No surveys, identification limited to accidental recoveries tracing
- Other (please specify)
- Do not know/not applicable

C4. What are the main assets/equipment used for the monitoring of underwater unexploded munitions in your Member State? (You may choose more than one answer)

- On site assessment re-iteration with assets/sensors used for identification
- Regular visual inspection of beaches
- Permanent surveillance of the marine activities exclusions
- Reporting and analysis of accidental recoveries
- Other (please specify)
- Do not know/not applicable

C4.1 Does this include a specific surveying of pollutants? [SINGLE CHOICE]

- Collection of samples and lab analysis
- Periodic sensors deployment
- Permanent sensors deployment
- Other (please specify)
- Do not know/not applicable

C5. Which are the main assets/equipment used for the disposal of underwater unexploded munitions in your Member State?

Equipment:

- Advanced underwater robotics
- Specialized divers
- Explosion effect mitigation equipment (e.g. bubble curtains)
- Other (please specify)
- Do not know/not applicable

Disposal strategy:

- Triggering on-site explosion
- Low-order controlled explosion
- Displacing in a safer place
- Removal to be disposed on-shore
- Complete on-shore process in-place for safe destruction/recycling of chemicals and explosives
- Other (please specify)
- Do not know/not applicable

C6. Which are the main protocols used for the monitoring of marine pollution in the vicinity of UXO depots?

- Sea-floor degradation visual monitoring (i.e. video, divers)
- Water sampling for lab analysis (incl. ICES IBTS samples)
- Sea-life sampling for lab analysis
- Seabed sampling for lab analysis
- Other (please specify)
- Do not know/not applicable

C7. Would you like to highlight one (or more) specific gaps in terms of capabilities to deal with underwater unexploded munitions in your Member State, including knowledge?

C8. Does your country have procedures in place for decontamination of chemical warfare agents with limited impact to the environment? [SINGLE CHOICE]

- Yes
- No
- Do not know/not applicable

C8.1 You indicated your country has procedures in place for decontamination of chemical warfare agents with limited impact to the environment. Could you briefly describe them?

C9. Are the areas of known depots subject to restrictions of navigation/anchoring/fishing/aquaculture etc.? [SINGLE CHOICE]

- Yes
- No
- Do not know/not applicable

C9.1 Are the areas of known depots subject to restrictions of construction/pipeline etc.? [SINGLE CHOICE]

- Yes
- No
- Do not know/not applicable

C9.2 Are the areas of known depots subject to restrictions of fishing/aquaculture etc.? [SINGLE CHOICE]

- Yes
- No
- Do not know/not applicable

C9.3 Are the areas of known depots subject to restrictions of navigation/anchoring etc.? [SINGLE CHOICE]

- Yes
- No
- Do not know/not applicable

Section D: Information about the practices in dealing with accidental recovery of dumped munitions at sea in different maritime communities

D1. Does your Member State have formal reporting protocols/procedures in place in case of accidental discoveries? [SINGLE CHOICE]

- Yes
- No
- Do not know/not applicable
- Other (please specify)

D1.1. Which of these protocols/procedures are used in your Member State?

- General guidelines (i.e. limited to a standard incident declaration form)
- Detailed guidelines (i.e. identifying UXO type and associated risks; taking immediate risk reduction measures)
- Standard Operating Procedures and methods for deciding which measures to implement
- Standard Operating Procedures for meeting baseline technical and operational security measures
- Standard Operating Procedures for meeting more stringent and additional technical and operational measures in case of higher level of threats
- Other (please specify)
- Do not know/not applicable

D1.2. In your opinion, which of these procedures needs to be improved?

- Standard Operating Procedures and methods for deciding which measures to implement

- Standard Operating Procedures for meeting baseline technical and operational security measures
- Standard Operating Procedures for meeting more stringent and additional technical and operational measures in case of higher level of threats
- Other (please specify)
- Do not know/not applicable

D1.3 What improvement is required to make such procedure(s) more effective?

D2. How frequent are removals of underwater unexploded munitions after accidental encounters? [SINGLE CHOICE]

- More than 75% of the cases
- Between 51% and 75% of the cases
- Between 25% and 50% of the cases
- Less than 25% of the cases
- Do not know/not applicable

D3. Are there financial rewards and/or compensations for the reporting of unexploded munitions by civil stakeholders? [SINGLE CHOICE]

- Yes
- No
- Do not know/not applicable

D3.1. Which of the following systems is used in your Member State? (You can choose more than one answer)

- Rewards (i.e. for reporting, or providing information)
- Compensation
- Sanction/Penalties for non-reporting
- Other (please specify)
- Do not know/not applicable

You previously stated your Member State uses the following systems: [PREVIOUS ANSWER]

D3.1.1 What improvement is required to make such procedure(s) more effective?

D4. Which of the following good practices on cooperation related to accidental recoveries is used in your Member State? (You can choose more than one answer)

- Cross-border training and specialisation of EOD staff
- Regular dedicated UXO survey campaigns
- Establishment of multilateral platforms for information exchange
- UXO shared trial facility and technologies/procedures benchmarks
- Joint operational exercises (e.g. military international cooperation)
- Cooperative RT&D to develop more effective capabilities

- Other (please specify)
- Do not know/not applicable

D4.1. Which of the following practices need to be improved? (You can choose more than one answer)

- Cross-border training and specialisation of EOD staff
- Regular dedicated UXO survey campaigns
- Establishment of multilateral platforms for information exchange
- UXO shared trial facility and technologies/procedures benchmarks
- Joint operational exercises (e.g. military international cooperation)
- Cooperative RT&D to develop more effective capabilities
- Do not know/not applicable

You previously stated the following practices need to be improved: [PREVIOUS ANSWER]

D4.1.1 What improvement is required to make such procedure(s) more effective?

D5. Which of the following best practices of disposal/removal with limited environmental impact is used in your Member State ? (You can choose more than one answer)

- Safety protocols
- Access restrictions and warning signs
- Mitigation measures when conducting in-situ destruction
- Dedicated shore facility for neutralization, dismantling and effective decontamination
- Other (please specify)
- Do not know/not applicable

D5.1. To what extent does this practice / do these practices achieve its/their goal(s)?' [SINGLE CHOICE]

- Very much
- Much
- Not much
- Not at all
- Do not know/not applicable

D5.1.1 What improvement is required to make such procedure(s) more effective?

Section E: International, national, and multilateral cooperation in the identification, assessment, management, and risk mitigation of underwater unexploded munitions

E1 Does your country have specific bilateral/multilateral procedures (in place for identifying, assessing, managing and or mitigating the risks of underwater unexploded munitions)? [SINGLE CHOICE]

- Yes
- No
- Do not know/not applicable

E1.1 You specified your country has specific bilateral/multilateral procedures. Could you briefly describe them?

E1.2 Are these procedures already scalable at an EU level? [SINGLE CHOICE]

- Yes
- No
- Do not know/not applicable

E1.3 Is it possible to extend them to other non-EU countries? [SINGLE CHOICE]

- Yes
- No
- Do not know/not applicable

E1.4 You previously indicated that it is possible to extend the procedures to other non-EU countries. To which level? Please specify

Final questions

F1. Would you be available for a follow-up interview? [SINGLE CHOICE]

- Yes
- No

F2. Would you like to share any document (i.e. databases, protocols, etc.) that you think could be useful to improve our understanding of underwater unexploded munitions? [SINGLE CHOICE]

- Please send me an email with instructions on how I can securely transfer files.
- All the documentation will be sent together with this form.
- No documentation can be shared.

Please upload any documents that you would like to share with us here:

[UPLOAD OPTION]

F3. If you consent to receive an e-mail with instructions on how to securely share files to ICF, please indicate:

The e-mail address ICF can use:

Your name and/or organization:

Interview questionnaire – all questions

Name	
Role	
Member State	
Authority	
Category	
Date & time	
Venue	
Interviewer	

Legend

EU/International institutions **(EUI)**

National/military authorities **(NM)**

Local and port authorities **(LP)**

NGO/Academic experts **(NGO)**

Maritime Communities **(MC)**

General knowledge on UXOs

1. About the knowledge you have on underwater unexploded munitions, can you briefly describe this knowledge area:

    a. Past/current impacts of underwater unexploded munitions

    b. Future impacts of underwater unexploded munitions

    c. Involvement your community/organisation in underwater unexploded munitions management

2. Has your Member State completed an UXO risk assessment? (NM, LP)

3. Are all types of hazardous materials covered? If not, which types are missing? (NM, LP)

4. How frequent are accidental encounters or recoveries of chemical and unexploded ordnances in your Member State? (NM, LP, MC)

5. What risks to persons and vehicles are entailed by underwater unexploded munitions in your Member State? (NM, LP, MC)

6. Which are the main risks while carrying out the operations of identification, monitoring and disposal of chemical and unexploded ordnances? How do you assign priorities in this sense? (NM, LP)

7. Are the munitions covered by sediments, or are they exposed (proud) on the seafloor? Are they encased in cargo holds or wrecks, or loose? Then, are they single munitions, or do they reside in clusters? What is the density – number of munitions per square kilometer? (NM, LP)

8. Which is the local situation with respect to underwater activities (i.e. dredging, fishing, sand winning, offshore (wind)industry, pipeline laying, etc.)? (MC)

9. Which is the impact and evolution of weather conditions, currents, changes in the seabed and the different seasons on underwater unexploded ordnances? (NGO)

Identification of capabilities

10. Does your Member State have in place mechanisms/procedures in place for reporting the activities? Could you briefly describe them? (NM, LP, MC)

11. Does your Member State have in place mechanisms/procedures in place for reporting the activities? Could you briefly describe them? (NM, LP, MC)

12. Are the known depots translated into restrictions of navigation/anchoring/fishing/aquaculture etc.? (NM, LP, MC)

13. Would you like to highlight one (or more) specific gaps in terms of capabilities, including knowledge? (NM, LP, MC)

14. How is UXO identification, monitoring and disposal process affected by the applicable EU and national health and environmental law? And are there any gaps? (EUI)

15. Does your country have in place guidelines and procedures on dealing with accidental recovery of dumped munitions at sea in different maritime communities (i.e. fisheries, transport, border police and navy) (NM, LP, MC)

16. Does your country have in place mechanisms / procedures / contingency plans for identifying, assessing, managing and or mitigating the environmental risks created by underwater unexploded ordnance? Could you briefly describe them? (NM, LP, MC)

17. Are there national procedures for decontamination of chemical warfare agents? (NM, LP)

18. Are you aware of any non-public documentation that can be made available to the study team for the purpose of the mapping/analysis of capabilities? (EUI, NM, LP, NGO,MC)

Identification of best practices in dealing with accidental recovery

19. In your Member State there were accidental encounters of underwater unexploded munitions? With which frequency? (NM, LP, MC)

20. Which bodies are in charge for initiating the response operations in case of accidental recoveries? (NM, LP, MC)

21. Is your institution aware of any existing exemplary response models for accidental recovery of unexploded munition? What is the level of effectiveness/efficiency of these procedures? (EUI, NM, LP, NGO,MC)

22. Is your institution aware of any ad-hoc forum or audience that the study can be promoted to? What is the level of interest in a workshop to promote and discuss common procedures? (EUI, NM, LP, NGO,MC)

23. Which procedures are in place in your country in case of accidental recovery of dumped munitions at sea? What is the level of effectiveness/efficiency of these procedures? (NM, LP, MC)

24. Can any cooperation achievements at national and/or regional level be highlighted? (NM, LP, MC)

25. Are you aware of any means of communication of common procedures and response models to the public through civil society? (i.e. Risks to tourists, children, workers) (NM, LP)

Other

26. Do you have any noteworthy remarks or observations? (EUI, NM, LP, NGO, MC)

27. Could you provide us with some key-stakeholders that we could contact during the study? (EUI, NM, LP, NGO, MC)

28. Could you provide us with data/datasets on UXO repositories or any other relevant information – including documentation – based on our interview? (EUI, NM, LP, NGO, MC)

Interview questionnaire – EUI

Interview Questionnaire [NAME]

Name	
Role	
Member State	
Authority	
Category	**EU / International institutions (EUI)**
Date & time	
Venue	
Interviewer	

Legend

EU/International institutions **(EUI)**

National/military authorities **(NM)**

Local and port authorities **(LP)**

NGO/Academic experts **(NGO)**

Maritime Communities **(MC)**

General knowledge on UXOs

1. About the knowledge you have on underwater unexploded munitions, can you briefly describe this knowledge area:

    a. Past/current impacts of underwater unexploded munitions

    b. Future impacts of underwater unexploded munitions

    c. Involvement your community/organisation in underwater unexploded munitions management

Identification of capabilities

2. How is UXO identification, monitoring and disposal process affected by the applicable EU health and environmental law? *Can you also give us any examples at national level?* And are there any gaps?

3. Are you aware of any non-public documentation that can be made available to the study team for the purpose of the mapping/analysis of capabilities?

Identification of best practices in dealing with accidental recovery

4. Is your institution aware of any existing exemplary response models for accidental recovery of unexploded munition? What is the level of effectiveness/efficiency of these procedures?

5. Is your institution aware of any ad-hoc forum or audience that the study can be promoted to? What is the level of interest in a workshop to promote and discuss common procedures?

Other

6. Do you have any noteworthy remarks or observations?

7. Could you provide us with some key-stakeholders that we could contact during the study?

8. Could you provide us with data/datasets on UXO repositories or any other relevant information – including documentation – based on our interview?

Interview questionnaire – LP

Interview Questionnaire [NAME]

Name	
Role	
Member State	
Authority	
Category	**Local and port authorities (LP)**
Date & time	
Venue	
Interviewer	

Legend

EU/International institutions **(EUI)**

National/military authorities **(NM)**

Local and port authorities **(LP)**

NGO/Academic experts **(NGO)**

Maritime Communities **(MC)**

General knowledge on UXOs

1. About the knowledge you have on underwater unexploded munitions, can you briefly describe this knowledge area:

    a. Past/current impacts of underwater unexploded munitions

    b. Future impacts of underwater unexploded munitions

    c. Involvement your community/organisation in underwater unexploded munitions management

2. Has your Member State completed an UXO risk assessment?

3. Are all types of hazardous materials covered? If not, which types are missing?

4. How frequent are accidental encounters or recoveries of chemical and unexploded ordnances in your Member State?

5. What risks to persons and vehicles are entailed by underwater unexploded munitions in your Member State?

6. Are the munitions covered by sediments, or are they exposed (proud) on the seafloor? Are they encased in cargo holds or wrecks, or loose? Then, are they single munitions, or do they reside in clusters? What is the density – number of munitions per square kilometer?

Identification of capabilities

7. Does your Member State have in place mechanisms/procedures in place for reporting the activities? Could you briefly describe them?

8. Does your Member State have in place mechanisms/procedures in place for reporting the activities? Could you briefly describe them?

9. Are the known depots translated into restrictions of navigation/anchoring/fishing/aquaculture etc.?

10. Would you like to highlight one (or more) specific gaps in terms of capabilities, including knowledge?

11. Does your country have in place guidelines and procedures on dealing with accidental recovery of dumped munitions at sea in different maritime communities (i.e. fisheries, transport, border police and navy)

12. Does your country have in place mechanisms / procedures / contingency plans for identifying, assessing, managing and or mitigating the environmental risks created by underwater unexploded ordnance? Could you briefly describe them?

13. Are there national procedures for decontamination of chemical warfare agents?

14. Are you aware of any non-public documentation that can be made available to the study team for the purpose of the mapping/analysis of capabilities?

Identification of best practices in dealing with accidental recovery

15. In your Member State there were accidental encounters of underwater unexploded munitions? With which frequency?

16. Which bodies are in charge for initiating the response operations in case of accidental recoveries?

17. Is your institution aware of any existing exemplary response models for accidental recovery of unexploded munition? What is the level of effectiveness/efficiency of these procedures?

18. Is your institution aware of any ad-hoc forum or audience that the study can be promoted to? What is the level of interest in a workshop to promote and discuss common procedures?

19. Which procedures are in place in your country in case of accidental recovery of dumped munitions at sea? What is the level of effectiveness/efficiency of these procedures?

20. Can any cooperation achievements at national and/or regional level be highlighted?

21. Are you aware of any means of communication of common procedures and response models to the public through civil society? (i.e. Risks to tourists, children, workers)

Other

22. Do you have any noteworthy remarks or observations?

23. Could you provide us with some key-stakeholders that we could contact during the study?

24. Could you provide us with data/datasets on UXO repositories or any other relevant information – including documentation – based on our interview?

Interview questionnaire – MC

Interview Questionnaire [NAME]

Name	
Role	
Member State	
Authority	
Category	**Maritime Communities (MC)**
Date & time	
Venue	
Interviewer	

Legend

EU/International institutions **(EUI)**

National/military authorities **(NM)**

Local and port authorities **(LP)**

NGO/Academic experts **(NGO)**

Maritime Communities **(MC)**

General knowledge on UXOs

1. About the knowledge you have on underwater unexploded munitions, can you briefly describe this knowledge area:

    a. Past/current impacts of underwater unexploded munitions

    b. Future impacts of underwater unexploded munitions

    c. Involvement your community/organisation in underwater unexploded munitions management

2. How frequent are accidental encounters or recoveries of chemical and unexploded ordnances in your Member State?

3. What risks to persons and vehicles are entailed by underwater unexploded munitions in your Member State?

4. Which is the local situation with respect to underwater activities (i.e. dredging, fishing, sand winning, offshore (wind)industry, pipeline laying, etc.)?

Identification of capabilities

5. Does your Member State have in place mechanisms/procedures in place for reporting the activities? Could you briefly describe them?

6. Does your Member State have in place mechanisms/procedures in place for reporting the activities? Could you briefly describe them?

7. Are the known depots translated into restrictions of navigation / anchoring / fishing / aquaculture / etc.?

8. Would you like to highlight one (or more) specific gaps in terms of capabilities, including knowledge?

9. Does your country have in place guidelines and procedures on dealing with accidental recovery of dumped munitions at sea in different maritime communities (i.e. fisheries, transport, border police and navy)

10. Does your country have in place mechanisms / procedures / contingency plans for identifying, assessing, managing and or mitigating the environmental risks created by underwater unexploded ordnance? Could you briefly describe them?

11. Are you aware of any non-public documentation that can be made available to the study team for the purpose of the mapping/analysis of capabilities?

Identification of best practices in dealing with accidental recovery

12. In your Member State there were accidental encounters of underwater unexploded munitions? With which frequency?

13. Which bodies are in charge for initiating the response operations in case of accidental recoveries?

14. Is your institution aware of any existing exemplary response models for accidental recovery of unexploded munition? What is the level of effectiveness/efficiency of these procedures?

15. Is your institution aware of any ad-hoc forum or audience that the study can be promoted to? What is the level of interest in a workshop to promote and discuss common procedures?

16. Which procedures are in place in your country in case of accidental recovery of dumped munitions at sea? What is the level of effectiveness/efficiency of these procedures?

17. Can any cooperation achievements at national and/or regional level be highlighted?

Other

18. Do you have any noteworthy remarks or observations?

19. Could you provide us with some key-stakeholders that we could contact during the study?

20. Could you provide us with data/datasets on UXO repositories or any other relevant information – including documentation – based on our interview?

Interview questionnaire – NGO

Interview Questionnaire [NAME]

Name	
Role	
Member State	
Authority	
Category	**NGO / Academic experts (NGO)**
Date & time	
Venue	
Interviewer	

Legend

EU/International institutions **(EUI)**

National/military authorities **(NM)**

Local and port authorities **(LP)**

NGO/Academic experts **(NGO)**

Maritime Communities **(MC)**

General knowledge on UXOs

1. About the knowledge you have on underwater unexploded munitions, can you briefly describe this knowledge area:

    a. Past/current impacts of underwater unexploded munitions

    b. Future impacts of underwater unexploded munitions

    c. Involvement your community/organisation in underwater unexploded munitions management

2. Which is the impact and evolution of weather conditions, currents, changes in the seabed and the different seasons on underwater unexploded ordnances?

Identification of capabilities

3. How is UXO identification, monitoring and disposal process affected by the applicable EU and national health and environmental law? And are there any gaps?

4. Are you aware of any non-public documentation that can be made available to the study team for the purpose of the mapping/analysis of capabilities?

Identification of best practices in dealing with accidental recovery

5. Is your institution aware of any existing exemplary response models for accidental recovery of unexploded munition? What is the level of effectiveness/efficiency of these procedures?

6. Is your institution aware of any ad-hoc forum or audience that the study can be promoted to? What is the level of interest in a workshop to promote and discuss common procedures?

Other

7. Do you have any noteworthy remarks or observations?

8. Could you provide us with some key-stakeholders that we could contact during the study?

9. Could you provide us with data/datasets on UXO repositories or any other relevant information – including documentation – based on our interview?

Interview questionnaire – NM

Interview Questionnaire [NAME]

Name	
Role	
Member State	
Authority	
Category	**NGO / Academic experts (NGO)**
Date & time	
Venue	
Interviewer	

Legend

EU/International institutions **(EUI)**

National/military authorities **(NM)**

Local and port authorities **(LP)**

NGO/Academic experts **(NGO)**

Maritime Communities **(MC)**

General knowledge on UXOs

1. About the knowledge you have on underwater unexploded munitions, can you briefly describe this knowledge area:

    a. Past/current impacts of underwater unexploded munitions

    b. Future impacts of underwater unexploded munitions

    c. Involvement your community/organisation in underwater unexploded munitions management

2. Which is the impact and evolution of weather conditions, currents, changes in the seabed and the different seasons on underwater unexploded ordnances?

Identification of capabilities

3. How is UXO identification, monitoring and disposal process affected by the applicable EU and national health and environmental law? And are there any gaps?

4. Are you aware of any non-public documentation that can be made available to the study team for the purpose of the mapping/analysis of capabilities?

Identification of best practices in dealing with accidental recovery

5. Is your institution aware of any existing exemplary response models for accidental recovery of unexploded munition? What is the level of effectiveness/efficiency of these procedures?

6. Is your institution aware of any ad-hoc forum or audience that the study can be promoted to? What is the level of interest in a workshop to promote and discuss common procedures?

Other

7. Do you have any noteworthy remarks or observations?

8. Could you provide us with some key-stakeholders that we could contact during the study?

9. Could you provide us with data/datasets on UXO repositories or any other relevant information – including documentation – based on our interview?

Annex 4: Survey report

Introduction

The report presents an analysis of the answers received by ICF to the online survey on underwater unexploded munitions.

Objective of the online survey

As part of the Study on underwater unexploded munitions, ICF launched an online survey aimed at gathering insights and identifying priorities from national and military authorities (NM), local/port authorities (including coast guards) (LP), and maritime communities (fisheries (FI), marine engineering and construction entities (ME), and any other relevant stakeholders). The results of this survey feed into the Study.

Methodology

The online survey was launched on the 5th of November 2021 and remained open for 4 weeks until the 7th of December. Key targeted stakeholders were sent at least 2 rounds of reminders on the survey.

- The questionnaire included 42 open and closed-ended questions which covered multiple matters, namely:
- Information on existing unexploded munition at sea and mechanisms or approaches to monitor and remove these munitions;
- Capabilities employed for identification, monitoring and disposal of sea-dumbed unexploded munitions;
- Information about the practices in dealing with accidental recovery of dumbed munitions at sea in different maritime communities; and
- International, national, and multilateral cooperation in the identification, assessment, management, and risk mitigation of underwater unexploded munitions

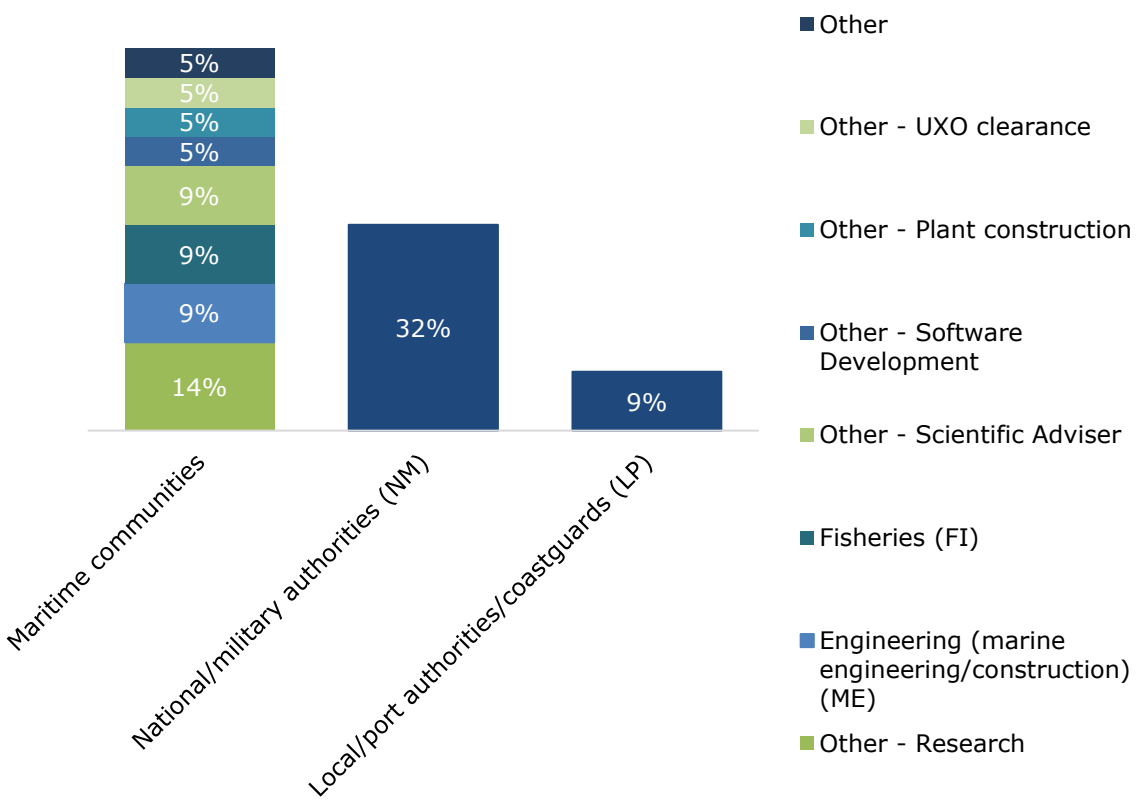
Profile of responses

Overall, the survey received 22 responses from 11 Member States plus Norway.[187] The Member States most represented were Germany (6 respondents), followed by Belgium, France, Latvia, Lithuania, Norway (2 respondents each) and Malta, the Netherlands, Portugal, Romania and Sweden (1 respondent each).

32% of respondents (7) answered the online survey on behalf of **national and/or military authorities.** 9% (2) answered on behalf of **local/port authorities**. 59% (13) answered on behalf of **maritime communities**, covering engineering / construction entities, fisheries, and any other relevant stakeholders (transport, environment, tourism, NGOs, etc.).

[187] BE, DE, ES, FR, LV, LT, MT, NL, NO, PT, RO, SE.

Figure 33. Profile of survey respondents[188] (A1)



Summary of responses

Information on existing (i) unexploded munition at sea and (ii) mechanisms or approaches to monitor and remove these munitions

Figure 34 provides information on the **main type of unexploded munition already identified or mapped in the territorial waters of the respondent**. Most respondents indicated that *artillery shells, naval mines* (include bottom mines and moored mines) and *torpedoes* are the main type of unexploded munition already identified or mapped (5 responses each). These are followed by *small calibre ammunitions* (4 responses) and by *hand grenade* (3 responses)*, mortar shells* (3 responses)*, rockets* (3 responses)*, missiles and bombs* (3 responses). *Submunitions (including cluster shells and cluster bombs), depth charges (mortars or drums), rifle grenade* and *fireworks* (detonation cord, blasting caps, ignitors) were indicated as the main type of unexploded munition by 2 responses each. Finally, there was only one response for the following munition types: *limpet mines, AT mines (antitank) and AP/AV mines (anti-personnel/vehicle).*

Figure 35 provides information on the **main associated chemicals.** 4 responses suggested that the explosive materials (nitroaromatic explosives/nitramines explosives e.g. TNT, DNT, RDX) are the main identified or mapped in the territorial waters, followed by chemical ammunitions (water chemical agents) (3 responses).

[188] N=22

Figure 34. Main type of unexploded munition already identified or mapped in the territorial waters[189] (B1.1)

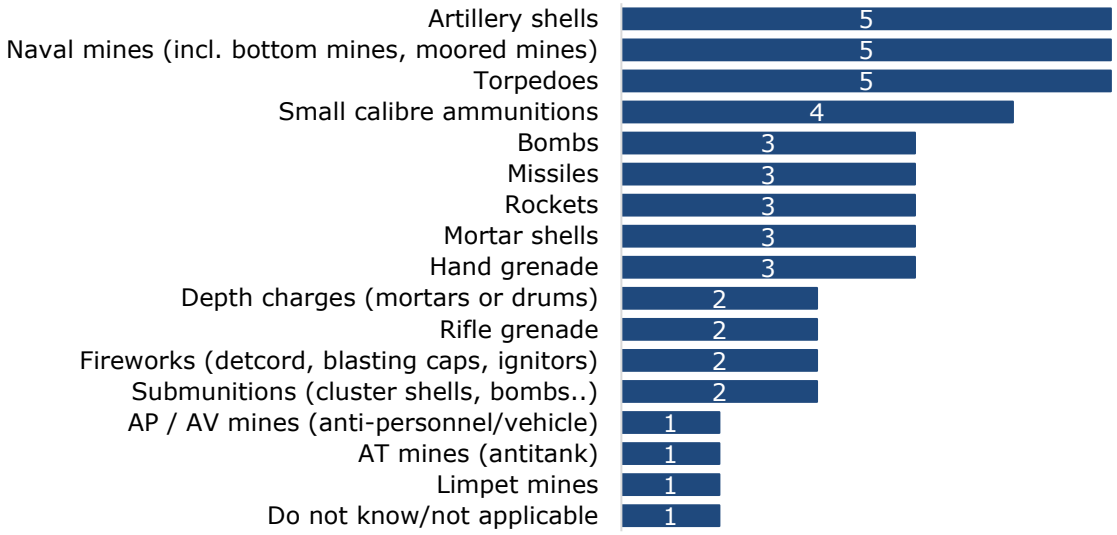


Figure 35. Main type of associated chemicals already identified or mapped in the territorial waters[190] (B1.2)

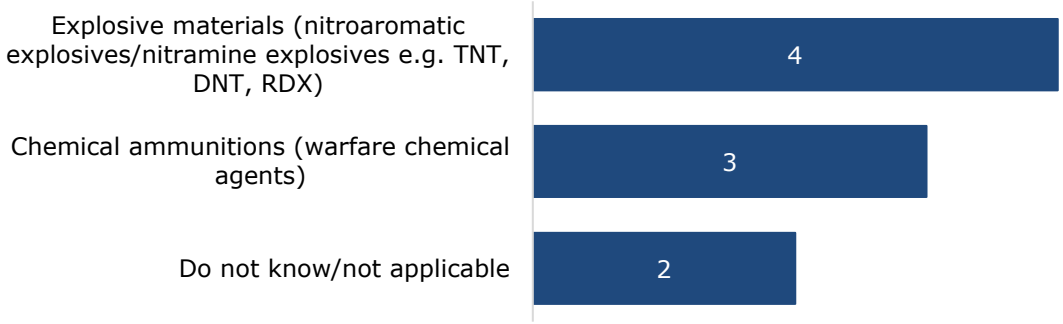


Figure 36 provides information on the **most concerning chemical hazards in the UXO found in their territorial waters**. The respondents indicated that the most concerning ones found in their Member States' water are nerve agents (organophosphates, e.g. Tabun) (2 responses) and *blistering agents such as sulphur mustard gas and arsenic-containing compounds* (2 responses). A minority of respondents also indicated *chemical weapons dumping area* (1 response); *choking agents such as phosgene* (1 response), and *TNT* (1 response).

[189] N= 7
[190] N= 7

Figure 36. Most concerning chemical hazards in the UXO found in respondents' territorial water[191] (B1.3)

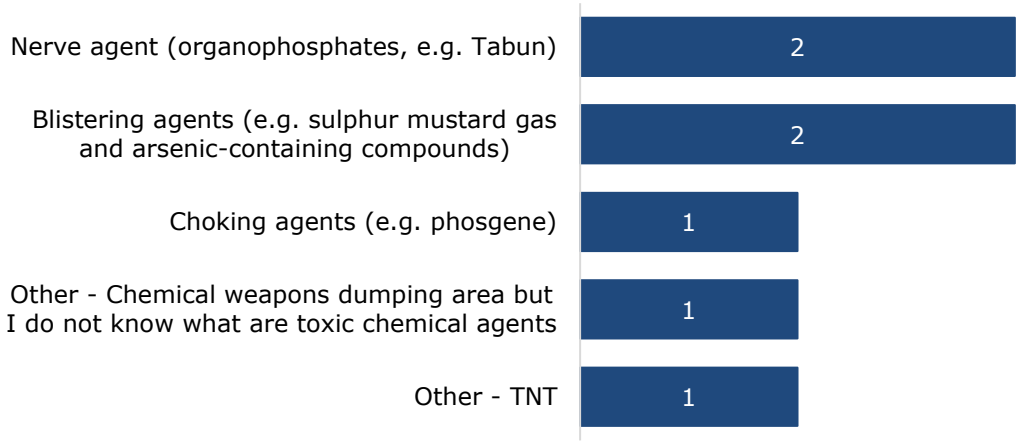
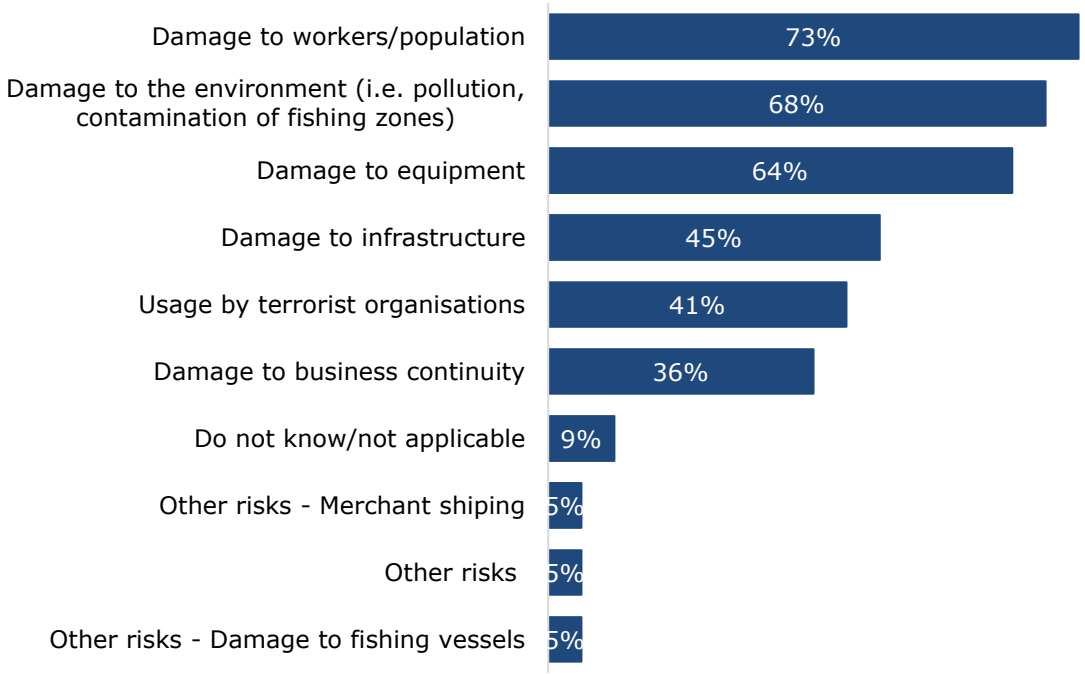


Figure 37 provides information on the main **risks posed by unexploded munitions**. *Damages to the workers/population* and to the *environment (i.e. pollution, contamination of fishing zones)* are perceived as the main risks by 73% of respondents (or 16 responses) and 68% of respondents (or 15 responses) respectively. Other risks identified are the *damages to equipment* (64% of respondents, or 14 responses), *to infrastructure* (45% of respondents, or 10 responses), *usage by terrorist organisations* (41% of respondents, or 9 responses) and *damage to business continuity* (36% of respondents, or 8 responses). Few more respondents mentioned *merchant shipping* (5% of respondents, or 1 response) and *damage to fishing vessels* (5% of respondents, or 1 response) as other risks posed by UXOs.

Figure 37. Main risks posed by underwater munition[192] (B2)



[191] N= 5
[192] N= 22

18 respondents also provided **information on the risks posed by unexploded munitions**. In terms of environmental damage, 7 respondents specified that the release of toxic warfare agents into the sea could pollute the water, harm marine life and have negative effects on fish and other biota. Other risks include, among others, the disruption of sea lines of communication (1 respondent), detonation of a HO explosive on a dishing vessel or dredger (1 respondent); unproper disposal of munition caught by fisherman (1 respondent); accidental initiation during offshore wind park construction (e.g. pile driving) (1 respondent); the presence of munitions on the shore side (1 respondent); damage to fishing (1 respondent). Figure 38 provides information on the extent of the impact and evolution of weather conditions, currents, changes in the seabed and the different seasons on the risks posed by underwater unexploded munitions. Half of the respondents (11 out of 22 respondents, or 50%) believe that weather conditions, currents, changes in the seabed and the different seasons have a *moderate impact* **on the risks posed by underwater unexploded munitions**. On the other hand, 18% of the respondents (4 respondents) believe that these factors have *a low or no impact* and 5% of respondents (1 respondent) indicated that they have a *high impact*.

Figure 38. Extent of the impact and evolution of weather conditions, currents, changes in the seabed and the different seasons on the risks posed by underwater unexploded munitions[193] (B3)

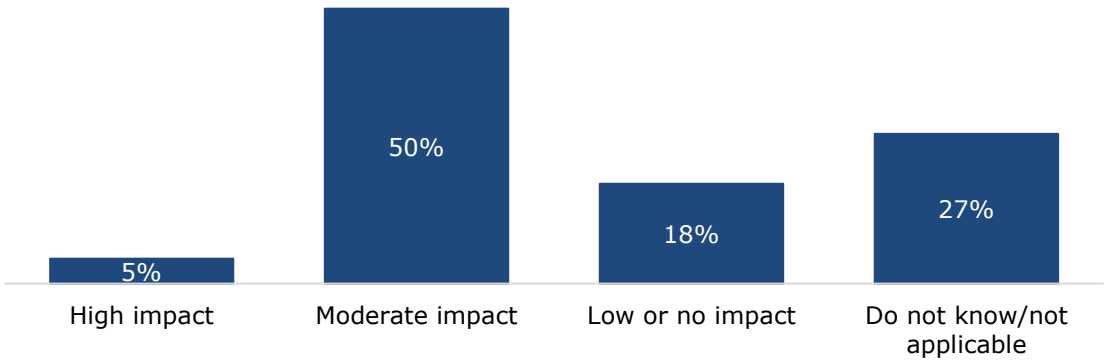


Figure 39 provides information on the risks posed by underwater munitions. Respondents were asked to rank on a scale ranging from 1 (most concerning) to 5 (least concerning) **a number of risks posed by underwater munitions**, and in particular: (i) exposure of UXO on accessible shores; (ii) alternance of exposure and burial of UXOs on the seabed making it impossible to declare a sector fully cleared; (iii) accelerated corrosion of the UXO shells; (iv) increased diffusion of the UXO pollutants. A total of 7 respondents replied to this question.

Exposure to UXO on accessible shores (beaches) was considered as the most concerning risk by 3 respondents. This risk is followed by *Alternance of exposure and burial of UXOs on the seabed making it impossible to declare a sector fully cleared* which is deemed the most concerning risk posed by underwater munition by 2 respondents.

[193] N= 22

Figure 39. Most concerning risks posed by underwater unexploded munitions[194] (B4), from most (1) to least (5) concerning

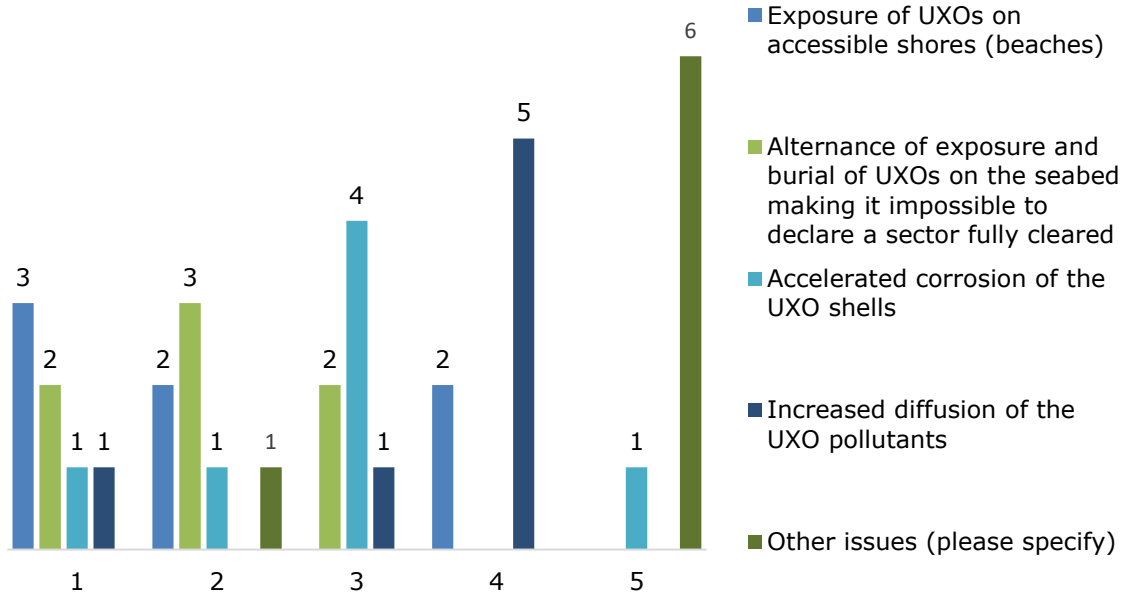
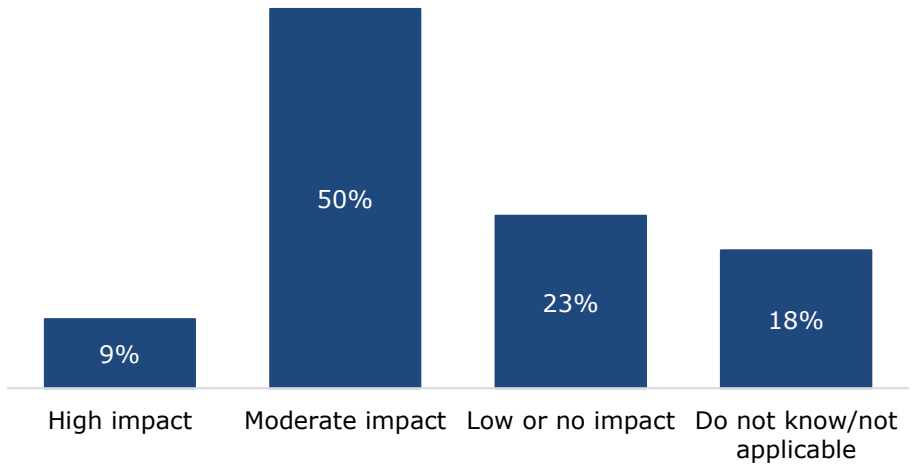


Figure 40 provides information on the extent of the impact and evolution of weather conditions, currents, changes in the seabed and the different seasons on the characteristics and location of underwater unexploded munitions. According to the respondents, weather conditions, currents, changes in the seabed and the different season have a *moderate impact* (50%, 11 respondents) on the **characteristics and location of underwater unexploded munitions**. Instead, 23% (or 5) of respondents believe these factors have a *low or no impact* and 9% (or 2) of respondents believe they have a *high impact*.

Figure 40. Extent of the impact and evolution of weather conditions, currents, changes in the seabed and the different seasons on the characteristics and location of underwater unexploded munitions[195] (B5)

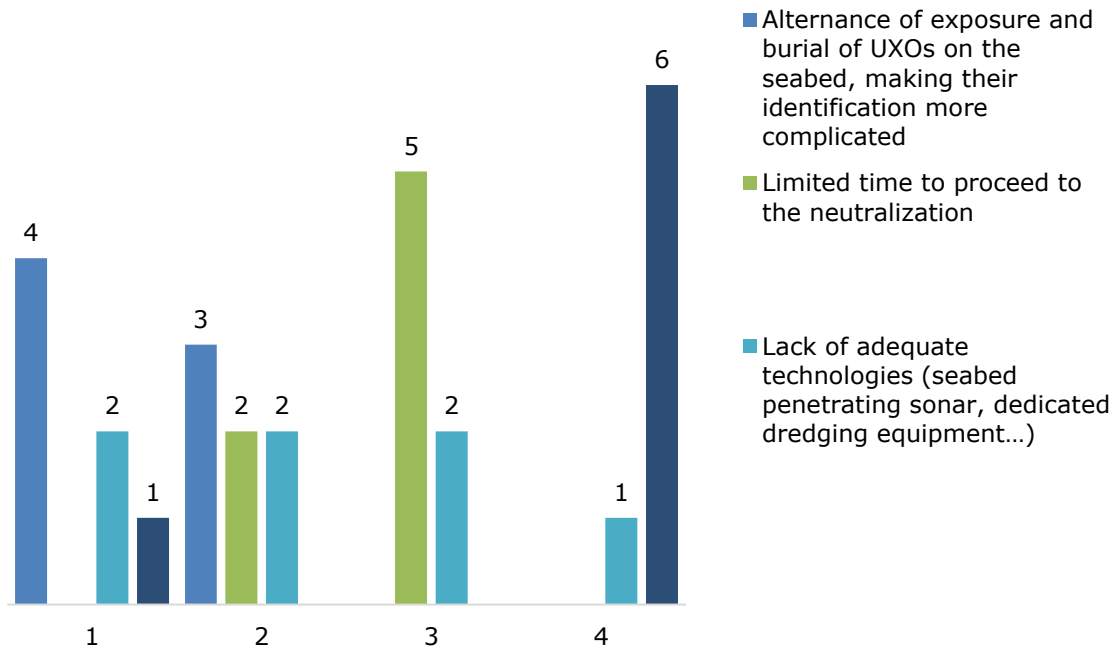


[194] N= 7
[195] N= 22

Figure 41 provides information on the most concerning challenges posed by unexploded underwater munitions. Respondents were asked to rank on a scale ranging from 1 (most concerning) to 4 (least concerning) a series of **challenges posed by unexploded underwater munitions**, and in particular (i) alternance of exposure and burial of UXOs on the seabed, making their identification more complicates; (ii) limited time to proceed to neutralisation; (iii) lack of adequate technologies (seabed penetrating sonar, dedicated dredging equipment, etc).

Respondents agree that *alternance of exposure and burial of UXOs on the seabed* is the most concerning (4 respondents) and the second most concerning challenge (3 respondents). The *limited time to proceed to the neutralisation* was deemed the third most concerning challenge by 5 respondents. Respondents also indicated that the lack of adequate technologies is the most concerning (2 respondents), the second most concerning (2 respondents) and third most concerning (2 respondents) of the challenges posed by unexploded underwater munitions. A respondent mentioned that the lack of budget/resources and the will to address the issues as 'other issues' and considers it the most concerning challenge. Finally, 6 respondents indicated that 'other risks' are the least concerning risks.

Figure 41. Most concerning challenges posed by unexploded underwater munitions[196] (B6) – from most (1) to least (4) concerning



4.1.4.1 Capabilities employed for identification, monitoring and disposal of sea-dumbed unexploded munitions

Figure 42 provides information on the **authorities responsible** in their respective Member State for the (i) **identification** (i.e. seafloor surveys, in-situ visual inspection), (ii) **monitoring** (i.e. seafloor surveys, in-situ visual inspection), and (iii) **disposal** (i.e. in-situ neutralization and/or destruction, displacement in a safer disposal location, recovery and destruction on-shore, etc.) of underwater unexploded munition. Overall, 9 respondents each answered to the question about the authorities responsible during the identification, monitoring and disposal phases.

[196] N= 7

Law enforcement and military authorities were identified as the main authorities responsible for the identification (8 respondents), monitoring (4 respondents) and disposal (8 respondents) of underwater unexploded munition by almost all the respondents in their respective Member States. Whilst the main authorities responsible for identification and disposal are law enforcement authorities, in Germany the responsible authority in these two phases is the SH State Police. When it comes to the monitoring phase, there are different authorities involved across EU Member States. Indeed, in Malta the responsible authorities for monitoring underwater unexploded munitions are the local and port authorities, whilst in Belgium are the Baltic ordinance safety board and the HELMOC. In Belgium, the federal and regional public services are the responsible authorities with the exception of one WWI disposal area where competent authorities are the environmental services. Finally, a respondent mentioned that Spain does not have a monitoring phase.

Figure 42. Authorities responsible for the identification, monitoring and disposal across EU Member States (C1)

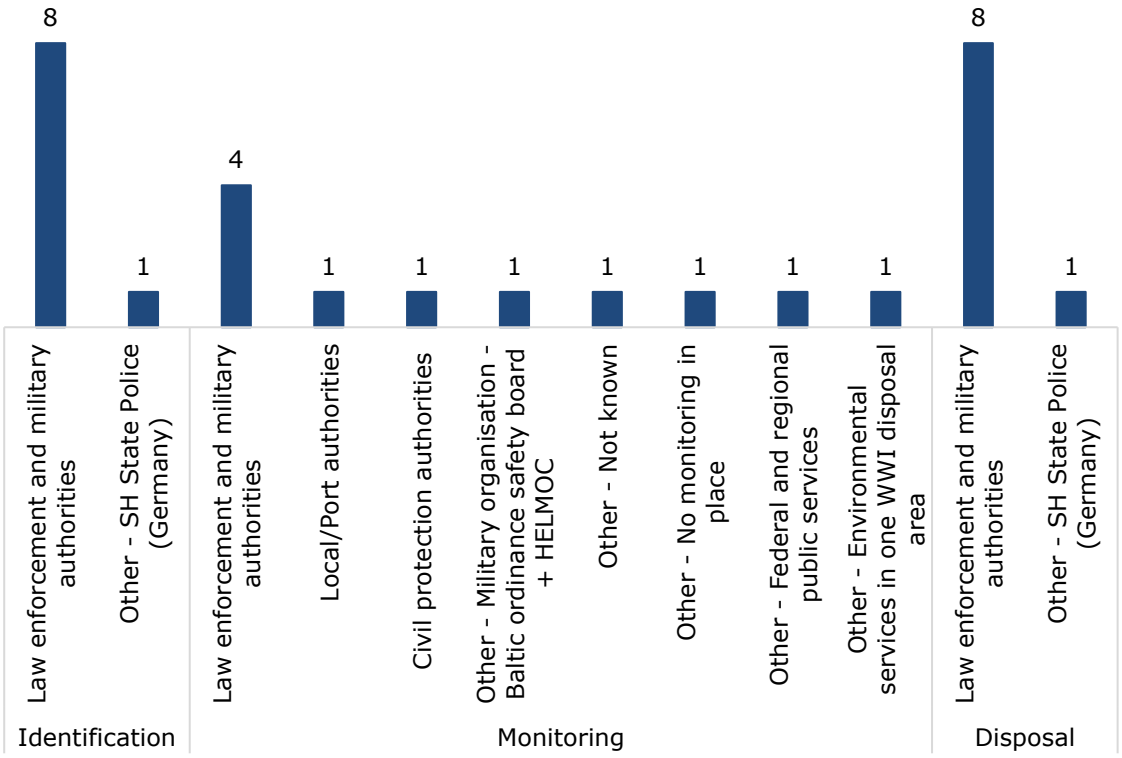


Figure 43 provides information on sea environment users' awareness of who to contact in case of UXO encounters. Out of 22 respondents, 12 respondents (or approximately 55%) believe that the users of the sea environment are *much aware* on who to contact in case of UXO accidental encounters. On the other hand, 5 respondents (23%) believe that the sea environment users are generally not aware while only 2 respondents (9%) believe that they are very much aware.

Figure 43. Sea environment users' awareness of who to contact for UXO[197] (C2)

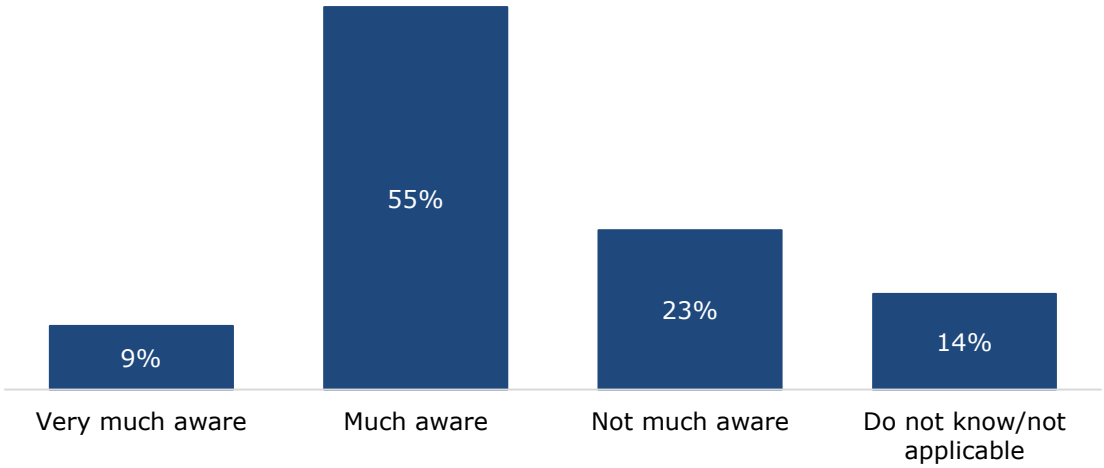
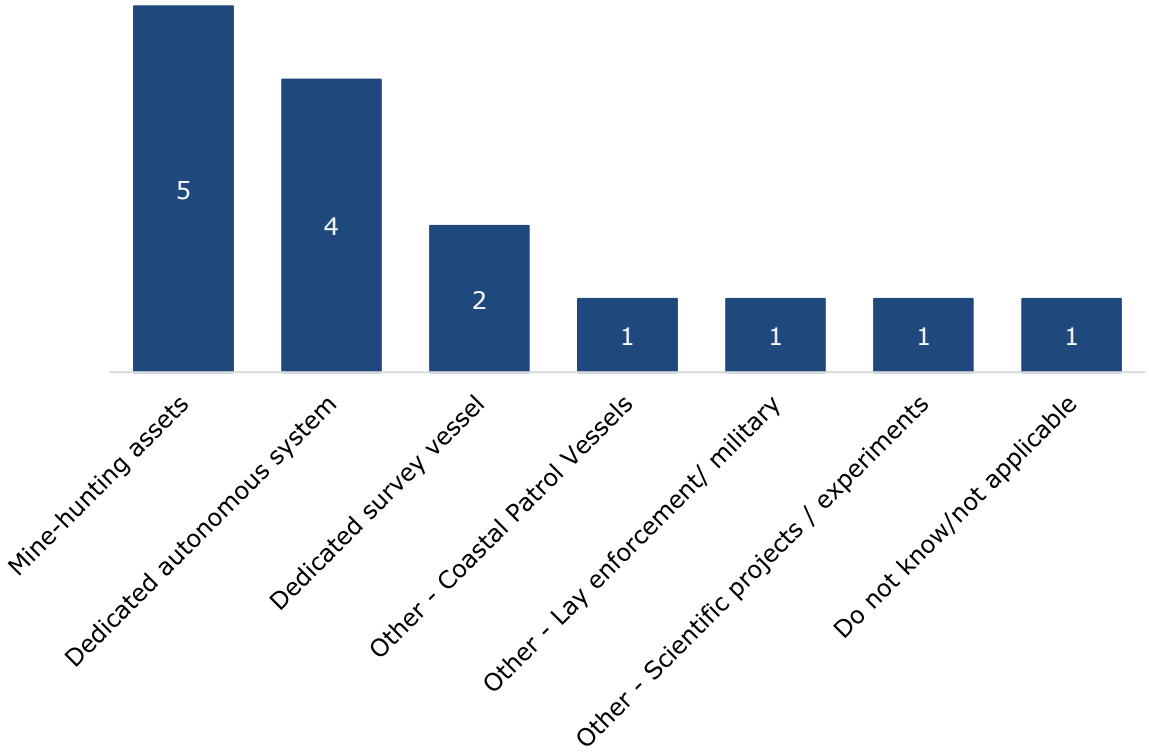


Figure 44 and Figure 45 provide information on the main assets/equipment and sensors used for the in-situ identification of underwater unexploded munitions. The **main assets used for the in-situ identification** of underwater unexploded munitions are *mine-hunting assets* (5 respondents, out of 7), followed by *dedicated autonomous system* (4 respondents), *dedicated survey vessel* (2 respondents). Other assets mentioned are law enforcement/military (1 respondent), scientific projects/experiments (1 respondent) and coastal patrol vessels (1 respondent). Instead, the **main sensors used for the in-situ identification** are *EODs* (5 respondents), followed by *high-frequency sonars* (4 respondents), *electro-optic camera* (3 respondents), *magnetometer* (2 respondents), *chemical detector (on-site/laboratory)* (2 respondents) and *AUV-based optical camera* (1 respondent). As regards the **periodicity**, whilst 5 respondents indicated that they carry out *on-demand surveys related to specific off-shore projects*, 3 respondents mentioned that they do *not conduct survey and that the identification is limited to accidental recoveries tracing*. Also, a respondent indicated that *seabed of TTW is regularly surveyed in national plans* (1 respondent, another one that the in-situ identification is carried out *by NAVY plans every year*, and another respondent mentioned that they conduct *scientific projects/experiment*).

[197] N= 22

Figure 44. Main assets/equipment used for the in-situ identification of underwater unexploded munitions[198] (C3)



[198] N= 7.

Figure 45. Main sensors used for the in-situ identification of underwater unexploded munitions[199] (C3)

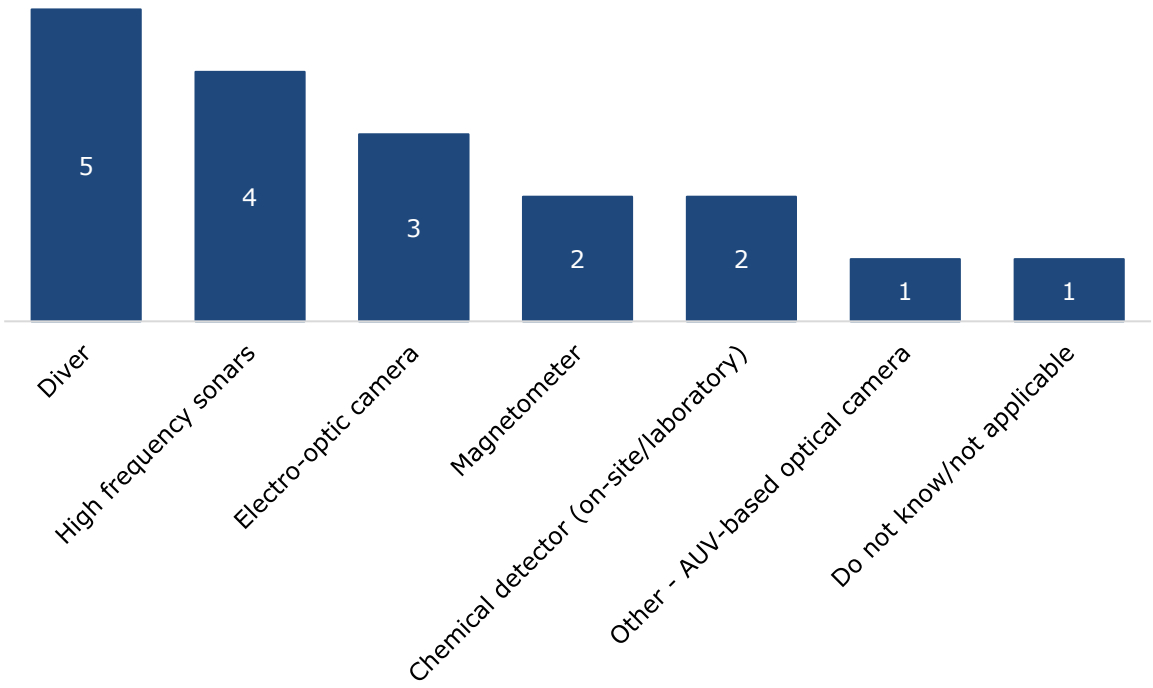


Figure 46 provides information on the main assets/equipment used for the monitoring of underwater unexploded munitions. According to most respondents, the main assents/equipment used for the **monitoring of underwater unexploded munitions** are *the reporting and analysis of accidental recoveries* (3 respondents, out of 7). These are followed by the p*ermanent surveillance of the marine activities' exclusions* (2 respondents), *on-site assessment re-iteration with assets/sensors used for identification* (2 respondents) and *regular visual inspection of beaches* (1 respondent). Respondents were also asked to specify whether this includes a **specific surveys of pollutants**. An equal number of respondents indicated that they do not know (2 respondents, out of 6) and the *deployment of periodic sensors* (2 respondents).

[199] N= 7.

Figure 46. Main assets/equipment used for the monitoring of underwater unexploded munitions[200] (C4)

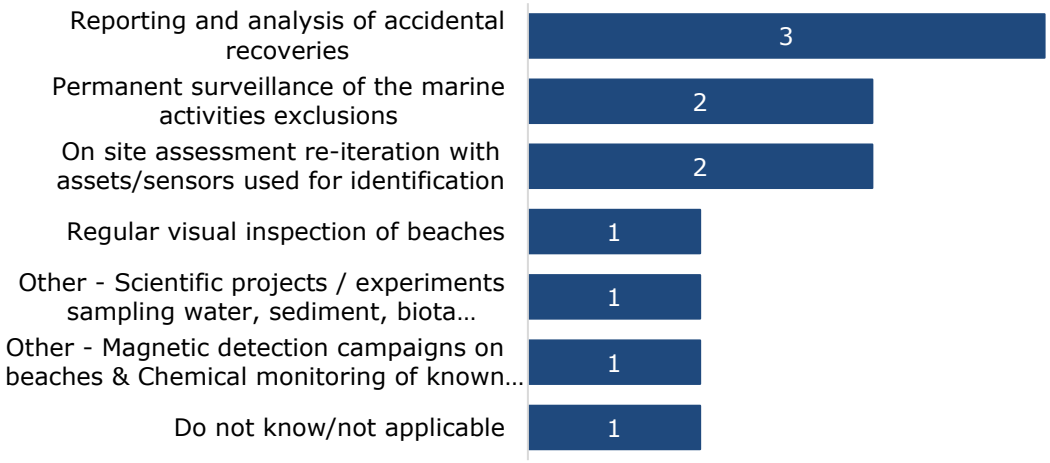


Figure 47 provides information on the main assets/equipment used the **disposal of underwater unexploded munitions**. Out of 7 respondents, 6 indicated that the main equipment used to this end are *specialized drivers*. These are followed by advanced underwater robotics (4 respondents) and *explosion effect mitigation equipment* (e.g. bubble curtains) (1 respondent). Another respondent also mentioned NAVY EOD.

Figure 47. Main assets/equipment used for the disposal of underwater unexploded munitions[201] (C5)

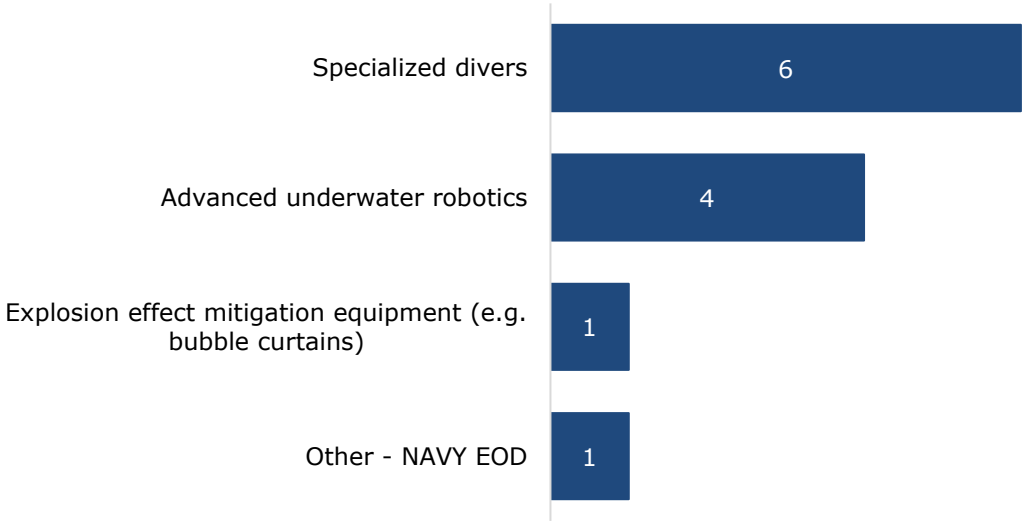


Figure 48 provides information on the UXO **disposal strategy**. The *displacement in a safer place* was mentioned by most respondents (5 respondents, out of 7), followed by *triggering on-site explosion* (4 respondents) and *removal to be disposed onshore* (3 respondents). *Low-order controlled explosion* and *complete on-shore process in-place for safe destruction/recycling of chemicals and explosives* were also indicated by 2 respondents each. A respondent also mentioned that WU UXO is normally moved to shallow waters before destruction to reduce the effect of the pressure wave, and another one highlighted that the capacity onshore is not sufficient.

[200] N= 7
[201] N= 7

Figure 48. UXO disposal strategy[202] (C5)

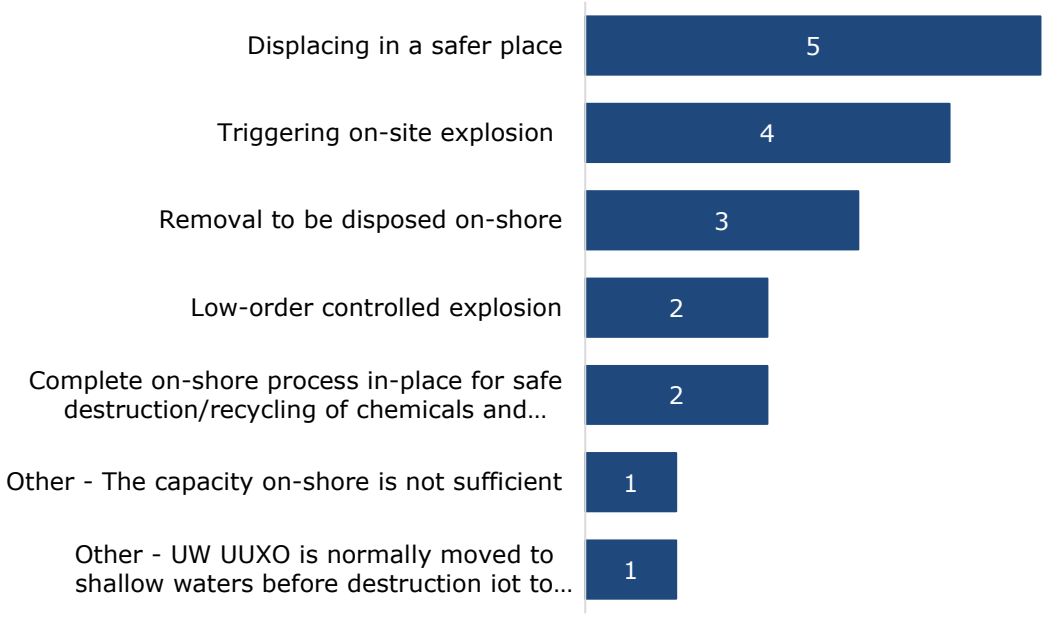
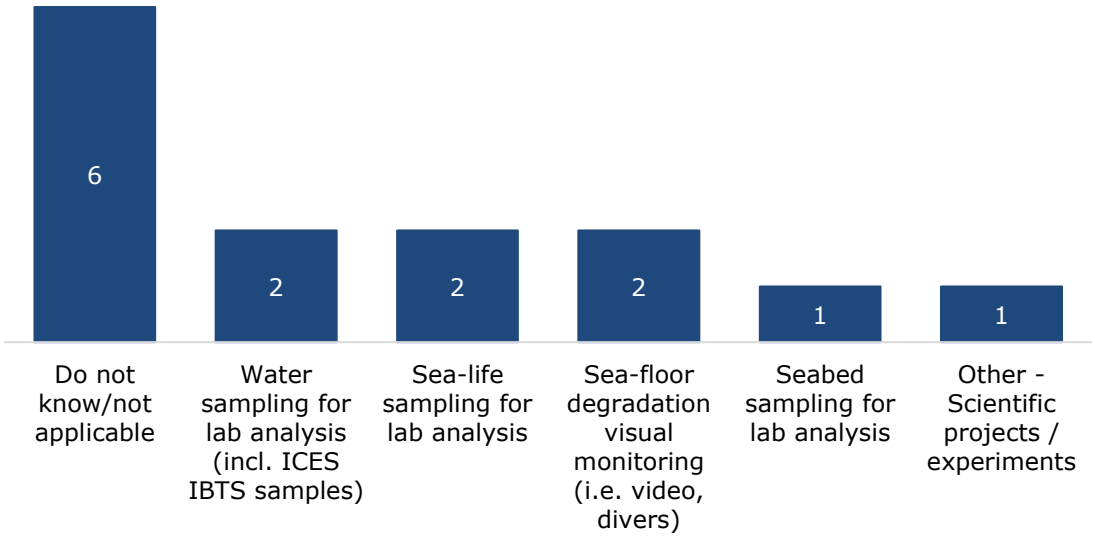


Figure 49 provides information on the **protocol used for the monitoring of marine pollution in the vicinity of UXO depots**. Most respondents (6 respondents, out of 9) indicated that they do now know what the **main protocols** are. According to the other respondents instead, the main protocol used are the *water sampling for lab analysis (incl. ICES IBTS samples)* (2 respondents) and the *sea-floor degradation visual monitoring (i.e. video, drivers) (*2 respondents). A minority of respondents also indicated *sea-life sampling for lab analysis* and *seabed sampling for lab analysis* (1 respondent each).

Figure 49. Protocols used for the monitoring of marine pollution in the vicinity of UXO depots[203] (C6)



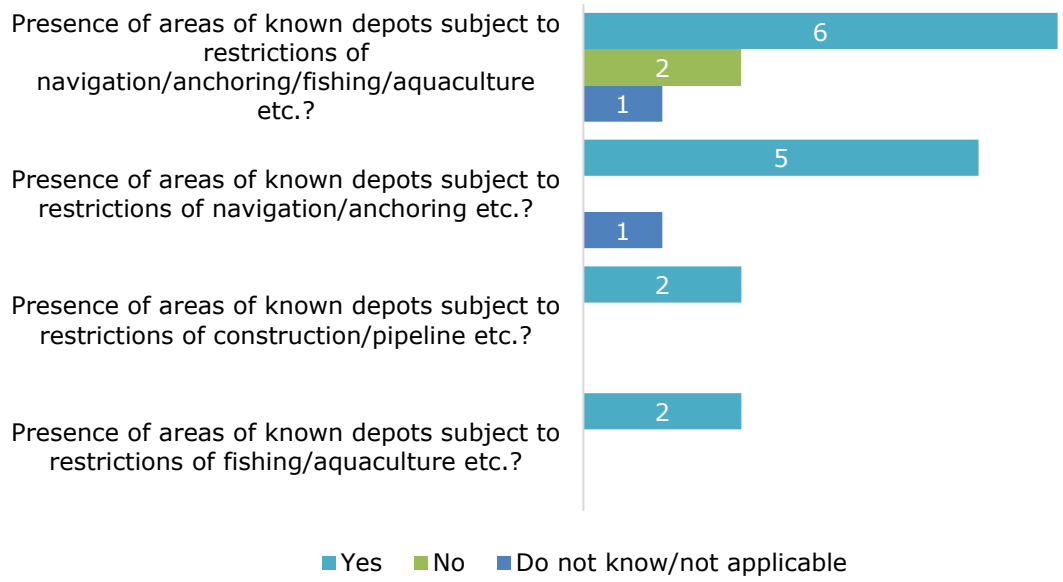
[202] N= 7
[203] N= 9

Only 3 respondents answered to the question about the **specific gaps in terms of capabilities** to deal with underwater unexploded munitions. While one of them mentioning the political decision for remediation of highly contaminated marine areas and the relevant technologies available, another one referred to the lack of rules to allow civilian companied to conduct EOD UW. Finally, one respondent indicated the lack of digital exchange of data between UXO databases of Coastguard (responsible for reporting and maritime safety messages) hydrographic office (responsible for notice to mariners) and navy (responsible for neutralising or disposal).

Furthermore, most respondents (4 respondents, out of 9) referred that their Member States (BE, DE, LV, RO) have **procedures in place for decontamination of chemical warfare agents with limited impact to the environment.** More specifically, in BE there are treatment facilities available on mainland and the EOD team leader conducts specific threat assessments. In DE the system for decontamination is provided by Geka Munster[204], whilst RO applies the International Convention for the Prevention of Pollution from Ships (MARPOL).[205] .

Figure 50 provides information on the **presence of areas of known depots subject to restriction**. 6 respondents (out of 9) indicated that there are areas of known depots subject to restrictions of *navigation/anchoring/fishing/aquaculture etc*. against 2 respondent that mentioned that there aren't areas subject to these types of restrictions. Only 2 respondents answered to whether there are areas of known depots subject to *restrictions of construction/pipeline* and *restrictions of fishing/aquaculture etc.* They both answered in the affirmative in relation to both restrictions. Finally, almost all respondents (5 respondents) indicated that there are areas of known depts subject to *restriction of navigation/anchoring*.

Figure 50. Presence of areas of known deports subject to different restrictions[206] (C9)



[204] https://www.geka-munster.de/home/
[205] International Maritime Organization, 1973. International Convention for the Prevention of Pollution from Ships (MARPOL). Available at: http://library.arcticportal.org/1699/
[206] N= 9

4.1.4.2 Information about the practices in dealing with accidental recovery of dumbed munitions at sea in different maritime communities

Figure 51 provides information about the **formal reporting protocols/procedures in place in case of accidental discoveries**. Most respondents (15 respondents out of 22, or 68%) answered that they have protocols/procedures in place, whilst 2 respondents (or 9%) answered that they do not have protocols/procedures in place.

Figure 51. Formal reporting procedures/protocols in place in Member States[207] (D1)

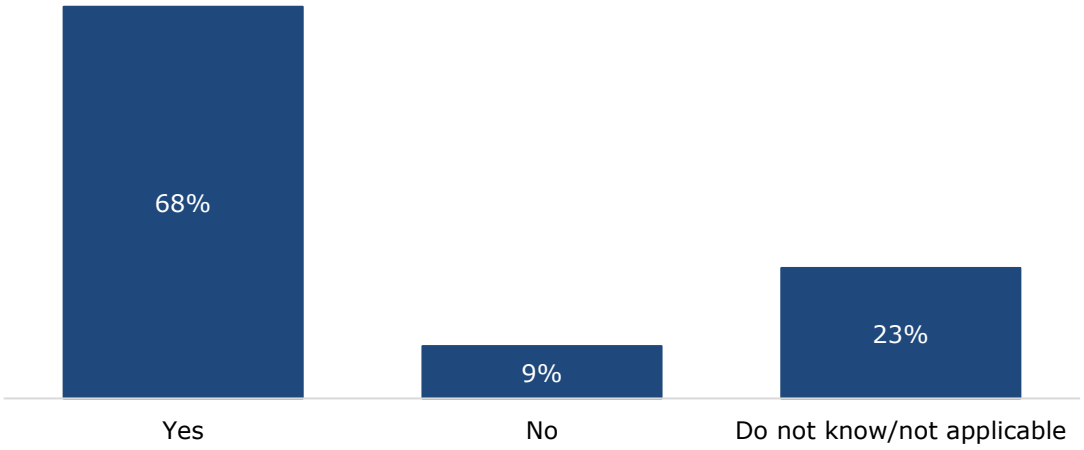


Figure 52 provides information on the types of protocols/procedures in the Member States having formal reporting protocols/procedures in place in case of accidental discoveries. The **main types of protocols/procedure used** are *general guidelines (i.e. limited to a standard incident declaration form)* (10 responses, out of 15 respondents). They are followed by *Detailed guidelines (i.e. identifying UXO type and associated risks; taking immediate risk reduction measures)* (6 responses), *Standard Operating Procedures for meeting baseline technical and operational security measures* (6 responses), *Standard Operating Procedures for meeting more stringent and additional technical and operational measures in case of higher level of threats* (6 responses), and *Standard Operating Procedures and methods for deciding which measures to implement* (6 responses).

[207] N= 22

Figure 52. Types of protocol/procedures in place in Member States[208] (D1.1)

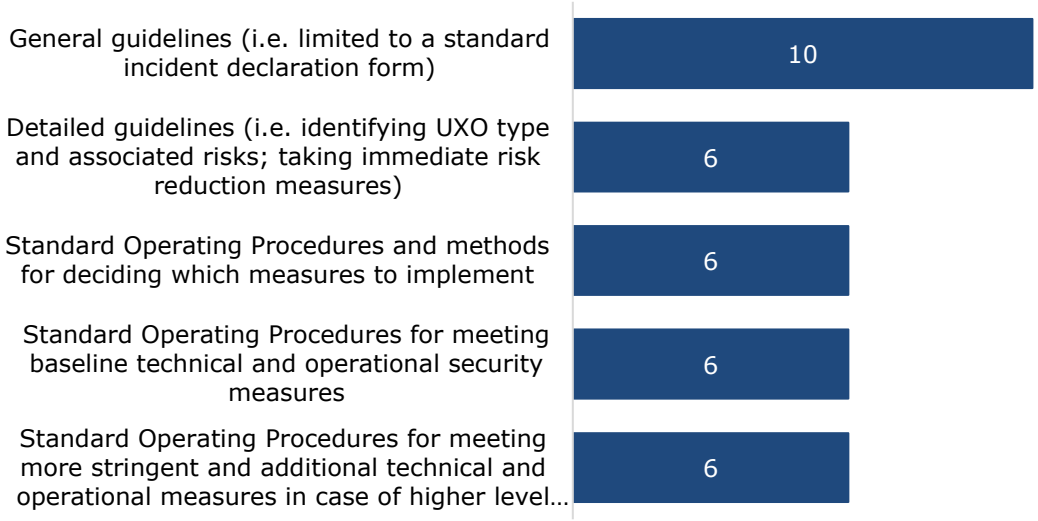
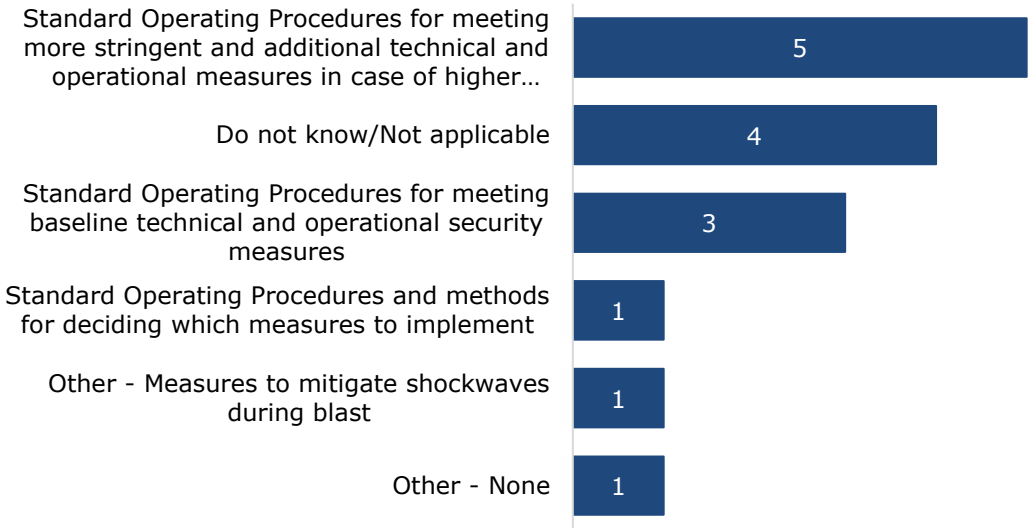


Figure 53 provides information on which **protocols/procedures need to be improved**. Most respondents (5 responses, out of 14 respondents) indicated that the *Standard Operating Procedures for meeting more stringent and additional technical and operational measures in case of higher level of threats* should be improved. Other protocols and procedures to improve are the *Standard Operating Procedures for meeting more stringent and additional technical and operational measures in case of higher level of threats* (3 responses), the *Standard Operating Procedures and methods for deciding which measures to implement* (1 response) and the *measures to mitigate shockwaves during blast* (1 response). According to one response, none of these protocols/procedures need to be updated.

Figure 53. Current procedures/protocols to be improved[209]



In order to **improve these procedures/protocols**, the respondents suggested the following measures: shock mitigation procedure and availability of technical assets to protect infrastructure in specific cases (1 respondent); adoption of standard NATO procedures (1 respondent); Re-adjust interfaces of coordination between entities and

[208] N= 15
[209] N= 14

to update SOP regarding state of the art technology / procedures (1 respondent); write the SOP(1 respondent); harmonized procedures and one focal point for launching the contingency response(1 respondent); move the ammunition to shallow water in order to have effective barriers to protect the environment from the shockwave (1 respondent); exchange of data between UXO databases of different government agencies (1 respondent); procedures for dealing with chemical agents (1 respondent); establishment of a national group of SME's to look into these matters (1 respondent); simplification of procedures so as to be well-understandable (1 respondent).

Figure 54 provides information on the **frequency of removals of underwater unexploded munitions** after accidental encounters. 4 respondents (out of 9) indicated that they occur in more than 75% of the cases whilst 2 respondents mentioned that they occur in less than 25 % of the cases.

Figure 54. Frequency of removals of underwater unexploded munitions after accidental encounters[210] (D2)

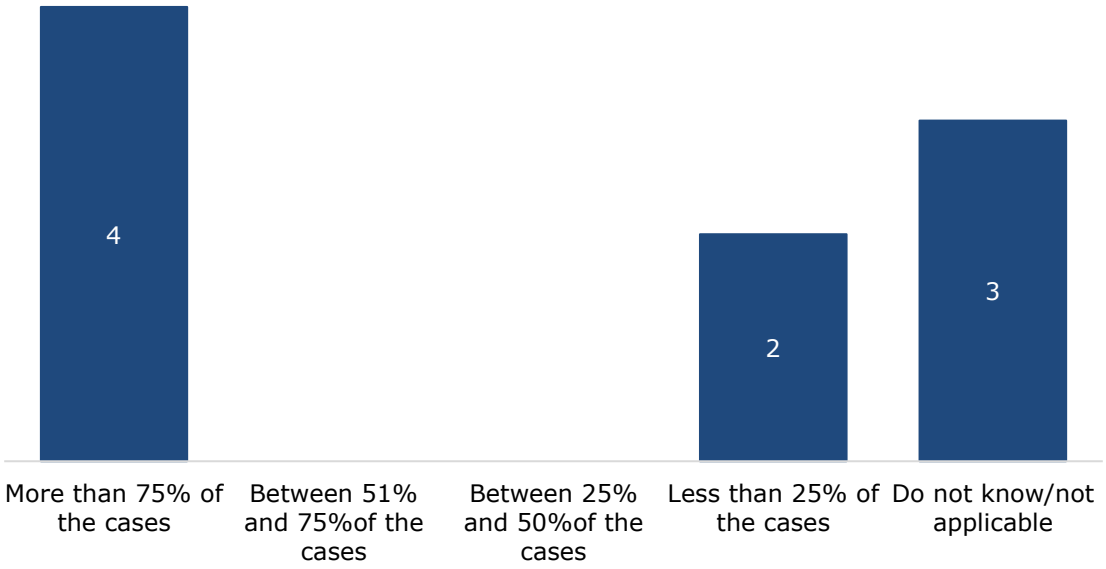


Figure 55 provides information on the **availability of financial rewards and/or compensation for the reporting of unexploded munition by civil stakeholders**. While almost all respondents indicated that there are no **financial rewards and/or compensations systems for civil stakeholders,** 2 respondents (or 9%) mentioned that in France there are financial rewards and/or compensation systems. More specifically, they indicated that in France there are not only rewards/compensation for reporting or providing information but also sanctions/penalties in case of non-reporting.

[210] N= 9

Figure 55. Availability of financial rewards and/or compensation for the reporting of unexploded munitions by civil stakeholders[211] (D3)

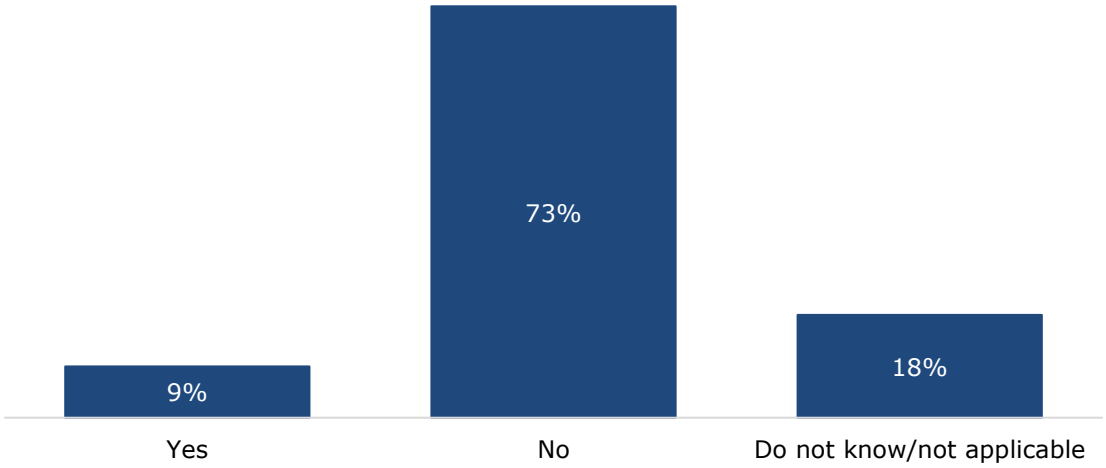


Figure 56 provides information on the **good practices related to accidental recoveries**. *The joint operational exercise (e.g. military international cooperation)* is the most used in the respondents' Member States (6 responses, out of 9 respondents). This is followed by *cross-border training and specialisation of EOD staff* (5 responses), *establishment of multilateral platforms for information exchange* (4 responses), *cooperative RT&D to develop more effective capabilities* (2 responses), and *regular dedicated UXO survey campaigns* (2 responses). A minority of respondents also indicated *UXO shared trial facility and technologies/procedures benchmarks* (1 response) and *scientific experiments* (1 response).

[211] N= 22

Figure 56. Good practices related to accidental recoveries adopted in the respondents' Member States[212] (D4)

Figure 57 provides information on the current **good practices that should be improved**. According to 4 responses (out of 7 respondents), the *establishment of multilateral platforms for information exchange* should be improved. A minority of the respondents indicated that also the following practices should be improved: *regular dedicated UXO survey campaigns* (2 responses), *joint operational exercises (e.g. military international cooperation)* (2 responses), *cross-border training and specialisation of EOD staff* (2 responses). According to one respondent, also the UXO shared trial facility and technologies/procedures benchmarks should be improved. In order to make these practices/procedures more effective, the respondents suggested the following measures: *information shearing amongst counties and members of different organisations* (1 response), *language skills and the will of competent authority to cooperate with regard to improved procedures* (1 response), *continuous training and prevention of loss of knowledge in EOD community* (1 response), *political support for further integration of different coast guard partners into one Coast Guard Centre* (1 respondent), sh*ared budgets for joint project*s (1 respondent), *flexible and innovative data exchange systems* (1 respondent).

[212] N= 9

Figure 57. Current good practices that should be improved[213] (D4.1)

Figure 58 provides information on the **best practices of disposal/removal with limited environmental impact**. The following best practices are the most used in the respondents' Member States: *mitigation measures when conducting in-situ destruction* (7 responses out of 9 respondents), *access restrictions and warning signs* (6 responses), *safety protocols* (5 responses). These are followed by *dedicated shore facility for neutralisation, dismantling and effective decontamination* (3 responses).

Figure 58. Best practices of disposal/removal with limited environmental impact used in the respondents' Member States[214] (D5)

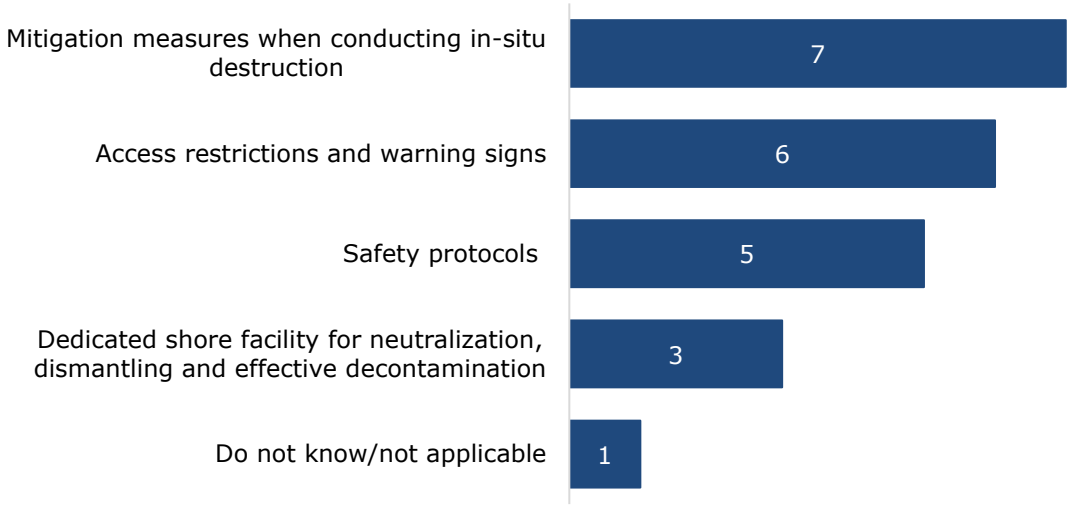
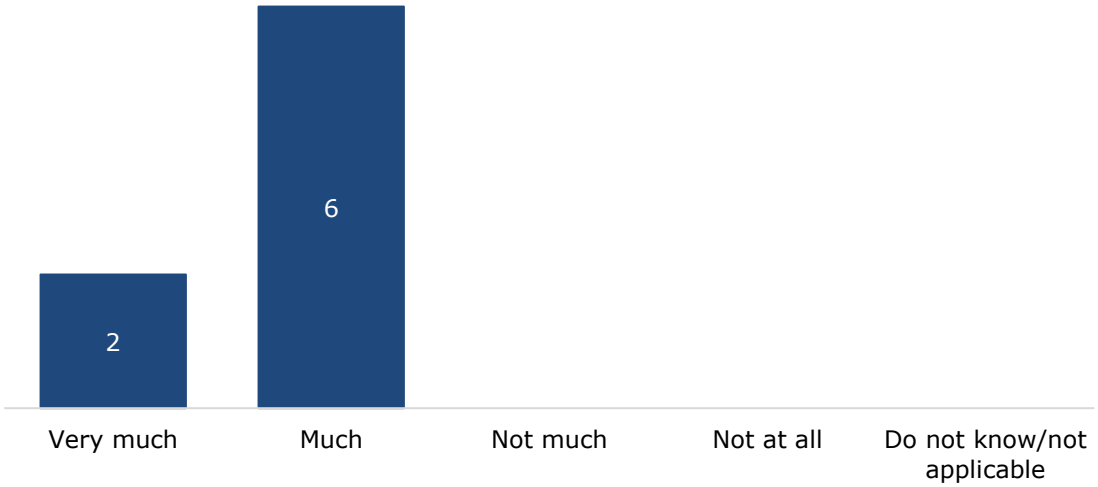


Figure 59 provides information on the extent to which the above-mentioned practices achieve their goal in the respondents' view. According to the respondents, these practices *very much* (2 respondents, out of 8) and *much* (6 respondents) achieve their goal(s).

[213] N=7
[214] N=9

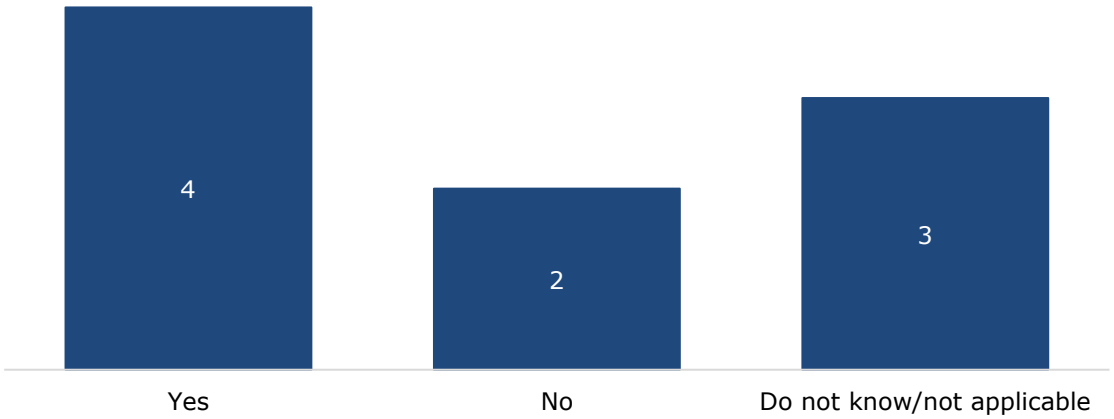
Figure 59. Extent to which these practices achieve their goal(s)[215] (D5.1)



4.1.4.3 International, national, and multilateral cooperation in the identification, assessment, management, and risk mitigation of underwater unexploded munitions

Figure 60 provides information on the presence of bilateral and/or multilateral procedures in place for identifying, assessing, managing and/or mitigating the risks of underwater unexploded munitions. According to 4 respondents out of 9, their Member States (BE, LV, LT) have specific **bilateral/multilateral procedures in place**. More specifically, both the Lithuanian and the Belgian respondent mentioned that they follow NATO procedures. In addition to NATO procedures, one Belgian respondent also indicated that they are part of the ABNL cooperation.

Figure 60. Presence of bilateral/multilateral procedures in place for identifying, assessing, managing and/or mitigating the risks of underwater unexploded munitions[216] (E1)



The 4 respondents who indicated the presence of bilateral and multilateral procedures in place in their Member States were also asked whether – in their opinion - these

[215] N=8
[216] N= 9

procedures are scalable at EU level and could be extended to other non-EU countries. When it comes to the EU level, 3 respondents do not know and 1 respondent answered in the affirmative. In terms of non-EU countries instead, whilst 3 respondents do not know, 1 respondent answered in the negative.

Annex 5: Relevant capabilities for identification, monitoring and disposal of sea-dumped unexploded weapons - definitions

In mine warfare processes (and thus applicable to UXOs), **detection** refers to the process of scanning the seabed (and the water column, in case of mines) up to the point of detecting a 'mine-like echo' (MILEC), with sufficient detail to declare it a 'mine-like contact' (MILCO). The challenge is to ensure:

- High probability of *detection* (PD), as each explosive object left undetected in an area represents a risk for later operations;
- Mitigation of *false-alarm* risks (PFA) Tagging high numbers of inert objects (e.g. rocks, sea litter) as MILCO will increase the cost of identification operations;
- Satisfactory seabed scanning productivity (generally expressed in km²/h), combining the 'swath' (width of the seabed scan) and the inspection speed;
- All of these parameters are interrelated (the swath is limited by the minimum sensor signal-to-noise ratio required for a sufficient PD/PFA; the speed is related to the sensor noise, etc.)

In mine warfare, the **classification** process consists of two main steps:

- Step 1: The object looks like an explosive artifact;
- Step 2: The object represents a concrete danger and requires immediate measures: either proceed immediately to identification and possible neutralisation, or declare the area a danger zone.

Identification covers the successive steps followed to determine the MILCO, including:

- Step 1: MILCO confirms the presence of a possibly explosive artefact;
- Step 2: it is a naval mine/torpedo/shell/bomb, etc. (category);
- Step 3: it is this type of… (e.g. a 155mm artillery shell) (type);
- Step 4: it is a conventional or a chemical weapon (CW) (sub-type);
- Step 5: in case of a CWA, the chemical is… (e.g. Adamsite);
- Step 6: condition and casing integrity (e.g. corroded, leaking);
- Step 7: the explosion triggering status is… (e.g. primed but not fused).

Monitoring refers to the regular assessment of known UXO depots, for example to update:

- Geo-location of known UXOs, or, at a broader scale, the current extent of the known depot (UXOs might be further dragged by fishing gear, currents, etc.);
- Loss or gain of sedimentary cover over the depot;
- Degree of corrosion of the UXO, integrity of the casing;
- Presence, level, extent of chemical pollution created by the depot.

Disposal includes any form of neutralisation to lower the risk created by the UXO:

- By detonating it on site after establishing a safety perimeter. This is the most common - although least environmentally friendly - method. It generally consists of triggering the detonation through the use of a dedicated explosive charge (i.e. shaped charge generating a plasma jet) able to transmit enough energy to the explosive compound to detonate;
- By deflagration - a technique based on a smaller shaped charge that, if successful, burns the explosive charge without causing a detonation ('low order' disposal). This technique is not reliable for historic UXOs, whose explosive compound ageing level cannot be anticipated – either it is significantly degraded and might not burn completely, or it remains as good as new and will detonate with its full original strength;
- By dragging the UXO out of its original location (further/deeper) if the on-site disposal appears too dangerous (to protect adjacent structures, highly protected species etc.). The UXO can then be safely disposed of, or simply brought to a depth out of reach for most human activities and less prone to corrosion;

- Some countries (e.g. Germany) allow UXOs to be brought onshore for disposal, but this remains a somewhat unusual practice.

Depending on the classification system used, the operations might not be completed in a continuous sequence, as they might require the involvement of divers or the deployment of other assets. For example, the first step can be achieved with acoustic sensors (high frequency sonar imagery), then optic sensors and, ultimately, visual inspection.

Annex 6: Responsible authorities involved in the management of UXO

This annex provides an overview of the authorities involved in the management of recovered – voluntary or accidental – underwater UXOs. 'Management' is understood here as:

- Authorities responsible for coordinating and identifying underwater UXOs;
- Procedures for reporting and monitoring UXOs;
- Environmental implications.

4.1.5 Authorities responsible for coordination and identification

Belgium

In Belgium, the responsibility for coordination and identification of UXOs is organised at two levels:

- Overall responsibility for accidentally encountered UXOs lies with the **Belgian Coast Guard** (MRCC), which should also be the first point of contact. The Coast Guard is then responsible for contacting the joint 24/7 EOD Belgian and Dutch Navies team (Beneficial Cooperation – EOD task force), responsible for disposal;
- The province of Flanders – adjacent to the North Sea – is responsible for monitoring and preventive action. A private UXO detection company[217] surveys beaches after storms (when UXOs could have washed ashore) or when a first encounter with a UXO has been signalled.

Bulgaria

The **Bulgarian Navy** is the main authority in Bulgaria for the identification and disposal of UXOs. Its involvement is not always triggered by the same procedure, however[218]:

- If tourists or divers encounter a UXO, they are required to alert 112 (emergency number). The information is transmitted to the Ministry of the Interior, which alerts the governor, who requests the involvement of the Navy;
- If fishers encounter a UXO while carrying out their activities at sea, they must first alert the maritime authorities, which will then request the involvement of the Navy;
- In the case of an investment project, such as ports, the port authorities must request the Navy's assistance;
- Traffic control is involved where an area must be closed off in order to deal with the UXO.

France

In France, monitoring and disposal of sunken munition is organised at different levels:

- **Three Sea Prefects** (*Préfets de la Mer*) acting under the direct authority of the *Sécrétariat Général de la Mer* (SGM), itself under the authority of the Prime Minister's Office[219]. Their role is to **implement interministerial coordination efforts** between the French Navy (*Marine Nationale*), the key actor responsible for monitoring and disposal of UXOs, and other relevant maritime entities (civilian security, port authorities, Ministry of the Environment, Maritime Affairs/Fisheries Directorate, etc);
- The **French mine action force** (Ministry of Defence - *Ministère des Armées*). Three specific **UXO teams allow for an immediate response** 24/7 at sea, on board civilian ships, on beaches and in naval ports;

[217] BE: *Service d'Enlèvement et de Destruction d'Engins Explosifs* (SEDEE) ; NL: *Dienst voor de opruiming en vernietiging van ontploffingstuigen* (DOVO).
[218] Interview with BG military authorities – BG 01.
[219] Interviews with FR national authorities – FR 08; FR MC – UXO specialist – FR 07.

- **Civil Protection** (under the Ministry of the Interior) is in charge of **other ports and civilian ships inland**;
- *Centres Régionaux Operationnels de Surveillance et de Sauvetage* (**CROSS**) are the French MRCC attached to the Sea Prefect.

Germany

In Germany, responsibility for munitions in the marine environment is shared between five coastal state governments (*Länder*) and the federal government, based on where the relevant object is found. **Federal authorities** ensure defence, including civil protection, as well as the integrity of the State border, both on land and at sea. In addition, federal authorities oversee the safety of sea traffic throughout Germany. The main federal authorities are:

- **German armed forces** provide EOD services for their own munitions and those of NATO partners, and objects produced after May 1945 by foreign nations;
- **German federal police EOD services** focusing on improvised explosive devices (IEDs) (airports and rail system) and trafficking of explosives or CBRN material[220].

All State governments have authorised one specific entity to take action if munitions produced before May 1945 are encountered (on land and in fresh or sea waters)[221]. Identification, monitoring and disposal of recovered warfare material is handled by the locally responsible State service. Private service providers are contracted and closely supervised by State governments on a task-specific basis. None of the coastal State's EOD services are equipped to handle chemical warfare agents. Instead, assistance is requested from the CBRN squad of the closest county fire service, armed forces, or a GEKA- Munster[222] task force[223].

Italy

In Italy, responsibility for monitoring and disposal of (non-chemical) sunken munitions is divided into two main categories[224]:

- For **'occasional disposal'** – neutralising (not exploding) an accidentally encountered UXO once it has been identified falls within the responsibility of the Ministry of Defence and is coordinated by **Geniodife**. Geniodife is responsible for requesting the intervention of the ***Servizio Difesa Antimezzi Insidiosi*** (SDAI)[225] of the Italian Navy for neutralisation;
- For '**systematic disposal'** – monitoring within a specific area in Italian waters (sea, lakes, internal waterways falls within the responsibility of Geniodife, which calls upon the SDAI to coordinate the neutralisation of the identified UXO[226]. However, the actual neutralisation is carried out by private companies accredited by the Ministry of Defence. Systematic disposal can take place either at the

[220] Other authorities include: German Customs; German Waterways Administration; German Federal Maritime and Hydrographic Agency.
[221] The legal bases are State directives, and the responsible entity varies: i) State police (Schleswig-Holstein, Bremen); ii) Metropolitan fire department (Hamburg); iii) land survey administration (Lower Saxony); iv) civil protection (Mecklenburg-Western Pomerania).
[222] Company for the Disposal of Chemical Warfare Agents and Remnants of War (https://www.geka-munster.de).
[223] Interview with DE NGO/academia – DE 01.
[224] Interview with IT MC – UXO specialist – IT 01.
[225] Defence service for action against dangerous means.
[226] Coordination here implies determining procedures for disposal and training disposal units, if necessary.

request of someone who is monitoring for a wide variety of reasons, or for the purposes of building (e.g. ports)[227].

In both cases, prefects of the relevant areas are responsible for coordinating the activities of the actors involved in the disposal (e.g. closing transport/transit, getting permissions to move the UXO if necessary for the disposal).

Disposal of chemical munitions falls within the responsibility of the *Civitavecchia NRBC* unit within the Ministry of Defence. Even when the UXO was encountered and identified underwater, it is transported to Civitavecchia to be disposed of according to very specific procedures.

Neutralisation of an encountered UXO is **not mandatory** in the context of risk assessment prior to infrastructure works. If a UXO is identified, it is the responsibility of the entity in charge of the infrastructure project to decide whether disposal will take place or not.

Lithuania

In Lithuania, the first point of contact in the event of an accidental encounter with a UXO is the **MRCC**, which is in charge of search and rescue. Subsequently, responsibility for handling UXOs is divided in two[228]:

- If the UXO was encountered by the military or within an area under military responsibility, the Lithuanian Navy is responsible;
- If the UXO was encountered by civilians, the civilian explosive ordnance disposal teams is responsible.

The Netherlands

In the Netherlands, the procedures of UXOs investigation, surveying and identification can be initiated in two ways:

- Persons or organisations intending to carry out construction or infrastructure plans in a certain area are obliged to be aware of the possible presence of UXOs in the area;
- A municipality's executive board can decide to proactively track and dispose of UXOs (under Chapters X and XI of the Dutch Municipalities Act, which lay out responsibilities in terms of public order and security)[229].

Certified companies can be hired by the responsible entities to undertake tracking[230]. For disposal, maritime **UXO operations** fall solely within the purview of the Netherlands EOD Authority, which is part of the Ministry of Defence[231]. The Authority is also alerted (usually by the Coast Guard) in the event of accidental recovery.

[227] Risk from UXOs introduced in: Legislative Decree 66/2010 establishes the need to look for and neutralise or neutralise accidentally encountered UXO; Law 177/2012 establishes that for building sites it is mandatory to carry out a risk assessment.
[228] Interview with LT military authorities – LT 01.
[229] Municipality of Dordrecht (2010). World War II Explosives detection and disposal manual (*Handleiding opsporing en ruiming explosieven Tweede Wereldoorlog*); Ministry of the Interior and Kingdom Relations (2018). Advice assessment framework and knowledge centre for conventional explosives (*Advies afwegingskader en kenniscentrum conventionele explosieven*); Municipality of Goirle (2020). Dealing with unexploded World War II explosives (*Beleidsnota Omgaan met niet-gesprongen explosieven uit de Tweede Wereldoorlog*). Policy note; Ministry of Defence (2019). Questions asked by the members of the House, with answers given by the government (*Vragen gesteld door de leden der Kamer, met de daarop door de regering gegeven antwoorden*); Dutch Coast Guard (*Kustwacht Nederland*), 2021. Explosives.
[230] Op. cit., Netherlands Enterprise Agency (2018); Op. cit., Netherlands Enterprise Agency (2020). See also footnote 229.
[231] See also footnote 229.

The Ministry of Defence and the Directorate-General for Public Works and Water Management, part of the Ministry of Infrastructure and Water Management, are both responsible for **munition dumps**[232]. The Ministry of Infrastructure and Water Management holds responsibility for water quality in the Netherlands, while the Directorate-General for Public Works and Water Management specifically monitors water quality near munition dumps[233].

Sweden

The interview carried out in the context of this Study[234] identified that responsibility for identifying UXOs and coordinating relevant action falls within the purview of the **Royal Swedish Navy**.

Reporting and monitoring

Belgium

There are no specific guidelines or rules on the steps to **report accidental encounters** with UXOs. Fishers are informed of the need to contact the MRCC (BE Coast Guard).

The risk of accidental encounters with UXOs is well known in Belgium, given that the seafloor is sandy and subject to numerous currents that cover and uncover UXOs very quickly. The government of Flanders, through a private company, carries out regular surveys, usually after heavy storms and as part of risk assessments for future infrastructure work. It bears the cost of these assessments.

Interviews[235] revealed that the Belgian Navy also conducts surveys of the North Sea floor, through its regular mine-hunting exercises with the Dutch Navy.

Bulgaria

There are no specific guidelines, rules or requirements for **reporting accidental encounters** with UXOs in Bulgaria[236]. Tourists and divers generally alert 112 and **fishers** report any sightings to the relevant maritime authorities.

One of the interviews[237] noted that vessels encountering items at sea that constitute a danger should alert the traffic control authorities, presumably to ensure that the suspected danger area is closed to traffic to avoid incidents.

Apart from accidental detections, **UXO surveys have been carried out in the Black Sea, within the framework of either investment or research projects**[238].

[232] Op. cit., Dutch Provincial Executive (2019).
[233] See also footnote 229.
[234] Interview with SE military authorities – SE 01.
[235] Interview with BE military authorities – BE 01.
[236] Ibid.
[237] Interview with BG MC – Transport and tourism entities – BG 05.
[238] Apart from accidental detection, UXO surveys have been carried out within the framework of investment projects in the Black Sea, including expansion of the Burgas Port (BG), South Stream Project (BG), Midia Gas Development Project (RO). Interview with BG military authorities – BG 02; See also Op. cit. Dimitriu R.G. et al. (2017); Fellows (2019). Fellows International Limited win Black Sea marine UXO survey contract (https://www.fellowsint.com/case-studies/fellows-international-limited-win-black-sea-marine-uxo-survey-contract).

France

The stakeholder interviewed did not highlight specific guidelines for **reporting** accidental encounters with UXOs. Fishers are well aware that if they do come across one such device, they must respect the following procedure:

- The fisher notifies CROSS;
- The fisher takes a photo of the ammunition and sends it directly to the Maritime Prefecture.

The Prefecture analyses the photo and, depending on the level of risk, orders a rapid intervention by the deminers on board, or asks the fisher to release the ammunition into the water at a defined location so that the deminers can process it later.

The government only pays for the discovery of ammunition if an immediate intervention by the deminers is ordered. Until 2016, the State systematically paid for any munitions found, financed by Germany, as war damage. The end of this provision led the French State to take over only if an urgent intervention was necessary.

Navigation channels into key ports, as well as anchorage areas in these ports, are **monitored** once or twice a year by the mine warfare force[239].

In the context of port or offshore works for renewable energies, private demining companies may be contracted by project owners to assess the risk posed by munitions. The contract holder is initially responsible for conducting the hazard study, which, together with the State services for history and documentation, aims to assess the risk of discovery of UXOs. When this work is complete, research and identification of UXO can be carried out by the companies in a second phase and in agreement with the State services, which remain responsible for the elimination of any devices discovered. In the event of a proven risk, and depending on its importance, another site may be chosen for these installations.

Research and identification of munitions can be also carried out by these private companies. However, the removal and destruction of discovered UXOs can be only carried out by State services.

Germany

Due to Germany's federal structure and the division of competences between the federal government and State governments, the Central Command for Maritime Emergencies (CCME)[240] serves as the 24/7 response centre, enabling central **access/reporting** by multiple maritime agencies in Germany. The German Waterways Police Reporting and Coordination Centre, integrated in CCME, serves as the national point of contact[241] for encounters of munitions at sea. The CCME was established in 2013 and by 2018, the numerous reports (from police, scientific bodies, private companies, etc.) had helped to register 21,546 objects[242].

The German Programme on Underwater Munitions has an expert advisory role. Under the Ministry for Energy Transition, Agriculture, Environment, Nature and Digitalisation (MELUND) of the State of Schleswig-Holstein, the programme is responsible for the publication of yearly reports on munitions contamination of German marine waters[243].

[239] Ibid.
[240] https://www.havariekommando.de
[241] https://www.schleswig-holstein.de/DE/UXO/EN/Themes/Subjects/Munitions_encountered.html
[242] https://www.schleswig-holstein.de/DE/UXO/Berichte/PDF/Berichte/ag_blano_fortschritt2018.html
[243] https://www.schleswig-holstein.de/DE/UXO/Berichte/berichte_node.html

Italy

There are no specific rules or guidelines for citizens to **report** 'occasional' accidentally encountered UXOs. The Ministry for the Environment has published a manual detailing the steps for fishers to follow if they encounter UXOs in the Southern Adriatic Sea[244]. The manual details and illustrates:

- Steps to take in order to ensure the safety of the whole crew;
- Different types of UXOs that can be encountered.

Should a UXO be accidentally encountered in Italian waters, the port authorities or **Guardia di Finanza** (law enforcement agency) is the first point of contact[245]. In the event of systematic disposal, the authorities responsible for risk assessment must contact the prefect when a UXO has been identified. The prefect is then responsible for contacting Geniodife.

The stakeholders interviewed[246] provided information on the status of **UXO monitoring** in Italian waters, which remains in its early stages. The Ministry of Defence, together with the Engineering Council, activated a georeferenced mapping of the areas undergoing UXO neutralisation. This work is being carried out progressively: when an entity is appointed as responsible for carrying out risk assessment and, if necessary, neutralisation of UXOs, they are required to provide the SDAI or the Italian Navy with the coordinates of the area to be surveyed. If a UXO is identified by the private company carrying out the risk assessment of the area, the Italian Navy intervenes to establish the UXO coordinates.

The Ministry of Defence collects the following information:

- Areas where risk assessments have already taken place and to what extent (e.g. depth of research);
- Exact location of the identified UXO.

This project is very much in its early stages and no draft or maps are publicly available as yet.

Lithuania

Interviews carried out for this Study highlighted that the only existing guidelines for **reporting** encountered UXOs focus on chemical UXOs. Published in the context of the CHEMSEA research project, they include a guidebook and a flyer on dumped chemical munitions, which are available to fishers who may come into contact with such material[247]. No additional special rules have been defined for other communities at sea, which should instead follow the information presented in the Workplan for the elimination of pollution incidents in the maritime area[248].

Beyond chemical munitions, there are no guidelines, although the following authorities are given responsibility for **monitoring**:

- Lithuanian Navy monitors its own UXO encounters;
- Lithuanian Transport Safety Administration (Hydrography Division) is in charge of all activities at sea;
- Port of Klaipeda administration.

[244] Op. cit., ICRAM (2001). Ministry of the Environment in cooperation with the Military CBRN unit.
[245] Interview with IT MC – UXO specialist – IT 01.
[246] Ibid.
[247] Interview with LT national authorities – LT 02.
[248] In Lithuanian only.

The Netherlands

The Ministry of Defence, in coordination with the Directorate-General for Public Works and Water Management (part of the Ministry of Infrastructure and Water Management), are responsible for **monitoring** UXOs in the country. Private companies can also be hired to assess the risk of UXOs prior to infrastructure works commencing.

The Netherlands' Ministry of Defence keeps a **register** of UXOs, but these data are not publicly available in their entirety[249]. In 2016, 20 UXOs were reported to the Dutch Coast Guard, of which 15 were destroyed and three were not found[250]. Maps have been created of detection and investigation areas[251].

Sweden

The stakeholders interviewed the Swedish Maritime Warfare Data Centre, within the Swedish Navy, as the responsible entity for UXO monitoring[252] . It regularly cooperates with other regional Baltic Sea countries.

Environmental implications

Understanding the impact of UXOs on the environment

The desk research and interviews carried out in the context of this Study highlighted that, overall, environmental concerns are not a priority within the activities of monitoring, identifying and disposing of UXOs.

In UXO **disposal**, three of the stakeholders interviewed[253] noted that environmental concerns come only after civil security. Some countries, such as France, noted that they use an acoustic device to scare off mammals and ensure that they are not hurt in the process of disposal.

During **monitoring**, there is little evidence that much research has been carried out at national level to understand UXO impacts on marine life.

Several research projects have focused on the Baltic, North and Adriatic Seas. They concluded that components of conventional and chemical munitions may leak into the marine environment, polluting sediment and water. This effect was mostly observed in multiple areas of the Baltic Sea and in the Adriatic Sea. Once released, these undergo a series of complicated chemical reactions, depending on the type of substance, environmental conditions, sediment composition and bacterial communities. Both CWA and explosive degradation products can be as toxic as their parent compounds, if not more so.

The studies revealed that corrosion of containers or low-order detonation can lead to the release of munition constituents, as observed for TNT. Released munition constituents can negatively affect biodiversity in the adjacent area, and are accumulated by marine biota. Observed environmental concentrations are currently low, but will grow in the event of increased input (e.g. corrosion progresss, anthropogenic disturbance of containers). Further laboratory analyses highlighted the toxicity of parent compounds and their degradation products. Those substances were identified as carcinogenic, mutagenic and causing enzymatic disturbance in mussels and fish. Adverse health effects were confirmed for a range of marine biota in the Baltic, Skagerrak and Adriatic Seas.

[249] Dutch Government (2017). Data request unexploded explosives (*Dataverzoek niet gesprongen explosieven*).
[250] Dutch Coast Guard (2016). Annual Report. There is no explicit reference to the remaining two, but from the data table it is apparent that UXOs reported in one year might be dealt with the next year.
[251] Dutch Association for UXO Detection (2021). Munition map (*Bommenkaart*); Barink Explosieven Opsporing (2021). Clearance map.
[252] Interview with SE military authorities – SE 01.
[253] BE, FR, IT.

Large-scale studies identify both CWA and explosives as an environmental threat for marine ecosystems.

International projects such as CHEMSEA (2011-2014) and DAIMON (2015-2019) have sought to analyse some well-known UXO dumpsites. However, they analysed the situation at a given point in time in a given area, and were not renewed once the end of the project was reached. As such, little information exists on the long-term impact of the UXOs as they progressively corrode in the marine environment.

Understanding the impact of the environment on UXOs

Munitions and other warfare materials can be displaced by natural and anthropogenic factors.

Natural factors include extreme weather events and currents. Natural movement of underwater munitions is usually restricted to shallow areas or limited in time. Directly after entering the marine environment munitions may still contain air, either due to the production process or as part of their functioning mechanism (e.g. sea mines). On some occasions, munitions were dumped in wooden packaging, increasing their flotation[254].

Official dumping stopped in the 1970s, under the London Convention, and contemporary movement of munitions on the seabed will typically be the result of **anthropogenic factors**. In both the Baltic Sea and in the Skagerrak, bottom-trawling is the main anthropogenic factor responsible for munitions relocation. In the Gotland Deep dumpsite, trawl marks are visible on the sonar images of the sea bottom, and overlap munition locations[255]. Large trawlers are heavy and use chains in front of the net, which penetrate the upper sediment layer and displace, uncover or even fish out munitions. There are a number of reports of fishers who were exposed to chemical munitions at sea during fishing operations, and munitions traces have also been found near fishing harbours, suggesting dumping of accidentally caught CWA prior to entering the port[256].

Dredging and other offshore industry activities may also affect munitions relocation by destabilising the sea bottom, as well as ploughing sediment for pipelaying and cables.

Munitions located on the seafloor may be moved by natural water currents as well. The extent to which munitions move depends on physical parameters. For example, tides, currents, waves, and high-energy storms may impact munitions mobility. Draft and lift forces also influence munitions mobility, with certain ammunition design having a higher likelihood of moving[257]. In terms of currents, the more buried a piece of munitions is, the more current speed is necessary to move it[258]. Therefore, proud munitions move more easily. Several factors influence burial[259], including sediment scour (when water erodes the sediment surrounding munitions during sub-critical current conditions, while certain shapes of ammunition (e.g. tapered, small ammunition) are easier to bury[260].

[254] Op. cit., HELCOM CHEMU (2013).
[255] Klusek, Z. and Grabowski, M. (2018). *Results of Acoustic Research in the CM Deploying Areas*. Dordrecht: Springer Netherlands.
[256] Beldowski, J., Klusek, Z., Szubska, M., Turja, R., Bulczak, A.I., Rak, D., Brenner, M., Lang, T., Kotwicki, L., Grzelak, K., Jakacki, J., Fricke, N., Ostin, A., Olsson, U., Fabisiak, J., Garnaga, G., Nyholm, J.R., Majewski, P., Broeg, K., Soderstrom, M., Vanninen, P., Popiel, S., Nawala, J., Lehtonen, K., Berglind, R. and Schmidt, B. (2016). 'Chemical Munitions Search & Assessment-An evaluation of the dumped munitions problem in the Baltic Sea'. *Deep-Sea Research Part II-Topical Studies in Oceanography*, 128, 85-95.
[257] Menzel, P. et al. (2017). 'Prediction of the initial Movement of Objects on the Sea Floor.' *Oceans*, Aberdeen.
[258] Op. cit., Menzel, P. et al. (2017).
[259] Menzel, P. et al. (2018). 'Towards a general prediction-model for the current-induced mobilisation of objects on the sea floor'. *Ocean Engineering,* 164, 160-167.
[260] Rennie, S. E., Brandt, A. and Friedrichs, C.T. (2017). ‚Initiation of motion and scour burial of objects underwater'. *Ocean Engineering*, *131*, 282-294.

Finally, munitions constituents and their degradation products may be present in the form of particles and dissolved matter. Both could be absorbed by bottom sediment and/or transported in the marine environment. One study on the impact of potentially leaked CWA on marine environment was particularly influential in the field, inspiring several other studies on the influence of dumped CWA on the ecosystem[261, 262] .

[261] Missiaen, T., Paka, V. and Emalyanov, E. (2006). *Modelling of ecological risks related to sea-dumped chemical weapons*. Synthesis report of the available data. www.mercw.org, MERCW; Zhurbas, V., Elken, J. and Vali, G. (2008). 'Pathways of suspended particles released in the bottom boundary layer of the Bornholm Deep, Baltic Sea (numerical simulations)'. *2008 Ieee/Oes Us/Eu-Baltic International Symposium*, 61-65; Zhurbas, V. and Paka, V. (2012). 'Dispersion of passive tracers in the Baltic Sea deep water as applied to dumped chemical weapons'. *Marine Technology Society Journal,* 46(1), 37-50; Jakacki, J., Golenko, M. and Zhurbas, V. (2018). *Estimation of potential leakage from dumped chemical munitions in the Baltic Sea based on two different modelling approaches. towards the monitoring of dumped munitions threat (modum): a study of chemical munitions dumpsites in the Baltic Sea*, pp. 153-181.

[262] Two studies focusing on munition constituent leakage in sediments and in the water column were also performed on the Baltic Sea and North Sea: Francken, F. and Hafez, A. (2009). 'A case study in modeling dispersion of yperite and CLARK I and II from munitions at Paardenmarkt, Belgium', *Mar Technol Soc J*, 43, 52-61.

Annex 7: Technologies/scientific approaches to identification, monitoring and disposal of sea-dumped unexploded weapons

Technologies/scientific approaches: acoustics

Underlying physics

A large difference exists between the very high propagation loss of electromagnetic waves in seawater (aggravated by the frequent turbidity for light waves) and the very low propagation loss of acoustic waves. The magnetic signature of a metallic object also spreads through water and sediment, albeit with a much stronger decay over distance when compared to acoustic waves. While radar and electro-optics are the prime detection sensors above water, sonar and magnetic are the prime detection sensors underwater. As magnetic anomalies are common in the seabed from many sources other than UXOs, acoustic sensors (sonar and sediment sounder) are the key types of sensors for UXO detection, confirmation and classification.

Sound waves propagate nearly five times faster in water than air, while remaining extremely slow compared to electromagnetic waves (1,500 m/s compared to 300 million m/s). Therefore, optic imaging features a characteristic wavelength expressed in hundreds of nanometres (very high resolution), while the acoustic imaging wavelength is expressed in metres (very low resolution). Wavelength determines the 'pixel size' of the sonar image. A 10m wavelength is sufficient to reveal the presence of a 150m long submarine, but centimetric wavelengths are required to reveal the shape of an UXO with enough pixels to differentiate it from a small rock. This corresponds to rather high frequencies (HF sonar), well above 100kHz (human hearing hardly reaches 12kHz).

Such high frequencies are commonly used underwater, but as frequency increases, propagation loss becomes significant, limiting the detection range to less than 100m[263]. Notably, the lower salinity of the Baltic Sea results in augmented ranges for high frequency sonars. Much like using a torch to find an object in a cave, HF sonar allows both an echo and a shade to be captured, allowing the assessment of a sonar MILEC as a likely MILCO.

The signal content of the 'light' (acoustic wave generated by the sonar to illuminate the sea floor) is optimised to separate the target echo from the backscattering of its surrounding. As every ping is less than one millisecond, many returns can be averaged to further reduce noise and enhance the target echo.

A key advantage of acoustic imaging is its total immutability to water turbidity, making it very effective in the penetration of unconsolidated sediment.

The main limit of this technology is the trade-off between the detection range and the number of pixels available in the echo. This limit is typically overcome by first using a detection sonar around 100kHz to detect MILECs, then get closer to each MILEC with a very-high frequency sonar (or, alternatively, a LiDAR or an electro-optic camera) to obtain enough detail to confirm MILCOs.

A new technology described by NATO-CMRE[264] uses the vibrational interaction of UXO casings with sound waves at lower frequency as a key discriminator: while the processing complexity is real, it might indeed simplify detection at several hundred metres of UXOs and even a first categorisation from wideband sonar in the 3-30 kHz range. The capacity for penetration in sediment is also multiplied by a factor of at least five. Overall, this detection strategy and signal processing innovation might prove a 'game changer' for the productivity of UXO detection surveys by more than an order of magnitude.

[263] The detection requires to capture the echo by the target of the emitted soundwave, i.e. the acoustic path is twice the target distance.

[264] Williams, D.P. (2019). 'Acoustic colour-based convolutional neural networks for UXO classification with low frequency sonar'. UACE2019 Conference Proceedings, 421-428.

HF sonar categories

Forward-looking sonar (FLS)

This sonar array is generally fitted on a retractable mast under the keel of a vessel, in a vertical well to deploy the sonar a few metres below the hull when operated. The well allows the sonar to be retracted when transiting or in very shallow waters. FLS is thus alternatively designated as high-frequency hull-mounted sonar (HMS).

FLS can be found not only on mine hunters, but on any vessel, including submarines, as mine and obstacle avoidance sonar (MOAS). They allow for the path of the vessel to be cleared of submerged threats (e.g. mines, IEDs, drifting objects), particularly in poorly charted shallow waters.

Variable depth sonar (VDS)

By replacing the retractable mast of the FLS with a cable-winch assembly, the HF sonar can be deployed at any depth, becoming a VDS. This egg-shaped sonar has better detection capability on the continental shelf, due to its maximised signal/noise ratio and a 360° capability. However, its use limits vessel speed to a maximum of 4-5kn and requires the vessel to be positioned directly above the UXO.

This solution overcomes the alteration of sonar wave propagation by the bath thermic layers or differences in salinity between the surface and the bottom. It also reduces the grazing angle of the waves and thus augments the acoustic shadow of the detected echoes, easing classification.

Propelled variable depth sonar (PVDS)

This sonar can be mounted on an ROV. The mine or UXO detection can be performed well in front of the mine hunter (150 to 250m) and/or deeper, increasing the detection distance and depth, as well as the reaction time in case of MILCO. It also increases the vessel safety distance during inspection[265] and allows the classification of a contact from a different angle/perspective.

Side scan sonar (SSS)

SSS relates to a clear directional focus of sonar scanning arrays and a reliance on the vessel trajectory to assemble successive sonar scans. It is designed specifically for the purpose of seabed surveys. The rectangular shape of the arrays makes it easy to integrate on ROVs, AUVs and towed bodies (TBs). TB ensures an optimum fly-over altitude over the sea floor to maximise the swath of the sonar survey. The TB must be very stable, as roll and pitch degrade and distort the sonar scans. The grazing angle of the sound waves results in significant shadows, offering high quality images of wrecks, anchor or trawler marks on the seafloor. However, the angle (and thus the shadow) is a function of the range, increasing the difficulty of automated interpretation.

After referencing the array position and bearing into absolute coordinates, successive sonar scans are processed by averaging the overlapping part of the scans (rolling average filter). Except for a flat horizontal seabed, this 'rolling carpet' image remains geometrically distorted, with a very precise TB attitude correction and bathymetric map would be required to correct this distortion.

Synthetic aperture sonar (SAS)

A large part of the sonar solution is based on successive sonar scans. As the sonar ping is perfectly timed, it is possible to consider a sequence of successive sonar scans as a single scan, 'fusing' the successive positions of the sonar array as a single large array. The larger the array the better the resolution, thus this 'synthetic array processing'

[265] Protects vessels from 'influence mines', designed to be triggered by the detection of ships' magnetic and/or acoustic signatures.

represents a valuable capability augmentation technique that is able to provide more accurate images from the same sonar device.

To achieve this, the raw returns of each sonar ping are delayed by the time interval between pings and enter the beamforming software as deported from the adjacent ones by the actual progression of the platform carrying the sonar.

Processing power is ever-increasing, thus SAS is primarily limited by the phase uncertainty resulting from the accuracy limits of the geometric determination of the successive position, which has to remain sub-millimetric for HF sonar: if the phase error exceeds 30°, adding more scans would degrade rather than improve the final result. This translates into limiting the SAS resolution increase about five to tenfold, which is already considerable.

Technological implementation of HF sonar

As the acoustic wavelength at 300kHz is only 5mm, the production of HF sonar requires sub-millimetric precision, i.e. micro-machining technologies with much lower capital investment to manufacture the 'wet-end' of the sonar compared to other types of sonar[266]. On the processing side, FPGAs are used more frequently than embarked computers (especially for sonar mounted on AUVs), as they offer massive parallel computing capabilities with greatly reduced size and electric power consumption.

Europe remains the world leader for mine-hunting sonar and civilian SSS/SAS, with a mix of large international groups (e.g. Thales, Atlas Elektronik, Ultra Electronics), well-established specialists (e.g. Kongsberg), and smaller outsiders (e.g. Xblue, Sonardyne). International prominent competitors in the SAS market include Coda Octopus and EdgeTech (US) and Kraken Robotics (CA).

The current trend in technological implementation involves the implementation of **SAS sonar on UUVs**. Compared to hull mounting, TB or tethered ROVs, this requires:

- An advanced physical integration, as compact as possible;
- A focus on low power consumption;
- A large data storage capacity;
- An ever-increasing embarked processing capacity with the ultimate (and long-term) aim of autonomously categorising MILCOs and transmitting ready-to-use contact logs at the end of each survey (or, for larger UUVs, even incorporate the autonomy to launch a sub-munition to neutralise the detected and categorised mine or UXO);
- A key enabler for developing AI-based UXO classification capability is the availability of large sets of proper 'learning data' – this could be an area of fruitful cooperation.

Alternatively, the miniaturisation of signal processing units allows **hand-held sonar systems** to be developed for EOD divers. This a-magnetic unit includes acoustic communications, underwater geo-referencing capabilities and an optional magnetic detector.

An important piece of diving equipment relates to the accuracy of navigation and positioning underwater. Given the difficulty of moving around underwater and the often-poor visibility, it is essential to have a positioning accuracy of less than 5m. This implies using satellite navigation systems (GPS, GLONASS, GALILEO, etc.) of military or scientific quality. The use of surveying or hydrographic equipment (although not easy

[266] Combined with the significant duality of the demand (military and offshore engineering), this makes it a true 'open serial product market' (as a comparison, ASW sonar is a niche market of multiplicate prototypes). It also results in a large diversity of designs and a capacity to promptly adopt innovations (piezo-composites, FPGA processors, etc.).

to use, it is independent of satellite systems) also makes it possible to obtain a high degree of accuracy, at least on the surface (geo-localised buoys).

As radio waves do not propagate underwater, dedicated acoustic pingers and receivers can provide accurate underwater positioning from the geo-localised buoys. They are often commercially branded as 'underwater GPS'. They require reference transponders to be deployed in the surveyed zone following a pattern, enabling proper triangulation of the mobile receptor.

Overall acoustic UXO survey capability

The dominant trend is the use of unmanned systems that are able to go closer to the seabed with high resolution HF sonar and an ever-increasing degree of autonomy. However, this comes with higher rates of MILCO false alarms (compared to a manned vessel equipped with FLS or VDS) for the following reasons:

- Side-scan sonar on a TB or AUV only provides a single angle of view of the MILEC, requiring a decision to grade it as MILCO from a single shadow profile;
- A manned mine-hunting vessel will slow down for each MILEC and manoeuvre under the direction of an expert operator to acquire several angles of view before confirming it as a MILCO with a much higher probability. This justifies European navies' choice to continue to combine manned and unmanned/autonomous vessels to get the best of both technologies.

In terms of sensors, HF sonar technology is truly mature but requires low-speed surveys (3-5kn) with a swathe limited to 30-100m at best, so at a rate below 1km²/h. Today, records must be downloaded for full processing, limiting the overall daily productivity.

The emerging alternative of using low frequency FLS from a manned vessel, with an advanced signal processing capability to detect and identify UXOs from their structural resonance, represents a paradigm shift in UXO survey strategy. If confirmed effective, it will radically transform survey strategies and capabilities for UXO identification and monitoring, with a potential of surveying at 10-12kn with a range above 1000m (15 to 20 km²/h) from a manned or autonomous surface vessel able to operate 24/7.

Technologies/scientific approaches: magnetic

As most UXOs include a ferro-magnetic metal casing, they can be detected by magnetometers[267].

The principal difference compared to acoustic detection is that magnetic waves decay more strongly over distance: in an open field, acoustic waves decay in the inverse ratio of distance, while magnetic influence decays in the inverse ratio of the cube of the distance. This means that the total magnetic anomaly for a 250-pound bomb (~110 kg) will decrease from 800 nano-Teslas (nT) at a distance of 1m, to 100 nT at a distance of 2m, to 12 nT at a distance of 4m, etc.

In addition, the Earth's intense magnetic field is present underwater and varies according to the iron content of the underlying substrate: detecting a UXO requires finding a very slight alteration (few nT) in an unsteady Earth field varying in the range of 20-50 milli-Teslas, depending on the location. Nor is the Earth's magnetic field stable over time, as the large magnetic masses of the liquid core of the Earth are in constant motion. Even the seafloor can contain significant natural iron deposits. For example, it is almost impossible to conduct magnetic detection surveys over volcanic lava.

While remaining challenging in terms of interpretation, magnetic anomaly detection is the next-most-used detection technology available underwater to detect man-made objects, and investment in advanced magnetic detection technologies remains similarly

[267] However, WW II mines such as the common German LMB were purposely built with non-magnetic materials to ensure they were undetectable by magnetic sensors.

driven by anti-submarine warfare. Like acoustics, the specificity of UXOs is that they constitute extremely small metallic masses compared to submarines.

Similarly to acoustics, magnetic detection applicable to UXOs is either passive (detecting a localised variation of the earth field) or active (generating a local magnetic field and measuring its eventual alteration by the presence of an UXO).

The probability of magnetic detection of UXOs remains very difficult to ascertain. German WW II LMB mines (680 kg TNT equivalent), for example, were manufactured in aluminium and remain impossible to detect. When a localised magnetic anomaly is recorded, it does not say how deep in the sediment the metallic object might be buried.

Magnetic anomalies do not provide UXO identification clues, but simply signal a man-made object. Identification is only possible visually when the suspected magnetic artefact is dug out and brought to light.

Passive magnetic sensing

The *fluxgate sensor* design is the most frequently used magnetometer construction technology for underwater environments. Complete sensor solutions are now available as IC chips because of advanced miniaturisation. In addition, fluxgates are not overly expensive, and are durable and compact. Although their detection range only goes up to 10m, their generally low power consumption is a benefit in UXO detection.

As an alternative detection device, proton (precession) magnetometers are more sensitive but more difficult to miniaturise. Physicists explain that 'the primary field triggers the precession of spins in the magnetometers. If no secondary fields are excited in response to this primary field, the spins in all magnetometers precess with the same amplitude and phase. However, any magnetic field induced in a target will affect the precession in different magnetometers in different ways.'[268] Therefore, the presence of a conductive object on the seabed or in the sediment is detected by monitoring the amplitude and phase in the sensors.

Current best performers are the caesium and potassium magnetometers. Caesium magnetometers are used for UXO surveys but provide magnetic field variations and are thus likely not as effective in actual seabed environments than the fluxgate gradiometers.

A reference sensor is required to cancel the large ambient magnetic field around the detection sensors, thus mitigating dynamic range and linearity requirements.

Active magnetic sensing

This option is known as magnetic induction tomography, first developed for industrial monitoring. As explained, 'this uses an oscillating "primary" magnetic field to induce electric currents in target objects that, in turn, produce "secondary" magnetic fields. By detecting these secondary fields one can, in principle, characterise any object that is an electrical conductor – as long as the object, sensors and primary source sufficiently close to one another.'[269] In simple terms, the object's presence alters the magnetic 'bubble' created by the active coils. Due to the complexity of the 'deconvolution' of this perturbation in characterising the object, using AI offers a credible alternative.

[268] Wogan, T. (2018). *Atomic magnetometers detect underwater objects*. Available at: https://physicsworld.com/a/atomic-magnetometers-detect-underwater-objects/
[269] Ibid.

Typical technological implementation of magnetic detection of UXOs

The first challenge is to avoid undermining the magnetic detection capability due to the magnetic signature of the underwater survey vehicle. Towing them on a distant 'glider' removes this issue.

As magnetic detection is generally used as a means to confirm the reality of an acoustic MILCO, the acoustic survey data have to be 'fused' in some way with the magnetic survey data. The process is eased if both types of sensors are used and processed concurrently on the same underwater vehicle.

In shallow waters and harbours, where large systems cannot be operated, hand-held magnetometers are available for EOD divers. Although less sensitive, they are an easy option for ferromagnetic metal presence confirmation capability.

The use of underwater video cameras is common although confined to clear waters, as they have a limited range of action in presence of turbidity. Light is required below 10-20m due to the limited penetration of solar light in water. It cannot be a prime detector of UXOs, but can provide high resolution images readily usable by UXO specialists.

LiDAR is a more advanced option for underwater detection based on the selective transmissibility in water of the green light wavelength of 532 nm, leading to ranges up to 50m for pulsed laser beams. LiDAR is able to provide a 3D survey very similar to the SSS but now on the nadir[270]. The resolution (in pixels) is far superior to acoustics, as the wavelength is many orders of magnitude shorter, albeit with the constraint of accurate motion compensation of the platform carrying the sensor.

LiDAR is also effective in dense seaweed cover, as the main echo averaged for the holographic reconstruction will remain the sea floor. On the other hand, it has no capacity to penetrate sediment.

Technologies/scientific approaches: chemical

There is a general scientific consensus that about 20% of the anthropogenic/human-made chemical tracers possibly detected in seawater relate to UXOs, but no quantitative assessment can be found. The chemical detection of such traces underwater remains the least developed in the domain of UXO identification, monitoring and disposal capability. Only a few dedicated programmes (CHEMSEA, ExPloTect) can be found and the desk review found no evidence of chemical sensors that might be suitable for real-time *in situ* assessment on underwater vehicles.

While embarked chemical sensors are the ideal solution, the technology has yet to reach sufficient development maturity and miniaturisation to be fitted on autonomous vehicles. To date, the chemical sensing options are:

In situ water sampling and remote analysis

This option is straightforward but costly. As described in ExPloTect, water samples are pumped by a remote TB, collected on board and then sent to a laboratory.

Material *in situ* filtering mechanisms

Small devices with adsorbing membranes are left for days or weeks in the seabed area to be assessed and then collected[271]. This method provides more robust data, in particular when pollutant concentrations are close to the diffuse pollution level. It is

[270] To overcome its short range, the LiDAR is mounted so as to illuminate the vertical below its carrier as it is the closest point of approach (CPA); this vertical downward beam of a directive sensor (LiDAR, sonar, etc) is traditionally called the 'nadir', the opposite of the zenith.
[271] A detailed description of an adsorbent device is provided in: Lotufo, G. and Rosen, G. (2020). 'Passive sampling of munitions constituents'. *Enviro Wiki*.

better targeted to specific chemicals, and consists of a membrane fitted in a handy casing, thus is easily deployed and retrieved by divers or underwater robots.

Biological *in situ* filtering organisms

The CHEMSEA[272] project used mussel baskets to collect the presence of pollutants in the seabed, using the capacity of the shellfish to concentrate and fix pollutants.

This approach strongly depends on the local oxygen content, as the mussels are displaced out of their habitats and possibly far deeper. This issue made that batch of CHEMSEA results uninterpretable.

Selective detection of explosives

The most common families of military-grade explosives (RDX, PETN, TNT) are known to be selectively detected by reversal electron attachment detection (READ) based on electrostatic membranes. Thus, explosives' molecules have an extremely large cross section for attaching zero-energy electron. No suitable sensors based on this technology and readily deployable underwater on ROVs or UUVs could be found.

The GEOMAR Research Institute is actively involved with industrial partners in the development of TNT trace detectors to monitor UXO pollution. The current technology readiness level is assessed at TRL 4-5. This means that, with continued investment, this technological capability gap could be resolved in a few years.

From the UDEMM[273] project, in 2019, GEOMAR edited a 'Practical Guide for Environmental Monitoring of Conventional Munitions in the Seas'. While being very useful, there is ample work to be done to create an international consensus on the chemical pollution monitoring methodology and toolbox. There is no consensus on the 'baseline background level' of these chemicals in the various seas, nor on the associated danger levels for marine life and the global seafood chain, including commercial fish and seafood.

Assets: vessels, remotely operated and unmanned vehicles

The detection and identification of underwater UXOs requires the implementation of sensing systems on naval platforms. Hull-mounted sensors have a limited range, meaning the ship might be closer to the explosives than a normal safety distance. MW vessels are specially designed to withstand significant shockwaves without enduring structural damage (resilient mounts to attach every equipment and machinery, flexible hull, e.g. in glass-reinforced composite, special structural design).

The propulsion system of these vessels is specially designed to allow precise survey tracks to be carried out even in the presence of wind, currents and sustained low-speed operation. Most are also equipped to deploy, operate and retrieve ROVs and AUV, as well as to embark and deploy diving teams.

Many Member States are undertaking substantial renovation programmes of their MW fleet and equipment. A number of these programmes are transnational, demonstrating well-established cooperation frameworks.

As this modernisation is accompanied by a reduction in overall fleet size, many decommissioned MW vessels from 'first rank navies' are sold and retrofitted to equip other nations. Again, this offers a favourable framework for international cooperation, cooperative training and know-how transfer.

[272] https://ec.europa.eu/regional_policy/en/projects/finland/chemsea-tackles-problem-of-chemical-munitions-in-the-baltic-sea;http://underwatermunitions.org//wp-content/uploads/2016/08/CHEMSEA_Findings_24.01.pdf
[273] https://udemm.geomar.de/

The EDA has recently conducted a comprehensive landscaping of European Mine Counter-Measures capabilities which has not been replicated in this Study. EU capabilities in this domain surpass those of all other nations.

Training facilities, expertise centres

According to military typologies, the technical skills required to deal with sunken UXOs belong to several naval critical capabilities areas, as defined by EDA or NATO:

- Naval mines warfare (NMW) and MCM;
- EOD;
- Military diver training and qualification (scuba, mixed gas or closed circuit);
- Naval robotics and interaction between divers and manned/unmanned systems;
- Harbour protection.

Dealing with historic UXOs represents a key live training opportunity for MCM capabilities, equipment validation, procedures validation, international cooperation, and permanent operational readiness assessment. In addition, UXO management capability can directly benefit from this naval capability framework, which involves:

- National MCM expertise and training centres;
- Bi- or multinational MCM expertise and training centres, such as EGUERMIN in Ostend (BE-NL);
- NATO naval mine-warfare Centre of Excellence (NMWCoE) in Kiel;
- NATO Centre of Maritime Research and Experimentation (CMRE) in La Spezia.

The EDA has no test facilities or operational training programmes but is similarly involved in incentivising the cooperation of voluntary Member States, with work identified on the MCM and harbour protection in the 2018 Capability Development Plan (CDP), and further detailed in 2020 as 'strategic context cases'. Ongoing EDA-sponsored activities subcontracted to industry possibly contributing to the UXO management challenge include:

- A study to define new concepts of operations (CONOPS) for MCM in the various Member States, led by ISDEFE;
- A study on the interactions between divers and manned/unmanned systems, also led by ISDEFE.

The EDA and the Permanent Structured Cooperation (PESCO) are also involved in the training of naval divers, with the aim of reaching common EOD qualifications and intervention procedures, enabling joint operations (mixed EOD diver teams) and better networked diving courses.

The stakeholders consulted highlighted a number of **training capabilities and expertise centres** to be further developed, including:

- Mitigation of environmental impacts of the on-site UXO disposal, by developing, adapting and validating mitigation devices and procedures, and subsequent operational training over the diversity of UXO threats and contexts;
- Development and management of underwater reference UXO detection and identification facilities for a variety of seabed configurations;
- Development of open UXO detection databases with unified taxonomies and data-models to be used for AI-based UXO identification algorithms from sonar and magnetic anomaly data.

Specific skills and qualifications

The detection, monitoring, and disposal of UXOs requires three distinct and complementary specialist qualifications:

- **Sonar operators –** detecting and classifying echoes and piloting MCM equipment (ROV, PVDS, etc.);

- **Underwater EOD** divers – searching, identifying, moving and destroying *in situ* or neutralising the devices;
- **Boatswains/bosuns -** launching and recovering devices such as PVDS, ROVs, AUVs, sweeping system or towed vehicle, etc.

Sonar operators

Even among NATO forces, qualification and training levels of mine warfare sonar operators are not formally standardised and depend on a wide variety of equipment and manufacturers. Sonar operator teams generally include:

- **Basic mine warfare sonar operators**, assigned to each sonar console and tasked with detecting and pre-classifying echoes of interest;
- **Advanced mine warfare sonar operators**, acting as operational supervisors of the basic detection. They are also in charge of setting up the sonar according to the environmental conditions. Supervision of the basic operators consists of orienting the research and completing the classification of echoes. They confirm the proper attribution of the detected contacts as MILCO and trigger the next sequence of operation (identification then neutralisation). They are also in charge of piloting PVDS or intervention ROVs.

Underwater EOD divers

Underwater EOD qualifications:

Within NATO forces, EOD qualifications for divers are standardised (including the competencies to be acquired at successive levels of training) and described in AEODP-10[274]. Only personnel holding this qualification are authorised to carry out EOD operations in maritime and underwater environments. The standard levels of EOD training for the handling of submerged munitions include:

- **UW EOR (Underwater Explosive Ordnance Reconnaissance)**: personnel trained for conducting simple ammunition searches while diving and identifying the family of ammunition (shell, bomb) and advising authorities on immediate safety measures;
- **UW EOC (Underwater Explosive Ordnance clearance)**: personnel already trained as UW EOR, able to participate in large area searches with acoustic means and in the presence of munitions with influence firings. These personnel are also trained and, under the orders of a team leader qualified to at least UW CMD, able to move and destroy underwater munitions;
- **UW CMD (Underwater Conventional Munition Disposal)**: personnel with the previous qualifications trained to carry out and direct operations to search for, identify, monitor and dispose of conventional munitions underwater and in the maritime environment;
- **UW IEDD (Underwater IEDD)**: personnel with the previous qualifications trained to perform and direct search, analysis, destruction and disposal of IEDs or booby traps in a maritime environment;
- **CRBN EOD (Chemical, Radiologic, Bacteriologic and Nuclear Explosive Ordnance Disposal)**: personnel already UW EOD, UW CMD and UW IEDD qualified. CRBN EOD personnel are able to participate in joint operations to search for, identify, destroy and neutralise submerged chemical munitions and in the maritime environment.

Notably, this training and these qualifications have no equivalent among civilian authorities.

[274] Op. cit., NATO (2020).

Diving qualifications:

Diving qualifications are a prerequisite for EOD qualifications, and each EU Member State seems to differ in their approach, procedures and safety rules. Globally, two main military diving approaches can be observed:

- A Latin approach (Italian and French) based on dynamic diving, inherited in France from the *Mousquemers* (Cousteau, Taillez and Dumas, the inventors of free diving equipment), giving a great deal of autonomy to the diver, who will be able to travel several thousand metres underwater during an EOD or UXO intervention dive;
- An Anglo-Saxon approach, inherited from helmet diving (more adapted to muddy environment) and therefore static and often connected to the surface, which will greatly limit the diver's autonomy and ability to move around underwater from the diving point.

These two approaches have led to the development of different equipment and different diving tables, preventing easy mixing of teams from other nations. This does not prevent joint diving operations, provided each nation applies its own national rules and aims for the same demining objectives[275].

Boatswains/bosuns

Deploying, operating and recovering ROVs and AUVs from a vessel requires specific skills and training. 'Bosuns' (or 'boatswains') are qualified seafarers for supervising deck operations and, on mine warfare units, receive specific training to operate the full range of robotised systems, especially towed or sweeping systems and teleoperated mine or UXO neutralisation devices. This training is not standardised within NATO, but personnel have broadly the same skills across the EU.

Similar to sonar operators, it is possible to distinguish between basic and advanced operator levels (chief of manoeuvre).

Operational approaches/constraints

Overall, the activities of disposal immediately follow the identification of an UXO, even without an assessment of its condition. In some circumstances, however, it can be necessary to determine the UXO explosive status (e.g. unprimed, primed but unfused, fused but not exploded), which can be required to assess the level of explosive risk of handling the UXO, and the overall integrity of the UXO casing to assess the risk of leakage in the case of chemical ammunitions. This information also determines the possible applicability of low-order neutralisation (see Task 4).

This specific type of neutralisation requires:

- Careful removal of sediment, generally with a hand-held suction system operated by the EOD diver;
- Careful removal of the marine growth in a specific area of the casing to allow for inspection;
- Good quality pictures.

When the UXO is found on a beach, barge or ship deck, this determination is even more important to mitigate the risks and decide on the most appropriate next step.

[275] The Allied Guide To Diving Operations (ADivP-1) is a reference document common to the WW II allies, which allows for the harmonisation of the conduct of diving operations and the qualifications of operators. For example, it will describe for each nation the need for a vessel carrying a recompression chamber (meeting NATO standards) in case of a diving accident.

Technologies/assets/equipment and qualifications

This type of equipment is identical to that used to maintain and inspect offshore metallic structures (piles, pipes, anchoring structures, etc) or to conduct underwater archeologic surveys, but with the specific risk of intervening on UXOs, which requires an EOD qualification.

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