Top-level criterion	Sub-criterion	Indicator																			
		Bathing sites	*Pile Position within dump site*	*Number of objects on a pile*	*Size of objects*	*Fishing intensity (fhr)*	*Fishing intensity (econ. Value)*	*Fishing effort*	*EC in Fish*	*EC in Mussels/ Passive Samplers*	*EC in Water*	*EC in Mammal*	*Environmental Vulnerability*	*Distance to Data Cables*	*Shipping density*	*Shipping lanes*	*Harbour Location*	*Anchorage Areas*	*Current velocity*	*Sediment Particle Size*	*Wave height*
Risk to Human Health	Beachgoers: Direct Contact	✓																			
	Fishing Crew: Bycatch					✓															
	Fishing Crew: Explosion			✓	✓	✓															
	Seafood Consumer: Contamination							✓	✓	✓											
	Shipping Crew and Passengers: Explosion			✓	✓										✓						
Risk to the Environment	Fish: Contamination								✓												
	Flora: Contamination										✓										
	Mammals: Contamination											✓									
	Molluscs: Contamination									✓											
Risk to the Economy	Cable Operator: Explosion													✓							
	Fishing Sector: Bycatch					✓															
	Fishing Sector: Explosion			✓	✓	✓															
	Fishing Sector: Fishing Ban							✓													
	Shipping Sector: Explosion			✓	✓										✓						
Risk of Misuse	Society: Terrorism				✓											✓			✓	✓	✓
Socio-economic Potential	Cable Operators: Space		✓																		
	Fishing Sector: Space		✓				✓														
	Marine Conservation: Space		✓										✓								
	Shipping Sector: Space		✓													✓	✓	✓			

Supplementary Table 1 Overview of Indicators per Sub-criterion. EC = explosive compounds

Risk/benefit (relevance confirmed at workshops)	Source	Pathways	Receptor Group	Receptor	Consequence	Possible Data (presented at SPRC-Workshops; datasets are categorised according to SPRC: orange = source, yellow = pathway, light green = receptor, dark green = consequence)	Available Data (based on SPRC-Workshops; data selected in bold; datasets are categorised according to SPRC: orange = source, yellow = pathway, light green = receptor, dark green = consequence)	Indicator Functions
Risk to Human Health from Contamination	Munition	- Seafood - Water --> Seafood - Water --> Sediment --> Seafood - Sediment --> Seafood - Sediment --> Water --> Seafood - Explosion --> Water --> Seafood - Explosion --> Sediment --> Seafood - Explosion --> Sediment --> Water --> Seafood	Humans	Seafood Consumer	Human Health	- Explosive Compounds based Health Impact on Seafood Consumer	- No	EC in Fish, Fishing effort --> Human Health
						- Explosive Compounds in Seafood Consumer	- No	
						- Explosive Compounds in Food Species - Fishing Intensity - EC in Biota - EC in Sediment - EC in Water	- Fishing intensity **- Fishing effort** **- EC in Fish (limanda limanda)** - EC in Sediment - EC in Water	
						- Amount of explosive material - Corrosion State - Current Velocity - Nr. explosions - Amount of Seafood Species	- Number of Objects on a Pile (photomosaics) - State of Corrosion of the Casing (photomosaics)	
Risk to Human Health (Shipping Workers/Passengers) through explosion		- Explosion --> Shock Wave		Shipping Workers/ Passengers		- Number of Fatalities of Shipping Workers/Passengers - Number of Injuries to Shipping Workers/Passengers	- No	Shipping density, Amount of explosive material (number of objects; Size of Objects) --> Human Health
						- Number of Explosions - Number of Workers/Passengers - Traffic Density - Amount of explosive material	**- Shipping Density** - Shipping lanes - Traffic density	
						- Amount of explosive material - Corrosion State - Distance of Water Ways	**- Number of Objects on a Pile (photomosaics)** **- Size of Objects on Pile(photomosaics)** - State of the Fuse (photomosaics) - State of Corrosion of the Casing (photomosaics)	
Risk to Human Health (Fishers) through explosion		- Explosion --> Shock Wave		Fishers		- Number of Fatalities of Fishers - Number of Injuries to Fishers	- No	Fishing intensity, Amount of explosive material (number of objects; Size of Objects) --> Human Health
						- Number of Explosions due to trawling - Trawling Intensity - Amount of explosive material	**- fishing intensity** - Fishing effort	
						- Amount of explosive material - Corrosion State	**- Number of Objects on a Pile (photomosaics)** **- Size of Objects on Pile(photomosaics)** - State of the Fuse (photomosaics)"	
Risk to Human Health through Bycatch		- Salvaging -->Direct Contact				- Number of Fatalities of Fishers - Number of Injuries to Fishers	- No	Fishing intensity --> Human Health
						- Number of salvaged objects	**- fishing intensity** - Fishing effort	
						- Number of Objects Present on Seafloor - Amount of explosive material in Object - Corrosion State - Trawling Intensity	- State of the Fuse (photomosaics)	
Risk to Human Health from Beaching		- Water --> Beaching - Sediment --> Water --> Beaching - Explosion --> Water --> Beaching - Explosion --> Sediment --> Water --> Beaching		Beach Visitors		- Number of Fatalities of Tourists - Number of Injuries to Tourists	- No	Distance to Public Beaches --> Human health
						- Number of Beachings - Number of Tourists - Distance to Beaches - Distance to Coast	**- Distance to Public Beaches**	
						- Amount of explosive material - Corrosion State - Current Velocity	- Number of Objects on a Pile (photomosaics) - State of Corrosion of the Casing (photomosaics)	
Risk to Fish Health from Contamination		- Prey - Water - Water --> Prey - Water --> Sediment - Water --> Sediment --> Prey - Sediment - Sediment --> Water - Sediment --> Water --> Prey - Explosion --> Water - Explosion --> Water --> Prey - Explosion --> Water --> Sediment - Explosion --> Water --> Sediment --> Prey - Explosion --> Sediment - Explosion --> Sediment --> Water - Explosion --> Sediment --> Water --> Prey	Fauna	Fish	Fauna Health	- Explosive Compounds based Health Impact on Fish	- Rates of liver tumors in fish (Limanda limanda)	EC in fish --> Fish Health
						- Explosive Compounds in Fish - Vulnerability of Fish to ECs	**- EC fish (limanda limanda)**	
						- Explosive Compounds in Prey - Explosive Compounds in Water - Explosive Compounds in Sediment	- EC concentration in Water	
						- Amount of explosive material - Corrosion State - Current Velocity - Number of Explosions	- Number of Objects on a Pile (photomosaics) - State of Corrosion of the Casing (photomosaics)	
Risk to Molluscs Health from Contamination		- Water - Water --> Sediment - Sediment - Sediment --> Water - Sediment --> Water - Explosion --> Water --> Sediment - Explosion --> Sediment - Explosion --> Sediment --> Water		Molluscs		- Explosive Compounds based Health Impact on Molluscs	- No	EC in molluscs/passive samplers --> Mollusc Health
						- Explosive Compounds in Molluscs - Vulnerability of Molluscs to ECs	**- EC in molluscs and passive samplers**	
						- Explosive Compounds in Water - Explosive Compounds in Sediment	- EC in Water	
						- Amount of explosive material - Corrosion State - Current Velocity - Number of Explosions	- Number of Objects on a Pile (photomosaics) - State of Corrosion of the Casing (photomosaics)	
Risk to Mammal Health from Contamination		- Prey - Water - Water --> Prey - Water --> Sediment - Water --> Sediment --> Prey - Sediment - Sediment --> Water - Sediment --> Water --> Prey - Explosion --> Water - Explosion --> Water --> Prey - Explosion --> Water --> Sediment - Explosion --> Water --> Sediment --> Prey - Explosion --> Sediment - Explosion --> Sediment --> Water - Explosion --> Sediment --> Water --> Prey		Mammals		- Explosive Compounds based Health Impact on Mammals	- No	EC in mammals (harbour purpoise; harbour seals) --> Mammal Health
						- Explosive Compounds in Mammals - Vulnerability of Mammals to EC	**- EC in harbour harbour purpoise** **- EC in harbour seals**	
						- Explosive Compounds in Prey - Explosive Compounds in Water - Explosive Compounds in Sediment	- EC in mussels - EC in Water - EC in fish	
						- Amount of explosive material - Corrosion State - Current Velocity - Number of Explosions	- Number of Objects on a Pile (photomosaics) - State of Corrosion of the Casing (photomosaics)	
Risk to Flora Health from Contamination		- Water - Water --> Sediment - Sediment - Sediment --> Water - Explosion --> Water - Explosion --> Water --> Sediment - Explosion --> Sediment - Explosion --> Sediment --> Water	Flora	Flora	Flora Health	- Explosive Compounds based Health Impact on Flora	- No	EC in water --> Flora Health
						- Explosive Compounds in Flora	- No	
						- Explosive Compounds in Water - Explosive Compounds in Sediment	**- EC concentration in Water**	
						- Amount of explosive material - Corrosion State - Current Velocity - Number of Explosions	- Number of Objects on a Pile (photomosaics) - State of Corrosion of the Casing (photomosaics)	
Economic Risk to Cable Operator through Property Damage		- Explosion --> Shock Wave	Economy	Cable Operators	Economic Loss	- Economic Value of Damaged Property - Economic loss for society through effect of cable damage, e.g. power failure etc.	- No	Distance to data cables --> Cable Operator
						- Number of Explosions - Amount of explosive material at Cable - Distance to cable - Cable Type	**- Distance to subsea cables**	
						- Amount of explosive material - Corrosion State - Water Depth - Sea Floor Morphology	- Number of Objects on a Pile (photomosaics) - Size of Objects on a Pile (photomosaics)	
Economic Potential for Cable Operator through More Space		- Clearance --> Free Area			Economic Potential	- Potential savings due to unobstructed cable laying - Potential to reduce cable length	- No	Pile Position within dump site --> Cable Operator
						- Distance to respective infrastructure on land - Distance to non-contaminated area	- Maritime Spatial Plan for German Sea - industrial and production facilities locations - Subsea cable locations	
						- Area cleared (+safety distance)	**- Munition locations**	
Economic Risk to Fishers through Fishing Ban		- Munition --> Contamination		Fisheries	Economic Loss	- Profit from fishing in the corresponding area - Explosive compounds in edible fish	- No - No	Fishing effort --> Fisheries
						- Explosive compounds in water - Explosive compounds in pray - Explosive compounds in sediment - Number of sessile edible fish	**- Fishing effort**	
						- Shockwave Intensity - Amount of explosives - Corrosion state - Number of explosions	- No	
Economic Risk to Fisheries through Explosion		- Explosion --> Shock Wave - Salvaging --> Explosion --> Shock Wave				- Economic Value of Damaged Property - Economic Value of Damaged Catch	- No	Fishing intensity, Amount Explosive Material (Number of objects; size of objects) --> Fisheries
						- Number of Explosions - Trawling Intensity - Amount of explosive material - Number of Salvaged Objects	**-fishing intensity** - Trawling intensity (HELCOM Dataset) - Traffic density	
						- Amount of explosive material - Corrosion State - Water Depth - Number of Objects Present on Seafloor	**- Number of Objects on a Pile (photomosaics)** - State of Corrosion of the Casing (photomosaics) **- Size of the Objects (photomosaics)** - State of Corrosion of the Fuse (photomosaics)	
Risk to Fisheries through Bycatch		- Salvaging --> Seafood				- Economic Value of Damaged Catch	- No	Fishing intensity --> Fisheries
						- Number of Salvaged Objects - Trawling Intensity	**- fishing intensity** - inside or outside trawling area (trawling prohibition within 2 nm)	
						- Corrosion State - Number of Objects Present on Seafloor	- State of Corrosion of the Fuse (photomosaics)	
Economic Potential for Fisheries through More Space		- Clearance --> Free Area			Economic Potential	- Economic potential of free space for fishing sector	- No	Pile Position within dump site, fishing intensity --> Fisheries
						- Fishing allowed or not? - Trawling intensity (Possibly irrelevant for the future, because no longer permissible) - Amount of economic fish in the area (According to Ms Gottschalk, a central question) - Distance to non-contaminated area	- Restricted areas **- Fishing intensity**	
						- Area cleared (+safety distance)	**- Munition locations** - Official Dumpsite site zones	
Risk to Shipping Sector through Explosion		- Explosion --> Shock Wave		Shipping	Economic Loss	- Economic Value of Damaged Property	- No	Shipping density, Amount Explosive Material (Number of objects; size of objects) --> Shipping
							- No	
						- Number of Explosions - Traffic Density - Amount of explosive material - Distance to Water Ways (GDWS highlights importance)	- Shipping lanes **- Shipping density**	
						- Amount of explosive material - Munition size (only large munition dangerous for ships) - State of Fuse (GDWS highlights importance) - Water Depth - Corrosion State	**- Number of Objects on a Pile (photomosaics)** - State of Corrosion of the Casing (photomosaics) **- Size of the Objects (photomosaics)** - State of Corrosion of the Fuse (photomosaics)	
Economic Potential for Shipping Sector through More Space		- Clearance --> Free Area			Economic Potential	- Economic potential to establish roadstead areas - Economic potential to reduce shipping time/distance	- No	Shipping lanes, Harbours locations, Anconarche areas, Pile Position within dump sites --> Shipping
							- No	
						- Distance to waterways/ harbors (access area)/ anchorage spots - Traffic intensity - Distance to non-contaminated area	**- Shipping lanes** **- Coastline with harbours** **- Anchorage Areas** - Geoseaportal (über BSH zur Verfügung gestellt) -IMO ships routeing guide	
						- Area cleared (+safety distance)	**- Munition locations** - Official Dumping site zones	
Marine Conservation through more Space		- Clearance --> Free Area	Marine Life		Nature Conservation	- Potential to improve	- No	Environmental vulnerability, Pile Position within dump site --> Environment
							- Environmental vulnerability (BRISK) - Conservation status	
						- Protection status/requirements of existing species - Protection status/requirements of existing habitat - Distance to existing protected areas - Distance to non-contaminated area - Tolerance requirements of adjacent areas	- Natura 2000 Sites	
						- Area cleared (+safety distance)	**- Munition locations**	
						- Other pollutants in the vicinity of the munitions sites	- Official Dumpsite site zones	
Risk to Society from Terrorism		Illegal removal of munition --> Use for Terrorism	Society		Human Health	Reported crimes	- No	Size of the Objects, Shipping lanes, Current velocity, Sediment particle size, wave height --> Society
						Surrounding infrastructure, well known dump sites, security control	**- Distance to shipping lanes** **- Current velocity** **- Sediment particle size** **- Wave height**	
						- Distance to coast - water depth	**- Size of the Objects (photomosaics)** - Number of Objects (photomosaics) - State of Corrosion of the Casing (photomosaics)	

Supplementary Table 2 SPRC-based Data Selection. EC = Explosive cpmpounds.

	Top-level Criteria						Clearance Priority Scores
	Risk to Human Health	Risk to the Economy	Risk to the Environment	Risk of Misuse	Clearance Cost	Socio-economic Potential	
Risk to Human Health	1.000						
Risk to the Economy	0.762***	1.000					
Risk to the Environment	0.249	-0.177	1.000				
Risk of Misuse	-0.420**	-0.651***	0.401*	1.000			
Clearance Cost	-0.200	0.080	-0.324*	-0.214	1.000		
Socio-economic Potential	0.653***	0.571***	-0.112	-0.518***	0.098	1.000	
Clearance Priority Scores	0.795***	0.550***	0.476**	-0.349*	-0.155	0.661***	1.000

Supplementary Table 3 Spearman correlations among top-level criteria and between top-level criteria and clearance priority scores. Asterisks indicate significance levels: (*) $p < 0.05$; (**) $p < 0.01$; (***) $p < 0.001$.

	Sub-criteria of Risk to Human Health					Risk to Human Health Scores
	Beachgoers: Direct Contact	Fishing Crew: Bycatch	Fishing Crew: Explosion	Consumer: Contamination	Shipping Crew and Passengers: Explosion	
Beachgoers: Direct Contact	1.000					
Fishing Crew: Bycatch	-0.666***	1.000				
Fishing Crew: Explosion	-0.648***	0.958***	1.000			
Consumer: Contamination	-0.313	0.535***	0.494**	1.000		
Shipping Crew and Passengers: Explosion	-0.428**	0.025	0.165	-0.169	1.000	
Risk to Human Health Scores	-0.353*	0.792***	0.797***	0.720***	0.096	1.000

Supplementary Table 4 Spearman correlations among Human Health sub-criteria and between Risk to Human Health sub-criteria and Risk to Human Health Scores. Asterisks indicate significance levels: (*) $p < 0.05$; (**) $p < 0.01$; (***) $p < 0.001$.

	Sub-criteria of Risk to the Environment				Risk to the Environment Scores
	Fish: Contamination	Flora: Contamination	Mammals: Contamination	Mollusks: Contamination	
Fish: Contamination	1.000				
Flora: Contamination	0.553***	1.000			
Mammals: Contamination	#DIV/0!	#DIV/0!	1.000		
Mollusks: Contamination	0.032	-0.412**	#DIV/0!	1.000	
Risk to the Environment Scores	0.384*	0.084	#DIV/0!	0.860***	1.000

Supplementary Table 5 Spearman correlations among Risk to the Environment sub-criteria and between Risk to the Environment sub-criteria and Risk to the Environment scores. Asterisks indicate significance levels: (*) $p < 0.05$; (**) $p < 0.01$; (***) $p < 0.001$.

	Sub-criteria of Risk to the Economy					Risk to the Economy Scores
	Cable Operators: Explosion	Fishing Sector: Bycatch	Fishing Sector: Explosion	Fishing Sector: Fishing Ban	Shipping Sector: Explosion	
Cable Operators: Explosion	1.000					
Fishing Sector: Bycatch	-0.017	1.000				
Fishing Sector: Explosion	0.005	0.931***	1.000			
Fishing Sector: Fishing Ban	-0.017	0.956***	0.968***	1.000		
Shipping Sector: Explosion	0.245	-0.070	0.065	-0.053	1.000	
Risk to the Economy Scores	0.014	0.884***	0.929***	0.910***	0.287	1.000

Supplementary Table 6 Spearman correlations among Risk to the Economy sub-criteria and between Risk to the Economy sub-criteria and Risk to the Economy Scores. Asterisks indicate significance levels: (*) $p < 0.05$; (**) $p < 0.01$; (***) $p < 0.001$.

	Sub-criteria of Socioeconomic Potential				Socioeconomic Potential Scores
	Cable: Space	Fishing: Space	Marine Conservation: Space	Shipping: Space	
Cable: Space	1.000				
Fishing: Space	0.959***	1.000			
Marine Conservation: Space	0.917***	0.898***	1.000		
Shipping: Space	0.964***	0.905***	0.919***	1.000	
Socioeconomic Potential Scores	0.991***	0.958***	0.932***	0.974***	1.000

Supplementary Table 7 Spearman correlations among Socioeconomic Potential sub-criteria and between Socioeconomic Potential sub-criteria and Socioeconomic Potential Scores. Asterisks indicate significance levels: (*) $p < 0.05$; (**) $p < 0.01$; (***) $p < 0.001$

Supplementary Text 1: Criterion Descriptions

The following text is based on:

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1 CRITERION DESCRIPTIONS

MCA-DuMP consists of six top-criteria, each of which is broken down into sub-criteria. This chapter describes every single criterion. Each criterion description is structured as follows.

Top-level Criterion

General Information

Short Criterion Description: A short description of the top-level criterion. With the exception of the top-level criterion Clearance Cost , it follows the SPRC logic [6].

Sub-Criteria: A list of all sub-criteria that belong to this top-level criterion.

Weight: The weight that was assigned to the top-level criterion by following the rules of the AHP (i.e., pairwise comparison with the other top-criteria) [6, 10].

Data Convergence

Use of Data: A description of how MCA-DuMP uses the data to produce model results. For top-criteria it always calculates a weighted mean and subsequently linearly normalises to a range from 0 to 10.

Attribute Table Field: The name of the attribute table field in which the final normalised result of the criterion can be found.

Sub-Criterion

General Information

Top-level criterion: The name of the top-level criterion to which this sub-criterion belongs.

Risk/Benefit Type: States whether the criterion addresses a risk, a benefit or neither [6].

Receptor: The affected receptor should the risk or benefit expressed by the risk or benefit materialise.

Short Criterion Description: A short description of the sub-criterion. With the exception of the top-level criterion Clearance Cost , and the details of the Risk of Misuse (Sections 1.5.1.1 through 1.5.1.5), it follows the SPRC logic [6].

Weight: The weight that was assigned to the sub-criterion by following the rules of the AHP (i.e., pair-wise comparison with the other sub-criteria that belong to the same top-level criterion) [6, 10].

Data Availability

Source/Pathway/Receptor/Consequence/Criterion Data: A list of all datasets that were considered for use to express this sub-criterion. More than one dataset can be used per sub-criterion. All selected datasets are highlighted in green. Source/pathway/receptor/consequence data are listed for Sections 1.2 through 1.6. Criterion data are listed for Section 1.7.

Selected Dataset:

Name: Official name of the dataset.

Short Data Description: A short description of the dataset, often directly copied from the data provider.

Data Provider: Name of the data provider (where applicable with information on the data portal).

Original Data Source: Link to the dataset description and the dataset.

Data Type: States whether the data are vector or raster data, which affects calculation, processing and use.

Available Since: Date the dataset was originally published.

Last Updated: Date the dataset was last updated (for publicly available datasets). Many datasets are updated regularly. This date informs about the version that is used in MCA-DuMP.

Last Received: Date the dataset was last received (for datasets that are not publicly available). Many datasets are updated regularly. This date informs about the version that is used in MCA-DuMP.

Calculation and Processing: A description of calculations and processing steps that were performed by the model developers before the data are used in MCA-DuMP. The resulting files of the calculation and processing are available on the MCA-DuMP. In some cases, calculation and processing are done only after data convergence.

Use of Data: A description of how MCA-DuMP uses the data to produce model results. It usually consists of several steps (e.g., measuring a distance or extracting a value from a raster cell) and a subsequent linear normalisation to a range from 0 or 1 to 10. If data convergence takes place, no description is given here.

Value Range: The value range from which MCA-DuMP normalises to 0 or 1 to 10. The actual value range of the dataset can be larger. If this is the case, the rationale for the upper or lower boundary of the value range is given.

Unit: The unit in which the values are measured.

Attribute Table Fields: The names of the attribute table fields in which the intermediate results and the final normalised result of the criterion can be found. Final criterion results are underlined.

Data Convergence

Calculation and Processing: A description of how data were converged and, in some cases, of subsequent calculations and processing steps that were performed by the model developers before the data are used in MCA-DuMP. The resulting files of the calculation and processing are available on the MCA-DuMP repository.

Use of Data: A description of how MCA-DuMP uses the data to produce model results. It usually consists of several steps (e.g., measuring a distance or extracting a value from a raster cell) and a subsequent linear normalisation to a range from 0 or 1 to 10.

Value Range: The value range from which MCA-DuMP normalises to 0 or 1 to 10. The actual value range of the dataset can be larger. If this is the case, the rationale for the upper or lower boundary of the value range is given.

Unit: The unit in which the values are measured.

Attribute Table Fields: The names of the attribute table fields in which the intermediate results and the final normalised result of the criterion can be found. Final criterion results are underlined.

Rejected Dataset

Name: Official name of the dataset.

Short Data Description: A short description of the dataset, often directly copied from the data provider.

Data Provider: Name of the data provider (where applicable with information on the data portal).

Original Data Source: Link to the dataset description and the dataset.

Data Type: States whether the data are vector or raster data.

Available Since: Date the dataset was originally published or provided to the developers of MCA-DuMP.

Last Updated: Date the dataset was last updated. Many datasets are updated regularly. This date informs about the version that was reviewed for use in MCA-DuMP.

Rationale for Rejection: The reason why the dataset was rejected.

Next steps/Recommendations

A list of measures that could be taken to improve MCA-DuMP's results, either by adapting the model or by collecting more or other data.

1.1 Pile Prioritisation

General Information

Short Criterion Description: This criterion describes the overall priority of munition piles for clearance.

Top-Criteria: Risk to Human Health, Risk to the Environment, Risk to the Economy, Risk of Misuse, Socioeconomic Potential, Clearance Cost

Weight: None

Data Convergence

Use of Data: Apply the weights of the top-criteria to their normalised values to calculate a weighted mean. Normalise from 0 to 10.

Attribute Table Field: PRIOresult

1.2 Risk to Human Health

General Information

Short Criterion Description: This criterion describes the overall risk posed by existing munition piles *(source)*, arising from the combination of all identified individual risks (sub-criteria), each defined by specific exposure mechanisms *(pathways)*, that have the credible potential to negatively affect humans *(receptors)* by causing harm to their health *(consequence)*.

Sub-Criteria: Beachgoers (Direct Contact), Fishing Crew (Bycatch), Fishing Crew (Explosion), Seafood Consumer (Contamination), Shipping Crew (Explosion)

Weight: 0.299

Data Convergence

Use of Data: Apply the weights of the sub-criteria to their normalised values to calculate a weighted mean. Normalise from 0 to 10.

Attribute Table Field: RHHresult

1.2.1 Beachgoers – Direct Contact

General Information

Top-level Criterion: Risk to Human Health

Risk/Benefit Type: Risk

Receptor: Beachgoers

Short Criterion Description: The criterion describes the risk of existing munition piles *(source)* releasing pieces of munitions that land on public beaches *(pathway)* and are picked up by beachgoers *(receptor)*, such as tourists and residents, causing injury *(consequence)* [1].

Weight: 0.192

Data Availability

Source Data: Yes

- Annotations of visual data of munition piles
    - Properties: Number of Objects on a Pile, State of Corrosion of the Casing *(rejected)*

Pathway Data: Yes

- Badestellen in Mecklenburg-Vorpommern (Swimming spots in Mecklenburg–Western Pomerania) **(selected)**
- Badestellen in Schleswig-Holstein (WFS SH swimming spots in Schleswig-Holstein) **(selected)**
    - Layer: Badestellen (Swimming spots)

Receptor Data: No

Consequence Data: No

Selected Dataset 1

Name: Badestellen in Mecklenburg-Vorpommern (Swimming spots in Mecklenburg-Western Pomerania)

Short Data Description: A dataset of the locations of swimming spots along Mecklenburg-Western Pomerania's coast.

Data Provider: Ministry of Economics, Labour and Health, the State Office for Health and Social Affairs, the regional health authorities, and the responsible environmental authorities in Mecklenburg-Western Pomerania (via Geoportal.de)

Original Data Source:
https://www.geoportal.de/Metadata/48b06521-8714-48c7-a356-568912b9c5a0

Data Type: Vector points

Available Since: 16.09.2024

Last Updated: 16.09.2024

Calculation and Processing: No processing before data convergence.

Use of Data: See data convergence.

Value Range: None

Unit: None

Attribute Table Fields: None

Selected Dataset 2

Name: Badestellen in Schleswig-Holstein (Swimming spots in Schleswig-Holstein) (Layer: Badestellen (Swimming spots))

Short Data Description: A dataset of the locations of swimming spots along Schleswig-Holstein's Baltic Sea coast.

Data Provider: Ministry of Justice and Health of the State of Schleswig-Holstein (via Geoportal.de)

Original Data Source:
https://www.geoportal.de/Metadata/3991341b-08e4-4c4b-ab8d-d64d6b8fd270

Data Type: Vector points

Available Since: 25.05.2012

Last Updated: 06.07.2023

Calculation and Processing: No processing before data convergence.

Use of Data: See data convergence.

Value Range: None

Unit: None

Attribute Table Fields: None

Data Convergence

Calculation and Processing: Datasets were merged into one point vector dataset. All points that were not located along the Baltic Sea coastline were deleted.

Use of Data: Measure the distance between the munition pile and the closest bathing site point. If the distance is ≥ 7,299 m, normalise to 1. If the distance is ≤ 1,462 m, normalise to 10. Otherwise, inversely normalise from 10 to 1.

Value Range: 1,462–7,299 (The minimum and maximum values are based on the IQR rule, i.e., $Q1 - 1.5 * IQR$ and $Q3 + 1.5 * IQR$, of the measured distance between all known munition piles (version from 11.04.2025) and the respective closest bathing site points of the processed dataset.)

Unit: m

Attribute Table Fields: bathingSitedistance, normBeachContact

Next steps/Recommendations

- IOW is currently developing a prediction model for munitions and parts thereof washing ashore at beaches. Once the model is verified, it would constitute a more reliable pathway dataset.
- The number of munitions at bathing sites would likely constitute more reliable (closer to the receptor) pathway data that could be added as an input into the function. Such data may be available at the MSZ Cuxhaven.
- The number of instances of injuries sustained due to direct contact with munitions at different locations would be valuable consequence data.

1.2.2 Fishing Crew – Bycatch

General Information

Top-level Criterion: Risk to Human Health

Risk/Benefit Type: Risk

Receptor: Fishing Crew

Short Criterion Description: The criterion describes the risk that existing munition piles or individual munitions of piles *(source)* are accidentally brought aboard a fishing vessel as bycatch and explode *(pathway)*, thereby causing harm to its crew *(receptor)* such as death or injury *(consequence)* [11].

This criterion diverges from the criterion "Fishing Sector – Bycatch". This difference is accounted for by placing more weight on the fishing intensity of smaller fishing vessels by accounting for the fishing time independently from the vessel size. The rationale is that crew on all fishing vessels, regardless of size, are subject to similar risk.

This criterion diverges from the criterion "Fishing Crew – Explosion". This difference is accounted for by considering only the fishing intensity and no additional visual data of munition piles (such as the Num-ber of Objects on a Pile or the Size of the Objects). The rationale is that an explosion of a munition aboard a ves-sel is likely to harm the crew regardless of the amount of explosive material.

Weight: 0.130

Data Availability

Source Data: Yes

- Annotations of visual data of munition piles
  - Properties: State of the Fuse *(rejected)*

Pathway Data: Yes

- Fishing intensity and effort 2016–2021 (VMS data)
  - Dataset: Fishing intensity total 2016–2021 **(selected)**
    - Data: fhr [fishing hours]

- Dataset: Fishing effort all gear types 2016–2021 *(rejected)*

Receptor Data: No

Consequence Data: No

Selected Dataset

Name: Fishing intensity and effort 2016–2021 (VMS data) (Dataset: Fishing intensity total 2016–2021)

Short Data Description: "This dataset contains fishing intensity and effort data 2016–2021 based on VMS data. The data has been provided to [the International Council for the Exploration of the Sea] ICES by Member States and processed to C-square resolution data products." [12] Data on the following mobile bottom-contacting gears are included: Dredges, Otter trawls, Demersal seines.

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/0195e2c6-6b83-49ea-a0db-41f14a316c87 (https://maps.helcom.fi/website/MADS/download/?id=human_activities163)

Data Type: Vector (Polygons)

Available Since: 26.05.2023

Last Updated: 26.05.2023

Calculation and Processing: The dataset was clipped to the area of interest. Data of *gear_group total* from the column *fhr* were accumulated per C-square for all years. The resulting polygons are used in MCA-DuMP.

Use of Data: Extract the polygon value at munition pile centroid. If the munition pile does not overlap with a polygon, assign the value 0. Normalise from 0 to 10.

Value Range: 0–562 (The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the processed dataset.)

Unit: Fishing hours

Attribute Table Fields: fishingintensity_fhr, normFishingCBycatch

Rejected Dataset

Name: Fishing intensity and effort 2016–2021 (VMS data) (Dataset: Fishing effort all gear types 2016–2021)

Short Data Description: "This dataset contains fishing intensity and effort data 2016–2021 based on VMS data. The data has been provided to [the International Council for the Exploration of the Sea] ICES by Member States and processed to C-square resolution data products." [12] Data on the following gear groups are included: Dredges, Bottom trawls, Pelagic trawls, Longlines, Traps, Nets, Demersal seines.

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/0195e2c6-6b83-49ea-a0db-41f14a316c87 (https://maps.helcom.fi/website/MADS/download/?id=human_activities161)

Data Type: Vector (Polygons)

Available Since: 26.05.2023

Last Updated: 26.05.2023

Rationale for Rejection: The selected dataset is superior because it is based on the same information but was already filtered for mobile bottom-contacting gears.

Next steps/Recommendations

- Assess whether data on the number of reported instances of munitions as bycatch are available. These would likely constitute more reliable (receptor) data.

1.2.3 Fishing Crew – Explosion

General Information

Top-level Criterion: Risk to Human Health

Risk/Benefit Type: Risk

Receptor: Fishing Crew

Short Criterion Description: The criterion describes the risk that existing munition piles or individual munitions on piles *(source)* may explode *(pathway)* in the vicinity of a fishing vessel and cause harm to its crew *(receptor)* such as death or injury *(consequence)* [13].

This criterion diverges from the criterion "Fishing Sector – Explosion". This difference is accounted for by placing more weight on the fishing intensity of smaller fishing vessels by accounting for the fishing time independently from the vessel size. The rationale is that crew on all fishing vessels, regardless of size, are subject to similar risk.

This criterion diverges from the criterion "Fishing Crew – Bycatch". This difference is accounted for by consi-dering not only the fishing intensity but also visual data of munition piles (Number of Objects on a Pile and Size of the Objects). The rationale is that the impact of an explosion underwater on the health of the crew onboard a fishing vessel will vary depending on whether and with what intensity the resulting shock-wave reaches the vessel, which depends on the amount of explosive material.

Weight: 0.247

Data Availability

Source Data: Yes

- Annotations of visual data of munition piles
  - Properties: Number of Objects on a Pile, Size of the Objects (median) **(selected)**
  - Properties: State of the Fuse *(rejected)*

Pathway Data: Yes

- Fishing intensity and effort 2016–2021 (VMS data)
  - Dataset: Fishing intensity total 2016–2021 **(selected)**
    - Data: fhr [fishing hours]
  - Dataset: Fishing effort all gear types 2016–2021 *(rejected)*

Receptor Data: No

Consequence Data: No

Selected Dataset 1

Name: Annotations of visual data of munition piles (Properties: Number of Objects on a Pile, Size of the Objects (median))

Short Data Description: Existing visual data show the size and number of individual munitions on munition piles.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: https://doi.pangaea.de/10.1594/PANGAEA.988426 (For security reasons the coordinates are not publicly available. For information on these data, please contact Jens Greinert at GEOMAR (jgreinert@geomar.de).)

Data Type: Photomosaics

Available Since: Varying

Last Received: 31.03.2025

Calculation and Processing: Photomosaics were annotated by three experts. They counted the number of objects and measured a subset of objects on each pile. The mean values of the expert assessments per pile (Number of Objects on a Pile and Size of the Objects (median)) were entered into a munition pile property table that is used as an input to MCA-DuMP.

A strong correlation was found for the number of objects and the area (in m²) of a munition pile. Numbers of objects per area of munition pile were not normally distributed but showed significant statistical difference for different dump sites. Hence, the values 0.57 (Kolberger Heide), 2.35 (Haffkrug), and 0.36 (Pelzerhaken) were used as conversion factors to calculate the number of objects per area for munition piles for which no visual data could be assessed. These are the median values of annotated munition piles in respective dump sites, except for Kolberger Heide, where the median of all piles was used due to a small sub-sample size.

Use of Data: See data convergence.

Value Ranges:

- Number of Objects: 1–829 (The minimum value was used to be able to calculate a case where an individual object shall be assessed with MCA-DuMP. The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the dataset.)
- Size of the Objects (median): 0.29–1.84 (The minimum value is the smallest median measured value for a pile by an expert. The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the dataset.)

Units:

- Number of Objects: None
- Size of the Objects: m

Attribute Table Fields: explosionFactor

Selected Dataset 2

Name: Fishing intensity and effort 2016–2021 (VMS data) (Dataset: Fishing intensity total 2016–2021)

Short Data Description: "This dataset contains fishing intensity and effort data 2016–2021 based on VMS data. The data has been provided to [the International Council for the Exploration of the Sea] ICES by Member States and processed to C-square resolution data products." [12] Data on the following mobile bottom-contacting gears are included: Dredges, Otter trawls, Demersal seines.

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/0195e2c6-6b83-49ea-a0db-41f14a316c87 (https://maps.helcom.fi/website/MADS/download/?id=human_activities163)

Data Type: Vector (Polygons)

Available Since: 26.05.2023

Last Updated: 26.05.2023

Calculation and Processing: The dataset was clipped to the area of interest. Data of *gear_group total* from the column *fhr* were accumulated per C-square for all years. The resulting polygons are used in MCA-DuMP.

Use of Data: Extract the polygon value at munition pile centroid. If the munition pile does not overlap with a polygon, assign the value 0. Normalise from 0 to 10.

Value Range: 0–562 (The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the processed dataset.)

Unit: Fishing hours

Attribute Table Fields: fishingintensity_fhr

Data Convergence

Calculation and Processing: No further processing.

Use of Data: If selected dataset 2 is normalised to 0, then normalise the criterion to 0. Otherwise, calculate an explosion factor for each munition pile by normalising both the Number of Objects on a Pile and the Size of the Objects (median) from 1 to 10 and subsequently calculating the arithmetic mean from both normalised values. Finally, calculate the arithmetic mean from the normalised values of both selected datasets.

Value Range: 0–10

Unit: None

Attribute Table Fields: normFishingCExplosion

Rejected Dataset 1

Name: Fishing intensity and effort 2016–2021 (VMS data) (Dataset: Fishing effort all gear types 2016–2021)

Short Data Description: "This dataset contains fishing intensity and effort data 2016–2021 based on VMS data. The data has been provided to [the International Council for the Exploration of the Sea] ICES by Member States and processed to C-square resolution data products." [12] Data on the following gear groups are included: Dredges, Bottom trawls, Pelagic trawls, Longlines, Traps, Nets, Demersal seines.

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/0195e2c6-6b83-49ea-a0db-41f14a316c87 (https://maps.helcom.fi/website/MADS/download/?id=human_activities161)

Data Type: Vector (Polygons)

Available Since: 26.05.2023

Last Updated: 26.05.2023

Rationale for Rejection: Selected dataset 2 is superior because it is based on the same information but was already filtered for mobile bottom-contacting gears.

Next steps/Recommendations

- Assess whether data on the number of reported instances of munitions as bycatch are available. These would likely constitute more reliable (receptor) data.
- Consider assessing risk as a function of additional properties of the munition on the munition pile (e.g., State of the Fuse).

1.2.4 Seafood Consumer – Contamination

General Information

Top-level Criterion: Risk to Human Health

Risk/Benefit Type: Risk

Receptor: Seafood Consumer

Short Criterion Description: The criterion describes the risk that existing munition piles *(source)* releasing explosive compounds into the water and sediment, entering the food chain *(pathway)*, ultimately reaching seafood consumers *(receptor)*, causing negative health effects *(consequence)* due to their carcinogenic and mutagenic properties. Note that recent studies have shown that mussels [14] and fish [15, 16] are not yet a cause for concern for human consumption.

Weight: 0.227

Data Availability

Source Data: Yes

- Annotations of visual data of munition piles
  - Properties: Number of Objects on a Pile, State of Corrosion of the Casing *(rejected)*

Pathway Data: Yes

- Fishing intensity and effort 2016–2021 (VMS data)
  - Dataset: Fishing intensity total 2016–2021 *(rejected)*
  - Dataset: Fishing effort all gear types 2016–2021 **(selected)**
    - Data: kwfhr [kilowatt fishing hours]
- Various Water Sampling Data *(rejected)*
- Explosives leaking from dumped munition contaminate fish from German coastal waters – a cause for chronic effects?
  - Baltic_North_Sea_L_limanda_TNT_R3 **(selected)**
- Various mussels and passive sampler datasets **(selected)**
  - AL609 Toxicology mussels and passive samplers in Lübeck bay
  - 05.07.22 Kolberger Heide mussels and passive samplers Toxicology
  - 08.03.23 Kolberger Heide mussels and passive samplers Toxicology
  - 29.08.23 Kolberger Heide mussels and passive samplers Toxicology
  - Toxi UDEMM Kolberger Heide mine mound mussel monitoring April16-March17

Receptor Data: No

Consequence Data: No

Selected Dataset 1

Name: Fishing intensity and effort 2016–2021 (VMS data) (Dataset: Fishing effort all gear types 2016–2021)

Short Data Description: "This dataset contains fishing intensity and effort data 2016–2021 based on VMS data. The data has been provided to [the International Council for the Exploration of the Sea] ICES by Member States and processed to C-square resolution data products." [12] Data on the following gear groups are included: Dredges, Bottom trawls, Pelagic trawls, Longlines, Traps, Nets, Demersal seines.

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/0195e2c6-6b83-49ea-a0db-41f14a316c87 (https://maps.helcom.fi/website/MADS/download/?id=human_activities161)

Data Type: Vector (Polygons)

Available Since: 26.05.2023

Last Updated: 26.05.2023

Calculation and Processing: The dataset was clipped to the area of interest. Data from the column *kwfhr* were accumulated per C-square for all years. The resulting polygons are used in MCA-DuMP.

Use of Data: Extract the polygon value at munition pile centroid. If the munition pile does not overlap with a polygon, assign the value 0. Normalise from 0 to 10.

Value Range: 0–148,838 (The maximum value is based on the IQR rule, i.e.,$Q3 + 1.5 * IQR$ of the processed dataset.)

Unit: kW fishing hours

Attribute Table Fields: fishingeffort_kwfhr

Selected Dataset 2

Name: Explosives leaking from dumped munition contaminate fish from German coastal waters – a cause for chronic effects? (File: Baltic_North-Sea_L_limanda_TNT_R3; Values: *L. limanda, bile, 2-ADNT*, *L. limanda, bile, 4-ADNT*, *L. limanda, bile, HMX*)

Short Data Description: The data show concentrations of various explosive compounds in fish from inside a munition dump site and from outside the dump site for comparison [16].

Data Provider: Thünen-Institute of Fisheries Ecology [CONMAR]

Original Data Source: https://www.openagrar.de/receive/openagrar_mods_00095690 (https://www.openagrar.de/servlets/MCRFileNodeServlet/openagrar_derivate_00058797/Baltic_North-Sea_L_limanda_TNT_R3.xlsx)

Data Type: XLSX (Points)

Available Since: 30.04.2024

Last Updated: Never

Calculation and Processing: Data of the fields *L. limanda, bile, 2-ADNT*, *L. limanda, bile, 4-ADNT*, and *L. limanda, bile, HMX* were added up to a total contamination value. Resulting sums were used to determine the median value for each sampling location. The resulting points with their value *ECFish* are used in MCA-DuMP.

Use of Data: Extract the *ECFish* point value from the data point closest to the munition pile centroid. If the distance from the munition pile to the sampling station is > 7,751 m, assign the value 4.5 ng/ml as *ECFish* (median of all sampling stations). The distance value was introduced to avoid munition piles being assigned to sampling stations at a great distance. The value was determined by applying the IQR rule, i.e., $Q3 + 1.5 * IQR$ to the distance between known munition piles (version from 11.04.2025) and the processed dataset. Normalise from 0 to 10.

Value Range: 0.0–30.5 (The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the processed dataset.)

Unit: ng/ml

Attribute Table Fields: ECFish, distance_fish

Selected Dataset 3

Name: AL609 Toxicology mussels and passive samplers in Lübeck bay, 05.07.22 Kolberger Heide mussels and passive samplers Toxicology, 08.03.23 Kolberger Heide mussels and passive samplers Toxicology, 29.08.23 Kolberger Heide mussels and passive samplers Toxicology (Fields*: 1,3-DNB_A, 1,3-DNB_B, 2,4-DNT_A, 2,4-DNT_B, TNT_A, TNT_B, 4-ADNT_A, 4-ADNT_B, 2-ADNT_A, 2-ADNT_B*), Toxi UDEMM Kolberger Heide mine mound mussel monitoring April16-March17 (Fields: *tnt_mean*, *4adnt_mean*, *2adnt_mean*)

Short Data Description: The data show concentrations of various explosive compounds in mussels and passive samplers in munition dump sites in the German Baltic Sea.

Data Provider: University Medical Center Schleswig Holstein (UKSH) [CONMAR]

Original Data Source: For information on these data, please contact Edmund Master, Jennifer Strehse, or Lillian Bünning at UKSH (maser@toxi.uni-kiel.de, strehse@toxi.uni-kiel.de, or buenning@toxi.uni-kiel.de).

Data Type: Vector (Points)

Available Since: Varying

Last Updated: 29.08.2024

Calculation and Processing: Data were filtered for mussel data (i.e., passive sampler data were removed) and data at 0 m above the seabed. Data in the columns mentioned above were averaged for each explosive compound and subsequently added up to a total contamination value. Note that measured explosive compounds were not identical for all selected datasets. However, those compounds that were not measured in all datasets only amounted to negligible concentrations. Hence, they could be included in the total contamination value. Where measurements were given in wet weight, they were converted to 11.5 % dry weight. Resulting sums were used to determine the median value for each sampling location. The resulting points with their field value *ECMussels* are used in MCA-DuMP.

Use of Data: Extract the *ECMussels* point value from the data point closest to the munition pile centroid. If the distance from the munition pile to the sampling station is > 3540 m, assign the value 0 ng/g as *ECMussels* (median of all sampling stations). The distance value was introduced to avoid munition piles being assigned to sampling stations at a great distance. The value was determined by applying the IQR rule, i.e., $Q3 + 1.5 * IQR$ to the distance between all known munition piles (version from 11.04.2025) and the sampling stations of the processed dataset. Normalise from 0 to 10.

Value Range: 0.0–1.4 (The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the processed dataset.)

Unit: ng/g (dry weight)

Attribute Table Fields: ECMussels, distance_mussel

Data Convergence

Calculation and Processing: No further processing.

Use of Data: If selected dataset 1 or selected datasets 2 and 3 are normalised to 0, then normalise the criterion to 0. Otherwise, calculate the arithmetic mean from the normalised values of selected datasets 2 and 3 and use the result to calculate the arithmetic mean with the normalised value of selected dataset 1.

Value Range: 0–10

Unit: None

Attribute Table Fields: normConsumerContamination

Rejected Dataset 1

Name: Fishing intensity and effort 2016–2021 (VMS data) (Dataset: Fishing intensity total 2016–2021)

Short Data Description: "This dataset contains fishing intensity and effort data 2016–2021 based on VMS data. The data has been provided to [the International Council for the Exploration of the Sea] ICES by Member States and processed to C-square resolution data products." [12] Data on the following mobile bottom-contacting gears are included: Dredges, Otter trawls, Demersal seines.

Data Provider: HELCOM

Original Data Source: https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/0195e2c6-6b83-49ea-a0db-41f14a316c87 (https://maps.helcom.fi/website/MADS/download/?id=human_activities163)

Data Type: Vector (Polygons)

Available Since: 26.05.2023

Last Updated: 26.05.2023

Rationale for Rejection: Selected dataset 1 is superior because we assume that a fishing ban would affect all gear types.

Rejected Dataset 2

Name: Various Water Sampling Data (Values: *RDX*, *DNB*, *TNT*, *4-ADNT*, *2-ADNT*)

Short Data Description: The data show concentrations of various explosive compounds in water samples in the German Baltic Sea. Data were collected as discrete samples with Niskin bottles over the course of numerous cruises.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: Some of the data are currently in the publication process via Pangea. Some are already available (https://doi.pangaea.de/10.1594/PANGAEA.974527).

Data Type: XLSX (Points)

Available Since: Currently being published

Last Updated: Never

Rationale for Rejection: Even though this dataset and selected dataset 2 are both pathway data, fish are considered closer to the receptor when following the SPRC logic of MCA-DuMP.

1.2.5 Shipping Crew and Passengers – Explosion

General Information

Top-level Criterion: Risk to Human Health

Risk/Benefit Type: Risk

Receptor: Shipping Crew and Passengers

Short Criterion Description: The criterion describes the risk that existing munition piles or individual munitions on piles *(source)* may explode in the vicinity of a vessel *(pathway)* and cause harm to its crew and passengers *(receptor)* such as death or injury *(consequence)* [13].

This criterion diverges from the criterion "Shipping Sector – Explosion". It places more weight on the traffic intensity of passenger ships. The rationale is that passenger ships are more likely to carry more people that could be harmed as the result of an explosion.

Weight: 0.204

Data Availability

Source Data: Yes

- Annotations of visual data of munition piles
  - Properties: Number of Objects on a Pile, Size of the Objects (median) **(selected)**
  - Properties: State of the Fuse *(rejected)*

Pathway Data: Yes

- HELCOM AIS Shipping density maps **(selected)**
  - Layers: 2016–2022 All shiptypes AIS Shipping Density
- AIS Schiffsverkehrsdichte (AIS shipping density) *(rejected)*
- EMODnet Human Activities *(rejected)*
  - EMSA Route Density Map
  - Vessel Density Map
- Various shipping lane datasets (*rejected*)
  - Verkehrsnetze (Schifffahrtswege) (Traffic network (shipping lanes))
  - Generalized Coastline
  - Anchorage Areas
  - Harbours (HOLAS 3)
  - IMO ships routeing guide

Receptor Data: No

Consequence Data: No

Selected Dataset 1

Name: Annotations of visual data of munition piles (Properties: Number of Objects on a Pile, Size of the Objects (median))

Short Data Description: Existing visual data show the size and number of individual munitions on munition piles.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: https://doi.pangaea.de/10.1594/PANGAEA.988426 (For security reasons the coordinates are not publicly available. For information on these data, please contact Jens Greinert at GEOMAR (jgreinert@geomar.de).)

Data Type: Photomosaics

Available Since: Varying

Last Received: Varying

Use of Data: See data convergence.

Calculation and Processing: Photomosaics were annotated by three experts. They counted the number of objects and measured a subset of objects on each pile. The mean values of the expert assessments per pile (Number of Objects on a Pile and Size of the Objects (median)) were entered into a munition pile property table that is used as an input to MCA-DuMP.

Median sizes of objects on munition piles were not normally distributed but showed significant statistical difference in median values for different dump sites. Hence, the values 0.82 (Kolberger Heide), 0.50 (Haffkrug), and 0.92 (Pelzerhaken) were given to munition piles for which no visual data could be assessed. These are the median values of annotated munition piles in respective dump sites, except for Kolberger Heide, where the median of all piles was used due to a small sub-sample size.

A strong correlation was found for the number of objects and the area (in m^2) of a munition pile. Numbers of objects per area of munition pile were not normally distributed but showed significant statistical

difference for different dump sites. Hence, the values 0.57 (Kolberger Heide), 2.35 (Haffkrug), and 0.36 (Pelzerhaken) were used as conversion factors to calculate the number of objects per area for munition piles for which no visual data could be assessed. These are the median values of annotated munition piles in respective dump sites, except for Kolberger Heide, where the median of all piles was used due to a small sub-sample size.

Value Ranges:

- Number of Objects: 1–829 (The minimum value was used to be able to calculate a case where an individual object shall be assessed with MCA-DuMP. The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the dataset.)
- Size of the Objects (median): 0.29–1.84 (The minimum value is the smallest median measured value for a pile by an expert. The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$, of the dataset.)

Units:

- Number of Objects: None
- Size of the Objects: m

Attribute Table Fields: explosionFactor

Selected Dataset 2

Name: HELCOM AIS Shipping density maps (Layers: 2016–2022 All shiptypes AIS Shipping Density)

Short Data Description: "This dataset represents the density of all IMO registered ships operating in the Baltic Sea. Shipping density is defined as the number of ships crossing a 1 x 1 km grid cell. Density maps are annual and created for the time period 2006–2022 per all ship types and by IMO ship category." "Raw AIS data used for creating the density maps is based on HELCOM AIS (Automatic Identification System) data. The HELCOM AIS network hosts all the AIS signals received by the Baltic Sea States since 2005." "The data was processed to produce density maps and traffic statistics." [17]

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/2558244b-0cea-46e9-8053-af6ef5d01853 (https://maps.helcom.fi/website/download/Traffic%20intensity-2006-2022.zip)

Data Type: Raster

Available Since: Unknown

Last Updated: 24.01.2022

Calculation and Processing: Data for the year 2022 for all ship types were clipped to the area of interest. The density values for all ship types except "Passenger" were used to calculate a cumulated traffic density using the r.series tool. The resulting "AllExceptPassenger" raster and the "Passenger" raster are used in MCA-DuMP.

Use of Data: Produce a 5,000 m buffer at the munition pile centroid. (The buffer value was determined based on calculations according to which the detonation of one investigated munition pile would require a safety distance of 4,082 m [18]. This value was rounded up to 5,000 m to produce a rounded distance at which no ship would be affected by the detonation of a munition pile.) Extract the cumulated traffic density for the buffered area for both rasters. Normalise from 0 to 10. Calculate the weighted arithmetic mean for both rasters, where the "Passenger" raster has a weight of 2 and the "AllExceptPassenger" raster has a value of 1.

Value Ranges:

- Passenger ships: 0–199,845 (The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$, of the cumulated traffic density for a buffered area for each grid cell of the processed dataset.)
- Non-passenger ships: 0–417,975 (The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$, of the cumulated traffic density for a buffered area for each grid cell of the processed dataset.)

Unit: None

Attribute Table Fields: trafficDensityHHPsum, trafficDensityHHNPsum

Data Convergence

Calculation and Processing: No further processing.

Use of Data: If both rasters of selected dataset 2 are normalised to 0, then normalise the criterion to 0. Otherwise, calculate an explosion factor for each munition pile by normalising both the Number of Objects on a Pile and the Size of the Objects (median) from 1 to 10 and subsequently calculating the arithmetic mean from both normalised values. Finally, calculate the arithmetic mean from the normalised values of both selected datasets.

Value Range: 0–10

Unit: None

Attribute Table Fields: normShippingCPExplosion

Rejected Dataset 1

Name: AIS Schiffsverkehrsdichte (AIS shipping density)

Short Data Description: For each grid cell, the number of ships per year that travelled through or stayed in this cell was counted. To calculate the average vessel traffic density, the total number of vessels in each cell was divided by the number of days in the month, and, for a better quantitative comparison, the number of vessels in the cell was converted to a unit area of 1 km². [19]

Data Provider: BSH

Original Data Source: https://data.bsh.de/SpatialData/Main/AIS_VTD/ (This dataset is not available anymore.)

Data Type: Raster/WCS

Available Since: Unknown

Last Updated: 16.09.2019

Rationale for Rejection: The selected dataset contains more recent data.

Rejected Dataset 2

Name: EMODnet Human Activities (EMSA Route Density Map)

Short Data Description: "The Route Density Map at 1 km resolution was created […] in 2019 and made available on EMODnet Human Activities" [20].

Data Provider: EMODnet

Original Data Source:
https://emodnet.ec.europa.eu/geonetwork/srv/eng/catalog.search#/metadata/74eef9c6-13fe-4630-b935-f26871c8b661

Data Type: Unknown

Available Since: 19.12.2019

Last Updated: 13.01.2025

Rationale for Rejection: This dataset and selected dataset 2 are considered similar.

Rejected Dataset 3

Name: EMODnet Human Activities (Vessel Density Map)

Short Data Description: "The maps are based on AIS data […]. The maps, GeoTIFF format, show shipping density in 1x1 km cells of a grid covering all EU waters and some neighbouring areas. Density is expressed as hours per square kilometre per month." [21]

Data Provider: EMODnet

Original Data Source:
https://emodnet.ec.europa.eu/geonetwork/srv/eng/catalog.search#/metadata/0f2f3ff1-30ef-49e1-96e7-8ca78d58a07c

Data Type: Unknown

Available Since: 11.03.2019

Last Updated: 04.03.2024

Rationale for Rejection: This dataset and selected dataset 2 are considered similar.

Rejected Datasets 4

Name: Various shipping lane datasets

Short Data Description: Datasets contain the water transport network for maritime shipping, coastline harbours, and anchorage areas. For more information on these data, please refer to the criterion description of the criterion "Distance to Shipping Lanes".

Data Provider: Various

Original Data Source: Various

Data Type: Vector

Available Since: Varying

Last Updated: Varying

Rationale for Rejection: To determine the risk for shipping crew and passengers, data on the real distribution of traffic density in the area of interest are considered of higher relevance than the location of shipping lanes, harbours, and anchorage areas. The latter do not contain any quantitative information on the occurrence of vessels.

Next steps/Recommendations

- Consider assessing risk as a function of additional properties of the munition on the munition pile (e.g., State of the Fuse).
- Consider implementing Gaussian kernel smoothing as described in this reference [2].

1.3 Risk to the Environment

General Information

Short Criterion Description: This criterion describes the overall risk posed by existing munition piles *(source)*, arising from the combination of all identified individual risks (sub-criteria) associated with releasing explosive compounds *(pathways)* that have the credible potential to negatively affect marine flora and fauna *(receptors)* by causing harm to them through their toxic properties (consequence).

Sub-Criteria: Fish (Contamination), Flora (Contamination), Mammals (Contamination), Molluscs (Contamination)

Weight: 0.271

Data Convergence

Use of Data: Apply the weights of the sub-criteria to their normalised values to calculate a weighted mean. Normalise from 0 to 10.

Attribute Table Field: RENresult

1.3.1 Fish – Contamination

General Information

Top-level Criterion: Risk to the Environment

Risk/Benefit Type: Risk

Receptor: Fish

Short Criterion Description: This criterion describes the risk of an existing munition pile (*source*) releasing explosive compounds into the water and sediment, entering the food chain (*pathway*), reaching and contaminating fish (*receptor*) and causing harm (*consequence*), such as killing or rendering fish infertile through their carcinogenic and mutagenic properties.

Weight: 0.295

Data Availability

Source Data: Yes

- Annotations of visual data of munition piles
    - Properties: Number of Objects on a Pile, State of Corrosion of the Casing *(rejected)*

Pathway Data: Yes

- Various Water Sampling Data *(rejected)*

Receptor Data: Yes

- Explosives leaking from dumped munition contaminate fish from German coastal waters – a cause for chronic effects?
    - Baltic_North_Sea_L_limanda_TNT_R3 **(selected)**

Consequence Data: Yes

- Explosives leaking from dumped munition contaminate fish from German coastal waters – a cause for chronic effects?
    - Baltic_North_Sea_L_limanda_diseases_R1 *(rejected)*

Selected Dataset

Name: Explosives leaking from dumped munition contaminate fish from German coastal waters – a cause for chronic effects? (File: Baltic_North-Sea_L_limanda_TNT_R3; Values: *L. limanda, bile, 2-ADNT*, *L. limanda, bile, 4-ADNT*, *L. limanda, bile, HMX*)

Short Data Description: The data show concentrations of various explosive compounds in fish from inside a munition dump site and from outside the dump site for comparison [16].

Data Provider: Thünen-Institute of Fisheries Ecology [CONMAR]

Original Data Source: https://www.openagrar.de/receive/openagrar_mods_00095690 (https://www.openagrar.de/servlets/MCRFileNodeServlet/openagrar_derivate_00058797/Baltic_North-Sea_L_limanda_TNT_R3.xlsx)

Data Type: XLSX (Points)

Available Since: 30.04.2024

Last Updated: Never

Calculation and Processing: Data of the fields *L. limanda, bile, 2-ADNT*, *L. limanda, bile, 4-ADNT*, and *L. limanda, bile, HMX* were added up to a total contamination value. Resulting sums were used to determine the median value for each sampling location. The resulting points with their value *ECFish* are used in MCA-DuMP.

Use of Data: Extract the *ECFish* point value from the data point closest to the munition pile centroid. If the distance from the munition pile to the sampling station is > 7,751 m, assign the value 4.5 ng/ml as *ECFish* (median of all sampling stations). Normalise from 0 to 10. The distance value was introduced to avoid munition piles being assigned to sampling stations at a great distance. The value was determined by applying the IQR rule, i.e., $Q3 + 1.5 * IQR$ to the distance between known munition piles (version from 11.04.2025) and the processed dataset.

Value Range: 0.0–30.5 (The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the processed dataset.)

Unit: ng/ml

Attribute Table Fields: ECFish, distance_fish, normFishCont

Rejected Dataset

Name: Explosives leaking from dumped munition contaminate fish from German coastal waters – a cause for chronic effects? (File: Baltic_North_Sea_L_limanda_diseases_R1)

Short Data Description: The data describe anomalies, such as tumours, found in fish from inside a munition dump site and from outside the dump site for comparison.

Data Provider: Thünen-Institute of Fisheries Ecology [CONMAR]

Original Data Source: https://www.openagrar.de/receive/openagrar_mods_00095690 (https://www.openagrar.de/servlets/MCRFileNodeServlet/openagrar_derivate_00058797/Baltic_North-Sea_L_limanda_diseases_R1.xlsx)

Data Type: XLSX (Points)

Available Since: 30.04.2024

Last Updated: Never

Rationale for Rejection: There remains an uncertainty about the relationship between the anomalies and the ECs. For example, tumours may result from a variety of causes, with munition's ECs possibly

being a small or no factor. In addition, "the health status of fish caught at the most contaminated site in the Baltic Sea was not worse compared to fish living in less contaminated areas" [16].

Next steps/Recommendations

- If a correlation between the contamination and diseases is observed in the future, the receptor dataset should be replaced with a consequence dataset.

1.3.2 Flora – Contamination

General Information

Top-level Criterion: Risk to the Environment

Risk/Benefit Type: Risk

Receptor: Flora

Short Criterion Description: This criterion describes the risk of an existing munition pile (*source*) releasing explosive compounds into the water and sediment (*pathway*), reaching and contaminating flora (*receptor*) and causing harm (*consequence*).

Weight: 0.192

Data Availability

Source Data: Yes

- Annotations of visual data of munition piles
  - Properties: Number of Objects on a Pile, State of Corrosion of the Casing *(rejected)*

Pathway Data: Yes

- Various Water Sampling Data **(selected)**

Receptor Data: No

Consequence Data: No

Selected Dataset

Name: Various Water Sampling Data (Values: *RDX*, *DNB*, *TNT*, *4-ADNT*, *2-ADNT*)

Short Data Description: The data show concentrations of various explosive compounds in water samples in the German Baltic Sea. Data were collected as discrete samples with Niskin bottles over the course of numerous cruises.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: Some of the data are currently in the publication process via Pangea. Some are already available (https://doi.pangaea.de/10.1594/PANGAEA.974527).

Data Type: XLSX (Points)

Available Since: Currently being published

Last Updated: Never

Calculation and Processing: Data were filtered for bottom water samples. Next, data in the columns *RDX*, *DNB*, *TNT*, *4-ADNT*, and *2-ADNT* were added up to a total contamination value. Data of the resulting column *Total EC* [explosive compounds] were assigned to a 4-km-hexagon grid and used to determine the median value for each hexagon. The resulting hexagons with their value *ECWater* are used in MCA-DuMP.

Use of Data: Extract the *ECWater* polygon value at munition pile centroid. If the munition pile does not overlap with a polygon, assign the value 2.9 ng/l as *ECWater* (median of all sampling stations). Normalise from 0 to 10.

Value Range: 0.0–16.6 (The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the processed dataset.)

Unit: ng/l

Attribute Table Fields: ECWater, normFloraCont

1.3.3 Mammals – Contamination

General Information

Top-level Criterion: Risk to the Environment

Risk/Benefit Type: Risk

Receptor: Mammals

Short Criterion Description: This criterion describes the risk of an existing munition pile (*source*) releasing explosive compounds into the water and sediment, entering the food chain (*pathway*), reaching and contaminating marine mammals (*receptor*), specifically harbour porpoises and seals, and causing harm (*consequence),* such as killing or rendering mammals infertile through their carcinogenic and mutagenic properties.

Weight: 0.231

Data Availability

Source Data: Yes

- Annotations of visual data of munition piles
    - Properties: Number of Objects on a Pile, State of Corrosion of the Casing *(rejected)*

Pathway Data: Yes

- Various Water Sampling Data *(rejected)*
- Explosives leaking from dumped munition contaminate fish from German coastal waters – a cause for chronic effects? *(rejected)*
- Various mussels and passive sampler datasets *(rejected)*

Receptor Data: Yes

- Results of the STV analysis of tissues and body fluids from harbour seals and harbour porpoises) **(selected)**

Consequence Data: No

Selected Dataset

Name: Ergebnisse der STV Analytik der Untersuchten Gewebe und Körperflüssigkeiten aus Seehunden und Schweinswalen (Results of the STV analysis of tissues and body fluids from harbour seals and harbour porpoises)

Short Data Description: The data show concentrations of various explosive compounds in the urine, muscle, kidney, liver, and bile of harbour porpoises and seals in the western part of the German Baltic Sea [22].

Data Provider: University Medical Center Schleswig Holstein (UKSH) [CONMAR]

Original Data Source:
https://www.umweltbundesamt.de/system/files/medien/11850/publikationen/129_2024_munitionsreste_in_der_meeresumwelt.pdf

Data Type: Text in PDF file.

Available Since: 01.09.2024

Last Updated: Never

Calculation and Processing: Data for all assessed specimens were added as points, and the explosive compound concentrations were added to the field *ECMammals*. The resulting points with their field value *ECMammals* are used in MCA-DuMP.

Use of Data: Extract the *ECMammals* point value from the data point closest to the munition pile centroid. Normalise from 0 to 10.

Value Range: 0–100 (The maximum value is arbitrary, since no sample showed a concentration above the limit of detection [22].)

Unit: ng/ml or ng/g

Attribute Table Fields: ECMammals, normMammalsCont

Next steps/Recommendations

- The relatively high weight given to this criterion by expert surveys suggests that future updates of the prioritisation list would benefit from its inclusion. To this end, research efforts should be directed to include measures of receptor and consequence data, such as explosive compounds in mammals and anomalies in mammals because of explosive compound contamination.

1.3.4 Molluscs – Contamination

General Information

Top-level Criterion: Risk to the Environment

Risk/Benefit Type: Risk

Receptor: Molluscs

Short Criterion Description: This criterion describes the risk of an existing munition pile (*source*) releasing explosive compounds into the water and sediment (*pathway*), reaching and contaminating molluscs (*receptor*) and causing harm (*consequence*).

Weight: 0.283

Data Availability

Source Data: Yes

- Annotations of visual data of munition piles
  - Properties: Number of Objects on a Pile, State of Corrosion of the Casing *(rejected)*

Pathway Data: Yes

- Various Water Sampling Data *(rejected)*

Receptor Data: Yes

- Various mussels and passive sampler datasets **(selected)**
  - AL609 Toxicology mussels and passive samplers in Lübeck bay
  - 05.07.22 Kolberger Heide mussels and passive samplers Toxicology

- 08.03.23 Kolberger Heide mussels and passive samplers Toxicology
- 29.08.23 Kolberger Heide mussels and passive samplers Toxicology
- Toxi UDEMM Kolberger Heide mine mound mussel monitoring April16-March17

Consequence Data: No

Selected Dataset

Name: AL609 Toxicology mussels and passive samplers in Lübeck bay, 05.07.22 Kolberger Heide mussels and passive samplers Toxicology, 08.03.23 Kolberger Heide mussels and passive samplers Toxicology, 29.08.23 Kolberger Heide mussels and passive samplers Toxicology (Fields*: 1,3-DNB_A, 1,3-DNB_B, 2,4-DNT_A, 2,4-DNT_B, TNT_A, TNT_B, 4-ADNT_A, 4-ADNT_B, 2-ADNT_A, 2-ADNT_B*), Toxi UDEMM Kolberger Heide mine mound mussel monitoring April16-March17 (Fields: *tnt_mean*, *4adnt_mean*, *2adnt_mean*)

Short Data Description: The data show concentrations of various explosive compounds in mussels and passive samplers in munition dump sites in the German Baltic Sea.

Data Provider: University Medical Center Schleswig Holstein (UKSH) [CONMAR]

Original Data Source: For information on these data, please contact Edmund Master, Jennifer Strehse, or Lillian Bünning at UKSH (maser@toxi.uni-kiel.de, strehse@toxi.uni-kiel.de, or buenning@toxi.uni-kiel.de).

Data Type: Vector (Points)

Available Since: Varying

Last Updated: 29.08.2024

Calculation and Processing: Data were filtered for mussel data (i.e., passive sampler data were removed) and data at 0 m above the seabed. Data in the columns mentioned above were averaged for each explosive compound and subsequently added up to a total contamination value. Note that measured explosive compounds were not identical for all selected datasets. However, those compounds that were not measured in all datasets only amounted to negligible concentrations. Hence, they could be included in the total contamination value. Where measurements were given in wet weight, they were converted to 11.5 % dry weight. Resulting sums were used to determine the median value for each sampling location. The resulting points with their field value *ECMussels* are used in MCA-DuMP.

Use of Data: Extract the *ECMussels* point value from the data point closest to the munition pile centroid. If the distance from the munition pile to the sampling station is > 3,540 m, assign the value 0 ng/g as *ECMussels* (median of all sampling stations). Normalise from 0 to 10. The distance value was introduced to avoid munition piles being assigned to sampling stations at a great distance. The value was determined by applying the IQR rule, i.e., $Q3 + 1.5 * IQR$ to the distance between all known munition piles (version from 11.04.2025) and the sampling stations of the processed dataset.

Value Range: 0.0–1.4 (The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the processed dataset.)

Unit: ng/g (dry weight)

Attribute Table Fields: ECMussels, distance_mussel, normMolluscsCont

Next steps/Recommendations

- Place moorings in areas where explosive compound concentration in water is highest to fill data gaps.

1.4 Risk to the Economy

General Information

Short Criterion Description: This criterion describes the overall risk posed by existing munition piles *(source)*, arising from the combination of all identified individual risks (sub-criteria), each defined by specific exposure mechanisms *(pathways)*, that have the credible potential to negatively affect economic sectors *(receptors)* by causing harm to their economic output or value *(consequence)*.

Sub-Criteria: Cable Operators (Explosion), Fishing Sector (Bycatch), Fishing Sector (Demand Loss), Fishing Sector (Explosion), Fishing Sector (Fishing Ban), Shipping Sector (Explosion), Tourism Sector (Demand Loss)

Weight: 0.096

Data Convergence

Use of Data: Apply the weights of the sub-criteria to their normalised values to calculate a weighted mean. Normalise from 0 to 10.

Attribute Table Field: RECresult

1.4.1 Cable Operators – Explosion

General Information

Top-level Criterion: Risk to the Economy

Risk/Benefit Type: Risk

Receptor: Cable Operators

Short Criterion Description: This criterion describes the risk that an existing munition pile (*source*) is brought to explosion and produces a pressure wave (*pathway*), affecting an underwater cable, causing harm to the cable operator (*receptor*) in the form of economic loss through cables being damaged or destroyed (*consequence*).

Weight: 0.168

Data Availability

Source Data: Yes

- Annotations of visual data of munition piles
  - Properties: Number of Objects on a Pile, Size of the Objects *(rejected)*

Pathway Data: Yes

- Industrie- und Produktionsanlagen im deutschen Seegebiet (Industrial and production facilities in the German sea area)
  - Features: High Voltage Cables; Data Cables **(selected)**
  - Numerous other features were rejected due to irrelevance for the risk receptor
- Flächenentwicklungsplan für deutsche Seegebiete 2024 Draft (Maritime Spatial Plan for German sea areas 2024 Draft)
  - Feature: Subseacable Buffer **(selected)**
  - Numerous other features were rejected due to irrelevance for the risk receptor
- Cables (HOLAS 3) **(selected)**

Receptor Data: No

Consequence Data: No

Selected Dataset 1

Name: Industrie- und Produktionsanlagen im deutschen Seegebiet (Industrial and production facilities in the German sea area) (Features: High Voltage Cables; Data Cables)

Short Data Description: A dataset of all high voltage and data cables in German waters and EEZ.

Data Provider: Bundesamt für Seeschifffahrt und Hydrographie (BSH) (Federal Maritime and Hydrographic Agency (Germany))

Original Data Source:
https://nokis.mdi-de-dienste.org/trefferanzeige?docuuid=f52650c0-cbd9-434d-bb33-a00800fefc69
(https://gdi.bsh.de/de/data/Production-and-Industrial-Facilities-in-the-German-Maritime-Area.zip)

Data Type: Vector/WFS

Available Since: 11.09.2007

Last Updated: 13.10.2024

Calculation and Processing: No processing before data convergence.

Use of Data: See data convergence.

Value Range: None

Unit: None

Attribute Table Fields: None

Selected Dataset 2

Name: Flächenentwicklungsplan für deutsche Seegebiete 2024 Draft (Maritime Spatial Plan for German sea areas 2024 Draft) (Feature: Subseacable Buffer)

Short Data Description: A dataset of buffers for existing and future cables in the German EEZ.

Data Provider: Bundesamt für Seeschifffahrt und Hydrographie (BSH) (Federal Maritime and Hydrographic Agency (Germany))

Original Data Source: https://www.geoseaportal.de/mapapps/?lang=de
(https://gdi.bsh.de/de/feed/Site-Development-Plan-in-the-German-Maritime-Area-2024-Draft.xml)

Data Type: Vector/WFS

Available Since: 07.06.2024

Last Updated: 07.06.2024

Calculation and Processing: Polygon data were converted to line data.

Use of Data: See data convergence.

Value Range: None

Unit: None

Attribute Table Fields: None

Selected Dataset 3

Name: Cables (HOLAS 3)

Short Data Description: A dataset of all high voltage and data cables in German waters and EEZ. "The dataset contains cables in the marine environment that were made available by HELCOM Contracting Parties in response to a data call. Data were collected by the HELCOM Secretariat in 2022." [23]

Data Provider: HELCOM

Original Data Source: https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/9026b43c-7da8-4a8f-8854-4a4dba50fb12 (Due to security concerns, this dataset is not publicly available anymore.)

Data Type: Vector/WFS

Available Since: 24.02.2023

Last Updated: 24.02.2023

Calculation and Processing: Polygon data were converted to line data.

Use of Data: See data convergence.

Value Range: None

Unit: None

Attribute Table Fields: None

Data Convergence

Calculation and Processing: Datasets were merged into one line vector dataset.

Use of Data: Measure the shortest distance between the munition pile and any cable in the used datasets. If the distance is > 5,000 m, normalise to 0. If the distance is ≤ 5,000 m, inversely normalise from 10 to 0.

Value Range: 0–5,000 (The maximum value was determined based on calculations according to which the detonation of one investigated munition pile would require a safety distance of 4,082 m [18]. This value was rounded up to 5,000 m to produce a rounded distance at which no ship would be affected by the detonation of a munition pile.)

Unit: m

Attribute Table Fields: cableDistance, normCableExplosion

Next steps/Recommendations

- Consider assessing risk as a function of the properties of the munitions on the munition pile (e.g., State of the Fuse).

1.4.2 Fishing Sector – Bycatch

General Information

Top-level Criterion: Risk to the Economy

Risk/Benefit Type: Risk

Receptor: Fishing Sector

Short Criterion Description: The criterion describes the risk that existing munition piles or individual munitions on piles *(source)* are accidentally brought aboard *(pathway)* a fishing vessel as bycatch and cause harm to the vessel and cargo owner *(receptor)* in the form of economic loss *(consequence)*.

This criterion diverges from the criterion "Fishing Crew – Bycatch". This difference is accounted for by placing more weight on the fishing intensity of larger fishing vessels by accounting not only for the fishing time but also the vessel size. The rationale is that the economic value of fishing vessels correlates with their size.

This criterion diverges from the criterion "Fishing Sector – Explosion". This difference is accounted for by considering only the fishing intensity and no additional visual data of munition piles (such as the Number of Objects on a Pile or the Size of the Objects). The rationale is that an explosion of a munition aboard a vessel is likely to damage the vessel and the catch regardless of the amount of explosive material.

Weight: 0.155

Data Availability

Source Data: Yes

- Annotations of visual data of munition piles
  - Properties: State of the Fuse *(rejected)*

Pathway Data: Yes

- Fishing intensity and effort 2016–2021 (VMS data)
  - Dataset: Fishing intensity total 2016–2021 **(selected)**
    - Data: kwfhr [kilowatt fishing hours]
  - Dataset: Fishing effort all gear types 2016–2021 *(rejected)*

Receptor Data: No

Consequence Data: No

Selected Dataset

Name: Fishing intensity and effort 2016–2021 (VMS data) (Dataset: Fishing intensity total 2016–2021)

Short Data Description: "This dataset contains fishing intensity and effort data 2016–2021 based on VMS data. The data has been provided to [the International Council for the Exploration of the Sea] ICES by Member States and processed to C-square resolution data products." [12] Data on the following mobile bottom-contacting gears are included: Dredges, Otter trawls, Demersal seines.

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/0195e2c6-6b83-49ea-a0db-41f14a316c87 (https://maps.helcom.fi/website/MADS/download/?id=human_activities163)

Data Type: Vector (Polygons)

Available Since: 26.05.2023

Last Updated: 26.05.2023

Calculation and Processing: The dataset was clipped to the area of interest. Data of *gear_group total* from the column *kwfhr* were accumulated per C-square for all years. The resulting polygons are used in MCA-DuMP.

Use of Data: Extract the polygon value at munition pile centroid. If the munition pile does not overlap with a polygon, assign the value 0. Normalise from 0 to 10.

Value Range: 0–123,013 (The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the processed dataset.)

Unit: kW fishing hours

Attribute Table Fields: fishingintensity_kwfhr, normCableExplosion

Rejected Dataset

Name: Fishing intensity and effort 2016–2021 (VMS data) (Dataset: Fishing effort all gear types 2016–2021)

Short Data Description: "This dataset contains fishing intensity and effort data 2016–2021 based on VMS data. The data has been provided to [the International Council for the Exploration of the Sea] ICES by Member States and processed to C-square resolution data products." [12] Data on the following gear groups are included: Dredges, Bottom trawls, Pelagic trawls, Longlines, Traps, Nets, Demersal seines.

Data Provider: HELCOM

Original Data Source: https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/0195e2c6-6b83-49ea-a0db-41f14a316c87 (https://maps.helcom.fi/website/MADS/download/?id=human_activities161)

Data Type: Vector (Polygons)

Available Since: 26.05.2023

Last Updated: 26.05.2023

Rationale for Rejection: The selected dataset is superior because it is based on the same information but was already filtered for mobile bottom-contacting gears.

Next steps/Recommendations

- Assess whether data on the number of reported instances of munitions as bycatch are available. These would likely constitute more reliable (receptor) data.

1.4.3 Fishing Sector – Explosion

General Information

Top-level Criterion: Risk to the Economy

Risk/Benefit Type: Risk

Receptor: Fishing Sector

Short Criterion Description: The criterion describes the risk that existing munition piles or individual munitions on piles *(source)* may explode in the vicinity or aboard a vessel, damaging the hull or other parts of the ship or possibly leading to the sinking of the vessel [13] *(pathway)*, causing harm to the owner of the fishing ship *(receptor)* in the form of economic loss *(consequence)*. Accordingly, the economic value of the vessels and their catch is at risk.

This criterion diverges from the criterion "Fishing Crew – Explosion". This difference is accounted for by placing more weight on the fishing intensity of larger fishing vessels by accounting not only for the fishing time but also the vessel size. The rationale is that the economic value of fishing vessels correlates with their size.

This criterion diverges from the criterion "Fishing Sector – Bycatch". This difference is accounted for by considering not only the fishing intensity but also visual data of munition piles (Number of Objects on a Pile and Size of the Objects). The rationale is that the impact of an explosion underwater on the fishing vessel will vary depending on whether and with what intensity the resulting shockwave reaches the vessel, which depends on the amount of explosive material.

Weight: 0.132

Data Availability

Source Data: Yes

- Annotations of visual data of munition piles
  - Properties: Number of Objects on a Pile, Size of the Objects (median) **(selected)**
  - Properties: State of the Fuse *(rejected)*

Pathway Data: Yes

- Fishing intensity and effort 2016–2021 (VMS data)
  - Dataset: Fishing intensity total 2016–2021 **(selected)**
    - Data: kwfhr [kilowatt fishing hours]
  - Dataset: Fishing effort all gear types 2016–2021 *(rejected)*

Receptor Data: No

Consequence Data: No

Selected Dataset 1

Name: Annotations of visual data of munition piles (Properties: Number of Objects on a Pile, Size of the Objects (median))

Short Data Description: Existing visual data show the size and number of individual munitions on munition piles.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: https://doi.pangaea.de/10.1594/PANGAEA.988426 (For security reasons the coordinates are not publicly available. For information on these data, please contact Jens Greinert at GEOMAR (jgreinert@geomar.de).)

Data Type: Photomosaics

Available Since: Varying

Last Received: Varying

Calculation and Processing: Photomosaics were annotated by three experts. They counted the number of objects and measured a subset of objects on each pile. The mean values of the expert assessments per pile (Number of Objects on a Pile and Size of the Objects (median)) were entered into a munition pile property table that is used as an input to MCA-DuMP.

Median sizes of objects on munition piles were not normally distributed but showed significant statistical difference in median values for different dump sites. Hence, the values 0.82 (Kolberger Heide), 0.50 (Haffkrug), and 0.92 (Pelzerhaken) were given to munition piles for which no visual data could be assessed. These are the median values of annotated munition piles in respective dump sites, except for Kolberger Heide, where the median of all piles was used due to a small sub-sample size.

A strong correlation was found for the number of objects and the area (in m²) of a munition pile. Numbers of objects per area of munition pile were not normally distributed but showed significant statistical difference for different dump sites. Hence, the values 0.57 (Kolberger Heide), 2.35 (Haffkrug), and 0.36 (Pelzerhaken) were used as conversion factors to calculate the number of objects per area for munition piles for which no visual data could be assessed. These are the median values of annotated munition piles in respective dump sites, except for Kolberger Heide, where the median of all piles was used due to a small sub-sample size.

Use of Data: See data convergence.

Attribute Table Fields: explosionFactor

Value Ranges:

- Number of Objects: 1–829 (The minimum value was used to be able to calculate a case where an individual object shall be assessed with MCA-DuMP. The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the dataset.)
- Size of the Objects (median): 0.29–1.84 (The minimum value is the smallest median measured value for a pile by an expert. The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the dataset.)

Units:

- Number of Objects: None
- Size of the Objects: m

Selected Dataset 2

Name: Fishing intensity and effort 2016–2021 (VMS data) (Dataset: Fishing intensity total 2016–2021)

Short Data Description: "This dataset contains fishing intensity and effort data 2016–2021 based on VMS data. The data has been provided to [the International Council for the Exploration of the Sea] ICES by Member States and processed to C-square resolution data products." [12] Data on the following mobile bottom-contacting gears are included: Dredges, Otter trawls, Demersal seines.

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/0195e2c6-6b83-49ea-a0db-41f14a316c87 (https://maps.helcom.fi/website/MADS/download/?id=human_activities163)

Data Type: Vector (Polygons)

Available Since: 26.05.2023

Last Updated: 26.05.2023

Calculation and Processing: The dataset was clipped to the area of interest. Data of *gear_group total* from the column *kwfhr* were accumulated per C-square for all years. The resulting polygons are used in MCA-DuMP.

Use of Data: Extract the polygon value at munition pile centroid. If the munition pile does not overlap with a polygon, assign the value 0. Normalise from 0 to 10.

Value Range: 0–123,013 (The maximum value is based on the IQR rule, i.e.,$Q3 + 1.5 * IQR$ of the processed dataset.)

Unit: kW fishing hours

Attribute Table Fields: fishingintensity_kwfhr

Data Convergence

Calculation and Processing: No further processing.

Use of Data: If selected dataset 2 is normalised to 0, then normalise the criterion to 0. Otherwise, calculate an explosion factor for each munition pile by normalising both the Number of Objects on a Pile and the Size of the Objects (median) from 1 to 10 and subsequently calculating the arithmetic mean from both normalised values. Finally, calculate the arithmetic mean from the normalised values of both selected datasets.

Value Range: 0–10

Unit: None

Attribute Table Fields: normFishingSExplosion

Rejected Dataset

Name: Fishing intensity and effort 2016–2021 (VMS data) (Dataset: Fishing effort all gear types 2016–2021)

Short Data Description: "This dataset contains fishing intensity and effort data 2016–2021 based on VMS data. The data has been provided to [the International Council for the Exploration of the Sea] ICES by Member States and processed to C-square resolution data products." [12] Data on the following gear groups are included: Dredges, Bottom trawls, Pelagic trawls, Longlines, Traps, Nets, Demersal seines.

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/0195e2c6-6b83-49ea-a0db-41f14a316c87 (https://maps.helcom.fi/website/MADS/download/?id=human_activities161)

Data Type: Vector (Polygons)

Available Since: 26.05.2023

Last Updated: 26.05.2023

Rationale for Rejection: Selected dataset 2 is superior because it is based on the same information but was already filtered for mobile bottom-contacting gears.

Next steps/Recommendations

- Assess whether data on the number of reported instances of munitions as bycatch are available. These would likely constitute more reliable (receptor) data.
- Consider assessing risk as a function of additional properties of the munition on the munition pile (e.g., State of the Fuse).

1.4.4 Fishing Sector – Fishing Ban

General Information

Top-level Criterion: Risk to the Economy

Risk/Benefit Type: Risk

Receptor: Fishing Sector

Short Criterion Description: The criterion describes the risk that munition piles *(source)* releasing explosive compounds into the water and sediment, entering the food chain *(pathway)*, may lead to a ban for the fishing sector *(receptor)*, thereby causing economic harm *(consequence)*.

Weight: 0.118

Data Availability

Source Data: No

Pathway Data: Yes

- Fishing intensity and effort 2016–2021 (VMS data)
  - Dataset: Fishing intensity total 2016–2021 *(rejected)*
  - Dataset: Fishing effort all gear types 2016–2021 **(selected)**
    - Data: kwfhr [kilowatt fishing hours]

Receptor Data: No

Consequence Data: No

Selected Dataset

Name: Fishing intensity and effort 2016–2021 (VMS data) (Dataset: Fishing effort all gear types 2016–2021)

Short Data Description: "This dataset contains fishing intensity and effort data 2016–2021 based on VMS data. The data has been provided to [the International Council for the Exploration of the Sea] ICES by Member States and processed to C-square resolution data products." [12] Data on the following gear groups are included: Dredges, Bottom trawls, Pelagic trawls, Longlines, Traps, Nets, Demersal seines.

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/0195e2c6-6b83-49ea-a0db-41f14a316c87 (https://maps.helcom.fi/website/MADS/download/?id=human_activities161)

Data Type: Vector (Polygons)

Available Since: 26.05.2023

Last Updated: 26.05.2023

Calculation and Processing: The dataset was clipped to the area of interest. Data from the column *kwfhr* were accumulated per C-square for all years. The resulting polygons are used in MCA-DuMP.

Use of Data: Extract the polygon value at munition pile centroid. If the munition pile does not overlap with a polygon, assign the value 0. Normalise from 0 to 10.

Value Range: 0–148,838 (The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the processed dataset.)

Unit: kW fishing hours

Attribute Table Fields: fishingeffort_kwfhr, normFishingBan

Rejected Dataset

Name: Fishing intensity and effort 2016–2021 (VMS data) (Dataset: Fishing intensity total 2016–2021)

Short Data Description: "This dataset contains fishing intensity and effort data 2016–2021 based on VMS data. The data has been provided to ICES by Member States and processed to C-square resolution data products." [12] Data on the following mobile bottom-contacting gears are included: Dredges, Otter trawls, Demersal seines.

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/0195e2c6-6b83-49ea-a0db-41f14a316c87 (https://maps.helcom.fi/website/MADS/download/?id=human_activities163)

Data Type: Vector (Polygons)

Available Since: 26.05.2023

Last Updated: 26.05.2023

Rationale for Rejection: The selected dataset is superior because we assume that a fishing ban would affect all gear types.

Next steps/Recommendations

- Consider merging munition pile data to areas or dumpsites to include them as source data. These data could be a proxy for the probability that a fishing ban is instituted over an area.

1.4.5 Shipping Sector – Explosion

General Information

Top-level Criterion: Risk to the Economy

Risk/Benefit Type: Risk

Receptor: Shipping Sector

Short Criterion Description: The criterion describes the risk that existing munition piles or individual munitions on piles *(source)* may explode in the vicinity of a vessel, damaging the hull or other parts of the ship or possibly leading to the sinking of the vessel [13] *(pathway)*, thereby causing harm to the owner of the ship *(receptor)* in the form of economic loss *(consequence)*.

This criterion diverges from the criterion "Shipping Crew and Passengers – Explosion". It places more weight on the traffic intensity of cargo ships. The rationale is that cargo ships are more likely to carry greater economic value that could be harmed as the result of an explosion.

Weight: 0.187

Data Availability

Source Data: Yes

- Annotations of visual data of munition piles
  - Properties: Number of Objects on a Pile, Size of the Objects (median) **(selected)**
  - Properties: State of the Fuse *(rejected)*

Pathway Data: Yes

- HELCOM AIS Shipping density maps **(selected)**
  - Layers: 2016–2022 All shiptypes AIS Shipping Density
- AIS Schiffsverkehrsdichte (AIS shipping density) *(rejected)*
- EMODnet Human Activities *(rejected)*
  - EMSA Route Density Map
  - Vessel Density Map
- Various shipping lane datasets (*rejected*)
  - Verkehrsnetze (Schifffahrtswege) (Traffic network (shipping lanes))
  - Generalized Coastline
  - Anchorage Areas
  - Harbours (HOLAS 3)
  - IMO ships routeing guide

Receptor Data: No

Consequence Data: No

Selected Dataset 1

Name: Annotations of visual data of munition piles (Properties: Number of Objects on a Pile, Size of the Objects (median))

Short Data Description: Existing visual data show the size and number of individual munitions on munition piles.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: https://doi.pangaea.de/10.1594/PANGAEA.988426 (For security reasons the coordinates are not publicly available. For information on these data, please contact Jens Greinert at GEOMAR (jgreinert@geomar.de).)

Data Type: Photomosaics

Available Since: Varying

Last Received: Varying

Calculation and Processing: Photomosaics were annotated by three experts. They counted the number of objects and measured a subset of objects on each pile. The mean values of the expert assessments per pile (Number of Objects on a Pile and Size of the Objects (median)) were entered into a munition pile property table that is used as an input to MCA-DuMP.

Median sizes of objects on munition piles were not normally distributed but showed significant statistical difference in median values for different dump sites. Hence, the values 0.82 (Kolberger Heide), 0.50 (Haffkrug), and 0.92 (Pelzerhaken) were given to munition piles for which no visual data could be assessed. These are the median values of annotated munition piles in respective dump sites, except for Kolberger Heide, where the median of all piles was used due to a small sub-sample size.

A strong correlation was found for the number of objects and the area (in m^2) of a munition pile. Numbers of objects per area of munition pile were not normally distributed but showed significant statistical difference for different dump sites. Hence, the values 0.57 (Kolberger Heide), 2.35 (Haffkrug), and 0.36 (Pelzerhaken) were used as conversion factors to calculate the number of objects per area for munition piles for which no visual data could be assessed. These are the median values of annotated munition piles in respective dump sites, except for Kolberger Heide, where the median of all piles was used due to a small sub-sample size.

Use of Data: See data convergence.

Value Ranges:

- Number of Objects: 1–829 (The minimum value was used to be able to calculate a case where an individual object shall be assessed with MCA-DuMP. The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the dataset.)
- Size of the Objects (median): 0.29–1.84 (The minimum value is the smallest median measured value for a pile by an expert. The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the dataset.)

Units:

- Number of Objects: None
- Size of the Objects: m

Attribute Table Fields: explosionFactor

Selected Dataset 2

Name: HELCOM AIS Shipping density maps (Layers: 2016–2022 All shiptypes AIS Shipping Density)

Short Data Description: "This dataset represents the density of all IMO registered ships operating in the Baltic Sea. Shipping density is defined as the number of ships crossing a 1 x 1 km grid cell. Density maps are annual and created for the time period 2006–2022 per all ship types and by IMO ship category." "Raw AIS data used for creating the density maps is based on HELCOM AIS (Automatic Identification System) data. The HELCOM AIS network hosts all the AIS signals received by the Baltic Sea States since 2005." "The data was processed to produce density maps and traffic statistics." [17]

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/2558244b-0cea-46e9-8053-af6ef5d01853 (https://maps.helcom.fi/website/download/Traffic%20intensity-2006-2022.zip)

Data Type: Raster

Available Since: Unknown

Last Updated: 24.01.2022

Calculation and Processing: Data for the year 2022 for all ship types were clipped to the area of interest. The density values for ship types "Cargo", "Container", "Rorocargo", and "Tanker" were used to calculate a cumulated traffic density using the r.series tool. The same was done for the remaining ship types. The resulting "AllCargoTypes" and the "AllExceptCargoTypes" rasters are used in MCA-DuMP.

Use of Data: Produce a 5,000 m buffer at the munition pile centroid. (The buffer value was determined based on calculations according to which the detonation of one investigated munition pile would require a safety distance of 4,082 m. [18] This value was rounded up to 5,000 m to produce a rounded distance at which no ship would be affected by the detonation of a munition pile.) Extract the cumulated traffic density for the buffered area for both rasters. Normalise from 0 to 10. Calculate the weighted arithmetic mean for both rasters, where the "AllCargoTypes" raster has a weight of 2 and the "AllExceptCargoTypes" raster has a value of 1.

Value Ranges:

- Cargo type ships: 0–365,371 (The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$, of the cumulated traffic density for a buffered area for each grid cell of the processed dataset.)
- Non-cargo type ships: 0–250,095 (The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$, of the cumulated traffic density for a buffered area for each grid cell of the processed dataset.)

Unit: None

Attribute Table Fields: trafficDensityECCsum, trafficDensityECNCsum

Data Convergence

Calculation and Processing: No further processing.

Use of Data: If both rasters of selected dataset 2 are normalised to 0, then normalise the criterion to 0. Otherwise, calculate an explosion factor for each munition pile by normalising both the Number of Objects on a Pile and the Size of the Objects (median) from 1 to 10 and subsequently calculating the arithmetic mean from both normalised values. Finally, calculate the arithmetic mean from the normalised values of both selected datasets.

Value Range: 0–10

Unit: None

Attribute Table Fields: normShippingSExplosion

Rejected Dataset 1

Name: AIS Schiffsverkehrsdichte (AIS shipping density)

Short Data Description: For each grid cell, the number of ships per year that travelled through or stayed in this cell was counted. To calculate the average vessel traffic density, the total number of vessels in each cell was divided by the number of days in the month, and, for a better quantitative comparison, the number of vessels in the cell was converted to a unit area of 1 km². [19]

Data Provider: BSH

Original Data Source: https://data.bsh.de/SpatialData/Main/AIS_VTD/ (This dataset is not available anymore.)

Data Type: Raster/WCS

Available Since: Unknown

Last Updated: 16.09.2019

Rationale for Rejection: The selected dataset contains more recent data.

Rejected Dataset 2

Name: EMODnet Human Activities (EMSA Route Density Map)

Short Data Description: "The Route Density Map at 1 km resolution was created […] in 2019 and made available on EMODnet Human Activities" [20].

Data Provider: EMODnet

Original Data Source:
https://emodnet.ec.europa.eu/geonetwork/srv/eng/catalog.search#/metadata/74eef9c6-13fe-4630-b935-f26871c8b661

Data Type: Unknown

Available Since: 19.12.2019

Last Updated: 13.01.2025

Rationale for Rejection: This dataset and selected dataset 2 are considered similar.

Rejected Dataset 3

Name: EMODnet Human Activities (Vessel Density Map)

Short Data Description: "The maps are based on AIS data […]. The maps, GeoTIFF format, show shipping density in 1x1 km cells of a grid covering all EU waters and some neighbouring areas. Density is expressed as hours per square kilometre per month." [21]

Data Provider: EMODnet

Original Data Source:
https://emodnet.ec.europa.eu/geonetwork/srv/eng/catalog.search#/metadata/0f2f3ff1-30ef-49e1-96e7-8ca78d58a07c

Data Type: Unknown

Available Since: 11.03.2019

Last Updated: 04.03.2024

Rationale for Rejection: This dataset and selected dataset 2 are considered similar.

Next steps/Recommendations

- Consider assessing risk as a function of additional properties of the munition on the munition pile (e.g., State of the Fuse).
- Consider implementing Gaussian kernel smoothing as described in this reference [2].

1.5 Risk of Misuse

General Information

Short Criterion Description: This criterion describes the overall risk posed by existing munition piles *(source)*, that they could be recovered from the seafloor and their explosive material used *(pathways)* to negatively affect society *(receptors)* by harming people or critical infrastructure *(consequence)*.

Sub-Criterion: Terrorism (Society)

Weight: 0.124

Data Convergence

Use of Data: Uses the result of this top-level criterion's only sub-criterion.

Attribute Table Field: RMIresult

1.5.1 Society – Terrorism

General Information

Top-level Criterion: Risk of Misuse

Risk/Benefit Type: Risk

Receptor: Society

Short Criterion Description: This criterion describes the overall risk posed by existing munition piles *(source)*, that they could be recovered from the seafloor and their explosive material used *(pathways)* to negatively affect society *(receptors)* by harming people or critical infrastructure *(consequence)*.

Subsub-Criteria: Current Velocity, Distance to Shipping Lanes, Sediment Particle Size, Size of the Objects, Wave Height

Weight: 1.000

Data Availability

Source Data: Yes

- Annotations of visual data of munition piles
  - Properties: Size of the Objects (median) **(selected)**
  - Properties: Number of Objects on a Pile, State of Corrosion of the Casing *(rejected)*

Pathway Data: Yes

- Distance to shipping lane **(selected)**
- Mean Current Velocity **(selected)**
- Mean Wave Height **(selected)**
- SGE_SeabedSediments_1_to_100000 **(selected)**
- Verkehrsnetze (Schifffahrtswege) (Traffic network (shipping lanes)) **(selected)**
  - Feature: WaterwayLink
- Generalized Coastline **(selected)**
  - Feature: coastline_harbour
- Anchorage Areas **(selected)**
- Harbours (HOLAS 3) *(rejected)*
- IMO ships routeing guide *(rejected)*
- Baltic Sea Wave Analysis and Forecast *(rejected)*

Receptor Data: No

Consequence Data: No

Data Convergence

Calculation and Processing: No further processing.

Use of Data: Apply the weights of the subsub-criteria to their normalised values to calculate a weighted mean. Normalise from 0 to 10.

Value Range: 0–10

Unit: None

Attribute Table Fields: RMIresult

1.5.1.1 Current Velocity

General Information

Sub-Criterion: Society – Terrorism

Risk/Benefit Type: Risk

Receptor: Society

Short Criterion Description: This criterion describes that the lower the current velocity, the easier it is to salvage munitions (and therefore the higher the risk of misusing them).

Weight: 0.200

Data Availability

Source Data: No

Pathway Data: Yes

- Mean Current Velocity **(selected)**

Receptor Data: No

Consequence Data: No

Selected Dataset

Name: Mean Current Velocity

Short Data Description: This is a raster dataset of the mean current velocity in the Baltic Sea with a resolution of 200 m. Monthly means were calculated for the years 2017–2023.

Data Provider: Leibniz Institute for Baltic Sea Research Warnemünde (IOW) [CONMAR]

Original Data Source: For information on these data, please contact Ulf Gräwe at IOW (ulf.graewe@io-warnemuende.de).

Data Type: Raster

Available Since: Unknown

Last Received: 23.07.2024

Calculation and Processing: The annual mean for each raster cell was calculated.

Use of Data: Extract the raster cell value at the munition pile centroid. Inversely normalise from 10 to 0.

Value Range: 0.0–1.5 (The maximum value is the limit of operation during explosive ordnance disposal [13].)

Unit: m/s

Attribute Table Fields: current, normCurrent

1.5.1.2 Distance to Shipping Lanes

General Information

Sub-Criterion: Society – Terrorism

Risk/Benefit Type: Risk

Receptor: Society

Short Criterion Description: This criterion describes that the larger the distance to shipping lanes, the easier it is to salvage munitions (and therefore the higher the risk of misusing them). The closer a munition pile is to a shipping lane, the more likely a misuse activity will be observed.

Weight: 0.200

Data Availability

Source Data: No

Pathway Data: Yes

- Verkehrsnetze (Schifffahrtswege) (Traffic network (shipping lanes)) **(selected)**
  - Feature: WaterwayLink
- Generalized Coastline **(selected)**
  - Feature: coastline_harbour
- Anchorage Areas **(selected)**
- Harbours (HOLAS 3) *(rejected)*
- IMO ships routeing guide *(rejected)*

Receptor Data: No

Consequence Data: No

Selected Dataset 1

Name: Verkehrsnetze (Schifffahrtswege) (Feature: WaterwayLink)

Short Data Description: The dataset contains the water transport network for maritime shipping within the area of responsibility of the Federal Maritime and Hydrographic Agency (BSH) and its associated infrastructure facilities [24].

Data Provider: BSH

Original Data Source:
https://nokis.mdi-de-dienste.org/trefferanzeige?docuuid=85a1d598-287e-4efd-8799-c655b59d4453
(https://gdi.bsh.de/de/data/Transport-Networks-Water-Transport-Network.zip)

Data Type: Vector (Lines)

Available Since: 05.01.2017

Last Updated: 07.06.2024

Calculation and Processing: No processing before data convergence.

Use of Data: See data convergence.

Value Range: None

Unit: None

Attribute Table Fields: None

Selected Dataset 2

Name: Generalized Coastline (Feature: Costline_Harbour)

Risk/Benefit Type: Risk

Receptor: Society

Short Data Description: "This dataset contains an automatically derived coastline of the North Sea and Baltic Sea from different scale ranges of the Electronic Navigational Chart (ENC) corresponding to the relative coverage area. The ENCs are produced in accordance with the valid international standard S-57. It consists of generalised lines in the different ENC scale ranges Approach, Harbour and Berthing. The derived coastline consists of natural and man-made (e.g., piers) elements. As an alternative, there is a further coastline available." [25]

Data Provider: BSH

Original Data Source:
https://nokis.mdi-de-dienste.org/trefferanzeige?docuuid=826cb51f-d49b-4c54-b911-63ab66ebca7a
(https://gdi.bsh.de/de/data/Generalised-Coastline.zip)

Data Type: Vector (Lines)

Available Since: Unknown

Last Updated: 03.10.2024

Calculation and Processing: No processing before data convergence.

Use of Data: See data convergence.

Value Range: None

Unit: None

Attribute Table Fields: None

Selected Dataset 3

Name: Anchorage Areas

Short Data Description: The dataset contains the anchorage areas for maritime shipping within the area of responsibility of the Federal Maritime and Hydrographic Agency (BSH). [26]

Data Provider: BSH

Original Data Source For information on these data, please contact the customer service at BSH (customer@bsh.de).

Data Type: Vector (Polygons)

Available Since: Unknown

Last received: 29.11.2024

Calculation and Processing: No processing before data convergence.

Use of Data: See data convergence.

Value Range: None

Unit: None

Attribute Table Fields: None

Data Convergence

Calculation and Processing: Polygon data were converted to line data. Datasets were merged into one line vector dataset.

Use of Data: Measure the shortest distance between the munition pile and the closest point on any line. If the distance is ≥ 7,364 m, normalise to 10. If the distance is < 7,364 m, normalise from 0 to 10.

Value Range: 0–7,364 (The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$, of the measured distance between all known munition piles (version from 11.04.2025) and the respective closest shipping lane points of the processed dataset.)

Unit: m

Attribute Table Fields: shippingLanedistance, normShippingLaneDistance

Rejected Dataset 1

Name: Harbours (HOLAS 3)

Short Data Description: "The dataset contains points and polygons data of the ports and ferry terminals in the Baltic Sea downloaded from, respectively, EMODnet and OSM, and HELCOM AIS." [27]

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/ger/catalog.search#/metadata/798cffb0-8dac-47cc-83a4-143e32aa3294

Data Type: Vector (Points and Polygons)

Available Since: 21.02.2023

Last Updated: 21.02.2023

Rationale for Rejection: Selected dataset 2 is superior, since it is more detailed in two ways. (1) It contains more and smaller harbours. (2) It shows the part of the coastline that is considered a harbour by BSH, while this dataset only appears to cover the main section of the harbours.

Rejected Dataset 2

Name: IMO ships routeing guide

Short Data Description: This dataset includes digitised deep-water routes, traffic separation schemes, precautionary areas and inshore traffic zones in the Baltic Sea [28].

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/ger/catalog.search#/metadata/60712fe9-ce1b-4fc6-b0b6-46e44f9bf134

Data Type: Vector (Polygons)

Available Since: Unknown

Last Updated: 01.01.2017

Rationale for Rejection: This dataset is considered too old.

Next Steps/Recommendations

- Consider assessing distance-weighted shipping density around a munition pile's location instead of measuring distance to shipping lanes.
- Perform a more in-depth assessment of the safety distance/maximum value of 5,000 m by analysing additional munition piles.
- Check whether the inshore traffic zone at Graal-Müritz in rejected dataset 2 still exists.
- Consider adding Distance to Coast in general as a criterion.

1.5.1.3 Sediment Particle Size

General Information

Sub-Criterion: Society – Terrorism

Risk/Benefit Type: Risk

Receptor: Society

Short Criterion Description: This criterion describes that the greater the sediment particle size, the higher the probability of good underwater visibility, and hence, the easier it is to salvage munitions (and therefore the higher the risk of misusing them).

Weight: 0.200

Data Availability

Source Data: No

Pathway Data: Yes

- SGE_SeabedSediments_1_to_100000 **(selected)**

Receptor Data: No

Consequence Data: No

Selected Dataset

Name: SGE_SeabedSediments_1_to_100000

Short Data Description: Sediment was classified based on granulometric analyses of more than 17,000 irregularly distributed sediment samples. Sediment samples were classified by grain size distribution. [29]

Data Provider: BSH

Original Data Source:
https://nokis.mdi-de-dienste.org/trefferanzeige?docuuid=b4e219de-344f-4db5-a4f7-ec6fa276529b
(https://gdi.bsh.de/de/data/Seabed-Sediments-on-a-scale-of-1-100-000-in-German-Baltic-Sea.zip)

Data Type: Vector/WFS

Available Since: Unknown

Last Updated: 04.05.2023

Calculation and Processing: Sediment categories were sorted according to their grain size and assigned to the normalisation range, with 0 representing sediments that are most likely to reduce underwater visibility and 10 representing the opposite.

Use of Data: Extract the polygon value at munition pile centroid. Convert categories in the field *sediment* into the values of the normalisation range from 0 to 10.

Value Range: None, since the data are categorised.

Unit: None

Attribute Table Fields: sediment, normSedimentSize

Next Steps/Recommendations

- It is preferable to use data for underwater visibility instead of using sediment classes as a proxy. For a model update, it is, therefore, recommended to use data from clearance activities in dump sites and replace this criterion with underwater visibility.

1.5.1.4 Size of the Objects

General Information

Sub-Criterion: Society – Terrorism

Risk/Benefit Type: Risk

Receptor: Society

Short Criterion Description: This criterion describes that the smaller the size of the munitions, the easier it is to salvage them (and therefore the higher the risk of misusing them).

Weight: 0.200

Data Availability

Source Data: Yes

- Annotations of visual data of munition piles
  - Property: Size of the Objects (median) **(selected)**

Pathway Data: No

Receptor Data: No

Consequence Data: No

Selected Dataset

Name: Annotations of visual data of munition piles (Property: Size of the Objects (median))

Short Data Description: Existing visual data show the size of individual munitions on munition piles.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: https://doi.pangaea.de/10.1594/PANGAEA.988426 (For security reasons the coordinates are not publicly available. For information on these data, please contact Jens Greinert at GEOMAR (jgreinert@geomar.de).)

Data Type: Photomosaics

Available Since: Varying

Last Received: Varying

Calculation and Processing: Photomosaics were annotated by three experts. They measured a subset of the counted objects on each pile. The mean value of the expert assessments per pile (Size of the Objects (median)) was entered into a munition pile property table that is used as an input to MCA-DuMP.

Median sizes of objects on munition piles were not normally distributed but showed significant statistical difference in median values for different dump sites. Hence, the values 0.82 (Kolberger Heide),

0.50 (Haffkrug), and 0.92 (Pelzerhaken) were given to munition piles for which no visual data could be assessed. These are the median values of annotated munition piles in respective dump sites, except for Kolberger Heide, where the median of all piles was used due to a small sub-sample size.

Use of Data: Inversely normalise from 10 to 1.

Value Range: 0.29–1.84 (The minimum value and maximum value are based on the IQR rule, i.e., $Q1 - 1.5 * IQR$ and $Q3 + 1.5 * IQR$ of the dataset.)

Unit: m

Attribute Table Fields: normSize_median

Next Steps/Recommendations

- Continue the assessment of munition piles as more visual data become available in the future.
- Perform the assessment of munition piles for which video footage is available.
- Reassess piles that are partially cleared during the immediate action programme or other clearance activities in the future.
- Discuss this criterion with authorities, since larger objects may be more challenging to salvage but may also pose a greater risk of misuse due to their greater net explosive mass.

1.5.1.5 Wave Height

General Information

Sub-Criterion: Society – Terrorism

Risk/Benefit Type: Risk

Receptor: Society

Short Criterion Description: This criterion describes that the lower the wave height, the easier it is to salvage munitions (and therefore the higher the risk of misusing them).

Weight: 0.200

Data Availability

Source Data: No

Pathway Data: Yes

- Mean Wave Height **(selected)**
- Baltic Sea Wave Analysis and Forecast *(rejected)*

Receptor Data: No

Consequence Data: No

Selected Dataset

Name: Mean Wave Height

Short Data Description: This is a raster dataset of the mean significant wave height in the Baltic Sea with a resolution of 200 m. Monthly means were calculated for the years 2017–2023.

Data Provider: Leibniz Institute for Baltic Sea Research Warnemünde (IOW) [CONMAR]

Original Data Source: For information on these data, please contact Ulf Gräwe at IOW (ulf.graewe@io-warnemuende.de).

Data Type: Raster

Available Since: Unknown

Last Received: 23.07.2024

Calculation and Processing: The annual mean for each raster cell was calculated.

Use of Data: Extract the raster cell value at the munition pile centroid. Inversely normalise from 10 to 0.

Value Range: 0.0–3.0 (The maximum value is the limit of operation during explosive ordnance disposal [13].)

Unit: m

Attribute Table Fields: waveHeight, waveHeight

Rejected Dataset

Name: Baltic Sea Wave Analysis and Forecast

Short Data Description: "This Baltic Sea wave model product provides forecasts for the wave conditions in the Baltic Sea. The Baltic forecast is updated twice a day providing a new six days forecast with hourly instantaneous data for significant wave height, wave period and wave direction for total sea, wind sea and swell, the Stokes drift, and two parameters for the maximum wave. […] The product grid has a horizontal resolution of 1 nautical mile." [30]

Data Provider: Copernicus

Original Data Source:
https://data.marine.copernicus.eu/product/BALTICSEA_ANALYSISFORECAST_WAV_003_010/services

Data Type: Raster

Available Since: Unknown

Last Updated: Daily

Rationale for Rejection: The selected dataset is superior, since it has a higher resolution than this dataset.

1.6 Socioeconomic Potential

General Information

Short Criterion Description: This criterion describes the overall potential from removing a munition pile *(source)*, thereby freeing up space *(pathway)* for different economic sectors or non-economic usages *(receptors)*, thus contributing to their development *(consequence)*.

Sub-Criteria: Cable Operators (Space), Fishing Sector (Space), Marine Conservation (Space), Shipping Sector (Space)

Weight: 0.077

Data Convergence

Use of Data: Apply the weights of the sub-criteria to their normalised values to calculate a weighted mean. Normalise from 0 to 10.

Attribute Table Field: SEPresult

1.6.1 Cable Operators – Space

General Information

Top-level Criterion: Socioeconomic Potential

Risk/Benefit Type: Benefit

Receptor: Cable Operators

Short Criterion Description: This criterion describes the potential of removing an existing munition pile (*source*), thereby freeing up space (*pathway*) for cable operators *(receptor)*. This may increase the area where cables can be laid, potentially allowing them to be more cost-efficient *(consequence)*.

Weight: 0.203

Data Availability

Source Data: Yes

- MBES Munition Contacts **(selected)**
- German contaminated areas *(rejected)*

Pathway Data: Yes

- Industrie- und Produktionsanlagen im deutschen Seegebiet (Industrial and production facilities in the German sea area) *(rejected)*
- Flächenentwicklungsplan für deutsche Seegebiete 2024 Draft (Maritime Spatial Plan for German sea areas 2024 Draft) *(rejected)*
- Cables (HOLAS 3) *(rejected)*

Receptor Data: No

Consequence Data: No

Selected Dataset

Name: MBES Munition Contacts

Short Data Description: A dataset of potential and confirmed munition piles and objects that was annotated by experts on MBES data.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: For information on these data, please contact Jens Greinert at GEOMAR (jgreinert@geomar.de).

Data Type: Munition and pile annotations as polygons.

Available Since: Varying

Last Updated: 10.12.2024

Calculation and Processing: Individual centroids of confirmed munition distribution were calculated for each dump site where munition pile prioritisation is under investigation.

Use of Data: Measure the shortest distance between the munition pile and the closest centroid. If the distance is ≥ 3,000 m, normalise to 10. If the distance is < 3,000 m, normalise from 0 to 10.

Value Range: 0–3,000

Unit: m

Attribute Table Fields: contaminatedAreadistance, normContaminatedAreaDistance, normCableSpace

Rejected Dataset 1

Name: German Contaminated Areas

Short Data Description: A dataset of all munition-contaminated areas as compiled by a report by the BLANO expert group "Munitions in the Seas" [1, 31]. The dataset was updated after the initial publication.

Data Provider: Amucad.org

Original Data Source: https://legacy.amucad.org/map (This dataset is not available anymore.)

Data Type: Vector/WMS

Available Since: Unknown

Last Updated: Unknown

Rationale for Rejection: This dataset is mainly based on information that was collected in 2011 and does not represent the geographic extent of the actual contamination that has been documented since then.

Rejected Dataset 2

Name: Industrie- und Produktionsanlagen im deutschen Seegebiet (Industrial and production facilities in the German sea area)

Short Data Description: A dataset of all high voltage and data cables in German waters and EEZ.

Data Provider: Bundesamt für Seeschifffahrt und Hydrographie (BSH) (Federal Maritime and Hydrographic Agency (Germany))

Original Data Source:
https://nokis.mdi-de-dienste.org/trefferanzeige?docuuid=f52650c0-cbd9-434d-bb33-a00800fefc69
(https://gdi.bsh.de/de/data/Production-and-Industrial-Facilities-in-the-German-Maritime-Area.zip)

Data Type: Vector/WFS

Available Since: 11.09.2007

Last Updated: 13.10.2024

Rationale for Rejection: It is not plausible to link socioeconomic benefits of freeing up space for cable operators to the location of existing cables. New cables will be installed where logistics requires it and not where existing cables are present.

Rejected Dataset 3

Name: Flächenentwicklungsplan für deutsche Seegebiete 2024 Draft (Maritime Spatial Plan for German sea areas 2024 Draft) (Feature: Subseacable Buffer)

Short Data Description: A dataset of buffers for existing and future cables in the German EEZ.

Data Provider: Bundesamt für Seeschifffahrt und Hydrographie (BSH) (Federal Maritime and Hydrographic Agency (Germany))

Original Data Source: https://www.geoseaportal.de/mapapps/?lang=de (https://gdi.bsh.de/de/feed/Site-Development-Plan-in-the-German-Maritime-Area-2024-Draft.xml)

Data Type: Vector/WFS

Available Since: 07.06.2024

Last Updated: 07.06.2024

Rationale for Rejection: It is not plausible to link socioeconomic benefits of freeing up space for cable operators to the location of existing cables. New cables will be installed where logistics requires it and not where existing cables are present.

Rejected Dataset 4

Name: Cables (HOLAS 3)

Short Data Description: A dataset of all high voltage and data cables in German waters and EEZ. “The dataset contains cables in the marine environment that was made available by HELCOM Contracting Parties in response to a data call. Data were collected by the HELCOM Secretariat in 2022.” [23]

Data Provider: HELCOM

Original Data Source: https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/9026b43c-7da8-4a8f-8854-4a4dba50fb12 (Due to security concerns, this dataset is not publicly available anymore.)

Data Type: Vector/WFS

Available Since: 24.02.2023

Last Updated: 24.02.2023

Rationale for Rejection: It is not plausible to link socioeconomic benefits of freeing up space for cable operators to the location of existing cables. New cables will be installed where logistics requires it and not where existing cables are present.

Next steps/Recommendations

- For the selected dataset a more complex algorithm than simply measuring the distance to the centroid might be more appropriate to account for the density of munition piles. Therefore, a reassessment of the use of the selected dataset is recommended.

1.6.2 Fishing Sector – Space

General Information

Top-level Criterion: Socioeconomic Potential

Risk/Benefit Type: Benefit

Receptor: Fishing Sector

Short Criterion Description: This criterion describes the potential of removing an existing munition pile (*source*), thereby freeing up space (*pathway*) for the fishing sector *(receptor)*. This may increase the area where fishing can take place, potentially allowing the sector to be more profitable *(consequence)*.

Weight: 0.244

Data Availability

Source Data: Yes

- MBES Munition Contacts **(selected)**
- German contaminated areas *(rejected)*

Pathway Data: Yes

- Fishing intensity and effort 2016–2021 (VMS data)
  - Dataset: Fishing intensity all gear types 2016–2021 **(selected)**
    - Data: totval [total economic value]
  - Dataset: Fishing effort all gear types 2016–2021 *(rejected)*
- Restricted Areas (Kolberger Heide)

Receptor Data: No

Consequence Data: No

Selected Dataset 1

Name: MBES Munition Contacts

Short Data Description: A dataset of potential and confirmed munition piles and objects that was annotated by experts on MBES data.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: https://doi.pangaea.de/10.1594/PANGAEA.988426 (For security reasons the coordinates are not publicly available. For information on these data, please contact Jens Greinert at GEOMAR (jgreinert@geomar.de).)

Data Type: Munition and pile annotations as polygons.

Available Since: Varying

Last Updated: 10.12.2024

Calculation and Processing: Individual centroids of confirmed munition distribution were calculated for each dump site where munition pile prioritisation is under investigation.

Use of Data: Measure the shortest distance between the munition pile and the closest centroid. If the distance is ≥ 3,000 m, normalise to 10. If the distance is < 3,000 m, normalise from 0 to 10.

Value Range: 0–3,000

Unit: m

Attribute Table Fields: contaminatedAreadistance, normContaminatedAreaDistance

Selected Dataset 2

Name: Fishing intensity and effort 2016–2021 (VMS data) (Dataset: Fishing intensity total 2016–2021)

Short Data Description: "This dataset contains fishing intensity and effort data 2016–2021 based on VMS data. The data has been provided to ICES by Member States and processed to C-square resolution data products." [12] Data on the following gear groups are included: Dredges, Bottom trawls, Pelagic trawls, Longlines, Traps, Nets, Demersal seines. It contains the property *totval* for the economic value of the catch in the C-square.

Data Provider: HELCOM

Original Data Source: https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/0195e2c6-6b83-49ea-a0db-41f14a316c87 (https://maps.helcom.fi/website/MADS/download/?id=human_activities163)

Data Type: Vector (Polygons)

Available Since: 26.05.2023

Last Updated: 26.05.2023

Calculation and Processing: The dataset was clipped to the area of interest. Data of *gear_group total* from the column *totval* were accumulated per C-square for all years. The resulting polygons are used in MCA-DuMP.

Use of Data: Extract *totval* polygon value at munition pile centroid. If the munition pile does not overlap with a polygon, assign the value 0. Normalise from 0 to 10.

Value Range: 0–114,565 (The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the processed dataset.)

Unit: Unknown

Attribute Table Fields: fishingIntensityValue, normFishingIntensityValue

Data Convergence

Calculation and Processing: No further processing.

Use of Data: Calculate the arithmetic mean from both normalised values.

Value Range: 0–10

Unit: None

Attribute Table Fields: normFishingSpace

Rejected Dataset 1

Name: German Contaminated Areas

Short Data Description: A dataset of all munition-contaminated areas as compiled by a report by the BLANO expert group "Munitions in the Seas" [1, 31]. The dataset was updated after the initial publication.

Data Provider: Amucad.org

Original Data Source: https://legacy.amucad.org/map (This dataset is not available anymore.)

Data Type: Vector/WMS

Available Since: Unknown

Last Updated: Unknown

Rationale for Rejection: This dataset is mainly based on information that was collected in 2011 and does not represent the geographic extent of the actual contamination that has been documented since then.

Rejected Dataset 2

Name: Fishing intensity and effort 2016–2021 (VMS data) (Dataset: Fishing effort all gear types 2016–2021)

Short Data Description: "This dataset contains fishing intensity and effort data 2016–2021 based on VMS data. The data has been provided to ICES by Member States and processed to C-square resolution data products." [12]

Data Provider: HELCOM

Original Data Source: https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/0195e2c6-6b83-49ea-a0db-41f14a316c87 (https://maps.helcom.fi/website/MADS/download/?id=human_activities161)

Data Type: Vector (Polygons)

Available Since: 26.05.2023

Last Updated: 26.05.2023

Rationale for Rejection: Selected dataset 2 is superior because it is based on the same information but was already filtered for mobile bottom-contacting gears. Furthermore, this dataset contains no information on the economic value of the catch.

Rejected Dataset 3

Name: Restricted Areas (Kolberger Heide)

Short Data Description: A polygon of areas to which access is restricted for any vessel.

Data Provider: BSH

Original Data Source: These data can be viewed in publicly available nautical charts.

Data Type: Vector (Polygons)

Available Since: Unknown

Last Updated: Unknown

Rationale for Rejection: It is not clear what would happen to a restricted area if a munition pile in it were to be removed, i.e., whether the restricted area would be made available for use by the fishing sector. Accordingly, it is unclear how to prioritise munition piles based on their location in a restricted area.

Next steps/Recommendations

- For selected dataset 1, a more complex algorithm than simply measuring the distance to the centroid might be more appropriate to account for the density of munition piles. Therefore, a reassessment of the use of the selected dataset is recommended.

1.6.3 Marine Conservation – Space

General Information

Top-level Criterion: Socioeconomic Potential

Risk/Benefit Type: Benefit

Receptor: Marine Environment

Short Criterion Description: This criterion describes the potential of removing an existing munition pile (*source*), thereby freeing up space (*pathway*) for the marine environment *(receptor)*. This may

increase the area where marine conservation areas can be established, potentially allowing them to be more effective *(consequence)*.

Weight: 0.297

Data Availability

Source Data: Yes

- MBES Munition Contacts **(selected)**
- German contaminated areas *(rejected)*

Pathway Data: Yes

- Natura 2000 Sites *(rejected)*

Receptor Data: Yes

- Environmental vulnerability (BRISK)
  - Four separate seasonal vector grids **(selected)**
- Conservation status of habitat types and species: datasets from Article 17, Habitats Directive 92/43/EEC reporting *(rejected)*

Consequence Data: No

Selected Dataset 1

Name: MBES Munition Contacts

Short Data Description: A dataset of potential and confirmed munition piles and objects that was annotated by experts on MBES data.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: https://doi.pangaea.de/10.1594/PANGAEA.988426 (For security reasons the coordinates are not publicly available. For information on these data, please contact Jens Greinert at GEOMAR (jgreinert@geomar.de).)

Data Type: Munition and pile annotations as polygons.

Available Since: Varying

Last Updated: 10.12.2024

Calculation and Processing: Individual centroids of confirmed munition distribution were calculated for each dump site where munition pile prioritisation is under investigation.

Use of Data: Measure the shortest distance between the munition pile and the closest centroid. If the distance is ≥ 3,000 m, normalise to 10. If the distance is < 3,000 m, normalise from 0 to 10.

Value Range: 0–3,000

Unit: m

Attribute Table Fields: contaminatedAreadistance, normContaminatedAreaDistance

Selected Dataset 2

Name: Environmental vulnerability (BRISK)

Short Data Description: "A vector grid in 2 x 2 km resolution showing the environmental sensitivity and the underlying themes that have caused the final vulnerability […] for the Baltic Sea area." [32] We use the value from the column "SUM", which is a weighted vulnerability index.

Data Provider: HELCOM-BRISK

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/ger/catalog.search#/search?resultType=details&sortBy=relevance&fast=index&_content_type=json&from=1&to=20&any=Environmental%20vulnerability

- https://maps.helcom.fi/website/MADS/download/?id=539e9a27-9de2-4ec5-b92e-4483aa7acc3a
- https://maps.helcom.fi/website/MADS/download/?id=9b2d1c32-7323-4e5e-aea4-3865ab9d6633
- https://maps.helcom.fi/website/MADS/download/?id=720bab94-aad9-47ae-bef7-a9a24865e6e0
- https://maps.helcom.fi/website/MADS/download/?id=2a7a0489-112b-42d1-ac5b-55e128fa2b18

Data Type: Vector (Polygons)

Available Since: 13.02.2013

Last Updated: 13.02.2013

Calculation: The dataset was clipped to the area of interest. Data from column *SUM* for all four seasons were used to calculate the arithmetic annual mean value. The resulting polygons are used in MCA-DuMP.

Use of Data: Extract the *SUM* polygon value at the munition pile centroid. Normalise from 0 to 10.

Value Range: 0–8.5 (The maximum value is the highest value in the processed dataset.)

Unit: None

Attribute Table Fields: environmentalVulnerability, normEnvironmentalVulnerability

Data Convergence

Calculation and Processing: No further processing.

Use of Data: Calculate the arithmetic mean from both normalised values.

Value Range: 0–10

Unit: None

Attribute Table Fields: normMarineSpace

Rejected Dataset 1

Name: German Contaminated Areas

Short Data Description: A dataset of all munition-contaminated areas as compiled by a report by the BLANO expert group “Munitions in the Seas” [1, 31]. The dataset was updated after the initial publication.

Data Provider: Amucad.org

Original Data Source: https://legacy.amucad.org/map (This dataset is not available anymore.)

Data Type: Vector/WMS

Available Since: Unknown

Last Updated: Unknown

Rationale for Rejection: This dataset is mainly based on information that was collected in 2011 and does not represent the geographic extent of the actual contamination that has been documented since then.

Rejected Dataset 2

Name: Natura 2000 Sites

Short Data Description: "Natura 2000 is an ecological network of protected areas, set up to ensure the survival of Europe's most valuable species and habitats. Natura 2000 is based on the 1979 Birds Directive and the 1992 Habitats Directive. Natura 2000 is the key instrument to protect biodiversity in the European Union. The European database of Natura 2000 sites consists of a compilation of the data submitted by the Member States of the European Union and is generally updated once a year." [33]

Data Provider: EEA

Original Data Source:
https://www.eea.europa.eu/en/datahub/datahubitem-view/6fc8ad2d-195d-40f4-bdec-576e7d1268e4
(https://sdi.eea.europa.eu/data/95e717d4-81dc-415d-a8f0-fecdf7e686b0)

Data Type: Vector (Polygons)

Available Since: Unknown

Last Updated: 23.04.2024

Rationale for Rejection: It is not plausible to link socioeconomic benefits of freeing up space for maritime conservation to the location of existing conservation areas. Establishment of new areas will be determined by political and administrative processes and protection requirements and not by the location of existing conservation areas.

Rejected Dataset 3

Name: Conservation status of habitat types and species: datasets from Article 17, Habitats Directive 92/43/EEC reporting

Short Data Description: "All Member States are requested by the Habitats Directive (92/43/EEC) to monitor habitat types and species listed in its annexes and send a report every 6 years following an agreed format. The assessment of conservation status is based on information about the status and trends of species populations and of habitats at the level of the biogeographical or marine region. The spatial dataset contains habitat and species distribution data (10 km grid cells) as reported by Member States. The tabular dataset this includes information on habitat areas, population sizes, trends, pressures and threats, and conservation status at the national biogeographical level and on conservation status and trends in conservation status at the EU biogeographical level." [34]

Data Provider: EEA

Original Data Source:
https://www.eea.europa.eu/en/datahub/datahubitem-view/d8b47719-9213-485a-845b-db1bfe93598d
(https://sdi.eea.europa.eu/data/9f71b3e3-f8ec-442b-a2d5-c3c190605ac4)

Data Type: Vector (Polygons) and Tables

Available Since: 27.08.2020

Last Updated: 27.08.2020

Rationale for Rejection: Even though this dataset is more up to date than selected dataset 1, it has numerous shortcomings. Firstly, the resolution of polygons is larger and not a consistent grid. Secondly, all habitat types are evaluated individually in a non-numerical fashion, which would have required translation into numerical values.

Next steps/Recommendations

- For selected dataset 1, a more complex algorithm than simply measuring the distance to the centroid might be more appropriate to account for the density of munition piles. Therefore, a reassessment of the use of the selected dataset is recommended.
- Implement a more recently published alternative to selected dataset 2.

1.6.4 Shipping Sector – Space

General Information

Top-level Criterion: Socioeconomic Potential

Risk/Benefit Type: Benefit

Receptor: Shipping Sector

Short Criterion Description: This criterion describes the potential of removing an existing munition pile (*source*), thereby freeing up space (*pathway*) for the shipping sector *(receptor)*. This may increase the area where shipping can take place, potentially allowing the sector to be more cost-efficient *(consequence)*.

Weight: 0.255

Data Availability

Source Data: Yes

- MBES Munition Contacts **(selected)**
- German contaminated areas *(rejected)*

Pathway Data: Yes

- Verkehrsnetze (Schifffahrtswege) (Traffic network (shipping lanes)) **(selected)**
  - Feature: WaterwayLink
  - Numerous other features were rejected due to irrelevance for the risk receptor
- Generalized Coastline **(selected)**
  - Feature: coastline_harbour
  - Numerous other features were rejected due to irrelevance for the risk receptor
- Anchorage Areas **(selected)**
- Harbours (HOLAS 3) *(rejected)*
- IMO ships routeing guide *(rejected)*

Receptor Data: No

Consequence Data: No

Selected Dataset 1

Name: MBES Munition Contacts

Short Data Description: A dataset of potential and confirmed munition piles and objects that was annotated by experts on MBES data.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: https://doi.pangaea.de/10.1594/PANGAEA.988426 (For security reasons the coordinates are not publicly available. For information on these data, please contact Jens Greinert at GEOMAR (jgreinert@geomar.de).)

Data Type: Munition and pile annotations as polygons.

Available Since: Varying

Last Updated: 10.12.2024

Calculation and Processing: Individual centroids of confirmed munition distribution were calculated for each dump site where munition pile prioritisation is under investigation.

Use of Data: Measure the shortest distance between the munition pile and the closest centroid. If the distance is ≥ 3,000 m, normalise to 10. If the distance is < 3,000 m, normalise from 0 to 10.

Value Range: 0–3,000

Unit: m

Attribute Table Fields: contaminatedAreadistance, normContaminatedAreaDistance

Selected Dataset 2

Name: Verkehrsnetze (Schifffahrtswege) (Feature: WaterwayLink)

Short Data Description: The dataset contains the water transport network for maritime shipping within the area of responsibility of the Federal Maritime and Hydrographic Agency (BSH) and its associated infrastructure facilities. [24]

Data Provider: BSH

Original Data Source:
https://nokis.mdi-de-dienste.org/trefferanzeige?docuuid=85a1d598-287e-4efd-8799-c655b59d4453
(https://gdi.bsh.de/de/data/Transport-Networks-Water-Transport-Network.zip)

Data Type: Vector (Lines)

Available Since: 05.01.2017

Last Updated: 07.06.2024

Calculation and Processing: No processing before data convergence.

Use of Data: See data convergence.

Value Range: None

Unit: None

Attribute Table Fields: None

Selected Dataset 3

Name: Generalized Coastline (Feature: Costline_Harbour)

Short Data Description: "This dataset contains an automatically derived coastline of the North Sea and Baltic Sea from different scale ranges of the Electronic Navigational Chart (ENC) corresponding to the relative coverage area. The ENCs are produced in accordance with the valid international standard S-57. It consists of generalised lines in the different ENC scale ranges Approach, Harbour and Berthing. The derived coastline consists of natural and man-made (e.g., piers) elements. As an alternative, there is a further coastline available." [25]

Data Provider: BSH

Original Data Source:
https://nokis.mdi-de-dienste.org/trefferanzeige?docuuid=826cb51f-d49b-4c54-b911-63ab66ebca7a
(https://gdi.bsh.de/de/data/Generalised-Coastline.zip)

Data Type: Vector (Lines)

Available Since: Unknown

Last Updated: 03.10.2024

Calculation and Processing: No processing before data convergence.

Use of Data: See data convergence.

Value Range: None

Unit: None

Attribute Table Fields: None

Selected Dataset 4

Name: Anchorage Areas

Short Data Description: The dataset contains the anchorage areas for maritime shipping within the area of responsibility of the Federal Maritime and Hydrographic Agency (BSH) [26].

Data Provider: BSH

Original Data Source For information on these data, please contact the customer service at BSH (customer@bsh.de).

Data Type: Vector (Polygons)

Available Since: Unknown

Last Received: 29.11.2024

Calculation and Processing: No processing before data convergence.

Use of Data: See data convergence.

Value Range: None

Unit: None

Attribute Table Fields: None

Data Convergence (selected datasets 2, 3 and 4)

Calculation and Processing: Polygon data were converted to line data. Datasets were merged into one line vector dataset.

Use of Data: Measure the shortest distance between the munition pile and the closest point on any line. If the distance is ≥ 5,000 m, normalise to 0. If the distance is < 5,000 m, inversely normalise from 10 to 0.

Value Range: 0–5,000 (The maximum value was determined based on calculations according to which the detonation of one investigated munition pile would require a safety distance of 4,082 m. This value was rounded up to 5,000 m to produce a rounded distance at which no ship would be affected by the detonation of a munition pile.)

Unit: m

Attribute Table Fields: shippingLanedistance, normShippingLaneDistance

Data Convergence (all)

Calculation and Processing: No further processing.

Use of data (all): Calculate the arithmetic mean from both normalised values.

Value Range: 0–10

Unit: None

Attribute Table Fields: normShippingSpace

Rejected Dataset 1

Name: German Contaminated Areas

Short Data Description: A dataset of all munition-contaminated areas as compiled by a report by the BLANO expert group "Munitions in the Seas" [1, 31]. The dataset was updated after the initial publication.

Data Provider: Amucad.org

Original Data Source: https://legacy.amucad.org/map (This dataset is not available anymore.)

Data Type: Vector/WMS

Available Since: Unknown

Last Updated: Unknown

Rationale for Rejection: This dataset is based on information that was collected in 2011 and does not represent the geographic extent of the actual contamination that has been documented since then.

Rejected Dataset 2

Name: Harbours (HOLAS 3)

Short Data Description: "The dataset contains points and polygons data of the ports and ferry terminals in the Baltic Sea downloaded from, respectively, EMODnet and OSM, and HELCOM AIS." [27]

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/ger/catalog.search#/metadata/798cffb0-8dac-47cc-83a4-143e32aa3294

Data Type: Vector (Points and Polygons)

Available Since: 21.02.2023

Last Updated: 21.02.2023

Rationale for Rejection: Selected dataset 2 is superior, since it is more detailed in two ways. (1) It contains more and smaller harbours. (2) It shows the part of the coastline that is considered a harbour by BSH, while this dataset only appears to cover the main section of the harbours.

Rejected Dataset 3

Name: IMO ships routeing guide

Short Data Description: This dataset includes digitised deep-water routes, traffic separation schemes, precautionary areas and inshore traffic zones in the Baltic Sea. [28]

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/ger/catalog.search#/metadata/60712fe9-ce1b-4fc6-b0b6-46e44f9bf134

Data Type: Vector (Polygons)

Available Since: Unknown

Last Updated: 01.01.2017

Rationale for Rejection: This dataset is considered too old.

Next steps/Recommendations

- For selected dataset 1, a more complex algorithm than simply measuring the distance to the centroid might be more appropriate to account for the density of munition piles. Therefore, a reassessment of the use of the selected dataset is recommended.
- Perform a more in-depth assessment of the safety distance/maximum value of 5,000 m by analysing additional munition piles.
- Check whether the inshore traffic zone at Graal-Müritz in rejected dataset 3 still exists.

1.7 Clearance Cost

General Information

Short Criterion Description: This criterion describes the relative cost of clearing a given munition pile. We selected factors identified in the German framework for land-based munition clearance as contributing to clearance resource intensity and adapted them to the marine context. We used these factors as sub-criteria for Clearance Cost. We oriented the scores so that higher values indicate higher priority for clearance. Thus, a higher Clearance Cost score represents lower expected clearance costs relative to other piles. [35]

Sub-Criteria: Burial Depth, Current Velocity, Distance to Harbours, Distance to Protected Areas, Distance to Shipping Lanes, Distance to Treatment Facility, Distance to Bathing Sites, Layering of Objects on a Pile, Number of Objects on a Pile, Sediment Particle Size, Size of the Objects, State of Corrosion of the Casing, State of the Fuze, Traffic Density, Variability within a Pile, Wave Height

Weight: 0.134

Data Convergence

Use of Data: Apply the weights of the sub-criteria to their normalised values to calculate a weighted mean. Normalise from 0 to 10.

Attribute Table Field: CEEresult

1.7.1 Burial Depth

General Information

Top-level Criterion: Clearance Cost

Risk/Benefit Type: Neither

Receptor: None

Short Criterion Description: This criterion describes that the less the munitions are buried, the easier it is to salvage them (and therefore with lower cost). Munitions that are buried require dredging activities, which are costlier and make clearance more complex.

Weight: 0.074

Data Availability

Criterion Data: Yes

- Annotations of visual data of munition piles

- Property: Burial Depth **(selected)**

Selected Dataset

Name: Annotations of visual data of munition piles (Property: Burial Depth)

Short Data Description: Existing visual data show the burial depth of munitions on munition piles.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: https://doi.pangaea.de/10.1594/PANGAEA.988426 (For security reasons the coordinates are not publicly available. For information on these data, please contact Jens Greinert at GEOMAR (jgreinert@geomar.de).)

Data Type: Photomosaics

Available Since: Varying

Last Received: Varying

Calculation and Processing: Photomosaics were visually assessed by four experts. The following scale was used to determine the most deeply buried munition on each pile.

- Not buried: 0
- A little buried (scour visible): 1
- Medium buried: 2
- Strongly buried (identification not possible): 3
- Completely buried (only for magnetic data): 4

The mean value of the expert assessments per pile was entered into a munition pile property table that is used as an input to MCA-DuMP.

Burial Depth values of munition piles were not normally distributed and showed no significant statistical difference in median values for different dump sites. Hence, the value 2.00 was given to all munition piles for which no visual data could be assessed. This is the overall median value of annotated munition piles.

Use of Data: Inversely normalise from 10 to 0.

Value Range: 0–4

Unit: None

Attribute Table Fields: normBurial

Next steps/Recommendations

- Continue the assessment of munition piles as more visual data become available in the future.
- Perform the assessment of munition piles for which video footage is available.
- Reassess piles that are partially cleared during the immediate action programme or other clearance activities in the future.
- Assess a potential correlation between the sediment type and the burial depth to attempt a prediction for munition piles for which no visual data are available.

1.7.2 Current Velocity

General Information

Top-level Criterion: Clearance Cost

Risk/Benefit Type: Neither

Receptor: None

Short Criterion Description: This criterion describes that the lower the current velocity, the easier it is to salvage munitions (and therefore with lower cost). A higher current velocity at the site requires the use of bigger vessels or longer downtimes, which makes work costlier.

Weight: 0.079

Data Availability

Criterion Data: Yes

- Mean Current Velocity **(selected)**

Selected Dataset

Name: Mean Current Velocity

Short Data Description: This is a raster dataset of the mean current velocity in the Baltic Sea with a resolution of 200 m. Monthly means were calculated for the years 2017–2023.

Data Provider: Leibniz Institute for Baltic Sea Research Warnemünde (IOW) [CONMAR]

Original Data Source: For information on these data, please contact Ulf Gräwe at IOW (ulf.graewe@io-warnemuende.de).

Data Type: Raster

Available Since: Unknown

Last Received: 23.07.2024

Calculation and Processing: Data were clipped to the area of interest. The annual mean for each raster cell was calculated.

Use of Data: Extract the raster cell value at the munition pile centroid. Inversely normalise from 10 to 0.

Value Range: 0.0–1.5 (The maximum value is the limit of operation during explosive ordnance disposal [13].)

Unit: m/s

Attribute Table Fields: current, normCurrent

1.7.3 Distance to Bathing Sites

General Information

Top-level Criterion: Clearance Cost

Risk/Benefit Type: Neither

Receptor: None

Short Criterion Description: This criterion describes that the larger the distance to bathing sites, the easier it is to salvage munitions (and therefore with lower cost). A shorter distance to a bathing site increases the requirements for necessary protection measures (e.g., against a planned or a potential undesired detonation), which is costlier.

Weight: 0.037

Data Availability

Criterion Data: Yes

- Badestellen in Mecklenburg-Vorpommern (Swimming spots in Mecklenburg-Western Pomerania) **(selected)**
- Badestellen in Schleswig-Holstein (WFS SH swimming spots in Schleswig-Holstein) **(selected)**
    - Layer: Badestellen (Swimming spots)

Selected Dataset 1

Name: Badestellen in Mecklenburg-Vorpommern (Swimming spots in Mecklenburg-Western Pomerania)

Short Data Description: A dataset of the locations of swimming spots along Mecklenburg-Western Pomerania's coast.

Data Provider: Ministry of Economics, Labour and Health, the State Office for Health and Social Affairs, the regional health authorities, and the responsible environmental authorities in Mecklenburg-Western Pomerania (via Geoportal.de)

Original Data Source:
https://www.geoportal.de/Metadata/48b06521-8714-48c7-a356-568912b9c5a0

Data Type: Vector points/WFS

Available Since: 16.09.2024

Last Updated: 16.09.2024

Calculation and Processing: No processing before data convergence.

Use of Data: See data convergence.

Value Range: None

Unit: None

Attribute Table Fields: None

Selected Dataset 2

Name: Badestellen in Schleswig-Holstein (Swimming spots in Schleswig-Holstein)

Short Data Description: A dataset of the locations of swimming spots along Schleswig-Holstein's Baltic Sea coast.

Data Provider: Ministry of Justice and Health of the State of Schleswig-Holstein (via Geoportal.de)

Original Data Source:
https://www.geoportal.de/Metadata/3991341b-08e4-4c4b-ab8d-d64d6b8fd270

Data Type: Vector points/WFS

Available Since: 25.05.2012

Last Updated: 06.07.2023

Calculation and Processing: No processing before data convergence.

Use of Data: See data convergence.

Value Range: None

Unit: None

Attribute Table Fields: None

Data Convergence

Calculation and Processing: Datasets were merged into one point vector dataset. All points that were not located along the Baltic Sea coastline were deleted.

Use of Data: Measure the shortest distance between the munition pile and the closest bathing site point. If the distance is ≥ 500 m, normalise to 10. If the distance is < 500 m, normalise to 0 (costs are expected to be consistent once the value drops below the safety distance of 500 m).

Value Range: 0–500 (The maximum value is a common safety distance during EOD activities.)

Unit: m

Attribute Table Fields: bathingSitedistance, normBathingSiteDistance

Next steps/Recommendations

- Perform a more in-depth assessment of the safety distance/maximum value of 5,000 m by analysing additional munition piles.

1.7.4 Distance to Harbours

General Information

Top-level Criterion: Clearance Cost

Risk/Benefit Type: Neither

Receptor: None

Short Criterion Description: This criterion describes that the smaller the distance to a suitable harbour, the easier it is to supply a clearance vessel and to hand over munitions (and therefore with lower cost). A larger distance to a suitable harbour increases the duration for the transport of staff, fuel, material, and munitions to be handed over, which is costlier.

Weight: 0.059

Data Availability

Criterion Data: Yes

- Generalized Coastline *(rejected)*
  - Feature: coastline_harbour
- Harbours (HOLAS 3) *(rejected)*

Rejected Dataset 1

Name: Generalized Coastline (Feature: Costline_Harbour)

Short Data Description: "This dataset contains an automatically derived coastline of the North Sea and Baltic Sea from different scale ranges of the Electronic Navigational Chart (ENC) corresponding to the relative coverage area. The ENCs are produced in accordance with the valid international standard S-57. It consists of generalised lines in the different ENC scale ranges Approach, Harbour and Berthing. The derived coastline consists of natural and man-made (e.g., piers) elements. As an alternative, there is a further coastline available." [25]

Data Provider: BSH

Original Data Source:
https://nokis.mdi-de-dienste.org/trefferanzeige?docuuid=826cb51f-d49b-4c54-b911-63ab66ebca7a
(https://gdi.bsh.de/de/data/Generalised-Coastline.zip)

Data Type: Vector (Lines)

Available Since: Unknown

Last Updated: 03.10.2024

Rationale for Rejection: With the dataset it is not possible to distinguish between harbours that are suitable for the transport of staff, fuel, material, and munitions to be handed over.

Rejected Dataset 2

Name: Harbours (HOLAS 3)

Short Data Description: "The dataset contains points and polygons data of the ports and ferry terminals in the Baltic Sea downloaded from, respectively, EMODnet and OSM, and HELCOM AIS." [27]

Data Provider: HELCOM

Original Data Source: https://metadata.helcom.fi/geonetwork/srv/ger/catalog.search#/metadata/798cffb0-8dac-47cc-83a4-143e32aa3294

Data Type: Vector (Points and Polygons)

Available Since: 21.02.2023

Last Updated: 21.02.2023

Rationale for Rejection: With the dataset it is not possible to distinguish between harbours that are suitable for the transport of staff, fuel, material, and munitions to be handed over.

Next steps/Recommendations

- Together with stakeholders or a competent authority, identify harbours that are suitable for performing the tasks laid out in the short criterion description.

1.7.5 Distance to Protected Areas

General Information

Top-level Criterion: Clearance Cost

Risk/Benefit Type: Neither

Receptor: None

Short Criterion Description: This criterion describes that the larger the distance to protected areas, the easier it is to salvage munitions (and therefore with lower cost). A shorter distance to a protected area (or a location inside a protected area) increases the requirements for necessary protection measures (e.g., against a planned or a potential undesired detonation), which is costlier.

Weight: 0.053

Data Availability

Criterion Data: Yes

- Natura 2000 sites **(selected)**

Selected Dataset

Name: Natura 2000 sites

Short Data Description: The dataset is a spatial dataset of Natura 2000 sites with "extracted areas that are within or proximity of the Baltic Sea coastline" […]. "Natura 2000 is the key instrument to protect biodiversity in the European Union. It is an ecological network of protected areas, set up to ensure the survival of Europe's most valuable species and habitats." [36]

Data Provider: European Environment Agency (EEA) (via HELCOM)

Original Data Source: https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/47a94309-c72b-4a1a-8982-ed24ae829220

Data Type: Vector/WFS

Available Since: Unknown

Last Updated: 19.01.2022

Calculation and Processing: None

Use of Data: Check whether the munition pile centroid lies within the polygon. If yes, normalise to 0. If no, measure the shortest distance between the munition pile centroid and the closest point of any polygon. If the distance is ≥ 500 m, normalise to 10. If the distance is < 500 m, normalise from 0 to 10.

Value Range: 0–500 (The maximum value is a common safety distance during EOD activities.)

Unit: m

Attribute Table Fields: protectedAreasdistance, normProtectedAreaDistance

Next steps/Recommendations

- Consider weighing the different types of Natura 2000 sites differently (e.g., national parks could be weighed higher than other types).

1.7.6 Distance to Shipping Lanes

General Information

Top-level Criterion: Clearance Cost

Risk/Benefit Type: Neither

Receptor: None

Short Criterion Description: This criterion describes that the larger the distance to shipping lanes, the easier it is to salvage munitions (and therefore with lower cost). A shorter distance to a shipping lane increases the requirements for necessary protection measures (e.g., against a planned or a potential undesired detonation), which is costlier.

Weight: 0.058

Data Availability

Criterion Data: Yes

- Verkehrsnetze (Schifffahrtswege) (Traffic network (shipping lanes)) **(selected)**
  - Feature: WaterwayLink
- Generalized Coastline **(selected)**
  - Feature: coastline_harbour

- Anchorage Areas **(selected)**
- Harbours (HOLAS 3) *(rejected)*
- IMO ships routeing guide *(rejected)*

Selected Dataset 1

Name: Verkehrsnetze (Schifffahrtswege) (Feature: WaterwayLink)

Short Data Description: The dataset contains the water transport network for maritime shipping within the area of responsibility of the Federal Maritime and Hydrographic Agency (BSH) and its associated infrastructure facilities [24].

Data Provider: BSH

Original Data Source:
https://nokis.mdi-de-dienste.org/trefferanzeige?docuuid=85a1d598-287e-4efd-8799-c655b59d4453
(https://gdi.bsh.de/de/data/Transport-Networks-Water-Transport-Network.zip)

Data Type: Vector (Lines)

Available Since: 05.01.2017

Last Updated: 07.06.2024

Calculation and Processing: No processing before data convergence.

Use of Data: See data convergence.

Value Range: None

Unit: None

Attribute Table Fields: None

Selected Dataset 2

Name: Generalized Coastline (Feature: Costline_Harbour)

Short Data Description: "This dataset contains an automatically derived coastline of the North Sea and Baltic Sea from different scale ranges of the Electronic Navigational Chart (ENC) corresponding to the relative coverage area. The ENCs are produced in accordance with the valid international standard S-57. It consists of generalised lines in the different ENC scale ranges Approach, Harbour and Berthing. The derived coastline consists of natural and man-made (e.g., piers) elements. As an alternative, there is a further coastline available." [25]

Data Provider: BSH

Original Data Source:
https://nokis.mdi-de-dienste.org/trefferanzeige?docuuid=826cb51f-d49b-4c54-b911-63ab66ebca7a
(https://gdi.bsh.de/de/data/Generalised-Coastline.zip)

Data Type: Vector (Lines)

Available Since: Unknown

Last Updated: 03.10.2024

Calculation and Processing: No processing before data convergence.

Use of Data: See data convergence.

Value Range: None

Unit: None

Attribute Table Fields: None

Selected Dataset 3

Name: Anchorage Areas

Short Data Description: The dataset contains the anchorage areas for maritime shipping within the area of responsibility of the Federal Maritime and Hydrographic Agency (BSH) [26].

Data Provider: BSH

Original Data Source For information on these data, please contact the customer service at BSH (customer@bsh.de).

Data Type: Vector (Polygons)

Available Since: Unknown

Last Received: 29.11.2024

Calculation and Processing: No processing before data convergence.

Use of Data: See data convergence.

Value Range: None

Unit: None

Attribute Table Fields: None

Data Convergence

Calculation and Processing: Polygon data were converted to line data. Datasets were merged into one line vector dataset.

Use of Data: Measure the shortest distance between the munition pile and the closest point on any line. If the distance is ≥ 500 m, normalise to 10. If the distance is < 500 m, normalise from 0 to 10.

Value Range: 0–500 (The maximum value is a common safety distance during EOD activities.)

Unit: m

Attribute Table Fields: shippingLanedistance, normShippingLaneDistance

Rejected Dataset 1

Name: Harbours (HOLAS 3)

Short Data Description: "The dataset contains points and polygons data of the ports and ferry terminals in the Baltic Sea downloaded from, respectively, EMODnet and OSM, and HELCOM AIS." [27]

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/ger/catalog.search#/metadata/798cffb0-8dac-47cc-83a4-143e32aa3294

Data Type: Vector (Points and Polygons)

Available Since: 21.02.2023

Last Updated: 21.02.2023

Rationale for Rejection: Selected dataset 2 is superior, since it is more detailed in two ways. (1) It contains more and smaller harbours. (2) It shows the part of the coastline that is considered a harbour by BSH, while this dataset only appears to cover the main section of the harbours.

Rejected Dataset 2

Name: IMO ships routeing guide

Short Data Description: This dataset includes digitised deep-water routes, traffic separation schemes, precautionary areas and inshore traffic zones in the Baltic Sea [28].

Data Provider: HELCOM

Original Data Source: https://metadata.helcom.fi/geonetwork/srv/ger/catalog.search#/metadata/60712fe9-ce1b-4fc6-b0b6-46e44f9bf134

Data Type: Vector (Polygons)

Available Since: Unknown

Last Updated: 01.01.2017

Rationale for Rejection: This dataset is considered too old.

Next Steps/Recommendations

- Consider assessing distance-weighted shipping density around a munition pile's location instead of measuring distance to shipping lanes.
- Perform a more in-depth assessment of the safety distance/maximum value of 5,000 m by analysing additional munition piles.
- Check whether the inshore traffic zone at Graal-Müritz in rejected dataset 2 still exists.

1.7.7 Distance to Treatment Site

General Information

Top-level Criterion: Clearance Cost

Risk/Benefit Type: Neither

Receptor: None

Short Criterion Description: This criterion describes that the smaller the distance to a treatment site or facility at sea, the easier it is to supply and hand over munitions (and therefore with lower cost). A larger distance to a treatment site or facility increases the duration for the transport of munitions to be treated at sea, which is costlier.

Weight: 0.059

Data Availability

Criterion Data: No

Next steps/Recommendations

- Follow the developments during the immediate action programme to see if information regarding a possible location for a treatment facility becomes available.

1.7.8 Layering of Objects on a Pile

General Information

Top-level Criterion: Clearance Cost

Risk/Benefit Type: Neither

Receptor: None

Short Criterion Description: This criterion describes that the weaker the layering of the munitions on a pile, the easier it is to salvage them (and therefore with lower cost). Stronger layering increases the complexity of a clearance operation (e.g., objects have to be removed in a specific order) and, thus, its duration, which is costlier.

Weight: 0.069

Data Availability

Criterion Data: Yes

- Annotations of visual data of munition piles
  - Property: Layering of Objects on a Pile **(selected)**

Selected Dataset

Name: Annotations of visual data of munition piles (Property: Layering of Objects on a Pile)

Short Data Description: Existing visual data show the layering of munitions on munition piles.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: https://doi.pangaea.de/10.1594/PANGAEA.988426 (For security reasons the coordinates are not publicly available. For information on these data, please contact Jens Greinert at GEOMAR (jgreinert@geomar.de).)

Data Type: Photomosaics

Available Since: Varying

Last Received: Varying

Calculation and Processing: Photomosaics were visually assessed by four experts. The following scale was used to determine the layering of objects on each pile.

- None: 0
- Weak: 1
- Medium: 2
- Strong: 3

The mean value of the expert assessments per pile was entered into a munition pile property table that is used as an input to MCA-DuMP.

Layering values of munition piles were not normally distributed but showed significant statistical difference in median values for different dump sites. Hence, the values 1.50 (Kolberger Heide), 2.25 (Haffkrug), and 1.38 (Pelzerhaken) were given to munition piles for which no visual data could be assessed. These are the median values of annotated munition piles in respective dump sites, except for Kolberger Heide, where the median of all piles was used due to a small sub-sample size.

Use of Data: Inversely normalise from 10 to 0.

Value Range: 0–3

Unit: None

Attribute Table Fields: normLayering

Next steps/Recommendations

- Continue the assessment of munition piles as more visual data become available in the future.
- Perform the assessment of munition piles for which video footage is available.

- Reassess piles that are partially cleared during the immediate action programme or other clearance activities in the future.
- Assess a potential correlation between the area of a munition pile and the layering of objects on a pile to attempt a prediction for munition piles for which no visual data are available.

1.7.9 Number of Objects on a Pile

General Information

Top-level Criterion: Clearance Cost

Risk/Benefit Type: Neither

Receptor: None

Short Criterion Description: This criterion describes that the smaller the number of objects on a pile, the easier it is to salvage them (and therefore with lower cost). A higher number increases the duration of a clearance operation, which makes it costlier.

Weight: 0.069

Data Availability

Criterion Data: Yes

- Annotations of visual data of munition piles
  - Property: Number of Objects on a Pile **(selected)**

Selected Dataset

Name: Annotations of visual data of munition piles (Property: Number of Objects on a Pile)

Short Data Description: Existing visual data show the number of individual munitions on munition piles.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: https://doi.pangaea.de/10.1594/PANGAEA.988426 (For security reasons the coordinates are not publicly available. For information on these data, please contact Jens Greinert at GEOMAR (jgreinert@geomar.de).)

Data Type: Photomosaics

Available Since: Varying

Last Received: Varying

Calculation and Processing: Photomosaics were annotated by three experts. They counted the number of objects on each pile. The mean value of the expert assessments per pile was entered into a munition pile property table that is used as an input to MCA-DuMP.

A strong correlation was found for the number of objects and the area (in m^2) of munition piles for which visual data could be assessed. Numbers of objects per area of munition pile were not normally distributed but showed significant statistical difference for different dump sites. Hence, the values 0.57 (Kolberger Heide), 2.35 (Haffkrug), and 0.36 (Pelzerhaken) were used as conversion factors to calculate the number of objects per area for munition piles for which no visual data could be assessed. These are the median values of annotated munition piles in respective dump sites, except for Kolberger Heide, where the median of all piles was used due to a small sub-sample size.

Use of Data: Inversely normalise from 10 to 1.

Value Range: 1–829 (The minimum value was used to be able to calculate a case where an individual object shall be assessed with MCA-DuMP. The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$ of the dataset.)

Unit: None

Attribute Table Fields: normNumber

Next steps/Recommendations

- Continue the assessment of munition piles as more visual data become available in the future.
- Perform the assessment of munition piles for which video footage is available.
- Reassess piles that are partially cleared during the immediate action programme or other clearance activities in the future.
- Assess a potential correlation between the area of a munition pile and the Number of Objects on a Pile to attempt a prediction for munition piles for which no visual data are available.

1.7.10 Sediment Particle Size

General Information

Top-level Criterion: Clearance Cost

Risk/Benefit Type: Neither

Receptor: None

Short Criterion Description: This criterion describes that the greater the sediment particle size, the higher the probability of good underwater visibility, and, hence, the easier it is to salvage munitions (and therefore with lower cost). Smaller sediment particles are mobilised more easily, which may lead to downtimes until sufficient visibility is reached.

Weight: 0.064

Data Availability

Criterion Data: Yes

- SGE_SeabedSediments_1_to_100000 **(selected)**

Selected Dataset

Name: SGE_SeabedSediments_1_to_100000

Short Data Description: Sediment was classified based on granulometric analyses of more than 17,000 irregularly distributed sediment samples. Sediment samples were classified by grain size distribution [29].

Data Provider: BSH

Original Data Source:
https://nokis.mdi-de-dienste.org/trefferanzeige?docuuid=b4e219de-344f-4db5-a4f7-ec6fa276529b
(https://gdi.bsh.de/de/data/Seabed-Sediments-on-a-scale-of-1-100-000-in-German-Baltic-Sea.zip)

Data Type: Vector/WFS

Available Since: 04.05.2023

Last Updated: 04.05.2023

Calculation and Processing: Sediment categories were sorted according to their grain size and assigned to the normalisation range, with 0 representing sediments that are most likely to reduce underwater visibility and 10 representing the opposite.

Use of Data: Extract the polygon value at munition pile centroid. Convert categories in the field *sediment* into the values of the normalisation range from 0 to 10.

Value Range: None, since the data are categorised.

Unit: None

Attribute Table Fields: sediment, normSedimentSize

Next Steps/Recommendations

- It is preferable to use data for underwater visibility instead of using sediment classes as a proxy. For a model update, it is, therefore, recommended to use data from clearance activities in dump sites and replace this criterion with underwater visibility.

1.7.11 Size of the Objects

General Information

Top-level Criterion: Clearance Cost

Risk/Benefit Type: Neither

Receptor: None

Short Criterion Description: This criterion describes that the smaller the size of the munitions, the easier it is to salvage them (and therefore with lower cost). Larger munitions require the use of larger and more powerful clearance equipment, which is costlier.

Weight: 0.059

Data Availability

Criterion Data: Yes

- Annotations of visual data of munition piles
  - Property: Size of the Objects (max) **(selected)**

Selected Dataset

Name: Annotations of visual data of munition piles (Property: Size of the Objects (max))

Short Data Description: Existing visual data show the size of individual munitions on munition piles.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: https://doi.pangaea.de/10.1594/PANGAEA.988426 (For security reasons the coordinates are not publicly available. For information on these data, please contact Jens Greinert at GEOMAR (jgreinert@geomar.de).)

Data Type: Photomosaics

Available Since: Varying

Last Received: Varying

Calculation and Processing: Photomosaics were annotated by three experts. They measured a subset of the counted objects on each pile. The mean value of the expert assessments per pile (maximum object size) was entered into a munition pile property table that is used as an input to MCA-DuMP.

Maximum sizes of objects on munition piles were not normally distributed but showed significant statistical difference for different dump sites. Hence, the values 1.20 (Kolberger Heide), 0.93 (Haffkrug), and 1.21 (Pelzerhaken) were given to munition piles for which no visual data could be assessed. These are the median values of annotated munition piles in respective dump sites, except for Kolberger Heide, where the median of all piles was used due to a small sub-sample size.

Use of Data: Inversely normalise from 10 to 1.

Value Range: 0.33–1.98 (The minimum value and maximum value are based on the IQR rule, i.e., $Q1 - 1.5 * IQR$ and $Q3 + 1.5 * IQR$ of the dataset.)

Unit: m

Attribute Table Fields: normSize_max

Next steps/Recommendations

- Continue the assessment of munition piles as more visual data become available in the future.
- Perform the assessment of munition piles for which video footage is available.
- Reassess piles that are partially cleared during the immediate action programme or other clearance activities in the future.

1.7.12 Corrosion of the Casing

General Information

Top-level Criterion: Clearance Cost

Risk/Benefit Type: Neither

Receptor: None

Short Criterion Description: This criterion describes that the less the munition casings on a pile are corroded, the easier it is to salvage them (and therefore with lower cost). Stronger corrosion increases the complexity of a clearance operation (e.g., as objects may break apart during clearance) and, thus, its duration, which is costlier.

Weight: 0.064

Data Availability

Criterion Data: Yes

- Annotations of visual data of munition piles
  - Property: State of Corrosion of the Casing **(selected)**

Selected Dataset

Name: Annotations of visual data of munition piles (Property: State of Corrosion of the Casing)

Short Data Description: Existing visual data show the state of corrosion of munition casings on munition piles.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: https://doi.pangaea.de/10.1594/PANGAEA.988426 (For security reasons the coordinates are not publicly available. For information on these data, please contact Jens Greinert at GEOMAR (jgreinert@geomar.de).)

Data Type: Photomosaics

Available Since: Varying

Last Updated: Varying

Calculation and Processing: Photomosaics were visually assessed by four experts. The following scale was used to determine the state of corrosion of munition casings on each pile.

- None: 0
- Assumed none/corrosion at the surface: 1
- Holes and cracks visible/deformation due to corrosion: 2
- Large holes/strong corrosion: 3
- Over 50 % gone/almost complete corrosion: 4
- Complete corrosion/loose explosives: 5

The mean value of the expert assessments per pile was entered into a munition pile property table that is used as an input to MCA-DuMP.

State of Corrosion of the Casing values of munition piles were not normally distributed and showed no significant statistical difference in median values for different dump sites. Hence, the value 1.75 was given to all munition piles for which no visual data could be assessed. This is the overall median value of annotated munition piles.

Use of Data: Use of Data: Inversely normalise from 10 to 0.

Value Range: 0–5

Unit: None

Attribute Table Fields: normCorrosion

Next steps/Recommendations

- Continue the assessment of munition piles as more visual data become available in the future.
- Perform the assessment of munition piles for which video footage is available.
- Reassess piles that are partially cleared during the immediate action programme or other clearance activities in the future.

1.7.13 State of the Fuze

General Information

Top-level Criterion: Clearance Cost

Risk/Benefit Type: Neither

Receptor: None

Short Criterion Description: This criterion describes that if munitions are not equipped with a fuze it is easier to salvage them (and therefore with lower cost). If munitions are equipped with a fuze this increases the complexity of a clearance operation (because object handling is more delicate and decisions on clearance mode need to be taken on an object-by-object basis) and, thus, its duration, which is costlier.

Weight: 0.053

Data Availability

Criterion Data: Yes

- Annotations of visual data of munition piles
  - Property: State of the Fuze **(selected)**

Selected Dataset

Name: Annotations of visual data of munition piles (Property: State of the Fuze)

Short Data Description: Existing visual data allow for an assessment of the state of the fuze of munitions on munition piles.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: https://doi.pangaea.de/10.1594/PANGAEA.988426 (For security reasons the coordinates are not publicly available. For information on these data, please contact Jens Greinert at GEOMAR (jgreinert@geomar.de).)

Data Type: Photomosaics

Available Since: Varying

Last Received: Varying

Calculation and Processing: Photomosaics were visually assessed by four experts. The following scale was used to determine the state of the fuze of the objects on each pile.

- Confirmed No Fuze: 0
- Assumed No Fuze: 1
- Mixed: 2
- Fuzed: 3

The mean value of the expert assessments per pile was entered into a munition pile property table that is used as an input to MCA-DuMP.

State of the Fuze values of munition piles were not normally distributed and showed no difference in median values for different dump sites. Hence, the value 1 was given to munition piles for which no visual data could be assessed. This is the median value of annotated munition piles in respective dump sites and overall.

Use of Data: Use of Data: Inversely normalise from 10 to 0.

Value Range: 0–3

Unit: None

Attribute Table Fields: normFuze

Next steps/Recommendations

- Continue the assessment of munition piles as more visual data become available in the future.
- Perform the assessment of munition piles for which video footage is available.
- Reassess piles that are partially cleared during the immediate action programme or other clearance activities in the future.

1.7.14 Traffic Density

General Information

Top-level Criterion: Clearance Cost

Risk/Benefit Type: Neither

Receptor: None

Short Criterion Description: This criterion describes that the lower the traffic density, the easier it is to salvage munitions (and therefore with lower cost). A higher traffic density increases the number of

necessary deterrence measures of other vessels and interruptions during clearance work and, thus, downtimes, both of which increase costs.

Weight: 0.059

Data Availability

Criterion Data: Yes

- HELCOM AIS Shipping density maps **(selected)**
  - Layers: 2016–2022 All shiptypes AIS Shipping Density
- AIS Schiffsverkehrsdichte (AIS shipping density) *(rejected)*

Selected Dataset

Name: HELCOM AIS Shipping density maps (Layers: 2016–2022 All shiptypes AIS Shipping Density)

Short Data Description: "This dataset represents the density of all IMO registered ships operating in the Baltic Sea. Shipping density is defined as the number of ships crossing a 1 x 1 km grid cell. Density maps are annual and created for the time period 2006–2022 per all ship types and by IMO ship category." "Raw AIS data used for creating the density maps is based on HELCOM AIS (Automatic Identification System) data. The HELCOM AIS network hosts all the AIS signals received by the Baltic Sea States since 2005." "The data was processed to produce density maps and traffic statistics." [17]

Data Provider: HELCOM

Original Data Source:
https://metadata.helcom.fi/geonetwork/srv/eng/catalog.search#/metadata/2558244b-0cea-46e9-8053-af6ef5d01853 (https://maps.helcom.fi/website/download/Traffic%20intensity-2006-2022.zip)

Data Type: Raster

Available Since: Unknown

Last Updated: 24.01.2022

Calculation and Processing: Data for years 2016–2022 for all ship types were clipped to the area of interest. The density values for these years were used to calculate a mean traffic density using the r.series tool. The resulting raster is used in MCA-DuMP.

Use of Data: Produce a 500 m buffer at the munition pile centroid (500 m is a common safety distance during EOD activities). Extract the cumulated traffic density for the buffered area. Inversely normalise from 10 to 0.

Value Range: 0–1,420 (The maximum value is based on the IQR rule, i.e., $Q3 + 1.5 * IQR$, of the cumulated traffic density for a buffered area for each grid cell of the processed dataset.)

Unit: None

Attribute Table Fields: trafficDensitysum, normTrafficDensity

Rejected Dataset

Name: AIS Schiffsverkehrsdichte (AIS shipping density)

Short Data Description: For each grid cell, the number of ships per year that travelled through or stayed in this cell was counted. To calculate the average vessel traffic density, the total number of vessels in each cell was divided by the number of days in the month, and, for a better quantitative comparison, the number of vessels in the cell was converted to a unit area of 1 km². [19]

Data Provider: BSH

Original Data Source: https://data.bsh.de/SpatialData/Main/AIS_VTD/ (This dataset is not available anymore.)

Data Type: Raster/WCS

Available Since: Unknown

Last Updated: 16.09.2019

Rationale for Rejection: The selected dataset contains more recent data.

1.7.15 Variability of a Pile

General Information

Top-level Criterion: Clearance Cost

Risk/Benefit Type: Neither

Receptor: None

Short Criterion Description: This criterion describes that the lower the variability of the munitions on a pile, the easier it is to salvage them (and therefore with lower cost). A higher variability increases the complexity of a clearance operation (e.g., objects have to be identified individually, sorted, and possibly cleared with different tools and methods) and, thus, its duration, which is costlier.

Weight: 0.059

Data Availability

Criterion Data: Yes

- Annotations of visual data of munition piles
  - Property: Variability of a Pile **(selected)**

Selected Dataset

Name: Annotations of visual data of munition piles (Property: Variability of a Pile)

Short Data Description: Existing visual data show the variability of munitions on munition piles.

Data Provider: GEOMAR Helmholtz Centre for Ocean Research Kiel [CONMAR]

Original Data Source: https://doi.pangaea.de/10.1594/PANGAEA.988426 (For security reasons the coordinates are not publicly available. For information on these data, please contact Jens Greinert at GEOMAR (jgreinert@geomar.de).)

Data Type: Photomosaics

Available Since: Varying

Last Received: Varying

Calculation and Processing: Photomosaics were visually assessed by four experts. The following scale was used to determine the variability of each pile.

- None – 0
- Very weak (only one or two objects differ from the main type; two types of boxes) – 1
- Weak (e.g., several types of boxes) – 2
- Medium – 3
- Strong (a complete mess) – 4

The mean value of the expert assessments per pile was entered into a munition pile property table that is used as an input to MCA-DuMP.

A strong correlation was found for the number of objects and the area (in m²) of munition piles for which visual data could be assessed. Hence, values of munition piles for which no visual data could be assessed were determined by applying the general regression formulation.

Use of Data: Inversely normalise from 10 to 0.

Value Range: 0–4

Unit: None

Attribute Table Fields: normVariability

Next steps/Recommendations

- Continue the assessment of munition piles as more visual data become available in the future.
- Perform the assessment of munition piles for which video footage is available.
- Reassess piles that are partially cleared during the immediate action programme or other clearance activities in the future.

1.7.16 Wave Height

General Information

Top-level Criterion: Clearance Cost

Risk/Benefit Type: Neither

Receptor: None

Short Criterion Description: This criterion describes that the lower the wave height, the easier it is to salvage munitions (and therefore with lower cost). Higher waves at the site requires the use of bigger vessels or lead to longer downtimes, which makes work costlier.

Weight: 0.085

Data Availability

Criterion Data: Yes

- Mean Wave Height **(selected)**
- Baltic Sea Wave Analysis and Forecast *(rejected)*

Selected Dataset

Name: Mean Wave Height

Short Data Description: This is a raster dataset of the mean significant wave height in the Baltic Sea with a resolution of 200 m. Monthly means were calculated for the years 2017–2023.

Data Provider: Leibniz Institute for Baltic Sea Research Warnemünde (IOW) [CONMAR]

Original Data Source: For information on these data, please contact Ulf Gräwe at IOW (ulf.graewe@io-warnemuende.de).

Data Type: Raster

Available Since: Unknown

Last Received: 23.07.2024

Calculation and Processing: Data were clipped to the area of interest. The annual mean for each raster cell was calculated.

Use of Data: Extract the raster cell value at the munition pile centroid. Inversely normalise from 10 to 0.

Value Range: 0.0–3.0 (The maximum value is the limit of operation during explosive ordnance disposal [13].)

Unit: m

Attribute Table Fields: waveHeight, normWaveHeight

Rejected Dataset

Name: Baltic Sea Wave Analysis and Forecast

Short Data Description: "This Baltic Sea wave model product provides forecasts for the wave conditions in the Baltic Sea. The Baltic forecast is updated twice a day providing a new six days forecast with hourly instantaneous data for significant wave height, wave period and wave direction for total sea, wind sea and swell, the Stokes drift, and two parameters for the maximum wave. […] The product grid has a horizontal resolution of 1 nautical mile." [30]

Data Provider: Copernicus

Original Data Source:
https://data.marine.copernicus.eu/product/BALTICSEA_ANALYSISFORECAST_WAV_003_010/services

Data Type: Raster

Available Since: Unknown

Last Updated: Daily

Rationale for Rejection: The selected dataset is superior, since it has a higher resolution than this dataset.

Supplementary Text 2: Analysis of the correlation results

Correlations among top-level criteria and between top-level criteria and clearance priority scores

The top-level criteria show no critical collinearity because no correlation between their scores exceeded ±0.8 (Supplementary Table 3), supporting their use as separate decision factors. Risk to Human Health is the top-level criterion that has the strongest correlation with clearance priority scores (see Supplementary Table 3 for the correlation matrix). This correlation is partly driven by a few piles with unusually high Risk to Human Health scores. These piles also have the highest overall priority scores (Table 1).

Risk to the Environment also displays a notable correlation with clearance priority scores. Risk to the Economy and Socioeconomic Potential, despite having the lowest weights, exhibit a relatively strong correlation with clearance priority scores. Clearance Cost shows no significant correlation, while Risk of Misuse shows a moderate negative correlation with clearance priority scores (Supplementary Table 3).

Correlations between the top-level criteria (Supplementary Table 3) show that Risk of Misuse is negatively correlated with Risk to Human Health, Risk to the Economy and Socioeconomic Potential. This negative correlation likely reflects opposing spatial patterns in the underlying risks. Risk of Misuse increases when munitions are easier to salvage, such as when objects are smaller and piles are farther from areas with intensive shipping activity. By contrast, multiple risks and opportunities within the other top-level criteria increase with larger objects or greater proximity to shipping activity. For example, explosion-related risks increase with object size because larger objects contain more explosive material and therefore produce stronger shockwaves. These risks also increase with shipping activity because greater vessel traffic exposes more vessels to the hazard. The opposing spatial patterns produce lower Risk of Misuse scores where several other risk scores are higher, and vice versa. This subdued effect on the final prioritization score should be communicated transparently, especially because clearance businesses assigned relatively high importance to Risk of Misuse.

Risk to Human Health and Risk to the Environment are not significantly correlated, consistent with the fact that their sub-criteria capture largely different risks. Risk to the Environment comprises only contamination-related risks and indicators. Risk to Human Health, in contrast, includes one contamination-related sub-criterion concerning seafood safety but primarily comprises risks related to explosions, direct contact and bycatch, represented by indicators of munition-pile characteristics, such as the size and number of objects, and fishing intensity.

By contrast, Risk to Human Health and Risk to the Economy are strongly correlated, reflecting similarities in the risks comprising the two top-level criteria. Both criteria include risks associated with explosions and fishing activities, and therefore draw on overlapping indicators about object size, munition location and fishing activity.

Correlations among sub-criteria and between sub-criteria and top-level criteria

Fishing-related activities and seafood contamination have the highest correlation with the top-level criterion of Risk to Human Health (Supplementary Table 4). The risk of direct contact for beachgoers shows a moderate negative correlation with the Risk to Human Health scores, likely because it was negatively correlated with the other sub-criteria. This negative intercorrelation may result from the distinct spatial patterns of the indicators used to measure the respective

sub-criteria, rather than from opposing patterns in the underlying risks themselves. The risk of direct contact is currently measured by the distance from a pile to the nearest bathing site, whereas the other risks are measured using fishing and shipping intensity and size and number of objects on a pile. Spatially explicit records of munition items found on beaches could provide a more direct measure of the risk to beachgoers and might reveal a different relationship with the other Risk to Human Health sub-criteria.

The risk of seafood contamination has a strong positive correlation with the Risk to Human Health scores, despite there being no confirmed case of contamination of seafood by sea-dumped munitions. This finding points to the magnitude of the effect that this sub-criterion would have if such cases would be discovered, thus, at the need for continued monitoring of contamination risks. The high correlation between explosion risk and bycatch risk for fishing crews (Supplementary Table 4) likely reflects data limitations. Both sub-criteria use fishing intensity as an indicator, whereas explosion risk also incorporates object size and the number of objects. Spatially explicit data on observed bycatch events could distinguish bycatch risk more clearly from explosion risk.

The risk of contamination for mollusks is the sub-criterion showing the strongest correlation with its top-level criterion Risk to the Environment (Supplementary Table 5). Fish contamination correlates moderately and flora contamination is not significant. The sub-criterion for mammal contamination received a score of zero for all piles because no mammal contamination had been observed. It therefore shows no variation across piles and does not contribute to differences in the Risk to the Environment score. However, this score does not demonstrate that the underlying risk is zero. Future contamination cannot be ruled out and should be monitored.

The sub-criteria of Risk to the Economy that relate to the fishing sector show strong positive correlations with the top-level criterion score (Supplementary Table 6) as well as high intercorrelation (Supplementary Table 6). This alignment reflects that the sub-criteria capture related but distinct pressures within a single economic domain. For instance, physical damage from explosions was considered by stakeholders to be meaningfully different from regulatory constraints associated with fishing bans. More data collection for each of the fishing-related sub-criteria would increase the ability to reflect their specific risks.

All four sub-criteria of the Socioeconomic Potential correlate strongly with the top-level criterion score (Supplementary Table 7), and with each other (Supplementary Table 7). This finding suggests that different sectors will value the same areas that would become available after clearance, highlighting the potential for future conflict over the use of cleared areas and the importance of initiating early dialogue among affected sectors as part of inclusive maritime spatial planning.