

Appendix to Rozemeijer M.J.C., de Stigter H., Lindeboom H. (2019) Establishing a methodology to define criteria for a risk based impact assessment for offshore sea-floor massive sulphide extraction. Proceedings 48th Underwater Mining Conference 2019, Sanya, China: 13 pp.

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Tables

Table a Overview of the pressures encountered by several authors. Starting point were the ODEMM pressures (White et al., 2013). Pressures No 1-17; ODEMM, Listed in MSFD; Pressures 18-24: ODEMM, NOT listed in MSFD. Pressures 25-37: Added based on literature. The initials in the column Origin represent the different authors: Ortega (2014): O; Coffey Natural Systems (2008): C; Steiner (2011): S; Luick (2012): L; MFE (2011) (M); van Dover (2014): vD; ISA (2011): I; Narita et al. (2015). The final selection of pressures is given in bold							
No	Pressure	Pressure Definition	Origin	1st selection	Remarks	2nd selection	Remarks
1	Smothering	Cover habitat surface with materials falling to the seafloor from activities in the water column (e.g. waste substances from aquaculture cages), on land (e.g. in runoff or effluent), or around activities (e.g. around trawling gear), or from disposal of materials onto the seafloor (e.g. disposal of materials from dredging). Smothering may lead to reduced functioning (e.g. feeding) or mortality of benthic animals living on, or in the seafloor.	MSFD	1	Acknowledged in relevant publications	1	
2	Sealing	Physical loss of habitat from sealing by permanent construction (e.g. Coastal defences, wind turbines)	MSFD	0	Not relevant, Ortega call this substrate loss which is essentially extraction	0	
3	Changes in siltation (sediment concentration)	Change in the concentration and/or distribution of suspended sediments in the water column from runoff, dredging etc.	MSFD	1	Acknowledged in relevant publications	1	
4	Abrasion	Physical interaction of human activities with the seafloor and with seabed fauna/flora causing physical damage and/or mortality (e.g. from trawling or anchoring)	MSFD	1	Acknowledged in relevant publications	1	
5	Selective extraction of non-living resources	Includes sand and gravel (aggregates) extraction, removal of surface substrates for exploration of seabed and subsoil, or removal of seawater for e.g. cooling industrial plants or for desalination	MSFD	1	Acknowledged in relevant publications	1	
6	Underwater sound	Underwater noise created from shipping, acoustic surveys, etc.	MSFD	1	Acknowledged in relevant publications	1	
7	Marine litter	Litter originating from numerous sources but entering the marine environment and consisting of different materials including: plastics, metal, glass, rubber, wood and cloth	MSFD	0	Acknowledged in relevant publications	0	
8	Thermal regime change	Change in temperature of the water (average, range or variability) e.g. due to outfalls from industrial plants	MSFD	1	Acknowledged in relevant publications	1	
9	Salinity regime change	Change in salinity (average, range or variability), e.g. due to outfalls from industrial plants or alterations in coastal structures affecting mixing	MSFD	1	Acknowledged in relevant publications	0	Appeared not relevant in the finale evaluation
10	Introduction of synthetic compounds	Introduction of manmade compounds such as pesticides, antifoulants and pharmaceuticals into marine waters	MSFD	1	Acknowledged in relevant publications	1	
11	Introduction of non-synthetic compounds	Introduction of heavy metals and hydrocarbons into marine waters	MSFD	1	Acknowledged in relevant publications	1	
12	Introduction of radionuclides	Introduction of radionuclides into marine waters	MSFD	0	Hardly mentioned and Ortega 2014 estimated no impacts	0	

13	Nitrogen and Phosphorus enrichment	Input of fertilisers, and other Nitrogen and Phosphorous rich substances, including any subsequent associated deoxygenation	MSFD	1	Acknowledged in relevant publications	0	Only mentioned once and no impacts envisioned
14	Input of organic matter	Organic enrichment and any subsequent deoxygenation, e.g. from industrial and sewage effluent into rivers and coastal areas, or from the waste from aquaculture or from fishing discards	MSFD	0	Hardly mentioned and Ortega 2014 estimated no impacts	0	
15	Introduction of microbial pathogens	Introduction of microbial pathogens into marine waters	MSFD	0	Hardly mentioned and Ortega 2014 estimated no impacts	0	
16	Introduction of non-indigenous species and translocations	Introduction of non-indigenous species and translocations by the activities of a particular sector (e.g. through exchange of ballast waters by shipping or from release of individuals from aquaculture)	MSFD	0	Not to be considered, surface impact	0	
17	Selective extraction of species	Extraction (and subsequent mortality) of any marine fauna (vertebrate or invertebrate) from their natural habitat, including incidental non-target catch (e.g. by commercial fishing, recreational angling and collecting/harvesting).	MSFD	1	Acknowledged in relevant publications	1	
18	Death or injury by collision	Death or injury of marine fauna due to impact with moving parts of a human activity, e.g. marine mammals with ships/jet skis, seabirds with wind turbines etc.	ODEMM	1	Acknowledged in relevant publications	0	Not valid for benthos, plankton or fish
19	Barrier to species movement	Preventing the natural movement of motile marine fauna along a key route of travel (e.g. a migration route) due to barrages, causeways, wind turbines, and other man-made structures.	ODEMM	1	Acknowledged in relevant publications	1	
20	Emergence regime change	Changes to natural sea level regime (average, range or variability) due to barrages or other manmade structures such as coastal defences	ODEMM	1	Acknowledged in relevant publications	1	
21	Water flow rate changes	Changes in currents (speed, direction or variability) due to barrages or other manmade structures such as coastal defences	ODEMM	1	Acknowledged in relevant publications	1	
22	PH changes	Changes in pH (average, range or variability) e.g. due to run off from land-based industry	ODEMM	1	Acknowledged in relevant publications	1	
23	Electromagnetic changes	Change in the amount and/or distribution and/or periodicity of electromagnetic energy emitted in a marine area (e.g. from electrical sources such as underwater cables)	ODEMM	1	Acknowledged in relevant publications	1	
24	Change in wave exposure	Change in the size, number, distribution, and/or periodicity of waves along a coast due to installation of coastal structures	ODEMM	0	Not to be considered, surface impact	0	
25	Waste generation	Waste consisting of different materials including oils and fats, plastics, metal, glass, rubber, wood, etc. Arising from general operations	O, C, S	0	Added by Ortega but is alike Marine litter	0	
26	Substrate loss	Surface seafloor area removed by means of excavation. Change in substrate type due to loss of key characteristic features (physical and/ or biological). Natural substrate is lost and replaced by a different kind of substrate (different soil characteristics)	O, C, S, M, vD	0	Added by Ortega but is alike Selective extraction of non living resources	0	
27	Introduction of other substances	Introduction of solids, liquids or gases not covered by other introduction types	O, C, S, vD	0	Sufficiently covered by other pressures	0	
28	Visual disturbance	Change in normal behaviour of species (e.g., avoidance of an area by birds) due to presence of humans; vessels or machinery	O, C	0	Not to be considered, surface impact	0	
29	Underwater light	Introduction of light for visualisation of SMT operations in deep waters.	O, C, S, M, vD, I	1	Acknowledged in relevant publications	1	
30	Vibration	Vibration waves induced by excavation, vertical transport and processing on board	O, C, vD, N	1	Acknowledged in relevant publications	1	

31	Emissions of NOx, SO2	Atmospheric emissions product of combustion processes (e.g., vessel engine)	O, C	0	Not to be considered, surface impact	0	
32	Emissions of particulate matter to atmosphere	Atmospheric emissions product of combustion process (e.g., vessel engine)	O, C, M, N	0	Not to be considered, surface impact	0	
33	Atmospheric noise	Atmospheric sound generated by vessel operations, on board processing and general operations and transferred to the atmosphere	O, C, M, N	0	Not to be considered, surface impact	0	
34	Entanglement	Entanglement of megafauna (cetacean, turtles etc.), in subsurface equipment including umbilicals, anchor lines, mooring lines, marker buoy lines, power cabling or hydraulic lines is a possibility	C, M	1	Acknowledged in relevant publications	0	Not valid for benthos, plankton or fish
35	Surface light	Introduction of light for visualisation of vessel operations at the surface.	C, S, M	0	Not to be considered, surface impact	0	
36	Oxygen regime change	changes in dissolved oxygen contents may occur by releasing the excess water with increased levels	N	1	Overlooked by most, seems important	1	
37	Gushing out the methane and CO2 in the sediment	gushing out the methane in the sediment and CO2 stored in liquid and hydrate state by activities (e.g. pressures) ranging into the atmosphere	N	0	Not to be considered, surface impact	0	

Stage	SMT									Tailing release		Mentioned of total	Percentage of total	Omitted	
	Activity	Moving the tool	Cutting of soil	Suction of material	Depositing or loss of (waste) material (in piles)	Seafloor visualisation	Seafloor installations	Positioning tool by sonar	Raising/lowering machine to vessel	Umbilicals (and hydraulic lines, power cables, anchor lines, mooring lines)	Tailings release			Jet stream hitting bottom floor	Pre-stripping of unconsolidated surface sediment
Reference															
Ortega 2014	1	1	1	0	1	0	1	0	0	1	0	6	55	0	0
CNS 2008	1	1	1	1	0	1	1	1	1	1	1	10	91	1	0
MFE 2011	1	1	1	1	1	0	1	1	1	1	0	9	82	1	1

Table c Activities linked to pressures. White at al. (2013) was used as a starting point for the pressures. Ortega (2014) (O), Coffey Natural Systems (2008) (C) and MFE (2011) (M) were analysed. When a pressure was mentioned for a activity the first initial is given. When an impact was estimated the cell is coloured red. Not coloured cells mean no impact envisioned by those authors.

Activity	Moving the tool	Cutting of soil	Suction of material	Depositing or loss of (waste) material (in piles)	Seafloor visualisation	Seafloor installations	Positioning tool by sonar	Raising/lowering machine to vessel	Umbilicals (and hydraulic lines, power cables, anchor lines, mooring lines)	Tailings release	Jet stream hitting bottom floor
Pressure											
Smothering	O, C	O, C, M	O, C, M	C, M	O	C	O	C		O, C, M	C
Changes in siltation (sediment concentration)	O, C	O, C, M	O, C, M	C, M	O		O	C		O, C, M	C
Abrasion	O, C	O	O		O	C	O	C		O	
Selective extraction of non living resources	O, C, M	O, C, M	O, M		O		O			O	
Underwater sound	O, M	O, C, M	O, M		O, M		O, M			O	
Thermal regime change	O, C	O, C	O		O		O			O, C	
Salinity regime change	O	O	O		O		O			O, C, M	
Introduction of synthetic compounds	O, C	O, C	O		O		O			O, C, M	
Introduction of non-synthetic compounds	O, C	O, C, M	O	C, M	O		O			O, C, M	C
Nitrogen and Phosphorus enrichment	O	O	O		O		O			O	
Selective extraction of species	O, C	O, C, M	O, C		O, C		O			O	
Death or injury by collision	O	O	O		O		O			O	
Barrier to species movement	O	O, C	O		O		O			O	
Emergence regime change	O	O, C	O		O		O			O	
Water flow rate changes	O	O, C	O		O		O			O	
PH changes	O	O, C	O		O		O			O	
Electromagnetic changes	O	O	O		O		O		C	O	
Underwater light	O, C, M	O, C, M	O, C, M		O, M		O			O	
Vibration	O	O, C	O		O		O			O	
Entanglement								M	C, M		
Oxygen regime change	C			C						C	

Table d Pressures linked to ecological components. Since White at al. (2013) was not designed for SMS deposits, Ortega (2014) was used as a starting point for the pressures. Ortega (2014) (O), Coffey Natural Systems (2008) (C) and MFE (2011) (M) were analysed. When a pressure was linked to ecological components the first initial is given. When an impact was estimated to be substantial enough the initial is coloured red. Black initials mean no impact envisioned by those authors. Empty cells or missing initials mean that no link between pressure and ecological component given.

Ecological components	Vent benthos	Non-vent Benthos	Stony corals and octocorals	Habitat change	Deep sea zooplankton	Deep sea fish	Deep sea zone commercial fish	Mid-water zooplankton	Mid-water zone fish	Photic zone zooplankton	Photic zone fish	Photic zone commercial fish
Pressure												
Smothering	O, C, M	C, M	O	O, C	O	O, M	O,	O	O, M	O	M	O, M
Changes in siltation (sediment concentration)	O, C, M	C, M	O	O, C, M	O, M	O, M	O	O, C, M	O, C, M	C, M	C, M	O, M
Abrasion	O, C	C	O, C	O, C		M	O		M		M	O, M
Selective extraction of non-living resources	O, C, M	C, M	O, C, M	O, C, M		O	O					O
Underwater sound	O, C, M	C, M	O	O, C, M	O, C, M	O, C, M	O					O
Thermal regime change	O	C	O, C	C		O	O					O
Introduction of synthetic compounds	O, C, M	C	O	C	O, C, M	O, C, M	O	C, M	C, M	O, C, M	C, M	O, M
Introduction of non-synthetic compounds	O, C, M	C, M	O, C, M	C, M	O, C, M	O, C, M	O, M	O, C, M	O, C, M	O, C, M	C, M	O, C, M
Selective extraction of species	O, C, M	C, M	O, C, M	O, C, M	C	O, C	O					O, M
Barrier to species movement	O		O	O	O	O	O					O
Emergence regime change	C	C	C	C								
Water flow rate changes	C	C	C	C								
PH changes	O, C	C	O, C	O, C	O	O	O					O
Electromagnetic changes	C	C	C	C	C	C		C	C	C	C	
Underwater light	O, M	M	O, M	M	O, C	O, C	O					O
Vibration	O		O	O	O							
Oxygen regime change	O, C	C	O, C	C	O	O						

Table e ecological components linked to ecosystem functions and services. Letters are initials indicating the literature in which the function or services was encountered. MFE (2011) (M) was used as a starting point for the functions and services. Other authors Armstrong et al. (2012): A; Kaikonen et al. (2018): K; Turner et al., (2019): T; Ortega (2014): O; Coffey Natural Systems (2008): C. Orange blocks, Ecosystem components that predominantly participated in structure, functions and services. Red framework: functions that are encountered in most authors.

	Ecosystem structure			Functions or supporting services						Provisioning service		Cultural service
	Habitat	Biodiversity	Key species	Nutrient recycling	chemosynthetic primary production	Food web functioning	Ecosystem functioning	Breeding & nursery grounds	Recovery & resilience	Genetic diversity	Harvestable biomass	Protected species
Vent benthos	M, A, K, T	A, K, T, O, C	M, O, C	A, K, O, C	A, K, T, O, C	A, K, T, O, C	M, A, K, T, O	T	M, A, K, T, O	A, T, O, C	A, C, T	
Non-vent benthos	M, A, K, T, O	A, K, T, C	M, O, C	A, K, T, C	T, C	A, K, T, O, C	M, A, K, T, O	T	M, A, K, O	A, T, C	C	M
Stony corals and octocorals	M, A, K, T, O	A, K, C	M, O, C	A, K, C	A	A, K, T, O, C	M, A, K, T, O	T	M, A, K, O	A, C		M
Habitat	M, A, K, T, O	A, K		A, K, C	A, K, T	A, K	M, A, K	A, K, T	M, A, K, O, C		A, K	
Deep sea zooplankton	M, A	A	M	C	T	A, T, O, C	M, A, K, T, O, C		M, A, O			M
Deep sea fish	M, A, K, O	A	M	C	T	A, K, T, O, C	M, K, T, O, C	A, K, O	M, A, K	A	O	M
Deep sea zone commercial fish	M, A, K, O	A, K	M	C	T	K, T, O, C	M, K, T, O, C	O	M, A, K, O	A	M, A, K, T, O	M
Mid-water zooplankton	M		M	C	T	T, O, C	M, T, O, C		M, O			M
Mid-water zone fish	M	K	M	C	T	K, T, C	M, T, C	O	M, O		O	M
Photic zone zooplankton	M	C	M	C	T	T, O, C	M, T, O, C		M, O			M
Photic zone fish	M	K, C	M	C	T	K, T, C	M, T, C	O	M, O			M

Photic zone commercial fish	M	K, C	M	C	T	K, T, C	M, T, C	O	M, O	M		M, A, T, O
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