Supplementary material to article:

Spatial Cumulative Assessment of Impact Risk - Implementing Ecosystem-Based Management for Enhanced Sustainability and Biodiversity in the Black Sea

Elena Bișinicu*[1], Valeria Abaza[1], Laura Boicenco[2], Adrian Filimon[1], George Emanuel-Harcotă[1, 3], Oana Marin[1], Andra Oros[4], Elena Pantea [1], Alina Spînu [5], Florin Timofte[2], George Țiganov[6], Oana Vlas[1], and Luminița Lazăr*[4]

[1] Ecology and Marine Biology Department, National Institute for Marine Research and Development "Grigore Antipa", 300 Mamaia Blvd., 900581 Constanta, Romania; ebisinicu@alpha.rmri.ro; vabaza@alpha.rmri.ro; afilimon@alpha.rmri.ro; gharcota@alpha.rmri.ro; omarin@alpha.rmri.ro; epantea@alpha.rmri.ro; ovlas@alpha.rmri.ro

[2] National Institute for Marine Research and Development "Grigore Antipa", 300 Mamaia Blvd., 900581 Constanta, Romania; lboicenco@alpha.rmri.ro, ftimofte@alpha.rmri.ro

[3] University of Bucharest, Doctoral School of Ecology, Bucharest, Romania, gharcota@alpha.rmri.ro

[4] Chemical Oceanography and Marine Pollution Department, National Institute for Marine Research and Development "Grigore Antipa", 300 Mamaia Blvd., 900581 Constanta, Romania; aoros@alpha.rmri.ro, llazar@alpha.rmri.ro

[5] Chemical Oceanography and Coastal Engineering Department, National Institute for Marine Research and Development "Grigore Antipa", 300 Mamaia Blvd., 900581 Constanta, Romania, aspinu@alpha.rmri.ro

[6] Living Marine Resources Department, National Institute for Marine Research and Development "Grigore Antipa", 300 Mamaia Blvd., 900581 Constanta, Romania, gtiganov@alpha.rmri.ro

*Correspondence: ebisinicu@alpha.rmri.ro (EB); llazar@alpha.rmri.ro (LL)

Table S1. The classifications for activities and pressures by referencing previous categorizations established in the Marine Strategy Framework Directive

Activity (sector) MSFD	Activity (specific)	Pressure (general) MSFD	Pressure (Specific)	Ecosystem Component MSFD	Ecosystem Component (specific)
Urban uses	WWTP	Input of nutrients and organic matter	Input of nutrients and organic matter	Water column	Pelagic - Coastal -FPK
					Pelagic - Coastal -ZPK
					Benthic-Coastal-Macroalgae
					Benthic-Coastal-Seagrass
		Input of other substances	Introduction of Non-synthetic compounds	Coastal (pelagic)	Pelagic habitats
				Sublittoral sediment	Infralittoral mud
			Introduction of Synthetic compounds	Coastal (pelagic)	Pelagic habitats

Activity (sector) MSFD	Activity (specific)	Pressure (general) MSFD	Pressure (Specific)	Ecosystem Component MSFD	Ecosystem Component (specific)
				Sublittoral sediment	Infralittoral mud
Extraction of oil and gas, including infrastructure	Oil & gas exploitation	Input of other substances	Introduction of Non-synthetic compounds	Shelf (pelagic)	Pelagic habitats
			Introduction of Synthetic compounds	Sublittoral sediment	Offshore circalittoral mixed sediments (50-100m)
Coastal defence and flood protection	Coastal protection infrastructure	Physical disturbance to seabed (temporary or reversible)	Deposition on seabed	Infralittoral rock and biogenic reef	[Cystoseira] spp. in eulittoral rockpools
				Infralittoral mud	[Zostera] beds in infralittoral sediments
	Beach nourishment	Physical loss (due to permanent change of seabed substrate or morphology and to extraction of seabed substrate)	Seabed sealing	Littoral sediment	Benthic - Littoral sediment (0-5m)
	Coastal protection infrastructure				
	Beach nourishment			Sublittoral sediment	Benthic - Infralittoral sand (5-20m)
	Coastal protection infrastructure				
	Beach nourishment		Seabed removal		Benthic - Circalittoral sand
				Infralittoral rock and biogenic reef	[Cystoseira] spp. in eulittoral rockpools
				Infralittoral mud	[Zostera] beds in infralittoral sediments
Transport — shipping	Shipping	Input or spread of non-indigenous species	Input or spread of non-indigenuous phytoplankton species	Water column	Pelagic - Variable salinity - FPK
					Pelagic - Coastal -FPK
					Pelagic - Shelf - FPK
			Input or spread of non-indigenuous microzooplankton species		Pelagic - Variable salinity - MICROZPK
					Pelagic - Coastal - MICROZPK
					Pelagic - Shelf - MICROZPK
			Input or spread of non-indigenuous zooplankton species		Pelagic - Variable salinity - ZPK
					Pelagic - Coastal - ZPK
					Pelagic - Shelf - ZPK

Activity (sector) MSFD	Activity (specific)	Pressure (general) MSFD	Pressure (Specific)	Ecosystem Component MSFD	Ecosystem Component (specific)
			Spread of *Mnemiopsis leidyi*		Pelagic - Variable salinity - Jellyfish
					Pelagic - Coastal - Jellyfish
					Pelagic - Shelf - Jellyfish
			Spread of *Beroe ovata*		Pelagic - Variable salinity - Jellyfish
					Pelagic - Coastal - Jellyfish
					Pelagic - Shelf - Jellyfish
			Spread of *Rapana venosa*	Sublittoral rock	Benthic - Infralittoral rock and biogenic reef
				Sublittoral sediment	Benthic - Infralittoral sand (5-20m)
					Benthic - Circalittoral rock and biogenic reef
					Benthic - Circalittoral mixed sediment
			Input or spread of non-indigenuous macrozoobenthos species	Littoral rock and biogenic reef	Benthic - Littoral rock and biogenic reef
				Infralittoral mud	Benthic - Infralittoral mud
Fish and shellfish harvesting (professional, recreational)	Benthic trawls and dredges - operations	Physical disturbance to seabed (temporary or reversible)	Seabed abrasion	Sublittoral sediment	Benthic - Infralittoral sand (5-20m)
					Benthic - Circalittoral sand
	Harvesting by scuba diving	Extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities)	Extraction of mussels - manual	Infralittoral rock and biogenic reef	Infralittoral rock and biogenic reef
Coastal defence and flood protection	Coastal protection infrastructure	Changes to hydrological conditions	Changes to hydrological conditions		Benthic - [Cystoseira] spp. in eulittoral rockpools
				Infralittoral mud	Benthic - [Zostera] beds in infralittoral sediments

Tabel S2. Risk evaluated through the assessment of scores assigned to criteria (after Piet et al., 2019, Piet et al., 2017, Borgwardt et al., 2019, Piet et al., 2021, Piet et al., 2023, Knights et al., 2015)

Extent	Score
Exogenous The activity occurs outside of the area occupied by the ecosystem component, but one or more of its pressures would reach the ecosystem component through dispersal	0
Trace The activity overlaps with the ecosystem component by up to 1% of the area occupied by the EC in the case study area	0.01
Site The activity overlaps with the ecosystem component by between 1 and 5% of the area occupied by the EC in the case study area	0.03
Local The activity overlaps with the ecosystem component by between 5 and 50% of the area occupied by the EC in the case study area	0.37
Widespread patchy The activity overlaps with the ecosystem component by between 50 and 100% of the area occupied by the EC in the case study area, but the distribution within that area is patchy	0.67
Widespread even The activity overlaps with the ecosystem component by between 50 and 100% of the area occupied by the EC in the case study area, and is evenly distributed across that area	1
Dispersal	
None The pressure does not disperse in the environment	0
Moderate The pressure disperses, but stays within the local environment	0.05
High The pressure disperses widely and can disperse beyond the local environment	0.15
Frequency	
Rare	1
Occasional	2
Frequent	5
Very frequent	9
Continuous	12
Hazard	
Lethal high	100
Lethal low	10

Negligible	0.001
Sublethal high	1
Sublethal low	0.1
Magnitude	
High (H)	0.5
Low (L)	0.01
Medium (Med)	0.1
None	0
Maximum (Max)	1
Very low (VL)	0.1
Behavior	
Very Low	0.005
Low	0.05
Moderate	0.5
High	1
Not relevant	NR
Resilience	
Birds	55
Circalittoral rock and other hard substrata	6
Deep-sea bed	55
Fish & Cephalopods	55
Infralittoral rock and other hard substrata	6
Littoral rock and other hard substrata	1
Littoral sediment	1
Mammals	55
Pelagic water column	1
Reptiles	55
Sublittoral sediment	6

Table S3. Specific activities and ecosystem components- IR%

Specific activities and ecosystem components	IR %
[Cystoseira] spp. in eulittoral rockpools	**13.52%**
Beach nourishment	10.26%
Coastal protection infrastructure	3.27%
[Zostera] beds in infralittoral sediments	**13.52%**
Beach nourishment	10.26%
Coastal protection infrastructure	3.27%
Benthic - [Cystoseira] spp. in eulittoral rockpools	**0.78%**
Coastal protection infrastructure	0.78%
Benthic - [Zostera] beds in infralittoral sediments	**1.48%**
Coastal protection infrastructure	1.48%

Benthic - Circalittoral mixed sediment	**8.40%**
Shipping	8.40%
Benthic - Circalittoral rock and biogenic reef	**8.40%**
Shipping	8.40%
Benthic - Circalittoral sand	**9.49%**
Beach nourishment	0.04%
Benthic trawls and dredges - operations	9.45%
Benthic - Infralittoral mud	**0.16%**
Shipping	0.16%
Benthic - Infralittoral rock and biogenic reef	**8.40%**
Shipping	8.40%
Benthic - Infralittoral sand (5-20m)	**18.07%**
Beach nourishment	0.22%
Benthic trawls and dredges - operations	9.45%
Coastal protection infrastructure	0.00%
Shipping	8.40%
Benthic - Littoral rock and biogenic reef	**0.14%**
Shipping	0.14%
Benthic - Littoral sediment (0-5m)	**11.63%**
Beach nourishment	10.26%
Coastal protection infrastructure	1.37%
Benthic-Coastal-Macroalgae	**1.08%**
WWTP	1.08%
Benthic-Coastal-Seagrass	**1.08%**
WWTP	1.08%
Infralittoral mud	**0.06%**
WWTP	0.06%
Infralittoral rock and biogenic reef	**0.77%**
Harvesting by scuba diving	0.77%
Offshore circalittoral mixed sediments (50-100m)	**0.03%**
Oil & gas exploitation	0.03%
Pelagic - Coastal - Jellyfish	**0.30%**
Shipping	0.30%
Pelagic - Coastal - MICROZPK	**0.32%**
Shipping	0.32%
Pelagic - Coastal -FPK	**0.64%**
Shipping	0.32%
WWTP	0.31%
Pelagic - Coastal -ZPK	**0.31%**
WWTP	0.31%
Pelagic - Shelf - FPK	**0.32%**
Shipping	0.32%
Pelagic - Shelf - Jellyfish	**0.72%**

Shipping	0.72%
Pelagic - Shelf - MICROZPK	**0.32%**
Shipping	0.32%
Pelagic - Variable salinity - Jellyfish	**0.01%**
Shipping	0.01%
Pelagic - Variable salinity - MICROZPK	**0.01%**
Shipping	0.01%
Pelagic habitats	**0.04%**
Oil & gas exploitation	0.01%
WWTP	0.02%