Supplementary materials

This section provides additional information on the comparative analysis of WFD and MSFD in Portuguese Coastal Waters.

While WFD integration rules are explicitly defined, MSFD did not define any integration rules for the criteria. Portugal assessment followed the Common Procedure defined by OSPAR, structured around three indicator categories comprising the primary criteria: Category I (nutrient enrichment, representing pressure or source), Category II (direct biological effects, such as chlorophyll-a), and Category III (indirect effects, including oxygen depletion or harmful algal blooms).

1. Temporal assessment

The WFD operates on six-year river basin management cycles, each beginning with the publication of a River Basin Management Plan (RBMP) and an associated Programme of Measures (PoM) (Reporting years, 2009, 2015, and 2021). Interim progress reports assessing PoM implementation are required every three years [18, 19], while RBMP reporting occurs every six years (1st WFD cycle covered 2010-2015, the 2nd 2016-2021 and the 3rd 2022-2027).

The MSFD aims to achieve or maintain Good Environmental Status (GES) at the scale of marine regions and sub-regions. Eutrophication is assessed under Descriptor 5, integrating nutrient enrichment, direct biological responses and indirect effects such as harmful algal blooms or oxygen depletion. MSFD assessments also follow a six-year adaptative management cycle, structured into five steps: (i) initial assessment of environmental status, (ii) definition of GES characteristics, (iii) establishment of environmental targets, (iv) monitoring programmes, and (v) Programmes of Measures. Achievement of GES is assessed at the end of each cycle and used to inform the subsequent cycle. The first cycle covered 2012-2017, the second 2018-2023 and the third cycle began in 2024 [20].

The reporting data period is also different.

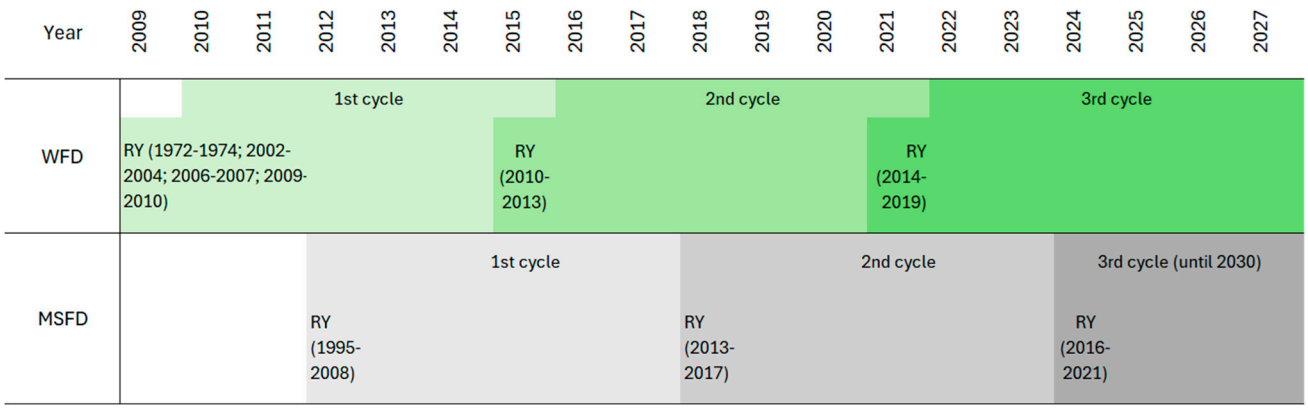


Figure S1 - Timeline of implementation and reporting cycles for the WFD and the MSFD. Between brackets, the data used for reporting years for each evaluation cycle. RY – Reporting Year.

2. *Water bodies and water masses correspondence*

The following table correlates the different designations of water bodies between Directives.

Table S1 - WFD coastal waters typologies (A) and respective hydrographic regions (RH) and water masses (CW-coastal waters, T-territorial waters) and corresponding MSFD reporting coastal areas (AC - coastal area A, BC - coastal area B and CC - coastal area C. A5-A6, A6-A7, AC-BC and BC-CC are coastal boundary areas.

WFD				MSFD
WFD_ Water Typology	WFD_coastal hydrographic regions	Number and water mass category	Main rivers	MSFD_coastal reporting areas
A5	RH1	2CW + 1T	Minho, Lima	AC
	RH2	1CW + 1T	Cávado, Ave, Leça	
	RH3	1CW + 1T	Douro	
	RH4	5CW + 1T	Vouga, Mondego e Liz	
	RH5	1CW	Tagus, various western riverbanks and streams ("Ribeiras de Oeste")	
A5-A6	RH5	1T	Tagus, various western riverbanks and streams ("Ribeiras de Oeste")	AC-BC
A6	RH5	2CW	Tagus, various western riverbanks and streams ("Ribeiras de Oeste")	BC
	RH6	2CW + 1T	Sado, Mira	
	RH8	1CW	Various riverbanks and streams from Algarve ("Ribeiras do Algarve")	
A6-A7	RH8	1T	Various riverbanks and streams from Algarve ("Ribeiras do Algarve")	BC - CC
A7	RH8	3CW	Various riverbanks and streams from Algarve ("Ribeiras do Algarve")	CC
	RH7	2CW + 1T	Guadiana	

3. *Water Framework Directive: indicators, variables and thresholds variability*

Table S2 summarises the eutrophication-related quality elements assessed under WFD across three evaluation cycles for Portuguese coastal waters (A5, A6 and A7).

Table S2 - Core eutrophication indicators, variables, spatial coverage, statistical metrics, evaluation periods, reference values and ecological class boundaries used under the Water Framework Directive (WFD) for Portuguese coastal waters (A5, A6 and A7) across three assessment cycles. * Declared provisional values.

WFD - QUALITY ELEMENTS

	Core eutrophication indicators	Variables	Area	Metrics	Assessment seasons	Reference values	Frontier Classes				
							High	Good	Moderate	Poor	Bad
1st cycle	Nutrients	Nitrate+Nitrite (mgN/L)	A6 + A7 (RH8)	Median	quarterly			≤ 25			
		Ammonia (mgN/L)						≤ 1			
		Phosphate (mgP/L)						≤ 0.1			
		Nitrate+Nitrite µmol/L)	A5 (RH1, RH2, RH3)			2.93*		≤ 25 mgN/L			
		Ammonia (µmol/L)				1.96*		≤ 1 mgN/L			
		Phosphate (µmol/L)				0.23*		≤ 0.1 mgP/L			
		Nitrate+Nitrite µmol/L)	A6 (RH6) + A7 (RH7)					<2.5*			
		Ammonia (µmol/L)						<1*			
		Phosphate (µmol/L)						<0.3 *			
		All nutrients	A5 (RH4) + A5+A6 (RH5)			not defined					
	Biomass	Phytoplankton (Chla (µg/L)	A5	90th Percentile	Feb-Oct (6x)	5.3	<8	8-12	12-17.5	17.5-26.5	>26.5
			A6+A7			4	6-8	9-12			
		Phytoplankton	A5	Bloom Frequency %		25 (three blooms a year)	<33.3	33.3-41.7	41,7-50	50-58.3	>58.3
			A6+A7								
	Oxygen deficiency	Dissolved Oxygen (%sat)	A5	Median	quarterly	100*		<90			
			A6+A7		quarterly						
2nd cycle	Nutrients	Nitrate+Nitrite (mgN/L)	A5 +A6 +A7	90th Percentile	quarterly	0.13					
		Ammonia (mgN/L)				0.07					
		Phosphate (mgP/L)				0.02					
	Biomass	Phytoplankton (Chla (µg/L)	A5	90th Percentile	Feb-Oct (6x)	5.3	8	12	17.5	26.5	
			A6+A7			4	6	9	13.5	20	
	Oxygen deficiency	Dissolved Oxygen (%sat)	A5 +A6 +A7	90th Percentile	quarterly	117					
3rd cycle	Nutrients	Nitrate+Nitrite (mgN/L)	A5 +A6 +A7	90th Percentile	quarterly	0.13	<0.13	0.13-0.26	≥0.26		
		Ammonia (mgN/L)				0.07	<0.07	0.07-0.14	≥0.14		
		Phosphate (mgP/L)				0.02	<0.02	0.02-0.04	≥0.04		
	Biomass	Phytoplankton (Chla (µg/L)	A5	90th Percentile of averaged annual value	Feb-Oct (6x)	5.3	8	12			
			A6+A7			4	6	9			

Oxygen deficiency	Dissolved Oxygen (%sat)	A5 +A6 +A7	90th Percentile	quarterly	117	105,3-128,7	81,9-105,2 and 128,8-140,4	<81,9 and >140,4	

* preliminary values

4. *Marine Strategy Framework Directive indicators, variables and thresholds variability*

Table S3 summarizes the criteria and variables used under MSFD to assess eutrophication (Descriptor 5) for the Portuguese coastal subdivisions (AC, BC, CC) across three cycles.

Table S3 – Marine Strategy Framework Directive (MSFD) criteria for eutrophication assessment (Descriptor 5) in Portuguese coastal subdivisions (AC, BC, CC) across three cycles, showing indicator variables, metrics, evaluation periods and reference and limit values.

MSFD - CRITERIA

	Core eutrophication indicators	Variables	Area	Metrics	Assessment seasons	Reference values	Limit values
1st cycle	Nutrients	DIN (µmol/L)	AC+BC+CC	Average	Nov-Jan	8	12
		DIP (µmol/L)				0.5	0.8
	Biomass	Chl-a (µg/L)	AC	90th Percentile	Feb-Oct	4.7	7.1
			BC			3.2	4.8
			CC			3.6	5.4
		Phytoplankton	AC+BC+CC	species composition frequency of blooms		-	-
	Oxygen deficiency	Bottom oxygen (mg/L)	AC+BC+CC	90th Percentile	Year round	>6	<4
2nd cycle	Nutrients	DIN (µmol/L)	AC+BC+CC	Average	Nov-Jan	8	12
		DIP (µmol/L)				0.5	0.8
	Biomass	Chl-a (µg/L)	AC	90th Percentile	Feb-Oct	8	12
			BC+CC			4.5	8.2
		CLA-Sat (µg/L)	AI			2.1	3.2
			BI			2	3
			CI			1.8	2.7
		Phytoplankton	AC+BC+CC	number, spatial and temporal coverage of HABs	Feb-Oct	-	-
	Oxygen deficiency	Bottom oxygen (mg/L)	AC+BC+CC	90th Percentile	Year round	>6	<4
3rd cycle	Nutrients	DIN (µmol/L)	AC+BC+CC	Average	Dec-Feb	8	12
		DIP (µmol/L)				0.5	0.8
	Biomass	Chl-a (µg/L)	AC	Average	Mar-Oct	8	12
			BC+CC			4.5	8.2
		Phytoplankton	AC+BC+CC	number, spatial and temporal coverage of HABs		-	-
	Oxygen deficiency	Bottom oxygen (mg/L)	AC+BC+CC	5th Percentile	Jul-Oct	< 6	

5. *Ecological Quality Ratios (EQRs)*

Table A4 compares the Ecological Quality Ratios (EQR) boundaries applied by the WFD and the MSFD for eutrophication indicators across cycles. The WFD applies EQRs to chlorophyll-a based on EU intercalibration class boundaries [51], revised in 2013 [52] and 2018 [53]. The MSFD did not use EQRs in the 1st and 2nd cycles, relying instead on reference/limit values (Table A3). In the 3rd cycle, MSFD adopted a normalized EQR scheme (0-1) [50] with five equidistant classes (0-0.2 to 0.8-1.0) [54].

Table S4 – Comparison of Ecological Quality Ratios (EQR) boundaries used by the WFD

	Directive	Variables	Areas	EQR High	Good	Moderate	Poor	Bad
1st cycle	WFD	Nutrients		-	-	-	-	-
		Phytoplankton - Chl-a	A5+A6+A7	>0.67	[0.44-0.67[	[0.30-0.44[	[0.2-0.3[	<0.2
		Phytoplankton blooms (%)	A5	>0.75	[0.6-0.75[	[0.5-0.6[	[0.43-0.5[	<0.43
		Dissolved Oxygen		-	-	-	-	-
	MSFD	Nutrients						
		Chl-a				Not defined		
		Dissolved Oxygen						
2nd cycle	WFD	Nutrients		-	-	-	-	-
		Phytoplankton - Chl-a	A5+A6+A7	>0.67	[0.44-0.67[	[0.30-0.44[	[0.2-0.3[	<0.2
		Dissolved Oxygen		-	-	-	-	-
	MSFD	Nutrients						
		Chl-a				Not defined		
		Dissolved Oxygen						
3rd cycle	WFD	Nutrients		-	-	-	-	-
		Phytoplankton - Chl-a	A5	0.67	0.44	0.3	0.2	
			A6+A7	0.88	0.49	0.3	0.2	
		Dissolved Oxygen		-	-	-	-	-
	MSFD	Nutrients						
		Chl-a	AC+BC+CC	≥0.8-1	≥0.6-0.8	≥0.4-0.6	≥0.2-0.4	≥0.0-0.2
		Dissolved Oxygen						