LIFE24-PRE-IT-LIFE-MAPPER

Guidelines for **MAP**ping, **P**rot**E**cting, and **R**estoring Marine Ecosystems

Milestone	Literature Review on habitat condition assessment
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Summary

This milestone summarizes the scientific information collected in Task 2.3 of WP 2 on how the condition of marine habitats is assessed in the literature. The search covered 44 studies (2001–2025) and focused on the indicators used, whether condition thresholds are defined, how threshold boundaries are set and reference conditions are identified, which policy frameworks they address, and whether spatial (extent) thresholds are provided.

The evidence base is dominated by Mediterranean studies (42 of 44) on three NRR habitat groups: macroalgal forests, seagrass beds, and sponge, coral and coralligenous beds. Almost all studies (40 of 44) define condition thresholds, mostly as five-class schemes on an Ecological Quality Ratio (EQR) scale developed for the Water Framework Directive (WFD) or the Marine Strategy Framework Directive (MSFD). Reference conditions are rarely based on truly undisturbed sites: they are more often identified from other regions, derived from the best values observed within a study, or built from expert-based conceptual models. No study provides spatial thresholds such as a favourable reference area or range. The available methods therefore address only the condition component of the Nature Restoration Regulation (NRR).

Introduction

The Nature Restoration Regulation (EU 2024/1991) requires Member States to put in place restoration measures for marine habitats listed in its Annex II, with targets referring both to the area of habitats in good condition and to the extension needed to reach favourable reference areas. Implementing these targets requires agreed indicators, quantitative thresholds separating good from not-good condition, and robust reference conditions against which current condition can be measured.

Within LIFE MAPPER, WP2 addresses habitat mapping and condition assessment. Task 2.3 aims to provide guidelines for assessing the condition of marine habitats, with a focus on setting thresholds between good and not-good condition and accounting for their spatial and temporal variability. This report fulfils Milestone MS2 by synthesising the information on these topics from literature review. Its results feed into the questionnaire to experts (MS3), the online workshop, and the condition-assessment chapter of the LIFE MAPPER manual.

Methods

Research articles were identified through Google Scholar and Web of Science using a combination of keywords including: *Cystoseira* AND status AND condition; *Posidonia* AND status AND condition; *Cymodocea* AND status AND condition; coralligenous AND status AND condition; shellfish beds AND status AND condition; maerl beds AND status AND condition. This research returned a number of 199 records from which were selected the papers that could answer the questions in the Excel file. Moreover, further articles were selected from the bibliography of included articles. A total of 44 records were screened. For each study, information covering four main blocks was retrieved:

- **Context:** MSFD region and subregion, country, location, Habitats Directive habitat type, NRR habitat group and EUNIS code, target species.
- **Indicator:** index or metric used, kind of indicator (status- or pressure-based) and key ecological features addressed (structure, functioning, resilience, sensitivity, biodiversity).
- **Thresholds and reference:** whether condition thresholds are included and their values, whether values are rescaled to 0–1 (EQR), how threshold boundaries are set, and the reference condition used.
- **Policy relevance:** EU policy (WFD, MSFD, Habitats Directive) and Regional Sea Convention addressed, spatial thresholds (favourable reference area/range) and their units, and suitability for NRR restoration plans.

During synthesis, the reference conditions described in each study were grouped into six approaches (Table 2).

Results

The 44 studies were published between 2001 and 2025, with most published after 2010 (20 in 2011–2018 and 19 in 2019–2025). They are strongly concentrated in the Mediterranean Sea (42 studies), particularly the Western Mediterranean (23), followed by the Adriatic (6), Aegean-Levantine (6), and Ionian and Central Mediterranean (3) subregions. Only two studies refer to the North-East Atlantic (Bay of Biscay and Iberian coast). Italy is the most represented country (17 studies).

In terms of NRR habitat groups, studies cover macroalgal forests (18), seagrass beds (13) and sponge, coral and coralligenous beds (12); one study covers both macroalgal forests and seagrass beds.

- **Indicators**

Indicators are mostly status-based (33 studies), describing the state of the community/habitat; seven are pressure-based (e.g. ALEX for non-indigenous species, ESCA based on species sensitivity) and two combine status and pressure components. Almost all indicators address habitat structure (37 studies: cover, density, species composition, canopy height). Functioning (1 study), resilience (2 experimental studies) and sensitivity (2) are rarely addressed. Table 1 lists the main indices by habitat group.

Table 1. Main indices, policy framework and dominant reference approach by NRR habitat group.

Habitat group	Main indices (number of studies)	Main policy	Dominant reference approach
Macroalgal forests (n = 18)	CARLIT (8), EEI-c (2), CFR (2), reef-EBQI (2), ECOfast, ALEX, experimental tipping points (2)	WFD (12 of 18)	Least-disturbed reference sites (5) and reference values adopted from other regions (6)
Seagrass beds (n = 13)	PREI, POMI, BiPo, WePOSI, MediSkew, CymoSkew, CYMOX, ZoNI, Conservation Index, density classes	WFD (9 of 13)	Best values observed within the study (7)
Sponge, coral and coralligenous beds (n = 12)	ESCA (2), MACS (2), MAES, CBQI, CAI, Cor-EBQI, CavEBQI, NAMBER, BARCS, COARSE	MSFD (9 of 12)	Expert-based / conceptual models (5)

- **Condition thresholds**

Data availability for setting Reference conditions is the weakest point of current assessment methods. Truly pristine conditions are acknowledged to be absent in most Mediterranean coastal areas, and the studies use six different approaches to cope with such data gaps (Table 2):

Table 2. Approaches used to define reference conditions.

Approach	Studies	Examples
Adopted from literature or other regions	14	CARLIT applied with the reference sites of Ballesteros et al. (2007); southern Mediterranean studies adopting NW Mediterranean or NE Atlantic references; national PREI reference values

Approach	Studies	Examples
Expert-based or conceptual model	10	Hypothetical "ideal" condition (maximum score for each metric) in EBQIs, MACS and BARCS
Best values observed within the study	9	Best two or three sites (POMI, CYMOX, ZoNI, WePOSI); "theoretical optimal site" (CAI, MAES)
Least-disturbed reference sites	7	Scandola, North Menorca and Ibiza-Formentera MPAs; Montecristo Island; Strunjan Nature Reserve; Natura 2000 sites in the Aegean
Experimental controls	2	Unmanipulated full-canopy plots in field experiments
None or simulated	2	Current baseline only (COARSE); simulated undisturbed state (methodological study)

Approaches differ markedly between habitat groups. Least-disturbed reference sites are used mainly for macroalgal forests, through the CARLIT reference network. For seagrass meadows, reference values are most often the best values observed within the study area, which makes thresholds dependent on the sampled area. For coralligenous and deep-sea habitats, where historical data and pristine sites are lacking, expert-based conceptual models prevail. When reference values are transferred between regions, the factors used to define them (e.g. coastal morphology, substrate, exposure, slope) also change, limiting comparability.

- **Policy relevance and spatial thresholds**

Thresholds were developed mainly to address the WFD (24 studies, including two also addressing the MSFD) and the MSFD (17, including the same two). Only one study refers to the Habitats Directive, and four do not target any specific policy. Within WFD, the water body quality is assessed using habitat-forming species as biological quality elements, thus indices adopted reflect such an approach rather than the condition of the habitat itself. Regional Sea Conventions are rarely addressed explicitly: six studies refer to the Barcelona Convention (one also to OSPAR), mainly through the IMAP framework and the Action Plan for coralligenous and other calcareous bio-concretions.

None of the 44 studies provide spatial thresholds such as favourable reference areas or ranges. Only one study includes an area-based component in its index (expected seagrass meadow coverage above 90% of the sea bottom), and one measures current meadow extent without a threshold. As a result, all studies but one were judged partially suitable for NRR restoration

plans: they provide a quantitative condition assessment with a good-condition threshold, but no threshold for the habitat area.

Gaps and implications for the NRR

- **Spatial components are missing.** No favourable reference areas or ranges were reported. Setting them will require dedicated approaches (e.g. historical distribution, modelling, expert knowledge).
- **Reference conditions are rarely independent.** Most references are borrowed from other regions, derived from the sites studied, or expert-based. Thresholds based on the best observed values are not transferable between datasets, and shifting baselines are rarely addressed.
- **Water quality is not habitat condition.** WFD indices may classify a site as good even where the most sensitive habitat-forming species have been lost, or where degradation is driven by pressures they do not capture (e.g. overgrazing, invasive species). Therefore, the use of existing indices and threshold values requires careful scrutiny. Assessment tools developed under the WFD or other frameworks may provide valuable information, but they should not be assumed to be suitable proxies for habitat condition without demonstrating their ecological relevance to the habitat and restoration objectives under consideration
- **Lack of harmonisation.** Different indices place the good/moderate boundary at different values, and few thresholds are based on pressure-state relationships or ecological tipping points. Structure dominates, while functioning and resilience are rarely assessed.

Next steps

The results obtained and the gaps identified within this work will be used along with the outcomes of questionnaires and the assessment of environmental policies approaches (NRR, MSFD, HD, WFD) to draft chapters on the condition assessment and favourable reference area of the LIFE MAPPER manual (Tasks 2.3 and 2.4), including recommendations for harmonising thresholds and defining reference conditions across Mediterranean subregions.

List of studies screened

MF = macroalgal forests; SG = seagrass beds; SCC = sponge, coral and coralligenous beds; HD = Habitats Directive.

#	Study	Group	Index / indicator	Policy	Reference approach
1	Benedetti-Cecchi et al. 2015	MF	Canopy biomass vs turf cover (tipping point)	–	Experimental controls
2	Rindi et al. 2017	MF	Canopy cover vs turf cover; recovery length	–	Experimental controls
3	Fraschetti et al. 2021	MF + SG	NEAT	MSFD	Adopted from literature
4	De La Fuente et al. 2018	MF	CARLIT	WFD	Adopted from literature
5	Blanfuné et al. 2017	MF	CARLIT	WFD	Adopted from literature
6	Kytinou et al. 2023	MF	ECOfast	MSFD	Expert-based
7	Thibaut et al. 2017	MF	reef-EBQI	MSFD	Expert-based
8	Verdura et al. 2023	MF	Cover, biomass and density classes	–	Expert-based
9	Bermejo et al. 2013	MF	CARLIT	WFD	Least-disturbed sites
10	Ballesteros et al. 2007	MF	CARLIT	WFD	Least-disturbed sites
11	Blanfuné et al. 2016	MF	CARLIT	WFD	Adopted from literature
12	Asnaghi et al. 2009	MF	CARLIT	WFD	Adopted from literature
13	Orlando-Bonaca et al. 2021	MF	EEI-c	WFD	Least-disturbed sites
14	Orfanidis et al. 2011	MF	EEI-c	WFD	Least-disturbed sites
15	Piazzi et al. 2018	MF	ALEX	MSFD	Expert-based (theoretical)

#	Study	Group	Index / indicator	Policy	Reference approach
16	Nikolaou et al. 2023	MF	reef-EBQI (macroalgal compartment)	WFD	Expert-based
17	Guinda et al. 2014	MF	CFR	WFD	Least-disturbed sites
18	Anteur et al. 2024	MF	CFR	WFD	Adopted from literature
19	Bahbah et al. 2020	MF	CARLIT	WFD	Adopted from literature
20	Tursi et al. 2022	SG	Shoot density, LAI, density classes	MSFD	Adopted from literature
21	Gerakaris & Panayotidis 2021	SG	WePOSI	WFD	Best observed values
22	Romero et al. 2007	SG	POMI	WFD	Best observed values
23	Cozza et al. 2019	SG	Conservation Index; molecular markers	–	Best observed values
24	McKellar et al. 2025	SG*	Threshold-setting methods (simulated data)	MSFD	None / simulated
25	Denti et al. 2023	SG	PREI; Conservation Index	WFD	Adopted from literature
26	Moreno et al. 2001	SG	Conservation Index	HD	Best observed values
27	Güreşen et al. 2020	SG	CI, SI, PSI, PI; BiPo; EBQI	WFD	Adopted from literature
28	Scarcelli et al. 2025	SG	PREI	WFD + MSFD	Adopted from literature
29	Orlando-Bonaca et al. 2015	SG	MediSkew	WFD + MSFD	Least-disturbed sites
30	Orfanidis et al. 2010	SG	CymoSkew	WFD	Best observed values
31	Oliva et al. 2012	SG	CYMOX	WFD	Best observed values

#	Study	Group	Index / indicator	Policy	Reference approach
32	García-Marín et al. 2013	SG	ZoNI	WFD	Best observed values
33	Cánovas-Molina et al. 2016	SCC	MAES	MSFD	Best observed values
34	Ferrigno et al. 2017	SCC	CBQI	MSFD	Expert-based
35	Enrichetti et al. 2019	SCC	MACS	MSFD	Expert-based
36	Pierdomenico et al. 2021	SCC	MACS	MSFD	Adopted from literature
37	Deter et al. 2012	SCC	CAI	WFD	Best observed values
38	Astruch et al. 2025	SCC	Cor-EBQI	MSFD	Expert-based
39	Motta et al. 2025	SCC	NAMBER	MSFD	Adopted from literature
40	Enrichetti et al. 2025	SCC	BARCS	MSFD	Expert-based
41	Cecchi et al. 2014	SCC	ESCA	WFD	Least-disturbed sites
42	Rastorgueff et al. 2015	SCC	CavEBQI	MSFD	Expert-based
43	Piazzi et al. 2015	SCC	ESCA	WFD	Adopted from literature
44	Gatti et al. 2015	SCC	COARSE	MSFD	None (current baseline)

The Excel file is available at the following link:
Annex MS2_criteria_threshold_condition.xlsx