



MONITORING OF MACROALGAE USING THE CARLIT METHODOLOGY ALONG THE COASTS OF THE CIRCEO PROMONTORY AND THE ISLANDS OF VENTOTENE AND ZANNONE

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Introduction

Macroalgae are widely recognized as reliable biological indicators of environmental quality due to their high sensitivity to anthropogenic pressures and their rapid response to environmental changes. Under conditions of moderate disturbance, structuring brown macroalgae belonging to the order Fucales, such as *Cystoseira* s.l. (*Cystoseira* sensu lato), tend to decline and are progressively replaced by more tolerant taxa, including Corallinales. Under stronger and more persistent stress conditions, opportunistic taxa such as Ulvales and cyanobacteria typically become dominant [1,7].

Macroalgal monitoring in this study was performed using the CARLIT (CARTography of LIToral) method, originally developed in Spain [2] and applied in Italy since 2005 by ISPRA and several regional environmental protection agencies (ARPA). The method was adapted to the Italian coastal context through modifications to the list of macroalgal communities to be surveyed and to the classification of “Relevant Geomorphological Situations” (RGS). CARLIT consists of a visual census of macroalgal communities occurring along rocky shorelines, within a narrow vertical range immediately above (+20 cm) and below (–50 cm) mean sea level, combined with the assessment of the associated geomorphological features.

The three water bodies investigated in this study (Circeo Promontory, Ventotene Island, and Zannone Island) were selected among the 17 identified in the Lazio Region based on the presence of coastal geomorphological features suitable for the application of the CARLIT method. Approximately 78% of the Lazio coastline consists of low sandy shores [4], which are unsuitable for this type of monitoring. Field surveys were carried out between 2021 and 2025 during spring (April–June), when macroalgal communities reach their peak development.

The analysis of macroalgal assemblages revealed a “high” ecological quality class for all three investigated water bodies, confirming the widespread occurrence of species belonging to the genus *Cystoseira* s.l., which are considered indicators of well-preserved habitats and high ecological quality. Continuous or nearly continuous belts of *Ericaria amentacea* were observed along the coasts of Ventotene and Zannone, whereas along the Circeo Promontory macroalgal communities were generally well structured and exhibited good coverage, although some transects showed partial discontinuities.

Materials and Methods

Circeo, Ventotene, Zannone

Figure 1 shows the geographical framework of the water bodies investigated in this study. Monitoring activities carried out through sector-based and surveys conducted on the islands using continuous sampling, aimed at a preliminary assessment of the investigated areas (20 km surveyed).

Georeferenced transects

As required by the CARLIT protocol [2,3], for each water body, three representative coastal transects of 1 km were selected based on the results of the reconnaissance phase. Each transect was subdivided into 20 sectors of 50 m.

Snorkeling surveys

Sampling was conducted using the *visual census technique* from small boats and through direct in-water observations.

Community identification

Relevant geomorphological features and dominant algal communities were recorded in standardized field sheets according to the categories defined by the CARLIT protocol.

EQR calculation

The CARLIT index is calculated as the weighted mean of vegetation sensitivity values according to coastline length, corresponding to an ecological quality value. By comparing this observed value with the regional reference value for the Mediterranean Sea, the Ecological Quality Ratio (EQR) is obtained. The EQR ranges from 0 to 1 and is divided into five classes corresponding to the ecological status categories defined by the Italian Ministerial Decree 260/2010 [2,3].



Figure 1 – Water bodies monitored using the CARLIT methodology (from ARPA, 2025)

The determination of ecological quality values clearly depends on the presence or absence of indicator species (*Cystoseira* s.l.).

Ventotene Island and Zannone Island - transects characterized by high cliffs were dominated by Dictyotales assemblages (mainly *Dictyota dichotoma*, *Dictyota fascicola*, and *Dictyota mediterranea*). Abundant concretions of *Lithophyllum byssoides* were also observed, although they did not form trottoir structures. *Cystoseira compressa* assemblages characterized transects with metric boulders. Continuous and nearly continuous belts of *Ericaria amentacea* were observed along low-cliff transects, indicating the high ecological quality of the islands.

The ecological status of the water bodies “Ventotene Island” and “Zannone Island” was classified as “high” both when applying continuous sampling during reconnaissance and sector-based sampling during monitoring (**Table 1** and **Figure 3**).

The peculiar coastal morphology of the islands, characterized by low cliffs with slopes typical of high cliffs and by sun-exposed terraces of low cliffs completely covered by *Cystoseira* s.l. populations and located in front of high vertical cliffs, requires expert judgment for proper data interpretation. In the present case, it was concluded that the distribution of *Cystoseira compressa* and *Ericaria amentacea* assemblages is more strongly influenced by the slope of the rocky shore within the infralittoral fringe than by the type of coast (high or low cliff). Coastal slope plays a crucial role in the presence and development of *Cystoseira* s.l. [5], as it regulates solar irradiation, a key factor for the growth of these macroalgae.

Table1 - Classification of coastal transects and water bodies

	EQR	Ecological Status
transect 1 - Circeo	0,69	Good
transect 2 - Circeo	1,20	High
transect 3 - Circeo	0,52	Moderate
Circeo Promontory	0,81	High
transect 1 - Ventotene	0,86	High
transect 2 - Ventotene	1,20	High
transect 3 - Ventotene	0,90	High
Ventotene Island	1,00	High
transect 1 - Zannone	1,14	High
transect 2 - Zannone	1,00	High
transect 3 - Zannone	0,80	High
Zannone Island	1,00	High

Results and Discussion



Figure 3 – Cartographic representation of the ecological status of the monitored transects (ARPA, 2025)

Circeo Promontory - transects characterized by high cliffs were dominated by *Ellisolandia elongata*. *Cystoseira compressa* was present along most of the coastline as sparse stands. *Ericaria amentacea* was recorded as a continuous belt in transect 2. Overall, the water body was classified as having “high” ecological status, with a mean EQR value of 0.81 (**Table 1** and **Figure 3**).

The continuous belt of *Ericaria amentacea* present was the subject of a preliminary study [6], initiated following annual observations along the promontory that had revealed reduced reproductive development of the thalli. The study highlighted variations in the organization of reproductive structures during the reproductive period, with thalli bearing conceptacles not organized into receptacles and occurring in lower numbers than hair crypts. Furthermore, a shift in the reproductive period to July was observed, later than recorded in previous years. The year 2021 was the last in which macroalgal monitoring in the same study area documented the maximum reproductive development of the *Ericaria amentacea* belt.

Conclusions

The analyzed coasts of Lazio exhibit a high ecological status.
The CARLIT method is confirmed as a rapid and effective tool for monitoring macroalgae.

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