A METHODOLOGICAL APPROACH TO ASSESSING THE CONSERVATION STATUS OF COASTAL HABITATS: THE CASE STUDY OF CALABRIA (SOUTHERN ITALY)

Antonio Morabito, Carmelo Maria Musarella, Giuseppe Caruso, Giovanni Spampinato

Abstract: The Mediterranean coasts are threatened by human activities that cause changes andalterations in the coastal ecosystems. This study aims to assess the impact of urbanisation on the conservation status of EEC Directive 43/92 habitats. A total of 73 vegetation relevés were carried out, which allowed us to recognise 13 habitats. The total diversity of plant species per habitat was measured with the Shannon-Wiener Index (H') used to assess naturalness (Na), considering native, alien and disturbance species separately. The analysis showed that the highest values of H' were found in habitats 1430, 2110 and 2240 while lower values were observed in habitats 2270*, 2250*,2210. The results showed that habitats 2270* and 2250* show a lower naturalness value than habitats 1210, 1240, 2110 and 2240, with higher naturalness values and therefore a low disturbance. This methodology can be used by managers to identify the most sensitive coastal dunes and implement a conservation strategy.

Keywords: Diversity; Naturalness; Directive Habitat; alien and disturbing species.

Antonio Morabito, Mediterranea University of Reggio Calabria, Italy, antonio.morabito@unirc.it, 0009-0002-2087-6731
Carmelo Musarella, Mediterranea University of Reggio Calabria, Italy, carmelo.musarella@unirc.it, 0000-0002-0120-190X
Giuseppe Caruso, Agricultural Technical Institute "V. Emanuele II", Italy, giuseppe.caruso@unirc.it, 0009-0006-4370-0375
Giovanni Spampinato, Mediterranea University of Reggio Calabria, Italy, gspampinato@unirc.it, 0000-0002-7700-841X

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Introduction

Coastal ecosystems are particularly vulnerable and highly endangered, as they are considered among the most threatened by urbanization and anthropogenic fragmentation [1, 2,3]. Since the 50s and 60s of the last centuries, coasts of Mediterranean basin, have been deeply anthropized becoming very attractive tourist destinations in the world [4]. This drastically changed the vegetation and ecological diversity formerly characterising these habitats [5, 6, 7, 8, 9, 10, 11, 12].

Coastal exploitation for tourism has promoted the rapid spread of ruderal and synanthropic species in coastal ecosystems, as well as the establishment of invasive alien ones [13, 14, 15]. These changes profoundly affect the plant communities of coastal habitats, sometimes leading to the disappearance of typical species. [16,17]. Invasions of alien species are among the most serious pressures on ecosystems and one of the main threats to biodiversity conservation [18], especially for coastal ecosystems [19]. Many authors have pointed out that the spread of synanthropic and alien species in coastal ecosystems also causes serious disturbances in physical processes, and that the loss of diversity of native psammophilous species reduces the ability of ecosystems to maintain their functioning in an environment more affected by climate change. [2, 3].

Habitats play a fundamental role in conserving biodiversity and ecosystem services, and therefore merit specific protection measures. [20,21]. From this perspective, habitat monitoring is of great importance both for assessing the conservation status of the environment and for identifying priorities and critical issues in the management of the coastal ecosystem [22]. According to Carboni et al. (2009) [20], the vegetation of coastal habitats can be used as a good indicator to assess the biodiversity and conservation status of coastal habitats.

Mediterranean coastal ecosystems host high ecological diversity due to both diversity in species composition and environmental heterogeneity [23, 7]. Today, the designation of protected areas (PA) and the implementation of the Natura 2000 network are central to reversing the loss of biodiversity in Europe. [24]. Several scientific approaches are focused on quantifying human-induced change using indices such as species richness and diversity in order to assess the conservation status of coastal dunes [25,26, 27]. In ecological studies, the Shannon-Wiener diversity index (H') [28], is frequently used in vegetation analysis [20], and in methods applied to the assessment of the conservation status of coastal habitats [29].

The aim of this research, which takes the coastal habitats of Calabria as a case study, is to propose a methodology useful for assessing the conservation status of coastal environments. This methodology is a biodiversity assessment based on the analysis of vegetation and landscape, considering human the impact on coastal habitats. The coastal vegetation of Calabria is quite well known thanks to many studies, mainly performed applying the phytosociological method by various authors [30,31,32,33,34,35]. In particular, this study aims to assess the conservation status of coastal habitats by applying diversity indices to the species composition of the phytocenosis; geographicinformation system (GIS), and analysis of the habitat diversity through the study of vegetation.

Materials and methods

As a case study, we analyse coastal habitats of the Calabria region (Southern Italy) in the central Mediterranean, which has a coastline of about 700 km [36].

Coastal habitats analysis was based on vegetation relevés carried out from 2018 to 2021, applying the phytosociological method of the Zurich-Montpellier school. Seventy-three unpublished relevés with 367 species were carried out (Supplementary Materials Appendix 1). The matrix of phytosociological relevés was analysed by a multivariate analysis for the definition of statistical based cenological assemblages. The abundance-dominance cover values Braun-Blanquet scale were converted to the numerical value scale proposed by Van der Maarel [37]. The software used for the organisation of the raw data and the subsequent statistical analyses were: Microsoft Excel 2010; PAST version 4.13; R 4.1.1 R Core Team 2021.

The cluster analysis of the relevés matrix used the average linkage criterion (UPGMA) and the Chord distance algorithm to identify homogeneous plant assemblage. The interpretation of habitats was performed according to the following literature [38, 39, 40, 41, 42, 43].

Plant species diversity was assessed by combining the relevés for each habitat type and calculating the Shannon-Wiener H′ index for each relevé, then averaging it across the habitat relevés [28].

$$H' = -\sum_{j=1}^{s} pi \ \log pi$$

where pi = coverage of the ith species compared to the entire community; S= number of species.

As highlighted by Grunewald and Schubert [26], Pinna et al.; [44], Caldaresi et al., [45], the Shannon-Wiener index (H') allows the evaluation of the Naturalness (N)of a habitat, but in addition to considering native and alien species, we have also considered disturbance species, so species typical of synanthropic habitats (e.g. uncultivated land, ruderal environments, weedy species, etc-).

$$N = H' \text{ (without alien and disturbing plant species)} / H'$$

The N index assumes values ranging from 0 to 1, where 0 indicates that plant diversity consists entirely of alien and disturbance species, while 1 indicates the absence of the latter in phytocenosis. Alien species were identified in accordance with the Portal to the Flora of Italy [46], while plant communities and disturbance species were verified considering the "Prodromo della vegetation d'Italia" [47] as well as the contributions of other authors [30,9]. In particular, syntaxonomic references of plant communities belonging to the anthropogenic vegetation classes *Stellarietea mediae* Tüxen, Lohmeyer & Preising ex Von Rochow 1951 and *Galio aparines-Urticetea dioicae* Passarge ex Kopecký 1969 were taken for disturbance species according to Biondi & Blasi [45].

Results

The analysis of the relevés carried out on coastal vegetation identified the following habitat types of Annex 1 to European Directive 43/92: 1210 - Annual vegetation of drift lines;); 2110 - Embryonic shifting dunes; 2120 - Shifting dunes along the shoreline with *Ammophila arenaria* ('white dunes'); 2210 - *Crucianellion maritimae* fixed beach dunes, 2230* - Malcolmietalia dune grasslands; 2240 - Brachypodietaliadune grasslands with annuals; 2250* - Coastal dunes with *Juniperus* spp.; 2260 - Cisto-Lavanduletalia dune sclerophyllous scrubs; - 2270* Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*; 1240 - Vegetated sea cliffs of the Mediterranean coasts with endemic Limonium spp.; 1410 - Mediterranean salt meadows (*Juncetalia maritimi*); 1420 - Mediterranean and thermo-Atlantic halophilous scrubs (Sarcocornetiea fruticosi); 1430 - Halo-nitrophilous scrubs *(Pegano-Salsoletea)*.

The plant communities that characterized the coastal habitat types have a distribution that follows the typical succession of other Mediterranean coastal, begins with the annual vegetation on the coastline and continues with the psammophilous herbaceous communities of the embryonic and mobile dunes (habitat 1210; 2110; 2120) up to the shrub or forest communities on the stabilized dunes (2230;2240;2250*;2260 and 2270*).

The biodiversity values of the coastal habitats (Figure 1) show that the Shannon-Wiener index (H^+) species is higher for habitats 1430, 2260, 2110 and 2240. Lower values have been found in habitats 1420, 2250* and 2270*.

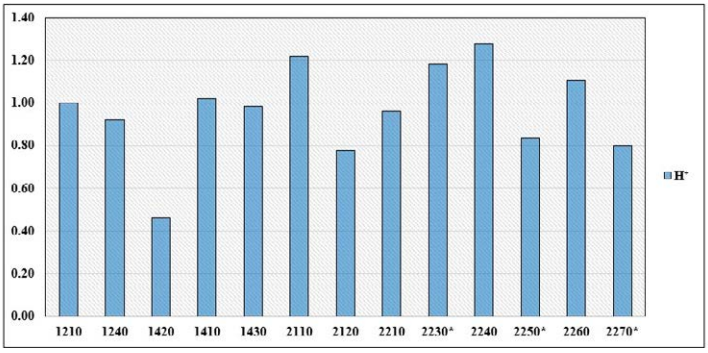

Figure 1 – Biodiversity values Shannon-Wiener index (H') in the coastal habitats.

The highest naturalness values (N), equal to 1, were found in habitats 1240, 1420, 1410, 2230 (Fig. 2), while the lowest values, about 0.8, were observed for habitats 2270*, 2250* and 2210, which have been found to be more susceptible to disturbance because they are home to a high number of synanthropic species as *Galactites tomentosus* Moench*, Reichardia picroides* (L.) Roth) and alien species as *Acacia saligna* (Labill.) H.L. Wendl. *Oxalis pes-caprae* L.

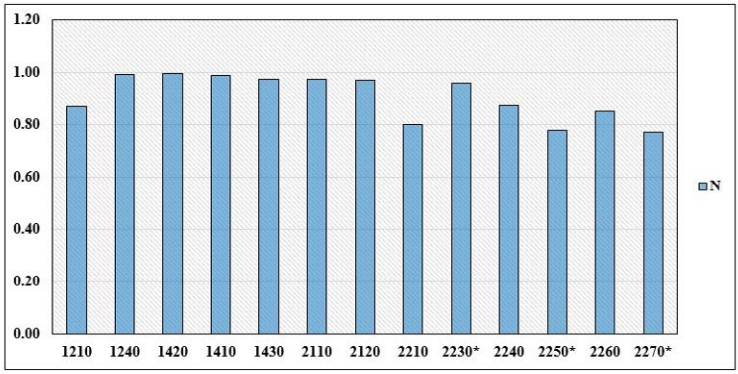

Figure 2 – Values of the naturalness index (N) in the coastal habitats.

Figure 3 shows that in habitats 2270*, 2250*, 2230 2210 the *H' values* of disturbance species (*H' dist*.) are higher than the H^+ values of typical species (H*'* typ.),unlike habitats 1210, 1240, 1410, 1420, and 2260 where the greatest diversity (H^+) isrepresented by typical species.

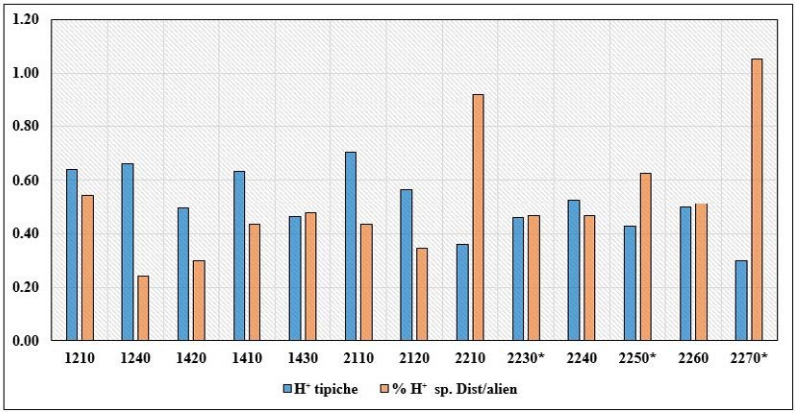

Figure 3 – Percentage values of the H' index of typical species (% H'sp. Typ) and those ofdisturbance and alien species (% H' sp. Dist/Alien) in coastal habitats.

Discussion and conclusions

The analysis of habitat plant communities using naturalness indices based on biodiversity was found to be helpful in assessing the impact of human activity on coastal habitats, conversely to what has been shown in other studies [48]. The low values of naturalness index (Na) are not only due to the presence of alien taxa in the study area, but also to the presence of synanthropic species, which are

indicators of disturbance. The analysis carried out shows that coastal habitats 2270* and 2250 have low naturalness values due to the significant contribution to the biodiversity of alien and disturbing species, highlighting that, in agreement with other studies [49], the seaside tourist exploitation of the coasts promotes the spread of invasive and disturbing species that constitute the most important threat to coastal habitats not only in open habitat closer to the coastline but also and above all in more stabilized ones, such as grey dunes and forests. Among these, we can observe habitat types 2270*, 2250* and 2210, the latter in agreement with other studies [6,50] are considered the most sensitive to anthropogenic disturbance. Habitat 2210 (*Crucianellion maritimae* fixed beach dunes) is considered at risk in all Mediterranean coasts; while habitat 2250* following Acosta et al., [5] also in Calabria is currently limited to the few coastal stretches not exploited for tourists or residential purposes. Habitat 2270* is the one that has the greatest presence of anthropogenic species in agreement with Bonari et al [51] and Sarmati et al., [10] for other Italian territories. Probably one of the main causes for the establishment of these weeds and ruderal communities is trampling consequent to tourist exploitation. Habitat 2250* is also in bad conservation status, in agreement with other studies [12] and shows a marked area reduction due to human activity throughout the Mediterranean biogeographical region. According to Acosta [52], the species richness of coastal dune habitats is maximum in the intermediate dune, while synanthropic species are more frequent in the inland habitat.

The presence and spread of alien species within the wooded dunes tend to create further critical issues for the protection of coastal habitats, modifying their diversity in different ecosystems [53], including *Acacia saligna* used for reforestation, produces a litter that takes a long time to degrade, and this negatively affects soil availability.

Our findings emphasize the need to prioritize monitoring activities in wooded dunes and stable dunes due to the higher presence of alien and disturbance species in these habitats that reduce biodiversity and pose a threat to the conservation of these habitat types.

The use of diversity indicators in vegetation analysis is suitable for identifying the changes caused by invasive and synanthropic species. This approach can also be used to monitor and evaluate the conservation status of habitats of community interest according to EEC Directive 43/92. Overall, the methodological approach used can provide valuable support for implementing a conservation strategy that aligns with the integrated management of coastal ecosystems in the Mediterranean.

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