Research Article

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Environmental quality assessment of the Sicilian coast using a multi-disciplinary approach

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Abstract A multidisciplinary approach for the assessment of the environmental quality of the Sicilian coast is presented. This approach can be adopted for any Mediterranean coastline. The territory was divided into elementary areas and for each of them we reported the most important taxa, belonging to fauna and vascular, bryophytic and algal flora, from a biogeographic point of view in order to evaluate punctual and general levels of biodiversity conservation. The comparative analysis showed that the main circumsicilian islands and the carbonate promontories of the Tyrrhenian coast present the highest degree of biodiversity. The coastal lagoons located in the south-eastern Sicily, even though characterized by a lower number of taxa, are also interesting areas deserving top priority in conservation plans.

Key words*:* Endemic flora and fauna, habitat monitoring, Mediterranean islands, multivariate analysis

Introduction

Humankind has affected the Mediterranean basin area in many ways. Although it is one of the places where civilizations have developed, in the past few centuries the scale of these impacts has catastrophically grown up. This has led to the disappearance of habitats and species at a rate that can only be estimated for the last 200 years. Hence monitoring programs are needed in order to know the extent of the phenomenon and the areas where the conservation efforts have to be concentrated. Since resources for conservation purposes are limited, analyses are required to prioritize taxa and areas. Coastal habitats play and important role in biodiversity conservation, indeed nearly 13% of the Italian endemics occur on sandy or rocky coasts (Domina et al. 2012). The assessment procedures for extinction risk of taxa are well-defined and universally accepted (IUCN 2012; Rossi et al. 2016) whereas these procedures have not still defined for the areas (Fenu et al. 2017). Advances in remote sensing and GIS software greatly improved large-scale habitat measurements. However, the degree of resolution of this technique is still inadequate for many purposes, such as the detailed monitoring of many habitats that occur along the coast (e.g. temporary Mediterranean pools or ephemeral therophytic grasslands). Lists and distribution maps of taxa are probably the most commonly used surrogates for biodiversity at both local and broader scales.

For the Sicilian coasts a study, dating back about 30 years ago and based on a multidisciplinary approach of flora, vegetation and fauna, exists (Raimondo et al. 1990). In order to verify the validity of this approach, this methodology was taken back and updated with the data collected during these 30 years and with the help of advanced information technologies.

Material and methods

The Sicilian coast and surrounding islands were divided in 130 elementary areas according to Raimondo et al. (1990). The areas numbered from 1 to 115 are located along the Sicilian coast and correspond to the projection on the ground of squares of 10 × 10 km. The areas from 116 to 130 correspond to the 15 main smaller islands surrounding Sicily (Fig. 1). These areas were classified, for analysis purposes, in 6 categories: a) *islands*, for areas corresponding to the little islands; b) *beaches*, for areas with coastline dominated (80% at least) by sandy or shingle beaches; c) *lagoons* for areas with a lagoon; d) *cliffs*, for areas with coastline dominated by cliffs; e) *artificial* for areas with clustered cities or industrial settlements; f) *inlands*, for areas almost completely devoid of coastline. For each area the most peculiar taxa, belonging to fauna and the vascular, bryophytic and algal flora, from a biogeographic point of view were recorded. Fungi have not been included in this study because contributions concerning their distribution along the Sicilian coast are still too fragmented (Zambonelli et al. 2014; Compagno et al. 2016). We included taxa endemic to the Italian territory and those occurring also outside this territory but present in Sicily at the limit of their distribution or threatened and in a very small number of individuals. The distribution of the phytobentos was assessed on a bibliographic basis considering records published from 1950 to 2009 (Giaccone et al. 1985; Furnari et al. 2003; Furnari et al. 2010; Guiry & Guiry 2017). In particular, Mediterranean endemic taxa recorded exclusively in the considered area together with rare and threatened taxa, not necessarily Mediterranean taxa, were considered. As concerns bryophytes, nomenclature follows Söderström et al. (2015) and Ros et al. (2013). Data were obtained from literature as well as from the database of Sicilian bryophytes managed at the Bryological laboratory of the Department STEBICEF, of the University of Palermo. Higher plants distribution is taken from Giardina et al. (2007) and updated with latest field observations and corrections. Nomenclature is according Euro+Med Plantbase / PESI (de Jong et al. 2015; http://www.emplantbase.org/ - last accessed last access 04/2017) where not updated by more recent specific monographies.

Distributive faunistic data come from direct field observation and from the most updated literature on the investigated groups. Nomenclature follows Fauna Europaea (version 2.6, http://www.fauna-eu.org– last access 04/2017) where not updated by more recent specific monographies.

The areas have been divided into 6 classes on the basis of the number of considered taxa recorded as follows: 1) more than 41 taxa; 2) between 31 and 40; 3) between 19 and 30; 4) between 11 and 18; 5) between 6 and 10; 6) 5 or less taxa (Fig. 2).

A Principal Coordinates Analisys (PCoA) was performed on the areas using the binary data (presence /absence of taxa) collected. The software used is PAST 3.15 (Hammer et al. 2001; Hammer 2016).

Results

According to the selected eco-geographical categories, the 130 areas were classified as follows: 65 belong to coastline dominated by beaches, 22 to coastline dominated by cliffs, 18 almost completely devoid of coastline, 15 correspond to an island, 6 include a lagoon, and 4 are dominated by clustered cities or industrial settlements (Table 1).

In total, 644 specific and subspecific taxa, belonging to Chromista (33), Plantae (296) and Animalia (315) have been included in this study (Table 2).

The areas with a greater level of environmental quality are patently the richest in taxa of high biogeographic value. According to the categories defined above there are 15 areas with high biodiversity, belonging to class 1, and, descending, 19 belonging to class 2, 22 to class 3, 33 to class 4, 15 to class 5 and 26 to class 6. This distribution differs from a normal one for the high number of areas poor or lacking in taxa of high biogeographic interest. The richest areas in taxa are the islands surrounding Sicily and those including Monte Pellegrino, Monte Gallo, the Zingaro, Monte Cofano, the salterns of Trapani, and the area of Selinunte.

Table 1. Ecogeographical and taxa richness categories of the studied areas.

Category	Number	%
a) islands	15	11.54
b) beaches	65	50.00
c) lagoons	6	4.62
d) cliffs	22	16.92
e) artificial	4	3.08
f) inlands	18	13.85

Category	Number	%
1) > 41 taxa	15	11.54
2) 31-40 taxa	19	14.62
3) 19-30 taxa	22	16.92
4) 11-18 taxa	33	25.38
5) 6-10 taxa	15	11.54
6) < 5 taxa	26	20.00

Table 2. Summary of the considered taxa.

Kingdom	Class	Order	Taxa
Chromista	Phaeophyceae		33
Plantae	Florideophyceae		22
	Polytrichopsida		2
	Bryopsida		20
	Marchantiopsida		11
	Jungermanniopsida		13
	Polypodiopsida		2
	Gnetopsida		1
	Magnoliopsida		182
	Liliopsida		43
			296
Animalia	Aracnidia	Araneae	4
		Oribatida	1
		Pseudoscorpiones	2
			7
	Entognatha	Collembola	5
	Insecta	Blattodea	5
		Coleoptera	136
		Dermaptera	1
		Hemiptera	18
		Hymenoptera	3
		Lepidoptera	1
		Neuroptera	2
		Odonata	1
		Orthoptera	16
		Phasmida	1
			184
	Malacostraca		15
	Bivalvia		1
	Gastropoda		47
	Reptilia		20
	Aves		30
	Mammalia		6
	TOT		315
TOT			644

The poorest areas are those located in NE Tyrrhenian coast and those almost completely devoid of coastline (Fig. 2). The occurrence of taxa of high biogeographic interest follows the same pattern highlighted in Raimondo & Venturella (1991).

The PCoA (Fig. 3) discriminates the areas corresponding to the smaller islands from those

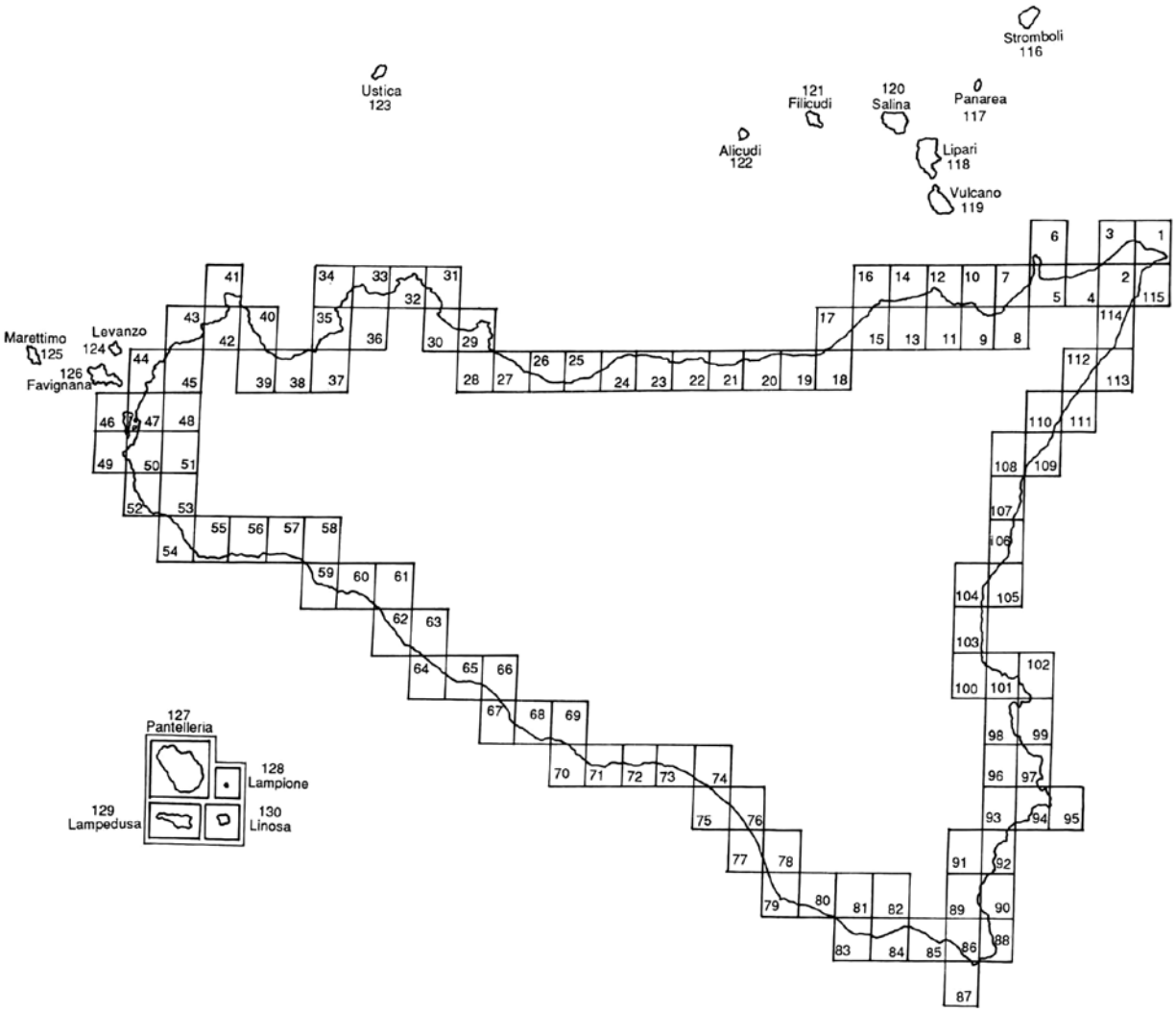

Fig. 1. Sicilian coast and the circumsicilian islands divided in the 130 elementary study areas (from Raimondo et al. 1990).

lying along the coast of the main island. A certain interval occurs for the areas that host lagoons and for those occupied by large artificial surfaces. Some areas belonging to cliffs (richer in taxa) can be distinguished from the core that includes internal areas, beaches and cliffs poorer in taxa.

Discussion

The main difference with the previous evaluation (Raimondo et al. 1990, Raimondo & Venturella 1991) is the highest number of considered taxa, including the algae and a larger sampling of animal species. However, the results obtained overlap with those obtained in the first survey. This confirms the validity of the approach based also on a lower number of taxa.

Thus, the greater richness is concentrated in some areas of the north-western, the south-eastern Sicily and circumsicilian islands (Table 3). Moreover, the incidence of endemic or phytogeographic significance in these districts is known for the presence of priority habitats. Few areas host lagoons and even though they are not the richest in species number, play an important role for migratory flows and sedentary flora and fauna.

It should be stressed that part of the richness registered in islands and sea cliffs is due to a deeper knowledge that we have of these place in comparison with low shores.

Since coastal systems are complex, an integrated approach is necessary. This involves the use of many proxies that have to be correlated and interrelated. The extra value of using an integrated approach can only be reached by linking the different components of the system once their relationships are understood. The approach adopted here is simple in its wording but requires a good amount of base data. Data on consistency and population dynamics of the considered taxa will allow to carry out further analysis (Fenu et al. 2017).

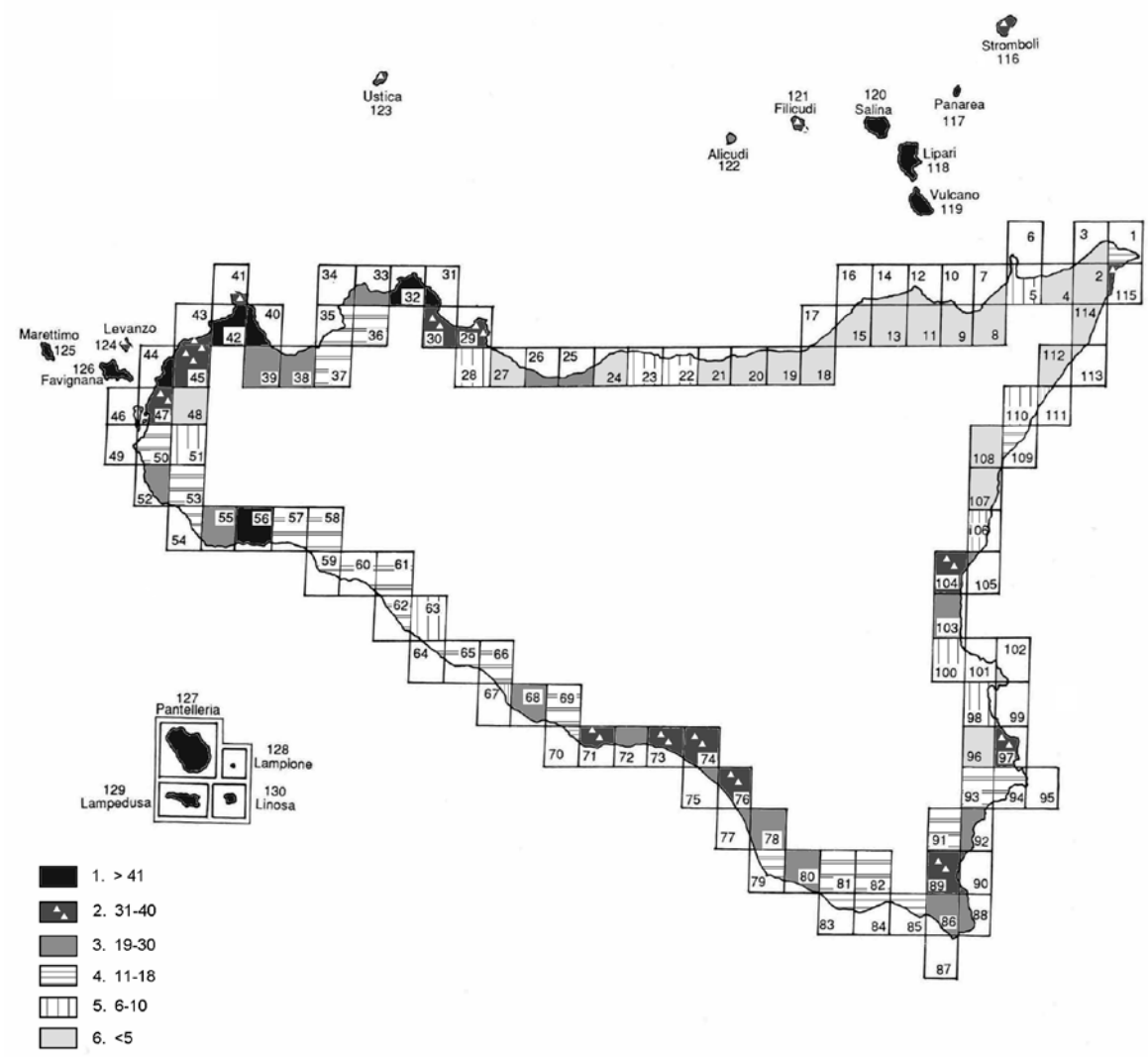

Fig. 2. Incidence of the considered taxa along the Sicilian coast.

The obtained results confirm that the Sicilian coast has been greatly altered by man with few exceptions in some promontories and shores. Despite the fact that few areas have been heavily transformed by humans (coastal cities and industries) all the areas have evident signs of direct or indirect tampering. Even in the uninhabited, islets of Isola delle Femmine and Lampione, the former at 800 m from the coast, the latter at 18 km from Lampedusa, the habitats are heavily shaken by the real gull colonies nesting. Fortified by human dumps on the mainland they are reproducing at very high rates and nitrifying the islands with their excrements. This results in the disappearance of threatened endemic species in favour of widely distributed nitrophilous ones. This highlights the heavy influence of human activities even in areas where these are not directly exercised.

Beaches resulted less rich in taxa in comparison with cliffs, this is due to the intrinsic nature of these territories which, by the way, are not conservative (Giovino et al. 2015) but also is due to the fact that they have been more subject to human changes for touristic, agricultural, residential and industrial purposes (Venturella et al. 2015). As a result of land transformations at the beginning of the 20th century, lagoon areas have become less and less numerous, remaining shelter habitats for several plant and animal species. Hence, they are habitat of great importance and conservation priority. It should also be stressed the importance of preserving the coastal environments of the mainland because the populations living there show greater genetic and morphological variability than those of the islands (Giovino et al. 2015; Astuti et al. 2017; Domina et al. 2017a, 2017b).

The Mediterranean islands have always been seen as a source of great biodiversity and are therefore widely studied and monitored (Celesti-Grapow et al. 2016). The areas with promontories and lagoons are genuine reservoirs of biodiversity and as such should be safeguarded. For example,

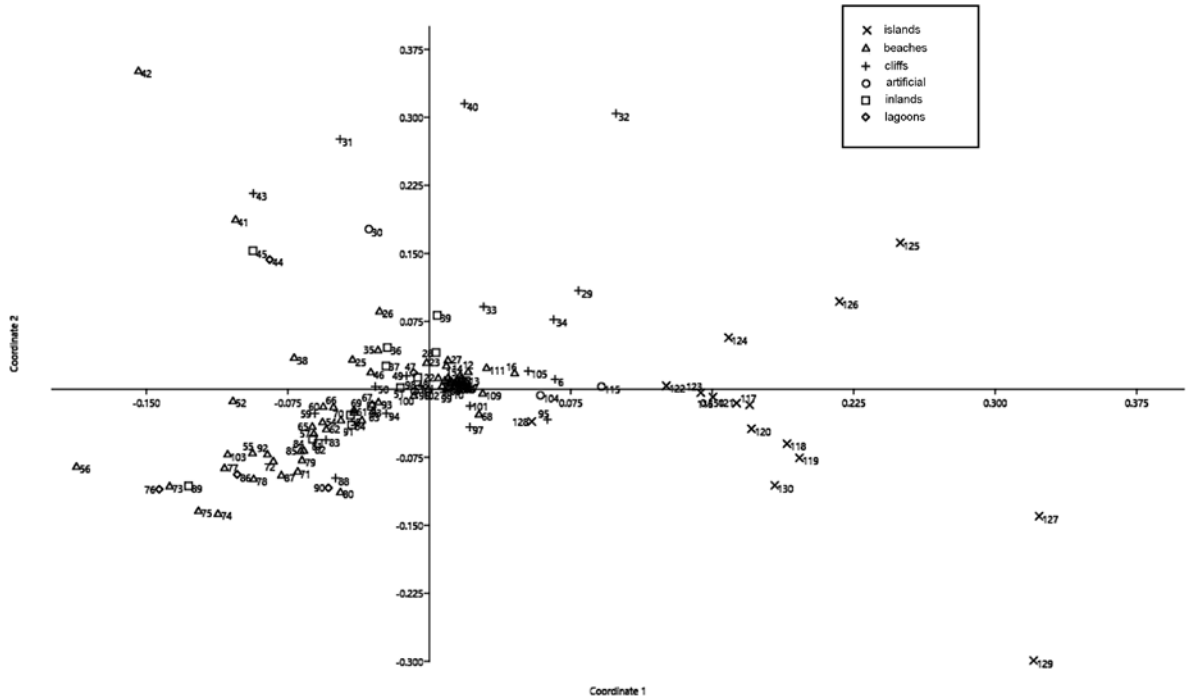

Fig. 3. Principal Coordinates Analysis of the 130 areas based on the 644 distributive data using Gower Similarity index. PC1. Eigenvalue 0.097194, % variance 22.73; PC2: Eigenvalue 0.048178, % variance 11.27.

Table 3. List of ecogeographical and taxa richness categories of the study areas.

Area	ecogeographical category	Number of taxa	Taxa richness
1	beaches	12	4
2	inlands	0	6
3	beaches	4	6
4	beaches	2	6
5	beaches	9	5
6	cliffs	15	4
7	beaches	0	6
8	beaches	0	6
9	beaches	5	6
10	lagoons	6	5
11	inlands	1	6
12	beaches	4	6
13	inlands	0	6
14	beaches	2	6
15	beaches	5	6
16	beaches	9	5
17	beaches	3	6
18	beaches	2	6
19	beaches	1	6
20	beaches	2	6
21	beaches	2	6
22	beaches	7	5
23	beaches	10	5
24	beaches	5	6
25	beaches	23	3
26	beaches	22	3

Area	ecogeographical category	Number of taxa	Taxa richness
27	beaches	5	6
28	inlands	7	5
29	cliffs	34	2
30	artificial	33	2
31	cliffs	49	1
32	cliffs	68	1
33	cliffs	30	3
34	cliffs	23	3
35	beaches	15	4
36	inlands	12	4
37	inlands	12	4
38	beaches	23	3
39	inlands	22	3
40	cliffs	61	1
41	beaches	38	2
42	beaches	57	1
43	cliffs	39	2
44	lagoons	56	1
45	inlands	32	2
46	beaches	17	4
47	lagoons	34	2
48	inlands	4	6
49	cliffs	6	5
50	cliffs	15	4
51	inlands	7	5
52	beaches	28	3

Table 3. Continued.

Area	ecogeographical category	Number of taxa	Taxa richness
53	inlands	11	4
54	beaches	15	4
55	beaches	27	3
56	beaches	54	1
57	beaches	15	4
58	inlands	11	4
59	cliffs	18	4
60	beaches	15	4
61	beaches	11	4
62	beaches	14	4
63	beaches	10	5
64	beaches	12	4
65	beaches	19	4
66	beaches	14	4
67	beaches	9	5
68	beaches	23	3
69	beaches	12	4
70	beaches	12	4
71	beaches	32	2
72	beaches	21	3
73	beaches	32	2
74	beaches	31	2
75	beaches	30	3
76	lagoons	32	2
77	beaches	25	3
78	beaches	24	3
79	beaches	19	4
80	beaches	29	3
81	inlands	16	4
82	inlands	15	4
83	cliffs	14	4
84	beaches	17	4
85	beaches	17	4
86	lagoons	28	3
87	beaches	28	3
88	cliffs	30	3
89	inlands	32	2
90	lagoons	32	2
91	inlands	12	4
92	beaches	29	3
93	beaches	11	4
94	cliffs	12	4
95	cliffs	30	3
96	inlands	4	6
97	cliffs	32	2
98	artificial	6	5
99	cliffs	11	4
100	beaches	6	5
101	cliffs	12	4
102	cliffs	3	6
103	beaches	30	3
104	artificial	35	2
105	cliffs	24	3
106	cliffs	6	5
107	cliffs	1	6
108	inlands	2	6
109	beaches	11	4
110	beaches	7	5
111	beaches	10	5
112	beaches	4	6
113	beaches	2	6
114	beaches	4	6
115	artificial	35	2
116	islands	40	2
117	islands	42	1
118	islands	50	1
119	islands	53	1
120	islands	51	1
121	islands	37	2
122	islands	29	3
123	islands	34	2
124	islands	38	2
125	islands	80	1
126	islands	60	1
127	islands	94	1
128	islands	19	4
129	islands	104	1
130	islands	55	1

the areas close to large human settlements as Mount Pellegrino and mount Gallo near the city of Palermo, the salterns near the city of Trapani and the wet areas close to the industrial plant of Gela. These are threatened not only by the direct expansion of these settlements but also by the reflections of the activities carried out in these areas. Biodiversity loss is a critical issue in coastal environments. The identification of local biodiversity ‘‘hotspots’’ (particularly species rich habitats) becomes indispensable in coastal management in order to identify conservation priorities. It is necessary not only to conserve biologically rich hotspots but also species poor-habitats containing unique or endangered elements.

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