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Coastal dynamics vs beach users attitudes and perceptions to enhance environmental conservation and management effectiveness

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ABSTRACT

This work carries out a landscape analysis for the last 60 years to compare the degree of preservation of two areas on the same Italian coastline characterized by different environmental protection levels: a National designated protected areas and a highly tourist coastal destination. The conversion of natural land-covers into human land uses were detected for protected and unprotected coastal stretches highlighting that the only establishment of a protected area is not enough to stem undesirable land-use outcomes. A survey analysis was also conducted to assess attitudes of beach users and to evaluate their perception of natural habitats, beach and coastal water quality, and coastal dynamic over time. The results of 2071 questionnaires showed that there is similarity between subjective and objective data. However, several beach users perceived a bad quality of coastal water in the legally unprotected coastal area. The implications from a planning and management perspective are discussed.

1. Introduction

Coastal areas are among the most productive ecosystems worldwide and are crucial for humans because they deliver a flow of valuable ecosystem services that include marketable goods and products, such as fisheries and recreational opportunities, and non-marketed services, like natural hazard regulation (e.g. erosion control), nutrient cycling, and wildlife habitats (e.g. Barbier et al., 2011; Ghermandi and Nunes, 2013; Liquete et al., 2013; Potts et al., 2014; Wilson et al., 2002). However, coastal areas are exposed to changing environmental pressures because of their spatial location and attributes (Turner and Schaafsma, 2015). The increased human pressures due to tourism, pollution, eutrophication, urbanization, land reclamation, and over fishing altered the most ecologically important and valuable coastal features, processes and functions to obtain additional social and economic benefits (e.g. Batista et al., 2014; Ducrotoy and Yanagi, 2008; Lejeusne et al., 2010; Lotze et al., 2006; van der Meulen and Salman, 1996), particularly in the case of sandy beaches (Acosta et al., 2006; Brown and McLachlan, 2002; Defeo et al., 2009; McLachlan et al., 2013; Schlacher et al., 2007). As a consequence, beaches and coastal dunes disappeared in many locations, and several ecosystem services are degraded or lost, such as the provision of food and nesting habitat to migratory birds, storm protection, nutrient recycling, coastal protection against erosion, decreased scenery of beaches, as well as the recreational opportunities (EC, 2014; MEA, 2005).

Sustainable management of coastal areas is one of the main challenges humanity is facing today because it must ensure the maintenance of the natural structure and functioning of ecosystems in order to provide ecosystem services (Turner and Schaafsma, 2015) for current and future generations (Ducrotoy and Yanagi, 2008). However, complementary human assets, such as skills, time, money and energy are then required to extract societal goods and other benefits from such services (Atkins et al., 2014).

The increasing concern on these issues has encouraged scientific and policy arenas to reconcile the human needs in coastal region development by implementing, actions for the environmentally sustainable exploitation of the coastal zones through informed decisions (Borja et al., 2017).

Understanding the key processes that structure ecosystems is crucial to design and implement effective long-term management plans of natural resources (Holling and Meffe, 1996). Several studies (e.g. Aretano et al., 2013; Ellis et al., 2011; Malavasi et al., 2013; Potter, 2013; Shalaby and Tateishi, 2007) demonstrated the effectiveness of multi-temporal landscape analysis to identify the main processes

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driving changes in the ecosystem and their effects over time. The assessment of land use and land cover change trends over time is a significant tool for decision-making in conservation and environmental assessment even though it is not always possible to establish clear cause-effect relationships. For instance, it can be used to identify particularly critical or vulnerable locations, deserving special consideration from stakeholders and decision makers, in order to improve the effectiveness of conservation policies by establishing protection priorities and specific management strategies (e.g. Falcucci et al., 2007; Martínez-Fernández et al., 2015; Petrosillo et al., 2009; Ruiz-Benito et al., 2010; Sánchez-Cuervo et al., 2012).

Coastal areas are complex socio-ecological systems characterized by interactions between ecological structure and functioning, physico-chemical processes and where multiple socio-economic interests coexist (Elliott et al., 2017; Marin et al., 2009). In this perspective the management of coastal resources should reflect the relationships among all ecosystem components, including humans, as well as the resulting socioeconomic impacts (Yáñez-Arancibia et al., 2013). In addition, to reach a consensus for sustainable management of coastal systems and their resources, it is necessary the support of all sectors of administration (EC, 2007; Newton and Elliott, 2016) and the engagement of their different stakeholders, such as local communities, landowners, visitors, decision makers, as key actors in coastal planning and management (e.g. Bell et al., 2013; Borja et al., 2017; Brown et al., 2016; Petrosillo et al., 2013). This issue is particularly important for beaches, since they represent a major attraction and a primary resource of local economy in many coastal areas worldwide, attracting more tourists and recreational users than any other coastal ecosystem (Hall, 2001; Maguire et al., 2011; Marin et al., 2009).

Many coastal zones, including both landscapes and seascapes, are designated as natural protected areas to protect natural capital and/or relevant cultural heritage for a broad range of human activities. However, there are different levels of protection/management that may range from highly protected areas where no extraction, deposition or other damaging activities are allowed, to areas where only minimal restrictions are needed to protect the features (Potts et al., 2014).

In order to give a contribution to face the above challenge, this paper aims to explore the landscape dynamic given by 60 years (1954–2013) and the attitude of users both within protected areas (national park) and outside, across the wider landscape. This analysis may be used to assess whether the levels of protection proposed over time have been effective in ensuring the long-term conservation and management of natural resource inside the protected coastal area, such as avoiding or mitigating undesirable landscape changes caused by increasing human demand inside and outside the protected area. In addition another aim of the research was to investigate the beach users attitudes and perceptions of the issues that can affect the environmental quality of beaches in the two coastal areas (protected and non-protected). In this perspective, a survey analysis was specifically designed to determine beach users perceptions about coastal features, quality of coastal water and the coastal evolution over time. The accuracy of beach users perceptions has been compared with the objective data resulting from a landscape change analysis and official statistics on the quality of coastal waters. The possible implications of the results from a planning and management perspective are discussed.

2. Materials and methods

2.1. Study area

The study area (Fig. 1) is located in a wide coastal plain covering a surface of about 12,000 ha and stretching for about 44 km along the coast of the municipalities of Latina, Sabaudia, San Felice Circeo and Terracina in the province of Latina (Latium, Italy). In this area it is possible to identify two zones separated by the promontory of Circeo: 1) the coastal area of Latina and Sabaudia that includes the Circeo National Park (about 25 km) that we will denote as “protected coastal area”, and 2) the coastal area of San Felice Circeo and Terracina (about 10 km) that we will denote as “unprotected coastal area”.

The Circeo National Park has been established with the Italian Law n. 285/1934 with the objective to preserve, protect and enhance the natural heritage and to promote the development of tourism and eco-compatible businesses. Currently, the Park extends for an area of 8,9 ha encompassing five main ecosystems: the plain forest, four coastal lagoons (Sabaudia, Caprolace, Monaci and Fogliano), separated from the sea by coastal dunes, the promontory of Circeo, with a maximum elevation of 541 m and the island of Zannone. The protected coastal area is characterized by an extensive dune system with a raised ecological value due to the presence of priority and community habitats identified under the EU Habitats Directive 92/43/CEE as Coastal dunes with *Juniperus* spp., *Malcolmietalia* dune grasslands and *Brachypodietalia* dune grasslands.

On the other hand, the sandy coastal area in San Felice Circeo and Terracina, is urbanized and characterized by private and public beaches, holiday houses and tourism infrastructures. The resulting “waterfront” is, thus, characterized by a low degree of naturalness and a high density of urban and logistic facilities related to tourist activities.

2.2. Land use and land cover change analysis

Three vector land cover maps were produced for the years 1954, 1988, and 2013 to investigate the coastal dynamics during the period from 1954 to 2013. These maps were obtained from the interpretation and digitization, in a GIS environment (ArcGIS 10.1 ©ESRI), of aerial ortho-photos taken during the summer at about 1 m resolution.

The choice of an appropriate land cover classification system represents a crucial step in the evaluation of landscape management (Wilson et al., 2002), since it contributes to the knowledge of the phenomena in progress. The land cover classification system used in this research is based on the European CORINE (Coordination of Information of the Environment) Land Cover project that uses a hierarchical nomenclature in three levels, which is homogeneous across Europe (EEA, 2007).

The third level of detail for natural and semi-natural areas was extended in this work in order to distinguish coastal features such as beaches, natural dunes and dunes that were modified by human activities, here called “human-modified dunes” (Fig. 2). As a result, eight land cover types were identified and mapped (Table 1) to describe both spatial and temporal coastal dynamics and to assess changes in natural capital. The topological consistency of polygonal coverage in the map was verified and validated through field surveys.

Based on the three land cover maps, for 1954, 1988, and 2013, a change detection (CD) analysis was carried out. CD identifies a collection of methods of analysis that evaluates and quantifies changes in patterns within the landscape at the time T_1 compared to the time T_2 ($T_1 + \tau$) (Singh, 1988). For this reason the CD analysis represents an optimal tool to identify the locations of land use changes and also the direction and magnitude of these changes. The overlay of land cover maps has been performed by using the topological operation of “intersection”, which allows creating a new digital land cover map derived from the two maps at the time T_1 and T_2 where the new polygon generated retain the attributes of the original ones. In this way a transition matrix was obtained showing the changes in the landscape mosaic by contrasting the surface of land cover types of the map at time T_1 (rows) and those of the map at time T_2 (columns). At the time T_1, landscape features (land-covers) have a certain distribution in the landscape considered. After a period of time (T_2), each of them can remain intact or partly (or all) converted into another feature (land-cover). The totals per row and per column indicate the surface of each land cover type at the time T_1 and at the time T_2 respectively. The main diagonal line refers to the surface of land cover types remaining unchanged during the time window considered (Supplementary Fig. 1).

Fig. 1. Study area. Photos of the beaches in the municipality of (a) Sabaudia (coastal protected area) and (b) San Felice Circeo (coastal unprotected area).

2.3. Coastal water data

The quality of sea water is an important factor in determining the attractiveness of beaches (EC, 2011).

The assessment of the indicator "surface water status" follows the requirements of the Legislative Decree 152/06, the main environmental legislation in Italy for the implementation of the Water Framework Directive 2000/60/EC (Italian legislation - Ministerial Decree 260/10). The legislation requires defining at least every 3 years the quality of marine coastal water bodies, evaluating their ecological and chemical status with a standard methodology. In particular, the chemical status is evaluated considering priority chemical pollutants, while the ecological status is evaluated combining biological quality elements, physical and chemical parameters and non-priority chemical pollutants. These data for the period 2011–2013 have been published by the Regional Environmental Protection Agency of Latium (ARPA Lazio, 2015).

The microbiological water quality has been also monitored during the bathing season for two faecal bacteria, *Escherichia coli* and intestinal enterococci, which may indicate the presence of pollution, usually originating in sewage or livestock waste. The results of the monitoring are used to assess, according to the Bathing Water Directive (2006/7/EC), the quality of the bathing waters in four quality classes (excellent, good, sufficient, poor), and to provide information to the public on the quality of the bathing waters. Data concerning the state of bathing

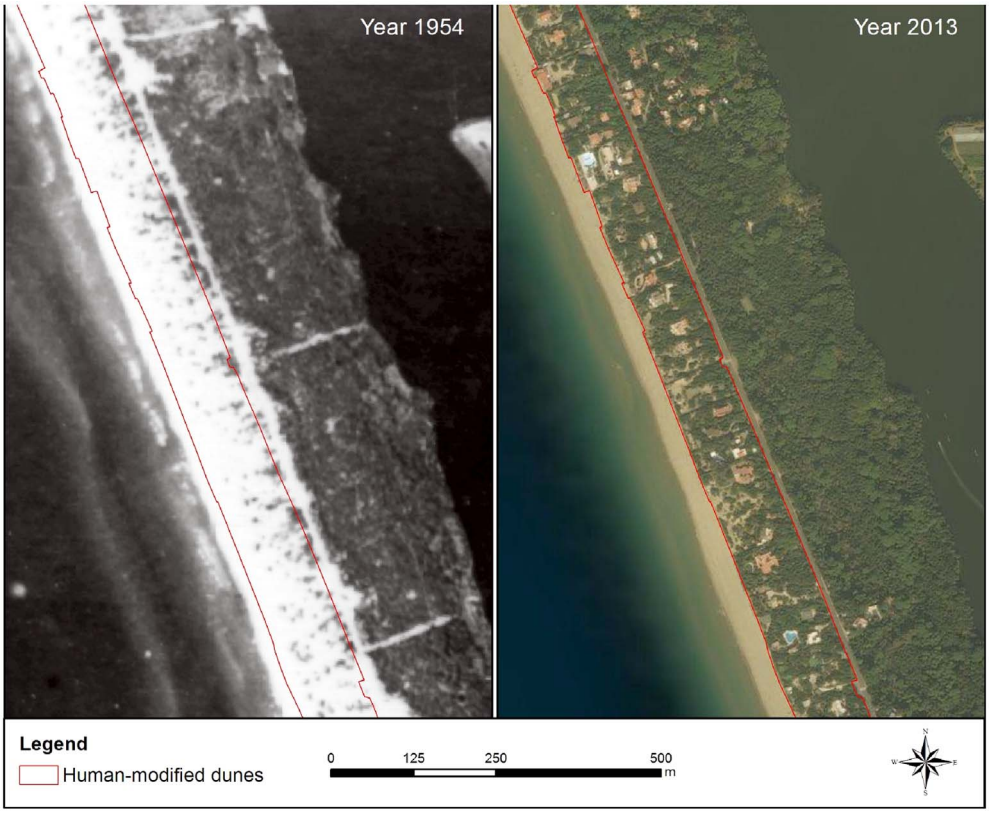


Fig. 2. Photo of the human modified dune from 1954 to 2013.

waters have been collected for the years 2012 and 2013 from the Water Information System for Europe (WISE) (EEA, 2016).

2.4. Survey analysis

The need for considering beach user preferences, opinions, concerns, demand and for promoting their active participation in the protection and the sustainable development of the coast is acknowledged by several authors (e.g. Ferreira et al., 2012; Nordstrom and Mitteager, 2001; Roca and Villares, 2008; Williams and Micallef, 2011). In this respect, and with aim to encourage beach user compliance, during the months of August and September in the years 2012 and 2013, along the beach of the municipalities of Sabaudia and San Felice Circeo, a questionnaire has been delivered in public and private beaches (lidos and equipped beaches) to investigate the attitudes and perceptions of users of coastal areas concerning the environmental features, how they have changed over time, and the quality of coastal waters. The distribution of the questionnaire was carried out by the Circeo Park team and by private and equipped beaches managers because they were interested to take information on the habits and perceptions of the users of the coast.

It is a semi-structured questionnaire that includes an open-ended question and multiple closed questions where the possible answers have been selected to facilitate its compilation and the interpretation of the results. Before the survey, ten questionnaires were distributed to people to verify whether the adequacy and comprehension of the questions. Consequently, the final version of the questionnaire was structured in one general and two specific sections, and one final question. Each interview lasted 5–10 min (Table 2).

As highlighted in Table 2, the general section of the questionnaire aims at characterizing the sample. The first specific section is organized in five questions to give information on attitudes of users such as how respondents enjoy coastal areas, namely which type of beach, when, how often, and why they choose to enjoy a specific coastal ecosystem. The second specific section is structured in eight questions to provide insight into what people perceive by observing beaches and coastal waters and whether people perceive an improvement or worsening of coastal ecosystems over time. Finally, the last question allowed the respondents to provide some recommendations for improving the quality of coastal ecosystems and the services offered.

Even though the two coastlines are both characterized by approximately the same number of public and private beaches, along the

Table 1
Land cover classes observed and mapped in the study area according to the CORINE Land Cover (CLC) classification.

CLC Level 1	CLC Level 2	CLC Level 3	Land cover class mapped in the study area
1. Artificial surfaces			Urban areas
	1.2 Industrial, commercial and transport units	1.2.1 Industrial or commercial units	Breakwater barriers
2. Agricultural areas			Agricultural areas
3. Forest and semi-natural areas	3.1 Forests		Natural areas with vegetation
	3.2 Scrub and/or herbaceous vegetation associations		
3. Forest and semi-natural areas	3.3 Open spaces with little or no vegetation	3.3.1 Beaches, dunes, sands	Beaches
			Natural dunes
			Human-modified dunes
5. Water bodies	5.2 Marine waters	5.2.1 Coastal lagoons	Coastal lagoons

Table 2
Questions asked during the survey analysis.

Section	Question
General	Age
	Type of user
	Place of residence
First specific section (attitudes of users)	When do you enjoy this coastal area?
	How often do you enjoy this coastal area?
	Where do you usually prefer to go?
	Why do you choose this beach?
	Do you use the walkways to reach the beach?
Second specific section (perception of users)	Do you think sandy dunes are present along this beach?
	In your opinion, is this beach wide or narrow?
	Usually, do you see marine litter along this beach?
	In your opinion, is this beach clean?
	In your opinion, how is the coastal water quality of this beach?
	In your opinion, how is the overall quality of this beach?
	Do you know how this coastal area was in the past?
	How this coastal area has changed over time?
Last question	Do you think that this coastline can be improved? If yes, how?

18 km-long Sabaudia (protected) coastal area private beaches are spaced from each other by large public beaches. Differently happens along the San Felice Circeo area, where all types of beaches are smaller and concentrated along 5 km of sandy coastline. To gather data more representative of the entire coastal shoreline, the questionnaires were distributed along 12 stretches of public beach and 19 private beaches belonging the two municipalities, respectively 13 sampling points on the waterfront of San Felice Circeo and 18 on Sabaudia (Fig. 3). The sampling density were characterized by a mean distance between sampling points of 350 m in San Felice Circeo and 850 m in Sabaudia.

For each answer descriptive statistics were computed on the sub-samples representative of the unprotected and protected coastal area (respectively the municipality of San Felice Circeo and Sabaudia. A Chi-square Test was applied to test whether the type of the coastal trait (protected or unprotected), the type of the beach (public or private), the provenience of the user (local people, tourists) can result in a different beach users perception of the coastal features and sea-water quality.

Rule mining techniques were used to verify possible associations of interest among the given answers. Association rules are a suitable form of data mining introduced by Agrawal et al. (1993) to extract correlations, frequent patterns, associations or casual structures among sets of items within a database, and for this reason, they are usefully utilized to obtain an idea of what concept structures exist in the available data. A proper statistic toolbox (ARMADA, Association Rule Miner and Deduction Analysis by James Malone, 2003) has been used to extract one simple rule from the data set: what is the most probable co-occurrence of answers among people declaring the “beach quality is good”. The utilized toolbox works as follow:

LHS Item(s) → RHS Item(s)

given an antecedent item/s (LHS or Left Hand Side) ARMADA looks for the consequent item/s (RHS or Right Hand Side).

Each association of LHS and RHS is defined as a rule. Each rule could be composed by LHS and RHS having one or several items. Two statistic parameters are utilized to rank the mined associations (rules):

- minimum confidence, expressed as percentages of times the

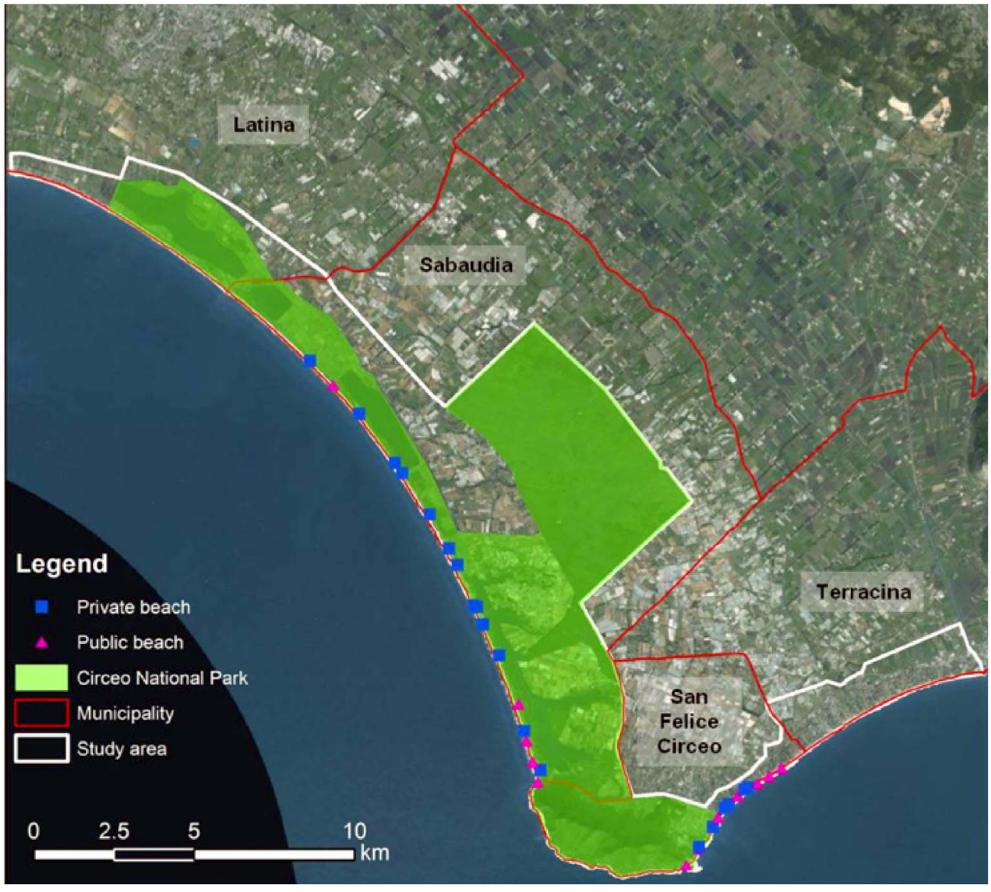
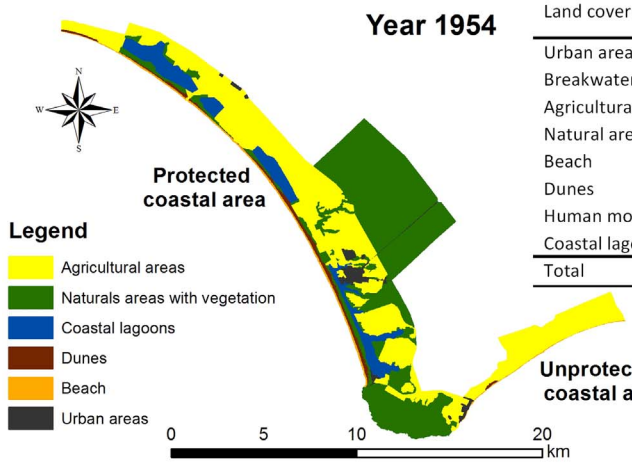
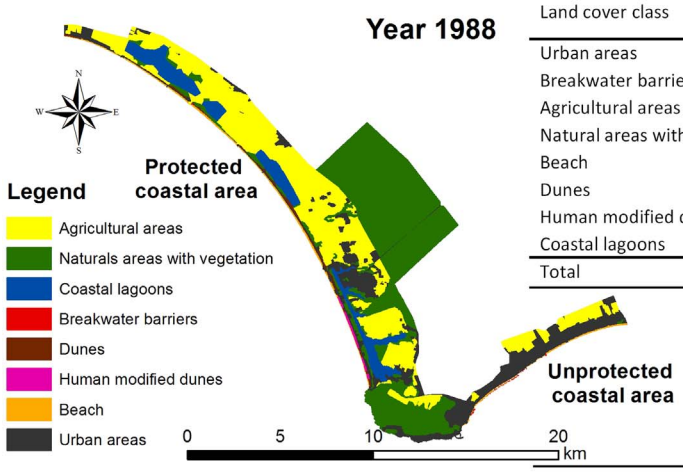


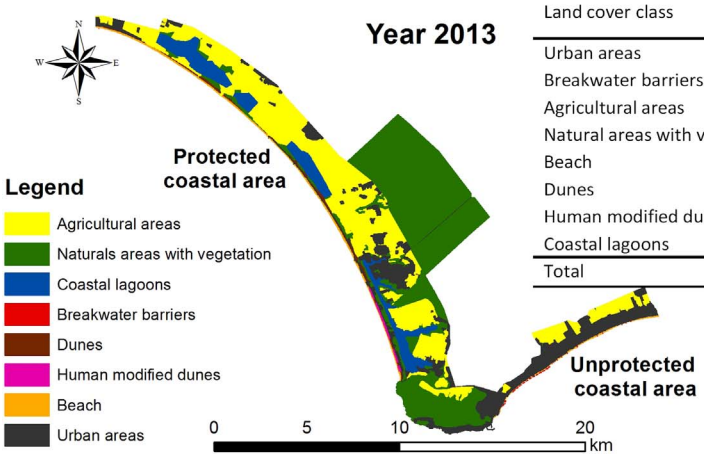
Fig. 3. Location of public and private beaches sampled during the survey analysis in the municipalities of San Felice Circeo (unprotected coastal area) and Sabaudia (protected coastal area).



Land cover class	1954	
	Area (ha)	%
Urban areas	201.6	1.7
Breakwater barriers	--	--
Agricultural areas	5,188.7	43.5
Natural areas with vegetation	4,989.1	41.8
Beach	134.5	1.1
Dunes	315,5	2.6
Human modified dunes	--	--
Coastal lagoons	1,101.5	9.2
Total	11,930.9	100



Land cover class	1988	
	Area (ha)	%
Urban areas	1,776.9	14.9
Breakwater barriers	2.1	0
Agricultural areas	3,966.9	33.3
Natural areas with vegetation	4,701.2	39.5
Beach	105.5	0.9
Dunes	204.5	1.7
Human modified dunes	40.7	0.3
Coastal lagoons	1,101.5	9.3
Total	11,899.2	100



Land cover class	1988	
	Area (ha)	%
Urban areas	1,776.9	14.9
Breakwater barriers	2.1	0
Agricultural areas	3,966.9	33.3
Natural areas with vegetation	4,701.2	39.5
Beach	105.5	0.9
Dunes	204.5	1.7
Human modified dunes	40.7	0.3
Coastal lagoons	1,101.5	9.3
Total	11,899.2	100

Fig. 4. Land-cover maps and the extent of each land cover class (in hectares and in %) in the study area for the years 1954, 1988, and 2013.

association is true;
- minimum support, expressed as percentages of times the given rule appears in the dataset.

The dataset could be mined without a priori rules, or could be mined imposing a specific LHS or RHS. The values of confidence and support are thus used to rank the mined rules.

The method was used to provide an evaluation on what are the "pleasure factors" or "antecedents" (here LHS) influencing the general perception of "beach quality" or consequent (here RHS), hence potentially providing the reason why a particular stretch of beach is frequented.

At first the analysis was trained on the whole dataset without specified imposed rules in order to explore the data set. Subsequently the analysis was trained imposing the consequent (RHS) "good beach quality" in order to search for the antecedent (LHS), both on the whole dataset and on the sub-samples "protected" and "unprotected". In this way the resulting statistics provided by support and confidence were used to evaluate if "pleasure factors" could experience some variation between the "protected" and "unprotected" area.

Table 3
Transition matrix to interpret the land-cover changes from 1954 to 1988.

Classification		Year 1988									
		Agricultural areas	Natural areas with vegetation	Costal lagoons	Breakwater barriers	Natural dunes	Anthropic dunes	Sea	Beach	Urban areas	Total
Year 1954	Agricultural areas	3807.9	52.9	–	0.1	–	–	1.1	6.2	1320.6	5188.7
	Natural areas with vegetation	157.0	4639.2	–	–	–	–	–	–	192.8	4989.1
	Costal lagoons	–	–	1101.5	–	–	–	–	–	–	1101.5
	Breakwater barriers	–	–	–	0.0	–	–	–	–	–	0,0
	Natural dunes	–	9.1	–	–	197.3	40.6	–	13.8	54.8	315.5
	Anthropic dunes	–	–	–	–	–	0.0	–	–	–	0.0
	Sea	–	–	–	1.7	0.6	–	0.0	13.1	4.3	0.0
	Beach	–	–	–	0.3	6.6	0.1	50.4	71.8	5.4	134.5
	Urban areas	1.9	–	–	–	–	–	0.0	0.6	199.1	201.6
Total		3966.9	4701.2	1101.5	2.1	204.5	40.7	0.0	105.5	1776.9	10,016.8

Table 4
Transition matrix to interpret the land-cover changes from 1988 to 2013.

Classification		Year 2013									
		Agricultural areas	Natural areas with vegetation	Costal lagoons	Breakwater barriers	Natural dunes	Anthropic dunes	Sea	Beach	Urban areas	Total
Year 1989	Agricultural areas	3.888,0	1.0	–	–	–	–	–	–	77.8	3966.9
	Natural areas with vegetation	7.1	4690.8	–	–	–	–	–	–	3.3	4701.2
	Costal lagoons	–	–	1101.5	–	–	–	–	–	–	1101.5
	Breakwater barriers	–	–	–	2.0	–	–	0.0	0.1	–	2.1
	Natural dunes	–	0.1	–	–	200.9	0.2	0.5	2.5	0.3	204.5
	Anthropic dunes	–	–	–	–	–	40.6	–	–	0.1	40.7
	Sea	–	0.1	–	0.3	–	–	0.0	50.6	0.3	0.0
	Beach	–	–	–	0.0	0.1	0.4	5.9	94.0	5.1	105.5
	Urban areas	–	6.0	–	–	0.3	–	–	0.1	1770.5	1776.9
Total		3895.1	4698.0	1101.5	2.3	201.3	41.2	0.0	147.2	1857.4	11,788.3

Table 5
Status of the biological, physical-chemical elements and pollutants of marine coastal water bodies in the study area during the period 2011–2013 (Source: ARPA Lazio, 2015).

Municipality	Marine coastal water body	Biological quality elements	Physical-chemical quality elements	Chemical pollutants
Latina and Sabaudia (protected coastal area)	From Torre Astura to Torre Paola	High	Good	No exceeding
San Felice Circeo (unprotected coastal area)	From Torre Paola to Porto San Felice Circeo	High	Good	No exceeding
Terracina (unprotected coastal area)	From Porto San Felice Circeo to Punta Stendardo	High	Good	No exceeding

Table 6
Respondents profile in terms of sampling location, age, type of user, place of residence.

Descriptor	%
Sampling location	
San Felice Circeo	47
Sabaudia	53
Age	
≤ 30	30
31–60	58
> 60	12
Type of user	
Permanent resident	14
Seasonal resident	71
Tourist	15
Place of residence	
Region of Latium	86
Other regions of Italy	12
Foreign	2

3. Results

3.1. Land cover maps and results of the change detection analysis

Three land cover maps of both protected (Latina and Sabaudia municipalities) and unprotected coastal area (San Felice Circeo and Terracina municipalities) were elaborated for the years 1954, 1988 and 2013 and on the basis of the land cover classes reported in Table 1 (Fig. 4). For the three periods the most representative classes in terms of surface are “Agricultural areas” and “Natural areas with vegetation”. These coarse-grained classes have faced a reduction over time covering > 85% of the study area in 1954 and > 70% in the other two periods (1988 and 2013).

The first transition matrix for the first period (1954–1988) accounts for 16% of coastal area change (Table 3). In addition to the land cover classes identified in Table 1, the transition matrix shows also the class “Sea” highlighting a process of beach erosion in 1988 in comparison to 1954. The land cover class “Agricultural areas” decreases of 23.5% from 1954 to 1988 for its conversion in “Urban areas” above all in the unprotected coastal area, even if it remains the most extended class in

Table 7
Percentage of respondents concerning the beach users attitudes differentiated for the municipalities of San Felice Circeo (coastal unprotected area) and Sabaudia (coastal protected area).

Question	% of respondents		
	San Felice Circeo (coastal unprotected area)	Sabaudia (protected area)	Total
When do you enjoy this coastal area?			
Summer	36	38	74
Winter	1	1	2
Always	10	14	24
How often do you enjoy this coastal area?			
Regularly	41	44	85
Occasionally	6	9	15
Where do you usually prefer to go?			
Public beach	21	29	50
Private beach	26	24	50
Why do you choose this beach?			
Beauty	16	36	52
Habit	15	13	28
Cleanness	12	17	29
Services and comfort	8	13	22
Easy of reaching	15	12	27
Presence of friends/ family	15	14	29
Do you use the walkways to reach the beach?			
Yes	28	42	70
No, they are too far away	16	8	24
No, there are not	3	3	6

both years. The class “Urban areas”, slightly present in 1954, shows an expansion over this period of time at the expenses of other land cover classes along all the shoreline of San Felice Circeo and Terracina (unprotected coastal area). This expansion is mainly due to the increase of several tourist infrastructures such as hotels, lidos and secondary homes. The intensification of human activities affected also the patterns of dunes in the protected area and led to the distinction between “Anthropic” dunes, identified in 1988, and “Natural” dunes. These last ones show a decrease of 35% because mostly replaced by “human-modified dunes” and “Urban areas”. Another class showing a significant change over this period of time is “Beach” that, during the first period shows a decrease of 22% mainly due to erosion processes (50.4 ha). In order to face this erosion process of the beaches, several “Breakwater barriers” were built during this period of time and can be identified in 1988. The extent of “Natural areas with vegetation” seems to be rather stable with a lower degree of change (a decrease of about 6%), mainly due to its conversion into “Urban areas” and “Agricultural areas”.

The second transition matrix (Table 4), concerning the second period 1988–2013, registers a low degree of change (1%) of coastal ecosystems. From the land-cover maps of 1988 and 2013 it has been recognized an increase of “Urban areas”, above all in the unprotected coastal area, and of the new class “Anthropic dunes” in the protected coastal area. Moreover, the land-cover class showing an increase of its extent is “Beach”, specifically in the unprotected coastal area, that increased of about 50.6 ha probably due to the presence of breakwater barriers in '80 that favoured beach nourishment in the coastal part of San Felice Circeo.

3.2. The quality of coastal waters

Data concerning biological quality elements, physical and chemical parameters related to eutrophication phenomena and priority chemical pollutants for the period 2011–2013 highlight a high or good ecological and chemical status of the coastal waters in the study area (ARPA Lazio, 2015) (Table 5). Concerning the microbial quality the bathing water quality data in 2012 and 2013 can be viewed in WISE where data are aggregated and visualized on national and station level and detailed information are given from 2005 till 2015. As published in the official documentation of the in charge institution, the Regional Environmental Protection Agency, in all the monitoring locations located in the study area, coastal bathing waters meet at least good water quality in 2012 and 2013 highlighting clean and safe waters, according to the official threshold (EEA, 2016) (Supplementary Table 1).

3.3. Survey analysis

A total of 2071 questionnaires were collected. The socio-demographic characteristics of respondents (sampling location, age, type of user, place of residence) are shown in Table 6. The sample resulted uniformly distributed in the two coastal areas of San Felice Circeo and Sabaudia. The most of the beach users age was between 31 and 60 years (58%). Respondents were composed of permanent residents (they reside during the whole year in the area, 14%), seasonal residents (they reside only in summer, 71%), and tourists (they enjoy this coastline occasionally, 15%). According to the place of residence, 86% of respondents live in Latium, while 12% live in other regions of Italy and only 2% come from abroad.

Concerning the beach users attitudes (Table 7), as expected people prefer enjoying beaches during summer (74%), even if a modest fruition is registered throughout the year (24%). Most of beach interviewed (85%) enjoy these coastal areas regularly and they are equally distributed between public (50%) and private beaches (50%). Exploring the reason why people choose to enjoy the coastal area, most of them declare that its beauty is the main attraction (52%), above all in the municipality of Sabuadia. Many interviewed use walkways to reach the beach (70%), above all in the protected area of Sabaudia (42%).

Fig. 5 shows how beach users perceive the main factors that can determine the attractiveness of the beach. The presence of dune systems is recognized as a natural habitat above all in the coastline of Sabaudia, where effectively the beaches are characterized by extensive dune systems. Many people perceived these beaches wide (76%) and clean (73%), and rarely or never they have seen marine litter along the beaches in both coastal areas. Concerning the awareness of the quality of coastal seawater, most of the interviewed (81%) have perceived a good quality, while 14% have perceived a poor quality especially in the municipality of San Felice Circeo. In general, the results of the statistical analysis highlight statistically significant differences between beach users perceptions in protected and unprotected coastal areas for what concerns the water quality and the coastal dynamics.

Fig. 6 focuses on the spatial distribution of people that perceive a poor quality level of coastal seawater in the study area highlighting that most of them have been interviewed in beaches along the unprotected coastal area.

Overall, the majority of respondents declared a “good quality of the beach”. In this regard, the results of the association rules highlight that the answer “the overall beach quality is good” shows high correlation (in terms of support and confidence) with the answer “high water quality”, followed by “clean beach” and “wide beach”, both in the whole dataset and in the sub-samples “protected” and “unprotected” areas (Table 8). Further, it should be noted that among the rules with two-dimensional LHS, the one characterized by the higher confidence is: “clean beach and clean water”, and in absolute terms its support is maximum in the sub-sample “protected area”. Similar associations arise from the data (whole dataset) also when there are not mined specific rules (Supplementary Table 2).

The perception of the landscape dynamics is different between people that enjoy the protected area of Sabaudia and those of the unprotected coastal area of San Felice Circeo. Specifically, half of those surveyed know the history of the coastal area and 39% noticed an improvement over time, while 57% perceived a worsening mainly in the protected coastline of Sabaudia.

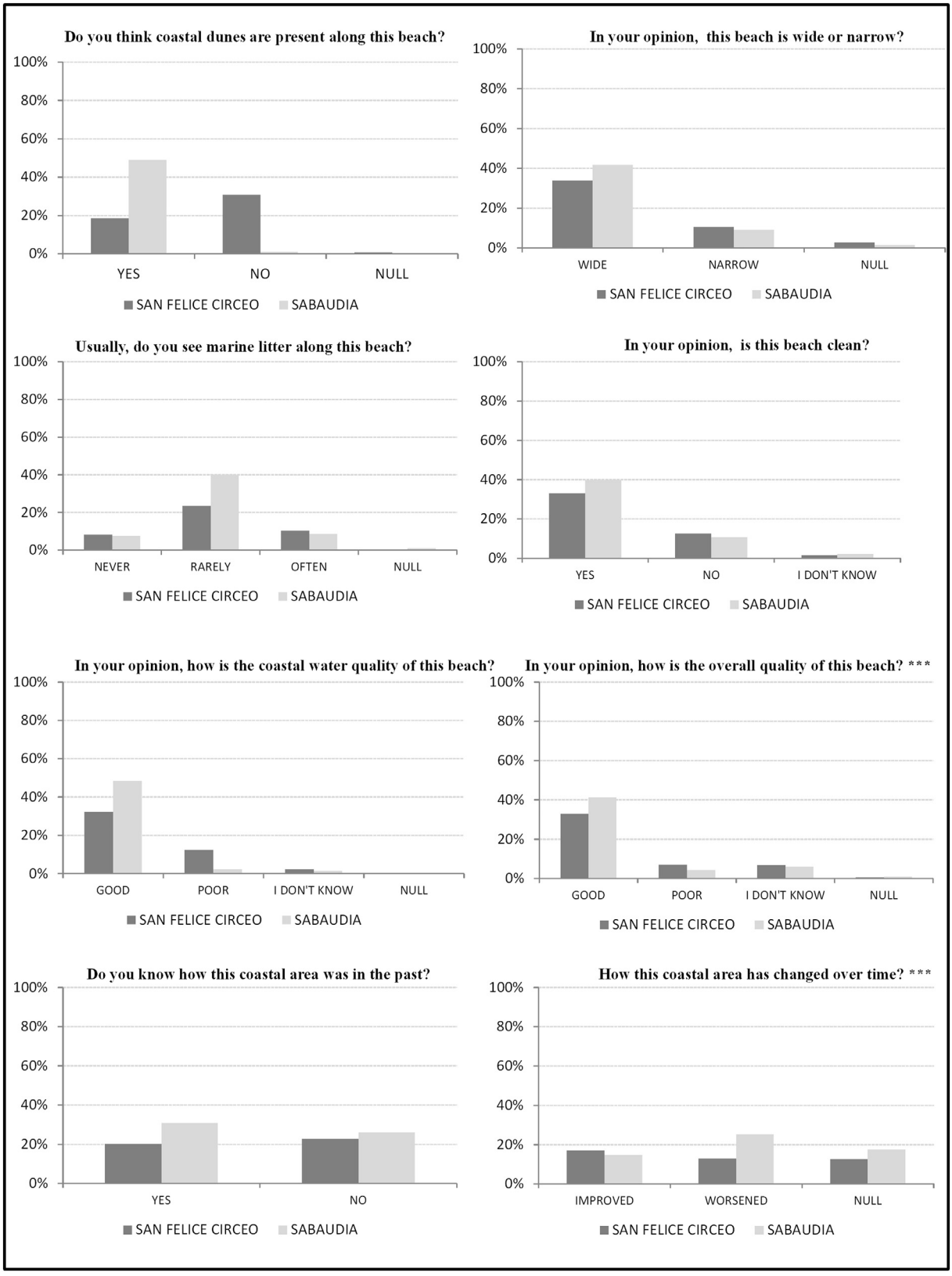


Fig. 5. Percentage distribution of answers differentiated for the municipalities of San Felice Circeo (coastal unprotected area) and Sabaudia (coastal protected area) to the questions related to the perception of beach users. ***p-value $<$ 0.001.

4. Discussion

The high presence of people, the morphology of the sandy coastal systems, as well as the relative proximity to urban areas make the coastal ecosystems under study highly exposed and vulnerable to human pressures. In this respect, the retrospective analysis supports the identification of the possible driving forces behind the coastal dynamics. Along the analysed areas it is evident how tourism, leading to

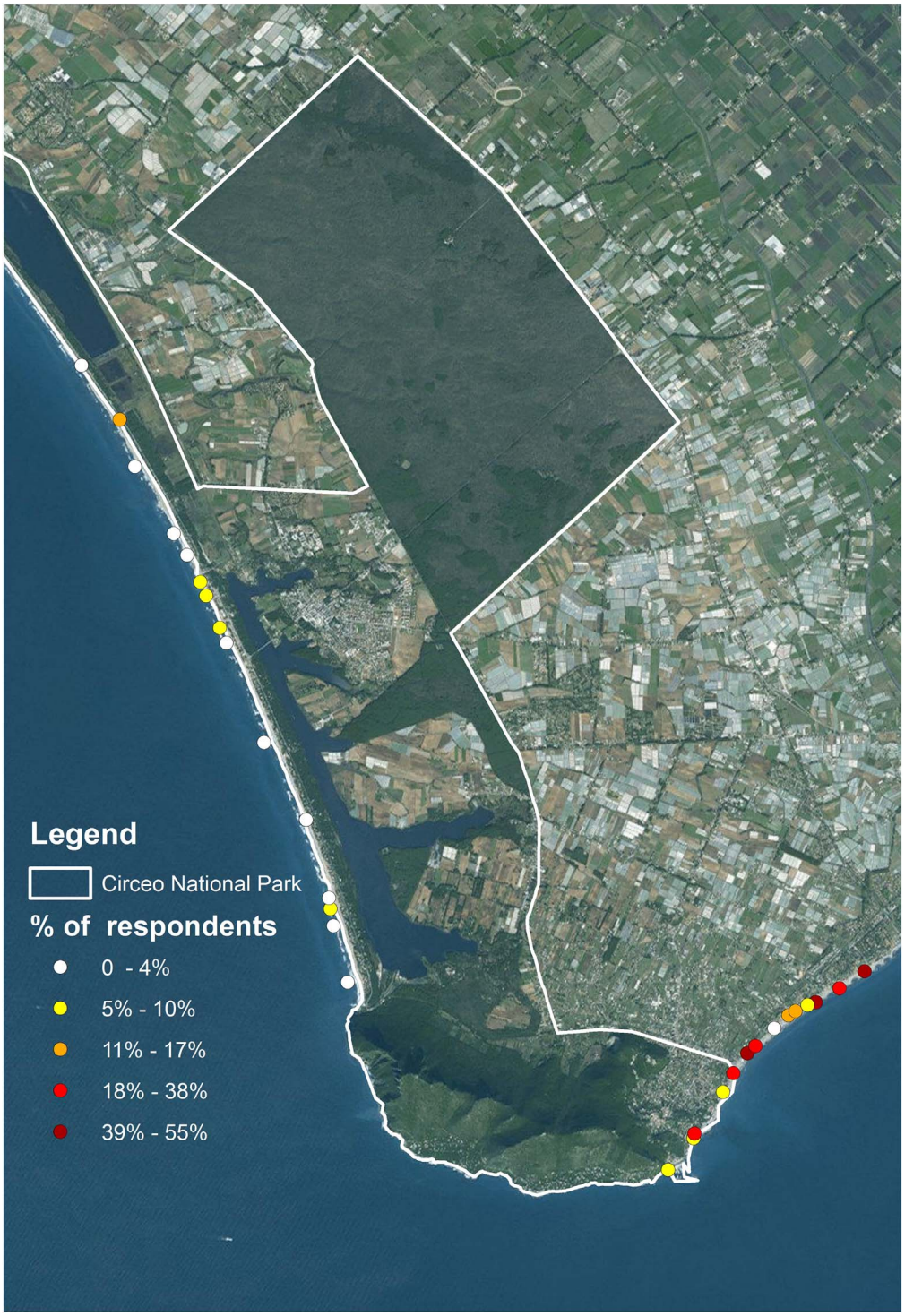


Fig. 6. Percentage of interviewed that perceived a poor quality of coastal waters in each public and private beach sampled during the survey.

the building of several infrastructures such as secondary homes, hotel and lidos, was the most driving force deeply affecting the natural identity of these coastal areas. Moreover, the coastal change detection helps to identify areas more susceptible to change and to recognize that not all the changes in land cover classes have the same significance from an ecological viewpoint. In this perspective, changes of natural land cover classes (such as natural areas with vegetation, beaches and dune systems) versus human land cover classes (agricultural or urban) have been considered unwanted land-use outcomes (strong negative changes) since they irreversibly damaged the ecological features of ecosystems leading to the loss of several ecosystem goods and services provided by coastal areas. The transformation of agricultural areas in urban areas is a negative change because even if this conversion interests two different human land-uses (from agriculture to urban), this transformation can imply the loss of important ecosystem services such as pollination, biological control and food production. On the other side, change from a human land use class towards a natural/semi-natural land-use class have been considered as positive change because it promotes the supply of natural capital. As Fig. 6a shows, during the first period (1954–1988), very few positive changes were observed in the study area, mainly located in the Circeo National Park and in relation to the re-naturalization or forestation of small agricultural areas (Fig. 7a$_3$).

Table 8
Results of mined associations. LHS and RHS stand for Left Hand Side and Right Hand Side of the mined association. In this case was mined the LHS and given the RHS. Each association is an abbreviated text referred to the questions of the questionnaire (e.g. clean beach is referred to the question "in your opinion this beach is clean?").

	LHS				RHS	Support	Confidence	Area
Rules	Good seawater quality			>	Good beach quality	91.3	94.3	Protected area
	Clean beach			>	Good beach quality	84.1	98.7	
	Clean beach	Good seawater quality		>	Good beach quality	83	98.7	
	Wide beach			>	Good beach quality	82.3	95.9	
	Wide beach	Good seawater quality		>	Good beach quality	80.6	96.2	
Rules	Good seawater quality			>	Good beach quality	76	94.8	Unprotected area
	Clean beach			>	Good beach quality	73.8	95.9	
	Wide beach			>	Good beach quality	71.9	89.2	
	Clean beach	Good seawater quality		>	Good beach quality	67.1	97.4	
	Clean beach	Wide beach		>	Good beach quality	63.2	97	
	Wide beach	Good seawater quality		>	Good beach quality	61	96.6	
	Clean beach	Wide beach	Good seawater quality	>	Good beach quality	55.7	98.3	
Rules	Good water quality			>	Good beach quality	82.9	95	Whole dataset
	Clean beach			>	Good beach quality	80.2	97	
	Wide beach			>	Good beach quality	77.2	92.8	
	Clean beach	Good seawater quality		>	Good beach quality	75.3	98.1	
	Wide beach	Good seawater quality		>	Good beach quality	71.1	96.4	
	Clean beach	Wide beach		>	Good beach quality	69.4	98.1	
	Clean beach	Wide beach	Good seawater quality	>	Good beach quality	65.5	98.7	

Surprisingly, despite the official designation of the Circeo National Park, in the protected coastal area several strong negative changes have occurred mainly in dune systems and in natural areas with vegetation. These land covers suffered serious degradation mechanisms related mainly to the increase of urban settlements and tourist infrastructures (Fig. 7a$_1$).

The widespread coastal urbanization occurred also in the entire unprotected coastal area of San Felice Circeo and Terracina converting agroecosystems into urban areas (Fig. 7a$_2$).

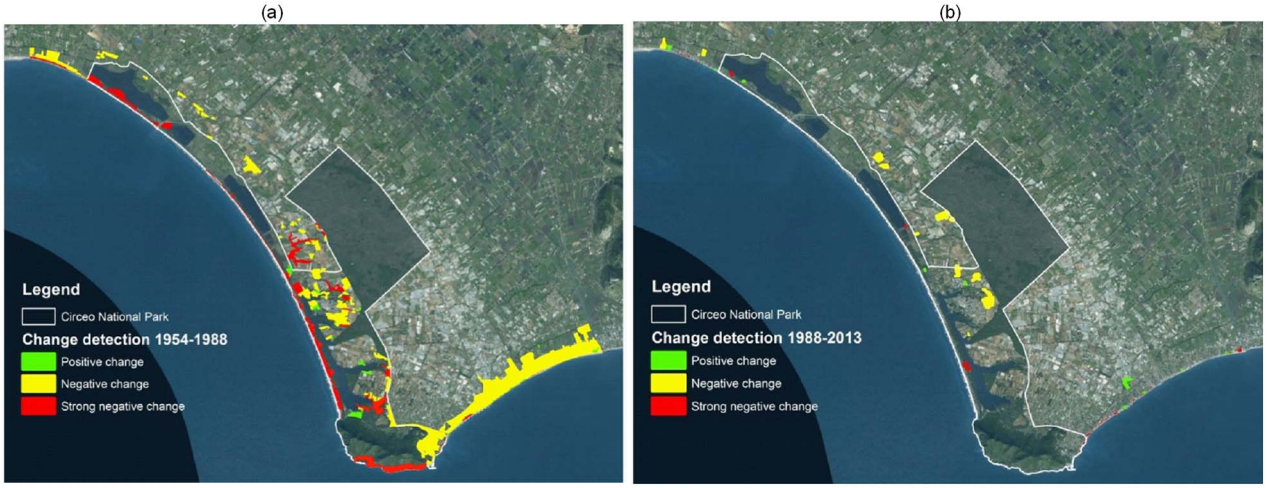
During the second period (1988–2013) the coastal area seems more or less stable with a very small percentage of change (Fig. 7b), and most of the strong negative changes occurred along the coastline in the unprotected coastal area. Most likely, it can be an effect of the entry into force of the National Italian Law on Protected Areas (Italian Law n. 394/1991). This law provided guidelines, methodologies and clear and unitary rules for the institution and management of protected areas, allowing only interventions and activities that are strictly compliant with the primary purpose of the conservation of ecosystems and biodiversity. Specifically, this Law introduced new planning and management tools (Park Plan and Socio-Economic Development Plan) to protect the landscape and seascape, historical and cultural values of the territory, to recover the integrity of natural habitats, to divide the territory into zones with different forms of use and protection, and to foster sustainable economic growth and landscape identity. Moreover, as highlighted in other case studies (Petrosillo et al., 2009; Petrosillo et al., 2010) the presence of a local management authority, by setting conservation priorities and specific monitoring systems, can play an important role in supporting the natural capital and the ecosystem services provision of the area. Therefore, after the entry into force of the National Law on Protected Areas, the Circeo National Park started to adopt new and more constraining planning and management criteria by conforming them to the new rules. Although the park management authority was established only in 2007, it contributed to mitigate the threats to the natural capital avoiding and reducing potential negative changes by realizing some local-scale interventions to recover or improve the integrity of natural habitats, as for coastal dune systems, where several walkways were installed along the protected coastline to stem the impact of the human trampling on dunes vegetation.

An important indicator of beach attractiveness is the quality of coastal seawater. Data on coastal seawater quality confirm that there are not bacterial or chemical pollution as well as the related health risks. In agreement with these results most of those interviewed recognized a good quality of coastal seawaters, however the 15% of respondents, mostly in San Felice Circeo, perceived a poor seawater quality. The spatial distribution of this result (Fig. 6) further highlights how this negative perception increases with increasing distance from the protected area. However, this assessment can assume a local meaning and the related interpretation should be properly analysed. Therefore, the proposed question about "the quality of coastal seawater" could be susceptible to several misperceptions of the possible disturbing factors, i.e. floating vegetable materials or marine litters, like in the case of floating leaves or dead leaves of *Posidonia oceanica* accumulated on the beaches, could be often interpreted as waste material and as a nuisance by beach users (Triviño et al., 2016; Zurlini and Müller, 2008), while it is an indicator of good coastal ecosystem quality.

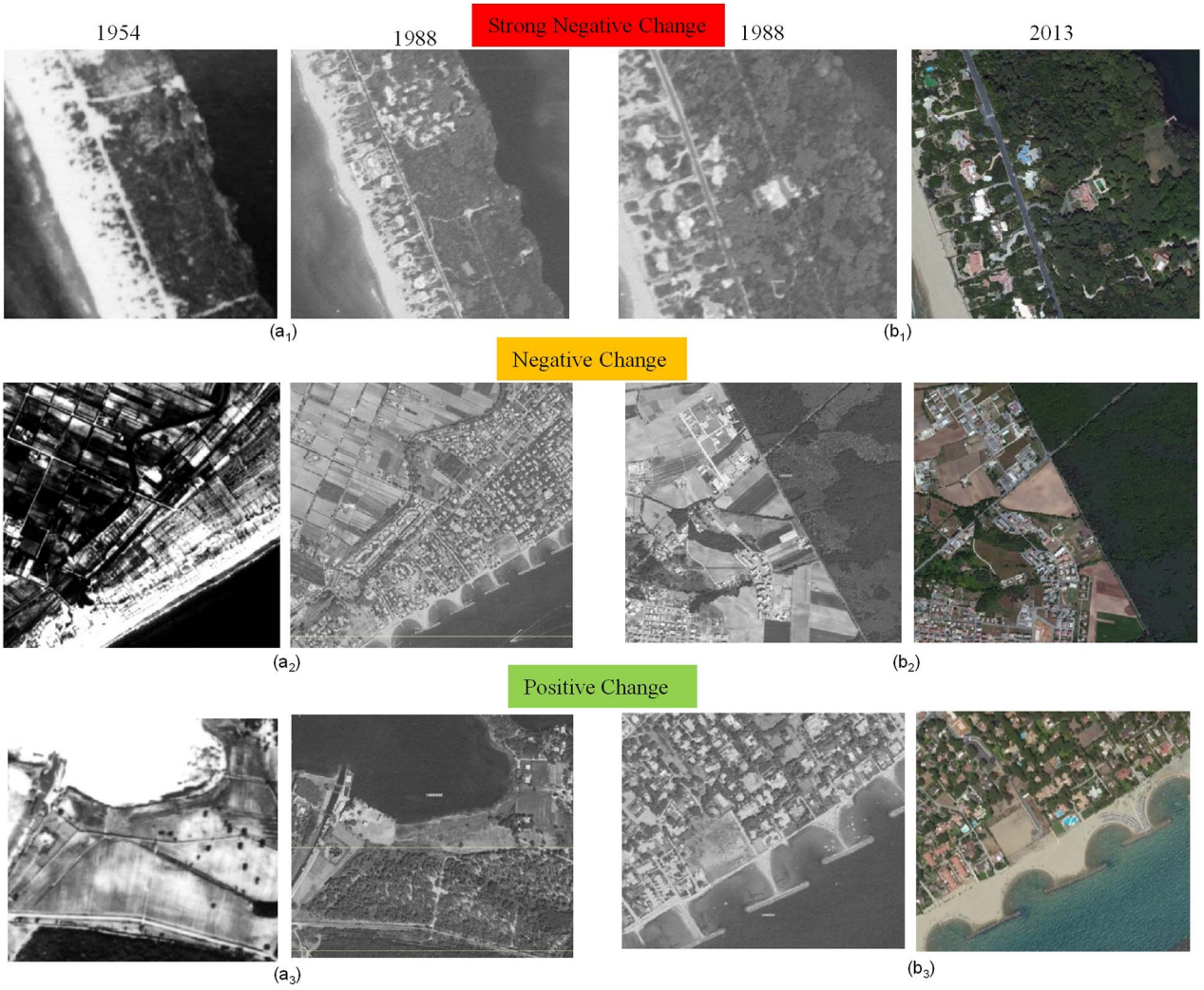
However, this result should not be overlooked because the perception that a coastal seawater quality is "poor" can keep many people from enjoying a natural resource that is safe and inexpensive and may lead beachgoers to drive further then necessary to avoid beaches that are perceived to be unsafe (Pendleton et al., 2001). In addition, this result reflects the case of low perception of environmental security (sensu Zurlini and Müller, 2008) without any objective reason for such concern, and it could happen that people will initiate activities to mitigate the perceived risk, with negative economic consequences because they will invest money in activities that are not needed (Petrosillo et al., 2010) (e.g. the removal of dead leaves that become a waste and a significant cost for beach fruition).

The rule mining technique let to detect noteworthy associations among the given answers by interviewed, suggesting that a strong relationship exists between the quality of the beach and the quality of coastal seawater, the cleanness and the width of a beach. These results are in line with the results obtained from previous researches on the public perception of beach quality, and where parameters such as water quality, cleanness of beach, scenery, facilities and safety are resulted as of the highest priority for beach users (e.g. Botero et al., 2013; Lozoya et al., 2014; Marin et al., 2009; Roca and Villares, 2008).

The survey analysis has been useful also in evaluating whether people are aware of the coastal ecosystem dynamics since they can provide a perception depending to their traditional knowledge of the area. In this context, the half of the sample surveyed did not know how the coastal ecosystem was in the past, most probably because they were occasionally users or too young. However, among those knowing the history of the study area, the analysis highlights that some people recognize an improvement of the coastal landscape. This perception could be probably related to the protection and recovery interventions



Land cover class 1954	Land cover class 1988	Type of change
Natural	Urban	Strong Negative
Natural	Agricultural	Strong Negative
Agricultural	Urban	Negative
Agricultural	Natural	Positive
Urban	Natural	Positive



(caption on next page)

Fig. 7. Results of the change detection in the study area from 1954 to 1988 (a) and from 1988 to 2013 (b) and examples of strong negative, negative and positive changes occurred in the study area during these two periods.

realized in the natural protected area but also to the beach protection works executed in the unprotected coastal area of San Felice Circeo and Terracina, resulting in a widening of the beaches (Fig. 7b_3). However, in accordance to the change detection, most of the beach users perceived a worsened of the coastal landscape, mostly in the natural protected coastal area, where many strong negative changes occurred in the past leading to a degradation of natural features and, consequently, to the loss of ecosystem goods and services. For this reason, respondents proposed that it would be essential that the management authority will implement direct conservation measures for restoration of ecosystems, habitats, species and their services, and promote the conscious use of the landscape with the raising of public awareness of environmental and coastal features.

5. Conclusions

One of the most successful strategy to achieve the long-term conservation of nature with its associated ecosystem services and cultural values is the establishment of protected areas that are clearly defined, recognized, and managed through legal or other effective means (Dudley, 2008). However, this study pointed out that the only designation of a protected area, as a "top-down" procedure that recognizes only the natural value of an area but without any planning and management power, without a competent authority with a more detailed understanding and concern for ecological and disturbance processes, and without the involvement of local authorities and communities, could be not effective for the long-term natural capital conservation. The Italian Law n. 394/1991 with more constraining planning and management criteria was the solution to avoid undesirable changes and threats to the maintenance of the natural capital and the provision of ecosystem services in the protected area. Moreover, the success of any ecosystem protection strategy cannot be obtained simply by extending the protected area and designations alone, but it depends also by the way the interactions between natural habitats conservation policy and human activities are managed (Papageorgiou and Vogiatzakis, 2006; Petrosillo et al., 2009). For this reason, an adaptive management of coastal landscape dynamic, expanding the idea of "learning by doing" to "learning from what has already been done" (Jones et al., 2013) is essential to avoid the mistakes of the past and predicting short and long-term effects on the coastal landscape.

A second aspect is that Europe's biodiversity can be found also outside the borders of designated protected areas (Papageorgiou and Vogiatzakis, 2006). In particular, many unprotected natural and semi-natural areas sustain numerous habitats and thus the provision of several ecosystem services (Cox and Underwood, 2011). For this reason, if unprotected natural and semi-natural ecosystems are managed in a manner that allows for the maintenance and, where necessary, restoration of ecosystems, habitats, species and their services across the wider landscape, both within protected areas and outside, it is possible to realize significant additional biodiversity gains.

A third issue that needs to be considered by managers is the spatial scale. Usually, most conservation and management interventions occur at local scales, as the recovery interventions on coastal dunes in the study area, because the management priorities depend on local problems. However, changes in broad-scale drivers, such as land-use, can dramatically influence the effectiveness of local-scale conservation and planning (Wiens, 2009). On the contrary, the absence of significant broad changes does not exclude the existence of hidden local threats that cannot be detected with the photo interpretation (Malavasi et al., 2013). For this reason planning and management interventions at multiple scales are requested, along with the monitoring of the ecosystems response across those scales (Turner et al., 2002).

We recognize that a limitation of our analysis is the use of changes in land-use/land-cover as a proxy for natural capital flow. The study gives more importance to the qualitatively structural component of biodiversity without any reference to the quantitatively compositional and functional aspects. However, interpreting land-use/land-cover changes in terms of natural capital flow allows for the identification of the resources at risk and the forces that drive the risk. Another critical aspect not considered in our analysis and that can be fundamental in large scales case studies is that we have not considered data regarding the Marine Strategy Framework Directive descriptors for a better evaluation of the environmental status of marine waters and to investigate on different anthropogenic pressures. For this reason, the development of this research will be focused on a comprehensive ecosystem analysis aimed to bridge the gap between policy (i.e., the EU Water Framework Directive, Marine Strategy Framework Directive, Habitat and Birds Directives) and science (creation of assessment tools, indicators, etc.) and it will include broad-scale monitoring with the potential to account for ecosystem level changes in response to both anthropogenic and natural pressures.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version, at http://dx.doi.org/10.1016/j.marpolbul.2017.09.003. These data include the Google map of the most important areas described in this article.

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