~~**Beach litter collection and preliminary analysis in five pocket beaches of the north Sardinia Island (Italy) – Baseline**~~

What can beach litter tell about local management: a comparison of five pocket beaches of the North Sardinia island (Italy)

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Highlights

- A total of 7,975 marine debris were collected on five pocket beaches
- 90% were plastic items and likely came from land-based sources
- Waste density ranged from 2.80 items/m^2 to less than 0.05 items/m^2
- Communication campaigns should be implemented to prevent littering

Abstract

Our study provides a first dataset on marine litter collected at five pocket beaches situated in the northern Sardinia (Italy). The monitoring method refers to the operational guidelines for rapid beach assessment of beach waste described by UNEP. We classified the 7975 items collected according to the eight categories and 99 types. Their analysis indicates that plastic is the most common litter category and, plastic fragments are the most frequent debris. The density ranges from 0.05 to 2.82 item/m^2. The top 10 highly present marine litter reveals that land-based litter is the main source, probably due to the lack of waste management, massive tourism and recreational activities. In addition, landscape morphology affects the redistribution of marine litter. Overall, these first results are part of a wider study on the presence of marine litter in the pocket beaches of north Sardinia to provide coastal managers and policy makers mitigation strategies.

Keywords

Marine litter; plastic pollution; beach sampling; pocket beaches and marine protected areas; Sardinia (Italy); coastal geomorphology.

Introduction

According to the United Nations Environment Program (UNEP) "marine litter is any persistent, manufactured or processed solid material discarded, disposed or abandoned in the marine and coastal environment", (UNEP, 2009; 2019; UNEP & NOAA, 2011). In addition, marine and coastal litter can be classified according to their material type (plastic, glass, metal, cloth, paper, rubber and wood, Hanke et al., 2013), deriving from four main sources namely recreational litter, fishing debris, sewage-related debris and shipping waste (Somerville et al., 2003).

The impacts of marine litter are well documented in the literature. Indeed, the review of Derraik (2002) on the pollution of the marine environment by plastic debris highlighted that plastic pollution is a threat to marine biodiversity, already at risk from overfishing, climate change and other forms of anthropogenic disturbance. Marine litter also bears potential economic implications to maritime activities, such as fisheries and the aquaculture sectors (UNEP, 2014). Furthermore, Storrier et al. (2007), Somerville et al. (2003), Galgani et al. (2019) and Araújo and Costa (2019) reported that the aesthetic

degradation of beaches by marine litter results in lost revenue from tourism, which required clean-up operations by local authorities in order to attract visitors.

Furthermore, marine litter is recognized a particularly wide-spread problem that has been included in the Marine Strategy to achieve good environmental status in all EU marine waters by 2020. The aim for marine litter descriptor is to ascertain those properties and quantities of marine litter do not cause harm to the coastal and marine environment (EU-MSDF, 2008). Nevertheless, few studies focused on beach debris in pocket beaches or marine protected areas, mostly because of the small dimensions of the pocket beaches or due to the beach monitoring protocols. Consequently, useful information for policy makers or managers are also sparse.

The study aims to provide baseline information on the distribution, amount and categories of marine litter collected in 2017-2019 on five pocket beaches located in the northern Sardinia (fig. 1), which can used to helps direct both local and regional litter management efforts and to develop strategies to decrease the presence of litter in coastal zones. The pilot sites are Cala dei Ponzesi, Cala Spalmatore, La Pelosa beach, Fiume Santo and Porto Ferro beach and present different geomorphological and anthropogenic characteristics (tab. 1).

Sites	Location	Geomorphological characteristics	Tourism
Cala dei Ponzesi	North-eastern part of Asinara island Protected Marine Area	About 70 m length, less than 20 m wide, beach slope about 6°. E-W direction. Landward morphology irregular and hilly.	Most popular beach of Asinara (Corbau et al., 2019).
Cala Spalmatore	Southern part of Asinara island Protected Marine Area	It is about 300 m long, and about 10 to 15 m wide. The beach slope is about 2-3°. The hinterland is characterized by the presence of a coastal wetland. E-W direction	Tourism is strongly regulated, and not allowed to tourist.
La Pelosa	NW terminal tract of the Gulf of Asinara Urban area	About 300 m long, 10 to 40 m wide, with a gentle slope (about 2-3°) Orientation N320° and classified as cuspate foreland (Zenkovich, 1964).	Resort with high ecological values Marine debris removal activities by local authority
Fiume Santo	North Sardinia, between Porto Torres and Stintino Natural area	About 1500 m, and 15-20 m wide, with a gentle slope (2-3°) The beach is oriented N300°.	Very popular destination despite the ordinance prohibiting bathing
Porto Ferro	North-West Sardinia between Capo Caccia and Argentiera Natural area	1000 m long, 15-20m wide, gently sloped (about 2°). Bordered onshore by well-developed foredunes. Orientation N350°-N360°.	Very touristic popular destination (Buosi et al., 2017)

Table 1: Main characteristics of the five pocket beaches

The beach litter samplings were performed in December 2017 and March-July-October 2019 to monitor variation on the quantity and composition due to seasonal environmental changes in presence flow between low and high touristic seasons. The sampling was performed following the operational guidelines for the rapid beach assessment of beach waste described by UNEP (2009; 2016) and by the Joint Research Centre under the Marine Strategy Framework Directive (Galgani et al., 2013). The beach stretch was divided in 5-m wide transects and within each transect, all litter, ranging from 2.5 to 50 cm, were collected and classified using the list of Marine Litter for the Macro Litter (Galgani et al., 2013).

The beach cleanliness was also assessed through Alkalay et al. (2007) Clean Coast Index (CCI) using the following equation:

$$\mathrm{CCI} = (\text{Total litter on transect/total area of transect}) \times \mathrm{K}$$

with K (coefficient) = 20.

According to the scale provided by Alkalay et al. (2007) the beach can be classified as Very clean (CCI = 0 -2), Clean (CCI= 2-5), Moderate (CCI = 5-10), Dirty (10-20) and Extremely dirty (CCI = >20).

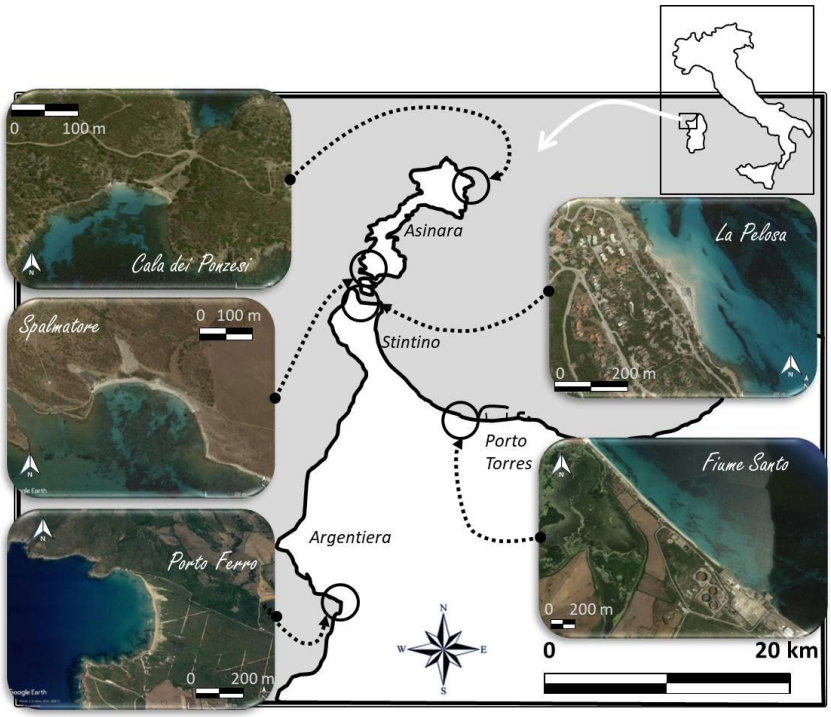

Figure 1: The five study areas: Cala dei Ponzesi, Cala Spalmatore, Porto Ferro, La Pelosa and Fiume Santo.

The results showed a heterogeneous distribution of marine litter between the different surveys and the different sites, in particular regarding to the number of collected item (fig. 2). Indeed, a total of 7,975 coastal debris items (ranging from 2.5 to 50 cm) were collected, with a maximum of 3,208 items at Porto Ferro in August 2019, and a minimum of 88 items at Fiume Santo on December 2017. A large number of items (1902 items) was also observed at Cala dei Ponzesi in December 2017. At Cala Spalmatore, the number of wastes was lower (less than 200), while at Pelosa beach the collected debris items varied between 200 and 500.

In general, plastic items represented about 90% of the litter independently on the season, but ranged from a minimum of 60% at La Pelosa to a maximum of 97% at Porto Ferro and Cala dei Ponzesi. Our results agree with numerous studies like UNEP/MAP-MED POL/WHO (2008) or OSPAR Commission (2007) which report that plastic items account for 50-80% of litter items found on beaches, paper items were nevertheless numerous on la Pelosa (Dec-2017 and Aug-2019). Construction material items represented from 5% to 15% of the items collected at Fiume Santo, Cala dei Ponzesi, Cala Spalmatore and la Pelosa. Lastly, metallic waste was collected at Fiume Santo (12%), Cala dei Ponzesi (7%) and la Pelosa (6%). Rubber and wood items were almost absent (less than 5%).

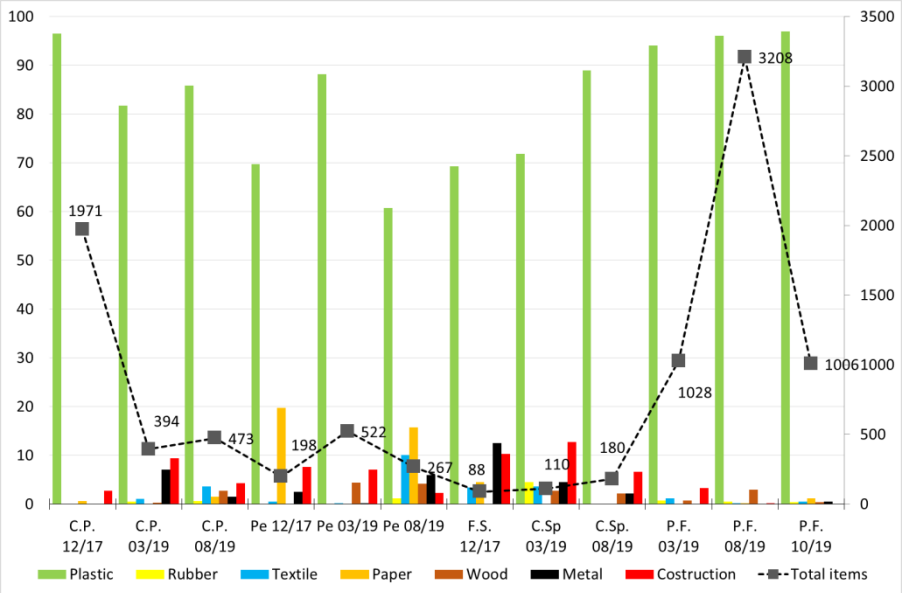

Figure 2: Composition of the debris items collected (C.P: Cala dei Ponzesi, Pe: La Pelosa, F.S.: Fiume Santo, C.Sp. Cala Spalmatore, P.F.: Porto Ferro. *The numbers indicate the period of the survey (e.g. 12/17 = December 2017) and number of items collected in each site. The left y-axis indicates the percent of the different categories (plastic, rubber, Textile and etc.), while the right Y-axis refers to the total items*

Furthermore, waste density is generally quite high (tab. 2), ranging from 2.8 items/m^2 (Cala dei Ponzesi) to less than 0.05 items/m^2 (Fiume Santo), a result that agrees with other studies performed along the Adriatic and Ionian coast (Vlachogianni et al., 2018) or in Sardinia and in other beaches as observed by Hengstmann et al. (2017). The cleanness index varies between a minimum of 1 (extremely clean beach) to a maximum of 56 (very dirty beach, tab. 2). Only two beaches are classified as dirty or very dirty: Cala dei Ponzesi and Porto Ferro, which extremely dirty in August 2019, and dirty in spring and autumn 2019. On the other hand, the beaches of Cala Spalmatore and La Pelosa are classified as clean and very clean.

	Cala dei Ponzesi			La Pelosa			F. Santo	C. Spalmatore		Porto Ferro		
	Dec 17	Mar 19	Aug 19	Dec 17	Mar 19	Aug 19	Dec 17	Mar 19	Aug 19	Mar 19	Aug 19	Oct 19
Items/m^2	**2,82**	0,57	0,66	0,08	0,21	0,11	0,05	0,09	0,14	0,57	**1,75**	0,56
CCi	**56**	11	13	2	4	2	1	2	3	11	**35**	11

Table 2: Calculation of the litter density and cleanness index values.

Considering that the presence of waste is the consequence of a series of factors and conditions as indicated by Hengstmann et al. (2017), we assume that the variability observed in this study is mainly due to human influences and secondly geomorphological control. Except the presence of non-sourced plastic fragments sized between 2,5 and 50 cm, land-based litter is the main source of marine litter most probably related to poor waste management, tourism and recreational activities, as indicated by other authors (Munari et al., 2016; Vlachogianni et al., 2018; Nachite et al., 2019; Grelaud and Ziveri, 2020). Indeed, shopping bags, plastic rings from bottles, plastic caps, food containers, drink bottles, cigarettes butts, lolly sticks were frequently found. Cotton bud sticks are also included in the top 10 items, especially at Porto Ferro (418 cotton bud sticks in August 2019). Paper items, glass fragments, wood fragments and, textiles items, even less frequently observed, are also included in the top ten item list.

Furthermore, the presence of lolly sticks in all the surveys also lead to the hypothesis that tourism is not the main cause of marine debris accumulation, which is also confirmed by the absence or less frequent presence of specific tourist items like ice cream sticks or chip forks. In addition, our results highlight that marine litter is not simple a waste management problem, but is also related to the use of short-lived/single-use items. Therefore, we assume that recent adopted UE strategy on plastic will lead to a drastic reduction in use and impact of disposable plastic items on the beaches (leading to a reduction of marine debris accumulation).

The marine litter distribution should also be attributed, albeit to a lesser extent, to local fishing activities as demonstrated by the presence of ropes among the 10 most frequently found items on the beach of Fiume Santo that is characterized by trawling activities (Rodella et al., 2019). The influence of local fishing on marine debris distribution has also been observed by other authors. For example, Hengstmann et al. (2017) showed that fishing activities play a variable role (minor/major) in the distribution of marine litter on the beach on the Isle of Rügen (Baltic sea). This result therefore shows the importance of considering secondary activities in waste distribution and, in particular, that local socio-economic aspects should be taken considered for the definition of long- and short-term strategies.

The geomorphological control on the marine litter distribution may be observed through the types and number of debris found on the two pocket beaches (Cala dei Ponzesi and Cala Spalmatore), both located inside a protected area subjected to severe control procedures on tourism. Indeed, the beach of Cala dei Ponzesi is characterized by a slightly accentuated slope and is bordered landward by dunes and hilly morphology (about 20 m high), while Cala Spalmatore has a low profile, with low foredunes (less than 1 m) behind which a small humid area develops. Consequently, the geomorphological profile of Cala dei Ponzesi should favor the deposition and accumulation of debris on the backshore, while at Cala Spalmatore beach the debris may have been transported and deposited further inland during storm events.

Such control was observed by Haarr et al. (2019) who reported that beach slope greater than 35° represents a limiting factor to litter deposition, and may represent a useful criterion to assess the presence or accumulation of marine litter.

Finally, this study highlights the efficiency of the measures adopted by the local authority of La Pelosa, which presents a low cleanness index, to tackle marine litter (only site with marine debris removal activities by the local authority). Conversely, communication campaigns to prevent littering and its impacts combined with specific actions could be implemented at Porto Ferro to raise awareness of tourists on marine litter, which presents a higher number of items during the touristic season. For instance, similarly to the suggestions by Asensio-Montesinos (2020), stakeholders and agencies might introduce on the beach the installation of educational materials and informational posters, enhance environmental education programs and improve facilities for garbage disposal. This baseline information gives the managers and policy makers information to plan mitigation strategies, and a benchmark against which to determine changes due to anthropic and/or natural events. In addition, the cleanness index may be used by the local authorities and manager to provide information on the pressures and to develop cleaning strategies to reduce marine litter pollution.

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