MARINE LITTER SURVEYS ON BOCCASETTE BEACH (ROVIGO, ITALY)

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Abstract – This study aims to evaluate the abundance and accumulation of the beach marine litter in relation to the main human activities and during some different meteorological conditions. Five surveys were performed along Boccasette spit, in the Veneto Regional Park of Po Delta (northern Adriatic Sea), adapting the DeFishGear protocol for beach litter. The debris was collected and analysed, and the beach cleanliness was evaluated applying the Clean Coast Index. Boccasette beach can be classified as moderately clean from late summer to winter and as clean during spring and summer. The main litter macro-category is represented by artificial polymer materials (96 %), while the others macro-categories represent the 4 % of collected items. The main sources of the marine litter have been attributed to improper waste disposal and fishing/aquaculture activities. Our results suggest that specific management approaches are needed to minimize the impacts of river's flooding events. Finally, involvement activities of fishermen and fish-farmers should be performed in order to reduce the release of new marine litter and to implement the awareness regarding the plastic pollution.

Introduction

The presence of marine litter is a huge environmental problem, affecting beaches on a global scale, with physical, chemical, biological and economic implications [13]. Nowadays, the reduction of marine litter in the marine environment is recognised as a priority challenge to preserve the ecosystem and human health [1]. Since a large part of plastic debris is floating, an increasing load of marine litter is scattered over long distances, and then settle in sediments where it may persist for centuries [4] [5] [7] [17]. As a matter of fact, sandy shores are important sinks for debris, which after stranding generally becomes trapped in/under sand or might be blown farther inland [10] [11].

Considering all involved variables influencing the debris dispersion, it is difficult to establish sources, modes of transport and accumulation zones, even if such aspects are crucial to improve our knowledge on marine litter issues. Indeed, such information represents a primary tool for the development of the management strategies to reduce marine litter and to verify their effectiveness [13]. The understanding of how human activities influence the marine litter scattering in the Mediterranean Sea region assumes great importance, especially where the bathing seasons last long and beaches are generally crowded and close to residential areas [3] [15].

The main purpose of this paper is to perform an initial assessment of the abundance and accumulation of beach litter along a sandy beach in the northern part of the Po Delta, in

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relation to the main human activities and to meteorological events. Therefore, we try to answer to the following questions:

- What is the quantity and the composition of stranded marine litter?
- What are the differences in litter composition related to some different extreme meteorological events?
- What are the impacts of the human activities on the composition and distribution of the marine litter?

This study has been performed within the NET4mPLASTIC Project (European Programme CBC Interreg Italy-Croatia), which aims to develop new technologies for monitoring micro and macro plastic in the Adriatic Sea, in order to quantify the marine litter presence and its possible accumulation zones in four pilot sites.

Materials and Methods

The Po Delta area lies on the Natura 2000 Italian network that include Sites of Community Importance (Habitat Directive, 92/43/CEE) and Special Protection Areas (79/409/CEE). The coastal zones bordering the Po Delta are characterised by dune systems and bars, sometimes connected to spits that delimit wide lagoon areas [19]. Specifically, the Barbamarco lagoon lies in the Veneto Regional Park of Po Delta between the Po di Maistra river (to the NW) and Busa di Tramontana river (to the SE). The lagoon is separated from the Adriatic Sea by a barrier island and two sandy spits. Boccasette beach is located in Porto Tolle municipality (Rovigo, Italy), on the north-western spit of Barbamarco lagoon system, and is about 4.4 km long (Figure 1). Boccasette is considered as a semi-rural area [21], and the main human activities are generally fishery and aquaculture, while local tourist activities occur only during the summer season.

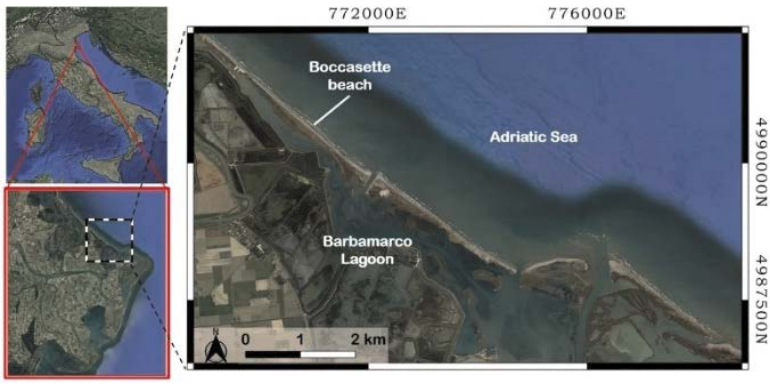

Figure 1 – Study area (Map created using QGIS, processed by Google satellite).

On Boccasette beach, five marine litter monitoring campaigns were carried out between November 2019 and October 2020. The meteorological conditions observed during

the surveys, and the main information related to human activities affecting the environment are reported in Table 1.

Table 1 – General surveys information: cloud cover scale, Beaufort wind force scale and event notes.

Date	Cloud cover	Beaufort scale	Event notes
Nov 2019	Cloudy	7 – Near gale	At the beginning 1st sea-storm, high-water and flooding of Po
Dec 2019	Clear	4 – Moderate breeze	After 1st sea-storm; declining phase of high-water and flooding of Po
Feb 2020	Clear	4 – Moderate breeze	After 2nd sea-storm
June 2020	Clear	4 – Moderate breeze	After Covid-19 lockdown and before tourist season
Oct 2020	Clear	1 – Light air	After tourist season

The location of the sampling area was selected according to the following criteria [21]: minimum length of 100 m longshore for a fixed 100-metre stretch; low/moderate slope (~ 1.5 – 4.5°); breakwaters or jetties absence; easy beach access guaranteed all year round; no/few additional human cleaning activities.

Therefore, the sampling area covered a 100 m long shore-parallel line, on-field divided in 10 transects (10 m wide) with a variable length depending on hydrodynamic conditions (min. 19.61 m; max. 47.46 m). The boundaries of the sampling site and of each transect were measured using a dGPS (Leica GS16) and geo-referenced in the coordinate system WGS 84 UTM 32 N. In addition, a photogrammetric survey was carried out using an "Unmanned Aerial System Vehicle" (model 4 pro obsidian DJI phantom multirotor drone equipped with a high-resolution camera – 20 Mpixel) in order to generate an orthomosaic image for each campaign. The geo-referenced orthophotos were imported in QGIS software to calculate the sampling area in order to relate the number of collected items to a defined surface (Figure 2).

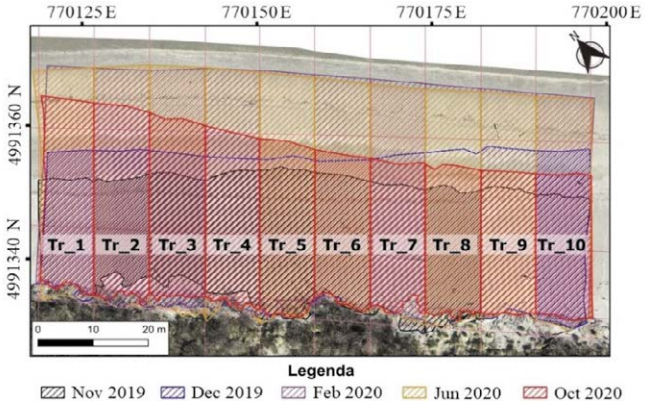

Figure 2 – Transects and sampling site for each survey, highlighted by five different colours (on February 2020 orthophoto).

Adapting [14], all stranded litter items (ranging from 2.5 cm to 50 cm) were collected and classified according to the potential main sources of release and buoyancy properties (i.e. density, weight and surface-to-volume ratio). Furthermore, the density of marine litter items per square meter [12] was calculated and then the beach cleanliness status was evaluated using the Clean Coast Index (CCI, Table 2 and Table 3) [2].

Table 2 – Clean Coast Index: value and definition for each quality class.

Quality	Value	Definition
Very clean	0 – 2	No litter is seen
Clean	2 – 5	No litter is seen over a large area
Moderate	5 – 10	A few pieces of litter can be detected
Dirty	10 – 20	A lot of litter on the shore
Very dirty	> 20	Most of the beach is covered with litter

Results

A total of 5578 debris items were collected and the average marine litter density is 0.35 items/m^2 (± 0.13 SD) (Table 3). In particular, the calculated density of autumn/winter period (Nov - Dec 2019 and Oct 2020) is higher than the late-winter/early-summer period. These values heavily depend on the dimensions of the beach and seasonality. The calculation of the Clean Coast Index (CCI) indicates that Boccasette beach was moderately clean during the autumn and winter season, and clean from February to June 2020 (Table 3).

Table 3 – Marine litter density and Clean Coast Index for each survey.

Date	Area (m^2)	Collected items (n.)	Marine litter density (items/m^2)	CCI [(items/m^2) • K]
Nov-2019	2326.94	1015	0.44	8.72
Dec-2019	2912.59	1203	0.41	8.26
Feb-2020	4372.92	1078	0.25	4.93
Jun-2020	4412.81	801	0.18	3.36
Oct-2020	3063.03	1481	0.48	9.67

Our results indicate that the collected items can be referred to 8 macro categories of materials (artificial polymer materials, rubber, cloth/textile, paper/cardboard, processed/worked wood, metal, glass/ceramics, unidentified and/or chemicals) and to 105 categories of items (identified by an alphanumeric code: "G + number"). The main macro-category of materials is artificial polymer (plastic), representing about 96 % of collected items, while the other macro-categories represent the 4 % of the total.

Depending on the main sources of release, the items have been categorized in:

- Improper waste disposal: 55 represented categories and 3708 items collected, referring to improper waste disposal and urban wastewater, whose release and transport into the marine environment is mainly driven by river; the most represented are: "G79 - Plastic pieces 2.5-50 cm" (17.75 %), "G21 - Plastic caps/lids drinks" (8.87 %), "G5 - Plastic bag collective role; what remains from rip-off plastic bags" (8.79 %) and "G95 - Cotton bud sticks" (8.58 %);
- Fishing/aquaculture activities: 14 represented categories and 1640 items collected, referring to maritime activities (including fishing and aquaculture), whose release may be more or less accidental; the most represented are: "G82 - Polystyrene pieces 2.5-50 cm" (47.13 %) identified as products of fragmentation or degradation of fishing boxes, and "G45 - Mussels nets" (41.16 %).

Regarding the two subsets, the values have been normalized (by dividing the number of collected items of each subset, with the number of total categories), and the relative percentage has been reported in Figure 3.

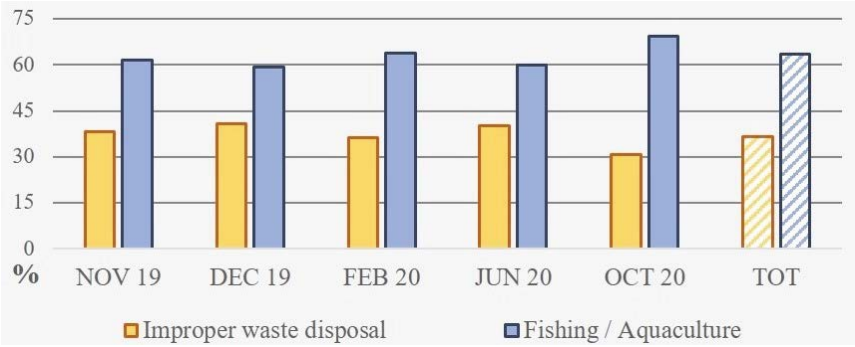

Figure 3 – Comparison of the percentage between improper waste disposal and fishing/aquaculture activities items, for each survey. Last columns: comparison of the total percentage.

In proportion, it is possible to observe a preponderance of the items attributed to the fishing/aquaculture subset compared to the improper waste disposal. Referring to the variation of items categories collected concurrently with the extreme meteorological events, we notice an increase of mussel nets and a substantial reduction of polystyrene pieces in November 2019 and February 2020. Furthermore, a considerable increase of polystyrene pieces (mostly fragments of fishing box) related to fishing activities has been observed during the survey of October 2020.

The classification of the items according to their buoyancy properties indicates that:

- Sinking items included 38 categories and 2524 items; the most represented are: “G79 - Plastic pieces 2.5-50 cm”, “G21 - Plastic caps/lids drinks”, "G95 - Cotton bud sticks";
- Floating items were associated to 30 categories and 2790 items collected; the most represented are: "G82 - Polystyrene pieces 2.5-50 cm", "G45 - Mussels nets", "G5 - Plastic bag collective role; what remains from rip-off plastic bags".

Even regarding the two subsets just listed, the values have been normalized and the relative percentage has been reported in Figure 4.

In general, there is a preponderance of the floating items compared to the sinking one, except for the survey of November 2019, in which it has been observed a considerable reduction of polystyrene pieces (floating) and an additional increase of plastic pieces (G79) and cotton bud sticks (G95).

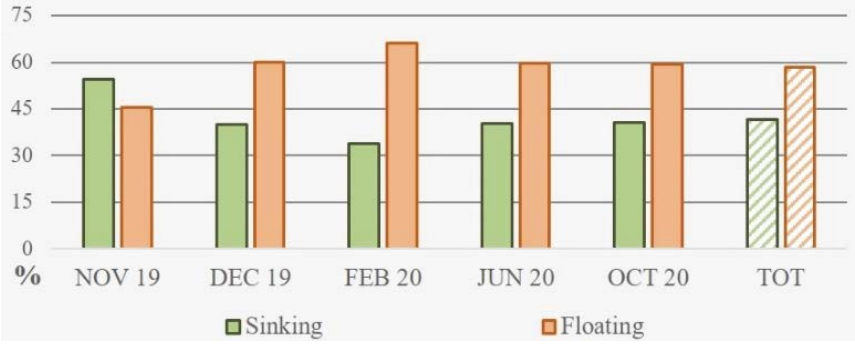

Figure 4 – Comparison of the percentage between sinking and floating items for each survey. Last columns: comparison of the total percentage.

Discussion

In this study, five marine litter surveys were performed to define the density of stranded items and the cleanliness level of Boccasette beach. The collected items have been referred to the main human activities that have caused the release in the environment. In addition, we linked the main results the items' buoyancy properties.

Regarding the beach marine litter density, our results (0.35 items/m^2, ± 0.13 SD) are in agreement with previous studies conducted on Boccasette beach (0.38 items/m^2, ± 0.26 SD) [21]. However, from field observations, it emerged that the marine litter accumulation mainly occurs in the upper sector of the beach, where the presence of vegetation or beach wrack may trap the items. Therefore, the effective marine litter accumulation zone is smaller than the whole beach, and this can result in marine litter density underestimation, but also overestimation of the results of Clean Coast Index. For this reason, despite for Boccasette beach the CCI values obtained, are encouraging, it would be more appropriate to use a multidisciplinary approach (for example, by also integrating the "Accumulation Index" [6]), that can take into account more local variables to define cleanliness level.

Concerning the marine litter composition, we do not generally observe a precise trend of the identified categories. However, the decrease of all collected items in June 2020 (Table 3), compared to the other surveys, can be explained as a result of some main contributing factors, which are: Covid-19 restrictive measures, forced interruption of human activities, delay of starting tourist season and beach management activities.

During spring 2020 the Covid-19 lockdown negatively impacted all human activities. Indeed, the fishing/aquaculture activities have been interrupted and the tourist

season, that in Italy usually starts in May, in 2020 started in June. That caused a delay in the beach management activities along Boccasette spit, in particular the mechanized cleaning activities performed by the local authorities or the beach resorts' managers (usually carried out during summer seasons, close to beach facilities, located approximately 1000 m northward of the sampling site). Despite having been maintained the main criterion of site selection (no/few additional human cleaning activities), we believe that such cleaning activities may have directly influenced the marine litter abundance in June 2020.

It has been argued that the main human activities performed in a specific area affect the typology of the marine litter stranded on the adjacent coastal area (e.g. [8]). Our results show as the highest number of stranded marine litter on Boccasette beach are usually related to improper waste disposal. However, considering the scarce presence of items directly attributable to tourist activities (food packaging, beach use related cosmetic bottles, straws, etc.) on Boccasette beach the impact related to tourism can be considered less relevant compared to other studies (e.g. [18]). Moreover, the abundance of items referable to urban wastewater (e.g. cotton bud sticks, plastic pieces including many filters from wastewater spill), suggests that the study area is affected by a constant marine litter input, whose release and transport into the marine environment is most probably driven by the Po river.

Our results also indicate that fishing/aquaculture activities are also responsible of the presence of marine debris along Boccasette beach prevail over the improper waste disposal. Specifically, during October 2020 survey (just after fishery closed season, which occurs in August) it is possible to observe a considerable increase of polystyrene pieces associated to fishing activities. Similar results have been obtained by [20], which reported that high debris in autumn could also be related to intensive fishing activities. In addition, the increase of the marine litter observed at October 2020 could not be attributed to meteorological events since before the survey the marine and weather conditions were calm. Therefore, we believe that the restart of fishing activities (post-lockdown and post fishery closed season) may have mainly contributed to the accumulation of polystyrene fragments from fishing boxes on the beach.

Furthermore, concerning the aquaculture, an exceptional abundance of mussel nets (that also belong the floating subset) has been observed in February 2020 mostly as a consequence of some sea-storms occurred in winter season. In concomitance of extreme meteorological events, it is possible to observe a variation of specific collected items, also related to buoyancy properties. Generally, it has been generally observed a predominance of floating stranded marine litter compared to the sinking ones, except at November 2019. In fact, in this occasion sinking items prevailed on the floating ones. We refer this trend to the timing of the monitoring campaign, that has been conducted just at the beginning of the extreme events (Table 1). The increase of sinking items (also related to wastewater release) could be related to Po flooding and high-water. Such impact of flooding events on marine litter transporting has been reported by different authors. For instance, [9] observed a large amount of marine debris was washed up on the beaches of Geoje Island (South Korea) after a period of heavy rainfall in July 2011, affecting the island's tourism industry. Furthermore, the results of [16] showed a potential worldwide plastic mobilisation increase (even tenfold) during flood events. However, it is difficult identified when exactly the marine litter accumulates on the beaches, and further studies are needed to understanding the pathways of marine litter in the environment, and in particular in highly dynamic ecosystems as the lagoons.

Conclusion

In this study, the quantification and categorization of the macro litter along a sandy spit of the Po Delta have been analysed, in relation to meteorological conditions and main human activities. The results indicate that along Boccasette beach the evaluation of the marine litter density and Clean Coast Index can be used for management purpose. However, we suggest that the monitoring activities should be modified by dividing the stretch in different zones, according to geomorphological criteria, and integrating a multidisciplinary approach.

The distribution of the marine litter shows that most of the items were fragments of artificial polymer materials, of which the 69 % of the items were released from land-based human activities (improper waste disposal), while about 31 % were related to fishery and aquaculture activities. Consequently, much of the marine litter found on Boccasette beach can be associated to local economic activities, and also to external sources (wastewater), confirming the role of the fluvial transport and of the meteorological factors. Therefore, specific management approaches are needed to minimize the impacts of river's flooding events. In addition, our results suggest that specific educative activities for fishermen and fish-farmers should be performed in order to reduce the release of new marine litter and to implement the awareness regarding the plastic pollution.

Finally, the importance of human factors has been illustrated in relation to the Covid-19 specific situation. The low abundance of marine litter items collected during early-summer 2020 could also be related to the positive impact of the lockdown restrictive measures. Litter impacts on beaches include deterioration of coastal and marine environment, human health hazards, and substantial financial investments for cleaning activities. Therefore, additional data are needed regarding the spatiotemporal trends of marine litter in different coastal environments.

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References

[1] Addamo A.M., Brosich A., Chaves Montero M.D.M., Giorgetti A., Hanke G., Molina Jack M.E., Vinci M. (2019) - *Marine litter database: Lessons learned in compiling the first pan-European beach litter database*, EUR 29469 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-97867-8.

[2] Alkalay R., Pasternak G., Zask A. (2007) - *Clean-coast index-a new approach for beach cleanliness assessment*, Ocean Coast. Manag. 50 (5), 352 - 362.

[3] European Commission (2016) - *Study on specific challenges for a sustainable development of coastal and maritime tourism in Europe*, Luxembourg. Publ. Office Eur. Union 348.

[4] Goldberg E.D. (1995) - *The health of the oceans–a 1994 update*, Chem. Ecol. 10, 3-8.

[5] Goldberg E.D. (1997) - *Plasticizing the seafloor: an overview*, Environ. Technol. 18, 195 - 202.
[6] Grelaud M., Ziveri P. (2020) - *The generation of marine litter in Mediterranean island beaches as an effect of tourism and its mitigation*, Sci. Rep., 10(1), 1 - 11.
[7] Hansen J. (1990) - *Draft position statement on plastic debris in marine environments*, Fisheries 15, 16 - 17.
[8] Hinojosa I.A., Thiel M. (2009) - *Floating marine debris in fjords, gulfs and channels of Southern Chile*, Mar. Pollut. Bull. 58, 341 - 350.
[9] Jang Y.C., Hong S., Lee J., Lee M.J., Shim W.J. (2014) - *Estimation of lost tourism revenue in Geoje Island from the 2011 marine debris pollution event in South Korea*, Mar. Poll. Bull., 81(1), 49-54.
[10] Jayasiri H.B., Purushothaman C.S., Vennila A. (2013) - *Quantitative analysis of plastic debris on recreational beaches in Mumbai*, India, Mar. Pollut. Bull. 77, 107 - 112.
[11] Kusui T., Noda M. (2003) - *International survey on the distribution of stranded and buried litter on beaches along the Sea of Japan*, Mar. Pollut. Bull. 47, 175 - 179.
[12] Lippiatt S., Opfer S., Arthur C. (2013) - *Marine Debris Monitoring and Assessment*, NOAA Technical Memorandum NOS-OR&R-46.
[13] Madricardo F., Ghezzo M., Nesto N., Kiver M., Joseph W., Faussone G.C., Fiorin R., Mackelworth P.C., Basta J., De Pascalis F., Kruss A., Petrizzo A., Moschino, V. (2020) - *How to deal with seafloor marine litter: an overview of the state-of-the-art and future perspectives*, Front. Mar. Sci. 830.
[14] Palatinus A., Kovač Viršek M., Kaberi E. (2015) - *DeFishGear protocols for sea surface and beach sediment sampling and sample analysis*.
[15] Pasternak G., Zviely D., Ribic C.A., Ariel A., Spanier E. (2017) - *Sources, composition and spatial distribution of marine debris along the Mediterranean coast of Israel*, Mar. Pollut. Bull. 114, 1036 - 1045.
[16] Roebroek C.T., Harrigan S., Van Emmerik T.H., Baugh C., Eilander D., Prudhomme C., Pappenberger F. (2021) - *Plastic in global rivers: are floods making it worse?*, Environ. Res. Lett., 16(2), 025003.
[17] Ryan P.G. (1987) - *The origin and fate of artefacts stranded on islands in the African sector of the Southern Ocean*, Environ. Conserv. 14, 341 - 346.
[18] Schmid C., Cozzarini L., Zambello E. (2021) - *Microplastic's story*, Mar. Poll. Bull. 162, 111820.
[19] Simeoni U., Corbau C. (2009) - *A review of the Delta Po evolution (Italy) related to climatic changes and human impacts*, Geomorphology, 107 (1-2), 64 - 71.
[20] Topçu E.N., Tonay A.M., Dede A., Öztürk A.A., Öztürk B. (2013) - *Origin and abundance of marine litter along sandy beaches of the Turkish Western Black Sea Coast*, Mar. Environ. Res., 85, 21-28.
[21] Vlachogianni T., Fortibuoni T., Ronchi F., Zeri C., Mazziotti C., Tutman P., Bojanić Varezić D., Palatinus A., Trdan S., Peterlin M., Mandić M., Markovic O., Prvan M., Kaberi H., Prevenios M., Kolitari J., Kroqi G., Fusco M., Kalampokis E., Scoullos M. (2018) - *Marine litter on the beaches of the Adriatic and Ionian Seas: An assessment of their abundance, composition and sources*, Mar. Poll. Bull. 131, 745 - 756.