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# TESIS DOCTORAL

**Distribución y composición de residuos sólidos en playas mediterráneas y atlánticas (Alicante y Cádiz). Relaciones con la geomorfología y usos de las playas e implicaciones para la gestión**

**Distribution and composition of beach litter in Mediterranean and Atlantic coasts (Alicante and Cádiz). Relationships with geomorphology and beach uses and implications for management**

por

FRANCISCO ASENSIO MONTESINOS

Director:

Dr. Giorgio Anfuso

# ÍNDICE

**AGRADECIMIENTOS……i**
**LISTA DE PUBLICACIONES…… iii**
**RESUMEN……iv**
***ABSTRACT*……v**
**1. INTRODUCCIÓN GENERAL Y OBJETIVOS……...…1**
1.1. Las Características de la Costa y los Residuos Sólidos……..1
1.2. Objetivos……...…3
**2. ÁREA DE ESTUDIO……4**
2.1. El litoral Mediterráneo de Alicante: La Costa Blanca del País Valencià…….4
*2.1.1. Contexto social, cultural y económico*……4
*2.1.2. Condiciones ambientales*…….7
2.2. El litoral Atlántico de Cádiz: La Costa de la Luz de Andalucía……10
*2.2.1. Contexto social, cultural y económico*……..10
*2.2.2. Condiciones ambientales*……...12
**3. MATERIALES Y MÉTODOS……15**
3.1. Características generales……...15
*3.1.1. Los tipos de playas*……15
3.2. Evaluación de residuos sólidos……19
*3.2.1. Cuantificación y clasificación de residuos*……19
*3.2.2. Análisis de las bases de datos*……22
*3.2.3. Análisis y clasificación mediante espectroscopia Raman* …… 24
**4. RESULTADOS……26**
4.1. Los residuos sólidos en la costa de Alicante.……26
4.2. Los residuos sólidos en la costa de Cádiz.……32
4.3. Las colillas en la costa: un problema común.……37
**5. DISCUSIÓN……41**
5.1. Las playas mediterráneas de Alicante……....41
5.2. Las playas atlánticas de Cádiz……48
5.3. Las colillas y su impacto……...56
**6. CONCLUSIONES……...……61**
**BIBLIOGRAFÍA……...……...…63**
**Material complementario……...75**
Tabla S1. Grupos de residuos por tipo de material……75
Fotografías de residuos observados en Alicante……79
Fotografías de residuos observados en Cádiz……80

**ARTÍCULOS DE INVESTIGACIÓN**

- **Anexo I: Beach litter distribution along the western Mediterranean coast of Spain**
- **Anexo II: Seasonal comparison of beach litter on Mediterranean coastal sites (Alicante, SE Spain)**
- **Anexo III: Litter behaviour on Mediterranean cobble beaches, SE Spain**
- **Anexo IV: Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain)**
- **Anexo V: Characterization of plastic beach litter by Raman spectroscopy in South-western Spain**
- **Anexo VI: Abundance and Distribution of Cigarette Butts on Coastal Environments: Examples from Southern Spain**

**PLAN DE INVESTIGACIÓN**

**DOCUMENTO DE ACTIVIDADES FORMATIVAS**

**INFORME DEL DIRECTOR**

**INFORME DEL FACTOR DE IMPACTO Y CUARTIL**

**INFORME DE LA CONTRIBUCIÓN DEL DOCTORANDO**

**CONFORMIDAD DE LOS AUTORES**

## ÍNDICE DE TABLAS

**Tabla 1.** Metodología de clasificación por tipo de residuos (EA/NALG, 2000)…….21

**Tabla 2**. Número de los 10 tipos de residuos recientes o "nuevos" más abundantes durante el periodo de estudio en cada evaluación…….31

**Tabla 3**. Fechas de los estudios realizados sobre colillas en playas……39

**Tabla 4**. Número de evaluaciones y valores de abundancia de colillas (media y mediana) por tipología de playas……..40

**Tabla S1**. Códigos y descripción de los grupos de residuos por tipo de material…….75

# ÍNDICE DE FIGURAS

**Figura 1**. Localización de las provincias de Alicante y Cádiz……....4

**Figura 2**. Costa urbanizada de Alicante: Playa de La Mata en Torrevieja…….….5

**Figura 3**. Postal de la playa del Postiguet, Alicante (año 1970)……6

**Figura 4**. Costa urbanizada de Alicante: Playa de Ponent en Benidorm y Playa Carrer la Mar en El Campello……..6

**Figura 5**. Rosa de viento en la costa de Alicante para el periodo 1958 – 2021……7

**Figura 6**. Rosa de Altura significante para oleaje en Alicante para el periodo 1958 – 2021……..8

**Figura 7**. La costa más natural de Alicante: la Cala d'Ambolo y la Cala del Moraig ubicadas en la parte norte de la provincia (Xàbia y Poble Nou de Benitatxell)……...8

**Figura 8**. La costa más natural de Alicante: las playas de Les Ortigues y El Pinet ubicadas al sur de la provincia (Guardamar del Segura y Elx)……..…….9

**Figura 9**. Costa urbanizada de Cádiz: arriba, la Playa de la Victoria (Cádiz) en los años 60; abajo, a la izquierda, la Playa de la Caleta (Cádiz) y, a la derecha, la playa de la Cachucha (Puerto Real) en la actualidad……..11

**Figura 10**. La costa más natural de Cádiz: panorámica de una de las calas de Roche, Chiclana de la Frontera (arriba); abajo a la izquierda la playa de la Princesa Alejandra (Conil de la Frontera) y a la derecha la playa de Camposoto, San Fernando…….13

**Figura 11**. Rosa de viento en la costa de Cádiz para el periodo 2012 – 2021 ……...13

**Figura 12**. Rosa de Altura significante para oleaje en Cádiz para el periodo 2012 – 2021……..14

**Figura 13**. Ejemplos de los tipos de playas estudiadas: a la izquierda la Platja de Llevant (Alicante) y a la derecha la playa de la Caleta (Cádiz), urbanas…..……..16

**Figura 14**. Ejemplos de los tipos de playas estudiadas: a la izquierda la playa El Portet (Alicante) y a la derecha la playa de Valdelagrana (Cádiz), semiurbanas……16

**Figura 15**. Ejemplos de los tipos de playas estudiadas: arriba a la izquierda la Calas del Cuartel (Alicante) y arriba a la derecha la playa de Bolonia (Cádiz); abajo a la izquierda la Cala del Xarco y abajo a la derecha la Cala Cantalars (Alicante), rurales.……17

**Figura 16**. Ejemplos de los tipos de playas estudiadas: a la izquierda la Platja Gran (Isla de Nueva Tabarca, Alicante) y, a la derecha, la playa de Trafalgar (Cádiz), remotas…….18

**Figura 17**. Perfil transversal de playa idealizado que muestra las posiciones del nivel del mar y las zonas de playa estudiadas……..19

**Figura 18**. Espectrómetro Raman dispersivo Jasco, modelo NRS-7200 con láseres de excitación de 532 nm, 785 nm y 1064 nm de longitud de onda. Máxima resolución 0.7 $cm^{-1}$. Intervalo espectral 10 – 8000 $cm^{-1}$…….….25

**Figura 19**. Localización de los lugares estudiados de Alicante……..26

**Figura 20**. Residuos de playa durante la primavera del 2018 en la costa de Alicante. **a)** Composición de los residuos y **b)** Fuentes u origen de los residuos……..…27

**Figura 21**. Residuos de playa durante el verano del 2018 en la costa de Alicante…….….28

**Figura 22**. Gráfico de interacción. Comparación de valores medios de residuos por tipología de playa en primavera y verano……29

**Figura 23**. Localización de las 5 playas investigadas durante el invierno en Alicante……30

**Figura 24**. Localización de las playas estudiadas de Cádiz…….....32

**Figura 25**. Composición de los residuos de playa durante octubre de 2018 en la costa de Cádiz…33

**Figura 26**: Espectros Raman de referencia pertenecientes a varias muestras de residuos: un vaso (PP), un tapón (PE-HD), una cucharilla (PS), una botella (PET) y una de derivación de PVC. Abajo, las fotografías realizadas a 20 aumentos a dichas muestras: Polipropileno (PP) y Polietileno (PE); poliestireno (PS), tereftalato de polietileno (PET) y cloruro de polivinilo (PVC)…….35

**Figura 27**. Proporciones por tipo de plástico…….36

**Figura 28**. Fragmentos de plástico analizados, provenientes de una de las playas estudiadas (escala en centímetros) …….37

**Figura 29**. Localización de las tres provincias estudiadas……38

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## LISTA DE PUBLICACIONES

Esta tesis doctoral se basa en las siguientes seis publicaciones (Anexos I; II; III; IV; V; VI), a las que se hará referencia mediante la siguiente numeración:

| | |
|---|---|
| Asensio-Montesinos et al., **I** | Asensio-Montesinos, F., Anfuso, G., & Williams, A.T. (2019). Beach litter distribution along the western Mediterranean coast of Spain. *Marine Pollution Bulletin, 141*, 119-126. |
| Asensio-Montesinos et al., **II** | Asensio-Montesinos, F., Anfuso, G., Randerson, P., & Williams, A.T. (2019). Seasonal comparison of beach litter on Mediterranean coastal sites (Alicante, SE Spain). *Ocean & Coastal Management, 181*, 104914. |
| Asensio-Montesinos et al., **III** | Asensio-Montesinos, F., Anfuso, G., Williams, A.T., & Sanz-Lázaro, C. (2021). Litter behaviour on Mediterranean cobble beaches, SE Spain. *Marine Pollution Bulletin, 173*, 113106. |
| Asensio-Montesinos et al., **IV** | Asensio-Montesinos, F., Anfuso, G., Oliva Ramírez, M., Smolka, R, García Sanabria, J., Fernández-Enríquez, A., Arenas, P., & Macías Bedoya, A. (2020). Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain). *Regional Studies in Marine Science, 34*, 101050. |
| Asensio-Montesinos et al., **V** | Asensio-Montesinos, F., Oliva Ramírez, M., González-Leal, J.M., Carrizo, D., & Anfuso, G. (2020). Characterization of plastic beach litter by Raman spectroscopy in south-western Spain. *Science of the Total Environment, 744,* 140890. |
| Asensio-Montesinos et al., **VI** | Asensio-Montesinos, F., Oliva Ramírez, M., Aguilar-Torrelo, M. T., & Anfuso, G. (2021). Abundance and Distribution of Cigarette Butts on Coastal Environments: Examples from Southern Spain. *Journal of Marine Science and Engineering, 9*(2), 129. |

## RESUMEN

Los residuos marinos son todos aquellos materiales procesados que se desechan, se depositan o se abandonan de manera voluntaria o involuntaria en playas, o que acaban llegando a los ambientes marinos y costeros a través de diferentes medios. En el marco de esta tesis doctoral, la cantidad y composición de los residuos sólidos en la costa ha sido estudiada en un periodo de cuatro años: desde 2018 hasta 2021. Los estudios se han realizado en primavera, verano, otoño e invierno, y en diferentes tipos de ambientes costeros: Mediterráneos y Atlánticos. Se han llevado a cabo un total de 187 evaluaciones de residuos en 59 playas de Alicante y 40 de Cádiz que, junto con otros estudios complementarios, sumaron un total de 349 visitas a 124 playas. Los lugares seleccionados cubren diferentes tipologías de playa según su nivel de urbanización y cantidad de visitantes, que aumentan progresivamente de sitios remotos y rurales a parcialmente urbanizados y urbanos. De todos los residuos, el plástico fue, por lo general, el material más frecuente y, dentro de ellos, los residuos más numerosos fueron las colillas de cigarrillos. Los residuos se relacionaron principalmente con los usuarios de las playas, con vertidos de aguas residuales y con actividades pesqueras. Además, se comparó la abundancia y la composición de residuos en periodos diferentes para relacionarlos con el número de usuarios y situaciones climáticas u oceanográficas particulares. Complementariamente, se realizaron diferentes estudios geomorfológicos para tener una información más detallada de las playas investigadas. Las playas de Alicante se clasificaron según el tipo de sustrato o sedimento, es decir, playas con arena, grava, cantos rodados, plataforma rocosa, etc. En las playas de Cádiz, más parecidas entre ellas geomorfológicamente hablando, se optó por realizar un estudio más detallado mediante perfiles topográficos de playas, ya que todos los sitios estudiados en la costa atlántica están compuestos por playas arenosas y, además, están influenciados por mareas de entre 2 y 4 m de amplitud (ambiente mesomareal), variaciones mucho mayores que aquellas observadas en las playas mediterráneas (que son micromareales). Además, se realizó la identificación de los materiales plásticos que formaban parte de los residuos de playa mediante espectroscopia Raman, una técnica que permitió la clasificación de dichos residuos según su composición. Finalmente, se destacó el tema de las colillas en ambientes costeros por ser el residuo personal más abundante en el mundo y por tener un gran potencial de contaminación.

**ABSTRACT**

Marine litter includes all those processed materials that are discarded, deposited or abandoned voluntarily or involuntarily on beaches, or that end-up in marine and coastal environments through different inputs. In this research, the amount and composition of beach litter has been studied over a period of three years: from 2018 to 2021. Field works have been carried out in spring, summer, autumn and winter, and in different types of coastal environments: Mediterranean and Atlantic. A total of 187 litter assessments have been carried out at 56 beaches in Alicante and 40 in Cádiz. All such assessments, together with other complementary studies, reached a total of 349 visits in 124 beaches. The sites selected were classified into different typologies according to the level of urbanization and number of beach visitors, aspects that progressively increase from remote and rural to village and urban environments. Regarding beach litter composition, plastic was generally the most frequent material and, among plastic items, cigarette butts were the most numerous items. Litter was mainly related to beach users, sewage discharges and fishing activities. In addition, the abundance and composition of litter in different periods were compared in order to relate them to the number of users and particular climatic or oceanographic conditions. In addition, different geomorphological studies were carried out to obtain more detailed information on the beaches investigated. The beaches of Alicante were classified according to the type of substrate or sediment, i.e. sand, gravel, pebbles, rocky platform, etc. On the beaches of Cádiz, which are geomorphologically more similar among them and composed of sand, it was decided to carry out a more detailed study making beach topographic profiles. All the sites studied on the Atlantic coast are influenced by tides between 2 and 4 m in amplitude (mesotital environment), which are much greater than those of Mediterranean beaches (microtidal). In addition, the identification of the plastic materials that formed part of the beach litter was carried out using Raman spectroscopy, a technique that allowed plastic litter classification into different types. Finally, the problem of cigarette butts in coastal environments was analysed in detail since they constitute the most abundant personal litter item in the world and have a high pollution potential.

# 1. INTRODUCCIÓN GENERAL Y OBJETIVOS

## 1.1. Las Características de la Costa y los Residuos Sólidos

La costa es la zona marítimo terrestre o espacio comprendido ente la línea de bajamar y el límite hasta donde alcanzan las olas en los mayores temporales conocidos (Real Decreto 876/2014). Dicha área también se le puede denominar litoral, este término hace referencia a la franja de tierra que bordea el mar o la zona que une los ecosistemas terrestres con los ecosistemas acuáticos (Suárez de Vivero, 1999). Entre las zonas morfológicas litorales y marinas más destacables se encuentran archipiélagos, islas, penínsulas, istmos, cabos, acantilados, deltas, golfos, bahías y, en general, las playas. Estas últimas pueden ser definidas como acumulaciones detríticas de arena, grava o cantos en ambientes deposicionales litorales (Davis, 1978). Los ecosistemas costeros como las playas son ambientes muy dinámicos que están en continuo cambio y evolución ya que se pueden producir alteraciones anuales, mensuales, diarias o incluso horarias, bien por causas naturales o antrópicas. Los sedimentos de las playas están sujetos a un transporte continuo en dirección transversal y longitudinal bajo la acción del oleaje, que constituye, por lo general, el factor dinámico dominante (Johnson, 1919; King, 1972; Bird, 1984; Carter, 1988).

Entre las distintas partes principales de un perfil ideal de la zona litoral desde mar hacia tierra se puede diferenciar en primer lugar el *shoreface* o la zona infralitoral (Dabrio, 1989), también conocida como playa sumergida, que es la franja comprendida desde la base del *foreshore* hasta el nivel de base del oleaje. A continuación, se encuentra el *foreshore* o zona intermareal o de batida (Dabrio, 1989), que es donde se produce el recorrido de la marea. La *beach face* es la cara de la playa donde se dan los procesos de *swash-backswash* (flujo-reflujo), es decir la zona donde el oleaje rompe en la orilla y da lugar a un flujo de agua que sube y baja en la cara de la playa, y donde se produce una intensa erosión durante las tormentas (Lanckriet, 2014). Finalmente se encuentra el *backshore* o zona supralitoral, también conocido como trasplaya (Dabrio, 1989), que es la parte seca de la playa, que solo es afectada por fuertes tormentas coincidiendo con mareas vivas (CERC, 1984).

En el medio natural, las alteraciones en la costa se pueden producir por agentes dinámicos como, por ejemplo, temporales marítimos o fuertes precipitaciones. El aspecto de una misma playa puede variar mucho a lo largo del año y se pueden encontrar diferencias importantes, por ejemplo, entre invierno y verano. Sin embargo, las alteraciones por motivos naturales, no tienen

un impacto negativo tan grande como los cambios en el medio producidos por causas de origen antrópico. Algunos ejemplos son las construcciones ubicadas cerca o dentro del mar como viviendas, paseos marítimos, espigones y puertos. Otras actuaciones también pueden modificar el aspecto de la costa, ya sea para bien o para mal. Por ejemplo, la recuperación de un ecosistema costero mediante actuaciones que favorezcan su estado original, la eliminación de construcciones innecesarias e ilegales, o las controvertidas regeneraciones de playa que, a parte de los motivos económicos que las promueven, pueden afectar negativamente a diversas especies, modificando aspectos naturales y propios de cada playa como la granulometría y el color de la arena (Pranzini et al., 2016; Asensio-Montesinos et al., 2020). Por ello, cualquier actuación de origen antrópico puede tener implicaciones importantes en la costa que pueden afectar de diversas maneras a las especies presentes, al entorno físico o incluso a la economía local.

Son varias las causas antrópicas que afectan negativamente a muchas playas del mundo, quizá la más notable sea la construcción intensiva cerca del litoral. Sin embargo, la presencia de residuos en la costa durante las últimas décadas es bastante preocupante debido a todos los daños que estos causan a los ecosistemas y a las especies que los habitan. Además, todavía se desconocen los efectos perjudiciales que tendrán los residuos en el futuro. El interés y el estudio de estos residuos se ha incrementado en las últimas décadas y muchas investigaciones han contribuido en proporcionar datos muy valiosos a cerca de su abundancia, composición, orígenes, y efectos que pueden tener en la costa, en los visitantes y en la flora y fauna (Willoughby et al., 1997; Santos et al., 2005; Rosevelt et al., 2013; Ryan et al., 2014; Poeta et al., 2016a; Williams et al., 2016a; Rangel-Buitrago et al., 2017; Prevenios et al., 2018).

En las últimas décadas, la contaminación de los mares y océanos por parte de los residuos de origen antrópico se ha reconocido como un grave problema ambiental de escala global (Bergmann et al., 2015). Las zonas costeras se han visto cada vez más afectadas y amenazadas por las actividades humanas, siendo la contaminación y el cambio climático algunas de las presiones más importantes que afectan a estos entornos (Cabral et al., 2019). Citando al célebre naturalista Félix Rodríguez de la Fuente… "*lo que más nos diferencia de todas las otras épocas y culturas, y lo que más preocupa y más verdaderamente puede transformar de forma radical la posición de la humanidad en el presente, es la basura*". Hace unos 50 años, Félix Rodríguez de la Fuente, ya informó de las numerosas bolsas de plástico y de los envases sin retorno que llenarían España y el resto del mundo, y ya hablaba

de "la Civilización de la Basura" (Planeta Azul, 1972). Por lo tanto, el problema de los residuos en el medio natural no es nuevo, ya se conoce desde hace décadas y con el paso del tiempo ha ido a peor. En poco tiempo, los residuos generados por los humanos se han distribuido de manera tan amplia que prácticamente se encuentran en todas partes, llegando a colonizar incluso lugares inhabitados como islas muy remotas (Fauziah et al., 2021). Por todo ello, es necesario seguir estudiando los residuos para poder combatir su eterna presencia y todos los daños que causan al medio natural.

En la actualidad, la presencia de los residuos sólidos en playas se ha convertido en un tema de investigación que lleva cobrando una importancia exponencial desde que se empezó a estudiar hace ya unas pocas décadas (Cesarano et al., 2021). De hecho, en el ámbito del turismo recreativo, los 5 criterios principales de preferencia (*the Big Five*) por los que los usuarios eligen una playa son: la seguridad, los servicios, la calidad del agua, el paisaje y la ausencia de residuos sólidos (Micallef et al., 1999; Morgan, 1999; Ünal y Williams, 1999; Ergin et al., 2004; Williams y Micallef, 2009; McKenna et al., 2011; Williams, 2011). Los *Big Five* están relacionados entre ellos (Asensio-Montesinos et al., 2019b) y la importancia de cada uno varía según la edad de los entrevistados, el género, la educación, la herencia cultural, etc. (Williams, 2011), así como el país donde se hayan realizado las encuestas (Botero et al., 2013).

### 1.2. Objetivos

Los objetivos de este estudio son la caracterización de la composición y abundancia de los residuos sólidos en la costa, prestando especial atención al material más abundante, el plástico, que se clasificará de acuerdo con su composición, según los tipos más utilizados en la actualidad. También se llevará a cabo la caracterización de la morfología de las playas investigadas y de su tipología o usos. Finalmente, se relacionará la presencia de los residuos con el medio físico de cada playa y con los usos de las mismas para comprender los diferentes comportamientos y la distribución de los residuos en ambientes costeros.

## 2. ÁREA DE ESTUDIO

El área de estudio se localiza en el sur de la Península Ibérica, territorio rodeado por el Mar Mediterráneo (desde Barcelona hasta Cádiz) y por el Océano Atlántico (desde Cádiz hasta el País Vasco). En detalle, el presente trabajo se ha realizado en diversas playas pertenecientes a dos provincias españolas: Alicante y Cádiz (Figura 1).




**Figura 1**. Localización de las provincias de Alicante y Cádiz.

### 2.1. El litoral Mediterráneo de Alicante: La Costa Blanca del País Valencià

#### *2.1.1. Contexto social, cultural y económico*

La provincia de Alicante (SE de la Península), con miles de años de historia humana, ha sido testigo del paso de diversas civilizaciones y pueblos de lo más diversos, cuales los íberos, griegos, fenicios, cartagineses, romanos, alanos, visigodos, árabes y magrebíes, entre otros. El sorprendente legado social y cultural que nos dejaron en tiempos pasados se puede consultar y observar hoy en día en numerosos estudios y museos. En muchas ocasiones, los restos históricos que nos dejaron estos antepasados son objetos (o fragmentos de objetos) de gran valor cultural provenientes de la vida cotidiana de los tiempos en los que vivieron. Pero, en la actualidad, la situación ha cambiado considerablemente y los restos de los materiales que dejaremos a las generaciones venideras o incluso en el registro geológico serán muy diferentes en cuanto a composición, cantidad e implicaciones ambientales.

En el año 2020, la población residente de la provincia de Alicante contaba con 1.879.888 habitantes, una cifra bastante importante si consideramos que la mayoría de las personas viven cerca de la costa y que la provincia de Alicante es de las que menos superficie tiene del territorio español (5.817 km$^2$). Actualmente, la densidad de población la convierte en la 5ª provincia más poblada de España. Existen varias zonas de alta densidad de población, pero la más destacable es, sin duda, la de la franja litoral de la provincia de Alicante también conocida como la "Costa Blanca", nombre inventado por una aerolínea internacional con el fin de promocionar vuelos a esta parte de la costa en el año 1957. A lo largo de todo el litoral, de sur a norte, existen varias ciudades muy importantes y con bastante población como por ejemplo Orihuela, Torrevieja, Elx, Alicante, Benidorm, y Dénia, entre otras. Ciudades que han crecido muchísimo debido al desarrollo turístico y al rápido proceso de urbanización desde 1950 hasta la actualidad. Casi un 20% de la población es de nacionalidad extranjera, una cifra muy alta en comparación al resto de provincias españolas. Esto se debe a que Alicante es un destino elegido por personas procedentes de distintas regiones del planeta. Además, cada año la provincia recibe miles de visitantes tanto nacionales como internacionales, especialmente en la temporada estival. Todos estos antecedentes hacen que actualmente la provincia alicantina sea de las más pobladas y diversas de España y esto se refleja en las diferentes actividades laborales y sociales a las que las personas dedican su tiempo y de las cuales proceden la gran parte de los residuos de los que trata este estudio.

Varios municipios costeros han experimentado un cambio importante en temas de urbanismo durante las últimas décadas que ha resultado en una transformación de sus playas al modificar las características naturales con la presión antrópica (Figura 2).



**Figura 2**. Costa urbanizada de Alicante: Playa de La Mata en Torrevieja.

La mayoría de los municipios de la costa de Alicante viven del turismo y se dedican al sector de los servicios desde hace muchos años. Por ejemplo, la emblemática playa del Postiguet situada en el centro de la bahía de Alicante ya presentaba en el año 1970 una elevada actividad turística, además de una intensiva construcción de viviendas cerca de la costa (Figura 3). Por lo que la construcción y los servicios de manutención han sido los principales promotores de la economía en gran parte del litoral.



**Figura 3**. Postal de la playa del Postiguet, Alicante (año 1970).

En unas décadas, algunos pueblos se han convertido en grandes ciudades debido al crecimiento del turismo residencial y estacional, como el caso de la ciudad de Benidorm, que pasó de ser un pueblo de pescadores en los años 50, a una de las ciudades con más rascacielos del mundo por metro cuadrado en la actualidad. Otros pueblos no han crecido tanto, como es el caso de El Campello, sin embargo, también presentan una elevada actividad turística y un litoral bastante urbanizado (Figura 4).

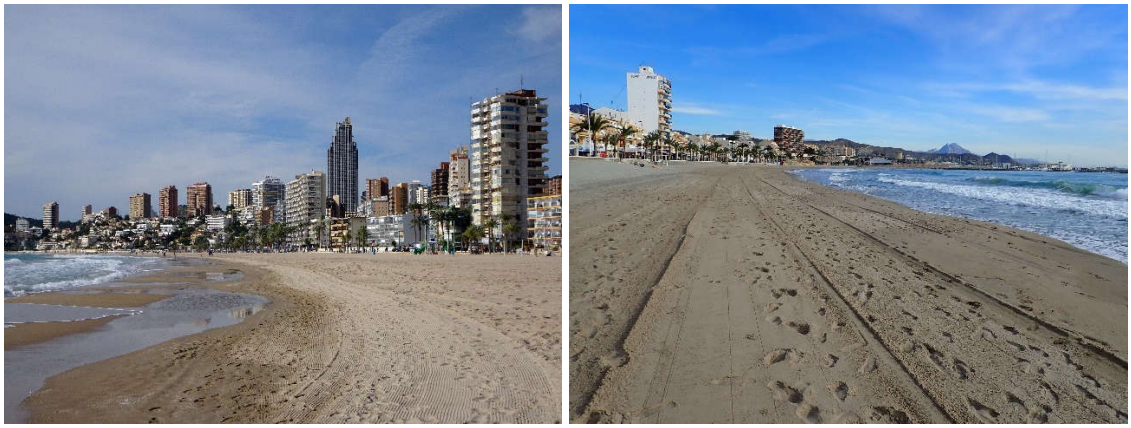


**Figura 4**. Costa urbanizada de Alicante: Playa de Ponent en Benidorm (izquierda) y playa Carrer la Mar (derecha) en El Campello (Fotografías por cortesía de Enzo Pranzini y Hugo Corbí).

### *2.1.2. Condiciones ambientales*

El litoral de Alicante se encuentra en la parte del Mediterráneo occidental, un mar con características oceanográficas y biogeográficas propias. El Mediterráneo cuenta con una biodiversidad excepcional a pesar de ocupar menos del 1% de la superficie oceánica mundial. Los aportes de agua dulce que recibe de tierra son escasos y las temperaturas son relativamente elevadas, al igual que la evaporación, esto lo convierte en uno de los mares con mayor salinidad, de 38 g/L. El mayor aporte de agua que recibe es a través del estrecho de Gibraltar: el agua atlántica menos salina, entra en superficie, mientras que el agua mediterránea más salina y densa sale por el fondo. Este fenómeno crea diferencias biogeográficas importantes que distinguen la parte del Mediterráneo occidental, de la parte más oriental.

El clima apacible de Alicante es clasificado como de estepa local, con una temperatura media anual de 17,7 °C y más de 300 días de sol al año que, junto con la oferta turística, convierten a la Costa Blanca en uno de los destinos preferidos de muchos turistas durante la mayor parte del año. La gente local a menudo denomina esta provincia como "*la millor terreta del món*", en parte debido a su buen clima durante casi todo el año. Los vientos, proceden mayoritariamente del ENE y NNE, con velocidades medias que superan los 8 m/s. Aunque con velocidades inferiores, los vientos procedentes de tierra, esencialmente de direcciones occidentales, adquieren también cierta importancia (Figura 5).

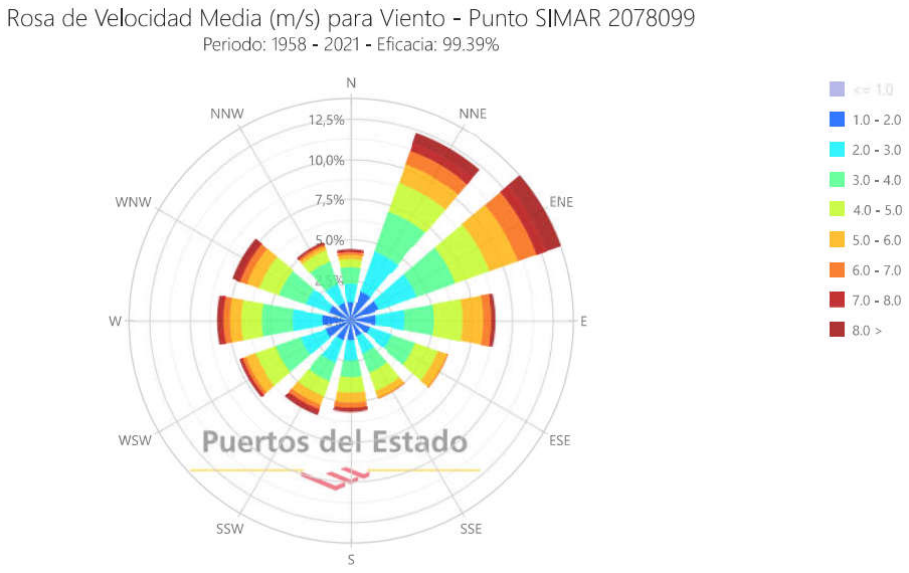



**Figura 5**. Rosa de viento en la costa de Alicante para el periodo 1958 – 2021.

El litoral de Alicante es micromareal, es decir el rango de marea es menor de 2 m de amplitud. Debido a la orientación costera, el oleaje predominante es de procedencia E con una altura significante de unos 2 m, y con menor influencia de procedencia ESE y SSE (Figura 6).

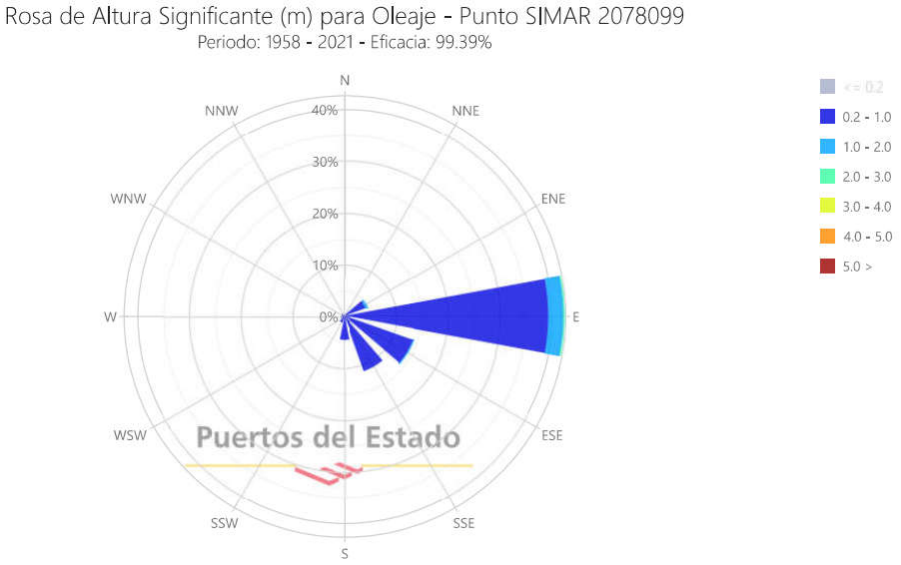



**Figura 6**. Rosa de Altura significante para oleaje en Alicante para el periodo 1958 – 2021.

Se trata de una costa de morfología caprichosa, mayoritariamente de orientación NE–SO con excepciones en la parte norte (orientada NO–SE) y sur (NNE–SSO). Sin duda, es una tierra de contrastes, donde la Cordillera Subbética se mezcla con el mar Mediterráneo dando lugar a grandes acantilados con calas remotas de aguas cristalinas y turquesas a sus pies, especialmente en el centro–norte de la provincia (Figura 7).



**Figura 7**. La costa más natural de Alicante: la Cala d'Ambolo (izquierda) y la Cala del Moraig (derecha) ubicadas en la parte norte de la provincia (Xàbia y Poble Nou de Benitatxell).

A lo largo de toda la Costa Blanca se alternan playas con plataforma rocosa (proveniente de antiguos acantilados hoy en día ya erosionados), playas

compuestas de bloques, cantos rodados, grava, o arena de una complejidad de tamaños y colores de lo más peculiar (Asensio-Montesinos 2019a; 2020). La parte sur, pertenece a la Cuenca del Bajo Segura, y las largas playas en esta parte del litoral se componen en su gran mayoría de arena fina (Figura 8).



**Figura 8**. La costa más natural de Alicante: las playas de Les Ortigues (izquierda) y El Pinet (derecha) ubicadas al sur de la provincia (Guardamar del Segura y Elx).

El conocimiento de las características que forman parte del paisaje costero constituye una buena base de datos y un buen punto de partida para tener una idea más amplia del tipo de litoral o del tipo de playas que se van a estudiar. Por ello, se han tenido en cuenta una serie de estudios realizados previamente donde las playas fueron evaluadas desde el punto de vista paisajístico mediante la metodología desarrollada por Ergin et al. (2004). Esta metodología conocida como "*Coastal Scenic Evaluation System (CSES)*", tiene en consideración 26 parámetros; 18 físicos/naturales y 8 humanos/antrópicos, que se evalúan uno por uno utilizando rangos de puntuaciones (de 1 a 5). Además, la metodología utiliza la lógica difusa mediante una serie de cálculos matemáticos que permiten corregir en parte posibles errores del evaluador que hayan podido ocurrir durante las observaciones (Ergin et al., 2004, 2006a). Finalmente, cada playa se clasifica en cinco clases (I–V) según un valor "*D*" obtenido de las puntuaciones de todos los parámetros que influyen en el paisaje. Este valor permite obtener un ranking que puede oscilar desde playas muy naturales y de gran belleza escénica o de gran interés paisajístico (Clase I) hasta playas muy urbanizadas o con nulo valor paisajístico (Clase V). La metodología *CSES* ya se ha aplicado en numerosas playas (>1000) repartidas por todo el mundo (Rangel-Buitrago, 2019). Algunos ejemplos son los estudios realizados en Croacia (Ergin et al., 2006b), Pakistán (Ullah et al., 2010), Reino Unido (Phillips et al., 2010), Turquía (Ergin et al., 2010), Marruecos (Williams y Khattabi, 2015), Cuba (Anfuso et al., 2017), Brasil (da Costa Cristiano et al., 2018), España (Iglesias et al., 2018), la Antártida y muchos

otros lugares (Anfuso et al., 2019). En Alicante, se tuvieron en consideración los datos obtenidos previamente en 56 sitios costeros durante el año 2017 (Asensio-Montesinos et al., 2017, 2019a) mediante la metodología *CSES* (Ergin et al., 2004). Los sitios elegidos en dichos estudios fueron los mismos que se seleccionaron para el posterior estudio de residuos sólidos de los que trata parte de esta tesis. El paisaje costero de Alicante se caracteriza principalmente por poseer bastantes playas con características de origen antrópico cerca de sitios urbanos o urbanizados, resultando en lugares con poco interés paisajístico (de Clase IV y V), también tiene playas de Clase III que pueden presentar características variadas en sus parámetros paisajísticos, sin embargo, Alicante todavía conserva algunos tramos naturales que le dan un gran valor paisajístico. Algunos ejemplos son las playas con acantilados (Figura 7) que pueden llegar a registrar altos valores paisajísticos (playas de Clase I y II). Los parámetros de los que más se benefician algunas playas alicantinas son los acantilados y sus características, las playas de arena, el tipo de marea (< 2 m), la claridad y color del agua, y en algunas ocasiones las vistas, las dunas, los valles y el perfil del horizonte, así como algunas características especiales como salientes rocosos, islas o cuevas. Por otro lado, otros parámetros afectan de manera negativa a muchas de las playas como pueden ser el ruido, las viviendas cerca del litoral, las infraestructuras, el tipo de acceso o los residuos entre otros.

## 2.2. El litoral Atlántico de Cádiz: La Costa de la Luz de Andalucía

### *2.2.1. Contexto social, cultural y económico*

La provincia de Cádiz, situada en el suroeste de Andalucía (SO de la Península Ibérica), cuenta con numerosos vestigios de una larga historia, de hecho, la ciudad de Cádiz es conocida como la más antigua de occidente. Se pueden citar algunos ejemplos de antiguas civilizaciones que pasaron por la provincia como los tartesios, fenicios, cartagineses, romanos, bizantinos, visigodos, musulmanes, o vikingos entre otros.

En la actualidad, la población de la provincia de Cádiz cuenta con 1.244.049 habitantes (año 2020). La mayoría de los municipios grandes de más de 40.000 personas, se localizan en el entorno del litoral. Los más destacables para este estudio debido a su localización y número de habitantes son Cádiz, San Fernando, El Puerto de Santa María, Chiclana de la Frontera, Sanlúcar de Barrameda y Puerto Real. Otros pueblos gaditanos con menos habitantes también destacan por ser conocidos internacionalmente. Por un lado, el pueblo de Barbate

es popular por el arte milenario de la pesca en almadraba del codiciado Atún Rojo (*Thunnus thynnus*) y por su singular enclave del Cabo Trafalgar, un lugar de gran interés histórico, natural y paisajístico. Destaca también Tarifa, el lugar más meridional de la Península Ibérica y uno de los pueblos más turísticos de Cádiz, donde se encuentra la popular playa de Bolonia. Tarifa también es reconocido internacionalmente por la práctica de deportes náuticos y de viento, actividades que se ven favorecidas por los frecuentes y fuertes vientos de levante y de poniente que pasan por el estrecho de Gibraltar. Así, el turismo juega un papel importante en la provincia de Cádiz, aunque en el pasado nunca ha registrado (y tampoco hoy en día registra) un turismo de masas como se observa en la parte mediterránea de Andalucía.

La provincia de Cádiz tiene playas totalmente urbanas (Figura 9) que han sufrido cambios importantes debido a las actividades que se han desarrollado en sus inmediaciones como la pesca, el comercio o el turismo.



**Figura 9**. Costa urbanizada de Cádiz: arriba, la Playa de la Victoria (Cádiz) en los años 60; abajo, a la izquierda, la Playa de la Caleta (Cádiz) y, a la derecha, la playa de la Cachucha (Puerto Real) en la actualidad.

Varios municipios costeros de la provincia cuentan con diferentes tipos de puertos y en algunos lugares se producen diversos productos como la sal,

salazones, conservas, etc. También existen instalaciones industriales importantes que se dedican a la construcción naval, aeronáutica, petroquímica, energética y metalurgia.

### *2.2.2. Condiciones ambientales*

El litoral atlántico de Cádiz se encuentra conectado a la parte este del Océano Atlántico Norte. Las características geográficas del Océano Atlántico lo convierten en el segundo océano más grande del planeta, y en el que más aportes de agua dulce recibe, provenientes de grandes ríos como el Mississippi, el Amazonas y el Congo. La temperatura varía mucho ya que oscila desde -2°C a 30°C debido a que el Atlántico se extiende de polo a polo pasando por el Ecuador y la salinidad media es de unos 36 g/L. Las aguas del Atlántico Norte circulan en el sentido de las agujas del reloj (al contrario que en la parte sur) debido al efecto Coriolis producido por la rotación terrestre. Las corrientes circulares que se forman debido a este hecho favorecen grandes acumulaciones de residuos también conocidas como "islas de plástico", en el caso de la concentración de residuos del Atlántico Note; está documentada como la segunda concentración más grande de residuos flotantes en el planeta y abarca más de un millón de kilómetros cuadrados.

La costa atlántica gaditana, junto con la costa de la provincia de Huelva, es también conocida como "Costa de la Luz". El nombre se debe a la fuerte luz del sol que brilla en todas las estaciones del año y que se refleja en sus arenales costeros y los rojos atardeceres que se pueden observar desde el litoral, únicos y sorprendentes en comparación al resto de la costa española debido a que este tramo del litoral tiene una orientación NO–SE, por lo que las playas miran hacia donde se pone el sol. El clima de Cádiz se clasifica como cálido y templado con una temperatura media anual de 18,5°C. Las playas que se observan en la provincia están compuestas por arena de tonos dorados (Figura 10). Muchas de estas playas son muy largas y algunas alcanzan varios kilómetros mientras que otras están delimitadas por algún cabo, pequeños acantilados o infraestructuras antrópicas. Algunas de ellas tienen gran interés paisajístico ya que se encuentran en entornos remotos, rurales y poco urbanizados por lo que conservan muchas características naturales.



**Figura 10**. La costa más natural de Cádiz: panorámica de una de las calas de Roche, Chiclana de la Frontera (arriba); abajo a la izquierda la playa de la Princesa Alejandra (Conil de la Frontera) y a la derecha la playa de Camposoto, San Fernando.

El viento en el litoral de Cádiz sopla desde dos direcciones principales; la primera, coincide con los fuertes vientos de levante de procedencia E y ESE, mientras que la segunda dirección corresponde a los vientos de poniente que proceden del ONO, O y NNO. Las velocidades del viento pueden superar fácilmente los 8 m/s desde cualquier dirección (Figura 11).

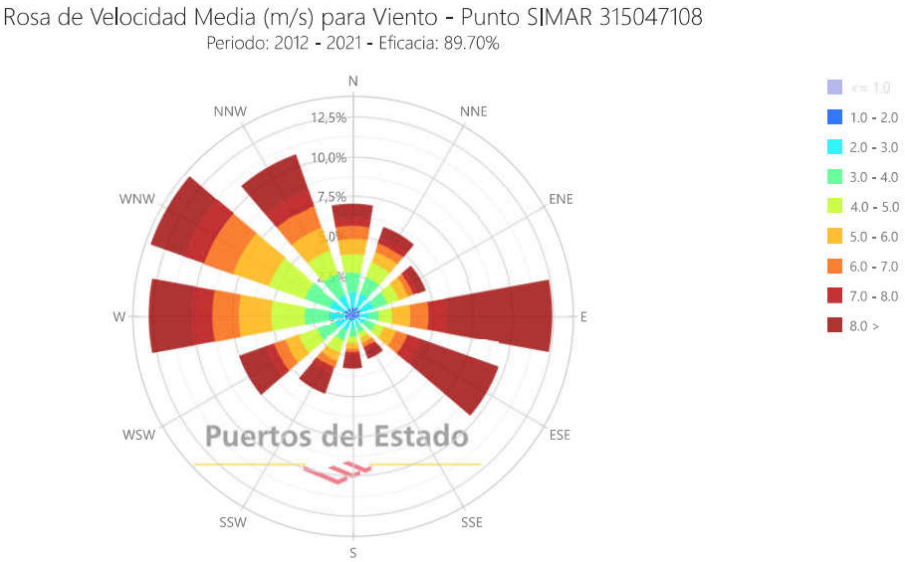



**Figura 11**. Rosa de viento en la costa de Cádiz para el periodo 2012 – 2021.

Debido a la amplitud de marea, las playas de Cádiz pueden ser muy diferentes según la hora y el día en el que se visiten, ya que este fenómeno afecta principalmente a la anchura de la playa. El litoral Atlántico de Cádiz es principalmente de características mesomareales, es decir, su rango de marea tiene una amplitud entre 2 y 4 m. En detalle, dicho rango mareal se da desde Sanlúcar de Barrameda hasta Cabo Trafalgar. Sin embargo, debido a la proximidad del Mar Mediterráneo y a la geomorfología costera de la zona del Estrecho de Gibraltar, las condiciones de marea cambian desde el Cabo Trafalgar hasta Tarifa y este tramo litoral presenta rango micromareal, es decir, inferior a 2 m. El oleaje procede principalmente del oeste con una altura significante que llega hasta los 4 m (Figura 12).

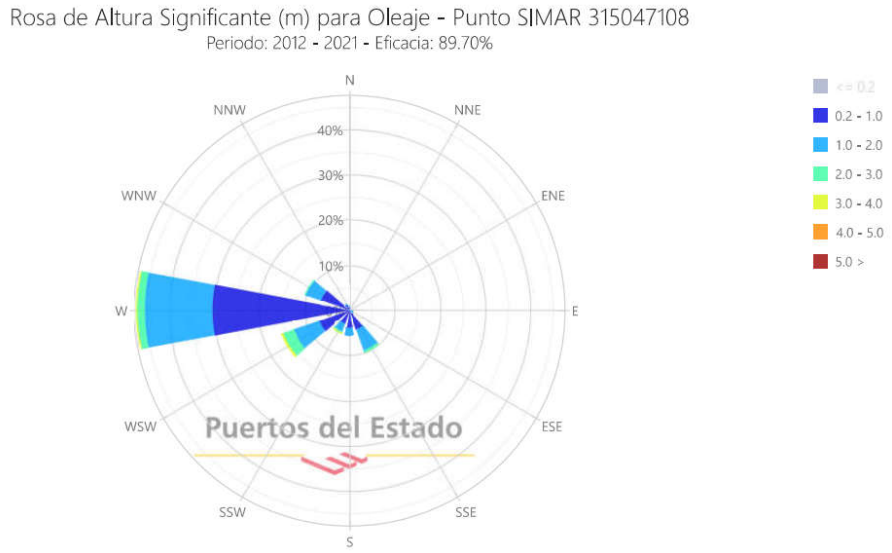



**Figura 12**. Rosa de Altura significante para oleaje en Cádiz para el periodo 2012 – 2021.

Las características paisajísticas de las playas de Cádiz fueron analizadas mediante la metodología de Ergin et al. (2004) por otros investigadores. Dichos resultados se pueden consultar en los artículos publicados por Williams et al. (2012) y Mooser et al. (2018), así como en la guía de playas publicada por Mooser y Anfuso (2018) donde ponen de manifiesto el elevado valor paisajístico de algunas de las playas gaditanas de Clase I y II. Principalmente debido a que muchos lugares de la costa están alejados de centros urbanos, lo que beneficia las puntuaciones obtenidas en los parámetros naturales y antrópicos. La presencia de arena de tonalidades doradas en prácticamente todo el litoral, las dunas, la vegetación, las vistas, los acantilados y otras características especiales se pueden observar en muchas de las playas. Pero irremediablemente también están presentes algunas playas urbanas con puntuaciones paisajísticas más bajas

debido al ruido, al tipo de acceso, a las construcciones o infraestructuras presentes o bien a los residuos.

## 3. MATERIALES Y MÉTODOS

Las metodologías aplicadas en esta investigación se presentan en dos partes diferenciadas. La primera parte está relacionada con la caracterización y clasificación de las playas y de algunas características geomorfológicas, así como el grado de urbanización y el tipo de visitantes. La segunda parte trata del estudio de los residuos sólidos en ambientes costeros y todo lo relacionado con su cuantificación, clasificación y análisis.

### 3.1. Características generales

#### *3.1.1. Los tipos de playas*

Partiendo de la idea de que cada playa es única y de que existen diversas maneras de catalogar una playa o clasificar un sitio costero según sus características propias, se ha optado por clasificar los lugares involucrados en esta investigación siguiendo la metodología de Williams y Micallef (2009) conocida como el Sistema de Registro y Evaluación de Zonas de Baño (*Bathing Area Registration and Evaluation System "BARE"*). Dicha metodología consiste en clasificar cualquier sitio del litoral atendiendo a una descripción clara y sencilla que, esencialmente, tiene en cuenta el tipo de entorno que rodea cada playa y su accesibilidad. Es decir, se basa en la presencia o ausencia y en la tipología de determinadas características antropogénicas. Así, dicha clasificación incluye cinco tipos de playas: urbanas, semiurbanas, rurales, remotas y resort. En esta investigación no se tuvo en cuenta la categoría de resort, ya que esta tipología de playa está pensada para países donde un sector o bien toda la playa está totalmente gestionada por algún establecimiento privado como puede ser un hotel. En España, no existe este tipo de playas privadas ya que, según la Ley de Costas vigente (Ley 2/2013), las playas son en todo caso dominio público. Según Williams y Micallef (2009), las características básicas para clasificar las playas según su entorno son las siguientes:

- **Playas urbanas** (Figura 13). Este tipo de playas atienden a grandes poblaciones que tienen servicios públicos bien establecidos como escuelas, bancos, oficinas de correos, bares, centros comerciales, etc. En las proximidades se pueden encontrar actividades comerciales como la pesca

y la navegación. Las playas urbanas están dentro o junto a la zona urbana y generalmente están abiertas al público (Williams y Micallef, 2009).



**Figura 13**. Ejemplos de los tipos de playas estudiadas: a la izquierda la Platja de Llevant (Alicante) y a la derecha la playa de la Caleta (Cádiz), urbanas.

- **Playas semiurbanas** (Figura 14). Denominadas "*village beaches*" en inglés, son playas localizadas fuera del centro urbano principal, pero al que se puede llegar por medios de transporte público o privado. Se encuentran en lugares donde existe una población pequeña pero permanente que refleja el acceso a servicios comunitarios organizados, pero a pequeña escala: escuela(s), tienda(s), etc. También incluyen las playas de pueblos turísticos, utilizados principalmente en los meses de verano (Williams y Micallef, 2009).



**Figura 14**. Ejemplos de los tipos de playas estudiadas: a la izquierda la playa El Portet (Alicante) y a la derecha la playa de Valdelagrana (Cádiz), semiurbanas.

- **Playas rurales** (Figura 15). Las zonas rurales se encuentran localizadas fuera de los entornos urbanos o urbanizados. No es posible llegar a ellas con transporte público y prácticamente no tienen infraestructuras para los usuarios. Sin embargo, en el Mediterráneo hay algunas excepciones y en la temporada estival se pueden ver infraestructuras relacionadas con el

uso recreativo en playas rurales. Las playas rurales tienen poco o ningún desarrollo frente a la playa, pero pueden tener algunas viviendas residenciales, generalmente de 0 a 10 pero pueden haber más dependiendo del espacio disponible. Pueden ser viviendas temporales que se utilicen por ejemplo solo en verano o bien viviendas permanentes en las que viven todo el año. Sin embargo, no existen centros comunitarios como escuelas, tiendas, restaurantes, etc. Los usuarios de las playas rurales las valoran por su tranquilidad y sus cualidades naturales (Williams y Micallef, 2009).



**Figura 15**. Ejemplos de los tipos de playas estudiadas: arriba a la izquierda la Calas del Cuartel (Alicante) y arriba a la derecha la playa de Bolonia (Cádiz); abajo a la izquierda la Cala del Xarco y abajo a la derecha la Cala Cantalars (Alicante), rurales.

- **Playas remotas** (Figura 16). Se definen en gran medida por su dificultad de acceso (en barco o a pie – con una caminata de por lo menos 300 m). Pueden estar contiguas a las zonas rurales o semiurbanas, pero nunca contiguas a zonas urbanas. No disponen de transporte público y en el caso de que haya viviendas temporales, estas son muy limitadas en número, por lo general menos de 5. En el Mediterráneo, pueden encontrarse restaurantes y segundas residencias en la temporada de verano, ocupadas

por unas pocas personas que pueden vivir allí permanentemente (Williams y Micallef, 2009).



**Figura 16**. Ejemplos de los tipos de playas estudiadas: a la izquierda la Platja Gran (Isla de Nueva Tabarca, Alicante) y, a la derecha, la playa de Trafalgar (Cádiz), remotas.

Las playas de Cádiz, compuestas por arena y con características meso (2 – 4 m) y micromareales (< 2 m), presentaban un perfil de playa diferente según el sitio evaluado y, por eso, fueron clasificadas desde un punto de vista morfodinámico. Para ello, se utilizó un GPS-Diferencial (*Leica RX900*) del Departamento de Ciencias de la Tierra de la Universidad de Cádiz con el que se realizaron todos los levantamientos de playa tomando valores de posición (x, y) y elevación (z) con una precisión del centímetro. Los perfiles se realizaron en condiciones de bajamar, desplazándose desde la playa seca hasta el nivel del mar perpendicularmente hasta la orilla. Las condiciones de marea se obtuvieron a partir del Anuario de Marea y esto permitió establecer los días más adecuados para llevar a cabo los levantamientos topográficos y el estudio de los residuos sólidos. Para determinar la posición del nivel medio del mar y de los niveles de bajamar y pleamar en los perfiles topográficos de las playas investigadas (obtenidos por medio del GPS diferencial), se llevaron a cabo cálculos de corrección de marea usando la tabla de corrección del Anuario de Marea. Dichos cálculos tienen en cuenta el rango mareal y la duración de la marea en el día del levantamiento topográfico y la elevación y la hora en las que se tomó la posición del nivel del mar. Los perfiles topográficos se representaron en hojas Excel y se usaron para calcular la pendiente del intermareal y tener indicaciones sobre las dimensiones de las diferentes partes de la playa, su pendiente intermareal y estado morfodinámico. En cuanto al estado morfodinámico, se trata de distinguir entre playas disipativas, intermedias y reflectivas (Carter, 1988) y entre tipos de rompiente de oleaje (esencialmente derrame, o *spilling* en inglés y voluta, o *plunging*) para ver cómo éstos afectan a la tipología y abundancia de residuos.

### 3.2. Evaluación de residuos sólidos

#### *3.2.1. Cuantificación y clasificación de residuos*

La cuantificación y clasificación general de los residuos sólidos se realizó de acuerdo con los criterios seguidos por diferentes administraciones y organizaciones que se dedican al estudio de los residuos y la protección del medio natural (EA/NALG, 2000; Cheshire y Adler, 2009; OSPAR Commission, 2010; Opfer et al., 2012), así como numerosas investigaciones previas que también han estudiado los residuos en la costa (Velander y Mocogni, 1999; Williams et al., 2016a; Vlachogianni et al., 2018).

Por lo general, el área evaluada en cada playa tenía una longitud de 100 metros de largo y comprendía desde la zona desde el nivel del agua del mar en el momento de la evaluación hasta el final de la playa, a menudo delimitado por construcciones antrópicas (paseos, edificios, casas, etc.) o bien por elementos naturales como dunas, acantilados, vegetación, etc. Dentro del área de evaluación, se realizaron varios transectos paralelos a la línea de costa y espaciados entre ellos unos 5 m, con el fin de poder cubrir visualmente toda la superficie considerada de la playa (Figura 17). Sin embargo, según el estudio y los propósitos que se quieran investigar, el área de muestreo varió y, en ocasiones muy específicas, llegó a abarcar toda la superficie de algunas playas (Asensio-Montesinos et al., **III**).

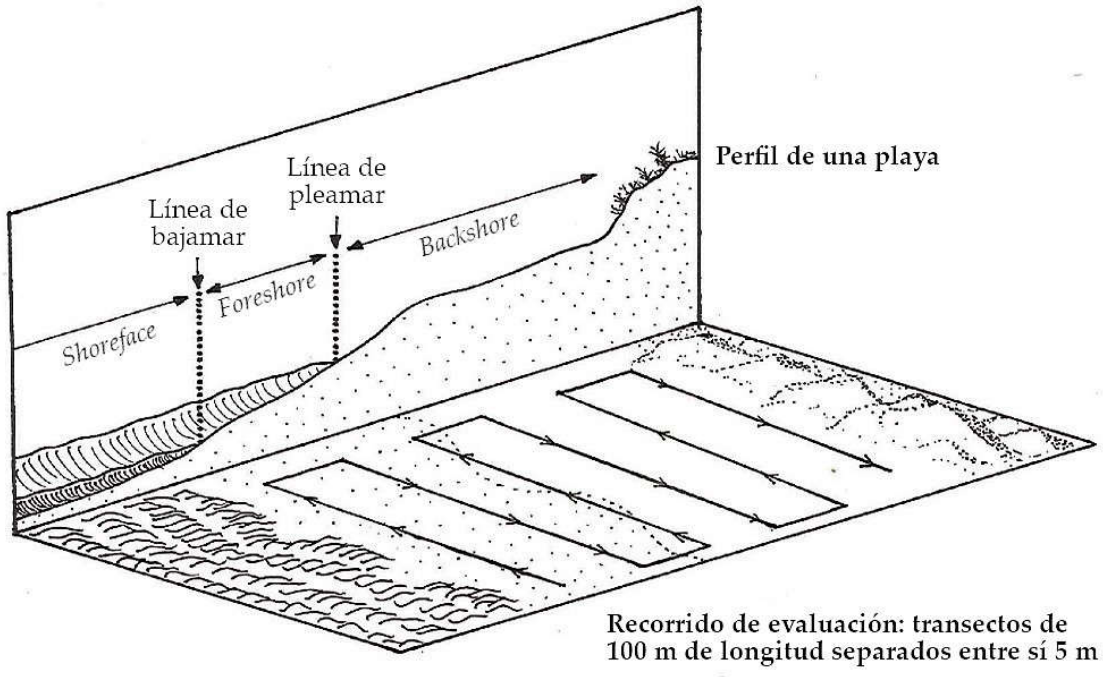



**Figura 17**. Perfil transversal de playa idealizado que muestra las posiciones del nivel del mar y las zonas de playa estudiadas (modificado de Asensio-Montesinos et al., **IV**).

En el marco de este estudio, para clasificar los residuos por categorías o grupos, se decidió tener en cuenta más de una lista de evaluación (EA/NALG, 2000; Cheshire y Adler, 2009; OSPAR Commission, 2010; Opfer et al., 2012), que resultó en una Lista Maestra de más de 180 grupos o categorías de residuos utilizada previamente por Williams et al. (2016a). A esta lista, se le iban añadiendo o quitando grupos según los resultados obtenidos en cada investigación (Material Complementario – Tabla S1). También hay que resaltar como la foto-guía de identificación de residuos en playas recopilada por Nachite (2019) fue muy útil para llevar a cabo la clasificación e identificación de algunos residuos en particular.

Para clasificar una playa según la cantidad y tipología de los residuos se pueden aplicar distintas metodologías o técnicas una vez se ha hecho la evaluación, aunque no sea estrictamente necesario, puede ser de utilidad. Por una parte, está una metodología que clasifica las playas según su grado de limpieza en varias categorías teniendo en cuenta un rango numérico (Alkalay et al., 2007): "Muy limpio" (0–2), "Limpio" (2–5), "Moderadamente sucio" (5–10), "Sucio" (10–20) y "Extremadamente sucio" (+20). Para ello es necesario conocer el área evaluada y el número de ítems contabilizados. Es decir, solamente se necesitan valores de abundancia. A continuación, se aplica la siguiente fórmula con la que se calcula el índice de limpieza costera (*Clean-Coast Index* o *CCI*, Alkalay et al. (2007):

$$\mathrm{CCI} = \frac{Residuos\ totales\ en\ el\ área\ de\ muestreo}{Superficie\ total\ del\ área\ de\ muestreo} \times \mathrm{K}$$

Por razones estadísticas, así como por comodidad, la ecuación incorpora el coeficiente K= 20, para que los valores que determinan la categoría del grado de limpieza sean enteros y no decimales.

Otra clasificación es la desarrollada por La Agencia de Medio Ambiente y el Grupo Nacional de Basura Acuática de Reino Unido. La clasificación obtenida a partir de los residuos está basada en la abundancia de diferentes categorías que incluyen desde residuos generales de pequeño tamaño hasta residuos de gran tamaño o incluso acumulaciones (EA/NALG, 2000). También tiene en cuenta otras categorías como residuos relacionados con las aguas residuales y aquellos potencialmente peligrosos, entre otros (Tabla 1). Se ha utilizado en muchas investigaciones llevadas a cabo en diferentes países del mundo (Quintela et al.,

2012; Williams et al., 2016a, 2016b; Botero et al., 2017; Rangel-Buitrago et al., 2017; Corraini et al., 2018). La aplicación de esta metodología da como resultado una clasificación en cuatro categorías bien diferenciadas: "A" (muy bueno), "B" (bueno), "C" (regular) y "D" (malo). Este método fue el más utilizado durante las evaluaciones ya que es práctico, sencillo de aplicar y con gran potencial para una rápida interpretación de la contaminación en zonas litorales (Asensio-Montesinos et al., 2019b).

**Tabla 1.** Metodología de clasificación por tipo de residuos (EA/NALG, 2000).

| | **Category** [1] | **Type** | **A** | **B** | **C** | **D** |
|---|---|---|---|---|---|---|
| 1 | Sewage Related Debris | General | 0 | 1–5 | 6–14 | 15+ |
| | | Cotton Buds | 0–9 | 10–49 | 50–99 | 100+ |
| 2 | Gross Litter | | 0 | 1–5 | 6–14 | 15+ |
| 3 | General Litter | | 0–49 | 50–499 | 500–999 | 1000+ |
| 4 | Harmful Litter | Broken Glass | 0 | 1–5 | 6–24 | 25+ |
| | | Other | 0 | 1–4 | 5–9 | 10+ |
| 5 | Accumulations | Number | 0 | 1–4 | 5–9 | 10+ |
| 6 | Oil | | Absent | Trace | Nuisance | Objectionable |

[1] Categories: **General Sewage litter** – items include: feminine hygiene products (sanitary towels, tampons and applicators, contraceptives, toilet paper, faeces of human origin. **Cotton Bud Sticks** – harmless in themselves but they denote a sewage input. **Gross Litter** (at least one dimension >50 cm) – include: shopping trolleys, pieces of furniture, road cones, large plastic or metal containers; bicycles, prams; tyres; and large items of processed wood e.g. pallets. Driftwood is not included. **General litter** (all other items <50 cm in dimension) - include drink cans, food packaging, cigarette packets, etc. **Potentially Harmful Litter** (dangerous to either humans or animals using the beach) – includes: sharp broken glass (counted as a separate category), medical waste (e.g. used syringes), colostomy bag, sharps (metal wastes, barbed wire, etc.), soiled disposable nappies, containers marked as containing toxic products, other dangerous products such as flares, ammunition and explosives ammunition and dead domestic animals. **Accumulations of litter** – discrete aggregations of litter clearly visible when approaching the survey area, either as a result of being blown by the wind or dumped by users of the beach, and in the high water strandline, often in seaweed. **Oil and other oil like substances** – all oil waste (mineral or vegetable), either from fresh oil spills or the presence of weathered oil deposits and tarry wastes. ***Faeces*** (Non-Human) - Dogs (sheep or horse *faeces* are not be counted).

### *3.2.2. Análisis de las bases de datos*

Los datos obtenidos del trabajo de campo fueron copiados a hojas Excel donde, una vez clasificados los residuos por tipo de material (vidrio, metal, plástico, etc.) en sus correspondientes grupos (botellas, tapones, colillas, etc.) y por playas, se contabilizaron de diferentes maneras según los objetivos propuestos. Por ejemplo, se realizaron cálculos para ver la cantidad de residuos por playa, por tipología (remotas, urbanas, etc.), por tipo de sedimento (arena, grava, cantos, plataforma rocosa, etc.), por tipo de gestión (trabajos de limpieza, si los hay), por morfología (playas disipativas, reflectivas, etc.), por zona de playa (*backshore*, *shoreface*, etc.) o por localización de las playas (territorios, ciudades, pueblos, bahías, etc.). También se elaboraron diferentes gráficos circulares, de barras o de valores medios que mostraban de manera clara los resultados, por ejemplo, agrupando los residuos por tipo de material o según su procedencia.

Se tuvo que modificar las tablas de datos iniciales para su posterior tratamiento estadístico mediante los programas informáticos "R" (*https://www.r-project.org/*), "PAST" (*https://www.nhm.uio.no/english/research/infrastructure/past/*), y "PRIMER V.6 + PERMANOVA" (*Plymouth Marine Laboratory, UK*). Según la tipología de los datos y los resultados obtenidos en cada estudio, se optó por la técnica o técnicas estadísticas más adecuadas que podían llevarse a cabo y que mejor explicasen los resultados obtenidos. A continuación, se explican las técnicas estadísticas utilizadas durante las investigaciones:

- **Gráficos de cajas** (*boxplots*): también conocidos como diagramas de cajas, permiten visualizar medidas estadísticas clave de un conjunto de datos, por ejemplo, de una variable específica que se quiera estudiar. Son muy útiles para representar datos cuantitativos de residuos ya que en estos se puede representar la media, la mediana, los cuartiles, los valores atípicos y los valores máximos y mínimos, así como la distribución de los datos que muestra si los datos tienen una distribución normal o con algún tipo de sesgo positivo o negativo.
- **Histogramas** (o gráficos de barras): son representaciones gráficas de una variable en forma de barras, donde la longitud de cada barra es proporcional a la frecuencia de los valores representados.
- **Análisis de la varianza**: también se conoce como "*ANOVA*" que proviene de su denominación en inglés "*ANalysis Of VAriance*". Esta herramienta de análisis permite comparar grupos de medidas y se suele utilizar para comparar entre varios grupos distintos. Si los datos cumplen una serie de

requisitos (independencia, normalidad y homogeneidad de varianzas), se puede llevar a cabo el *ANOVA* y será posible calcular si los valores medios son iguales o no en los distintos grupos estudiados. Es decir, es una forma de saber si los resultados obtenidos en un experimento son o no significativos.

- **Gráficos de interacciones**: este tipo de gráficos se suele utilizar para observar las interacciones de varios factores según una variable en particular. En muchos casos se utilizan durante el análisis de la varianza.
- **Análisis Multidimensional no Paramétrico**: en inglés se conoce como "*non-metric Multidimensional Scaling*" (*nMDS*), es una representación gráfica de las muestras en dos o tres dimensiones. Este tipo de análisis parte de una matriz de similitud o disimilitud. Se representan las distancias en esa matriz de similitud, se cogen dos muestras al azar y se colocan espacialmente en función de su distancia, luego se coloca otra nueva muestra a la distancia de las dos que le corresponda y así sucesivamente con todas las muestras. Esto hace que dicho análisis se represente gráficamente de una manera distinta cada vez que se ejecuta, aunque con resultados muy similares para su posterior interpretación. La distancia entre muestras representada en el gráfico es lo más importante de este tipo de análisis, es decir, las muestras que estén más juntas son más parecidas, mientras que las muestras más alejadas son más distintas entre sí.
- **Análisis cluster**: es una técnica multivariante cuya finalidad es la de dividir un conjunto de objetos en grupos similares. Parte de una matriz de similitud y disimilitud que se basa en comparar todas las muestras entre sí. Por ejemplo, dos muestras con un 100% de similitud indicaría que son iguales o que es la misma muestra. Por el contrario, un 100% de disimilitud indicaría que ambas muestras no tienen nada en común. Existen numerosos índices para calcular la disimilitud, aunque los más conocidos y utilizados son la distancia Euclídea y la distancia Bray-Curtis. La distancia Euclídea se utiliza más para datos de variables ambientales (p. ej. temperatura) mientras que el índice de Bray-Curtis se utiliza para otro tipo de variables, por ejemplo, variables biológicas como la biomasa. En el caso de los residuos se optó por utilizar el índice de Bray-Curtis, porque la mayoría de los residuos tienen una distribución relacionada con los comportamientos humanos. Además, las bases de datos con las que se trabajan están repletas de ceros y, si se utilizara la distancia Euclídea, el

cero sería considerado como un valor más y no como la ausencia de una determinada variable.

- **Análisis de componentes principales**: en inglés se conoce como "*Principal Component Analysis*" o "*PCA*". Es otra técnica multivariante que permite reducir la dimensionalidad de un conjunto de datos, permitiendo que se hallen las causas de la variabilidad de un conjunto de datos. Las ventajas de esta técnica es que permite reducir el número de variables y que los ejes son interpretables, uno de los principales motivos del porqué se utiliza esta técnica. Sin embargo, presenta algunos inconvenientes, como por ejemplo que solo se puede hacer con distancia Euclídea y que el número de variables ha de ser menor que el número de muestras, además las distancias en el gráfico final no son bien preservadas.

### *3.2.3. Análisis y clasificación mediante espectroscopia Raman*

La espectroscopia Raman es una técnica espectroscópica muy utilizada en física de la materia condensada para estudiar las características de los materiales. Esta técnica lleva el nombre del Doctor Chandrasekhara Venkata Raman, un físico hindú que logró el premio Nobel de Física en 1930 por el descubrimiento del efecto Raman. Con este método de análisis de los materiales, la muestra se ilumina con luz monocromática (con una sola frecuencia o longitud de onda, por lo general procedente de un rayo láser) y el espectro de la luz esparcida se analiza para encontrar la luz con frecuencias cambiadas o "picos" Raman. Cada pico corresponde a un modo de vibración del material. De esta manera, al analizar un material, se obtiene un espectro que puede estar compuesto por varios picos Raman. Según la localización de estos picos en el espectro obtenido se puede saber qué tipo de material es el que se ha analizado. Cada pico viene determinado por un número de onda específico que es muy útil para la identificación de cada material o tipo de material.

Numerosos residuos plásticos fueron analizados mediante la espectroscopia Raman, que es capaz de permitir la diferenciación entre los materiales fabricados con plástico. Para ello, se utilizó un espectrómetro (*Jasco, NSR 7200*) de la Facultad de Ciencias de la Universidad de Cádiz y el software *Spectra Manager* de "Jasco Corporation" (Figura 18). Para el análisis de las muestras se seleccionaron los siguientes parámetros: longitud de onda del láser = 532,19 nm; apertura = 200 μm × 1000 μm; objetivo = 20 aumentos; potencia del láser = 6 mW; tiempo de exposición del láser = 5 s; acumulación para promediar

los espectros = 2. Los espectros Raman se midieron con una resolución de unos 5 $cm^{-1}$ en los rangos de 1135 - 1844 $cm^{-1}$ y 2604 - 3177 $cm^{-1}$.

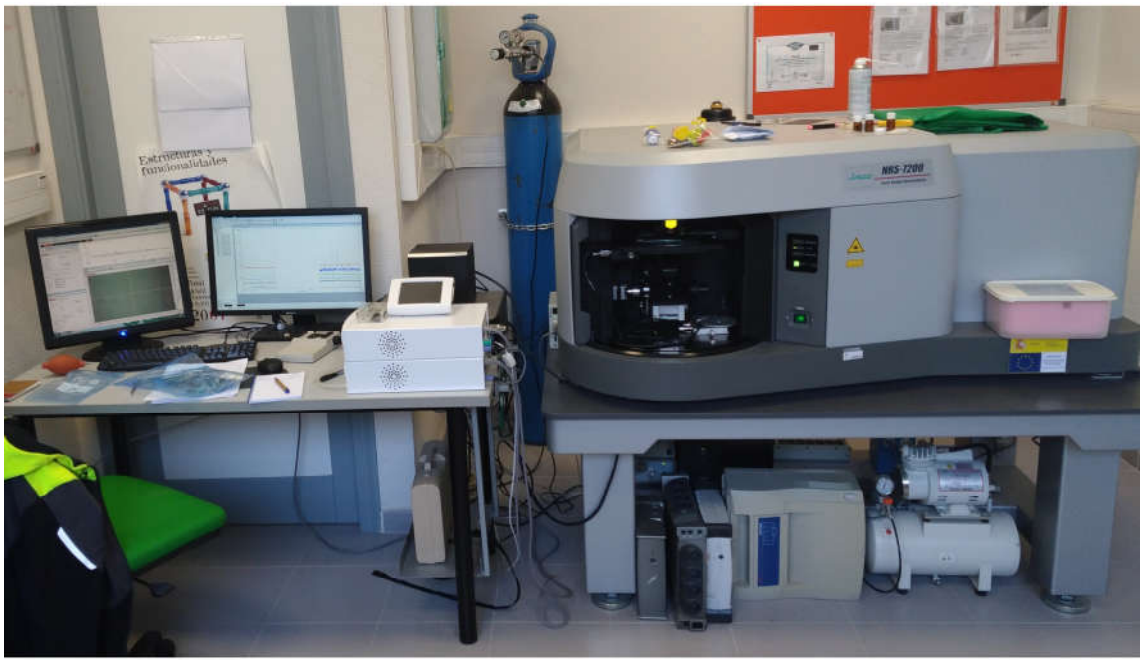



**Figura 18**. Espectrómetro Raman dispersivo Jasco, modelo NRS-7200 con láseres de excitación de 532 nm, 785 nm y 1064 nm de longitud de onda. Máxima resolución 0.7 $cm^{-1}$. Intervalo espectral 10 – 8000 $cm^{-1}$.

Los espectros Raman obtenidos de cada muestra se identificaron de acuerdo a numerosos artículos científicos publicados en los últimos años (Allen et al., 1999; Polarz et al., 2002; Lenz et al., 2015; Zhao et al., 2015; Dehaut et al., 2016; Käppler et al., 2016; Ribeiro-Claro et al., 2017; Syakti et al., 2017). Los números de onda ($cm^{-1}$) o *"wavelength"* en inglés, junto con las figuras proporcionadas en dichas investigaciones fueron esenciales para el reconocimiento de los diferentes tipos de plásticos. Sin embargo, algunas muestras no pudieron identificarse mediante esta técnica porque presentaban colores que producían fluorescencia, p. ej. algunos materiales plásticos de tonalidades moradas y naranjas.

## 4. RESULTADOS

### 4.1. Los residuos sólidos de la costa de Alicante

Un total de 56 sitios fueron visitados durante la primavera del año 2018 (Figura 19) con el fin de estimar la cantidad y composición de los residuos sólidos del litoral de Alicante (Asensio-Montesinos et al., **I**).

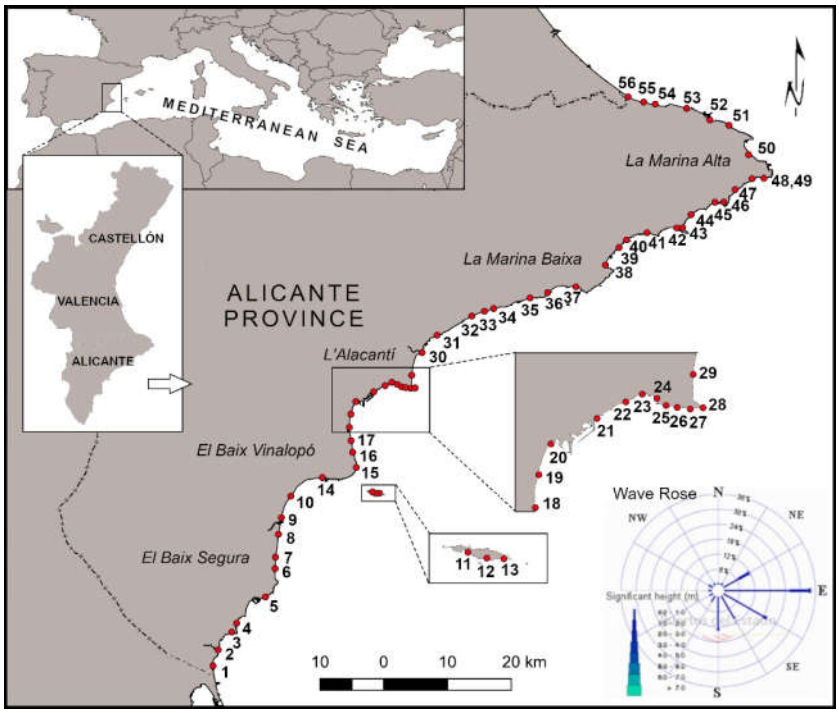



**Figura 19**. Localización de los lugares estudiados de Alicante (Asensio-Montesinos et al., **II**).

En el marco de este primer estudio, se evaluaron un total de 20 sitios urbanos, 17 sitios semiurbanos y 19 sitios con diversas características naturales que incluyen lugares rurales y remotos. Se llegaron a contabilizar 10.101 residuos pertenecientes a 116 categorías o grupos distintos en un área de 201.686 m$^2$. Las cantidades de residuos variaron según la playa y oscilaron entre 0,05 y 0,373 ítems/m$^2$, con un valor medio de 0,062 ítems/m$^2$. La diversidad de residuos, expresada en número de categorías de residuos también varió, oscilando entre 11 y 59. El plástico fue el material mayoritario (8.345 residuos) y llegó a representar un 82,6% de todos los residuos contabilizados, seguido del papel y el cartón (5,6%), alfarería y cerámica (3,4%), metal (3,2%), ropa (2,3%), vidrio (1,5%), goma o caucho (0,6%), madera procesada (0,5%) y otros materiales (0,3%, Figura 20a). El 45,6% de todos los residuos pertenecían al grupo de las colillas de cigarrillos que se encontraron en mayor número en los sitios urbanos (2.431 colillas), aunque también se observaron en sitios semiurbanos y naturales (1.148 y 1.028 colillas respectivamente).

De hecho, los análisis multivariantes mostraron algunas relaciones interesantes entre playas de la misma tipología y entre playas con la misma cantidad de residuos. Las tendencias generales observadas muestran que las playas más limpias son las semiurbanas, seguidas de las urbanas y finalmente las naturales que presentan gran variabilidad en cuanto a abundancia y composición de residuos. Estos resultados deben ser considerados teniendo en cuenta algunos factores importantes: el número de visitantes suele ser mayor cuanto más accesible y urbana sea una playa, y la limpieza de la playa, que se hace de forma manual o mecánica en playas urbanas y semiurbanas mientras que, en playas más naturales, se hace manualmente o simplemente no se hace.

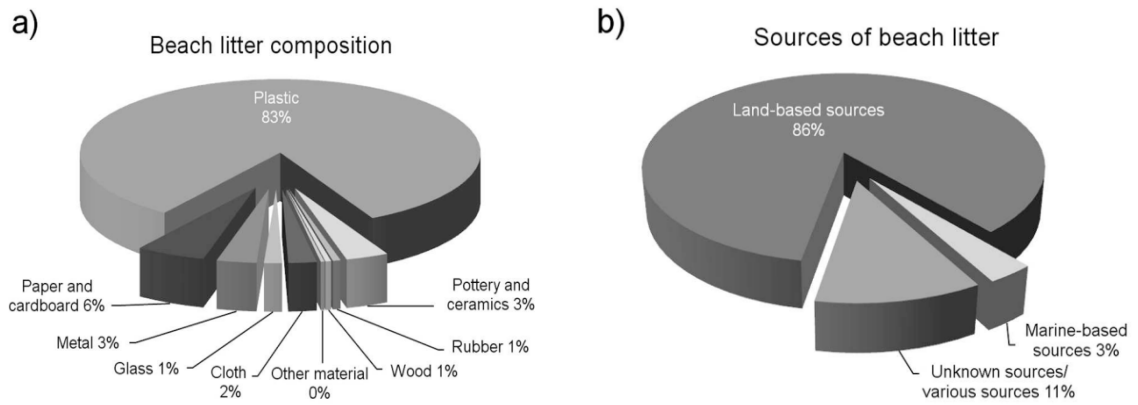



**Figura 20**. Residuos de playa durante la primavera del 2018 en la costa de Alicante. **a)** Composición de los residuos y **b)** Fuentes u origen de los residuos (Asensio-Montesinos et al., **I**).

Finalmente, en cuanto al origen de los residuos, la mayoría (el 86%) se relacionó con fuentes terrestres, mientras que solo un 3% se pudo relacionar con fuentes de origen marino. No se pudo determinar el origen del 11% restante de residuos (Figura 20b). Los residuos de origen terrestre se relacionaron esencialmente con los usuarios de playa y con la presencia de aguas residuales, mientras que aquellos de origen marino, fueron relacionados con actividades pesqueras.

Una vez se demostró con el primer estudio (Asensio-Montesinos et al., **I**) que el número de visitantes es extremadamente relevante en cuanto a la abundancia y tipología de residuos en la costa, se decidió repetir el estudio en los mismos lugares, pero en esta ocasión durante el verano (Asensio-Montesinos et al., **II**). En verano la población alicantina aumenta considerablemente su número debido a las condiciones climáticas favorables que coinciden con este periodo vacacional. En esta segunda investigación realizada en el mes de agosto de 2018 (Asensio-Montesinos et al., **II**) se obtuvieron datos de las cantidades de residuos con la finalidad de compararlas con las cantidades registradas en primavera

(Asensio-Montesinos et al., **I**). En esta ocasión se clasificaron los sitios naturales en remotos (9) y rurales (10), y el resto de sitios en semiurbanos (17) y urbanos (20) de la investigación previa. Se llegaron a contabilizar un total de 20.857 residuos en los 56 sitios estudiados, es decir, más del doble de lo que se contabilizó en primavera (marzo 2018). Los residuos más numerosos volvieron a ser las colillas de cigarrillos que, en esta ocasión, se triplicaron en número, sumando un total de 12.843. El plástico representó de nuevo el material dominante (83,6%), seguido del papel y el cartón (8,6%), metal (2,6%), ropa (1,6%), alfarería y cerámica (1%), madera procesada (0,9%), vidrio (0,7%), goma (0,5%) y otros (0,4%, Figura 21).

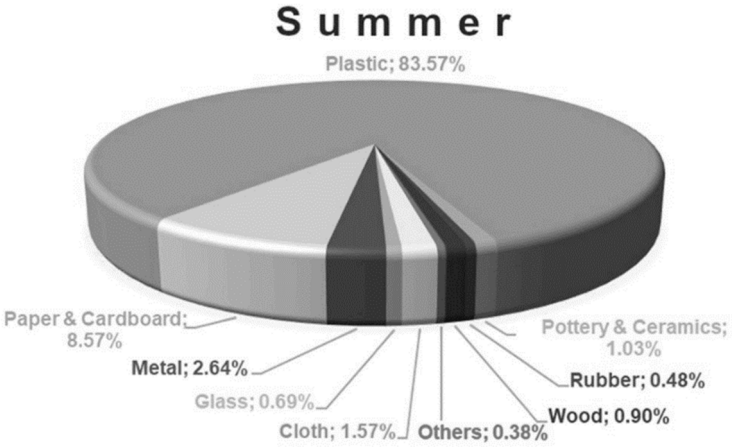



**Figura 21**. Residuos de playa durante el verano del 2018 en la costa de Alicante (Asensio-Montesinos et al., **II**).

A fin de encontrar relaciones entre limpieza de playa y abundancia de residuos, se recopilaron datos referentes a la frecuencia y tipo de limpieza de playa. Se observó cómo, a pesar de que las operaciones de limpieza son más frecuentes en verano, hubo un incremento de residuos en esa época del año. Esto sugiere que los usuarios constituyen la principal fuente de contaminación por residuos sólidos en las playas estudiadas. Algunos residuos se relacionaron con evidencias de aguas residuales y con actividades pesqueras, frecuentemente con la pesca con caña desde la costa.

Otro factor a tener en cuenta, fue la tipología de playa ya que se observaron diferencias importantes entre los residuos según el tipo de playa, que a su vez se relaciona con la abundancia de usuarios. En esta investigación también se compararon las playas de arena con el resto de playas que estaban compuestas, además de arena, por grava, cantos rodados, bloques, etc. o presentaban una plataforma rocosa. La importancia en dicha comparación está en que las playas de arena se pueden limpiar con maquinaria pesada mientras

que el resto no. Los resultados mostraron que las playas de arena contenían menos residuos que las otras playas, probablemente por los diferentes métodos de gestión y limpieza aplicados en cada situación.

Las playas también obtuvieron peores calificaciones en cuanto al grado de contaminación por residuos (EA/NALG, 2000) durante la temporada estival respecto a la temporada previa. Las playas urbanas fueron las que más residuos registraron, seguidas de las rurales, las semiurbanas y las remotas (Figura 22). Un análisis de la varianza mostró diferencias significativas en la cantidad de residuos entre primavera y verano para los factores referentes a la estación y al tipo de playa.

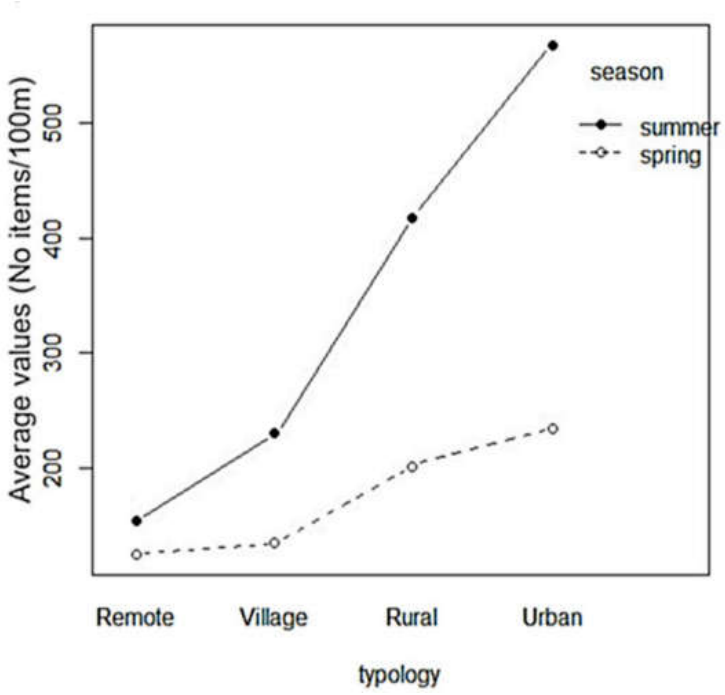



**Figura 22**. Gráfico de interacción. Comparación de valores medios de residuos por tipología de playa en primavera y verano (Asensio-Montesinos et al., **II**).

Después de demostrar mediante estos estudios previos (Asensio-Montesinos et al., **I**, **II**) que los usuarios tienen un gran efecto en la abundancia y tipología de residuos se optó por intentar comprender la distribución y abundancia de los residuos desde otro enfoque. Esta vez se quiso observar el comportamiento que tienen los residuos en condiciones de poca o nula influencia humana posible, con el objetivo de ver y demostrar que otros factores influyen en la abundancia y tipología de residuos (Asensio-Montesinos et al., **III**). Para ello se tuvieron en cuenta diferentes parámetros ambientales como la altura del oleaje y su procedencia, la velocidad del viento y su procedencia, la temperatura ambiental, las características geomorfológicas del litoral, el tipo de sustrato o la

longitud y anchura de cada playa, entre otros. En este estudio se seleccionaron un total de cinco playas de cantos rodados (2 rurales y 3 remotas), consideradas de las más inaccesibles y poco visitadas o conocidas de la provincia de Alicante (Figura 23).

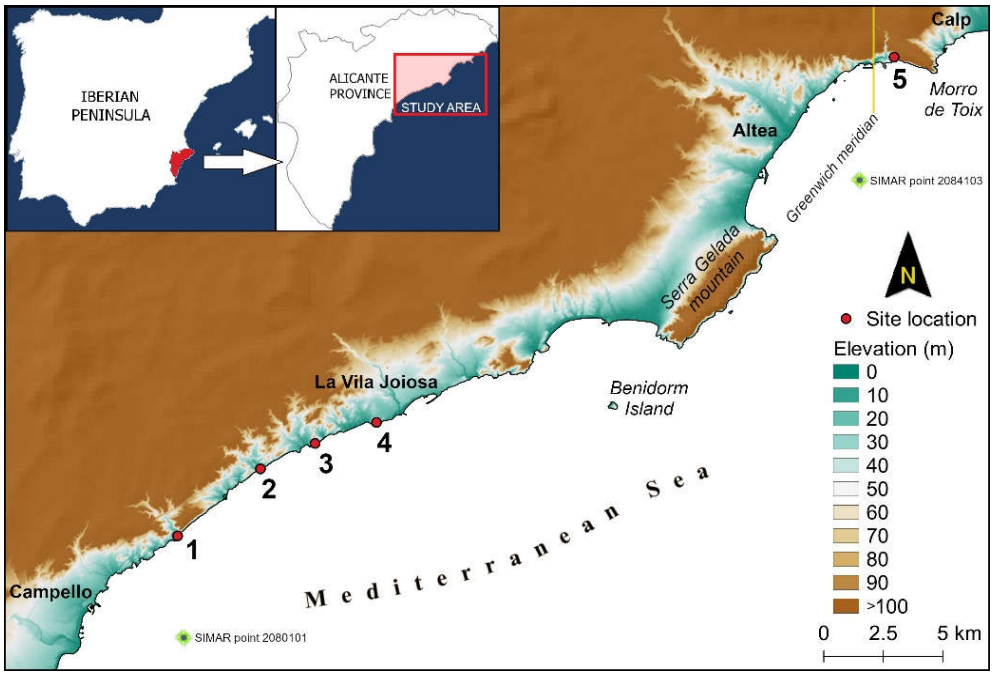



**Figura 23**. Localización de las 5 playas investigadas durante el invierno en Alicante (Asensio-Montesinos et al., **III**).

Después de retirar todos los residuos de las cinco playas, estas se visitaron cada dos semanas desde diciembre hasta marzo de 2021 y los residuos se marcaron con un color específico en cada visita con el fin de poder fácilmente identificar los nuevos aportes de residuos. En la primera evaluación se registraron un total de 150 residuos en las cinco playas llegando a sumar un total de 722 al final del estudio y demostrando así la facilidad que tienen los residuos de acumularse en playas en muy poco tiempo. Se registraron un total de 130 categorías distintas de residuos y se contabilizaron 3.418 residuos durante todo el estudio, de los cuales el 70,5% eran residuos "nuevos" u observados por primera vez y el 29,5% restante eran residuos que se observaron en más de una ocasión. Los residuos estaban compuestos por plástico (77,1%), metal (7,3%), ropa (5%), papel y cartón (3,9%), goma (2,3%), madera (1,5%), otros materiales (1,3%), vidrio (1,2%) y residuos orgánicos (0,4%). Los residuos más abundantes fueron trozos de plástico duro, poliestireno expandido y trozos de film, seguido de las colillas, los tapones de botellas, recipientes de bebida y fragmentos de papel, entre otros (Tabla 2).

**Tabla 2**. Número de los 10 tipos de residuos recientes o "nuevos" más abundantes (> 2%) durante el periodo de estudio en cada evaluación (Asensio-Montesinos et al., **III**).

| **Beach litter categories** | **S1** | **S2** | **S3** | **S4** | **S5** | **S6** | **S7** |
|---|---|---|---|---|---|---|---|
| Hard Plastic pieces 2,5 cm > < 50 cm | 41 | 67 | 136 | 49 | 119 | 120 | 72 |
| Foamed Plastic pieces 2,5 cm > < 50 cm | 13 | 86 | 101 | 13 | 20 | 23 | 34 |
| Film Plastic pieces 2,5 cm > < 50 cm | 13 | 17 | 22 | 18 | 30 | 39 | 33 |
| Cigarettes, butts & filters | 0 | 15 | 39 | 1 | 14 | 26 | 34 |
| Caps/lids | 3 | 13 | 25 | 6 | 7 | 17 | 12 |
| Drinks (bottles, containers and drums) < 2L | 2 | 3 | 41 | 2 | 11 | 8 | 6 |
| Paper fragments 2,5 cm - 50 cm | 1 | 4 | 4 | 4 | 10 | 15 | 30 |
| Cloth pieces 2,5 cm - 50 cm | 2 | 7 | 10 | 7 | 14 | 17 | 6 |
| Fishing line (angling) | 6 | 11 | 9 | 1 | 6 | 15 | 15 |
| Metal fragments 2,5 cm - 50 cm | 7 | 6 | 8 | 8 | 8 | 9 | 11 |
| Total | 88 | 229 | 395 | 109 | 239 | 289 | 253 |

Algunos residuos observados durante el estudio eran potencialmente peligrosos para los visitantes de la playa y para algunas especies animales. Los resultados mostraron que los aportes fueron diferentes durante toda la investigación. Después de marcar los residuos de un día específico, estos iban desapareciendo con el tiempo en las evaluaciones posteriores, sin embargo, casi siempre solía quedar algún remanente. En ocasiones, los residuos remanentes eran más numerosos que en evaluaciones previas, revelando de esta manera la relevancia de los procesos de enterramiento y exhumación a los que se exponen los residuos en playas de cantos. Los parámetros ambientales como la altura del oleaje y la dirección de aproximación, así como el viento, fueron factores importantes que tuvieron implicaciones en la distribución, composición y abundancia de algunos residuos. Las tormentas aportaron nuevos residuos capaces de flotar en el agua, como la madera procesada o las botellas de plástico. Sin embargo, las tormentas también se llevaron residuos de una playa (playa la Malladeta) debido a su morfología específica y la escasa anchura de la playa seca. En ese caso el oleaje llegó hasta la base del acantilado dándose así procesos de reflexión que transportaron los residuos mar adentro. Los usuarios también fueron responsables de la presencia de algunos residuos y de un incremento en

su abundancia, esto quedó registrado en las playas más frecuentadas del estudio y en las últimas evaluaciones, justamente cuando las playas recibían más visitas.

Los análisis multivariantes mostraron agrupaciones muy interesantes que relacionaban la cantidad y tipo de residuos con cada una de las siete evaluaciones realizadas en las cinco playas. Mediante dichos análisis se mostraron las playas y las evaluaciones que eran más parecidas o distintas entre sí, y se pudieron demostrar adecuadamente los motivos principales de dicha ordenación. La tipología de playa asociada al tipo de visitantes y los usos fueron factores clave: p. ej. las dos playas rurales presentaron muchas similitudes entre sí. La temporalidad también resultó ser importante ya que, a medida que avanzaba el estudio, se generaban más residuos (muchos de ellos provenientes de los usuarios) y los resultados de las evaluaciones iban pareciéndose más entre sí.

### 4.2. Los residuos sólidos de la costa de Cádiz

En este estudio se evaluó, en octubre de 2018 la presencia de residuos sólidos en un total de 40 playas de la provincia de Cádiz (Asensio-Montesinos et al., **IV**). Los sitios se seleccionaron arbitrariamente intentando cubrir la mayor parte del litoral estudiado (Figura 24) e incluyeron playas remotas (5), rurales (11), semiurbanas (13) y urbanas (11).

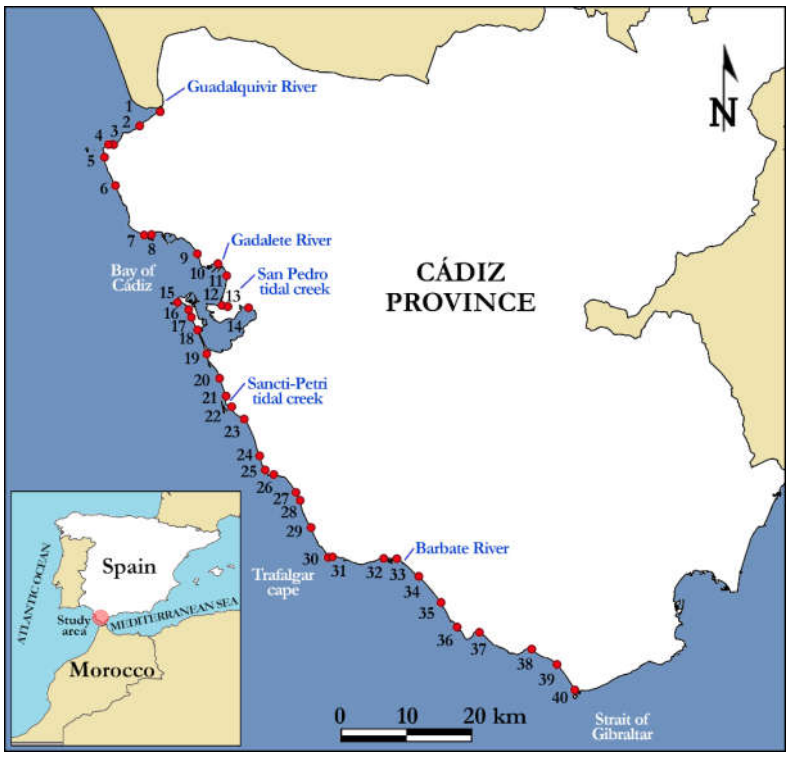



**Figura 24**. Localización de las playas estudiadas de Cádiz (Asensio-Montesinos et al., **V**).

En cuanto a los residuos, se contabilizaron un total de 16.123 elementos pertenecientes a 120 categorías. Los residuos se contabilizaron según la zona de la playa y en la línea de bajamar se observaron el 2,1% del total, en el *foreshore* el 7,8%, en la línea de pleamar el 64,2% y finalmente en el *backshore* el 25,8% de todos los residuos. El plástico fue el material predominante (88,5%), seguido de la ropa (3,9%), el papel y el cartón (1,6%), goma (1,6%), metal (1,6%), vidrio (0,9%), madera (0,8%), alfarería y cerámica (0,7%), residuos orgánicos (0,2%) y otros materiales indeterminados (0,1%, Figura 25). Las colillas fueron el residuo más numeroso que llegó a representar el 67,4% del total.

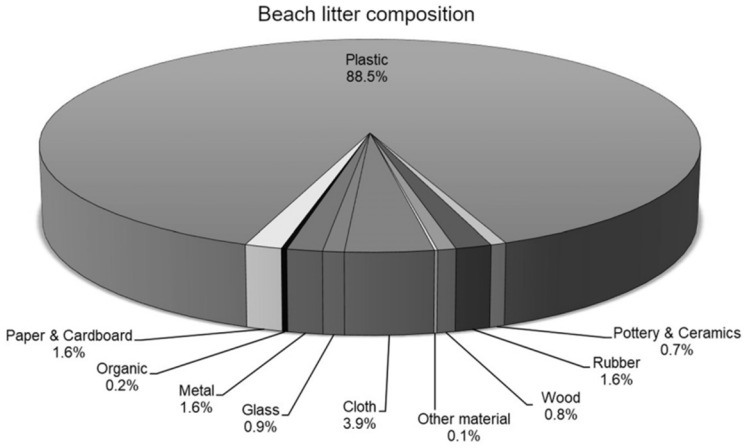



**Figura 25**. Composición de los residuos de playa durante octubre de 2018 en la costa de Cádiz (Asensio-Montesinos et al., **IV**).

En cuanto al grado de contaminación (EA/NALG, 2000), solo un sitio obtuvo el grado de residuos "A" (muy bueno) y 19 obtuvieron el grado "B" (bueno), mientras que 13 sitios obtuvieron un grado "C" (regular) y 7 sitios grado "D" (malo). Las playas remotas registraron grados "B" o "C", las playas urbanas y urbanizadas registraron los peores grados ("C" y "D"), mientras que las rurales registraron los cuatro grados ("A"–"D").

La presencia y abundancia de algunos residuos se relacionaron principalmente con las actividades de los usuarios (un 80% aprox.), con vertidos de aguas residuales en aquellos lugares más cercanos a ríos (5,5%) y en menor medida con actividades pesqueras (2,1%). La distancia de cada playa a ríos como el Guadalquivir, también afectó a la diversidad de los residuos y las playas más cercanas a desembocaduras tenían, por lo general, residuos más diversos que las playas más alejadas. Aunque hubo mucha variabilidad, las playas más limpias se observaron al sur de la provincia, mientras que las playas más sucias se observaron en distintos puntos, destacan la Cala del Aceite y Los Bateles

especialmente por su abundancia de colillas y la playa de Bajo de Guía por su abundancia y diversidad de residuos en general.

Las características de los residuos se relacionaron también con el estado morfodinámico de las playas investigadas, esencialmente asociados a la pendiente de la zona intermareal de la playa. Para caracterizar dicha variable, se realizaron varios perfiles topográficos con un GPS diferencial y según los resultados obtenidos, las playas se clasificaron en disipativas (13), intermedias (16) o reflectivas (11). Cada uno de estos estados se relaciona con un tipo de rompiente que puede relacionarse con el aporte de los residuos. Por ejemplo, el tipo de rompiente en voluta (*plunging*) removiliza más los sedimentos de la playa y los residuos que el tipo de rompiente en derrame. Las playas disipativas se correspondían con aquellas de pendiente suave ($\tan \beta \cong 0{,}02$) y, generalmente, poco energéticas, como la playa de Valdelagrana (Figura 14). Se observaron también playas intermedias, como La Princesa Alejandra (Figura 10), y playas reflectivas, es decir playas muy energéticas de gran pendiente ($\tan \beta \cong 0{,}10$), compuestas generalmente por arena gruesa como la playa de Trafalgar (Figura 16). Se intentó encontrar alguna posible relación entre estos tres tipos de estados morfodinámicos y la acumulación/tipología de residuos sólidos, pero no se observó una tendencia clara.

La siguiente investigación se centró únicamente en los residuos plásticos del litoral gaditano (Asensio-Montesinos et al., **V**). Para este propósito, previamente se tuvieron que recolectar todos los plásticos contabilizados en el estudio anterior (Asensio-Montesinos et al., **IV**). Los residuos fueron clasificados inicialmente por grupos (fragmentos de plástico duro, trozos de film, envoltorios, bastoncillos del oído, tapones, botellas, etc.) y luego fueron identificados utilizando diversas técnicas. Algunos fueron clasificados directamente mediante la información identificativa (si todavía la conservaban) y que consiste en un número del uno al siete que está asociado a un tipo de plástico: 1-PET; 2-PE-HD; 3-PVC; 4-PE-LD; 5-PP; 6-PS; 7-Otros. El resto de las muestras se identificó mediante la técnica Raman que mostró diferencias importantes entre los tipos de plásticos, tanto en los espectros Raman como en las fotografías realizadas con el microscopio (Figura 26).

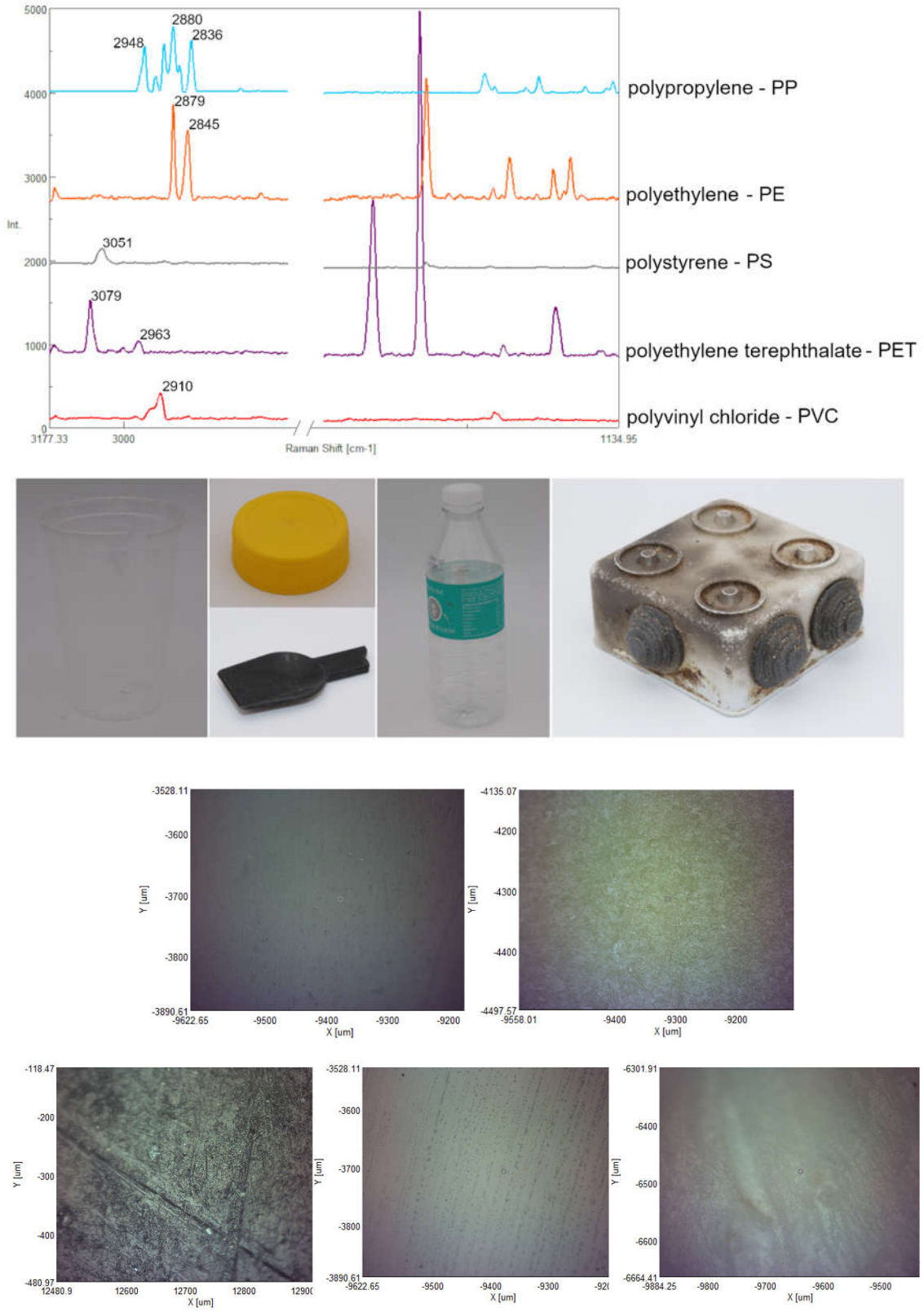



**Figura 26**: Espectros Raman de referencia pertenecientes a varias muestras de residuos: un vaso (PP), un tapón (PE-HD), una cucharilla (PS), una botella (PET) y una de derivación de PVC (Asensio-Montesinos et al., **V**). Abajo, las fotografías realizadas a 20 aumentos a dichas muestras: Polipropileno (PP) y Polietileno (PE); poliestireno (PS), tereftalato de polietileno (PET) y cloruro de polivinilo (PVC).

Un total de 14.261 residuos plásticos, pertenecientes a 57 grupos diferentes fueron incluidos en este estudio. En la línea de bajamar solo se vieron el 2% de los residuos de plástico y en el *foreshore* el 6%, mientras que en la línea de pleamar y en el *backshore* se encontraron la gran mayoría de ellos (67 y 25% respectivamente). El acetato de celulosa (CA), fue el material plástico más numeroso (79%) del total, ya que se corresponde con el grupo de las colillas de cigarrillos: el residuo predominante en muchas de las playas investigadas. El siguiente material predominante en las playas del estudio fue el polipropileno (PP, 9%), seguido del polietileno (PE, 8%). El resto estaba compuesto en menores proporciones por poliestireno (PS), polietileno tereftalato (PET) y cloruro de polivinilo (PVC, Figura 27).

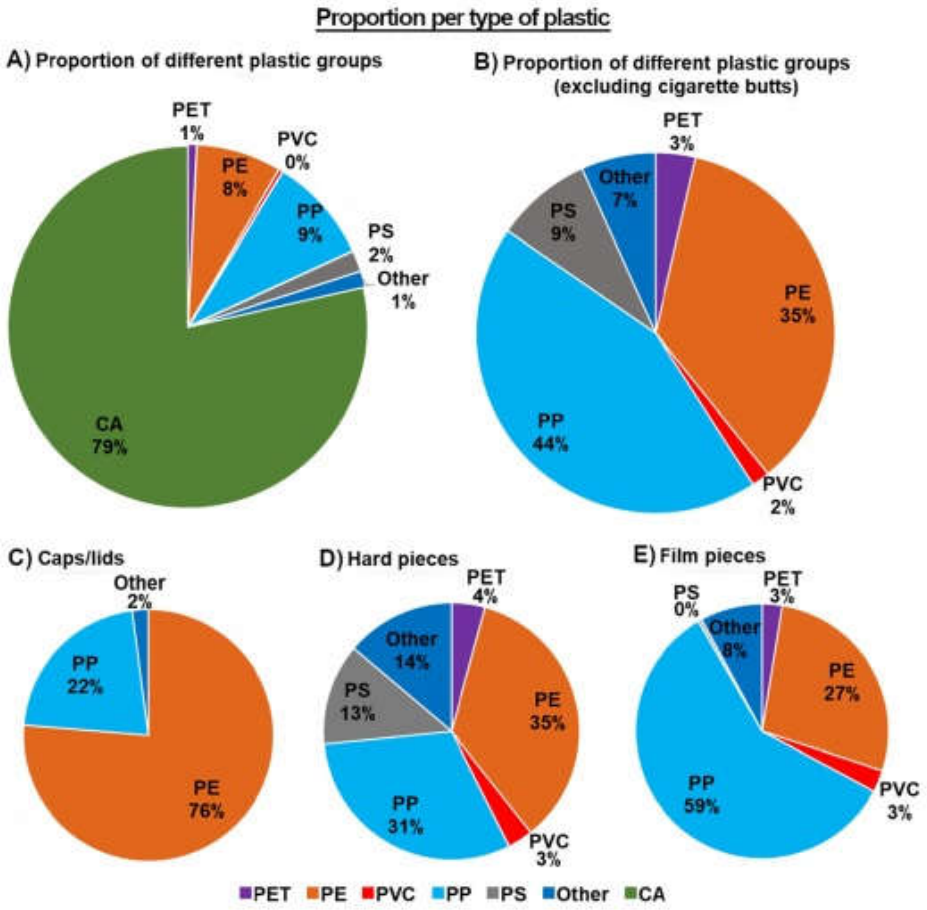



**Figura 27**. Proporciones por tipo de plástico (Asensio-Montesinos et al., **V**).

Los residuos relacionados con la actividad de fumar eran los más comunes en el área de estudio (principalmente colillas, aunque también era habitual encontrar algunos mecheros). Los siguientes residuos más numerosos fueron los fragmentos duros (Figura 28) y los trozos de film, seguidos de los bastoncillos del oído, cuerdas y cordeles relacionados con la pesca, envoltorios de comida, tapones y por último los plásticos de un solo uso. Los residuos plásticos se

relacionaron con los usuarios de la playa, con actividades pesqueras y con vertidos de aguas residuales. Aproximadamente, un 85% de los residuos se atribuyeron a fuentes de origen terrestre mientras que solo un 2% tenían un origen marino. De otros residuos (13%) no fue posible determinar su origen, por lo que podrían provenir tanto de fuentes terrestres como marinas. De otros residuos muy específicos pudo determinarse incluso el fabricante y, por lo tanto, las marcas más comunes de los productos más desechados que terminan en la playa.



**Figura 28**. Fragmentos de plástico analizados, provenientes de una de las playas estudiadas (escala en centímetros).

### 4.3. Las colillas en la costa: un problema común

Por ser el residuo más numeroso, en el marco de un último estudio, se decidió estudiar la abundancia y distribución de las colillas en diferentes playas con el fin de comprender mejor su comportamiento en la playa (Asensio-Montesinos et al., **VI**). Para este estudio se tuvieron en cuenta 188 evaluaciones de residuos, llevadas a cabo en diferentes playas del sur de España (Figura 29): Alicante (Asensio-Montesinos et al., **I**; **II**), Cádiz (Asensio-Montesinos et al., **IV**) y Ceuta (Aguilar-Torrelo, 2019; Asensio-Montesinos et al., **VI**; 2021).




**Figura 29**. Localización de las tres provincias estudiadas (Asensio-Montesinos et al., **VI**).

Las colillas están consideradas como uno de los residuos personales más desechados o abandonados en todo el mundo. En España se han observado en todo tipo de playa siendo los propios usuarios los principales responsables de su presencia; no obstante, las colillas también pueden ser arrastradas por los ríos y las corrientes hasta llegar a la orilla. Los principales factores que facilitaron la acumulación de colillas en playas fueron la estacionalidad y el número de usuarios, la tipología de playa (remota, rural, semiurbana o urbana), el tipo de sedimento de la playa y los métodos y la frecuencia de las operaciones de limpieza. Un total de 29.919 colillas fueron contabilizadas en tan solo 18,8 kilómetros de línea de costa ya que por cada una de las 188 evaluaciones se consideraron 100 m de largo (Tabla 3; Asensio-Montesinos et al., **VI**). Sin embargo, el ancho de playa no era siempre el mismo y hubo desde evaluaciones en las que solamente se pudo realizar un par de transectos (Asensio-Montesinos et al., **I**; **II**), mientras que en otras fueron necesarios más (Asensio-Montesinos et al., **I**; **II; IV**), dependiendo de la anchura de la playa en el momento de la evaluación (Figura 17). De todos los datos utilizados para este estudio, los valores generales muestran que la media fue de 159 colillas por 100 m de playa (0,038 colillas/$m^2$). El tipo de datos utilizados es muy variable y existen algunos valores atípicos muy altos que sesgan el promedio hacia valores más altos, por lo que en estos casos la mediana también es un valor adecuado para hacerse una idea de las cantidades de colillas en el medio costero. La mediana presentó un valor de 68 colillas por 100 m de playa (0,021 colillas/$m^2$).

**Tabla 3.** Fechas de los estudios realizados sobre colillas en playas (Asensio-Montesinos et al., **VI**).

| No. | Fecha | Provincia | Sitios[1] | Media y mediana | Media y mediana (Colillas/m²) |
|---|---|---|---|---|---|
| 1 | Marzo-Abril 2018 | Alacant | 56 | 82/40.5 | 0.023/0.013 |
| 2 | Agosto 2018 | Alacant | 56 | 229/121 | 0.061/0.041 |
| 3 | Octubre 2018 | Cádiz | 40 | 271/90 | 0.040/0.013 |
| 4 | Febrero 2019 | Ceuta | 12 | 18.5/6 | 0.008/0.002 |
| 5 | Marzo 2019 | Ceuta | 12 | 44/27 | 0.023/0.020 |
| 6 | Abril 2019 | Ceuta | 12 | 73/76.5 | 0.040/0.038 |

[1] El número de sitios evaluados se escogió de acuerdo a los kilómetros de costa de cada provincia.

Las cantidades de colillas observadas en las playas estudiadas por lo general varían según la fecha en la que se han realizado las evaluaciones. Así, los resultados muestran que la estacionalidad es un factor de gran relevancia ya que en verano o poco después, se registraron los valores más altos de colillas como en Alicante y Cádiz durante agosto y octubre de 2018 (Asensio-Montesinos et al., **II**; **IV**). Contrariamente, los valores más bajos de colillas se registraron en la costa ceutí durante los meses de febrero y marzo de 2019 cuando apenas hay usuarios en la playa. Valores intermedios presentaron las evaluaciones realizadas en Alicante y Ceuta durante el mes de abril, que corresponde a una época en la que los usuarios no son tan numerosos como en verano, pero empiezan a acudir en mayor número debido a las condiciones ambientales favorables.

El número de colillas varió también en función de la tipología de playa, poniendo de manifiesto un aumento considerable de colillas según aumenta el nivel de urbanización de las zonas consideradas. De este modo, las playas remotas registraron los valores más bajos (mediana = 9 colillas/100 m de playa), seguidas de las playas rurales que triplicaron su densidad (mediana = 31 colillas/100 m de playa). Finalmente, las playas semiurbanas registraron un valor de 83 colillas/100 m y las playas urbanas fueron aquellas que obtuvieron los peores resultados con un valor de 114 colillas por playa (Tabla 4). La media de colillas por playa registró valores más altos que la mediana, especialmente en playas rurales debido a la gran variabilidad en el número de colillas, tal y como se observa en el rango de valores de la Tabla 4.

**Tabla 4**. Número de evaluaciones y valores de abundancia de colillas (media y mediana) por tipología de playas (Asensio-Montesinos et al., **VI**).

| Tipología | Evaluaciones | Media y mediana | Rango de valores | Total | Media y mediana ($m^2$) |
|---|---|---|---|---|---|
| Remote | 32 | 21/9.5 | 0–135 | 684 | 0.010/0.003 |
| Rural | 37 | 162/31 | 0–1,358 | 5,994 | 0.053/0.013 |
| Village | 53 | 155/83 | 3–1,069 | 8,206 | 0.038/0.028 |
| Urban | 66 | 228/114 | 0–1,612 | 15,035 | 0.043/0.031 |

La accesibilidad es otro factor interesante a tener en cuenta ya que, por lo general, las playas más accesibles contenían un mayor número de colillas que aquellas más inaccesibles o alejadas, por ejemplo, de aparcamientos. Se hizo una comparación entre playas que estaban a menos de 200 m de una zona de aparcamiento, playas que estaban entre 200 y 300 m y playas que estaban a más de 300 m de algún parking, estas últimas consideradas playas remotas en el ambiente mediterráneo. Los resultados mostraron un incremento de colillas desde las playas más alejadas (media = 55; mediana = 8), pasando por las playas a media distancia (media = 80; mediana = 59) hasta las playas más cercanas a parkings (media = 186; mediana = 90), la mayoría de estas últimas muy urbanizadas.

La composición sedimentológica o tipología de los materiales que constituyen cada playa también influye indirectamente en el número de colillas contabilizadas. Los resultados mostraron como, a partir de 108 evaluaciones de residuos realizadas en playas de arena, se registró una media de 211 colillas (mediana = 91), mientras que, en el resto de las 80 evaluaciones llevadas a cabo en playas compuestas por grava, cantos, etc., se registró una media de 89 colillas por 100 m de playa (mediana = 27).

Finalmente, se observó que las colillas, al igual que otros muchos residuos, no se acumulan homogéneamente en las playas, sino que están distribuidas de manera distinta según la zona del perfil de playa. Algunas colillas se acumulan en la orilla por la acción de las mareas y las corrientes que las han traído, mientras que otras se acumulan en el *backshore* o playa seca. En las playas mediterráneas como las de Alicante y Ceuta se acumulan principalmente en el *backshore* y al final de la playa, justo donde suele comenzar algún elemento antrópico o natural como bien puede ser una edificación, un paseo marítimo, un acantilado, una duna, etc.

En las playas Atlánticas de Cádiz se acumularon principalmente en la línea más alta de marea y en el *backshore*, donde los usuarios suelen permanecer más tiempo. Se registraron valores muy altos de colillas en correspondencia de la marca de pleamar (o *strand line* en inglés) en playas con características mesomareales, que corresponden a las playas desde Sanlúcar de Barrameda en el NO de Cádiz hasta las playas situadas en Cabo Trafalgar (Barbate, Cádiz). En estas playas gaditanas, el 73,6% de las colillas se encontraron en la línea de pleamar y el 22% en el *backshore*. En el *foreshore* y en la línea de bajamar se registraron pocas colillas (4,1 y 0,3% respectivamente).

## 5. DISCUSIÓN

### 5.1. Las playas mediterráneas de Alicante

Las cantidades de residuos observadas en la costa mediterránea de Alicante presentan gran variabilidad espacial y oscilan entre un valor mínimo y máximo de respectivamente 0,005 y 0,661 ítems/m$^2$. Los valores medios de abundancia de residuos observados en la costa de Alicante son a grosso modo similares a aquellos reportados por otros estudios; así, los valores obtenidos durante la primavera (0,062 ítems/m$^2$, Asensio-Montesinos et al., **I**) son muy similares a aquellos reportados en la costa marroquí del Mediterráneo (0,059 y 0,048 ítems/m$^2$, Nachite et al., 2019) mientras que aquellos registrados durante la temporada estival (0,116 ítems/m$^2$, Asensio-Montesinos et al., **II**) resultan parecidos a los valores (0,138 ítems/m$^2$) reportados en las playas turísticas de Río de Janeiro, Brasil (Oigman-Pszczol y Creed, 2007).

En cuanto a las variaciones estacionales, los valores de abundancia de residuos cambian considerablemente entre la primavera y verano tal como se observa en otros estudios, por ejemplo, en la costa Mediterránea de Marruecos, donde los residuos resultan ser ligeramente más abundantes en otoño (0,059 ± 0,032 ítems/m$^2$) que en primavera (0,048 ± 0,026 ítems/m$^2$, Nachite et al., 2019). Variaciones estacionales en la abundancia de residuos son comunes también en otros lugares, p. ej. en algunas playas de Chile se observan más residuos en otoño (0,25 ítems/m$^2$) que en invierno (0,17 ítems/m$^2$, Barría-Herrera et al., 2021) aunque, por otro lado, Terzi y Seyhan (2017) no detectan diferencias estacionales evidentes en la abundancia y composición de los residuos de las playas del Mar Negro, salvo un ligero aumento en la cantidad de plástico en verano.

En Alicante, la mayor parte de los residuos contabilizados en la costa están compuestos por plástico, material que representa el 83 – 84% del total. Otros estudios también llevados a cabo en la costa mediterránea permiten demostrar como el plástico representa el material dominante con más del 80% del total de los residuos, hecho también observado, p. ej. en el noreste del Mediterráneo (Aydın et al., 2016) y en algunas playas italianas (Munari et al., 2016; Legambiente, 2017). En otras partes del mundo el plástico también representa el porcentaje mayoritario, como en Sudáfrica (83,4%, Madzena y Lasiak, 1997), o en la costa del Mar Negro de Bulgaria, donde predominan las categorías de residuos plásticos como colillas, tapones, vasos y fragmentos de plástico (Simeonova y Chuturkova, 2019). En algunos lugares, el plástico llega a superar el 90% de todos los residuos contabilizados, como en el caso de la costa belga (Van Cauwenberghe et al., 2013) o en la Ciudad del Cabo en Sudáfrica (Chitaka y von Blottnitz, 2019). En Alicante, las colillas constituyen el grupo mayoritario tanto en primavera como en verano, seguidos en ambas épocas por otras categorías de residuos como los fragmentos de plástico, los trozos de papeles, los bastoncillos del oído o los envoltorios. Dichas observaciones han sido confirmadas en diferentes lugares por estudios llevados a cabo por instituciones públicas de investigación y organizaciones no gubernamentales (UNEP, 2015; Ocean Conservancy, 2016; Vlachogianni et al., 2018).

En el marco de este estudio se ha observado como la procedencia de los residuos mayoritarios es claramente terrestre, siendo los usuarios de playa la principal fuente de contaminación. Del mismo modo, en el Mediterráneo, Prevenios et al. (2018) también identifican como los residuos proceden esencialmente de fuentes de origen terrestre y, entre ellas, destacan la relevancia del turismo de recreación. El ejemplo más claro de un residuo relacionado con los usuarios de playa es representado por las colillas de cigarrillos que, en su gran mayoría, son desechadas directamente en la propia playa. La predominancia de las colillas ha sido confirmada en el marco de diferentes estudios (Martinez-Ribes et al., 2007; Loizidou et al., 2018). Los problemas asociados a la presencia de cigarrillos en las playas han llamado recientemente la atención de muchos investigadores y muchos estudios se han centrado únicamente en este tipo de residuo tan abundante a nivel mundial (Novotny et al., 2009; Kungskulniti et al., 2018; Araújo y Costa, 2019; Green et al., 2021). Sin embargo, no siempre es posible determinar la procedencia de un residuo y, en algunos casos, esto resulta bastante difícil o imposible. Es por ello que algunos estudios agrupan en una misma categoría los residuos que tienen un origen desconocido (Prevenios et al., 2018;

Vlachogianni et al., 2018). Otras observaciones realizadas en el marco de este estudio y confirmadas por otros autores, apuntan a que, en determinadas playas, p. ej. cerca de las desembocaduras de ríos u otros cursos de agua temporales, algunos grupos de residuos son más numerosos de lo habitual. Entre dichos residuos se encuentran aquellos relacionados con las aguas residuales: toallitas húmedas, bastoncillos del oído, aplicadores de tampones, preservativos, etc., poniendo así en evidencia el mal funcionamiento de los sistemas de depuración. Los residuos flotantes como botellas y tapones también suelen aparecer en playas cercanas a desembocaduras. Este aporte de residuos desde tierra hacia el mar por diferentes cursos de agua es de los más importantes: los ríos se pueden considerar como uno de los medios principales de transporte y dispersión de residuos mal gestionados hasta el medio marino y costero (González-Fernández et al., 2021) en el cual son luego transportados por el viento y las corrientes (Rech et al., 2014). Los residuos que terminan llegando al medio marino pueden flotar y recorrer grandes distancias (Hohn, 2011) sin llegar a hundirse ni descomponerse (Rizzo et al., 2021).

En Alicante se ha visto como la tipología de playa constituye un factor clave en la abundancia y tipos de residuos ya que este concepto está relacionado con su accesibilidad y determina el tipo de usuarios que las frecuentan, así como su número. Basándose en observaciones llevadas a cabo en algunas playas de la zona de estudio de esta tesis, autores como Cabezas-Rabadán et al. (2019) demuestran como los usuarios más jóvenes prefieren lugares con muchas características naturales principalmente por el interés paisajístico (p. ej. Cala d'Ambolo, Figura 7), mientras que otros usuarios de mayor edad o familias, prefieren playas de tipo urbano ya que suelen ser más accesibles y están equipadas con diferentes infraestructuras que garantizan una mayor comodidad. La relación directa entre abundancia de residuos y número de visitantes se confirma en las playas más urbanizadas que presentan más residuos en comparación a las otras tipologías de playa, tal como observan también Maziane et al. (2018) y Nachite et al. (2019) en la costa de Marruecos. Los análisis multivariantes (Asensio-Montesinos et al., **I**; **II**; **III**) muestran que, en cuanto a la composición de residuos, las playas más visitadas y con más residuos resultan ser las más parecidas entre si y esto se debe principalmente al comportamiento inadecuado de los propios usuarios. Algunos grupos específicos de residuos cuales colillas, envoltorios de comida y otros plásticos de un solo uso como cuchillos, tenedores, cucharas o pajitas, son muy comunes en determinadas playas urbanas.

Este estudio ha puesto de manifiesto como otro factor importante a tener en cuenta en la abundancia y tipología de residuos resulta ser el tipo de sedimento o sustrato de la playa (arena, cantos rodados, plataforma rocosa, etc.) que determina el tipo de gestión y de limpieza que se puede realizar en cada sitio. Además, los usuarios generalmente prefieren playas de arena, seguidas de las playas de grava, cantos, bloques y barro (Ergin et al., 2004). Por ende, las playas de arena son las más propensas a recibir residuos por parte de los usuarios. Por lo general, los sitios con arena se limpian siempre que sea posible con maquinaria pesada (p. ej. tractores con máquinas de rastrillado y cribado), mientras que los sitios con plataforma rocosa, grava, cantos o bloques se limpian manualmente por personal cualificado. Algunos sitios remotos y rurales no tienen una buena gestión de limpieza debido principalmente a la dificultad de acceso. De hecho, la dificultad de realizar limpiezas manualmente en estos lugares facilita la acumulación de residuos tanto de origen terrestre como marino. Los valores generales de abundancia de residuos por metro cuadrado muestran que las playas de arena contienen menos residuos que el resto tanto en los muestreos de primavera como de verano. La limpieza de la playa en verano se realiza con mucha mayor frecuencia que en primavera debido al aumento del número de usuarios en las playas, sin embargo, a pesar de los esfuerzos de limpieza, los residuos resultan más numerosos en verano. Por este motivo las playas de cantos muestran peores calificaciones en cuanto a la composición y número de residuos (EA/NALG, 2000). El tamaño de los residuos también presenta diferencias entre tipos de playas, ya que en las playas que se limpian con máquinas de rastrillado y cribado, a menudo urbanas o semiurbanas, los residuos de menor tamaño son predominantes ya que en su mayoría no se quedan retenidos en los tamices de retención como las colillas y los bastoncillos (Williams, 2011) y, en ocasiones, los tapones (Nachite et al., 2019) y otros trozos de plástico de pequeño tamaño. Los residuos grandes a menudo suelen aparecer en playas remotas donde es difícil su recogida y pueden permanecer durante largos periodos de tiempo. En el marco de este estudio se llegaron a detectar algunos puntos muy importantes de contaminación por residuos sólidos con implicaciones serias para la salud de los usuarios y de la fauna costera. Gracias a ello, dichos lugares como la playa de San Gabriel o la playa de Agua Amarga, poco después fueron noticia en diferentes medios de comunicación que resaltaron los problemas principales de contaminación observados en este estudio (Ecologistas en Acción, 2019; Diario INFORMACIÓN, 2019).

En base a los resultados obtenidos, se pueden realizar algunas propuestas para disminuir los residuos en las variadas playas de Alicante. Como en muchos otros lugares, se llegó a la conclusión de que invertir en programas de educación podía ser de las mejores soluciones para combatir la presencia de residuos. Un objetivo común de todos los gobiernos debería estar enfocado a favorecer un cambio en la cultura de las personas para que dejen de verter residuos al medio natural. El cumplimiento de la ley en temas de contaminación debería estar más controlado y un mayor número de sanciones a empresas o personas que contaminan también podría mitigar la contaminación por residuos sólidos. Otros aspectos importantes a considerar son las infraestructuras de la playa, como las papeleras, que deben ser suficientes a cubrir las exigencias del lugar (Williams y Micallef, 2009). En los sitios más inaccesibles se sugiere una mejora de gestión ya que la limpieza en muchas ocasiones queda a merced de voluntarios.

El estudio en la costa de Alicante sobre el comportamiento de los residuos sólidos en playas de cantos rodados (Asensio-Montesinos et al., **III**) revela interesantes resultados que confirman un estudio previo realizado por Williams y Tudor (2001) en una playa de características similares de Gales, Reino Unido. Los sitios fueron investigados durante el invierno, temporada en la que resultan ser poco visitados por usuarios por lo que la abundancia y el comportamiento de los residuos registra una influencia marítima bastante alta en comparación a los otros estudios realizados en el litoral alicantino. Tal como se ha dicho anteriormente, la composición de los residuos a menudo constituye una herramienta muy útil para determinar su procedencia (EA/NALG, 2000; Bergmann et al., 2015) así como la tipología y el uso de cada playa (Ocean Conservancy, 2010). Así, su composición o aspecto ya ha sido valorado en otros estudios para determinar su procedencia local o foránea (Wade et al., 1991; Munari et al., 2016; Ryan, 2020). En el caso de las playas remotas y rurales estudiadas durante el invierno por Asensio-Montesinos et al. (**III**), la interpretación de las etiquetas que contenían algunos residuos permitieron determinar su procedencia de otros países. A modo de ejemplo, cabe destacar un tapón de plástico perteneciente a una conocida marca de agua embotellada "Nongfu Spring" procedente de China, que seguramente proviene de embarcaciones de dicho país ya que el mismo modelo de tapón fue observado recientemente en playas australianas (Smith et al., 2018) y en las playas de Svalbard (Falk-Andersson et al., 2021). Otros residuos tienen un origen local y están relacionados con el tipo de usuarios que suele visitar estas playas en invierno, principalmente pescadores. Algunos residuos son potencialmente

peligrosos para los usuarios de playa o la fauna marina y costera, ya que dichos elementos pueden producir daños importantes de diferentes maneras (punción, laceración, etc.), algo que se ha documentado en numerosas ocasiones (Ocean Conservancy 2010; 2016; Haig et al., 2014; Hardesty et al., 2015; Duncan et al., 2017). Las evidencias de aguas residuales también llegan a estas playas rurales y remotas, aunque no en tanta cantidad como se ha observado en otras playas de Alicante (Asensio-Montesinos et al., **I**; **II**), tendencia también observada en algunas playas remotas en Colombia (Williams et al., 2016b) y en playas rurales de Cuba (Botero et al., 2017). Las tasas de acumulación de los residuos observadas en las 5 playas investigadas del litoral de Alicante, son más bajas en comparación con otros estudios llevados a cabo en Sudáfrica, en la isla de Corfú (Mar Jónico) o las Islas Seychelles (Chitaka y von Blottnitz, 2019; Prevenios et al., 2018; Dunlop et al., 2020). Sin embargo, en otros lugares todavía más remotos como la Antártida donde la presencia humana es muy baja o casi nula, otros estudios demuestran la existencia de playas con densidades muy bajas o nulas de residuos (Convey et al., 2002; Anfuso et al., 2020). La capacidad de los residuos de recolonizar una playa se puso de manifiesto al haber retirado inicialmente todos los residuos de las playas e ir apuntando cada poco tiempo las nuevas aportaciones, tal y como ya observaron Williams y Tudor (2001) hace 20 años en una playa remota poco visitada.

El aporte de residuos según la categoría se relaciona con eventos de tormentas marítimas que traen a la costa residuos flotantes como botellas. Los vientos procedentes de tierra también tienen una influencia importante ya que transportan numerosos fragmentos de poliestireno expandido (*PS*). La relevancia del viento en el transporte de residuos fue también evidenciada por Eriksson et al. (2013) en playas de islas subantárticas. Sin embargo, no siempre los residuos se van acumulando en la playa, pues según el tipo de residuo y la playa, estos dejan de observarse en algún momento del estudio por diversas circunstancias. Por una parte, la gestión de algunas de estas playas, por ejemplo, las rurales, favorece que los residuos más grandes como las botellas, sean recogidos por los servicios de limpieza o algunos visitantes. En las playas remotas los residuos de mayores dimensiones permanecen más tiempo debido a que no son limpiadas. Dichas diferencias en la gestión según el tipo de playa confirman las observaciones previas a lo largo del mismo litoral de Asensio-Montesinos et al. (**I**, **II;** 2019a; 2020) que evalúan en diferentes periodos del año muchos más sitios pertenecientes a estas tipologías.

En las playas investigadas por Asensio-Montesinos et al. (**III**), los residuos están sometidos a procesos de enterramiento entre los cantos rodados de la playa y son exhumados por la acción de las olas o de los usuarios al caminar. Aquellos residuos más pequeños y que no flotan resultan ser más propensos a permanecer en la playa durante más tiempo. Así, se demostró que los residuos pueden permanecer en la playa varios meses y es posible encontrar algunos que han permanecido durante años. Otros estudios también demuestran que muchos de los residuos de playa permanecen cubiertos por el sedimento antes de ser exhumados, especialmente los de menor tamaño (Williams y Tudor, 2001; Kusui y Noda, 2003; Lavers y Bond, 2017). En las playas de Senegal los residuos enterrados resultaron ser 25 veces más numerosos que aquellos en superficie (Tavares et al., 2020). En playas remotas de la Antártida también se encontraron residuos que permanecieron allí semienterrados durante muchos años (Anfuso et al., 2020). En este estudio llevado a cabo mediante el marcaje de los residuos con diferentes colores (Asensio-Montesinos et al., **III**) se observa un incremento de la cantidad de residuos de una evaluación a otra revelando de esta manera la importancia de los procesos de exhumación y como ésta, conjuntamente a la desaparición de otros residuos, indican un posible enterramiento de los mismos. El estudio de los residuos enterrados en playa ha sido ignorado durante tiempo debido a las dificultades que conlleva y a la falta de métodos adecuados (Kusui y Noda, 2003), especialmente en playas de cantos rodados – por lo que los pocos estudios existentes conciernen esencialmente playas arenosas (Ogi y Fukumoto, 2000; Kusui y Noda, 2003; Ryan et al., 2009; Lavers y Bond, 2017). Debido al oleaje, las corrientes y el viento, algunos residuos observados en el marco de este estudio (Asensio-Montesinos et al., **III**) son transportados de una playa a otra, hecho que se pudo determinar mediante el análisis detallado de los datos. Esta transferencia de residuos de una a playa a otra se observó en la costa israelí donde muchos de los residuos permanecían temporalmente en una playa antes de ser reemplazados por otros de playas vecinas (Bowman et al., 1998).

La geomorfología costera también tiene implicaciones en la dispersión y el transvase de residuos entre playas ya que la presencia o ausencia de cabos u otros salientes rocosos influye en las características (dirección e intensidad) de las corrientes litorales que transportan los residuos. Las estructuras antrópicas como espigones y puertos también influyen en la distribución de los residuos transportados *longshore* y depositados aguas arriba o aguas abajo de las estructuras dependiendo de las condiciones ambientales. Todos estos salientes naturales o antrópicos dividen la costa en celdas morfológicas (Anfuso et al.,

2011), unidades morfológicas en las que se acumulan los residuos y donde se mueven de un lado a otro y, a veces, pasando de una celda a otra.

Finalmente, la relación entre los parámetros ambientales y la abundancia y distribución de los residuos fue estudiada también mediante análisis multivariantes (p. ej. *nMDS* y *Cluster*) que mostraron las principales relaciones entre playas y residuos según la época del muestreo. Este tipo de análisis para buscar similitudes entre playas según su composición de residuos atendiendo a sus características fue también utilizado por otros investigadores en distintos sitios (Tudor et al., 2002; Rech et al., 2014; Rangel-Buitrago et al., 2018).

### 5.2. Las playas atlánticas de Cádiz

La abundancia media de los residuos en el litoral de Cádiz fue de 0,06 ítems/m$^2$ y osciló entre 0,003 y 0,26 ítems/m$^2$ (Asensio-Montesinos et al., **IV**), valores similares a aquellos observados por Gago et al. (2014) y Vlachogianni (2019) en Galicia y varias playas del Mar Adriático y del Mar Jónico y, en general, más bajos que aquellos reportados en las costas de Brasil (Santos et al., 2009), Chile (Thiel et al., 2011), California (Rosevelt et al., 2013), Turquía (Topçu et al., 2013), Colombia (Rangel-Buitrago et al., 2017) y Australia (Lavers et al., 2019) pero más abundantes de aquellos observados en China (Zhou et al., 2016) y Reino Unido (Watts et al., 2017). La abundancia y el contenido de los residuos variaron de una playa a otra influenciados por la morfología de la costa y las dimensiones de cada playa, por el viento, el oleaje, las corrientes y las mareas, así como por el número de visitantes, las infraestructuras o las modalidades y frecuencia de limpieza. Así, de acuerdo con Thiel et al. (2013) y Poeta et al. (2016b), la abundancia de residuos en la costa está muy influenciada por las condiciones ambientales. El viento puede jugar un papel muy importante en la distribución de los residuos (Kako et al., 2010), especialmente en Cádiz donde incide con gran fuerza (Figura 11). En cuanto a la composición de los residuos, Asensio-Montesinos et al. (**IV**) reportaron como el plástico representa el material mayoritario, con valores de casi el 90% de todos los residuos, observaciones que coinciden con aquellas de muchos otros autores (Topçu et al., 2013; Šilc et al., 2018). Desde hace unas pocas décadas, los plásticos ya forman cerca del 90% de todos los residuos de algunas playas (Ryan y Moloney, 1990). La tipología de la playa adquiere gran relevancia en la abundancia de los residuos ya que otros factores como la gestión o el tipo y número de usuarios están estrechamente relacionados con este factor. Las playas urbanas o semiurbanas presentan unas

cantidades de residuos muy parecidas, probablemente debido al tipo de usuarios y al tipo de gestión que en ellas se lleva a cabo. Las playas rurales muestran gran variabilidad entre ellas, aquellas con muchos visitantes suelen tener una buena gestión y la abundancia de residuos es usualmente baja, mientras que aquellas que no presentan muchas visitas normalmente no reciben los mismos esfuerzos de gestión y esto se refleja en la abundancia y el contenido de los residuos. Las playas remotas son las que menos residuos registran en comparación al resto de tipologías, tal y como se evidencia en la costa mediterránea (Maziane et al., 2018; Asensio-Montesinos et al., **I**; **II**).

Los residuos más numerosos en las playas gaditanas (Asensio-Montesinos et al., **IV**) son las colillas de cigarrillos, tal y como se observa en otros lugares de la costa española (Martinez-Ribes et al., 2007; Munari et al., 2016; Asensio-Montesinos et al., **II**). El resto de los grupos más numerosos representan menos del 6% de todos los residuos, y algunos están principalmente relacionados con los usuarios de playa, como los plásticos de un solo uso (Asensio-Montesinos et al., **IV**). Los residuos relacionados con la pesca representan menos del 3% del total. Este bajo porcentaje en comparación con otros grupos de residuos también se reportó en la costa mediterránea española (Asensio-Montesinos et al., **II**). Pese a su baja proporción, su presencia en la playa puede suponer un grave peligro para varias especies animales y los usuarios, que pueden sufrir laceraciones y enredos (Ballance et al., 2000; Dau et al., 2009; Thiel et al., 2011; Williams et al., 2013). En lugares remotos con una gran influencia marina como por ejemplo las islas, los residuos relacionados con la pesca pueden representar un porcentaje mucho mayor, tal y como se demostró en la Isla Pájaro (Walker et al., 1997), en las Islas Malvinas (Otley y Ingham, 2003), en las Islas Midway (Ribic et al., 2012), o en el archipiélago de las Laquedivas (Kaviarasan et al., 2020).

En el litoral de Cádiz (Asensio-Montesinos et al., **IV**), la mayor parte de los residuos tiene un origen terrestre y local, así como se observa en otros estudios (Claereboudt, 2004; Silva-Cavalcanti et al., 2009). Cerca del 80% se relaciona directamente con los usuarios de playa, mientras que un 5,5% son residuos ligados a vertidos de aguas residuales procedentes de tierra, tendencia que se observa también en la vecina costa de Marruecos (Maziane et al., 2018; Nachite et al., 2019). Entre los residuos sólidos encontrados en playa, Asensio-Montesinos et al. (**V**) identifican varias marcas comerciales, algunas de procedencia local y otras fabricadas en otras provincias españolas o bien en otros países. Las marcas comerciales más comunes identificadas mediante las etiquetas todavía visibles

en algunos residuos corresponden a *Nestlé*, *Coca-Cola*, *PepsiCo* y *Danone*, entre otras. Una confirmación de dichas observaciones se obtuvo al publicarse la lista de "Los peores infractores del mundo en cuanto a contaminación por plásticos", encabezada precisamente por *Coca-Cola*, *PepsiCo*, *Nestlé* y *Danone* (Changing Markets Foundation, 2020). En cuanto al origen de los residuos en el litoral de Cádiz (Asensio-Montesinos et al., **IV**), unos pocos ítems provienen del exterior, tanto de países cercanos (p. ej. Portugal y Marruecos) desde donde llegan a través de las corrientes marinas, como de países más alejados (p. ej. Alemania y Polonia), bien porque son abandonados en la playa por turistas de esos países o llegan a la costa porque son arrojados al mar desde barcos de dichos países cuando transitan por las aguas costeras de la zona estudiada. Debido a la buena conectividad entre los mares y océanos y a la globalización, los residuos no conocen límites ni fronteras, y pueden recorrer grandes distancias desde donde son fabricados o desechados hasta llegar a su destino final. Un ejemplo excelente a nivel mundial de distribución de residuos sólidos a través del medio marino hace referencia al vertido accidental en enero de 1992 de 28.800 patitos y de otros muñecos de goma que tuvo lugar en mitad del océano Pacífico desde un carguero procedente de Hong Kong con rumbo a Washington. Los patitos fueron distribuidos por las corrientes marinas recorriendo miles de kilómetros y llegando finalmente a las playas de distintas partes del mundo (Hohn, 2011). De hecho, cada vez son más los estudios que registran residuos procedentes de otros países (Garrity y Levings, 1993; Williams y Simmons, 1997; Kei, 2005; Topçu et al., 2013; Ryan, 2020; Falk-Andersson et al., 2021).

La diversidad de residuos en el litoral de Cádiz (Asensio-Montesinos et al., **IV**), expresada como número de grupos o categorías de residuos (Material Complementario – Tabla S1) presenta valores muy diferentes según el sitio ya que varía desde 7 hasta un total de 50 grupos de residuos distintos detectados en un sector de playa de 100 m de largo, siendo la media de unos 27 grupos por playa. Esto indica diferentes aspectos importantes a tener en cuenta. Una diversidad muy alta de residuos en una playa sugiere que ésta se encuentra cerca de una fuente de contaminación importante, por ejemplo, de un río. Así se ha observado en las playas de la parte norte de la provincia de Cádiz, donde se registra un incremento tanto del número de residuos como del número de grupos de residuos a medida que nos acercamos a la desembocadura del Río Guadalquivir. Otros ejemplos similares se observan cerca del Río San Pedro y del Río Barbate. Dichas tendencias de acumulación fueron previamente registradas por Williams et al. (2016a) en playas de Cádiz; en ese mismo trabajo se observó

cómo el contenido de los residuos también varía según las gestiones y el tipo de limpieza de cada playa. Además, una gran diversidad de residuos complica los métodos de limpieza porque puede requerir la aplicación de un mayor número de técnicas necesarias para su retirada.

En el marco de este estudio (Asensio-Montesinos et al., **IV**) no se observan relaciones claras entre el estado morfodinámico de las playas (disipativas, intermedias y reflectivas) y la acumulación de residuos. Esto puede deberse a diferentes causas; puede ser que no exista una relación clara entre dichos factores o, más probablemente, la influencia humana (que determina el número y tipo de residuos y las operaciones de limpieza) resulta ser tan notable que enmascara la relevancia del estado morfodinámico de la playa.

La influencia humana también afecta a la distribución de los residuos en las diferentes zonas de la playa ya que la mayor parte de los residuos son abandonados por los usuarios en el *backshore* y luego la acción del oleaje y las mareas los agrupa en determinadas zonas, por ejemplo, en correspondencia de la marca de pleamar (Asensio-Montesinos et al., **IV**). En cuanto a la distribución de los residuos en las diferentes partes de la playa, se observa una cierta tendencia en playas con una influencia mareal importante: generalmente menos del 10% de todos los residuos se concentra en el *foreshore* o zona intermareal, mientras que cerca del 90% se encuentra entre la línea de pleamar y el *backshore* o playa seca. La zonación de los residuos a lo largo de la playa, aparte de estar influenciada por el comportamiento de los usuarios, está en gran parte ligada a las condiciones ambientales. La geomorfología, la acción de las olas y las mareas y el grado de exposición al viento y al oleaje afectan a la distribución y características de los residuos en el litoral (Velander y Mocogni, 1999; Williams y Tudor, 2001; Williams et al., 2017). Otros estudios también realizan observaciones parecidas, por ejemplo, en la Antártida, la mayor parte de los residuos se observan en la zona alta de la playa (Anfuso et al., 2020) y, en otras costas, como en la costa de Mumbai (India), la acumulación de residuos se da principalmente en la orilla y dicha tendencia ha sido objeto de estudios específicos (Jayasiri et al., 2013). La zonación de los residuos está influenciada por diversos factores, siendo la geomorfología (p. ej. la anchura de la playa seca), la hidrodinámica costera y la tipología de residuos (dimensiones y densidad) los más importantes (Kataoka et al., 2013). Además, en algunos lugares se ha llegado a documentar que la abundancia y tamaño de los residuos aumentan desde la orilla hasta el *backshore*, lo que indica que la playa seca constituye una zona de acumulación importante,

en especial para los residuos de gran tamaño (Olivelli et al., 2020). Algunos autores como Bowman et al. (1998) consideran el *backshore* como una trampa muy efectiva para muchos residuos, ya que pueden quedar allí retenidos durante mucho tiempo.

La densidad de población en un determinado lugar también es un factor importante que puede afectar a la cantidad de residuos, esto se ha observado principalmente en el Mediterráneo (Bergmann et al., 2015), pero podría aplicarse a muchas otras áreas donde el turismo es importante, como en la costa gaditana. De hecho, las playas cercanas a centros muy poblados, como aquellas pertenecientes a la parte noroeste de la provincia y las playas de la Bahía de Cádiz, muestran mayores cantidades de residuos que aquellas situadas en las comarcas del sur que presentan un menor número de habitantes (Asensio-Montesinos et al., **IV**).

El hecho de que la mayor parte de los residuos contabilizados en las playas de Cádiz estuviera constituida por plástico hizo que el segundo artículo que concierne al litoral gaditano se centrara en este material (Asensio-Montesinos et al., **V**). Resulta que la cantidad de plástico en las playas oscila desde un 40%, porcentaje que corresponde a la playa con menos residuos plásticos, hasta un 97% que se observa en una playa donde casi la totalidad de los residuos está compuesta por algún tipo de plástico. Los residuos plásticos registran un total de 57 grupos o categorías y, en cuanto a su distribución en la playa, la mayoría se encuentra en la línea de pleamar y en el *backshore*. Sin contar las colillas, entre los grupos de plástico más comunes en las playas se encuentran los fragmentos o piezas de plástico, y los bastoncillos del oído, tal como se ha observado en la costa italiana (Battisti et al., 2016). Los fragmentos de plástico y los bastoncillos también están entre los 3 grupos más numerosos de residuos procedentes de los ríos (Tramoy et al., 2019), confirmando así, como los ríos y otros cursos de agua constituyen importantes vías de entrada al medio marino de estos residuos.

En el litoral de Cádiz (Asensio-Montesinos et al., **IV**; **V**), la abundancia y tipología de los residuos varía entre tipos de playa, siendo las remotas las que menos residuos registran. Los valores de abundancia registrados resultan ser inferiores a los reportados en costas cercanas, como en Marruecos (Maziane et al., 2018) o Alicante (Asensio-Montesinos et al., **II**). Las playas rurales muestran más residuos que las remotas, en especial la playa de Camposoto y la Cala del Aceite, ambas muy visitadas, presentan valores similares a las playas turísticas de Alicante (Asensio-Montesinos et al., **II**). Sin embargo, las playas rurales

marroquíes contienen menos residuos que las playas rurales de Cádiz (Maziane et al., 2018; Nachite et al., 2019). La diferencia entre las playas remotas y rurales de un sector costero como puede ser la provincia de Cádiz es evidente y uno de los motivos principales es el número de usuarios que visita cada tipo de playa. La dificultad de llegar hasta algunos sitios remotos y, por el contrario, la facilidad de acceso que tienen algunas playas rurales hace que esto quede registrado en el número de residuos que se suelen encontrar en cada tipología de playa. Las playas semiurbanas por lo general reciben más visitas que las tipologías previas debido a su entorno urbanizado y todas las facilidades que eso conlleva para los usuarios. Las playas gaditanas de esta tipología suelen presentar más residuos que sus correspondientes en Marruecos o Alicante (Maziane et al., 2018; Nachite et al., 2019; Asensio-Montesinos et al., **II**). En cuanto a las playas urbanas del litoral de Cádiz, estas suelen registrar, con respecto a las otras topologías de playa, mayor abundancia de residuos, probablemente porque reciben un gran número de usuarios en comparación con el resto de tipologías mencionadas. Entonces, por lo general, las playas urbanas de Cádiz son aquellas que más residuos contienen y su abundancia presenta valores similares a aquellos observados en playas mediterráneas (Ariza et al., 2008; Maziane et al., 2018; Nachite et al., 2019; Asensio-Montesinos et al., **II**), donde esta tipología está muy bien representada. Las playas urbanas, al servir a grandes poblaciones (Williams y Micallef, 2009), están predispuestas a recibir más residuos por parte de los usuarios u otras fuentes (p. ej. agua de escorrentía urbana), por ello los esfuerzos de limpieza en estas playas suelen ser mayores que en otras tipologías de playa. Lamentablemente, a pesar de dichos esfuerzos, estos no resultan suficientes para mantener la playa libre de residuos.

La aplicación de la técnica Raman para la determinación de los residuos sólidos (Asensio-Montesinos et al., **V**) resulta ser de gran precisión ya que permite determinar la composición de la gran mayoría de los residuos plásticos que se clasificaron teniendo en consideración los principales tipos utilizados en el mercado. En cuanto a problemas en las mediciones Raman de determinados objetos hay que señalar como los espectros obtenidos muestran a veces diferencias en la intensidad de la señal cuando la muestra ha estado a la merced de las condiciones ambientales durante mucho tiempo. Cierto disturbio e incertidumbre en las mediciones se debe también a la presencia de picos o bandas en el espectro Raman según el color o los aditivos que contiene cada muestra. El procesado de los materiales plásticos conlleva la adición de muchos tintes y numerosos aditivos que les confieren otras propiedades y cuyas combinaciones

se ha descrito como "infinita" (Avendaño, 1992). Entre todos los residuos plásticos observados a lo largo del litoral de Cádiz (Asensio-Montesinos et al., **V**), el acetato de celulosa contenido en las colillas, resulta ser el compuesto más representado con casi el 80% del total de los residuos. Las colillas presentan mayor abundancia en las playas urbanas debido al mayor número de usuarios. Por lo general las colillas se acumulan en la línea de pleamar, debido a que son arrastradas allí por la marea llenante, una observación realizada también por Claereboudt (2004) y Williams et al. (2017).

La composición del tipo de plástico está, a veces, relacionada con el grupo al que pertenece dicho residuo, pero otras veces un mismo grupo de residuos puede estar compuesto por distintos tipos de plástico. Por ejemplo, en el caso de los fragmentos (Asensio-Montesinos et al., **V**), es imposible establecer un claro criterio de clasificación debido a la gran variabilidad de su composición: fragmentos de plásticos de aspecto parecido pueden estar compuestos por diferentes tipos de plástico. Así, para clasificarlos, es necesario analizar el mayor número de muestras posibles. El plástico predominante sin contar el acetato de celulosa resulta ser el polipropileno (PP), seguido por el polietileno (PE) (Asensio-Montesinos et al., **V**). Ambos plásticos tienen abundancia muy similar (9 y 8% respectivamente) y tanto uno como otro se encuentran en todas las playas estudiadas debido al amplio uso de estos plásticos en la fabricación de objetos. Algunos residuos hechos de PP corresponden a los envoltorios de comida, pajitas, cucharas, tenedores, vasos, recipientes, bastoncillos del oído, palitos de "chupa-chups", bolígrafos, tapones y juguetes, entre otros. De PE están compuestos otros residuos como por ejemplo bolsas, cuerdas y cordeles, pinzas de la ropa, tapones, etc. La diferencia principal frente a la exposición a las condiciones ambientales entre estos dos tipos principales de plástico es que el PP es más susceptible a la degradación por los rayos ultravioleta de la luz solar, pero es más resistente al agrietamiento por tensión. Además, el PE es muy barato y fácil de producir, y tiene buenas propiedades para determinados usos, por ejemplo, es resistente a muchos disolventes (Strong, 1996). El poliestireno (PS) se encontró en proporciones más bajas, y es esperable que su proporción siga bajando en las playas porque uno de sus usos principales, además de la fabricación del PS expandido (conocido como *foam* o *foamed plastic* en inglés), es el de la fabricación de plásticos de un solo uso relacionados con el almacenamiento de alimentos. Algunos ejemplos son las cucharillas, platos, vasos, etc. que poco a poco se están retirando del mercado con la ayuda de medios legales como leyes que regulan su producción y comercialización. Como

por ejemplo la Directiva (UE) 2019/904, que se centra en reducir el consumo desmesurado de los productos de plástico de un solo uso. En el marco de este estudio se ha visto como este tipo de plástico una vez que haya estado en contacto con las condiciones ambientales durante un tiempo, es muy fácil que se fragmente o se rompa, debido principalmente a su gran rigidez. Otro aspecto negativo es que es sensible a muchísimos disolventes (Strong, 1996). El polietileno tereftalato (PET) también registra proporciones bajas en el litoral de Cádiz (Asensio-Montesinos et al., **V**), cerca del 1%, y está esencialmente representado por recipientes de bebidas. La mayor parte de los recipientes que tienen un aspecto transparente, están fabricados por este material como, por ejemplo, las botellas de agua o los recipientes de comida. Es rígido, pero parcialmente flexible. Se ha utilizado también en la industria textil para dar resistencia a las fibras (Strong, 1996), por lo que estudios a otras escalas de observación, por ejemplo, a nivel de microplásticos (partículas < 5 mm), podrían revelar mayor abundancia de este tipo de plástico. Tras el PET, el policloruro de vinilo (PVC) representa menos del 1% y se encuentra principalmente en fragmentos y objetos específicos como por ejemplo tubos, envoltorios y algunas botellas. Es uno de los plásticos más versátiles (Avendaño, 1992) y se usa mucho en el campo de la construcción. Otros plásticos observados por Asensio-Montesinos et al. (**V**) se clasifican en la categoría de "otros" debido a su composición mixta o a la presencia de algún tipo de plástico distinto a los mencionados anteriormente. Sin contar el acetato de celulosa ligado principalmente a las colillas, Polarz et al. (2002), la abundancia por tipos de plástico resulta coincidir con los datos de producción de plásticos en Europa (Plastics Europe, 2019) que muestran claramente como el PP y el PE constituyen los tipos de plástico más utilizados. Estos resultan ser los más abundantes en varios grupos de plástico como por ejemplo en fragmentos duros, en fragmentos de film o en tapones (Asensio-Montesinos et al., **V**). Otro estudio realizado en una playa de Japón también muestra como estos materiales, especialmente el PE, son los más abundantes (Nakashima et al., 2011). Las proporciones mayoritarias en estos dos polímeros también se confirman a otras escalas de observación, p. ej. en la costa de Indonesia o en la costa sur de Sri Lanka (India), la mayoría de las micropartículas compuestas de plástico resultaron estar fabricadas de PE y PP (Syakti et al., 2017; Koongolla et al., 2018). En otro estudio realizado en la costa de Uruguay, se documenta como el plástico ingerido por las gaviotas está compuesto en su mayoría por PE y PP, aunque también se llegó a encontrar PS, PVC y PET, entre otros (Lenzi et al., 2016). La toxicidad que puede causar cada

uno de estos plásticos difiere en función de sus componentes principales y de los aditivos utilizados. Analizando los productos plásticos que se utilizan en la industria del consumo de alimentos, Zimmermann et al. (2019) demuestran que el PVC tiene alta toxicidad, mientras que el PET o el PE de alta densidad presentan baja o nula toxicidad. Otros plásticos como el PE de baja densidad, el PS o el PP variaron mucho en cuanto a su potencial tóxico (Zimmermann et al., 2019). En el litoral de Cádiz (Asensio-Montesinos et al., **V**), se han detectado muchos residuos compuestos por PP, relacionados con el tabaco o con otros hábitos de consumo, p. ej. envoltorios de paquetes de tabaco, de comida y de pajitas. En cuanto a los colores de los plásticos, se observan ciertas diferencias (Asensio-Montesinos et al., **V**), por ejemplo, los fragmentos de film son mayormente transparentes y de color blanco, mientras que los fragmentos de plástico duro son transparentes o presentan color blanco, azul y verde, como observaron otros investigadores, p. ej. en playas de Indonesia (Syakti et al., 2017). La gama de colores también varía de unas muestras a otras debido a los diferentes tintes utilizados en su fabricación y a las condiciones ambientales a las que los residuos han estado expuestos.

### 5.3. Las colillas y su impacto

Las colillas representan el residuo más numeroso por excelencia en las playas estudiadas entre 2018 y 2019 (Asensio-Montesinos et al., **I**; **II**; **IV**; **V**) y, por ello, se decidió realizar una investigación especifica centrada en este tema considerando también datos del litoral de Ceuta donde se llevaron a cabo evaluaciones de residuos sólidos en los meses de febrero, marzo y abril de 2019 (Aguilar-Torrelo, 2019; Asensio-Montesinos et al., **VI**). En Ceuta, en el mes de febrero 2019 se observa una escasa abundancia de colillas con respecto a aquella registrada en las provincias de Cádiz y Alicante (Asensio-Montesinos et al., **VI**), hecho principalmente relacionado a que en febrero apenas hay usuarios en las playas. Pero, en el mes siguiente, es decir en marzo 2019, se observa un incremento en el número de colillas. En Alicante, durante el mismo mes del año anterior (2018) se registran valores muy parecidos de abundancia de colillas ya que, en dicha época, empieza a incrementarse el número de visitantes. Otras campañas, llevadas a cabo en Cádiz durante el mes de octubre (2018), es decir, poco después del verano, y en Ceuta durante el mes de abril (2019), registran valores de abundancia parecidos entre sí y mucho más altos de aquellos registrados anteriormente. Finalmente, las evaluaciones llevadas a cabo durante

el verano de 2018 en Alicante son aquellas que más colillas registran. Las diferencias observadas según la época del muestreo claramente reflejan la afluencia de visitantes a la playa que aumenta en condiciones de buen tiempo con un máximo en verano (Asensio-Montesinos et al., **II**) y valores elevados en los meses previos o posteriores (Asensio-Montesinos et al., **I**; **IV**), al contrario de lo que sucede por ejemplo en invierno (Asensio-Montesinos et al., **III**). De acuerdo con Asensio-Montesinos et al. (**VI**) algunas playas presentan valores extremadamente altos de colillas y esto sirve para evidenciar cuales son los sectores costeros más contaminados. Un elevado número de colillas está principalmente asociado a un elevado número de usuarios, conclusión confirmada por Simeonova et al. (2017), Araújo y Costa (2019) y Oztekin et al. (2020). Después de haber realizado cientos de evaluaciones en playa, se puede afirmar que cualquier tipo de usuarios puede verter colillas, independientemente del sexo, edad o procedencia. La falta de educación es un factor importante que tienen en común las personas que vierten colillas al medio natural y, para limitar o eliminar dicho comportamiento, se deberían impulsar campañas educativas dirigidas a todos los usuarios de playa y a los alumnos de todos los niveles educativos. A pesar de los esfuerzos de gestión durante la temporada estival, las colillas son mucho más numerosas durante estos meses por lo que los esfuerzos de limpieza deberían mejorar, especialmente en las playas donde estos residuos son más numerosos. Además, las sanciones a los usuarios que contaminan podrían también ayudar a solucionar parte del problema, pues hay personas que solo modifican sus comportamientos cuando les afecta directamente, p. ej. cuando les sancionan económicamente o con trabajos sociales.

En relación a la tipología de playa, la abundancia en colillas registra un aumento lineal desde las playas remotas y rurales hasta las playas semiurbanas y urbanas (Asensio-Montesinos et al., **VI**). Estos resultados son esperables ya que la tipología de playa a menudo se relaciona con el número de usuarios (Williams y Micallef, 2009). En algunas playas remotas no se llevan a cabo acciones de limpieza o estas son muy poco frecuentes debido a la localización de estos lugares que frecuentemente tampoco cuentan con papeleras para la recogida de residuos (Mooser et al., 2018; Asensio-Montesinos et al., 2019a). A pesar de lo anterior, en esta tipología de playa, las colillas no suelen ser los elementos mayoritarios debido a la baja presencia de usuarios. La falta de transporte público a dichas playas y su dificultad de acceso en algunos casos (Williams y Micallef, 2009) son aspectos que desaniman los usuarios a visitarlas y así apenas se observan en ellas residuos relacionados directamente con los visitantes. Esta tendencia se observa

también en la costa de Marruecos o en la costa del Mar Báltico, donde no se encuentran colillas en las playas remotas (Maziane et al., 2018; Kataržytė et al., 2020). La presencia de residuos en playas remotas está condicionada principalmente por los aportes marinos y por la baja frecuencia con la que se retiran (Schmuck et al., 2017). Dichas observaciones evidencian como la gestión de estas playas también es importante: se deben llevar a cabo acciones de limpieza con mayor frecuencia. Según Asensio-Montesinos et al. (**VI**) las playas de tipo rural muestran resultados muy variados en cuanto al número de colillas y, a pesar de que en algunos lugares no hay casi rastro de estos residuos, en otros la abundancia es tan alta como se ha observado en alguna playa urbana. La gran abundancia de colillas en playas rurales se debe principalmente a la facilidad de acceso que a veces presentan estas playas, especialmente las del Mediterráneo que tienen carreteras de acceso a pocos metros de la línea de costa. Otro factor que es importante remarcar es la dificultad de retirar las colillas en algunas de estas playas, pues muchas de ellas están formadas por cantos rodados, bloques, o presentan una plataforma rocosa, elementos que impiden cualquier tipo de limpieza con maquinaria pesada; la retirada de colillas debe hacerse manualmente, lo que conlleva más tiempo y esfuerzo por parte del personal de limpieza. La instalación de más papeleras en algunas de estas playas rurales y su adecuado mantenimiento podría ayudar a disminuir el número de residuos. Sin embargo, esto se debe hacer en respecto del ambiente costero ya que la adición de elementos antrópicos en la playa influye de forma negativa en su valor escénico (Ergin et al., 2004). Las playas semiurbanas no muestran una dispersión tan alta en los valores de abundancia de colillas debido a que la mayoría de estas tienen un uso parecido entre sí y las operaciones de limpieza se llevan a cabo durante todo el año. Los valores más altos de colillas en playas semiurbanas se deben a que dichos lugares son muy frecuentados. Por ello, pese a sus características semiurbanas, la composición y abundancia de residuos es parecida a aquellas de las playas urbanas. Finalmente, las playas urbanas registran el mayor número de colillas y una mayor variabilidad en los datos. Las playas con un mayor número de colillas se evaluaron en Alicante durante el verano y en Cádiz, resultados debidos principalmente al elevado número de personas que las frecuenta y a las grandes dimensiones de dichas playas que pueden acoger a muchos usuarios.

La accesibilidad de cada playa también es un factor a tener en cuenta para comprender la abundancia de colillas en determinados sitios. Playas con aparcamientos muy próximos registraron valores muy altos en el número de

colillas, y viceversa. Dichas observaciones coinciden con lo observado por Oztekin et al. (2020) que reportan como la accesibilidad a las playas durante los meses de verano es un factor importante que afecta a la cantidad de residuos. A conclusiones parecidas llegan también Williams y Simmons (1999) que observan como en playas fluviales del sur de Gales, la abundancia de vertidos también está relacionada con la accesibilidad a las orillas, especialmente mediante vehículos a motor.

Con respecto a las relaciones entre colillas y composición de los sedimentos de playa, Asensio-Montesinos et al. (**VI**) observan como playas compuestas por arena contienen por lo general más colillas que playas compuestas por otro tipo de sustrato. Tal como se ha visto anteriormente, el tipo de sustrato, es decir, los sedimentos que componen la playa, representa un factor importante que determina el tipo de limpieza (Taylor y Owens, 1997). En ocasiones, las operaciones de limpieza de grandes acumulaciones de residuos en determinadas playas y/o épocas del año, requieren de técnicas y maquinaria específica que pueden tener costes económicos elevados (Zielinski et al., 2019). Las máquinas de limpieza pesadas son capaces de limpiar grandes superficies de playas, sin embargo, se ha documentado en varias ocasiones que son poco respetuosas con el ambiente costero y afectan a las características geomorfológicas propias de la playa (Nordstrom, 1994; Roig-Munar, 2004), por ejemplo, la formación de dunas embrionarias, y pueden también producir daños a distintas especies de plantas y animales (Ariza y Leatherman, 2012). Las máquinas de limpieza mecánicas no son del todo efectivas en la recogida de colillas (Williams, 2011) tal y como ya se mencionó para algunos de los residuos de menor tamaño. En las playas, su retirada por parte de los servicios de limpieza tiene una baja efectividad en comparación al resto de residuos de mayor tamaño (Ariza et al., 2008) ya que las colillas suelen pasar por los tamices de las máquinas cribadoras y, por ende, permanecer en la playa durante mucho tiempo (Williams, 2011). Para retirar las colillas y otros residuos de pequeño tamaño, las limpiezas manuales son mucho más precisas y respetuosas con el medio (Williams et al., 2016a; Maziane et al., 2018) aunque también hay que emplear más tiempo y esfuerzo físico. Las colillas pueden ser muy persistentes en los entornos naturales y pueden constituir una fuente muy importante de contaminación por metales (Moerman y Potts, 2011). Al menos 150 componentes de las colillas se consideran altamente tóxicos, de los cuales 44 se encuentran en grandes cantidades. Aunque los rayos ultravioleta (UV) del sol acaban rompiendo el filtro en partes pequeñas

en condiciones ambientales ideales, el material de origen nunca desaparece; se diluye en el agua o el suelo (Slaughter et al., 2011).

Finalmente, en cuanto a la distribución de las colillas, estas no lo hacen por igual a lo largo del perfil de playa, observándose diferencias entre zonas de una misma playa – aspectos importantes que habría que considerar en cualquier plan de gestión de los residuos. En el caso de las playas mediterráneas como las de Alicante y Ceuta, las colillas se acumulan principalmente en el *backshore* o playa seca y dentro de esta zona, en la parte más alejada de la orilla, que corresponde al final de la playa seca y a menudo es donde la playa limita con vegetación, dunas, un paseo marítimo, bares, viviendas u otro tipo de edificaciones. La acumulación en el límite hacia tierra de la playa se debe principalmente a: i) la dificultad de las máquinas pesadas de limpieza de retirar residuos cerca de estructuras (muros, vallas, pasarelas de acceso a la playa, etc.); ii) al trasiego de personas que caminan al lado (p. ej. a lo largo de un paseo marítimo) del límite hacia tierra de la playa y, desde, allí vierten directamente residuos a la playa y, secundariamente, iii) a la acción del viento que arrastra allí las colillas. En el caso de las playas atlánticas de Cádiz, las colillas se acumulan principalmente en el *backshore* y en la línea de pleamar, por diferentes razones. En cuanto a la gran abundancia de colillas observada en el *backshore*, esta se debe a que las colillas son vertidas directamente por los usuarios en esta zona. En cuanto a las acumulaciones en la línea de pleamar, se ha observado como en playas de gran anchura intermareal, cuando la playa está en condiciones de bajamar, muchos de los usuarios no permanecen en el *backshore,* sino que se desplazan hacia la orilla para permanecer más cerca del agua bien sea para pescar, bañarse o por cualquier otro motivo. Este comportamiento hace que los usuarios utilicen la parte del *foreshore* que se ha quedado emergida al bajar la marea, para sus actividades de recreo y ocio y que allí viertan las colillas. Cuando la marea empieza a subir, arrastra las colillas hacia tierra y las agrupa en la línea de pleamar. Cuando la marea vuelve a bajar, las colillas se quedan en dicha línea, y es allí donde usualmente son contabilizadas durante las observaciones de campo que se suelen realizar en condiciones de bajamar.

## 6. CONCLUSIONES

En el marco de esta tesis doctoral se han llevado a cabo varias campañas para caracterizar los residuos sólidos en diferentes lugares del litoral de Alicante y Cádiz. A pesar de la ubicación geográfica, en todas las playas turísticas que suelen incluir principalmente playas urbanas y semiurbanas, prevalecen los residuos plásticos y, entre ellos, las colillas.

En cuanto al origen de los residuos, la mayor parte se atribuye a los usuarios, o procede de los vertidos de aguas residuales y/o de las actividades pesqueras. Los residuos no se distribuyen por igual entre playas y tampoco a lo largo del perfil de una misma playa. Las diferencias entre tipos de playa a menudo condicionan el tipo y abundancia de usuarios que las visitan y esto influye de manera directa en la composición y abundancia de residuos. Las playas remotas apenas registran residuos relacionados con los usuarios, mientras que en las rurales puede darse una gran variabilidad relacionada al número de visitantes y al tipo y frecuencia de las operaciones de limpieza. Los residuos de gran tamaño y de procedencia marina, suelen encontrarse con mayor frecuencia en playas remotas y rurales. Las playas semiurbanas y urbanas tienen residuos relacionados esencialmente con los usuarios debido a que suelen registrar un gran número de visitantes.

Los análisis multivariantes llevados a cabo han permitido identificar diferencias y similitudes entre las distintas evaluaciones de playa realizadas. Así, dichos análisis han permitido relacionar entre si los datos observados en las diferentes playas en cuanto a contenido de residuos, patrones de distribución de usuarios, y presencia/ausencias de operaciones de limpieza y/o situaciones ambientales específicas como p. ej. el impacto de una tormenta. Por lo general, los patrones de población (es decir la cantidad de habitantes de la zona) y el número de usuarios que visitan la playa, suelen ser los principales aspectos que determinan el número de residuos presentes en una playa.

En cuanto a los componentes más relevantes de los residuos plásticos, el acetato de celulosa, relacionado con las colillas de cigarrillos, es el compuesto más común, seguido por el polipropileno (PP) y el polietileno (PE). Algunos residuos como botellas, tapones, bolígrafos, palitos de “chupa-chups”, juguetes, cuerdas y cordeles, entre otros, están compuestos por PP. Otros residuos como las anillas de plástico del pack de latas, las bolsas, botellas, productos de limpieza, cucharas, guantes, envoltorios de comida, tapones, juguetes, bolsas de red, cabos, boyas, aplicadores de tampones, pinzas de la ropa, etc. están

fabricados con PE. Por otra parte, algunos residuos como las cajas para almacenar con hielo el pescado capturado están compuestas de poliestireno (PS), al igual que otros residuos como las boyas artesanales, o piezas de PS utilizadas en el empaquetamiento de productos. Las botellas transparentes y otros recipientes similares están compuestos por polietileno de tereftalato (PET). Además, se ha demostrado que los residuos de plástico atraviesan las fronteras nacionales e internacionales, por lo que la contaminación por plásticos constituye un problema a escala global que todos los países deben abordar conjuntamente y un gran reto para la industria y los consumidores.

Los resultados obtenidos en el marco de esta tesis pueden servir a las administraciones y entidades locales encargadas de gestionar la limpieza de la costa para tomar decisiones adecuadas según el tipo de playa con el fin de mejorar su estado ambiental en cuanto a la presencia de residuos. Cada playa es única y es aconsejable gestionarla de la forma más adecuada teniendo en cuenta los factores (p. ej. la estacionalidad del turismo, la tipología de la playa, la accesibilidad, el tipo de sedimento, etc.) que más influyen en la abundancia de residuos. Además, las técnicas de evaluación de residuos utilizadas pueden servir para evaluar la eficacia de limpieza y cuestionarse algunos galardones de playa (p. ej. Q de Calidad Turística, Bandera Azul, Certificado ISO, Verificación EMAS, etc.).

Finalmente, en el marco de esta investigación, se ha demostrado como la acumulación de residuos difiere según la zona de la playa, por lo que sería interesante centrar las medidas de gestión de los residuos en aquellas zonas más contaminadas p. ej. el limite hacia tierra de la playa, la orilla, la marca de la línea de pleamar o el *backshore*, pero sin olvidar el *foreshore* que acumula menos residuos que pueden retirarse fácilmente a mano.

Por otro lado, es importante tener en cuenta que las acciones de limpieza, aunque necesarias, no resolverán el problema de los residuos ya que sólo proporcionan una solución temporal. Es importante y urgente realizar más esfuerzos en materia de educación pública. Acciones como programas de educación ambiental dirigidos al público en general y, en particular, a los usuarios de playa, la mejora de las instalaciones para depositar residuos, así como la instalación o mejora de materiales educativos y carteles informativos en la playa serían de gran ayuda. Deberían mejorarse los programas de limpieza llevados a cabo en playas urbanas y semiurbanas y, especialmente, aquellos llevados a cabo en playas remotas y rurales en las que actualmente se realizan de

manera esporádica. Finalmente, se ha observado que la falta de colaboración de algunos municipios en temas de investigación es un verdadero problema en el avance del conocimiento.

Quizá futuros estudios sean capaces de investigar y explicar de manera más precisa y exhaustiva las relaciones existentes entre distribución y composición de residuos y características geomorfológicas de la playa. Aunque ciertas relaciones se han observado en el marco de este estudio en playas de cantos de Alicante, al fin de obtener un mayor conocimiento de dichas relaciones sea probablemente preciso llevar a cabo campañas a pequeña escala temporal, de 1-2 días, al fin de limitar al mínimo la influencia humana, es decir los nuevos aportes de residuos y las operaciones de limpieza que enmascaran la dinámica natural de los residuos.

## BIBLIOGRAFÍA


1. Aguilar-Torrelo, M.T., 2019. Distribución y características de los residuos sólidos en el litoral de Ceuta. Trabajo de Fin de Grado. Facultad de Ciencias del Mar y Ambientales, Universidad de Cádiz, p. 79.
2. Alkalay, R., Pasternak, G., Zask, A., 2007. Clean-coast index—a new approach for beach cleanliness assessment. Ocean & Coastal Management, 50(5-6), 352-362.
3. Allen, V., Kalivas, J.H., Rodriguez, R.G., 1999. Post-consumer plastic identification using Raman spectroscopy. Applied spectroscopy, 53(6), 672-681.
4. Anfuso, G., Bolívar-Anillo, H.J., Asensio-Montesinos, F., Portantiolo Manzolli, R., Portz, L., Villate Daza, D.A., 2020. Beach litter distribution in Admiralty Bay, King George Island, Antarctica, 160, 111657.
5. Anfuso, G., Pranzini, E., Vitale, G., 2011. An integrated approach to coastal erosion problems in northern Tuscany (Italy): Littoral morphological evolution and cell distribution. Geomorphology, 129(3-4), 204-214.
6. Anfuso, G., Williams, A.T., Martínez, G.C., Botero, C.M., Hernández, J.C., & Pranzini, E., 2017. Evaluation of the scenic value of 100 beaches in Cuba: Implications for coastal tourism management. Ocean & Coastal Management, 142, 173-185.
7. Anfuso, G., Williams, A.T., Rangel-Buitrago, N., 2019. Examples of Class Divisions and Country Synopsis for Coastal Scenic Evaluations. En: Rangel-Buitrago, N. (Ed.): Coastal Scenery - Evaluation and Management. Coastal Research Libray V. 26. Springer, 247 pp. ISSN: 2211-0577.
8. Araújo, M.C.B., Costa, M.F., 2019. A critical review of the issue of cigarette butt pollution in coastal environments. Environmental Research, 172, 137-149.
9. Ariza, E., Jiménez, J.A., Sardá, R., 2008. Seasonal evolution of beach waste and litter during the bathing season on the Catalan coast. Waste Management, 28(12), 2604-2613.
10. Ariza, E., Leatherman, S.P. 2012. No-smoking policies and their outcomes on US beaches. Journal of Coastal Research, 28(1A), 143-147.

11. Asensio-Montesinos, F., Anfuso, G., Aguilar-Torrelo, M.T., Oliva Ramírez, M., 2021. Abundance and Temporal Distribution of Beach Litter on the Coast of Ceuta (North Africa, Gibraltar Strait). Water, 13(19), 2739.
12. Asensio-Montesinos, F., Anfuso, G., Corbí, H., 2017. Evaluación paisajística de las playas de Alicante (Mediterráneo occidental) mediante parámetros físicos y antropogénicos: implicaciones para la gestión. Geo-Temas, 17, 183-186.
13. Asensio-Montesinos, F., Anfuso, G., Corbí, H., 2019a. Coastal scenery and litter impacts at Alicante (SE Spain): management issues. Journal of Coastal Conservation, 23(1), 185-201.
14. Asensio-Montesinos, F., Molina-Gil, R., Bolívar-Anillo, H.J., Botero, C.M., Pranzini, E., Anfuso, G., 2019b. Las preferencias de los usuarios en la elección de una playa: Los "Big Five" y su alcance en la gestión costera. C. Milanés, R. Lastra, P. Sierra-Correa (Eds.), Estudios de caso sobre manejo integrado de zonas costeras en Iberoamérica: Gestión, riesgo y buenas prácticas (1st ed.), Corporación Universidad de la Costa, Barranquilla (2019), pp. 144-192.
15. Asensio-Montesinos, F., Pranzini, E., Martinez-Martinez, J., Cinelli, I., Anfuso, G., Corbí, H., 2020. The origin of sand and its colour on the south-eastern coast of Spain: Implications for erosion management. Water, 12(2), 377.
16. Avendaño, L., 1992. Iniciación a los plásticos. Centro Español de Plásticos, España, 153 pp.
17. Aydın, C., Güven, O., Salihoğlu, B., Kıdeyş, A.E., 2016. The influence of land use on coastal litter: an approach to identify abundance and sources in the coastal area of Cilician Basin, Turkey. Turkish Journal of Fisheries and Aquatic Sciences, 16(1), 029-039.
18. Ballance, A., Ryan, P.G., Turpie, J.K., 2000. How much is a clean beach worth? The impact of litter on beach users in the Cape Peninsula, South Africa. South African Journal of Science, 96(5), 210-213.
19. Barría-Herrera, J., Vergara-Cortés, H., Contreras-López, M., Rangel-Buitrago, N., 2021. A seasonal comparison of litter impacts along the Viña del Mar-Concón coastal strip, Valparaiso region of Chile. Marine Pollution Bulletin, 172, 112854.
20. Battisti, C., Poeta, G., Pietrelli, L., Acosta, A.T., 2016. An unexpected consequence of plastic litter clean-up on beaches: Too much sand might be removed. Environmental Practice, 18(4), 242-246.
21. Bergmann, M., Gutow, L., Klages, M., 2015. Marine Anthropogenic Litter (p. 447). Springer Nature.
22. Bird, E.C.F., 1984. Coasts: an introduction to coastal geomorphology. Basil Blackwell, 320 pp.
23. Botero, C.M., Anfuso, G., Milanes, C., Cabrera, A., Casas, G., Pranzini, E., Williams, A.T., 2017. Litter assessment on 99 Cuban beaches: A baseline to identify sources of pollution and impacts for tourism and recreation. Marine Pollution Bulletin, 118(1-2), 437-441.
24. Botero, C., Anfuso, G., Williams, A.T., Palacios, A., 2013. Perception of coastal scenery along the Caribbean littoral of Colombia. Journal of Coastal Research, (65 (10065)), 1733-1738.

25. Bowman, D., Manor-Samsonov, N., Golik, A., 1998. Dynamics of litter pollution on Israeli Mediterranean beaches: a budgetary, litter flux approach. Journal of Coastal Research, 418-432.
26. Cabezas-Rabadán, C., Rodilla, M., Pardo-Pascual, J.E., Herrera-Racionero, P., 2019. Assessing users' expectations and perceptions on different beach types and the need for diverse management frameworks along the Western Mediterranean. Land Use Policy 81, 219–231
27. Cabral, H., Fonseca, V., Sousa, T., Costa Leal, M., 2019. Synergistic effects of climate change and marine pollution: An overlooked interaction in coastal and estuarine areas. International journal of environmental research and public health, 16(15), 2737.
28. Carter, R.W.G., 1988. Coastal environments. Academic Press, 617 pp.
29. CERC (Coastal Engineering Research Centre), 1984: Shore Protection Manual. U.S. Army Corps of Engineers. Res. Center. Printing Office. Washington.
30. Cesarano, C., Aulicino, G., Cerrano, C., Ponti, M., Puce, S., 2021. Scientific knowledge on marine beach litter: A bibliometric analysis. Marine Pollution Bulletin, 173, 113102.
31. Changing Markets Foundation, 2020. Talking Trash: The Corporate Playbook of False Solutions. Disponible en: https://talking-trash.com/
32. Cheshire, A., Adler, E., 2009. UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter.
33. Chitaka, T.Y., von Blottnitz, H., 2019. Accumulation and characteristics of plastic debris along five beaches in Cape Town. Marine Pollution Bulletin, 138, 451-457.
34. Claereboudt, M.R., 2004. Shore litter along sandy beaches of the Gulf of Oman. Marine Pollution Bulletin, 49(9-10), 770-777.
35. Convey, P., Barnes, D., Morton, A., 2002. Debris accumulation on oceanic island shores of the Scotia Arc, Antarctica. Polar Biology, 25(8), 612-617.
36. Corraini, N.R., de Lima, A.D.S., Bonetti, J., Rangel-Buitrago, N., 2018. Troubles in the paradise: Litter and its scenic impact on the North Santa Catarina island beaches, Brazil. Marine Pollution Bulletin, 131, 572-579.
37. da Costa Cristiano, S., Portz, L.C., Anfuso, G., Rockett, G.C., Barboza, E.G., 2018. Coastal scenic evaluation at Santa Catarina (Brazil): Implications for coastal management. Ocean & Coastal Management, 160, 146-157.
38. Dau, B.K., Gilardi, K.V., Gulland, F.M., Higgins, A., Holcomb, J.B., Leger, J.S., Ziccardi, M.H., 2009. Fishing gear–related injury in California marine wildlife. Journal of Wildlife Diseases, 45(2), 355-362.
39. Davis, R.A. (Ed.)., 1978. Coastal sedimentary environments. Springer-Verlag, New York Inc.
40. Dabrio, C., 1989. Playas e islas barrera-lagoon. En A. Arche (ed.): Sedimentología. Vol. I. Servicio de publicaciones del C.S.I.C. Madrid, 349-394.
41. Dehaut, A., Cassone, A.L., Frère, L., Hermabessiere, L., Himber, C., Rinnert, E., ... & Paul-Pont, I., 2016. Microplastics in seafood: Benchmark protocol for their extraction and characterization. Environmental Pollution, 215, 223-233.
42. Diario INFORMACIÓN, 2019. Bandera negra de Ecologistas en Acción para las playas de San Gabriel y Agua Amarga por los vertidos sin control. Disponible en:

https://www.informacion.es/alicante/2019/06/14/bandera-negra-ecologistas-accion-playas-5398764.html (Consultado el 13 de octubre de 2021).
43. Directiva (UE) 2019/904. DIRECTIVA (UE) 2019/904 DEL PARLAMENTO EUROPEO Y DEL CONSEJO de 5 de junio de 2019 relativa a la reducción del impacto de determinados productos de plástico en el medio ambiente. Diario Oficial de la Unión Europea. 19 pp.
44. Duncan, E.M., Botterell, Z.L., Broderick, A.C., Galloway, T.S., Lindeque, P.K., Nuno, A., Godley, B.J., 2017. A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. Endangered Species Research, 34, 431-448.
45. Dunlop, S.W., Dunlop, B.J., Brown, M., 2020. Plastic pollution in paradise: Daily accumulation rates of marine litter on Cousine Island, Seychelles. Marine Pollution Bulletin, 151, 110803.
46. EA/NALG, 2000. Assessment of Aesthetic Quality of Coastal and Bathing Beaches. Monitoring Protocol and Classification Scheme. Environment Agency and The National Aquatic Litter Group, London, p. 15.
47. Ecologistas en Acción, 2019. Banderas Negras, Informe 2019. Área Medio Marino de Ecologistas en Acción. En: https://www.ecologistasenaccion.org/122337/informe-banderas-negras-2019/ (Consultado el 16 de octubre de 2021).
48. Ergin, A., Karaesmen, E., Micallef, A., Williams, A.T., 2004. A new methodology for evaluating coastal scenery: fuzzy logic systems. Area, 36(4), 367-386.
49. Ergin, A., Karakaya, T., Micallef, A., Radic, M., Williams, A.T., 2006b. Coastal scenic evaluation: a study of some Dalmatian (Croatia) areas. Journal of Coastal Research, 898-902.
50. Ergin, A., Özölçer, İ.H., Şahin, F., 2010. Evaluating coastal scenery using fuzzy logic: Application at selected sites in Western Black Sea coastal region of Turkey. Ocean Engineering, 37(7), 583-591.
51. Ergin, A., Williams, A.T., Micallef, A., 2006a. Coastal scenery: appreciation and evaluation. Journal of Coastal Research, 22(4), 958-964.
52. Eriksson, C., Burton, H., Fitch, S., Schulz, M., van den Hoff, J., 2013. Daily accumulation rates of marine debris on sub-Antarctic island beaches. Marine Pollution Bulletin, 66(1-2), 199-208.
53. Falk-Andersson, J., Tairova, Z., Drægni, T.T., Haarr, M.L., 2021. Methods for determining the geographical origin and age of beach litter: Challenges and opportunities. Marine Pollution Bulletin 172, 112901.
54. Fauziah, S.H., Rizman-Idid, M., Cheah, W., Loh, K.H., Sharma, S., NoorMaiza, M.R., ... & George, M., 2021. Marine debris in Malaysia: A review on the pollution intensity and mitigating measures. Marine Pollution Bulletin, 167, 112258.
55. Gago, J., Lahuerta, F., Antelo, P., 2014. Characteristics (abundance, type and origin) of beach litter on the Galician coast (NW Spain) from 2001 to 2010. Scientia Marina, 78(1), 125-134.
56. Garrity, S.D., Levings, S.C., 1993. Marine debris along the Caribbean coast of Panama. Marine Pollution Bulletin, 26(6), 317-324.

57. González-Fernández, D., Cózar, A., Hanke, G., Viejo, J., Morales-Caselles, C., Bakiu, R., ... & Tourgeli, M., 2021. Floating macrolitter leaked from Europe into the ocean. Nature Sustainability, 4(6), 474-483.
58. Green, D.S., Tongue, A.D., Boots, B., 2021. The ecological impacts of discarded cigarette butts. Trends in Ecology & Evolution.
59. Haig, S.M., D'Elia, J., Eagles-Smith, C., Fair, J.M., Gervais, J., Herring, G., Schulz, J.H., 2014. The persistent problem of lead poisoning in birds from ammunition and fishing tackle. Condor 116 (3), 408–428
60. Hardesty, B.D., Good, T.P., Wilcox, C., 2015. Novel methods, new results and science-based solutions to tackle marine debris impacts on wildlife. Ocean & Coastal Management, 115, 4-9.
61. Hohn, D., 2011. Moby-Duck: The True Story of 28,800 Bath Toys Lost at Sea & of the Beachcombers, Oceanograp hers, Environmentalists & Fools Including the Author Who Went in Search of Them. Penguin.
62. Iglesias, B., Anfuso, G., Uterga, A., Arenas, P., Williams, A.T., 2018. Scenic value of the Basque Country and Catalonia coasts (Spain): impacts of tourist occupation. Journal of Coastal Conservation, 22(2), 247-261.
63. Jayasiri, H.B., Purushothaman, C.S., Vennila, A., 2013. Plastic litter accumulation on high-water strandline of urban beaches in Mumbai, India. Environmental Monitoring and Assessment, 185(9), 7709-7719.
64. Johnson, D.W., 1919. Shore processes and shoreline development. Stanhope Press, 584 pp.
65. Kako, S.I., Isobe, A., Magome, S., 2010. Sequential monitoring of beach litter using webcams. Marine Pollution Bulletin, 60(5), 775-779.
66. Käppler, A., Fischer, D., Oberbeckmann, S., Schernewski, G., Labrenz, M., Eichhorn, K. J., Voit, B., 2016. Analysis of environmental microplastics by vibrational microspectroscopy: FTIR, Raman or both?. Analytical and bioanalytical chemistry, 408(29), 8377-8391.
67. Kataoka, T., Hinata, H., Kato, S., 2013. Analysis of a beach as a time-invariant linear input/output system of marine litter. Marine Pollution Bulletin, 77(1-2), 266-273.
68. Kataržytė, M., Balčiūnas, A., Haseler, M., Sabaliauskaitė, V., Lauciūtė, L., Stepanova, K., ... & Schernewski, G., 2020. Cigarette butts on Baltic Sea beaches: Monitoring, pollution and mitigation measures. Marine Pollution Bulletin, 156, 111248.
69. Kaviarasan, T., Naik, S., Sivadas, S.K., Dhineka, K., Sambandam, M., Sivyer, D., ... & Murthy, M.R., 2020. Assessment of litter in the remote beaches of Lakshadweep Islands, Arabian Sea. Marine Pollution Bulletin, 161, 111760.
70. Kei, K., 2005. Beach Litter in Amami Islands, Japan, 26. South Pacific Studies, pp. 15–24.
71. King, C.A.M., 1972. Beaches and Coasts. Edward Arnold. 570 pp.
72. Koongolla, J.B., Andrady, A.L., Kumara, P.T.P., Gangabadage, C.S., 2018. Evidence of microplastics pollution in coastal beaches and waters in southern Sri Lanka. Marine Pollution Bulletin, 137, 277-284.
73. Kungskulniti, N., Charoenca, N., Hamann, S.L., Pitayarangsarit, S., Mock, J., 2018. Cigarette waste in popular beaches in Thailand: High densities that demand

environmental action. International journal of environmental research and public health, 15(4), 630.
74. Kusui, T., Noda, M., 2003. International survey on the distribution of stranded and buried litter on beaches along the Sea of Japan. Marine Pollution Bulletin, 47(1-6), 175-179.
75. Lanckriet, T., 2014. Near-bed hydrodynamics and sediment transport in the swash zone. University of Delaware.
76. Lavers, J.L., Bond, A.L., 2017. Exceptional and rapid accumulation of anthropogenic debris on one of the world's most remote and pristine islands. Proceedings of the National Academy of Sciences, 114(23), 6052-6055.
77. Lavers, J.L., Dicks, L., Dicks, M.R., Finger, A., 2019. Significant plastic accumulation on the Cocos (Keeling) Islands, Australia. Scientific Reports, 9(1), 1-9.
78. Lenz, R., Enders, K., Stedmon, C.A., Mackenzie, D.M., Nielsen, T.G., 2015. A critical assessment of visual identification of marine microplastic using Raman spectroscopy for analysis improvement. Marine Pollution Bulletin, 100(1), 82-91.
79. Lenzi, J., Burgues, M.F., Carrizo, D., Machín, E., Teixeira-de Mello, F., 2016. Plastic ingestion by a generalist seabird on the coast of Uruguay. Marine Pollution Bulletin, 107(1), 71-76.
80. Ley 2/2013, de 29 de mayo, de protección y uso sostenible del litoral y de modificación de la Ley 22/1988, de 28 de julio, de Costas. «BOE» núm. 129, de 30 de mayo de 2013, páginas 40691 a 40736 (46 págs.).
81. Loizidou, X.I., Loizides, M.I., Orthodoxou, D. L., 2018. Persistent marine litter: small plastics and cigarette butts remain on beaches after organized beach cleanups. Environmental Monitoring and Assessment, 190(7), 1-10.
82. Legambiente, 2017. Beach Litter 2017. Survey in Mediterranean Area. pp. 16. May 2017. Disponible en: www.legambiente.it
83. Madzena, A., Lasiak, T., 1997. Spatial and temporal variations in beach litter on the Transkei coast of South Africa. Marine Pollution Bulletin, 34(11), 900-907.
84. Martinez-Ribes, L., Basterretxea, G., Palmer, M., Tintoré, J., 2007. Origin and abundance of beach debris in the Balearic Islands. Scientia Marina, 71 (2), 305–314.
85. Maziane, F., Nachite, D., Anfuso, G., 2018. Artificial polymer materials debris characteristics along the Moroccan Mediterranean coast. Marine Pollution Bulletin, 128, 1-7.
86. McKenna, J., Williams, A.T., Cooper, J.A.G., 2011. Blue Flag or Red Herring: Do beach awards encourage the public to visit beaches?. Tourism Management, 32(3), 576-588.
87. Micallef, A., Morgan, R., Williams, A.T., 1999. User preferences and priorities on Maltese beaches–Findings and potential importance for tourism. Coastal Environment Management, EUCC-ITALY/EUCC.
88. Moerman, J.W., Potts, G.E., 2011. Analysis of metals leached from smoked cigarette litter. Tobacco Control, 20(Suppl 1), i30-i35.
89. Mooser, A., Anfuso, G., 2018. Playas y paisaje: guía de las 50 playas más atractivas de Andalucía. Servicio de Publicaciones de la Universidad de Cádiz, 2018. 301 pp.

90. Mooser, A., Anfuso, G., Mestanza, C., Williams, A.T., 2018. Management implications for the most attractive scenic sites along the Andalusia Coast (SW Spain). Sustainability, 10(5), 1328.
91. Morgan, R., 1999. Preferences and priorities of recreational beach users in Wales, UK. Journal of Coastal Research, 653-667.
92. Munari, C., Corbau, C., Simeoni, U., Mistri, M., 2016. Marine litter on Mediterranean shores: analysis of composition, spatial distribution and sources in north-western Adriatic beaches. Waste Management, 49, 483-490.
93. Nachite, D., 2019. Photo Guide for Monitoring Marine Litter on the Mediterranean Moroccan Beaches. Coordination Nationale du Programme National de Surveillance et d'Evaluation de la Pollution de la Méditerranée (Maroc; mai, 2019, 73 pp).
94. Nachite, D., Maziane, F., Anfuso, G., Williams, A.T., 2019. Spatial and temporal variations of litter at the Mediterranean beaches of Morocco mainly due to beach users. Ocean & Coastal Management, 179, 104846.
95. Nakashima, E., Isobe, A., Magome, S., Kako, S.I., Deki, N., 2011. Using aerial photography and in situ measurements to estimate the quantity of macro-litter on beaches. Marine Pollution Bulletin, 62(4), 762-769.
96. Nordstrom, K. F., 1994. Beaches and dunes of human-altered coasts. Progress in physical Geography, 18(4), 497-516.
97. Novotny, T.E., Lum, K., Smith, E., Wang, V., Barnes, R., 2009. Cigarettes butts and the case for an environmental policy on hazardous cigarette waste. International journal of environmental research and public health, 6(5), 1691-1705.
98. Ocean Conservancy, 2010. Trash travels: from our hands to the sea, around the globe, and through time. International Coastal Cleanup, 2010 Report, ISBN 978-0-615-34820-9.
99. Ocean Conservancy, 2016. Ocean Conservancy 30th Anniversary International Coastal Cleanup Ocean Conservancy. Washington DC.
100. Ogi, H., Fukumoto, Y., 2000. A sorting method for small plastic debris floating on the sea surface and stranded on sandy beaches. In: Bulletin of the Faculty of Fisheries, 51. Hokkaido University, pp. 71–93, 2
101. Oigman-Pszczol, S.S., Creed, J.C., 2007. Quantification and classification of marine litter on beaches along Armação dos Búzios, Rio de Janeiro, Brazil. Journal of Coastal Research, 23(2), 421-428.
102. Olivelli, A., Hardesty, B.D., Wilcox, C., 2020. Coastal margins and backshores represent a major sink for marine debris: insights from a continental-scale analysis. Environmental Research Letters, 15(7), 074037.
103. Opfer, S., Arthur, C., Lippiatt, S., 2012. NOAA Marine Debris Shoreline Survey Field Guide. US National Oceanic and Atmospheric Administration Marine Debris Program.
104. OSPAR Commission, 2010. Guideline for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area.
105. Otley, H., Ingham, R., 2003. Marine debris surveys at Volunteer Beach, Falkland Islands, during the summer of 2001/02. Marine Pollution Bulletin, 46(12), 1534-1539.

106. Oztekin, A., Bat, L., Baki, O. G., 2020. Beach litter pollution in Sinop Sarikum Lagoon coast of the southern Black Sea. Turkish Journal of Fisheries and Aquatic Sciences, 20(3), 197-205
107. Phillips, M.R., Edwards, A.M., Williams, A.T., 2010. An incremental scenic assessment of the Glamorgan Heritage Coast, UK. Geographical Journal, 176(4), 291-303.
108. Planeta Azul, 1972. Documental Planeta Azul: El Okavango (emitido el 19/08/1972). Programación TVE (1968–1974).
109. Plastics Europe, 2019. Plastics – The Facts 2019. An Analysis of European Plastics Production, Demand and Waste Data. 2019. Plastics Europe, 42 pp.
110. Poeta, G., Battisti, C., Bazzichetto, M., Acosta, A.T., 2016b. The cotton buds beach: marine litter assessment along the Tyrrhenian coast of central Italy following the marine strategy framework directive criteria. Marine Pollution Bulletin, 113(1-2), 266-270.
111. Poeta, G., Conti, L., Malavasi, M., Battisti, C., Acosta, A.T.R., 2016a. Beach litter occurrence in sandy littorals: The potential role of urban areas, rivers and beach users in central Italy. Estuarine, Coastal and Shelf Science, 181, 231-237.
112. Polarz, S., Smarsly, B., Schattka, J.H., 2002. Hierachical porous carbon structures from cellulose acetate fibers. Chemistry of materials, 14(7), 2940-2945.
113. Pranzini, E., Anfuso, G., Botero, C.M., Cabrera, A., Campos, Y.A., Martinez, G.C., Williams, A.T., 2016. Sand colour at Cuba and its influence on beach nourishment and management. Ocean & Coastal Management, 126, 51-60.
114. Prevenios, M., Zeri, C., Tsangaris, C., Liubartseva, S., Fakiris, E., Papatheodorou, G., 2018. Beach litter dynamics on Mediterranean coasts: Distinguishing sources and pathways. Marine Pollution Bulletin, 129(2), 448-457.
115. Quintela, A., Silva, C.P., Calado, H., Williams, A., 2012. The relation of litter with bathing areas typologies, number of users and scenic value. The case study of São Miguel (Azores). Journal of Coastal Conservation, 16(4), 575-584.
116. Rangel-Buitrago, N. (Ed.)., 2019. Coastal Scenery: Evaluation and Management (Vol. 26). Springer.
117. Rangel-Buitrago, N., Gracia, A., Vélez-Mendoza, A., Mantilla-Barbosa, E., Arana, V.A., Trilleras, J., Arroyo-Olarte, H., 2018. Abundance and distribution of beach litter along the Atlantico Department, Caribbean coast of Colombia. Marine Pollution Bulletin, 136, 435-447.
118. Rangel-Buitrago, N., Williams, A., Anfuso, G., Arias, M., Gracia, A., 2017. Magnitudes, sources, and management of beach litter along the Atlantico department coastline, Caribbean coast of Colombia. Ocean & Coastal Management, 138, 142-157.
119. Real Decreto 876/2014, de 10 de octubre, por el que se aprueba el Reglamento General de Costas. Publicado en: «BOE» núm. 247, de 11 de octubre de 2014, páginas 83098 a 83216 (119 págs.). Ministerio de Agricultura, Alimentación y Medio Ambiente.
120. Rech, S., Macaya-Caquilpán, V., Pantoja, J.F., Rivadeneira, M.M., Madariaga, D.J., Thiel, M., 2014. Rivers as a source of marine litter–a study from the SE Pacific. Marine Pollution Bulletin, 82(1-2), 66-75.
121. Ribeiro-Claro, P., Nolasco, M.M., Araújo, C., 2017. Characterization of microplastics by Raman spectroscopy. Comprehensive Analytical Chemistry, 75, 119-151.

122. Ribic, C.A., Sheavly, S.B., Klavitter, J., 2012. Baseline for beached marine debris on Sand Island, Midway Atoll. Marine Pollution Bulletin, 64(8), 1726-1729.
123. Rizzo, A., Rangel-Buitrago, N., Impedovo, A., Mastronuzzi, G., Scardino, G., Scicchitano, G., 2021. A rapid assessment of litter magnitudes and impacts along the Torre Guaceto marine protected area (Brindisi, Italy). Marine Pollution Bulletin, 173, 112987.
124. Roig-Munar, F.X., 2004. Análisis y consecuencias de la modificación artificial del perfil playa-duna provocado por el efecto mecánico de su limpieza. Investigaciones Geográficas (España), (33), 87-106.
125. Rosevelt, C., Los Huertos, M., Garza, C., Nevins, H.M., 2013. Marine debris in central California: Quantifying type and abundance of beach litter in Monterey Bay, CA. Marine Pollution Bulletin, 71(1-2), 299-306.
126. Ryan, P.G., 2020. Land or sea? What bottles tell us about the origins of beach litter in Kenya. Waste Management, 116, 49–57.
127. Ryan, P.G., Lamprecht, A., Swanepoel, D., Moloney, C.L., 2014. The effect of fine-scale sampling frequency on estimates of beach litter accumulation. Marine Pollution Bulletin, 88(1-2), 249-254.
128. Ryan, P.G., Moloney, C.L., 1990. Plastic and other artefacts on South African beaches: Temporal trends in abundance and composition. S. AFR. J. SCI./S.-AFR. TYDSKR. WET., 86(7), 450-452.
129. Ryan, P.G., Moore, C.J., Van Franeker, J.A., Moloney, C.L., 2009. Monitoring the abundance of plastic debris in the marine environment. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 1999-2012.
130. Santos, I.R., Friedrich, A.C., Do Sul, J.A.I., 2009. Marine debris contamination along undeveloped tropical beaches from northeast Brazil. Environmental Monitoring and Assessment, 148(1), 455-462.
131. Santos, I.R., Friedrich, A.C., Wallner-Kersanach, M., Fillmann, G., 2005. Influence of socio-economic characteristics of beach users on litter generation. Ocean & Coastal Management, 48(9-10), 742-752.
132. Schmuck, A.M., Lavers, J.L., Stuckenbrock, S., Sharp, P.B., Bond, A.L., 2017. Geophysical features influence the accumulation of beach debris on Caribbean islands. Marine Pollution Bulletin, 121(1-2), 45-51.
133. Šilc, U., Küzmič, F., Caković, D., Stešević, D., 2018. Beach litter along various sand dune habitats in the southern Adriatic (E Mediterranean). Marine Pollution Bulletin, 128, 353-360.
134. Silva-Cavalcanti, J.S., Barbosa de Araujo, M.C., Ferreira da Costa, M., 2009. Plastic litter on an urban beach—a case study in Brazil. Waste Management & Research, 27(1), 93-97.
135. Simeonova, A., Chuturkova, R., 2019. Marine litter accumulation along the Bulgarian Black Sea coast: Categories and predominance. Waste Management, 84, 182-193.
136. Simeonova, A., Chuturkova, R., Yaneva, V., 2017. Seasonal dynamics of marine litter along the Bulgarian Black Sea coast. Marine Pollution Bulletin, 119(1), 110-118.

137. Slaughter, E., Gersberg, R.M., Watanabe, K., Rudolph, J., Stransky, C., Novotny, T.E., 2011. Toxicity of cigarette butts, and their chemical components, to marine and freshwater fish. Tobacco control, 20(Suppl 1), i25-i29.
138. Smith, S.D.A., Banister, K., Fraser, N., Edgar, R.J., 2018. Tracing the source of marine debris on the beaches of northern New South Wales, Australia: the bottles on beaches program. Marine Pollution Bulletin, 126, 304–307.
139. Strong, A.B., 1996. Plastics: materials and processing. Prentice Hall, Inc. New Jersey (675 pp. ISBN: 0-13-678822-X).
140. Suárez de Vivero, J.L., 1999. Delimitación y definición del espacio litoral. Jornadas sobre el litoral de Almería: caracterización, ordenación y gestión de un espacio geográfico celebradas en Almería, 20 a 24 de Mayo de 1997. Pag: 13-23.
141. Syakti, A.D., Bouhroum, R., Hidayati, N.V., Koenawan, C.J., Boulkamh, A., Sulistyo, I., ... & Wong-Wah-Chung, P., 2017. Beach macro-litter monitoring and floating microplastic in a coastal area of Indonesia. Marine Pollution Bulletin, 122(1-2), 217-225.
142. Tavares, D.C., Moura, J.F., Ceesay, A., Merico, A., 2020. Density and composition of surface and buried plastic debris in beaches of Senegal. Science of the Total Environment, 737, 139633.
143. Taylor, E., Owens, E.H., 1997. Specialized mechanical equipment for shoreline cleanup. In International Oil Spill Conference (Vol. 1997, No. 1, pp. 79-87). American Petroleum Institute.
144. Terzi, Y., Seyhan, K., 2017. Seasonal and spatial variations of marine litter on the south-eastern Black Sea coast. Marine Pollution Bulletin, 120(1-2), 154-158.
145. Thiel, M., Bravo, M., Hinojosa, I.A., Luna, G., Miranda, L., Núñez, P., ... & Vásquez, N., 2011. Anthropogenic litter in the SE Pacific: an overview of the problem and possible solutions. Revista de Gestão Costeira Integrada-Journal of Integrated Coastal Zone Management, 11(1), 115-134.
146. Thiel, M., Hinojosa, I.A., Miranda, L., Pantoja, J.F., Rivadeneira, M.M., Vásquez, N., 2013. Anthropogenic marine debris in the coastal environment: a multi-year comparison between coastal waters and local shores. Marine Pollution Bulletin, 71(1-2), 307-316.
147. 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. Marine Environmental Research, 85, 21-28.
148. Tramoy, R., Colasse, L., Gasperi, J., Tassin, B., 2019. Plastic debris dataset on the Seine river banks: Plastic pellets, unidentified plastic fragments and plastic sticks are the Top 3 items in a historical accumulation of plastics. Data in brief, 23, 103697.
149. Tudor, D.T., Williams, A.T., Randerson, P., Ergin, A., Earll, R.E., 2002. The use of multivariate statistical techniques to establish beach debris pollution sources. Journal of Coastal Research, 36, 716–725.
150. Ullah, Z., Johnson, D., Micallef, A., Williams, A.T., 2010. Coastal scenic assessment: unlocking the potential for coastal tourism in rural Pakistan via Mediterranean developed techniques. Journal of Coastal Conservation, 14(4), 285-293.
151. Ünal, Ö., Williams, A.T., 1999. Beach visits and willingness to pay: Çeşme Peninsula, Turkey. MEDCOAST 99 – EMECS 99 Joint Conference, Land-Ocean Interactions:

Managing Coastal Ecosystems, 9 – 13 November 1999, Antalya, Turkey, E. Özhan (Editor)
152. UNEP, 2015. Marine Litter Assessment in the Mediterranean 2015, vol. 48. Vassileos Konstantinou, Athens, Greece, pp. 45
153. Van Cauwenberghe, L., Claessens, M., Vandegehuchte, M.B., Mees, J., Janssen, C.R., 2013. Assessment of marine debris on the Belgian Continental Shelf. Marine Pollution Bulletin, 73(1), 161-169.
154. Velander, K., Mocogni, M., 1999. Beach litter sampling strategies: is there a 'best'method?. Marine Pollution Bulletin, 38(12), 1134-1140.
155. Vlachogianni, T., 2019. Assessing marine litter on Mediterranean beaches. Filling in the knowledge gaps via a participatory-science initiative. MIO-ECSDE.
156. Vlachogianni, T., Fortibuoni, T., Ronchi, F., Zeri, C., Mazziotti, C., Tutman, P., ... & Scoullos, M., 2018. Marine litter on the beaches of the Adriatic and Ionian Seas: An assessment of their abundance, composition and sources. Marine Pollution Bulletin, 131, 745-756.
157. Wade, B.A., Morrison, B., Jones, M.A.J., 1991. A study of beach litter in Jamaica. Caribbean Journal of Science, 27 (3–4), 190–197.
158. Walker, T.R., Reid, K., Arnould, J. P., Croxall, J.P., 1997. Marine debris surveys at Bird Island, South Georgia 1990–1995. Marine Pollution Bulletin, 34(1), 61-65.
159. Watts, A.J., Porter, A., Hembrow, N., Sharpe, J., Galloway, T.S., Lewis, C., 2017. Through the sands of time: Beach litter trends from nine cleaned north cornish beaches. Environmental Pollution, 228, 416-424.
160. Williams, A.T., 2011. Definitions and typologies of coastal tourism destinations, (In), Disappearing Destinations: Climate change and future challenges for coastal tourism, (eds.), Andrew Jones and Mike Phillips, 47-66, CABI, UK.
161. Williams, A.T., Khattabi, A., 2015. Beach scenery at nador province, Morocco. Journal of Coastal Conservation, 19(5), 743-755.
162. Williams A.T., Micallef, A. (eds.)., 2009. Beach management: principles and practices. Earthscan, London 480 pp.
163. Williams, A.T., Micallef, A., Anfuso, G., Gallego-Fernández, J.B., 2012. Andalusia, Spain: an assessment of coastal scenery. Landscape Research, 37(3), 327-349.
164. Williams, A.T., Pond, K., Ergin, A., Cullis, M.J., 2013. The hazards of beach litter. In Coastal hazards (pp. 753-780). Springer, Dordrecht.
165. Williams, A.T., Randerson, P., Allen, C., Cooper, J.A.G., 2017. Beach litter sourcing: A trawl along the Northern Ireland coastline. Marine Pollution Bulletin, 122(1-2), 47-64.
166. Williams, A.T., Randerson, P., Di Giacomo, C., Anfuso, G., Macias, A., Perales, J.A., 2016a. Distribution of beach litter along the coastline of Cádiz, Spain. Marine Pollution Bulletin, 107(1), 77-87.
167. Williams, A.T., Rangel-Buitrago, N.G., Anfuso, G., Cervantes, O., Botero, C.M., 2016b. Litter impacts on scenery and tourism on the Colombian north Caribbean coast. Tourism Management, 55, 209-224.
168. Williams, A.T., Simmons, S.L., 1997. Estuarine litter at the river/beach interface in the Bristol Channel, United Kingdom. Journal of Coastal Research, 1159-1165.

169. Williams, A.T., Simmons, S. L., 1999. Sources of riverine litter: the river Taff, South Wales, UK. Water, Air, and Soil Pollution, 112(1), 197-216.
170. Williams, A.T., Tudor, D.T., 2001. Litter burial and exhumation: spatial and temporal distribution on a cobble pocket beach. Marine Pollution Bulletin, 42(11), 1031-1039.
171. Willoughby, N.G., Sangkoyo, H., Lakaseru, B.O., 1997. Beach litter: an increasing and changing problem for Indonesia. Marine Pollution Bulletin, 34(6), 469-478.
172. Zhao, S., Zhu, L., Li, D., 2015. Microplastic in three urban estuaries, China. Environmental Pollution, 206, 597-604.
173. Zhou, C., Liu, X., Wang, Z., Yang, T., Shi, L., Wang, L., ... & Zhang, C., 2016. Assessment of marine debris in beaches or seawaters around the China Seas and coastal provinces. Waste Management, 48, 652-660.
174. Zielinski, S., Botero, C.M., Yanes, A., 2019. To clean or not to clean? A critical review of beach cleaning methods and impacts. Marine Pollution Bulletin, 139, 390-401.
175. Zimmermann, L., Dierkes, G., Ternes, T.A., Völker, C., Wagner, M., 2019. Benchmarking the in vitro toxicity and chemical composition of plastic consumer products. Environmental Science & Technology, 53(19), 11467-11477.

**Páginas web consultadas**

- https://es.climate-data.org/
- https://www.geoenciclopedia.com/
- https://www.ine.es/
- https://www.r-project.org/
- https://www.red2000.com/
- https://www.marqalicante.com/
- http://www.museosdeandalucia.es/web/museodecadiz

## Material Complementario

**Tabla S1.** Códigos y descripción de los grupos de residuos por tipo de material (Asensio-Montesinos et al., 2021).

| CODE | DESCRIPTION | MATERIAL |
|---|---|---|
| CL01 | Clothing | Cloth |
| CL02 | Furnishing | Cloth |
| CL03 | Canvas, sailcloth & sacking (hessian) | Cloth |
| CL04 | Shoes (leather) | Cloth |
| CL05 | Towels/rags | Cloth |
| CL06 | Backpacks & bags | Cloth |
| CL07 | Rope & Strings /net pieces (non-nylon) | Cloth |
| CL08 | Gloves (non-rubber) | Cloth |
| CL09 | Towels/rags | Cloth |
| CL10 | Rope/net pieces (non-nylon) | Cloth |
| CL11 | Fabric pieces | Cloth |
| CL12 | Sanitary towels/panty liners/backing strips | Cloth |
| CL13 | Toilet fresheners | Cloth |
| CL14 | Cloth pieces 0 - 2,5 cm | Cloth |
| CL15 | Cloth pieces 2,5 cm - 50 cm | Cloth |
| CL16 | Cloth pieces > 50 cm | Cloth |
| CL17 | Hair bands | Cloth |
| CL18 | Cloth labels | Cloth |
| CL19 | Bracelets | Cloth |
| CL20 | Sanitary Mask | Cloth |
| CL21 | Hats and caps | Cloth |
| CLXX | Other textiles (please specify in other item box*) | Cloth |
| GL01 | Beverage Bottles | Glass |
| GL02 | Other Bottles | Glass |
| GL03 | Jars | Glass |
| GL04 | Tableware (plates & cups) | Glass |
| GL05 | Incandescent Lights globes/bulbs | Glass |
| GL06 | Fluorescent light tubes/globes / bulbs | Glass |
| GL07 | Glass buoys | Glass |
| GL08 | Glass fragments 0 - 2,5 cm | Glass |
| GL09 | Glass fragments 2,5 cm - 50 cm | Glass |
| GL10 | Glass fragments > 50 cm | Glass |
| GLXX | Other glass items (please specify in other item box*) | Glass |
| ME01 | Metal Medical Containers / tubes | Metal |
| ME02 | Aerosol/Spray cans | Metal |
| ME03 | Bottle caps, lids & pull tabs | Metal |
| ME04 | Drink cans | Metal |
| ME05 | Electric appliances | Metal |
| ME06 | Fishing weights | Metal (Pb) |
| ME07 | Fishing lures / hooks | Metal |
| ME08 | Fishing traps & pots | Metal |
| ME09 | Foil wrappers | Metal |
| ME10 | Food cans | Metal |
| ME11 | Industrial scrap | Metal |
| ME12 | Oil drums | Metal |
| ME13 | Paint tins | Metal |
| ME14 | Lobster/crab pots and tops | Metal |
| ME15 | Wire, wire mesh, barbed wire | Metal |
| ME16 | Disposable BBQ's | Metal |
| ME17 | Tableware (forks & knives) | Metal |
| ME18 | Tableware (plates, cups, spoons) | Metal |
| ME19 | Batteries | Metal |
| ME20 | Metal fragments 0 - 2,5 cm | Metal |
| ME21 | Metal fragments 2,5 cm - 50 cm | Metal |
| ME22 | Metal fragments > 50 cm | Metal |
| ME23 | Nails and screws | Metal |
| ME24 | Hair clips | Metal |

| | | |
|---|---|---|
| ME25 | Fishing rod pieces | Metal |
| ME26 | Metal bottle | Metal |
| MEXX | Other Metal items (please specify in other item box*) | Metal |
| OR01 | Bagged dog faeces | Organic |
| OR02 | Food residues | Organic |
| OR04 | Dead marine animal (please specify) | Organic |
| OR05 | Dead terrestrial animal (please specify ) | Organic |
| ORXX | Other Organic items (please specify in other item box*) | Organic |
| PP01 | Bags | Paper • Cardboard |
| PP02 | Cardboard | Paper • Cardboard |
| PP03 | Tubes for fireworks | Paper • Cardboard |
| PP04 | Cigarette packets | Paper • Cardboard |
| PP05 | Cigarette butts papers | Paper • Cardboard |
| PP06 | Cups | Paper • Cardboard |
| PP07 | Paper (including newspapers & magazines) | Paper • Cardboard |
| PP08 | Cartons e.g. tetrapak (milk) | Paper • Cardboard |
| PP09 | Cartons e.g. tetrapak (other) | Paper • Cardboard |
| PP10 | Paper fragments 0 - 2,5 cm | Paper • Cardboard |
| PP11 | Paper fragments 2,5 cm - 50 cm | Paper • Cardboard |
| PP12 | Paper fragments > 50 cm | Paper • Cardboard |
| PP13 | Firecrackers | Paper • Cardboard |
| PP14 | Cardboard fishing box | Paper • Cardboard |
| PPXX | Other paper items (please specify in other item box*) | Paper • Cardboard |
| PW01 | Paraffin or wax pieces 0 - 1 cm | Paraffin or wax |
| PW02 | Paraffin or wax pieces 1 - 10 cm | Paraffin or wax |
| PW03 | Paraffin or wax pieces >10 cm | Paraffin or wax |
| PL01 | Syringes | Plastic |
| PL02 | 4/6-pack yokes | Plastic |
| PL03 | Bags (e.g. shopping) | Plastic |
| PL04 | Small plastic bags, e.g., freezer bags | Plastic |
| PL05 | Drinks (bottles, containers and drums) < 2L | Plastic |
| PL06 | Drinks (bottles, containers and drums) > 2L | Plastic |
| PL07 | Cleaner (bottles, containers and drums) < 2L | Plastic |
| PL08 | Cleaner (bottles, containers and drums) > 2L | Plastic |
| PL09 | Cosmetics (bottles & containers e.g. sun lotion, shampoo, shower gel, deodorant) | Plastic |
| PL10 | Engine oil containers and drums < 2 L | Plastic |
| PL11 | Engine oil containers and drums > 2 L | Plastic |
| PL12 | Jerry cans (square plastic containers with handle) | Plastic |
| PL13 | Medical Containers / tubes | Plastic |
| PL14 | Injection gun containers | Plastic |
| PL15 | Other bottles, containers and drums | Plastic |
| PL16 | Knives, forks | Plastic |
| PL17 | Spoons, stirrers | Plastic |
| PL18 | Straws | Plastic |
| PL19 | Hard Plastic Food containers (fast food, lunch boxes & similar) | Plastic |
| PL20 | Foamed Plastic Food containers (fast food, lunch boxes & similar) | Plastic |
| PL21 | Balloons | Plastic |
| PL22 | Gloves | Plastic |
| PL23 | Cotton bud sticks | Plastic |
| PL24 | Cigarettes, butts & filters | Plastic |
| PL25 | Hard Plastic Cups | Plastic |
| PL26 | Foamed Plastic Cups | Plastic |
| PL27 | Food wrappers | Plastic |
| PL28 | Crates | Plastic |
| PL29 | Car parts | Plastic |
| PL30 | Caps/lids | Plastic |
| PL31 | Cigarette lighters | Plastic |
| PL32 | Pens | Plastic |
| PL33 | Combs/hair brushes | Plastic |
| PL34 | Crisp/sweet packets and lolly sticks | Plastic |
| PL35 | Toys & party poppers | Plastic |
| PL36 | Fertiliser/animal feed bags | Plastic |
| PL37 | Cigar tips | Plastic |

| | | |
|---|---|---|
| PL38 | Fishing gear (lures, traps & pots) | Plastic |
| PL39 | Mesh bags (vegetable, oyster nets & mussel bags) | Plastic |
| PL40 | Baskets, crates & trays | Plastic |
| PL41 | Foam (insulation & packaging) | Plastic (PU) |
| PL42 | Rope (diameter more than 1 cm) | Plastic |
| PL43 | String and cord (diameter less than 1 cm) | Plastic |
| PL44 | Tangled nets/cord/rope and string | Plastic |
| PL45 | Fish boxes | Plastic (PS) |
| PL46 | Fishing line (angling) | Plastic |
| PL47 | Light sticks (tubes with fluid) inluding bags | Plastic |
| PL48 | Floats/Buoys | Plastic |
| PL49 | Buckets | Plastic |
| PL50 | Strapping bands | Plastic |
| PL51 | Industrial packaging, plastic sheeting, tarpaulin or other woven plastic bags, palette wrap | Plastic |
| PL52 | Fibreglass fragments | Plastic |
| PL53 | Hard hats | Plastic |
| PL54 | Shotgun cartridges | Plastic |
| PL55 | Shoes/sandals | Plastic |
| PL56 | Plastic bag ends | Plastic |
| PL57 | Resin pellets | Plastic |
| PL58 | Lobster and fish tags | Plastic |
| PL59 | Nets and pieces of net < 50 cm | Plastic |
| PL60 | Nets and pieces of net > 50 cm | Plastic |
| PL61 | Tampons and tampon applicators | Plastic |
| PL62 | Hard Plastic pieces 0 - 2,5 cm | Plastic |
| PL63 | Hard Plastic pieces 2,5 cm > < 50 cm | Plastic |
| PL64 | Hard Plastic pieces > 50 cm | Plastic |
| PL65 | Film Plastic pieces 0 - 2,5 cm | Plastic |
| PL66 | Film Plastic pieces 2,5 cm > < 50 cm | Plastic |
| PL67 | Film Plastic pieces > 50 cm | Plastic |
| PL68 | Foamed Plastic pieces 0 - 2,5 cm | Plastic (PS) |
| PL69 | Foamed Plastic pieces 2,5 cm > < 50 cm | Plastic (PS) |
| PL70 | Foamed Plastic pieces > 50 cm | Plastic (PS) |
| PL71 | Artificial flowers | Plastic |
| PL72 | Masks and snorkel tubes | Plastic |
| PL73 | Bracelets | Plastic |
| PL74 | Torch and lanterns | Plastic |
| PL75 | Tubes | Plastic |
| PL76 | Pieces of beach umbrella | Plastic |
| PL77 | Wad-container from hunting cartridge | Plastic |
| PL78 | Adhesive tape roll and fragments | Plastic |
| PL79 | Cable ties / clamps | Plastic |
| PL80 | Scourer | Plastic |
| PL81 | Clothes pegs | Plastic |
| PL82 | Eye drops | Plastic |
| PL83 | Sunglasses | Plastic |
| PL84 | Foamed Plastic containers (fishing) | Plastic (PS) |
| PL85 | Manual razor | Plastic |
| PL86 | Test tubes | Plastic |
| PL87 | Grid | Plastic |
| PL88 | Hair bands | Plastic |
| PL89 | Medical plasters | Plastic |
| PL90 | Hair clips | Plastic |
| PL91 | Beach ashtray | Plastic |
| PL92 | Tissue packets, wipes packs, tampax packages… | Plastic |
| PLXX | Other plastic items (please specify in other item box*) | Plastic |
| PT01 | Construction material (brick, cement, pipes) | Pottery • Ceramics |
| PT02 | Octopus pots | Pottery • Ceramics |
| PT03 | Other ceramic/pottery items (please specify in other item box*) | Pottery • Ceramics |
| PT04 | Tableware (plates & cups) | Pottery • Ceramics |
| PT05 | Ceramic fragments 0 - 2,5 cm | Pottery • Ceramics |
| PT06 | Ceramic fragments 2,5 cm - 50 cm | Pottery • Ceramics |
| PT07 | Ceramic fragments > 50 cm | Pottery • Ceramics |

| | | |
|---|---|---|
| PTXX | Other Ceramic items (please specify in other item box*) | Pottery • Ceramics |
| RB01 | Balloons, including plastic valves, ribbons, strings etc. | Rubber |
| RB02 | Boots | Rubber |
| RB03 | Tyres and belts | Rubber |
| RB04 | Rubber bands | Rubber |
| RB05 | Condoms | Rubber |
| RB06 | Footwear (flip-flops) | Rubber |
| RB07 | Gloves (typical washing up gloves) | Rubber |
| RB08 | Gloves (industrial/professional gloves) | Rubber |
| RB09 | Rubber fragments 0 - 2,5 cm | Rubber |
| RB10 | Rubber fragments 2,5 cm - 50 cm | Rubber |
| RB11 | Rubber fragments > 50 cm | Rubber |
| RB12 | Tennis ball | Rubber |
| RB13 | Elastic octopus straps | Rubber |
| RB14 | Tube | Rubber |
| RBXX | Other Rubber items (please specify in other item box*) | Rubber |
| WO01 | Corks | Wood |
| WO02 | Pallets | Wood |
| WO03 | Crates | Wood |
| WO04 | Fishing traps and pots | Wood |
| WO05 | Ice lolly sticks / | Wood |
| WO06 | Chip forks, chopsticks & toothpicks | Wood |
| WO07 | Paint brushes | Wood |
| WO08 | Fish boxes | Wood |
| WO09 | Matches & fireworks | Wood |
| WO10 | Logs, sticks and plant debris < 1 cm diameter | Wood |
| WO11 | Logs, sticks and plant debris > 1 cm diameter | Wood |
| WO12 | Wood fragments 0 - 2,5 cm | Wood |
| WO13 | Wood fragments 2,5 cm - 50 cm | Wood |
| WO14 | Wood fragments > 50 cm | Wood |
| WOXX | Other Wood items (please specify in other item box*) | Wood |
| YY01 | Other medical items (swabs, bandaging, ban aid, etc.) | Medical waste |
| YY02 | Silica gel packets | Silica |
| YY03 | Insulating cloth | Other |
| YY04 | Shoe insoles | EVA foam, polypropylene… |
| YY05 | Sponge | Other |
| YY06 | Cable | Other |
| YY07 | Electronic | Other |
| YY08 | Leather pieces | leather |
| YY09 | Wetsuit boots | Neoprene |
| YYXX | Other (please specify in other item box*) | Other |

**Fotografías de residuos costeros observados durante el estudio en Alicante**










**Fotografías de residuos costeros observados durante el estudio en Cádiz**










# ARTÍCULOS DE INVESTIGACIÓN

## Anexo I

Publicación **I**.

# Beach litter distribution along the western Mediterranean coast of Spain

F. Asensio-Montesinos[1], G. Anfuso[1], A.T. Williams[2]

[1]Faculty of Marine and Environmental Sciences, University of Cádiz, Polígono Río San Pedro s/n, 11510 Puerto Real, Cádiz, Spain

[2]Faculty of Architecture, Computing and Engineering, University of Wales Trinity Saint David (Swansea), Mount Pleasant, Swansea, Wales, UK

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Baseline

# Beach litter distribution along the western Mediterranean coast of Spain

F. Asensio-Montesinos[a], G. Anfuso[a,*], A.T. Williams[b]

[a] Faculty of Marine and Environmental Sciences, University of Cádiz, Polígono Río San Pedro s/n, 11510 Puerto Real, Cádiz, Spain
[b] Faculty of Architecture, Computing and Engineering, University of Wales Trinity Saint David (Swansea), Mount Pleasant, Swansea, Wales, UK

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ABSTRACT

The amount and composition of beach litter was assessed, during spring 2018, at 56 sites along the coast of Alicante Province, on the western Mediterranean Sea. Selected sites covered "natural" (19), "village" (17) and "urban" (20) bathing areas and a total of 10,101 litter items was counted in an area of 201,686 $m^2$. Plastic represented the dominant material with 8345 items, i.e. 82.6% of all debris; paper and cardboard numbered 566 items (i.e. 5.6%); pottery and ceramics 348 (3.4%); metal 325 (3.2%); cloth 231 (2.3%); glass 147 (1.5%); rubber 64 (0.6%); wood 46 (0.5%) and other materials summed 29 items, i.e. 0.3% of all debris. Cigarette butts, 45.6% of total items, were observed at different coastal sites: i.e. 1028 units at natural, 1148 at village and 2431 at urban sites. Despite the efforts of local administrations, which enforced cleaning operations at most sites, litter items were essentially related to beachgoers followed by wastewater discharges and fishing activities.

Numerous research carried out on coastal visitors in Malta, UK, Turkey, USA and Spain, have demonstrated that five parameters (the "Big Five") are the most significant in the choice of a beach destination by tourists: safety, water quality, facilities, scenery and NO litter (Williams and Micallef, 2009), and the latter is the focus of this paper. The order of these parameters is not the same at all countries; in Spain, litter is in third place (Ergin et al., 2004; Williams, 2011) and, at other localities (e.g. the Cape Peninsula, South Africa), cleanliness was the most significant factor in influencing beach choice for both local and non-local visitors (Ballance et al., 2000). Surveys carried out by Ünal and Williams (1999) showed that the majority of Turkish beach users disliked the presence of litter and 30% considered litter as the most important aspect for any beach selection. Additionally beach type influences the ordering, e.g. safety is not deemed important on a remote beach, but very important on a resort beach.

Litter accumulation along the coast is a considerable problem linked to different human activities and causes harmful environmental effects on the aesthetic deterioration of beaches (Gabrielides et al., 1991). Different litter types are related to land-based sources, especially significant here is the role played by rivers together with people who on leaving recreational beaches simply leave behind all packaging, bottles, etc. that they brought to the beach. Litter also comes from marine-based sources, e.g. litter discarded to the sea from ships and afterward transported by currents (especially floating items) until it lands on different, and often remote, coastal sites (Lavers and Bond, 2017). About 100,000 t per year of plastic waste from European Union countries end up in the sea; c. 60 t/yr consist of single-use plastic items, whose use has exponentially increased from the 1950s (Seas at Risk, 2017). A huge annual consumption is observed of cigarette butts (580 billion items), beverage bottles (46 billion), takeaway packaging (2.5 billion), coffee cups (16 billion) and 36.4 billion drinking straws (Seas at Risk, 2017). In order to apply more efficient coastal management plans, it is mandatory to know the origin, composition and density of litter at different coastal sites.

The 56 investigated sites are distributed along the Province of Alicante, in the Spanish south-eastern coast (Fig. 1). Surveyed areas distribution was arbitrarily selected to uniformly cover the whole length of the investigated area. This includes, from north to south, small sandy beaches, gravel and pebbles beaches with high cliffs and, finally, other sandy beaches intercalating rocky shores and low cliffed sectors. Artificial coast sectors recorded along the whole area, include ports, breakwaters, concrete seawalls, summer houses and condominiums, and nourished beaches. Waves, which prevalently approach from the I and II quadrants, give rise to a NE-SW littoral transport (Fig. 1). For decades, this area, known as "Costa Blanca", has been subject to intense tourism due to factors, such as, good weather conditions, presence of clear and turquoise water, beach facilities, etc. In addition, intense real estate development and construction of houses near the coastline resulted in an urban landscape mainly frequented by national and international tourists.

Data used in this paper were collected from 03/26/2018 to 04/03/2018. Diverse methodologies were applied at each site, such as beach

* Corresponding author.
*E-mail address:* giorgio.anfuso@uca.es (G. Anfuso).

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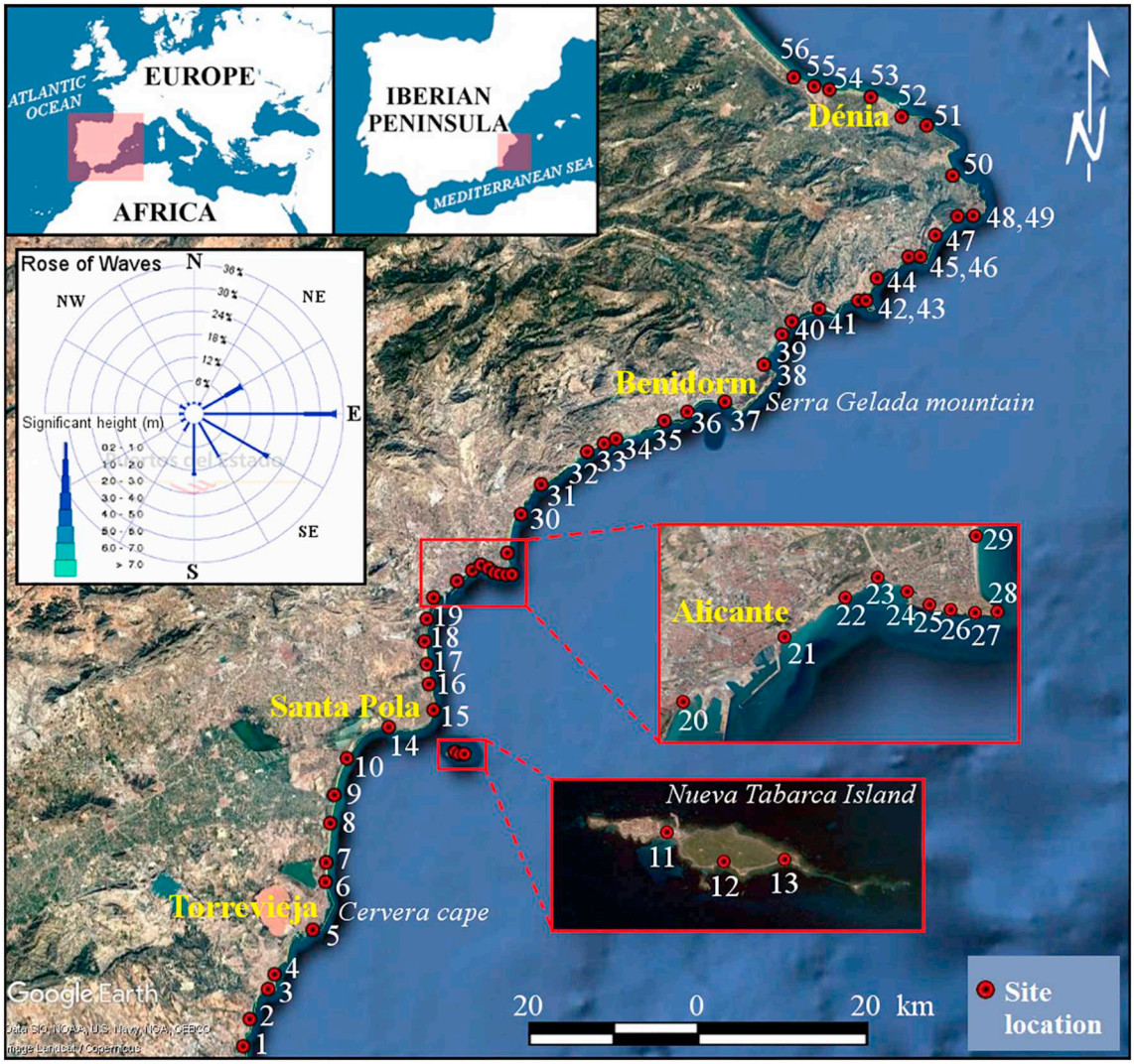



**Fig. 1.** Location map showing the fifty-six study sites. Detailed information according to site numbering is indicated in Table 2. Wave rose for Alicante area, observation period: 2006–2014 (source: www.puertos.es, accessed October 2018). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

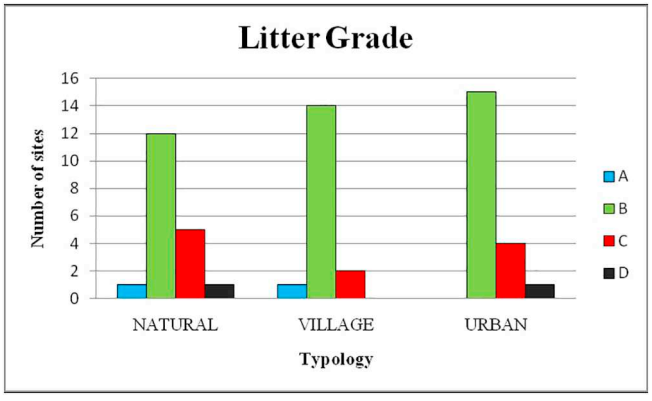



**Fig. 2.** Litter Grade (EA/NALG, 2000) by beach type along the study area.

typology determination according to the Bathing Area Registration and Evaluation (BARE) system (Williams and Micallef, 2009) and litter characterization following the EA/NALG (2000) technique. According to the latter, the standard sampling unit consisted of a 100-metre long coastal sector and the observer recorded litter data whilst moving along 5 m separated transects parallel to the coastline in order to cover the entire usable beach, from the shoreline up to the landward limit of the beach (a seawall, dune foot, etc.).

Data was collected according to the EA/NALG (2000) methodology and inserted into a matrix and, for each one of the seven considered litter typologies a Litter Grade was obtained ranging from "A" (Excellent) to "D" (Poor). The final score of each site corresponded to the lowest grade obtained (Fig. 2). Further, the presence/quantification of a wide number of litter groups was also assessed by combining three litter classifications from different entities, i.e. the United Nations Environment Programme (UNEP), National Oceanic and Atmospheric Administration (NOAA) and OSPAR Commission (Cheshire and Adler, 2009; OSPAR, 2010; Opfer et al., 2012). Coastal sites, according to their occupation level, included "remote and rural" (hereinafter referred to as "natural" areas, $n = 19$), village ($n = 17$) and urban areas ($n = 20$) in accordance with the BARE system.

An amount of 10,101 litter items, belonging to 116 groups, was counted at the 56 coastal sites, over a total beach surface of 201,686 $m^2$

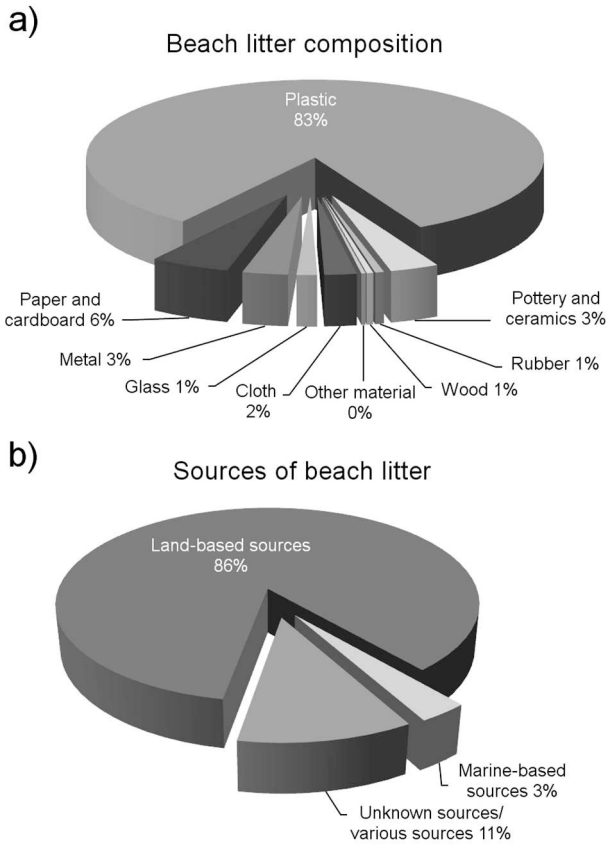



**Fig. 3.** Most represented beach litter categories. a) Litter composition and b) Sources of beach litter.

or 300 transects (i.e. a total of 30 km). Litter items were composed by different materials (Fig. 3a): plastic was the most represented (82.6%) followed by paper and cardboard (5.6%), pottery and ceramics (3.4%), metal (3.2%), cloth (2.3%), glass (1.5%), rubber (0.6%), wood (0.5%) and other unknown materials (0.3%). Similar distributions have been found in studies carried out on several European beaches (Addamo et al., 2017), in the southern coast of the Mediterranean (Aydın et al., 2016; Munari et al., 2016) and in other seas and oceans (Kusui and Noda, 2003; Nelms et al., 2017; Portz et al., 2018).

With respect to plastics, it should be noted that cigarettes butts and filters were the most common items accounting for 4607 items (Avg: 0.023 items/$m^2$), equivalent to 45.6% of the total, these proportions being close to the ones presented for the Balearic Islands by Martinez-Ribes et al. (2007). The most common groups within the plastics are cigarette butts (55.2%), hard plastic pieces (8.8%), cotton bud sticks (also known as Q tips, 6.9%), food wrappers (5.4%), caps/lids (3.2%), foamed pieces (2.7%), straws (2.4%), film pieces (2,4%), fishing lines (1.9%), crisp/sweet packets and lolly sticks (1.5%), string and cord (ø < 1 cm, 1.4%), bags (1.4%) and drinks (< 2 L, 1%). Other litter groups (> 0.5% of the total) can be observed in Table 1. Litter diversity, expressed as number of litter groups at each site, varied from 11 to 59 groups and, the average, was 26 groups per site. Other relevant information such as number of items per 100 m and number of items per $m^2$ at each site was also obtained (Table 2).

As regards litter origin, most (86%) comes from land-based sources, e.g. cigarettes butts, Q tips, food wrappers, paper fragments, film plastic pieces, construction material, caps/lids, glass fragments, crisp/sweet packets and lolly sticks, metal bottle caps, lids and pull tabs, foil wrappers, drinks (< 2 L), etc. Normally, such kinds of items are transported by rivers, wind, municipal drainage systems or are directly discharged on the beach by users. A smaller litter proportion (3%) was linked to marine-based sources related to fishing activities (Fig. 3b). As an example, the most common are fishing lines, string and cord (ø < 1 cm), plastic rope (ø > 1 cm), plastic fishing gear (e.g. lures, traps and pots), metal fishing lures/hooks, floats and buoys. This type of litter is quite common, e.g. in the Adriatic Sea (Laglbauer et al., 2014; Munari et al., 2016). Other items (11%) have unknown source or different potential sources (e.g. hard plastic pieces, foamed plastic pieces, cloth rope and strings, clamps, rubber fragments, among others). Several litter groups cannot be directly related to a particular source because they can have a number of potential sources, pathways of entry and geographic origins (Veiga et al., 2016). In addition, these types of materials are usually very fragmented and are difficult to identify (Prevenios et al., 2018).

**Table 1**
Category codes for most common litter items at the 56 sites.

| Material | UNEP Code | Description | Total of items | % of the total |
|---|---|---|---|---|
| Plastic | PL01 | Bottle caps and lids | 267 | 2.64 |
| | PL02 | Bottles < 2 L | 113 | 1.12 |
| | PL04 | Knives, forks, straws… (cutlery) | 283 | 2.80 |
| | PL07 | Plastic bags (opaque and clear) | 143 | 1.42 |
| | PL11 | Cigarettes, butts and filters | 4607 | 45.61 |
| | PL18 | Monofilament line | 157 | 1.55 |
| | PL19 | Rope | 142 | 1.41 |
| | – | Cotton bud sticks | 573 | 5.67 |
| | – | Food wrappers | 452 | 4.47 |
| | – | Crisp/sweet packets and lolly sticks | 127 | 1.26 |
| | – | Hard pieces | 732 | 7.25 |
| | – | Film pieces | 199 | 1.97 |
| | FP01 | Foam sponge | 224 | 2.22 |
| Cloth | CL04 | Rope and string | 71 | 0.70 |
| | CL06 | Other cloth (including rags) | 79 | 0.78 |
| | – | Sanitary towels/panty liners | 64 | 0.63 |
| Glass and ceramic | GC01 | Construction material | 299 | 2.96 |
| | GC07 | Glass or ceramic fragments | 187 | 1.85 |
| Metal | ME02 | Bottle caps, lids and pull tabs | 110 | 1.09 |
| | ME03 | Aluminium drink cans | 51 | 0.50 |
| | ME06 | Foil wrappers | 95 | 0.94 |
| Paper | PC01 | Paper (fragments, magazines…) | 440 | 4.36 |

**Table 2**
Beach categorization. Location and main characteristics of investigated sites: Map number (Fig. 1), site name and location, beach type, number of items per 100 m, number of items per $m^2$, number of litter groups and Litter Grade.

| No map | Coastal site (and municipality) | Beach Type | No items per 100 m | No items per $m^2$ | No litter groups | Litter grade |
|---|---|---|---|---|---|---|
| 1 | Las Higuericas (Pilar de la Horadada) | Village | 220 | 0.052 | 38 | B |
| 2 | Mil Palmeras (Pilar de la Horadada) | Urban | 101 | 0.020 | 23 | B |
| 3 | La Caleta/Cabo Roig (Orihuela) | Urban | 144 | 0.035 | 33 | B |
| 4 | La Estaca (Orihuela) | Urban | 51 | 0.012 | 22 | B |
| 5 | Playa del Cura (Torrevieja) | Urban | 270 | 0.068 | 21 | B |
| 6 | Torrelamata (Torrevieja) | Urban | 165 | 0.051 | 26 | B |
| 7 | Les Ortigues (Guardamar del Segura) | Remote | 235 | 0.064 | 41 | B |
| 8 | Babilònia (Guardamar del Segura) | Village | 157 | 0.071 | 17 | B |
| 9 | Els Tossals (Guardamar del Segura) | Remote | 238 | 0.130 | 54 | C |
| 10 | El Pinet (Elx) | Rural | 37 | 0.014 | 18 | B |
| 11 | Tabarca (Alacant) | Village | 577 | 0.098 | 35 | C |
| 12 | Faroleta (Alacant) | Remote | 36 | 0.050 | 19 | A |
| 13 | Platja Gran (Alacant) | Remote | 84 | 0.123 | 23 | B |
| 14 | Gran Playa (Santa Pola) | Urban | 496 | 0.078 | 27 | B |
| 15 | Calas del Cuartel (Santa Pola) | Rural | 119 | 0.050 | 31 | C |
| 16 | El Carabassí (Elx) | Remote | 153 | 0.037 | 30 | B |
| 17 | Arenales del Sol (Elx) | Urban | 210 | 0.071 | 27 | B |
| 18 | El Saladar (Alacant) | Urban | 230 | 0.050 | 30 | B |
| 19 | Agua Amarga (Alacant) | Rural | 688 | 0.373 | 59 | C |
| 20 | San Gabriel (Alacant) | Urban | 534 | 0.130 | 38 | D |
| 21 | El Postiguet (Alacant) | Urban | 140 | 0.025 | 18 | B |
| 22 | Serragrossa (Alacant) | Urban | 205 | 0.184 | 41 | C |
| 23 | Albufereta (Alacant) | Urban | 92 | 0.021 | 21 | C |
| 24 | Almadraba (Alacant) | Urban | 90 | 0.009 | 26 | B |
| 25 | Cala dels Jueus (Alacant) | Village | 186 | 0.148 | 38 | B |
| 26 | Cala Cantalars (Alacant) | Rural | 327 | 0.158 | 25 | B |
| 27 | Cala Palmera (Alacant) | Rural | 333 | 0.162 | 29 | C |
| 28 | Cap de l'Horta (Alacant) | Remote | 135 | 0.034 | 25 | D |
| 29 | Playa San Juan (Alacant) | Urban | 547 | 0.057 | 38 | C |
| 30 | Riu Sec (Campello) | Village | 122 | 0.048 | 22 | C |
| 31 | Morro Blanc (Campello) | Village | 90 | 0.032 | 27 | B |
| 32 | Carritxar (La Vila Joiosa) | Remote | 75 | 0.054 | 29 | B |
| 33 | El Xarco (La Vila Joiosa) | Rural | 57 | 0.033 | 24 | B |
| 34 | Bon-Nou (La Vila Joiosa) | Rural | 63 | 0.021 | 22 | B |
| 35 | El Torres (La Vila Joiosa) | Village | 222 | 0.055 | 21 | B |
| 36 | Cala Finestrat (Finestrat) | Urban | 106 | 0.011 | 17 | B |
| 37 | Llevant (Benidorm) | Urban | 391 | 0.059 | 32 | B |
| 38 | Racó de L'Albir (Alfàs del Pi) | Urban | 166 | 0.034 | 24 | B |
| 39 | Cap Negret (Altea) | Village | 21 | 0.005 | 11 | A |
| 40 | L'Olla (Altea) | Village | 77 | 0.057 | 18 | B |
| 41 | Racó del Corb (Calp) | Remote | 131 | 0.118 | 36 | C |
| 42 | Morelló (Calp) | Urban | 126 | 0.062 | 19 | B |
| 43 | Cala de la Fossa (Calp) | Urban | 115 | 0.055 | 15 | B |
| 44 | Cala Fustera (Benissa) | Village | 75 | 0.048 | 15 | B |
| 45 | L'Ampolla (Teulada-Moraira) | Village | 157 | 0.040 | 17 | B |
| 46 | El Portet (Teulada-Moraira) | Village | 38 | 0.029 | 14 | B |
| 47 | Cala del Moraig (Poble Nou de Benitatxell) | Rural | 94 | 0.036 | 22 | B |
| 48 | Granadella (Xàbia) | Rural | 196 | 0.078 | 31 | B |
| 49 | Ambolo (Xàbia) | Remote | 36 | 0.026 | 22 | B |
| 50 | L'Arenal (Xàbia) | Urban | 503 | 0.044 | 33 | C |
| 51 | Les Rotes (Dénia) | Rural | 90 | 0.066 | 24 | B |
| 52 | Marineta Cassiana (Dénia) | Village | 93 | 0.036 | 22 | B |
| 53 | Les Marines (Dénia) | Village | 66 | 0.020 | 22 | B |
| 54 | Els Molins (Dénia) | Village | 58 | 0.015 | 26 | B |
| 55 | Almadrava (Dénia) | Village | 65 | 0.014 | 17 | B |
| 56 | Les Deveses (Dénia) | Village | 68 | 0.014 | 23 | B |

Regarding litter distribution and beach typology, village areas were the ones with the lowest litter density (0.046 items per $m^2$), followed by urban (0.054 items/$m^2$) and natural areas (0.085 items/$m^2$). It should be noted that cigarette butt abundance greatly varied according to beach typology, from 1028 units at 19 natural sites (0.025 items/$m^2$), 1148 at 17 village sites (0.020) to 2431 at 20 urban sites (0.023). This is equivalent to an average content per 100 m long beach sector of 54 cigarette butts at natural coastal sites, 67 at village sites and 121 at urban sites. The positive correlation between abundance and level of urbanization has also been observed in the Baltic (MARLIN, 2013). Dealing with Q tips, 122 items were observed at natural sites, 53 at village sites and 398 at urban sites. A low density compared to other Mediterranean beaches (Martinez-Ribes et al., 2007; Poeta et al., 2016; Prevenios et al., 2018; Vlachogianni et al., 2018), despite this, their occurrence should not be ignored since they indicate wastewater presence.

A box plot was used to visually summarize and compare litter amounts at investigated sites (Fig. 4), which indicated a great difference

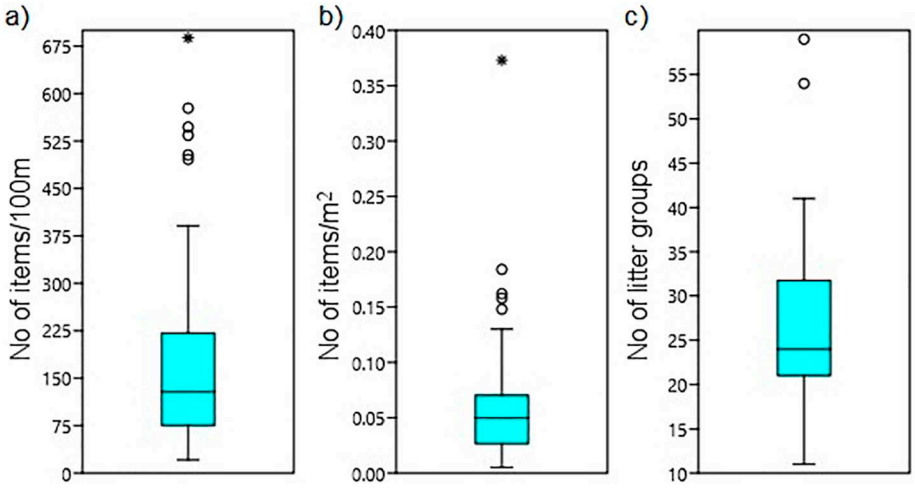



**Fig. 4.** Box plots for the number of items, litter density and number of litter groups. Boxes enclose from the 25% to the 75% of data. Associated standard deviations and median values are also depicted (implemented with "PAST" software).

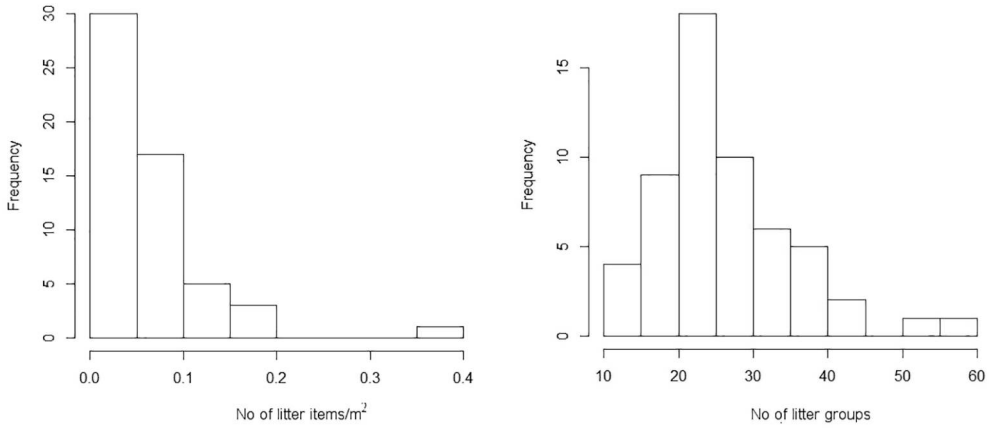



**Fig. 5.** Frequency of litter density (left) and litter diversity (right), implemented with "R" computer program (http://www.r-project.org/).

among surveyed places both in litter density and composition. Abundance and diversity are so high at some sites (Table 2) that the statistical program considered them outliers when compared with the rest (Fig. 4a: no 19, 11, 29, 20, 50, 14; Fig. 4b: no 19, 22, 27, 26, 25; Fig. 4c: no 19, 9). Coastal sites had amounts between 0.05 and 0.373 items/$m^2$ and presented 11 to 59 different litter groups and the frequency histograms of litter data are shown in Fig. 5. Total concentrations of beach litter produce a general unimodal distribution skewed to the right.

Beach litter composition usually varied according to beach typology, from natural to urban areas. For example, there are rural coastal sites where litter composition is very similar to village or urban ones. Field observations indicated that an important factor for influencing the type and abundance of litter was the number of beachgoers. Differences in litter abundance (expressed as items/$m^2$) varied according to beach typology: the average content (red dots) is higher in natural sites followed by urban and village sites (Fig. 6).

A few sites obtained an "A" grade due to low litter content and even the absence of some litter categories (sites no 12 and 39, Table 2). Other sites with a "B" grade show general litter (50–499), harmful litter (1–5 items), sewage related debris (1–5 items general sewage debris or 10–49 Q tips) and, finally gross litter (1–5 items; Table 2). This qualification is considered acceptable although its management issues should not be ignored. Sites with a "C" grade should be considered for immediate coastal management action because their low rating is due to two principal reasons: the first is the presence of general litter (500–999 items in sites no 19, 11, 50 and 29, Table 2) - the last three beaches in Table 2 have 456, 324 and 348 cigarette butts, respectively. The second reason is the presence of broken glass (6–24 items), observed at sites no 27, 15, 9, 22 and 30. Other places obtained a "C" grade because of the presence of general sewage related debris and gross litter (6–14 items), correspondingly observed in beaches no 23 and 41 (Table 2). Finally, grade "D" sites had > 25 broken glass (site no 28) and > 100 Q tips (site no 20, Table 2). Litter grading was slightly worse than the one recorded for the same coastal sites by Asensio-Montesinos et al. (2019) because previous authors counted litter items along a 100-m transect parallel to the coastline and not along the total beach surface as in this paper.

Due to the great diversity of litter groups ($n$ = 116), 10 new groups were created for statistical analysis: cigarette butts, food wrappers, paper and cardboard, single-use plastics, cotton bud sticks, caps/lids, hard plastic pieces, film plastic pieces, glass fragments and foam plastic pieces. A multivariate analysis has allowed establishment of some relationships between sites and litter. To visualize the multivariate patterns among beach litter observations, nonmetric multidimensional

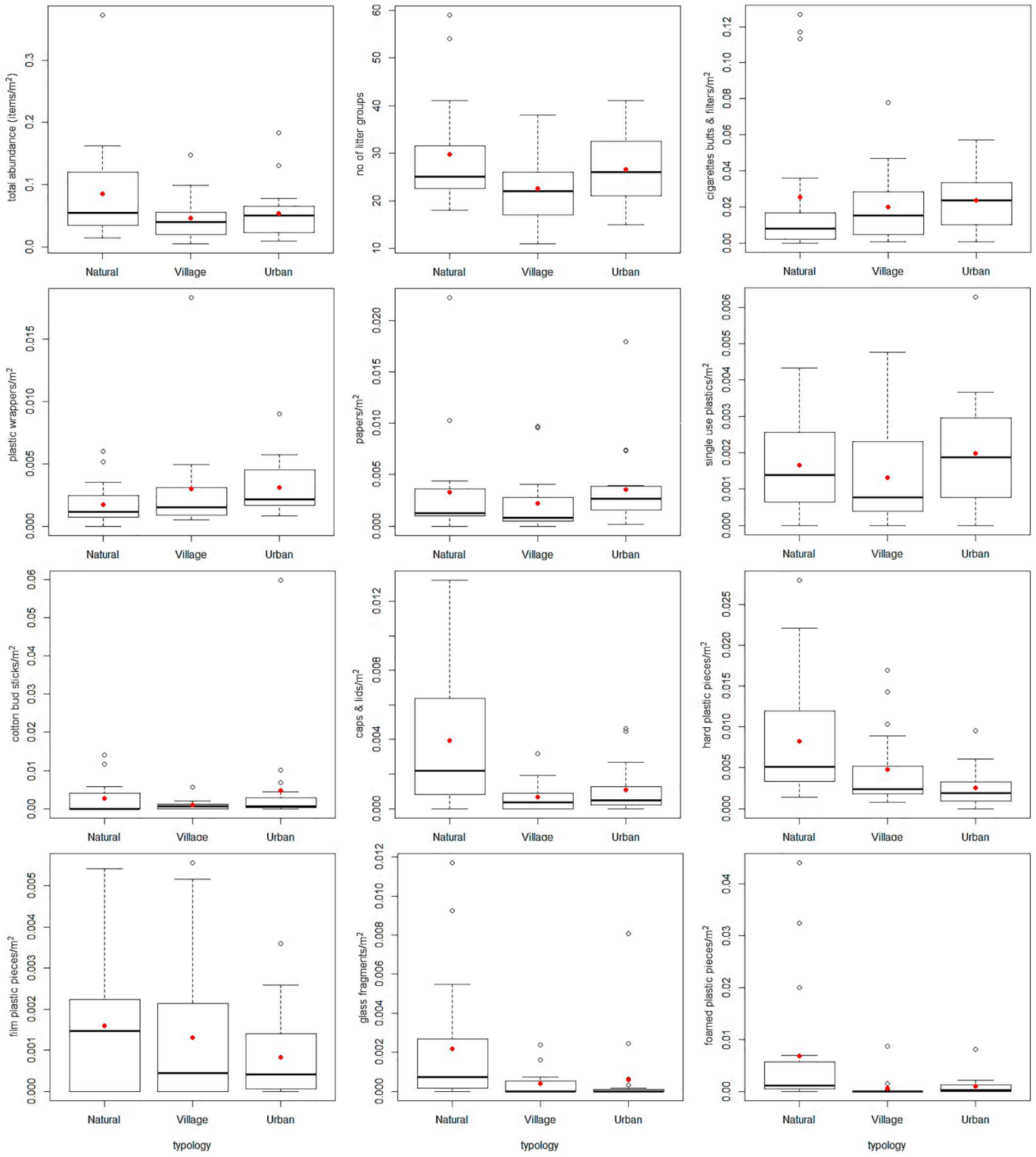



**Fig. 6.** Density of litter groups by beach typology (implemented with "R" computer program (http://www.r-project.org/).

scaling (nMDS) was performed on the Bray–Curtis distances (Fig. 7). Sites that are close together are similar in litter composition and the graph area that links the furthest sites of each beach type is similar in urban and village areas, whilst the area of the natural sites is much larger and more dispersed (Fig. 7). Finally, cluster analysis showed the dissimilarity of all coastal sites, according to beach litter content (Fig. 8). Typology and Litter Grade for each site was also observed and different sectors can be identified: Sector 1 includes the most remote

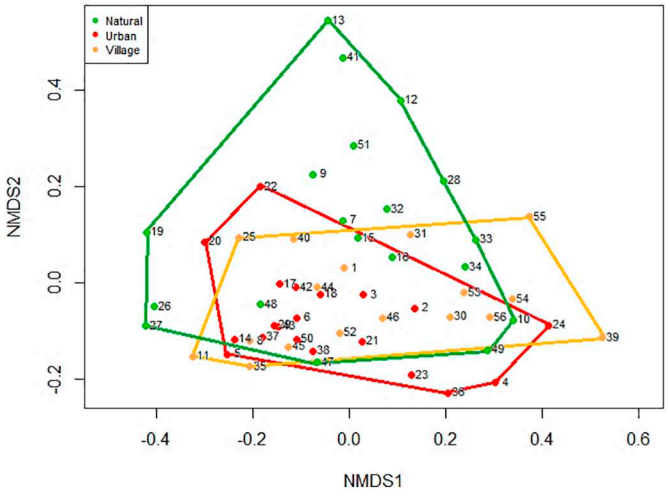



**Fig. 7.** Nonmetric multidimensional scaling (nMDS) implemented with "R" computer program (http://www.r-project.org/). The green, red and yellow dots correspond to natural, urban and village sites respectively. The maximum dispersion area for each group has been marked. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

sites with litter grades "B" and "C". Sector 2 includes the group on the left as village and urban areas (grades "B" and "C") and the group to the right, i.e. village and natural areas (grades "A" and "B"). Sector 3 mostly consists of natural together with a few village sites with different litter grades (from "A" to "D"). Sector 4 includes areas similar to the previous sector, but with a greater number of cigarette butts (grades "B" and "C"). Sector 5 comprises the most similar sites, mostly urban and a few village areas (grades "B", "C" and "D"; Fig. 8).

The cleanest beaches were to be found in village areas, followed by urban areas, with the dirtiest beaches recorded in natural areas. A similar trend was observed along the Catalan coast (NE Spain) by Ariza et al. (2008). Trends observed at Alicante coast are mainly due to two reasons: i) the number of visitors, which is greater in urban than other beaches and, ii) cleanup, which is manual and/or mechanical at village/urban beaches, and manual or non-existent at natural beaches. Relationships between litter composition and beach typology are quite often recorded but, at places, other factors, e.g. number of visitors and cleanup days, acquire more importance. Litter composition was very heterogeneous at natural beaches because the presence (or absence) of cleaning operations. Lastly, urban and village sites were quite alike since both typologies had a similar number of visits and cleanup actions.

The majority of beach litter comes from land-based sources, especially, gross litter, general litter and harmful litter, beach users being mainly responsible for littering at the most frequented beaches; this behaviour has also been observed in other countries such as Cuba (Botero et al., 2017). Evidences presented in this paper showed that cigarette butts were the principal litter item found as was reported from 2014 to 2016 in the German Baltic Sea coast by Haseler et al. (2018), by the Ocean Conservancy (2016) in the USA and Balas et al. (2003) in Turkey. Along the coast of Alicante, in general, litter quantity was low but, at places exceeded 49 items per 100 m-transect.

Some items (especially cigarette butts) principally appeared on the backshore but, the largest quantities of items were generally observed at the landward beach limit. Efficiency of mechanical cleaning for cigarette butts is low (Ariza et al., 2008), and this aspect, together with their high consumption rates (80.3 million cigarette packs were sold this year in Alicante, www.hacienda.gob.es, accessed October 2018) and the absence of adequate management actuations, make them a very common waste on many beaches around the world (Martinez-Ribes et al., 2007; Oigman-Pszczol and Creed, 2007; Williams et al., 2016; Seas at Risk, 2017; Kungskulniti et al., 2018). Environmental awareness should be emphasized to change the behaviour of beach users, along with improvement of current cleanup programs, especially in natural areas and at the sites showing poor litter grades, i.e. "C" and "D".

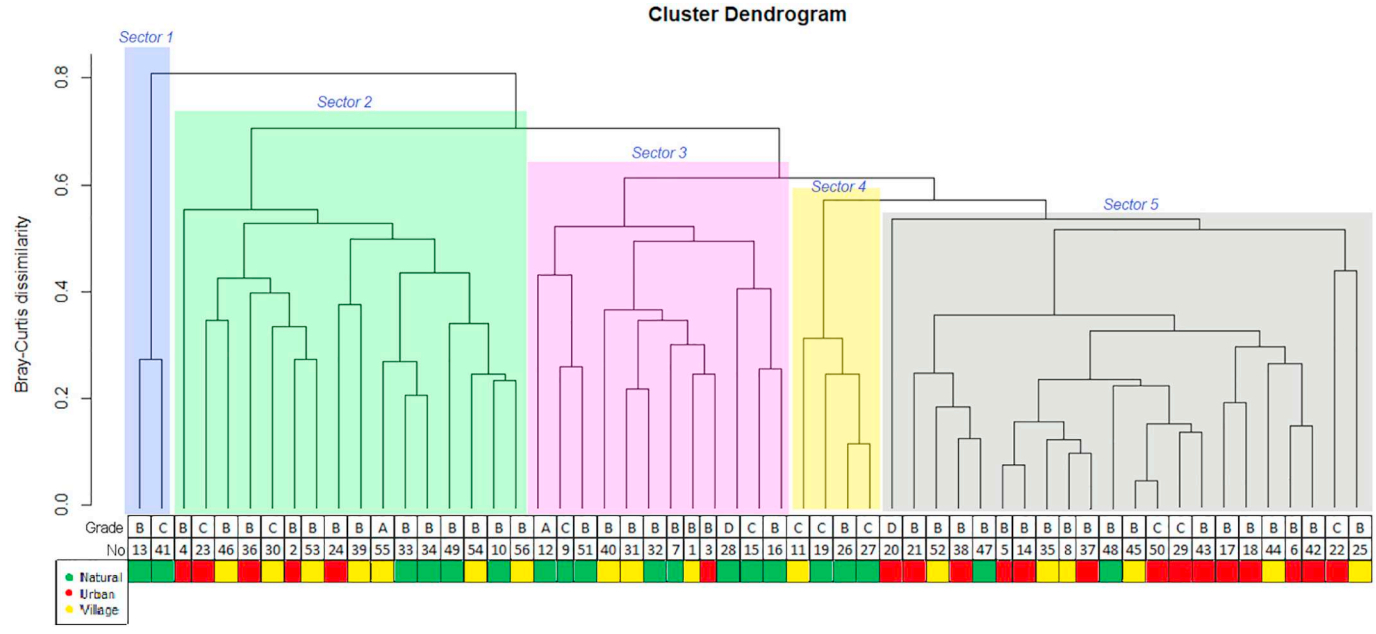



**Fig. 8.** Cluster dendrogram showing dissimilarity analysis among sites according to their litter composition, implemented with "R" computer program (http://www.r-project.org/).

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## References

Addamo, A.M., Laroche, P., Hanke, G., 2017. Top Marine Beach Litter Items in Europe. EUR 29249 EN, Publications Office of the European Union, Luxembourg. https://doi.org/10.2760/496717. (ISBN 978-92-79-87711-7, JRC108181).

Ariza, E., Jiménez, J.A., Sardá, R., 2008. Seasonal evolution of beach waste and litter during the bathing season on the Catalan coast. Waste Manag. 28 (12), 2604–2613.

Asensio-Montesinos, F., Anfuso, G., Corbí, H., 2019. 2019. Coastal scenery and litter impacts at Alicante (SE Spain): management issues. J. Coast. Conserv. 23, 185–201.

Aydın, C., Güven, O., Salihoğlu, B., Kıdeyş, A.E., 2016. The influence of land use on coastal litter: an approach to identify abundance and sources in the coastal area of Cilician Basin, Turkey. Turk. J. Fish. Aquat. Sci. 16 (1), 029–039.

Balas, C.E., Ergin, A., Williams, A.T., Kok, L., Demerci, D., 2003. In: Ozhan (Ed.), Marine Litter Assessment for Antalya, Turkey, Beaches. Proc. of the 6th Int. Conf. on the Med. Environment, 2003. MEDCOAST. Middle East Technical University, Ankara, Turkey, pp. 1037–1046.

Ballance, A., Ryan, P.G., Turpie, J.K., 2000. How much is a clean beach worth? The impact of litter on beach users in the Cape Peninsula, South Africa. S. Afr. J. Sci. 96 (5), 210–230.

Botero, C.M., Anfuso, G., Milanes, C., Cabrera, A., Casas, G., Pranzini, E., Williams, A.T., 2017. Litter assessment on 99 Cuban beaches: a baseline to identify sources of pollution and impacts for tourism and recreation. Mar. Pollut. Bull. 118 (1–2), 437–441.

Cheshire, A., Adler, E., 2009. UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter.

Conservancy, Ocean, 2016. Ocean Conservancy 30th Anniversary International Coastal Cleanup Ocean Conservancy, Washington DC. http://www.oceanconservancy.org, Accessed date: October 2018.

EA/NALG, 2000. Assessment of Aesthetic Quality of Coastal and Bathing Beaches. Monitoring Protocol and Classification Scheme. Environment Agency and The National Aquatic Litter Group, London.

Ergin, A., Karaesmen, E., Micallef, A., Williams, A.T., 2004. A new methodology for evaluating coastal scenery: fuzzy logic systems. Area 36, 367–386.

Gabrielides, G.P., Golik, A., Loizides, L., Marino, M.G., Bingel, F., Torregrossa, M.V., 1991. Man-made garbage pollution on the Mediterranean coastline. Mar. Pollut. Bull. 23, 437–441.

Haseler, M., Schernewski, G., Balciunas, A., Sabaliauskaite, V., 2018. Monitoring methods for large micro-and meso-litter and applications at Baltic beaches. J. Coast. Conserv. 22 (1), 27–50.

Kungskulniti, N., Charoenca, N., Hamann, S.L., Pitayarangsarit, S., Mock, J., 2018. Cigarette waste in popular beaches in Thailand: high densities that demand environmental action. Int. J. Environ. Res. Public Health 15 (4), 630.

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 (1–6), 175–179.

Laglbauer, B.J., Franco-Santos, R.M., Andreu-Cazenave, M., Brunelli, L., Papadatou, M., Palatinus, A., ... Deprez, T., 2014. Macrodebris and microplastics from beaches in Slovenia. Mar. Pollut. Bull. 89 (1–2), 356–366.

Lavers, J.L., Bond, A.L., 2017. Exceptional and rapid accumulation of anthropogenic debris on one of the world's most remote and pristine islands. Proc. Natl. Acad. Sci. 114 (23), 6052–6055.

MARLIN, 2013. Final report of the Baltic marine litter project MARLIN. In: Litter Monitoring and Raising Awareness 2011–2013, (29 pp.).

Martinez-Ribes, L., Basterretxea, G., Palmer, M., Tintoré, J., 2007. Origin and abundance of beach debris in the Balearic Islands. Sci. Mar. 71 (2), 305–314.

Munari, C., Corbau, C., Simeoni, U., Mistri, M., 2016. Marine litter on Mediterranean shores: analysis of composition, spatial distribution and sources in North-Western Adriatic beaches. Waste Manag. 49, 483–490. https://doi.org/10.1016/j.wasman.2015.12.010.

Nelms, S.E., Coombes, C., Foster, L.C., Galloway, T.S., Godley, B.J., Lindeque, P.K., Witt, M.J., 2017. Marine anthropogenic litter on British beaches: a 10-year nationwide assessment using citizen science data. Sci. Total Environ. 579, 1399–1409.

Oigman-Pszczol, S.S., Creed, J.C., 2007. Quantification and classification of marine litter on beaches along Armação dos Búzios, Rio de Janeiro, Brazil. J. Coast. Res. 23 (2), 421–428.

Opfer, S., Arthur, C., Lippiatt, S., 2012. NOAA Marine Debris Shoreline Survey Field Guide. US National Oceanic and Atmospheric Administration Marine Debris Program.

OSPAR Commission, 2010. Guideline for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area.

Poeta, G., Battisti, C., Bazzichetto, M., Acosta, A.T., 2016. The cotton buds beach: Marine litter assessment along the Tyrrhenian coast of central Italy following the marine strategy framework directive criteria. Mar. Pollut. Bull. 113 (1–2), 266–270.

Portz, L., Manzolli, R.P., Garzon, N., 2018. Management priorities in San Andres Island Beaches, Colombia: associated risks. J. Coast. Res. 85, 1421–1425.

Prevenios, M., Zeri, C., Tsangaris, C., Liubartseva, S., Fakiris, E., Papatheodorou, G., 2018. Beach litter dynamics on Mediterranean coasts: distinguishing sources and pathways. Mar. Pollut. Bull. 129 (2), 448–457.

Seas at Risk, 2017. Single-use plastics and the marine environment. In: Leverage Points for Reducing Single-Use Plastics. June 2017, . http://www.seas-at-risk.org/24-publications/800-single-use-plastic-and-the-marine-environment.html, Accessed date: June 2018.

Ünal, Ö., Williams, A.T., 1999. In: Ozhan, E. (Ed.), Beach Visits and Willingness to Pay: Çeşme Peninsula, Turkey. Proceedings of the MEDCOASTEMECS 99 joint conference, land-ocean interactions: Managing coastal ecosystems. Middle East Technical University Press, Ankara, pp. 1149–1162.

Veiga, J.M., Fleet, D., Kinsey, S., Nilsson, P., Vlachogianni, T., Werner, S., Galgani, F., Thompson, R.C., Dagevos, J., Gago, J., Sobral, P., Cronin, R., 2016. Identifying Sources of Marine Litter. MSFD GES TG Marine Litter Thematic Report; JRC Technical Report; EUR 28309. https://doi.org/10.2788/018068.

Vlachogianni, T., Fortibuoni, T., Ronchi, F., Zeri, C., Mazziotti, C., Tutman, P., ... Mandić, M., 2018. Marine litter on the beaches of the Adriatic and Ionian Seas: an assessment of their abundance, composition and sources. Mar. Pollut. Bull. 131, 745–756.

Williams, A.T., 2011. Definitions and typologies of coastal tourism beach destinations. In: Jones, A., Phillips, M. (Eds.), Disappearing Destinations: Climate Change and Future Challenges for Coastal Tourism. CABI, Wallingford, pp. 47–66 (296 pp).

Williams, A.T., Micallef, A., 2009. Beach Management. Principles and Practice. Earthscan, London (480 pp. ISBN: 978-1-84407-435-8).

Williams, A.T., Randerson, P., Di Giacomo, C., Anfuso, G., Macias, A., Perales, J.A., 2016. Distribution of beach litter along the coastline of Cádiz, Spain. Mar. Pollut. Bull. 107 (1), 77–87.

**Anexo II**

Publicación **II**.

# Seasonal comparison of beach litter on Mediterranean coastal sites (Alicante, SE Spain)

F. Asensio-Montesinos[1], G. Anfuso[1], P. Randerson[2], A.T. Williams[3]

[1]Faculty of Marine and Environmental Sciences. University of Cádiz, Polígono Río San Pedro s/n, 11510, Puerto Real, Cádiz, Spain

[2]School of Biosciences, Cardiff University, Cardiff, Wales, UK

[3]Faculty of Architecture, Computing and Engineering, University of Wales Trinity Saint David (Swansea), Mount Pleasant, Swansea, Wales, UK

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# Seasonal comparison of beach litter on Mediterranean coastal sites (Alicante, SE Spain)

F. Asensio-Montesinos[a], G. Anfuso[a,*], P. Randerson[b], A.T. Williams[c]

[a] Faculty of Marine and Environmental Sciences. University of Cádiz, Polígono Río San Pedro s/n, 11510, Puerto Real, Cádiz, Spain
[b] School of Biosciences, Cardiff University, Cardiff, Wales, UK
[c] Faculty of Architecture, Computing and Engineering, University of Wales Trinity Saint David (Swansea), Mount Pleasant, Swansea, Wales, UK

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ABSTRACT

Presence of beach litter was assessed during spring and summer seasons 2018, at 56 sites along the coast of Alicante Province (SE Spain). Selected sites covered "remote" (9), "rural" (10) "village" (17) and "urban" (20) bathing areas. In an area of 201,700 $m^2$, a total of 10,101 litter items (Avg: 0.062 items $m^{-2}$) was counted in spring, and 20,857 (Avg: 0.116 items $m^{-2}$) in summer. The most significant seasonal evolution was observed in the cigarette butt, group which increased from 4607 to 12843 units. Plastic represented the dominant material in both seasons (82.6 and 83.5% respectively). Litter items increased greatly during the summer season despite the increasing frequency of cleaning operations and were essentially related to beach users activities. Secondarily, beach litter was related to wastewater discharges and fishing activities. Beach litter management along investigated sites must be based on plans to reduce litter sources. For that, it is necessary to consider beach typology along with the seasonal influx of visitors to define the most appropriate management actions, not forgetting the implementation of environmental education, essential in schools and media.

## 1. Introduction

Tourism is one of the most important and lucrative industries in the world (Klein et al., 2004; UNWTO, 2018) and global international tourist arrivals grew by 4.4% (1184 million people) in 2015, by 3.9% (1235 million people) in 2016, and by 7% (1326 million people) in 2017 (UNWTO, 2016, 2017, 2018). A total of 267.4 million international tourist arrivals was recorded at Southern Europe in 2017 of which 81.7 million pertain to Spain (UNWTO, 2018). This region is characterized by a Mediterranean climate: mild temperatures associated with annual precipitation in winter and a hot, dry season in summer (Rana and Katerji, 2000) very attractive for the "3S" tourism. The great enhancement of summer population causes a number of problems that are difficult to manage, e.g. the increase of beach litter in bathing areas. This is a major issue since a clean beach is one of the five main priorities for beach tourists around the world (Williams, 2011; Williams et al., 2016a).

Marine litter is any persistent, manufactured or processed solid material discarded, disposed or abandoned in marine and/or coastal environments, including such materials transported into the marine environment from land through rivers, wind, etc. (Coe and Rogers, 2012; Cheshire and Adler, 2009). On the coast, litter items come from land and marine sources (Sheavly and Register, 2007; Coe and Rogers, 2012) in different proportions depending on the study area. Marine litter results from land-based (approximately 80%) and sea-based activities, in addition, most litter is composed of plastic material (Allsopp et al., 2006; Bergmann et al., 2015; Seas at Risk, 2016). Litter items are discharged directly on the beach by users, especially in the summer season, when the population increases in tourist destinations, where more than 75% of the annual waste production is generated (Galgani et al., 2013).

The problems caused by the presence of litter on coasts and beaches have been extensively and variously documented over the last few decades. These issues always have an anthropogenic origin and negatively affect different ecosystems with significant consequences: the ingestion of litter items by seabirds (Kenyon and Kridler, 1969; Pettit et al., 1981; Slip and Burton, 1991; Cadée, 2002), marine turtles (Tomás et al., 2002; Schuyler et al., 2014), fish (Romeo et al., 2015) and marine mammals (Forrester et al., 1975); wildlife entanglement by the loss of fishing gear (Jones, 1995; Walker et al., 1997); transport of non-indigenous species (Barnes, 2002; Kiessling et al., 2015; Gracia C. et al., 2018); presence of hazardous materials (Williams et al. 2000, 2013); and even economic status, with the loss of tourism and recreation potential (Nelson et al., 1999; Ballance et al., 2000; Krelling et al., 2017).

* Corresponding author.
*E-mail address:* giorgio.anfuso@uca.es (G. Anfuso).

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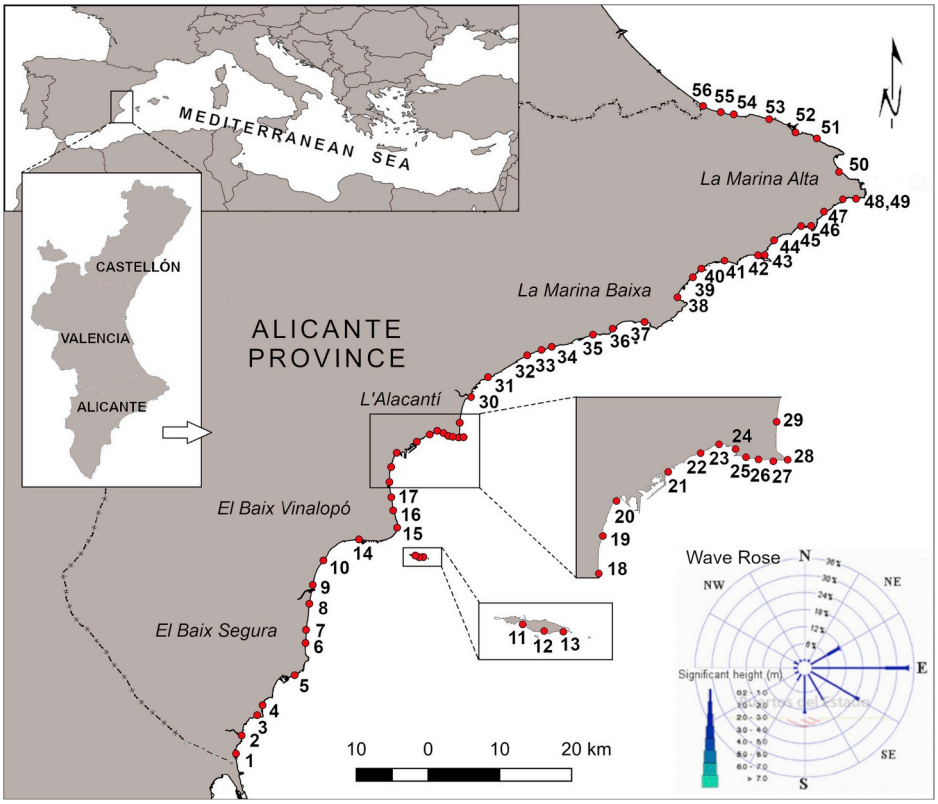



**Fig. 1.** The map shows the fifty-six study sites. Detailed information according to site numbering is specified in Table 2. Wave rose for Alicante area, observation period: 2006–2014 (source: www.puertos.es, accessed February 2019).

Litter is definitely a threat to marine life and human health, with relevant economic, social and environmental impacts.

At present, marine litter is a multi-sectoral, cultural and transboundary problem, so taking action to curb its increase is a social duty that involves everyone. In addition, knowledge of abundance and composition of beach litter in different zones through diverse studies is essential to the appropriate development of any management strategy.

## 2. The Alicante Province coastline

The Alicante Province coastline, also known as the "Costa Blanca", is one of the most traditional tourist destinations on the Spanish Mediterranean coast and this study covered remote, rural, village and urban bathing areas within the region. The latter category includes internationally well-known places (e.g. Benidorm) with housing essentially oriented to residential tourism (Vera-Rebollo et al., 1990), a "sun, sea and sand (3S) market" (Dodds and Kelman, 2008) with a relevant economic value (Houston, 2013). Five coastal regions of Alicante: "El Baix Segura" with approximately 43.5 km of coastal length, "El Baix Vinalopó" (27 km), "L'Alacantí" (46 km), "La Marina Baixa" (32 km) and "La Marina Alta" (70.3 km) are shown in Fig. 1. To the north, in the regions of "Marina Alta" and "Marina Baixa", the mountainous landscape, with coastal cliffs, gives rise to pocket beaches composed of sand, gravel and pebbles.

The coast of the central region (l'Alacantí) is made up of cliffs and, generally, sand beaches. In the south, the coast of "Baix Vinalopó" and "Baix Segura" is composed of sand beaches, dunes and in places, small cliffs and/or rocky shores. Such features are also observed at Nueva Tabarca Island, located 3 km away from Santa Pola Cape. There, artisanal fishery and tourism activities, which attract up to 3500 visitors/day and 300,000/yr, are attempting to be compatible with their protection status of Marine Protected Areas (Ramos, 1995). The direction of littoral transport is from NE-SW in response to wind-generated waves (Fig. 1).

## 3. Methodology

In this paper diverse methodologies were used to determinate litter characteristics and abundance (EA/NALG, 2000; Cheshire and Adler, 2009) and beach typology (Williams and Micallef, 2009). In addition, statistical analysis was performed to define litter patterns; Analysis of variance, non-Multidimensional Scaling, Principal Component Analysis and Cluster analysis were also applied.

### 3.1. Litter quantification and grading

Data were collected in two field surveys carried out in March and August 2018 along a standard sampling unit consisting of a 100-m long coastal sector, i.e. 50 m apart from each side of an access point, extending from the landward beach limit to the shoreline (EA/NALG, 2000). This assessment methodology is also used by Cheshire and Adler (2009), OSPAR Commission (2010) and Opfer et al. (2012). The observer covered the entire beach surface by moving along 5 m separated transects parallel to the coastline. Each litter item was visually identified and categorized into a litter group (see Photo Guide in OSPAR Commission, 2010). The same sampling area was surveyed in summer and spring and was generally located in the central part of the beach. All coastal sites were assessed during bathing hours, approximately between 11 a.m. and 7 p.m. and cleaning operations were usually carried out early in the morning and/or in late afternoon. Locally, at few crowded beaches, manual cleaning operations are also carried out during bathing hours so, probably such beaches show at the end of the day only a slight increase in the number of litter items. Evidently, a site evaluated at the end of the day (after intensive use by beachgoers) may potentially show more items than at the beginning of the day, i.e. just before the arrival of beach users and/or just after beach clean-ups, this being theoretically more evident at urban beaches. Anyway, it is important to highlight that according to previous assumptions, there were

**Table 1**
Most frequent litter categories and their total number of items in study area.

| CODE | Description | No items. Spring | No items. Summer |
|---|---|---|---|
| CL01 | Clothing | 15 | 11 |
| CL07 | Rope & Strings/net pieces (non-nylon) | 71 | 108 |
| CL14[a] | Cloth pieces | 73 | 63 |
| FRD | Fishing-related debris | 314 | 260 |
| GL02 | Other Bottles | 9 | 7 |
| GL08[a] | Glass fragments | 138 | 137 |
| ME03 | Bottle caps, lids & pull tabs | 110 | 145 |
| ME04 | Drink cans | 51 | 70 |
| ME09 | Foil wrappers | 95 | 274 |
| ME22[a] | Metal fragments | 44 | 20 |
| PP02 | Cardboard | 47 | 92 |
| PP10[a] | Paper fragments | 440 | 1646 |
| PL03[a] | Bags (e.g. shopping) | 143 | 77 |
| PL05 | Drinks (bottles, containers and drums) < 2L | 82 | 63 |
| PL16[a] | Knives, forks, spoons, stirrers, straws, cups | 290 | 445 |
| PL24 | Cigarettes, butts & filters | 4607 | 12843 |
| PL27 | Food wrappers | 452 | 415 |
| PL30 | Caps/lids | 267 | 279 |
| PL34 | Crisp/sweet packets and lolly sticks | 127 | 170 |
| PL35 | Toys & party poppers | 18 | 49 |
| PL62[a] | Hard plastic pieces | 732 | 724 |
| PL65[a] | Film Plastic pieces | 199 | 1016 |
| PL68[a] | Foamed Plastic pieces | 224 | 429 |
| PL71 | Clamps | 33 | 37 |
| PL74 | Another caps/lids | 42 | 34 |
| PT01 | Construction material (brick, cement, pipes) | 299 | 198 |
| PT05[a] | Ceramic fragments 0–2,5 cm | 49 | 17 |
| RB09[a] | Rubber fragments | 31 | 26 |
| SI | Smoking Items | 23 | 41 |
| SRD | Sewage-related debris | 655 | 520 |
| WO05 | Ice lolly sticks | 7 | 62 |
| WO06 | Chip forks, chopsticks & toothpicks | 6 | 73 |
| WO12[a] | Wood fragments | 28 | 41 |
| Others | | 380 | 448 |
| Total | | 10101 | 20840 |

[a] Several related groups.

probably no important differences among assessments at urban beaches because within this study they were always sampled under the same conditions, i.e. in the afternoon.

The litter grade was determined by counting the number and type of items at each coastal site according to the U.K. Environmental Authority National Aquatic Litter Group litter assessment protocol (EA/NALG, 2000, Table A1), which has been utilized in many diverse countries, such as, Spain (Micallef et al., 2011; Williams et al., 2016b); Portugal (Quintela et al., 2012); Morocco (Khattabi et al., 2009; Maziane et al., 2018); Italy (Semeoshenkova et al., 2017); Turkey (Balas et al., 2004); Malta (Micallef and Williams, 2004); UK (Tudor and Williams, 2003, 2008; Williams et al., 2014); Colombia (Williams et al., 2016a; Rangel-Buitrago et al., 2017); Cuba (Botero et al., 2017); Brazil (Corraini et al., 2018) and India (Ganesapandian et al., 2011), among others. In this method, which is easy to apply and accurate, a total of seven categories or parameters are assessed. It gives a beach rating that describes the aesthetic quality as “A” grade (Very Good), “B” (Good), “C” (Fair) and “D” (Poor). Beach litter items are classified in each grade according to their abundance. Accumulations are classified according to their number of occurrence and oil is evaluated by its presence/absence. The final grading is the worst grade for any of the above parameters, i.e. if a beach were graded “B” for all categories except one, which is “D”, the overall Grade assigned to the beach would be “D”. Since litter grading categories show great differences in the number of items (Table A1), small differences in the number of litter items counted at different beaches because of different surveying time do not affect beach grading classification.

### 3.2. Beach typology

Following the Bathing Area Registration and Evaluation (BARE) system (see Chapter 9, Williams and Micallef, 2009), each coastal site was classified into four beach types, according to the difficulty of access, level of coastal occupation and community services:

- Remote areas are mainly defined by difficulty of access (largely by boat or on foot – a walk of 300 m or more). They are not supported by public transport and have very limited (0–5, if any) temporary summer housing. In the Mediterranean (as in this study), restaurants and second homes may be found in the summer season, occupied by a few people who may live there permanently (Williams and Micallef, 2009).
- Rural areas are located outside the urban/village environment. They are not readily accessible by public transport and have virtually no facilities. In the Mediterranean, summer beach-related recreational facilities may be found associated with rural bathing areas. Housing in rural areas is limited (generally 0–10 but may be more depending on the size of the coast) and is of a temporary (summer months) or permanent nature but without community focal centres. They are valued by beachgoers for their quietness and natural qualities (Williams and Micallef, 2009).
- Village areas are located outside the main urban environment but supported by public transport and associated with a small, but permanent, population reflecting access to organized community services. The village environment would also include ‘tourist villages’, mainly utilized in summer months (Williams and Micallef, 2009).
- Urban areas serve large populations with well-established public services. In the proximity of urban areas can be found commercial activities such as fishing/boating harbours and marinas. Urban beaches are located within or adjacent to the urban area (Williams and Micallef, 2009).

### 3.3. Statistical analysis

From the initial 138 litter categories, 33 new groups were chosen for statistical analysis (Table 1). Some categories were combined because of their similarity: for example, Cloth pieces group (CL14*) combined three size categories: 0–2.5 cm (CL14), 2.5–50 cm (CL15) and >50 cm (CL16). Another example is the group of Fishing-related debris (FRD) that combined Fishing lures/hooks (ME07), Fishing gear (PL38), Rope (PL42), String and cord (PL43), Fishing line (PL44), Light sticks (PL47) and Floats/buoys (PL48). In other cases, categories were combined appropriately where individual numbers of items were very low.

Two-factor analysis of variance (ANOA) was performed with respect to season and beach typology. To investigate the relationships among coastal sites according to litter content, multivariate analyses were performed using several methods: Non-metric multidimensional scaling (nMDS), Principal Component analysis (PCA) and Cluster analysis (CA).

## 4. Results and discussion

### 4.1. Litter magnitudes and composition

A total of 10,101 items in spring and 20,840 items in summer were counted at the 56 surveyed beaches (Table 1). Litter diversity (expressed in number of groups/categories) was similar for spring and summer and, by combining different litter classifications (EA/NALG, 2000; Cheshire and Adler, 2009; OSPAR Commission, 2010; Opfer et al., 2012), 120 and 129 litter categories were respectively identified. Average litter abundances during spring and summer respectively were 0.062 items $m^{-2}$ and 0.116 items $m^{-2}$. Litter content varied

**Table 2**
Location and general characteristics of the investigated sites.

| No Map | Coastal site | Beach Typology | Coastal type* | Items per $m^{-2}$ spring/summer | | No items per beach (100 m) spring/summer | | Litter groups per beach (100 m) spring/summer | | Litter Grade spring/summer | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Las Higuericas | Village | 1 | 0.052 | 0.080 | 220 | 342 | 38 | 31 | B | C |
| 2 | Mil Palmeras | Urban | 1 | 0.020 | 0.097 | 101 | 495 | 23 | 39 | B | B |
| 3 | Cabo Roig | Urban | 1 | 0.035 | 0.084 | 144 | 350 | 33 | 30 | B | B |
| 4 | La Estaca | Urban | 1 | 0.012 | 0.043 | 51 | 175 | 22 | 23 | B | B |
| 5 | Playa del Cura | Urban | 1 | 0.068 | 0.192 | 270 | 759 | 21 | 26 | B | C |
| 6 | Torrelamata | Urban | 1 | 0.051 | 0.077 | 165 | 250 | 26 | 37 | B | B |
| 7 | Les Ortigues | Remote | 1 | 0.064 | 0.070 | 235 | 258 | 41 | 34 | B | B |
| 8 | Babilònia | Village | 1 | 0.071 | 0.168 | 157 | 374 | 17 | 25 | B | B |
| 9 | Els Tossals | Remote | 1 | 0.130 | 0.119 | 238 | 217 | 54 | 29 | C | C |
| 10 | El Pinet | Rural | 1 | 0.014 | 0.037 | 37 | 97 | 18 | 21 | B | B |
| 11 | Tabarca | Village | 1, 2, 3, 5 | 0.098 | 0.161 | 577 | 946 | 35 | 34 | C | C |
| 12 | Faroleta | Remote | 2, 3, 5 | 0.050 | 0.040 | 36 | 29 | 19 | 13 | A | B |
| 13 | Platja Gran | Remote | 2, 3, 5 | 0.123 | 0.065 | 84 | 44 | 23 | 12 | B | B |
| 14 | Gran Playa | Urban | 1 | 0.078 | 0.076 | 496 | 488 | 27 | 33 | B | B |
| 15 | Calas del Cuartel | Rural | 1, 4, 5 | 0.050 | 0.078 | 119 | 187 | 31 | 31 | C | B |
| 16 | El Carabassí | Remote | 1 | 0.037 | 0.045 | 153 | 187 | 30 | 30 | B | B |
| 17 | Arenales del Sol | Urban | 1 | 0.071 | 0.187 | 210 | 554 | 27 | 27 | B | C |
| 18 | El Saladar | Urban | 1 | 0.050 | 0.131 | 230 | 607 | 30 | 34 | B | C |
| 19 | Agua Amarga | Rural | 2, 4 | 0.373 | 0.661 | 688 | 1221 | 59 | 70 | C | D |
| 20 | San Gabriel | Urban | 1 | 0.130 | 0.114 | 534 | 468 | 38 | 34 | D | D |
| 21 | El Postiguet | Urban | 1 | 0.025 | 0.116 | 140 | 655 | 18 | 38 | B | C |
| 22 | Serragrossa | Urban | 2, 3, 6 | 0.184 | 0.416 | 205 | 463 | 41 | 47 | C | C |
| 23 | Albufereta | Urban | 1 | 0.021 | 0.115 | 92 | 485 | 21 | 29 | C | C |
| 24 | Almadraba | Urban | 1 | 0.009 | 0.021 | 90 | 208 | 26 | 29 | B | B |
| 25 | Cala dels Jueus | Village | 4, 5 | 0.148 | 0.167 | 186 | 210 | 38 | 29 | B | B |
| 26 | Cala Cantalars | Rural | 4 | 0.158 | 0.132 | 327 | 273 | 25 | 23 | B | C |
| 27 | Cala Palmera | Rural | 4 | 0.162 | 0.213 | 333 | 438 | 29 | 37 | C | D |
| 28 | Cap de l'Horta | Remote | 4, 5 | 0.034 | 0.042 | 135 | 166 | 25 | 36 | D | D |
| 29 | Playa San Juan | Urban | 1 | 0.057 | 0.075 | 547 | 718 | 38 | 37 | C | C |
| 30 | Riu Sec | Village | 2, 3 | 0.048 | 0.024 | 122 | 60 | 22 | 19 | C | C |
| 31 | Morro Blanc | Village | 1, 5 | 0.032 | 0.042 | 90 | 118 | 27 | 22 | B | B |
| 32 | Carritxar | Remote | 3 | 0.054 | 0.064 | 75 | 88 | 29 | 28 | B | B |
| 33 | El Xarco | Rural | 3 | 0.033 | 0.022 | 57 | 38 | 24 | 18 | B | B |
| 34 | Bon-Nou | Rural | 1, 2 | 0.021 | 0.071 | 63 | 215 | 22 | 16 | B | B |
| 35 | El Torres | Village | 1, 2, 3 | 0.055 | 0.095 | 222 | 380 | 21 | 27 | B | B |
| 36 | Cala Finestrat | Urban | 1 | 0.011 | 0.113 | 106 | 1099 | 17 | 34 | B | D |
| 37 | Llevant | Urban | 1 | 0.059 | 0.217 | 391 | 1449 | 32 | 34 | B | D |
| 38 | Racó de L'Albir | Urban | 2 | 0.034 | 0.058 | 166 | 281 | 24 | 29 | B | B |
| 39 | Cap Negret | Village | 2, 3 | 0.005 | 0.024 | 21 | 95 | 11 | 32 | A | B |
| 40 | L'Olla | Village | 2, 3 | 0.057 | 0.133 | 77 | 180 | 18 | 19 | B | B |
| 41 | Racó del Corb | Remote | 3 | 0.118 | 0.167 | 131 | 186 | 36 | 40 | C | C |
| 42 | Morelló | Urban | 1, 4 | 0.062 | 0.091 | 126 | 186 | 19 | 30 | B | B |
| 43 | Cala de la Fossa | Urban | 1 | 0.055 | 0.121 | 115 | 254 | 15 | 31 | B | B |
| 44 | Cala Fustera | Village | 1 | 0.048 | 0.098 | 75 | 152 | 15 | 22 | B | B |
| 45 | L'Ampolla | Village | 1 | 0.040 | 0.047 | 157 | 186 | 17 | 26 | B | B |
| 46 | El Portet | Village | 1 | 0.029 | 0.058 | 38 | 75 | 14 | 22 | B | B |
| 47 | Cala del Moraig | Rural | 1, 2, 3 | 0.036 | 0.357 | 94 | 933 | 22 | 46 | B | C |
| 48 | Granadella | Rural | 2, 3 | 0.078 | 0.223 | 196 | 562 | 31 | 46 | B | C |
| 49 | Ambolo | Remote | 2, 3 | 0.026 | 0.151 | 36 | 209 | 22 | 33 | B | B |
| 50 | L'Arenal | Urban | 1 | 0.044 | 0.125 | 503 | 1417 | 33 | 34 | C | D |
| 51 | Les Rotes | Rural | 3,4 | 0.066 | 0.154 | 90 | 209 | 24 | 28 | B | B |
| 52 | Marineta Cassiana | Village | 1 | 0.036 | 0.078 | 93 | 203 | 22 | 30 | B | B |
| 53 | Les Marines | Village | 1 | 0.020 | 0.046 | 66 | 155 | 22 | 22 | B | B |
| 54 | Els Molins | Village | 1 | 0.015 | 0.042 | 58 | 163 | 26 | 22 | B | B |
| 55 | Almadrava | Village | 1 | 0.014 | 0.025 | 65 | 119 | 17 | 17 | B | B |
| 56 | Les Deveses | Village | 1 | 0.014 | 0.034 | 68 | 164 | 23 | 36 | B | B |

Coastal type: 1 Sand; 2 Gravel; 3 Boulders; 4 Rocky shore; 5 *Posidonia oceanica* 'banquettes'; 6 Partially artificial coast.

considerably from place to place with great changes in the composition and abundance, according to season, with the greatest abundance observed at a rural beach, i.e. "Agua Amarga" (site no. 19, Table 2) with 0.373 items $m^{-2}$ in spring and 0.661 items $m^{-2}$ in summer. The lowest abundance was respectively observed at a village beach, i.e. Cap Negret (0.005 items $m^{-2}$, site no. 39, Table 2) in spring, and at an urban beach, i.e. "Almadraba" (0.021 items $m^{-2}$, site no. 24, Table 2) in summer. The beach of "Agua Amarga" presents an extended rocky shore and easy access, this making it frequented by fishermen all year round. "Cap Negret" is a pebble beach, very uncomfortable to stay on for several hours or to take a swim, for these reasons most users prefer to go to the two, easily accessible, adjacent beaches. Almadraba Beach, which was nourished years ago, is composed of sand (essentially) and mud sediments and for this reason, is not very attractive to beachgoers. As the type of sediment influences the cleaning method, investigated beaches were grouped into two categories, i.e. "sand beaches", which are mechanically cleaned, and "other beaches", e.g. rocky shore beaches, gravel and boulder beaches, etc. (Table 2), which are manually cleaned. Probably, because of the greater efficiency of the mechanical cleaning compared to the manual one, the average litter amount is lower on sand beaches (Fig. 2). Additionally, litter on pebble beaches tends to be buried more deeply than on sand beaches and is exhumed only when storm waves attack the beach. Care must be taken regarding litter counts on these beaches otherwise surface litter might be attributed to

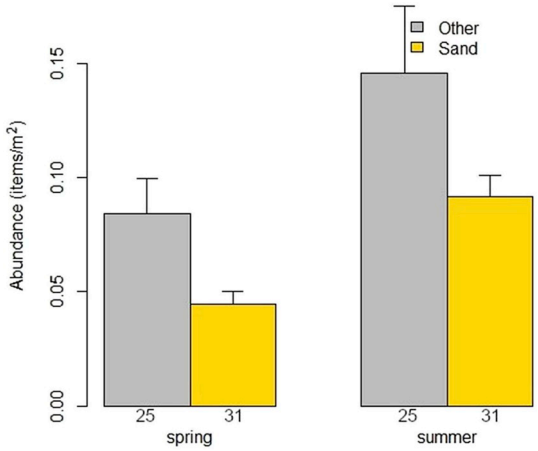



**Fig. 2.** Bar graphs that show mean values of litter (items $m^{-2}$) by sediment type: 31 sand beaches and 25 with other characteristics (see Table 2).

new inputs of litter rather than the emergence to the surface of buried litter (Williams and Tudor, 2001).

The first evaluation included Holy Week; during that period beaches are often cleaned up because they start to record a litter increase due to increased tourist pressure. In summer cleaning efforts are much greater, as are the number of beach users. It is difficult to compare the effectiveness of beach cleaning operations carried out at different beaches since each municipality has its own cleaning system. Palazón et al. (2016) evaluated investments of local municipalities in beach management actions such as beach cleanness, facilities, etc. but did not record any evident relationship.

Litter densities at the Adriatic and Ionian Seas, presented average values of 0.67 items $m^{-2}$ (Vlachogianni et al., 2018); 0.41–0.63 items $m^{-2}$ at the Black Sea (Topçu et al., 2013), and 3.41 items $m^{-2}$ at Japan and Russian beaches (Kusui and Noda, 2003). Similar average densities to those found in this paper have been observed along the Brazilian coast (0.138 items $m^{-2}$) as observed by Oigman-Pszczol and Creed (2007). However, densities recorded in this paper were greater than ones obtained at some other places, e.g. 0.043 items $m^{-2}$ were recorded in the China Seas (Zhou et al., 2016), maximum values of 0.045 items $m^{-2}$ along the Bulgarian Black Sea coastline by Simeonova and Chuturkova (2019) and zero to 0.3 items $m^{-1}$ in Antarctica (Convey et al., 2002). Considering the great population (1,838,819 inhabitants in 2018) and the elevated number of national and international visitors at the Alicante coast, values of litter abundance are low compared to other, similar Mediterranean areas (Vlachogianni, 2019).

Although there is a lot of information about coastal litter abundance, it is difficult to compare studies carried out because of the use of different methodologies (Anfuso et al., 2015). In fieldwork carried out by different researchers, the sampling unit can differ. Beach typology, geographic conditions, etc., even the expression of results may vary, e.g. items $m^{-1}$ (Martinez-Ribes et al., 2007), items per beach in 100 m length (Maziane et al., 2018), items $m^{-2}$ (Vlachogianni et al., 2018), items in 100 $m^{-2}$ (Oigman-Pszczol and Creed, 2007; Zhou et al., 2016), etc. Results also may be expressed by weight (e.g. kg per 100 m, gr per $m^2$, etc.) e.g. Madzena & Lasiak (1997); Kusui & Noda (2003); Maziane et al. (2018) but, where beach litter groups containing light and very numerous items (e.g. cigarette butts, film, food wrappers, paper fragments, foamed plastic, etc.) are well represented, even result interpretation can be complicated.

According to individual litter categories established by different entities, i.e. UNEP, OSPAR Commission, and NOAA (Cheshire and Adler, 2009; OSPAR Commission, 2010; Opfer et al., 2012), the Top 10 (most abundant) Marine Beach Litter Items in the study area have been identified for each season. These categories and codes conformed to Williams et al. (2016b):

- For spring: Cigarettes, butts & filters (PL24), Hard plastic pieces (0–2.5 cm, PL62), Cotton bud sticks (PL23), Food wrappers (PL27), Construction material (PT01), Caps/lids (PL30), Paper fragments (0–2.5 cm, PP10), Straws (PL18), Paper fragments (2.5–50 cm, PP11) and Foamed plastic pieces (0–2.5 cm, PL68).
- For summer: Cigarettes, butts & filters (PL24), Paper fragments (2.5–50 cm, PP11), Film plastic pieces (2.5 > < 50 cm, PL66), Food wrappers (PL27), Cotton bud sticks (PL23), Hard plastic pieces (0–2.5 cm, PL62), Hard Plastic pieces (2.5 > < 50 cm, PL63), Paper fragments (0–2.5 cm, PP10), Film Plastic pieces (0–2.5 cm, PL65) and Caps/lids (PL30).

Many of the above listed items have also been documented in other studies as very common (e.g. UNEP, 2015; Ocean Conservancy, 2016; Surfrider Foundation, 2016; Legambiente, 2017; Vlachogianni et al., 2018; Simeonova and Chuturkova, 2019). Principal beach litter composition expressed as number of total items per group(s), are presented in Table 1. Much of these items are discarded by beach users, particularly cigarette butts, which were the most abundant items in this paper's research, as has also been observed at other bathing areas by Martinez-Ribes et al. (2007), Oigman-Pszczol and Creed (2007), Topçu et al. (2013), Williams et al. (2016b) and Kungskulniti et al. (2018). Specifically, the number of cigarette butts recorded in spring (4607 units) tripled in summer (12,843 units). At the European scale, the same seasonal trend has been recorded for all the top 10 beach litter items (Addamo et al., 2017).

Litter items were composed of different materials (Fig. 4): plastic being the most represented (83.6–82.6%), followed by paper and cardboard (8.6–5.6%), pottery and ceramics (3.4–1%), metal (3.2–2.6%), cloth (2.3–1.6%), glass (1.5–0.7%), rubber (0.6–0.5%), wood (0.5–0.9%) and other materials (0.3–0.4%). Similar percentages, especially for plastics, were found in other studies carried out on different coastal zones: from 75.3% to 83.4% at the Adriatic Sea (Peraš et al., 2017; Šilc et al., 2018), 76% on British beaches (Nelms et al., 2017), 81% on Mediterranean beaches (Munari et al., 2016; Legambiente, 2017), 83.1% on sand beaches of Chile (Thiel et al., 2013) and 83.4% on the coast of South Africa (Madzena and Lasiak, 1997). Over the past few years, at several places, e.g. the Belgian coast (Van Cauwenberghe et al., 2013) and Cape Town in Africa (Chitaka and von Blottnitz, 2019), plastics exceeded 90% of the total debris composition.

Spring/summer differences in beach litter content for a specific material was linked to the number of beachgoers. A clear increase in pieces of Paper & Cardboard and Plastic in summer, e.g. single-use plastics and cigarette butts was observed. A small increase was seen in Wood (i.e. ice lolly sticks, chip forks, fragments, etc.) and other materials (i.e. medical waste, silica, silicone, etc., Fig. 3). In the study area, the rest of the recorded materials varied in abundance but showed a decrease of their proportion with respect to the total (Fig. 3). For example, in spring, the proportion of metal was 3.24% with 325 items, while in summer it represented 2.64% with 549 metal items; a similar trend occurred with clothing that ranged from 231 to 327 items and rubber, from 64 to 100 items.

Despite the relatively low numbers of glass fragments and glass bottles and their low seasonal variability (147 units in spring and 144 in summer, Table 1), there was a reduction in seasonal percentage, i.e. 1.46% and 0.69% respectively for spring and summer surveys. Contrary to the rest of materials found in summer, Pottery & Ceramics decreased in percentage (from 3.45 to 1.03%, Fig. 3) and in number of items (from 348 to 215 units, Table 1).

Summing up, the increase of people on the beach generally caused more paper, cardboard, plastic, cloth, wood, metal and other processed materials to be found. The quantity of Glass remained constant, probably due to non-selective clean-up operations. The fact that Pottery &

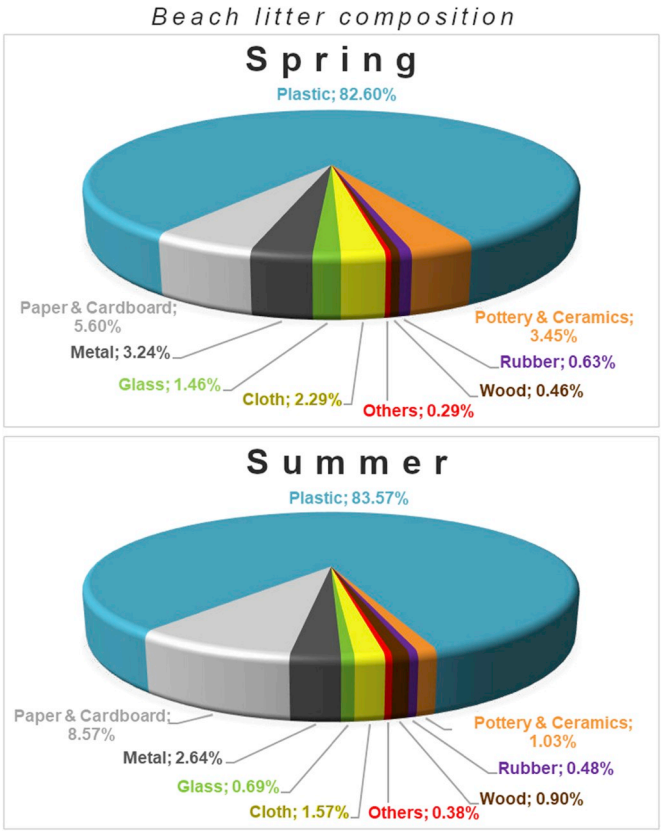



**Fig. 3.** Beach litter composition.

Ceramics decreased was probably due to both the improvement of cleaning efforts during summer and their natural borrowing because of good weather conditions observed during summer months. Concerning dangerous items, the highest numbers (especifically glass fragments), were recorded at "Cala Palmera" and "Cap de l'Horta" (sites no. 27 and 28, Table 2) with more than twenty fragments found in both seasons. These two sites are usually cleaned by hand but the result seems to be not very satisfactory. Fishing Related Debris (FRD) such as hooks and fishing lines, may be dangerous to both beach users and animals (seabirds, dogs, etc.). FRD presence, which ranged from 314 items in spring to 260 in summer (Table 1), was common to all types of beaches but was especially related to rural and remote areas. Sewage Related Debris (SRD), e.g. Cotton buds and sanitary towels, were frequently observed (especially in Alicante Bay, Fig. 4) and, since they present evidences of transport, it is possible that they were related to the "Rambla de las Ovejas" and "Rambla de la Albufereta" streams that flow into the bay of Alicante, and to the Segura River in Guardamar. Examples of gross litter items, such as three car tyres and metal pieces, were found, in spring and summer surveys, at "El Racó del Corb" (no. 41, Table 2); this reflects the lack of any kind of management at remote areas, probably due to the difficulty of access.

### 4.2. Litter sources and dynamics

Some litter groups are easily related to specific activities/uses (e.g. smoking, fishing from the beach, construction, etc.) and their potential sources (land or sea-based) can be certainly recognised. But, for most times, identification of source is difficult since an item can have different origins (Veiga et al., 2016); in this context, the category of "unknown/mixed sources" is common in many recent studies (Prevenios et al., 2018; Vlachogianni et al., 2018). On the Costa Blanca, litter comes mainly from land sources (>80%), especially when

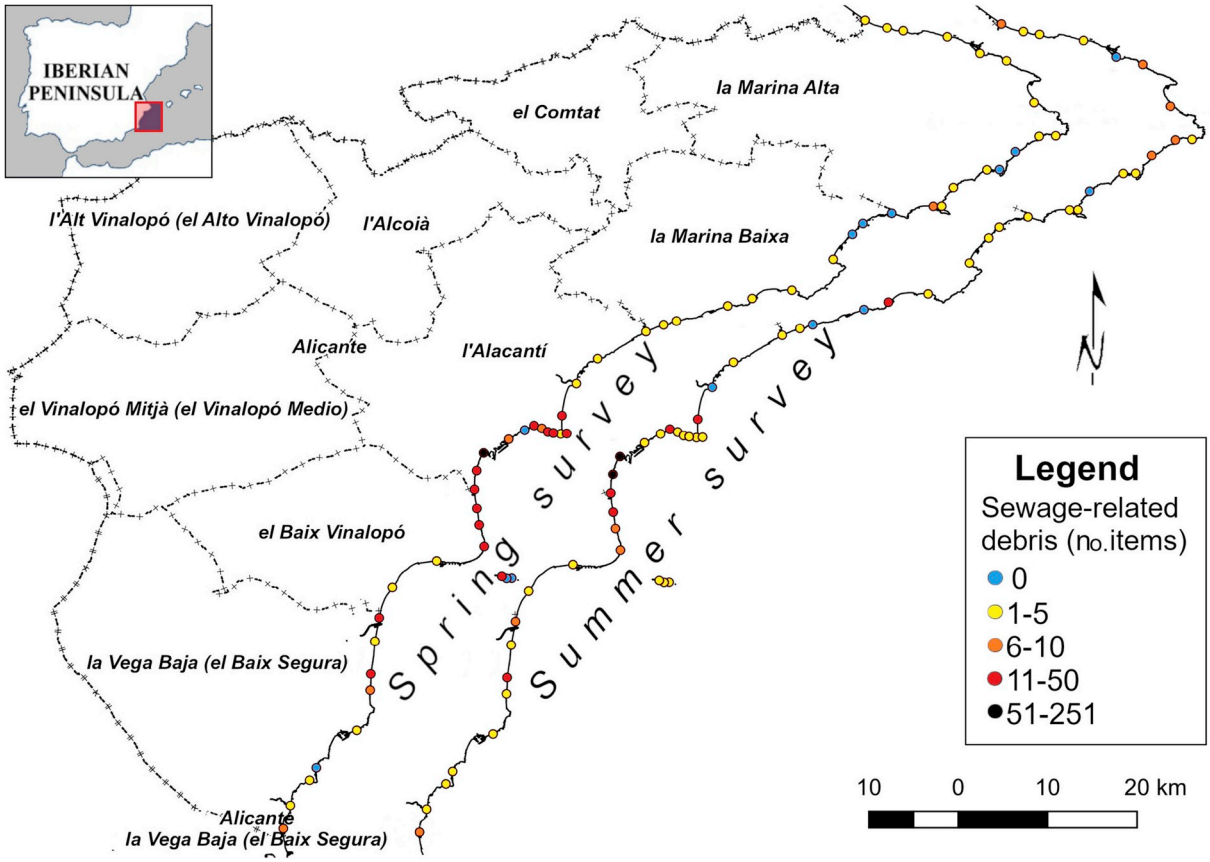



**Fig. 4.** Average values (no. items per 100 m) of litter for spring and summer surveys.

discarded directly onto the beach (e.g. cigarette butts and food wrappers) due to beachgoer activities. A small percentage (approximately <4%, composed of hooks, lures, fishing line, string and cord, etc.) can be linked to sea-based sources. The rest pertain to mixed or unknown sources.

The negative impacts of river supplies (e.g. Segura river, site no. 9, Fig. 1, Table 2) and of temporary watercourses flowing onto the coast (e.g. "Rambla de las Ovejas" and "Rambla de la Albufereta", sites no. 20 and 23, Fig. 1, Table 2) is reflected by the presence and/or great amount of specific items related to wastewater discharges (i.e. cotton bud sticks, wet wipes, tampons, etc.) or floating litter such as plastic bottles. The continuous contribution of litter to these areas has generated local pollution linked to a lot of hard plastic pieces (<1 cm in Els Tossals Beach) that could not be counted in this study. The high pollution observed at the natural reserve of the Segura River mouth was awarded with the negative award "Bandera Negra" (Black Flag) established by EA Ecologistas en Acción, 2018.

### 4.3. Beach Typology and Litter Grade

Each investigated site was assorted according to the BARE and Litter Grade classifications (Williams and Micallef, 2009; EA/NALG, 2000). Below are the results by beach typology:

(a) **Remote**: A total of nine sites are located into this category. The greatest diversity of litter grades was observed in spring (Fig. 5): "A": very good (1 site); "B": good (5); "C": fair (2) and "D": poor (1). In spring, highest litter density was found at "Els Tossals" beach (no. 9, Litter Grade "C," 0.130 items $m^{-2}$) at the mouth of the Segura River, while the lowest amount was observed at "Ambolo" (no. 49, Litter Grade "B", 0.026 items $m^{-2}$) a pocket-beach composed by gravel. In summer, highest litter densities were recorded at "Racó del Corb" (no. 41, Litter Grade "C", 0.167 items $m^{-2}$), while the lowest densities were observed at "La Faroleta" (no. 12, Litter Grade "B", 0.040 items $m^{-2}$). "Racó del Corb" is a gravel beach where cleaning operations are not performed daily and "La Faroleta", located at Tabarca Island, is characterized by a low abundance of users and high accumulations of *Posidonia oceanica* 'banquettes'. Average litter density in remote areas was 0.071 items $m^{-2}$ in spring, and 0.085 items $m^{-2}$ in summer. Lastly, remote areas show low beach litter densities (Fig. 6).

(b) **Rural**: Ten sites were sampled. In spring, coastal sites obtained intermediate Litter Grades: 7 grade "B" and 3 grade "C". Very different results are observed in summer: 5 sites with grade "B", 3 grade "C" and 2 grade "D" (Fig. 5). Only one beach ("Calas del Cuertel") improved in summer season (from "C" to "B") in reference to the Litter Grade though the amount of beach litter was higher in summer (no. 15, Table 2). Five coastal sites became dirtier and/or

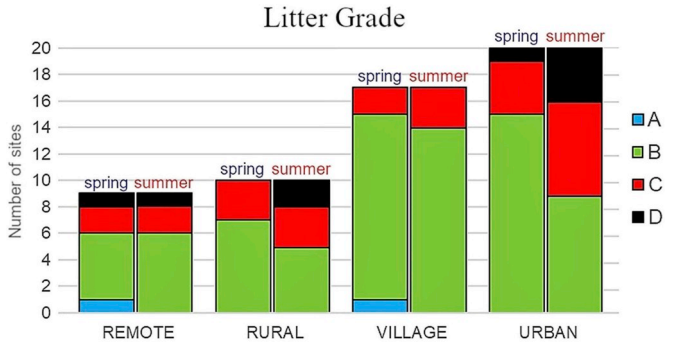



**Fig. 5.** Litter Grade (EA/NALG, 2000) by beach typology along the study area for each season.

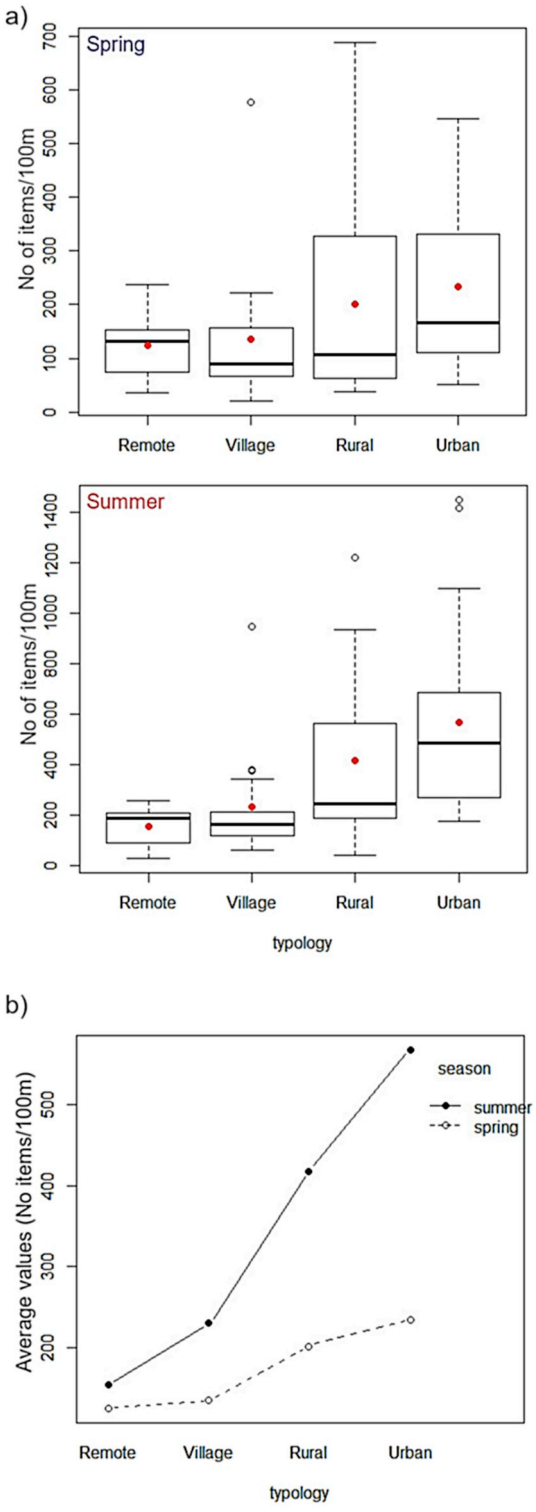



**Fig. 6.** Box plots showing the number of items along the study area for spring and summer. Boxes enclose 50% of data. Associated standard deviations (whiskers), averages (red dots) and median values (black lines) are also depicted. White dots belong to sites with a very high amount of litter compared to the rest, so the program considers them as outliers. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

more dangerous (no. 19, 26, 47 and 48, Table 2) and the other four were conserved to the same Litter Grade (no. 10, 33, 34 and 51, Table 2). Highest density was documented at "Agua Amarga" (site no. 19) in both seasons (0.373 and 0.661 items $m^{-2}$ with grades "C" and "D") whilst the lowest density was observed at "El Pinet" in spring, and at "El Xarco" in summer with 0.014 and 0.022 items $m^{-2}$ respectively, both with grade "B" (no. 10 and 33, Table 2). Average litter density ranged from 0.099 (spring) to 0.195 items $m^{-2}$ (summer), i.e. from 200 to 417 items per 100 m (Fig. 6a). Rural areas show greater data distribution than other areas for spring; summer appears to be an outlier that corresponds to the very polluted beach of "Agua Amarga" (previously mentioned), in this season data distributions are similar to urban areas (Fig. 6a).

(c) **Village**: Seventeen sites in all. One belonged to Litter Grade "A", fourteen to grade "B" and two to grade "C" in spring. In addition, in summer, were observed fourteen sites graded as "B" and three "C" (Fig. 5). Litter Grade of village areas recorded very few variations: only two beaches (no. 1 and no. 39, Table 2) changed their grade negatively. Highest litter density was observed at "Cala dels Jueus" (spring) and "Babilònia" (summer) with 0.148 and 0.168 items $m^{-2}$ correspondingly, while the lowest amount was recorded at "Cap Negret" in both seasons (0.005 and 0.024 items $m^{-2}$). Litter densities reached average values of 0.046 items $m^{-2}$ in spring and 0.078 in summer (135 and 231 litter items per beach respectively, Fig. 6a). The distribution of the data is similar to the remote areas, despite this, village areas have some atypical value as in the case of Tabarca Beach in spring or the beaches of Tabarca, El Torres and Babilònia in summer (Fig. 6a).

(d) **Urban**: A total of twenty sites were classified in this category. In spring, most coastal urban sites (15) obtained grade "B", followed by grades "C" and "D" (4 and 1 sites). In summer there was an evidently negative trend in litter grades: 9 sites with grade "B", 7 with "C" and 4 with "D" (Fig. 5). The density of litter items was higher at "Serragrossa" for both seasons (no. 22, Table 2) possibly because it was a fishing area close to a breakwater. During spring, litter density was highest at "San Gabriel" (Avg: 0.130 items $m^{-2}$) where a nearby stream was observed (no. 20, Table 2). In summer, the maximum concentration of litter was at the "Llevant" beach in Benidorm (no. 37, Avg: 0.217 items $m^{-2}$, Table 2), which attracts a high and constant number of tourists attracted by a great diversity of activities (Martinez-Ibarra, 2011). The lowest density of litter was found at "Cala Finestrat" with 0.011 items $m^{-2}$ (spring, no. 36, Table 2) and "Almadraba" beach with 0.022 items $m^{-2}$ (summer, no. 24, Table 2). Litter densities reached average values of 0.054 items $m^{-2}$ in spring and 0.123 in summer, i.e. 234 and 268 litter items respectively (Fig. 6a). These beaches have the highest averages of all typologies. In addition, there were two atypical values in summer (Fig. 6a), corresponding to two crowded beaches: Llevant and L'Arenal (no. 37 and 50, Fig. 1, Table 2). The greatest differences between spring and summer averages were in urban areas, followed by rural, village and remote areas (Fig. 6b).

Considering the diverse beach typology and their associated, services/activities the differences that appear in litter composition are probably related to beachgoers. Examples in Table A2 show clear differences in litter composition related to the presence/absence of people in remote and urban areas. Authors such as Cabezas-Rabadán et al. (2019) working in beach user's perceptions, demonstrated though questionnaires that young people preferred semi-natural and pebbly beaches such as "Granadella" and "Ambolo" (sites no. 48 and 49, Table 2) mainly because of their attractive coastal scenery, while the elderly and families preferred urban and sand beaches (generally with more safety and facilities), and prioritized more water quality and sediment cleanliness, proximity from their houses, and presence of facilities. In the European context, this behaviour is related to preferences of beach users for choice a coastal site: safety, facilities, excellent scenery, good water quality and no litter (Williams and Micallef, 2009).

Litter grading indicated possible risk-related categories and Fig. 5 showed that Grade was strictly related to beach typology. A total of forty-three sites obtained "good" litter grades ("A" and "B"), and thirteen sites received "bad" ones ("C" and "D") in the spring season. In summer, litter grades usually changed for the worse: zero sites had a grade "A", thirty-four sites a grade "B" and twenty-two sites with grades "C" and "D" (Fig. 5). The grade "A" (non-existent in summer) and "B" represents a good environmental condition. Although grade "B" is considered good, their management should not be ignored. Finally, grades "C" and "D" require immediate and appropriate management by the responsible municipalities. In addition, management should be emphasized in the summer period as the coast is generally dirtier than the previous season (Fig. 5 and Table 2).

Numerical results for each site showed a general increase in number of items (except for eight sites, Table 2). Litter Grade was not so precise in terms of quantity, but it reflected the dangerousness of a site according to its litter categories. For example, a site with total items between 49 and 499 was graded as "B" (general litter), so a beach can be "B" in spring with 50 items, and the same beach can still be "B" with 400 items in summer. Alternatively, there are beaches that have similar litter density but belong to different grades due to litter categories (Harmful Litter, Sewage Related Debris, etc.). Number of items and litter grade are complementary, for this, their values should be conjointly analysed (Table 2). Some sites reported lower amounts of litter in summer period, but litter grading worsened (e.g. sites no. 12 and 26, Table 2).

Among the seven categories evaluated (EA/NALG, 2000), ones that worsened their final classification were General Litter (i.e. cigarette butts, plastic bottles, cans, bottle caps, pieces of film plastic and paper, food packaging, etc.). Harmful Litter (i.e. broken glass) and Sewage Related Debris (SRD), i.e. cotton bud sticks, sanitary towels, etc. (Fig. 4). Other categories (e.g. Accumulations) also worsened at a few places but were not responsible for the final grade obtained.

Application of these methodologies requires knowledge of the number of items and can maximize the importance of the smallest ones, e.g. cigarette butts. Despite their small size, they can cause multiple harmful impacts, as evidenced by Kungskulniti et al. (2018). Some studies present data on litter weight, but this can lead to confusion due to the difference in size and type of material for each item. For example, in the study of Maziane et al. (2018), cigarettes represented 25% in number, while in weight they represented only 0.8% of all sampled litter.

### 4.4. Statistical analyses: ANOVA, nMDS, PCA and cluster

Relationships between seasonal litter distribution and beach typology were illustrated by box plots (Fig. 6a), which show that, in most cases, data groups are positively skewed with a few large outlier values, indicating the need to transform data values by log (x+1). The residuals of the two-factor ANOVA model with transformed data were tested for normality using Q-Q and histogram plots, and for homogeneity of variance using Bartlett's tests and a plot against fitted values, which confirmed the validity of the model. ANOVA showed very highly significant effects ($P < 0.001$) for both factors (season and typology), but no significant effect of the interaction ($P = 0.4$) indicating the effect of typology on the mean abundance of beach litter to be similar in both seasons (Fig. 6a and b). Differences between individual means were tested for significance using Tukey's HSD and 95% family-wise confidence intervals. Significant differences were found between spring and summer overall means, and between the following pairs of typologies: village, remote, rural (spring) and urban (spring) versus urban (summer), and rural (summer) versus village (spring). These results indicate strong differences in beach litter abundance both between the seasons and between the beach typologies sampled, although these differences were greater in the summer due to the increased numbers of

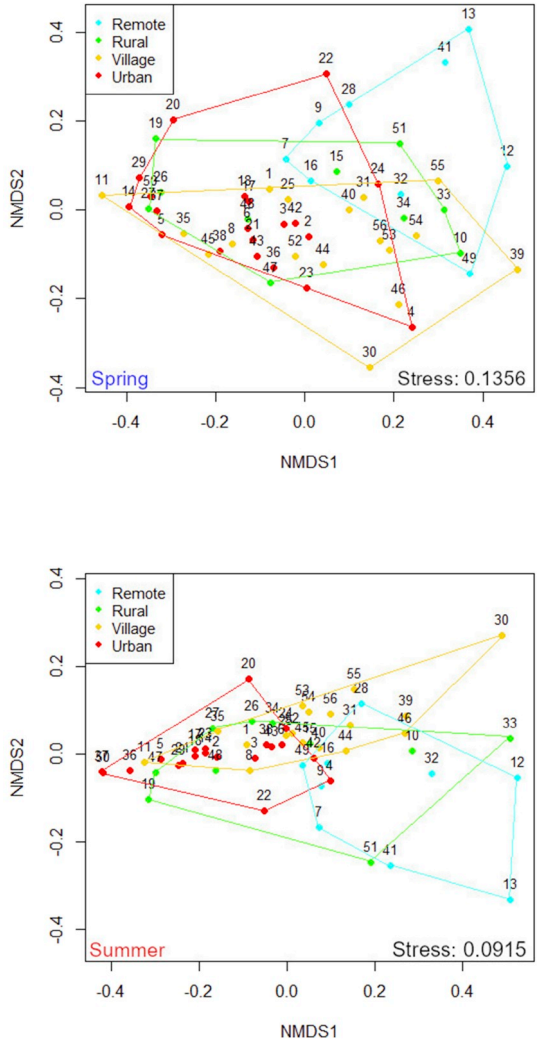



**Fig. 7.** Ordination of spring and summer data by Non-metric multidimensional scaling. Cyan, green, orange and red dots correspond to remote, rural, village and urban sites respectively. The maximum dispersion area for each category has been marked. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

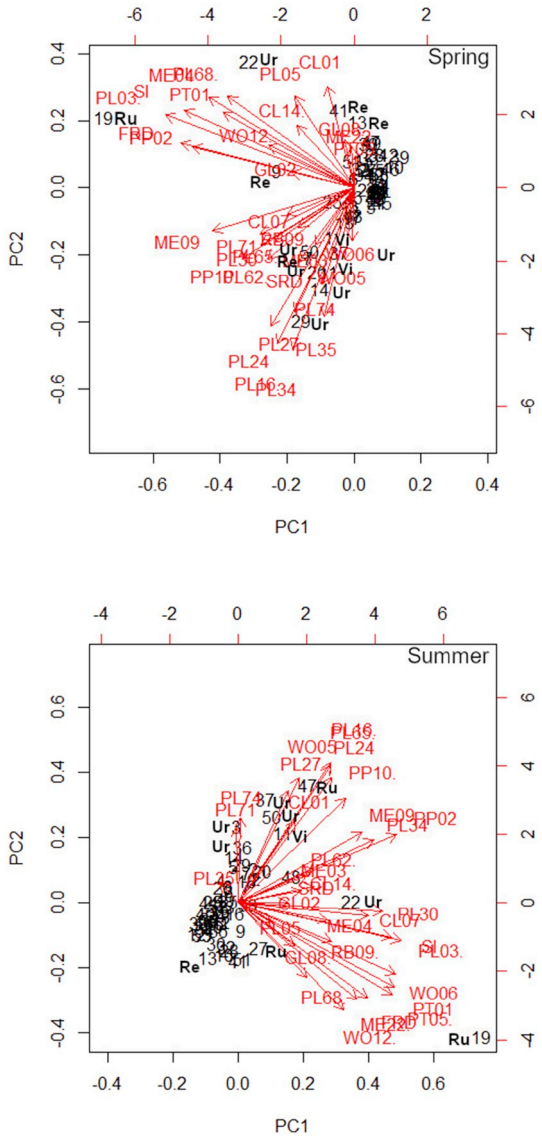



**Fig. 8.** Principal Component Analysis for spring and summer data.

visitors and the consequently higher numbers of litter items (Fig. 6b and Table 2). Remote areas, due to their difficult access and lack of facilities, generally reported fewer visitors, and litter related to beachgoers was only occasionally observed. Village areas generally had fewer visitors than urban areas, suggesting slower accumulation of litter and its effective removal by the current cleaning management programs. Only when the number of visitors to these areas increased, did litter abundance reach values similar to those observed in urban areas: Tabarca beach was a clear example (no. 11, Table 2). Finally, Rural areas do not present significant differences in litter abundance with respect to urban areas, probably because clean-up efforts are not well implemented.

Interpreting a variety of multivariate analyses aims to give an overview of the patterns of litter distribution among beaches. Nonmetric multidimensional scaling (nMDS) was performed to visualize multivariate patterns among coastal sites and litter observations in each season: sites close together on the plot have similar beach litter composition (Fig. 7). The polygon enclosing each beach type is much larger and more dispersed in spring than summer, especially for urban and village sites (Fig. 7). The disproportionate increase in the abundance of some beach user-related items in summer and increased cleaning effort are likely to have reduced the differences in litter content between urban and village sites. This methodology demonstrated differences and similarities between sites according to their litter composition (see examples in Table A2). It should be noted in Fig. 7 that beaches located in the left part of the graphs usually are more contaminated (especially in the left-upper part). Beach typology and coastal drift can influence this difference, although the intensive use given to each beach is usually a decisive factor in determining litter typologies.

Principal Component Analysis (PCA) ordinated both the sites and the variables (litter groups) onto constructed axes based on a calculated matrix of similarity among variables. Two principal axes (components) were displayed in the form of a scatter plot for each season: graphs accounting for 32.3% (spring) and 39.7% (summer) of the total variance within the data (Fig. 8). Sites which lie around the edges of the main grouping can easily be associated with the litter categories shown at the end of each vector. For example, site number 20 with the SRD group for spring season, site no. 19 with FRD group for both seasons, or the most popular/frequented sites in summer (i.e. no. 11, 37, 47, 48 and 50, Table 2) with groups directly related to beachgoers (CL01, PL27, PL24, PL65, PL16, PP10, WO05, etc., Fig. 8, Table 1).

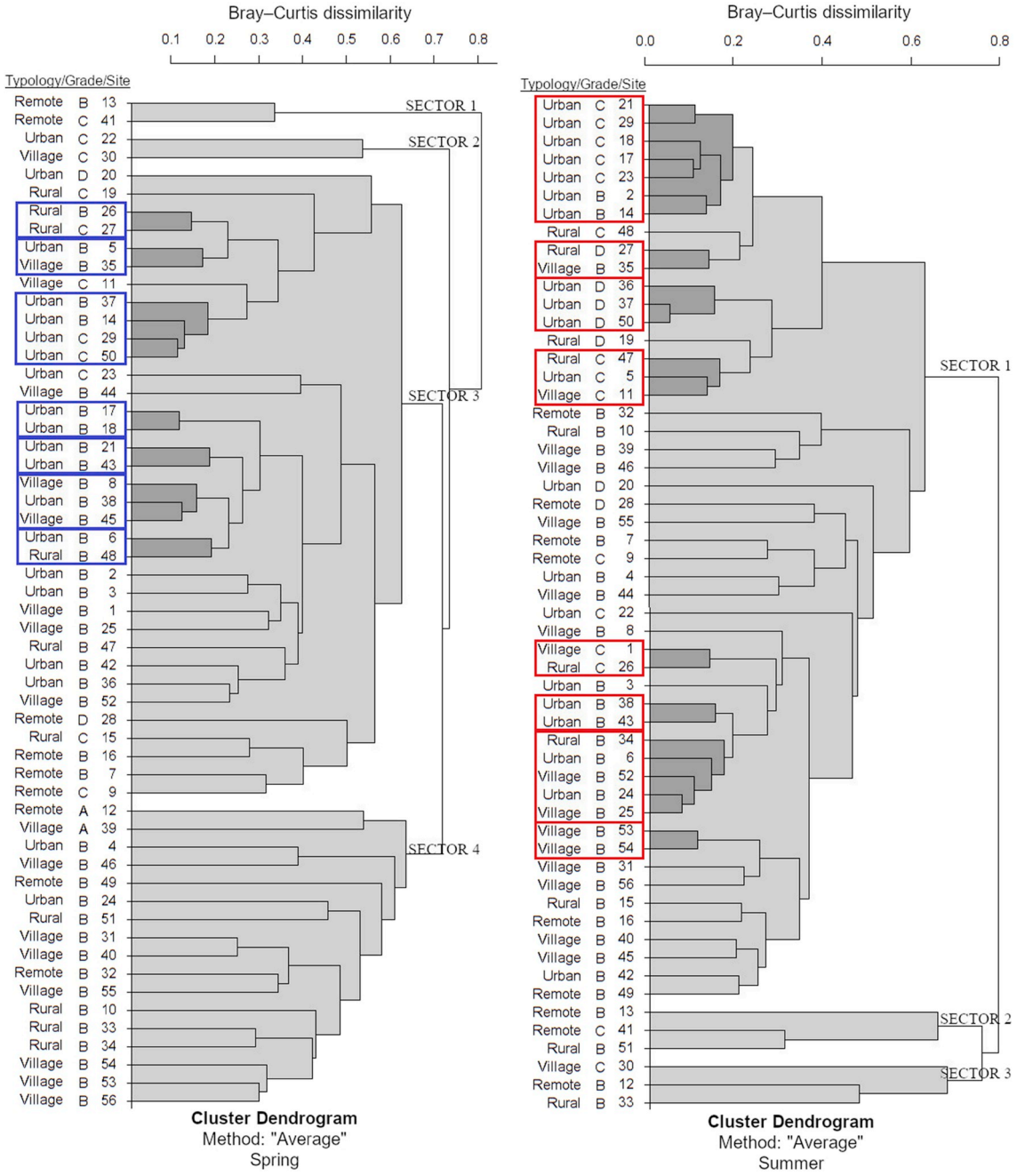



**Fig. 9.** Cluster dendrogram showing dissimilarity analysis on Bray–Curtis distances among coastal sites according to their litter composition.

Finally, Cluster Analysis (CA) showed the dissimilarity (or similarity) of all sites for spring and summer, according to litter content (Fig. 9). The vertical axis represents the investigated sites and the horizontal scale on the dendrogram (Fig. 9) represents the distance or dissimilarity between them. The vertical position of each split, shown by a short bar, gives the hierarchical clustering of datasets. Typology and Litter Grade for each site were also observed. For example, observing thresholds of Bray-Curtis dissimilarity 0.2 and 0.7 to compare spring and summer results, different sectors (light grey colour; 0.7) can be identified and the most similar sites (dark grey colour; 0.2) were recognized according to their beach litter composition (Fig. 9). In sector 3 of the Spring Cluster there were sites very similar in litter composition (in blue squares: 7 small groups composed of 2, 3 and 4 coastal sites were identified). While in sector 1 of the Summer Cluster, 8 groups composed of 2–7 sites were identified in red squares. When comparing the two clusters of Fig. 9, it can be seen how differences are reduced in summer because there are fewer sectors and more similar sites. Sites with the greatest similarity presented different typologies: in spring there were urban (11), village (3) and rural (3) sites, while in summer prevailed urban (15), village (7) and rural (4). It should be emphasized that these rural sites generally were highly frequented, and remote areas were not present in these groupings. This indicated once again that littering considerably increased according to the number of visitors.

### 4.5. Some considerations for coastal management

Effective measures must be taken to reduce beach pollution, such as:

- Specific environmental education programs must be carried out at

different levels for public and private entities. The educational system can play a huge role in this context. For this message to be effective requires a long time period but it can be done with full scale government insistence. The 'drink driving' and 'seat belt safety' campaigns' carried out in the UK have been an unqualified success in cutting down deaths/accidents (a similar trend has occurred in Spain). A change in the culture of people in order to stop littering must be the aim of all governments.

- Better enforcement of existing laws to prevent pollution and punish polluters. 'Make the polluter pay' is a common enough saying and many laws exist but implementation of these laws is the problem. At the very least bye laws should address all issues of concern to beach users including generation of noise, unpleasant behaviour, fires, dog fouling, litter. etc. If properly patrolled, beach fines could be the answer to try to cut down the number of items, as hitting people via their pocket tends to bring about a behaviour change. For example (Table 1), food wrappers (452 and 415 for spring and summer), knives, forks, spoons, stirrers, cups (290 and 445 for spring and summer) and crisp packets and lolly sticks (127 and 170 for spring and summer) almost certainly arise from discarded beach user food items. With respect to fishing items (314 and 260 for spring and summer), it might be harder to identify culprits; similarly, the sewage items found (655 and 520 for spring and summer). Cotton bud sticks (573 and 399 for spring and summer) are a particular and much more serious issue, as these are usually not dispensed with on a beach, but arrive via the toilet flushing route and therefore indicate a sewage pathway to the beach. This suggests that municipal collectors are probably illegally discharging wastewaters into the beach or some outfall is too short or broken, causing items to be transported back to the beach by currents and waves. Urgent actions are required to solve the problem.
- More restrictive laws and environmental campaigns (especially in summer) focused on beach smokers. Change can be achieved. For example, the presence of unsightly cigarette butts can be eliminated by a realistic ban on beach smoking. New Jersey USA, has banned smoking apart for a small reserved beach area; Florida is considering the same. Ariza and Leatherman (2012) have given a good account of the USA situation. At Bibione beach Italy, smoking for 400m from the water's edge to the back shore will be prohibited from May 2019; Queensland, Australia has banned smoking at all public beaches (The Guardian, 2019). In Spain, a group of beaches has been declared "smoke-free", specifically 110 beaches in 2018, almost all located in Galicia. However, today there is no law prohibiting smoking on the Spanish beaches.
- Implementation, in several languages, of panels at the beach regarding environmental information. These must be sited at the entrance to the beach, with the panels being not too cluttered and having both pictures and words.
- Implementation of systems to capture litter transported in streams to prevent its arrival at the sea. Also, provision of adequate litter bins at appropriate intervals along a beach and regularly cleaned are imperative to try to take control of beach litter. A ratio of 1:150 beach users is recommended (Williams and Micallef, 2009) so that a preliminary sorting of litter is done at source (Fig. 10a). Bins could be colour coded for groupings, easily visible and not too much of a distraction in the environment.
- Environmental management of recreational fishing from the beach. Beach zoning constitutes sound management. Just as swimming and fishing are not compatible, if boating occurs at a beach then boat channels separating bathing and boating/jet ski related activities should be clearly delineated, mainly using lines with marker buoys. These should also be able to specify land-use sub-zones such as dog-free zones and conservation areas. Other recreational activities, such as, picnicking and camping should also be controlled.
- Implementation of specific cleaning operations at remote/rural sites. Local NGOs, voluntary beach cleans etc. could be implemented in order to help cut down litter found on these beaches. The Ocean Conservancy in the USA and Marine Conservation Society, UK are leaders in this field in their respective countries.
- A long-term monitoring programme related to base-line studies should be implemented to detect early signs of any environmental decay.
- If smoking is to be allowed, then disposal at beach access points into recycled metal cans to be used as ashtrays, is effective (Fig. 10b). Cardboard ashtrays are a quick and easy solution, but are less durable and involve unnecessary cardboard production (Fig. 10c). Plastic ashtrays can be reused, but are often non-existent or insufficient in number.
- Deposit refund systems. These are currently in use in, for example, Iceland where drink bottles taken to a designated spot can be exchanged for small coins. The items, as well as being removed from the beach can then be recycled.




**Fig. 10.** (a) A good example of a beach litter bins, Alicante. (b) Beach Ashtrays at Shell Beach (Saint Barth, Caribbean Sea), image source: Susan Mines. (c) Cardboard ashtray dispenser at Bonaire (Caribbean Sea), source: www.cleanbeachcaribbean.com.

- Tourist taxes when applied could also be used to ensure clean beaches.

## 5. Conclusions

This paper investigates litter composition, seasonal distribution in spring (201,700 $m^2$, a total of 10,101 litter items, average 0.062 items $m^{-2}$) and summer: (20,857, average 0.116 items $m^{-2}$) and litter origin at 56 coastal sites along the Mediterranean Sea beaches of Alicante Province (SE Spain) coastline. Sites covered "remote" (9), "rural" (10) "village" (17) and "urban" (20) bathing areas. Plastics were the main component found seasons (82.6 in spring, 83.5% in summer), but cigarette butts were prolific in their numbers (4607 to 12,843 respectively) and the bulk of litter can be attributed to beach goers, wastewater discharges (6.5 in spring, 2.5% in summer) and fishing activities consisted of 3.1 and 1.2% respectively of the litter items found.

The paper proposes a number of actions that, if implemented, could significantly reduce the abundance of several litter items and the proposed methodologies can help coastal managers at the study area and at other similar areas, to take the best decisions for different beach types. Beach cleanliness assessment based on the Litter Grade methodology was an effective and useful tool to evaluate the local coast's efficiency of cleaning operations and when required, to propose improvements and/or retire beach awards. However, stopping litter at source must be the mantra for effective beach management. Implementing environmental education, in schools and media is essential.

Each coastal sector is different due to its particular management regime, cleaning strategy, local culture, number of visitors, policy and other aspects. Plastics and cigarette butts prevail in tourist zones despite the geographic location. The lack of collaboration of some municipalities in research topics is a real problem in the advancement of knowledge. Anyone should be able to access public information; municipalities should not ignore scientific studies that provide so much data and ideas to improve coastal management.

Future works can be devoted to assessing the effectiveness of beach clean-ups by carrying out surveys before and after beach cleaning operations. An interesting topic would be to carry out several surveys at the same place during one day to see if litter item amounts increase or decrease according to beach user frequentation.

Table A.1
Beach grading system based on litter categories. Grading: A, Very good; B, Good; C, Fair; D, Poor (EA/NALG, 2000).

| | Category | Type | A | B | C | D |
|---|---|---|---|---|---|---|
| 1 | Sewage Related Debris | General | 0 | 1–5 | 6–14 | 15+ |
| | | Cotton Buds | 0–9 | 10–49 | 50–99 | 100+ |
| 2 | Gross Litter | | 0 | 1–5 | 6–14 | 15+ |
| 3 | General Litter | | 0–49 | 50–499 | 500–999 | 1000+ |
| 4 | Harmful Litter | Broken Glass | 0 | 1–5 | 6–24 | 25+ |
| | | Other | 0 | 1–4 | 5–9 | 10+ |
| 5 | Accumulations | Number | 0 | 1–4 | 5–9 | 10+ |
| 6 | Oil | | Absent | Trace | Nuisance | Objectionable |
| 7 | Faeces | | 0 | 1–5 | 6–24 | 25+ |

**Categories: General Sewage litter** - items include: feminine hygiene products sanitary towels, tampons and applicators, contraceptives. toilet paper, faeces of human origin. **Cotton Bud Sticks** – harmless in themselves but they denote a sewage input. **Gross Litter** (at least one dimension >50 cm) - include: shopping trolleys, pieces of furniture, road cones, large plastic or metal containers; bicycles, prams; tyres; and large items of processed wood e.g. pallets. Driftwood is not included. **General litter** (all other items <50 cm in dimension) - include drink cans, food packaging, cigarette packets, etc. **Potentially Harmful Litter** (dangerous to either humans or animals using the beach) - includes: sharp broken glass (counted as a separate category), medical waste (e.g. used syringes), colostomy bag, sharps (metal wastes, barbed wire, etc.), soiled disposable nappies, containers marked as containing toxic products, other dangerous products such as flares, ammunition and explosives ammunition and dead domestic animals. **Accumulations of litter** – discrete aggregations of litter clearly visible when approaching the survey area, either as a result of being blown by the wind or dumped by users of the beach, and in the high water strandline, often in seaweed. **Oil and other oil like substances** - all oil waste (mineral or vegetable), either from fresh oil spills or the presence of weathered oil deposits and tarry wastes. **Faeces (Non Human) -** Dogs **(**sheep or horse faeces are not be counted).

Table A.2
Number of items counted in 100 m-long sectors at four beaches: Platja Gran, Racó del Corb (Remote beaches), Llevant and L'Arenal (Urban beaches).

| Site | Season survey | Beach Litter Categories | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paper fagments | Plastic cutlery | Plastic Bottles | Cigarettes | Wrappers | Caps & lids | Foamed pieces | All other items |
| 13 | Spring | 1 | 0 | 15 | 0 | 0 | 9 | 30 | 29 |
| 41 | Spring | 3 | 0 | 27 | 0 | 0 | 1 | 36 | 64 |
| 37 | Summer | 63 | 30 | 3 | 1203 | 26 | 6 | 2 | 129 |
| 50 | Summer | 73 | 33 | 0 | 1166 | 10 | 3 | 6 | 126 |

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## References

Addamo, A.M., Laroche, P., Hanke, G., 2017. Top Marine Beach Litter Items in Europe. EUR 29249 EN. Publications Office of the European Union, Luxembourg978-92-79-87711-7https://doi.org/10.2760/496717, JRC108181. 2017.
Allsopp, M., Walters, A., Santillo, D., Johnston, P., 2006. Plastic Debris in the World's Oceans. Greenpeace, Amsterdam, Netherlands, pp. 44.
Anfuso, G., Lynch, K., Williams, A.T., Perales, J.A., Pereira da Silva, C., Nogueira Mendes, R., Maanan, M., Pretti, C., Pranzini, E., Winter, C., Verdejo, E., Ferreira, M., Veiga, J., 2015. Comments on marine litter in oceans, seas and beaches: characteristics and impacts. Ann Mar Biol Res 2 (1), 1008.
Ariza, E., Leatherman, S.P., 2012. No-smoking policies and their outcomes on U.S. beaches. J. Coast. Res. 28 (1A), 143–147.
Balas, C.E., Ergın, A., Williams, A.T., Koc, L., 2004. Marine litter prediction by artificial intelligence. Mar. Pollut. Bull. 48 (5–6), 449–457.
Ballance, A., Ryan, P.G., Turpie, J.K., 2000. How much is a clean beach worth? The impact of litter on beach users in the Cape Peninsula, South Africa. South Afr. J. Sci. 96 (5), 210–230.
Barnes, D.K., 2002. Biodiversity: invasions by marine life on plastic debris. Nature 416 (6883), 808.
Bergmann, M., Gutow, L., Klages, M. (Eds.), 2015. Marine Anthropogenic Litter. Springer.
Botero, C.M., Anfuso, G., Milanes, C., Cabrera, A., Casas, G., Pranzini, E., Williams, A.T., 2017. Litter assessment on 99 Cuban beaches: a baseline to identify sources of pollution and impacts for tourism and recreation. Mar. Pollut. Bull. 118 (1–2), 437–441.
Cabezas-Rabadán, C., Rodilla, M., Pardo-Pascual, J.E., Herrera-Racionero, P., 2019. Assessing users' expectations and perceptions on different beach types and the need for diverse management frameworks along the Western Mediterranean. Land Use Policy 81, 219–231.
Cadée, G.C., 2002. Seabirds and floating plastic debris. Mar. Pollut. Bull. 44 (11), 1294–1295.
Cheshire, A., Adler, E., 2009. UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter.
Chitaka, T.Y., von Blottnitz, H., 2019. Accumulation and characteristics of plastic debris along five beaches in Cape Town. Mar. Pollut. Bull. 138, 451–457.
Coe, J.M., Rogers, D. (Eds.), 2012. Marine Debris: Sources, Impacts, and Solutions. Springer Science & Business Media.
Conservancy, Ocean, 2016. Ocean Conservancy 30th Anniversary International Coastal Cleanup Ocean Conservancy. Washington DC. www.oceanconservancy.org.
Convey, P., Barnes, D., Morton, A., 2002. Debris accumulation on oceanic island shores of the Scotia Arc, Antarctica. Polar Biol. 25 (8), 612–617.
Corraini, N.R., de Lima, A.D.S., Bonetti, J., Rangel-Buitrago, N., 2018. Troubles in the paradise: litter and its scenic impact on the North Santa Catarina island beaches, Brazil. Mar. Pollut. Bull. 131, 572–579.
Dodds, R., Kelman, I., 2008. How climate change is considered in sustainable tourism policies: a case of the Mediterranean islands of Malta and Mallorca. Tour. Rev. Int. 12 (1), 57–70.
EA/NALG, 2000. Assessment of Aesthetic Quality of Coastal and Bathing Beaches. Monitoring Protocol and Classification Scheme. Environment Agency and The National Aquatic Litter Group, London.
EA Ecologistas en Acción, 2018. Informe Banderas Negras 2018. Área Medio Marino de Ecologistas en Acción. pp. 70. https://www.ecologistasenaccion.org/?p=99126, Accessed date: February 2019.
Forrester, D.J., White, F.H., Woodard, J.C., Thompson, N.P., 1975. Intussusception in a Florida manatee. J. Wildl. Dis. 11 (4), 566–568.
Galgani, F., Hanke, G., Werner, S., De Vrees, L., 2013. Marine litter within the European marine strategy framework directive. ICES (Int. Counc. Explor. Sea) J. Mar. Sci. 70 (6), 1055–1064.
Ganesapandian, S., Manikandan, S., Kumaraguru, A.K., 2011. Marine litter in the northern part of Gulf of Mannar, southeast coast of India. Res. J. Environ. Sci. 5 (5), 471–478.
Gracia, C.A., Rangel-Buitrago, N., Flórez, P., 2018. Beach litter and woody-debris colonizers on the Atlantico department Caribbean coastline, Colombia. Mar. Pollut. Bull. 128, 185–196.
Houston, J.R., 2013. The economic value of beaches – a 2013 update. Shore Beach 81 (1), 3–10.
Jones, M.M., 1995. Fishing debris in the Australian marine environment. Mar. Pollut. Bull. 30 (1), 25–33.
Kenyon, K.W., Kridler, E., 1969. Laysan albatrosses swallow indigestible matter. Auk 86 (2), 339–343.
Khattabi, A., Williams, A.T., Ergin, A., 2009. Assessment of quality and attraction of the sandy beaches of Nador province – Morocco. In: In: Bayed, A. (Ed.), Sandy Beaches and Coastal Zone Management – Proc. The Fifth International Symposium on Sandy Beaches, Rabat, Morocco, vol. 6. Travaux de l'Institut Scientifique, Rabat, Série générale, pp. 59–64.
Kiessling, T., Gutow, L., Thiel, M., 2015. Marine litter as habitat and dispersal vector. In: Bergmann, M., Gutow, L., Klages, M. (Eds.), Marine Anthropogenic Litter. Springer, Cham.
Klein, Y.L., Osleeb, J.P., Viola, M.R., 2004. Tourism-generated earnings in the coastal zone: a regional analysis. J. Coast. Res. 1080–1088.
Krelling, A.P., Williams, A.T., Turra, A., 2017. Differences in perception and reaction of tourist groups to beach marine debris that can influence a loss of tourism revenue in coastal areas. Mar. Policy 85, 87–99. https://doi.org/10.1016/j.marpol.2017.08.021.
Kungskulniti, N., Charoenca, N., Hamann, S.L., Pitayarangsarit, S., Mock, J., 2018. Cigarette waste in popular beaches in Thailand: high densities that demand environmental action. Int. J. Environ. Res. Public Health 15 (4), 630.
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 (1–6), 175–179.
Legambiente, 2017. Beach Litter 2017. Survey in Mediterranean Area. pp. 16. May 2017. www.legambiente.it February 2019.
Madzena, A., Lasiak, T., 1997. Spatial and temporal variations in beach litter on the Transkei coast of South Africa. Mar. Pollut. Bull. 34 (11), 900–907.
Martinez-Ibarra, E., 2011. The use of webcam images to determine tourist–climate aptitude: favourable weather types for sun and beach tourism on the Alicante coast (Spain). Int. J. Biometeorol. 55 (3), 373–385.
Martinez-Ribes, L., Basterretxea, G., Palmer, M., Tintoré, J., 2007. Origin and abundance of beach debris in the Balearic Islands. Sci. Mar. 71 (2), 305–314.
Maziane, F., Nachite, D., Anfuso, G., 2018. Artificial polymer materials debris characteristics along the Moroccan Mediterranean Coast. Mar. Pollut. Bull. 128, 1–7.
Micallef, A., Williams, A.T., 2004. Application of a novel approach to beach classification in the Maltese Islands. Ocean Coast Manag. 47 (5–6), 225–242.
Micallef, A., Williams, A.T., Gallego Fernandez, J.B., 2011. Bathing area quality and landscape evaluation on the Mediterranean coast of Andalucia, Spain. J. Coast. Res. 87–95.
Munari, C., Corbau, C., Simeoni, U., Mistri, M., 2016. Marine litter on Mediterranean shores: analysis of composition, spatial distribution and sources in North-Western Adriatic beaches. Waste Manag. 49, 483–490. https://doi.org/10.1016/j.wasman.2015.12.010.
Nelms, S.E., Coombes, C., Foster, L.C., Galloway, T.S., Godley, B.J., Lindeque, P.K., Witt, M.J., 2017. Marine anthropogenic litter on British beaches: a 10-year nationwide assessment using citizen science data. Sci. Total Environ. 579, 1399–1409.
Nelson, C., Botterill, D., Williams, A.T., 1999. The beach as leisure resource: measuring user perceptions of beach debris pollution. World Leisure & Recreation 42 (1), 38–43.
Oigman-Pszczol, S.S., Creed, J.C., 2007. Quantification and classification of marine litter on beaches along Armação dos Búzios, Rio de Janeiro, Brazil. J. Coast. Res. 421–428.
Opfer, S., Arthur, C., Lippiatt, S., 2012. NOAA Marine Debris Shoreline Survey Field Guide. US National Oceanic and Atmospheric Administration Marine Debris Program.
OSPAR Commission, 2010. Guideline for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area.
Palazón, A., Aragonés, L., López, I., 2016. Evaluation of coastal management: study case in the province of Alicante, Spain. Sci. Total Environ. 572, 1184–1194.
Peraš, I., Divanović, M., Pešić, A., Joksimović, A., Marković, O., Đurović, M., Mandić, M., 2017. Composition and abundance of beach litter in Montenegro (south Adriatic Sea). Studia Marina 30 (1), 17–27 2017.
Pettit, T.N., Grant, G.S., Whittow, G.C., 1981. Ingestion of plastics by Laysan albatross. Auk 98 (4), 839–841.
Prevenios, M., Zeri, C., Tsangaris, C., Liubartseva, S., Fakiris, E., Papatheodorou, G., 2018. Beach litter dynamics on Mediterranean coasts: distinguishing sources and pathways. Mar. Pollut. Bull. 129 (2), 448–457.
Quintela, A., Silva, C.P., Calado, H., Williams, A.T., 2012. The relation of litter with bathing areas typologies, number of users and scenic value. The case study of São Miguel (Azores). J. Coast. Conserv. 16 (4), 575–584.
Ramos, A.A., 1995. Reserva marina de Tabarca: evaluación ecológica y socioeconómica de los efectos de una propuesta pionera. "La gestión de los espacios marinos protegidos en el Mediterráneo Occidental" J. Guirado (Coor.). Inst. Est. Almerienses, pp. 181–186.
Rana, G., Katerji, N., 2000. Measurement and estimation of actual evapotranspiration in the field under Mediterranean climate: a review. Eur. J. Agron. 13 (2–3), 125–153.
Rangel-Buitrago, N., Williams, A.T., Anfuso, G., Arias, M., Gracia, A., 2017. Magnitudes, sources, and management of beach litter along the Atlantico department coastline, Caribbean coast of Colombia. Ocean Coast Manag. 138, 142–157.
Romeo, T., Pietro, B., Pedà, C., Consoli, P., Andaloro, F., Fossi, M.C., 2015. First evidence of presence of plastic debris in stomach of large pelagic fish in the Mediterranean Sea. Mar. Pollut. Bull. 95 (1), 358–361.
Schuyler, Q., Hardesty, B.D., Wilcox, C., Townsend, K., 2014. Global analysis of anthropogenic debris ingestion by sea turtles. Conserv. Biol. 28 (1), 129–139.
Seas at Risk, 2016. Circular economy: reducing marine litter at its source. 2 pp. www.seas-at-risk.org February 2019.
Semeoshenkova, V., Newton, A., Contin, A., Greggio, N., 2017. Development and application of an integrated beach quality index (BQI). Ocean Coast Manag. 143, 74–86.
Sheavly, S.B., Register, K.M., 2007. Marine debris & plastics: environmental concerns, sources, impacts and solutions. J. Polym. Environ. 15 (4), 301–305.
Šilc, U., Küzmič, F., Caković, D., Stešević, D., 2018. Beach litter along various sand dune habitats in the southern Adriatic (E Mediterranean). Mar. Pollut. Bull. 128, 353–360.
Simeonova, A., Chuturkova, R., 2019. Marine litter accumulation along the Bulgarian Black Sea coast: categories and predominance. Waste Manag. 84, 182–193.
Slip, D.J., Burton, H.R., 1991. Accumulation of fishing debris, plastic litter, and other artefacts, on Heard and Macquarie Islands in the Southern Ocean. Environ. Conserv. 18 (3), 249–254.
Surfrider Foundation Europe, 2016. Environmental report of the ocean initiatives 2016. Y &R paris 2016. pp. 72. February 2019. www.surfrider.eu.
The Guardian, 2019. First Italian Beach Bans Smoking to End Scourge of Cigarette Butts.
Thiel, M., Hinojosa, I.A., Miranda, L., Pantoja, J.F., Rivadeneira, M.M., Vásquez, N., 2013. Anthropogenic marine debris in the coastal environment: a multi-year comparison

between coastal waters and local shores. Mar. Pollut. Bull. 71 (1–2), 307–316.
Tomás, J., Guitart, R., Mateo, R., Raga, J.A., 2002. Marine debris ingestion in loggerhead sea turtles, Caretta caretta, from the Western Mediterranean. Mar. Pollut. Bull. 44 (3), 211–216.
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.
Tudor, D.T., Williams, A.T., 2003. Public perception and opinion of visible beach aesthetic pollution: the utilisation of photography. J. Coast. Res. 1104–1115.
Tudor, D.T., Williams, A.T., 2008. Important aspects of beach pollution to managers: wales and the Bristol Channel, UK. J. Coast. Res. 735–745.
UNEP, 2015. Marine Litter Assessment in the Mediterranean 2015, vol. 48. Vassileos Konstantinou, Athens, Greece, pp. 45.
UNWTO, 2016. Tourism Highlights, 2016 Edition. (Madrid).
UNWTO, 2017. Tourism Highlights, 2017 Edition. (Madrid).
UNWTO, 2018. Tourism Highlights, 2018 Edition. (Madrid).
Van Cauwenberghe, L., Claessens, M., Vandegehuchte, M.B., Mees, J., Janssen, C.R., 2013. Assessment of marine debris on the Belgian continental shelf. Mar. Pollut. Bull. 73 (1), 161–169.
Veiga, J.M., Fleet, D., Kinsey, S., Nilsson, P., Vlachogianni, T., Werner, S., Galgani, F., Thompson, R.C., Dagevos, J., Gago, J., Sobral, P., Cronin, R., 2016. Identifying Sources of Marine Litter. MSFD GES TG Marine Litter Thematic Report; JRC Technical Report. EUR 28309https://doi.org/10.2788/018068.
Vera-Rebollo, J.F., Ponce Herrero, G., Dávila Linares, J.M., Ramon-Morte, A., 1990. Evaluación del grado de especialización turística de los municipios litorales valencianos. Invest. Geográficas 8, 83–112 1990.
Vlachogianni, T., 2019. Assessing marine litter on Mediterranean beaches. Filling in the knowledge gaps via a participatory-science initiative. MIO-ECSDE Unpublished report, p. 42.
Vlachogianni, T., Fortibuoni, T., Ronchi, F., Zeri, C., Mazziotti, C., Tutman, P., et al., 2018. Marine litter on the beaches of the Adriatic and Ionian Seas: an assessment of their abundance, composition and sources. Mar. Pollut. Bull. 131, 745–756.
Walker, T.R., Reid, K., Arnould, J.P., Croxall, J.P., 1997. Marine debris surveys at bird island, south Georgia 1990–1995. Mar. Pollut. Bull. 34 (1), 61–65.
Williams, A.T., 2011. Definitions and typologies of coastal tourism destinations. In: Jones, Andrew, Phillips, Mike (Eds.), Disappearing Destinations: Climate Change and Future Challenges for Coastal Tourism. CABI, UK, pp. 47–66.
Williams, A.T., Micallef, A., 2009. Beach Management. Principles and Practice. Earthscan, London, 978-1-84407-435-8pp. 480.
Williams, A.T., Tudor, D.T., 2001. Litter burial and exhumation: spatial and temporal distribution on a cobble pocket beach. Mar. Pollut. Bull. 42 (11), 1031–1039.
Williams, A.T., Pond, K., Phillipp, R., 2000. Chapter 12: aesthetic aspects. In: Bartram, J., Rees, G. (Eds.), Monitoring Bathing Waters, pp. 283–311.
Williams, A.T., Pond, K., Ergin, A., Cullis, M.J., 2013. The hazards of beach litter. In: In: Finkl, C. (Ed.), Coastal Hazards. Coastal Research Library, vol.1000 Springer, Dordrecht.
Williams, A.T., Randerson, P., Alharbi, O.A., 2014. From a millennium base line to 2012: beach litter changes in Wales. Mar. Pollut. Bull. 84 (1–2), 17–26.
Williams, A.T., Rangel-Buitrago, N.G., Anfuso, G., Cervantes, O., Botero, C.M., 2016a. Litter impacts on scenery and tourism on the Colombian north Caribbean coast. Tour. Manag. 55, 209–224.
Williams, A.T., Randerson, P., Di Giacomo, C., Anfuso, G., Macias, A., Perales, J.A., 2016b. Distribution of beach litter along the coastline of Cádiz, Spain. Mar. Pollut. Bull. 107 (1), 77–87.
Zhou, C., Liu, X., Wang, Z., Yang, T., Shi, L., Wang, L., et al., 2016. Assessment of marine debris in beaches or seawaters around the China Seas and coastal provinces. Waste Manag. 48, 652–660.

**Anexo III**

Publicación **III**.

## Litter behaviour on Mediterranean cobble beaches, SE Spain

F. Asensio-Montesinos[1,2], G. Anfuso[1], A.T. Williams[3], C. Sanz-Lázaro[2,4]

[1]Department of Earth Sciences, Faculty of Marine and Environmental Sciences, University of Cádiz, Polígono Río San Pedro s/n, 11510 Puerto Real, Cádiz, Spain

[2]Multidisciplinary Institute for Environmental Studies (MIES), University of Alicante, P.O. Box 99, E-03080 Alicante, Spain

[3]Faculty of Architecture, Computing and Engineering, University of Wales, Trinity Saint David, Swansea SA1 8EW, Wales, UK

[4]Department of Ecology, University of Alicante, PO Box 99, E-03080 Alicante, Spain

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# Litter behaviour on Mediterranean cobble beaches, SE Spain

F. Asensio-Montesinos [a,b,*], G. Anfuso [a], A.T. Williams [c], C. Sanz-Lázaro [b,d]

[a] Department of Earth Sciences, Faculty of Marine and Environmental Sciences, University of Cádiz, Polígono Río San Pedro s/n, 11510 Puerto Real, Cádiz, Spain
[b] Multidisciplinary Institute for Environmental Studies (MIES), University of Alicante, P.O. Box 99, E-03080 Alicante, Spain
[c] Faculty of Architecture, Computing and Engineering, University of Wales, Trinity Saint David, Swansea SA1 8EW, Wales, UK
[d] Department of Ecology, University of Alicante, PO Box 99, E-03080 Alicante, Spain

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ABSTRACT

Despite the large research effort on reporting quantities of coastal litter, the dynamics of this litter is not yet sufficiently understood. Litter inputs in five cobble beaches located in the Mediterranean (Spain) were studied over three months during winter by biweekly litter tagging. Plastic represented the dominant material that reached the beaches (77%). In remote and narrow beaches, storms constituted the main driver in litter dynamics, favouring the accumulation of floating items such as plastic bottles and wood fragments as well as the largest but contrasting effects, increasing litter inputs and outputs from the beach, respectively. In rural beaches, beach users, mainly fisher people, but also tourists, contributed to a notable input of litter to the beach. Burial and exhumation of litter were reported as common occurring processes. Better management actions are required to improve beach environmental quality.

## 1. Introduction

Litter is a major and constantly growing global environmental issue (Tudor and Williams, 2004; Rech et al., 2014). Several million tonnes (Mt) of litter currently enter the ocean every year from different sources (Jambeck et al., 2015) and is a cause of great concern to beach managers (Tudor and Williams, 2008). Marine litter or debris is been defined as *any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment* (UNEP, 2009, 13). The vast majority of litter derives from land-based sources such as villages, towns, landfills, private households, etc. and, because of improper disposal, passes through rivers and streams into the ocean (Golik and Gertner, 1992; Sheavly and Register, 2007; Rech et al., 2014). Litter can also be directly discarded in coastal environments by beach users (Nachite et al., 2019), as well as having a marine-based origin, from recreational and fishing boats, aquaculture and shipping in general (Earll et al., 1999; Coe and Rogers, 2012). Litter constitutes a serious hazard (Williams et al., 2013; Campbell et al., 2019) as has been shown by several previous studies during decades (Wallace, 1985; Azzarello and Van Vleet, 1987; Pemberton et al., 1992; Laist, 1997; Duncan et al., 2017). Birds, fish, invertebrates, mammals, reptiles and amphibians have been found entangled in marine debris (Ocean Conservancy, 2010). Lost or abandoned fishing gear and plastic bags are the greatest impact items to marine wildlife (Ocean Conservancy, 2016). Other dangerous items to wildlife include consumer products, such as food wrappers, straws, caps/lids, and smoking-related items (Ocean Conservancy, 2016).

The shoreline is widely used in litter monitoring because of its connection to land-based sources and accessibility, therefore litter accumulates there (GESAMP, 2019). Beach litter along the world's coasts is not only an important topic in marine pollution (Bergmann et al., 2015; Williams and Rangel-Buitrago, 2019), but also affects economies such as tourism (Botero et al., 2013a; Krelling et al., 2017; Houston, 2018). The presence of beach litter is one of the "Big Five" reasons to determine beach choice (Williams and Micallef, 2009; McKenna et al., 2011; Botero et al., 2013b) and beaches can be classified according to their anthropogenic environment, into different beach typologies such as resort, urban, village, rural and remote (Williams and Micallef, 2009; Williams, 2011). Litter categories and abundance can depend on the number of visitors (Nachite et al., 2019; Asensio-Montesinos et al., 2019b). In remote beaches located on islands, marine-based sources usually are the most important, e.g. fishing (Kaviarasan et al., 2020) and often observed is beach litter from foreign countries (Williams and Simmons, 1997a; Kei, 2005; Topçu et al., 2013).

* Corresponding author at: Department of Earth Sciences, Faculty of Marine and Environmental Sciences, University of Cádiz, Polígono Río San Pedro s/n, 11510 Puerto Real, Cádiz, Spain.
*E-mail address:* francisco.asensio@uca.es (F. Asensio-Montesinos).

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Plastic is the most common litter material found on the coast (Kusui and Noda, 2003; Bergmann et al., 2015; Simeonova and Chuturkova, 2019). It is estimated that 70% of marine litter remains on the ocean bottoms, while the other 30% is retained equally between the water column and beaches (UNEP, 2005). Global plastic production reached 368 Mt. in 2019 (Plastics Europe, 2020) and considering the amount of litter that has been yearly discarded into the environment over decades, it is expected that large quantities of litter will end up on the coast in the next few years. Furthermore, the coast acts as a great "barrier" between terrestrial and aquatic ecosystems. On urbanised coasts, beaches are generally cleaned during the bathing season by the various administrations (Williams, 2011), but in rural areas, cleaning activities in beaches are not generally performed and litter may remain for several months (Anfuso et al., 2020; Ecoplaya Alicante, 2020; Maiklem, 2020).

These isolated areas are suitable for accurate estimates of beach litter abundance (Lavers and Bond, 2017; Dunlop et al., 2020; Ryan, 2020), however, a limited number of researchers have attempted to quantify short-term dynamics of beach litter (Williams and Tudor, 2001). Different methodologies have been applied, e.g. daily collections of marine litter (Eriksson et al., 2013; Chitaka and von Blottnitz, 2019), beach litter monitoring using webcams (Kako et al., 2010), periodical litter assessments (Prevenios et al., 2018) and litter mark-recapture/tagging (Williams and Tudor, 2001). Among these methods, litter tagging provides accurate information on the litter dynamics by periodical quantification of the inputs (Garrity and Levings, 1993; Bowman et al., 1998; Williams and Tudor, 2001; Kataoka et al., 2013).

The aim of this paper was to study the dynamics of marine litter in rural and remote cobble beaches located on the southeastern coast of Spain. A periodical litter mark-recapture/tagging following Williams and Tudor (2001), was used to quantify litter inputs and correlate them with environmental parameters.

## 2. Materials and methods

### 2.1. Physical background

The study area is located in the southeast of the Iberian Peninsula, in the municipalities of "Campello", "La Vila Joiosa" and "Calp", in the province of Alicante. Five beaches were selected for this study, all located between the External Zone of the Betic *Cordillera* and the coastal waters of the Western Mediterranean Sea (Fig. 1). The northern part of the Alicante coast is characterized by several cliffed sectors (Yébenes et al., 2002), as a result of intensive faulting and folding. The proximity of mountain ranges to the sea has completely conditioned the coastal profile and gives the beaches great scenic beauty (Alfaro et al., 2008; Asensio-Montesinos et al., 2019a).

The involved beaches are mainly composed of cobble and boulder sediments, with sizes ranging from −6 to −9 Phi (64–512 mm, according to Blott and Pye, 2012) and show reflective morphodynamic states (Masselink and Short, 1993). They are high energy beaches with little sign of anthropogenic activities/structures (Fig. 2) that could affect the natural processes and morphology, which are only influenced by waves and tide (Wright et al., 1987). Tides in the area show a micro-tidal range (<2 m, according to Davies, 1964). In microtidal beaches, litter accumulations are usually concentrated at the high tide level and backshore area (Kei, 2005; Asensio-Montesinos et al., 2020a), which has been considered an efficient trap for litter (Bowman et al., 1998). All beaches are characterized by accumulations of *Posidonia oceanica* "banquettes" that reach >1 m in height and cover several square metres of beach surface. When the leaves of this Mediterranean plant accumulate on the beach, they protect against erosion processes because they contribute to stabilization of coastal sediments (Belmonte et al., 2001). These accumulations come from submerged seagrass meadows that in the past occupied large areas (Sánchez-Lizaso et al., 1994).

According to the beach typology classification of Williams and Micallef (2009), beaches no. 1 and 2 are essentially rural with few users daily observed (0−10) during the study period. Rural beaches are located outside the urban/village environment and are not accessible by

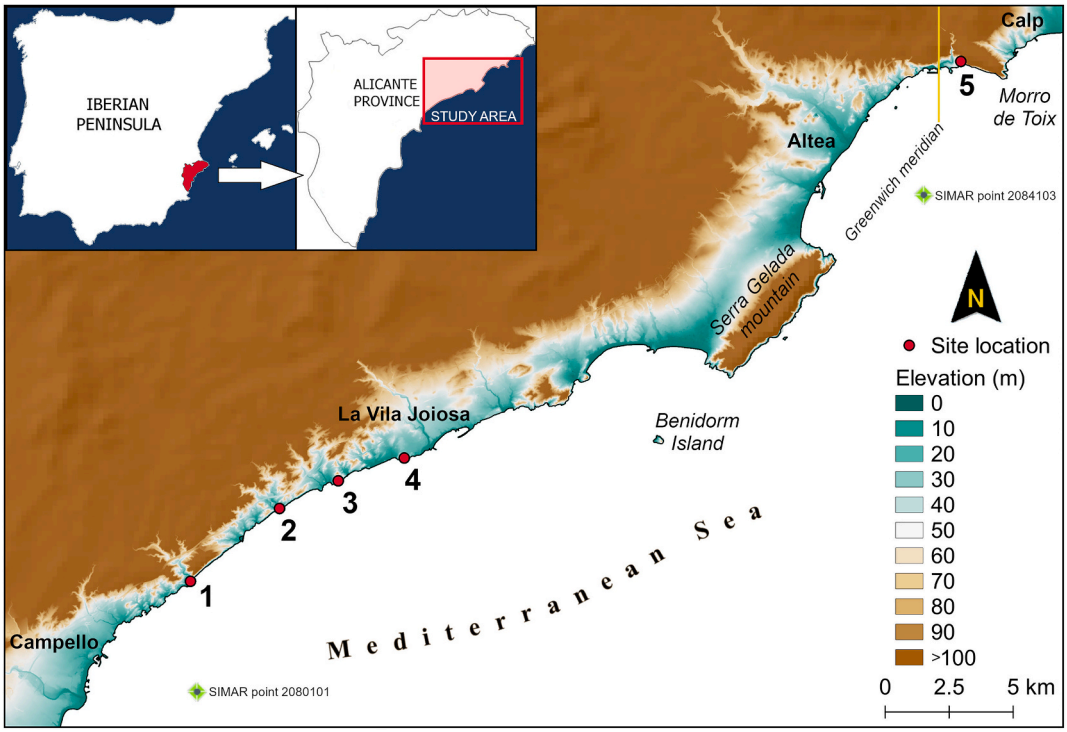



**Fig. 1.** Location of study area with the position of the beaches sampled.




**Fig. 2.** In rows, the five beaches investigated. The first column shows the beaches in 3D with a bird's eye view. The second and third columns respectively show a southward and eastward view of each beach.

public transport (Williams and Micallef, 2009). While beaches no. 3, 4 and 5 are remote (i.e. remote Mediterranean beaches are defined by difficulty of access, mainly by foot after a walk of 300 m or more) with very few users observed (0–5, see Fig. 2), i.e. all studied beaches are characterized by a low abundance of users. Users observed on the beaches were usually fishermen that spend several hours on the beach and in some cases, people hiking and, at the end of the study period, by tourists. Rural and remote areas investigated in this paper are valued by beach users for their natural qualities. Additional data for each beach are presented in Table 1.

### 2.2. Field surveys

Data were collected in seven field campaigns carried out from December 2020 to March 2021, at five beaches ranging in length between 50 and 250 m, all of them consisting of cobbles backed by cliffs (Figs. 1 and 2). The distribution of surveyed coastal sites was selected according to their geomorphological characteristics and other logistical reasons, such as proximity. Satellite images (from Google Earth), bibliography (DPA, 2010; Iváñez-Rugero, 2020) and previous field studies (Asensio-Montesinos et al., 2019a, 2019b) were used to select the least visited and most remote beaches in the province of Alicante. All are unpopular and/or have difficult access compared to common Mediterranean beaches. In line with previous litter studies in remote cobble beaches (Anfuso et al., 2020), the entire beach surface was covered and assessed by two researchers that moved along cross-shore parallel transects spaced 2 m apart. The beach surface was examined from the strandline to the backshore area because the pattern of litter distribution on cobble beaches is often irregular (Williams and Tudor, 2001). The backshore included a cliff base and ancient beach ridges, composed of cobbles, pebbles and *P. oceanica* "banquettes" (Fig. 2). The backshore is the most diversified zone of a cobble beach because different sediment grain sizes coexist and a great variety of litter items was observed there. The five beaches were visited between 8 a.m. and 3 p.m. Litter was classified according to a Masterlist of beach litter with 183 litter categories that take into consideration the type of material and size following "The Environment Agency and The National Aquatic Litter Group" (UK) (EA/NALG, 2000), "The United Nations Environment Programme" (UNEP, 2009), "OSPAR Commission" (OSPAR Commission, 2010), and finally, "The National Oceanic and Atmospheric Administration" (Opfer et al., 2012). A few new categories were also added such as sanitary masks, bracelets, bins, fishing rod pieces, hair

**Table 1**
Location and main characteristics of investigated beaches.

| Beach no. and name | 1. Lloma de Reixes | 2. Carritxar | 3. Xarco–Caleta[a] | 4. Malladeta | 5. Racó del Corb |
|---|---|---|---|---|---|
| Municipality | Campello | La Vila Joiosa | La Vila Joiosa | La Vila Joiosa | Calp |
| Geographical coordinates | 38°27′27.40″N 0°20′31.92″O | 38°28′56.53″N 0°18′4.94″O | 38°29′29.42″N 0°16′28.92″O | 38°29′55.88″N 0°14′41.35″O | 38°37′56.77″N 0° 0′36.96″E |
| Length assessed (m) | 336 | 258 | 50 | 200 | 113 |
| Width max. assessed (m) | 20 | 12 | 12 | 7 | 18 |
| Width min. assessed (m) | 11 | 8 | 7 | 0 | 8 |
| Area assessed ($m^2$) | 4621 | 2451 | 672 | 1280 | 1469 |
| Orientation | NNE–SSW | ENE–WSW | NE–SW | ESE–WNW | NE–SW |
| Facing to | ESE | SSE | SE | SSW | SE |
| Geomorphology | Open beach | Open beach | Pocket beach | Open beach | Pocket beach |
| Surrounding geological materials | Marls, calcarenites and limestones | Marls, calcarenites and limestones | Marls, calcarenites and limestones | Conglomerates, sandstones, gravels, sands, silts and clays | Marls, sandstones and conglomerates |
| Cobbles origin | Alluvial deposits and cliff slides | Alluvial deposits and cliff slides | Cliff slides | Cliff slides | Cliff slides |
| Beach typology | Rural | Rural | Remote | Remote | Remote |
| Type of access and difficulty | By foot: normal By car: difficult | By foot: difficult By car: very difficult | By foot: very difficult By car: not possible | By foot: difficult By car: not possible | By foot: very difficult By car: not possible |
| Distance to paved road | 300 m | 154 m | 1117 m | 310 m | 305 m |
| Slope of access to the beach | Low (<5%) | Low (<5%) | Medium (5−25%) | Medium (5−25%) | High (>25%) |
| Parking and no. of spaces | Yes (<10) | Yes (<10) | No | No | No |
| Level of occupation | Low | Low | Very low | Very Low | Low |
| Recreational activities observed on the beach | Angling, camping and picnicking | Angling, camping and picnicking | Enjoy the coastal scenery | Enjoy the scenery and picnicking | Enjoy the scenery and picnicking |
| Services | Bins | Bins | No | No | No |

[a] This beach has no official name and it is located between the beaches of 'El Xarco' and 'La Caleta'.

bands, hats and caps, etc. "Pottery & ceramics" category was not counted/marked because very little debris was observed, and such items were part of the environment and usually remain there. In addition, "Pottery and ceramics" on beaches could be of historical interest (Rouillard et al., 2014; Maiklem, 2020). Data were represented by litter abundance and average litter accumulation rates on the surveyed beaches for a 15 day time-span (i.e. the average time interval between following surveys) per 100 m beach to make data obtained easily comparable with other studies. The accumulation process is not usually a linear one because it records great temporal variability, therefore daily accumulation rates presented within this study are only indicative.

By cleaning a specific area and using marking methods, it is possible to record litter input rates, accumulation times and movement patterns (Williams and Simmons, 1997b). The methodology used in this paper was applied 20 years ago on a UK cobble beach by Williams and Tudor (2001). This was probably the first study to highlight the importance of burial and exhumation of litter on cobble beaches and demonstrated the rapid recolonization of litter on an unfrequented pocket beach (Williams and Tudor, 2001). Within the framework of this research, on 1st December 2020, the five investigated beaches were cleaned of all visible surface litter. Then, every two weeks during three months (13th December 2020-17th March 2021) a total of seven surveys were carried out. During each survey, all beach litter was counted and marked in situ with a specific waterproof permanent colour on each survey to differentiate newly arrived items ("fresh" litter) from the ones observed in previous surveys (Williams and Tudor, 2001). The colours used were: red (13th December); blue (28th December); green (12th January); orange (28th January); yellow (12th February); brown (27th February); and purple (17th March). Only items of litter observed on the beach surface were counted and those items that were floating, or outside the study area were not included in these surveys. Photographic evidence of many tagged items was obtained to verify their reappearance and condition in subsequent surveys. From the results obtained in this type of study, the probability of double counting as a consequence of litter disintegration is minimal (Williams and Tudor, 2001). Waterproof permanent paint may rub off on some specific items over the weeks, e.g. on rusty metal items, but this issue was solved by re-marking these items with their corresponding colour during each survey.

For relating litter inputs to environmental factors, oceanographic data series during the study period were obtained from the "Puertos del Estado" website (www.puertos.es, accessed on 19th April 2021). Datasets of wind (average wind speed and direction) and wave parameters (significant wave height, peak period and prevailing wave direction) are obtained from the closest SIMAR ("SImulación MARina") points to the studied beaches, i.e. the beaches nos. 1, 2, 3 and 4 are closer to the SIMAR point 2080101 and beach no. 5 to the SIMAR point 2084103 (Figs. 1 and 3). The SIMAR virtual database is obtained through numerical wave modelling from wind time series by means of an energy balance equation that has been validated by numerous studies and used in practical applications along the Spanish coast (Tomás et al., 2004). In addition, the maximum and minimum daily ambient temperature data were obtained from "Agencia Estatal de Meteorología" (datosclima.es, accessed on 20th April 2021).

### 2.3. Statistical analysis and data processing

To compare litter composition among beaches and surveys, a non-parametric multi-dimensional scaling (nMDS) was performed. Objects are represented as points, such that the distance between points matches the observed dissimilarities (Groenen and van de Velden, 2005). Additionally, the cluster technique was carried out as a complementary classification technique to the nMDS. For this purpose, the dataset was normalised, i.e. the number of items per beach was converted into items/$m^2$. Then, according to the characteristics of the dataset and the differences between the minimum and maximum values, it was decided to perform a fourth root transformation. Analyses were made based on the Bray–Curtis dissimilarity index (Bray and Curtis, 1957) as the abundance of the litter items is zero-inflated. Two independent analyses were performed; one for the fresh litter data and another one for the total litter data. In the nMDS plots, to identify litter categories that showed the highest weight in the ordination of the beaches during the different surveys, the litter categories with a Pearson correlation above 0.5 were represented as vectors from a central point in a two-dimensional space. The orientation of the vectors with respect to the distribution of the beaches is related to the composition of the most important items present, which in turn is related to the use made of each beach. The analyses were conducted using PRIMER V.6 + PERMANOVA (Plymouth Marine Laboratory, UK). All statistical tests were conducted with a significance level of $\alpha = 0.05$.

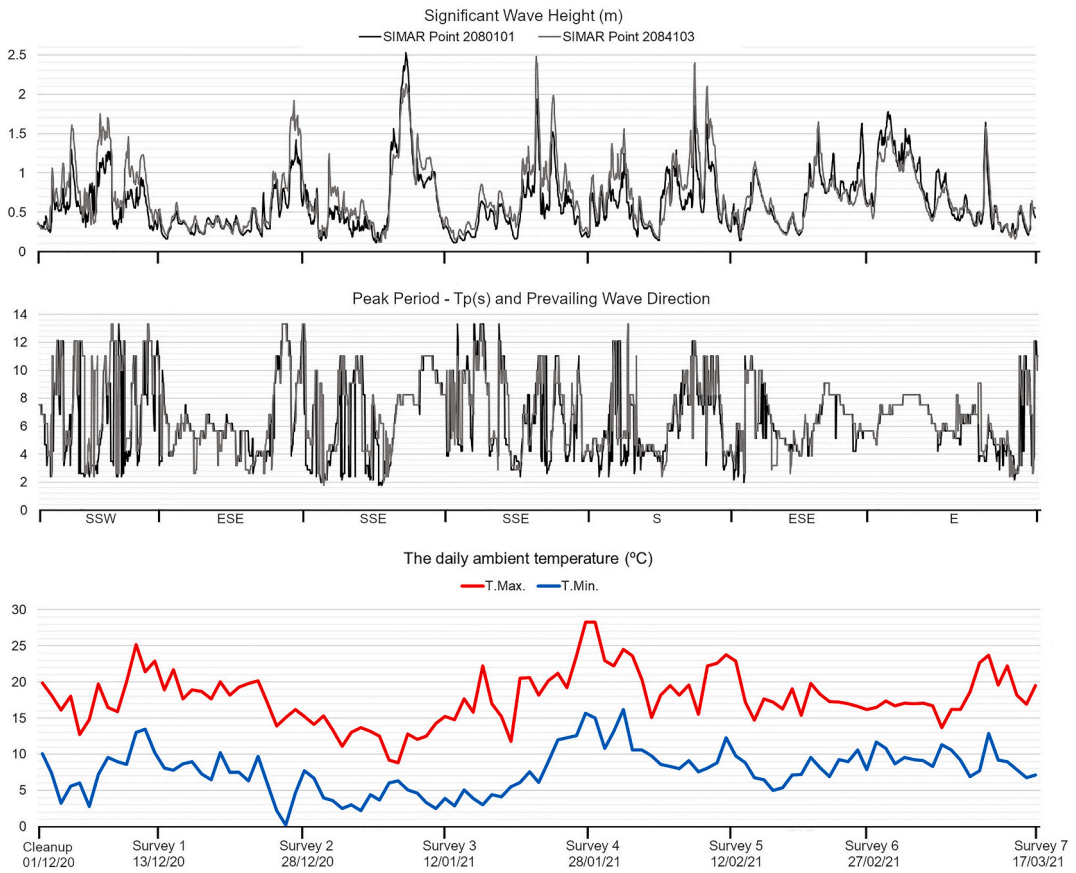



**Fig. 3.** Environmental parameters: Significant wave height (m), peak period or Tp (s), prevailing wave direction and daily ambient temperature. Sources: "Puertos del Estado" (www.puertos.es) and "Estaciones meteorológicas de AEMET" (datosclima.es).

## 3. Results

### 3.1. Beach litter dynamics

During the clean-ups at the beginning of this study (1st December 2020), from one to five large bags of litter were removed per beach. Due to uncertainty in previous accumulation times, the collected beach litter was not counted. Two weeks later, 150 fresh items were recorded at the first survey (13th December 2020), rising to 722 by the final survey (17th March 2021, Table S1). A total of 130 litter categories were recorded that principally included plastic, metal, cloth, paper, rubber, wood, glass, and other materials.

An amount of 3418 litter items were counted on the five beaches investigated during the entire study period, 2410 of them were constituted by fresh items (Table S1). The rest (1008) were remaining items that were counted more than once (Table S1). Fig. 4 shows all beach litter accumulation over the study period. Results showed that inputs during the studied period were quite different within surveys, but after some time the accumulated litter tended to become similar among beaches (Fig. 4). Litter counted at a specific survey, tended to disappear over time, but despite this a few items generally remained. Beaches no. 1 and 2 recorded the highest amount of litter (Table S1, Fig. 4); however, they are also the largest beaches (Table 1, Fig. 2). Considering the seven surveys carried out at each beach, the average number of litter items per 100 m beach ranged from 66, 42, 56, 29 to 63 items from beach no.1 to beach no.5, respectively. The number of litter items/$m^2$ was very low and similar for all beaches (Fig. S1), all falling in the category "Very clean" according to the Clean Coastal Index (CCI; Alkalay et al., 2007). In the study area there is little connectivity between beaches, but it is important to give an idea about this process, as it can be of great interest for researchers and local administrators.

Accumulation rates ranged from 0.4 to 6.9 items·$day^{-1}$·100 $m^{-1}$ (Table S2). There was a notable increase in the number and accumulation rates of items in the third survey (Fig. 4 and Tables S1 and S2) due to a strong marine storm that occurred during the days preceding the survey (Fig. 3). On beach no. 4 this trend was not observed because of the reduced width of the dry beach (in some cases less than 1 m) so waves during the storm were expected to reach the cliff base resulting in the formation of reflected waves that favoured erosive processes that transported litter items offshore (Fig. 2). Generally, from the first to the last survey, was observed an increasing trend in the number of new items appearing on beaches, particularly in the last two field visits (surveys 6 and 7, Figs. 4 and S1; from more detail of these items see Fig. 5). Concerning beach users' abundance, a clear increase of paper fragments related to users was observed during the study period: only one fresh paper fragment was recorded at the first survey and 30 in the final (Table 2). Different specific examples of beach litter dynamics are displayed in Fig. S3.

Multivariate analysis showed that beaches no. 1 and 2 presented similar litter composition, while the rest presented different trends (Figs. 6 and 7). In beach no. 3, the remains of *P. oceanica*, as well as litter items, have also accumulated in less quantity than in nearby beaches (Table S1). Results of surveys carried out in the beach no. 4 also presented a different trend from the one observed at other beaches. Beach no. 5 shares geomorphological characteristics with beach no. 3 but it receives as many users as beaches 1 and 2 (Table 1). With regard to the seven surveys, they tend to become similar over time (Fig. 6 and Table S4).

### 3.2. Beach litter composition and typology

Fresh beach litter was composed of plastic (77.1%), followed by

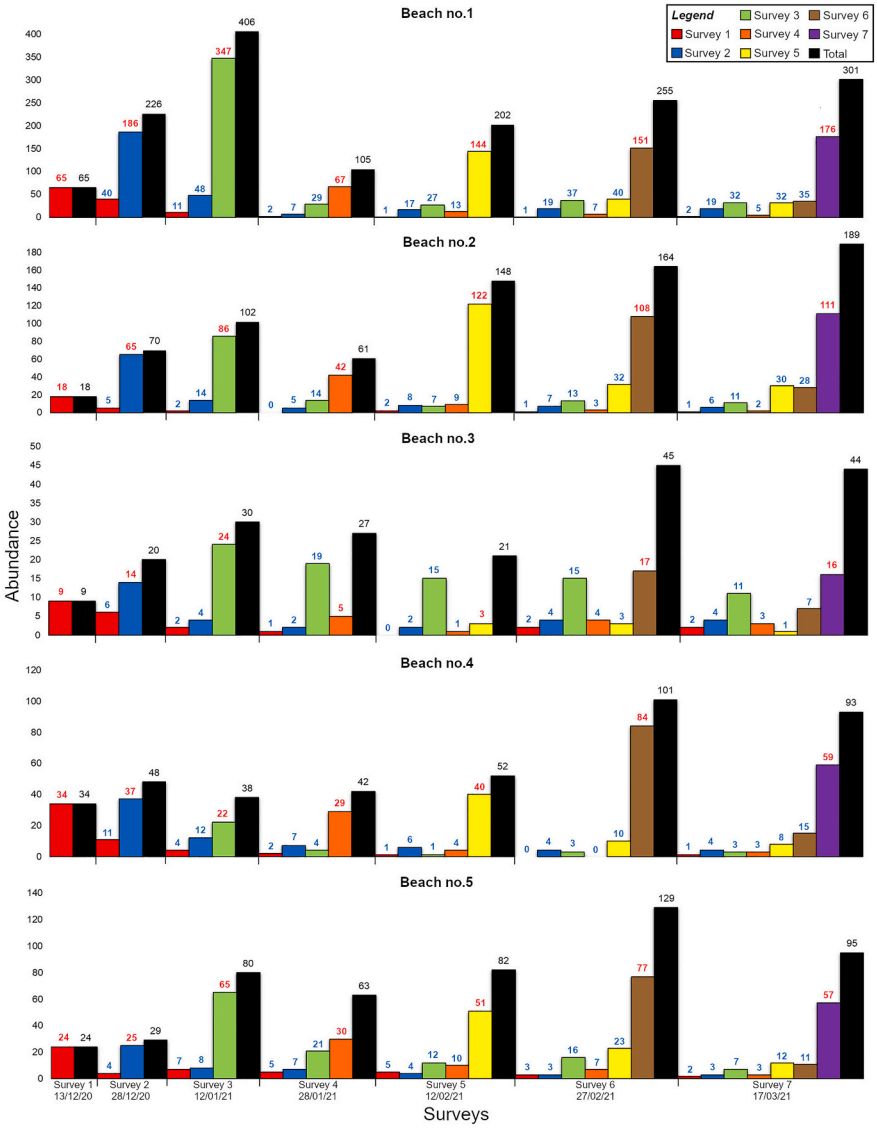



**Fig. 4.** Litter abundance in the five studied beaches (no. items per beach). Numbers in red represent the accumulated fresh litter content among consecutive surveys. Numbers in blue represent the remaining litter. The colours of each bar belongs to the litter that was counted in the same survey (see the legend and X-axis): in survey no. 1, new litter items were marked in red, in survey no. 2 new litter items were marked in blue (and litter marked in red was also counted and considered as remaining litter); in survey no. 3, new litter items were marked in green and litter marked in red and blue, i.e. the remaining litter, was also counted, and so on. The black bars represent the total amount of litter, i.e. remaining + fresh litter, at each survey. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

metal (7.3%), cloth (5%), paper & cardboard (3.9%), rubber (2.3%), wood (1.5%), other materials (1.3%), glass (1.2%), and organic (0.4%). The most abundant litter items (>2%) in the study area have been identified for the entire period (Table 2) and included hard plastic pieces (2.5–50 cm, 25.1%), foamed plastic pieces (2.5–50 cm, 12%), film plastic pieces (2.5–50 cm, 7.1%), cigarettes, butts & filters (5.4%), caps/lids (3.4%), Drinks (bottles, containers and drums) < 2 L (3%), paper fragments (2.5–50 cm, 2.8%), cloth pieces (2.5–50 cm, 2.6%), fishing line (angling, 2.6%), and metal fragments (2.5–50 cm, 2.4%).

The bulk of the litter observed were plastic pieces, due to the high energy hydrodynamic conditions associated with cobble beaches and the high buoyancy of plastics. Table 2 shows the number of the most abundant fresh litter items during the study period, e.g. plastic pieces (Fig. 5d). Most litter categories recorded few items. For example, some rare or uncommon residues observed in rural and remote beaches were cosmetics, sandals, toys (Fig. 5e), tyres, sponge scourers, sunglasses, rags, nail clippers, among others. Cigarette butts, caps/lids (Fig. 5f), drinks, paper fragments and others items (Fig. 5g–k), which are abundant in the Mediterranean (Nachite et al., 2019; Vlachogianni, 2019) and in other places (Ocean Conservancy, 2016), were present in this study in only small proportions (<6%). This is substantiated by some litter categories, being positively correlated to beach users, e.g. cloth pieces (*CL15*), paper fragments (*PP11*) and cigarette butts (*PL24*, Fig. 6). Other categories such as hard and film plastic pieces (*PL63*, *PL66*) were also positively correlated. Rural beaches no. 1 and 2 are similar in terms of litter composition related to beach use, accessibility, management, etc. (Table 1, Figs. 6 and 7). Several rubber fragments (*RB10*) and octopus elastic straps (*RB13*) were found during the first surveys on beach no. 3 (Fig. 6). The latest surveys of remote beaches no. 4 and 5 also resemble the surveys carried out on rural beaches no. 1 and 2 (Fig. 6). The similarity of values obtained between consecutive surveys increased in the latest surveys (Table S4). Cluster analysis shows that, regarding fresh litter, the most comparable surveys take place in beach no. 1, e.g. surveys 2, 3, 5 and 6, Fig. 7 the most accessible and visited beach of this study (Table 1). Other groupings can be seen in the surveys of beaches no. 4 and 5 (Fig. 7). However, it is again observed that beach no. 3 is the most different from the rest because it is the least visited, the most remote and the smallest beach (Table 1 and Fig. 7). The survey 3 of beach no. 4 is very different from the rest, as mentioned above, due to the erosive processes produced by the storm that removed a large part of beach litter (Fig. 7). Regarding total litter, the results of Cluster analysis show obvious groupings where the composition of litter from the same beach is similar throughout the study (see groupings by colour in Fig. 7).

Some of the litter items observed during the study were potentially dangerous to users and animals that live or frequent beach. For example, fishing-related debris (Fig. 5l) such as lures, hooks (Fig. 5l, m) and

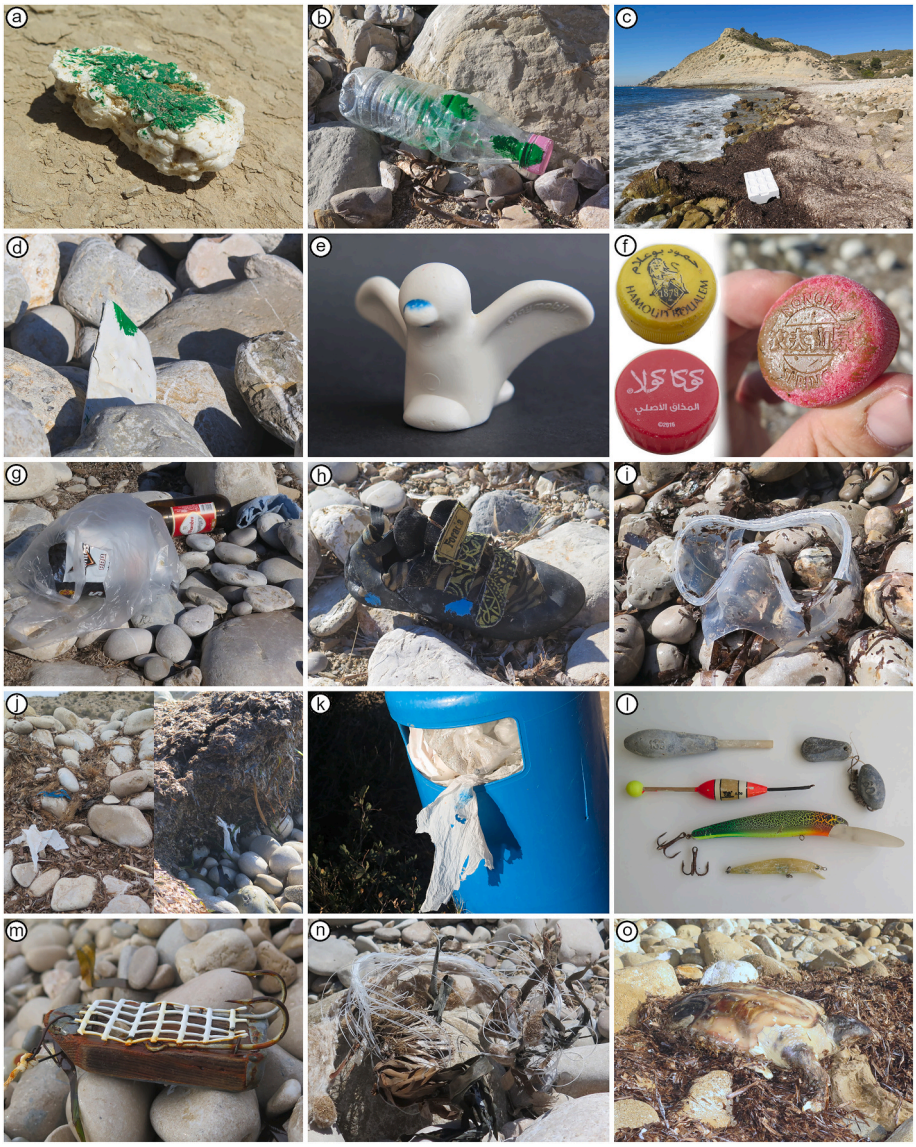


**Fig. 5.** Examples of litter items: a) piece of expanded polystyrene foam; b) plastic bottle; c) foamed plastic box; d) hard plastic piece; e) Playmobil Bird White, Part Number: 6102170; f) caps/lids; g) litter accumulation; h) climbing shoe; i) dive mask; j) buried litter; k) litter bin; l) fishing related items; m) fishing lure with hooks; n) fishing line; o) marine turtle.

**Table 2**
Number of most abundant fresh litter (i.e. top ten litter items) during the study period recorded at each survey.

| Beach litter categories | S1 | S2 | S3 | S4 | S5 | S6 | S7 |
|---|---|---|---|---|---|---|---|
| Hard plastic pieces 2.5–50 cm | 41 | 67 | 136 | 49 | 119 | 120 | 72 |
| Foamed plastic pieces 2.5–50 cm | 13 | 86 | 101 | 13 | 20 | 23 | 34 |
| Film plastic pieces 2.5–50 cm | 13 | 17 | 22 | 18 | 30 | 39 | 33 |
| Cigarettes, butts & filters | 0 | 15 | 39 | 1 | 14 | 26 | 34 |
| Caps/lids | 3 | 13 | 25 | 6 | 7 | 17 | 12 |
| Drinks (bottles, containers and drums) < 2 L | 2 | 3 | 41 | 2 | 11 | 8 | 6 |
| Paper fragments 2.5–50 cm | 1 | 4 | 4 | 4 | 10 | 15 | 30 |
| Cloth pieces 2.5–50 cm | 2 | 7 | 10 | 7 | 14 | 17 | 6 |
| Fishing line (angling) | 6 | 11 | 9 | 1 | 6 | 15 | 15 |
| Metal fragments 2.5–50 cm | 7 | 6 | 8 | 8 | 8 | 9 | 11 |
| Total | 88 | 229 | 395 | 109 | 239 | 289 | 253 |

fishing lines (Fig. 5n) can cause lacerations, entanglements and other serious problems to humans and animals. There was little fishing-related debris, mostly linked to shore angling. Fishing-related debris were found on all studied beaches, being more abundant in beach no. 1 and 2, specially surveys 6 and 7 (Table S5). Other hazardous items are broken glass, nails, screws, razors, knives, wires, some metal and plastic fragments (Fig. 5d), and other cutting items (all of them observed in this study), which can cause foot lacerations and other potential dangers (Whiting, 1998; Williams et al., 2013). Other harmful litter items detected during the study period were fiberglass fragments, sanitary masks and manufactured/processed wood fragments. Biohazard items were also recorded and related to the presence of sewage-related debris that accounted for 1.2% of all fresh litter observed, some examples were sanitary towels, tampon applicators, cotton bud sticks, eye drops and condoms. Further, a few dead animals were observed, sometimes so degraded that identification was difficult: a sea turtle (probably *Eretmochelys imbricata*, Fig. 5o), a fish (*Trachinus draco*), two seagulls (probably *Larus michahellis*), a cuttlefish (*Sepia officinalis*), worms for fishing (*Perinereis aibuhitensis*) and a small goat, the head of which was found in another part of the beach.

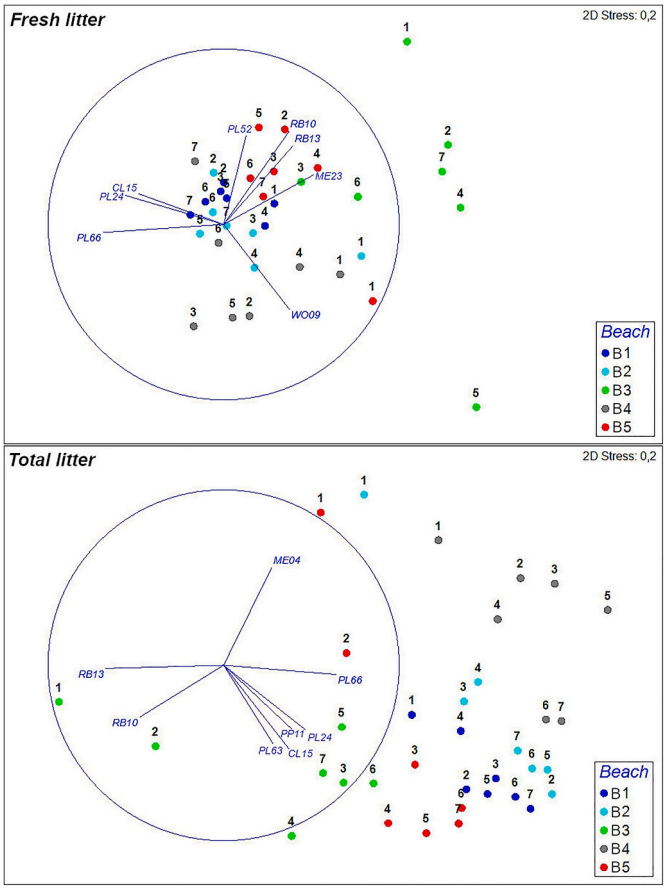



**Fig. 6.** Non multi-dimensional scaling ordination for fresh litter and total litter based on the litter categories abundance. The colours (blue, cyan, green, grey and red) correspond to each of the five beaches, while the labels 1 to 7 correspond to the surveys. Vector labels refer to litter categories that showed a Pearson correlation above 0.5: *CL15* (cloth pieces), *ME04* (drink cans), *ME23* (metal fragments), *PP11* (paper fragments), *PL24* (cigarette butts), *PL52* (fiberglass fragments), *PL63* (hard plastic pieces), *PL66* (film plastic pieces), *RB10* (rubber fragments), *RB13* (octopus elastic straps), *WO09* (matches & fireworks). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

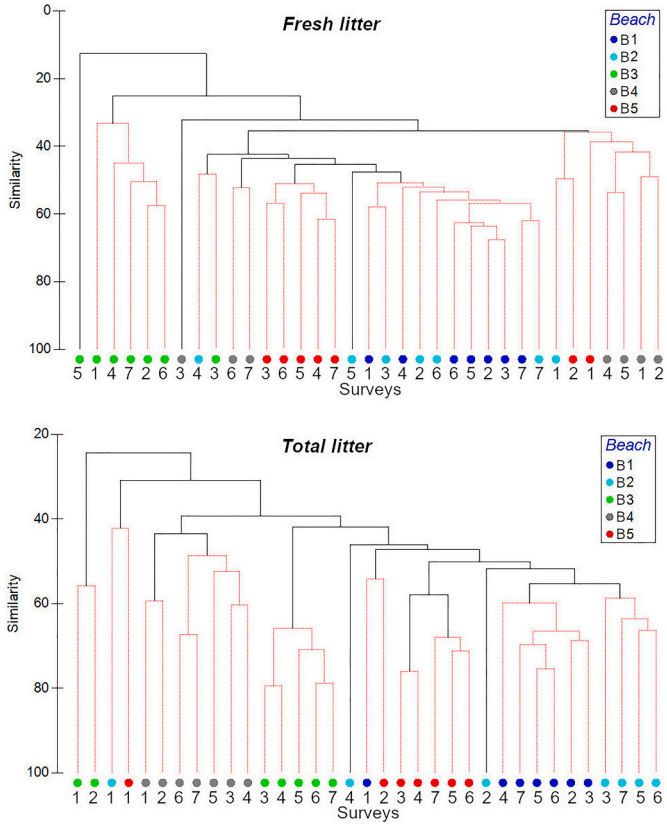



**Fig. 7.** Cluster analysis for fresh and total litter based on the litter categories abundance.

## 4. Discussion

### 4.1. Litter composition and sources

Beach litter composition helps to identify the litter source (EA/NALG, 2000; Bergmann et al., 2015; Ryan, 2020) as well as the typology and use of the beach (Ocean Conservancy, 2010; Asensio-Montesinos et al., 2019b). Results obtained in this study concerning beach litter composition differed from other studies that have reported higher percentages of plastic (82.6–92.2%) and, generally, lower percentages of other materials in different seasons (Kusui and Noda, 2003; Topçu et al., 2013; Asensio-Montesinos et al., 2019b, 2020a, 2020b; Nachite et al., 2019; Vlachogianni, 2019). In some of these studies, "Paper & cardboard" category showed higher proportions than this study because they were counted on beaches in months where users were more abundant. Reliable observations have also been reported in other countries, such as Bulgaria, Cuba and Morocco (Botero et al., 2017; Nachite et al., 2019; Simeonova and Chuturkova, 2019).

The bulk of the litter observed in this study consisted of plastic pieces that have different composition and their origin is often unknown (Bergmann et al., 2015). A very similar result accounted for the highest percentage of plastic pieces (2.5−50 cm, i.e. 26%) were recently reported by Vlachogianni (2019) on 23 Mediterranean beaches of coastal and marine protected areas, including beaches of different typologies (e.g. resort, remote, rural, village and urban) defined by Williams and Micallef (2009). Asensio-Montesinos et al. (2020b) estimated that most of the hard plastic pieces on Cádiz province beaches (Andalusia, Spain) are composed of polyethylene (PE, 35%), polypropylene (PP, 31%), polystyrene (PS, 13%), polyethylene terephthalate (PET, 4%), polyvinyl chloride (PVC, 3%) and other types of plastics (14%). In Europe, these types of plastics generally coincide with the highest plastics demand by resin type in 2019 (Plastics Europe, 2020). In this study, many of these hard plastic pieces (approx. 35%) comprised transparent fragments of beverage bottles, usually made of PET. This proportion was estimated in some of the surveys that recorded the greatest litter abundance, and bottle fragments accounted for between 23% and 72% of all hard plastic pieces. Foamed plastic pieces come from marine and terrestrial inputs. These fragment types observed in remote beaches are mainly composed of expanded polystyrene foam (PS) and polyurethane foam (PU, Anfuso et al., 2020), which have high buoyancy due to their composition (Mark, 1998). This fragmentation of foamed plastic occurs due to their exposure to sunlight and abrasion processes (Biber et al., 2019; Turner, 2020). In some beaches located in SW Spain, film plastic pieces are composed of PP (59%), PE (27%), PET (3%), PVC (3%) and other materials (8%, Asensio-Montesinos et al., 2020b).

Concerning beach litter origin, litter comes from both local and foreign sources (Wade et al., 1991; Munari et al., 2016; Ryan, 2020) and allochthonous litter can severely endanger marine ecosystems through the biological invasion of non-native attached biota (Rech et al., 2016). In this study a large amount of litter categories had a local origin and reflect a contamination linked to beach users and near-residents that could have deposited litter directly on the beach surface. Approximately, 30% of the sampled litter was directly related to beach users (fishermen, beachgoers, sportsmen, etc.). However, other items with positive buoyancy had an unknown origin. Examples of litter directly

related to users found in this investigation were hair bands and clips, bracelets, sun glasses, sandals, pieces of a beach umbrella, cigarette packets, cutlery, glass fragments, some fishing related items, foil wrappers, food wrappers, etc. as well as recent accumulations of food-related litter (Fig. 5g). Litter items related to sports have a local origin and were probably abandoned or lost in the vicinity of the beaches. Some examples are the tennis balls observed on beach no. 4, probably coming from one of the numerous tennis courts near this beach. Other items related to climbing were found on beach no. 5; e.g. a steel carabiner and a climbing shoe (Fig. 5h), where climbing is regularly practised on the beach cliff (Fig. 2). Snorkel tubes and diving masks used to appear arbitrarily on all beaches (except beach no. 3). They were probably lost by beachgoers during the summer and have been washed ashore by the sea during the winter period (Fig. 5i). Other items related to sport were observed only once, for example a swim cap and a digital wristwatch. Further items may have been left for many years at sea or buried in marine sediment until they washed up on beaches. Some of these particular examples are a model of rubber sandal very common in the 1980s and 1990s (*Hobeky*) and a small plastic toy from 1999 (Fig. 5e) which had bryozoans attached.

Local users were also responsible for the 6.2% of fresh litter consisting of fishing-related debris, ranging from 4.6 to 10.2% among beaches (Table S5). Although these percentages are low, they are higher than those reported in other beach assessments in the Mediterranean and Atlantic littoral of Spain (1.2 to 3.1%; Asensio-Montesinos et al., 2019b, 2020a), which could be because those investigated in previous works included village and urban areas where fishing does not usually occur. The present study agrees with previous ones that beach typology is a key factor that determines beach litter composition, an observation also reported by other studies (Rangel-Buitrago et al., 2018; Nachite et al., 2019). However, the percentages found in this study coincide within the range of other reported works for the Mediterranean Sea where fishing-related items overall comprise less than 10% of total litter items found (Vlachogianni et al., 2018, 2020). In contrast, in three Galician beaches (NW Spain), litter related to fishing and aquaculture represented an average value of 14, 23 and 38% (Gago et al., 2014) because Galicia province has the largest fleet and the highest aquaculture production in Spain. During the surveys it was observed that fishermen generated not only fishing-related debris, but also general litter, i.e. beer cans, cigarette butts, cable ties, adhesive tape roll and fragments, lanterns, foil wrappers, tools, clothes, etc. Wildlife can be injured or killed by discarded fishing lines, hooks and nets (Ocean Conservancy, 2010, 2016; Hardesty et al., 2015) while fishing weights (made of lead, Fig. 5l) are highly toxic if ingested (Haig et al., 2014). Humans and their litter may have been responsible for the death of animals, as has already been demonstrated on numerous occasions in the case of turtles and seabirds (Ocean Conservancy, 2010; Duncan et al., 2017). Dead animals on the beach can also be a biological hazard to other species because they can be a source of food, with lethal consequences (National Geographic, 2019). Microbiological hazards are related to the presence of dead animals and other litter items that can present high amounts of *Escherichia coli* (Philipp, 1993). The bacterium *E. coli* may be associated with dog *faeces*, observed at the end of the study (surveys 6 and 7; beaches no. 2, 4 and 5) when an increase of beach users occurred. A litter increase at the end of the study was probably due to the increase of users (often observed in small groups) and beach recreational activities linked to the improvement in weather conditions (Fig. 3). Additionally, it could also be because an increase of items probably due to fragmentation of plastic pieces mainly made of foam (Fig. 5a).

Nearby coastal settlements are responsible for the sewage-related debris, i.e. sanitary towels (essentially), tampon applicators, cotton bud sticks, eye drops and condoms that accounted for 1.2% of all fresh litter observed. They represent most offensive litter contamination type (Tudor and Williams, 2008) and their presence has been documented on many coasts around the world (Tudor et al., 2002; Munari et al., 2016; Botero et al., 2017; Ocean Conservancy, 2010). Recently, on the Alicante coast, sewage-related debris reached average values of 6.5% (spring) and 2.5% (summer) for all beach litter (Asensio-Montesinos et al., 2019b). Differences compared to this study are mainly due to seasonality, which is related to the number of resident people near the coast, and the number and type of sites studied (e.g. the five beaches investigated were far from rivers or streams and villages or cities).

Finally, in some cases, identification of labels on the litter (Kei, 2005; Smith et al., 2018; Asensio-Montesinos et al., 2020b; Ryan, 2020) showed a foreign origin. Several plastic cap/lids were found with different inscriptions in Arabic and Chinese languages (Fig. 5f). In the first case, Arabic bottle caps may come from ships (Ryan, 2020) or could also be transported by currents from their country of origin, e.g. Morocco, Algeria or Tunisia. In the second case, Chinese bottle caps may come from Chinese ships (Ryan, 2020), which cross the Mediterranean Sea through important routes such as the Suez Canal and the Strait of Gibraltar. The same model of Chinese bottle cap (Fig. 5f) was found on the beaches of New South Wales, Australia (Smith et al., 2018) and recently on the west coast of Svalbard (Falk-Andersson et al., 2021).

### 4.2. Distribution patterns of beach litter

Accumulation rates recorded within this study were lower than reported in Corfu Island (Ionian Sea, Central Mediterranean), Cape Town (South Africa), and Cousine Island (Seychelles, Prevenios et al., 2018; Chitaka and von Blottnitz, 2019; Dunlop et al., 2020) and were, together with litter patterns, clearly influenced by both anthropogenic and environmental factors.

On the one hand, the type of users determines litter categories and the number of users determines litter abundance, but management (through clean-up operations) can help to reduce the amount of litter. On the other hand, environmental factors have a major impact in litter distribution. The capacity of litter to recolonize natural beaches within a short time period was also reported by Williams and Tudor (2001). For example, the high buoyancy of plastics and sea-storms, e.g. before survey 3, favoured their transport across the sea surface to the coast (Table 2). Wind is another relevant factor in litter distribution. Eriksson et al. (2013) also demonstrated that the combined effects of environmental factors such as maximum tide height and wind speed and direction are related to variation in daily litter accumulation rates. During the study period, the highest wind speed values were recorded in the first month and mostly blew from inland (max. wind speed: 19.3 m/s from WNW direction), resulting in a considerable number of foamed plastic fragments observed in survey 2 (Table 2). According to the Beaufort Scale, wind at these velocities “breaks twigs off trees, generally impedes progress and the wave crests begin to break into spindrift”.

Beaches no. 1 and 2 were managed during the study period by the municipal services. Cleaning actions were carried out and consisted of emptying of litter bins and occasionally in removal by hand of the largest visible items. This would explain the disappearance of gross litter and other items of a considerable size, such as bottles or fish boxes (Fig. 5b, c). For example, at survey 3 on beach no. 1, of the 36 plastic bottles counted, only 4 of them were observed again at the following survey. In addition, as observed in one case, isolated beach users performed individual removal of beach litter of some of the bulkiest items, such as large bottles of water. The abundance of some litter categories changed over the study period due to storm occurrence and the abundance of beach users. As an example, concerning storms, 41 new bottles appeared after the storm that took place in early January (survey 3, Table 2).

When a certain amount of litter appeared on the beach, over time this same amount tends to decrease and generally small items from previous surveys tend to remain (Fig. 4, Table S3). Different dynamics of the recorded litter was observed:

(i) there were litter items that once observed remained on the beach during the whole study period;
(ii) few litter items were observed on the beach only once;

(iii) others items appeared and remained for several weeks and then disappeared;
(iv) some litter observed on the beach on a certain day disappeared weeks later and was seen again some time later (some litter presented this trend more than once, i.e. October 2021 some marked litter such as small plastic fragments and processed wood still remained on the studied beaches);
(v) few floating litter observed from the beach, disappeared and were seen again weeks later on another beach.

In the first case/example, items that remained on the beach were small, heavy and had negative buoyancy (e.g. metal and glass fragments). In the second and third cases, beach litter disappeared because it was removed by people or buried into the sediment (Fig. 5j), transported away by wind or waves, or simply was not seen by observers [e.g. during survey 4 (28th January 2021) on beach no. 1, a film plastic piece marked in blue colour was observed inside a litter bin (that came from survey 2 carried out on 28th December 2020), Fig. 5k]. The fourth case can be related to the last three circumstances mentioned above. The fifth case demonstrates that litter may be exchanged between nearby or adjacent beaches. In survey 3 of beaches no. 1 and 2, two wood fragments were marked (in green) on each beach, two weeks later (survey 4), no wood fragments were observed on beach no. 1 and the three wood fragments appeared on beach no. 2 (Table S3). This is supported by coastal orientation, NE–SW aligned, and oceanographic data. The prevailing approaching wave direction before the third and fourth surveys was from the SSE, confirming the possible movement of items from beach no. 1 to beach no. 2 (Fig. 3).

Litter buried on a beach has often been underestimated. Some studies have shown that a large proportion of beach litter remains buried in the sediment before being exhumed (Williams and Tudor, 2001; Lavers and Bond, 2017). Litter fragments frequently become buried and are later exhumed on beaches, with smaller fragments tending to remain in the sediments for longer periods (Kusui and Noda, 2003). A lot of beach surveys have ignored the litter buried in the sediments because appropriate survey methods have been lacking, and very few studies have sampled buried litter (Kusui and Noda, 2003). Some researchers have applied methods for surveying litter buried in the sand (Ogi and Fukumoto, 2000; Kusui and Noda, 2003; Ryan et al., 2009; Lavers and Bond, 2017) but on cobble beaches it is more difficult to carry out this type of sampling. A substantial proportion of beach litter may be buried: e.g. in Henderson Island, 68% of beach debris (<10 cm), was buried in the sediment (Lavers and Bond, 2017), while in the beaches of Senegal the density of buried litter was 25 times higher than at the beach surface (Tavares et al., 2020). A notable decrease in the number of litter items observed between successive surveys, e.g. from S6 to S7, Fig. 4 could be largely due to the burial of many of these items within the cobbles, but other factors such as personal recollections by beach visitors or environmental factors may also play an important role. The present study has demonstrated the burial and exhumation of some specific litter items such as hard plastic pieces, foamed plastic pieces, plastic and metal caps/lids, film plastic pieces, metal fragments, rubber fragments, etc. However, during surveys, it is difficult to know exactly which items first seen were buried. Some labelled litter were buried and then were exhumed, these form part of the remaining litter, as can be seen in Fig. 4 and Table S1.

Changes in litter quantity between surveys five to six, illustrate the process of exhumation.

- Beach 1, green coated litter increases. Mainly hard plastic pieces, film plastic pieces, and metal/plastic bottle caps.
- Beach 2, green coated litter increases. E.g. foamed plastic pieces, caps/lids, foil wrappers, string and cord.
- Beach 3, red, blue and orange coated litter increases. E.g. fragments (foamed plastic, rubber, film plastic), tubes, cables and sanitary towels.
- Beach 4 orange coated litter disappears in survey 6 but reappears in survey 7. E.g. fragments (metal, foamed plastic and rubber).
- Beach 5, green coated litter increases. E.g. fragments (metal, paper, film and foamed plastic) and shoe insoles.

Beach accumulation surveys can be used to estimate litter flows into the marine environment, but litter inputs from the sea can be influenced by numerous factors, including weather conditions, ocean currents and coastal geomorphology (Anfuso et al., 2011; Chitaka and von Blottnitz, 2019). The complex coastal morphology of the study area (e.g. the presence of headlands and extended rock shore platforms) determines the sheltering of some beaches to wind, waves action and litter inputs not associated with longshore currents. For example, beaches no. 3 and 5 are pocket beaches (Fig. 2) only directly affected by wind/wave approaching from a limited range of directions because they are protected by headlands and submerged rock shore platforms. Such structures divide the coast into sectors or basic units also named morphological “cells” (Anfuso et al., 2011). Cells are usually limited by natural features (e.g., a promontory) or human structures (e.g., a port) and may include coastal stretches belonging to different municipalities, provinces or countries. The interaction between wave propagation patterns and limits of a cell (typology, dimensions, etc.) determines the distribution of erosion/accretion areas within a cell (Anfuso et al., 2011, 2014). Similarly, longshore distribution patterns of beach litter are also controlled by coastal compartmentalisation. Two of the main morphological cells observed in this study (Alicante Cape-South of Serra Gelada and Northeast of Serra Gelada-Toix Cape, Fig. 1) are separated by a natural limit (i.e. Serra Gelada mountain, Benidorm) that gives rise to cliffs more than 400 m high covering 6 km of coast between the bays of Benidorm and Altea (Yébenes et al., 2002). Several sub-cells are created within these two cells due to the emplacement of anthropogenic structures (such as harbours and breakwaters), which form artificial fixed limits that allow only a one-way transport of floating litter (Fig. 1). In the first cell (from Alicante Cape to Serra Gelada mountain), litter transport between beach no. 1 and no. 2 occurs because there are no natural or anthropogenic structures that prevent it (Fig. 1). Among beaches no. 2, 3 and 4 it is more difficult for litter items to move because there are small headlands that act as retaining barriers (Figs. 1 and 2). In the second cell (from Serra Gelada mountain to Toix Cape, Fig. 1), beach no. 5 is very far away from the rest. It is very difficult for litter to be transported from one of the first four beaches to the latter (or vice versa) because beach no. 5 is separated from the rest by the Serra Gelada sea cliffs and, secondarily, by anthropogenic structures such as harbours and breakwaters located in “La Vila Joiosa”, “Benidorm” and “Altea” municipalities.

### 4.3. Litter influences: human and environmental factors

Previous observations regarding the abundance and composition of litter and relationships with human and environmental factors were supported by statistical analyses using nMDS and cluster, which are suitable to compare litter composition in different areas (Tudor et al., 2002; Rech et al., 2014; Rangel-Buitrago et al., 2018; Asensio-Montesinos et al., 2019b).

Beach litter composition was similar for beaches no. 1 and 2 due to the similarities between these two beaches. Both are rural beaches where the same beach activities are carried out (angling, picnicking, etc.). Beach no. 3 is different from the rest since it receives few visitors because it is not very popular and presents a difficult access. Moreover, being a small pocket beach bordered by headlands, it receives little inputs from longshore transport. Beach no. 4 has very distinctive geomorphological and usage characteristics that differ from the rest. Beach no. 5 is the most similar, from a morphological point of view, to beach no. 3, but records more visitors, so the nMDS analysis groups beach no. 5 close to beaches no. 1 and 2. Regarding surveys, initially they are less similar as there is less litter on the beach, but as new inputs

linked to storm events or beach use take place, the similarities increase between samples. Generally, the last surveys (6 and 7) tend to be similar in all beaches, but in beach no. 3, due to the increase of specific litter related to beach users, e.g. cigarette butts due to the improvement of weather conditions. This observation can be explained by the fact that beach no. 3 is by far the most remote of all sampled beaches and thus, no or little increment of beach users was to be expected.

A strong storm had important implications for litter composition in some beaches. This is observed in survey 3 of beach no. 4, where erosional processes at the cliff base linked to the storm could have removed a large part of the beach litter, resulting in the lowest accumulation rate reported in this beach during the study. Also, survey 3 of beach no. 3 recorded the arrival of fresh litter, which was quite different from other surveys and constituted the largest accumulation rate reported in this beach during the study. A storm might have the capacity to increase the input of litter to the beach simulating the cases of other beaches that have important inputs from other sources, such as beach users. The effect of beach storms seems to be more important in narrow beaches and ones that are more remote.

The analysis of the structure of the total litter showed connections by beach and survey. Trends were similar to those observed in the analyses for fresh litter but in this case, groupings by beach are clearer and there is less overlap between points (Fig. 6). Survey 1 is the most different due to the short-period accumulation time. As litter accumulates through time the composition of beaches no. 1, 2, 4 and 5 tend to become similar and related to beach users' presence and high litter abundance. Generally, remote beaches had more unique characteristics that differentiate them from the rest except when there is an increase in the number of beach users. Surveys that most differ from the rest were usually the first ones (surveys 1 and 2, Fig. 7) because the beaches were cleaned at the beginning of the study and they had little accumulated litter. Both analyses (nMDS and Cluster) coincide in the grouping patterns according to litter composition and abundance. Therefore, both methods have been demonstrated to be useful in perceiving differences and similarities between surveys and beaches. This is very useful to relate litter presence with factors such as users, beach use, occurrence of storms, etc.

## 5. Conclusions

This study shows the behaviour of litter on five cobble beaches and its relationship with human and environmental parameters. The understanding of beach litter inputs and dynamics on this type of natural beaches, which are increasingly valued and visited by users, will allow better coastal management measures to improve their current environmental status. This research has shown that on the beaches investigated, when beach users are not very abundant, litter accumulates in small amounts (2 items·day$^{-1}$·100 m$^{-1}$). Observations carried out in this paper show that much of the recorded litter consisted of buried items that later were exhumed. Litter burial and exhumation processes on cobble beaches are recurrent, so litter should be removed as soon as possible to avoid burial and subsequent exhumation. Energetic storms bring fresh litter from the sea generally contributing to the increase of specific litter categories, such as plastic bottles. People are also responsible for the appearance of other specific litter items on remote and rural beaches. While some people such as fishermen and other marine users discard litter of different materials and sizes (fishing line, cigarette butts, small and large plastic bags, single-use plastics, hairbands, pens, lanterns, drinks, food containers, etc.), other people such as cleaners and volunteers, collect it. However, during the period of this research, an imbalance was observed in the area investigated and litter amounts increased because i) clean-up operations are not frequently carried out; ii) usually litter items removed included only those observed on the beach surface and iii) recollected litter during the clean-up operations includes only the largest and most visible items (e.g., bottles, large bags, etc.). Therefore, smaller items are expected to remain buried or embedded within cobbles for long periods while larger items are expected to have a limited life because they are likely to be removed by waves and currents and during beach clean-up operations. The type of litter material is also an influencing factor, as heavier and more durable items such as glass or metal will tend to stay on the beach longer than lighter and less durable items such as plastic. Even when appropriate clean-up activities are carried out, some litter items composed of different sizes and materials remain for several weeks, even months, especially small items.

The best way to achieve a clean cobble beach is to prevent litter from reaching it. Litter will continue to appear on the beach surface because of exhumation and supplies from the sea (or land) to the shore, so clean-up actions are essential. Indeed, more specific measures can be taken to prevent direct dumping of litter by beach users, and at the same time, to avoid subsequent burial of beach litter. Regarding management actions, it is possible to make some recommendations to reduce beach pollution, according to results obtained in this work. Occasionally, more precise clean-up actions could be carried out, in which smaller litter is collected and not ignored. Education is the key and the promotion of a responsible behaviour can help to reduce the amount of litter ending up in the coastal environment. Sound environmental management of recreational activities should be mandatory and in remote and rural beaches: angling, picnicking and camping should be controlled. In many cases, these activities are practised by beach users in the same day. It essentially requires better enforcement of existing laws to prevent pollution and inform and punish polluters. Beach fines could be the answer to change beach users' erroneous behaviours. More restrictive laws and environmental campaigns focused on fishermen and other kinds of users are also required.

Lastly, in future similar studies, the sampling period between successive surveys (two weeks) could be reduced since the wave climate changes very rapidly and beach users' abundance varies greatly, strongly conditioning the quantity and typology of daily accumulated litter.

## CRediT authorship contribution statement

Conceptualization, A.-T.W.; Data curation and Investigation, F.A.-M.; Funding acquisition and Resources, C.S.-L.; Methodology and Software, F.A.-M. and C.S.-L.; Supervision and Validation, G.A. and A.-T.W.; Visualization, G.A. Writing - original draft, F.A.-M. and G.A.; Writing - review & editing, A.-T.W and C.S.-L.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpolbul.2021.113106.

## References


Alfaro, P., Andreu, J.M., Estévez, A., Pina, J.A., Yébenes, A., 2008. Itinerarios Geológicos Por la Provincia de Alicante. In: Publicaciones de la Universidad de Alicante, Alicante, Spain; p, p. 317.

Alicante, Ecoplaya, 2020. Red de voluntarios de limpieza de playas en Alicante. Available online. (Accessed 26 May 2021).

Alkalay, R., Pasternak, G., Zask, A., 2007. Clean-coast index—a new approach for beach cleanliness assessment. Ocean Coast. Manag. 50 (5–6), 352–362.

Anfuso, G., Pranzini, E., Vitale, G., 2011. An integrated approach to coastal erosion problems in northern Tuscany (Italy): Littoral morphological evolution and cell distribution. Geomorphology 129 (3–4), 204–214.

Anfuso, G., Martinez-del-Pozo, J.A., Rangel-Buitrago, N., Nachite, D., 2014. Morphological cells along the Ragusa littoral (Sicily, Italy). Geomorphol. Relief Process. Environ. 3, 203–218.

Anfuso, G., Bolívar-Anillo, H.J., Asensio-Montesinos, F., Portantiolo Manzolli, R., Portz, L., Villate Daza, D.A., 2020. Beach litter distribution in Admiralty Bay, King George IslandAntarctica, 160, 111657.

Asensio-Montesinos, F., Anfuso, G., Corbí, H., 2019. Coastal scenery and litter impacts at Alicante (SE Spain): management issues. J. Coast. Conserv. 23 (1), 185–201.

Asensio-Montesinos, F., Anfuso, G., Randerson, P., Williams, A.T., 2019. Seasonal comparison of beach litter on Mediterranean coastal sites (Alicante, SE Spain). Ocean Coast. Manag. 181, 104914.

Asensio-Montesinos, F., Anfuso, G., Oliva Ramírez, M., Smolka, R., García Sanabria, J., Fernández Enríquez, A., Macías Bedoya, A., 2020. Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain). Reg. Stud. Mar. Sci. 34, 101050.

Asensio-Montesinos, F., Oliva Ramírez, M., González-Leal, J.M., Carrizo, D., Anfuso, G., 2020. Characterization of plastic beach litter by Raman spectroscopy in South-Western Spain. Sci. Total Environ. 744, 140890.

Azzarello, M.Y., Van Vleet, E.S., 1987. Marine birds and plastic pollution. Mar. Ecol. Prog. Ser. 37 (2/3), 295–303.

Belmonte, A., Ruiz, J.M., Uriarte, A., Giménez, F., 2001. Methodological approach to the study and "follow-up" of an environmental impact study (EIS) of aquaculture in the open sea. Available online. In: Uriarte, A., Basurco, B. (Eds.), Environmental impact assessment of Mediterranean aquaculture farms, 2001. CIHEAM, Zaragoza, pp. 91–100.

Bergmann, M., Gutow, L., Klages, M., 2015. Marine anthropogenic litter. In: Springer Nature, p. (p. 447)..

Biber, N.F., Foggo, A., Thompson, R.C., 2019. Characterising the deterioration of different plastics in air and seawater. Mar. Pollut. Bull. 141, 595–602.

Blott, S.J., Pye, K., 2012. Particle size scales and classification of sediment types based on particle size distributions: review and recommended procedures. Sedimentology 59 (7), 2071–2096.

Botero, C., Anfuso, A., Williams, A.T., Palacios, A., 2013a. Perception of coastal scenery along the Caribbean littoral of Colombia. In: Conley, D.C., Masselink, G., Russell, P. E., O'Hare, T.J. (Eds.), Proceedings 12th International Coastal Symposium (Plymouth, England), Journal of Coastal Research, Special Issue No. 65, pp. 1733–1738.

Botero, C., Anfuso, G., Williams, A.T., Zielinski, S., Da Silva, C.P., Cervantes, O., Cabrera, J.A., 2013b. Reasons for beach choice: European and Caribbean perspectives. J. Coast. Res. 65, 880–885.

Botero, C.M., Anfuso, G., Milanes, C., Cabrera, A., Casas, G., Pranzini, E., Williams, A.T., 2017. Litter assessment on 99 Cuban beaches: a baseline to identify sources of pollution and impacts for tourism and recreation. Mar. Pollut. Bull. 118 (1–2), 437–441.

Bowman, D., Manor-Samsonov, N., Golik, A., 1998. Dynamics of litter pollution on Israeli Mediterranean beaches: a budgetary, litter flux approach. J. Coast. Res. 418–432.

Bray, J.R., Curtis, J.T., 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr. 27 (4), 325–349.

Campbell, M.L., Peters, L., McMains, C., de Campos, M.C.R., Sargisson, R.J., Blackwell, B., Hewitt, C.L., 2019. Are our beaches safe? Quantifying the human health impact of anthropogenic beach litter on people in New Zealand. Sci. Total Environ. 651, 2400–2409.

Chitaka, T.Y., von Blottnitz, H., 2019. Accumulation and characteristics of plastic debris along five beaches in Cape Town. Mar. Pollut. Bull. 138, 451–457.

Coe, J.M., Rogers, D., 2012. Marine debris: sources, impacts, and solutions. Springer Science & Business Media.

Conservancy, Ocean, 2010. Trash travels: from our hands to the sea, around the globe, and through time. In: International Coastal Cleanup, 2010 Report, ISBN 978-0-615-34820-9.

Conservancy, Ocean, 2016. 30th Anniversary International Coastal Cleanup Ocean Conservancy, Washington DC, 2016.

Davies, J.L., 1964. A morphogenic approach to world shorelines. Z. Geomorphol. 127–142.

Diputación Provincial de Alicante (DPA), 2010. In: Senderos de la Arena. Guía de Playas de la Provincia de Alicante. Diputación de Alicante, Área de Medio Ambiente, Alicante, Spain, p. 248.

Duncan, E.M., Botterell, Z.L., Broderick, A.C., Galloway, T.S., Lindeque, P.K., Nuno, A., Godley, B.J., 2017. A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. Endanger. Species Res. 34, 431–448.

Dunlop, S.W., Dunlop, B.J., Brown, M., 2020. Plastic pollution in paradise: daily accumulation rates of marine litter on Cousine IslandSeychelles, 151, 110803.

EA/NALG, 2000. In: Assessment of Aesthetic Quality of Coastal and Bathing Beaches. Monitoring Protocol and Classification Scheme. Environment Agency and The National Aquatic Litter Group, London, p. 15.

Earll, R.C., Moore, J., Williams, A.T., 1999. The Measurement of Oily Waste and Garbage Disposed of into the Marine Environment by Shipping. Great Britain, Maritime and Coastguard Agency.

Eriksson, C., Burton, H., Fitch, S., Schulz, M., van den Hoff, J., 2013. Daily accumulation rates of marine debris on sub-Antarctic island beaches. Mar. Pollut. Bull. 66 (1–2), 199–208.

Europe, Plastics, 2020. Plastics – the Facts 2020. An analysis of European plastics production, demand and waste data. In: Plastics Europe (64 pp).

Falk-Andersson, J., Tairova, Z., Drægni, T.T., Haarr, M.L., 2021. Methods for determining the geographical origin and age of beach litter: Challenges and opportunities. Marine Pollution Bulletin 172, 112901.

Gago, J., Lahuerta, F., Antelo, P., 2014. Characteristics (abundance, type and origin) of beach litter on the Galician coast (NW Spain) from 2001 to 2010. Sci. Mar. 78 (1), 125–134.

Garrity, S.D., Levings, S.C., 1993. Marine debris along the Caribbean coast of Panama. Mar. Pollut. Bull. 26 (6), 317–324.

Geographic, National, 2019. Cada vez más gente come animales marinos muertos, con consecuencias letales. Available online. https://www.nationalgeographic.es/medio-ambiente/2019/05/cada-vez-mas-gente-come-animales-marinos-muertos-con-consecuencias-mortales. (Accessed 29 April 2021).

GESAMP, 2019. Guidelines for the monitoring and assessment of plastic litter and microplastics in the ocean, 130pp. In: Kershaw, P.J., Turra, A., Galgani, F. (Eds.), GESAMP Reports and Studies, No. 99. GESAMP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection, London, UK. https://doi.org/10.25607/OBP-435.

Golik, A., Gertner, Y., 1992. Litter on the Israeli coastline. Mar. Environ. Res. 33 (1), 1–15.

Groenen, P.J., van de Velden, M., 2005. Multidimensional scaling. In: Encyclopaedia of statistics in behavioural science.

Haig, S.M., D'Elia, J., Eagles-Smith, C., Fair, J.M., Gervais, J., Herring, G., Schulz, J.H., 2014. The persistent problem of lead poisoning in birds from ammunition and fishing tackle. Condor 116 (3), 408–428.

Hardesty, B.D., Good, T.P., Wilcox, C., 2015. Novel methods, new results and science-based solutions to tackle marine debris impacts on wildlife. Ocean Coast. Manag. 115, 4–9.

Houston, J.R., 2018. The economic value of America's beaches—a 2018 update. Shore & Beach 86 (2), 3–13.

Iváñez-Rugero, B., 2020. Problemas Ambientales e Impacto Ambiental en el Litoral del Municipio de El Campello (Alicante). In: Universidad de Alicante, Trabajo Fin de Grado, p. 81.

Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Law, K.L., 2015. Plastic waste inputs from land into the ocean. Science 347 (6223), 768–771.

Kako, S.I., Isobe, A., Magome, S., 2010. Sequential monitoring of beach litter using webcams. Mar. Pollut. Bull. 60 (5), 775–779.

Kataoka, T., Hinata, H., Kato, S., 2013. Analysis of a beach as a time-invariant linear input/output system of marine litter. Mar. Pollut. Bull. 77 (1–2), 266–273.

Kaviarasan, T., Naik, S., Sivadas, S.K., Dhineka, K., Sambandam, M., Sivyer, D., Murthy, M.R., 2020. Assessment of litter in the remote beaches of Lakshadweep IslandsArabian Sea, 161, 111760.

Kei, K., 2005. In: Beach Litter in Amami Islands, Japan, 26. South Pacific Studies, pp. 15–24.

Krelling, A.P., Williams, A.T., Turra, A., 2017. Differences in perception and reaction of tourist groups to beach marine debris that can influence a loss of tourism revenue in coastal areas. Mar. Policy 85, 87–99.

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 (1–6), 175–179.

Laist, D.W., 1997. Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In: Marine Debris. Springer, New York, NY, pp. 99–139.

Lavers, J.L., Bond, A.L., 2017. Exceptional and rapid accumulation of anthropogenic debris on one of the world's most remote and pristine islands. Proc. Natl. Acad. Sci. 114 (23), 6052–6055.

Maiklem, L., 2020. Mudlarking: Lost and Found on the River Thames. Bloomsbury.

Mark, J.E., 1998. Polymer Data Handbook. Oxford University Press, Inc.

Masselink, G., Short, A.D., 1993. The effect of tide range on beach morphodynamics and morphology: a conceptual beach model. J. Coast. Res. 785–800.

McKenna, J., Williams, A.T., Cooper, J.A.G., 2011. Blue flag or red herring: do beach awards encourage the public to visit beaches? Tour. Manag. 32 (3), 576–588.

Munari, C., Corbau, C., Simeoni, U., Mistri, M., 2016. Marine litter on Mediterranean shores: analysis of composition, spatial distribution and sources in north-western adriatic beaches. Waste Manag. 49, 483–490.

Nachite, D., Maziane, F., Anfuso, G., Williams, A.T., 2019. Spatial and temporal variations of litter at the Mediterranean beaches of Morocco mainly due to beach users. Ocean Coast. Manag. 179, 104846.

Ogi, H., Fukumoto, Y., 2000. A sorting method for small plastic debris floating on the sea surface and stranded on sandy beaches. In: Bulletin of the Faculty of Fisheries, 51. Hokkaido University, pp. 71–93, 2.

Opfer, S., Arthur, C., Lippiatt, S., 2012. NOAA Marine Debris Shoreline Survey Field Guide. US National Oceanic and Atmospheric Administration Marine Debris Program.

OSPAR Commission, 2010. Guideline for monitoring marine litter on the beaches in the OSPAR maritime area.

Pemberton, D., Brothers, N.P., Kirkwood, R., 1992. Entanglement of Australian fur seals in man-made debris in Tasmanian waters. Wildl. Res. 19 (2), 151–159.

Philipp, R., 1993. Community needlestick accident data and trends in environmental quality. Public Health 107 (5), 363–369.

Prevenios, M., Zeri, C., Tsangaris, C., Liubartseva, S., Fakiris, E., Papatheodorou, G., 2018. Beach litter dynamics on Mediterranean coasts: distinguishing sources and pathways. Mar. Pollut. Bull. 129 (2), 448–457.
Rangel-Buitrago, N., Gracia, A., Vélez-Mendoza, A., Mantilla-Barbosa, E., Arana, V.A., Trilleras, J., Arroyo-Olarte, H., 2018. Abundance and distribution of beach litter along the Atlantico department, Caribbean coast of Colombia. Mar. Pollut. Bull. 136, 435–447.
Rech, S., Macaya-Caquilpán, V., Pantoja, J.F., Rivadeneira, M.M., Madariaga, D.J., Thiel, M., 2014. Rivers as a source of marine litter–a study from the SE Pacific. Mar. Pollut. Bull. 82 (1–2), 66–75.
Rech, S., Borrell, Y., García-Vazquez, E., 2016. Marine litter as a vector for non-native species: what we need to know. Mar. Pollut. Bull. 113 (1–2), 40–43.
Rouillard, P., Espinosa, A., Moratalla, J., 2014. Villajoyosa antique (Alicante, Espagne): Territoire et topographie. In: Le sanctuaire de La Malladeta, Vol. 141. Casa de Velázquez.
Ryan, P.G., 2020. Land or sea? What bottles tell us about the origins of beach litter in Kenya. Waste Manag. 116, 49–57.
Ryan, P.G., Moore, C.J., Van Franeker, J.A., Moloney, C.L., 2009. Monitoring the abundance of plastic debris in the marine environment. Philos. Trans. R. Soc. B: Biol. Sci. 364 (1526), 1999–2012.
Sánchez-Lizaso, J.L., Guillén, J.E., Ramos, A.A., Aranda, A., Bayle, J.T., 1994. Áreas marinas protegidas de la Comunidad Valenciana. Necesidad y Objetivos. In: Honrubia, En J. (Ed.), (Coord.) La Comunitat Valenciana en l'Europa Unida Tomo XI. Generalitat Valenciana, pp. 43–48.
Sheavly, S.B., Register, K.M., 2007. Marine debris & plastics: environmental concerns, sources, impacts and solutions. J. Polym. Environ. 15 (4), 301–305.
Simeonova, A., Chuturkova, R., 2019. Marine litter accumulation along the bulgarian Black Sea coast: categories and predominance. Waste Manag. 84, 182–193.
Smith, S.D.A., Banister, K., Fraser, N., Edgar, R.J., 2018. Tracing the source of marine debris on the beaches of northern New South Wales, Australia: the bottles on beaches program. Mar. Pollut. Bull. 126, 304–307.
Tavares, D.C., Moura, J.F., Ceesay, A., Merico, A., 2020. Density and composition of surface and buried plastic debris in beaches of Senegal. Sci. Total Environ. 737, 139633.
Tomás, A., Méndez, F.J., Medina, R., Losada, Í.J., Menéndez, M., Liste, M., 2004. Bases de datos de oleaje y nivel del mar, calibración y análisis: el cambio climático en la dinámica marina en España. In: El Clima entre el Mar y la Montaña, 2004. Asociación Española de Climatología y Universidad de Cantabria, Cantabria, Spain.
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.
Tudor, D.T., Williams, A.T., 2004. Development of a 'Matrix scoring technique' to determine litter sources at a Bristol Channel beach. J. Coast. Conserv. 10 (1), 119–127.
Tudor, D.T., Williams, A.T., 2008. Important aspects of beach pollution to managers: Wales and the Bristol Channel, UK. J. Coast. Res. 24 (3 (243)), 735–745.
Tudor, D.T., Williams, A.T., Randerson, P., Ergin, A., Earll, R.E., 2002. The use of multivariate statistical techniques to establish beach debris pollution sources. J. Coast. Res. 36, 716–725.
Turner, A., 2020. Foamed polystyrene in the marine environment: sources, additives, transport, behavior, and impacts. Environmental Science & Technology 54 (17), 10411–10420.
UNEP, 2005. Marine Litter: An Analytical Overview. In: United Nations Environment Programme, Nairobi, Kenya, p. 58.
UNEP, 2009. Marine Litter: A Global Challenge. In: United Nations Environment Programme, Nairobi, Kenya, p. 232.
Vlachogianni, Th., 2019. Assessing Marine Litter on Mediterranean Beaches. Filling in the knowledge gaps via a participatory-science initiative, MIO-ECSDE.
Vlachogianni, T., Fortibuoni, T., Ronchi, F., Zeri, C., Mazziotti, C., Tutman, P., Scoullos, M., 2018. Marine litter on the beaches of the adriatic and ionian seas: an assessment of their abundance, composition and sources. Mar. Pollut. Bull. 131, 745–756.
Vlachogianni, T., Skocir, M., Constantin, P., Labbe, C., Orthodoxou, D., Pesmatzoglou, I., Scoullos, M., 2020. Plastic pollution on the Mediterranean coastline: generating fit-for-purpose data to support decision-making via a participatory-science initiative. Sci. Total Environ. 711, 135058.
Wade, B.A., Morrison, B., Jones, M.A.J., 1991. A study of beach litter in Jamaica. Caribb. J. Sci. 27 (3–4), 190–197.
Wallace, N., 1985. Debris entanglement in the marine environment: a review. In: Proceedings of the Workshop on the Fate and Impact of Marine Debris. NOAA Technical Memo. NMFS, NOAA-TM-MMFS-SWFC-54. US Department of Commerce, Honolulu, Hawaii, pp. 259–277.
Whiting, S.D., 1998. Types and sources of marine debris in fog bayNorthern Australia, 36 (11), 904–910.
Williams, A.T., 2011. Definitions and typologies of coastal tourism destinations. In: Jones, A., Phillips, M. (Eds.), Disappearing Destinations: Climate Change and Future Challenges for Coastal Tourism. CABI, UK, pp. 47–66.
Williams, A.T., Micallef, A., 2009. Beach Management. Principles and Practice. Earthscan, London, ISBN 978-1-84407-435-8, 480 pp.
Williams, A.T., Rangel-Buitrago, N., 2019. Marine litter: solutions for a major environmental problem. J. Coast. Res. 35 (3), 648–663.
Williams, A.T., Simmons, S.L., 1997. Estuarine litter at the river/beach interface in the Bristol Channel, United Kingdom. J. Coast. Res. 1159–1165.
Williams, A.T., Simmons, S.L., 1997. Movement patterns of riverine litter. Water Air Soil Pollut. 98 (1), 119–139.
Williams, A.T., Tudor, D.T., 2001. Litter burial and exhumation: spatial and temporal distribution on a cobble pocket beach. Mar. Pollut. Bull. 42 (11), 1031–1039.
Williams, A.T., Pond, K., Ergin, A., Cullis, M.J., 2013. The hazards of beach litter. In: Coastal Hazards. Springer, Dordrecht, pp. 753–780.
Wright, L.D., Short, A.D., Boon Iii, J.D., Hayden, B., Kimball, S., List, J.H., 1987. The morphodynamic effects of incident wave groupiness and tide range on an energetic beach. Mar. Geol. 74 (1–2), 1–20.
Yébenes, A., Alfaro, P., Delgado, J., Estévez, A., Soria, J.M., 2002. Sea cliffs resulting from late miocene extensional tectonics: the Serra gelada case study (Betic cordillera, Spain). Geomorphology 42 (3–4), 197–211.

# SUPPORTING INFORMATION TO

## Litter behaviour on Mediterranean cobble beaches, SE Spain

Francisco Asensio-Montesinos, Giorgio Anfuso, Allan Thomas Williams, Carlos Sanz-Lázaro

**Table S1**. Number of total litter, fresh litter and remaining litter.

| | Beach no. and name | Survey 1 | Survey 2 | Survey 3 | Survey 4 | Survey 5 | Survey 6 | Survey 7 | Total |
|---|---|---|---|---|---|---|---|---|---|
| Total litter | 1. Lloma de Reixes | 65 | 226 | 406 | 105 | 202 | 255 | 301 | 1560 |
| | 2. Carritxar | 18 | 70 | 102 | 61 | 148 | 164 | 189 | 752 |
| | 3. Xarco–Caleta | 9 | 20 | 30 | 27 | 21 | 45 | 44 | 196 |
| | 4. Malladeta | 34 | 48 | 38 | 42 | 52 | 101 | 93 | 408 |
| | 5. Racó del Corb | 24 | 29 | 80 | 63 | 82 | 129 | 95 | 502 |
| | Total: | 150 | 393 | 656 | 298 | 505 | 694 | 722 | 3418 |
| Fresh litter | 1. Lloma de Reixes | 65 | 186 | 347 | 67 | 144 | 151 | 176 | 1136 |
| | 2. Carritxar | 18 | 65 | 86 | 42 | 122 | 108 | 111 | 552 |
| | 3. Xarco–Caleta | 9 | 14 | 24 | 5 | 3 | 17 | 16 | 88 |
| | 4. Malladeta | 34 | 37 | 22 | 29 | 40 | 84 | 59 | 305 |
| | 5. Racó del Corb | 24 | 25 | 65 | 30 | 51 | 77 | 57 | 329 |
| | Total: | 150 | 327 | 544 | 173 | 360 | 437 | 419 | 2410 |
| Remaining litter | 1. Lloma de Reixes | 0 | 40 | 59 | 38 | 58 | 104 | 125 | 424 |
| | 2. Carritxar | 0 | 5 | 16 | 19 | 26 | 56 | 78 | 200 |
| | 3. Xarco–Caleta | 0 | 6 | 6 | 22 | 18 | 28 | 28 | 108 |
| | 4. Malladeta | 0 | 11 | 16 | 13 | 12 | 17 | 34 | 103 |
| | 5. Racó del Corb | 0 | 4 | 15 | 33 | 31 | 52 | 38 | 173 |
| | Total: | 0 | 66 | 112 | 125 | 145 | 257 | 303 | 1008 |

**Table S2.** Litter accumulation rates for a 15 day time-span (Fresh litter items per 100 m beach) and daily accumulation rates (Fresh litter items·day$^{-1}$·100 m$^{-1}$).

| Beach no. and name | Cleanup-S1 | S1-S2 | S2-S3 | S3-S4 | S4-S5 | S5-S6 | S6-S7 |
|---|---|---|---|---|---|---|---|
| 1. Lloma de Reixes | 19; 1.6 | 55; 3.7 | 103; 6.9 | 20; 1.2 | 43; 2.9 | 45; 3.0 | 52; 2.9 |
| 2. Carritxar | 7; 0.6 | 25; 1.7 | 33; 2.2 | 16; 1.0 | 47; 3.2 | 42; 2.8 | 43; 2.4 |
| 3. Xarco–Caleta | 18; 1.5 | 28; 1.9 | 48; 3.2 | 10; 0.6 | 6; 0.4 | 34; 2.3 | 32; 1.8 |
| 4. Malladeta | 17; 1.4 | 19; 1.2 | 11; 0.7 | 15; 0.9 | 20; 1.3 | 42; 2.8 | 30; 1.6 |
| 5. Racó del Corb | 21; 1.8 | 22; 1.5 | 58; 3.8 | 27; 1.7 | 45; 3.0 | 68; 4.5 | 50; 2.8 |

**Table S3**. Type of examples (from I to V) described in the text and fresh litter recorded at each survey ("S").

| E.g. | Item | Colour code | Beach no. and name | S1 | S2 | S3 | S4 | S5 | S6 | S7 |
|---|---|---|---|---|---|---|---|---|---|---|
| i) | Cloth piece | Green | 3. Xarco–Caleta | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| i) | Incandescent Light bulb | Green | 3. Xarco–Caleta | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| i) | Metal fragment 2.5 - 50 cm | Green | 3. Xarco–Caleta | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| ii) | Fibreglass fragment | Blue | 1. Lloma de Reixes | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| ii) | Sanitary mask | Yellow | 1. Lloma de Reixes | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| ii) | Diving mask | Red | 4. Malladeta | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| iii) | Small plastic bag | Orange | 2. Carritxar | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| iii) | Tennis ball | Red | 4. Malladeta | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| iii) | Sunglasses | Green | 5. Racó del Corb | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| iv) | Cable | Red | 4. Malladeta | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| iv) | Fibreglass fragment | Red | 3. Xarco–Caleta | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| iv) | Foamed Plastic 2.5 cm > < 50 cm | Red | 5. Racó del Corb | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| v) | Wood fragments 2.5 cm - 50 cm | Green | 1. Lloma de Reixes | 0 | 0 | 2 | 0 | 0 | 0 | 1 |
| v) | Wood fragments 2.5 cm - 50 cm | Green | 2. Carritxar | 0 | 0 | 2 | 3 | 1 | 1 | 1 |
| v) | Drink bottles < 2L | Blue | 1. Lloma de Reixes | 0 | 2 | 1 | 0 | 0 | 0 | 0 |
| v) | Drink bottles < 2L | Blue | 2. Carritxar | 0 | 0 | 1 | 0 | 0 | 0 | 0 |

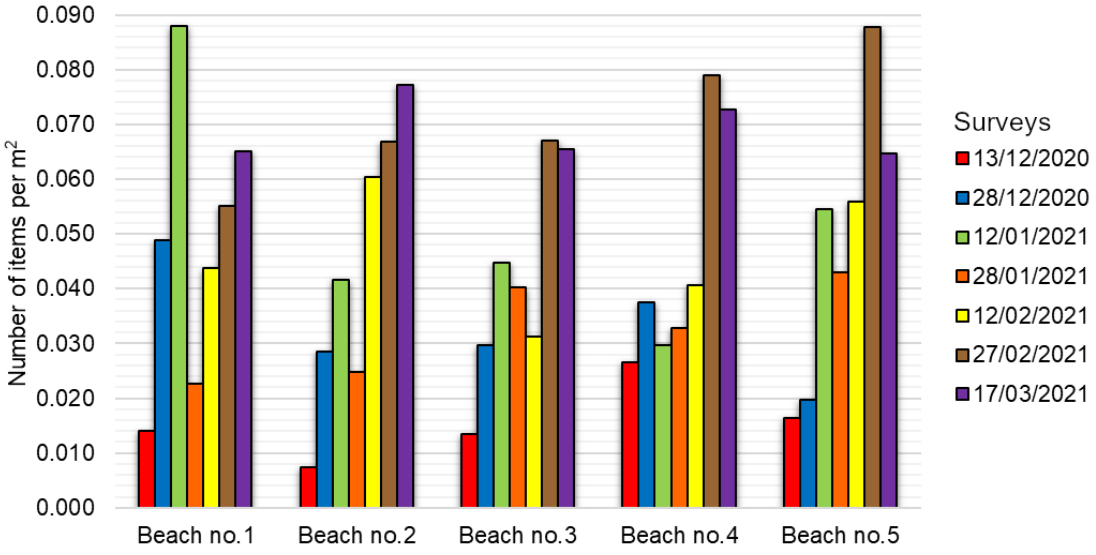
**Table S4**. Summary tables of the similarity matrix (Bray–Curtis distances coefficient matrix) between consecutive surveys for fresh litter and total litter.

| Fresh litter | Beach no. 1 | Beach no. 2 | Beach no. 3 | Beach no. 4 | Beach no. 5 | Total litter | Beach no. 1 | Beach no. 2 | Beach no. 3 | Beach no. 4 | Beach no. 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S1-S2 | 55.9 | 34.6 | 42.5 | 49.0 | 27.1 | S1-S2 | 62.7 | 33.2 | 55.8 | 59.5 | 44.8 |
| S2-S3 | 67.8 | 43.4 | 29.1 | 38.3 | 39.6 | S2-S3 | 68.9 | 50.1 | 47.8 | 56.0 | 53.4 |
| S3-S4 | 53.2 | 44.3 | 28.6 | 36.5 | 52.3 | S3-S4 | 56.9 | 48.5 | 79.6 | 60.3 | 76.1 |
| S4-S5 | 59.3 | 46.0 | 31.7 | 53.8 | 54.1 | S4-S5 | 63.5 | 54.1 | 69.1 | 59.2 | 65.8 |
| S5-S6 | 63.2 | 53.3 | 25.4 | 40.2 | 49.5 | S5-S6 | 75.5 | 66.4 | 71.9 | 44.0 | 71.3 |
| S6-S7 | 62.4 | 57.5 | 55.6 | 52.4 | 60.1 | S6-S7 | 73.2 | 65.1 | 78.9 | 67.3 | 66.3 |

**Table S5**. Number and percentage of fresh fishing–related items per survey respect to total fresh items.

| Beach no. and name | S1 | S2 | S3 | S4 | S5 | S6 | S7 | Total | % |
|---|---|---|---|---|---|---|---|---|---|
| 1. Lloma de Reixes | 5 | 8 | 5 | 5 | 8 | 11 | 21 | 63 | 5.5 |
| 2. Carritxar | 4 | 8 | 7 | 2 | 6 | 6 | 13 | 46 | 8.3 |
| 3. Xarco–Caleta | 1 | 1 | 4 | 0 | 0 | 2 | 1 | 9 | 10.2 |
| 4. Malladeta | 1 | 2 | 2 | 0 | 1 | 7 | 4 | 17 | 5.6 |
| 5. Racó del Corb | 0 | 1 | 3 | 1 | 1 | 5 | 4 | 15 | 4.6 |
| Total: | 11 | 20 | 21 | 8 | 16 | 31 | 43 | 150 | 6.2 |

**Figure S1**. Number of total items/m$^2$ per beach in each survey.



**Anexo IV**

Publicación **IV**.

## Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain)

F. Asensio-Montesinos[1], G. Anfuso[1], M. Oliva Ramírez[2], R. Smolka[1], J. García Sanabria[3], A. Fernández Enríquez[3], P. Arenas[4], A. Macías Bedoya[5]

[1]Departamento de Ciencias de la Tierra, Facultad de Ciencias del Mar y Ambientales, Universidad de Cádiz, Puerto Real, España, Spain

[2]Departamento de Biología Facultad de Ciencias del Mar y Ambientales, Universidad de Cádiz, Puerto Real, España, Spain

[3]Departamento de Historia, Geografía y Filosofía, Facultad de Filosofía y Letras, Cádiz, España, Spain

[4]Departamento de Historia, Geografía y Filosofía, Facultad de Ciencias Sociales y de la Comunicación, Jerez de la Frontera, España, Spain

[5]Departamento de Historia, Geografía y Filosofía, Facultad de Ciencias del Mar y Ambientales, Universidad de Cádiz, Puerto Real, España, Spain

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# Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain)

F. Asensio-Montesinos [a], G. Anfuso [a,*], M. Oliva Ramírez [b], R. Smolka [a], J. García Sanabria [c], A. Fernández Enríquez [c], P. Arenas [d], A. Macías Bedoya [e]

[a] Departamento de Ciencias de la Tierra, Facultad de Ciencias del Mar y Ambientales, Universidad de Cádiz, Puerto Real, España, Spain
[b] Departamento de Biología Facultad de Ciencias del Mar y Ambientales, Universidad de Cádiz, Puerto Real, España, Spain
[c] Departamento de Historia, Geografía y Filosofía, Facultad de Filosofía y Letras, Cádiz, España, Spain
[d] Departamento de Historia, Geografía y Filosofía, Facultad de Ciencias Sociales y de la Comunicación, Jerez de la Frontera, España, Spain
[e] Departamento de Historia, Geografía y Filosofía, Facultad de Ciencias del Mar y Ambientales, Universidad de Cádiz, Puerto Real, España, Spain

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ABSTRACT

A total amount of 16,123 beach litter items, appertaining to 120 litter groups, was identified at 40 bathing areas along the coast of Cádiz, Spain. Selected areas covered remote (5), rural (11), village (13) and urban (11) sites with different morphodynamic states. The observer recorded litter data along 100 m (longshore) coastal sectors, cross-shore extended from the shoreline up to the landward limit of the beach. Litter was quantified at the low tide water level (where 2.1% of the total litter amount was recorded), along the foreshore (7.8%), at the high tide water level (64.2%) and backshore area (25.8%). Litter was dominated by plastics and cloth, related to the activity of beachgoers and wastewater discharges at places close to rivers and tidal creeks mouths. Specific location and morphodynamic characteristics of each site, number of users and clean-up operations were important factors that determined the content of beach litter.

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## 1. Introduction

Any manufactured or processed solid waste material, usually inert, that comes into the marine environment from different sources is defined as marine litter or marine debris (UNEP, 2005). Litter is observed along shorelines (Coe et al., 1997; Santos et al., 2009), pelagic, benthic marine and lake systems all around the Earth (Galgani et al., 2000; Thiel et al., 2013; Driedger et al., 2015). At beaches, it generally consists of a wide assortment of plastics, paper, metal, cloth, wood, glass and other materials, which may come from different sources such as rivers and estuaries, the sea, beach users, etc.

Litter enters the ocean environment from marine or land activities but it is estimated that 80% of beach litter is linked to land-based sources (Allsopp et al., 2006). These sources include illegal dumping, landfills, storm-water drains, petrochemical plants and other industries, as well as direct inputs in coastal areas, such as trash left by recreational beach users, or fly-tipping and other improper disposal by consumers. Items can be carried to the marine environment by wind, sewage, runoff and rivers (Browne et al., 2011; Wright et al., 2013).

The marine-based sources include all types of sea-going vessels and offshore installations (Earll et al., 1996). Common is the illegal dumping of plastic waste from ships and the release of plastic resin pellets and other cargo when shipping containers are lost at sea (Andrady, 2011; Hohn, 2012). It has been estimated that 6.8 million containers of metal, 426,000 of glass and 639,000 of plastic materials are disposed every day (Horsman, 1982).

In the marine environment, on average, 60%–80% of debris items consist of plastics but this fraction, in certain areas, can be higher than 95% (Gregory and Andrady, 2003; OSPAR Commission, 2007). Such values are essentially linked to greater plastic durability and persistence, combined with rising production of plastics and low rates of recovery (Driedger et al., 2015): a 25-fold increase in the production of plastic resin products was observed between 1960 and 2000 with a recovery rate of less than 5% (Moore et al., 2001; McDermid and McMullen, 2004). The World plastic production almost reached 350 million tonnes in 2017, which 102 million t pertain to China, followed by Europe, with 64 million t (Plastics Europe, 2018).

Plastic debris can be in their original (or close-to-original) form when collected, e.g. bottles, microbeads or resin pellets, or composed of smaller pieces of plastic resulting from the breakdown of primary debris through a combination of photo- and thermal-oxidative degradation by ultraviolet radiation, mechanical weathering, and biodegradation, but complete mineralization

* Corresponding author.
*E-mail address:* giorgio.anfuso@uca.es (G. Anfuso).

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may not be possible, or then only after hundreds or thousands of years (Corcoran et al., 2009; Gregory and Andrady, 2003).

Plastic litter produces negative effects on biota and the ecosystem due to ingestion (Van Franeker et al., 2011; Browne et al., 2011) together with entanglement of animals in abandoned nets, fishing lines, ropes and ribbons (Gregory, 2009; Votier et al., 2011), which are the most abundant plastic items in the oceans and comprise 15.8% of the total number of debris items collected along marine shorelines (Santos et al., 2009). At some places (e.g. in the North East Atlantic), they are the second most common item found on the beach (Gregory and Andrady, 2003).

Ingestion of plastic may cause internal bleeding, abrasion and ulcers, as well as of digestive tract blockage (Wright et al., 2013). In littoral zones, accumulation of sinking plastic debris and the dragging of fishing nets may disrupt bottom sediments, displace or smother infauna, and affect the structure and functioning of benthic microbial communities (Goldberg, 1995).

Additives are added to plastics during production processes in order to improve their properties. Since they are not covalently bound but simply mixed with the plastic polymer, they disperse easily in the environment (Savoca et al., 2018). Also, many heavy metals have been used as additives and inappropriate plastic use may lead to their undesirable release (Hahladakis et al., 2018). In addition, due to their hydrophobic nature, plastics can adsorb a series of toxic from seawater such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), other persistent organic pollutants (POPs) and heavy metals (Rochman et al., 2014). Single and combined effects of plastics and other contaminants were studied in some marine organisms (Karami et al., 2016). These chemicals have the potential to accumulate in the tissues of marine organisms and cause specific effects, including behavioural changes, alterations in metabolic processes and endocrine disruption (Anderson et al., 2016).

Accumulation of plastic debris in coastal areas poses a hazard to swimmers and divers, and carries a risk of minor cuts or abrasion injuries to beachgoers (Sheavly and Register, 2007; Williams, 2011). It also deters recreational beach usage giving rise to related economic problems because a loss of recreational beach attractiveness (Smith et al., 1997; Ogi and Fukumoto, 2000; Krelling et al., 2017). As observed by Morgan et al. (1995), Williams (2011) and Anfuso et al. (2014), five parameters (the 'Big Five') are of the greatest importance to coastal tourists: safety, facilities, water quality, no litter and scenery. A clean beach is one of the most important characteristics of a seaside resort required by visitors, with the negative effects of beach litter being especially linked to the presence of potentially hazardous and unaesthetic items such as sanitary and medical waste, all of which cause damage to the local, national and international image of a resort. These issues are reflected in loss of tourism days (Philipp, 1993; Tudor and Williams, 2004) and resultant damage to leisure/tourism related activities, since visitors are especially interested in coastal tourism that is one of the world's largest industries (Klein et al., 2004), with beaches being a major player in this market (Houston, 2013). This is especially true in Spain that has the second largest tourist incomes worldwide and the highest in Europe (in 2017 it recorded 81.8 million tourist arrivals who brought in c. US$ 68 billion, UNWTO, 2018).

Beach cleaning operations are often mandatory and costly and constitute the main tool for ensuring litter free beaches. For example, in 1993, $1.4 million was spent cleaning the Bohuslan coast of Sweden (Olin et al., 1995); more than US$1 million was spent in 1988 and 1989 cleaning up the coasts of Santa Monica and Long Beach in California (Kauffman and Brown, 1991); UK municipalities spend around €18 million per year to remove beach litter and in the Netherlands and Belgium, annual costs for beach clean-up operations is €10.4 million (Mouat et al., 2010). Others researchers such as Ariza et al. (2008a) reported the annual declared investment on beach maintenance, cleaning and conservation by each one of the 38 municipalities along the Catalonian coast (NE Spain). The average annual cost per beach was €133,113, with maximum values of €845,820, which did not include sand management operations directly carried out and funded by the National Spanish Government.

Very few beach litter surveys have been reported for Spain and studies published in international journals invariably relate to the Mediterranean rather than the Atlantic coastline, e.g. Gabrielides et al. (1991), Ariza et al. (2008b), Roca et al. (2008) and Asensio-Montesinos et al. (2019a,b). For the Atlantic side of Andalusia, a few limited observations have been carried out within the CoastWatch program (Jurado et al., 2006 and unpublished reports) and, for the Cádiz Bay area, by Williams et al. (2016). The main research objective of this paper was to quantify and characterize beach litter spatial variability at the investigated area, the Atlantic coast of Cádiz Province in SW Spain and to relate such observations with both beach physical and usage aspects.

## 2. Study area

### 2.1. Physical setting

This paper investigates litter characteristics and distribution at 40 beaches belonging to 12 coastal municipalities of Cádiz Province (SW Spain). The littoral studied, 192 km in length, is NW–SE oriented and faces the Atlantic Ocean (Fig. 1). The study area shows meso-tidal conditions from Sanlúcar de Barrameda to Cape Trafalgar, and a micro-tidal environment from there to Tarifa, on the Gibraltar Strait (Fig. 1).

Western winds are generally related to Atlantic low-pressure systems and blow from the WNW to the WSW directions. The eastern winds, blowing from the ESE direction, are originally formed over the Mediterranean Sea and greatly increase in velocity due to the channelling effect through the Gibraltar Strait. Due to the coastline orientation, western winds give rise to both sea and swell waves. Eastern winds have no important fetch principally giving rise to sea waves. Significant wave height values are usually lower than 1 m and approach from the SW to the WNW directions (Anfuso et al., 2016). Because of the coastline orientation, prevailing littoral drift currents flow to the SE. A secondary, opposite drift is also occasionally recorded, and associated with wind-driven waves generated by strong winds blowing from the S and SE.

Different rivers and tidal creeks directly flow into the investigated costal sector; ones being the Guadalquivir River (657 km in length, which passes through big cities such as Córdoba and Seville), the Guadalete River (172 km long), the Barbate River (76 km long) and two tidal creeks, namely San Pedro and Sancti-Petri (Fig. 1).

### 2.2. Investigated beaches characteristics

Generally, the Atlantic coast of Cádiz Province is constituted by long and strait beaches. At places they are backed by cliffs (e.g. no. 25 and 26, Table 1) and located in small bays enclosed between headlands (e.g. no. 15 and 36, Table 1) or partially closed by groins and other coastal structures (e.g. no. 10 and 16, Table 1), especially at the northern end of the province (Muñoz Pérez and Gutiérrez-Mas, 1999).

They essentially show "dissipative", "intermediate", "reflective" and "rocky shore/low tide terrace" beaches (Wright and Short, 1984; Masselink and Short, 1993; Anfuso and Gracia, 2005), with the dissipative ones showing small seasonal variations (Anfuso et al., 2003, 2008; Avila-Serrano et al., 2009; Rangel-Buitrago and Anfuso, 2011).

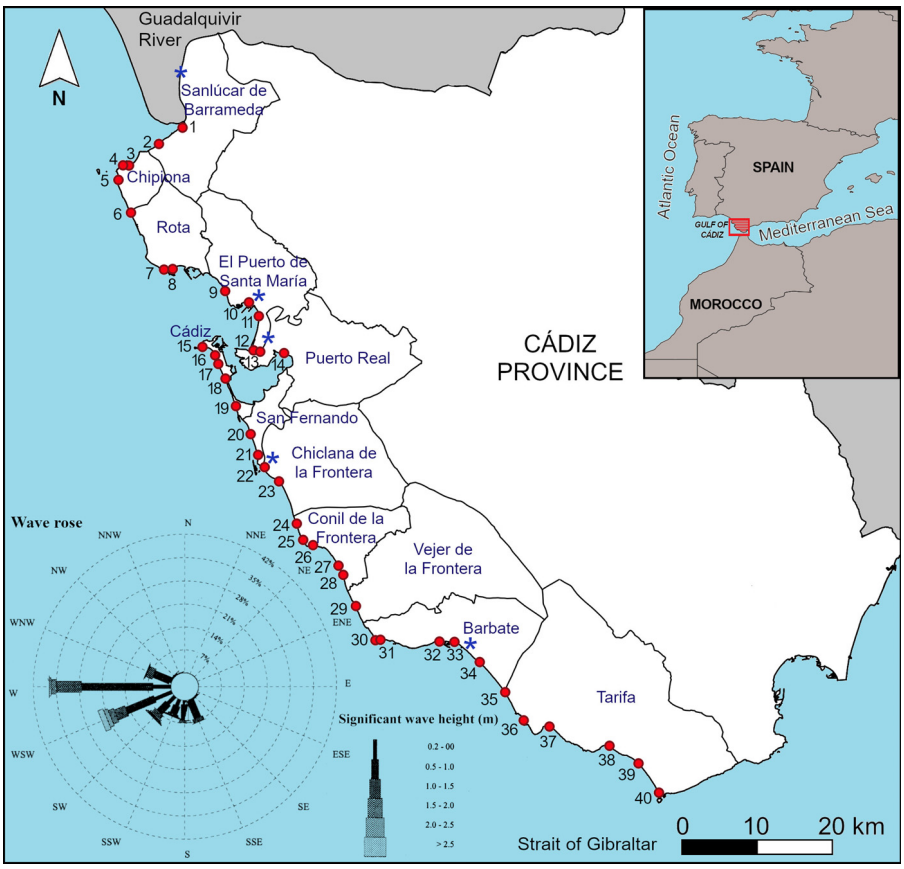



**Fig. 1.** Study area showing the investigated beaches along the Sanlúcar de Barrameda-Tarifa coast and the wave rose for the Cádiz area. The location of main river mouths and tidal creeks is indicated by blue asterisks.

Beach sediments are composed of fine, medium and coarse sand (Ortega-Sánchez et al., 2008; Poizot et al., 2013) with presence of quartz, plagioclase, low percentages of carbonates and heavy minerals. Cádiz beaches are fundamentally frequented for swimming and sunbathing by local beachgoers and national and international tourists from May to September but have an important recreational use during all the year because they are a place of meeting for walk, play sports, enjoy the scenery and other activities such as photography. With regard to the fishing sector, the Gulf of Cádiz is one of the most important Spanish fishing grounds, where the main fishing methods are trawling, minor gears and encirclement (SGP, 2018).

### 2.3. Land use and beach management

Cádiz Province is a densely populated area with 1,238,714 inhabitants (year: 2018), i.e. 15% of the Andalusia Region and 2.7% of the whole of Spain (www.ine.es, accessed May 2019). In 2018, it recorded 2,644,277 stay-night visitors, 1,668,278 being national and 975,999 international visitors (www.dipucadiz.es/patronatoturismocadiz/observatorio-turistico, accessed May 2019), essentially interested in coastal tourism because of the good weather conditions that make bathing possible during several months of the year (Williams et al., 2016).

Generally, beach clean-ups are carried out throughout the year by manual and mechanical means, especially from June to September when efforts in beach cleaning operations increase considerably. For example, in Tarifa, the number of workers increases by up to four times; in El Puerto de Santa María, three work shifts are performed per day (morning, afternoon and evening), while during the rest of the year (October–May) only one per day is performed. In the latter municipality, some 11,211 kg of glass, 21,096 kg of plastic, 2040 kg of paper, and 1,143,580 kg of mixed waste from mechanical cleaning, manual collection and paper beach-bins were collected in 2018.

## 3. Materials and methods

### 3.1. Coastal geomorphology determination

A DGPS (model Leica GPS900 System) was used to locate investigated sites, to calculate beach extension and determine beach morphology (Fig. 1). A topographic profile was obtained at each investigated beach in correspondence of the area sampled for beach litter evaluation (Fig. 2). Beach profiles were extended from the backshore to the low tide water level and beach foreshore slope was calculated and used to determine the morphodynamic beach state (Anfuso and Gracia, 2005). Topographic data were collected in autumn 2018, reflecting constructive beach states (Anfuso and Gracia, 2005).

### 3.2. Litter quantification and litter grade

A survey was carried out at low tide conditions at each one of the 40 investigated beaches from 10 to 23 October 2018. The observer recorded all litter items found in a 100 m wide shore-parallel beach section (extended at 50 m at either side from a beach access point), by progressively moving along 5 m shore-parallel spaced lines (Fig. 2) covering a beach surface between the low water strandline to the landward boundary (EA/NALG, 2000), which encompasses >90% of the beach litter available (Tudor and Williams, 2001). Specifically, except for recreational beaches, the

**Table 1**
Location and main characteristics of investigated beaches: Map number (Fig. 1), site name, number of items per zone, density (items $m^{-1}$), percentage of plastics, beach typology and morphodynamic state.

| No. | Beach | Litter abundance | | | | Total items | Density (items $m^{-1}$) | Plastic content (%) | Beach typology | Morphodynamic beach state |
|---|---|---|---|---|---|---|---|---|---|---|
| | | LTWL[a] | Foreshore | HTWL[b] | Backshore | | | | | |
| 1 | BAJO DE GUIA | 84 | 184 | 864 | 134 | 1266 | 2.110 | 77.5 | Village | Reflective |
| 2 | LA JARA | 7 | 20 | 414 | 32 | 473 | 0.946 | 93.4 | Village | Intermediate |
| 3 | MICAELA | 83 | 84 | 74 | 273 | 514 | 1.285 | 91.1 | Village | Intermediate |
| 4 | CRUZ DEL MAR | 5 | 5 | 31 | 49 | 90 | 0.180 | 82.2 | Urban | Intermediate |
| 5 | LA REGLA | 0 | 15 | 167 | 88 | 270 | 0.450 | 93 | Urban | Dissipative |
| 6 | LA BALLENA | 0 | 77 | 634 | 149 | 860 | 1.433 | 95.8 | Village | Dissipative |
| 7 | LA COSTILLA | 54 | 29 | 116 | 289 | 488 | 0.697 | 71.7 | Urban | Intermediate |
| 8 | ROMPIDILLO | 13 | 8 | 309 | 40 | 370 | 0.740 | 92.2 | Urban | Intermediate |
| 9 | SANTA CATALINA | 0 | 28 | 294 | 42 | 364 | 0.728 | 94.8 | Village | Dissipative |
| 10 | LA PUNTILLA | 6 | 24 | 85 | 17 | 132 | 0.132 | 88.6 | Urban | Intermediate |
| 11 | VALDELAGRANA | 1 | 23 | 59 | 45 | 128 | 0.128 | 88.3 | Village | Dissipative |
| 12 | LEVANTE | 24 | 62 | 35 | 24 | 145 | 0.181 | 65.5 | Remote | Dissipative |
| 13 | RÍO SAN PEDRO | 3 | 72 | 127 | 287 | 489 | 0.978 | 84.9 | Village | Reflective |
| 14 | LA CACHUCHA | 0 | 40 | 145 | 168 | 353 | 0.353 | 39.9 | Urban | Dissipative |
| 15 | LA CALETA | 9 | 48 | 276 | 80 | 413 | 0.590 | 70.5 | Urban | Reflective |
| 16 | STA MARÍA DEL MAR | 0 | 13 | 893 | 289 | 1195 | 1.328 | 93.4 | Urban | Dissipative |
| 17 | LA VICTORIA | 0 | 52 | 393 | 141 | 586 | 0.733 | 83.3 | Urban | Dissipative |
| 18 | CORTADURA | 1 | 11 | 28 | 180 | 220 | 0.183 | 81.4 | Village | Dissipative |
| 19 | TORREGORDA | 16 | 19 | 44 | 160 | 240 | 0.343 | 71.3 | Rural | Reflective |
| 20 | CAMPOSOTO | 1 | 27 | 874 | 5 | 907 | 1.008 | 92.3 | Rural | Intermediate |
| 21 | PLAYA CANINA | 0 | 4 | 32 | 26 | 62 | 0.078 | 71 | Remote | Intermediate |
| 22 | SANCTI-PETRI | 0 | 4 | 41 | 153 | 198 | 0.198 | 85.4 | Rural | Reflective |
| 23 | LA BARROSA | 6 | 6 | 525 | 679 | 1216 | 1.216 | 96.5 | Village | Intermediate |
| 24 | EL PUERCO | 0 | 7 | 56 | 41 | 104 | 0.149 | 78.8 | Rural | Intermediate |
| 25 | PRINCESA ALEJANDRA | 0 | 0 | 47 | 47 | 94 | 0.235 | 80.9 | Rural | Intermediate |
| 26 | CALA DEL ACEITE | 9 | 287 | 1206 | 58 | 1560 | 2.600 | 97.4 | Rural | Intermediate |
| 27 | LOS BATELES | 1 | 70 | 1699 | 38 | 1808 | 2.260 | 97.2 | Urban | Dissipative |
| 28 | CASTILNOVO | 0 | 12 | 34 | 23 | 69 | 0.086 | 60.9 | Remote | Dissipative |
| 29 | EL PALMAR | 0 | 0 | 82 | 199 | 281 | 0.562 | 96.4 | Village | Dissipative |
| 30 | TRAFALGAR | 1 | 0 | 24 | 7 | 32 | 0.080 | 84.4 | Remote | Reflective |
| 31 | CAÑOS DE MECA | 3 | 4 | 98 | 17 | 122 | 0.305 | 88.5 | Rural | Reflective |
| 32 | HIERBABUENA | 3 | 19 | 337 | 36 | 395 | 0.658 | 94.7 | Rural | Reflective |
| 33 | EL CARMEN | 1 | 0 | 174 | 66 | 241 | 0.482 | 94.2 | Urban | Dissipative |
| 34 | RETIN BARBATE | 0 | 1 | 35 | 50 | 86 | 0.215 | 66.3 | Remote | Intermediate |
| 35 | ATLANTERRA | 0 | 1 | 25 | 108 | 134 | 0.268 | 96.3 | Village | Intermediate |
| 36 | LOS ALEMANES | 10 | 0 | 18 | 34 | 62 | 0.155 | 75.8 | Village | Reflective |
| 37 | BOLONIA | 1 | 0 | 31 | 15 | 47 | 0.094 | 87.2 | Rural | Intermediate |
| 38 | VALDEVAQUEROS | 0 | 0 | 4 | 7 | 11 | 0.022 | 45.5 | Rural | Reflective |
| 39 | LOS LANCES NORTE | 1 | 2 | 8 | 1 | 12 | 0.024 | 83.3 | Rural | Reflective |
| 40 | LOS LANCES SUR | 1 | 0 | 20 | 65 | 86 | 0.215 | 88.4 | Village | Intermediate |
| Total | | 344 | 1258 | 10 358 | 4162 | 16 123 | 0.611 | | | |

[a]Low tide water level.
[b]High tide water level.

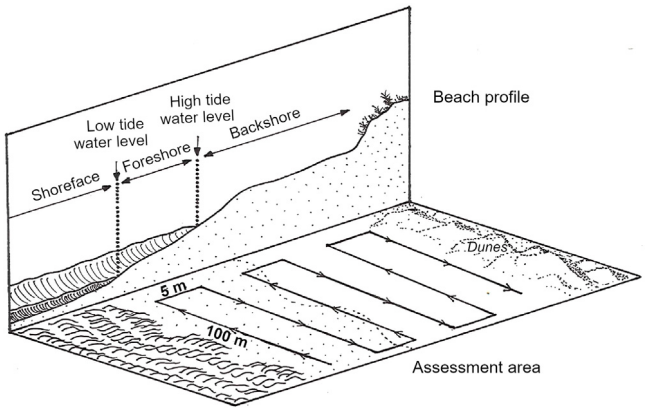



**Fig. 2.** Idealized beach cross-shore profile showing water level positions and beach zones surveyed.

high water strandline together with the landward boundary are the main beach litter nodal points and litter items found between the strand line and the low tide level constitute <2% of beach litter (Williams et al., 2014).

Based on previous works (Jurado et al., 2006; Williams et al., 2016) and exploratory field visits, a Masterlist of 183 categories of litter reported by EA/NALG (2000), Cheshire and Adler (2009), OSPAR Commission (2010) and Opfer et al. (2012) classifications, was compiled according to their material composition (Dixon and Dixon, 1981) and size (Ribic, 1998); 120 out of the 183 established categories were recorded at the 40 sites surveyed. The beaches were visited between 9 a.m. and 2 p.m. and, generally, few users were observed during the sampling period.

A beach Litter Grade was calculated using the EA/NALG (2000) methodology (Table 2). According to the presence/absence and quantity of nine categories of litter items, each beach was rated from "A" (excellent quality, i.e. very clean site) to "D" grade (poor quality, i.e. very dirty site).

### 3.3. Beach typology

Coastal site typologies were assessed according to their occupation level following to the Bathing Area Registration and Evaluation (BARE) classification system (Williams and Micallef, 2009): 4 out of the 5 existing categories were identified in this paper, i.e. remote, rural, village and urban beaches.

**Table 2**
Results of litter survey according to the EA/NALG (2000) methodology.

| Category | Type | A | B | C | D |
|---|---|---|---|---|---|
| Sewage related debris | General[a] | 0 | 1–5 | 6–14 | 15+ |
| | Cotton buds | 0–9 | 10–49 | 50–99 | 100+ |
| Gross litter | >50 cm[b] | 0 | 1–5 | 6–14 | 15+ |
| General litter | < 50 > 1 cm[c] | 0–49 | 50–499 | 500–999 | 1000+ |
| Harmful litter | Broken glass | 0 | 1–5 | 6–24 | 25+ |
| | Other[d] | 0 | 1–4 | 5–9 | 10+ |
| Accumulations | Number | 0 | 1–4 | 5–9 | 10+ |
| Oil | | Absent | Trace | Nuisance | Objectionable |
| Faeces | | 0 | 1–5 | 6–24 | 25+ |

[a]General Sewage Debris: Sanitary towels, tampons, contraceptives, nappies, toilet paper, etc.
[b]Gross Litter: Car parts, trolleys, broken umbrellas, fishing buoys, jerry cans, etc.
[c]General Litter: Plastic bottles, cans, bottle caps, pieces of plastic or paper, food packaging, etc.
[d]Harmful Litter: Sharps (hooks, wires), medical waste, fishing threads, etc.

### 3.4. Statistical analysis

Analysis of variance (ANOVA) was applied for litter amount comparisons among beach zones, i.e. the low tide water level, foreshore, high tide water level and backshore (Fig. 2). Principal component analysis (PCA) was also carried out to establish relationships among sites and litter aggrupation in order to identify social patterns of behaviour or beaches that differ from the rest. According to Martinez-Ribes et al. (2007), for the multivariate analysis, 14 litter groups were selected and essentially related to different litter sources and human activities: Drinking, Food, Users, Sewage Related Debris (SRD), Smoking, Fishing Related Debris (FRD), Building, Styrofoam, Organic, Hard Plastic Pieces (HPP), Cardboard and Paper (C.P), Film Plastic Pieces (FPP), Processed Wood and Plastic Bags.

## 4. Results and discussion

### 4.1. Beach litter abundance and composition

A total amount of 16,123 items (Avg: 403 items per beach), belonging to 120 categories were counted at 40 Atlantic beaches of Cádiz during October 2018. At every beach from 4 to 12 transects (400–1200 m) were covered, reaching a total length of 26,100 m assessed at the 40 beaches. Along the study area, an average value of 0.61 items $m^{-1}$ (or 0.06 items $m^{-2}$) was observed and this values ranged from 0.022–2.600 items $m^{-1}$(0.003–0.26 items $m^{-2}$). In general, the average litter abundance is lower than observed at other beaches in Brazil, Chile, California, Turkey, Colombia or Australia (Santos et al., 2009; Thiel et al., 2011; Rosevelt et al., 2013; Topçu et al., 2013; Rangel-Buitrago et al., 2017; Lavers et al., 2019) although, there are also beaches with smaller litter content in China and U.K. (Zhou et al., 2016; Watts et al., 2017).

The abundance and content of beach litter varied from place to place along the investigated area for diverse reasons. Such variability was due to physical (e.g. beach morphology, winds, waves, tides, location and orientation, etc.) and anthropogenic parameters (e.g. number of beach visitors, presence of facilities, beach clean-ups programmes, etc.). In addition, depending on the environmental conditions, the temporal patterns of beach litter can be very variable (Thiel et al., 2013; Poeta et al., 2016). Therefore, all data were recollected in the same daily period. The highest litter density was found at "Los Bateles" with 1808 items (no. 27, Table 1) while the lowest was observed at "Valdevaqueros" with only 11 items (no. 38, Table 1). Researchers such as Gago et al. (2014) observed similar values at the Galician coast (NW Spain). In the Mediterranean, Vlachogianni (2019) detected similar values for beach litter content — except for the most polluted beach (located in the Adriatic Sea).

Smoking items, mainly cigarette butts, were the most numerous and summed 10,865 units in the study area, i.e. 67.4% of the total amount (Table 3). In other recent studies at Spanish beaches (Martinez-Ribes et al., 2007; Munari et al., 2016; Asensio-Montesinos et al., 2019a,b), cigarette butts also represented the most abundant litter item. There are very persistent in the environment and can be a major source of metal contamination (Moerman and Potts, 2011). In addition, mechanical cleaning is less effective for removing cigarettes than for general litter (Ariza et al., 2008b). The rest of the surveyed groups represented less than 6% and is also be attributed to beachgoers, such as drinking and food items, etc. (Table 3). Fishing items and plastic bags represented less than 3% of the total (with 336 and 110 items respectively, Table 3); such items may be harmful to coastal environments, wildlife and beach users, specially hooks and fishing lines (Dau et al., 2009; Thiel et al., 2011; Williams et al., 2013). Plastic bags, which are included in the top 10 marine debris items globally (Ocean Conservancy, 2018), are accumulated in large concentrations, e.g. >70% of total items, on the deep-sea floor (Galgani et al., 1996). Bags have been used since approximately the 60 s and since more than 20 years there is evidence of their negative impacts on many species; recently, some countries such as Spain are implementing measures to reduce their use (BOE, 2018), and other neighbouring countries, such as Morocco, have already prohibited them (Nachite et al., 2019).

In terms of litter diversity, expressed as number of litter categories observed at each site. An average of 27 categories per beach was observed; the highest value was recorded at "Bajo de Guía" (no.1, Table 1) with 50 categories, while at "Los Lances N" only 7 categories were reported (no. 39, Table 1). According to Poeta et al. (2016), a great number of litter categories is due to different potential sources and require the application of different clean-ups techniques.

Most beach litter items were composed of plastic materials and this group represented 88.54% of the total litter composition (Fig. 3), followed by cloth (3.88%), paper & cardboard (1.63%), rubber (1.58%), metal (1.56%), glass (0.94%), wood (0.81%), pottery & ceramics (0.69%), organic (0.24%) and other unidentified materials (0.14%). Very similar values were reported along the North Cornwall coast (SW U.K) by Watts et al. (2017). The percentage of plastic content at the investigated beaches varied according to site from 40 per cent, to 97 per cent (Table 1), with an average value per beach of 83%. Results confirmed that plastic is the most abundant material at beaches, as documented by many authors (Topçu et al., 2013; Šilc et al., 2018).

### 4.2. Beach litter sources and dynamics

Evidence recorded from this study suggested that most beach litter comes from land-based sources and is of local or national

**Table 3**
Beach litter amount and categories selected for the principal component analysis.

| Groups | Items included | Items in the study area | % |
|---|---|---|---|
| Drinking | Bottles, cups, straws, tins, glass fragments, etc. | 692 | 4.3 |
| Food | Wrappers, cutlery, toothpicks, ice and sweets sticks, etc. | 594 | 3.7 |
| Users | Sandals and shoes, toys, umbrella pieces, clothing labels and items, coins, balloons, medicines... | 328 | 2.0 |
| Sewage | Cotton bud sticks, sanitary towels, panty liners, wet wipes, condoms, etc. | 884 | 5.5 |
| Smoking | Cigarettes, butts and filters, cigarette lighters, cigarette packets, etc. | 10,865 | 67.4 |
| Fishing | Fishing lures/ hooks, fishing lines (angling), light sticks, floats/buoys, etc. | 336 | 2.1 |
| Building | Brick, cement, pipes, etc. | 120 | 0.7 |
| Styrofoam | Foamed plastic pieces (0–>50 cm) | 89 | 0.6 |
| Organic | Dog faeces and dead animals | 39 | 0.2 |
| Hard plastic | Pieces (0–<50 cm) | 751 | 4.7 |
| Cardboard and paper | Fragments (0–50 cm) | 221 | 1.4 |
| Film plastic | Pieces (0–>50 cm) | 799 | 5.0 |
| Processed wood | Pallets, Ice lolly sticks, wood fragments, corks, etc. | 63 | 0.4 |
| Plastic bags | e.g. shopping, freezer bags, etc. | 110 | 0.7 |
| Others | | 232 | 1.4 |
| Total | | 16,123 | 100 |

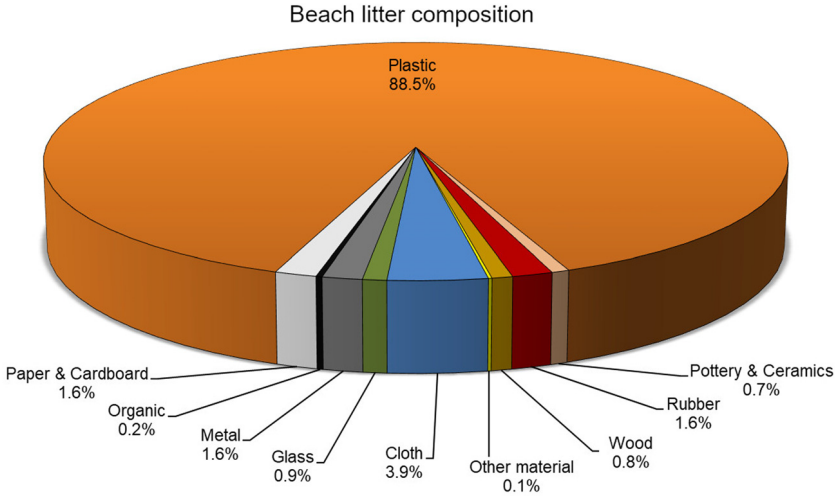



**Fig. 3.** Beach litter composition by material type.

origin. Many litter groups or categories were closely related to beach users. Fig. 4a shows a relationship between beachgoers' affluence and litter abundance: sites with a low amount of beach users have a very similar litter amount and it is very low if compared to other areas; while the sites with an average affluence are those that generally contain more litter items, among them there are important differences that are observed in data dispersion (Fig. 4b). However, sites with the highest number of users are not the ones that show most items, probably because they attract or require more management actions (Fig. 4a, b). Gabrielides et al. (1991) have argued that the distance from beaches to population centres is an important factor that can increase beach litter. Indeed, in the Cádiz area, Alves et al. (2014) demonstrated through questionnaires (>700, sampling error of 4%) that the great number of beach users during high season causes unpleasant consequences, for example, accumulation of litter.

Some litter items provided from different countries, reach the Andalusian coasts because they are dumped directly by ships into the sea or by international tourists on the beach. Examples were a hard food container (from Portugal), a bottle cap (Morocco), a cleaner bottle (Turkey), a food wrapper and other items related to navigation (Germany). Garrity and Levings (1993) also identified marine litter from other countries along the coast of Panama. Evidences suggest that litter can travel hundreds of kilometres, especially through the aquatic environment due to connectivity, and end up very far from its source. In some coastal sites such as the Amami Islands (Japan), foreign litter can represent up to 70% of the total (Kei, 2005).

Rivers and tidal creeks play an important role in accumulation, transport and distribution of litter. For example, on beaches located close to the mouth of the Guadalquivir River, the diversity of litter gradually changed depending on their distance/location: at site 1, close to the Guadalquivir River mouth, were recorded 50 categories, 42 at site 2, 35 at site 3, etc. (Table 1, Fig. 1). Beaches located close to other river mouths also registered a greater number of categories in comparison to other sites, good examples are "Río San Pedro" with 34 groups (no.13, Table 1, Fig. 1) or Barbate beaches (no. 32, 33 and 34, Table 1) with 31 different groups. Such a trend was also observed in Cádiz Province by Williams et al. (2016) who also evidenced litter content variability according to beach clean-up actions. In other areas, similar trends, i.e. litter abundance varying according to clean-up efforts and distance from river mouth, were observed by Williams and Simmons (1997), Araújo and Costa (2007) and Rech et al. (2014).

Evidences of wastewater was recorded due to the presence of cotton bud sticks, wet wipes, sanitary towels, tampons and tampon applicators, condoms, etc. The presence of such items constitutes a big problem when their number increases disproportionately, usually after heavy rainy events (Phillips et al., 2011), as they indicate faecal bacteria (e.g. *Escherichia coli*) and Enterococcus presence in beach water and sand, which may cause health problems to beach users (Heaney et al., 2009; Sánchez Moreno et al., 2019). At "Bajo de Guía", "La Costilla" and "La Cachucha", a total of 212, 126 and 155 units of wet wipes were counted

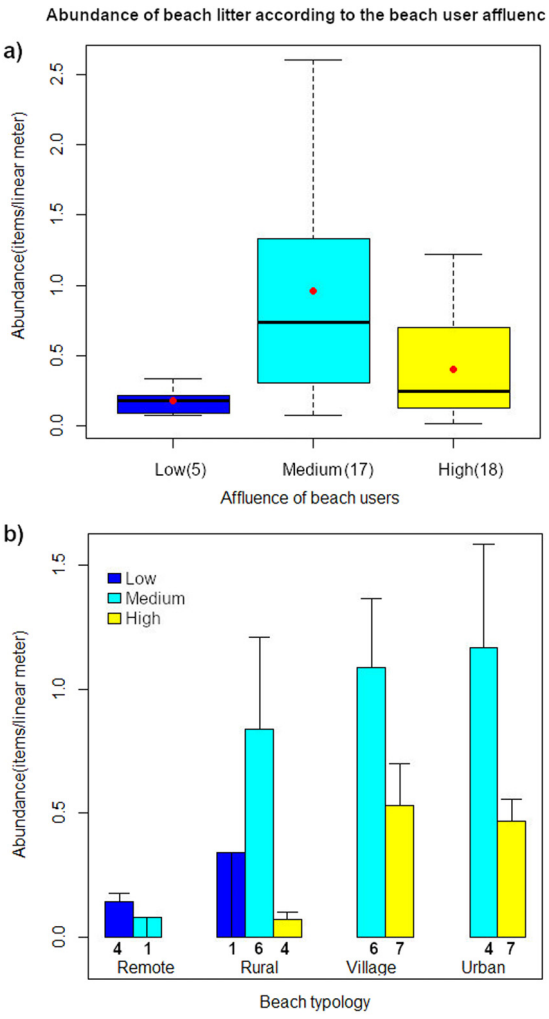



**Fig. 4.** (a) Abundance of beach litter according to beach users affluence. (b) Litter abundance and number of beaches in each category.

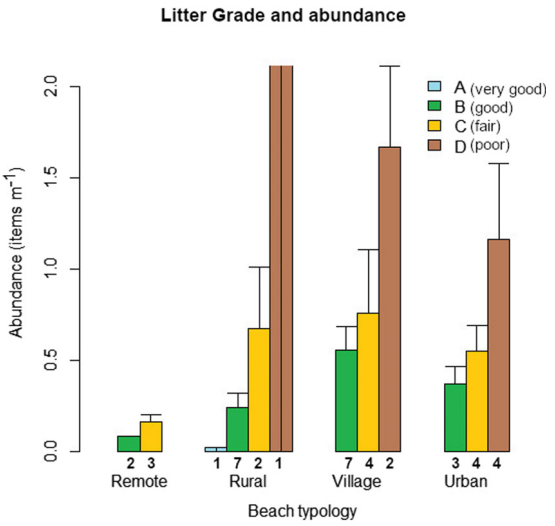



**Fig. 5.** Litter Grade (EA/NALG, 2000) and beach litter abundance (items $m^{-1}$) by beach typology. The number below each bar indicates beaches in each category.

respectively (beaches no. 1, 7 and 14, Table 1, Fig. 1). Cotton bud sticks record values of 62 and 98 units at "Bajo de Guía" and "La Costilla". This is indicating either that wastewater collectors are discharging directly onto the beach, that the outfall is too short, or that the presence of broken pipes causes currents and waves to return items to the beach.

Evidences of sewage related debris (SRD) at "Bajo de Guía" (no. 1, Fig. 1) are linked to the Guadalquivir River, while at "La Cachucha" (no. 14, Fig. 1) probably illegal discharges or wastewater management systems which are not functioning properly are responsible for the high amount of SRD. "La Costilla", located in Rota municipality, is a very exposed beach and it seems that there are temporary inputs linked to rain events. In previous studies (Williams et al., 2016), evidences of wastewater discharges were observed among the most polluted beaches of the Bay of Cádiz (i.e. San Pedro tidal creek). Poeta et al. (2016) registered a high number of cotton buds in Italy during Autumn and Winter seasons, when rivers have large discharges, and attributed this issue to the inefficiency of sewage treatment plants.

### 4.3. Beach typology and litter grade

According to the BARE system (Williams and Micallef, 2009) and the EA/NALG (2000) technique (Table 2), beaches assessed in this paper belonged to the remote (5), rural (11), village (13) and urban (11) typologies and presented different litter grades (Fig. 5, Table 4).

A mean of abundance of 0.13 items $m^{-1}$ was recorded at remote, 0.51 items $m^{-1}$ at rural, 0.79 items $m^{-1}$ at village and 0.72 items $m^{-1}$ at urban beaches (Fig. 5).

Only one site had grade "A", nineteen sites had grade "B", thirteen sites grade "C" and, finally, seven sites presented grade "D" (Table 4). There are clear differences between beach typology according to the grading: the most visited beach typologies (village and urban) registered worse litter grades, i.e. "C" and "D". Remote beaches scored either "B" or "C" grade, while rural beaches scored all grades ("A"–"D"). Litter abundance was mainly related to the number of visitors (Fig. 4b) and the presence/absence of cleaning efforts. Sites that scored poorly generally received more visitors than the rest (Fig. 5) and most litter items in the study area came from beach users. It is therefore necessary to modify management at those beaches where major problems have been identified. For example, by adapting cleaning operations or by avoiding new discharges.

### 4.4. Beach morphology and litter distribution

Coastal morphology, tidal action and the degree of exposure to wind and waves theoretically affect beach litter distribution/characteristics (Velander and Mocogni, 1998; Williams and Tudor, 2001; Williams et al., 2017), however, the natural distribution due to these factors is heavily disturbed by the excessive beach use on many coastal sites. The tidal range can also influence the abundance and distribution of beach litter. For example, a high tidal range can cause litter accumulations at different beach zones (e.g. on the high water line, as observed in the field), also the tide may bring or take away some items. A micro tidal range typically has a small foreshore area depending on beach slope and litter accumulations normally are concentrated at the high tide level and the backshore. As a general result, meso-tidal beaches (from no. 1 to 30, Fig. 1) presented 0.73 items $m^{-1}$, while micro-tidal beaches 0.30 items $m^{-1}$ (from no. 31 to 40, Fig. 1). This subject requires more detailed studies as other factors such as beach typology and differences in cleaning efforts, which are managed along the study area by 12 different municipalities (Fig. 1), have an important influence. Further, along the study area, meso-tidal beaches received much more litter contributions from rivers and streams (i.e. the Guadalquivir and Guadalete

**Table 4**
Beach grading according to nine litter categories (EA/NALG, 2000). The final rating (shaded area) of each site is based on the lowest score obtained. For sites location see Fig. 1.

| Category | Site location/type | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sewage-related debris | General | D | B | C | A | B | A | D | C | B | B | A | C | B | D | B | B | C | A | B | B | A | B | A | B | B | B | B | A | B | A | B | B | B | B | A | B | A | A | A | B |
| | Cotton buds | C | A | C | A | B | A | C | B | A | B | A | A | A | A | A | A | B | B | A | A | A | A | A | A | A | B | A | A | A | A | A | A | B | A | A | A | A | A | A | A |
| Gross litter | e.g. chairs | A | A | A | B | A | A | A | A | A | A | A | A | A | A | B | A | A | A | B | A | A | A | A | A | B | B | A | A | A | B | A | A | A | C | A | A | A | A | A | B |
| General litter | e.g. bottles | D | B | C | B | B | C | B | B | B | B | B | B | B | B | B | D | C | B | B | C | B | B | D | B | B | D | D | B | B | A | B | B | B | B | B | B | A | A | A | B |
| Harmful litter | Broken Glass | C | B | B | B | B | A | A | B | B | C | C | C | B | B | C | B | C | C | C | B | B | A | B | B | A | B | B | C | A | A | A | A | B | B | B | B | B | A | A | A |
| | Others | B | A | B | A | B | B | B | A | A | A | A | B | B | B | B | B | A | A | A | A | A | A | A | B | A | A | A | A | A | B | A | A | A | A | B | B | B | A | A | A |
| Accumulations | number | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A |
| Oil | | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A |
| Faeces | | C | A | B | A | B | A | A | B | B | A | A | A | A | C | B | B | A | A | A | A | A | A | A | B | A | A | B | A | A | A | B | A | A | A | A | A | A | B | A | |

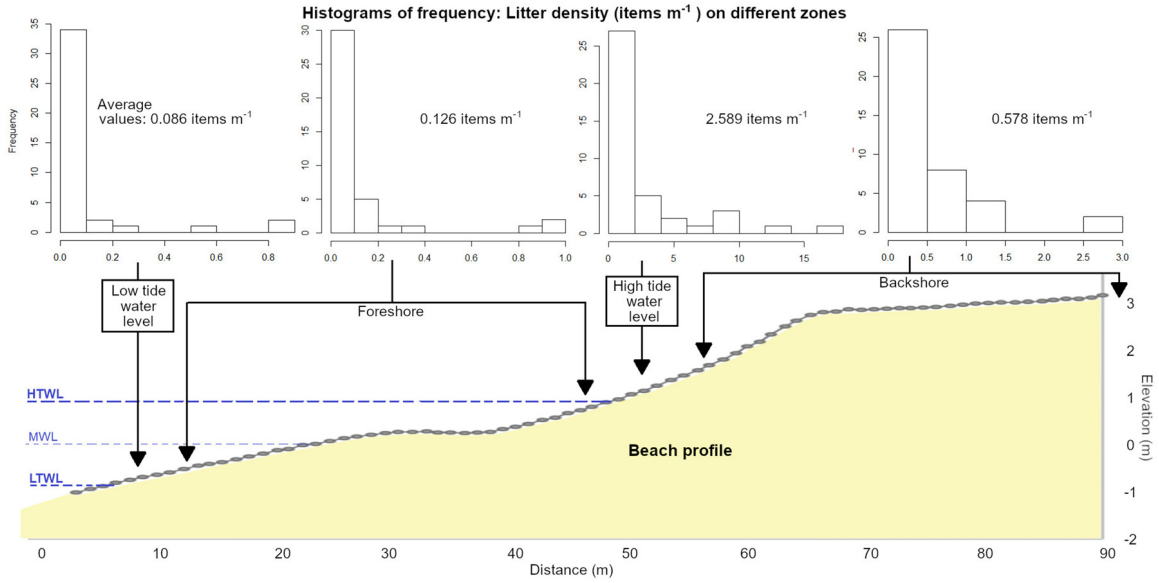



**Fig. 6.** Average litter density and histograms of frequency at different beach zones.

rivers, San Pedro and Sancti-Petri tidal creeks) than micro-tidal beaches (the Barbate River, Fig. 1). In addition, the number of meso-tidal investigated beaches tripled micro-tidal ones.

The mean abundance and number of litter categories per beach zone was 0.09 items $m^{-1}$ and 3 l categories for the low tide water level, 0.13 items $m^{-1}$ and 7 categories for the foreshore area, 2.59 items $m^{-1}$ and 17 categories for the high tide water level, and finally, 0.58 items $m^{-1}$ and 16 l categories for the backshore area (Fig. 6). This characteristic distribution is associated with the presence of people on the beach and different environmental conditions such as tides and wind action. Litter dumped directly on the beach was often abandoned on the backshore, where users stay most of the time. However, at the high water level most of the beach litter was found because it is accumulated by the rising tide and swash-backwash processes. A few specific litter categories (e.g. plastic bottles or glass fragments) were accumulated at specific beach sectors, as evidenced by Kei (2005) on Japanese islands.

Fig. 6 showed the litter density at different beach zones. In this paper most beach litter items (64% of the total amount) were found at the high tide water level and, secondly, on the backshore (26%). In the foreshore zone, litter items were less abundant: foreshore recorded 8% of the total amount, while the low tide water level only 2%. Such an average trend varied from place to place (Fig. 7).

Close to sea water level, low quantities of items were found. At fifteen beaches even no items were recorded (Table 1). Maximum values observed in this beach zone were >80 l items per 100 m near the Guadalquivir River mouth (sites no. 1 and 3, Table 1). Further, the variation of the distribution of specific litter groups i.e. cigarettes butts, glass fragments, hard plastic pieces, film plastic pieces and foam fragments, along the foreshore zone of the investigated beaches (which showed different morphodynamic states) was examined, but no clear relationships were observed. Low litter abundance was a common trend and atypical results were only recorded at three beaches (no. 1, 3 and 26, Fig. 7). At the high tide water mark, 4 to 1699 items per 100 m (sites no. 38 and 27, Table 1, Fig. 1) were observed and related to beach users. They were accumulated there by the flooding tide, a process that is demanding further research efforts (Jayasiri et al., 2013). On the backshore, the amount of beach litter varied considerably, from 1 to 679 items (no. 39 and 23, Table 1). Such important differences were generally due to beach use: at rural beaches people often go to practice wind sports, while at village beaches people specially go to spend the day laying on the sand or bathing.

The calculation of the upper foreshore beach slope allowed classification of the investigated beaches into dissipative (13), intermediate (16) and reflective (11) morphodynamic states; representative examples were presented in Fig. 8.

Litter distribution was not homogeneous along the Spanish beaches of the Mediterranean Sea as it was evidenced in more than 100 beach litter assessments conducted in 2018 by Asensio-Montesinos et al. (2019b). At many places, due to the small beach dimensions and micro-tidal regime, only one survey transect

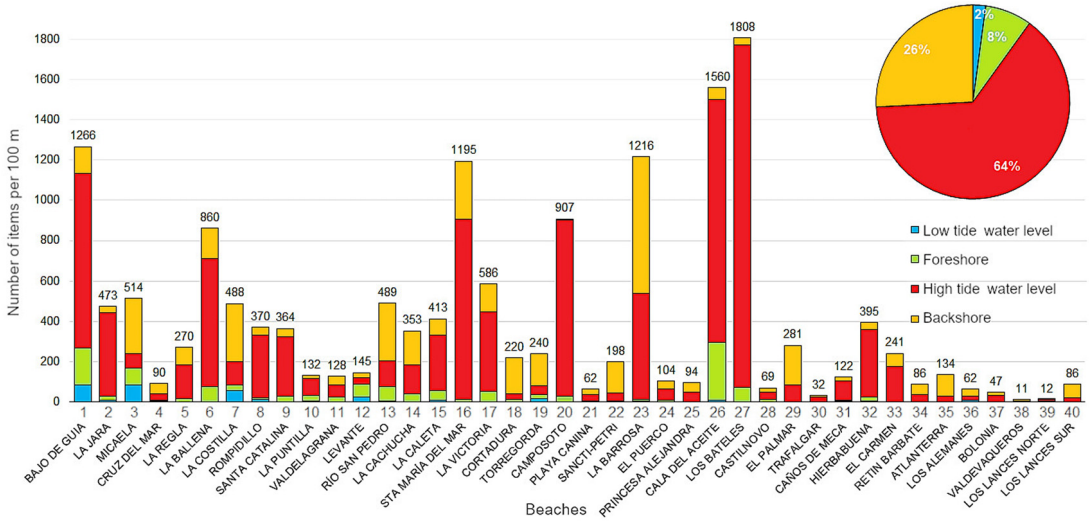



**Fig. 7.** Total number of items (in 100 m length) per beach and their abundance at each beach zone. The pie chart at the upper right corner shows average litter abundance values at each beach zone.

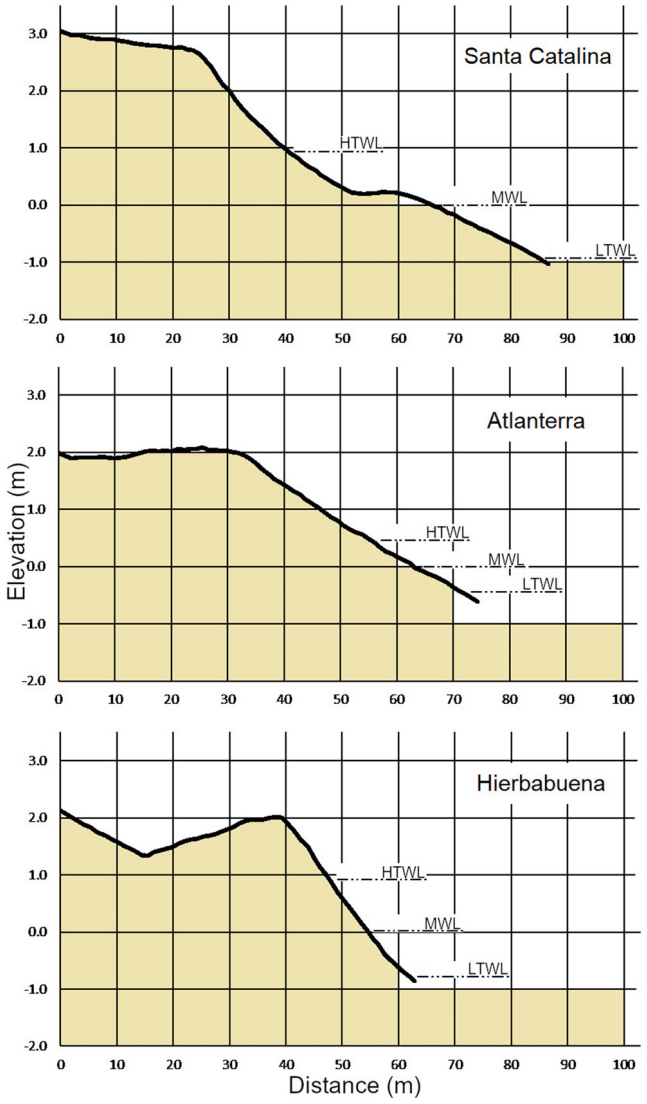



**Fig. 8.** Beach profile classification. Slope values determined the morphodynamic beach state (see Table 1).

was located at the water line and along the backshore area. Regarding the differences observed between the Atlantic beaches investigated in this paper and the Mediterranean ones (Asensio-Montesinos et al., 2019b), the most remarkable aspect is the location of the most polluted transect: at the beaches investigated in this paper it was located at the high tide water level, while at the Mediterranean beaches it corresponded with the most landward transect of the backshore, i.e., the beach landward limit (normally a wall, houses/buildings, dunes, vegetation line, etc.). These differences show that apart from dumping, the tidal range, morphology of the beach, its size and environment, all influence the distribution and abundance of beach litter. In addition, winds can also play an important role (Kako et al., 2010). Generally, Mediterranean coastal sites show the greatest litter densities due to the combination of a densely populated coastline, shipping in coastal waters and a negligible tidal flow, supported by a limited water exchange (Bergmann et al., 2015).

Litter abundance in each beach zone varied depending on the beach typology. The high tide water level was the most polluted on urban beaches (almost 4 items per linear metre), followed by rural (2.5 items $m^{-1}$), village (2.4 items $m^{-1}$) and remote beaches (0.3 items $m^{-1}$). Secondarily, the backshore area had the highest litter amounts on the village beaches with one item per metre, followed by the urban ones with 0.6 items $m^{-1}$. In the foreshore areas few litter items were observed, maximum values being recorded at village beaches with 0.1 and 0.2 items $m^{-1}$ at low tide water level and the foreshore respectively (Fig. 9).

### 4.5. Statistical analysis

Analysis of variance (ANOVA) were performed to compare litter amount at the four different beach zones investigated. For this, normality and homogeneity of variance were tested using Kolmogorov–Smirnov and Bartlett tests respectively. Data were "$\sqrt{x+1}$" transformed if variances were significantly different at $p = 0.05$ and "$\ln(x+1)$" transformed if variance was still heterogeneous. The ANOVA showed highly significant effects ($P < 0.001$) for the "zone" factor. Analysis results confirmed field observations and suggested that differences were due to beach use, influenced by tide. Differences among individual means of values were tested for significance using Tukey HSD (Honestly Significant Difference) and 95% family-wise confidence intervals. Significant differences were found among the following beach zones: the backshore, the high tide water level and the foreshore

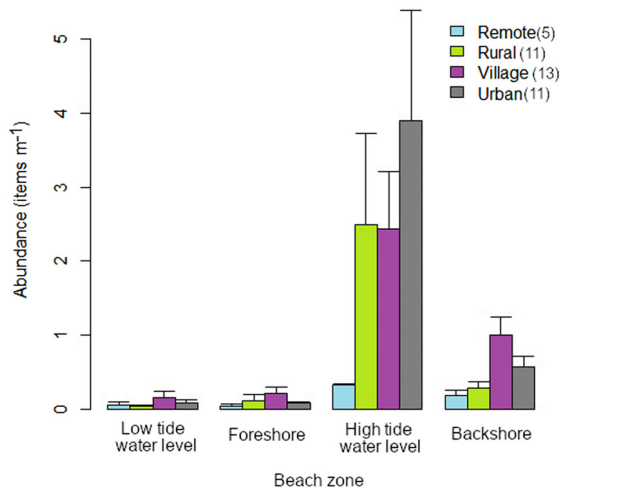



**Fig. 9.** Abundance of litter by beach zone for remote, rural, village and urban areas.

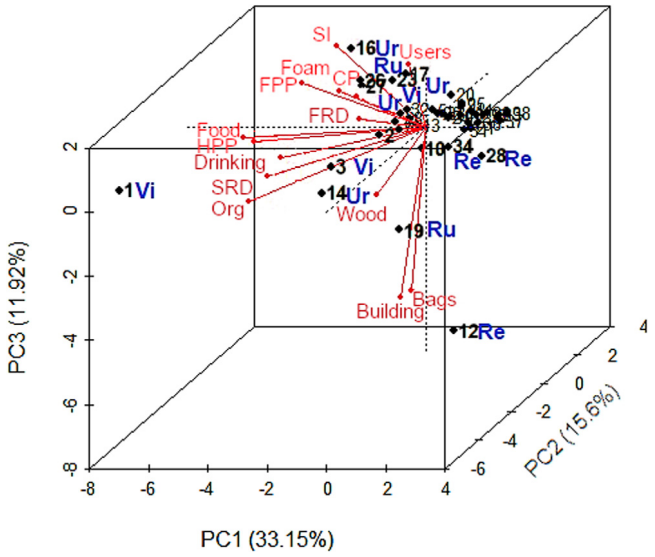



**Fig. 10.** Principal component analysis.

*versus* the low tide water level, and secondary, the high tide water level and the backshore *versus* the foreshore. NO significant differences were found between litter amount on the high tide water level and the backshore zones. On one hand, the backshore is where people spend most of their time and it is usually where they dump different items (cigarette butts, food wrappers, etc.). On other hand, the high tide water level receives diverse litter items from the backshore and the sea.

In Fig. 10, the Principal Component Analysis showed that most of the variability is explained by those categories of items related to sewage discharges (SRD) and beach users, i.e. Organic, Paper & Cardboard (P.C), Food, Smoking Items (SI) and other specific items (Users).

The graph accounted for 61% of the total variance within the data and evidenced the three sites most polluted by sewage and organic matter (i.e. no. 1, 3 and 14, Table 1, Fig. 1). Plastic bags and building items were associated with a remote and a rural beach (no. 12 and 19, Table 1, Figs. 1 and 2a). Finally, other beaches were grouped because they presented items clearly linked to beach users (no. 16, 17, 23, 26, 27, Table 1, Fig. 1). Hence, PCA was a good tool to relate sites with litter categories and beachgoers activities.

## 5. Conclusions

This paper analysed litter composition, origin and abundance at 40 beaches along the coastline of Cádiz. Coastal sites covered "remote" (5), "rural" (11) "village" (13) and "urban" (11) bathing areas. Plastics were the main material found (88.5%), but cigarette butts represented 67% of the total amount (with 10,833 units) and the majority of beach litter was attributed to beach users (nearly 80%), wastewater discharges (5.5%) and fishing activities (2.1%). Styrofoam (0.6%) could also be mostly related to sea sources (related to fishing). An unknown percentage of film plastic pieces (less than 5%) was attributed to beachgoers, but it was observed that most of these pieces were provided by tobacco packages and the film that wraps straws. Hard plastic pieces represented 4.7% of the total items and had different origins. A small part (0.7%) belonged to objects related to building. The rest of the articles could not be related to any specific sources or activities. Further, beaches presented many different kinds of items, some of them, very uncommon such as paint buckets, hunting cartridges, etc.

Generally, the beaches of Cádiz were fairly clean compared to others, except for some particular coastal sites. The bulk of beach litter was distributed among the high tide water level and the backshore zone. A multivariate analysis established in what sites litter content differed, highlighting possible different issues of pollution or waste management. In the study area, the northwest coast (including 3 municipalities, with an average litter content of 541 items per 100 m) and the Bay of Cádiz (5 municipalities, avg: 443 items) are more polluted than the regions of "La Janda" (3 municipalities, avg: 436 items) and "Campo de Gibraltar" (1 municipality, avg: 59 items), to the south. This was probably related to population patterns as the number of inhabitants in these four regions in 2018 was respectively of 115,953, 425,998, 57,717, and 18,169 inhabitants.

Regarding management, it is possible to make some recommendations based on the results obtained in this paper. Two different kind of management measures are needed:

(i) Management focused on recovering the natural conditions of the beaches (urgent operative actions). It has been shown that litter accumulation differs according to the beach zone, so it would be interesting to focus management measures on those areas of the beach most polluted (principally the high tide line and the backshore) that represent 90% of the total litter amount, but do not forget the intertidal zone that accumulates less litter (i.e. c. 10%), that can be easily removed by hand. It is important to note that cleaning actions, although necessary, will not solve the problem of beach litter and, only provide a temporal solution.

(ii) Management focused on addressing the origin of the problem. As it was previously said, the main source of litter (principally plastics) found at the beaches of Cádiz are the users. Therefore, more efforts in respect of public education are important and urgently needed in the region. Actions like environmental education programmes, improvement of facilities for depositing garbage as well as the installation or improvement of educational materials and informational posters on the beach would be of great help.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## References

Allsopp, M., Walters, A., Santillo, D., Johnston, P., 2006. Plastic Debris in the World's Oceans. Greenpeace International, Amsterdam.

Alves, B., Benavente, J., Ferreira, Ó., 2014. Beach users' profile, perceptions and willingness to pay for beach management in Cadiz (SW Spain). J. Coast. Res. 70 (sp1), 521–527.

Anderson, J.C., Park, B.J., Palace, V.P., 2016. Microplastics in aquatic environments: implications for Canadian ecosystems. Environ. Pollut. 218, 269–280. http://dx.doi.org/10.1016/j.envpol.2016.06.074.

Andrady, A.L., 2011. Microplastics in the marine environment. Mar. Pollut. Bull. 62 (8), 1596–1605.

Anfuso, G., Benavente, J., Del Río, L., Gracia, F.J., 2008. An approximation to short-term evolution and sediment transport pathways along the littoral of Cadiz Bay (SW Spain). Environ. Geol. 56 (1), 69–79.

Anfuso, G., Del Pozo, J.M., Gracia, F.J., López-Aguayo, F., 2003. Long-shore distribution of morphodynamic beach states along an apparently homogeneous coast in SW Spain. J. Coast. Conserv. 9 (1), 49–56.

Anfuso, G., Gracia, F.J., 2005. Morphodynamic characteristics and short-term evolution of a coastal sector in SW Spain: implications for coastal erosion management. J. Coast. Res. 1139–1153.

Anfuso, G., Rangel-Buitrago, N., Cortés-Useche, C., Castillo, B.I., Gracia, F.J., 2016. Characterization of storm events along the Gulf of Cádiz (eastern central Atlantic Ocean). Int. J. Climatol. 36 (11), 3690–3707.

Anfuso, G., Williams, A.T., Hernández, J.C., Pranzini, E., 2014. Coastal scenic assessment and tourism management in western Cuba. Tour. Manag. 42, 307–320.

Araújo, M.C., Costa, M., 2007. An analysis of the riverine contribution to the solid wastes contamination of an isolated beach at the Brazilian Northeast. Manag. Environ. Qual.: Int. J. 18 (1), 6–12.

Ariza, E., Jiménez, J.A., Sardá, R., 2008a. A critical assessment of beach management on the Catalan coast. Ocean Coast. Manag. 51 (2), 141–160.

Ariza, E., Jiménez, J.A., Sardá, R., 2008b. Seasonal evolution of beach waste and litter during the bathing season on the Catalan coast. Waste Manag. 28 (12), 2604–2613.

Asensio-Montesinos, F., Anfuso, G., Randerson, P., Williams, A.T., 2019b. Seasonal comparison of beach litter on Mediterranean coastal sites (Alicante, SE Spain). Ocean Coast. Manag. 181, 104914.

Asensio-Montesinos, F., Anfuso, G., Williams, A.T., 2019a. Beach litter distribution along the western Mediterranean coast of Spain. Mar. Pollut. Bull. 141, 119–126.

Avila-Serrano, G.E., Santa Rosa del Río, M.A., Anfuso-Melfi, G., Benavente-González, J., Guardado-France, R., González-Yajimovich, O., Velázquez-González, E.K., 2009. Sediment variations and littoral transport at La Victoria Beach, Cádiz, Spain. Cienc. Mar. 35 (3), 259–269.

Bergmann, M., Gutow, L., Klages, M. (Eds.), 2015. Marine Anthropogenic Litter. Springer.

BOE, 2018. Real Decreto 293/2018, de 18 de mayo, sobre reducción del consumo de bolsas de plástico y por el que se crea el Registro de Productores. Bol. Oficial Estado 122, 52591–52601, https://www.boe.es/eli/es/rd/2018/05/18/293 (accessed May 2019).

Browne, M.A., Crump, P., Niven, S.J., Teuten, E., Tonkin, A., Galloway, T., Thompson, R., 2011. Accumulation of microplastic on shorelines woldwide: sources and sinks. Environ. Sci. Technol. 45 (21), 9175–9179.

Cheshire, A., Adler, E., 2009. UNEP/IOC guidelines on survey and monitoring of marine litter.

Coe, J.M., Andersson, S., Rogers, D.B., 1997. Marine debris in the Caribbean region. In: Marine Debris. Springer, New York, NY, pp. 25–33.

Corcoran, P.L., Biesinger, M.C., Grifi, M., 2009. Plastics and beaches: a degrading relationship. Mar. Pollut. Bull. 58 (1), 80–84.

Dau, B.K., Gilardi, K.V., Gulland, F.M., Higgins, A., Holcomb, J.B., Leger, J.S., Ziccardi, M.H., 2009. Fishing gear–related injury in California marine wildlife. J. Wildl. Dis. 45 (2), 355–362.

Dixon, T.R., Dixon, T.J., 1981. Marine litter surveillance. Mar. Pollut. Bull. 12 (9), 289–295.

Driedger, A.G., Dürr, H.H., Mitchell, K., Van Cappellen, P., 2015. Plastic debris in the Laurentian Great Lakes: a review. J. Gt. Lakes Res. 41 (1), 9–19.

EA/NALG, 2000. Assessment of Aesthetic Quality of Coastal and Bathing Beaches. Monitoring Protocol and Classification Scheme. Environment Agency and The National Aquatic Litter Group, London, p. 15.

Earll, R.C., Everard, M., Lowe, N., Pattinson, C., Williams, A.T., 1996. Measuring and Managing Litter in Rivers, Estuaries and Coastal Waters: A Guide to Methods. R. Earll Ltd, p. 78.

Gabrielides, G.P., Golik, A., Loizides, L., Marino, M.G., Bingel, F., Torregrossa, M.V., 1991. Man-made garbage pollution on the mediterranean coastline. Mar. Pollut. Bull. 23, 437–441.

Gago, J., Lahuerta, F., Antelo, P., 2014. Characteristics (abundance, type and origin) of beach litter on the Galician coast (NW Spain) from 2001 to 2010. Sci. Mar. 78 (1), 125–134.

Galgani, F., Leaute, J.P., Moguedet, P., Souplet, A., Verin, Y., Carpentier, A., …, Mahe, J.C., 2000. Litter on the sea floor along European coasts. Mar. Pollut. Bull. 40 (6), 516–527.

Galgani, F., Souplet, A., Cadiou, Y., 1996. Accumulation of debris on the deep sea floor off the French Mediterranean coast. Mar. Ecol. Prog. Ser. 142, 225–234.

Garrity, S.D., Levings, S.C., 1993. Marine debris along the Caribbean coast of panama. Mar. Pollut. Bull. 26 (6), 317–324.

Goldberg, E.D., 1995. Emerging problems in the coastal zone for the twenty-first century. Mar. Pollut. Bull. 31 (4–12), 152–158.

Gregory, M.R., 2009. Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Philos. Trans. R. Soc.: Biol. Sci. 364 (1526), 2013–2025.

Gregory, M.R., Andrady, A.L., 2003. Plastics in the marine environment. Plast. Environ. 379, 389–390.

Hahladakis, J.N., Velis, C.A., Weber, R., Iacovidou, E., Purnell, P., 2018. An overview of chemical additives present in plastics: migration, release, fate and environmental impact during their use, disposal and recycling. J. Hazard. Mater. 344, 179–199. http://dx.doi.org/10.1016/j.jhazmat.2017.10.014.

Heaney, C.D., Sams, E., Wing, S., Marshall, S., Brenner, K., Dufour, A.P., Wade, T.J., 2009. Contact with beach sand among beachgoers and risk of illness. Am. J. Epidemiol. 170 (2), 164–172.

Hohn, D., 2012. Moby-Duck: The True Story of 28,800 Bath Toys Lost at Sea. Union Books, London.

Horsman, P.V., 1982. The amount of garbage pollution from merchant ships. Mar. Pollut. Bull. 13 (5), 167–169.

Houston, J.R., 2013. The economic value of beaches – A 2013 update. Shore Beach 81 (1), 3–10.

Jayasiri, H.B., Purushothaman, C.S., Vennila, A., 2013. Plastic litter accumulation on high-water strandline of urban beaches in Mumbai, India. Environ. Monit. Assess. 185 (9), 7709–7719.

Jurado, V., Castro, M., Corral, C., Ruiz, C., Lara, R., Acosta, J., Macías, A., Gracia, J., 2006. Cuidemos la Costa 2004–2005. Consejerías de Medio Ambiente y Educación, Junta de Andalucía, Red CoastWatch, Sevilla, p. 64.

Kako, S.I., Isobe, A., Magome, S., 2010. Sequential monitoring of beach litter using webcams. Mar. Pollut. Bull. 60 (5), 775–779.

Karami, A., Romano, N., Galloway, T., Hamzah, H., 2016. Virgin microplastics cause toxicity and modulate the impacts of phenanthrene on biomarker responses in African catfish (*Clarias gariepinus*). Environ. Res. 151, 58–70. http://dx.doi.org/10.1016/j.envres.2016.07.024.

Kauffman, J., Brown, M., 1991. California marine debris action plan. In: Magoon, O.T. Converse, H. Tippie, V. Tobin, L.T. Clark, D. (Eds.), Coastal Zone '91. Proceedings of the Seventh Symposium on Coastal and Ocean Management, Long Beach, California, July 8–12, 1991, pp. 3390–3406.

Kei, K., 2005. Beach litter in amami islands, Japan. South Pac. Stud. 26, 15–24.

Klein, Y.L., Osleeb, J.P., Viola, M.R., 2004. Tourism-generated earnings in the coastal zone: a regional analysis. J. Coast. Res. 1080–1088.

Krelling, A.P., Williams, A.T., Turra, A., 2017. Differences in perception and reaction of tourist groups to beach marine debris that can influence a loss of tourism revenue in coastal areas. Mar. Policy 85, 87–99.

Lavers, J.L., Dicks, L., Dicks, M.R., Finger, A., 2019. Significant plastic accumulation on the Cocos (Keeling) Islands, Australia. Sci. Rep. 9 (1), 7102.

Martinez-Ribes, L., Basterretxea, G., Palmer, M., Tintoré, J., 2007. Origin and abundance of beach debris in the Balearic Islands. Sci. Mar. 71 (2), 305–314.

Masselink, G., Short, A.D., 1993. The effect of tide range on beach morphodynamics and morphology: a conceptual beach model. J. Coast. Res. 785–800.

McDermid, K.J., McMullen, T.L., 2004. Quantitative analysis of small-plastic debris on beaches in the Hawaiian archipelago. Mar. Pollut. Bull. 48 (7–8), 790–794.

Moerman, J.W., Potts, G.E., 2011. Analysis of metals leached from smoked cigarette litter. Tobacco Control 20 (Suppl 1), i30–i35.

Moore, S.L., Gregorio, D., Carreon, M., Weisberg, S.B., Leecaster, M.K., 2001. Composition and distribution of beach debris in orange County, California. Mar. Pollut. Bull. 42, 241–245.

Morgan, R., Bursahoglu, B., Hapoglu-Balas, L., Jones, T.C., Ozhan, E., Williams, A.T., 1995. Beach user opinions and beach ratings: a pilot study on the Turkish Aegean coast. In: Ozhan, E. (Ed.), Proceedings of the Second International Conference on the Mediterranean Coastal Environment. MedCoast 95, pp. 373–383.

Mouat, J., Lozano, R.L., Bateson, H., 2010. Economic Impacts of Marine Litter. Kommunenes Internasjonale Miljøorganisasjon.
Munari, C., Corbau, C., Simeoni, U., Mistri, M., 2016. Marine litter on Mediterranean shores: analysis of composition, spatial distribution and sources in north-western Adriatic beaches. Waste Manag. 49, 483–490.
Nachite, D., Maziane, F., Anfuso, G., Williams, A.T., 2019. Spatial and temporal variations of litter at the Mediterranean beaches of Morocco mainly due to beach users. Ocean Coast. Manag. 179, 104846.
Ocean Conservancy, 2018. Building a Clean Swell: 2018 Report. International Coastal Cleanup, Ocean Conservancy, Washington DC, www.oceanconservancy.org (accessed June 2019).
Ogi, H., Fukumoto, Y., 2000. A Sorting Method for Small Plastic Debris Floating on the Sea Surface and Stranded on Sandy Beaches. Bulletin of the Faculty of Fisheries-Hokkaido University, Japan.
Olin, R., Carlsson, B., Stahre, B., 1995. The west coast of Sweden–the rubbish tip of the north sea. coastal and riverine litter: problems and effective solutions. pp. 12–18.
Opfer, S., Arthur, C., Lippiatt, S., 2012. NOAA Marine Debris Shoreline Survey Field Guide. US National Oceanic and Atmospheric Administration Marine Debris Program.
Ortega-Sánchez, M., Fachin, S., Sancho, F., Losada, M.A., 2008. Relation between beachface morphology and wave climate at trafalgar beach (Cádiz, Spain). Geomorphology 99 (1–4), 171–185.
OSPAR Commission, 2007. Monitoring of marine litter in the ospar region. ospar pilot project on monitoring marine beach litter. p. 75.
OSPAR Commission, 2010. Guideline for monitoring marine litter on the beaches in the OSPAR maritime area.
Muñoz Pérez, J.J., Gutiérrez-Mas, J.M., 1999. Tipología y eficacia de los espigones de escollera construidos para la mejora de la estabilidad de las playas del litoral atlántico de la provincia de Cádiz. Bol. Geol. Minero 110–111, 53–56.
Philipp, S.F., 1993. Racial differences in the perceived attractiveness of tourism destinations, interests, and cultural resources. J. Leisure Res. 25 (3), 290–304.
Phillips, M.C., Solo-Gabriele, H.M., Reniers, A.J.H.M., Wang, J.D., Kiger, R.T., Abdel-Mottaleb, N., 2011. Pore water transport of enterococci out of beach sediments. Mar. Pollut. Bull. 62 (11), 2293–2298.
Plastics Europe, 2018. Plastics – the facts 2018. an analysis of european plastics production, demand and waste data.
Poeta, G., Battisti, C., Bazzichetto, M., Acosta, A.T., 2016. The cotton buds beach: Marine litter assessment along the tyrrhenian coast of central Italy following the marine strategy framework directive criteria. Mar. Pollut. Bull. 113 (1–2), 266–270.
Poizot, E., Anfuso, G., Méar, Y., Bellido, C., 2013. Confirmation of beach accretion by grain-size trend analysis: Camposoto beach, Cádiz, SW Spain. Geo-Mar. Lett. 33 (4), 263–272.
Rangel-Buitrago, N., Anfuso, G., 2011. Coastal storm characterization and morphological impacts on sandy coasts. Earth Surf. Process. Landf. 36 (15), 1997–2010.
Rangel-Buitrago, N., Williams, A., Anfuso, G., Arias, M., Gracia, A., 2017. Magnitudes, sources, and management of beach litter along the Atlantico department coastline, Caribbean coast of Colombia. Ocean Coast. Manag. 138, 142–157.
Rech, S., Macaya-Caquilpán, V., Pantoja, J.F., Rivadeneira, M.M., Madariaga, D.J., Thiel, M., 2014. Rivers as a source of marine litter–a study from the SE Pacific. Mar. Pollut. Bull. 82 (1–2), 66–75.
Ribic, C.A., 1998. Use of indicator items to monitor marine debris on a New Jersey beach from 1991 to 1996. Mar. Pollut. Bull. 36 (11), 887–891.
Roca, E., Riera, C., Villares, M., Fragell, R., Junyent, R., 2008. A combined assessment of beach occupancy and public perceptions of beach quality: a case study in the Costa Brava, Spain. Ocean Coast. Manag. 51 (12), 839–846.
Rochman, C.M., Hentschel, B.T., Teh, S.J., 2014. Long-term sorption of metals is similar among plastic types: implications for plastic debris in aquatic environments. PLoS One 9 (e85433), http://dx.doi.org/10.1371/journal.pone.0085433.
Rosevelt, C., Los Huertos, M., Garza, C., Nevins, H.M., 2013. Marine debris in central California: Quantifying type and abundance of beach litter in Monterey Bay, CA. Mar. Pollut. Bull. 71 (1–2), 299–306.
Sánchez Moreno, H., Bolívar-Anillo, H.J., Soto-Varela, Z.E., Pichón Gonzaléz, C., Villate Daza, D.A., Anfuso, G., 2019. Microbiological water quality and sources of contamination along the coast of the Department of Atlántico (Caribbean sea of Colombia), Preliminary results. Mar. Pollut. Bull. 142, 303–308.
Santos, I.R., Friedrich, A.C., Do Sul, J.A.I., 2009. Marine debris contamination along undeveloped tropical beaches from northeast Brazil. Environ. Monit. Assess. 148 (1–4), 455–462.
Savoca, D., Arculeo, M., Barreca, S., Buscemi, S., Caracappa, S., Gentile, A., ...Pace, A., 2018. Chasing phthalates in tissue of marine turtles from the Mediterranean sea. Mar. Pollut. Bull. 127, 165–169. http://dx.doi.org/10.1016/j.marpolbul.2017.11.069.
SGP(Secretaría General de Pesca), 2018. La flota española. In: Situación a 31de Diciembre de 2018. Gobierno de España. Ministerio de Agricultura, Pesca y Alimentación, p. 16.
Sheavly, S.B., Register, K.M., 2007. Marine debris & plastics: environmental concerns, sources, impacts and solutions. J. Polymers Environ. 15 (4), 301–305.
Šilc, U., Küzmič, F., Caković, D., Stešević, D., 2018. Beach litter along various sand dune habitats in the southern Adriatic (E Mediterranean). Mar. Pollut. Bull. 128, 353–360.
Smith, V.K., Zhang, X., Palmquist, R.B., 1997. Marine debris, beach quality, and non-market values. Environ. Resour. Econ. 10 (3), 223–247.
Thiel, M., Bravo, M., Hinojosa, I.A., Luna, G., Miranda, L., Núñez, P., ., Vásquez, N., 2011. Anthropogenic litter in the SE Pacific: an overview of the problem and possible solutions. Rev. Gestão Costeira Integr.-J. Integr. Coast. Zone Manag. 11 (1).
Thiel, M., Hinojosa, I.A., Miranda, L., Pantoja, J.F., Rivadeneira, M.M., Vásquez, N., 2013. Anthropogenic marine debris in the coastal environment: a multi-year comparison between coastal waters and local shores. Mar. Pollut. Bull. 71 (1–2), 307–316.
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.
Tudor, D.T., Williams, A.T., 2001. Transect size and other threshold levels in beach litter measurement. Shore Beach 69 (4), 13–18.
Tudor, D.T., Williams, A.T., 2004. Development of a 'Matrix Scoring Technique'to determine litter sources at a Bristol Channel beach. J. Coast. Conserv. 10 (1), 119–127.
UNEP(United Nations Environment Programme), 2005. Marine litter: An analytical overview. In: UNEP'S Regional Seas Programme United Nations Environment Programme. Ed. UNEP, p. 47.
UNWTO (World Tourism Organization), 2018. UNWTO Tourism Highlights, two thousand and eighteenth ed. UNWTO, Madrid, http://dx.doi.org/10.18111/9789284419876.
Van Franeker, J.A., Blaize, C., Danielsen, J., Fairclough, K., Gollan, J., Guse, N., ., Olsen, B., 2011. Monitoring plastic ingestion by the northern fulmar Fulmarus glacialis in the North Sea. Environ. Pollut. 159 (10), 2609–2615.
Velander, K.A., Mocogni, M., 1998. Maritime litter and sewage contamination at Cramond Beach Edinburgh—a comparative study. Mar. Pollut. Bull. 36 (5), 385–389.
Vlachogianni, Th, 2019. Assessing marine litter on Mediterranean beaches. In: Filling in the Knowledge Gaps Via a Participatory-Science Initiative. MIO-ECSDE.
Votier, S.C., Archibald, K., Morgan, G., Morgan, L., 2011. The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality. Mar. Pollut. Bull. 62 (1), 168–172.
Watts, A.J., Porter, A., Hembrow, N., Sharpe, J., Galloway, T.S., Lewis, C., 2017. Through the sands of time: Beach litter trends from nine cleaned north cornish beaches. Environ. Pollut. 228, 416–424.
Williams, A.T., 2011. Definitions and typologies of coastal tourism destinations. In: Jones, Andrew, Phillips, Mike (Eds.), Disappearing Destinations: Climate Change and Future Challenges for Coastal Tourism. CABI, UK, pp. 47–66.
Williams, A.T., Micallef, A., 2009. Beach Management, Principles & Practice. Earthscan, London, ISBN: 978-1-84407-435-8, p. 480.
Williams, A.T., Pond, K., Ergin, A., Cullis, M.J., 2013. The hazards of beach litter. In: Coastal Hazards. Springer, Dordrecht, pp. 753–780.
Williams, A.T., Randerson, P., Alharbi, O.A., 2014. From a millennium base line to 2012: Beach litter changes in Wales. Mar. Pollut. Bull. 84 (1–2), 17–26.
Williams, A.T., Randerson, P., Allen, C., Cooper, J.A.G., 2017. Beach litter sourcing: A trawl along the Northern Ireland coastline. Mar. Pollut. Bull. 122 (1–2), 47–64.
Williams, A.T., Randerson, P., Di Giacomo, C., Anfuso, G., Macias, A., Perales, J.A., 2016. Distribution of beach litter along the coastline of Cádiz, Spain. Mar. Pollut. Bull. 107 (1), 77–87.
Williams, A.T., Simmons, S.L., 1997. Estuarine litter at the river/beach interface in the Bristol Channel, United Kingdom. J. Coast. Res. 1159–1165.
Williams, A.T., Tudor, D.T., 2001. Litter burial and exhumation: spatial and temporal distribution on a cobble pocket beach. Mar. Pollut. Bull. 42 (11), 1031–1039.
Wright, E.L., Black, C.R., Cheesman, A.W., Turner, B.L., Sjögersten, S., 2013. Impact of simulated changes in water table depth on ex situ decomposition of leaf litter from a neotropical peatland. Wetlands 33 (2), 217–226.
Wright, L.D., Short, A.D., 1984. Morphodynamics variability of surf zones in Australia. In: Handbook of Coastal Processes and Erosion. CRC Press, Boca Raton, Flórida, pp. 35–64.
Zhou, C., Liu, X., Wang, Z., Yang, T., Shi, L., Wang, L., ., Zhang, C., 2016. Assessment of marine debris in beaches or seawaters around the China Seas and coastal provinces. Waste Manag. 48, 652–660.

**Anexo V**

Publicación **V**.

## Characterization of plastic beach litter by Raman spectroscopy in south-western Spain

Francisco Asensio-Montesinos[1], Milagrosa Oliva Ramírez[2], Juan María González-Leal[3,4], Daniel Carrizo[5], Giorgio Anfuso[1]

[1]Departamento de Ciencias de la Tierra, Facultad de Ciencias del Mar y Ambientales. Universidad de Cádiz. Campus Río San Pedro s/n. Puerto Real 11510. Cádiz. Spain.

[2]Departamento de Biología, Facultad de Ciencias del Mar y Ambientales. Universidad de Cádiz. Campus Río San Pedro s/n. Puerto Real 11510. Cádiz. Spain.

[3]IMEYMAT. Instituto Universitario de Investigación en Microscopía Electrónica y Materiales, Facultad de Ciencias. Universidad de Cádiz. Campus Río San Pedro s/n. Puerto Real 11510. Cádiz. Spain.

[4]Departamento de Física de la Materia Condensada, Facultad de Ciencias. Universidad de Cádiz. Campus Río San Pedro s/n. Puerto Real 11510. Cádiz. Spain.

[5]Centro de Astrobiología (CSIC-INTA), 28850, Torrejón de Ardoz, Madrid, Spain.

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# Characterization of plastic beach litter by Raman spectroscopy in South-western Spain

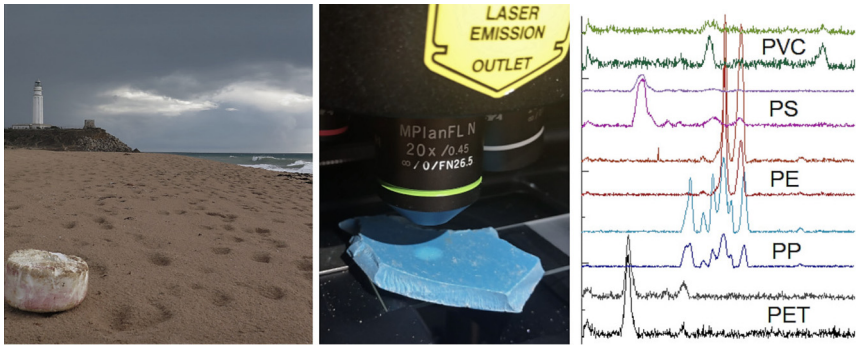
Francisco Asensio-Montesinos [a,*], Milagrosa Oliva Ramírez [b], Juan María González-Leal [c,d], Daniel Carrizo [e], Giorgio Anfuso [a]

[a] Departamento de Ciencias de la Tierra, Facultad de Ciencias del Mar y Ambientales, Universidad de Cádiz, Campus Río San Pedro s/n, Puerto Real 11510, Cádiz, Spain
[b] Departamento de Biología, Facultad de Ciencias del Mar y Ambientales, Universidad de Cádiz, Campus Río San Pedro s/n, Puerto Real 11510, Cádiz, Spain
[c] IMEYMAT, Instituto Universitario de Investigación en Microscopía Electrónica y Materiales, Facultad de Ciencias, Universidad de Cádiz, Campus Río San Pedro s/n, Puerto Real 11510, Cádiz, Spain
[d] Departamento de Física de la Materia Condensada, Facultad de Ciencias, Universidad de Cádiz, Campus Río San Pedro s/n, Puerto Real 11510, Cádiz, Spain
[e] Centro de Astrobiología (CSIC-INTA), 28850 Torrejón de Ardoz, Madrid, Spain

## HIGHLIGHTS

- Plastic litter is mainly observed at the high tide line and the backshore area.
- Cigarette butts are a major problem in most of visited beaches.
- Excluding cigarette butts, PP and PE are the most abundant types of plastics.
- Beach litter can be attributed to beach users, fishing or wastewater discharges.
- White, transparent and blue are the main colours of the hard plastic pieces.

## GRAPHICAL ABSTRACT




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## ABSTRACT

The characteristics and distribution of plastic litter were evaluated in October 2018 at 40 beaches along the coast of Cádiz Province, in Spain. A total of 14,261 plastic items, appertaining to 57 litter groups, were identified along the study area at different beach zones, i.e. at low tide water level (2%), along the foreshore (6%), at high tide water level (67%) and in the backshore area (25%). Plastic items have a great floatability, being this one of the main reasons for their proportional dominance among beach litter, especially in the wrack line. Hundreds of measurements were made of different items using Raman spectroscopy, an effective technique to determine the type of plastic. Cellulose acetate represented the most abundant material (79%) linked to cigarette butts, followed by polypropylene, 9% and polyethylene, 8%. The remaining were composed by polystyrene, polyethylene terephthalate and polyvinyl chloride. Smoke related items were the most common in the study area, followed by film and hard pieces, cotton bud sticks, fishing strings, food wrappers, caps/lids and single-use plastics. Beach litter can be related to beachgoers but some categories can be attributed to fishing activities or wastewater discharges. Plastics cause a multitude of damages to the coastal ecosystem, due to their toxic components and adsorbed substances and their facility of fragmentation and dispersion. Principal objective is the compositional characterization of plastic beach litter items and their spatial variability. It is therefore important to avoid unnecessary consumption, promote recycling and use other materials that are less harmful to the environment.

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* Corresponding author.
*E-mail addresses:* francisco.asensio@uca.es (F. Asensio-Montesinos), milagrosa.oliva@uca.es (M. Oliva Ramírez), juanmaria.gonzalez@uca.es (J.M. González-Leal), dcarrizo@cab.inta-csic.es (D. Carrizo), giorgio.anfuso@uca.es (G. Anfuso).

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## 1. Introduction

At a global scale, increasing human population and associated economic growth has led to an increase in the demand for consumable goods such as those made of polymer-based materials, i.e. plastics. Plastic is considered one of the most versatile materials and, in comparison to other solid materials such as metal or ceramics, it shows some special characteristic: e.g. low melting point, high elongation, low density, low thermal conductivity, electrical resistance, optical clarity and is easily coloured (Strong, 1996). Plastic is applied in many fields as packaging, building and construction, medical, recreational, appliances, housewares, transport, entertainment, etc. (Andrady and Neal, 2009). As a result, annual production of plastics has increased from 1.5 million tonnes in the 1950s to approximately 359 million tonnes in 2018 (Plastics Europe, 2019). Plastics can be released into the environment from a variety of sources and, once in the environment, they are exposed to a variety of mechanical and chemical weathering processes facilitating the disintegration into smaller fragments (Andrady, 2011).

Marine litter is currently 60% to 80% constituted by plastic, reaching 95% in some areas (Gregory and Andrady, 2003; OSPAR Commission, 2007). In Europe, 80% of plastic production is made up of six main polymers: polypropylene (PP), high and low-density polyethylene (HDPE and LDPE), polyvinyl chloride (PVC), polyurethane (PUR), polyethylene terephthalate (PET) and polystyrene (PS) (Plastics Europe, 2016; Bringer et al., 2020). Its abundance in the environment is linked to the great plastic durability and persistence, combined with rising production of plastics and low rates of recovery (Driedger et al., 2015).

Accumulation rates obtained by means of beach surveys may be used as proxy indicators for the determination of litter flows into the ocean (Cheshire et al., 2009; Ryan et al., 2009). Previous studies have shown that litter abundance and composition are influenced by different factors including proximity to metropolitan areas and access to the public (Lamprecht, 2013; Willis et al., 2017) as well as beach characteristics and water movements (Critchell and Lambrechts, 2016; Ryan et al., 2018).

Plastic litter produces negative effects on biota and the ecosystem because of ingestion of micro- and mesoplastic by organisms (Allsopp et al., 2006; Browne et al., 2011; Van Franeker et al., 2011), the entanglement of animals in abandoned nets, fishing lines, ropes and ribbons (Gregory, 2009; Votier et al., 2011), the dispersion of chemical compounds as additives (Savoca et al., 2018), heavy metals (Nakashima et al., 2012; Turner, 2016), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and other persistent organic pollutants (POPs) (Rochman et al., 2014) producing behavioural changes, changes in metabolic processes and endocrine disruption in marine organisms (Anderson et al., 2016). In addition, plastic debris can provide a mechanism for the spread of invasive species (Bryan et al., 2012; Gall and Thompson, 2015) due to their long-dispersal time in marine environments (Thiel et al., 2003).

Due to the above mentioned adverse impacts, plastics have been proposed to be classified as hazardous materials (Rochman et al., 2013; Williams et al., 2013). Recently, UNEP (2014) estimated that plastic debris has cost $13 billion in damage to ecosystems per year and issued a report that proposed the use of a "plastic footprint" to manage the plastic burden in the environment. Arguably, plastic pollution is the second most important global environmental issue after climate change (Lee et al., 2015).

For the Atlantic coast of Andalusia, observations on beach litter have been carried out for the Cádiz Province by Williams et al. (2016), Asensio-Montesinos et al. (2020) and Cruz et al. (2020), but no detailed characterization of the composition of mesoplastics (from 5 to 200 mm) and macroplastics debris (>200 mm) has been carried out. In this context, it is crucial to investigate the abundance of plastic marine debris and its characteristics on beaches to gain a better understanding of the status of plastic marine debris contamination, potential environmental impacts and cleaning strategies. Main research objective of the present work was the compositional characterization of plastic beach litter items and their spatial variability long the Atlantic coast of Cádiz Province (South-western Spain).

## 2. Material and methods

### 2.1. Study area

The studied area, 192 km in length, is located in the SW coast of Spain (Fig. 1). A total amount of 40 beaches, located in 12 municipalities facing the Atlantic Ocean coast of Cádiz Province, have been characterized from the Guadalquivir River mouth to the Gibraltar Strait (Fig. 1). Surveyed beaches distribution was arbitrarily selected to uniformly cover the whole length of the studied area. The investigated beaches are composed of golden sand with a meso-tidal environment (tidal range between 2 and 4 m) from beach no. 1 to 30, and micro-tidal conditions (range < 2 m) from no. 31 to 40 (Fig. 1). The coast of Cádiz has a medium-low tourist density compared to other areas in Spain and cover different types of bathing areas.

Beach typology determination was applied at each site according to the Bathing Area Registration and Evaluation (BARE) system, described by Williams and Micallef (2009). The typologies identified were "Remote", "Rural", "Village" and "Urban", according to the accessibility and type of buildings they present. Remote beaches are defined by their difficulty of access, i.e. largely by boat or on foot — a walk of 300 m or more (Williams and Micallef, 2009). Rural beaches are valued by users for their quietness and natural qualities because they have little or no beachfront development, sometimes, they may have some residential houses (Williams and Micallef, 2009). A village beach is located outside the main urban environment and related to a small but permanent population. They may be reached by public transport (Williams and Micallef, 2009). Finally, urban beaches serve great populations with well-established public services (Williams and Micallef, 2009). The definitions are simple and clear but each beach is unique, so the application of this classification may present some difficulty.

### 2.2. Sampling method and preparation

Litter assessment was carried out at low tide conditions at the 40 studied beaches in October 2018. The observer recorded all litter items found in a 100 m wide shore-parallel section in the middle of the beach, by moving along 5 m shore-parallel spaced lines. This method covers the entire usable beach, from the shoreline up to the landward boundary (Asensio-Montesinos et al., 2020, p. 4). This sampling area is recommended by several entities (UNEP, OSPAR Commission, NOAA) and has been illustrated by different litter survey field guides and reports (Cheshire et al., 2009; OSPAR Commission, 2007; Nachite, 2019; Opfer et al., 2012; Vlachogianni, 2019).

According to previous studies (Jurado et al., 2006; Williams et al., 2016) and field visits, a Masterlist of 183 categories of litter reported by EA/NALG (2000), Cheshire et al. (2009), OSPAR Commission (2010) and Opfer et al. (2012) classifications, was compiled based on material composition (Dixon and Dixon, 1981) and size (Ribic, 1998). From the 183 established categories, 57 consisted of plastic materials. All plastic items were collected for subsequent identification in the laboratory by means of a micro-Raman spectroscope. Litter was grouped by beach according to material typology (pieces of film, pieces of hard plastic, caps, etc.) for their identification. Last, it was also used a specific photo-guide based on observations carried out along the Mediterranean coast of Morocco, which showed a great diversity of litter items (Nachite, 2019).

### 2.3. Microscopic and spectroscopic analysis

The type of plastic material was determined by using a Raman spectrometer (Jasco, model NSR 7200) using the *Spectra Manager* software from Jasco Corporation. The following parameters were used: laser wavelength = 532.19 nm; aperture = 200 μm × 1000 μm; objective =

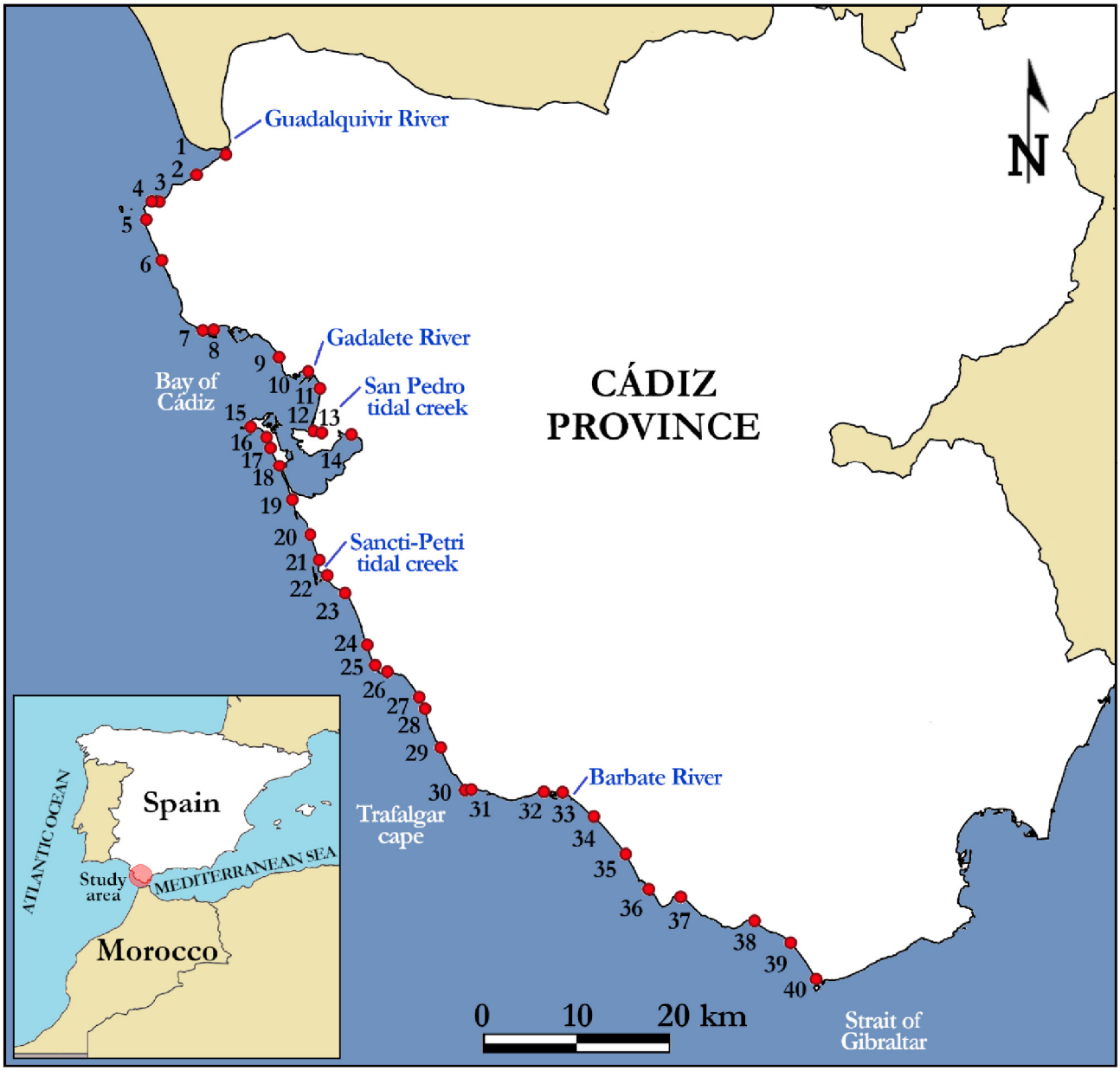



**Fig. 1.** Map location (see information of the beaches in Table S1).

20× magnification; laser power = 6 mW; laser exposure time = 5 s; accumulation for spectra averaging = 2. Raman spectra were measured with a resolution of about 5 $cm^{-1}$ in the ranges of 1135–1844 $cm^{-1}$ and 2604–3177 $cm^{-1}$. These wavenumber ranges are those where polymers show their characteristic Raman bands.

Because of the fluorescence shown by some items (typically in the case of orange or purple coloured items), and for black colour items, laser exposure times where conveniently reduced to improve the signal-to-noise ratio (SNR) or to avoid sample damages, respectively. For weakly-active Raman items, the laser exposure times were conveniently increased to improve the SNR (for example, in the case of some transparent plastic films).

Reference Raman spectra were obtained from verified samples of polypropylene (PP), low-density polyethylene (LDPE), high-density polyethylene (HDPE), polystyrene (PS), polyethylene terephthalate (PET) and polyvinyl chloride (PVC). Other reference Raman spectra reported in other studies were also considered for this investigation, i.e. Allen et al. (1999), Dehaut et al. (2016), Käppler et al. (2016), Lenz et al. (2015), Polarz et al. (2002), Ribeiro-Claro et al. (2017), Syakti et al. (2017) and Zhao et al. (2015). The figures of different Raman spectra and the numbers of the main and secondary Raman peaks were very useful for this purpose. A number of supposed plastic items could not be corresponded against reference spectra and were categorised as "other" if their texture, shape, colour and characteristic Raman bands corresponded with a plastic material. Finally, plastics were grouped into seven categories: cellulose acetate (CA); polypropylene (PP); polyethylene (PE); polystyrene (PS); polyethylene terephthalate (PET), polyvinyl chloride (PVC), and "other".

## 3. Results and discussion

### 3.1. Beach plastic litter: abundance and distribution

At each studied site, the beach surface investigated was covered by means of 4 to 12 longshore transects (400–1200 m) obtaining a total length of 26 km. Plastic represented 88.5% of all beach litter items

**Table 1**
Category codes for litter items in the 40 sites surveyed.

| Code | Litter categories | Number of items | % |
|---|---|---|---|
| PL24 | Cigarettes, butts and filters | 10,833 | 75.9 |
| PL65,66 | Film plastic pieces | 797 | 5.6 |
| PL62,63 | Hard plastic pieces | 751 | 5.3 |
| PL23 | Cotton bud sticks | 315 | 2.2 |
| PL42,43 | Rope, string and cord | 289 | 2 |
| PL27 | Food wrappers | 248 | 1.7 |
| PL30,74 | Caps/lids | 224 | 1.6 |
| PL16,17,18 | Knives, forks, spoons, stirrers, straws | 191 | 1.3 |
| PL34 | Crisp/sweet packets and lolly sticks | 129 | 0.9 |
| PL03,04 | Bags | 110 | 0.8 |
| PL68,69,70 | Foamed plastic pieces | 89 | 0.6 |
| PL05,06 | Drinks (bottles, containers and drums) | 44 | 0.3 |
| PL25 | Hard plastic cups | 25 | 0.2 |
| PL35 | Toys and party poppers | 25 | 0.2 |
| | Other | 206 | 1.4 |

accounted in the study area (Asensio-Montesinos et al., 2020, p. 6). The percentage of plastic content at the investigated beaches varied according to each specific site, from 39.9% to 97.4% (no. 14 and 26, Fig. 1, Table S1).

A total of 14,275 plastic items were counted and 57 plastic litter groups were identified at the 40 surveyed beaches, the most numerous were presented in Table 1. A high variability was observed in the number of plastic items as they ranged from 5 to 1758 items per 100 m of beach length (nos. 38 and 27, Table S1, Fig. S1). In addition, all plastic items were identified at different beach zones, i.e. at low tide water level (2% of the total amount), along the foreshore (6%), at high tide water level (67%) and in the backshore area (25%, Fig. S1).

Selected beaches covered Remote (Andrady and Neal, 2009), Rural (Bringer et al., 2020), Village (Bryan et al., 2012) and Urban (Bringer et al., 2020) bathing areas that presented relevant differences in the number of plastic items (Figs. S1 and S2). Considering data regarding litter abundance, a "Kruskal-Wallis" test determined significant differences among beach typologies ($p$-value = 0.013). Pair-wise comparisons were performed with the "Mann-Whitney" test, which showed relevant differences between remote vs village and urban ($p$-values = 0.008 and 0.003 respectively). The same analysis was performed using cigarette butts that represented the most abundant item along the coast investigated, but also at many other places (Ocean Conservancy, 2017, 2018, 2019). Mentioned test evidenced relevant differences between remote vs rural, village and urban ($p$-values = 0.036, 0.003 and 0.002 respectively, Mann-Whitney test).

In following lines results were presented according to beach typology:

i) Remote areas were the least visited and they contained few plastic items compared to the rest, with an average of 53 items per 100 m of beach length (median = 45, Fig. S2). Levante Beach presented the highest concentration of litter (no. 12. Table S1 and Fig. S2) since, because of its location in the middle of the Bay of Cádiz, constitutes a sheltered area in which litter entering from the open ocean, the Guadalete River and nearby locations, is accumulated (Fig. 1). When comparing litter data by beach typology, remote areas of the Atlantic coast of Cádiz are cleaner than the corresponding areas on the Spanish and Moroccan Mediterranean coasts (Asensio-Montesinos et al., 2019; Maziane et al., 2018).

ii) Rural areas generally contained much more litter (307 items) than the previous category (median = 108) and two sites were the most polluted (Figs. S1 and S2), i.e. a pocket beach called "Cala del Aceite" (no. 26, Fig. 1), and "Camposoto" beach (no. 20, Fig. 1). Both beaches were heavily visited and showed beach restaurants during summer time. These results are close to the ranges of values found in similar beaches in the Spanish Mediterranean coast by Asensio-Montesinos et al. (2019); however, Moroccan rural beaches contain less litter respect to the beaches investigated in this paper (Maziane et al., 2018; Nachite et al., 2019).

iii) Village areas had an average of 420 items (median = 345, Fig. S2). They generally received more visits than the previous categories because their urbanized environment. Two beaches contained more plastic than the rest (Fig. S2), i.e. "La Barrosa", which received many users and is located near the Sancti-Petri tidal creek (no. 23, Fig. 1), and "Bajo de Guía", which is mainly used for fishing activities in the Guadalquivir River mouth (no. 1, Fig. 1). Village beaches in the Cádiz Province presented more litter than the Moroccan ones (Maziane et al., 2018; Nachite et al., 2019), and much more than other Spanish Mediterranean coastal sites (Asensio-Montesinos et al., 2019).

iv) Finally, urban areas generally were the most visited and had greatest average values, i.e. 468 items (median = 290, Fig. S2). Outliers were the beach of "Los Bateles" in front of Conil municipality (no. 27, Fig. 1) and a pocket beach called "Santa María del Mar", in the city of Cádiz (no. 16, Fig. 1). This category generally contained high quantity of litter and this was also observed at similar Mediterranean beaches by Ariza et al. (2008), Asensio-Montesinos et al. (2019), Maziane et al. (2018) and Nachite et al. (2019). This trend may be due to that, despite the implementation of cleaning operations, urban beaches are visited by an elevated number of users since they serve very populated areas (Williams and Micallef, 2009).

### 3.2. Plastic litter identification: composition and proportions

Raman spectroscopy has shown good results for identifying the majority of beach plastic litter. Some reference measurements are shown in Fig. 2A. Due to several reasons, it was not possible to determinate a small percentage (from 0.29% to 12.86%, Table S1) of the plastic recollected at a few beaches. This was because, on one hand, auxiliary products are often used in plastics to give them different functional characteristics. These products are additives (stabilizers, plasticizers, lubricants, UV filters, colorants, etc.) and, for several decades, their number has been described as "infinite" (Avendaño, 1992) due to their huge number and the multiple combinations among them. Because of additives, a determined type of plastic can have different Raman spectra as illustrated in Fig. S3, where polyethylene (PE) caps of different colours are compared. On the other hand, some plastic items appeared much damaged due to their long exposition in coastal environment, where water, wind, sun, and the beach substrate (sand, boulders, etc.) wear litter items surface affecting the quality/intensity of the Raman bands.

Regarding the type of plastic, cellulose acetate (CA) represented 79% of the total amount identified (Fig. 3A). This is linked to cigarette butts (Polarz et al., 2002) that contain more than 4000 toxic chemicals (Kurmus and Mohajerani, 2020) and constitute a very common item in different beaches (Munari et al., 2016; Kungskulniti et al., 2018), representing one of the most abundant waste in the world. Cellulose acetate (the filter material of cigarette butts) is a synthetic polymer made of cellulose (a natural polymer of vegetable origin) through a process known as acetylation that includes the addition of acetic anhydride and acetic acid. At the end of the process, plasticizers are added (such as polyethylene glycol). Cellulose is readily biodegraded by organisms that use the cellulose enzyme. Due to the modification of the polymer by chemical processes, the product obtained (cellulose acetate) is photodegradable, but has a limited potential for biodegradation (Kungskulniti et al., 2018). Although ultraviolet rays from the sun will eventually break the filter into smaller pieces under ideal environmental conditions, the source material never disappears; it essentially becomes diluted in water or soil (Novotny et al., 2009). A high variability in the study area was observed for this litter group that ranged from 0

to 93% (Table S1). The low density of CA was essentially recorded in remote or rural areas (Mean values: 8 and 245 units respectively) where the presence of people was low in the backshore zone in comparison to other sites (Table 2). On the contrary, high densities usually were observed in village (318 items) or urban beaches (360 items, Table 2), much frequented by beach users. Most of cigarette butts were accumulated at the strandline because of the tidal action (Table 2) as also observed by Claereboudt (2004), Tudor and Williams (2001) and Williams et al. (2017).

Polypropylene (PP), observed in all the studied beaches (Table S1), presented an average content of 9% of the total (Fig. 3A), ranging from 2.7% to 48.8%. A wide number of litter items recollected in this study were made up of PP, e.g. bottles, containers, drums, knives, forks, spoons, stirrers, straws, hard plastic food containers, cotton bud sticks, hard plastic cups (Fig. 2B), food wrappers, caps/lids, pens, lolly sticks, toys, string and cord, small light sticks, strapping bands, hard plastic pieces, film plastic pieces and syringes. This type of plastic is somewhat more susceptible to ultraviolet (UV) and oxidative degradation than PE but is more resistant to stress cracking (Strong, 1996).

Polyethylene (PE), found in all the studied beaches, showed similar proportions than PP with an average content of 8%, ranging from 2% to 85.3% (Fig. 3A and Table S1). Many of the items measured were made of PE: e.g. pack yokes, bags, drinks, cleaner products, spoons, gloves, food wrappers, caps/lids (Fig. 2B), toys, mesh bags, foam (insulation & packaging), string and cord, big light tubes, floats/buoys, tampon applicators, hard plastic pieces, film plastic pieces, eye drops, cloth pegs, artificial flowers, adhesive tape roll, hunting cartridges, etc. PE is relatively insensitive to most solvents, has a high electrical resistance and, for instance, is a good thermal insulator. In addition, PE is cheap and easy to manufacture (Strong, 1996).

Polystyrene (PS) represented 2% of the total plastic (Fig. 3A) and ranged from 0 (or non-detected) to 20% in the study area (Table S1). Within this study PS was observed especially in single-use plastics such as knives, forks, spoons (Fig. 2B), stirrers, cups and food containers but also appeared in other plastic categories, e.g. cigarette lighters, toys, pens and hard pieces. Polystyrene items break easily because their fragility, in part, due to its rigidity. Another negative aspect is PS sensitivity to all solvents (Avendaño, 1992). Foamed PS also appeared in several beaches, in foam pieces, drinking cups, food containers, packaging or fishing floats. PS is very abundant in form of fragments and presents a great floatability so it is a well-known waste on the coast: 5.6% were found on the low tide water line and 12.3% in the foreshore, while 40.4% were found at the high-tide water line and the other 41.6% in the backshore. Although it is not as abundant as other types of litter, it is frequent since it can be found even in the most remote beaches due to its facility of dispersion by wind and currents. PS is sensitivity to aromatic and chlorinated solvents but is resistant to water and is utilized in many applications, for example in food packaging (Strong, 1996).

Polyethylene terephthalate (PET) represented only 1% of the total amount (Fig. 3A), ranging from 0 to 24% (Table S1). Beach litter made of PET was linked to drinks (Fig. 2B), hard food containers, food wrappers, hard plastic pieces and film plastic pieces. This type of plastic is characterized by its transparency and is the most commonly used in food and drinks packaging. Further, it is the most important of the thermoplastic polyesters, i.e. airtight and rigid but also partially flexible. In the textile application, it is used to give resistance to fibres and is also used for its clarity and ruggedness in films (Strong, 1996).

Polyvinyl chloride (PVC) represented 0.3% within the total amount identified (Fig. 3A) and ranged from 0 to 9.8% (Table S1). The items corresponded mostly to pieces of hard plastic and pieces of film but other PVC objects such as tubes, sweet wrappers, toys, bottles and different types of boxes were also found (Fig. 2B). Is the most versatile type of plastic and, to be used, has to contain a number of additives such as stabilizers, lubricants, plasticizers, other polymers, etc. (Avendaño, 1992). Rigid PVC (without plasticizers) is used in pipes, blinds, carpentry, decorative, etc. and plasticized PVC is used as an insulating coating for cables, flexible pipes and hoses, films for various uses, etc. (Avendaño, 1992).

Other non-determinate plastics appeared among the samples, representing 1% of the total amount (Fig. 3A). Hard plastic pieces, food wrappers, film plastic pieces, tubes, caps, toys, lighters and beach ashtrays are some of the items classified in this category.

Plastic proportions by resin types characterized in this research (excluding cigarette butts) reflected the distribution of the most common polymers in Europe, i.e. PP (44%) and PE (27%, Fig. 3B). In fact, some groups of litter are mostly composed of these two types of plastic, for example caps and lids (Fig. 3C). Within other more heterogeneous groups such as hard plastic pieces, PE and PP are also the most common (Fig. 3D). According to Plastics Europe (2019), PE is the most common type of plastic (29%) that includes HDPE and LDPE, followed by PP (19%). Differences between the production of plastic types and beach litter may be mainly due to the use made of each material and the ability to be reused or recycled. These results can be compared with other studies, for example, in Ookushi beach (Japan), PE and PP were the most numerous plastic materials (Nakashima et al., 2011) and, in the case of microplastic polymers, PP and PE were predominant in a coastal area of Indonesia (Syakti et al., 2017). In a study concerning plastic ingestion by seagulls, Lenzi et al. (2016) observed as most common plastic materials were composed by PE, PP, polyamide (PA), PS, PVC and PET.

In the case of plastic consumer products, Zimmermann et al. (2019) demonstrated that PVC or bioplastics such as polylactic acid (PLA) presented high toxicity, while PET and HDPE caused low or had no toxicity meanwhile the toxicity of LDPE, PS and PP varied a lot.

Taking in mind the previous observations, it is important for the industry to choose the best material for each purpose (e.g. products not inducing toxicity), considering that, in many cases, different products will end up abandoned in the environment.

### *3.3. Number of items per litter category and its relation with the type of plastic*

Table 1 shows the most numerous items founded in beaches by litter group(s). The total area assessed was approximately 292,800 $m^2$. The first position in the ranking was for cigarette butts with more than 10,000 units in the study area, with important differences according to beach typology and beach zone (Table 2). Cigarettes butts are considered the most common form of personal litter in the world (Novotny and Slaughter, 2014; Curtis et al., 2017). There are a wide variety of approaches to their classification; for example, cigarette butts are considered as plastic in 19% of studies and placed in an isolated category in another 16% (Araújo and Costa, 2019). These residues are small but are generated in large amounts. Yearly, 4.5 trillion cigarettes are littered in the environment and according to a report by the Ocean Conservancy (2011), approximately 52 million cigarettes were removed from coastal environments over 27 years.

The next position in the rank is for film plastic pieces with almost 800 units in the study area; the majority have been identified as straw wrappers and tobacco packet wrappers, made of PP. Film pieces are also composed by other type of plastics, the most common was PP (59%) followed by PE (27%) but also appeared films composed by PVC, PET, PS and other types of plastics (Fig. 3E). There were observed several colours but the ones that predominated were the transparent one with 80% of the total followed by white with 12%. The rest of the colours in film plastic pieces only represented 8% (Fig. 3F).

Hard plastic pieces were the following common group represented with 751 items, or 5.3% of the total. They were one of the most complex groups of beach litter that exists, since pieces of plastic of all types have been measured. The majority were represented by PE (35%) and PP (31%), followed by PS (13%), PET (4%) and PVC (3%). The rest (14%) belonged to the "other" category (Fig. 3D). It was very interesting the great number of colours presented in the hard plastic pieces category, being white, transparent and blue the most common (Fig. 3G), being

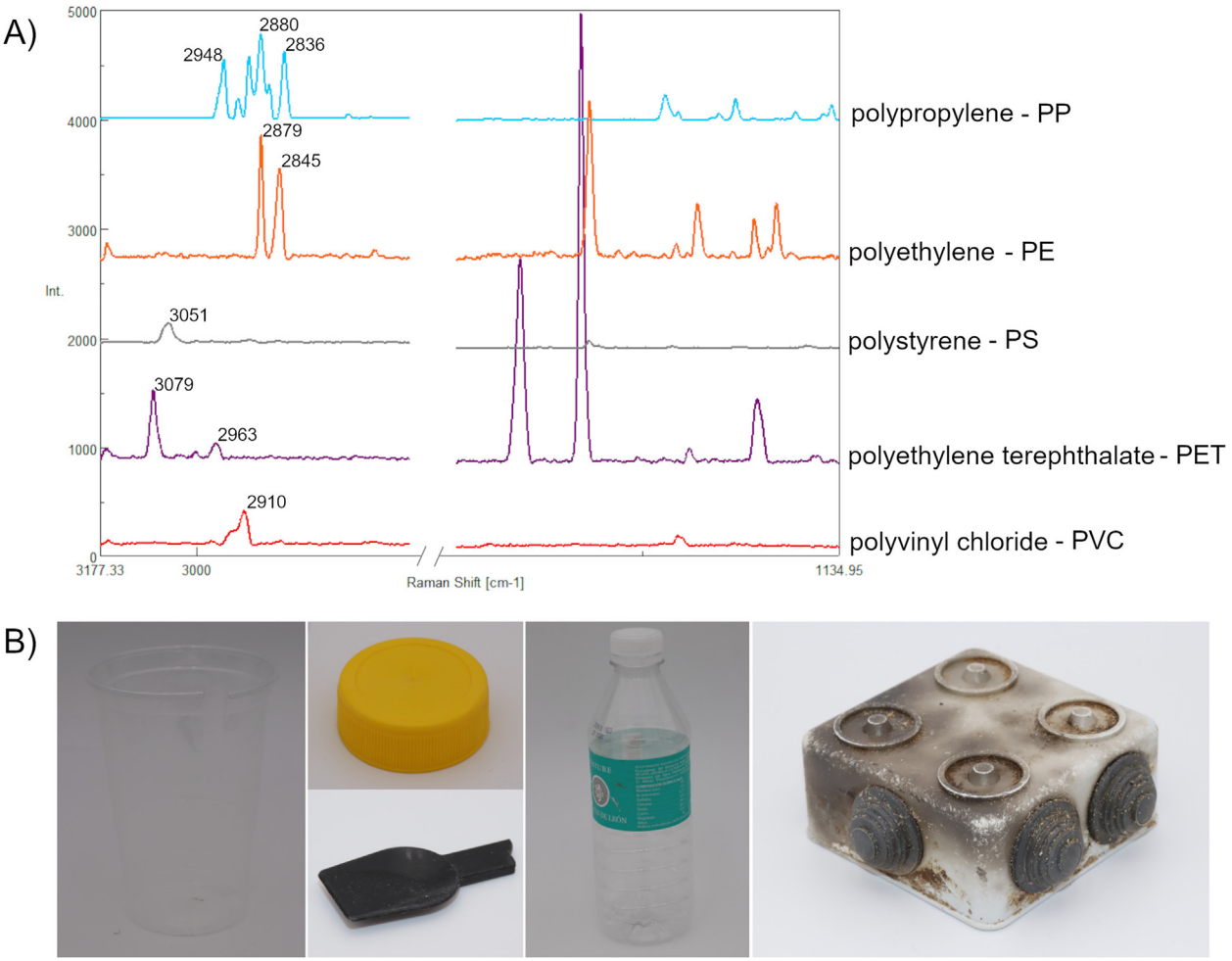



**Fig. 2.** Raman spectra of reference items composed by PP, PE, PS, PET and PVC (A). Reference items (PP – cup; HDPE – bottle cap; PS – spoon; PET – bottle; PVC – box) photographed with the naked eye (B).

white and blue colours commonly observed in other studies (Syakti et al., 2017). In addition, each colour presents a slight variability due to the specific dye used and the type and time of exposure that the item recorded to environmental conditions.

### *3.4. Origin and sources of plastic litter*

Regarding plastic litter origin, it was observed as: i) most (85%) came from land-based sources, e.g. cigarette butts, cotton bud sticks, food wrappers, drinks, etc. Most of them were directly discharged on the beach by users and a small percentage was transported by wind, rivers or municipal drainage systems; ii) a smaller litter proportion (2%) was linked to marine-based sources related to fishing activities, e.g. fishing lines, string and cord, rope, floats and buoys and iii) other items (13%) had different potential sources, e.g. hard and foamed pieces.

Some beach litter items contained information such as origin and manufacturer, i.e. the brand. Many of the items containing this information were manufactured close to where they were found, e.g. food wrappers from Sanlúcar de Barrameda municipality or Seville (the bordering Province to the NE). Others items were distributed near to where they were found even if they were made somewhere else, e.g. toys, food wrappers and food containers from South-eastern Spain (Valencia, Alicante and Murcia). In other cases, some items may have been transported from other sites by tourists, examples were food wrappers from Poland, Germany and Italy. Rivers were also relevant litter sources, e.g. food wrappers, caps, and films proceeding from Seville were identified on the northernmost beaches, close to the Guadalquivir River mouth. Marine currents can also carry litter, even from different countries such as a food container worn out from Portugal in a remote beach (no. 12, Fig. 1), at least 125 km approx. from this country. Another similar example was a bottle cap from Morocco in a rural beach (no. 19, Fig. 1), at least 78 km approx. from this neighbouring country. In Morocco bottle caps and lids represented the most numerous beach litter item as evidenced by Maziane et al. (2018) and Nachite et al. (2019). Ships and fishing activities were also a potential source of beach litter because fishing related debris were common in a lot of beaches but their number was considered low in comparison to other litter groups. In this investigation fishing items represented less than 3% of the total. On a remote beach (no. 34, Fig. 1, Table S1), a bottle of cleaning products from Turkey was also found in very good condition, probably fallen or thrown from a boat. The origin of other items found were, and will remain, a real mystery, such as different items with Japanese letters found in an urban beach. Lastly, plastic beach litter from well-known brands (e.g. Nestlé, Coca-Cola, PepsiCo, Danone, etc.) were very frequently observed at many beaches.

## 4. Conclusions

According to the literature and data obtained in the present paper, plastic is generally the predominant material on beaches. In the Atlantic coast of Cádiz, the majority of plastic litter was distributed on beaches parts as follows: firstly, at the high tide water level where tidal action tends to group beach litter; secondly, at the backshore zone due to the

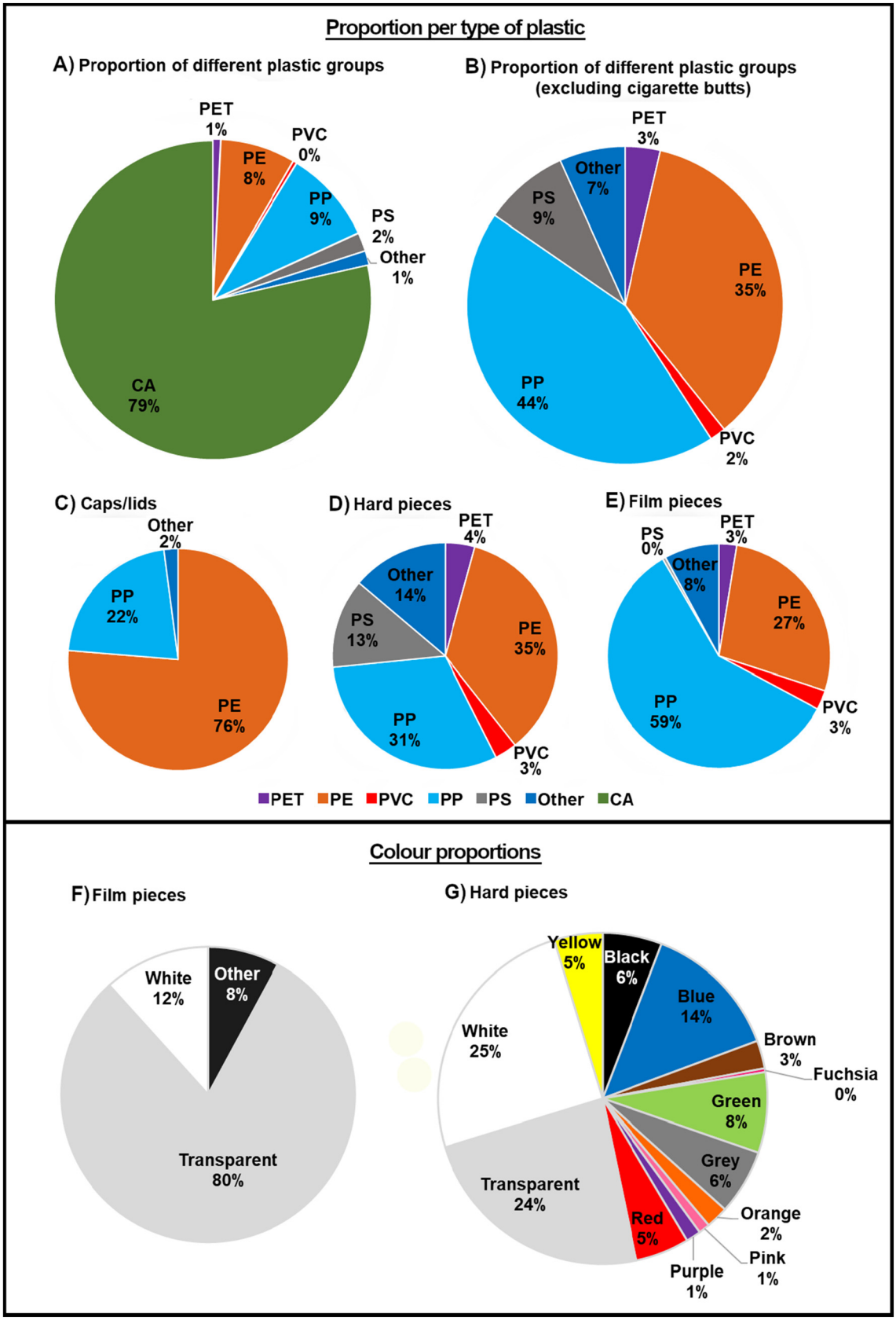



**Fig. 3.** Percentage data: types of plastic (A) and types of plastic excluding cigarette butts (B). Percentage by some groups: caps and lids (C), hard plastic pieces (D) and film plastic pieces (E). Percentage by colour: hard plastic pieces (F) and film plastic pieces (G).

**Table 2**
Mean and median values per beach area of cigarette butts distribution according to beach typology.

| | Remote | Rural | Village | Urban | Total |
|---|---|---|---|---|---|
| Low tide water level | 0/0 | 1/0 | 2/0 | 0/0 | 1/0 |
| Foreshore | 1/0 | 21/0 | 9/0 | 7/1 | 11/0 |
| High tide water level | 6/1 | 206/24 | 187/72 | 295/121 | 199/31 |
| Backshore | 1/0 | 17/2 | 120/76 | 57/32 | 59/19 |
| Total | 8/1 | 245/59 | 318/254 | 360/178 | |

great number of beach users observed in this area and the landward presence of urban structures (e.g. promenades, bars, etc.). The rest of plastic litter was distributed along the foreshore and at the low tide water level. Concerning beach typology, it was evident a clear direct relationship between the number of visitors and litter content. The top three most abundant plastic items were cigarette butts, film fragments and hard pieces.

This work is the first characterization of beach litter along several kilometres in the Iberian Peninsula coastline using Raman spectroscopy. This method represents a good tool to differentiate among different types of plastic. Hundreds of samples (2322) composed by several colours and sizes were analysed with good results. Samples with different states of conservation have also been analysed, some of them being very degraded by the environmental conditions to which they were exposed to.

Cellulose acetate (CA) was the most common plastic group, followed by polypropylene (PP) and polyethylene (PE). Within specific plastic categories, such as film and hard pieces, PE and PP were the most common types of plastic. Undetermined plastic samples can be analysed by conventional Raman microscopy; this technique provided during the last few years, new analytical applications in different disciplines, e.g. in marine sciences with a great importance in microplastics identification.

When plastic gets into the environment, through improper disposal, it can end up causing damage to ecosystems. Despite is more common to see the physical damage caused by plastics because marine organisms ingestion or entanglement in plastic items, the chemical risk associated with plastic items is also very relevant; as an example, smoking items, very common in Spanish beaches, cause foremost contamination due to their relevant toxicity. Hence, to protect the environment, people should stop littering (not only on the beach) and the industry should use plastic or other components that not induce toxicity or damage to wildlife since most objects we use end up abandoned on the coast. It has been shown that plastic waste crosses national and international borders, making it a global problem that all countries must address and a major challenge for factories and consumers.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2020.140890.

## CRediT authorship contribution statement

**Francisco Asensio-Montesinos:** Conceptualization, Methodology, Software, Investigation, Data curation, Formal analysis, Writing - original draft. **Milagrosa Oliva Ramírez:** Writing - original draft, Investigation, Formal analysis, Resources, Visualization. **Juan María González-Leal:** Methodology, Investigation, Software, Resources, Writing - review & editing. **Daniel Carrizo:** Visualization, Writing - review & editing. **Giorgio Anfuso:** Conceptualization, Writing - review & editing, Supervision, Project administration.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## References

Allen, V., Kalivas, J.H., Rodriguez, R.G., 1999. Post-consumer plastic identification using Raman spectroscopy. Appl. Spectrosc. 53 (6), 672–681. https://doi.org/10.1366/0003702991947324.

Allsopp, M., Walters, A., Santillo, D., Johnston, P., 2006. Plastic Debris in the world's Oceans. Greenpeace, Netherlands (44 pp).

Anderson, J.C., Park, B.J., Palace, V.P., 2016. Microplastics in aquatic environments: implications for Canadian ecosystems. Environ. Pollut. 218, 269–280. https://doi.org/10.1016/j.envpol.2016.06.074.

Andrady, A.L., 2011. Microplastics in the marine environment. Mar. Pollut. Bull. 62, 1596–1605.

Andrady, A.L., Neal, M.A., 2009. Applications and societal benefits of plastics. Philos. Trans. R. Soc. B: Biol. Sci. 364 (1526), 1977–1984.

Araújo, M.C.B., Costa, M.F., 2019. A critical review of the issue of cigarette butt pollution in coastal environments. Environ. Res. 172, 137–149. https://doi.org/10.1016/j.envres.2019.02.005.

Ariza, E., Jiménez, J.A., Sardá, R., 2008. Seasonal evolution of beach waste and litter during the bathing season on the Catalan coast. Waste Manag. 28 (12), 2604–2613. https://doi.org/10.1016/j.wasman.2007.11.012.

Asensio-Montesinos, F., Anfuso, G., Randerson, P., Williams, A.T., 2019. Seasonal comparison of beach litter on Mediterranean coastal sites (Alicante, SE Spain). Ocean Coast. Manage. 181, 104914. https://doi.org/10.1016/j.ocecoaman.2019.104914.

Asensio-Montesinos, F., Anfuso, G., Oliva Ramírez, M., Smolka, R., García Sanabria, J., Fernández Enríquez, A., Arenas, P., Macías Bedoya, A., 2020. Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain). Reg. Stud. Mar. Sci., 101050 https://doi.org/10.1016/j.rsma.2020.101050.

Avendaño, L., 1992. Iniciación a los plásticos. Centro Español de Plásticos, España (153 pp).

Bringer, A., Thomas, H., Prunier, G., Dubillot, E., Bossut, N., Churlaud, C., Clérandeau, C., Le Bihanic, F., Cachot, J., 2020. High density polyethylene (HDPE) microplastics impair development and swimming activity of Pacific oyster D-larvae, *Crassostrea gigas*, depending on particle size. Environ. Pollut. 260, 113978. https://doi.org/10.1016/j.envpol.2020.113978.

Browne, M.A., Crump, P., Niven, S.J., Teuten, E., Tonkin, A., Galloway, T., Thompson, R., 2011. Accumulation of microplastic on shorelines worldwide: sources and sinks. Environ. Sci. Technol. 45 (21), 9175–9179. https://doi.org/10.1021/es201811s.

Bryan, S.E., Cook, A.G., Evans, J.P., Hebden, K., Hurrey, L., Colls, P., Jell, J.S., Weatherley, D., Firn, J., 2012. Rapid, long-distance dispersal by pumice rafting. PLoS One 7 (7), e40583. https://doi.org/10.1371/journal.pone.0040583.

Cheshire, A.C., Adler, E., Barbière, J., Cohen, Y., Evans, S., Jarayabhand, S., Jeftic, L., Jung, R.T., Kinsey, S., Kusui, E.T., Lavine, I., Manyara, P., Oosterbaan, L., Pereira, M.A., Sheavly, S., Tkalin, A., Varadarajan, S., Wenneker, B., Westphalen, G., 2009. UNEP/IOC guidelines on survey and monitoring of marine litter. UNEP Regional Seas Reports and Studies, No. 186; IOC Technical Series No. 83 (xii + 120 pp).

Claereboudt, M.R., 2004. Shore litter along sandy beaches of the Gulf of Oman. Mar. Pollut. Bull. 49 (9–10), 770–777. https://doi.org/10.1016/j.marpolbul.2004.06.004.

Critchell, K., Lambrechts, J., 2016. Modelling accumulation of marine plastics in the coastal zone; what are the dominant physical processes? Estuar. Coast. Shelf Sci. 171, 111–122. https://doi.org/10.1016/j.ecss.2016.01.036.

Cruz, C.J., Muñoz-Perez, J.J., Carrasco-Braganza, M.I., Poullet, P., Lopez-Garcia, P., Contreras, A., Silva, R., 2020. Beach cleaning costs. Ocean Coast. Manage. 188, 105118. https://doi.org/10.1016/j.ocecoaman.2020.105118.

Curtis, C., Novotny, T.E., Lee, K., Freiberg, M., McLaughlin, I., 2017. Tobacco industry responsibility for butts: a model tobacco waste act. Tob. Control. 26 (1), 113–117. https://doi.org/10.1136/tobaccocontrol-2015-052737.

Dehaut, A., Cassone, A.L., Frère, L., Hermabessiere, L., Himber, C., Rinnert, E., Paul-Pont, I., 2016. Microplastics in seafood: benchmark protocol for their extraction and characterization. Environ. Pollut. 215, 223–233. https://doi.org/10.1016/j.envpol.2016.05.018.

Dixon, T.R., Dixon, T.J., 1981. Marine litter surveillance. Mar. Pollut. Bull. 12 (9), 289–295. https://doi.org/10.1016/0025-326X(81)90078-3.

Driedger, A.G., Dürr, H.H., Mitchell, K., Van Cappellen, P., 2015. Plastic debris in the Laurentian Great Lakes: a review. J. Great Lakes Res. 41 (1), 9–19. https://doi.org/10.1016/j.jglr.2014.12.020.

EA/NALG, 2000. Assessment of Aesthetic Quality of Coastal and Bathing Beaches. Monitoring Protocol and Classification Scheme. Environment Agency and The National Aquatic Litter Group, London 15 pp.

Gall, S.C., Thompson, R.C., 2015. The impact of debris on marine life. Mar. Pollut. Bull. 92 (1–2), 170–179. https://doi.org/10.1016/j.marpolbul.2014.12.041.

Gregory, M.R., 2009. Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Philos. Trans. R. Soc. B: Biol. Sci. 364 (1526), 2013–2025. https://doi.org/10.1098/rstb.2008.0265.

Gregory, M.R., Andrady, A.L., 2003. Plastics in the marine environment. In: Andrady, A.L. (Ed.), Plastics and the Environment. John Wiley & Sons, New Jersey, pp. 379–401.

Jurado, V., Castro, M., Corral, C., Ruiz, C., Lara, R., Acosta, J., Macías, A., Gracia, J., 2006. Cuidemos la Costa 2004–2005. Consejerías de Medio Ambiente y Educación, Junta de Andalucía. Red CoastWatch, Sevilla, p. 64.
Käppler, A., Fischer, D., Oberbeckmann, S., Schernewski, G., Labrenz, M., Eichhorn, K.J., Voit, B., 2016. Analysis of environmental microplastics by vibrational microspectroscopy: FTIR, Raman or both? Anal. Bioanal. Chem. 408 (29), 8377–8391. https://doi.org/10.1007/s00216-016-9956-3.
Kungskulniti, N., Charoenca, N., Hamann, S.L., Pitayarangsarit, S., Mock, J., 2018. Cigarette waste in popular beaches in Thailand: high densities that demand environmental action. Int. J. Environ. Res. Public Health 15 (4), 630. https://doi.org/10.3390/ijerph15040630.
Kurmus, H., Mohajerani, A., 2020. The toxicity and valorization options of cigarette butts. Waste Manag. 104, 104–118. https://doi.org/10.1016/j.wasman.2020.01.011.
Lamprecht, A., 2013. The Abundance, Distribution and Accumulation of Plastic Debris in Table Bay, Cape Town, South Africa. Doctoral dissertation. University of Cape Town.
Lee, J., Lee, J.S., Jang, Y.C., Hong, S.Y., Shim, W.J., Song, Y.K., ... Hong, S., 2015. Distribution and size relationships of plastic marine debris on beaches in South Korea. Arch. Environ. Contam. Toxicol. 69 (3), 288–298. https://doi.org/10.1007/s00244-015-0208-x.
Lenz, R., Enders, K., Stedmon, C.A., Mackenzie, D.M.A., Nielsen, T.G., 2015. A critical assessment of visual identification of marine microplastic using Raman spectroscopy for analysis improvement. Mar. Pollut. Bull. 100 (1), 82–91. https://doi.org/10.1016/j.marpolbul.2015.09.026.
Lenzi, J., Burgues, M.F., Carrizo, D., Machín, E., Teixeira-de Mello, F., 2016. Plastic ingestion by a generalist seabird on the coast of Uruguay. Mar. Pollut. Bull. 107 (1), 71–76. https://doi.org/10.1016/j.marpolbul.2016.04.016.
Maziane, F., Nachite, D., Anfuso, G., 2018. Artificial polymer materials debris characteristics along the Moroccan Mediterranean coast. Mar. Pollut. Bull. 128, 1–7. https://doi.org/10.1016/j.marpolbul.2017.12.067.
Munari, C., Corbau, C., Simeoni, U., Mistri, M., 2016. Marine litter on Mediterranean shores: analysis of composition, spatial distribution and sources in north-western Adriatic beaches. Waste Manag. 49, 483–490. https://doi.org/10.1016/j.wasman.2015.12.010.
Nachite, D., 2019. Photo Guide for Monitoring Marine Litter on the Mediterranean Moroccan Beaches. Coordination Nationale du Programme National de Surveillance et d'Evaluation de la Pollution de la Méditerranée (Maroc; mai, 2019, 73 pp).
Nachite, D., Maziane, F., Anfuso, G., Williams, A.T., 2019. Spatial and temporal variations of litter at the Mediterranean beaches of Morocco mainly due to beach users. Ocean Coast. Manage. 179, 104846. https://doi.org/10.1016/j.ocecoaman.2019.104846.
Nakashima, E., Isobe, A., Magome, S., Kako, S., Deki, N., 2011. Using aerial photography and in situ measurements to estimate the quantity of macro-litter on beaches. Mar. Pollut. Bull. 62 (4), 762–769. https://doi.org/10.1016/j.marpolbul.2011.01.006.
Nakashima, E., Isobe, A., Kako, S., Itai, T., Takahashi, S., 2012. Quantification of toxic metals derived from macroplastic litter on Ookushi Beach, Japan. Environ. Sci. Technol. 46 (18), 10099–10105. https://doi.org/10.1021/es301362g.
Novotny, T.E., Slaughter, E., 2014. Tobacco product waste: an environmental approach to reduce tobacco consumption. Curr. Environ. Health Rep. 1, 208–216. https://doi.org/10.1007/s40572-014-0016-x.
Novotny, T.E., Lum, K., Smith, E., Wang, V., Barnes, R., 2009. Filtered cigarettes and the case for an environmental policy on cigarette waste. Int. J. Environ. Res. Public Health (6), 1691–1705.
Ocean Conservancy, 2011. Tracking Trash: 25 Years of Action for the Ocean. International Coastal Cleanup 25th Anniversary Report (80 pp).
Ocean Conservancy, 2017. 2017 Report: Together for Our Ocean 28 pp.
Ocean Conservancy, 2018. 2018 Report: Building a Clean Swell (28 pp).
Ocean Conservancy, 2019. 2019 Report: The Beach and Beyond (32 pp).
Opfer, S., Arthur, C., Lippiatt, S., 2012. NOAA Marine Debris Shoreline Survey Field Guide. US National Oceanic and Atmospheric Administration Marine Debris Program.
OSPAR Commission, 2007. OSPAR Pilot Project on Monitoring Marine Beach Litter. Monitoring of Marine Litter in the OSPAR Region 75 pp.
OSPAR Commission, 2010. Guideline for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area (84 pp).
Plastics Europe, 2016. Plastics – The Facts 2016 – An Analysis of European Plastics Production, Demand and Waste Data, 2016. PlasticsEurope.
Plastics Europe, 2019. Plastics – The Facts 2019. An Analysis of European Plastics Production, Demand and Waste Data. 2019. PlasticsEurope (42 pp).
Polarz, S., Smarsly, B., Schattka, J.H., 2002. Hierachical porous carbon structures from cellulose acetate fibers. Chem. Mater. 14 (7), 2940–2945. https://doi.org/10.1021/cm011271r.
Ribeiro-Claro, P., Nolasco, M.M., Araújo, C., 2017. Characterization of microplastics by Raman spectroscopy. Compr. Anal. Chem. 75, 119–151.
Ribic, C.A., 1998. Use of indicator items to monitor marine debris on a New Jersey beach from 1991 to 1996. Mar. Pollut. Bull. 36 (11), 887–891. https://doi.org/10.1016/S0025-326X(98)00064-2.
Rochman, C.M., Browne, M.A., Halpern, B.S., Hentschel, B.T., Hoh, E., Karapanagioti, H.K., ... Thompson, R.C., 2013. Classify plastic waste as hazardous. Nature 494, 169–171. https://doi.org/10.1038/494169a.
Rochman, C.M., Hentschel, B.T., Teh, S.J., 2014. Long-term sorption of metals is similar among plastic types: implications for plastic debris in aquatic environments. PLoS One 9 (1), e85433. https://doi.org/10.1371/journal.pone.0085433.
Ryan, P.G., Moore, C.J., Van Franeker, J.A., Moloney, C.L., 2009. Monitoring the abundance of plastic debris in the marine environment. Philos. Trans. R. Soc. B: Biol. Sci. 364 (1526), 1999–2012. https://doi.org/10.1098/rstb.2008.0207.
Ryan, P.G., Perold, V., Osborne, A., Moloney, C.L., 2018. Consistent patterns of debris on South African beaches indicate that industrial pellets and other mesoplastic items mostly derive from local sources. Environ. Pollut. 238, 1008–1016. https://doi.org/10.1016/j.envpol.2018.02.017.
Savoca, D., Arculeo, M., Barreca, S., Buscemi, S., Caracappa, S., Gentile, A., ... Pace, A., 2018. Chasing phthalates in tissues of marine turtles from the Mediterranean sea. Mar. Pollut. Bull. 127, 165–169. https://doi.org/10.1016/j.marpolbul.2017.11.069.
Strong, A.B., 1996. Plastics Materials and Processing. Prentice-Hall, Inc. New Jersey (675 pp. ISBN: 0-13-678822-X).
Syakti, A.D., Bouhroum, R., Hidayati, N.V., Koenawan, C.J., Boulkamh, A., Sulistyo, I., ... Wong-Wah-Chung, P., 2017. Beach macro-litter monitoring and floating microplastic in a coastal area of Indonesia. Mar. Pollut. Bull. 122 (1-2), 217–225. https://doi.org/10.1016/j.marpolbul.2017.06.046.
Thiel, M., Hinojosa, I., Vásquez, N., Macaya, E., 2003. Floating marine debris in coastal waters of the SE-Pacific (Chile). Mar. Pollut. Bull. 46 (2), 224–231. https://doi.org/10.1016/S0025-326X(02)00365-X.
Tudor, D.T., Williams, A.T., 2001. Investigation of Litter Problems in the Severn Estuary/Bristol Area. Environment Agency, R and D, Tech Report E1-082/T.R (301 pp).
Turner, A., 2016. Heavy metals, metalloids and other hazardous elements in marine plastic litter. Mar. Pollut. Bull. 111 (1–2), 136–142. https://doi.org/10.1016/j.marpolbul.2016.07.020.
UNEP, 2014. Plastic Waste Causes Financial Damage of US$13 Billion to Marine Ecosystems Each Year as Concern Grows over Microplastics. United Nations Environment Programme, Nairobi June 2014. 5 pp. Available at. https://www.oceanrecov.org/assets/files/news/UNEP%20YearBook-23.6.2014.pdf Accessed May 2020.
Van Franeker, J.A., Blaize, C., Danielsen, J., Fairclough, K., Gollan, J., Guse, N., ... Olsen, B., 2011. Monitoring plastic ingestion by the northern fulmar Fulmarus glacialis in the North Sea. Environ. Pollut. 159 (10), 2609–2615. https://doi.org/10.1016/j.envpol.2011.06.008.
Vlachogianni, Th., 2019. Assessing Marine Litter on Mediterranean Beaches. Filling in the Knowledge Gaps Via a Participatory-Science Initiative. MIO-ECSDE (42 pp).
Votier, S.C., Archibald, K., Morgan, G., Morgan, L., 2011. The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality. Mar. Pollut. Bull. 62 (1), 168–172. https://doi.org/10.1016/j.marpolbul.2010.11.009.
Williams, A.T., Micallef, A., 2009. Beach Management, Principles & Practice. Earthscan, London, UK, p. 445.
Williams, A.T., Pond, K., Ergin, A., Cullis, M.J., 2013. The hazards of beach litter. Coastal Hazards. Springer, Dordrecht, pp. 753–780.
Williams, A.T., Randerson, P., Di Giacomo, C., Anfuso, G., Macias, A., Perales, J.A., 2016. Distribution of beach litter along the coastline of Cádiz, Spain. Mar. Pollut. Bull. 107 (1), 77–87. https://doi.org/10.1016/j.marpolbul.2016.04.015.
Williams, A.T., Randerson, P., Allen, C., Cooper, J.A.G., 2017. Beach litter sourcing: a trawl along the Northern Ireland coastline. Mar. Pollut. Bull. 122 (1–2), 47–64. https://doi.org/10.1016/j.marpolbul.2017.05.066.
Willis, K., Hardesty, B.D., Kriwoken, L., Wilcox, C., 2017. Differentiating littering, urban runoff and marine transport as sources of marine debris in coastal and estuarine environments. Sci. Rep. 7, 44479. https://doi.org/10.1038/srep44479.
Zhao, S., Zhu, L., Li, D., 2015. Microplastic in three urban estuaries, China. Environ. Pollut. 206, 597–604. https://doi.org/10.1016/j.envpol.2015.08.027.
Zimmermann, L., Dierkes, G., Ternes, T.A., Völker, C., Wagner, M., 2019. Benchmarking the in vitro toxicity and chemical composition of plastic consumer products. Environ. Sci. Technol. 53 (19), 11467–11477. https://doi.org/10.1021/acs.est.9b02293.

SUPPORTING INFORMATION TO

# Characterization of plastic beach litter by Raman spectroscopy in south-western Spain.

Asensio-Montesinos, F., Oliva Ramírez, M., González-Leal, J.M., Carrizo, D., & Anfuso, G.

**Table S1**

Location and main characteristics of studied beaches: identifier (Map number, Fig. 1), beach name and typology, percentage of plastics, number of plastic items per 100 m, and proportion of different groups considered.

| ID | Beach name | Beach typology | Plastic litter (%) | N° plastic items | Proportion of different groups* of plastics (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | PET | PE | PVC | PP | PS | Other | CA | Ind. |
| 1 | BAJO DE GUIA | Village | 77.5 | 980 | 0.6 | 5.4 | 0.2 | 11.2 | 2.0 | 1.0 | 66.6 | 12.9 |
| 2 | JARA | Village | 93.4 | 442 | 0.7 | 11.1 | 0.5 | 6.8 | 4.8 | 1.8 | 65.4 | 9.0 |
| 3 | MICAELA | Village | 91.1 | 468 | 2.4 | 6.8 | 1.7 | 10.3 | 9.6 | 2.1 | 54.3 | 12.8 |
| 4 | CRUZ DEL MAR | Urban | 82.2 | 74 | 5.4 | 20.3 | 1.4 | 24.3 | 4.1 | 5.4 | 35.1 | 4.1 |
| 5 | REGLA | Urban | 93 | 251 | 2.0 | 8.0 | 0.8 | 19.1 | 2.8 | 4.8 | 59.8 | 2.8 |
| 6 | BALLENA | Village | 95.8 | 825 | 0.5 | 6.2 | 0.1 | 5.3 | 0.6 | 0.2 | 87.0 | 0.0 |
| 7 | COSTILLA | Urban | 71.7 | 350 | 0.3 | 6.3 | 0.0 | 40.6 | 0.3 | 0.0 | 50.9 | 1.7 |
| 8 | ROMPIDILLO | Urban | 92.2 | 340 | 0.9 | 9.4 | 0.0 | 16.8 | 4.1 | 0.9 | 66.2 | 1.8 |
| 9 | SANTA CATALINA | Village | 94.8 | 345 | 0.0 | 2.3 | 0.3 | 7.8 | 0.6 | 1.4 | 87.2 | 0.3 |
| 10 | PUNTILLA | Urban | 88.6 | 116 | 1.7 | 10.3 | 3.4 | 31.0 | 7.8 | 4.3 | 40.5 | 0.9 |
| 11 | VALDELAGRANA | Village | 88.3 | 113 | 0.9 | 14.2 | 0.0 | 19.5 | 0.9 | 1.8 | 62.8 | 0.0 |
| 12 | LEVANTE | Remote | 65.5 | 95 | 5.3 | 85.3 | 1.1 | 3.2 | 0.0 | 0.0 | 0.0 | 5.3 |
| 13 | RÍO SAN PEDRO | Village | 84.9 | 415 | 0.5 | 3.4 | 0.0 | 10.4 | 1.9 | 1.0 | 77.8 | 5.1 |
| 14 | CACHUCHA | Urban | 39.9 | 144 | 0.7 | 38.2 | 0.7 | 17.4 | 5.6 | 4.2 | 33.3 | 0.0 |
| 15 | CALETA | Urban | 70.5 | 290 | 0.3 | 7.2 | 0.0 | 9.7 | 2.4 | 2.1 | 65.5 | 12.8 |
| 16 | SANTA MARÍA DEL MAR | Urban | 93.4 | 1115 | 0.4 | 2.5 | 0.1 | 3.5 | 1.3 | 0.2 | 85.9 | 6.1 |
| 17 | VICTORIA | Urban | 83.3 | 487 | 0.2 | 7.2 | 0.2 | 11.3 | 0.8 | 1.2 | 76.2 | 2.9 |
| 18 | CORTADURA | Village | 81.4 | 183 | 1.6 | 31.1 | 0.5 | 19.1 | 1.1 | 2.2 | 44.3 | 0.0 |
| 19 | TORREGORDA | Rural | 71.3 | 171 | 0.6 | 24.0 | 0.6 | 21.6 | 2.3 | 2.3 | 48.5 | 0.0 |
| 20 | CAMPOSOTO | Rural | 92.3 | 838 | 0.1 | 2.3 | 0.2 | 2.7 | 0.7 | 0.5 | 93.4 | 0.0 |
| 21 | PLAYA CANINA | Remote | 71 | 45 | 4.4 | 51.1 | 0.0 | 40.0 | 0.0 | 2.2 | 2.2 | 0.0 |
| 22 | SANCTI-PETRI | Rural | 85.4 | 163 | 1.8 | 19.0 | 1.2 | 14.7 | 3.1 | 6.1 | 54.0 | 0.0 |
| 23 | BARROSA | Village | 96.5 | 1173 | 0.2 | 2.0 | 0.0 | 4.4 | 1.1 | 1.1 | 91.1 | 0.0 |
| 24 | PUERCO | Rural | 78.8 | 80 | 3.8 | 35.0 | 0.0 | 48.8 | 0.0 | 3.8 | 5.0 | 3.8 |
| 25 | PRINCESA ALEJANDRA | Rural | 80.9 | 76 | 3.9 | 34.2 | 1.3 | 9.2 | 9.2 | 3.9 | 34.2 | 3.9 |
| 26 | CALA DEL ACEITE | Rural | 97.4 | 1520 | 0.5 | 2.2 | 0.3 | 4.4 | 0.7 | 0.9 | 89.3 | 1.8 |
| 27 | BATELES | Urban | 97.2 | 1758 | 0.1 | 3.2 | 0.1 | 2.8 | 0.5 | 0.4 | 91.7 | 1.2 |
| 28 | CASTILNOVO | Remote | 60.9 | 42 | 2.4 | 42.9 | 0.0 | 11.9 | 0.0 | 2.4 | 40.5 | 0.0 |
| 29 | PALMAR | Village | 96.4 | 271 | 0.0 | 4.4 | 0.0 | 3.3 | 0.4 | 0.4 | 88.6 | 3.0 |
| 30 | TRAFALGAR | Remote | 84.4 | 25 | 24.0 | 24.0 | 4.0 | 8.0 | 8.0 | 28.0 | 4.0 | 0.0 |
| 31 | CAÑOS DE MECA | Rural | 88.5 | 108 | 2.8 | 20.4 | 0.9 | 13.0 | 1.9 | 3.7 | 54.6 | 2.8 |
| 32 | HIERBABUENA | Rural | 94.7 | 372 | 1.3 | 10.2 | 0.3 | 10.5 | 0.3 | 6.7 | 69.1 | 1.6 |
| 33 | CARMEN | Urban | 94.2 | 228 | 0.4 | 8.3 | 0.4 | 19.3 | 3.1 | 1.3 | 67.1 | 0.0 |
| 34 | RETIN BARBATE | Remote | 66.3 | 57 | 3.5 | 21.1 | 0.0 | 17.5 | 14.0 | 3.5 | 40.4 | 0.0 |
| 35 | ATLANTERRA | Village | 96.3 | 129 | 0.8 | 13.2 | 0.0 | 11.6 | 0.0 | 2.3 | 71.3 | 0.8 |
| 36 | ALEMANES | Village | 75.8 | 41 | 7.3 | 24.4 | 9.8 | 12.2 | 2.4 | 7.3 | 36.6 | 0.0 |
| 37 | BOLONIA | Rural | 87.2 | 40 | 0.0 | 2.5 | 0.0 | 15.0 | 2.5 | 0.0 | 77.5 | 2.5 |
| 38 | VALDEVAQUEROS | Rural | 45.5 | 5 | 20.0 | 40.0 | 0.0 | 20.0 | 20.0 | 0.0 | 0.0 | 0.0 |
| 39 | LANCES NORTE | Rural | 83.3 | 10 | 0.0 | 20.0 | 0.0 | 20.0 | 20.0 | 0.0 | 40.0 | 0.0 |
| 40 | LANCES SUR | Village | 88.4 | 76 | 1.3 | 17.1 | 2.6 | 22.4 | 9.2 | 3.9 | 40.8 | 2.6 |

*Groups: polyethylene terephthalate (PET); polyethylene (PE); polyvinyl chloride (PVC); polypropylene (PP); polystyrene (PS); polytetrafluoroethylene, poly(methyl methacrylate), polycarbonate, etc. (Other); cellulose acetate (CA); indeterminate (Ind.).

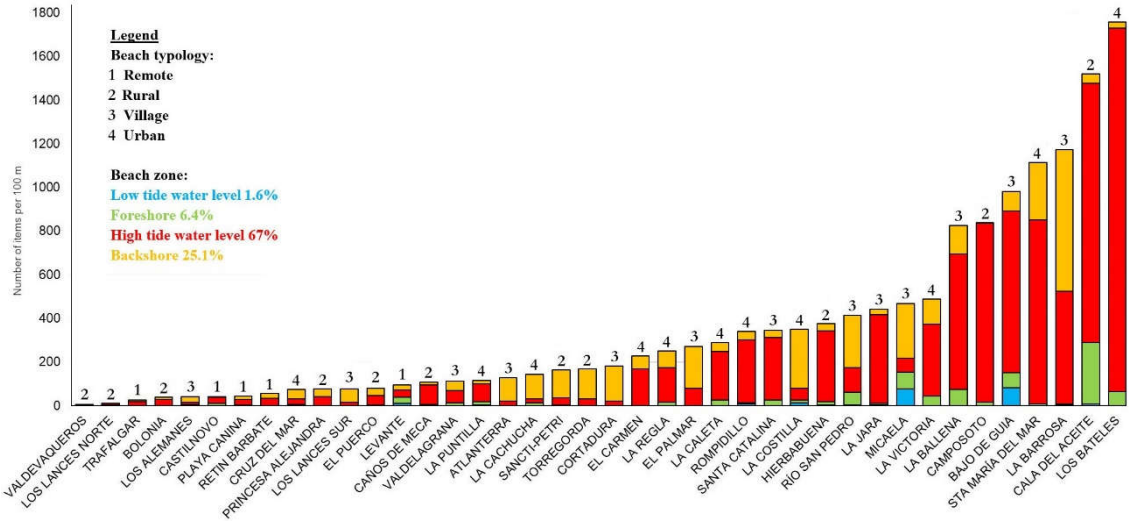



**Fig. S1.** Number of plastic litter per 100 m beach. The percentage of litter by beach zone also has represented.

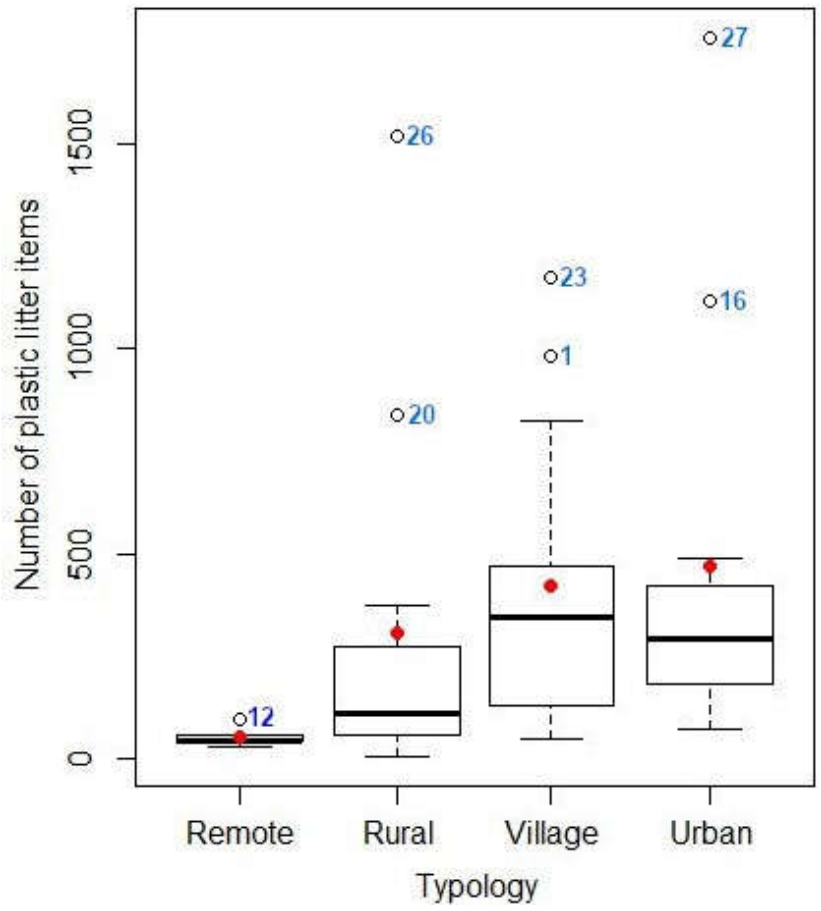



**Fig. S2.** Box plots obtained considering the number of items. Boxes enclose from the 25% to the 75% of data. Red dots represent the mean value, black lines the median and outliers represent the most polluted beaches within each beach typology group.

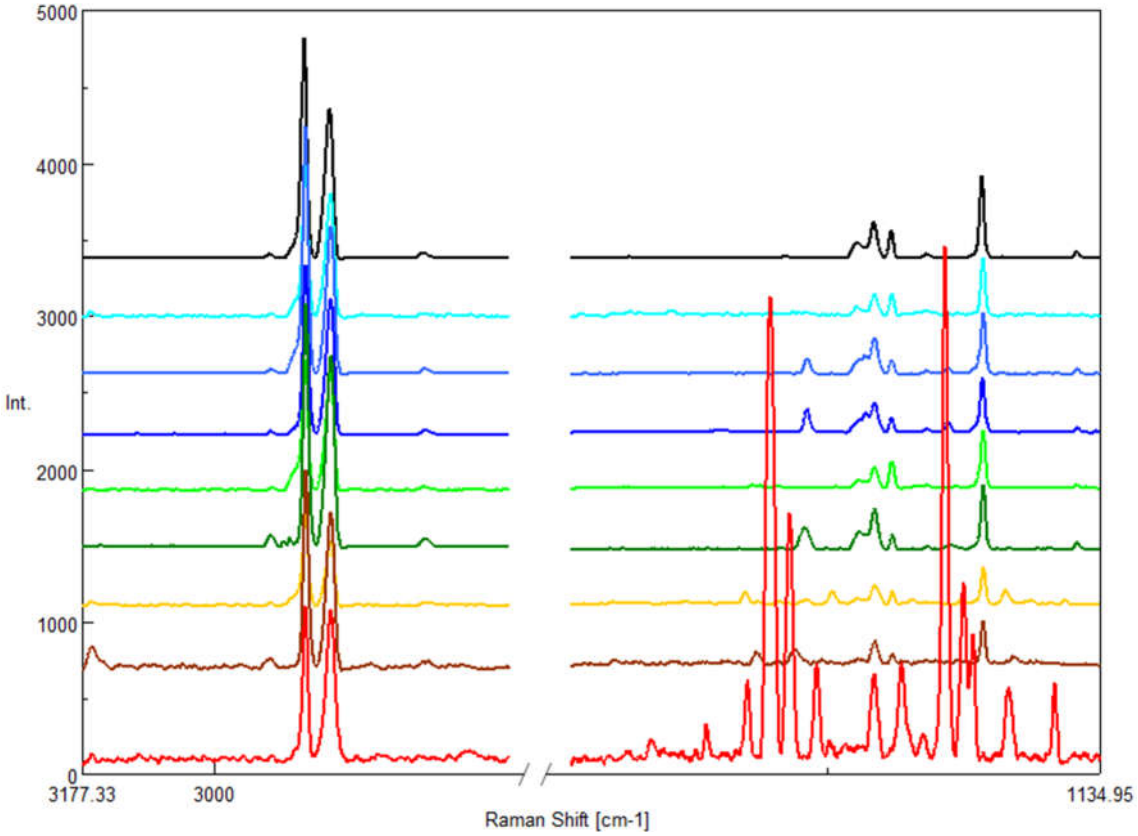



**Fig. S3.** Raman spectra of bottle caps of different colours made of polyethylene (PE). The colours of each Raman spectrum correspond to the colour of each cap analysed. The first Raman spectra corresponds to a white cap but is presented in black. It highlights the intensity and the different Raman peaks in red bottle caps.

**Anexo VI**

Publicación **VI**.

# Abundance and Distribution of Cigarette Butts on Coastal Environments: Examples from Southern Spain

Francisco Asensio-Montesinos[1,2], Milagrosa Oliva Ramírez[3], María Teresa Aguilar-Torrelo[1] and Giorgio Anfuso[1]

[1]Departamento de Ciencias de la Tierra, Facultad de Ciencias del Mar y Ambientales, Campus Río San Pedro s/n, Universidad de Cádiz, Puerto Real, 11510 Cádiz, Spain

[2]Instituto Multidisciplinar para el Estudio del Medio (IMEM), Universidad de Alicante, PO Box 99, E-03080 Alicante, Spain

[3]Departamento de Biología, Facultad de Ciencias del Mar y Ambientales, Campus Río San Pedro s/n, Universidad de Cádiz, Puerto Real, 11510 Cádiz, Spain

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# Abundance and Distribution of Cigarette Butts on Coastal Environments: Examples from Southern Spain

**Francisco Asensio-Montesinos [1,2], Milagrosa Oliva Ramírez [3], María Teresa Aguilar-Torrelo [1] and Giorgio Anfuso [1,*]**

[1] Departamento de Ciencias de la Tierra, Facultad de Ciencias del Mar y Ambientales, Campus Río San Pedro s/n, Universidad de Cádiz, Puerto Real, 11510 Cádiz, Spain; francisco.asensio@uca.es (F.A.-M.); mariateresa.aguilartorrelo@alum.uca.es (M.T.A.-T.)
[2] Instituto Multidisciplinar para el Estudio del Medio (IMEM), Universidad de Alicante, E-03080 Alicante, Spain
[3] Departamento de Biología, Facultad de Ciencias del Mar y Ambientales, Campus Río San Pedro s/n, Universidad de Cádiz, Puerto Real, 11510 Cádiz, Spain; milagrosa.oliva@uca.es
* Correspondence: giorgio.anfuso@uca.es

**Abstract:** Litter on beaches is one of the most difficult problems in coastal management and every year, much efforts and public money are invested to try to alleviate and solve the problem. Cigarette butts (CB) are among the most widespread abandoned personal items in the world. In Spain, they are found on all types of beaches, where they are discarded by beach users; however, rivers and streams can also deposit CB on shores. This paper analyses the abundance of CB on different beaches in Southern Spain in order to address and better understand this relevant environmental problem and propose sound solutions to decrease or eliminate their presence. The main factors favouring CB accumulation were identified, namely the seasonality and number of beach users, beach typology (remote, rural, village or urban sites), type of beach sediment and methods and frequency of cleaning operations. Mean and median CB abundance values per 100 m of beach length, calculated from all the data used in this study, were 159 and 68 items, respectively. The largest number of CB were observed at urban sites, followed by village, rural and remote beaches. Further, sand beaches registered higher values of CB than cobble or pebble beaches.

**Keywords:** Alacant; beach; Cádiz; Ceuta; cleaning efforts; marine litter; plastic pollution; smokers; tobacco product waste

check for updates

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## 1. Introduction

Litter is typically observed on almost all beaches and oceans around the world since it is able to reach most isolated areas of the planet, such as deep environments [1], e.g., the Mariana Trench [2], or extremely remote sites such as Antarctica [3,4]. Coastal systems receive litter from land-based sources (e.g., through rivers and sewerage systems) and from sea-based sources (e.g., fishing boats and infrastructures at sea) [5]. The presence of litter is also the result of intentional actions, e.g., when it is abandoned directly onto the beach by users such as beachgoers and fishers, among others [6]. Marine litter and associated contaminants have accumulated and transferred to biota in coastal areas, the open sea and the water column over several decades [7].

Within beach litter, cigarette butts (CB) constitute one of the most abundant items. The presence of this type of personal waste has been very well documented in different beaches around the world [8–13], including Spain [14–16]. Their presence on the coast can be used as an indicator of beach management efficiency [17], environmental consciousness [18] and beach pollution linked to beachgoers [19]. In addition, the presence of CB has an aesthetic impact on beaches [6] that can affect the "Sun, Sea and Sand" (3S) tourism [20]. Smoking is an activity that produces waste that comprises a large number of different materials:

for example, from only one packet of cigarettes, various types of items are dumped on the beach: at least, 20 cigarettes filters made of cellulose acetate and tobacco, a cardboard cigarette packet, two pieces of inner foil packaging and, finally, two pieces of outer plastic packaging made of polypropylene (PP), all of which are very commonly found on beaches in Southern Spain [21].

Cigarette butts contain four main components: a filter, burned and unburned tobacco, ashes and paper. There are over 5000 compounds present in cigarettes, among these, at least 150 (of which 44 are found in large amounts) are considered to be highly toxic [22]. When burned, many of the chemicals present in cigarettes produce new compounds [23,24]. These compounds can contaminate the soil after leaching by rainwater and are superficially transported to aquatic environments where they can be detected [22].

Toxicity due to the presence of CB in aquatic environments has been demonstrated by numerous investigations including different marine species from unicellular organisms such as foraminifera [25] to larger ones such as invertebrates and fish [22,26]. Environmental groups have expressed concerns for marine creatures that ingest littered filters [8,27]. A laboratory study by Micevska et al. (2006) found that CB were found to be acutely toxic to a freshwater cladoceran organism and a marine bacterium and that the main cause of toxicity was attributed to nicotine and ethylphenol in their leachates [28]. Filter fibres are treated with titanium dioxide and packed using triacetin (glycerol triacetate). Most cigarette filters are surrounded by two layers of paper and/or rayon wrapping, which contain chemicals, such as glues to hold the paper together, and alkali metal salts of organic acids in order to maintain burning while the cigarette is being smoked [22]. Slaughter et al. (2011) showed that the toxicity of cigarette butt leachate increased from unsmoked cigarette filters (no tobacco) to smoked cigarette filters (no tobacco) to smoked CB (smoked filter + tobacco) [22]. They confirmed the toxicity of CB to fish and some other representative marine organisms such as daphnids and marine bacteria. Moreover, other studies have also shown that heavy metals and chemicals in cigarette butt leachate may be acutely toxic to marine species [29].

The occurrence of different metals in cigarettes is mainly attributed to the cultivation and growth of tobacco [30]. Insecticide, herbicides and pesticide application may also introduce metals to the tobacco leaf [31]. Further introduction of metals may occur during cigarette manufacture [32,33] or during the application of brightening agents on the wrapping paper [34]. The response of biota to the metals is extremely different according to the tolerance of each specie to the amount and type of metals present [35]. Furthermore, pesticides, which potentially remain in unsmoked cigarettes, may contribute to the toxicity of cigarette leachate. Ethylphenol is commonly used in the tobacco industry as a tobacco flavouring agent and is present in cigarette smoke [36]. Ethylphenol is bioaccumulated in aquatic organisms [22]. Chemical additives are often introduced to make tobacco products more attractive to consumers. For example, sugars and humectants make smoke milder and easier to inhale, humectants can prolong shelf life, ammonia may enhance the delivery of nicotine and menthol and eugenol effectively numb the throat [37]. Approximately 600 additives were in use by major American cigarette companies in 1994 [38].

Cigarettes discarded onto beaches can be ingested by children, domestic animals and wildlife, causing severe health risks [39]. Nicotine in tobacco products is rapidly absorbed by oral and intestinal mucosa and nicotine-related symptoms develop rapidly (<4 h) after ingestion. Symptoms include nausea, vomiting, salivation, convulsions, bradycardia with hypotension, cardiac arrhythmias and respiratory depression [40]. Reports of accidental ingestion of butts are not uncommon among children, especially those <6 years old [41]. In young children, 1–2 mg may be toxic, causing nausea and vomiting in low doses, and more extensive neurological symptoms with higher doses [42]. CB ingestion in wildlife (for example, marine turtles or sea birds) is rare but CB ingestion in pets is frequent. In dogs, this ingestion can cause excessive salivation, excitement, tremors, vomiting, lack of coordination and weakness (signs have been reported at doses as low as 1 mg/kg) [43].

The quantification of filters in coastal environments as well as the role of aging on filter toxicity merits further research. Enhanced public awareness about the toxicity of discarded CB in marine and coastal areas may help to decrease their environmental hazards. Research concerning the impacts of smoked cigarette filters on marine life is crucial for consolidating a remedial policy [44].

This paper analyses the abundance of CB in different coastal sites in Southern Spain. The most contaminated sites are identified in order to address and better understand CB distribution and abundance according to beach characteristics. Solutions to decrease or eliminate CB from these sites are proposed.

## 2. Materials and Methods

This paper examines CB items' abundance counted in 188 beach litter assessments carried out by a research group belonging to the University of Cádiz (Spain). The assessments were carried out in different Southern Spanish provinces (Figure 1) such as the mesotidal coast of Cádiz Province and the microtidal coasts of Alacant and Ceuta. Ceuta is located in North Africa, in the Gibraltar Strait area, but administratively belongs to Spain. Data were obtained from March 2018 to April 2019 and general information on the investigated areas and their litter content can be consulted in previously published papers [15,16,21,45].




**Figure 1.** Study area: the provinces of Cádiz, Ceuta and Alacant (Southern Spain).

All coastal sites have been categorized into four of the five beach typologies according to the definitions of Williams and Micallef (2009): Remote, Rural, Village and Urban bathing areas [46]. In addition, the type of beach sediment has been categorized into two groups, i.e., "sand" and "other" (coarser sediments such as gravel, boulder, etc., and rocky shore). Sediment characteristics strongly determine cleaning operations modalities, i.e., mechanical clean-up is usually carried out on sand beaches (e.g., beach cleaners) [47] and manual operations at other beach locations [15].

A beach sector of 100 m in length has been investigated at each coastal site according to a well-established method widely used during recent decades by the science community [5,48–52]. The assessed width of each beach ranged from the water position at the moment of the survey (usually coinciding with the low tide level) to the landward end of the beach represented by dune toe, a seawall/revetment, etc., and such surface was covered by an observer that moved along 5 m apart transects parallel to the shoreline. All cigarette butts that were seen with the naked eye were counted, even if they were half-buried.

Box plots were used to represent the number of CB, and results in the text were expressed as mean and median values because distributions were skewed towards higher values, i.e., mean value > median value. The mean (or average value) is conventionally a popular estimator of the midpoint in a dataset, but is greatly affected by outliers, i.e., any

single value of the data set that is extremely high or low compared to the rest. For this reason, in this study, the median value is taken as a better measure of the midpoint.

## 3. Results and Discussion

A total of 29,919 cigarette butts was counted in 188 litter assessments (Table 1) that covered a total length of 18.8 km of coastline. Mean and median values of CB abundance per 100 m of beach length, calculated from all data used in this research, were 159 (0.038 CB/$m^2$) and 68 (0.021 CB/$m^2$), respectively, with important differences between beaches.

**Table 1.** Number of sites according to each research and data of cigarette butts (CB).

| No. | Date | Province | Sites [1] | Mean/Median Values | Mean/Median Density Values (CB/$m^2$) |
|---|---|---|---|---|---|
| 1 | March–April 2018 | Alacant | 56 | 82/40.5 | 0.023/0.013 |
| 2 | August 2018 | Alacant | 56 | 229/121 | 0.061/0.041 |
| 3 | October 2018 | Cádiz | 40 | 271/90 | 0.040/0.013 |
| 4 | February 2019 | Ceuta | 12 | 18.5/6 | 0.008/0.002 |
| 5 | March 2019 | Ceuta | 12 | 44/27 | 0.023/0.020 |
| 6 | April 2019 | Ceuta | 12 | 73/76.5 | 0.040/0.038 |

[1] The number of sites assessed was chosen according to the kilometres of coast length investigated in each province.

Outliers were identified and corresponded with sites showing a great number of CB. Different factors affect CB abundance on beaches, such as seasonality (which determines the number of visitors), beach typology, type of sediment, and beach accessibility [12,14,15,53–56]. These factors are investigated in detail in following sections.

### 3.1. Seasonality

The presence of CB varied considerably from beach to beach according to the season in which the survey was carried out (Table 1, Figure 2a). Assessments carried out in the summer or shortly after, e.g., surveys at Alacant and Cádiz beaches [15,16], were generally the ones that recorded the highest number of CB. In Alacant, a mean value of 229 items per 100 m unit of beach length (median = 121) was observed, and in the case of Cádiz, CB abundance reached a mean value of 271 items (median = 90).

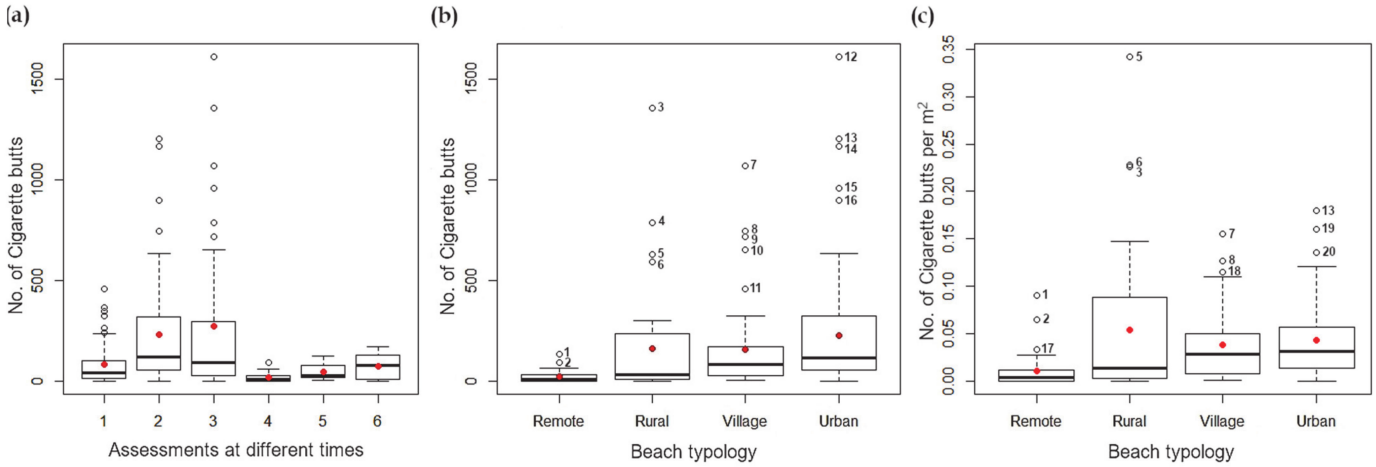



**Figure 2.** (**a**) Box plots of cigarette butts (CB) abundance according to different seasons: 1-Alacant-March/April 2018. 2-Alacant-August 2018. 3-Cádiz-October 2018. 4-Ceuta-February 2019. 5-Ceuta-March 2019. 6-Ceuta-April 2019; (**b**) Box plots of CB per beach typology; (**c**) Box plots of CB/$m^2$ per beach typology. Boxes enclose 50% of data, associated standard deviations are represented with whiskers, averages with red dots, and median values with black lines. Outliers were marked from no. 1 to no. 20 (see Table 2 for more information).

**Table 2.** Beaches that contained an unusual number of cigarette butts (CB) according to beach typology.

| No.[1] | Beach Name | Typology | Province | Sediment | Date | No. of CB | No. of CB/m$^2$ |
|---|---|---|---|---|---|---|---|
| 1 | El Desnarigado | Remote | Ceuta | Other | April 2019 | 135 | 0.090 |
| 2 | Cala d'Ambolo | Remote | Alacant | Other | August 2018 | 90 | 0.065 |
| 3 | Cala del Aceite | Rural | Cádiz | Sand | October 2018 | 1358 | 0.226 |
| 4 | Camposoto | Rural | Cádiz | Sand | October 2018 | 786 | 0.088 |
| 5 | Agua Amarga | Rural | Alacant | Other | August 2018 | 631 | 0.342 |
| 6 | Cala del Moraig | Rural | Alacant | Other | August 2018 | 594 | 0.228 |
| 7 | La Barrosa | Village | Cádiz | Sand | October 2018 | 1069 | 0.155 |
| 8 | Tabarca | Village | Alacant | Other | August 2018 | 744 | 0.127 |
| 9 | La Ballena | Village | Cádiz | Sand | October 2018 | 718 | 0.110 |
| 10 | Bajo de Guía | Village | Cádiz | Sand | October 2018 | 653 | 0.105 |
| 11 | Tabarca | Village | Alacant | Other | April 2018 | 456 | 0.078 |
| 12 | Los Bateles | Urban | Cádiz | Sand | October 2018 | 1612 | 0.121 |
| 13 | Llevant | Urban | Alacant | Sand | August 2018 | 1203 | 0.180 |
| 14 | L'Arenal | Urban | Alacant | Sand | August 2018 | 1166 | 0.103 |
| 15 | Sta. María del Mar | Urban | Cádiz | Sand | October 2018 | 958 | 0.115 |
| 16 | Cala Finestrat | Urban | Alacant | Sand | August 2018 | 896 | 0.092 |
| 17 | Els Tossals | Remote | Alacant | Sand | August 2018 | 60 | 0.033 |
| 18 | Río San Pedro | Village | Cádiz | Sand | October 2018 | 323 | 0.115 |
| 19 | Playa del Cura | Urban | Alacant | Sand | August 2018 | 632 | 0.160 |
| 20 | Arenales del Sol | Urban | Alacant | Sand | August 2018 | 400 | 0.135 |

[1] The numbering of these beaches corresponds tothe outliers showed in Figure 2b,c.

This was mainly due to the high number of national and international tourists that visit the beach and coastal villages and cities in Spain during summer holidays (Figure 3). The huge accumulation of CB during summer months takes place despite the increased efforts by municipalities in beach cleaning operations. This suggests that present waste management plans must be improved and that educational initiatives and penalties are needed to enhance beachgoer's responsibility. Whoever pollutes should pay or carry out community works (e.g., beach clean-ups). During the assessments, it was noted that beachgoers that throw away CB and other items are both national and international tourists, young and old, men and women, that go to the beach alone or with friends/relatives. Therefore, education is key and the media have a responsibility to promote good behavioural conduct in the population. Anti-pollution campaigns should be implemented every year before the summer period to prevent and hence reduce beach littering.



**Figure 3.** Three Mediterranean urban beaches located in the province of Alacant. In each shot, there are smoking beachgoers.

In contrast, the assessments that recorded the lowest values of CB were in February and March and corresponded to the surveys carried out in Ceuta. In April, an increase in CB abundance was observed, both in Alacant and Ceuta (Table 1, Figure 2a). This increase is related to the increased number of beach visitors at the beginning of good weather conditions that determine seasonal peaks of visitors in summer [45]. Visitor numbers is a determining factor in the presence of CB and other recreational litter items on beaches, as observed by numerous researchers in different places [11,55,57].

### 3.2. Beach Typology

An interesting factor to take into consideration in littering studies is beach typology, which deals with beach background environment and greatly determines the number and type of beach users. Median values of CB numbers increased linearly according to beach typology, from Remote beaches (9 items), Rural (31) and Village (83) to Urban (114 items, see black lines in Figure 2b). Figure 2c shows the same trend, expressed as CB/m$^2$ in 100 m beach length. However, if data are only expressed as CB numbers per m$^2$, the real number of CB on a beach can be underestimated (see Appendix A for more detailed information). Outliers should not be ignored and taken into consideration to improve sound management measures. Beaches that were considered as an outlier within each typology are shown in Table 2.

#### 3.2.1. Remote

A total of 32 assessments were carried out on remote beaches and 10 assessments did not record any CB items. Overall, a total number of 684 CB items were counted. Therefore, remote beaches contained the lowest number of CB (mean = 21; median = 9; Table 3, Figure 2b)—this being the combination of different variables that are difficult to quantify.

**Table 3.** Number of assessments, mean and median CB values per beach typology.

| Typology | Assessments | Mean/Median Values | Range of Values | Total | Mean/Median Values (m$^2$) |
|---|---|---|---|---|---|
| Remote | 32 | 21/9.5 | 0-135 | 684 | 0.010/0.003 |
| Rural | 37 | 162/31 | 0-1358 | 5994 | 0.053/0.013 |
| Village | 53 | 155/83 | 3-1069 | 8206 | 0.038/0.028 |
| Urban | 66 | 228/114 | 0-1612 | 15,035 | 0.043/0.031 |

On one hand, such results are linked to the level of beach management, which is the lowest compared to other beach typologies since litter bins and clean-up operations are usually not observed/implemented in such beaches [58,59]. On the other hand, the number of visitors to these beaches is quite low due to the difficulty of access (mainly by boat or on foot—a walk of 300 m or more is needed), and the fact that they are not supported by public transport [46]. Hence, the total amount of litter discarded by the limited number of visitors on remote beaches is very small. Very similar circumstances occur in other countries, for example, generally, no CB were observed in remote beaches located on the Baltic Sea [56]. Another example of remote beaches without CB items are those along the Moroccan Mediterranean coast [60]. In order to improve beach quality, and considering that major litter quantities on remote and inaccessible beaches may be linked to marine-based sources and less frequent clean ups [61], remote beaches must not be ignored by coastal managers that have to implement sound management actions. In this paper, on the Desnarigado beach (no. 1, Ceuta, Table 2), 135 CB items were counted in April—during this month, the beach recorded a greater influx of visitors than previous months. It is also one of the smallest and most popular beaches investigated in this paper. The high number of CB recorded in Ambolo Beach—90 CB items (no. 2, Alacant, Table 2)—is linked to the fact that it is a very narrow pocket of beach of only 100 m in length, which is overcrowded in the summer months due to its scenic beauty [59], despite the risk of landslides (Figure 4a).




**Figure 4.** Mediterranean coastal sites at Alacant Province: (**a**) Ambolo, remote beach; (**b**) Granadella, rural beach; (**c**) Cap de l'Horta, remote beach; (**d**) beach cleaner in "l'Ampolla", village beach.

#### 3.2.2. Rural

A total of 37 assessments were carried out on rural beaches and no CB items were recorded in 5 assessments. Overall, a total number of 5994 CB items were counted (Table 3). Rural beaches do not usually have as many visitors as village or urban beaches but there are some exceptions, particularly in the Mediterranean where they are accessible from numerous roads that run parallel to the coastline (Figure 4b). Further, due to their physical characteristics and location, rural beaches are associated with lower management efforts than more urbanised beaches. They are also greatly valued by visitors for their natural qualities [46] and some of them can receive as many visits as the more urbanised beaches do. This is reflected in the mean values of CB recorded along the investigated coasts (Figure 2b): rural beaches outnumbered village beaches (see the red dots in Figure 2b) because they recorded more dispersed data and presented some outliers, i.e., rural beaches with a great number of CB (mean = 162; median = 31, Table 3, Figure 2b). The atypical values in rural beaches (no. 3–6, Table 2) were linked to the large number of visitors during summer, the easy accessibility for beachgoers observed in most of them and the difficulty of carrying out cleaning operations with mechanical tools. Cleaning operations are difficult due to the impossibility of access for beach cleaners and, at places, type of substrate composition such as boulders, cobbles and rocky shores (e.g., Granadella beach with boulders and some beaches of "Cap de l'Horta" with a rocky shore, Figure 4b,c).

#### 3.2.3. Village

A total of 53 assessments were carried out on village beaches and 8206 CB items were counted in total. All the beaches of this typology were found to have CB items (mean = 155; median = 83, Table 3, Figure 2b). Village beaches are located outside the main urban environment and related to a small but permanent population compared to urban beaches [46]. In these beaches, the number of CB was less dispersed than on rural beaches (Figure 2b) due to management actions being generally well established by local municipalities for village beaches. The highest recorded values were due to various specific circumstances. Firstly, in the Cádiz coast, beaches such as "La Barrosa" and "La Ballena" (no. 7 and 9, Table 2) received as many visitors as urban beaches during the summer months. In addition, they belong to a mesotidal environment (tidal range between 2 and 4 m), which favours the accumulation of the smallest and lightest items such as CB in specific beach zones, e.g., the high tide line. In the case of Bajo de Guía beach (no. 10, Cádiz, Table 2), the high number of CB was mainly due to the fact that it is located at the mouth of the Guadalquivir River and rivers are an important source of beach litter [62,63]. Additionally, this last beach, together with CB items, recorded a high quantity of fishing debris [16], making it one of the most contaminated in the Cádiz Province. Secondly, assessments on village beaches that recorded massive CB abundance in Alacant were carried out on Tabarca beach (no. 8 and 11, Table 2), which is surrounded by one of the most important and oldest marine reserves in Spain [64], which records thousands of visitors in the summer months [65].

#### 3.2.4. Urban

Urban beaches (Figure 3) recorded the greatest number and dispersion in the number of CB, as observed by comparing the mean and median values with those recorded in other beach typologies (Figure 2b). A total of 66 assessments were carried out on urban beaches and 15,035 CB were counted (mean = 228; median = 114, Table 3, Figure 2b). No CB items were observed on the San Amaro beach (Ceuta) in February, one of the months that registered the lowest temperatures and fewest beach visitors. The highest numbers of CB items (no. 12-16, Table 2) were due to the high number of beach users at these sites, and were also related to great beach dimensions that required more transects in their assessment. Therefore, as the number of transects increased during the assessment, the chance of finding more CB also increased. The increase in CB and other litter items in urban beaches was also observed at different sites such as on the Baltic Sea coast [56], Morocco [66] and Senegal [67].

### *3.3. Accessibility*

Accessibility is an interesting factor that has to be taken into account because it strongly determines the number of users. An attempt has been made in this paper to compare CB assessments made on beaches close to a car park (less than 200 m), at a medium distance (200–300 m), and at beaches where parking was more than 300 m away. Unfortunately, the massive level of construction recorded close to the coast has left us with a desolate scene that made this comparison difficult: 79% of the assessments were carried out on beaches with a car park close, 5% were carried out in beaches located at a medium distance and, finally, the other 16% were in locations far from a car park. In spite of this, the trend is as expected: the further away the beach was from the car park, the fewer CB items were counted. The mean and median values for each case were 186 and 90 items, respectively, for beaches close to a parking area, 80 and 59 for medium cases and, finally, 55 and 8 for beaches far away from parking areas. This confirmed that lowest CB values were observed at beaches at a distance of more than 300 m from the parking area. On the contrary, beaches with a great abundance of CB were quite accessible and located near to a car park. In the Black Sea coast, tourism-related recreational litter showed an increase in the summer months, with accessibility being an important factor [55]. The accessibility of the shores,

particularly for vehicles (e.g., in riverine environments), also influenced the degree of littering [62].

### 3.4. Beach Sedimentology

The type of sediment is an important factor since it strongly determines the type of cleaning operation [47]. Assessments carried out on sandy beaches ($n$ = 108) presented mean and median CB items values of 211 and 91, respectively. Assessments on other beaches ($n$ = 80) showed mean and median values of 89 and 27, respectively. Along the investigated areas, mechanical cleaning is carried out on practically all urban sand beaches (Figure 4d) since it is easy for administrations because few workers and efforts are needed compared to manual operations. However, in some places, because of the great amount of litter, the implementation of more effective and expensive techniques is sometimes required [68]. However, the use of heavy equipment is also less respectful of the coastal environment because it damages small dunes, vegetation, and even bird and turtle species that nest at the coast [6,69,70]. Mechanic operations (Figure 4d) also contribute to erosion and change the physical characteristics of the beach [71]. Moreover, this type of cleaning does not collect all the litter, as it leaves behind small-sized items such as plastic fragments, cotton bud sticks, bottle caps and CB [6,17,60,72,73] that are more efficiently recollected by manual clean-up operations [60,73]. The results also indicate that considering each beach typology, sandy beaches contain more CB items, which are frequently buried or semi-buried in the sand [14,74]. In cobble beaches, the burial of (essentially) small items was also observed [75]. Last, despite the implementation and efficiency of cleaning operations, it must be highlighted that beach users greatly value sandy beaches, much more than gravel or pebble ones [76,77], so the former receive huge numbers of visitors and, in consequence, more CB items are present on them.

### 3.5. Cigarette Butt Distribution in Beach Environment

Cigarette butts and many other items are not distributed in a homogeneous way along the cross-shore beach profile [16,75,78,79]. On the Mediterranean beaches assessed in this paper, i.e., at Alacant and Ceuta, most CB items were found on the dry beach and many of them were accumulated near the landward limit of the beach [15,16]. On the Atlantic beaches such as those of Cádiz, most CB items were counted in correspondence of the high tide water level due to the effect of the flooding tide that moves whatever is located in the foreshore and on the dry beach inland, where the users spend most of their time [16]. At mesotidal places, most CB items (73.6% of the total amount) were found at the high tide water level and, secondly, on the backshore (22%). In the foreshore zone, CB items were less abundant: foreshore recorded 4.1% of the total amount, while at the low tide water level, only 0.3% was recorded [16]. Such information regarding CB distribution according to tidal conditions and/or the presence of human structures in the backshore are very useful to plan adequate clean-up operations.

## 4. Conclusions

Each beach is unique and their management is the responsibility of local municipalities and administrations. It is advisable to manage each beach in the most appropriate way, taking into consideration the determinant factors (e.g., tourism seasonality, beach typology, accessibility, type of sediment, etc.) that most influence the abundance of beach litter. Almost all studies conducted on beach litter have shown that the dominant material is plastic, with CB often being the most common item. In addition, their abundance is often underestimated because CB are often buried in coastal sediments or rapidly washed away by waves and currents. According to this, beach clean-ups should be carried out with special attention at the beach landward limit (usually coinciding with a seawall, a promenade, dunes, etc.) on both tidal and micro-tidal beaches. On tidal coasts (e.g., the Cádiz coast), special attention should be devoted to the high tide line. Proper cleaning operations according to the characteristics of a beach are essential to reduce the number

of CB items, but are not enough to solve the problem. Authorities have to emphasise anti-pollution campaigns to educate the general public and, particularly, beachgoers.

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## Appendix A

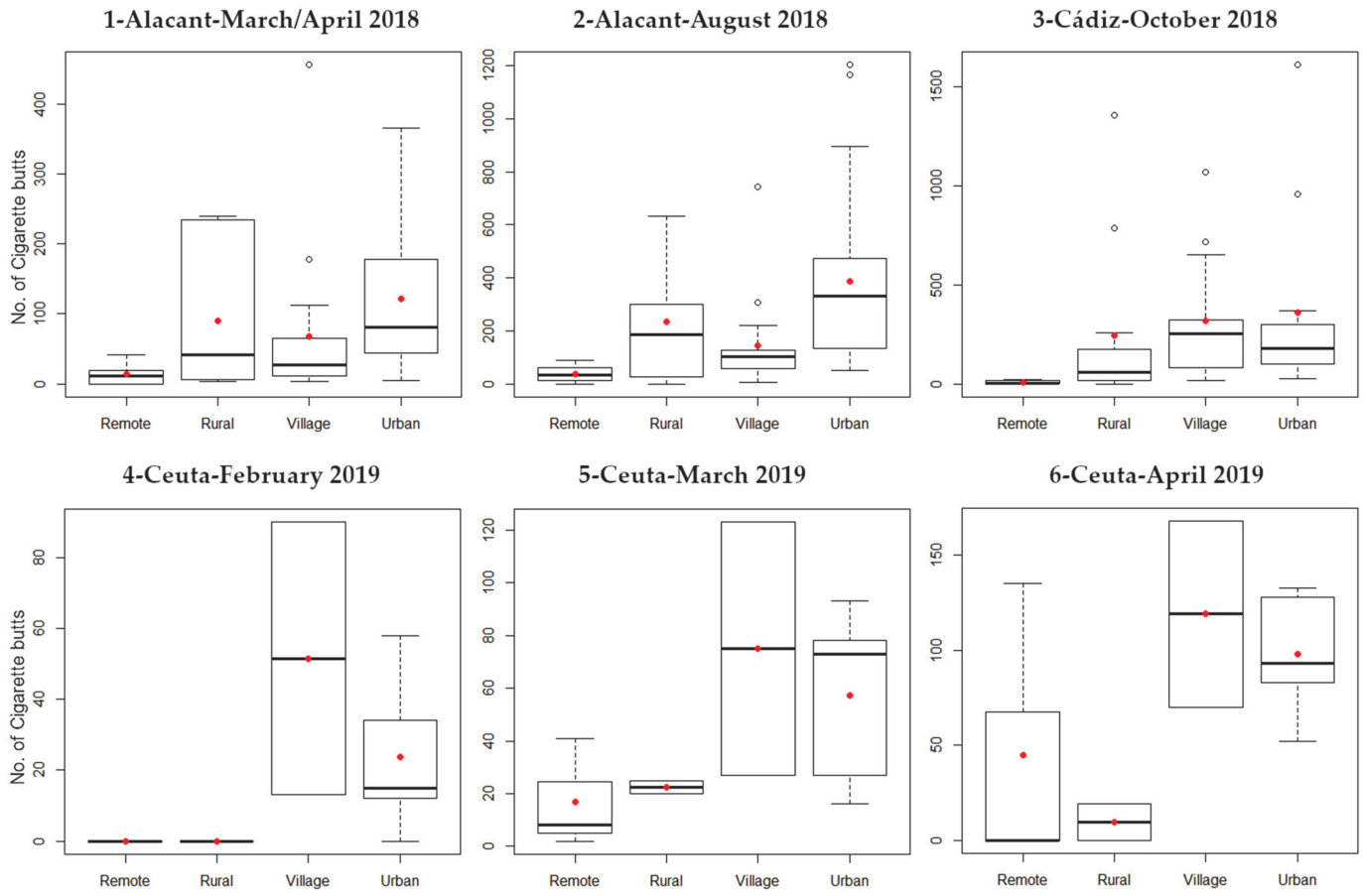



**Figure A1.** Box plots of total number of cigarette butts per beach typology in each one of the six surveys.

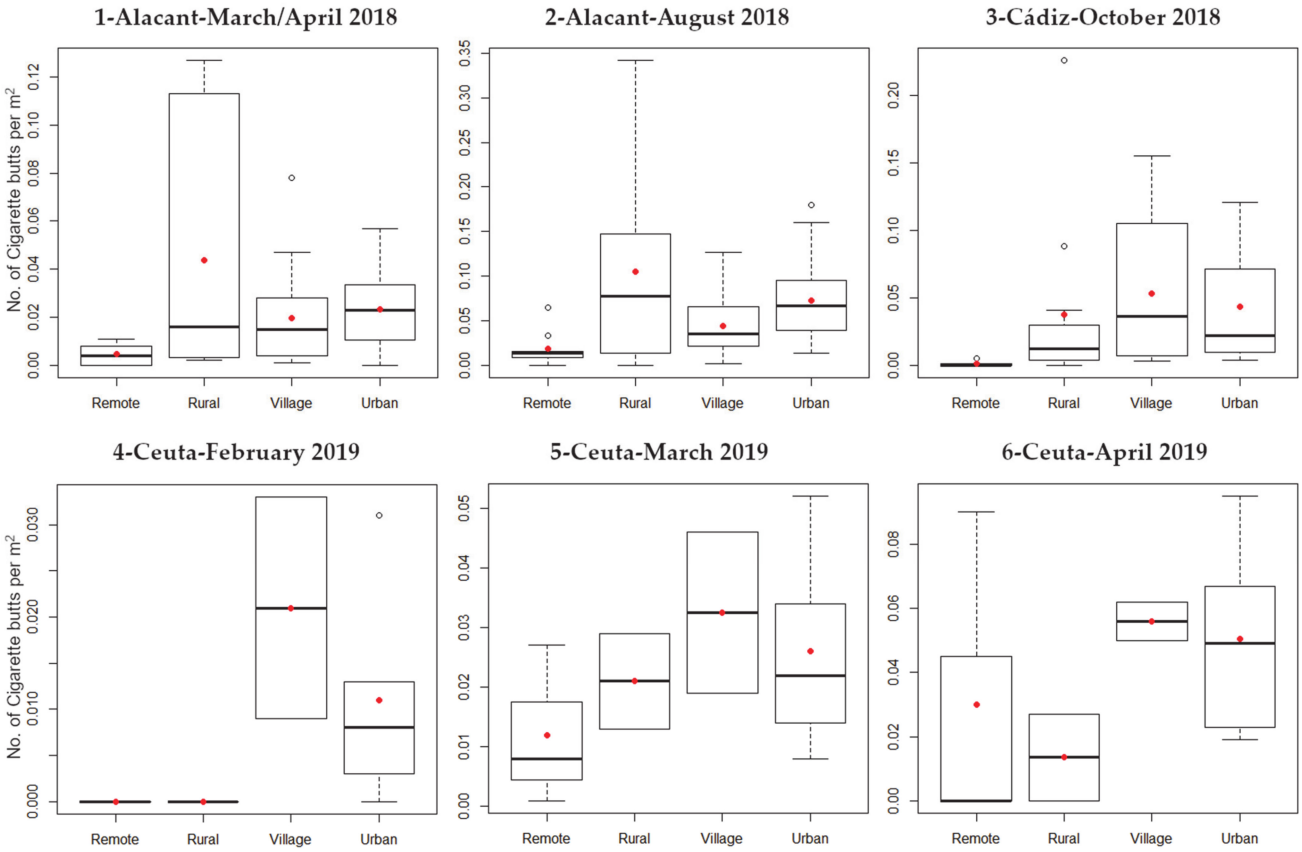



**Figure A2.** Box plots of cigarette butts density (CB/$m^2$) per beach typology in each one of the six surveys.

## References


1. Aguilar, R.; Marín, P.; Álvarez, H.; Blanco, J.; Sánchez, N. *Plastic in the Deep: An Invisible Problem. How the Seafloor Becomes a Plastic trap*; Oceana: Washington, DC, USA, 2020; p. 24.
2. Chiba, S.; Saito, H.; Fletcher, R.; Yogi, T.; Kayo, M.; Miyagi, S.; Ogido, M.; Fujikura, K. Human footprint in the abyss: 30 year records of deep-sea plastic debris. *Mar. Policy* **2018**, *96*, 204–212. [CrossRef]
3. Convey, P.; Barnes, D.K.; Morton, A. Debris accumulation on oceanic island shores of the Scotia Arc, Antarctica. *Polar Biol.* **2002**, *25*, 612–617. [CrossRef]
4. Anfuso, G.; Bolívar-Anillo, H.J.; Asensio-Montesinos, F.; Manzolli, R.P.; Portz, L.; Daza, D.A.V. Beach litter distribution in Admiralty Bay, King George Island, Antarctica. *Mar. Pollut. Bull.* **2020**, *160*, 111657. [CrossRef] [PubMed]
5. UNEP. *Marine Litter: A Global Challenge*; UNEP: Nairobi, Kenya, 2009; p. 232.
6. Ariza, E.; Leatherman, S.P. No-Smoking Policies and Their Outcomes on U.S. Beaches. *J. Coast. Res.* **2012**, *278*, 143–147. [CrossRef]
7. Cole, M.; Lindeque, P.; Halsband, C.; Galloway, T.S. Microplastics as contaminants in the marine environment: A review. *Mar. Pollut. Bull.* **2011**, *62*, 2588–2597. [CrossRef] [PubMed]
8. Ocean Conservancy. Trash Travels: From Our Hands to the Sea, Around the Globe and Through Time. 2010 Report, 60p. Available online: https://oceanconservancy.org/wp-content/uploads/2017/04/2010-Ocean-Conservancy-ICC-Report.pdf (accessed on 13 October 2020).
9. Kungskulniti, N.; Charoenca, N.; Hamann, S.; Pitayarangsarit, S.; Mock, J. Cigarette Waste in Popular Beaches in Thailand: High Densities that Demand Environmental Action. *Int. J. Environ. Res. Public Health* **2018**, *15*, 630. [CrossRef] [PubMed]
10. Loizidou, X.I.; Loizides, M.I.; Orthodoxou, D. Persistent marine litter: Small plastics and cigarette butts remain on beaches after organized beach cleanups. *Environ. Monit. Assess.* **2018**, *190*, 414. [CrossRef]
11. Araújo, M.C.B.; Costa, M.F. A critical review of the issue of cigarette butt pollution in coastal environments. *Environ. Res.* **2019**, *172*, 137–149. [CrossRef] [PubMed]
12. Simeonova, A.; Chuturkova, R. Marine litter accumulation along the Bulgarian Black Sea coast: Categories and predominance. *Waste Manag.* **2019**, *84*, 182–193. [CrossRef]
13. Rangel-Buitrago, N.; Barría-Herrera, J.; Vergara-Cortés, H.; Contreras-López, M.; Agredano, R. A snapshot of the litter problem along the Viña del Mar-Concón coastal strip, Valparaíso region. *Chile. Mar. Pollut. Bull.* **2020**, *160*, 111524. [CrossRef]
14. Martinez-Ribes, L.; Basterretxea, G.; Palmer, M.; Tintoré, J. Origin and abundance of beach debris in the Balearic Islands. *Sci. Mar.* **2007**, *71*, 305–314. [CrossRef]

15. Asensio-Montesinos, F.; Anfuso, G.; Randerson, P.; Williams, A. Seasonal comparison of beach litter on Mediterranean coastal sites (Alicante, SE Spain). *Ocean. Coast. Manag.* **2019**, *181*, 104914. [CrossRef]
16. Asensio-Montesinos, F.; Anfuso, G.; Ramírez, M.O.; Smolka, R.; Sanabria, J.G.; Enríquez, A.F.; Arenas, P.; Bedoya, A.M. Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain). *Reg. Stud. Mar. Sci.* **2020**, *34*, 101050. [CrossRef]
17. Ariza, E.; Jiménez, J.A.; Sardá, R. Seasonal evolution of beach waste and litter during the bathing season on the Catalan coast. *Waste Manag.* **2008**, *28*, 2604–2613. [CrossRef] [PubMed]
18. Balčiūnas, A.; Blažauskas, N. Scale, origin and spatial distribution of marine litter pollution in the Lithuanian coastal zone of the Baltic Sea. *Baltica* **2014**, *27*, 39–44. [CrossRef]
19. Schernewski, G.; Balciunas, A.; Gräwe, D.; Gräwe, U.; Klesse, K.; Schulz, M.; Wesnigk, S.; Fleet, D.; Haseler, M.; Möllman, N.; et al. Beach macro-litter monitoring on southern Baltic beaches: Results, experiences and recommendations. *J. Coast. Conserv.* **2018**, *22*, 5–25. [CrossRef]
20. Krelling, A.P.; Williams, A.T.; Turra, A. Differences in perception and reaction of tourist groups to beach marine debris that can influence a loss of tourism revenue in coastal areas. *Mar. Policy* **2017**, *85*, 87–99. [CrossRef]
21. Asensio-Montesinos, F.; Ramírez, M.O.; González-Leal, J.M.; Carrizo, L.; Anfuso, G. Characterization of plastic beach litter by Raman spectroscopy in South-western Spain. *Sci. Total Environ.* **2020**, *744*, 140890. [CrossRef]
22. Slaughter, E.; Gersberg, R.M.; Watanabe, K.; Rudolph, J.; Stransky, C.; Novotny, T.E. Toxicity of cigarette butts, and their chemical components, to marine and freshwater fish. *Tob. Control.* **2011**, *20*, i25–i29. [CrossRef]
23. Moriwaki, H.; Kitajima, S.; Katahira, K. Waste on the roadside, 'poi-sute' waste: Its distribution and elution potential of pollutants into environment. *Waste Manag.* **2009**, *29*, 1192–1197. [CrossRef]
24. Novotny, T.E.; Lum, K.; Smith, E.; Wang, V.; Barnes, R. Filtered cigarettes and the case for an environmental policy on cigarette waste. *Int. J. Environ. Res. Public Health* **2009**, *6*, 1691–1705. [CrossRef] [PubMed]
25. Caridi, F.; Sabbatini, A.; Birarda, G.; Costanzi, E.; De Giudici, G.; Galeazzi, R.; Medas, D.; Mobbili, G.; Ricciutelli, M.; Ruello, M.L.; et al. Cigarette butts, a threat for marine environments: Lessons from benthic foraminifera (Protista). *Mar. Environ. Res.* **2020**, *162*, 105150. [CrossRef]
26. Green, D.S.; Kregting, L.; Boots, B. Smoked cigarette butt leachate impacts survival and behaviour of freshwater invertebrates. *Environ. Pollut.* **2020**, *266*, 115286. [CrossRef] [PubMed]
27. Savoca, M.S.; Tyson, C.W.; McGill, M.; Slager, C.J. Odours from marine plastic debris induce food search behaviours in a forage fish. *Proc. R. Soc. B Biol. Sci.* **2017**, *284*, 20171000. [CrossRef] [PubMed]
28. Micevska, T.; Warne, M.; Pablo, F.; Patra, R. Variation in, and Causes of, Toxicity of Cigarette Butts to a Cladoceran and Microtox. *Arch. Environ. Contam. Toxicol.* **2006**, *50*, 205–212. [CrossRef]
29. Dobaradaran, S.; Nabipour, I.; Saeedi, R.; Ostovar, A.; Khorsand, M.; Khajeahmadi, N.; Hayati, R.; Keshtkar, M. Association of metals (Cd, Fe, As, Ni, Cu, Zn and Mn) with cigarette butts in northern part of the Persian Gulf. *Tob. Control.* **2017**, *26*, 461–463. [CrossRef]
30. Tso, T.C. *Production, Physiology and Biochemistry of Tobacco Plant*; IDEALS: Beltsville, MA, USA, 1990; p. 785.
31. Frank, R.; Braun, H.E.; Suda, P.; Ripley, B.D.; Clegg, B.S.; Beyaert, R.P.; Zilkey, B.F. Pesticide residues and metal contents in flue-cured tobacco and tobacco soils of southern Ontario, Canada 1980–1985. *Tob. Sci.* **1987**, *21*, 40–45.
32. Baker, R.R.; Da Silva, J.R.P.; Smith, G. The effect of tobacco ingredients on smoke chemistry. Part I: Flavourings and additives. *Food Chem. Toxicol.* **2004**, *42*, 3–37. [CrossRef]
33. Baker, R.R.; Da Silva, J.R.P.; Smith, G. The effect of tobacco ingredients on smoke chemistry. Part II: Casing ingredients. *Food Chem. Toxicol.* **2004**, *42*, 39–52. [CrossRef]
34. Iskander, F.Y.; Klein, D.B.; Bauer, T.L. Determination of trace and minor elements in cigarette paper by neutron activation analysis. *Tappi J.* **1986**, *69*, 134–135.
35. Kabata-Pendias, A. *Trace Elements in Soils and Plants*, 4th ed.; CRC Press: Boca Raton, FL, USA, 2011; p. 548.
36. Clark, T.J.; Bunch, J.E. Quantitative Determination of Phenols in Mainstream Smoke with Solid-Phase Microextraction-Gas Chromatography—Selected Ion Monitoring Mass Spectrometry. *J. Chromatogr. Sci.* **1996**, *34*, 272–275. [CrossRef]
37. Pertschuk, M.; Glantz, S.A.; Slade, J.; Bero, L.; Hanauer, P.; Barnes, D.E. The Cigarette Papers. *J. Public Health Policy* **1998**, *19*, 236. [CrossRef]
38. Doull, J.; Frawley, J.P.; George, W. List of Ingredients Added to Tobacco in the manufacture of Cigarettes by Six Major American Cigarette Companies. *Tob. J. Int.* **1994**, *196*, 32–39.
39. Novotny, T.E.; Hardin, S.N.; Hovda, L.R.; Novotny, D.J.; McLean, M.K.; Khan, S. Tobacco and cigarette butt consumption in humans and animals. *Tob. Control.* **2011**, *20*, i17–i20. [CrossRef] [PubMed]
40. Hulzebos, C.V.; Walhof, C.; De Vries, T.W. Accidental ingestion of cigarettes by children. *Ned. Tijdschr. Geneeskd.* **1998**, *142*, 2569–2571. [PubMed]
41. Smolinske, S.; Spoerke, D.; Spiller, S.; Wruk, K.; Kulig, K.; Rumackt, B. Cigarette and Nicotine Chewing Gum Toxicity in Children. *Hum. Toxicol.* **1988**, *7*, 27–31. [CrossRef] [PubMed]
42. Salomon, M.E. Nicotine and tobacco preparations. In *Goldfrank's Toxicologic Emergencies*, 8th ed.; Goldfrank, L.R., Flomenbaum, N.E., Lewin, N.A., Howland, M.A., Hoffman, R.S., Nelson, L.S., Eds.; McGraw-Hill: New York, NY, USA, 2006; pp. 1221–1230.

43. Stanley, K.; Stabenau, E.; Landry, A. Debris ingestion by sea turtles along the Texas coast. In Proceedings of the Eighth Annual Workshop on Sea Turtle Conservation and Biology, Fort Fisher, NC, USA, 24–26 February 1988; NOAA Technical Memorandum. pp. 119–121.
44. Wright, S.L.; Rowe, D.; Reid, M.J.; Thomas, K.V.; Galloway, T.S. Bioaccumulation and biological effects of cigarette litter in marine worms. *Sci. Rep.* **2015**, *5*, 1–10. [CrossRef]
45. Asensio-Montesinos, F.; Anfuso, G.; Williams, A. Beach litter distribution along the western Mediterranean coast of Spain. *Mar. Pollut. Bull.* **2019**, *141*, 119–126. [CrossRef]
46. Williams, A.T.; Micallef, A. *Beach Management. Principles and Practice*; Earthscan: London, UK, 2009; p. 480.
47. Taylor, E.; Owens, E.H. Specialized mechanical equipment for shoreline cleanup. *Int. Oil Spill Conf. Proc.* **1997**, *1997*, 79–87. [CrossRef]
48. Cheshire, A.; Adler, E. UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter. United Nations Environment Programme/Intergovernmental Oceanographic Commission: Nairobi, Kenya, 2009.
49. OSPAR Commission. *Guideline for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area*; OSPAR Commission: London, UK, 2010; p. 84.
50. Opfer, S.; Arthur, C.; Lippiatt, S. *NOAA Marine Debris Shoreline Survey Field Guide*; NOAA Marine Debris Program; US National Oceanic and Atmospheric Administration Marine Debris Program: Silver Spring, MD, USA, 2012; p. 19.
51. Vlachogianni, T.; Fortibuoni, T.; Ronchi, F.; Zeri, C.; Mazziotti, C.; Tutman, P.; Mandić, M. Marine litter on the beaches of the Adriatic and Ionian Seas: An assessment of their abundance, composition and sources. *Mar. Pollut. Bull.* **2018**, *131*, 745–756. [CrossRef]
52. Nachite, D. *Photo Guide for Monitoring Marine Litter on the Mediterranean Moroccan Beaches*; Coordination Nationale du Pro-gramme National de Surveillance et d'Evaluation de la Pollution de la Méditerranée: Mai, Marocco, 2019; p. 73.
53. Kammler, M.; Schernewski, G. Spatial and temporal analysis of beach tourism using webcam and aerial photographs. *Coastline Rep.* **2004**, *2*, 121–128.
54. Taffs, K.H.; Cullen, M.C. The distribution and abundance of beach debris on isolated beaches of northern New South Wales, Australia. Australas. *J. Env. Man.* **2005**, *12*, 244–250.
55. Oztekin, A.; Bat, L.; Gokkurt-Baki, O. Beach litter pollution in Sinop Sarikum Lagoon coast of the southern Black Sea. *Turk. J. Fish. Aquat Sc.* **2019**, *20*, 197–205.
56. Kataržytė, M.; Balčiūnas, A.; Haseler, M.; Sabaliauskaitė, V.; Lauciūtė, L.; Stepanova, K.; Nazzari, C.; Schernewski, G. Cigarette butts on Baltic Sea beaches: Monitoring, pollution and mitigation measures. *Mar. Pollut. Bull.* **2020**, *156*, 111248. [CrossRef] [PubMed]
57. Simeonova, A.; Chuturkova, R.; Yaneva, V. Seasonal dynamics of marine litter along the Bulgarian Black Sea coast. *Mar. Pollut. Bull.* **2017**, *119*, 110–118. [CrossRef] [PubMed]
58. Mooser, A.; Anfuso, G.; Mestanza-Ramón, C.; Williams, A.T. Management Implications for the Most Attractive Scenic Sites along the Andalusia Coast (SW Spain). *Sustainability* **2018**, *10*, 1328. [CrossRef]
59. Asensio-Montesinos, F.; Anfuso, G.; Corbí, H. Coastal scenery and litter impacts at Alicante (SE Spain): Management issues. *J. Coast. Conserv.* **2018**, *23*, 185–201. [CrossRef]
60. Maziane, F.; Nachite, D.; Anfuso, G. Artificial polymer materials debris characteristics along the Moroccan Mediterranean coast. *Mar. Pollut. Bull.* **2018**, *128*, 1–7. [CrossRef]
61. Schmuck, A.M.; Lavers, J.L.; Stuckenbrock, S.; Sharp, P.B.; Bond, A.L. Geophysical features influence the accumulation of beach debris on Caribbean islands. *Mar. Pollut. Bull.* **2017**, *121*, 45–51. [CrossRef]
62. Williams, A.T.; Simmons, S.L. Sources of Riverine Litter: The River Taff, South Wales, UK. *Water Air Soil Pollut.* **1999**, *112*, 197–216. [CrossRef]
63. Rech, S.; Macaya-Caquilpán, V.; Pantoja, J.; Rivadeneira, M.M.; Madariaga, D.J.; Thiel, M. Rivers as a source of marine litter—A study from the SE Pacific. *Mar. Pollut. Bull.* **2014**, *82*, 66–75. [CrossRef] [PubMed]
64. Ramos-Esplá, A.; McNeill, S.E. The status of marine conservation in Spain. *Ocean. Coast. Manag.* **1994**, *24*, 125–138. [CrossRef]
65. Ramos-Esplá, A.A. La Reserva Marina de la Isla de Tabarca, una realidad después de un sueño. *Canelobre* **2012**, *60*, 284–297.
66. Nachite, D.; Maziane, F.; Anfuso, G.; Williams, A.T. Spatial and temporal variations of litter at the Mediterranean beaches of Morocco mainly due to beach users. *Ocean. Coast. Manag.* **2019**, *179*, 104846. [CrossRef]
67. Tavares, D.C.; Moura, J.F.; Ceesay, A.; Merico, A. Density and composition of surface and buried plastic debris in beaches of Senegal. *Sci. Total Environ.* **2020**, *737*, 139633. [CrossRef]
68. Zielinski, S.; Botero, C.M.; Yanes, A. To clean or not to clean? A critical review of beach cleaning methods and impacts. *Mar. Pollut. Bull.* **2019**, *139*, 390–401. [CrossRef]
69. La Marina Plaza. Costas Destruye una Duna en l'Estanyó de Dénia Donde Anidaba una Especie Protegida Durante su Enésima Regeneración. Available online: https://lamarinaplaza.com/2018/06/13/costas-destruye-una-duna-en-lestanyo-de-denia-donde-anidaba-una-especie-protegida-durante-su-enesima-regeneracion/ (accessed on 19 November 2020).
70. Econoticias. Deterioro de las dunas de Guadarranque de San Roque (Cádiz). Available online: https://www.ecoticias.com/medio-ambiente/204390/Deterioro-dunas-Guadarranque-San-Roque-Cadiz (accessed on 19 November 2020).
71. Nordstrom, K.F. Beaches and dunes of human-altered coasts. *Prog. Phys. Geogr. Earth Environ.* **1994**, *18*, 497–516. [CrossRef]

72. Williams, A.T. Definitions and typologies of coastal tourism destinations. In *Disappearing Destinations: Climate change and Future Challenges for Coastal Tourism*; Jones, A., Phillips, M., Eds.; CABI: Oxfordshire, UK, 2011; pp. 47–66.
73. Williams, A.T.; Randerson, P.F.; Di Giacomo, C.; Anfuso, G.; Macias, A.; Perales, J.A. Distribution of beach litter along the coastline of Cádiz, Spain. *Mar. Pollut. Bull.* **2016**, *107*, 77–87. [CrossRef]
74. Araújo, M.C.B.; Costa, M.F. From Plant to Waste: The Long and Diverse Impact Chain Caused by Tobacco Smoking. *Int. J. Environ. Res. Public Health.* **2019**, *16*, 2690.
75. Williams, A.T.; Tudor, D. Litter Burial and Exhumation: Spatial and Temporal Distribution on a Cobble Pocket Beach. *Mar. Pollut. Bull.* **2001**, *42*, 1031–1039. [CrossRef]
76. Ergin, A.; Karaesmen, E.; Micallef, A.; Williams, A.T. A new methodology for evaluating coastal scenery: Fuzzy logic systems. *Area* **2004**, *36*, 367–386. [CrossRef]
77. Ergin, A.; Williams, A.T.; Micallef, A. Coastal Scenery: Appreciation and Evaluation. *J. Coast. Res.* **2006**, *224*, 958–964. [CrossRef]
78. Costa, M.F.; Sul, J.A.I.D.; Silva-Cavalcanti, J.S.; Araújo, M.C.B.; Spengler, Â.; Tourinho, P.S. On the importance of size of plastic fragments and pellets on the strandline: A snapshot of a Brazilian beach. *Environ. Monit. Assess.* **2009**, *168*, 299–304. [CrossRef] [PubMed]
79. Jayasiri, H.; Purushothaman, C.S.; Vennila, A. Plastic litter accumulation on high-water strandline of urban beaches in Mumbai, India. *Environ. Monit. Assess.* **2013**, *185*, 7709–7719. [CrossRef]

# PLAN DE INVESTIGACIÓN

# PLAN DE INVESTIGACIÓN DE TESIS DOCTORAL
# R.D. 99/2011

## A. MEMORIA DEL PLAN DE INVESTIGACIÓN DE TESIS DOCTORAL

Apellidos: Asensio Montesinos Nombre: Francisco

D.N.I./Pasaporte: 45844356C/ PAJ286104 Programa de doctorado: Ciencias y Tecnologías Marinas

Escuela de Doctorado: Escuela de Doctorado de la Universidad de Cádiz

Título de la tesis: Distribución y composición de los residuos sólidos en ambientes costeros mediterráneos y atlánticos. Relaciones con las características geomorfológicas y los usos de las playas e implicaciones para la gestión.

Director Dr. Giorgio Anfuso

### 1.- Resumen

Resultados de investigaciones sobre las preferencias de los usuarios de playa apuntan que cinco parámetros son aquellos que más influyen en la elección de un sitio u otro: la ausencia de residuos sólidos, la calidad del agua, la seguridad, las infraestructuras y el paisaje (Morgan et al. 1995, McKenna et al. 2011 y Williams et al. 2012 entre otros). Este estudio propone una investigación de aquel que probablemente es el más importante, es decir, la presencia de residuos sólidos en la costa. Además, la presencia de residuos en el litoral condiciona también la calidad de otros parámetros de atracción como por ejemplo el paisaje, la calidad del agua y la seguridad. La investigación propuesta es particularmente interesante y novedosa porque aborda un grave problema a escala mundial y será totalmente pionera en la costa alicantina donde constituirá el primer estudio que se realice sobre esta temática y, en la costa gaditana, donde solamente se ha llevado a cabo un estudio publicado por Williams et al. (2016) pero que concierne exclusivamente la zona de la Bahía de Cádiz. En detalle, en el marco de esta investigación, se propone estudiar 56 sitios costeros en la provincia de Alicante, en el oeste del Mar Mediterráneo, y 40 playas en el litoral de Cádiz, en la costa Atlántica de Andalucía. En cada uno de estos sitios se evaluará la distribución y composición de los residuos sólidos que se relacionará con las características geomorfológicas y las tipologías (usos) de cada playa.

Así, un primer objetivo es la caracterización de la composición y abundancia de los residuos sólidos en el litoral mediante el conteo de los residuos presentes en sectores de 100 m paralelos a la línea de costa y extendidos desde la orilla hasta la parte final de la playa. Dentro de cada sector, el observador se desplaza a lo largo de transectos paralelos espaciados entre si 5 m. Además, en la costa gaditana se cogerán diferentes muestras de todos los residuos plásticos para determinar su composición con la técnica de espectroscopia Raman.

Un segundo objetivo es la caracterización de la morfología de las playas investigadas y de su tipología o usos. La caracterización morfológica se llevará a cabo mediante estudios sedimentológicos y topográficos, es decir, mediante observaciones sobre las características de los sedimentos que constituyen las playas investigadas diferenciando entre playas arenosas y de grava/cantos y, asimismo, se llevarán a cabo levantamientos topográficos mediante GPS diferencial en playas de arena para caracterizar su estado morfodinámico (Anfuso et al. 2003; Anfuso y Gracia, 2005). En cuanto a la tipología (o usos) de las playas, este parámetro está relacionado con su entorno y con el número de

visitas que reciben. En este trabajo de investigación se han clasificado en remotas, rurales, semiurbanas y urbanas según la clasificación de Williams y Micallef (2009).

Como tercer objetivo, se espera tener un conocimiento más profundo de la composición de residuos sólidos en las zonas de estudio y poder relacionarlos con el medio físico, la tipología de playa, el número de visitantes y conocer la posible fuente de los residuos (terrestre o marina). Considerando la abundancia y tipología de los residuos, estos se pueden relacionar con actividades concretas como la pesca (ej. hilos, cuerdas, cordeles y cabos de plástico), con la afluencia de bañistas o visitantes (ej. colillas, envoltorios, papeles…) con posibles fuentes de aguas residuales (bastoncillos del oído, toallitas húmedas, tampones y aplicadores…), etc. Los resultados obtenidos son una herramienta útil en gestión costera ya que se pueden aplicar medidas correctoras generales y específicas para mejorar la calidad ambiental de aquellos sitios que lo necesitan. Las metodologías usadas se pueden replicar en el tiempo y aplicar a cualquier otro sitio de costa.

Finalmente, para el análisis de los resultados se utilizarán programas informáticos de Sistemas de Información Geográfica (ej. QGIS), programas estadísticos (ej. R-project, SPSS, Past) o de tratamiento de datos (ej. Excel).

## 2.- Antecedentes y estado actual del tema

Algunos autores como Micallef *et al*. (1999), Ergin *et al*. (2004) o McKenna *et al*. (2011) entre otros, estudiaron las preferencias de los usuarios de playa realizando numerosas encuestas, y concluyeron que, además de la distancia a la que se encuentra el destino, los cinco parámetros más importantes a la hora de elegir un sitio costero son: seguridad, servicios, calidad del agua, paisaje y ausencia de residuos sólidos; también denominados “Big Five” (Williams, 2011).

Uno de los aspectos que más valoran los usuarios de las zonas costeras es la ausencia de residuos sólidos ya que su presencia disminuye el atractivo paisajístico de la playa y además constituye un riesgo para la salud de los usuarios debido al riesgo de cortes y laceraciones. La ausencia de residuos sólidos tiene gran interés en varias partes del mundo, por ejemplo, en el Caribe es el principal factor de atracción (Botero *et al*. 2013). Usuarios de playa en países como EE.UU., Turquía y España, consideran la ausencia de residuos como una de las tres razones principales a la hora de escoger una playa u otra (Williams, 2011).

El entorno de cada playa definirá la tipología de ésta, pudiendo diferenciar según el grado de antropización o naturalidad entre zonas más rurales o más urbanas. Esto a menudo se relaciona con la afluencia y el tipo de gente que las visita y, por consiguiente, los residuos varían de una zona a otra.

Más de 100 evaluaciones sobre residuos sólidos realizadas recientemente en la costa mediterránea ponen de manifiesto que los sitios más degradados se encuentran en áreas rurales o bien en zonas que no se gestionan, pese a que el número de visitantes es más elevado en zonas más urbanizadas, sobre todo en los meses de verano. Esto sugiere que los residuos en la costa están mejor gestionados en zonas urbanas y semiurbanas donde el flujo de turistas es mayor. Algunos autores atribuyen dichos resultados a dos motivos principales: los esfuerzos de limpieza están motivados por razones económicas y los visitantes locales y nacionales no se preocupan por la presencia de residuos sólidos (Botero *et al*. 2017). Las numerosas campañas y acciones de limpieza que se llevan a cabo cada año desinteresadamente por visitantes locales, grupos ecologistas y otros voluntarios en distintas partes del litoral (p. ej. *Clean Up the Med* en áreas mediterráneas) muestran el interés por los sitios sin residuos y que las razones económicas son las que más peso tienen en la gestión de un espacio costero. Por este motivo, no es de extrañar que las administraciones encargadas de la gestión de residuos actúen más por cuestiones económicas que ambientales y centren sus esfuerzos en zonas turísticas más accesibles, dejando de lado la gestión en otras zonas menos visitadas ya que generan poco o ningún beneficio económico.

En muchas ocasiones, las playas urbanas aparentemente están exentas de residuos sólidos, pero cuando se estudian en detalle, la cantidad de elementos encontrados puede superar aquellos observados en zonas rurales o remotas. El tipo de ítems, el tamaño y la cantidad con la que se aparecen puede llegar a ser muy distinta según el número de visitas y la tipología de playa. Esto se debe principalmente a la composición del sedimento (arena, grava, cantos rodados…) y al método de limpieza utilizado (manual, con maquinaria, etc.). Por lo general, las playas urbanas o semiurbanas compuestas por arena, se limpian con maquinaria pesada (principalmente tractores con máquinas de rastrillado y cribado), bastante comunes en zonas turísticas litorales. Una sola persona, con este tipo de sistema de limpieza puede retirar residuos sólidos en un área de grandes dimensiones en poco tiempo (desde 20000 a 30000 $m^2$/h) aunque con algunos problemas asociados que pueden afectar al medio natural costero. La retirada de restos vegetales de algas, troncos o fanerógamas marinas puede influir en el ecosistema; por ejemplo, en la distribución y abundancia de invertebrados costeros (Megías *et al*. 2017). Otros problemas son la compactación de la arena, la alteración y eliminación de dunas embrionarias y vegetación litoral asociada, los cambios en el perfil natural de una playa o la erosión (Nordstrom, 1994). Esto conlleva a un cambio en el medio costero que, con el tiempo transforma su carácter natural y dinámico por uno más artificial y estable que deja las playas como simples soportes físicos (Roig-Munar, 2004). Además, los residuos sólidos de menor tamaño atraviesan los tamices de retención de las máquinas limpiadoras que, por ende, dejan tras de sí un elevado número de ítems como colillas, bastoncillos del oído (Williams, 2011) y pequeños trozos de plástico u otros materiales. Muchos de estos artículos también se quedan enterrados en la arena, por lo que las playas con este tipo de sedimento esconden más ítems de los que se ven a simple vista y por ello los residuos no se pueden contabilizar en su totalidad en las evaluaciones de tipo visual.

Para evaluar el estado ambiental de una zona respecto a los residuos, se han utilizado a lo largo de los últimos años numerosas evaluaciones con metodologías diferentes según la zona y el tipo de residuo que se desea estudiar, véase Galgani *et al*. (2010). Por ello, es necesario enfatizar algunos aspectos a tener en cuenta a la hora de evaluar visualmente un sitio costero como puede ser una playa. En primer lugar, en la zona que se vaya a investigar es muy importante (según las observaciones realizadas en diferentes tipos de sitios), establecer un área que abarque todo el ancho de playa, pues los ítems se acumulan en cantidades distintas según la sección de la playa. Así, es aconsejable cubrir la orilla (por los residuos que llegan desde el agua), la playa seca (donde los usuarios pasan la mayor parte de su tiempo) y en especial donde termina la playa, es decir, el pie de duna, un muro artificial, el inicio de una zona con vegetación, viviendas, etc. Aquí los residuos se acumulan en mayor cantidad debido a varios factores: por la acción del viento, porque las máquinas limpiadoras no llegan hasta estas zonas y por la basura que se vierte desde la zona de servidumbre de tránsito. En cuanto a la longitud de costa evaluada, generalmente muchos investigadores y organizaciones (p. ej. UNEP, OSPAR y NOAA) han establecido como medida representativa, una distancia mínima de evaluación de 100 metros paralelos a la línea de costa.

Por otra parte, debido a la gran diversidad de residuos existentes y los nuevos grupos que se registran en otros estudios, las listas de evaluación ya establecidas que se utilizan son poco manejables, pues la mayoría no logra ajustarse a un sitio costero concreto (siempre faltan o sobran grupos) debido a la gran diversidad de residuos. Por ejemplo, existen listas de 42, 77, 116 o incluso de hasta 182 grupos diferentes (Lippiatt *et al*. 2013; Chesire *et al*. 2009; OSPAR Commission, 2010; Williams *et al*. 2016a), algunas poco y otras demasiado específicas ya que se invierte demasiado tiempo en localizar el grupo donde ubicar cada ítem. En este sentido, cuando se vaya a evaluar por primera vez los residuos sólidos de un sitio costero y no haya referencias sobre los elementos que se pueda encontrar, una buena estrategia de evaluación es utilizar una lista en blanco, y anotar todos los grupos y número de ítems que se vayan encontrando. Así, se obtiene una lista personalizada para un área determinada que se podrá utilizar en otras ocasiones y por otros investigadores para realizar un seguimiento u otras evaluaciones en áreas similares o zonas geográficas cercanas.

Cabe destacar que, entre otros, el método de evaluación EA/NALG (2000) es el más práctico, sencillo de aplicar y con gran potencial para la gestión de los residuos en las zonas costeras ya que

permite obtener una clasificación basada en diferentes categorías como: evidencias de aguas residuales, residuos de grandes y pequeñas dimensiones, residuos peligrosos, acumulaciones, aceite y heces. Además, se ha utilizado en más de media docena de países pertenecientes a Europa y América Latina (Williams *et al*. 2016a, 2016b; Botero *et al*. 2017; Rangel-Buitrago *et al*. 2017).

## 3.- Hipótesis y Objetivos

Entre las razones por las que se considera pertinente plantear esta investigación se encuentran las siguientes:

- La mayor parte de la población mundial vive cerca de la costa.
- Los ambientes costeros tienen una gran importancia para la biodiversidad tanto marina como terrestre y son de los más frágiles y degradados que existen.
- El elevado consumo de productos y la incesante producción de residuos son dos actividades que se han incrementado considerablemente durante las últimas décadas.
- Cada vez es más difícil encontrar lugares costeros prístinos en los que no haya presencia del ser humano. Los residuos son transportados por corrientes y pueden llegar a cualquier parte del mundo, aunque no esté habitada.
- Los problemas que los residuos causan en hábitats costeros. Mejorar la salud del litoral depende en gran parte de estudios como este ya que, para gestionar un espacio, antes hay que conocerlo y saber cuáles son los problemas presentes.
- El turismo durante décadas ha experimentado un continuo crecimiento. Este fenómeno económico moviliza a muchísimas personas según la época del año y el sitio, concretamente tiene gran repercusión en zonas costeras, beneficiando a la economía del lugar pero al mismo tiempo se producen más residuos y dificulta la gestión de la costa, especialmente en verano.

Hipótesis de partida:

- No existen dos sitios costeros iguales, por consiguiente, la cantidad y composición de los residuos será diferente en cada playa.
- Se esperan diferencias importantes en la composición y densidad de residuos sólidos según el tipo de playa (remota, rural, semiurbana, urbana).
- El tipo de sustrato determina el tipo de limpieza, por lo tanto, la cantidad y las categorías de residuos serán diferentes en playas de arena *versus* otras (plataforma rocosa, grava, cantos rodados, arribazones de *Posidonia oceanica*, etc.).
- La mayor parte de los residuos en playas urbanizadas estará relacionada con los usuarios de la playa.
- Se espera encontrar densidades de residuos que se encuentren dentro del rango publicado por otros estudios, desde cero en la Antártida (Convey et al. 2002) hasta 6.66 items $m^{-2}$ en Croacia (Vlachogianni, 2019).
- La distribución de los residuos en las playas no será homogénea y habrá diferentes zonas de acumulación según el tipo de playa y sus características naturales.
- Las zonas de acumulación de residuos serán diferentes en playas mediterráneas y atlánticas debido a las mareas.
- La abundancia de residuos clasificados por tipo de material plástico, generalmente se corresponderá con los datos de producción y consumo de cada tipo de plástico.

Entre los objetivos generales se pueden destacar algunos como:

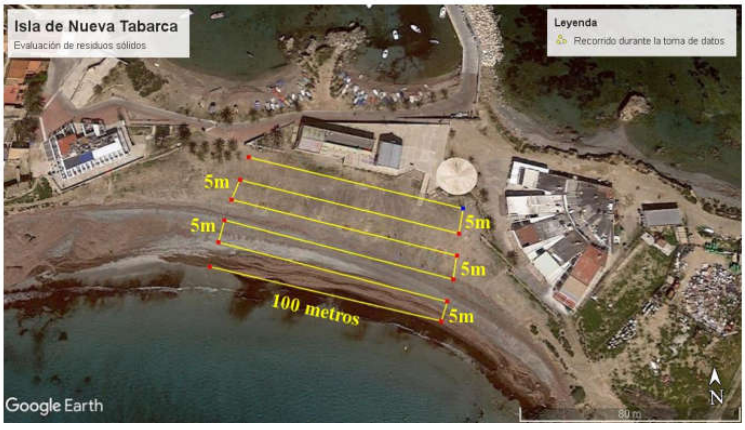
- Dar visibilidad al problema de los residuos sólidos y que sea conocido especialmente por las administraciones gubernamentales, las cuales son las que se encargan de la gestión de los espacios costeros. Este objetivo está completamente relacionado con el trabajo ya que, si no se le da visibilidad al problema, no se conoce, y por lo tanto no se actúa sobre él. Son precisamente las administraciones las que gestionan los residuos, por ello, es necesario que la información les llegue. Si a esto le sumamos la poca comunicación que existe entre las administraciones y las universidades, resulta que este objetivo se vuelve prioritario.

- Dar a conocer los resultados al público general para concienciar y cambiar su comportamiento para que gestionen adecuadamente sus residuos.
- Relacionar el tipo de residuos con su fuente o investigar su posible procedencia para proponer algunos consejos para la gestión y así aplicar las medidas correctoras más adecuadas y efectivas.
- Establecer relaciones entre la tipología de playa, la geomorfología o el grado de ocupación con la abundancia y composición de los residuos con el fin de mejorar las operaciones de limpieza.
- Estudiar las relaciones entre el estado morfodinámico de la playa (disipativo, intermedio o reflectivo) con la abundancia y composición de los residuos.
- Establecer contactos entre la comunidad científica que trabaje en temas de gestión costera para aprender, compartir conocimientos y realizar colaboraciones en futuras investigaciones y proyectos.
- Utilizar los datos obtenidos para tomar decisiones importantes que tengan repercusión en la gestión costera, como por ejemplo la denuncia social a través de ONGs como Ecologistas en Acción. (En su informe anual de Banderas Negras, se utilizaron parte de las evaluaciones preliminares de este trabajo llevadas a cabo en la costa mediterránea para determinar qué zona era la más deteriorada de toda la provincia de Alicante y otorgar así un galardón despectivo para visibilizar problemas de vertidos o posible contaminación).
- Evidenciar cuáles son los residuos más abundantes en cada zona, investigar por qué y dar algunas indicaciones que ayuden a su disminución.
- Determinar qué tipos de plásticos se pueden encontrar en la costa y cuál es su proporción.

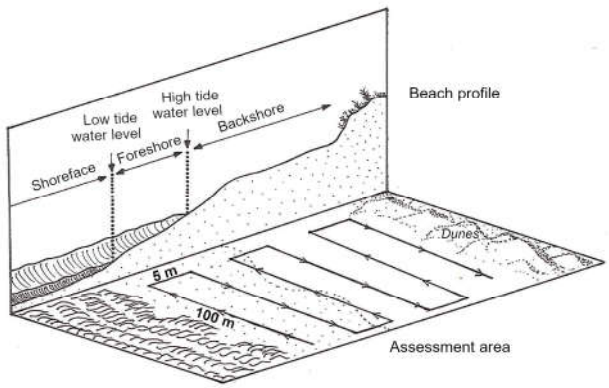
## 4.- Metodología

*Evaluaciones de residuos sólidos:*

Para **evaluar la abundancia y la tipología los residuos** sólidos se contabilizarán todos los ítems como se muestra en la siguiente figura, es decir, en transectos de 100 metros paralelos a la línea de costa y separados entre ellos por una distancia de 5 metros hasta cubrir por completo el ancho de cada sitio, es decir, desde la línea de costa hasta el final de la playa (un muro, edificios, pie de duna, etc.). Los distintos residuos se clasificarán en una lista de evaluación personalizada para el área de estudio que está compuesta por diferentes grupos, resultado de agrupar las listas de evaluación de diferentes entidades (UNEP, NOAA y OSPAR) y añadir nuevos grupos.




En Cádiz, al ser un ambiente costero mesomareal (mareas entre 2 y 4 metros de amplitud) tenemos nuevas zonas de muestreo que hay que tener en cuenta para contabilizar los residuos como la línea de marea baja, línea de marea alta y zona intermareal (en Alicante al ser un ambiente micromareal solamente se aprecia la mayor parte de las veces la línea del mar y la zona seca). El muestreo en Cádiz, se hará de la misma manera que en Alicante, teniendo en cuenta las nuevas zonas del intermareal. Tal y como se muestra en la figura.



Se evaluará el mayor número posible de sitios costeros. Lo ideal es cubrir todo el litoral de una forma más o menos homogénea en la medida de lo posible. El objetivo es hacer un mínimo de 40 sitios/playas por provincia de acuerdo con el tiempo disponible de trabajo. Se elegirán lo más arbitrariamente posible, pero también se intentará escoger alguna que sea emblemática o muy conocida. Seguramente en Alicante se hagan más evaluaciones debido a la buena accesibilidad que tiene este litoral, a la poca anchura que presenta el tramo costero y sobre todo al elevado número de playas que tiene conocidas (180 aprox.) y lo cerca que están unas de otras, en comparación con la provincia de Cádiz que tiene aproximadamente unas 83 playas, aunque en su parte atlántica su número es menor. La costa gaditana también presenta playas mucho más anchas y largas además de que algunas no son tan accesibles como las mediterráneas.

Listado propuesto de las zonas costeras que se van a investigar en Alicante y Cádiz. Ordenadas de izquierda a derecha y mirando desde el mar hacia tierra:

*Alicante:*

1. Las Higuericas
2. Mil Palmeras
3. Cabo Roig
4. La Estaca
5. Playa del Cura
6. Torrelamata
7. Les Ortigues
8. Babilònia
9. Els Tossals
10. El Pinet
11. Tabarca
12. Faroleta
13. Platja Gran
14. Gran Playa
15. Calas del Cuartel
16. El Carabassí
17. Arenales del Sol
18. El Saladar
19. Agua Amarga
20. San Gabriel
21. El Postiguet
22. Serragrossa
23. Albufereta
24. Almadraba
25. Cala dels Jueus
26. Cala Cantalars
27. Cala Palmera
28. Cap de l'Horta
29. Playa San Juan
30. Riu Sec
31. Morro Blanc
32. Carritxar
33. El Xarco
34. Bon-Nou
35. El Torres
36. Cala Finestrat
37. Llevant
38. Racó de L'Albir
39. Cap Negret
40. L'Olla
41. Racó del Corb
42. Morelló
43. Cala de la Fossa
44. Cala Fustera
45. L'Ampolla
46. El Portet
47. Cala del Moraig
48. Granadella
49. Ambolo
50. L'Arenal
51. Les Rotes
52. Marineta Cassiana
53. Les Marines
54. Els Molins
55. Almadrava
56. Les Deveses

*Cádiz:*

1. Bajo de Guía
2. La Jara
3. Micaela
4. Cruz del Mar
5. La Regla
6. La Ballena
7. La Costilla
8. Rompidillo
9. Santa Catalina
10. La Puntilla
11. Valdelagrana
12. Levante
13. Río San Pedro
14. La Cachucha
15. La Caleta
16. Sta. María del Mar
17. La Victoria
18. Cortadura
19. Torregorda
20. Camposoto
21. Playa Canina
22. Sancti-Petri
23. La Barrosa
24. El Puerco
25. Princesa Alejandra
26. Cala del Aceite
27. Los Bateles
28. Castilnovo
29. El Palmar
30. Trafalgar
31. Caños de Meca
32. Hierbabuena
33. El Carmen
34. Retín Barbate
35. Atlanterra
36. Los Alemanes
37. Bolonia
38. Valdevaqueros
39. Los Lances norte
40. Los Lances sur

*Levantamientos topográficos de las playas:*

Los **perfiles de playa** se realizarán con GPS-Diferencial en los mismos sitios donde se hicieron las evaluaciones de residuos. Para ello se cogerán puntos de latitud, longitud y elevación (x, y, z) desde la parte final de la playa hasta la línea de bajamar. Obteniendo de esta manera las coordenadas y la altura con la que obtendremos mediante una serie de correcciones matemáticas, el perfil de las playas seleccionadas. Estos perfiles, se van a realizar solamente en el litoral atlántico de Cádiz por diversos motivos:

- La cordillera subbética de la Península Ibérica que empieza en Cádiz, termina en Alicante con unos acantilados de gran altura que van a impedir, casi con total seguridad que el DGPS pueda conectarse a las antenas necesarias (se requiere la conexión a un mínimo de tres antenas para obtener una buena precisión por triangulación). Ya hay problemas en Cádiz con la conexión a las distintas antenas y apenas existen acantilados que interfieran en la señal, además, los que hay presentes no son muy altos.
- Muchas de las playas de Alicante en las que estudiamos los residuos están regeneradas y no tienen un perfil de playa natural, son escenarios costeros casi planos, donde vierten arena cada año y tienen una morfología artificial que cambia con cada intervención humana o con cada temporal. No se ha relacionado el estado morfodinámico de las playas en Alicante con los residuos porque el factor humano en esta costa es muy elevado, además estas playas son todas micromareales y el tipo de sustrato que existe en cada playa va a ser mucho más determinante a la hora de relacionarlo con los residuos. Por ello sí que se relacionará el tipo de sustrato de cada playa (arena, grava, cantos rodados, etc.) con los residuos. En Cádiz esto no se hará porque solo hay incluidas playas de arena, por ello, se realizarán los perfiles solo en Cádiz, para tener más datos y poder interpretar mejor los resultados.

*Aplicación de otras metodologías complementarias*

En Alicante, previamente a las evaluaciones de residuos, se realizaron diversas evaluaciones paisajísticas en los mismos sitios utilizando el método "**Coastal Scenic Evaluation**" (CSE) desarrollado por Ergin et al (2004). Se evaluaron en cada sitio un total de 26 parámetros (tanto físicos como antrópicos) teniendo así, un conocimiento mucho mejor de las características físicas y antrópicas principales de cada sitio. La información recopilada de esa investigación proporcionó una base de datos sólida y mostró algunas evidencias de dónde se encontraban aquellas zonas con más residuos sólidos. En Cádiz este trabajo no fue necesario, pues ya se contaba con esta información desde un principio (Williams et al. 2012; Mooser et al. 2018).

A cada sitio se le aplicará la metodología EA/NALG (2000) que cosiste en establecer una clasificación en uno de los cuatro grados de residuos que van desde "A" (excelente) a "D" (muy malo) según la presencia y cantidad de distintos tipos de residuos como por ejemplo aquellos que son perjudiciales, residuos generales, residuos grandes, residuos relacionados con aguas residuales, etc. Cada sitio tendrá el peor grado obtenido en cualquiera de las categorías de residuos. Por ejemplo, si una playa tiene para todas las categorías el grado "A" excepto para los residuos perjudiciales que tiene grado "C", esa playa será "C". Se puede hacer referencia a esta técnica como **"Litter Grade".**

Metodología de clasificación por tipo de residuos (EA/NALG, 2000).

| | Categoría | Tipo | A | B | C | D |
|---|---|---|---|---|---|---|
| 1 | Desechos relacionados con aguas residuales | General | 0 | 1-5 | 6-14 | 15+ |
| | | Bastoncillos | 0-9 | 10-49 | 50-99 | 100+ |
| 2 | Residuos grandes | >50cm | 0 | 1-5 | 6-14 | 15+ |
| 3 | Residuos generales | <50cm | 0-49 | 50-499 | 500-999 | 1000+ |
| 4 | Residuos perjudiciales | Vidrios rotos | 0 | 1-5 | 6-24 | 25+ |
| | | Otros | 0 | 1-4 | 5-9 | 10+ |
| 5 | Acumulaciones | Número | 0 | 1-4 | 5-9 | 10+ |
| 6 | Aceite | - | Ausente | Indicios | Molesto | Inaceptable |
| 7 | Heces | - | 0 | 1-5 | 6-24 | 25+ |

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La tipología de los sitios costeros se realizará acorde a la clasificación de Williams y Micallef (2009), más comúnmente conocida como **"Beach Typology"** basada en sitios remotos, rurales, semiurbanos, urbanos y resort. De acuerdo con el tipo de entorno, accesos, grado de construcción, etc. Esta clasificación se basa en una serie de descripciones acompañadas de diversas fotografías para cada tipo de costa, pero puede presentar alguna dificultad a la hora de clasificar un sitio ya que cada playa es distinta y sus particularidades no tienen por qué ajustarse en su totalidad a estas definiciones. Como ejemplo, se muestra la definición de una de las tipologías según sus características:

*Urban* Urban areas serve large populations with well-established public services such as primary schools, religious centres, banks, post offices, internet cafes and a well-marked central business district. In the proximity of urban areas can be found commercial activities such as fishing/boating harbours and marinas. Urban beaches are located within or adjacent to the urban area and are *generally* freely open to the public (see Figure 1.14).

(Williams y Micallef, 2009)



*Source:* Ministry of Education, Spain

**Figure 1.14** *Aerial view of an urban beach, adjacent to or fronting an urban area that serves a large population with well-established public services, la Rada, Spain*

(Williams y Micallef, 2009)

## 5.- Justificación de recursos disponibles

Contamos con todo lo necesario para poder llevar a cabo todas las metodologías propuestas: con una libreta, lápiz, bolígrafos, hojas de evaluaciones, cámara fotográfica, bolsas de basura, guantes y un vehículo es más que suficiente para el trabajo de campo.

Los perfiles topográficos se realizarán con el equipamiento del departamento de Ciencias de la Tierra de la Universidad de Cádiz (UCA), concretamente con el GPS diferencial.

La determinación de materiales plásticos con espectroscopia Raman se realizará con un microscopio Jasco NSR 7200 del departamento de Física de la Materia Condensada, en la Facultad de Ciencias de la Universidad de Cádiz. Este trabajo estará supervisado por el catedrático Juan María González-Leal, experto en microscopía electrónica y materiales.

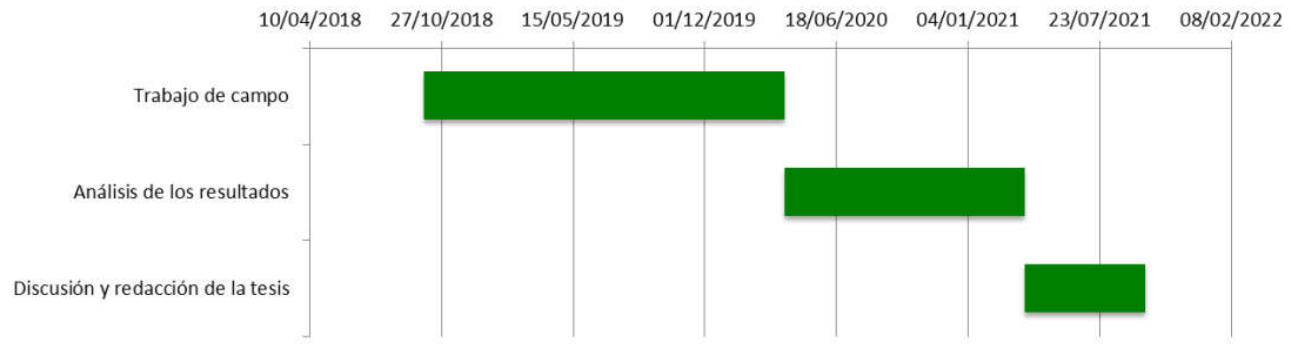
El resto del trabajo se realizará con ordenador y los distintos programas informáticos que se utilizarán

serán en su mayoría de libre acceso, si en algún momento se requiere algún programa de pago, lo utilizaremos con los recursos disponibles de la UCA.

Este trabajo estará en parte financiado por un Proyecto Puente de la UCA.

## 6.- Planificación temporal de trabajo

A continuación, se muestra un cronograma con la planificación general y teórica del proyecto.




En realidad, la planificación del trabajo es algo más compleja. El calendario de trabajo de campo y la periodicidad con la que se realizarán las evaluaciones es la siguiente:

- Primavera 2018 (marzo-abril): Evaluación de la costa de Alicante. Tiempo estimado de 15 días, evaluando varias playas al día.
- Verano 2018 (agosto): Evaluación de la costa de Alicante. Tiempo estimado de 1 mes (debido a la dificultad de trabajar en verano, es decir, aumenta el número de gente, aumenta el número de residuos, aumentan las temperaturas, el tráfico, etc.).
- Otoño 2018: Evaluación de la costa de Cádiz y toma de muestras. Tiempo estimado de 15 días para las evaluaciones de residuos y obtención de las muestras y de otros 15 días para la obtención de los datos con el DGPS.

Durante los periodos entre evaluaciones y después de haber terminado con la recogida de datos se procederá a pasar los datos en bruto de todas las evaluaciones a formato electrónico en hojas Excel. Así como el tratamiento de éstos mediante programas como R-studio o SPSS. El tratamiento que se le hará a los datos será similar al que ya han realizado otros investigadores en temas afines. Aun así, se podrá innovar con las técnicas utilizadas o con la representación de los datos, pues el tema de los residuos sólidos en playas es bastante novedoso y hay muchas formas de representar los resultados.

También se irán elaborando por orden cronológico los documentos que se publicarán como artículos científicos en diferentes revistas y formarán parte del proyecto de tesis. Conforme se vayan terminando estos documentos se enviarán a las revistas más adecuadas en cada caso para que se publiquen en la mayor brevedad posible.

Espectroscopía Raman: Se deberá limpiar (quitar restos de arena con una brocha), ordenar y clasificar las muestras de residuos plásticos de las 40 playas de Cádiz para su posterior estudio mediante espectroscopia Raman. Este trabajo puede requerir unos cuantos días, y se irá haciendo a medida que vayamos necesitando más muestras para analizar con el microscopio. Las muestras se guardarán en una estantería ubicada en una sala del Departamento de Ciencias de la Tierra. Se estima que podemos estar haciendo esta ordenación desde noviembre de 2018 hasta antes de terminar con el análisis Raman.

El tiempo estimado en el trabajo de laboratorio será desde febrero hasta noviembre de 2019 (10 meses) teniendo en cuenta varios factores:

- El microscopio que utilizamos para aplicar esta técnica también lo necesitan otros investigadores de la UCA, por lo que no tendré la posibilidad de trabajar cuando yo pueda o quiera.
- El trabajo con el microscopio es bastante laborioso, pues para medir cada muestra hay que realizar un procedimiento con una serie de pasos de varios minutos de duración: abrir puerta del microscopio, preparar la muestra, enfocar hasta la distancia que requiera cada muestra, cerrar la puerta para protegernos de la radiación, realizar dos medidas por ítem en ambas partes del espectro Raman (1500 y 2900 cm-1), alejar la lente del microscopio de la muestra y volver a abrir la puerta). Si tenemos en cuenta el número de muestras que puede haber en cada una de las 40 playas, medir todas las muestras de una sola playa nos puede llevar varios días.
- Los meses de julio y agosto trabajaré en Alicante, así que interrumpiremos las medidas.

Una vez se hayan medido todos los residuos plásticos, se deberán identificar uno por uno con ayuda de los espectros Raman y la bibliografía asociada. Además, se tendrá que elaborar una nueva hoja Excel, donde se organice la clasificación de los tipos de plásticos por playa. Este otro trabajo también requiere varios meses, pues hay miles de residuos plásticos y, por consiguiente, miles de mediciones que hay que determinar y clasificar. Posteriormente se procesará toda esta información para mostrar los resultados de la mejor forma posible mediante una o varias publicaciones con los investigadores involucrados.

Se espera tener un conocimiento más detallado sobre la abundancia de los diferentes tipos de plásticos en las playas estudiadas. La importancia de conocer que tipos de plásticos hay en los ambientes costeros es fundamental para tomar decisiones de fabricación, producción, consumo o gestión de residuos que mejoren la conservación y gestión del ambiente natural costero.

Durante la primera mitad del año 2020 se elaborará una publicación que trate solamente del estudio de los plásticos en las playas gaditanas mediante la técnica Raman.

Durante los últimos meses del año 2020 se tiene previsto estudiar también la costa atlántica y mediterránea marroquí (Tánger y Tetuán). Se realizarán varias salidas de campo desde septiembre a diciembre para obtener más datos que puedan complementar el proyecto de investigación. Debido al tiempo limitado de la estancia en Marruecos y a la elevada diversidad de residuos que existe, se tiene pensado estudiar entre 10 y 20 playas. Es decir, se intentará hacer lo mismo que en España, pero a menor escala. También se evaluará el paisaje costero mediante la técnica desarrollada por Ergin et al. (2004) en la costa marroquí. Esta estancia se podrá posponer unos meses si fuera necesario. En 2021 se verá la posibilidad de realizar una publicación conjunta con la Universidad Abdelmalek Essaâdi, que muestre los resultados de las investigaciones llevadas a cabo en Marruecos y se procederá a la redacción final de la tesis doctoral.

## 7.- Implicaciones éticas y/o de bioseguridad de la investigación propuesta.

Durante la recolección de residuos sólidos y manipulación durante su identificación se utilizará unos guantes para no entrar en contacto con sustancias que pueden ser perjudiciales para la salud.

También se toman las medidas de seguridad adecuadas en la manipulación del microscopio electrónico para medir las muestras mediante la técnica de Raman.

## 8.- Bibliografía.

1. Addamo, A. M., Laroche, P., & Hanke, G., 2017. Top Marine Beach Litter Items in Europe. EUR 29249 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-87711-7, doi:10.2760/496717, JRC108181
2. Anfuso, G., Del Pozo, J.M., Gracia, F.J., López-Aguayo, F., 2003. Long-shore distribution of morphodynamic beach states along an apparently homogeneous coast in SW Spain. J. Coast. Conserv. 9 (1), 49–56.
3. Anfuso, G., Gracia, F.J., 2005. Morphodynamic characteristics and short-term evolution of a coastal sector in SW Spain: implications for coastal erosion management. J. Coast. Res. 1139–1153

4. Anfuso, G., Lynch, K., Williams, A. T., Perales Vargas-Machuca, J. A., Pereira da Silva, C., Nogueira-Mendes, R., ... & Verdejo, E. (2015). Comments on Marine Litter in Oceans, Seas and Beaches: Characteristics and Impacts.
5. Arcangeli, A., I. Campana, D. Angeletti, F. Atzori, M. Azzolin, L. Carosso, V. Di Miccoli, A. Giacoletti, M. Gregorietti, C. Luperini, M. Paraboschi, G. Pellegrino, M. Ramazio, G. Sarà, and R. Crosti. 2017. Amount, composition, and spatial distribution of floating macro litter along fixed trans-border transects in the Mediterranean basin. Marine Pollution Bulletin, 10 pp. http://dx.doi.org/10.1016/j.marpolbul.2017.10.028
6. Ariza, E., Jiménez, J.A. & Sardá, R., 2008. Seasonal evolution of beach waste and litter during the bathing season on the Catalan coast. Waste Management, 28(12), 2604-2613.
7. Aydın, C., Güven, O., Salihoğlu, B., & Kıdeyş, A. E., 2016. The influence of land use on coastal litter: an approach to identify abundance and sources in the coastal area of Cilician Basin, Turkey. Turkish Journal of Fisheries and Aquatic Sciences, 16(1), 029-039.
8. Ballance, A., Ryan, P. G., & Turpie, J. K., 2000. How much is a clean beach worth? The impact of litter on beach users in the Cape Peninsula, South Africa. South African Journal of Science, 96(5), 210-230.
9. Botero, C. M., Anfuso, G., Milanes, C., Cabrera, A., Casas, G., Pranzini, E., & Williams, A. T. (2017). Litter assessment on 99 Cuban beaches: A baseline to identify sources of pollution and impacts for tourism and recreation. Marine pollution bulletin, 118(1-2), 437-441.
10. Botero, C., Anfuso, A., Williams, A.T., Zielinski, S., da Silva, C.P., Cervantes, O., Silva, L., & Cabrera, J.A. (2013). Reasons for beach choice: European and Caribbean perspectives. Journal of Coastal Research, SI 65: 880-885.
11. Cheshire, A. & Adler, E., 2009. UNEP/IOC guidelines on survey and monitoring of marine litter.
12. Convey, P., Barnes, D., & Morton, A. (2002). Debris accumulation on oceanic island shores of the Scotia Arc, Antarctica. Polar Biology, 25(8), 612-617.
13. EA/NALG, 2000. Assessment of Aesthetic Quality of Coastal and Bathing Beaches. Monitoring Protocol and Classification Scheme. Environment Agency and The National Aquatic Litter Group, London.
14. Ergin, A., Karaesmen, E., Micallef, A., & Williams, A. T. (2004). A new methodology for evaluating coastal scenery: fuzzy logic systems. Area, 36(4), 367-386.
15. Fossi, M. C., C. Pedà, M. Compa, C. Tsangaris, C. Alomar, F. Claro, C. Ioakeimidis, F. Galgani, T. Hema, S. Deudero, T. Romeo, P. Battaglia, F. Andaloro, I. Caliani, S. Casini, C. Panti, and M. Baini. 2017. Bioindicators for monitoring marine litter ingestion and its impacts on Mediterranean biodiversity. Environmental Pollution, 18 pp. https://doi.org/10.1016/j.envpol.2017.11.019
16. Gabrielides, G.P., Golik, A., Loizides, L., Marino, M.G., Bingel, F. & Torregrossa, M.V., 1991. Man-made garbage pollution on the Mediterranean coastline. Marine Pollution Bulletin, 23, 437-441.
17. Galgani, F., G. Hanke, S. Werner, and L. De Vrees. 2013. Marine litter within the European Marine Strategy Framework Directive. ICES Journal of Marine Science, 70(6), pp 1055-1064. https://doi.org/10.1093/icesjms/fst122
18. Haseler, M., Schernewski, G., Balciunas, A., & Sabaliauskaite, V., 2018. Monitoring methods for large micro-and meso-litter and applications at Baltic beaches. Journal of Coastal Conservation, 22(1), 27-50.
19. Jambeck, J. R., R. Geyer, C. Wilcox, T. R. Siegler, M. Perryman, A. Andrady, R. Narayan, and K. L. Law. 2015. Plastic waste inputs from land into the ocean. Science, 347(6223), pp 768-771. DOI: 10.1126/science.1260352
20. Jelil, S. N., and N Jain. 2014. A Rapid Assessment of Beach Litter in Mumbai Beaches. Technical Report: Reef Watch Marine Conservation: 25 pp. https://doi.org/10.13140/rg.2.1.4760.3449
21. Krelling, A. P., A. T. Williams, and A. Turra .2017. Differences in perception and reaction of tourist groups to beach marine debris that can influence a loss of tourism revenue in coastal areas. Marine Policy, 85, pp 87-99. https://doi.org/10.1016/j.marpol.2017.08.021
22. Kungskulniti, N., Charoenca, N., Hamann, S. L., Pitayarangsarit, S., & Mock, J., 2018. Cigarette Waste in Popular Beaches in Thailand: High Densities that Demand Environmental Action. International journal of environmental research and public health, 15(4), 630.
23. Laglbauer, B. J., Franco-Santos, R. M., Andreu-Cazenave, M., Brunelli, L., Papadatou, M., Palatinus, A., ... & Deprez, T., 2014. Macrodebris and microplastics from beaches in Slovenia. Marine Pollution Bulletin, 89(1-2), 356-366.
24. Lippiatt, S., Opfer, S., & Arthur, C. (2013). Marine Debris Monitoring and Assessment. NOAA Technical Memorandum NOS-OR&R-46.
25. MARLIN, 2013. Final report of the Baltic marine litter project MARLIN. Litter Monitoring and raising awareness 2011-2013. 29pp.
26. Martinez-Ribes, L., Basterretxea, G., Palmer, M., & Tintoré, J., 2007. Origin and abundance of beach debris in the Balearic Islands. Scientia Marina, 71(2), 305-314.

27. Maziane, F., D. Nachite, and G. Anfuso. 2018. Artificial polymer materials debris characteristics along the Moroccan Mediterranean coast. Marine Pollution Bulletin, 128, pp 1-7. https://doi.org/10.1016/j.marpolbul.2017.12.067
28. McKenna, J., A. T. Williams, and J. A. G. Cooper. 2011. Blue Flag or Red Herring: Do beach awards encourage the public to visit beaches?. Tourism Management, 32(3), pp 576-588. https://doi.org/10.1016/j.tourman.2010.05.005
29. Megías, C., Corbí, H., Riquelme, A., Abellán Fernández, A., & Ramos-Esplá, A. A. (2017). Modelización tridimensional y caracterización ecológica de playas con arribazones de Posidonia oceanica: ejemplos del sudeste de España. Geo-Temas, (17), 71-74. ISSN 1576-5172
30. Mooser, A., Anfuso, G., Mestanza, C., & Williams, A.T. (2018). Management Implications for the Most Attractive Scenic Sites along the Andalusia Coast (SW Spain). Sustainability, 10(5), 1-26. doi: 10.3390/su10051328
31. Morgan, R., B. Bursalioglu, L. Hapoglu-Balas, T. C. Jones, E. Ozhan, and A. T. Williams. 1995. Beach user opinions and beach ratings: A pilot study on the Turkish Aegean Coast. In Proceedings of the Second International Conference on the Mediterranean Coastal Environment. MedCoast 95, (ed.), E. Ozhan. 1995; pp 373-383.
32. Munari, C., C. Corbau, U. Simeoni, and M. Mistri. 2016. Marine litter on Mediterranean shores: analysis of composition, spatial distribution and sources in north-western Adriatic beaches. Waste Management, 49, pp 483-490. https://doi.org/10.1016/j.wasman.2015.12.010
33. Nachite, D., F. Maziane, G. Anfuso, and A. Macias. 2018. Beach Litter Characteristics Along the Moroccan Mediterranean Coast: Implications for Coastal Zone Management. Beach Management Tools - Concepts, Methodologies and Case Studies, 24, pp 795-819. https://doi.org/10.1007/978-3-319-58304- 4_40
34. Nelms, S. E., Coombes, C., Foster, L. C., Galloway, T. S., Godley, B. J., Lindeque, P. K., & Witt, M. J., 2017. Marine anthropogenic litter on British beaches: a 10-year nationwide assessment using citizen science data. Science of the Total Environment, 579, 1399-1409.
35. Nordstrom, K. F. (1994). Beaches and dunes of human-altered coasts. Progress in physical Geography, 18(4), 497-516.
36. Oigman-Pszczol, S. S., & Creed, J. C., 2007. Quantification and classification of marine litter on beaches along Armação dos Búzios, Rio de Janeiro, Brazil. Journal of Coastal Research, 421-428.
37. Opfer, S., Arthur, C. & Lippiatt, S., 2012. NOAA marine debris shoreline survey field guide. US National
38. Oceanic and Atmospheric Administration Marine Debris Program.
39. OSPAR Commission, 2010. Guideline for monitoring marine litter on the beaches in the OSPAR maritime area.
40. Pasquini, G., F. Ronchi, P, Strafella, G. Scarcella, and T. Fortibuoni. 2016. Seabed litter composition, distribution and sources in the Northern and Central Adriatic Sea (Mediterranean). Waste Management, 58, pp 41-51. https://doi.org/10.1016/j.wasman.2016.08.038
41. PNUE/PAM/MEDPOL. 2009. Results of the assessment of the status of marine litter in the Mediterranean, Meeting of MED POL Focal Points No. 334, 91 pp.
42. Poeta, G., Battisti, C., Bazzichetto, M., & Acosta, A. T., 2016. The cotton buds beach: Marine litter assessment along the Tyrrhenian coast of central Italy following the marine strategy framework directive criteria. Marine pollution bulletin, 113(1-2), 266-270.
43. Prevenios, M., Zeri, C., Tsangaris, C., Liubartseva, S., Fakiris, E., & Papatheodorou, G., 2018. Beach litter dynamics on Mediterranean coasts: distinguishing sources and pathways. Marine pollution bulletin, 129(2), 448-457.
44. Quintela, A., C. P. Silva, H. Calado, and A. T. Williams. 2012. The relation of litter with bathing areas typologies, number of users and scenic value. The case study of São Miguel (Azores). Journal of coastal conservation, 16(4): 575-584. DOI 10.1007/s11852-012-0197-0
45. R Core Team, 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.
46. Rangel-Buitrago, N., A. T. Williams, G. Anfuso, M. Arias, and A. Gracia C. 2017. Magnitudes, sources, and management of beach litter along the Atlantico department coastline, Caribbean coast of Colombia. Ocean & Coastal Management, 138, pp 142-157. https://doi.org/10.1016/j.ocecoaman.2017.01.021
47. Roig i Munar, F. X. (2004). Análisis y consecuencias de la modificación artificial del perfil playa duna provocado por el efecto mecánico de su limpieza. Investigaciones Geográficas (Esp), (33).
48. Seas at Risk. 2017. Single-use plastics and the marine environment. Leverage Points for reducing single-use plastics. June 2017. http://www.seas-at-risk.org/24-publications/800-single-use-plastic-andthe marine-environment.html.

49. Sheavly, S. B., and K. M. Register. 2007. Marine debris & plastics: environmental concerns, sources, impacts and solutions. Journal of Polymers and the Environment, 15(4), pp 301-305. https://doi.org/10.1007/s10924-007-0074-3
50. UNEP. 2009. Marine Litter: A Global Challenge. Nairobi: UNEP. 232 pp.
51. Veiga, J.M., Fleet, D., Kinsey, S., Nilsson, P., Vlachogianni, T., Werner, S., Galgani, F., Thompson, R.C., Dagevos, J., Gago, J., Sobral, P. & Cronin, R., 2016. Identifying Sources of Marine Litter. MSFD GES TG Marine Litter Thematic Report; JRC Technical Report; EUR 28309; doi:10.2788/
52. Vlachogianni, Th. (2019). Assessing marine litter on Mediterranean beaches. Filling in the knowledge gaps via a participatory-science initiative. MIO-ECSDE.
53. Vlachogianni, T., Fortibuoni, T., Ronchi, F., Zeri, C., Mazziotti, C., Tutman, P., ... & Mandić, M. (2018). Marine litter on the beaches of the Adriatic and Ionian Seas: An assessment of their abundance, composition and sources. Marine pollution bulletin, 131, 745-756.
54. Werner, S., A. Budziak, J. van Franeker, F. Galgani, G. Hanke, T. Maes, M. Matiddi, P. Nilsson, L. Oosterbaan, E. Priestland, R. Thompson, J. Veiga, and T. Vlachogianni. 2016. Harm caused by Marine Litter. MSFD GES TG Marine Litter - Thematic Report; JRC Technical report; EUR 28317 EN. doi:10.2788/690366
55. Williams, A. T., 2011. Definitions and typologies of coastal tourism beach destinations. In: Jones A, Phillips M (eds) Disappearing Destinations: Climate change and future challenges for coastal tourism. CABI, Wallingford, pp 47–66, 296 pp
56. Williams, A. T. & Micallef, A., 2009. Beach management. Principles and Practice. Earthscan, London. 480 pp. ISBN: 978-1-84407-435-8
57. Williams, A. T., Micallef, A., Anfuso, G., & Gallego-Fernandez, J. B. (2012). Andalusia, Spain: an assessment of coastal scenery. Landscape Research, 37(3), 327-349.
58. Williams, A. T., Randerson, P., Di Giacomo, C., Anfuso, G., Macias, A., & Perales, J. A. (2016a). Distribution of beach litter along the coastline of Cádiz, Spain. Marine pollution bulletin, 107(1), 77-87.
59. Williams, A. T., Rangel-Buitrago, N. G., Anfuso, G., Cervantes, O., & Botero, C. M. (2016b). Litter impacts on scenery and tourism on the Colombian north Caribbean coast. Tourism Management, 55, 209-224.
60. Yoshikawa, T., and K. Asoh. 2004. Entanglement of monofilament fishing lines and coral death. Biological Conservation, 117(5), pp 557-560. https://doi.org/10.1016/j.biocon.2003.09.025

JOSE MARIA GONZALEZ MOLINILLO, Director de la Escuela Internacional de Doctorado en Estudios del Mar de la Universidad de Cádiz

INFORMA

Que de acuerdo con los datos que constan en el expediente del interesado **D. FRANCISCO ASENSIO MONTESINOS**, con NIF nº **45844356C**, tiene aprobado plan de investigación por la Comisión Académica del Programa de Doctorado **Ciencias y Tecnologías Marinas** desde el 21-07-2020, habiendo actualizado la correspondiente memoria conforme se especifica a continuación:

| | |
|---|---|
| **Referencia** | PIN00155219 |
| **Fecha de presentación** | 28-02-2019 |
| **Título propuesto** | Estudio de la distribución y composición de los residuos sólidos en ambientes costeros mediterráneos (Alicante) y atlánticos (Cádiz). Relaciones con las características geomorfológicas del litoral e implicaciones para la gestión |
| **Avalado por** | Tutor: D. GIORGIO ANFUSO MELFI<br>Director: D. GIORGIO ANFUSO MELFI |
| **Resolución** | **Evaluación negativa (puede presentar nuevo plan en seis meses)** (emitida por la Comisión Académica con fecha 19-01-2020)<br>*Consta una actualización de esta memoria del plan de investigación de fecha posterior.* |

| | |
|---|---|
| **Referencia** | PIN00172535 |
| **Fecha de presentación** | 18-07-2020 |
| **Título propuesto** | Distribución y composición de los residuos sólidos en ambientes costeros mediterráneos y atlánticos. Relaciones con las características geomorfológicas y los usos de las playas e implicaciones para la gestión. |
| **Avalado por** | Tutor: D. GIORGIO ANFUSO MELFI<br>Director: D. GIORGIO ANFUSO MELFI |
| **Resolución** | **Evaluación positiva** (emitida por la Comisión Académica con fecha 21-07-2020)<br>*Esta memoria del plan de investigación es la más reciente aprobada por la Comisión Académica.* |

Lo que se hace constar en Cádiz, a 22 de noviembre de 2021.

El Director de la Escuela Internacional de Doctorado
en Estudios del Mar

Fdo.: José María González Molinillo

**DOCUMENTO DE ACTIVIDADES FORMATIVAS**

UCA Universidad de Cádiz

EIDEMAR, Escuela Internacional de Doctorado en Estudios del Mar

# INFORME DE PROGRESO DE ACTIVIDADES FORMATIVAS DE DOCTORADO
**(Estudios regulados por R.D. 99/2011 de 28 de Enero)**

Estudiante: **45844356C D. FRANCISCO ASENSIO MONTESINOS**
Programa de Doctorado: **8205 - Ciencias y Tecnologías Marinas**

## Actividad formativa: 8205B01 Publicaciones o artículos científicos

Tipo: **Obligatoria (mínimo 100.00 h.)** Horas realizadas:**1700.00 h.** **Actividad superada**

| Curso | Descripción | Documento justificativo | Horas |
|---|---|---|---|
| 2018/19 | Coastal scenery and litter impacts | Asensio- Montesinos_et_al_2018_JCC.pdf | 100.00 |
| 2019/20 | Beach litter (Alicante) | 2019_Asensio- Montesinos_et_al_MPB.pdf | 100.00 |
| 2019/20 | Seasonal comparison of beach litter | 2019_Asensio- Montesinos_et_al_OCM.pdf | 100.00 |
| 2020/21 | Beach litter (Cádiz) | Asensio- Montesinos_et_al_2020_RSMS.pdf | 200.00 |
| 2021/22 | Beach Litter Antártida | Anfuso_et_al_2020_MPB_Beach_litter_Anta...pdf | 100.00 |
| 2021/22 | Beach litter (Ceuta) | Asensio- Montesinos_et_al_2021_WATER.pdf | 200.00 |
| 2021/22 | Beach litter characterization | Asensio- Montesinos_et_al_2020_STOTEN.pdf | 200.00 |
| 2021/22 | Capítulo de libro: los "Big Five" | CapA_tulo_13._Los_Big_Five_.pdf | 100.00 |
| 2021/22 | Cigarette butts on Spanish beaches | Asensio- Montesinos_et_al_2021_JMSE.pdf | 200.00 |
| 2021/22 | Colour sand (Alicante) | Asensio- Montesinos_et_al_2020_WATER.pdf | 200.00 |
| 2021/22 | Litter behaviour on cobble beaches | Asensio- Montesinos_et_al_2021_MPB.pdf | 200.00 |

## Actividad formativa: 8205B02 Cursos o seminarios de formación para la investigación

Tipo: **Obligatoria (mínimo 100.00 h.)** Horas realizadas:**101.00 h.** **Actividad superada**

| Curso | Descripción | Documento justificativo | Horas |
|---|---|---|---|
| 2018/19 | Marine Spatial Planning with special reference to beach manageme | beachmanagement.pdf | 25.00 |
| 2019/20 | Curso ecoturismo en ecosistemas costeros y sostenibilidad | Curso_ecoturismo.pdf | 25.00 |
| 2020/21 | Clasificación paisajística del litoral | curso_pre_evento_1_Cuba.pdf | 3.00 |
| 2020/21 | Gestión y certificación de playas | curso_pre_evento_2_Cuba.pdf | 3.00 |
| 2021/22 | Curso Ilustración Científica | Certificado_curso_IlustraciA_n_Francisc...pdf | 20.00 |
| 2021/22 | Curso Residuos en Playas | Curso_Residuos_Playas_Marruecos.pdf | 25.00 |

## Actividad formativa: 8205P03 Asistencia y participación en congresos y workshops

Tipo: **Optativa** Horas realizadas:**400.00 h.** **Actividad superada**

| Curso | Descripción | Documento justificativo | Horas |
|---|---|---|---|
| 2018/19 | I Congreso Jóvenes Investigadores del Mar | JIS_del_Mar.pdf | 50.00 |
| 2018/19 | IX Jornadas de Geomorfología litoral | GeomorfologA_a_Litoral.pdf | 50.00 |
| 2018/19 | VI International Symposium on Marine Sciences | certificado_isms_oral.pdf | 100.00 |
| 2019/20 | Varaplayas 2019 | Varaplayas_2019_certificado.pdf | 100.00 |
| 2021/22 | 16th Bathurst Meeting | Congreso_mallorca_2019.pdf | 100.00 |

## Actividad formativa: 8205P04 Movilidad y estancias de investigación

Tipo: **Optativa** Horas realizadas:**32.00 h.** **Actividad superada**

| Curso | Descripción | Documento justificativo | Horas |
|---|---|---|---|
| 2019/20 | Actividades durante la estancia | estancia_UO.pdf | 32.00 |

## Actividad formativa: 8205P07 Participación en proyectos de I +D o contratos de investigación con empresas

Tipo: **Optativa** Horas realizadas:**400.00 h.** **Actividad superada**

| Curso | Descripción | Documento justificativo | Horas |
|---|---|---|---|
| 2020/21 | Actividades y certificado proyecto | Aportaciones_y_Certificado_al_Proyecto_...pdf | 100.00 |
| 2021/22 | Contrato Especialista Técnico (UA) | CONTRATO_ASENSIO_MONTESINOS_FRANCISCO.P...PDF | 100.00 |
| 2021/22 | Contrato Investigador 1 (UCA) | Contrato_UCA1.pdf | 100.00 |
| 2021/22 | Contrato Investigador 2 (UCA) | prA_rroga_contrato_UCA.pdf | 100.00 |

| **Actividad formativa:** 8205P09 Participación en actividades de difusión de la investigación | | | |
|---|---|---|---|
| Tipo: **Optativa** | Horas realizadas:**50.00 h.** | **Actividad superada** | |
| **Curso** | **Descripción** | **Documento justificativo** | **Horas** |
| 2018/19 | Conferencia Universidad de Alicante | conferencia_UA.pdf | 10.00 |
| 2018/19 | Geolodía Alicante | gdia18gui_alicante.pdf | 10.00 |
| 2018/19 | Geolodía Cádiz | gdia18gui_cadiz.pdf | 10.00 |
| 2018/19 | VII Seminario IBERMAR | seminarioUCA.pdf | 10.00 |
| 2021/22 | Geolodía Alicante (2020-2021) | GeolodA_a_20-21_Alicante.pdf | 10.00 |

| **Total horas actividades formativas completadas:** | **2683.00** |
|---|---|

Las horas especificadas corresponden a las reconocidas por la Comisión Académica del Programa en el día de la fecha.
El estudiante ha completado todos los requisitos de su plan de estudios para la superación de las actividades formativas.

Cádiz, a 19 de noviembre de 2021

# INFORME DEL DIRECTOR

Escuela de Doctorado de la Universidad de Cádiz
(EDUCA)

**Hospital Real**
Oficina de Posgrado
Universidad de Cádiz
Plaza Falla, 8
11002 Cádiz.

# ANEXO II
# MODELO DE INFORME FAVORABLE DEL DIRECTOR(ES) DE LA TESIS PARA EL DEPÓSITO DE TESIS DOCTORALES DESARROLLADAS DE ACUERDO CON EL REAL DECRETO 99/2011, DE 28 DE ENERO

D./Dª. Giorgio Anfuso, director de la tesis doctoral de D. Francisco Asensio Montesinos, alumno del programa de doctorado Ciencias y Tecnologías Marinas, regulado por el Real Decreto 99/2011, de 28 de enero, por el que se regulan las enseñanzas oficiales de doctorado, informa favorablemente la solicitud de autorización para el depósito de la tesis doctoral de D. Francisco Asensio Montesinos, titulada "**Distribución y composición de los residuos sólidos en ambientes costeros mediterráneos y atlánticos (Alicante y Cádiz). Relaciones con las características geomorfológicas y los usos de las playas e implicaciones para la gestión**", y desarrollada de acuerdo con los requisitos de control de calidad para las tesis doctorales recogidos en la memoria del programa de doctorado de referencia.

En Puerto Real, a 15 de noviembre de 2021



**Fdo.: Giorgio Anfuso**

**NOTA**
El Informe deberá venir acompañado de un pronunciamiento expreso del director (o directores) de la investigación acerca de la adecuación del resultado de la investigación (la tesis) al proyecto presentado en su momento, el correcto desarrollo del proceso de formación doctoral del doctorando y la validez y la oportunidad de los resultados de la investigación plasmados en la tesis.

**Sr. Presidente de la Comisión Académica del Programa de Doctorado** _____

**INFORME DEL FACTOR DE IMPACTO Y CUARTIL**

Los artículos de esta tesis doctoral denominada *"Distribución y composición de residuos sólidos en playas mediterráneas y atlánticas (Alicante y Cádiz). Relaciones con la geomorfología y usos de las playas e implicaciones para la gestión"*, están publicados en revistas científicas incluidas en Journal Citation Reports. A continuación, se muestra cada una de las publicaciones con sus principales indicadores generales de calidad de la producción científica referentes a 2020:

**Publicación I**: Asensio-Montesinos, F., Anfuso, G., Williams, A.T., 2019. Beach litter distribution along the western Mediterranean coast of Spain. *Marine Pollution Bulletin*, *141*, 119-126.
**Número de citas** (noviembre 2021): 50 (Fuente: Google Académico)
**Revista**: Marine Pollution Bulletin
**Categoría y Cuartil**: MARINE & FRESHWATER BIOLOGY (Q1); ENVIRONMENTAL SCIENCES (Q1)
**Factor de Impacto**: 5,553 (Fuente: Ministerio de Ciencia e Innovación)

**Publicación II**: Asensio-Montesinos, F., Anfuso, G., Randerson, P., Williams, A.T., 2019. Seasonal comparison of beach litter on Mediterranean coastal sites (Alicante, SE Spain). *Ocean & Coastal Management*, *181*, 104914.
**Número de citas** (noviembre 2021): 36 (Fuente: Google Académico)
**Revista**: Ocean & Coastal Management
**Categoría y Cuartil**: OCEANOGRAPHY (Q1); WATER RESOURCES (Q2)
**Factor de Impacto**: 3,284 (Fuente: Ministerio de Ciencia e Innovación)

**Publicación III**: Asensio-Montesinos, F., Anfuso, G., Williams, A.T., Sanz-Lázaro, C., 2021. Litter behaviour on Mediterranean cobble beaches, SE Spain. *Marine Pollution Bulletin, 173*, 113106.
**Número de citas** (noviembre 2021): 1 (Fuente: Google Académico)
**Revista**: Marine Pollution Bulletin
**Categoría y Cuartil**: MARINE & FRESHWATER BIOLOGY (Q1); ENVIRONMENTAL SCIENCES (Q1)
**Factor de Impacto**: 5,553 (Fuente: Ministerio de Ciencia e Innovación)

**Publicación IV**: Asensio-Montesinos, F., Anfuso, G., Oliva Ramírez, M., Smolka, R, García Sanabria, J., Fernández-Enríquez, A., Arenas, P., Macías Bedoya, A., 2020. Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain). *Regional Studies in Marine Science*, *34*, 101050.
**Número de citas** (noviembre 2021): 25 (Fuente: Google Académico)
**Revista**: Regional Studies in Marine Science
**Categoría y Cuartil**: ECOLOGY (Q3); MARINE & FRESHWATER BIOLOGY (Q3)
**Factor de Impacto**: 1,624 (Fuente: Ministerio de Ciencia e Innovación)

**Publicación V**: Asensio-Montesinos, F., Oliva Ramírez, M., González-Leal, J.M., Carrizo, D., Anfuso, G., 2020. Characterization of plastic beach litter by Raman spectroscopy in south-western Spain. *Science of the Total Environment*, *744*, 140890.
**Número de citas** (noviembre 2021): 12 (Fuente: Google Académico)
**Revista**: Science of the Total Environment
**Categoría y Cuartil**: ENVIRONMENTAL SCIENCES (Q1)
**Factor de Impacto**: 7,963 (Fuente: Ministerio de Ciencia e Innovación)

**Publicación VI**: Asensio-Montesinos, F., Oliva Ramírez, M., Aguilar-Torrelo, M.T. Anfuso, G., 2021. Abundance and Distribution of Cigarette Butts on Coastal Environments: Examples from Southern Spain.
**Número de citas** (noviembre 2021): 2 (Fuente: Google Académico)
**Revista**: Journal of Marine Science and Engineering
**Categoría y Cuartil**: OCEANOGRAPHY (Q2); MARINE ENGINEERING (Q2); OCEAN ENGINEERING (Q2)
**Factor de Impacto**: 2.458

**INFORME DE LA CONTRIBUCIÓN DEL DOCTORANDO**

Publicaciones y contribuciones asociadas al primer autor:

**I.** Asensio-Montesinos, F., Anfuso, G., & Williams, A.T. (2019). Beach litter distribution along the western Mediterranean coast of Spain. Marine Pollution Bulletin, 141, 119-126.

**II.** Asensio-Montesinos, F., Anfuso, G., Randerson, P., & Williams, A.T. (2019). Seasonal comparison of beach litter on Mediterranean coastal sites (Alicante, SE Spain). *Ocean & Coastal Management, 181*, 104914.

**III.** Asensio-Montesinos, F., Anfuso, G., Williams, A.T., & Sanz-Lázaro, C. (2021). Litter behaviour on Mediterranean cobble beaches, SE Spain. *Marine Pollution Bulletin, 173*, 113106.

**IV.** Asensio-Montesinos, F., Anfuso, G., Oliva Ramírez, M., Smolka, R, García Sanabria, J., Fernández-Enríquez, A., Arenas, P., & Macías Bedoya, A. (2020). Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain). *Regional Studies in Marine Science*, *34*, 101050.

El autor realizó el trabajo de campo, el tratamiento y análisis de datos y redactó gran parte del artículo.

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**V.** Asensio-Montesinos, F., Oliva Ramírez, M., González-Leal, J.M., Carrizo, D., & Anfuso, G. (2020). Characterization of plastic beach litter by Raman spectroscopy in south-western Spain. *Science of the Total Environment, 744*, 140890.

El autor realizó el trabajo de laboratorio, el tratamiento y análisis de datos y redactó gran parte del artículo.

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**VI.** Asensio-Montesinos, F., Oliva Ramírez, M., Aguilar-Torrelo, M.T. & Anfuso, G. (2021). Abundance and Distribution of Cigarette Butts on Coastal Environments: Examples from Southern Spain. *Journal of Marine Science and Engineering*, *9*(2), 129.

A partir de datos obtenidos en diferentes estudios (todos realizados por el autor con excepción de uno), el autor realizó el tratamiento y análisis de datos y redactó gran parte del artículo.

---

**CONFORMIDAD DE LOS AUTORES**

UCA Universidad de Cádiz

## Thesis by compendium of publications.
## Document of agreement and resignation of co-authors

D. /Dª.: Giorgio Anfuso, DNI o Passport: X1761231Y, co-author of the following publications:

Asensio-Montesinos, F., Anfuso, G., Williams, A.T. 2019. Beach litter distribution along the western Mediterranean coast of Spain. *Marine Pollution Bulletin*, *141*, 119-126.

Asensio-Montesinos, F., Anfuso, G., Randerson, P., & Williams, A. T. (2019). Seasonal comparison of beach litter on Mediterranean coastal sites (Alicante, SE Spain). *Ocean & Coastal Management*, *181*, 104914.

Asensio-Montesinos, F., Anfuso, G., Williams, A.T., & Sanz-Lázaro, C. (2021). Litter behaviour on Mediterranean cobble beaches, SE Spain. *Marine Pollution Bulletin, 173*, 113106.

Asensio-Montesinos, F., Anfuso, G., Oliva Ramírez, M., Smolka, R., García Sanabria, J., Fernández-Enríquez, A., Arenas, P., & Macías Bedoya, A. (2020). Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain). *Regional Studies in Marine Science*, *34*, 101050.

Asensio-Montesinos, F., Oliva Ramírez, M., González-Leal, J.M., Carrizo, D., & Anfuso, G. (2020). Characterization of plastic beach litter by Raman spectroscopy in south-western Spain. *Science of the Total Environment*, *744*, 140890.

Asensio-Montesinos, F., Oliva Ramírez, M., Aguilar-Torrelo, M.T. & Anfuso, G. (2021). Cigarette butts abundance and distribution on coastal environments: examples from Southern Spain. *Journal of Marine Science and Engineering*.

In accordance with the **Article 23.4** of the **Regulation UCA CG06-2012, June 27, 2012, which regulates the ordinance of doctoral studies at the University of Cádiz (BOUCA No. 208).**
**States his/her approval** to the presentation of above publications as a part of the doctoral thesis written by D. /Dª. Francisco Asensio Montesinos, entitled "**Distribución y composición de los residuos sólidos en ambientes costeros mediterráneos y atlánticos (Alicante y Cádiz). Relaciones con las características geomorfológicas y los usos de las playas e implicaciones para la gestión**".

**And expresses his/her resignation** to present said publications as a part of another doctoral thesis at any other University.

In Cádiz, 25 of November, 2021

Signed: 

Giorgio Anfuso

UCA Universidad de Cádiz

## Thesis by compendium of publications.
## Document of agreement and resignation of co-authors

D. /Dª.: Allan T. Williams, DNI o Passport: 706729706, co-author of the following publications:

Asensio-Montesinos, F., Anfuso, G., Williams, A.T. 2019. Beach litter distribution along the western Mediterranean coast of Spain. *Marine Pollution Bulletin*, *141*, 119-126.

Asensio-Montesinos, F., Anfuso, G., Randerson, P., & Williams, A. T. (2019). Seasonal comparison of beach litter on Mediterranean coastal sites (Alicante, SE Spain). *Ocean & Coastal Management*, *181*, 104914.

Asensio-Montesinos, F., Anfuso, G., Williams, A.T., & Sanz-Lázaro, C. (2021). Litter behaviour on Mediterranean cobble beaches, SE Spain. *Marine Pollution Bulletin, 173*, 113106.

In accordance with the **Article 23.4** of the **Regulation UCA CG06-2012, June 27, 2012, which regulates the ordinance of doctoral studies at the University of Cádiz (BOUCA No. 208).**
**States his/her approval** to the presentation of above publications as a part of the doctoral thesis written by D. /Dª. Francisco Asensio Montesinos, entitled "**Distribución y composición de los residuos sólidos en ambientes costeros mediterráneos y atlánticos (Alicante y Cádiz). Relaciones con las características geomorfológicas y los usos de las playas e implicaciones para la gestión**".

**And expresses his/her resignation** to present said publications as a part of another doctoral thesis at any other University.

In Cádiz, 25 of November, 2021



Signed: _____

UCA Universidad de Cádiz

**Thesis by compendium of publications.**
**Document of agreement and resignation of co-authors**

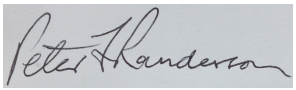
D. /Dª.: Peter Randerson, DNI o Passport: 553819331, co-author of the following publication:

Asensio-Montesinos, F., Anfuso, G., Randerson, P., & Williams, A. T. (2019). Seasonal comparison of beach litter on Mediterranean coastal sites (Alicante, SE Spain). *Ocean & Coastal Management*, *181*, 104914.

In accordance with the **Article 23.4** of the **Regulation UCA CG06-2012, June 27, 2012, which regulates the ordinance of doctoral studies at the University of Cádiz (BOUCA No. 208).**
**States his/her approval** to the presentation of above publications as a part of the doctoral thesis written by D. /Dª. Francisco Asensio Montesinos, entitled "**Distribución y composición de los residuos sólidos en ambientes costeros mediterráneos y atlánticos (Alicante y Cádiz). Relaciones con las características geomorfológicas y los usos de las playas e implicaciones para la gestión**".

**And expresses his/her resignation** to present said publications as a part of another doctoral thesis at any other University.

In Cádiz, 25 of November, 2021

Signed: _____ 

UCA Universidad de Cádiz

## Thesis by compendium of publications.
## Document of agreement and resignation of co-authors

D. /Dª.: Carlos Sanz Lazaro, DNI o Passport: 74235633M, co-author of the following publication:

Asensio-Montesinos, F., Anfuso, G., Williams, A.T., & Sanz-Lázaro, C. (2021). Litter behaviour on Mediterranean cobble beaches, SE Spain. *Marine Pollution Bulletin, 173*, 113106.

In accordance with the **Article 23.4** of the **Regulation UCA CG06-2012, June 27, 2012, which regulates the ordinance of doctoral studies at the University of Cádiz (BOUCA No. 208).**
**States his/her approval** to the presentation of above publications as a part of the doctoral thesis written by D. /Dª. Francisco Asensio Montesinos, entitled "**Distribución y composición de los residuos sólidos en ambientes costeros mediterráneos y atlánticos (Alicante y Cádiz). Relaciones con las características geomorfológicas y los usos de las playas e implicaciones para la gestión**".

**And expresses his/her resignation** to present said publications as a part of another doctoral thesis at any other University.

In Cádiz, 25 of November, 2021

CARLOS|SANZ|LAZARO

Digitally signed by CARLOS|SANZ|LAZARO
DN: cn=CARLOS|SANZ|LAZARO, sn=SANZ LAZARO, givenName=CARLOS, c=ES, o=ACCV, ou=CIUDADANOS, serialNumber=74235633M
Date: 2021.11.11 03:31:10 +01'00'

Signed: _____

UCA Universidad de Cádiz

## Thesis by compendium of publications.
## Document of agreement and resignation of co-authors

D. /Dª.: Milagrosa Oliva, DNI. 52926244R, co-author of the following publications:

Asensio-Montesinos, F., Anfuso, G., Oliva Ramírez, M., Smolka, R., García Sanabria, J., Fernández-Enríquez, A., Arenas, P., & Macías Bedoya, A. (2020). Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain). *Regional Studies in Marine Science*, *34*, 101050.

Asensio-Montesinos, F., Oliva Ramírez, M., González-Leal, J.M., Carrizo, D., & Anfuso, G. (2020). Characterization of plastic beach litter by Raman spectroscopy in south-western Spain. *Science of the Total Environment*, *744*, 140890.

Asensio-Montesinos, F., Oliva Ramírez, M., Aguilar-Torrelo, M.T. & Anfuso, G. (2021). Cigarette butts abundance and distribution on coastal environments: examples from Southern Spain. *Journal of Marine Science and Engineering*.

In accordance with the **Article 23.4** of the **Regulation UCA CG06-2012, June 27, 2012, which regulates the ordinance of doctoral studies at the University of Cádiz (BOUCA No. 208).**
**States his/her approval** to the presentation of above publications as a part of the doctoral thesis written by D. /Dª. Francisco Asensio Montesinos, entitled "**Distribución y composición de los residuos sólidos en ambientes costeros mediterráneos y atlánticos (Alicante y Cádiz). Relaciones con las características geomorfológicas y los usos de las playas e implicaciones para la gestión**".

**And expresses his/her resignation** to present said publications as a part of another doctoral thesis at any other University.

In Cádiz, 25 of November, 2021



Signed: __Milagrosa Oliva Ramirez_____

UCA | Universidac de Cadiz

## Thesis by compendium of publications.
## Document of agreement and resignation of co-authors

D. /Dª.: R. Smolka, DNI o Passport: X1761231Y, co-author of the following publication:

Asensio-Montesinos, F., Anfuso, G., Oliva Ramírez, M., Smolka, R., García Sanabria, J., Fernández-Enríquez, A., Arenas, P., & Macías Bedoya, A. (2020). Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain). *Regional Studies in Marine Science*, *34*, 101050.

In accordance with the **Article 23.4** of the **Regulation UCA CG06-2012, June 27, 2012, which regulates the ordinance of doctoral studies at the University of Cádiz (BOUCA No. 208).**
**States his/her approval** to the presentation of above publications as a part of the doctoral thesis written by D. /Dª. Francisco Asensio Montesinos, entitled "**Distribución y composición de los residuos sólidos en ambientes costeros mediterráneos y atlánticos (Alicante y Cádiz). Relaciones con las características geomorfológicas y los usos de las playas e implicaciones para la gestión**".

**And expresses his/her resignation** to present said publications as a part of another doctoral thesis at any other University.

In Cádiz, 25 of November, 2021

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## Thesis by compendium of publications.
## Document of agreement and resignation of co-authors

D. /Dª.: Javier Garcia Sanabria, DNI o Passport: 78566800L, co-author of the following publication:

Asensio-Montesinos, F., Anfuso, G., Oliva Ramírez, M., Smolka, R., García Sanabria, J., Fernández-Enríquez, A., Arenas, P., & Macías Bedoya, A. (2020). Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain). *Regional Studies in Marine Science*, *34*, 101050.

In accordance with the **Article 23.4** of the **Regulation UCA CG06-2012, June 27, 2012, which regulates the ordinance of doctoral studies at the University of Cádiz (BOUCA No. 208).**
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## Thesis by compendium of publications.
## Document of agreement and resignation of co-authors

D.: Alfredo Fernández-Enríquez, DNI o Passport: 31236140R, co-author of the following publication:

Asensio-Montesinos, F., Anfuso, G., Oliva Ramírez, M., Smolka, R., García Sanabria, J., Fernández-Enríquez, A., Arenas, P., & Macías Bedoya, A. (2020). Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain). *Regional Studies in Marine Science*, *34*, 101050.

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**And expresses his/her resignation** to present said publications as a part of another doctoral thesis at any other University.

In Cádiz, 11 of November, 2021

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**Thesis by compendium of publications.**
**Document of agreement and resignation of co-authors**

D. .: Pedro Arenas Granados, DNI 54356780Y , co-author of the following publications:

Asensio-Montesinos, F., Anfuso, G., Oliva Ramírez, M., Smolka, R., García Sanabria, J., Fernández-Enríquez, A., Arenas, P., & Macías Bedoya, A. (2020). Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain). *Regional Studies in Marine Science*, *34*, 101050.

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## Thesis by compendium of publications.
## Document of agreement and resignation of co-authors

D. /Dª.: Ana Macias Bedoya, DNI o Passport: 32.854.268-x, co-author of the following publication:

Asensio-Montesinos, F., Anfuso, G., Oliva Ramírez, M., Smolka, R., García Sanabria, J., Fernández-Enríquez, A., Arenas, P., & Macías Bedoya, A. (2020). Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain). *Regional Studies in Marine Science*, *34*, 101050.

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## Thesis by compendium of publications.
## Document of agreement and resignation of co-authors

D. /Dª.: Juan María González Leal, DNI o Passport: 75.873.882-X, co-author of the following publication:

Asensio-Montesinos, F., Oliva Ramírez, M., González-Leal, J.M., Carrizo, D., & Anfuso, G. (2020). Characterization of plastic beach litter by Raman spectroscopy in south-western Spain. *Science of the Total Environment*, *744*, 140890.

In accordance with the **Article 23.4** of the **Regulation UCA CG06-2012, June 27, 2012, which regulates the ordinance of doctoral studies at the University of Cádiz (BOUCA No. 208).**
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In Cádiz, 25 of November, 2021

Signed: _____

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## Thesis by compendium of publications.
## Document of agreement and resignation of co-authors

D. /Dª.: Daniel Carrizo, NIE: X4175166E, co-author of the following publication:

Asensio-Montesinos, F., Oliva Ramírez, M., González-Leal, J.M., Carrizo, D., & Anfuso, G. (2020). Characterization of plastic beach litter by Raman spectroscopy in south-western Spain. *Science of the Total Environment*, *744*, 140890.

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Signed: Daniel Carrizo

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## Thesis by compendium of publications.
## Document of agreement and resignation of co-authors

D. /Dª.: Maria Teresa Aguilar-Torrelo, DNI o Passport: 45120564S, co-author of the following publication:

Asensio-Montesinos, F., Oliva Ramírez, M., Aguilar-Torrelo, M.T. & Anfuso, G. (2021). Cigarette butts abundance and distribution on coastal environments: examples from Southern Spain. *Journal of Marine Science and Engineering*.

In accordance with the **Article 23.4** of the **Regulation UCA CG06-2012, June 27, 2012, which regulates the ordinance of doctoral studies at the University of Cádiz (BOUCA No. 208).**
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In Cádiz, 25 of November, 2021

Signed: AGUILAR TORRELO MARIA TERESA - 45120564S

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