Universidad de Oviedo

Programa de Doctorado en Ingeniería Química, Ambiental y Bioalimentaria

Análisis y evaluación del origen, componentes socioculturales y riesgos biológicos de la basura marina en el litoral asturiano

Analysis and evaluation of the origin, sociocultural components and biological risks of marine litter in the Asturian coast

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RESUMEN DEL CONTENIDO DE TESIS DOCTORAL

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RESUMEN (en español)

La basura marina, es decir, todo aquel material generado por el ser humano y descartado en el mar, ha pasado de ser un problema menor para los ecosistemas y la vida humana a convertirse en una de sus principales amenazas. La creciente preocupación pública sobre la basura ha estado motivada por el aumento de la generación de residuos y también por la divulgación de numerosas investigaciones sobre sus efectos negativos para el medio ambiente y la sociedad.
El origen de toda la basura del planeta es antropogénico, por lo que se trata de un problema global al utilizar el ser humano todos los ecosistemas del planeta. Los principales impactos que causa la basura marina se pueden englobar en dos grupos principales: los efectos sobre los ecosistemas y los efectos sobre el ser humano, incluyendo de tipo sanitario. Para luchar contra la basura marina de una manera eficiente es necesaria una doble estrategia: por una parte, conocer el estado de las zonas costeras respecto a la cantidad y el tipo de basura que existe, sus impactos negativos y su posible origen; además, hay que conocer el nivel de conocimiento e implicación que tiene la ciudadanía sobre el tema para promover su participación en la búsqueda de soluciones.
En este trabajo se han medido por primera vez los niveles de deposición de basura en diferentes puntos a lo largo de la costa de Asturias. Aun no habiéndose encontrado ninguna playa sin basura, los datos indican que la región se encuentra por debajo de la media global. Al igual que en el resto del planeta, los residuos de plástico (fragmentos de poliestireno, tapones, bolsas, bastoncillos, etc.) constituyen la gran mayoría de los contaminantes, seguidos de restos de materiales de pesca (redes, sedales, boyas). Los niveles de residuos están correlacionados en la región con actividades humanas tales como el uso recreativo de las playas, el tráfico marítimo y la actividad portuaria.
También se ha podido vincular la basura marina con la expansión de especies invasoras. Por una parte, se han descubierto los primeros indicios de dispersión de tres especies invasoras (*Austrominius modestus*, *Magallana gigas*, y *Amphibalanus amphitrite*) a través de objetos flotantes (botellas de plástico y cuerdas) depositados en la costa de Asturias. Además, se ha encontrado una correlación significativa entre el nivel de contaminación por basura marina con la invasión de la planta exótica *Cortaderia selloana* (hierba de la pampa). Esta planta, muy conocida en la región, se ha vinculado en esta tesis con la degradación ambiental y con la basura depositada en las playas. Su efecto negativo en la zona costera asturiana se mitiga por los esfuerzos desplegados para su gestión y control (que no de eliminación), influyendo negativamente en la percepción de la misma por los usuarios de la playa. Los usuarios de las playas asocian la presencia de basura con la invasión por especies exóticas, lo cual revela

conocimiento y concienciación en la población.
Los resultados del trabajo de campo muestran que la población que acude a las playas suele tener un mayor conocimiento y percepción del estado de las mismas en lo referente a la basura marina, especialmente si realizan labores de voluntariado tales como limpiezas de playas. Esto se ve reforzado por la frecuencia de visitas, teniendo una mejor percepción y mayor concienciación cuanto más se acude a la playa. Asimismo, se han constatado diferencias en la percepción y la actitud en función del género de los usuarios de la playa, teniendo los hombres una mayor predisposición a actuar para eliminar la basura de las playas. También se encontraron diferencias en la percepción dependiendo de la edad, siendo los más jóvenes menos conscientes del nivel de contaminación. Se ha verificado que el nivel de limpieza de la playa afecta a la conciencia de la gravedad de la contaminación por basuras marinas y por tanto a la actitud de la ciudadanía frente a la presencia de la misma. Las citadas actividades de voluntariado de recogida de basura, mejoran el estado estético de las playas, pero generan una imagen distorsionada de la realidad, dando la falsa sensación de un buen estado de la costa, lo cual influye en la percepción de los usuarios de la playa y su posterior actitud hacia la basura marina.
En resumen, los resultados planteados por esta tesis doctoral muestran que los niveles de basura marina, una de las mayores amenazas para el entorno marinos y costeros de todo el planeta, aún no son alarmantes en la región, aunque su presencia resulta evidente. Además, el nivel de conocimiento y concienciación por parte de la población es, en general, bastante alto, resultando una buena base para implementar medidas de control y campañas de sensibilización a fin de involucrar al conjunto de la población sobre un problema que afecta globalmente a toda la sociedad. Reducir la fuente de esta basura y así disminuir sus amenazas, tanto ambientales como sociales, es una tarea en la que toda la ciudadanía debe estar involucrada.

RESUMEN (en Inglés)

Marine litter, that is, all material generated by humans and discarded to the sea, has gone from being a minor problem for ecosystems and human life to becoming one of its main threats. The growing public concern about garbage has been motivated by the increase in the generation of waste and also by the dissemination of numerous studies on its negative effects for the environment and society. The origin of all the litter on the planet is anthropogenic, so it is a global problem while the human being uses all the ecosystems on the planet. The main impacts caused by marine garbage can be included into two main groups: the ecosystem effects and the human effects, including health. In order to fight against marine garbage in an efficient way, a twofold strategy is necessary: on the one hand, to know the state of coastal zones with respect to the quantity and type of garbage that exists, its negative impacts and its possible origin; in addition, it is necessary to know the level of knowledge and implication that citizens have on the subject in order to promote their participation in the search for solutions.
In this work, the levels of debris disposal in different points along the coast of Asturias have been measured for the first time. Although no beach has been found without litter, the data indicate that the region is below the global average. As in the rest of the planet, plastic waste (polystyrene fragments, plugs, bags, rods, etc.) represents the vast majority of pollutants, followed by the remains of fishing materials (nets, fishing lines, buoys). Garbage levels in the region are correlated with human activities such as recreational use of beaches, maritime traffic and port activity.
Also, marine debris has been linked to the expansion of invasive species. On the one hand, the first signs of dispersion of three alien invasive species (*Austrominius modestus*, *Magallana gigas*, and *Amphibalanus amphitrite*) have been discovered through floating objects (plastic bottles and ropes) deposited on the coast of Asturias. In addition, a significant correlation has been found between the level of marine debris deposition with the invasion of the exotic plant *Cortaderia selloana* (pampas grass). This plant, well known in the region, has been linked in this thesis with environmental degradation and with the garbage deposited on the beaches. Its negative effect on the Asturian coastal zone is mitigated by management and control efforts (not

elimination) of it, negatively influencing the perception of it by beach users. Beach users associate the presence of rubbish and invasion by exotic species, which shows knowledge and awareness in the population.
The fieldwork results show that the people who go to the beach tend to have a greater knowledge and perception of the state of it regarding marine garbage, especially if they carry out volunteer work such as beach clean-ups. This is reinforced by the frequency of visits, having a better perception and greater awareness the more people come to the beach. Differences in perception and attitude have also been reported depending on the gender of the beach users, with men having a greater predisposition to act in order to eliminate rubbish from the beaches. Differences were also found in perception depending on age, with the youngest being less aware of the level of pollution. It has been found that the level of cleanliness of the beach affects the awareness of the seriousness of pollution by marine litter and therefore the attitude of citizens to the presence of it. The above mentioned voluntary activities of garbage collection improve the aesthetic state of the beaches, but generate a distorted image of reality, giving the false sensation of a good state of the coast, which influences the perception of beach users and their subsequent attitude towards marine garbage.
In summary, the results presented by this doctoral thesis show that the marine litter deposition levels, one of the greatest threats to the marine and coastal environment of the entire planet, are still not alarming in the region, although its presence is evident and harmful. In addition, the level of knowledge and awareness by the population is, in general, quite high, resulting in a good basis for implementing control measures and awareness campaigns to involve the whole population on a problem that affects society globally. Reducing the source of this garbage and thus diminishing its threats, both environmental and social, is a task in which all citizens must be involved.

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1.- Datos personales solicitante	
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Acompaña acreditación por el Director de la Tesis de la aportación significativa del doctorando	X	
Acompaña memoria que incluye		
Introducción justificativa de la unidad temática y objetivos	X	
Copia completa de los trabajos *	X	
Resultados/discusión y conclusiones	X	
Informe con el factor de impacto de la publicaciones	X	
Se acompaña aceptación de todos y cada uno de los coautores a presentar el trabajo como tesis por compendio	X	
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Factor de impacto	1.971

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Coautor3 ◻ Doctor X No doctor	Indique nombre y apellidos	Marta Gomez Agenjo
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Trabajo, Artículo 2

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Inclusión en Science Citation Index o bases relacionadas por la CNEAI (indíquese)	Sí
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Trabajo, Artículo 3

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Fecha de publicación	En revisión
Fecha de aceptación	En revisión
Inclusión en Science Citation Index o bases relacionadas por la CNEAI (indíquese)	Sí
Factor de impacto	1.160

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Trabajo, Artículo 4

Titulo (o título abreviado)	Marine litter and public involvement in beach cleaning: Disentangling perception and awareness among adults and children, Bay of Biscay, Spain
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Índice

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Resumen

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La basura marina, es decir, todo aquel material generado por el ser humano y descartado en el mar, ha pasado de ser un problema menor para los ecosistemas y la vida humana a convertirse en una de sus principales amenazas. La creciente preocupación pública sobre la basura ha estado motivada por el aumento de la generación de residuos y también por la divulgación de numerosas investigaciones sobre sus efectos negativos para el medio ambiente y la sociedad. El origen de toda la basura del planeta es antropogénico, por lo que se trata de un problema global al utilizar el ser humano todos los ecosistemas del planeta. Los principales impactos que causa la basura marina se pueden englobar en dos grupos principales: los efectos sobre los ecosistemas y los efectos sobre el ser humano, incluyendo de tipo sanitario. Para luchar contra la basura marina de una manera eficiente es necesaria una doble estrategia: por una parte, conocer el estado de las zonas costeras respecto a la cantidad y el tipo de basura que existe, sus impactos negativos y su posible origen; además, hay que conocer el nivel de conocimiento e implicación que tiene la ciudadanía sobre el tema para promover su participación en la búsqueda de soluciones.

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También se ha podido vincular la basura marina con la expansión de especies invasoras. Por una parte, se han descubierto los primeros indicios de dispersión de tres especies invasoras (*Austrominius modestus*, *Magallana gigas*, y *Amphibalanus amphitrite*) a través de objetos flotantes (botellas de plástico y cuerdas) depositados en la costa de Asturias. Además, se ha encontrado una correlación significativa entre el nivel de contaminación por basura marina con la invasión de la planta exótica *Cortaderia selloana* (hierba de la pampa). Esta planta, muy conocida en la región, se ha vinculado en esta tesis con la degradación ambiental y con la basura depositada en las playas. Su efecto negativo en la zona costera asturiana se mitiga por los esfuerzos desplegados para su gestión y control (que no de eliminación), influyendo negativamente en la percepción de la misma por los usuarios de la playa. Los usuarios de las playas asocian la presencia de basura con la invasión por especies exóticas, lo cual revela conocimiento y concienciación en la población.

Los resultados del trabajo de campo muestran que la población que acude a las playas suele tener un mayor conocimiento y percepción del estado de las mismas en lo referente a la basura marina, especialmente si realizan labores de voluntariado tales como limpiezas de playas. Esto se ve reforzado por la frecuencia de visitas, teniendo una mejor percepción y mayor concienciación cuanto más se acude a la playa. Asimismo, se han constatado diferencias en la percepción y la

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En resumen, los resultados planteados por esta tesis doctoral muestran que los niveles de basura marina, una de las mayores amenazas para el entorno marino y costero de todo el planeta, aún no son alarmantes en la región, aunque su presencia resulta evidente. Además, el nivel de conocimiento y concienciación por parte de la población es, en general, bastante alto, resultando una buena base para implementar medidas de control y campañas de sensibilización a fin de involucrar al conjunto de la población sobre un problema que afecta globalmente a toda la sociedad. Reducir la fuente de esta basura y así disminuir sus amenazas, tanto ambientales como sociales, es una tarea en la que toda la ciudadanía debe estar involucrada.

Summary

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Marine litter, that is, all material generated by humans and discarded to the sea, has gone from being a minor problem for ecosystems and human life to becoming one of its main threats. The growing public concern about garbage has been motivated by the increase in the generation of waste and also by the dissemination of numerous studies on its negative effects for the environment and society. The origin of all the litter on the planet is anthropogenic, so it is a global problem while the human being uses all the ecosystems on the planet. The main impacts caused by marine garbage can be included into two main groups: the ecosystem effects and the human effects, including health. In order to fight against marine garbage in an efficient way, a twofold strategy is necessary: on the one hand, to know the state of coastal zones with respect to the quantity and type of garbage that exists, its negative impacts and its possible origin; in addition, it is necessary to know the level of knowledge and implication that citizens have on the subject in order to promote their participation in the search for solutions.

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Also, marine debris has been linked to the expansion of invasive species. On the one hand, the first signs of dispersion of three alien invasive species (*Austrominius modestus*, *Magallana gigas*, and *Amphibalanus amphitrite*) have been discovered through floating objects (plastic bottles and ropes) deposited on the coast of Asturias. In addition, a significant correlation has been found between the level of marine debris deposition with the invasion of the exotic plant *Cortaderia selloana* (pampas grass). This plant, well known in the region, has been linked in this thesis with environmental degradation and with the garbage deposited on the beaches. Its negative effect on the Asturian coastal zone is mitigated by management and control efforts (not elimination) of it, negatively influencing the perception of it by beach users. Beach users associate the presence of rubbish and invasion by exotic species, which shows knowledge and awareness in the population.

The fieldwork results show that the people who go to the beach tend to have a greater knowledge and perception of the state of it regarding marine garbage, especially if they carry out volunteer work such as beach clean-ups. This is reinforced by the frequency of visits, having a better perception and greater awareness the more people come to the beach. Differences in perception and attitude have also been reported depending on the gender of the beach users, with men having a greater predisposition to act in order to eliminate rubbish from the beaches. Differences were also found in perception depending on age, with the youngest being less aware of the level of pollution. It has been found that the level of cleanliness of the beach affects the awareness of the seriousness of pollution by marine litter and therefore the attitude of citizens to

the presence of it. The above mentioned voluntary activities of garbage collection improve the aesthetic state of the beaches, but generate a distorted image of reality, giving the false sensation of a good state of the coast, which influences the perception of beach users and their subsequent attitude towards marine garbage.

In summary, the results presented by this doctoral thesis show that the marine litter deposition levels, one of the greatest threats to the marine and coastal environment of the entire planet, are still not alarming in the region, although its presence is evident and harmful. In addition, the level of knowledge and awareness by the population is, in general, quite high, resulting in a good basis for implementing control measures and awareness campaigns to involve the whole population on a problem that affects society globally. Reducing the source of this garbage and thus diminishing its threats, both environmental and social, is a task in which all citizens must be involved.

Introducción

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La contaminación de los mares

La contaminación supone una de las mayores amenazas ambientales para la biodiversidad de los ecosistemas marinos. El uso desde la antigüedad de los mares como fuente de recursos, vías de comunicación y sumideros de deshechos ha ido degradándolos paulatinamente. Esta actitud descuidada se fundamentaba en la idea de que su enorme volumen de agua podría absorber cualquier impacto que el ser humano ejerciese sobre ellos sin repercusiones. Si bien esto no era cierto, no fue hasta mediados del siglo XX cuando el efecto de estas acciones de la sociedad sobre los mares no se hizo patente. Este cambio se debió a dos factores fundamentales: al aumento de la población humana y las comunicaciones marítimas, lo cual llevó ligado un aumento individual de los impactos; y al cambio, en los modos de consumo que han ido generando residuos cada vez más nocivos e imperecederos. Lógicamente, este incremento de la contaminación de los mares ha traído consigo un aumento de la percepción de dicha contaminación.

Este aumento de la conciencia de la contaminación marina conllevó, durante la segunda mitad del siglo XX, un desarrollo de medidas de gestión intergubernamentales que acabarían dando lugar a propuestas legislativas de organizaciones internacionales para la defensa del medio marino como el convenio MARPOL 73/78 de la Organización Marítima Internacional de la Organización de las Naciones Unidas (OMI – ONU) en 1978. Esta organización nació para "*[aplicar un] convenio internacional que versa sobre la prevención de la contaminación del medio marino por los buques a causa de factores de funcionamiento o accidentales*". También intervienen en la gestión de la contaminación marina la Agencia Europea de Medio Ambiente (EEA), fundada en 1990, cuyo fin es *"proporcionar información sólida e independiente sobre el medio ambiente [y] apoyar el desarrollo sostenible y contribuir a conseguir una mejora significativa y cuantificable del medio ambiente europeo facilitando información actualizada, específica, pertinente y fidedigna a los responsables de la política medioambiental y al público en general*"; y la Convención para la Protección del Medio Ambiente Marino del Atlántico del Nordeste (OSPAR) de 1992, que "*regula la cooperación internacional en cuanto a la protección medioambiental en el Atlántico del Nordeste. Complementa y actualiza la Convención de Oslo de 1972 sobre vertidos al mar y la Convención de París de 1974 sobre contaminación marina de origen terrestre*".

Sin embargo, el desarrollo de estas medidas contra la contaminación marina no ha impedido que desde hace más de cinco décadas no haya dejado de aumentar año tras año. La basura marina ha emergido como uno de los problemas más acuciantes y graves, pasando de estar prácticamente inadvertida a mediados del siglo XX a ser considerada actualmente la segunda mayor amenaza para la biodiversidad marina, sólo por detrás de la pérdida de hábitats (Goldberg, 1995; Gall and Thompson, 2015).

La basura marina

Imagen 1. Depósitos de basura marina en la isla de Kanapou, Hawai. (Fuente: NOAA)

El Programa Ambiental de las Naciones Unidas (UNEP) define la basura marina como *"cualquier material sólido persistente, manufacturado o procesado que se haya descartado, eliminado o abandonado en el medio marino y costero"*. La cantidad de basura marina que entra cada año en los mares nunca ha dejado de aumentar y este aumento guarda una estrecha relación con el desarrollo y extensión del uso del plástico, cuyas características le convierten en el material más utilizado diariamente en todo el mundo. Esto se debe principalmente a dos factores:

- **Polivalencia**: el plástico, al ser un material fácil de producir a muy bajo coste, ha desplazado a otros materiales más caros y de más difícil producción, haciéndole omnipresente en nuestra vida diaria y por tanto en los residuos que generamos. Esto, además, se ve empeorado por un aumento en el consumo de objetos de plástico que tras utilizarse se descartan y pasan a ser basura (Andrady, 2015; Galgani et al., 2015).

- **Vida media**: el plástico es un material que no se degrada en la naturaleza por medios químicos, es decir, no se descompone en moléculas más sencillas, si no que persiste en el medio, fragmentándose por la acción de los agentes físicos en pedazos cada vez más pequeños (Ryan et al., 2009; Eriksen et al., 2014). Esto hace que se acumule en los ecosistemas y con el tiempo se vaya fragmentando en partículas de mesoplástico y microplástico, generando problemas añadidos a los ecosistemas por el difícil tratamiento de partículas tan pequeñas (Fendall and Sewell, 2009; Andrady, 2015; Browne, 2015).

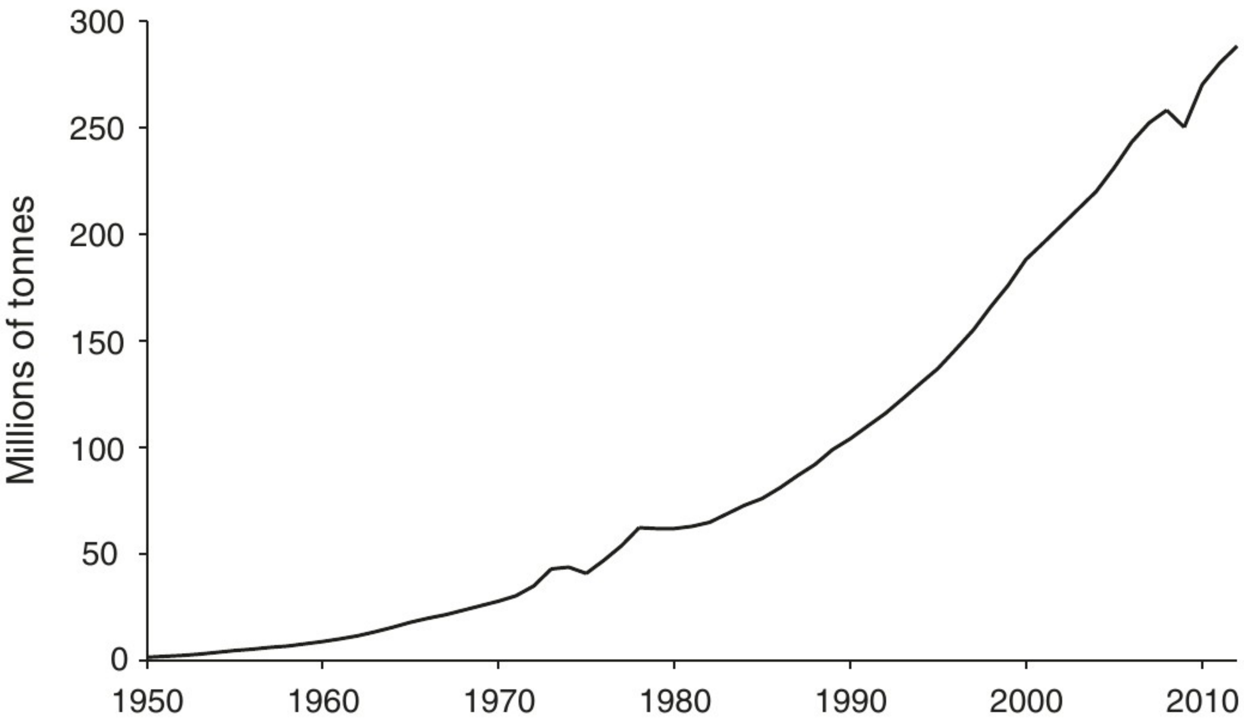

Figura 1. Evolución de la producción de plásticos desde 1950 hasta 2012 (Ryan, 2015).

Por los motivos expuestos, los plásticos conforman entre el 70% y el 90% de la basura que se encuentra en los océanos de todo el mundo (Derraik, 2002; Galgani et al., 2015). Esta proporción tan grande no se debe solamente a un aumento relativo de la cantidad de plásticos descartados frente a otros tipos de residuos, sino también a que su larga vida media hace que sea un material persistente en los ecosistemas (Barnes et al., 2009; Andrady, 2015). Los residuos de plástico han aumentado como resultado del aumento de la producción y uso de objetos de este material, que tampoco ha dejado de crecer desde su descubrimiento (PlasticsEurope, 2018).

Hay que tener en cuenta que la mayor parte de la basura marina se origina en tierra firme. Muchas de las fuentes de esta basura se pueden encontrar a cientos de kilómetros tierra adentro, lejos de las zonas costeras, y llegan a los mares a través de los ríos, que funcionan como vías de transporte de basura hacia los mares (Rech et al., 2014). Otras actividades que contribuyen a la generación de basura marina son las actividades de recreo costeras, las descargas de basura desde las poblaciones litorales y las actividades portuarias (Ryan et al., 2009; Leite et al., 2014).

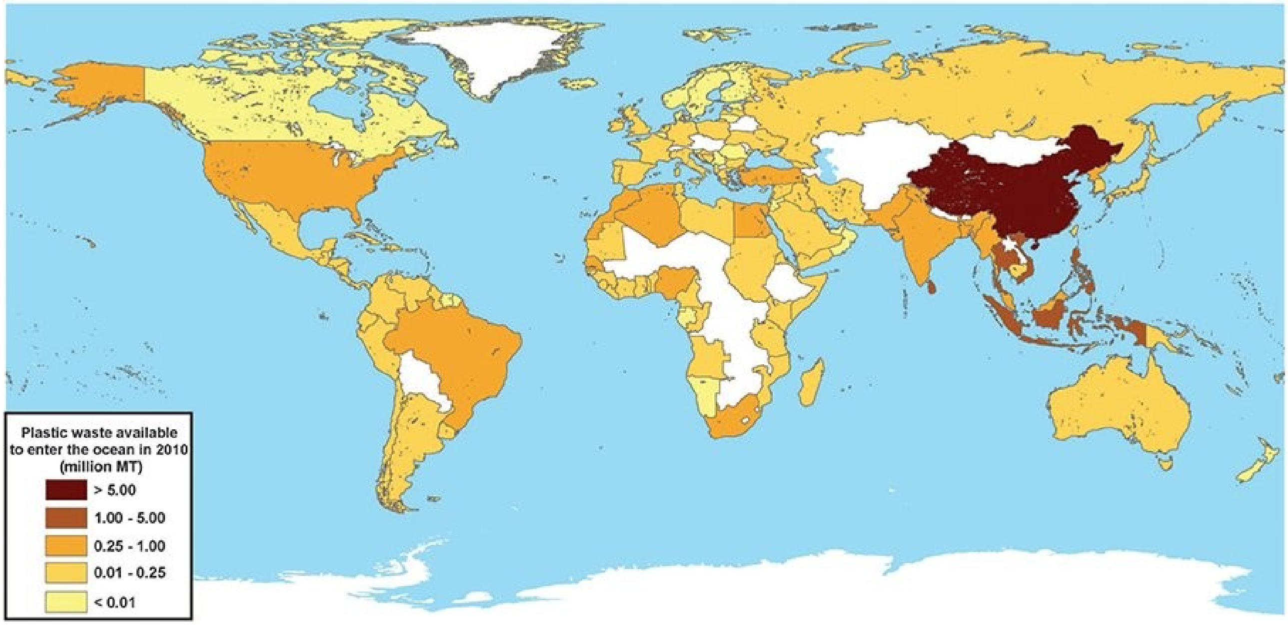

Figura 2. Mapa mundial de los vertidos de plásticos al mar en 2010 (en millones de toneladas métricas) (extraido de Jambeck et al., 2015).

Impactos conocidos

La acumulación de plásticos en el mar genera impactos nuevos en los ecosistemas que afectan a todos los seres vivos que habitan el mar y la costa. Estos efectos se pueden clasificar en dos grandes grupos dependiendo de si afectan a la fauna y flora marinas (efectos ambientales) o a las poblaciones humanas (efectos antrópicos).

Efectos medioambientales

- **Efectos sobre la fauna marina**: los restos de objetos flotando a la deriva afectan a la fauna cuando esta se ve atrapada entre ellos, disminuyendo su capacidad de movimiento y de supervivencia. De entre todos los componentes de la basura, los restos de pesca abandonados (redes y cuerdas) resultan los más dañinos, pues, por sus características, siguen cumpliendo la función con la que se generaron, incluso después de haber sido descartados en el mar, razón por lo que se les denomina "pesca fantasma". Además, la ingesta de basuras marinas por los animales (como cetáceos, peces o aves, entre otras) les puede llevar al ahogamiento o la asfixia (Laist, 1987; Gregory, 2009; Deudero and Alomar, 2015). Se han confirmado también numerosos casos de ingesta de basura por especies de animales que se alimentan en el mar, como peces (Romeo et al., 2015), aves (Cadée, 2002; Wilcox et al., 2015), tortugas (Schuyler et al., 2016) o cetáceos (El País, 2018a; Euronews, 2018). Especialmente los plásticos tienen un notable efecto negativo. Los plásticos no se digieren en el estómago de los animales, por lo que se van acumulando y provocando problemas en el desarrollo debido a la disminución de la capacidad de ingesta de alimentos hasta causarles la muerte. También la reacción de los jugos gástricos del estómago con los plásticos puede producir una digestión parcial que libera moléculas tóxicas para los animales (Schuyler et al., 2016; Fossi et al., 2018). Recientemente se ha podido relacionar la contaminación por plásticos con la infección y muerte de los corales (Lamb et al., 2018), lo cual abre una puerta a otros nuevos impactos desconocidos para la fauna marina.

- **Dispersión de especies invasoras**: Además de los efectos nocivos directos sobre la fauna, la basura marina funciona como una balsa artificial sobre la que muchos organismos pueden desarrollarse y/o utilizar como soporte flotante. Se han reportado casos de dispersión de especies de flora y fauna a través de los océanos (Aliani and Molcard, 2003; Gil and Pfaller, 2016; Carlton et al., 2017; Tutman et al., 2017), incluyendo algunas especies invasoras. Al añadir esto al efecto de degradación del medio ambiente que lleva asociada la acumulación de basura en las zonas costeras, se aumenta la probabilidad de propagación de especies invasoras en las nuevas zonas colonizadas (Campos et al., 2004; Domènech and Vilà, 2006, 2007).

Imagen 2. Depósitos de plásticos y otras basuras en el Playón de Bayas (Castrillón, Asturias) durante un muestreo en 2016.

Efectos antrópicos

- **Degradación del paisaje**: La acumulación de basura en las zonas costeras resulta estéticamente desagradable para las personas. La degradación del atractivo del paisaje determina que se descarten las playas con basura para el ocio, en favor de playas en un mejor estado. Esto afecta negativamente al turismo, que ve sus ganancias en riesgo por ello; y a su vez este sector turístico presiona a las administraciones para que tomen medidas para paliar la aparición de esta basura, lo que conlleva un coste económico (Somerville et al., 2003; Tudor and Williams, 2003; Nijkamp et al., 2008; Mouat et al., 2010; Newman et al., 2015).

- **Efectos sobre la pesca**: La basura flotante afecta también a la fauna de interés comercial tanto por efectos directos como estrangulamiento, lastre, etcétera, o por efectos de ingesta, disminuyendo su número, lo cual tiene un efecto negativo sobre la pesca. Además, la basura flotante puede quedarse atrapada entre las redes de pesca, disminuyendo también las capturas y amenazando la producción pesquera (Newman et al., 2015; Rochman et al., 2015; Romeo et al., 2015).

- **Efectos sobre la salud**: La basura marina también se ha relacionado con la dispersión de patógenos humanos como microorganismos fecales, bacterias patógenas y algas productoras de mareas rojas. Asimismo, algunos plásticos presentes en esta basura marina han sido detectados como acumuladores de sustancias tóxicas para la salud humana, tales como los productos organoclorados (bifenilos policlorados, PCB), bisfenol A y otros tóxicos orgánicos (Thompson et al., 2009; Koelmans et al., 2014; Kiessling et al., 2015; Koelmans, 2015; Newman et al., 2015; Kirstein et al., 2016).

El factor humano

Es necesario considerar la acción humana como parte del problema de la basura marina para conseguir verlo en perspectiva. Como se comentó antes, la basura marina tiene un origen exclusivamente antropogénico y, en su mayor parte, terrestre. La expansión del uso de materiales de plástico (principalmente) ha contribuido en gran medida del aumento de la producción de basura de manera global. Por ello, la actitud de la ciudadanía en la generación y eliminación de la basura tiene un papel clave en su manejo y gestión.

Este aumento de la cantidad de basura marina, en particular su acumulación en la costa, ha forzado a las administraciones públicas a tomar medidas para tratar de disminuir su cantidad, en muchos casos al verse presionadas por los usuarios, los sectores turístico y pesquero, grupos de defensa del medio ambiente y otros. Muchas de las medidas y políticas de gestión basan su eficacia en la aceptación y aplicación de las mismas por parte de la ciudadanía a la cual van dirigidas. A su vez, dicha aceptación depende del grado de concienciación y de conocimiento sobre dichos problemas. Por tanto, analizar el conocimiento y grado de concienciación de la ciudadanía, en especial en las zonas costeras, puede incentivar la aplicación de medidas de conservación y aumentar su efectividad (Chaniotis and Stead, 2007). La competencia de la legislación y regulación requiere un conocimiento del estado de la costa en lo referente a los niveles de basura que se encuentran a lo largo de una zona, a fin de rentabilizar los esfuerzos de eliminación o de optimizar las campañas de sensibilización. Además, este conocimiento resulta imprescindible como punto de referencia para valorar la efectividad de estas medidas a lo largo del tiempo, ya que si no se conoce el estado de la costa previo a la implementación de las medidas es imposible valorar de manera efectiva la eficacia de las mismas (Hartley et al., 2015).

La percepción del estado de limpieza de la costa por parte de la población resulta determinante para hacer efectivas las medidas contra las basuras marinas por un doble motivo: por un lado la falta de conocimiento de la situación hace disminuir el nivel de aceptación y de incorporación social de las nuevas medidas implementadas por las administraciones (Battisti and Gippoliti, 2018); y por otro lado, determina las medidas que se vayan a tomar, ya que las iniciativas populares dependen en gran medida del conocimiento de la sociedad sobre los problemas (Chaniotis and Stead, 2007). El conocimiento del estado del problema conduce a una mayor involucración pública tanto por la mejora individual y social de la conciencia sobre el problema, como por un aumento de la participación de la sociedad en la toma de soluciones, como pueden ser medidas sociales, políticas o acciones voluntarias (Veiga et al., 2016). Una sociedad informada y concienciada suele tomar mejores decisiones (Marin et al., 2009) y la concienciación de la población, además, tiene otro papel crucial para la lucha contra la basura: la reducción de su producción.

Imagen 3. Voluntarios recogiendo basuras en el Playón de Bayas (Castrillón). Crédito: Deborah Santos Hernández

Por estos motivos, parece necesario un conocimiento realista del impacto de la basura de la playa para poner a la población en perspectiva. Sin embargo, también se ha descrito en varios estudios que la población tiende a tener en menor consideración las playas ya contaminadas, adoptando incluso actitudes incívicas en dichos casos (Sibley and Liu, 2003; Perry et al., 2010).

En ocasiones, los esfuerzos de limpieza por parte de las administraciones resultan insuficientes, necesitan más recursos que los que se pueden asumir y muchas veces solamente dura el efecto unas pocas horas, hasta que la marea vuelva a depositar más basura en las playas. Este hecho, aun resultando perjudicial para el medio ambiente y para el ser humano, ayuda a poner en perspectiva la realidad de la situación para la ciudadanía, además de activar la alarma pública (Liu et al., 2013). Asimismo, la percepción del problema determina en muchos casos la toma de decisiones e incluso el cambio de actitudes, lo cual resulta imprescindible para eliminar el problema desde la base (Tudor and Williams, 2003; Wyles et al., 2016; Magaš et al., 2018).

El caso de Asturias

Las costas del Mar Cantábrico en general y las de Asturias en particular han sido poco estudiadas en materia de basura marina, sobre todo si se comparan con las de la costa mediterránea española. España, como miembro de la Unión Europea y la Convención para la Protección del Medio Ambiente Marino del Atlántico del Nordeste (OSPAR), es firmante de varios acuerdos que contemplan el estudio y la reducción de la basura marina en su costa atlántica. Como ya se comentó, la falta de información sobre su estado actual hace difícil la implementación de medidas de gestión, tanto de eliminación de la basura como a nivel de gestión administrativa de las fuentes. Además, los estudios de caso en el campo de la basura marina son de enorme importancia para el manejo de la misma, debido a la gran heterogeneidad de situaciones que existen por todo el planeta (Williams et al., 2005; Ioakeimidis et al., 2014).

La costa asturiana presenta un perfil que intercala acantilados calizos, intermareales rocosos, playas de piedra y playas de arena en una extensión de unos 330 km. Algunas de estas playas están enclavadas dentro de figuras de protección medioambiental, como es el caso de las playas de Andrín y Rodiles, dentro de espacios Natura 2000; o la playa de Xagó, dentro del paisaje protegido de Cabo Peñas. La conservación de estos arenales, por tanto, debe también considerarse en materia de basuras marinas y otros contaminantes y en este momento no hay estudios al respecto. Asturias cuenta con una larga tradición de pesca con 18 puertos pesqueros, destacando los de Luarca, Lastres, Gijón y Avilés; siendo estos dos últimos los puertos comerciales internacionales más grandes de la región. También existen múltiples asentamientos poblacionales repartidos a lo largo de la costa asturiana y en las proximidades de los tres ríos más importantes de la región; el Eo, el Navia y el Nalón, que vierten sus aguas a la costa cantábrica; estando por tanto todas las ciudades importantes de la región comunicadas, directa o indirectamente, con el Mar Cantábrico.

Por todo lo expuesto, el desarrollo de esta tesis supone no sólo una oportunidad para un estudio completamente novedoso en la región, en la que se contemplan tanto la basura marina desde un punto de vista científico y analítico, como las implicaciones y consecuencias sociales de la ciudadanía que la padece directamente sino también una oportunidad de aportar datos que puedan mejorar la gestión de esta basura marina para tratar de eliminarla.

Objetivos

Objetivos

El principal objetivo de esta tesis doctoral ha sido dilucidar el origen y el impacto de la basura marina en los ambientes costeros de Asturias, así como relacionar la percepción, el conocimiento y las acciones tomadas por los usuarios de la playa en la gestión de las basuras marinas. Con este fin, los objetivos específicos de la tesis han sido:

1. Revisión del estado de la costa asturiana en lo referente a la aparición y deposición de basura marina, incluyendo su tratamiento en los medios de comunicación.
2. Análisis del alcance de la cantidad de basura marina en Asturias mediante mapeo en las playas, empleando estrategias de muestreo por transectos.
3. Determinación de las posibles fuentes de origen de la basura y de las causas ambientales y sociales de su depósito en las playas.
4. Cuantificación de especies exóticas y/o potencialmente dañinas para los recursos naturales costeros, adheridas a la basura flotante en las playas asturianas.
5. Evaluación del grado de conocimiento y concienciación ciudadana y de las partes implicadas respecto al tema de la basura marina y sus riesgos asociados.

Objectives

Objectives

The main objective of this PhD thesis has been to elucidate the origin and impact of marine litter in the coastal environments of Asturias, as well as to relate the perception, knowledge and actions taken by beach users in the management of marine litter. To this end, the specific objectives of the thesis have been:

1. To review the state of the Asturian coast and the Cantabrian Sea with regards to the appearance and deposition of marine litter, including its treatment by mass media.

2. To analyse the extent of the amount of marine litter in Asturias by mapping the beaches with transect sampling strategies.

3. To determinate the possible sources of origin of the rubbish and the environmental and social causes of its deposit on the beaches.

4. To quantify the exotic and/or potentially harmful species to coastal natural resources associated to the litter on Asturian beaches.

5. To evaluate the degree of knowledge and awareness of citizens and the stakeholders, regarding the issue of marine litter and its associated risks.

Resultados

Resultados

Los resultados de la presente tesis doctoral has sido publicados en diferentes revistas científicas y cada publicación se corresponde con cada uno de los capítulos descritos en los resultados:

- **Capítulo 1.** Miralles, L., Gomez-Agenjo, M., Rayon-Viña, F., Gyraitė, G., Garcia-Vazquez, E., 2018. *Alert calling in port areas: Marine litter as possible secondary dispersal vector for hitchhiking invasive species*. Publicado en Journal for Nature Conservation.

- **Capítulo 2**. Rayon-Viña, F., Miralles, L., Gómez-Agenjo, M., Dopico, E., Garcia-Vazquez, E., 2018. *Marine litter in south Bay of Biscay: Local differences in beach littering are associated with citizen perception and awareness*. Publicado en Marine Pollution Bulletin.

- **Capítulo 3**. Rayon-Viña, F., Fernandez-Rodriguez, S., Ibabe, A., Dopico, E., Garcia-Vazquez, E., 2019. *Public awareness of coastal pollution and biopollution in Bay of Biscay. Implications for early detection and control*. Journal of Coastal Research. En revisión

- **Capítulo 4**. Rayon-Viña, F., Miralles, L., Fernandez-Rodríguez, S., Dopico, E., Garcia-Vazquez, E., 2019. *Marine litter and public involvement in beach cleaning: Disentangling perception and awareness among adults and children, Bay of Biscay, Spain*. Publicado en Marine Pollution Bulletin.

Los objetivos planteados para el desarrollo de la presente tesis doctoral fueron cubiertos de la siguiente manera:

- **Objetivo 1:** Revisión del estado de la costa asturiana en lo referente a la aparición y deposición de basura marina, incluyendo su tratamiento en los medios de comunicación. **Capítulos 1 y 2.**

  En estos artículos que se ha planteado el objetivo de analizar el estado de contaminación por basura marina en el litoral de Asturias reflejado en la prensa regional (Art. 2) y compararlo con datos objetivos obtenidos de muestreos de basura en las playas (Art. 1), cuyos resultados mas notables son una contradicción entre la cantidad de basura encontrada en los arenales respecto a la importancia dada por la prensa regional.

- **Objetivo 2:** Análisis del alcance de la cantidad de basura marina en Asturias mediante mapeo en las playas, empleando estrategias de muestreo por transectos. **Capítulos 1 y 3.**

  En estos artículos se ha planteado el objetivo de medir las cantidades de basura acumulada en las playas de Asturias, cuyos resultados mas notables son la presencia de basura en mayor o menor medida en todas las playas muestreadas a lo largo de la costa de Asturias, con predominancia de los plásticos y los restos de pesca.

- **Objetivo 3:** Determinación de las posibles fuentes de origen de la basura y de las causas ambientales y sociales de su depósito en las playas. **Capítulos 2 y 3.**

  En este artículo se ha planteado el objetivo de encontrar las fuentes de la basura marina encontrada en el litoral asturiano, cuyos resultados mas notables son que los puertos marítimos, ríos y aglomeraciones urbanas son las principales fuentes de basura marina en la región.

- **Objetivo 4:** Cuantificación de especies exóticas y/o potencialmente dañinas para los recursos naturales costeros, adheridas a la basura flotante de las playas asturianas. **Capítulos 1 y 3.**

  En estos artículos que se ha planteado el objetivo de cuantificar la presencia de especies exóticas invasoras en la basura y en la costa asturiana, cuyos resultados mas notables son la detección de especies invasoras asociadas a la basura marina y la relación de esta basura con la degradación ambiental y la invasión por hierba de la pampa (*Cortaderia selloana*)

- **Objetivo 5:** Evaluación del grado de conocimiento y concienciación ciudadana y de las partes implicadas respecto al tema de la basura marina y sus riesgos asociados. **Capítulos 2, 3 y 4.**

  En estos artículos se ha planteado el objetivo de medir el conocimiento y la concienciación de la población asturiana respecto a la basura marina y las invasiones biológicas, cuyos resultados mas notables son la determinación de una buena concienciación ciudadana en general aún con lagunas de conocimiento en algunos temas o por algunos grupos de población.

Capítulo 1

Alert calling in port areas:

Marine litter as possible secondary dispersal vector for hitchhiking invasive species

Miralles, L., Gomez-Agenjo, M., Rayon-Viña, F., Gyraitė, G., Garcia-Vazquez, E.

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Alert calling in port areas: Marine litter as possible secondary dispersal vector for hitchhiking invasive species

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ABSTRACT

Floating plastic debris, such as bottles and fishing gear, is a shelter for different species in the oceans. Litter may therefore help the spread of non-indigenous species (NIS). Here we have challenged the idea of using the abundance of marine litter present in a zone to estimate the risk of NIS introduction. To test this, a targeted sampling of plastic bottles and fishing gear (ropes and nets) was performed along 22 beaches from the Cantabrian coast where ports have been reported as a source of biological invasions. All items with attached organisms were collected and recorded. Genetic barcoding was used to ascertain the species and identify NIS. In total 17 species attached to plastic bottles and fishing gears were identified. Three of them, found on the two types of items, are catalogued as invasive species: *Austrominius modestus*; *Magallana gigas*; and, *Amphibalanus amphitrite*. Prevalence and mean intensity of non-indigenous biota on plastic bottles and fishing gear were not significantly different. The abundance of barnacles in litter was significantly correlated with that found from ports in the same region. The results suggest that ropes are able to transport different marine organisms and NIS as plastic bottles do. Monitoring biota on marine litter could serve as an additional tool for NIS detection.

1. Introduction

Marine debris in oceans has been recognized as a major concern in marine conservation (Sutherland et al., 2010). Much more than an aesthetic problem (Mouat, Lozano, & Bateson, 2010), marine debris has severe consequences for both sea life and human health (Gregory, 2009). The types and quantity of anthropogenic debris vary around the world, but plastic items represent a higher proportion everywhere and pose concerns due to their long life and harmful effects on marine life while they degrade (e.g. Gall & Thompson, 2015). Moreover, recent studies found significant amounts of fouling organisms on plastic debris (e.g.Gündoğdu, Çevik, & Karaca, 2017), as well as microfouling communities (Maso, Fortuno, de Juan, & Demestre, 2016). Other types of marine debris are also a matter of concern. Abandoned, Lost or otherwise Discarded Fishing Gear (ALDFG) have considerably increased over the last 50 years (Macfadyen, Huntinton, & Cappell, 2009). ALDFG made of natural materials such hemp, cotton or straw, take about 3–14 months to completely degrade in the water column; however, traditional fishing gears are increasingly replaced by modern gears made of stronger and cheaper modern materials that last much longer in the ocean. Abandoned nets can be in the ocean for years, travel long distances (Kaiser, Bullimore, Newman, Lock, & Gilbert, 1996). Plastic ALDFG represent a hazard for fish stocks and the marine environment (Macfadyen et al., 2009); animals can get trapped inside, a phenomenon known as ghost fishing, and many end up dying of suffocation when they cannot distinguish between ALDFG and preys (Kaiser et al., 1996). However, in general, marine litter studies are more focused on plastic and microplastic effects than ALDFG which were sometimes neglected (e.g. Dias & Lovejoy, 2012; Galgani, Hanke, & Maes, 2015, Galgani et al., 2015).

Debris provide a new habitat for marine species adding new surfaces for colonization by organisms (Gündoğdu et al., 2017; Harrison, Sapp, Schratzberger, & Osborn, 2011). When a species is carried outside their native distribution and start proliferating in non-native areas, it may cause severe environmental and economic damage (Colautti & Macssa, 2004). In the new habitat, the introduced non-indigenous species (NIS) individuals may compete for natural resources and space leading to a decrease of endemic species or even to their extinction (Gurevitch & Padilla, 2004). Therefore, the increase of biological invasions challenges biodiversity conservation (Simberloff et al., 2013). Ordered by abundance, the more common organisms living on marine trash are bryozoans, barnacles, polychaete worms, hydroids and mollusks

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(Barnes, Galgani, Thompson, & Barlaz, 2009), and precisely all these groups contain invasive species. Thus, floating objects are considered potential vectors of invasive species (Rech, Borrell, & García-Vazquez, 2016for a review), despite some studies about fouling biota on marine debris not detecting any invasive species (e.g. Aliani & Molcard, 2003; Gündoğdu et al., 2017). Regardless of the magnitude of the problem, data about organisms carried by marine litter are relatively scarce and concentrate on a few regions of the world like for example the Mediterranean Sea (Gündoğdu et al., 2017; Maso, Fortuno, de Juan, & Demestre, 2016; Aliani & Molcard, 2003). One of the gaps is the North Iberian coast (south Bay of Biscay); an increasing occurrence of NIS associated with maritime traffic in ports therein has been reported (Pejovic et al., 2015; Devloo-Delva et al., 2016; Miralles et al., 2016a). Ports are well known gates of biological invasions (e.g.Molnar, Gamboa, Revenga, & Spalding, 2008; Ardura, Planes, & Garcia-Vazquez, 2015), but the contribution of other types of vectors to the dispersal and establishment of NIS in the south Bay of Biscay is still unknown. Floating marine litter moves with the currents and can be a vector for regional dispersal of invasive species arriving to ports. If it was true, marine litter nearby ports should be prioritized for monitoring and removal, since it could be the origin of regional expansion of exotics otherwise enclosed in the ports. A comparison of biota carried by marine litter and biota associated with ports can help to address this issue. One of the most accurate methods to identify this biota is DNA barcoding. DNA barcodes (short DNA sequences that enable species identification) are useful tools to accelerate species-level analysis of marine biodiversity and to facilitate conservation and biosecurity efforts (Bucklin, Steinke, & Blanco-Bercial, 2011).

This study focused on metazoans attached to plastic bottles and fishing gear, as representative of two different litter types. DNA barcodes were employed to unambiguously identify the different species attached to these items, including NIS. Taking into account that the main regional entry of biological invasions through maritime traffic is the international port of Aviles, where several invasive species have been recently described (Pejovic et al., 2015; Devloo-Delva et al., 2016; Miralles et al., 2016a; Miralles, Dopico, Devlo-Delva, & Garcia-Vazquez, 2016b), we expect that the NIS found in ports would be carried further offshore by marine litter. Furthermore, the south central Bay of Biscay is under the influence of the eastwards Iberian Poleward current (Gil, 2003). Thus, the main objective of our study is to test if frequency of each NIS on litter items would be higher in the areas surrounding the ports and eastwards. For that reason, our departure hypothesis is that marine debris (in this case plastic bottles and ropes) can be a NIS dispersal vector in port areas.

2. Material and methods

2.1. Study area and sampling design

The study area was the coast of Asturias, north Spain, within the Cantabrian Sea (Bay of Biscay). This area is under the influence of the eastwards Iberian Poleward current, occurring at the beginning of every winter (Gil, 2003). Cape Peñas in the center of the coast divides it in two distinct geological and ecological zones, being more influenced by cold upwelling in the western area (e.g.Muñoz-Colmenero, Turrero, Horreo, & Garcia-Vazquez, 2012). Sampling was carried out during high-coefficient low tides, during the end of winter 2016 (February and March) well after the pass of the Iberian Poleward current (Gil, 2003).

Twenty-two beaches (Fig. 1) within the coastal region were analysed. Eight main ports within the same region were surveyed for metazoans (Miralles et al., 2016a). Four sub-areas were considered taking into account the Cape Peñas as a boundary between colder western and warmer eastern zones: the west side of Cape Peñas (beaches Verdicio, Xagó, Zeluán, San Juan de Nieva, Salinas, Bayas); the west adjacent area (Figueras, Arnao, Peñarronda, Navia, Barayo, Otur, El Silencio beaches); the east side of Cape Peñas (Bañugues, Xivares, Arbeyal, Peñarrubia beaches); the adjacent east area (Rodiles, Santa Marina, Poo, Andrín beaches).

Each beach was visited once. All plastic bottles and ALDFG were collected from the vegetation line to the waterline. In the largest beaches (Bayas, Salinas, Xagó and San Lorenzo) sampling was restricted to five meters above and five below the high tide waterline, since most marine debris were located therein. Ropes and nets were classified as natural (e.g. straw, esparto) or not-natural (plastic). Size was recorded of plastic bottles. All the items with attached biota were taken to the laboratory for further analysis.

2.2. Species taxonomy and status assignment

All attached metazoans were collected and preserved in ethanol at the Laboratory of Genetics of Natural Resources, University of Oviedo. Lindner (1978) taxonomic guide was employed for morphological identification of all samples to the lower possible taxonomic level. World Register of Marine Species (WoRMS - World Register of Marine Species, 2015) was followed for taxonomic nomenclature. Invasive species status was checked from the Global Invasive Species Database (International Union for Nature Conservation, http://www.iucngisd.org/gisd/search.php, accessed on April 2017). Up to 15 individuals per morphotype (presumably species) and item were genetically analyzed.

2.3. Genetic identification

Small pieces of muscle tissues of approximately 2 mm^3 were taken for DNA extraction following Estoup, Largiader, Perrot, and Chourrout (1996) protocol. The E.Z.N.A. Mollusc DNA Kit was employed for molluscs and crustaceans according to manufacturer's directions. DNA samples were stored at 4 °C for further analysis.

DNA amplification of a fragment of the cytochrome oxidase I (COI) gene was performed with universal primers jgLCO1490 and jgHCO2198 (Geller, Meyer, Parker, & Hawk, 2013). These primers anneal on DNA from a wide group of marine invertebrates belonging to different taxa (Geller et al., 2013). Minor modifications were applied from the PCR amplification protocol proposed by Geller et al. (2013). PCR mixtures contained 1x Taq buffer, 2.5 mM MgCl2, 2.5 mM dNTPs, 1 μM primer jgLCO1490, 1 μM primer jgHCO2198, 0.03 μ/μM Taq polymerase (Promega), 0.2 mg/ml BSA and 4 μl of isolated DNA; summing up a final volume of 40 μl. PCR products were resolved on 2% agarose gels stained with SimplySafe to confirm amplification before sequencing.

Amplification of the 18S rDNA was done following Miralles et al. (2016a) on specimens with no amplification of COI gene. PCR products were sent to the company Macrogen (Macrogen, 2016) for DNA sequencing.

All sequences were edited with BIOEDIT (Hall, 1999) software and contrasted with Bold Systems (BOLDsystems, 2015) and nBLAST software in NBCI (Coordinators, 2013) with online public databases BOLD (Ratnasingham & Hebert, 2007) and GenBank (National Center of Biotechnology Information, 2015) respectively. The threshold for species assignation was at least 97% nucleotide identity, maximum E-value = 1e-100.

2.4. Statistical analysis

The data were treated following epidemiological approach, considering marine litter as vectors of NIS (potential nuisance species). Prevalence was the proportion of bottles or ALDFG carrying NIS over the total number of items of each type. Mean intensity was the mean number of NIS individuals over the items with NIS.

Shapiro-Wilk test was employed to check normality in the dataset. Non-parametric Kruskal-Wallis test served to compare biota medians when normality was not assumed. IBM SPSS Statistics v.23 software was employed for these tests. Prevalence was compared between groups using Fisher exact test also available in the previously cited software.

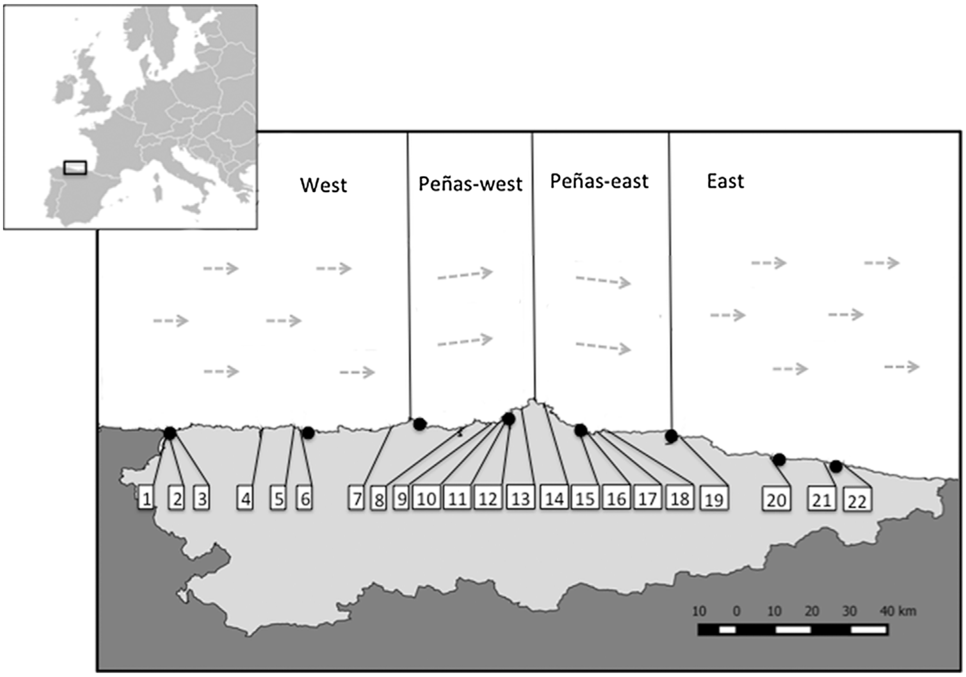

Fig. 1. Map of sampling locations: 1. Figueras, 2. Arnao, 3. Peñarronda, 4. Navia, 5. Barayo, 6. Otur 7. El Silencio, 8. Bayas, 9. Salinas, 10. San Juan de Nieva, 11. Zeluán, 12. Xagó, 13.Verdicio, 14. Bañugues, 15. Xivares, 16. Arbeyal, 17. San Lorenzo, 18. Peñarrubia, 19. Rodiles, 20. Santa Marina, 21. Poo and 22. Andrín. Ports are marked with a black circle and predominant direction of currents with grey arrows.

Diversity indices were calculated for the metazoans and the NIS. Species richness, Shannon and Simpson indices were obtained and compared using the software PAST (Hammer, Harper, & Ryan, 2001). Significance level: $\alpha = 0.05$.

3. Results

3.1. Marine debris on the shoreline

A total of 677 bottles were found from the sampled beaches (Table 1). In Santa Marina beach, a touristic place, 242 plastic bottles were found while in the small Zeluán beach 64 bottles were found, most of them located in the upper intertidal zone. In Playón de Bayas, 89 bottles were counted along 3 km. No bottles were found in Otur, San Lorenzo and El Silencio beaches, likely due to more frequent cleanings in the first two and because of relative geographical isolation and less visited El Silencio. In contrast more than 1000 ALDFG were found and at least one from each beach. They were principally ropes, all of them made of non-natural material (plastic or similar). As in the case of plastic bottles, their abundance varied among beaches, being more abundant in Xagó.

Eight bottles carried metazoans and were collected for biota study (Table 1). The prevalence of metazoans on bottles was 1.03% for the region, and varied between 25% in El Arbeyal to 0% in many of the studied beaches (Table 1). Adhered fauna was found on 18 ALDFG (Table 1) with a mean regional prevalence of 1.7%. Prevalence of biota was not significantly different between plastic bottles and ALDFG in the region (Fisher exact test with P = .232). Biota attached to the examined litter was not found in ten beaches (Arnao, Barayo, Otur, El Silencio, Salinas, San Juan de Nieva, Xivares, San Lorenzo, Santa Marina, Poo and Andrín).

At a larger spatial scale (i.e. coastal sub-area as described above) significant differences were found between areas for the proportion of items carrying attached biota, clearly less abundant at the east: 0.034, 0.013, 0.038 and 0.003 from east to west subareas (contingency Chi-square = 12.4599, P = .0059 for 3° of freedom).

3.2. Biota found on litter items

Most individuals were very small except for some gooseneck barnacles (*Lepas* sp.; Fig. 2). Individuals attached to six ropes were already dead and could not be genetically identified. From the remaining twelve ropes and the eight bottles with adhered fauna, a total number of 121 individuals were identified down to species level from genetic barcodes, corresponding to 17 species (Supplementary Table 1). Several mussels *Mytilus* spp. were identified only at genus level because BLAST and BOLD retrieved different species with exactly the same identity and coverage. A total number of 13 species were identified from COI gene and 4 from 18S rDNA. Barcode DNA sequences are available on

Table 1
Plastic bottles and ALDFG (ropes) in litter found from the beaches surveyed in south Central Bay of Biscay. Number of items (N), percentage of items with attached fauna (Biota carriers), status of such species (I for invasive, NIS for non-indigenous species, N for native, C for Cosmopolitan).

	Bottles			ALDFG - Ropes		
Beach	N	Biota carriers	Biota status	N (approx.)	Biota carriers	Biota status
Figueras	10	10%	NIS, N, I	10	10%	N
Arnao	8	–	–	7	–	–
Peñarronda	20	10%	C	60	3.33%	C
Navia	27	–	–	40	2.5%	N, NIS
Barayo	4	–	–	7	–	–
Otur	–	–	–	4	–	–
El Silencio	–	–	–	6	–	–
Bayas	89	–	–	200	1%	N
Salinas	3	–	–	50	–	–
San Juan de Nieva	43	–	–	150	–	–
Zeluán	64	1.56%	I	30	3.33%	N, NIS, I
Xagó	40	–	–	350	2.57%	C, N, NIS, I
Verdicio	24	4.16%	C	20	–	–
Bañugues	17	–	–	10	20%	N
Xivares	18	–	–	40	–	–
Arbeyal	4	25%	N	5	–	–
San Lorenzo	–	–	–	2	–	–
Peñarrubia	5	20%	C	3	–	–
Rodiles	10	10%	C	8	–	–
Santa Marina	242	–	–	25	–	–
Poo	7	–	–	3	–	–
Andrín	42	–	–	1	–	–

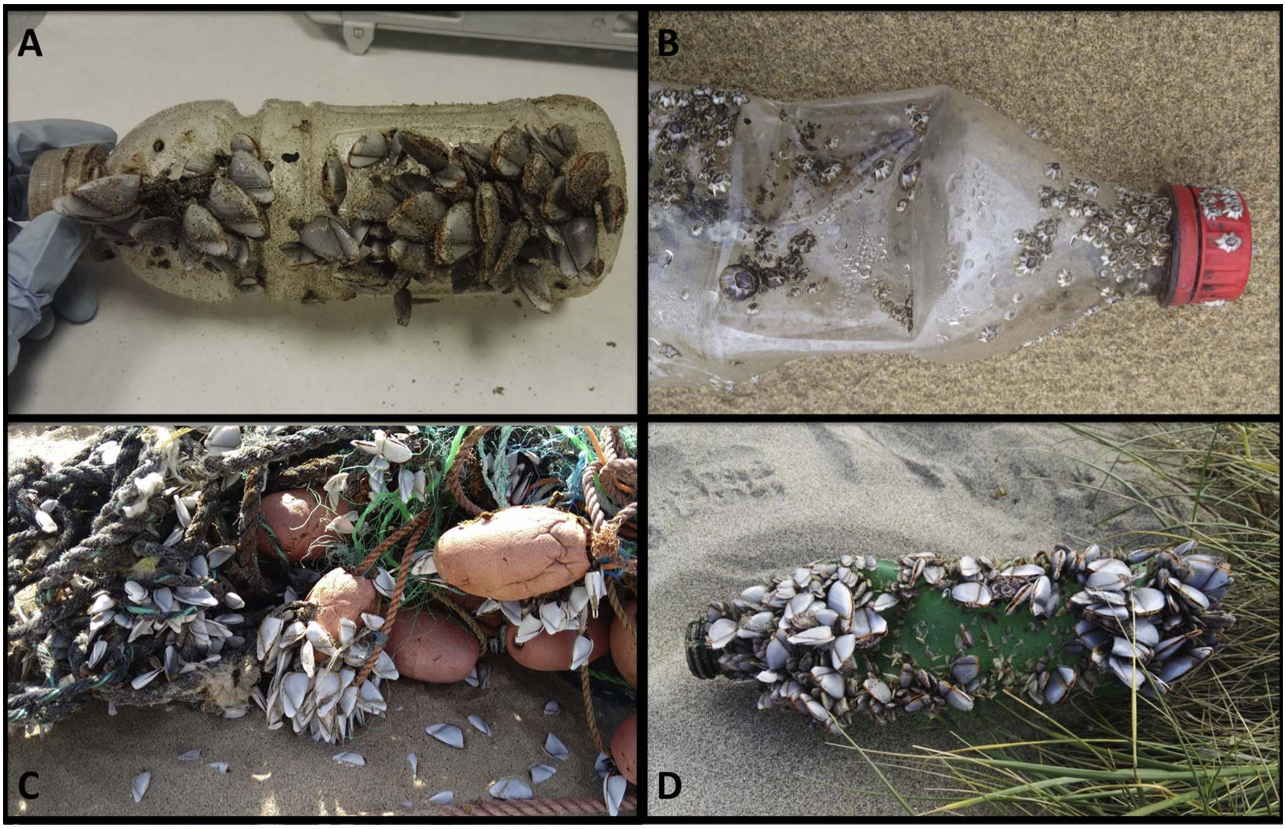

Fig. 2. Some examples of items (bottles and ropes) collected for the study. A. Bottle from Peñarronda Beach. Gooseneck barnacles *Lepas sp. (L. anatifera* and *L. pectinata)*. B. Bottle from Zeluán Beach. Barnacles (*Austrominius modestus* and *Amphibalanus amphitrite*). C. Ropes from Xagó Beach. Gooseneck barnacles *Lepas sp. (L. anatifera* and *L. pectinata)*. D. Bottle from Peñarronda Beach. Gooseneck barnacles *Lepas sp. (L. anatifera* and *L. pectinata)*.

GenBank database (https://www.ncbi.nlm.nih.gov/genbank/) under the accession numbers KY639386-KY639431 for COI gene and KY639432-KY639435 for 18S rDNA.

The species found on litter items in this study are listed in Table 2. More abundant species attached to bottles were cosmopolitan gooseneck barnacles *Lepas anatifera* and *Lepas pectinata* (Fig. 2A, C and D). Eight NIS out of 17 species were identified: *Amphibalanus amphitrite* (native to Indian and Pacific Ocean; Fig. 2B); *Austrominius modestus* (Australia; Fig. 2 B); *Magallana gigas* (Pacific Ocean); *Mytilus trossulus* (North Atlantic, North Pacific and Baltic Sea); *Eumida bahusiensis* (North Sea); *Neocasta laevigata* (Australia); *Neodexiospira nipponica* (Japan); and, *Paragorgia arborea* (North Sea). Three of these are catalogued as invasive species: *Amphibalanus amphitrite*; *Austrominius modestus*; and, *Magallana gigas*.

NIS prevalence for bottles and ALDFG was 0.0026 and 0.003, respectively. These values were not statistically significantly different (Fisher exact test with P = .900). The mean NIS intensity was 5.5 and 5.714 for bottles and ALDFG, respectively. Shapiro-Wilk test revealed

Table 2
Species attached to litter in the four areas considered within the region. Number of individuals found from the litter items analyzed and from ports of the same regions as in Miralles et al. (2016a). In bold, non-indigenous species for the region. Invasive species as in IUCN Global Invasive Species List are marked with **.

			West		Peñas-west		Peñas-east		East		Total region	
			Port	Litter	Port	Litter	Port	Litter	Port	Litter	Port	Litter
Crustacea	Cirripedia, Sessilia	***Amphibalanus amphitrite*** **	0	0	4	14	0	0	1	0	5	14
		Austrominius modestus **	3	0	1	8	0	0	11	0	15	8
		Perforatus perforatus	1	1	0	0	2	0	0	0	3	1
		Chthamalus stellatus	0	0	0	0	0	3	6	0	6	3
		Neoacasta laevigata	0	1	0	1	0	0	0	0	0	2
	Cirripedia, Pedunculata	*Lepas anatifera*	0	23	0	16	0	1	0	0	0	40
		Lepas pectinata	0	8	0	3	0	8	0	15	0	34
	Malacostraca, Decapoda	*Pachygrapsus marmoratus*	0	0	0	1	0	0	0	0	0	1
		Polybius henslowii	0	0	0	1	0	0	0	0	0	1
Mollusca	Bivalvia, Ostreoidea	***Magallana gigas*** **	1	1	0	7	0	0	44	0	45	8
	Bivalvia, Mytiloida	*Mytilus edulis*	3	1	0	1	0	1	0	0	3	3
		Mytilus galloprovincialis **	20	1	0	0	10	0	16	0	46	1
		Mytilus trossulus	5	0	0	1	4	0	4	0	13	1
	Gastropoda, Neogastropoda	*Tritia reticulata*	0	1	0	0	0	0	0	0	0	1
Annelida	Polychaeta, Phyllodocidae	***Eumida bahusiensis***	0	0	0	1	0	0	0	0	0	1
	Polychaeta, Sabellida	***Neodexiospira alveolata***	0	1	0	0	0	0	0	0	0	1
Cnidaria	Anthozoa, Alcionacea	***Paragorgia arborea***	0	0	0	1	0	0	0	0	0	1

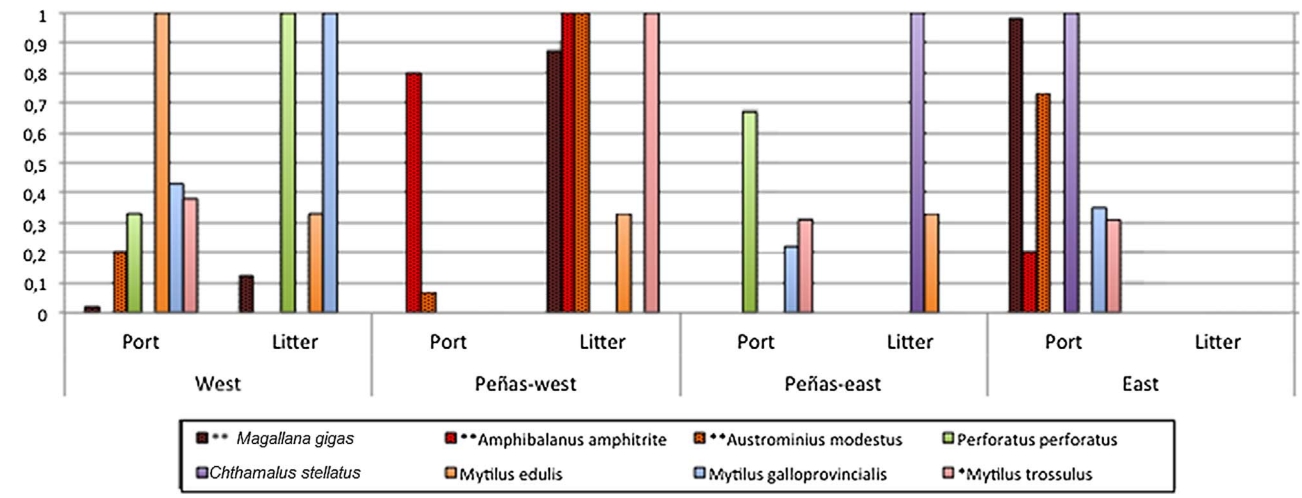

Fig. 3. Species found in common from ports and marine litter in the four coastal areas considered within south central Bay of Biscay. Invasive species as in IUCN Global Invasive Species List are marked with **; non-indigenous species are marked with *.

that NIS on bottles and ALDFG did not follow a normal distribution (P-value = .001). Non-parametric Kruskal-Wallis test provided a value of 7 with 7 d.f. and P = .429. Thus no significant differences in NIS mean intensity were found between bottles and ALDFG in this study, and the biota from the two types of items was considered together in further analyses. At item level, it was a significant negative correlation between the number of native and the number of NIS individuals (r = −0,6101, P = .004).

Not all the metazoans found on litter in this study had been found from ports (Table 2). Nine species were found only on marine litter, and included the NIS *Neocasta laevigata, Eumida bahusiensis, Neodexiospira alveolata* and *Paragorgia arborea*. The eight species in common between the present dataset and the port dataset obtained by Miralles et al. (2016a) were four barnacles and four bivalves, and included two invasive barnacles (*Austrominius modestus* and *Amphibalanus amphitrite*) and the globally invasive Japanese oyster *Magallana gigas* in addition to the NIS *Mytilus trossulus* (Fig. 3). Although not all the species present in ports were found attached to marine litter in the same subarea, in all the cases the species found on litter occurred in the same area or to the east of ports with the same species. Excluding the easternmost subarea where marine litter was less abundant and the eight species were absent, significant correlation was not found between the number of individuals of each species detected from ports and marine litter in the same subarea (r = 0.004, 22 d.f., P = .98). However, for barnacles positive significant correlation was found between the number of individuals of each species found from ports and from marine litter in the same subarea (r = 0.616, P = .032). For bivalves, however, such correlation was not significant and even negative (r = −0.177, P = .582) probably due to much higher frequency of *Mytilus* species in the ports while they were scarce on litter items.

4. Discussion

Marine debris (in this case plastic bottles and ropes) can act as a NIS dispersal vector in port areas of the Asturian coast (south Bay of Biscay). Furthermore, the hypothesis of metazoans travelling eastwards attached to marine litter in the present study would just work for barnacles, but not for all the species. For bivalves other sources of propagules of exotic species such as aquaculture are well known within the studied region (Tesfamariam Habtemariam, Arias, García-Vázquez, & Borrell, 2015; Semeraro et al., 2016). Thus, the relative impact of marine litter in their dispersal is likely to be much smaller than for barnacles which are mainly transported via maritime traffic or attached to floating devices.

The results of the present study revealed high diversity of metazoans, as well as of NIS, on ALDFG. The prevalence and intensity of rafting biota on ALDFG was similar to that on plastic bottles in south Bay of Biscay. Although the prevalence of biota on both types of litter was similar, higher diversity of rafting biota may encompass higher risk of further biological invasions. Studies relating to marine debris types with rafting species are still scarce, especially for fishing gear (Dias & Lovejoy, 2012), and our results contribute to addressing this knowledge gap. Cosmopolitan species such as goose barnacles were the most abundant organisms recorded in both types of items. Goose barnacles of *Lepas* genus are thought to be the most abundant animals attached to marine debris (Barnes, 2002), and our results supported that. These individuals enhance the settlement of other hitchhiking species, such as barnacles or mussels (Astudillo, Bravo, Dumont, & Thiel, 2009), through interactions like mutualism. Nevertheless, in the present study plastic bottles with *Lepas* did not contain any other attached fauna (Fig. 2), probably because they were not in the water column for long enough to allow other species to establish. The relationship between surface and number of fouling individuals could also be a matter of concern. Although not assessed in our study, according to Fazey & Ryan (2016), and Gündoğdu et al. (2017), there are strong relationships between surface area and number of fouling organisms.

Regarding the NIS detected in this study, *Amphibalanus amphitrite, Austrominius modestus* and *Magallana gigas* were found adhered to marine litter in other regions (Barnes & Milner, 2005). According to Winston, Gregory, and Stevens, 1997) these three species are usual hitchhikers of plastic surfaces which promote their worldwide spreading process. Furthermore, *Crassostrea gigas* has been reported as settling over mussel's beds due to their gregarious behavior (Cadée, 2001; Fey, Dankers, Steenbergen, & Goudswaard, 2010; Wolff & Reise, 2002); it occurred here in ropes from Zeluán and on a bottle from Figueras. However, within this study aggregations of NIS and native species were not frequent on the marine litter; on the contrary, significant negative correlation was found between NIS and native species. This phenomenon has been found at much larger scales on natural and artificial substrates and calls for ecosystem resilience against biological invasions due to native species richness (e.g. Byers & Noonburg, 2003; Fridley et al., 2007; Miralles et al., 2016a). It might also happen on litter items, and again emphasizes the value of protecting native biodiversity in all types of settings, as a possible source of resistance against invasions. This comparison should be taken with caution, since it is a small sample of items with adhered species and further studies would be needed to confirm these findings.

A drawback of the barcoding methodology employed here was the lack of adequate resolution for the genus *Mytilus*. These highly adaptive mussels have their shell shape conditioned by the surrounding environment (Inoue, Waite, Matsuoka, Odo, & Harayama, 1995), which makes it hard to differentiate individuals without molecular techniques. However, these species hybridize commonly in the wild and hybrids occur also in the study region (Crego-Prieto et al., 2014), hampering the use of mitochondrial markers for species identification. *Mytilus* individuals were found in both types of items, bottles and fishing gear. Taking into account that although native here, *Mytilus galloprovincialis,* is an invasive species (ISSG - Invasive Species Special Group, 2016), marine debris could act as a spreading vector if the objects found here with *Mytilus* reached other coasts. Regarding the NIS *Mytilus trossulus* found in this study, the species was recently reported from Asturias ports (Miralles et al., 2016a). It coexists with *Mytilus edulis* in the Baltic Sea and Canadian Atlantic coast (Innes & Bates, 1999), and hybridizes with *Mytilus galloprovincialis* (Hilbish et al., 2000). Barcoding approach for early detection of invasive species is a useful tool from the point of view of biosecurity (Pejovic et al., 2015), but its implementation should be improved with more barcodes, more accurate databases with reference voucher individuals, and a better knowledge of the relationships between closely related species.

As a final remark, there is an urgent need for more studies about the potential relationship among non-indigenous organisms and marine debris. Our study contributes to the still modest group of investigations demonstrating the increasing relationship among biological invasions and floating debris in the ocean. Although focused on two types of possible marine litter (ALDFG and plastic bottles), in general NIS found here on marine litter matched those from ports, but some NIS not detected in ports were found attached to litter items, for example one barnacle, two polychaetae and one anthozoan. Taking into account that our results and number of identified taxa were comparable to other recent studies (e.g. Aliani & Molcard, 2003; Gündoğdu et al., 2017) it could suggest that surveying biota attached to marine litter might be a way of detecting the arrival of NIS. Despite the fact that sources of litter can be difficult to identify, in all cases litter is linked in some way to human activities as well as ports, which provide gateways for marine invasions. Prioritizing this type of survey in areas nearby ports, harbors, and marinas should be recommended for early control of marine biological invasions.

5. Conclusions

This study confirms that NIS expansions could be reinforced by the presence of manufactured objects in the sea, such as plastic bottles and fishing gear. For the first time in North Iberia, the issue of marine litter as carrier vector of NIS has been tackled. Barnacles from Australia, *Austrominius modestus*; Pacific oysters *Magallana gigas*; the potentially invasive barnacle *Amphibalanus amphitrite*, and other 14 species were found attached to plastic bottles and fishing gear, in particular ropes. Barnacles attached to marine litter were significantly correlated with the abundance of the same species in ports. More efforts for controlling litter disposal are needed in this region to prevent expansion of NIS.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jnc.2018.01.005.

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Capítulo 2

Marine litter in south Bay of Biscay: Local differences in beach littering are associated with citizen perception and awareness

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Marine litter in south Bay of Biscay: Local differences in beach littering are associated with citizen perception and awareness

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ABSTRACT

Marine litter is often left by beachgoers. Thus, understanding beachgoers' perception and awareness is important. In this study, the amount and type of litter was measured from nine beaches of central south Bay of Biscay (Spain), and a survey about perception and awareness of the beach littering was conducted among beachgoers. The region could be considered moderately littered compared with other studies, with significant differences among beaches for litter amount and types. Plastic was the most abundant item, followed by fishing gear. Differences among beaches for awareness and litter perception correlated significantly with differences in litter amount. Perception was positively correlated with beach frequentation. Significant gender differences were found, males taking more actions against litter than females regardless how much litter they perceived. These results could be employed for designing campaigns of beach litter treatment and awareness raising, by taking into account local differences detected in this study.

1. Introduction

Marine litter is defined as all solid materials of anthropogenic origin that are discarded at the sea or reach the sea. This contamination is considered, after the habitat loss, one of the biggest threats to marine biodiversity (Goldberg, 1995; Santos et al., 2005). It has diverse origins: recreational and tourism-related litter, abandoned fishing gear, sewage-related debris and shipping waste are the main sources (Somerville et al., 2003), as well as ship discharges (Ryan et al., 2009; Dias and Lovejoy, 2012). Also, other important factor that affects litter abundance is the river proximity (Rech et al., 2014), especially taking into account tides and currents.

Plastic is the main component of marine litter, probably because it is an abundant, cheap material with many uses (Ribic et al., 1992; Derraik, 2002; Gregory, 2009; Dias and Lovejoy, 2012; Ryan et al., 2009; Pham et al., 2014). In 2014 > 250.000 tons of plastic were reported in sampling from seas all over the world (Eriksen et al., 2014). Its prevalence at sea is enormous. For example, in 2010 between 4.8 and 12.7 million metric tons (MT) reached the oceans all over the world (Jambeck et al., 2015). Plastic objects do not decompose as natural polymers do, but degrade into smaller pieces (microplastics) that are dangerous for the environment and could enter the food chain (Martins and Sobral, 2011; Browne, 2015; Jambeck et al., 2015). Other type of litter frequently found at sea is abandoned, lost or otherwise discarded fishing gear (ALDFG), which abundance has much increased over the last decades and is expected to be associated with ports and aquaculture areas (Moore and Allen, 2000; Lee et al., 2006; Macfadyen et al., 2009; Hong et al., 2014). Rivers are other potent vehicle of litter that ends at sea and is deposited on the coast depending on tides and currents (Rech et al., 2014; Löhr et al., 2017).

Marine litter is harmful for wildlife. There are many examples of animals suffocated, smothered, entangled, immobilized due to plastics and other litter floating in the sea (Gregory, 2009; Williams et al., 2011; Paleczny et al., 2015; Sarafraz et al., 2016). Many of them die after eating plastics (Laist, 1987; Somerville et al., 2003; Gregory, 2009), and even when it is not lethal, plastic ingestion reduces food intake capability, jeopardizing animal development, and its partial digestion can be toxic (Derraik, 2002; Gregory, 2009; Williams et al., 2011; Browne, 2015). Regarding the ecosystem diversity, floating litter is a potential vector for the introduction of invasive species attached to it (Barnes, 2002; Barnes and Milner, 2004; Gregory, 2009; Dias and Lovejoy, 2012; Gil and Pfaller, 2016; Rech et al., 2016). From the human point of view, there are also many problems with marine debris. Landscape degradation due to litter accumulation is aesthetically unpleasant, driving to a decrease of tourism and subsequent income fall (Somerville et al., 2003; Nijkamp et al., 2008; Roca and Villares, 2008; Sarafraz et al.,

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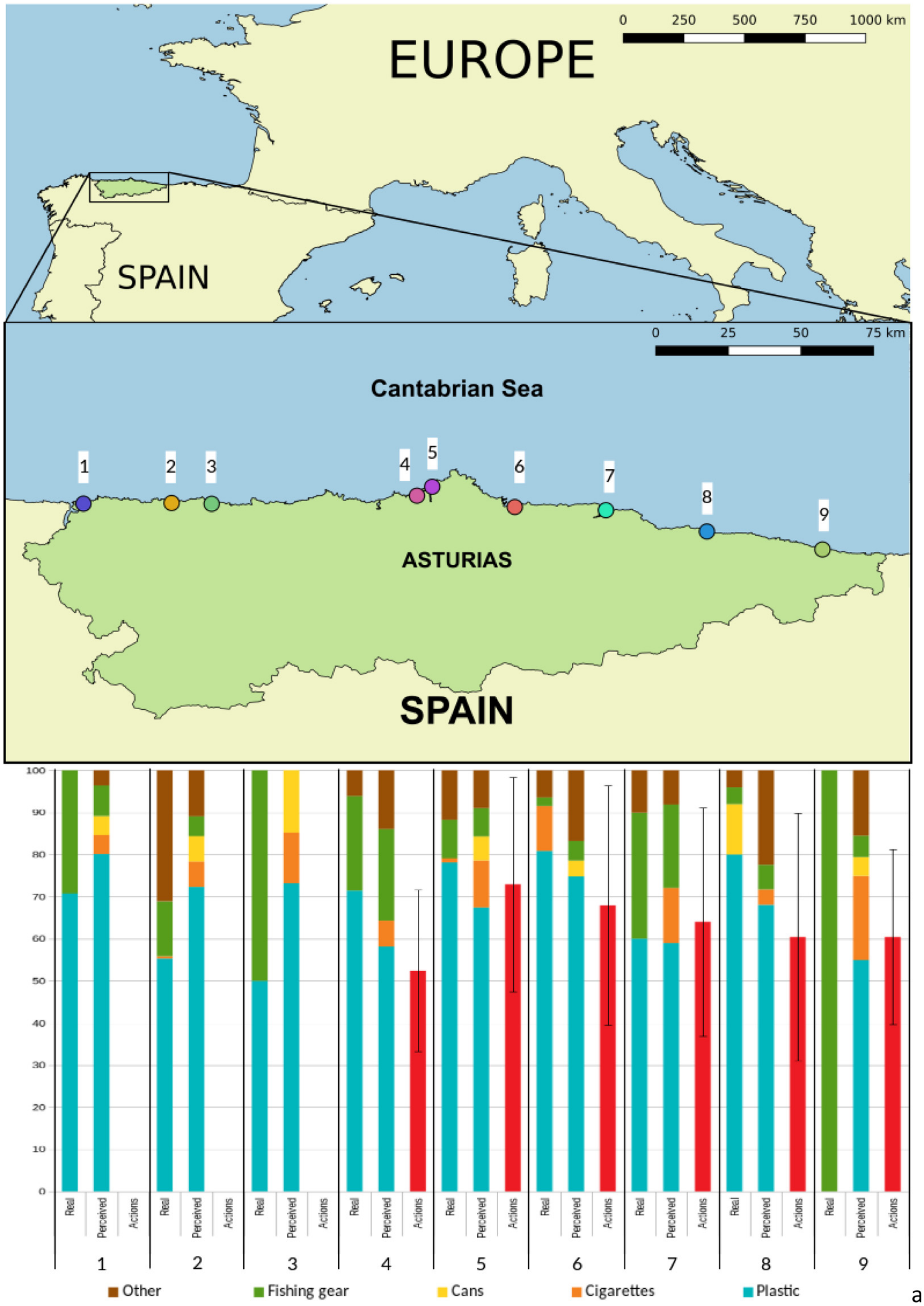

Fig. 1. Above: Location of the sampling beaches (1, Peñarronda; 2, Otur; 3, Navia; 4, Salinas; 5, Xagó; 6, San Lorenzo; 7, Rodiles; 8, Santa Marina; 9, Andrín) in Asturias region. Below: Graph showing the proportion of different types of litter (Real), their perception by beachgoers (Perceived), and mean score (×50), with standard deviation as vertical bars, of declared actions taken by the beachgoers (Actions), by beach.

2016). Off-coast litter often gets entangled with fishing gears, negatively affecting the fisheries sector, in addition to the direct effect on the fishing target species (Newman et al., 2015; Rochman et al., 2015). Last but not least, some authors have related coastal debris with human security and health problems (Thompson, 2015; Keswani et al., 2016).

All litter (including marine litter) is of anthropogenic origin (Galgani et al., 2015). Thus, humans are the main agents that can stop the problem. In the case of the coastal debris, for example, beachgoers may generate marine litter and at the same time are affected by it (Santos et al., 2005). It is well known that an increment of public awareness drives to a reduction of littering (Rees and Pond, 1995), and involving all the actors is sought to efficiently address this problem (Löhr et al., 2017). Beachgoers and other users of the coast have a role in decision making, because their opinions and demands will be taken into account by politicians, managers and the public administration (Hastings and Potts, 2013). For managers, knowing public perceptions

Table 1
Density of litter sampled (items/m^2) and factors that can affect litter occurrence in the beaches considered. The column "Stress" is the number of stressors (no protection status, no cleanings, no trash bins, river and/or port nearby).

Beach	Status	Cleanings	Trash bins	River	Port	Stress	Litter					
							Plastic	Cigarettes	Cans	Fishing gear	Other	Total items
Peñarronda	Protected	Yes	No	No	No	1	0.0393	0.0000	0.0000	0.0162	0.0000	0.0554
Navia	Unprotected	Yes	Yes	Yes	Yes	3	0.9368	0.0105	0.0000	0.2211	0.5263	1.6947
Otur	Unprotected	Yes	Yes	No	No	1	0.0062	0.0000	0.0000	0.0062	0.0000	0.0123
Salinas	Protected	Yes	Yes	No	Yes	1	0.0633	0.0000	0.0000	0.0199	0.0054	0.0886
Xagó	Protected	No	No	Yes	Yes	4	0.5592	0.0070	0.0000	0.0662	0.0836	0.7160
San Lorenzo	Unprotected	Yes	Yes	Yes	Yes	3	0.0751	0.0099	0.0000	0.0020	0.0059	0.0929
Rodiles	Protected	Yes	Yes	Yes	No	1	0.0073	0.0000	0.0000	0.0036	0.0012	0.0122
Santa Marina	Unprotected	Yes	Yes	Yes	Yes	3	0.1316	0.0000	0.0197	0.0066	0.0066	0.1645
Andrín	Protected	Yes	No	No	No	1	0.0000	0.0000	0.0000	0.0059	0.0000	0.0059

is important for designing management policies satisfactory for the users (Gutrich et al., 2005). Analyzing public knowledge leads to real improvements in environmental management (Marin et al., 2009). In the particular case of the coastal litter, it has been demonstrated that knowing public perceptions is useful for establishing administrative priorities (Santos et al., 2009). For example, littering behavior of the beachgoers has been related with how littered a beach is, since some people seem to assume it's acceptable littering an already littered place (Sibley and Liu, 2003).

For all the reasons above, it is increasingly necessary to acquaint public perception, knowledge and awareness about the problem of marine litter (Hartley et al., 2015). The perception of marine litter differs among people, especially for hardly visible or small objects (Lavers et al., 2016). It does also depend on socio-demographic factors, such as age, income level and educational background (Gutrich et al., 2005; Santos et al., 2005; Arafat et al., 2007; Marin et al., 2009; Slavin et al., 2012; Jefferson et al., 2014). Gender differences regarding litter perception and management have been found in some studies, with a higher level of awareness in females (e.g. Zelezny et al., 2000; Al-Khatib et al., 2009; Chen et al., 2011; Adebo and Ajewole, 2012; Slavin et al., 2012; Babaei et al., 2015). To engage society in environmental issues, these differences should be taken into account by environmental managers (Hartley et al., 2015).

The OSPAR Commission report (2010) reflected marine debris as a threat to marine environments and prompted more research and efforts to diminish marine littering. Spain, as a signatory of the convention, has a responsibility here. Despite its relevance and importance for management, studies on public perception about marine litter are scarce in the Iberian coasts and completely absent in the north coast of Spain (Williams et al., 2016). This area is especially interesting because, unlike other Spanish coasts, these are still relatively unmodified and some of them have marine spatial protection status, such as the Zones of Special Conservation ES1200006 in Villaviciosa estuary and ES1200055 around Cape Peñas (Natura 2000). Exotic species attached to marine litter items have been reported from the region (Miralles et al., 2018), making this studies about coastal trash especially urgent. In the present study, we measured the current littering state of the beaches in the central part of the south Bay of Biscay coast, and investigated if there was a relationship between beach littering and the knowledge/awareness of the beachgoers about marine litter. The departure hypothesis was a positive correlation between beachgoer awareness and beach litter perception. Also it's expected that women perceived beach littering better than men, thus they would be more aware. Finally, a positive correlation between the frequency of visits and the attitudes towards the marine debris is expected too.

2. Material and methods

2.1. Ethics statement

In the social survey, data confidentiality was ensured. All surveys were anonymous. Participants were not photographed and voices were not recorded to respect privacy. This study was approved by the competent Research Ethics Committee of the Principality of Asturias with reference 100/16.

2.2. Study location

Nine beaches distributed along the coast of Asturias (central south Bay of Biscay; NW Spain) were considered (Fig. 1). From west to east: 1) Peñarronda (GPS coordinates 43.5537, −6.9963), 2) Navia (43.5557, −6.7225), 3) Otur (43.5535, −6.5977), 4) Salinas (43.5787, −5.9581), 5) Xagó (43.6038, −5.9196), 6) San Lorenzo (43.5415, −5.6556), 7) Rodiles (43.5341, −5.3808), 8) Santa Marina (43.4658, −5.0710) and 9) Andrín (43.4109, −4.7084). They were selected for their relatively high affluence of beachgoers, similar accessibility and wave exposure. Several of these beaches are located inside protected spaces within Natura 2000 network: the Special Protection Area from Ría de Ribadesella to Ría de Tinamayor (Natura 2000 ES0000319), compromising beach of Andrín; the Special Protection Area of the Ría de Villaviciosa (Natura 2000 ES1200006) and the Partial Natural Reserve of the Ría de Villaviciosa (BOPA 61/1995, of 27 of April), compromising the beach of Rodiles; the Special Protection Area from Cabo Busto to Luanco (Natura 2000 ES1200055), compromising the beaches of Xagó and Salinas, the Protected Landscape of Cabo Peñas (BOPA 20/1995, of 12 of May), compromising the beach of Xagó; and the Natural Monument of the beach of Peñarronda (BOPA 126/2002, of 24 of October), compromising the beach of Peñarronda.

Sampling sites differed in stressors contributing to litter accumulation and mitigation factors which could reduce the probability of litter deposition (Table 1). As mitigation factors we considered: protection status, cleanings performed on the beach and trash bins presence. Expected litter donors (stressors) are ports (Moore and Allen, 2000; Lee et al., 2006; Hong et al., 2014) and rivers (Rech et al., 2014; Löhr et al., 2017). Here, we considered rivers located at a distance of 5 km or less at the west of the sampled beach because marine currents go eastwards in this area of Bay of Biscay coast (Garcia-Soto et al., 2002), and the same for ports (< 5 km distance at west). The vicinity to human settlements, although differing among beaches, was not considered because its role as a stressor (due to expectedly higher affluence of visitors) or a mitigation factor (due to a higher control of dumping) is not clear. Mitigation factors associated to the distance to settlements are beach cleanings and the presence of trash bins, that were considered directly. The presence of a stressor (river, port) and the absence of a mitigation factor (protection status, cleanings, trash bins) accounted for stress. The level of stress of a beach was calculated as the sum of stressor's presences plus the sum of mitigation factor's absences, with a possible minimum of 0 (far from rivers and ports, protected area, occurrence of cleanings, trash bins in the beach) and a maximum of 5 (absence of trash bins, no cleanings, no spatial protection, port and river closer than 5 km west).

2.3. Litter sampling protocol

Two to nine transects per beach (depending on the beach size) were randomly traced to measure litter quantity and type on the beach. They were 1 m wide, spaced 250 m to each other. Each transect went from the water line to the green line around the low tide, following the protocol developed by Velander and Mocogni (1999) and employed by Hong et al. (2014). A GPS and a 5 mW (3R Class) laser attached to a tripod were employed to trace transects. Litter sampling started 2 h before and ended 2 h after the low tide.

Litter sampling was carried out in February–March 2016. The beaches in this region are not cleaned during the winter, except in very rare cases of dumping, thus by the winter end we can have a clearer image of the real litter deposition on a beach. All items bigger than 2.5 cm were collected and classified by composition and size. After recording the data, the litter objects were disposed in trash containers for recycling.

2.4. Social survey

To measure the attitudes towards the marine litter, a simple open answer questionnaire was developed, addressed to beachgoers. In this region the beaches are frequently visited by locals for walking, sporting, playing and sport fishing, quite often on a daily basis weather permitting.

A pilot test containing a suite of eight questions was conducted to check for clarity and content validity. Ten experts were asked to examine and critically evaluate each question for its relevance, comprehensibility and easy to answer. Appropriate improvements were done following their advice. The five final questions (two of them formulated as multi-items) with better qualification were selected. After making the proposed changes, they were approved with total expert agreement.

After validating the questionnaire, a survey was conducted from March 24th to April 2nd 2016 in the nine beaches described above. The surveys were performed those dates because they coincided with Easter time, the beaches were still not daily cleaned, and the combination of regional holidays and weather improvement makes more locals to visit the coast. In each beach, beachgoers were politely intercepted and anonymously surveyed after obtaining their permission.

The validated questionnaire was administered face-to-face, individually, for about 5 min per participant. For description of the participant (never identified by name to respect anonymity) the following data were collected: **gender**; **age**, then classified by age groups: 18 to 30, 31 to 50 and > 50; and **beach frequentation**, where the participants were asked how often they visited the beach in the last year. For the latter, answers were classed in three groups: ***low***, from one to 12 days per year (once a month); ***medium***, from 12 to 52 days per year (once a week); and ***high*** from 52 to 365 days per year (everyday).

The five open answer questions were:

1. *How much litter do you perceive in this beach?*
2. *Which do you think is the most abundant litter type in this beach? – for five litter types: plastics, cans, cigarette butts, fishing gear, others.*
3. *What do you think is the more common origin of the litter in this beach? – with four different options, not mutually exclusive: sea, river, beachgoers, other.*
4. *What do you do to avoid litter in this beach?*
5. *When you go to the beach, do you bring bags or containers with you to take your litter away?*

Question 5 was posed because many beaches in the region do not have trash disposal facilities such as litter bins or containers, and for not littering the beachgoer has to take the trash with him/her for disposing it elsewhere.

The answers were recorded in writing and shown to the participant for confirmation.

Questions 1 and 2 served to estimate the level of perception about the littering status of each beach, and questions 4 and 5 reflected the awareness of the participants. Question 3 served as an internal control for test validity, since the answers in different sub-items should be negatively correlated to each other.

2.5. Data analysis

All litter objects found from the beaches were classified into 17 types: five size classes of plastic fragments (macroplastics: 2.5–5 cm, 5–10 cm, 10–15 cm, 15–20 cm and > 20 cm), expanded polystyrene fragments, bud sticks, plastic bags, plastic bottles, other plastics, fishing gear (ALDFG), cans, sanitary pads, cigarettes, fabric pieces, metal scraps and undefined debris. Litter density in each beach was calculated dividing the number of objects by the surface sampled and the result given as items per square meter. For further analyses the litter data were grouped in five main categories: plastic litter (all plastic items), cigarettes, cans, fishing gear, and other (the rest of the categories). Regarding the considered factors that contribute to accumulate or mitigate coastal litter in the studied beaches, each of the stressors (presence of rivers and ports nearby) and the absence of each mitigation factor (no protection status, no cleanings, no trash bins) was counted as 1 (maximum stress score per beach = 5; minimum = 0, as explained above).

Distribution normality of the considered variables was first checked using Shapiro-Wilk W test, and the appropriate non-parametric tests (the variables significantly differed from normality) were employed in further analysis. Correlations between the stressors and the litter densities were first explored with a Kendall's Tau-b correlation matrix. The type of litter affected by the stressors and mitigation factors influencing the analyzed beaches was determined from a Multivariate Linear Regression model. Differences in litter density among groups of beaches (categorized by the stressors i.e. presence of port, river, absence of cleanings and trash bins, no protection status) were analyzed through two-way permutation multivariate analysis of variance (PERMANOVA) using Bray-Curtis similarity index as distance measure.

The questionnaire content validated from experts had a final CVR (content validity ratio) of 1 for the selected items. Questionnaire answers were transformed to 1–5 Likert scales as it follows. First, all the answers given to each of the open question were grouped according to their similarity, then the groups were ranked from maximum to minimum, and categorized as a Likert scale. This was inspired in the methodology of the University of St Andrews CAPOD (2016), as done by Sharp et al. (2011) for statistical analysis. As an example, the answers to Question 1 (How much litter do you perceive in this beach?) could be: “Too much, it's the worst”, “It is disgusting how much litter I see”, “This beach is very, very dirty”. These would be scored as 5. If they were: “I can see quite a lot of litter”, “This beach has much litter”, “It has much litter but is not the dirtiest in the region”, they would be scored 4; and so on.

Question 1 was ranked from 1 (No) to 5 (A lot) reflecting the level of littering perception. For question 2, the abundance reported by the participant for each type of litter scored between 1 and 5, 5 and 1 being the most and least abundant types respectively. The answers to the question 3, the believed origin of the marine litter, was scaled in five levels: from 4, most probable origin, to 1, least probable origin, with 0 for not recognized as a potential origin. The answers to question 4 were categorized in three levels: 0, no actions; 1, not leaving litter after me; and 2, active beach cleaning. Answers to question 5 were categorized in two levels: 0, no (carrying bags for litter); and 1, yes. For the quality of the actual survey data, a Cronbach Alpha test was performed.

A correlation matrix was created using a Kendall's Tau-b index to find possible pairwise relationships between the answers to questionnaire items. A Multiple Linear Regression model was performed to identify significant drivers of the dependent variables "litter perception", "taking actions against litter" and "carrying a litter bag", with the density of litter and of each type of litter as independent variables. Finally, one-way PERMANOVA with Bray-Curtis similarity index was done to check the effect of participant's characteristics (age, gender or beach frequentation) on "litter perception" and "taking actions against litter".

Bonferroni correction for multiple comparisons was applied whenever relevant. All statistical analyses were done with the PAST 3.18 statistic software (Hammer et al., 2001).

3. Results

3.1. Beached litter

In the litter sampling we covered a total of 3467 m^2 all over the nine beaches (Fig. 1). The most littered beach was Navia (1.695 items/m^2) and the least Andrín (0.006 items/m^2), with an average of 0.316 and a standard deviation of 0.563 items/m^2 (Table 1).

Plastics were by far the most abundant items (64%), including polystyrene and hard plastic fragments, caps/lids, bags and swab sticks. Small 2.5–10 cm fragments represented 70% of the plastic samples (Supplementary Table 1). The next category in abundance was fishing gear (12%), including nets, buoys and fishing lines. Cigarettes and cans were found only from a few beaches. The general composition of litter differed among beaches (Fig. 1); for example, Andrín (beach #9) had only fishing gear while this type of litter was very scarce in Santa Marina and San Lorenzo (beaches #8 and #6 respectively in Fig. 1). Indeed, beaches did show significant differences in total litter composition (Pearson's χ^2 test of goodness of fit = 72.00, degrees of freedom d.f. = 64, P < 0.00001).

The Kendall's Tau-b correlation matrix (Supplementary Table 2) showed a significant positive relationship between the total litter density and the number of stressors (T_b = 0.7298, P = 0.0062). Multivariate linear regression model with the density of the different litter types as dependent variables did reveal the sum of stressors was a significant driver of the density of macroplastics and cigarettes (Table 2).

Two-way PERMANOVA analysis with river and ports as factors showed that the total litter density differed significantly due to the presence of ports (F = 2.412, d.f. = 1, P = 0.022); while significant effect of the rivers or significant interaction was not found (F = −27.002, d.f. = 1, P = 0.989; F = 0.969, d.f. = 1, P = 0.188 respectively). The presence of trash bins and the protection status did not provide significant differences for litter density (data not shown). On the other hand, the proximity of ports did influence significantly the total litter density, but not the density of any of the item types considered independently (data not shown).

The data of beach litter found in the present study, compared with examples of other regions in different areas of the world, suggested a moderate state of littering on the beaches, with some exceptions (Table 3).

Table 2
Results of the Multivariate Linear Regression model with the stressors as independent and the density of different litter types as dependent variables. Significant P-values are marked with asterisks.

Variable	Slope	Error	Intercept	Error	r	p
Plastics	0.1788	0.0746	−0.1555	0.1723	0.6714	0.0477*
Fishing gear	0.0259	0.0197	−0.0131	0.0455	0.4444	0.2307
Cigarettes	0.0029	0.0009	−0.0027	0.0022	0.7532	0.0191*
Cans	0.0016	0.0019	−0.0011	0.0045	0.3062	0.4229
Other	0.0583	0.0487	−0.0467	0.1125	0.4120	0.2705

Table 3
Comparison of litter densities in different coastal areas (non-exhaustive): mean value (in bold) and/or the maximum and minimum values (hyphenated) and/or the standard deviation (± following the value); n.d., not disclosed.

Region	Density (items/m^2)	Plastic (%)	Reference
Southwest Black Sea, Turkey	0.88 (0.008–5.06)	91	Topçu et al. (2013)
Bootless Bay, Papua New Guinea	15.3 (1.2–78.3)	89	Smith (2012)
Nakdong, South Korea	0.97–1.03	n.d.	Lee et al. (2013)
Kaosiung, Taiwan	0.9 (max. 3.227)	77	Liu et al. (2013)
Tasmania, Australia	0.016–2.03	60	Slavin et al. (2012)
Monterey, USA	1 ± 2.1	68	Rosevelt et al. (2013)
Asturias, Spain	0.3158 ± 0.5628	64	This study

3.2. Survey of beachgoers

A total of 201 beachgoers were interviewed, with an average age 41.84 years, a quite high mean frequency of visits to the beach of 97.26 days per year and a percentage of females of 47.19% (Table 4). Cronbach's alpha was 0.822, thus the survey can be considered internally consistent.

The beachgoers consulted found the beaches moderately littered, in average (mean 2.388, standard deviation SD 1.434; median 2). The Kendall's Tau-b correlation matrix (Supplementary Table 3) showed a highly significant positive correlation between the total litter density and the beachgoers perception (T_b = 0.24369, P < 0.0001), indicating that the beachgoers detected the litter present in the beaches. Perception and action against litter were not significantly correlated. The actions taken by the beachgoers were positively and significantly correlated with the decision of the beachgoers to carry litter bags (T_b = 0.17512, P-value < 0.001). As expected, and confirming survey validity, most of the different litter origins attributed by the participants were significantly and negatively correlated with each other (Supplementary Table 3).

Multiple Linear Regression model of the whole data (Table 5) revealed perception of plastic items as the main driver of differences in perception of marine litter (t = 4.223, P = 0.0002), and the decision of bringing litter bags was positively associated with the perception of cigarettes on the beach (t = 2.0375, P = 0.0430). The perception of ALDFG was significantly and negatively associated with the total litter perception, and individuals perceiving ALDFG as main litter type did score the beach as less littered. In this model, beachgoer's actions against littering were mediated positively by the litter perception (t = 2.973, P = 0.003), although the pairwise correlation between

Table 4
Characteristics of the beachgoers surveyed in each beach. N: number of people surveyed, gender: female percentage, age: mean and standard deviation of their age and Frequentation: average days and standard deviation they visit that beach.

Beach	N	% females	Age	Beach frequentation
Peñarronda	20	35.00	47.60 ± 17.00	84.85 ± 93.68
Navia	18	44.44	54.94 ± 13.29	110.33 ± 101.31
Otur	16	12.50	30.19 ± 8.25	162.78 ± 81.98
Salinas	25	52.00	46.08 ± 12.16	109.58 ± 97.45
Xagó	24	58.33	40.82 ± 15.29	96.79 ± 91.78
San Lorenzo	25	48.00	43.16 ± 16.41	140.88 ± 92.35
Rodiles	25	56.00	41.64 ± 10.82	39.92 ± 64.66
Santa Marina	24	41.67	37.67 ± 16.75	53.98 ± 71.50
Andrín	24	45.83	39.62 ± 12.59	61.25 ± 87.35
Total	201	47.19	41.84 ± 14.80	97.26 ± 94.98

Table 5
Multiple Linear Regression Model for the perception and attitudes as dependent variables. Independent variables were the perception of different types of litter, and the amount of litter perceived and the beliefs about its origin, respectively. Significant P-values are marked with *.

	Coefficient	SD	t	P
Litter perception				
Constant	3.445	0.766	4.497	0.00002*
Plastics	0.283	0.067	4.223	0.00004*
Cans	−0.145	0.093	−1.565	0.119
ALDFG	−0.329	0.108	−3.043	0.003*
Cigarettes	−0.096	0.142	−0.674	0.501
Other	−0.011	0.172	−0.065	0.948
Taking action				
Constant	1.124	0.089	12.678	≪0.0001*
Litter perception	0.078	0.026	2.973	0.003*
Sea origin	−0.023	0.035	−0.655	0.513
Beachgoer origin	0.006	0.029	0.223	0.824
River origin	0.012	0.025	0.428	0.669
Bringing litter bags				
Constant	0.781	0.064	12.258	≪0.0001*
Litter perception	−0.007	0.019	−0.384	0.701
Sea origin	0.0281	0.025	1.111	0.268
Beachgoer origin	−0.019	0.021	−0.918	0.359
River origin	0.04	0.019	2.038	0.042*

these two variables was not significant (Supplementary Table 3). Finally, the decision of carrying litter bags when going to the beach varied with the perception of cigarettes as main litter.

The type of litter perceived by the beachgoers differed greatly from reality. In general, plastics were considered to be the main type of litter in all beaches (Fig. 1). However, this was not always true, at least not in the moment of this study, since for example in Andrín (beach #9 in Fig. 1) only fishing gear was found and not any other plastic debris. Similarly, cans were believed to be the most common type of litter by many participants in the survey, although in reality this type of litter was found only from one beach (Santa Marina, beach #9; Fig. 1). Perception of cans varied among age groups, not being perceived by older people (> 50yo) in contrast with younger groups (18–30 and 31–50yo groups). Consistently with the results of the Multiple Linear Regression Model in Table 5, ALDFG was in general less perceived than the rest of items, and scored relatively low in average, although it was the second type of litter in abundance in the studied beaches.

The PERMANOVA analysis (Table 6) showed significant differences in perception depending on the beaches (F = 7.568, P < 0.01), with higher perception in Xagó and Otur, and lower on Andrín and Salinas (calculated but not shown). The age was a significant driver of the differences in litter perception (F = 7.3047, P < 0.001), with a noteworthy higher perception by the youngest group (18–30yo) (Fig. 2); the same happened for the beach frequentation to the beaches (F = 7.3047, P < 0.001), the more frequent the visits, the higher perception of litter (Fig. 2).

Table 6
Results of the PERMANOVA analyses for the perception and attitudes towards the marine litter. Significant P-values are marked with *.

Dependent variable	Factor	Statistic	d.f.	P-value
Perception	Beach	7.568	8	< 0.001*
	Age	8.6381	2	< 0.001*
	Frequentation	7.3047	2	< 0.001*
	Gender	0.30463	1	0.5589
Action	Beach	55.478	8	< 0.001*
	Age	1.1641	2	0.2378
	Frequentation	6.5757	2	< 0.001*
	Gender	3.2368	1	0.0379*
Carrying bags	Beach	1.6023	8	0.0224*
	Age	3.0167	2	< 0.001*
	Frequentation	0.46506	2	0.5339
	Gender	2.0941	1	0.1052

d.f.: degrees of freedom.

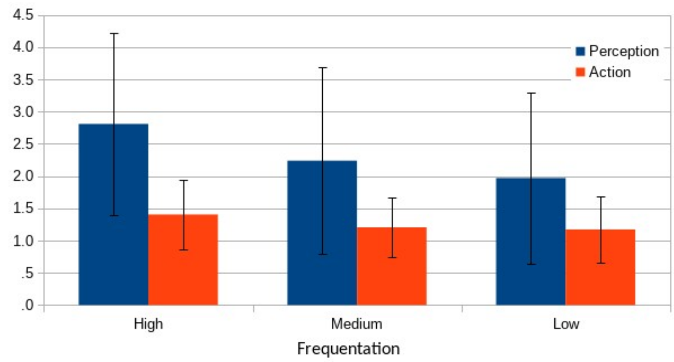

Fig. 2. Perception of beached litter (Perception) and attitude of taking action against litter (Action), by age groups (18–30, 31–50 and > 50 years) on the left, and by beach frequentation (High, Medium and Low) on the right. Results are presented as mean scores with standard deviations as vertical bars.

Taking actions against litter was different among beaches (F = 55.478, P < 0.001), with three beaches where no one declared to take his/her litter out of the beach nor to clean it (Navia, Otur and Peñarronda) (Fig. 1). This attitude varied significantly with the beach frequentation (F = 6.5757, P < 0.001), with more frequent visitors taking more actions (Fig. 2). Finally, carrying bags to withdraw litter from the beach showed differences among beaches (F = 1.6023, P = 0.0224), Otur being the beach where least people reported to carry bags (mean score = 0.67, standard deviation SD = 0.48) and San Lorenzo and Santa Marina where most people carried them (both, mean scores = 0.96, SD = 0.20). Regarding the age, the younger group (18–30yo) carried bags lesser (mean score = 0.74, SD = 0.45) than the older groups (31–50yo mean score = 0.89, SD = 31; > 50 mean score = 0.82, SD = 0.39).

For the gender, males and females scored similarly for litter perception, with mean score of 2.33 (SD = 1.31) and 2.46 (SD = 1.46) respectively and the difference was not significant (Table 6). The attitude of taking actions against litter was significantly different between genders (F = 3.237, P = 0.038), with more actions taken by males than by females, opposite to the expectations; males and females scored 1.31 (SD = 0.506) and 1.22 (SD = 0.51) over 2, respectively. For the particular action of bringing bags to the beach for taking the own litter back home, males and females scored (over 1) respectively 0.8 and 0.88, with no significant difference between them (Table 6). Interestingly, when analyzing the correlation between litter perception and taking actions against litter separately for each gender, in females a highly significant positive correlation was found (Kendall's tau $T = 0.21$, 89 d.f., P = 0.003). In contrast, no significant correlation was found between perception and action for males ($T = -0.001$, 108 d.f., P = 0.994). This means that the significant influence of perception in actions found in the Multiple Regression Model for the whole dataset (Table 5) was due to the females (Fig. 3).

4. Discussion

In this study, we present several findings of interest for the control and prevention of marine litter. First, the level of littering was different in the different beaches of the studied region, and this difference was explained principally from the sum of all the stressors considered (spatial protection, cleanings and trash bins being mitigation factors). The vicinity of ports was the only salient driver of the total amount of beach litter – not only of lost fishing gear; while the proximity of rivers did not significantly influence beached litter. This result contrasts with other regions in Asia and America where rivers are main drivers of

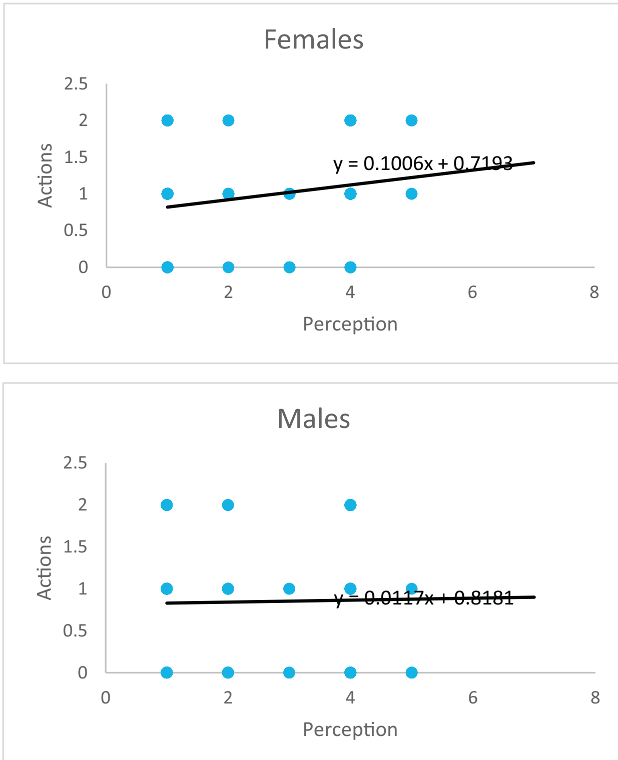

Fig. 3. Plot of the individual scores obtained for litter perception (X-axis) and taking actions against litter (Y-axis), for females (above; N = 91) and males (below; N = 110), in the survey conducted in this study. The equation of the slope is presented in the graph.

marine litter (e.g. Rech et al., 2014; Löhr et al., 2017), and emphasizes the idea of the problem of coastal litter needing to be addressed regionally. As Löhr et al. (2017) state, global commitments such as the UN sustainable development goals must be translated to regional and national levels. Moreover, our results suggest litter should be treated locally, perhaps at a short scale of individual beach. In this sense, the perception and attitudes of beachgoers were also significantly different among beaches, with some apparent drivers that should be taken into account for litter management – this will be commented below.

The amount of litter found in this study corresponded to a moderately littered region, as it falls in the lower half of the trash density found in other regions (Table 2). Plastic fragments were the most common litter in our survey (≈64%), and this coincides with most surveys of marine litter (e.g. Ryan et al., 2009; Pham et al., 2014; Löhr et al., 2017). The next type of item, in abundance, was lost or discarded fishing gear. This finding has especial relevance in this region, because ALDFG has recently been reported to carry alien invasive species (Miralles et al., 2018). Thus, the physical pollution due to discarded fishing gear would be accompanied by biological pollution, representing an additional risk for marine conservation in the region. Unlike other studies (Moore and Allen, 2000; Santos et al., 2005; Oigman-Pszczol and Creed, 2007), cigarette butts were not the main component of the litter sampled, representing only about the 1% (Table 1). Our results about cigarettes were more similar to Slavin et al. (2012)'s results from clean Tasmanian beaches, and Nelms et al. (2017) on British coasts, where this type of debris was not so abundant. Taking into account that Spain has a relatively high proportion of smokers (≈27% of Spaniards are casual or habitual smokers; National Institute of Statistics I.N.E., 2017), cigarette butts could be expected on beaches. Our result could be due to seasonality with a peak of smoker beachgoers on the summer season, as reported by Poeta et al. (2016) for Italian beaches, while our study was conducted in winter and early spring.

Public awareness (beach clean-ups, education programs and more) is crucial for marine litter treatment because many actors are involved in the problem (e.g. Kiessling et al., 2017; Löhr et al., 2017), and it is especially important in regions like this study's where locals visit frequently the coast. Perception is the first step. Although simplistic it is true that one can be aware of a problem only if the problem is perceived. Regarding the amount of litter, the clear correlation between the level of littering of the beach and the total litter perception of the beachgoers showed that people in this region tended to perceive accurately the quantity of beached litter. However, our results showed a mismatch between the reality of beach litter and beachgoers' perception, specifically regarding the type of litter perceived. Biases in global litter perception may be related not only with the density of items, but also with the hazardousness or the aesthetic impact of the particular type of items occurring on a beach, as reported by Tudor and Williams (2003). In our study, the dangerous ALDFG (Miralles et al., 2018) was generally overlooked by the consulted beachgoers. In contrast, although small plastic fragments are hard to detect by untrained people (Lavers et al., 2016), our study revealed participants perceived well plastic litter on the beach. The discrepancies in perception about other materials (Fig. 1), such as cans, suggests that answers are more given "by heart" than based on the real state of the beach, as other authors also reported (Roca and Villares, 2008). This means that beachgoers answers and attitudes are not always based on the objective reality but on past observations, beliefs, preconceptions that may influence how they perceive the reality. Investigating the origin of such perception could be a good point of departure to enhance coast health in the region.

Biased perception may influence actions against marine litter, even when the beachgoers are conscious of the problem; the participants in our study would not demand a stricter control of ALDFG if they do not perceive it. As suggested by Hartley et al. (2015), there is a need for showing the real state of the beach to improve visitor's perception and attitudes. However, in our study this strategy would work better in the females, since perception and actions were not significantly correlated in males (Fig. 3). While there were no significant differences between genders for the perception of the marine debris, male participants were slightly more inclined to take actions (marine litter removal), whether they perceived the beach was littered or not. This does not coincide with the results found by some authors about a greater awareness of females regarding littering (Al-Khatib et al., 2009; Perry et al., 2010; Chen et al., 2011; Adebo and Ajewole, 2012; Slavin et al., 2012; Babaei et al., 2015). In contrast, our study seems to be more coincident with other authors who did not find a consistent gender effect on waste management and awareness (Aaniamenga Bowan et al., 2014), with examples from other parts of Spain (Bernad-Beltrán et al., 2014) and Germany (Vogt and Nunes, 2014). In any case, campaigns showing the types of litter that are accumulated in the beaches of this southern Bay of Biscay region would surely increase awareness and promote conscious attitudes for beach cleaning and preventing littering (e.g. Löhr et al., 2017).

Some results of this study are not easy to explain; for example, the absence of declared actions against litter in the beaches located at the west of the surveyed area. This might be explained from the proximity with the neighboring region Galicia, where the catastrophic *Prestige* oil spill occurred in 2002 that caused enormous pollution with fuel in the coast and endangered all type of organisms, including humans (e.g. Suárez et al., 2005; Sánchez et al., 2006; Lobón et al., 2008). The westernmost area of this study was logically the most affected. It is possible the citizens still remember the problem and don't want to touch coastal litter, since fuel remains can be still found in some zones years after the accident, and indeed are causing lasting impacts on many organisms (e.g. Puente et al., 2009; Moreno et al., 2013; Crego-Prieto et al., 2013, 2014). On the other hand, this could be also related with the greater willingness to carry litter bags when they believe the river is the main source of debris. Another interesting result of our study was that beach frequentation affected positively the perception of marine litter and the actions taken (Fig. 2). This could be explained from a reinforcement in these attitudes when they are more exposed to the problem, leading to a higher awareness by more frequent visitors (e.g. Hartley et al., 2015). Concerning age, the differences in litter perception between the young group (Fig. 2) and the other groups is consistent with some other studies (Krauss et al., 1978; Arafat et al., 2007) where aging was linked with a laxer attitude towards littering. This could reflect a trend in perception, taking into account the relative novelty of the problematic and considering most of the awareness campaigns are aimed to younger age groups. The fact that youngsters, even perceiving more littering, were not willing to carry bags to unlitter suggests a drawback in this. This reflects the awareness of the new generations is high, but their role for solving the problem seems not completely understood, or at least not properly developed. Campaigns addressing this –from the awareness to the action- could have a good cost-benefit ratio.

This study may have management implications. Differences among beaches in the amount and type of litter, and in the beachgoers' knowledge and awareness suggest that a regional approach for the management of marine litter, and for raising public awareness campaigns, may not be efficient if it does not consider local differences. Supporting other authors (Kapoor, 2001; Santos et al., 2005; Roca and Villares, 2008), local characteristics should be taken into account in order to boost management effectiveness also in this central part of south Bay of Biscay. Here, the role of the ports as a source of marine litter should be considered, confirming other authors' data (Löhr et al., 2017), and especially ALDFG that represents an important part of the litter found in the surveyed area.

To conclude, this study is the first approach to a quantitative assessment of beach littering and its relation with beachgoers' perception and awareness in this region. Our results may contribute to a better understanding of the state of the south Bay of Biscay coast and could be used to improve administrations management and to increase the effectiveness of campaigns for raising awareness about this problem, in line with global initiatives of sustainable blue growth.

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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.2018.04.066.

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Capítulo 3

Public awareness of coastal pollution and biopollution in Bay of Biscay. Implications for early detection and control

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En revisión

Public awareness of coastal pollution and biopollution in Bay of Biscay. Implications for early detection and control

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Abstract

Marine environment is threatened by litter and invasive species, both related with human activities and especially with ports areas. On the other hand, knowledge and awareness of citizens of all ages are drivers of changes needed to improve environments. In this study, the density of macrolitter and alien invasive plant *Cortaderia selloana* were measured from six beaches surrounding the main international port of southwest Bay of Biscay (Asturias, Spain). The awareness of inhabitants of the zone was estimated from a social survey (N=130). The relationship between the beach littering level, invasion and the perception and awareness of adults and children were assessed. Litter levels were significantly associated with the port and also positively correlated with the invasion confirming higher invasiveness. Adults were more aware than children about both issues and their perception of litter and plant invasion were positively correlated. Results suggest the need of enhancing marine awareness at young ages.

Keywords

Marine litter; Biopollution; Invasive alien species; Social perception; Awareness

1. Introduction

Marine pollution, including macropollutants (or marine litter), is a global problem of thriving importance and adverse effects. It is the second cause of biodiversity losses and extinctions in the marine environments, exceeded only by habitat loss (Goldberg 1995; Santos et al. 2005). At the esame time, the invasion by biopollutants (invasive alien species, IAS) is another coming up hazard for the ecosystems that increases constantly and threatens global biodiversity (Gurevitch and Padilla 2004; Clavero and García-Berthou 2005; Molnar et al. 2008).

Marine litter has a double effect on the spread and establishment of IAS. On the one hand it gives the opportunity to many rafting and hitch-hiking species to use it as a vector for dispersal (Barnes 2002; Aliani and Molcard 2003; Barnes and Milner 2004; Gregory 2009; Kiessling et al. 2015; Rech et al. 2016; Tutman et al. 2017); and on the other hand, litter degrades the environment where it is deposited, facilitating the establishment of new IAS that are frequently tolerant and can live in disturbed spaces (Campos et al. 2004; Domènech and Vilà 2006). This double relationship between marine litter and IAS points out to maritime ports as contributors to the biological invasions mediated by marine litter. Their role as a providers of marine debris, pathway and hotpots of IAS transported by maritime traffic (Westphal et al. 2008; Griffiths et al. 2010; Rech et al. 2016; Carlton et al. 2017; Miralles et al. 2016, 2018) suggests a need for more attention to them. These two pollutants, IAS and litter, should be considered together when evaluating the environmental status of coasts surrounding the maritime ports, since litter seems to be a vehicle of IAS dispersal in port areas (Miralles et al. 2018).

Indeed, both marine litter and invasive species are produced by human activities (Derraik 2002, Molnar et al. 2008). The main proportion of marine litter is from inland origin (Jambeck et al. 2015; Nelms et al. 2017), and deliberated releases of ornamental plants are frequently the cause of coastal invasions (e.g. Campos et al. 2004; Kalusova et al. 2013). People do litter and introduce alien species, thus measures and actions aimed at controlling both IAS (Schüttler et al. 2011) and marine litter (Veiga et al. 2016) rely on people's agreement. The insight about this matters and the social and demographic factors influence public attitudes, as demonstrated in the Bay of Biscay by Rayon-Viña et al. (2018): younger and more frequent beach visitors were significantly more aware of marine litter than other population groups. The level of public acceptance of control policies is also influenced by the level of knowledge and awareness, for both marine litter (Santos et al. 2005; Marin et al. 2009; Slavin et al. 2012) and biological invasions (Starfinger et al. 2003; García-Llorente et al. 2008; Andreu et al. 2009).

Thus, coastal management should not only consider scientific-technical approaches but also social factors, like for example the awareness of the stakeholders and general public (Reaser 2001; Bremner and Park 2007).

The zones surrounding degraded areas, such as beaches around ports, can be good examples for investigating how citizens perceive marine pollutants and biopollutants and appreciate coastal conservation. Studies show that people tend to litter more in areas already littered or in a degraded state because those areas are perceived as not so important for conservation and thus acceptable to pollute (Sibley and Liu 2003). Moreover, good intentioned individuals or stakeholders may be tempted to introduce ornamental potential IAS plants, that are generally resistant there, for improving the aesthetic appearance of those otherwise not valued zones. If decorative IAS are appreciated by stakeholders and general public, managers and administrations may not see necessary to envisage eradication plans (Bardsley and Edwards-Jones 2006; Shackleton et al. 2007), since they may fear public opposition and lack of institutional trust if they act against citizen's initiatives (Estévez et al. 2015).

The present study was focused on the beaches surrounding the international port of Gijon, the biggest in the southwest Bay of Biscay, and on *Cortaderia selloana* (pampa grass) as IAS model species. This plant of south American origin was imported for ornamental purposes to many regions worldwide (Domènech et al. 2006) and is one of the most widespread invasive plants in the Bay of Biscay (e.g. Campos et al. 2004, Dopico et al. 2017). This robust species adapts well to degraded spaces, for example in fields subjected to many changes in their use (Domènech et al. 2005), and on the margins and lows of instable coastal dunes (Marcomini et al. 2017), thus it is expected to thrive in beaches already degraded under the port influence. There are social awareness and concern about the impact of pampa grass in the north of Spain (Dehnen-Schmutz et al. 2010).

The aim of the present study was two-fold. First we did examine the relationships between litter and plant IAS densities in beaches around Gijon maritime port. Second, people impressions about beach status, including litter and IAS, were analysed in order to identify possible knowledge gaps to be addressed in future environmental education campaigns. With the southwest Bay of Biscay as the case study, marine litter and pampa grass samplings and a social survey were performed. The departure hypotheses were:

i) The density of marine debris deposited on the beaches is expected to be influenced by the proximity to the port and the dominant currents in the area, as Miralles et al. (2018) showed;

ii) The density of IAS is expected to be higher in more disturbed beaches;

iii) Public perception and awareness of litter and IAS should be inversely correlated since, unlike garbage, many plant IAS are ornamental and visually aesthetic;

iv) Younger citizens should be more aware about litter and IAS, as found by Rayon-Viña et al. (2018) for litter in other beaches of the region, since older generations tend to relax their concerns about environmental conservation and in particular about litter (Slavin et al. 2012).

2. Material & Methods

2.1. Ethics statement

For developing the social study, confidentiality of personal data was ensured. All surveys were anonymous. Participants were not photographed nor their voices recorded to respect privacy. The Research Ethics Committee of the Principality of Asturias authorised this study with reference 66/17.

2.2. Site study

All studies were performed in Gijón, the largest city in Principality of Asturias (southwest Bay of Biscay, Spain) which has the biggest maritime hub from southwestern Bay of Biscay, called El Musel, shipping about 20 million tons every year (*Autoridad Portuaria de Gijón* - Gijón Port Authority 2017). Six beaches surrounding El Musel (43.56418, -5.68915) were chosen: one at the West, **Xivares** (43.57021, -5.71807), and five at the East: **Arbeyal** (43.54554, -5.69278), **Rinconín** (43.54868, -563939), **Peñarrubia** (43.55213, -562387), **Serín** (43.55045, -5.61022) and **La Ñora** (43.54793, -5.59031) (Figure 1). This asymmetric distribution of the beaches was chosen due to the fact that the main currents go eastwards in the Cantabrian coast (Charria et al. 2013).

[FIGURE 1]

Figure 1. Above: Location of the city of Gijón in northern Spain. Middle: Schematic map of Gijón with the sampling beaches (from West to East: Xivares, Arbeyal, Rinconín, Peñarrubia, Serín and Ñora), the location of the port of "El Musel", and the main sewage transport and its marine outfalls. In blue on the sea the arrows represent the direction of the currents. Below: Graphs of the sampled litter on each beach (items·km^{-2}) grouped by probable origin: L1, Leisure; L2, Hygiene; L3, ALDFG; & L4, Other; and PG17 the density of pampa grass (*Cortaderia selloana*) in the 2017 sampling and PG19 the density of pampa grass in the 2019 sampling (individuals·km^{2}).

The beaches were characterized from the number of factors that favor litter accumulation on the beaches, being absence of trash bins, absence of beach cleanings, the presence of urban and/or industrial sewage, river proximity (at 2 km or less) and all-year round beach use. Each trait scored 1 (its absence was 0). Regarding the port influence, it was scored 1 for a beach sheltered from the port influence, 2 for being indirectly affected and 3 for being directly affected –from the current direction and the beach situation in front of the port.

2.3. IAS model

In Asturias region 81 IAS plants and 43 potential invaders have been reported (www.asturias.es). Amongst them, *Cortaderia selloana* is the most infamous. The advance of its uncontrolled invasion in the region is covered by mainstream and specialized local and regional media, with frequent articles and alerts about new areas invaded and a general praise of the actions taken against this IAS by NGOs and public Administration (Table 1).

[TABLE 1]

Table 1. Summary of news about *Cortaderia selloana* and marine litter in Gijón for 2015-2017, by category: problem alert, management criticism, management praise (Non-exhaustive). The sources are the four main news media in the region: El Comercio, La Nueva España, La Voz de Asturias and Radio Televisión del Principado de Asturias. Links to online versions in the Supplementary Table 3.

This AIS species expanded in the region in the last decades (e.g. Dopico et al. 2017), being particularly harmful in coastal dunes (e.g. Campos et al. 2004). The species can be found in undermanaged degraded anthropogenic habitats because its environmental tolerance and robust constitution facilitates to invade this type of habitats (Domènech and Vilà 2006). In northern Spain the most affected zones are ruderal, like road and parking lot surroundings, industrial areas and other undermanaged areas (Domènech and Vilà 2007). This, added to its high tolerance to high salinity and water stress (García and Amparo 2017) is enabling its spread in many beaches and their surroundings in the region. For all this, both stakeholders and public are greatly concerned about this plant in north Spain (Dehnen-Schmutz et al. 2010).

In this study the number of *Cortaderia selloana* individuals was sampled *de visu* in the beaches two times: during the winters 2017-2018 and 2018-2019. The density of this IAS was calculated as individuals per km^2. The data were employed to document the advance of the plant in two consecutive years, and to check for a possible association with marine litter.

2.4. Marine litter sampling

The debris accumulated in the beaches was sampled during the 2017 wintertime (January-February), to avoid both the influence of tourism and the beach cleanings organized by the city council. In this way it can be reasonably ensured that the litter accumulation, if any, is due to local factors. During the low tide the whole sand surface of the beach was sampled, searching for any garbage bigger than 25 mm. All items were collected, photographed, classified by material, counted, then disposed into recycle bins. Litter items were grouped into four categories based on their origin: **leisure** (bags, bottles, cans, corks; **hygiene** (sanitary pads, bud sticks); **ALDFG** (abandoned, lost or discarded fishing gear); and **other**. The density of each type of litter was measured in items/m^2.

2.5. Social survey

Perception and opinions about marine litter and IAS were measured using a categorized opinion poll. A test questionnaire candidate with twelve questions was tested for consistency and clarity by 20 colleagues. Pertinent corrections were made and a final poll of nine questions were selected to compose the survey: eight with answers ranked with Likert scale and one open response question (#9). The Likert scale was 1 to 5 (plus Don't Know/Don't Answer, as 0). The questions were:

Being 1 none or very little and 5 very much,

1. *How much do you think litter impacts this beach?*
2. *How much do you think invasive species impact on this beach?*
3. *How much do you think beachgoers contribute to the litter of the beach?*
4. *How much do you think the port contributes to the litter of the beach?*
5. *How much do you think other sources contribute to the litter of the beach?*
6. *How much do you think urban wastes are correctly managed to not littering the beach?*
7. *How effective do you think the current management of invasive species is in this coast?*

8. How much do you think beach litter contributes to the enhancement of invasive species?

9. Please suggest ideas or actions to control invasive species in this coast.

Under the third departure hypothesis, scores in questions #1 and #2 should be negatively correlated, and the average score of #8 should be significantly smaller than both #1 and #2. Under the fourth hypothesis, scores in #1 and #2 and in #8 should be higher in the group of adolescents than in the adult group. Questions #3-5 investigate the litter sources perceived by the participants, and #6-7 tackle their satisfaction with current environmental management in the studied coast.

Some demographic data were collected in order to characterize the sample: **gender** (male, female); **age** (<50 or >50 years for adults) - these two variables were not asked but noted by the surveyor; **beach frequentation** during the last year (low frequenters, once a month or less; medium frequenters, once a month to once a week; high frequenters, more than once a week).

The survey was conducted in February-March 2017, face to face, to two different groups of participants: adult beachgoers polled on the target beaches, and high school students from 3rd (14-15 years old) and 4th (15-16 years old) year of Secondary Education (ESO, Spanish acronym) in Spain. In the Spanish curriculum of secondary education, children take annual courses with contents of environmental education in 1st, and 4th year of ESO, thus 4-y children were expected to be more aware about environmental problems than 3-y ones.

2.6. Data analysis

Normality was checked with Shapiro-Wilk tests, showing significant deviation from normality in all variables, thus non-parametric tests were used. Pairwise correlation using Kendall's Tau-b coefficient (better for non-normal data) was used to check for correlations between beach traits, litter and IAS density. To visualize graphically how the beaches are related to each other regarding the ensemble of data, the dataset was analyzed using a non-metric multidimensional scaling (nMDS).

In the social survey, the answers to the open question #9 were grouped by type of measure proposed for statistical analysis. For the rest of questions, the internal test reliability was checked using Cronbach's alpha, with the score in question #6 inverted. Pairwise correlations between questions using Kendall's Tau-b served to identify significant relationships between litter and IAS perception, opinions about management and impacts, and participant's traits.

Permutational analysis of variance (PERMANOVA) was performed to check differences between age groups and beach frequentation for the variables analysed. The suggestions for IAS management were compared between groups using Chi-Square statistics.

Statistical analyses were performed using the PAST 3.18 statistics software (Hammer et al. 2001), or R with Rstudio (RStudio Team, 2016) and R-commander (Fox et al., 2018) under Linux.

3. Results

3.1. Beach litter and IAS

The six beaches analysed covered a total surface of 112875 m^2. In average there were 0.0222 items·m^{-2}. The most littered beach was Peñarrubia (0.0457 items·m^{-2}), but Rinconín had higher densities of ALDFG (0.0020 items·m^{-2}), others (0.0340 items·m^{-2}) and leisure litter (0.0052 items·m^{-2}) (Figure 1). *Cortaderia selloana* densities varied from 3.64 and 2.51 individuals·m^{-2} in Peñarrubia and La Ñora respectively to 0 individuals·m^{-2} in Rinconín and Arbeyal (Table 2). By categories, the litter grouped as "Other" was the most (0.0686 items·m^{-2}) and ALDFG the least abundant (0.0045 items·m^{-2}).

3.2. Social perception

[TABLE 2]

Table 2. Environmental stressors in the sampled beaches. Litter density as number of items·m-² (x1000), and pampa grass *Cortaderia selloana* density as plants/km^2.

The non-metric multidimensional scaling analysis constructed based on the global dataset and the beach features separated the beaches more influenced by the port (Rinconín and Peñarrubia) from the rest, with a stress close to 0 (axis 1 with r = 0.9545, axis 2 with r = 0.1723) (Figure 2).

[FIGURE 2]

Figure 2. nMDS graph displaying the sampled beaches characterized by the litter items sampled. Symbols represent their position regarding the port: dots (Peñarrubia and Rinconín), directly influenced by the port;

squares (Serín and Ñora), indirectly influenced by the port; and diamond (Xivares and Arbeyal), sheltered from port influence.

Pampa grass *Cortaderia selloana* was present in four of the six beaches analysed (Figure 1). It was absent only from the two urban beaches where cleanings are systematically organized during the summer, Rinconín and Arbeyal (Table 2). In the other four beaches, Pampa grass densities varied from 3.94 individuals·km^{-2} in La Ñora to 0.470 in Serín. The correlation between the density of pampa grass and the sum of ranks of litter classes was positive and statistically significant in the uncleaned beaches; r = 0.952, 2 d.f., P = 0.048 (<0.05). In the second sampling year (winter 2018-2019), plant density increased in Xivares, Serín and La Ñora (Figure 1) confirming the expansive trend of the species in the region. Indeed, the correlation of pampa grass density in the studied beaches between the two sampling years was statistically significant (T_b = 0.714, $p < 0.05$) (Table 3).

[TABLE 3]

Table 3. Correlation matrix of litter and pampa grass density in 2017 and 2019 (P.grass 17, P.grass 19) and environmental stressors in the analyzed beaches. P-values above the diagonal and Kendall's Tau-b values under the diagonal. Significant results are in bold and the Tau value shaded.

Considering all the beaches, Kendall's Tau-b correlation matrix (Table 3) showed a significant negative correlation between beach cleaning and the density of *C. selloana* (T_b = -0.756, $p < 0.05$), which is logically expected. The density of hygiene items was significantly correlated with the absence of trash bins (T_b = 0.730, $p < 0.05$) and negatively with the presence of a river in the surroundings (T_b = -0.775, $p < 0.05$). The total litter density was highly significantly correlated with the exposure to the port effluents (T_b = 0.894, $p < 0.05$), as it was with the density of ALDFG items too (T_b = 0.745, $p < 0.05$). Litter density was negatively correlated with the industrial and urban sewage discharges (T_b = -0.730, $p < 0.05$), but this can be explained because discharges occur in the area nearby the port and urban beaches, not in the farther beaches more influenced by floating litter generated in the port due to currents.

3.2. Social perception and awareness

A total of 130 (68 adults and 62 children) persons were interviewed. Their profile is in Supplementary Table 1. Of the adult group 28 were younger (41%), and 40 older than 50-year old (59%). Of the children group there were 32 in 3rd year and 30 in 4th. For beach frequentation, 50 participants were frequent visitors (38.5%).

For the Likert-scaled questions, Cronbach's alpha value was 0.702. Values greater than 0.6 can be considered solid, so this value was considered acceptable.

In general, the participants seemed more aware about the IAS impact than about the litter. The port was identified as the main source of litter, followed by the beachgoers and other origins. The participants were generally more satisfied with IAS management than with litter management (Table 4).

[TABLE 4]

Table 4. Summary of public perception and opinion about litter and invasive species in Gijon beaches, by age and beach frequentation. In parenthesis: sample size.

The PERMANOVA analysis (Supplementary Table 2) showed significant differences by age (adults versus children) and beach frequentation in several perceptions and opinions. No significant differences were found between genders (data not shown). By age (Supplementary Table 2), adults perceived a higher impact of litter on the beaches than the children (PERMANOVA results of $F = 8.3617$, $p < 0.005$), and did attribute the litter origin to the beachgoers more than children did ($F = -5.3169$, $p < 0.05$). By beach frequentation, frequent visitors believed beach litter was due to beachgoers less than the rest of participants ($F = 7.2416$, $p < 0.005$), and so they did for the attribution of litter origin to the port ($F = 3.5823$, $p < 0.05$). Infrequent beachgoers were less satisfied with IAS management ($F = 2.6561$, $p < 0.05$). Finally, significant interaction was found between age and beach frequentation for the perception of IAS impacts ($F = -5.3169$, $p < 0.05$), being the medium frequenters (adults and children alike) more aware about this (Supplementary Table 2).

Considering the children separately, there were no significant differences by age in the answers to the survey except in their perception of the litter impact (Pearson χ^2 test = 10.060, $p = 0.039$), being 4th year (Y4) students significantly more aware than 3rd year (Y3) ones (Y4 Mean = 2.23, Y4 SD = 1.165; Y3

Mean = 1.37; Y3 SD = 1.238).

Regarding the expected negative association between the perception of IAS and litter impacts, it was not found in the whole dataset (Supplementary Table 3), where the correlation value between these two variables was not significant (Tau_b = 0.137, not significant applying Bonferroni). However, since differences by generation (adult versus children) were found for the perception of litter impact, we further analyzed each age group separately. The correlation was not significant for the children (T_b = 0.240, not significant applying Bonferroni), but significant and ***positive*** for the adults (T_b = 0.346, p = 0.0006).

In this study the adults had stronger opinions about litter than the children. The perception of litter impact was significantly correlated with the belief of the port being the main source of litter impact in the adults (T_b = 0.289, p = 0.0007), but not in the children (T_b = 0.184, p = 0.043, not significant applying Bonferroni). In the adults, the satisfaction with current litter management was significantly and negatively correlated with the perceived association between IAS and litter (T_b = -0.621, p < 0.0001), consistently with a significant negative correlation between the satisfaction with IAS management and the perception of litter impact (T_b = -0.552, p < 0.0001). In the children none of these correlations was significant (T_b = 0.057 with p= 0.656, and T_b = 0.187 with p = 0.162, respectively).

Other significant associations between perceptions and opinions were revealed from pairwise correlations (Supplementary Table 3). The attribution of litter origin to the port was significantly and positively correlated with the perception of litter impact (T_b = 0.260, p < 0.001); the more litter is attributed to the port, the more impact is perceived. Positive opinion about urban litter management was negatively associated to the litter perception and all its sources (beachgoers, port and other origins), which is quite coherent (Supplementary Table 2). Unexpectedly, positive significant correlation was found between the perceived impact of the IAS and the satisfaction about their management (T_b = 0.156, p < 0.001): those who perceived a stronger association between litter and IAS were more aware about IAS, and also had a better opinion about current litter management (T_b = 0.272, p < 0.001).

Regarding participant's suggestions for improving IAS management (Figure 3), the most frequent answer was "Don't know/ Don't answer" (50% adults and 90% children), followed by more control in ports and borders (adults) and more cleanings (children). A few participants did propose not to take actions anymore.

[FIGURE 3]

Figure 3. Suggestions for improving the management of IAS in the coasts of Gijón. Results are presented as percentages.

4. Discussion

The expectations of this study regarding IAS and littering were confirmed from the results. First, litter density was significantly correlated with the influence of Gijon port in the area surveyed. The influence of ports as donors of marine litter has been analysed, and confirmed, in studies carried out in the same and other regions (Westphal et al. 2008; Carlton et al. 2017; Garcia-Vazquez et al. 2018; Miralles et al. 2018; Rech et al. 2018), and the present results are aligned with them. Second, the density of the invasive plant *Cortaeria selloana* was significantly correlated with the beach littering status, despite limited number of beaches analysed. This supports the idea of coastal bioinvasions being promoted by other types of environmental degradation (Campos et al. 2004), and adds marine litter as one more factor to take into account when planning IAS eradication and other actions against biopollution.

The litter density found on the beaches sampled here was relatively low compared with other studies (Slavin et al. 2012; Topçu et al. 2013; Rosevelt et al. 2013; Lee et al. 2013), although not negligible: it should be taken into account that coastal litter represents only a low percentage of the total litter present in the surrounding sea (Basurko et al. 2015). Another difference from other studies was that hygiene items were not associated with rivers or sewage outfalls, unlike other cases (Ryan et al. 2009; Rech et al. 2014). This could be explained from a good maintenance of the riverine zones, and also to the small size of the rivers discharging on the bay of Gijón, which are short and do not cross any other cities. Hygiene residues were less abundant in beaches with trash bins, suggesting civic disposal of obnoxious and hazardous debris by beachgoers (Tudor and Williams 2003).

Absence of the invasive species *Cortaderia selloana* from the cleaned beaches reflects the success of the control of this species carried out in the cleaned, most touristic beaches (Arbeyal and Rinconín). While this is good for the cleaned beaches, where the invasion is being contained (Mack et al. 2000), it could drive to the user's misperception of the real magnitude of IAS and litter problems, as it happens in cleaned beaches of other regions (Löhr et al. 2017). This has been reported in some cases as a drawback of measures taken for environmental improvement, because the population may consider unnecessary to dedicate more efforts to combat littering (or IAS) in apparently clean zones (Schüttler et al. 2011).

Contrary to the departure hypotheses about environmental degradation and its main causes, the expectations about public awareness failed in our study. The expected negative correlation between IAS and litter perception (third departure hypothesis, justified from ornamental use of pampa grass in private houses) was not met; on the contrary, perception of litter and IAS by adult participants were significantly and positively correlated, reflecting what happens in reality in the beaches. In children, however, the perception of the two types of environmental threats was not significantly correlated. This would suggest a higher environmental awareness in adults than in children, opposite to our fourth expectation based on other studies (Slavin et al. 2012), and previous studies in Bay of Biscay where children were not considered (Rayon-Viña et al. 2018).

Perhaps misperception due to cleanings of the most frequented beaches, as in Schüttler et al. (2011) and Löhr et al. (2017), accounted for relatively little children awareness about litter and IAS in our study. The same factor –misperception due to frequent cleanings- could explain that, contrary to other studies (e.g. Wyles et al. 2017), more frequent beachgoers seemed not to perceive more litter and IAS impact than less frequent beach visitors. The latter attributed the presence of litter to beachgoers and ports, while at the same time were more satisfied with IAS management than frequent beachgoers.

The two cohorts of secondary education students did not differ regarding perception and awareness of the IAS problematic (Supplementary Table 2). However, it was expected because the Spanish educational system includes the concept of IAS and associated problems in the environmental sciences curricula of 1st and 4th year, thus Y4 students should have a fresher knowledge of the topic than Y3 ones. Perhaps these concepts were not sufficiently explained in class. As other authors, these results point out there is a need of improving the current curricula elements about IAS for a better knowledge and awareness in new generations (Reaser 2001; Krasny and Lee 2002; Bremner and Park 2007; Delaney et al. 2008). The high proportion of "no suggestions" for improving IAS management (Figure 3) emphasizes this idea, and also clashes with the relatively high media coverage of issues related with biological invasions in the region, at least in comparison with the topic of marine litter (Table 1), and in a way is discordant with the association between litter and IAS perceived –at least by adults. Perhaps the expected effect of a positive view of IAS as ornamental plants (Campos et al. 2004; Kalusova et al. 2013) was reflected here; although citizens know IAS can be a problem for local plants, they would not demand more actions for eradication of otherwise aesthetic plants.

Wyles et al. (2017) suggested that public perception of marine litter, and thus awareness, could be improved via voluntary beach cleanings. In the same way, a realistic approach to the problems caused by IAS could include campaigns for collective removal from affected areas, among other actions aimed at increasing social awareness (Starfinger et al. 2003; Dehnen-Schmutz et al. 2010). Good explanations of the adverse effects of IAS are indeed crucial, but the message should be adapted considering not only state of the art facts but also the real level of public knowledge and awareness (Andreu et al. 2009; Schüttler et al. 2011). In our study region, for example, our results suggest that more campaigns should be addressed specifically to children.

As a final remark, the results obtained in this study reveal strengths and weaknesses of public awareness about marine litter and IAS. These problems (marine litter and IAS) have no easy solution, but the whole planet is dealing with similar problems. A multidisciplinary and collective approach aimed at preventing littering and conserving native biodiversity would be recommended (Caulton and Mocogni 1987; Veiga et al. 2016).

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Figures

Figure 1. Above: Location of the city of Gijón in northern Spain. **Middle:** Schematic map of Gijón with the sampling beaches (from West to East: Xivares, Arbeyal, Rinconín, Peñarrubia, Serín and Ñora), the location of the port of "El Musel", and the main sewage transport and its marine outfalls. In blue on the sea the arrows represent the direction of the currents. **Below**: Graphs of the sampled litter on each beach (items·km^{-2}) grouped by probable origin: **L1**, Leisure; **L2**, Hygiene; **L3**, ALDFG; & **L4**, Other; and **PG17** the density of pampa grass (*Cortaderia selloana*) in the 2017 sampling and **PG19** the density of Pampa grass in the 2019 sampling(individuals·km^{-2}).

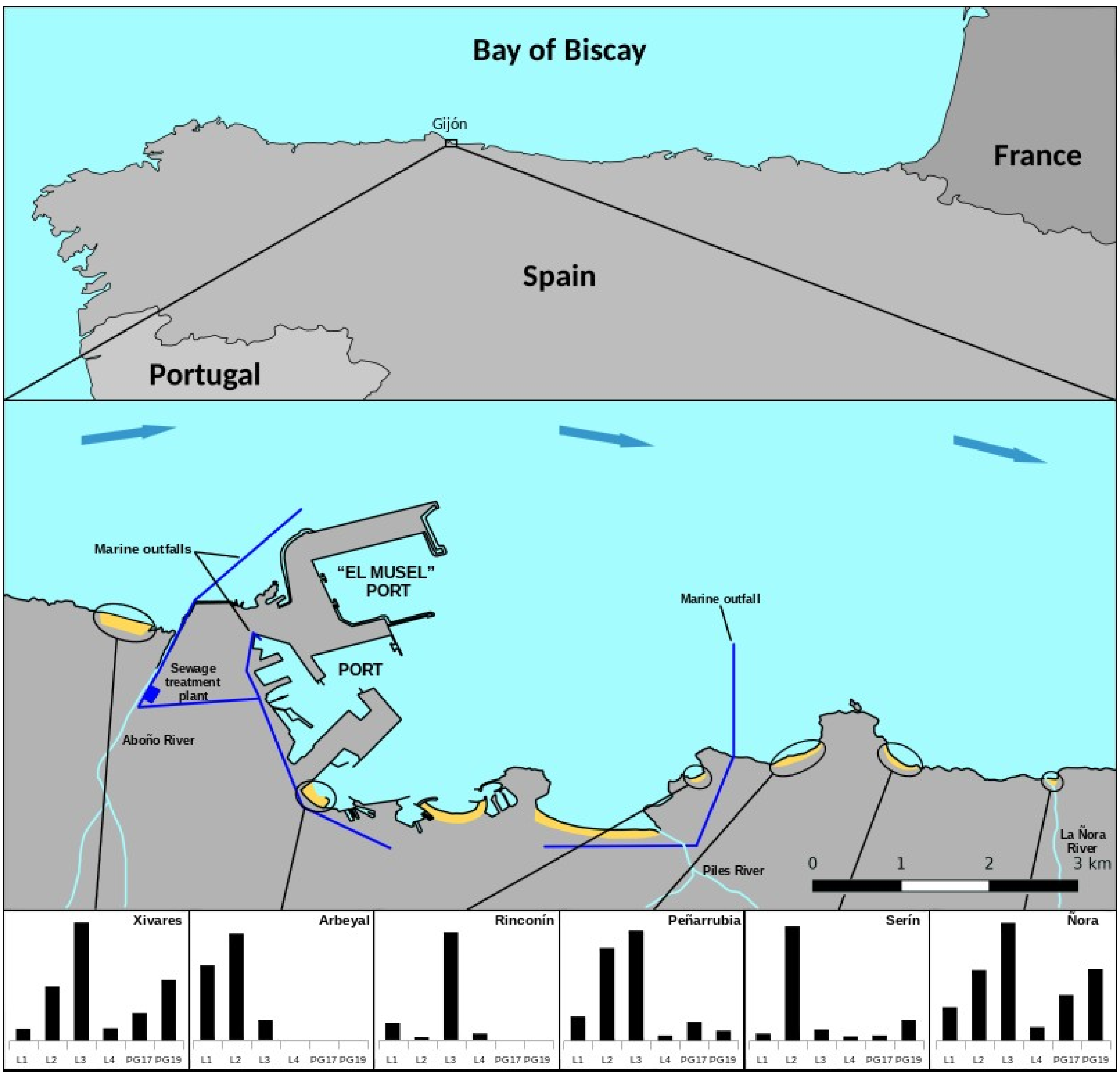


Figure 2. nMDS graph displaying the sampled beaches characterized by the litter items sampled. Symbols represent their position regarding the port: dots (Peñarrubia and Rinconín), directly influenced by the port; squares (Serín and Ñora), indirectly influenced by the port; and diamond (Xivares and Arbeyal), sheltered from port influence.

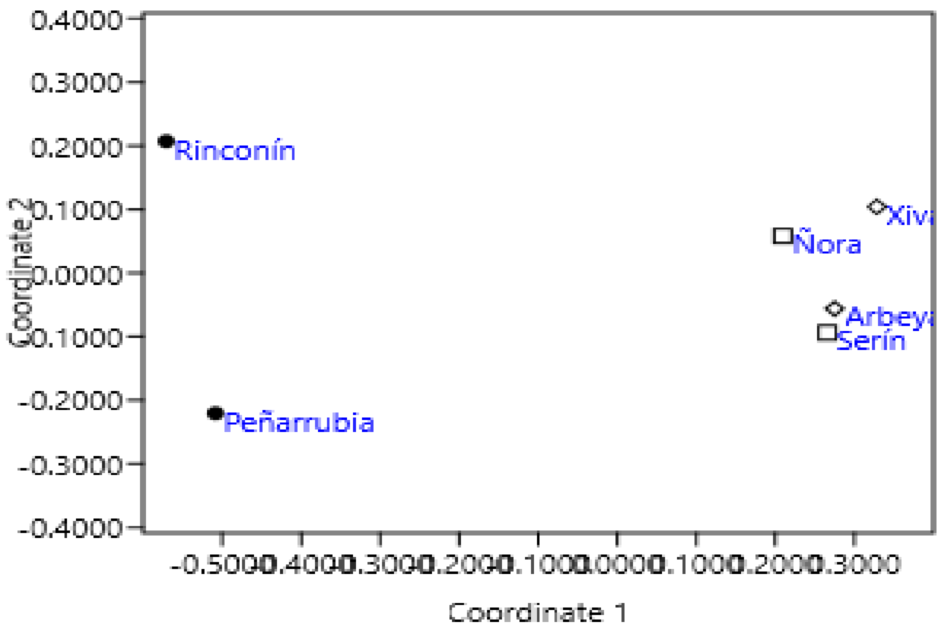
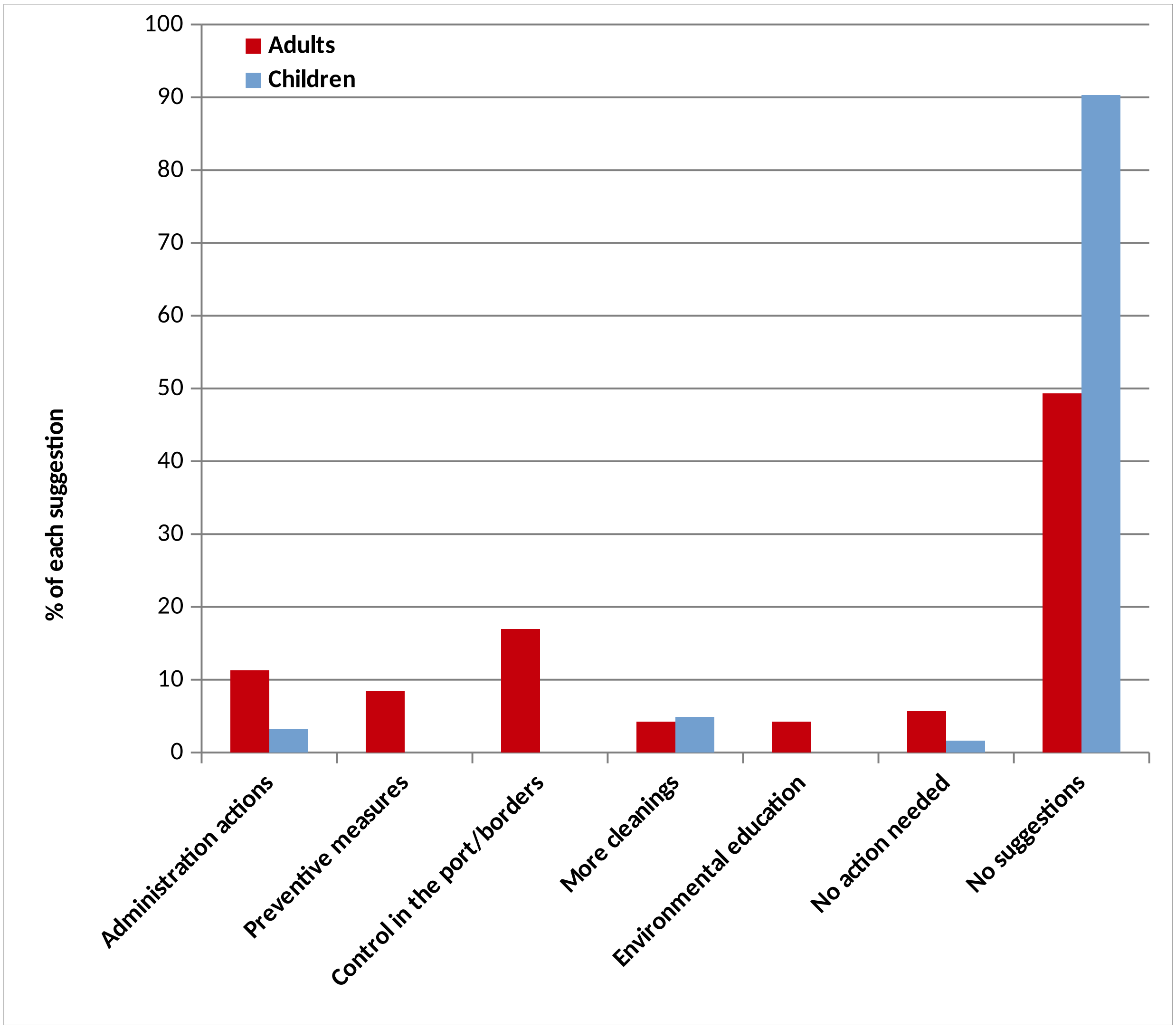


Figure 3. Suggestions for improving the management of IAS in the coasts of Gijón. Results are presented as percentages.



Tables

Table 1. Summary of news about *Cortaderia selloana* and marine litter in Gijón for 2015-2017, by category: problem alert, management criticism, management praise (Non-exhaustive). The sources are the four main news media in the region: El Comercio, La Nueva España, La Voz de Asturias and Radio Televisión del Principado de Asturias. Links to online versions in the Supplementary Table 3.

	2015			2016			2017		
	Problem alert	Management		Problem alert	Management		Problem alert	Management	
		Criticism	Praise		Criticism	Praise		Criticism	Praise
IAS	0.7	0.67	0.67	0.71	0	0.5	0.5	0.57	0.71
Litter	0.3	0.33	0.33	0.29	0	0.5	0.5	0.43	0.29
N	10	3	6	7	0	2	16	7	7

Table 2. Environmental stressors in the sampled beaches. Litter density as number of items·m-² (x1000), and pampa grass *Cortaderia selloana* density as plants·km⁻².

	Trash bins	Cleanings	Seasonality	River	Industrial sewage	Urban sewage	Port	P. grass 2017	P. grass 2019	Litter Density				
										Leisure	Hygiene	ALDFG	Other	Total litter
La Ñora	Yes	No	Summer	Yes	No	No	Indirect	2.5143	3.9429	1.8286	3.8857	0.7429	6.5143	12.9714
Serín	No	No	Summer	No	No	No	Indirect	0.4706	1.8824	0.6588	10.8235	0.3765	1.0353	12.8941
Peñarrubia	No	No	Summer	No	No	Yes	Direct	3.6364	1.9394	4.7273	18.3030	0.9697	21.6970	45.6970
Rinconín	Yes	Yes	All year	Yes	No	No	Direct	0.0000	0.0000	5.2000	0.8000	2.0000	34.0000	42.0000
Arbeyal	Yes	Yes	All year	No	Yes	No	Sheltered	0.0000	0.0000	4.7143	6.7143	0.0000	1.2143	12.6429
Xivares	Yes	No	All year	Yes	Yes	No	Sheltered	0.9643	2.1429	0.4167	1.9167	0.4333	4.1833	6.9500

Table 3. Correlation matrix of litter and pampa grass density in 2017 and 2019 (P.grass 17, P.grass 19) and environmental stressors in the analysed beaches. P-values above the diagonal and Kendall's Tau-b values under the diagonal. Significant results are in bold and the Tau value shaded.

		Trash bins	Cleanings	Seasonality	River	Industrial Sewage	Urban Sewage	Port	P. grass 17	P. grass 19	Leisure trash	Hygiene trash	Other trash	ALDFG	Total litter
Stressors	**Trash bins**		0.1588	**-0.0463**	**0.0463**	0.1588	0.0747	0.2500	0.2868	1.0000	1.0000	**0.0396**	0.6069	1.0000	0.3035
	Cleanings	0.5000		**-0.0463**	1.0000	0.4811	0.3729	1.0000	**0.0332**	**0.0332**	0.1227	0.3035	0.6069	1.0000	1.0000
	Freq.	**-0.7071**	**-0.7071**		0.3476	**0.0463**	0.2076	0.2781	0.0789	0.2094	0.8084	0.0896	0.8084	0.8084	0.2253
	River	**-0.7071**	0.0000	0.3333		1.0000	0.2076	1.0000	1.0000	0.3153	0.8084	**0.0291**	0.2253	0.2253	0.8084
	Indus. sewage	0.5000	0.2500	**0.7071**	0.0000		0.3729	**0.0214**	0.4244	0.7900	0.3035	0.6069	0.3035	0.1227	**0.0396**
	Urban sewage	-0.6325	-0.3162	-0.4472	-0.4472	-0.3162		0.1456	0.0922	0.7363	0.3290	0.1037	0.3290	0.3290	0.1037
	Port	-0.4083	0.0000	-0.3849	0.0000	**-0.8165**	0.5164		0.2315	-0.0772	0.0929	0.6744	0.0929	**0.0357**	**0.0117**
Macropollutants	**P.grass 17**	-0.3780	**0.7559**	-0.6236	0.0000	-0.2835	0.5976	0.5142		**0.0441**	0.6973	0.2433	0.4367	0.2433	0.4367
	P.grass 19	0.0000	-0.7559	-0.4454	0.3564	-0.0945	0.1195	0.8279	**0.7143**		0.2433	0.6973	1.0000	0.6973	1.0000
	Leisure trash	0.0000	0.5477	0.0861	-0.0861	-0.3652	0.3464	0.5963	-0.1380	-0.4140		0.8510	0.0909	0.1885	0.0909
	Hygiene trash	**0.7303**	-0.3652	-0.6025	**-0.7746**	-0.1826	0.5774	0.1491	0.4140	0.1380	0.0667		0.3476	0.5730	0.5730
	Other trash	0.1826	0.1826	0.0861	0.4303	-0.3652	0.3464	0.5963	0.2760	0.0000	0.6000	-0.3333		**0.0146**	0.1885
	ALDFG	0.0000	0.0000	-0.0861	0.4303	-0.5477	0.3464	**0.7454**	0.4140	0.1380	0.4667	-0.2000	**0.8667**		0.0909
	Total litter	-0.3652	0.0000	-0.4303	-0.0861	**-0.7303**	0.5774	**0.8944**	0.2760	0.0000	0.6000	0.2000	0.4667	0.6000	

Table 4. Summary of public perception and opinion about litter and invasive species in Gijon beaches, by age and beach frequentation. In parenthesis: sample size.

		Total	Adult High (42)	Adult Medium (10)	Adult Low (16)	Children High (8)	Children Medium (28)	Children Low (26)
Litter impact	**Mean ± SD**	2,94±1,334	3.1905 ± 1.6999	4.300 ± 0.8233	2.6875 ± 1.3525	2.3750 ± 0.9161	2.3929 ± 1.0306	2.3846 ± 1.2026
	Median	3	3.5	4.5	2	2	3	2
AIS impact	**Mean ± SD**	3,24±1,258	1.1190 ± 1.2337	2.300 ± 2.4518	1.5000 ± 1.8257	2.2500 ± 1.3887	1.4643 ± 1.1701	2.0000 ± 1.2961
	Median	3	1	2	1	2	2	2
Beachgoers origin	**Mean ± SD**	2,65±1,267	2.2381 ± 1.5588	3.7000 ± 1.8886	3.5625 ± 0.9639	3.5000 ± 1.1952	3.5000 ± 1.0715	3.3846 ± 0.9414
	Median	3	2	5	3	3.5	3	3.5
Port origin	**Mean ± SD**	2,81±1,363	2.0476 ± 1.4475	3.2000 ± 1.1353	2.9375 ± 1.4818	2.0000 ± 1.4142	2.6786 ± 1.2488	2.6923 ± 1.1923
	Median	3	1.5	4	3	2	3	3
Other origins	**Mean ± SD**	2,46±1,389	2.1190 ± 1.9153	4.0000 ± 0.6667	2.7500 ± 1.4376	2.5000 ± 1.6036	2.2143 ± 1.0666	2.6154 ± 1.4164
	Median	2	1	4	2	3	2	3
Satisfaction with litter management	**Mean ± SD**	2,18±1,303	2.0000 ± 1.9755	0.5000 ± 0.9718	1.6875 ± 1.4009	1.8750 ± 1.5526	1.8571 ± 1.3801	1.8462 ± 1.4337
	Median	2	1	0	1.5	2	2	2
Satisfaction with IAS management	**Mean ± SD**	2,53±1,326	1.5000 ± 1.6857	0.8000 ± 1.2293	2.5625 ± 1.8246	2.1250 ± 1.6421	1.0357 ± 1.3189	1.5000 ± 1.5033
	Median	2	1	0	3	2	0	2
AIS-Litter association	**Mean ± SD**	3,18±1,244	2.1667 ± 1.7519	3.1000 ± 1.7288	2.7500 ± 1.8797	2.3750 ± 1.5980	2.1786 ± 1.9447	1.6538 ± 1.6478
	Median	3	2.5	4	3.5	3	2.5	2

Capítulo 4

Marine litter and public involvement in beach cleaning:

Disentangling perception and awareness among adults and children, Bay of Biscay, Spain

Rayon-Viña, F., Miralles, L., Fernandez-Rodríguez, S., Dopico, E., Garcia-Vazquez, E.

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Marine litter and public involvement in beach cleaning: Disentangling perception and awareness among adults and children, Bay of Biscay, Spain

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A B S T R A C T

Coastal litter abundance and its effects have increased for years. Waste reduction is the most effective countermeasure to fight against this problem. Littering attitudes may have an effect on people's involvement in coastal cleanups. In this study, coastal litter perception, awareness about its impact and likely sources were investigated in local population from south Bay of Biscay, Spain. People of different age groups and commitment levels regarding litter were interviewed and their answers compared with data from the area. Results showed differences in perception between volunteers and non-volunteers, but not between children and adults. Interaction effect of age was found for awareness. Volunteers and children tended to erroneously attribute the main litter origin to beachgoers, more than non-volunteers or adults. Our results suggest that encouraging local population to clean beaches would contribute to improve their perception of the problem and their attitudes toward taking action.

1. Introduction

The abundance of marine litter in coastal zones has been steadily increasing for years (Hartley et al., 2015). It is defined as all solid materials of anthropogenic origin that are discarded at the sea or reach the sea from the land (Galgani et al., 2015). It has harmful effects on the ecology of the wildlife, such as damages on the marine and coastal biota (Derraik, 2002; Somerville et al., 2003; Gregory, 2009; Sarafraz et al., 2016) or introduction of invasive species (Barnes, 2002; Dias and Lovejoy, 2012; Gil and Pfaller, 2016; Miralles et al., 2018; Rech et al., 2018a). Humans are also affected by marine litter, which contributes heavily to landscape degradation (Somerville et al., 2003; Wyles et al., 2015; Sarafraz et al., 2016), negatively impacts fisheries (Newman et al., 2015; Rochman et al., 2015) and it may be linked to some harmful effects on human health (Thompson et al., 2009; Keswani et al., 2016).

Landscape degradation by littering is not only a matter of aesthetics, but also of economy. It restricts the leisure activities due to the people's reluctance to go to littered beaches. This has an economic impact in the local populations whose way of living relies on coastal tourism (McIlgorm et al., 2011; Newman et al., 2015). Indeed, coastal cleanups to enhance beach conditions also imply additional costs for the local administrations or stakeholders, making the economical footprint inevitable (Mouat et al., 2010). Thus, both stakeholders and local administrations have an interest in making beaches as clean as possible.

Given its anthropogenic origin (Galgani et al., 2015), the best way to reduce marine littering is to prevent its production from the main donors. Main sources of marine litter are coastal human settlements (Ryan et al., 2009), inland settlements that are connected with the coast by rivers (Rech et al., 2014), and beachgoers who dirty the beaches during their activities (Santos et al., 2005; Sarafraz et al., 2016). Focusing on the beachgoers, it seems clear that education is crucial for stopping littering behavior, since more aware people would reduce littering (Rees and Pond, 1995). In this regard, Santos et al. (2005) demonstrated that the litter input was negatively associated with the degree of literacy. On the other hand, more frequent beachgoers tend to be more aware about litter on the beach and its implications (Rayon-Viña et al., 2018), although higher beach use does not imply higher awareness (Santos et al., 2005). Taking all the above in consideration, a deeper understanding of the attitude and knowledge of citizens can improve marine litter management (Slavin et al., 2012).

Involving the beachgoers in the solution of this problem may efficiently increase their awareness, thus stop littering (Löhr et al., 2017). Several studies have suggested that hands-on or an experiential

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approach to marine litter is a good way to improve the awareness about this problem (Marin et al., 2009; Veiga et al., 2016; Wyles et al., 2016), especially among young adults or children (Hartley et al., 2015; Veiga et al., 2016; Wyles et al., 2016; Owens, 2018). It seems that volunteer groups are more aware of the problem, and more concerned about it than non-volunteers (Veiga et al., 2016; Owens, 2018). However, seeing a problem first hand may encourage people to address it. Marine litter perception is the first step in contributing to its solution. While there is a growing concern about this topic, and the idea of using experiential or citizen science methods to increase awareness is logical, no one has yet compared perceptions among general beachgoers and beach cleanup volunteers of varying ages. Also, involving volunteers in the study gives a better perspective while volunteers tend to show a higher implication and involvement in the topics they develop and clarify the causes leading such decisions can help to involve a larger number of people (Bang and Ross, 2009).

In this study we hypothesize that the active involvement in cleaning ups correlates with higher perception of marine litter, and also higher awareness as demonstrated by other authors (Veiga et al., 2016; Owens, 2018). We also expect higher awareness and concern in the group of volunteers than in the non-volunteer group. To test this hypothesis in the south Bay of Biscay (Spain), we contacted beach cleanup volunteers and non-volunteer beachgoers in the field and compared their perception and awareness about marine litter.

2. Material and methods

2.1. Marine litter quantification in the region

To have a general view of the littering level of the region, a previous litter sampling was performed between February–March 2016 (Rayon-Viña et al., 2018). In this study, targeting nine beaches along the coast of Asturias, all litter bigger than 2.5 cm was categorized by types from transects during low tide and density of litter items (items/m^2) was calculated. A parallel study did target litter bigger than 1.5 cm (Rech et al., 2018a) and quantified its density (items/m^2) from standardized quadrats. This data was used to compare the reality of the studied region according to the litter deposited and to compare with the citizens perceptions.

2.2. Ethics statement

All social data were obtained and managed following strict confidentiality rules. All surveys were anonymous. Participants were not photographed and their voices were not recorded to respect privacy. The answers recorded in writing were shown to the participants for their approval. Data of underage people was obtained after guardian's consent. This study was approved from the competent Research Ethics Committee of the Principality of Asturias with reference 66/17.

2.3. Social study

The social field study was conducted in the central part of the region of Asturias (SW Bay of Biscay; Fig. 1) between February and June of 2017, out of the summer touristic season. All the interviewees were from the region. Four groups of beachgoers were addressed, corresponding to: adults and children; and, general beachgoers and cleanup volunteers. While real age was not asked, adults (18 years old and over) were approximately 30 to 70 y.o., while children ranked from 10 to 16 y.o. All participants were local inhabitants of the surrounding cities and their frequentation to the beaches of the region tended to be similar.

Volunteers (both adults and children) were interviewed before beach cleanups organized by the University of Oviedo in different beaches of the region. For the volunteers, this was their first experience in beach cleaning. The interview was carried out before giving them instructions about litter collection and sorting. These cleanups typically include only visible objects (i.e., not microplastics or items smaller than 2.5 cm). Interviews of regular (non-volunteering) beachgoers occurred at regional beaches during the day. In addition to children interviewed in at the beach, some (non-volunteering) beach-going children were found via the High School IES "El Piles" in the city of Gijón.

A total of 208 people were surveyed: 75 volunteers and 133 general beachgoers; being 95 adults and 113 children, of balanced gender ratio in all the groups (Table 1). Differences between genders were not found for any question (data not shown).

2.4. Questionnaire design

Perception and awareness about marine litter was analyzed using a fast and easy questionnaire with four items:

1. How much litter do beaches have?
2. How much does the litter impact on the beach?
3. Which do you think is the most common beach litter material? Choose one among: Plastics; Abandoned, lost or otherwise discarded fishing gear (ALDFG); Glass or cans; Other materials.
4. Which do you think is the main origin of the beached litter? Choose one among: Household; Maritime activities & fishing; Beachgoers; Others.

This final questionnaire was curated from a first pilot test developed in the faculty and checked for its ease to understand. The validation consisted in a first test will faculty colleagues, some corrections and a later verification with relatives and friends for validation (Bolarinwa, 2015).

Questions #1 and #2 are respectively about litter quantity perception and awareness about beached litter. They were Likert scaled from 1 to 5, being 1 the lowest value (very few or none litter, very low or none impact) and 5 the highest (very much littered, very much impacted). Not know/Not answer (NK/NA) were recorded. Questions #3 and #4 are also about perception and awareness respectively, but more specific than the previous ones because they are referred to specific types of litter. For each question, answers were single choice (corresponding to the Likert scale 1–5), one for each potential origin or marine litter material. These questions were showed to all interviewees and the five possibilities explained both with the numeral and the verbal answer to avoid misconceptions. The number of individuals choosing each category in each group was the datum recorded for these two variables.

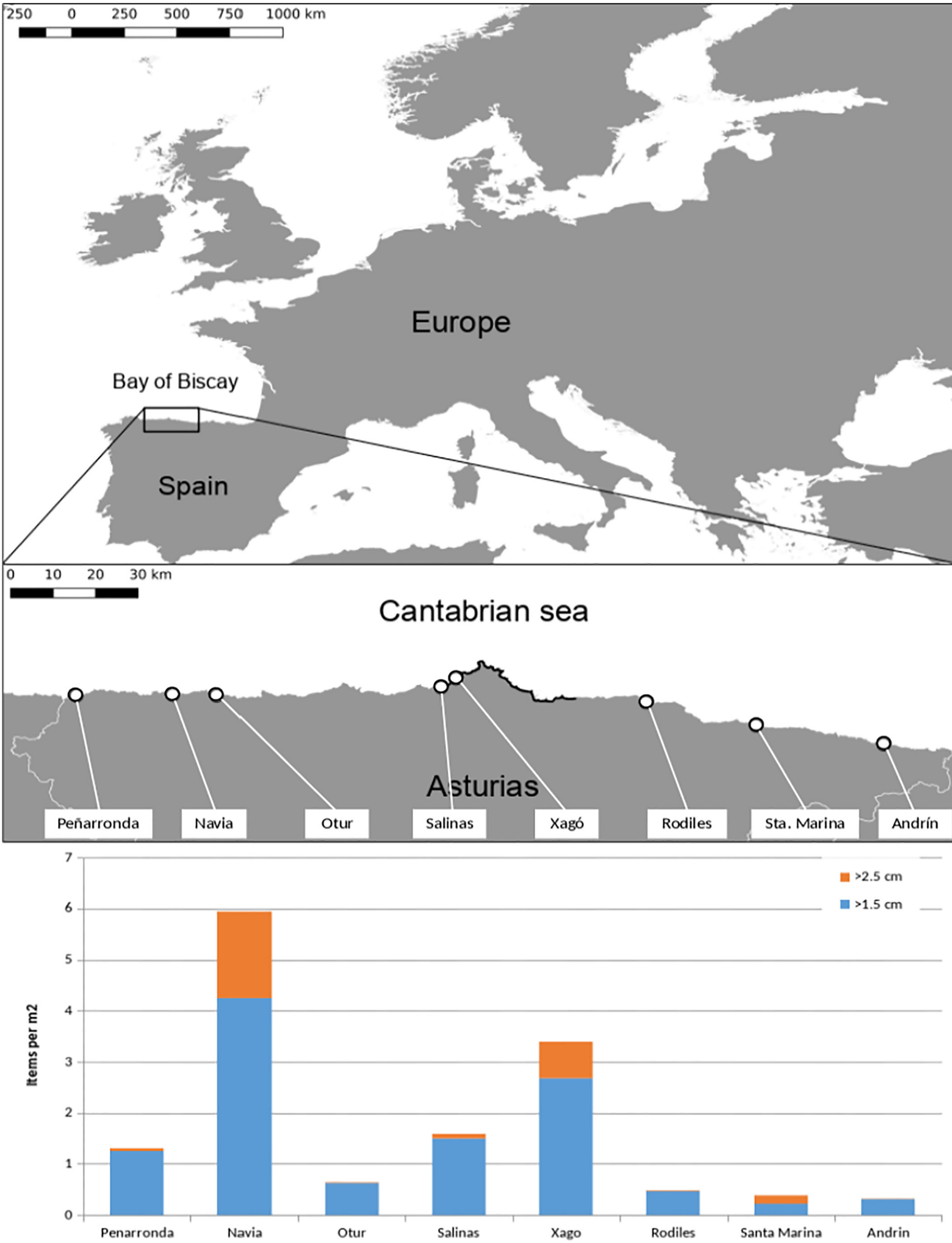
2.5. Statistical analysis

The differences between groups in litter perception and awareness (questions #1 and #2) were tested with two-way permutational analysis of variance (PERMANOVA). The few answers NK/NA were not computed for PERMANOVA statistical analysis. The differences among groups for questions #3 and #4 were tested using Pearson contingency X^2 tests. The significance threshold was set at $p < 0.05$.

The statistical analyses were performed with R using Rstudio (RStudio Team, 2016) and R-commander (Fox et al., 2018) under Linux.

3. Results

Regarding the general state of beaches in the region, data coming from the two studies published to date from this area (Rech et al., 2018a; Rayon-Viña et al., 2018) were highly consistent despite different sampling methodology (Fig. 1). The > 1.5 cm items counted in Rech et al. (2018a) and those > 2.5 cm sampled by Rayon-Viña et al. (2018) were highly significantly correlated for the eight beaches in common in the two studies ($r = 0.9417$, d.f = 6., $p = 0.0004$). On average, beaches in the region had 1.41 and 0.56 litter objects per m^2 of > 1.5 cm



(caption on next page)

Fig. 1. Map of the study zone and litter graphs. Above: location of Asturias in Europe and in the Iberian Peninsula. Middle: Location of the nine target beaches of the litter sampling (in white dots) and the location of the volunteers cleaning beaches and social perception surveys. Lower: graph of the litter density (it./m^2) of items from the Rech et al. (2018a) study (blue) and the Rayon-Viña et al. (2018) study (orange). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1
Social sample characteristics.

Actions	Age	Gender	N
Volunteers	Adults	Male	11
		Female	13
	Total adults		24
	Children	Male	24
		Female	27
	Total children		51
Total volunteers			75
Gral. public	Adults	Male	39
		Female	32
	Total adults		71
	Children	Male	29
		Female	33
	Total children		62
Total gral. public			133
Total			208

and > 2.5 cm respectively (SD 1.405 and 0.937 respectively). More litter was found, generally, at the west of Cape Peñas in the central area of the region. The higher litter accumulation in Navia beach is likely due to the influence of the large Navia river. Also, the central zone litter accumulation is explained from dominant currents (Rech et al., 2018a, 2018b).

For the perception of litter quantity (question #1), highly significant differences were found between volunteers and non-volunteers, but not between age groups (Table 2). Volunteers did perceive more litter on the beaches than non-volunteers (Fig. 2).

Regarding awareness (question #2), it had also a high significant effect from volunteering (Table 3), with volunteers being more aware of the litter impact than non-volunteers within each age group. However it was a significant interaction between age and volunteering, with the children volunteers group being more aware of the impacts than the adult volunteer group. Meanwhile in the non-volunteers groups, adults were more aware than children (Fig. 2).

For the perception of the types of beached litter (Fig. 3), most volunteers pointed out plastic as the most abundant type of litter. A few adults mentioned ALDFG, and several children chose glass or other types. In the groups of non-volunteers plastic was also the most frequently perceived litter type, although much less than among the volunteers. Both adults and children mentioned other types and glass in second and third place respectively, and one child (none adult) chose ALDFG. Only some no-volunteers did not answer this question (DK/NA = 16), being 9 children and 7 adults. The global contingency Chi-square was highly significant ($X^2 = 39.779$, d.f. = 9, $p \ll 0.05$). In the post-hoc analysis, significant differences were not found between age groups for volunteers nor for non-volunteers (data not shown), thus the age classes were combined. Highly significant differences were found between volunteers and non-volunteers ($X^2 = 30.248$, d.f. = 3, $p \ll 0.05$).

The awareness (or just opinion) about the origin of beached litter was also different among groups (Fig. 4), with a highly significant total $X^2 = 75.829$, d.f. = 9, $p \ll 0.05$. The post-hoc analysis revealed significant differences between adults and children within the group of volunteers ($X^2 = 20.01$, d.f. = 3, $p \ll 0.05$), and also between ages within the group of non-volunteers ($X^2 = 8.854$, d.f. = 3, p = 0.031), between the two groups of adults ($X^2 = 9.956$, d.f. = 3, p = 0.019) and between the two groups of children ($X^2 = 36.43$, d.f. = 3, $p \ll 0.05$). Children attributed the origin to beachgoers more than adults in both volunteers and non-volunteers groups, and volunteers more than non-volunteers; while household origin was chosen more by non-volunteers than by volunteers (Fig. 4). Again only a few non-volunteers did not answer this question (DK/NA = 3), being 2 adults and only 1 child.

4. Discussion

This study, although modest in sample size, provides some significant insights that could be useful for application in the fight against marine litter. First, the results obtained support the idea of an association between the perception of marine litter and volunteering for cleanups. Volunteers perceived significantly more beached litter than non-volunteers, independently of the age group. Second, and as expected because it happens in other regions (Owens, 2018; Santos et al., 2005; Slavin et al., 2012; Owens, 2018), the volunteers were more aware of litter impact than the non-volunteers. Third, children erroneously attributed beached litter to beachgoers as the main source significantly more than adults. These results will be explained next.

The beach litter sampling carried by Rayon-Viña et al. (2018), revealed that plastics were the most abundant type of litter items in Asturias, representing almost 70% of the items sampled, followed at a distance by ALDFG (12%). The perception of the most abundant litter type, plastics, was generally correct for the volunteers, while > 40% of non-volunteers (adults and children alike) did choose another type of litter as the most abundant. Taking personal actions against marine litter implies that one has a higher perception of litter quantity and impact (Hartley et al., 2015). However, in our study the questions were posed before the cleanups (that is, before taking action) in the case of volunteers, so their higher knowledge of beach status is likely not due to them having more recent or more accurate information about the real beach status than the non-volunteers, who were also contacted on the beaches. The results might be interpreted the other way around: perhaps the people that perceive more litter and know the type of litter beached would offer themselves to cleanup. Indeed, this should be taken with caution since it is speculative because with our study it is not possible to infer cause-effect relationships. The association of higher knowledge and taking action against litter could be instead the result of a previous higher level of concern motivating to search for information about marine litter. Plastics are by far the most abundant marine debris

Table 2
Results of the two-way permutational analysis of variance (PERMANOVA) test for the variable Litter perception (question #1).

Variable	Factor	Sum of sqrs	df	Mean square	F	p (same)
Litter perception	Volunteering	5.36566	1	5.36566	11.98	0.0006541*
	Age	0.0239451	1	0.0239451	0.05347	0.8174
	Interaction	0.642781	1	0.642781	1.435	0.2323
	Within	91.8116	205	0.447861		
	Total	97.7022	208			

Significant p-values are marked with asterisks.

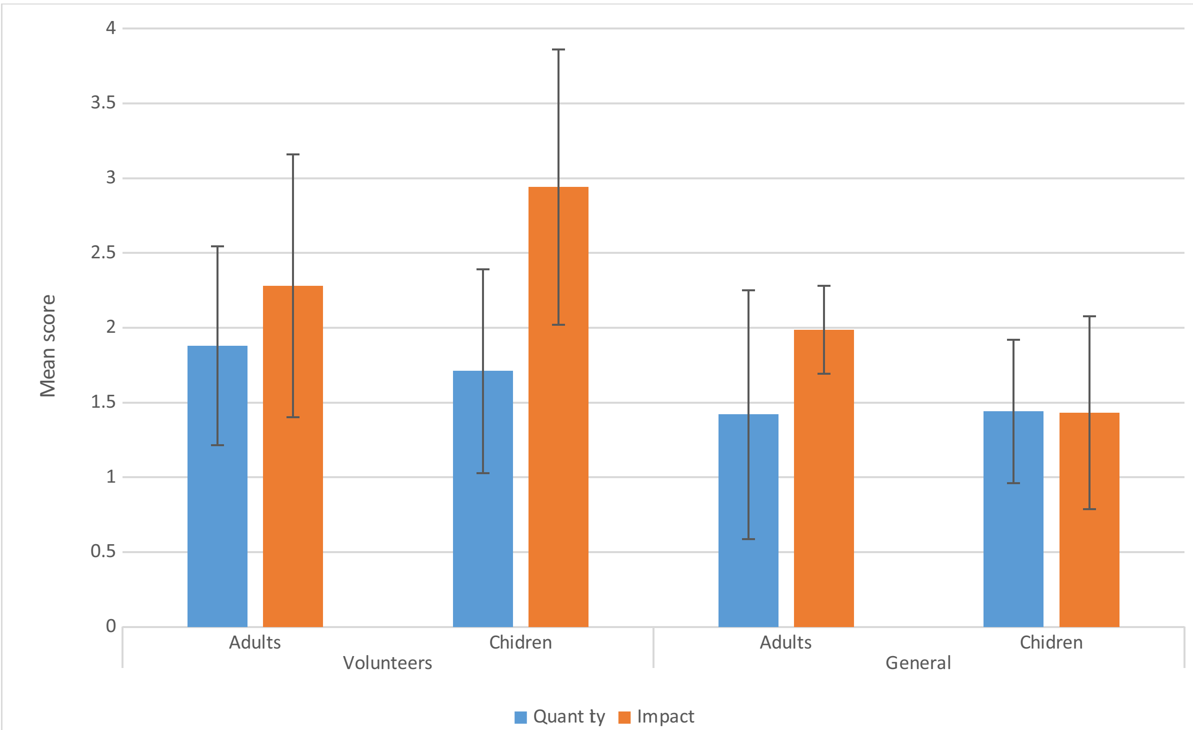


Fig. 2. Marine litter perception and awareness of volunteers and general public from different age groups (Adults and Children). Results are expressed as mean score in 1–5 Likert scale (standard deviation as capped bars).

material, here and in other regions, and its occurrence is well known (see for example Derraik, 2002; Ryan et al., 2009; Pham et al., 2014; Rech et al., 2018a; Rayon-Viña et al., 2018), this explains its general perception among who are paying more attention to the beached litter. In this way, perception is highly dependent on attention (e.g. Martins and Sobral, 2011).

Regarding the litter origin, Rech et al. (2018a) reported fishing and aquaculture gear as the second most abundant type of litter, after sewage, while household and leisure objects (that is, household and beachgoers together) ranked third place. In the present study, however, the volunteers did not identify correctly instead believing that beachgoers were the main source of beached litter, followed by household sources. The maritime origin, which is a more frequent source of beached litter in the region than household and beachgoers (Rech et al., 2018a), was chosen by fewer than 10% of participants in our study. These results are thus heavily biased toward beachgoers as the main contributors of marine litter. Beachgoers are the main contributors of the marine litter in other regions (e.g. Caulton and Mocogni, 1987; Santos et al., 2005), and there are signs at many beaches, as well as public campaigns urging no littering. Thus, it is easy to understand that the general public link beach litter with beachgoers. The reality is that in this and other regions aquaculture and fisheries account for a large proportion of marine litter, especially of fouled objects – objects carrying biota attached (Astudillo et al., 2009; Hinojosa and Thiel, 2009; Liu et al., 2015; Rech et al., 2016, 2018b).

Although our expectation was that there would be a greater difference between children and adults regardless of volunteering status given the amount of awareness promoted by cleanups at young ages (Hartley et al., 2015, Owens, 2018), this did not happen regarding litter perception; rather the opposite. In contrast, in our study children (regardless of volunteering status) more often attributed the litter source to beachgoers than adults, demonstrating a higher awareness about the problem – that was not linked with a significantly higher litter perception. This result disentangles in some way perception and awareness, at least in the children, and reinforces the idea of a higher perception as a result of in-real hands-on cleanups.

While the fight against marine debris has entailed information campaigns and cleanups conducted by Administrations, NGOs, local agents or companies, more recently researchers have better understood the advantages of hands-on public involvement in beach cleaning (Rayon-Viña et al., 2018; Wyles et al., 2016). To efficiently combat the issue of marine litter, improving public awareness about the topic is crucial, taking into account that we are part of both the problem and the solution (Marin et al., 2009; Veiga et al., 2016). The results of our simple but significant study suggest the importance of improving the perception of marine litter as a way for increasing the public participation to fight it. Awareness-raising campaigns would benefit from an emphasis in understanding local beach conditions, encouraging citizens to see their own coasts, and act accordingly. Local administrations might consider this and other similar studies, and take advantage of the

Table 3
Results of the two-way permutational analysis of variance (PERMANOVA) test for the variable Litter awareness (question #2).

Variable	Factor	Sum of sqrs	df	Mean square	F	p (same)
Awareness	Volunteering	47.9645	1	47.9645	91.23	4.08E−18*
	Age	0.133811	1	0.133811	0.2545	0.6145
	Interaction	18.3478	1	18.3478	34.9	1.43E−08*
	Within	107.785	205	0.52578		
	Total	173.229	208			

Significant p-values are marked with asterisks.

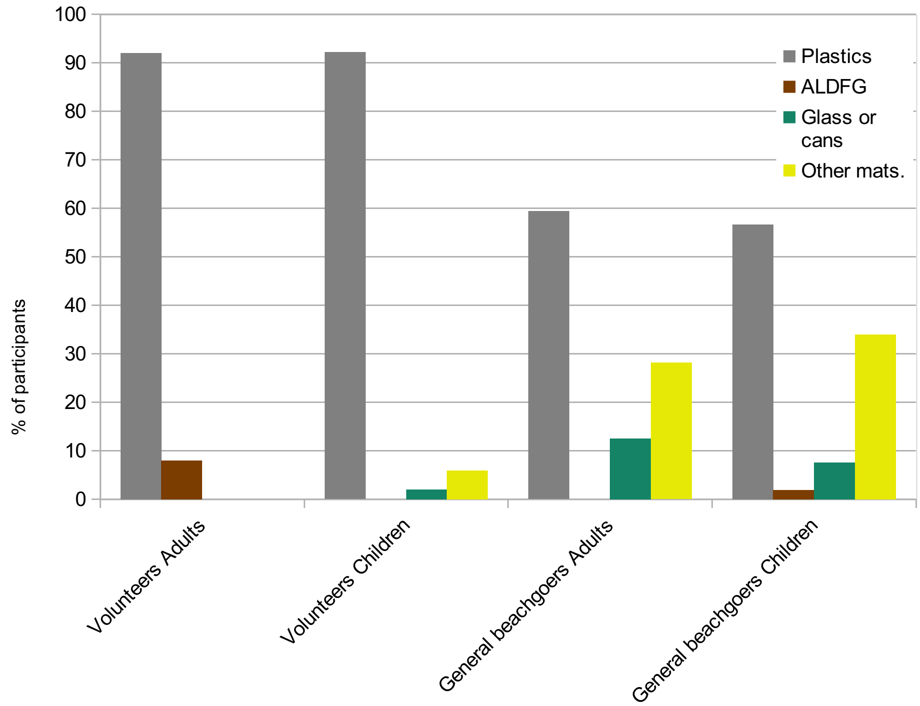


Fig. 3. Types of marine litter identified in this study, in percent of participants, presented by age (Adults, Children) and volunteering (Volunteers, General beachgoers).

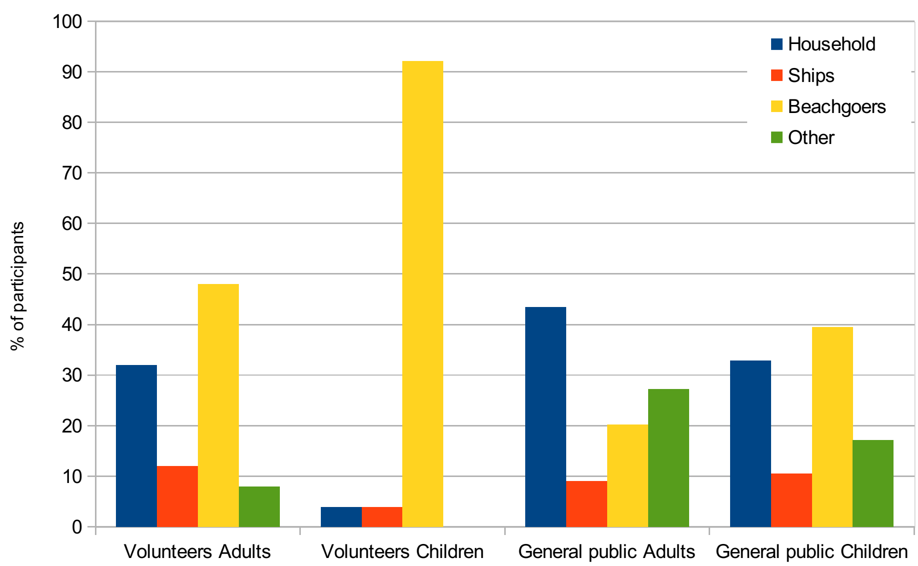


Fig. 4. Attribution of main sources of marine litter in the region studied, as percentage of participants. Results are presented by age (Adults, Children) and volunteering (Volunteers, General beachgoers).

power public awareness to solve this environmental threat. Also, this increase in local awareness can drive people not only to ask for better administration, but to start personal actions against the problem, as the volunteers do (Bruyere and Rappe, 2007; Shye, 2010).

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Discusión

Discusión

Basura marina en la costa asturiana

Los datos de los muestreos en la costa de Asturias obtenidos durante la realización de la presente tesis son coherentes con los publicados por Rech et al. (2018a). Los datos de Rech et al. (2018a) se obtuvieron mediante una metodología diferente, basada en cuadrantes menores y muestreo oportunista. Su coincidencia con los datos obtenidos en esta tesis empleando métodos distintos puede considerarse un indicador de la solvencia del presente trabajo, que es un reflejo sólido de la realidad de la basura en las playas de la región. En conjunto, muestran en buena medida el estado de la costa en lo referente a deposición y acumulación de basura marina. Las playas de Asturias presentaron un promedio de 0.32 (± 0.5628) objetos de basura por metro cuadrado, datos muy parecidos a los hallados en otros países europeos como Alemania, Irlanda o Escocia; y bastante alejados de los de zonas altamente contaminadas como las costas del Pacífico asiático (Lee et al., 2006; Barnes et al., 2009; Smith, 2012) (Tabla 1). Estos resultados sitúan a Asturias en una posición intermedia respecto a la cantidad de basura en sus costas, lo que puede considerarse algo positivo porque apuntaría a que los esfuerzos de prevención y limpieza necesarios para reducirla podrían ser relativamente moderados y de costes asumibles.

Tabla 1. Densidades de basura marina en diferentes regiones del mundo (a partir de Rayon-Viña et al., 2018). Los datos de objetos por metro cuadrado se muestran en promedio, los datos entre paréntesis representan los máximos y mínimos; y los datos tras un ± muestran la desviación estándar. n.d. no datos.

Región	Densidad (ob./m²)	Plástico (%)	Referencia
Israel	36.77 ± 23.48	71	(Golik and Gertner, 1992)
Dulcie y Oeno, Islas Pitcairn	0.24	53	(Benton, 1995)
Isla Inch, Irlanda	0.22	63	(Benton, 1995)
Firth of Forth, Escocia	0.4	n.d.	(Velander and Mocogni, 1998)
Bootless Bay, Papua Nueva Guinea	15.3 (1.2 - 78.3)	89	(Smith, 2012)
Mar Negro suroccidental	0.88 (0.008 -5.06)	91	(Topçu et al., 2013)
Tasmania, Australia	0.016 - 2.03	60	(Slavin et al., 2012)
Nakdong, Corea del Sur	0.97 - 1.03	n.d.	(Lee et al., 2013)
Kaosiung, Taiwan	0.9 (max. 3.227)	77	(Liu et al., 2013)
Monterrey, EE.UU.	1 ± 2.1	68	(Rosevelt et al., 2013)
Asturias, España	0.3158 ± 0.5628	64	(Rayon-Viña et al., 2018)
Chile	2.2 (0.5 - 44.5)	45	(Honorato-Zimmer et al., 2019)
Alemania	0.4 (0 - 1.9)	52	(Honorato-Zimmer et al., 2019)

No debería ignorarse, sin embargo, el hecho de que se han encontrado residuos plásticos, que son persistentes en los ecosistemas, y además que el aporte de basura es continuo, por lo que aun siendo una instantánea del momento actual, la tendencia de aparición de basura en los ecosistemas marinos (y costeros) se mantiene al alza desde hace décadas.

Los datos de composición de la basura son similares a los encontrados en otras costas del mundo (Ryan et al., 2009; Pham et al., 2014), y en revisiones de composición de la basura global (como Galgani et al., 2015), que señalan al plástico como el material predominante en la basura costera, acorde con el 64% encontrado en Asturias; si bien este porcentaje de plásticos es menor que el 70-90% referenciado en otros estudios. De todos estos residuos plásticos, el mayor grupo lo componen pedazos de plásticos producidos por la fragmentación de la basura, probablemente por efecto de la abrasión y radiación solar. La dificultad de atribuir un origen a estos fragmentos hace prácticamente imposible poder trazar su origen y por tanto también es complicado tratar de diseñar medidas enfocadas a impedir la deposición de estos materiales concretos. A la vista de los datos no se puede descartar que los plásticos de menor tamaño, conocidos como mesoplásticos (de entre 5 y 250mm) y microplásticos (menores de 5mm), también se encuentren en grandes cantidades como producto de la fragmentación de los plásticos más grandes. Este tema debería estudiarse en futuras investigaciones.

Las fuentes de la basura marina en la región son dispares, como se muestra en los estudios que componen la presente tesis. Los grandes puertos comerciales y pesqueros como pueden ser el Puerto de El Musel en Gijón o el Puerto de Avilés, se han relacionado con la presencia de basuras en las playas circundantes. Los grandes ríos de la región también se han señalado como donantes de basura a las playas, siendo casos notables el río Eo y las playas de Figueras y Peñarronda, el río Navia y la playa de Navia, el río Nalón y el Playón de Bayas y el río Sella y la playa de Santa Marina. En todos los casos (puertos y ríos) los depósitos de basura se sitúan principalmente en la vertiente oriental de las emisiones, dejando a la vista el efecto de las corrientes en la deposición de los residuos (Charria et al., 2013; Poeta et al., 2016a; Porter et al., 2016;-Leite et al., 2014).

Es de destacar la enorme cantidad de hisopos (conocidos popularmente como bastoncillos de los oídos) encontrada en este trabajo. Estos bastoncillos, hechos de algodón y plástico, se encontraron en grandes proporciones principalmente en la basura recogida de las playas de Xagó y Navia y estarían asociados a un procesamiento incorrecto (o ausente) de las aguas residuales urbanas, como se ha reportado en otras costas de España (Poeta et al., 2016b; Williams et al., 2016). Si a estos datos de Xagó y Navia se añaden los datos de los restos de toallitas húmedas que se tiran al retrete, los cuales también tienen sus máximas acumulaciones en dichas playas, se puede concluir que las Estaciones Depuradoras de Aguas Residuales (EDAR) próximas no están realizando correctamente sus funciones, hecho que ya ha sido recogido por la prensa (El País, 2018 https://elpais.com/politica/2018/07/24/actualidad/1532458329_809489.html) y condenado por la justicia europea (European Court Reports ECLI:EU:C:2011:260; European Court Reports ECLI:EU:C:2018:606).

El segundo tipo de material más común en la basura encontrada fueron los restos industriales de pesca (boyas, redes, sedales, etc). Serían característicos de zonas como Asturias, con una industria pesquera importante (Moore and Allen, 2000; Lee et al., 2006; Unger and Harrison, 2016; Löhr et al., 2017) y que ponen de manifiesto que la gestión de estos residuos no resulta óptima.

De estos datos obtenidos para la costa asturiana se podrían hacer también algunas inferencias indirectas interesantes y preocupantes. El Programa Ambiental de las Naciones Unidas estima que solamente el 15% de la basura que llega al mar acaba depositándose en la costa, quedando el 85% restante en el mar o hundido en el fondo marino (*Marine litter*, *an analytical overview*, 2005). Si además consideramos que una fracción (60%) de los plásticos que se arrojan al mar no flotan (Barnes et al., 2009) y que la cantidad de basuras en los fondos marinos no hace más que aumentar (Tekman et al., 2017), podemos afirmar que los datos de basura acumulada en la playa reflejan solamente una pequeña parte del total de la basura presente en el Mar Cantábrico. Sería urgente cuantificar la probablemente muy grande fracción de estas basuras generada en Asturias que acaba flotando lejos de la costa, en la plataforma continental o incluso en los fondos oceánicos.

Imagen 4. Restos de basura acumulados en la playa de Zeluán, Gozón

Los datos obtenidos muestran que las principales fuentes de basura en la región son los puertos y las aglomeraciones urbanas vertiendo a través de los ríos. Estos datos, aunque concuerdan con los de otros estudios (Topçu et al., 2013; Hong et al., 2014) y son similares a los propios de regiones con un industria pesquera, portuaria y zonas urbanas cerca de la costa (situación similar a la mayoría de la costa asturiana), tienen que tomarse con perspectiva. En numerosos estudios (Caulton and Mocogni, 1987; Santos et al., 2005; Sarafraz et al., 2016; Williams et al., 2016; Nelms et al., 2017), se ha puesto de manifiesto que el turismo y los usuarios de la playa son las principales fuentes de basura marina. Los muestreos de basura para esta tesis se realizaron en periodo invernal, lejos de la temporada de máxima afluencia de gente a las playas, por lo que no se podría descartar una situación de estacionalidad, tal como ya comentaron Poeta et al. (2016b). Estos datos se ven reforzados por la relativamente baja densidad de colillas de cigarrillos y otros materiales que han sido apuntados numerosas veces como residuos comúnmente dejados por usuarios de la playa en periodo vacacional (Santos et al., 2005; Oigman-Pszczol and Creed, 2007; Sheavly and Register, 2007). Teniendo esto en cuenta, si se considera que durante la temporada estival las actividades contaminantes no tendrían por qué disminuir sino al contrario, los datos de esta tesis se pueden considerar como los valores mínimos de basuras que se pueden registrar a lo largo del año y no se puede descartar que durante la época estival, cuando se produce una mayor afluencia de turismo, estos valores aumenten, considerando además el papel predominante del turismo costero en Asturias.

Basura marina y especies exóticas invasoras

En la presente tesis se ha podido confirmar también la relación entre la basura marina y la dispersión de especies exóticas invasoras, algo encontrado por primera vez en la región muy recientemente para invertebrados marinos (Rech et al., 2018a). Esta relación parece mediada por dos procesos diferentes: por la degradación ambiental y por los mecanismos de dispersión de ciertas especies, como algunos organismos sésiles, que son capaces de trasladarse pegados sobre plásticos, maderas y otros objetos flotantes.

Por otro lado, en esta tesis se muestra cómo las basuras marinas pueden también funcionar como balsas artificiales que dispersan distintas especies. Entre las especies encontradas en esta tesis se encuentran cuatro clasificadas como exóticas invasoras, y tres de ellas catalogadas como invasoras en esta región: *Amphibalanus amphitrite*, nativa de los océanos Índico y Pacífico; *Austrominius modestus*, nativa del Mar de Tasmania; *Magallana gigas*, nativa de la costa Pacífica de Asia; y *Mytilus trossulus*, que no está reconocida como invasora pero que es nativa de la costa Pacífica americana y del mar Báltico. Además de estas especies exóticas, muchas de las basuras encontradas tenían asociadas y/o incrustadas otras especies nativas de la costa cantábrica como *Chtamalus stellatus* y *Mytilus galloprovincialis*; o de distribución cosmopolita como *Lepas anatifera* y *Lepas anserifera*. Estas asociaciones son especialmente numerosas con los plásticos que tienen alta flotabilidad, pues representan una superficie muy estable para los organismos que requieren un sustrato que no varíe su posición en la columna de agua con el tiempo. Materiales como las botellas de agua o los restos de poliestireno expandido cumplen estos requisitos y además suelen fragmentarse poco con el tiempo, conformando amplias superficies donde los organismos pueden asentarse y crecer.

Estos datos concuerdan con los presentados por otros estudios en distintas regiones del mundo, como los expuestos por Carlton et al. (2017) y Gil and Pfaller (2016) para la costa americana del Pacífico; por Aliani and Molcard (2003) para el Mediterráneo occidental; por Tutman et al. (2017) en el Adriático; o por Rech et al. (2018b) para el Atlántico europeo y el Adriático. Se puede por tanto afirmar que en Asturias, al igual que en otras regiones del planeta, la basura marina está aumentando la disponibilidad de balsas artificiales sobre las que especies de biota pueden desarrollarse y extenderse. Asimismo, los componentes de plástico de la basura, al no ser biodegradables, son muy persistentes en las aguas, aumentando de manera exponencial su disponibilidad.

Imagen 5. Fotografías de diferentes especies de animales asociados a la basura encontradas durante los muestreos realizados durante el desarrollo de la presente tesis. 1) Balanos (*Amphibalanus amphitrite*) sobre una botella de plástico en Zeluán; 2) Gusanos tubícolas (Familia Serpulidae) sobre restos de nasas de pesca abandonadas en Xagó; 3) Percebes (Género *Lepas*) sobre una botella de plástico en San Juan de Nieva; y 4) Múltiples organismos (sobre todo *Lepas*) sobre restos de pesca en Xagó.

Teniendo en cuenta que la acumulación de basura en las playas y sus alrededores es un indicador del mal estado de conservación ambiental, ya sea por el efecto nocivo que tiene la basura sobre los ecosistemas (Gregory, 2009; Smith, 2012) o por el mal uso que se hace de los arenales (Santos et al., 2005; Slavin et al., 2012), se puede afirmar que algunas de las playas estudiadas se encuentran en un estado de conservación deficiente. En la presente tesis se ha podido evidenciar el paralelismo que existe entre esta degradación ambiental por basura marina con la aparición y el establecimiento de una especie exótica invasora muy abundante en la región, la hierba de la pampa (*Cortaderia selloana)*. Incluso con un número limitado de playas, los datos muestran que las peor conservadas y con mayor densidad expuestas a basura marina tienen también una mayor densidad de esta planta. Esto se corresponde con el carácter invasor de la planta y de su preferencia, como muchos otros organismos invasores, por ecosistemas degradados donde encuentran nichos que no pueden aprovechar especies más sensibles, y a partir de los cuales se expanden (Domènech and Vilà, 2006; García and Amparo, 2017). Aun basándose en un estudio de caso, estos datos dan una idea de la necesidad de un compromiso por la conservación y por la reducción de la basura marina y su impacto, para poder predecir sus efectos indirectos entre los cuales se encuentra el aquí descrito sobre la facilitación de la dispersión de especies exóticas. Cabe también mencionar la ausencia de la hierba de la pampa en playas muy expuestas a basuras pero que son periódicamente limpiadas y controladas por los servicios de limpieza, como es el caso de las playas urbanas del Arbeyal y El Rinconín, en Gijón. Este dato muestra que la lucha contra la basura puede servir para controlar especies invasoras y refuerza la importancia del tratamiento medioambiental integral de los espacios costeros.

Imagen 6. Hierbas de la pampa (*Cortaderaia selloana*) creciendo en los lindes de la playa de La Ñora.

Imagen 7. Voluntario recogiendo basuras en el Playón de Bayas (Castrillón). Crédito: Deborah Santos Hernández

La presente tesis muestra por primera vez un análisis pormenorizado de la percepción social del problema de la basura marina en Asturias. Estos datos ayudan a mostrar una imagen de la sociedad asturiana acerca del conocimiento y nivel de concienciación que posee sobre la basura marina en sus costas. Las medidas de gestión de la basura en la costa dependen de los municipios y no existe un registro por parte de las mismas ni de entidades de orden superior (Ley 2/2013; Real Decreto 876/2014). Que las medidas que los ayuntamientos tomen para reducir o evitar la presencia de basuras en las playas sean efectivas depende en gran medida del grado de información ciudadana sobre este problema. En general, los resultados muestran un alto nivel de conocimiento de la basura marina por parte de la ciudadanía, especialmente respecto a la cantidad de basura. La muestra aleatoria de población encuestada tiende a identificar los niveles de basura de las playas con bastante acierto, lo cual no es siempre una tarea sencilla si se tiene en cuenta que una fracción importante de esta basura son fragmentos de pequeño tamaño, muchas veces difíciles de reconocer (Martins and Sobral, 2011).

Sin embargo, esto no ocurre en todos los casos. Fijándose en la identificación del tipo de materiales que componen la basura, el nivel de acierto disminuye. Los residuos de plástico estaban bien representados en la adjudicación del público, mientras que éste no identificaba los restos de materiales de pesca, que por otra parte son bastante comunes en las playas de la región. Esta brecha en el conocimiento puede explicarse si se tiene en cuenta que la percepción no solamente depende de la cantidad de basura que se ve realmente, sino también de las asunciones *a priori* que se hagan. Por una parte, hay materiales que de manera más o menos consciente no se quieren ver, se “dejan pasar”, porque se asume que son inevitables en el ambiente; esto podría ser lo que explicase la menor percepción de restos de pesca, que se esperan encontrar en el mar (Perry et al., 2010). Por otra parte, también hay que considerar que la gente percibe en mayor medida los residuos dependiendo de la importancia que se le dé a cada uno, como ya señalaron Tudor and Williams (2003). Por ejemplo, el grueso de la población entrevistada estima más nocivo un preservativo que una botella de plástico; aún no encontrándose preservativos en ninguno de los muestreos de basura realizados, se tiende a mencionarlos como basura típica de las playas. Por último, muchas de las afirmaciones sobre la basura se pueden basar en asunciones hechas a partir de un conocimiento ajeno a la realidad, como por ejemplo en datos de otras regiones, habladurías, eventos puntuales, etc. Este sesgo en la percepción de la realidad de las basuras, aun no siendo un problema, debería de tenerse en cuenta a la hora de tratar de llevar a cabo campañas de concienciación por parte de la Administración pública.

Como se muestra en la presente tesis, la cantidad y tipos de basura son muy variables entre playas dentro de la región; como lo son también entre regiones de España (Williams et al., 2016) y entre zonas del globo (como se muestra en la Tabla 1); de lo que se deriva que el manejo de la basura requiere de un conocimiento exhaustivo tanto de la basura como de la población que la genera (Sheavly and Register, 2007). Esta diferenciación deja de manifiesto la necesidad de una aproximación local para optimizar el esfuerzo y maximizar el beneficio de las campañas de sensibilización sobre la basura. Estas campañas y la mitigación y prevención de basura en las playas deberían responder a las condiciones locales de cada zona, a escala de población o de concejo; es decir, de poco serviría que se destinasen fondos a prevenir o eliminar un tipo de basuras en un lugar que carece de ellas.

La manera más efectiva de luchar contra un problema es ir al origen, que en este caso sería la propia producción de basura. Tratar de concienciar a la población sobre la basura que se genera y los efectos negativos de su acumulación en los espacios naturales tanto para el ser humano como para la fauna y flora, es un método que *a priori* debería reducir la producción de residuos. Los resultados de esta tesis muestran cómo la participación en acciones de voluntariado para limpiar las playas se corresponden con un alto grado de preocupación por el estado de las basuras en la costa y con un alto acierto en la percepción de la basura; probablemente porque un mayor conocimiento deriva en una mayor concienciación (Fletcher et al., 2009; Marin et al., 2009; Wyles et al., 2016). Teniendo en cuenta, además, que la cantidad de basuras en las playas se relacionó con una mayor percepción de estas, resulta realista vincular en Asturias la basura con la percepción y con la concienciación, como ya mostraron otros estudios sobre el mismo tema (Hartley et al., 2015; Löhr et al., 2017). Al igual que en otros casos, el contacto con la realidad, en este caso las limpiezas de playas hechas por voluntarios, o cualquier otra actividad en las playas que muestre sus problemas al público, ayudará a mejorar la percepción de la gente y su concienciación sobre el problema (Wyles et al., 2016; Battisti and Gippoliti, 2018). Esto, sin embargo, entra en conflicto con las pretensiones de las administraciones y el público en general, que prefieren ver solamente playas limpias de las que se benefician mucho más. Existe pues un dilema entre no intervenir en las playas para mostrar el nivel del problema a la población que así adquiriría una visión real del mismo, y realizar intervenciones para tener unas playas limpias que contenten a la población local y atraigan al turismo. En cualquier caso, los datos de esta tesis muestran que la voluntad de tomar medidas contra la basura en las playas es mayor cuanto más se visitan, al igual que la percepción de dicha basura (Figura 3).

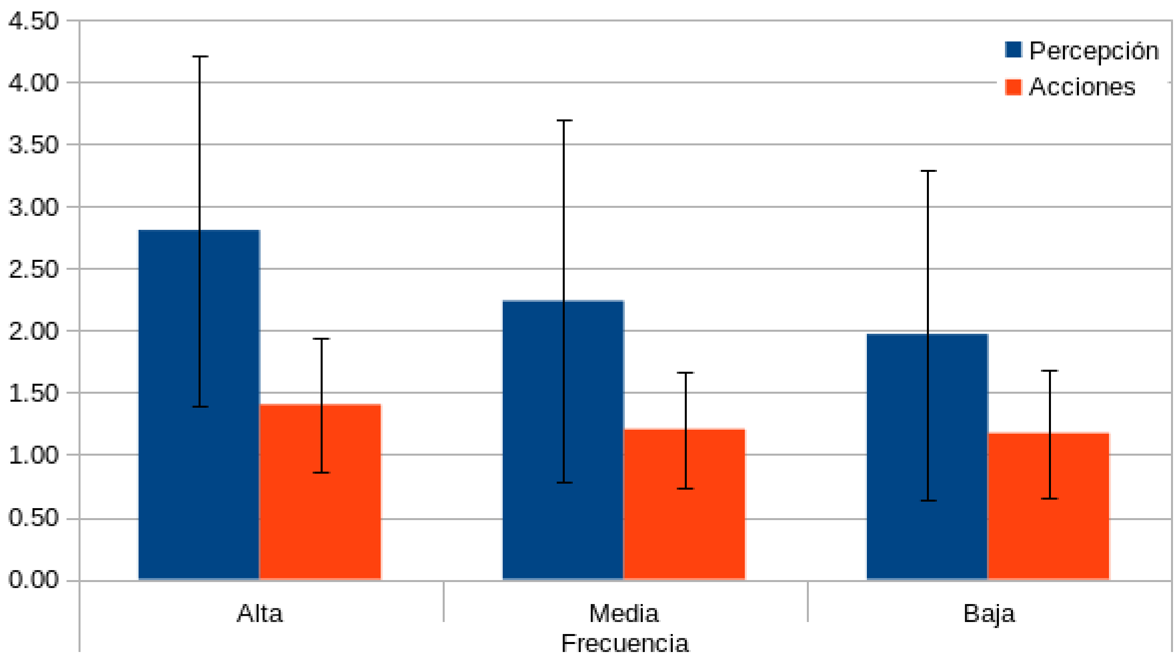

Figura 3. Variaciones en la percepción de la basura depositada en las playas (en azul) y la voluntad de actuar contra ella (en naranja) de la población encuestada para Rayon-Viña et al. (2018) considerando la frecuencia de visitas a la playa

Como ya se ha apuntado en otros estudios, existen factores poblacionales que pueden ser relevantes para entender y predecir la respuesta de la ciudadanía al problema de las basuras marinas (Santos et al., 2005; Arafat et al., 2007; Slavin et al., 2012). En la presente tesis se ha destacado la influencia significativa de la edad. Los jóvenes, por lo general y comparados con los adultos, tienen una menor percepción sobre la basura en las playas y una menor concienciación sobre su impacto. Para toda la población, percepción y concienciación aumentan con la frecuencia de visitas a las playas y, especialmente, si se participa en el voluntariado de limpieza de playas, confirmando el efecto reforzador de la concienciación en la toma de acciones. La aparente falta de conocimiento sobre la contaminación costera en las generaciones más jóvenes resulta bastante preocupante, pues es opuesta a lo esperado de una generación que, al contrario que generaciones anteriores, recibe una formación académica sobre estos temas, lo cual se supone que debería aumentar su implicación medioambiental para disminuir el impacto de la basura en los mares y costas. Las causas de esto pueden deberse a la asiduidad con que las playas son limpiadas por las administraciones durante el periodo estival, hecho que disminuye la percepción de la basura y por tanto la preocupación sobre estos temas (Marin et al., 2009). La falta de una implicación medioambiental fuerte, no considerando importantes las acciones personales como tirar basura (Arafat et al., 2007; Slavin et al., 2012), o una falta de conocimiento en profundidad sobre el tema, pueden generar también una despreocupación sobre esta cuestión (Steel et al., 2005). Aun así, una causa bastante peligrosa puede ser la interiorización de la basura en la playa como algo normal o inevitable, en contraste con la percepción de sus mayores, que han ido viendo un aumento paulatino de la cantidad de basura acumulada. Esto muestra la importancia de un conocimiento de la evolución de las basuras en las playas desde el estado natural (no contaminado) hasta el presente, así como la importancia de que estos datos lleguen a la sociedad y sean interiorizados por ella, para así tener una sociedad mejor informada, concienciada y, por tanto, responsable.

La identificación de las especies invasoras como amenaza para los ecosistemas costeros y marinos por parte del público encuestado fue también referenciada por primera vez en la región como resultado de la presente tesis. El público, en general, se encuentra bastante concienciado sobre el peligro de las especies invasoras, al menos referido a una especie tan reconocible en Asturias como es la hierba de la pampa (*Cortaderia selloana*), al contrario de lo que ocurre en otras zonas de España también invadidas por esta planta (Andreu et al., 2009). Sin embargo, se ha encontrado un alto grado de desconocimiento sobre las causas de esta amenaza y sus implicaciones. Los resultados de las encuestas revelan que mientras que en general la población demuestra un alto grado de preocupación por las invasiones biológicas, en una gran proporción no son capaces de enunciar medidas de control, de valorar dichas medidas ni de sugerir otras. Esto podría explicarse por la necesidad de la gente de tener un mayor conocimiento para atreverse a responder a dichas cuestiones. Sin embargo no parecieron encontrarse dificultades para responder en el caso de las basuras marinas y su gestión. Es por tanto probable que esta laguna de respuestas se deba más a una falta de conocimiento que a una falta de iniciativa para responder. En la región, la prensa generalista da una cobertura amplia a las noticias sobre las invasiones biológicas, pero apenas se hace mención a las amenazas y problemas que llevan asociadas. Esto, unido a una falta de seguridad por parte de las generaciones más jóvenes, deja de manifiesto que la información general sobre el tema resulta deficiente. Teniendo esto en cuenta y sabiendo que los organismos públicos de gestión toman medidas para tratar de disminuir las invasiones biológicas, la erradicación de estas especies tendría que acompañarse de campañas de información sobre las implicaciones ambientales, económicas y sociales que tienen las invasiones biológicas, y animar a participar en las erradicaciones, a fin de no generar una falsa impresión de que resulta innecesario o incluso inadecuado (Schüttler et al., 2011).

Conclusiones

Conclusiones

I. La cobertura por parte de la prensa generalista y no especializada de la región al problema de la basura en la costa de Asturias es bastante irregular y escasa. Se ha evidenciado la escasez de información técnica y publicaciones científicas respecto de estos temas. Las medidas de gestión de la basura en la costa dependen de los municipios y no existe un registro por parte de las mismas ni de entidades de orden superior, por lo que esta falta de información podría repercutir de manera negativa en la toma de medidas por parte de las administraciones y la población.

II. Los muestreos en las playas han evidenciado que la costa asturiana contiene basura marina en sus playas, en cantidades relativamente bajas acordes con las de otras costas atlánticas europeas y menores que las de regiones altamente contaminadas como las costas del Pacífico asiático. La basura en la costa refleja sólo una parte del total de basura marina, y se propone como acción necesaria evaluar su cantidad y efecto en la zona submareal y los fondos marinos del mar Cantábrico.

III. Se han identificado varias fuentes de basura en la región asturiana, que incluyen las aglomeraciones urbanas costeras, el tratamiento deficiente de la basura y las aguas residuales y los puertos marítimos, incluyendo los pesqueros y puertos internacionales como El Musel. Se propone una mejor gestión de los residuos sólidos urbanos especialmente en las zonas próximas a Xagó y Navia.

IV. Los resultados de esta tesis muestran que la basura puede funcionar como dispersor de especies a lo largo de la costa, entre ellas especies exóticas invasoras como *Amphibalanus amphitrite*, *Austrominius modestus* y *Magallana gigas*. Además, se ha encontrado una asociación significativa entre la densidad de basura y la de la planta invasora *Cortaderia selloana* en playas asturianas, probablemente por su buena adaptación a ambientes degradados. Esto refuerza la necesidad de reducir las basuras marinas para prevenir invasiones biológicas en la costa asturiana.

V. La ciudadanía asturiana encuestada muestra un nivel alto de concienciación sobre el problema de la basura marina, aunque su conocimiento de la basura real es inexacto. Se ha encontrado que las personas, adultos y jóvenes, que participan como voluntarias en actividades de limpieza de playas, y las que visitan frecuentemente la playa, tienen un conocimiento mayor del problema real. Los datos apoyan la necesidad de mejorar el nivel de información de la ciudadanía respecto a la basura marina para prevenir su producción y mejorar su gestión, habida cuenta que es una amenaza que no deja de crecer en las costas de todo el mundo.

Conclusions

Conclusions

I. The coverage by the general and non-specialist news media of the region to the problem of litter on the coast of Asturias is quite irregular and scarce. The scarcity of technical information and scientific publications on these subjects has been highlighted. Waste management measures on the coast depend on the municipalities and there is no record of them or in higher order entities, so this lack of information could have a negative impact on the taking of measures by administrations and the population.

II. Beaches sampling has shown that the Asturian coast contains marine garbage on its beaches in relatively low quantities in line with those of other European Atlantic coasts and smaller than those of highly polluted regions such as the Asian Pacific coasts. Litter on the coast reflects only a part of the total marine litter, and it is proposed as a necessary action to evaluate its quantity and effect on the subtidal zone and the seabed of the Cantabrian Sea.

III. Several sources of garbage have been identified in the Asturian region, including coastal urban agglomerations, deficient treatment of garbage and wastewater and seaports, including fishing ports and international harbours such as El Musel. Better management of solid urban waste is proposed, especially in the areas around Xagó and Navia.

IV. The results of this thesis show that garbage can function as a disperser of species along the coast, including invasive exotic species such as *Amphibalanus amphitrite*, *Austrominius modestus* and *Magallana gigas*. In addition, a significant association has been found between trash density and that of the invasive plant *Cortaderia selloana* on Asturian beaches, probably due to its good adaptation to degraded environments. This reinforces the need to reduce marine debris in order to prevent biological invasions of the Asturian coast.

V. The Asturian citizens surveyed show a high level of awareness of the problem of marine litter, although their knowledge of real litter is inaccurate. IIt has been found that people, adults and youngsters, who participate as volunteers in beach cleaning activities, and those who frequently visit the beach, have a greater knowledge of the real problem. The data support the need to improve the level of public information about marine litter in order to prevent its production and improve its management, given that it is an ever-growing threat on coasts around the world.

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