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Authors: Aitor Ibabe, Yaisel J. Borrell, Sara Knobelspiess and Eduardo Dopico

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Perspectives on the marine environment and biodiversity in recreational ports: the marina of Gijon as a case study

Ibabe, A.[1] Borrell, Y.J.[1], Knobelspiess, S. [2], Dopico, E.[3]

[1] Department of Functional Biology, University of Oviedo. C/ Julián Clavería s/n. 33006-Oviedo, Spain

[2]International Master in Marine Biological Resources (IMBRSea), Ghent University, Belgium

[3]Department of Educational Sciences, University of Oviedo. C/ Aniceto Sela s/n. 33005 Oviedo, Spain

* Corresponding author: ibabeaitor@gmail.com

ABSTRACT

Recreational ports are known to be sources of pollution to the coastal marine environment due to the pouring of pollutants or the transfer of invasive species to neighboring areas. Nonetheless, the responsibility of protecting the marine environment does not lie solely on the users of the ports, but also affects the rest of citizens. Thus, an effective communication is necessary between scientists and citizens to avoid the lack of knowledge and boost cooperation against these environmental problems. In this study, (focused on the marina of Gijon, Northwestern Spain) citizens set education and social media as the main sources of information, rarely considering science outreach. Also, their environmental knowledge showed to be based on a visual perception, rather than on a cognitive one, as marine litter was considered a great environmental problem, while invasive species and biofouling went unnoticed, remarking the lack of an effective communication from scientific sources.

Keywords: Marine biodiversity; Science literacy; Blue economy; Invasive species

INTRODUCTION

Marine ecosystems occupy two thirds of our planet. They represent a dynamic ecosystem of constant interaction of living organisms. The biodiversity they harbor is one of their main characteristics, but marine ecosystems are also an important source of services, as they support different economic activities that are necessary for human well-being. Marine species are used as providers of food, shelter, medicines and livelihoods and are also sources for economic activities like tourism and fishing. Moreover, sea outside, in the land zones, marine coastal environments and their biodiversity are a fundamental base for many ecosystem services, as they support the 90% of marine exploitation resources (Barnabé and Barnabé-Quet, 2000).

However, due to the increase of human pressures, global biodiversity indicators of marine ecosystems are showing an accelerated decline all over the world (Halpern et al., 2008; Butchart et al., 2010; McCauley et al., 2015). Overexploitation is one of the most important threats to the marine environment; fisheries and their continued resource consumption has led to a situation where the 33.1% of world fish stocks are subject to overfishing (Food and Agriculture Organization, 2018), triggering drastic reduction in species population sizes like it happened in the case of the Bluefin tuna (*Thunnus thynnus*) in the Mediterranean Sea (Block, 2019). Similarly, anthropogenic litter has become another serious problem for marine ecosystems, as debris ends up in the sea where marine life is harmed: some species can get strangled by nets, macroplastics can cause death due to indigestions and microplastics (plastics degraded into particles smaller than 5 mm) can enter the food chain and become sources of toxic chemicals that are released to the environment (Vélez-Rubio et al., 2018; Liu et al., 2019). All along with this, our oceans are facing many other threats that alter the ecosystems, such as climate change that is causing global declines in tropical and subtropical coral species (Hughes et al., 2017) or shipping-associated pollution that causes mortality among many marine species (Walker et al., 2019).

Not only open seas, but also coastal marine environments are critically affected by human activities. Due to the rapid human population growth, new land is being reclaimed from the sea, causing severe habitat destruction and biodiversity loses (Lai et al., 2015; Tay et al., 2018). Within coastal areas, human populations are typically constructed around ports where activities related to the marine environment and its services are carried out. Commercial ports are receptors of ships that travel around the world, and alter marine ecosystems by generating air pollution, greenhouse gases, oil and chemical spills, garbage or underwater noise pollution (Christensen et al., 2018; Wan et al., 2018; Papaefthimiou et al., 2019; Tidau and Briffa, 2019; Walker et al., 2019). In addition, shipping also facilitates the transfer and spread of invasive species (via ballast water or biofouling), which cause biodiversity losses all over the world (Bellard et al., 2016; Doherty et al., 2016). These species colonize new habitats and affect the local ecosystem by competing or predating and can also affect humans by bringing new infectious diseases and economic loses (Molnar et al., 2008; Walsh et al., 2016; Bayliss et al., 2017). Maritime shipping is known to be the first pathway for marine invasions both when moving people and goods, and when ballast water is loaded or unloaded (Zaiko et al., 2015), so that ports are very vulnerable to be colonized by invasive species (Drake and Lodge, 2004). Prevention is the most effective way to fight these invasions: once the alien species is stablished in an ecosystem, its eradication is a very complicated and expensive process (Simpson et al., 2009), this means that an early detection of arriving species must be done, when the population is still manageable.

In coastal urbanizations we can find, in addition to commercial ports, marinas where recreational boaters (local or foreign people) sail along the coast with leisure purposes. Vessel activities occurring inside these recreational docks also serve as inputs of boating-associated pollutants that can alter the local coastal marine ecosystem. The main pollution sources from recreational boating are fuel, oil and other chemicals discharged from powered boats (Burgin and Hardiman, 2011). These pollutants can be discharged due to engine activities, affecting species present in the ecosystem (Whitfield and Becker, 2014) but also by dilution from antifouling paints employed on ship hulls to prevent fouling by marine organisms (Schiff et al., 2004). Actually, as these treatments contain toxic chemicals for some organisms, they also have an effect against biological invasions via recreational boating, which has been classified as an important vector for secondary dispersal of non-indigenous and invasive species (Clarke Murray et al., 2011; Drake et al., 2017). Apart from this, recreational boating has also shown to be a source of plastic litter that ends in the marine environment, contributing to environmental degradation in the area (Milliken and Lee, 1990; Mehlhart and Blepp. 2012). Moreover, as these ports are typically located inside cities (to be close to local citizens that are its main users), they have a strong interaction with urban areas and land-based activities that can also be sources of pollution, such as rubbish that can reach water from urban runoff or landfills and affect the marine ecosystem (Walker et al., 2006; Munari et al., 2016).

At this point, an urgent solution is needed to fight this complex of environmental problems. To this day, several policies and protocols have been developed, in order to protect marine ecosystems and their biodiversity; MARPOL (The International Convention for the Prevention of Pollution from Ships) is one of them. Its main objectives are to prevent pollution by oils, harmful substances, dumping and air pollution produced by all kinds of vessels. The IAS (Invasive Alien Species) regulation enforced in Europe in 2015 (European Union, 2014) is another regulation that provides a set of measures for the prevention, early detection and management of invasive species in the European Union including plans that involve citizen science. Similarly, the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWMC) aims to prevent the spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for the management and control of ships' ballast water and sediments (International Maritime Organization, 2004). Finally, the European Marine Strategy Framework Directive (EU MSFD) that was adopted in 2008 is focused on the protection of biodiversity and the achievement of good ecological status of the European marine waters by 2020 (European Commission, 2008).

In order to accomplish these regulations and meet the established objectives, the collaboration of all the groups of society is required. Stakeholders and policy makers need to be aware of the existing problems and potential ways to manage them, in order to put in practice necessary actions. In the same way, public support can be critical for future projects (McKinley et al., 2017) and it is necessary to understand the present attitudes within the society, in order to develop educational activities where scientific information can be transferred to citizens.

Access to this information that can raise awareness about environmental sustainability is produced through various channels: education, scientific dissemination, personal contact with the environment, media… and all these information flows can provide useful knowledge and awareness when adequate receptivity is obtained. However, there is still a gap of communication and collaboration among scientists, citizens, policy makers and stakeholders that hinders the preservation of coastal ecosystems and their resources (Young et al., 2016).

There are many studies about science literacy, and how the knowledge level of a population affects the public opinion about scientific projects or findings. Facts like religious and political identities determine attitudes of individuals, such as in the case of global warming issue (McCright and Dunlap, 2011; Maibach, 2015), however, it has been seen that a higher education level and scientific knowledge may suppose a higher support for scientific research motivated by personal nonscientific concerns (Drummond and Fichhoff, 2017). This is why it is necessary to identify and support the best sources of information that can improve the level of knowledge among different groups that compose society. This way, a better management of environmental issues could be achieved, aiming the development of a blue economy, based on the sustainable consumption of marine resources and the protection of biodiversity (Silver et al., 2015).

Here we present the case study of the Gijon’s marina, a leisure port with 780 moorings distributed in four docks that is located in the city of Gijon, Asturias. This port has a regulation directed for all users of the marina: In order to avoid water pollution, all vessel users must comply with MARPOL directive, by using specific containers for the deposit of garbage, oils, bilges, fecal wastes or any other kind of wastes (IMO, 2011). Outside the leisure port, citizens are also responsible for maintaining the coastal environment on a good status; it is important to determine their level of awareness and the potential sources of information that contribute to a better comprehension of the potential environmental problems that the port may face. This study has the aim of defining the current perception that citizens show about the environmental conditions in the port and the potential impacts that can threaten the local marine biodiversity, also assessing the existing level of knowledge and the main sources of information that contribute it.

MATERIAL AND METHODS

A questionnaire was designed and personal and individually handed to random walkers at different parts of the city of Gijon, located in Asturias, Northwestern Spain (43° 20′ N, 6° 0′ W) (Figure 1). The questionnaire was composed by 13 items, including questions about the port of Gijon and its environmental status, about the knowledge level of respondents and their perception about environmental stressors (Supplementary table 1). All items were designed to be answered employing the Likert scale, with values from 1 to 5 excepting items 7, 8 and 9. The survey was carried out within October 2018 and April 2019 with a total of 200 respondents that were classified by sex, age, study level and by the frequency of their visits to the port area. The questionnaire was validated in a pilot trial with 15 volunteers; Cronbach's alpha was calculated for all the 13 items and for 10 items (excluding items 7, 8 and 9, that are not in Likert scale) obtaining values of 0,6564 and 0,6791 respectively.

In order to determine citizen`s general attitude towards the port, items 9, 11 and 12 were employed as they are related with the perception about the environmental status of the port and the effectiveness of its current environmental management strategies. As question 9 (is marine pollution a problem in this port?) is not in Likert scale, numerical values were given to responses, giving the value 1 to the answer "yes", 5 to the answer "no" and 3 to answers "probably" and "I don't know". This way a mean value for each respondent was built from these three items, resulting in a value from 1 to 5 that reflects the perception about the port, it`s activities and environmental status.

Statistical analyses were carried out with non-parametric tests done in PAST program (Hammer et al. 2001) after checking normality in the dataset. Responses given by each population groups were compared using the non-parametric Mann-Whitney test and p values were estimated using Bonferroni correction.

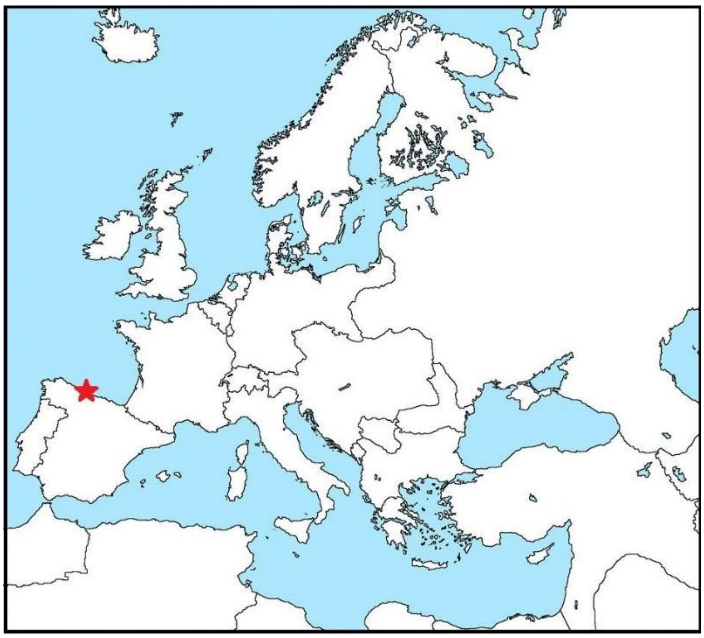

Figure 1. Geographical location of the Port of Gijon in Europe

RESULTS

Out of the 200 surveyed people, 117 (58,5%) were women and 83 (41,5%) were men. The 48% were younger than 30, and only 30 people were over 60 years of age. The education level was higher in most of the respondents (66,5%) and regarding the port visit frequency, the 62,5% of the answerers (125 people) affirmed that they seldom visited such areas, being the option "sometimes" the next most chosen one (39 people) (Figure 2).

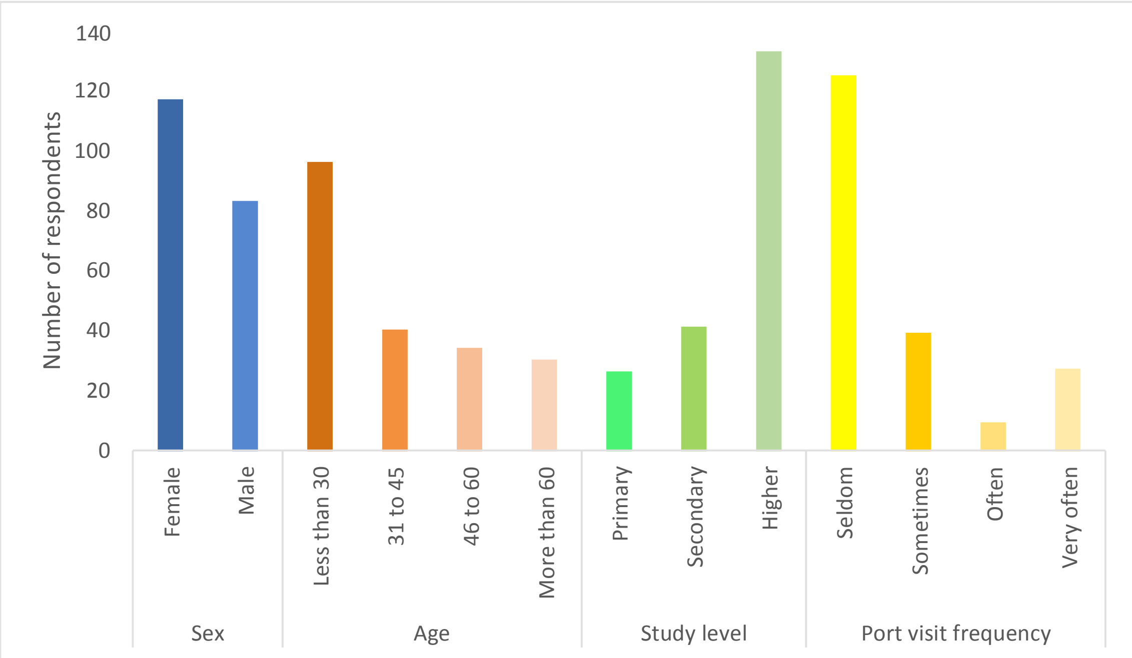

Figure 2. Grouping of the surveyed population by age, sex, study level and port visit frequency and the number of respondents belonging to each option.

Considering the whole dataset, the opinion that citizens have about the port resulted to be considerably negative, with a mean value of 1,92 out of 5. Citizens think that marine pollution is a problem in the port area (mean value 1,3 out of 5); although some people (9%) think that the port is in excellent or very good conditions, overall, citizens think that the marine ecosystem and its biodiversity are not in a healthy state in the port of Gijon (2,36 out of 5) and that there should be more effective measures to protect the environment (2,11 out of 5).

Regarding the population groups, statistically significant differences were found: those with higher studies showed a more negative point of view about the port, its regulation and environmental status than people with basic studies (p=0,0042). On the other hand, women had a more negative perception of the port than men (p=0,0076). Age also resulted to be a factor affecting the perception about the port, as older people (more than 60 years) showed to have the more positive opinion about the port when comparing to people between 46-60 year (p=0,0058), 31-45 years (p=0,0026) and people younger than 30 (p=0,0032) who showed a negative perception about the environmental status and the effectiveness of management strategies in the area.

In order to assess the level of knowledge/awareness of the population, respondents were asked about terms biodiversity and marine biosecurity. The level of knowledge about them turned out to be quite low in the population (2.76 on the Likert scale). The term marine biosecurity obtained a lower score than the term biodiversity (p = 0.0001), showing a greater level of ignorance towards it.

When analyzing the different population groups, statistically significant differences were found in many of them. As expected, people with a higher educational level showed a greater knowledge than those with basic studies (p=0,0008). Regarding age, it was seen that people over 60 years old showed the lowest level of knowledge (mean values of 2,2 out of 5), with significant differences with the population under 30 years (mean values of 2,82 out of 5) (p = 0.0035) and with people between 46 and 60 years (mean values of 2,69 out of 5) (p = 0.0003). In addition, men (mean knowledge level of 2,96) showed a higher level of knowledge than women (mean knowledge level of 2,62) (p = 0.0265). Regarding the frequency of visits to the port area, no significant difference was detected between groups.

Once the level of knowledge was established for each population group, the next question aimed to identify the main source of information that citizens consider best to raise awareness about biodiversity and marine biosecurity. Education was selected as the most important one, with 32.90% of the votes, followed by social media (21.22%). It is remarkable that literature and science outreach were rarely voted as sources of information, comparing with the 200 votes that education obtained, science outreach obtained 118 and literature only obtained 46 votes.

Regarding the different groups present in the population, almost all agreed that education is the main source of knowledge about the subject, however, people between 31 and 45 years believe that social media are the most important source nowadays, and people over 60 believe that other media such as press or television have more importance (Table 1).

Table 1. Number of votes that received each source of information from each population group. Shaded in grey the most voted sources of information for each group.

		Education		Science	Social	
Sex	Male	70	23	52	58	49
	Female	130	23	66	71	66
Study level	basic	39	7	16	9	14
	secondary	30	7	21	29	29
	higher	131	32	81	91	72
Port visit frequency	Seldom	137	25	75	66	73
	Sometimes	41	12	32	33	17
	Often	9	2	6	5	4
	Very Often	13	7	5	25	21
Age	Less than 30	114	16	48	58	48
	31 to 45	23	11	26	36	26
	46 to 60	35	9	33	27	11
	more than 60	28	10	11	8	30

Next, citizens were asked about the main factors that are causing pollution in the port area. Several options were handed for them (oil pollution, marine litter, invasive species, biofouling and others) to define the dangerousness for each one in Likert scale. Marine litter was the factor considered more dangerous by respondents, with a mean value of 4,28 out of 5 followed by oil pollution (=3,76) and other factors such as carbon spillage or industry (= 3,55). Marine litter was considered much more dangerous than invasive species (p= 1,72 E-33) or biofouling (p=3,01 E-31). In fact, these factors were the ones considered to be less important by respondents, with considerably lower mean scores in Likert scale: invasive species (= 2,69) and biofouling (=2,73) (Figure 3).

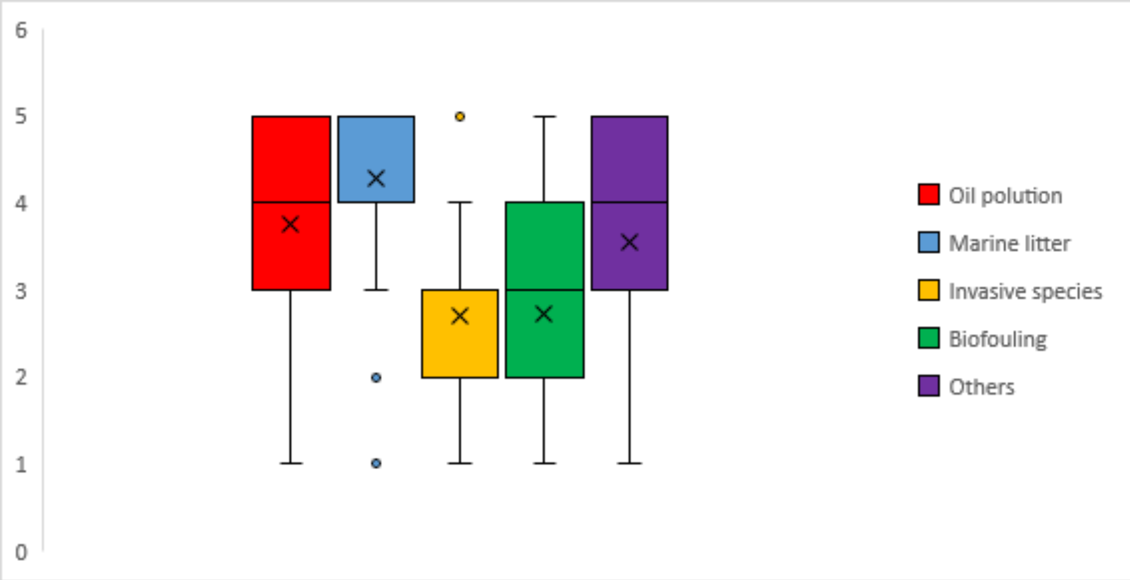

Figure 3. General opinion about the dangerousness of the environmental stressors causing problems in the port area (Likert scale).

Considering the population groups, the study level of respondents showed to affect the perception of the different environmental stressors (Figure 4); Invasive species are considered much more dangerous by people with basic studies than people with secondary (p= 0,0015) or higher studies (p= 0,0077). The same happens with other factors (including carbon spillage and industry), which are considered more dangerous by respondents with basic studies than those with secondary (p= 0,021) and higher studies (p= 0,016). In short, people with basic studies gave more importance to each and every environmental stressor than those with a more complete education.

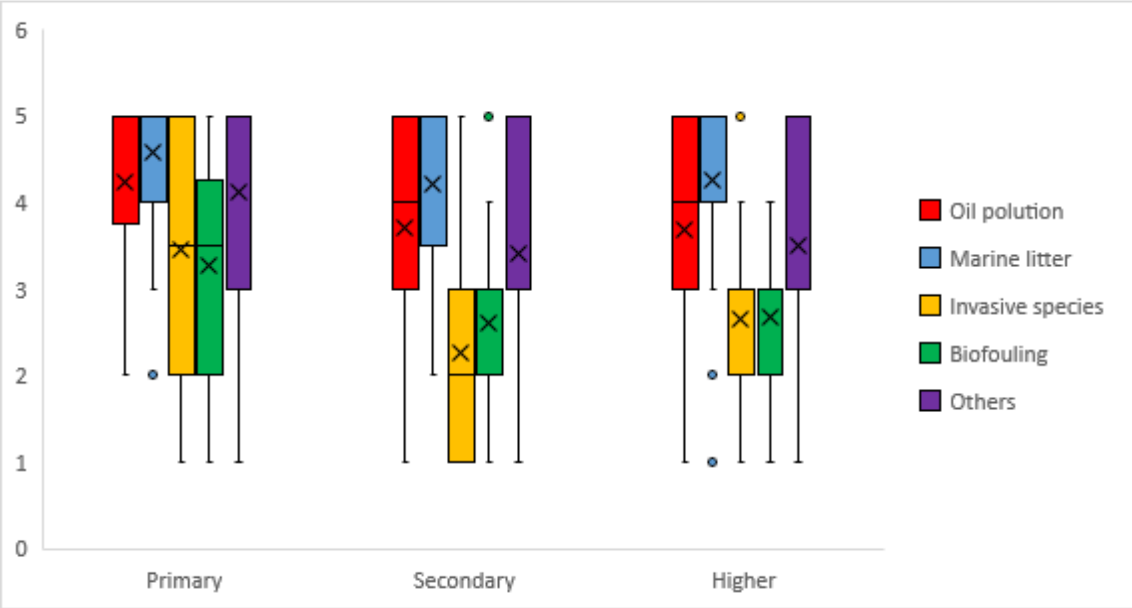

Figure 4. Level of dangerousness given to the environmental stressors (Likert scale) by respondents grouped by their study level.

Regarding age, people older than 60 years perceive oil pollution to be more dangerous than people younger than 30 (p= 0,033). The same happens with marine litter which is considered very dangerous (=4,60) by people older than 60, but not that much by people between 46 and 60 years (p= 0,0065). In the same way, people above 60 give a higher level of dangerousness to invasive species than those below 30 years old, that consider invasive species much less dangerous (p= 0,0069). The level of dangerousness for biofouling and other factors did not show statistically significant differences between ages (Figure 5).

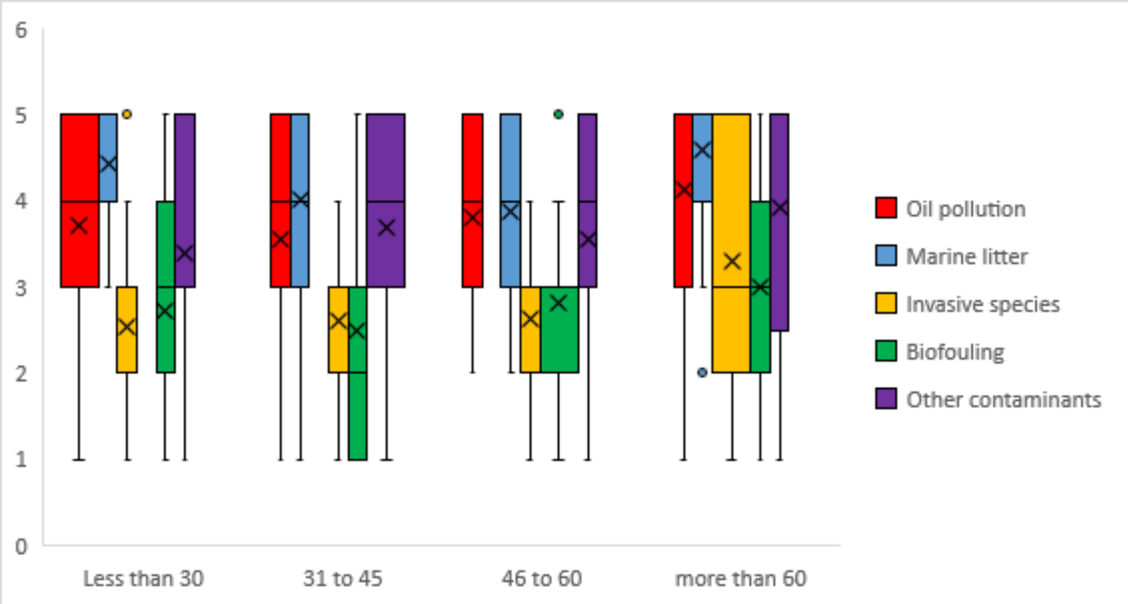

Figure 5. Level of dangerousness given to the environmental stressors (Likert scale) by respondents grouped by age.

Regarding sex, women gave a higher level of dangerousness to oil pollution (p= 0,0047), invasive species (p= 0,014), biofouling (p=0,026) and other contaminants (p=0,014) than men. For marine litter, both sexes showed a similar opinion, valuing it as the most problematic factor in the area (Figure 6).

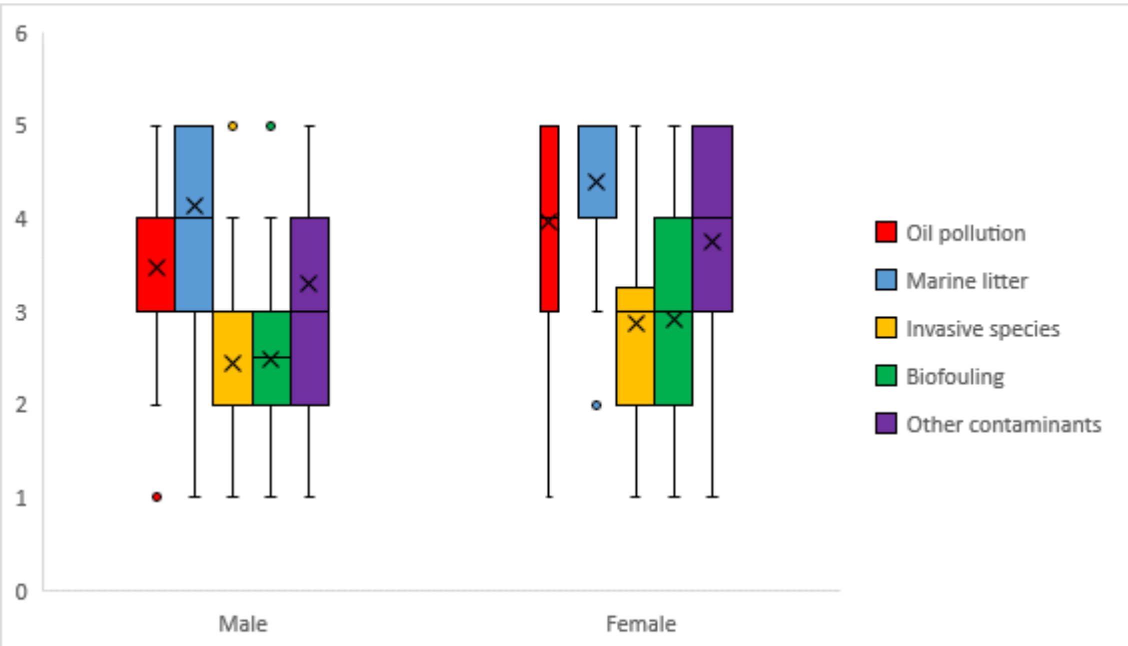

Figure 6. Level of dangerousness given to the environmental stressors (Likert scale) by respondents grouped by sex.

Statistically significant differences were also found when considering the visiting frequency to the port area. In fact, people going seldom to the port showed a higher concern about the potential dangers of oil pollution than those that visit the port very often (p=0,0078) (Figure 7). In the same way, people that visit the port area very often show a lower level of concern about the dangerousness of biofouling than those that visit the area seldom (p=0,0068).

Figure 7. Level of dangerousness given to the environmental stressors (Likert scale) by respondents grouped by port visit frequency.

DISCUSION

The results provide an overview of the opinion of the population about the leisure port of Gijon and their level of knowledge and awareness about the coastal marine environment. The surveyed people showed a general negative attitude regarding the port, qualifying it in a poor environmental status and considering as ineffective the management measures that are carried out for its protection. This attitude was more negative in those people with higher studies than in those with only basic studies, showing a higher level of awareness about the potential problems that the port may face, probably triggered by the higher level of knowledge obtained in the education process. These results show citizen concern about the environmental status of the port, which can be helpful at the time of designing management plans, as citizens with a high level of awareness and knowledge can give support for new regulation and policies (Bremner and Park, 2007; Owen and Parker, 2018).

However, despite confirming the critical reflection on the port by citizens, results show a low knowledge level about basic biological terms which could be a reflection of the lack of communication between scientists and citizens. These results are consistent with previous reports that highlight the need for increasing science literacy among the general public (Carley et al., 2013). In fact, people older than 60 years showed the lowest knowledge level related with marine biosecurity and biodiversity, which could be explained due to the high percentage (56,70%) of respondents with only a basic education level within this age range (see supplementary figure 1). On the other hand, regarding sex, surveyed men showed a higher level of knowledge than women when asked about biodiversity and marine biosecurity, which can be also explained with the education level for each sex, since the 4,87% of men had only basic studies, while for women, the percentage of individuals that only reached a primary education level was much higher (18,64%), that is, the more studies the more concern.

Our results show that literature and science outreach are the information sources considered to be less important or effective by respondents. This is consistent with previous studies that remarked the low level of effectivity for communication from these information sources (Gelcich et al., 2014) suggesting that there is a need to develop new methods to achieve an effective scientific communication. The low effectiveness of these information sources may be related with the low level of knowledge that showed the population. The specific communicative channels employed by these information sources (scientific articles, books, congress, seminars…) may be the reason of their low effectiviveness, as a very technical and difficult to understand language is used, mostly directed to experts.

To address this problem, changes must be done in the communication methods that are being employed by literature and science outreach, such as using a more understandable lexicon directed to a public with basic knowledge about the covered topics or also, the implementation of STEM education (integrated learning of Science, Technology, Engineering and Mathematics) in school centers, which is a method that can serve as a basis to promote an effective learning process that could be reflected in a population with a higher level of knowledge and, therefore, more aware and collaborative citizenship. Besides, there are reports showing that government employees and stakeholders employ official websites as main sources of scientific information (Young et al., 2016), which, along with scientific profiles tags on social media, is something to be considered as an alternative to traditional communication forms of scientific publications, since it hands an effective way to get the information to this part of the population that is implied in the elaboration and funding of management plans. To the date, studies have shown that social media are a great tool for science communication, for example, for bringing audience to oceanic exploration (Mitchell et al., 2019) or to the field of space science (Hwong et al., 2017).

It is important to remark that social media were considered as the most important information source by people between 31-45 years (which was the second group with the lowest level of knowledge after people older than 60). Nowadays, in the internet age, an alarming rise of fake news related to social media (Twitter, Facebook…) has been reported as they can be spread with ease by liking, sharing or also employing social bots (automated accounts impersonating humans) (Lazer et al., 2018). This leads to a situation where misinformation originated by fake news is getting more present within the users of social media. As we have seen in this study people attach great importance to this source of information, thus, it is important to take measures against these fake news in a way that prevents their spread. To do this it is necessary to elaborate methods for empowering individuals in order to be able of detecting these kinds of news, or preventing exposure of individuals to them.

Respondents that were older than 60 years old classified television and press as the main sources of scientific information followed by education. These media, specially science television have been reported as one of the most trusted sources of scientific information (Brewer and Ley, 2013) showing their potential of becoming a powerful channel for communication about the environment to the public, in this case, mainly to people above 60 years old.

The results obtained show that public perception about threats to the marine environment differs from the perception of scientific experts. This could be explained with the differences in the information sources employed by the public and scientists as it has been seen in this study: while literature and science outreach are sources of information rarely employed by citizens, scientific knowledge is mainly based on these kind of studies and data (Rubin et al., 2020).

This way, respondents classified marine litter and oil pollution as the main factors affecting the environment in the area; these factors appear to be the top marine environmental threats considered by the public, as seen in previous studies (Lotze et al., 2018). This importance given to marine litter and oil pollution indicates that citizens' knowledge is based on a visual perception of the environment that surrounds them, rather than on a cognitive perception (based on scientific information sources). Marine litter is something easily seen or detected by the passers-by who come to the port, as well as the oil stains that the boats release, however, other factors such as invasive species and biofouling, not being so visible, go unnoticed by the public. Indeed, our results show that people who seldom visit the port, give more importance to biofouling (they consider the accumulation of living organisms in the hulls of ships or in the docks as more dangerous) than those who visit it very often, which give much more importance to factors such as oil pollution (that can be visually perceptible in the waters of the port). This effect has been seen in other areas, such as In Scotland, for example, where the public saw oil spills as a greater threat than marine professionals, likely because oil spills are highly visible events and receive major press coverage (Howard and Parsons, 2006).

It is important to remark the perception that citizens show about the environmental threat of invasive species. Our results are consistent with (Colton and Alpert, 1998; Kleitou et al., 2019) that also concluded that there is a lack of awareness about this problem among citizens. Until now, it has been seen that leisure ports and recreational boating can be sources and vectors for the secondary dispersal of invasive species (Hirsch et al., 2016), but, as we have seen in this study, these invasion events go unnoticed by citizens that show much more awareness for other problems such as marine litter or oil pollution. It is necessary to transmit information about the danger of biological invasions to the population in order to raise awareness about this problem. To that end, it is necessary to continue investigating about biological invasions, since media attention seems to be associated with the production of scientific research (Geraldi et al., 2019) and more scientific dissemination strategies need to be developed in order to raise awareness about this problem in the local population.

CONCLUSIONS

Recreational ports are areas of leisure and economic activity that favor the cities. Even so, they are a focus of biological dangers (transport of invasive species in boats, dumping of waste to the sea, marine garbage ...) and it is necessary to develop measures to protect the marine ecosystem with the collaboration of all the parties.

In this study it has been seen that there is a critical attitude towards the Gijon marina and its management, but it has also been found that the level of knowledge about marine biodiversity and biosecurity is very low. Although the importance of education as the main source of information is stressed, it is mentionable that social media are also considered one of the main fount of knowledge, often with manipulated information that is very difficult to control and that can send erroneous information to users.

Finally, citizens also showed a visual perception about the problems that may affect the marine ecosystem, since factors such as marine litter, or oil contamination (conditions that can be perceived visually) are the ones considered to be most dangerous, comparing with other factors, also very problematic, as invasive species and biofouling, that being less visible factors, go unnoticed in the population that shows an evident lack of knowledge about these problems present in leisure ports.

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