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ABSTRACT

Marinas have a major ecological footprint, not only because of the pollution they generate but also because of the introduction and spread of non-indigenous species (NIS). This invites us to reconsider both the practices and infrastructures of marinas but also their uses and users, as marinas are increasingly recognized as places of well-being. The twofold objective of this article is to analyze the public's perception of environmental and ecological degradation in marinas and to assess the willingness to pay to improve their environmental quality. We conducted a field survey among residents and boaters of four marinas in France and showed that both have a relatively low knowledge of NIS, as well as of the responsibility of the boating activity for their spread. Other environmental degradations, such as the pollution generated by boats, are better identified and many agree on the positive economic impact of marinas. We showed a high willingness to pay to improve the environmental quality of marinas and on this basis make recommendations on how to encourage support for reducing environmental degradation. In particular, we discuss the appropriation of marinas by a wider population, including residents, young people and women. The challenge is for marinas to become multifunctional spaces, with the extension of their uses to a wider range of users going hand in hand with an improvement in their environmental quality.

1. Introduction

Marinas are a major and growing component of the coastal urbanization [1]. Like other marine infrastructure, they have a large ecological footprint leading to significant ecological and evolutionary impacts on marine biodiversity and ecosystems [2–5]. For example, harbor construction, which is increasing [1], leads to the fragmentation and destruction of natural habitats [6], which in turn alters the connectivity of marine populations [3]. Compared to natural habitats, marinas have also unique environmental characteristics, with a number of stressors such as noise pollution [7] or chemical pollution [8]. In addition, these artificial habitats, which are novel ones for marine species, exhibit peculiar biotic properties, such as a high abundance of non-indigenous species (NIS) [9–11], which are also key drivers of biodiversity change [12]. As the primary vector for the introduction and spread of NIS is ship fouling (i.e. species attached or associated with the ships' hull) [13], the incidence of NIS is increasing with the development of new infrastructure and shipping traffic and sailing [1,14,15]. It is also noteworthy that, in parallel with the negative ecological footprint mentioned above, marinas are also increasingly considered as potential habitats to contribute to the restoration of fish populations, particularly through the use of marinas as nurseries for local native fishes [16,17]. Marinas may thus be perceived both as degraded environments or refugees for some (overexploited) species. They are also viewed as recreational and economically attractive spaces, and are increasingly perceived as places of well-being in urban coastal areas [18–20], reflecting a demand for improving their environmental quality [21]. Facing these diverse facets of marinas, there is a growing attention in implementing eco-engineering designs and regulations for mitigating the impact of the abiotic and biotic stressors (including the aim to minimize the risk of NIS establishment), increasing their benefits (e.g., nurseries

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grounds for fishes) and promoting more "environmentally-friendly" infrastructures [22–24].

Despite the burgeoning research on ecological impacts of ports [22, 24] and the increasing number of articles on public perceptions of the marine environment [e.g., 25–27,20], there are still few studies analyzing willingness to pay (WTP) for improving environmental quality and/or decreasing the environmental footprint of marinas. From a public policy perspective, however, it is essential to know to what extent the environmental quality of marinas is valued. The monetary valuation literature mainly focused on marine protected areas [e.g. 28–32], wetland restoration [33–35] or water quality improvement [20,21,36,37], but in all cases, WTP were assessed to improve natural or recreational areas perceived as unique or threatened ecosystems. In contrast, marinas are highly entropized and degraded areas, which may explain why conservation or nature protection issues have received less public/research/stakeholders attention. To our knowledge, two studies assessed WTP focusing on marinas. The first assessed preferences for the development of a marina and marine leisure activities in South Korea [38]. However, the approach focused only on the positive aspects of marinas and the WTP valued is for benefiting from a new recreational space rather than for limiting a potential nuisance. The second assessed WTP to promote the use of renewable energy and waste management in ports, but did not look at valuing environmental improvements by limiting environmental degradation or NIS [31]. Although not focused on marinas, [39] assessed the WTP of residents and tourists for either the eradication or prevention of NIS in a protected area located on the Doñana National Park in Spain. The authors showed that WTP increased with the level of knowledge about NIS. Complementing this work, [37] assessed WTP for limiting the impact of NIS on the conservation of fish species diversity and showed low WTP of the public, in the order of €3.7 per capita.

In this work, we aimed at examining the perceptions and WTP for environmental quality improvements in marinas, including their ecological footprint through biosecurity measures on NIS. As perceptions and WTP are likely to vary according to current or potential users of marinas, the survey focused on users of marinas (sailboat, motorboat) and residents in the vicinity of these marinas. We surveyed 236 residents and 401 boat owners in four marinas in mainland France in spring 2022. In order to examine the factors influencing perceptions and preferences, we selected marinas in two very distinct regions (with their own culture, habits and heritage and different marine ecosystems and environments), namely the Atlantic and the Mediterranean coasts. Motivated by the finding of [40] that sensitivity to biosecurity measures for NIS would be lower in ports combining recreational boating and maritime trade, we selected two separate marinas in each of the two regions. One marina was dedicated solely to recreational boating while the other was located near ports that combine other maritime activities, including commercial and fishing activities and, for one of them, military activities. Although we focused on distinguishing between the perceptions and WTP of residents and boat owners, we were careful to balance motorboat owners and sailboat owners because of their different navigation and boat maintenance practices and environmental sensitivities [41]. Complementing this later companion paper, which provided an in-depth analysis of public perceptions based on a dedicated questionnaire (see Supplementary Material), the main contribution of this study is to analyze public perceptions and preferences based on WTP and their main determinants. We highlight the level of awareness and demand to limit the environmental degradation caused by marinas, which leads us to discuss the place of marinas in coastal areas and to question their uses and users.

2. Methods

2.1. Sampling plan and survey protocol

The survey was carried out in four marinas in mainland France (Brest, La Trinité-sur-mer, Port Camargue and Sète). In order to explore recurrences based on structuring variables that may influence perceptions and WTP, the choice of these marinas was motivated by their contrasting geographical situations (Atlantic versus Mediterranean coasts) and by their activities. The aim was to obtain a sub-set illustrative of the diversity of French marinas, not only in terms of the range of direct uses to which they are put, but also in terms of their distinct socio-cultural environment and the way in which they are appropriated by nearby residents. La Trinité-sur-Mer in the Atlantic and Port Camargue in the Mediterranean are two specialized marinas, while Brest in the Atlantic and Sète in the Mediterranean are also commercial ports. Brest has a military harbor as well. Brest and Sète are bordered by large neighboring municipalities with a high proportion of primary residences (90 % and 71 % respectively) whereas La Trinité-sur-Mer and Port Camargue are characterized by a high proportion of secondary residences (82 % in Port Camargue and 70 % in La Trinité-sur-Mer).

With regard to the representativeness of the sample, the survey design was based on separate criteria for residents and recreational boaters. For the residents, we were careful to balance the gender of the respondents and the age groups. Age and gender are critical issues in the provision of public goods and environmental preservation in particular, where women and young people have been shown to contribute more [16,42]. This distinction could not be realized for boaters, whose reference population is mostly composed of men, often over 60 years old. However, we did ensure that the proportion of sailing boats and motorboats was representative, bearing in mind that the reference proportion in the four ports is 65 % of sailboats. Indeed, following interviews prior to the survey, stakeholders (port managers and yachting associations) pointed to different behaviors between the two groups of boaters, with different maritime practices (duration of cruises, links between ports, etc.) but also more pronounced pro-environmental behaviors among sailboat owners.

2.2. The survey

Although the surveys for residents and recreational boaters were slightly different, they had the same structure and shared a majority of common questions. The survey was organized into five modules (Table

Table 1
Survey modules and number of questions per module and respondent categories.

Thematic modules	Number of questions		
	Common to both	Specific to residents	Specific to boaters
Perception of the relationship between the city and the marina (economic perception, degree of artificialization, frequency and reason for using the marina)	5	6	-
Perception of the positive and negative impacts of marinas on the environment	3	-	-
Perception of NIS (level of knowledge, mode of introduction and impact of boating on NIS spread)	10	-	-
Willingness to pay module (presentation of the scenario, WTP amount, motivations for payment and non-payment)	3		2
Socio-demographic profile	10	-	-
Boaters' practices (frequency of careening, types of activities and outings, good ecological practices)	-	-	34

1), with an additional module devoted to recreational boaters alone in order to gain a better understanding of their practices.

The first three modules were dedicated to identifying respondents' perceptions and knowledge of the relationship between the city and the marina, the impacts of marinas on the environment and of NIS in particular. This was followed by a module assessing the respondents' willingness to pay, and a module providing information on their socio-demographic characteristics. In order to gain a better understanding of the boaters' practices, a specific module was submitted to them immediately after the assessment of their perceptions.

In the survey we used the French translation of the English term 'non-local species' rather than 'non-indigenous species', which is easier to understand and less technical in French. Furthermore, in order to study preferences for improving the environmental quality of marinas, we asked several questions aimed at understanding the environmental sensitivity of the respondents and used the synthetic metric of [43] to assess respondents' sensitivity to nature. This measure, widely used in the literature, is based on a figurative representation of the relative weight that the respondent gives to nature, and provides a synthetic, simple and global measure of this sensitivity. It thus avoids the criticisms levelled at measures such as the New Ecological Paradigm (NEP) proposed by [44], which were criticized for providing an incomplete and biased measure of this sensitivity.

The willingness-to-pay scenario was included at the end of the questionnaire in order to ensure that the respondents were informed and aware of the environmental issues that marinas pose. It was formulated as follows: "*There has been an improvement in the environmental management of marinas with, for example, the development of numerous labels such as Clean Port, Biodiversity-Active Port, Blue Flag, etc. These environmental operations are costly and require additional staff. Subsidies are often granted but for short periods and usually on an experimental basis, for example for the development of protocols. In order to implement effective environmental conservation policies, marina funds therefore need to be sustainably financed by contributions from boaters and residents*". A non-linear scale allowed for the choice of an annual WTP level ranging from €0 to €250 or more (open answer) with the proposal that the corresponding budget be managed by the municipality in association with the port authority. The precise question was: "*Would you personally be willing to make an annual contribution to a specific budget that would be managed in collaboration between the municipality and the port? If you are in favor, we offer you a graduated list of amounts within which you can freely choose the level of your contribution. How much would you be willing to contribute for your household?*"

After thorough testing of the questionnaire, the survey was carried out from May to July 2022 face-to-face for residents (randomly selected from the street) and in a mixed way for boaters, with 146 people face-to-face and 255 online. The survey took an average of 10 min for residents and 20 min for boaters. Due to low presence of boaters in May, and partly because of Covid restrictions, it was more difficult to survey boaters on site, so the survey was also conducted online via boating associations and posters (with QR codes) in harbor master's offices.[1]

2.3. Synthetic indices on NIS

In order to analyze the respondents' perceptions of NIS we constructed two synthetic indices. The first is an index of NIS knowledge and is rated on a 0–3 scale. The index was constructed by aggregating the values given by the respondents to three questions: the knowledge of the NIS notion (0, 0.5, 1), the responsibility attributed to recreational boating in the dispersion of NIS (0, 0.5, 1) and the responsibility attributed to marinas as a recipient habitat and hub for introduction of NIS (0, 0.5, 1). The second index measured respondents' awareness of the responsibility of recreational boating on NIS establishment and spread. It was also measured on a 0–3 scale and was obtained by aggregating the values given by respondents to three questions: the responsibility attributed to (i) marinas in the establishment of NIS (0, 1), (ii) the biofouling on the hulls of ships in their spread within marinas (0, 1) and (iii) the long-distance navigation in their spread between marinas (0, 1).

2.4. Descriptive statistics, sub-sample comparison tests and econometric modelling of WTP

For NIS perceptions and observed willingness-to-pay, the descriptive statistics provided depend on the quantitative or qualitative characteristics of variables under consideration. The main statistical descriptors are the percentage and the mean. For NIS perceptions and indices, proportion comparison tests across various sub-sample (i.e., Residents vs Boaters, Sail-Boaters vs Motor-boaters, Male vs Female, etc.) were performed. With the validity conditions verified, we used a parametric proportion comparison test between two independent sub-samples; the statistic of the test for the difference in proportion (U) follows a standard normal distribution, ($U \equiv \mathcal{N}(0,1)$).

After assessing the number of protest answers and excluding them from the sample, we used the model of [33] and proceeded in two steps in order to analyze willingness to pay. First, we estimated the probability of having a positive WTP (dichotomous probit, taking the value 1 if the individual agrees to contribute, 0 otherwise) and estimated second, the amounts of strictly positive WTP (simple linear regression - ordinary least squares - on the logarithm of the WTP). This enabled us to identify the factors that determine choices at each step. For the comparison of average WTP across sub-samples, as the normal distribution conditions were not met, we used non-parametric Mann-Whitney U-tests.

3. Results

3.1. Characteristics of the sample and behaviors of boaters

Table 2 shows the main characteristics of the sample, with a relatively even distribution between marinas, revealing a slight over-representation of respondents over 45 and a predominance of sailboat owners among the recreational boaters.

Specific questions on boaters' practices were asked to characterize their behavior. It shows that 47 % of boaters declared that they go out very often (compared to 24 % a few times and 18 % only at weekends) and sometimes dock in other ports (53 % compared to 27 % often and 20 % never). Although the frequency of outings is fairly even between sailing boats and motorboats, sailing boats dock more often in other ports (34 % of them against only 12 % of motorboats). The majority of boaters regularly careen once a year (78 %), with no difference between sailboats and motorboats. Among them, 22 % of boaters do in-water hull cleaning, despite this practice is prohibited notably for the risk it entails for the environment.

3.2. Perceptions of marinas

When asked about their overall perception of the role and impacts of marinas (Table 3), the positive economic impacts are predominant for both residents and boaters. The negative impacts are mainly related to pollution, while the putative positive ecological impact is only marginally perceived (3 % for residents and 4 % for recreational boaters).

Residents and boaters share a relatively similar assessment of the negative environmental impacts of marinas. As Fig. 1 shows, the main negative impact perceived (by far) is pollution, followed to a lesser extent by marine infrastructure. Negative impact of NIS is perceived as marginal.

[1] Previous work find that mixed-mode surveys are an efficient and satisfactory way to increase the sample size and representativeness of a survey [42,45,46].

Table 2
Sampled population in each site.

	Residents			Boaters		
	Total	% men	%>45 years old	Total	% online	% sailboat owners
Port Camargue	66	48 %	68 %	154	41 %	51 %
Sète	54	46 %	56 %	86	77 %	74 %
Brest	60	48 %	50 %	108	93 %	63 %
La Trinité	56	52 %	54 %	53	47 %	77 %
Total	236	49 %	57 %	401	64 %	63 %

Table 3
Perceptions of the impact of ports on coastal areas per respondent categories.

	Residents	Boaters
Positive economic impact (attractiveness and job creation)	61 %	67 %
Negative economic impact (cost of maintaining infrastructure)	2 %	6 %
Negative ecological impact (mainly pollution from boats)	32 %	21 %
Positive ecological impact (creation of new ecological habitats)	3 %	4 %
Others	1 %	2 %

Note: One choice only. Respondents were asked to select the main impact of marinas (from a set of positive and negative impact categories)

We observe in Fig. 2 that 30 % of respondents (both residents and boaters) believe that marinas do not have any positive impact on the environment. Of the remaining 70 % attributing at least one positive environmental impact to marinas: 40 % of residents assign marinas the status of observation and research areas, while around 45 % of boaters assign marinas either refuge or nursery status. Note that the positive role of marinas and ports as a refuge or nursery is scientifically controversial, because the methods used can lead to an increase in NIS establishment [47] or a decrease of the diversity of fish assemblages at regional scale [48]. We however introduced it because many ecological projects in France aim to build supports on port infrastructure for this purpose, and we found it useful to measure public perception on this subject.

3.3. NIS perceptions

On a scale of 0–10 (questions C7 and D7 of the questionnaire, see Supplementary Material), residents and recreational boaters have on average similar perceptions of the role of marinas in introducing NIS (average of 4.5), with a greater sensitivity from owner of sailing boats (between 6 and 10). On a scale of 0–10 (questions D5 and D7 of the questionnaire), the role of recreational boat traffic in introducing NIS shows more contrasting results, with an average score of 4.9 for residents and 3.7 for recreational boaters. Here again, sailboats score proportionately higher than motorboats.

The perceptions on the main factors of NIS introduction (Table 4) and spread (Table 5) are, however, distinct between residents and boaters. The latter attach more importance to ballast water while residents more often mention more secondary or controversial processes, such as currents and storms -as discussed by [49] with tsunami-driven long-distance species transports-, or the impact of aquaculture. In addition, boaters are more aware of the role of long-distance shipping in the spread of NIS.

Confirming the findings of [46] on the relative unawareness of French boaters on a European scale, half of the boaters have a low level of knowledge of NIS, especially motorboat users (Table 6). Similarly, the level of knowledge of residents is overall low to medium. On the other hand, more than half of the boaters attribute a medium to high responsibility for the proliferation of NIS to their activity (responsibility index). Residents underestimate this responsibility, with 34 % of them attributing low responsibility and 43 % of them attributing medium responsibility to boating activities.

3.4. Willingness to pay

Sixteen respondents did not answer the WTP question, resulting in a sample of 621 observations. Among them, a substantial number of respondents (49.3 %) opted for a zero contribution. However, analysis of the reasons for non-payment revealed that these were mostly "false" zeros" or "protest answers" (41.7 %). Rather than a lack of interest or willing to pay in improving the environmental quality of marinas, these respondents explained their non-contribution choices by secondary arguments: "*I already contribute*" (22 %); "*It is not my responsibility to pay*" (24 %); "*The proposed policy is not appropriate*" (6 %); "*The money might be used for something else and I don't trust it*" (22 %). These reasons are akin to the protest answers observed by [20] concerning the improvement of the quality of coastal areas. Although instructive for decision-makers, these answers provide no information on the value that respondents place on the environmental quality of marinas, and on the amount they would be willing to pay to achieve it, but on the reasons external to this cause (problems of trust, implementation, payment terms) that justify their rejection.[2] Excluding them from the sample reduces the percentage of respondents with a zero WTP to 7.6 % (13 % for residents and 4 % for boaters). The average amounts of willingness to pay (Table 7) are slightly lower for residents (€29) than for recreational boaters (€34), with an important difference between sailing boats (€37) and motor boats (€29).

The econometric treatment of WTP makes it possible to identify the variables that determine, on the one hand, the fact of agreeing to contribute (Table 8) and, on the other hand, the level of the contribution (Table 9). All structuring and perception variables were tested, taking care to avoid correlations. The list of 31 perception and behavior variables and 11 socio-demographic variables that were introduced into the WTP modeling is provided in Supplementary Material. The probit model is globally valid as shown by the p-value associated with the likelihood ratio test (p-value <0.0001) (Table 8). We observe that four principal variables influence the probability of contributing, namely age, income, having made a donation to an environmental organization and belief that NIS have an impact on the marine environment, this latter predictor being assessed on a scale from 0–10 (see question C7 in Supplementary Material). In particular, being over 60 years old increases the probability of paying, which is also more frequent for the higher incomes (€3000 to €7500) and for those who have made donations to environmental organizations. Finally, people who think that NIS have a strong impact on the marine environment have a higher probability of having a positive WTP.

The model for the assessment of the level of the WTP values presented in Table 9 is also globally significant (p-value <0.0001) with an adjusted R^2 of 0.16. All variables were tested and only those that were significant at the 10 % level were retained. These explanatory variables are more numerous for the level of contribution than for the probability of a positive contribution. Among the common variables, relation to nature (measured by the scale of [43]), having made a donation to an environmental association and the level of knowledge of NIS also have a positive effect on contribution levels. In addition, gender and level of education (measured by the number of years of post-secondary education) are determining factors, with relatively higher contributions for men and for educated respondents. Conversely, having a positive environmental perception of marinas in terms of their role as refugees or as nurseries for local native fishes (i.e., larval capture and juvenile development) has a negative effect on the level of WTP. It is as if this positive environmental perception undermined their motivation to contribute.

[2] We invite readers to refer to the seminal works of [50] or [51] on the question of protest answers, their determinants and treatment.

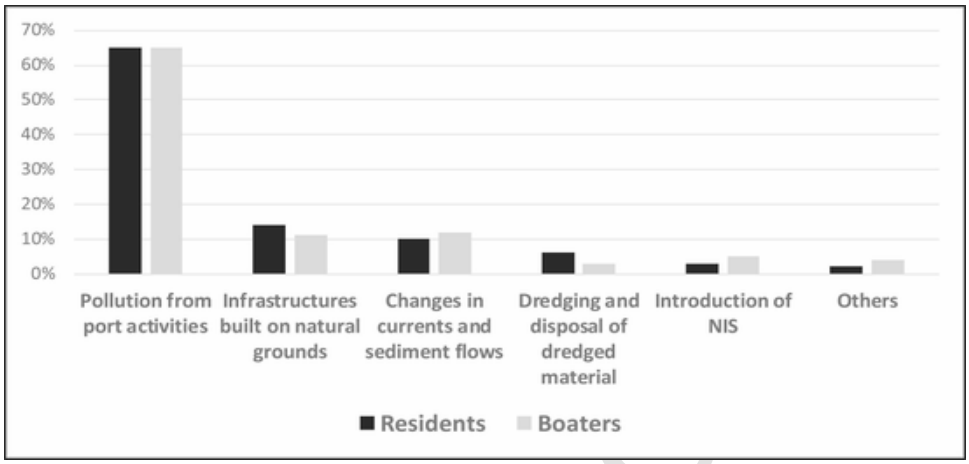

Fig. 1. Negative perceptions of the impact of marinas on the environment. Note. One choice only: Respondents selected what they see as the main negative impact.

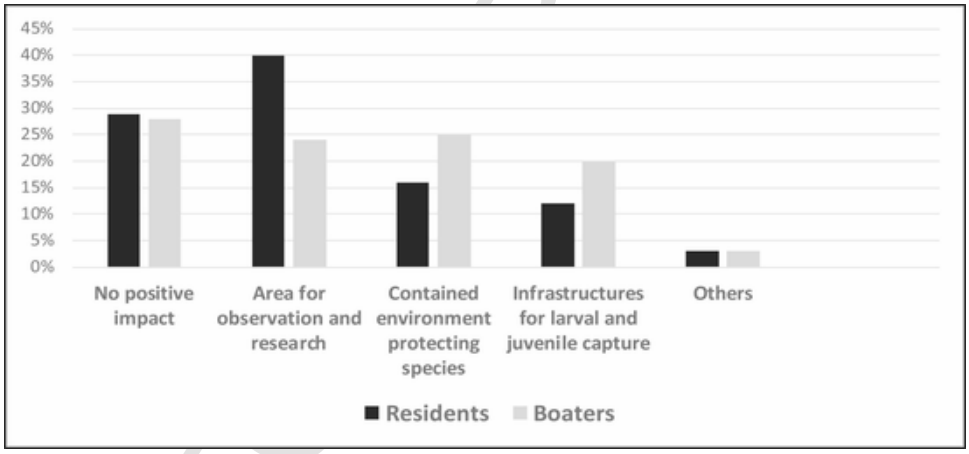

Fig. 2. Positive perceptions of the impact of marinas on the environment. Note. One choice only: Respondents selected what they see as the main positive impact.

Table 4
Perceptions of introduction vectors for NIS.

			Proportion comparison test (H_0 : *Equal proportion*)
	Residents	Boaters	p-value
Biofouling (organism attached) on boat hulls	39 %	35 %	0.2459
Ballast water release	20 %	37 %	0.0000
Currents and storms	19 %	9 %	0.0010
Use of non-local species for aquaculture	14 %	6 %	0.0029
Accidental releases from aquariums	6 %	9 %	0.1391
Others	2 %	4 %	0.1632

Note. Respondents selected only what they consider to be the main introduction vector (only one choice possible)

Table 5
Perceptions of factors responsible for the spread of NIS.

			Proportion comparison test (H_0 : *Equal proportion*)
	Residents	Boaters	p-value
Long-distance navigation	33 %	44 %	0.0064
Water temperature	28 %	27 %	0.3934
Non-regularity of fairings	15 %	17 %	0.3267
Type of boat (motor or sail)	13 %	4 %	0.0002
Number of outings	11 %	4 %	0.0050
Others	1 %	4 %	0.0060

Note. Respondents selected only what they consider to be the main factor responsible for the spread of NIS (only one choice possible)

4. Discussion

4.1. High WTP, quality of life and socio-demographic profiles

The high average level of the WTP (32 euros) and the low proportion of respondents who were not willing to contribute (7.6 %) show a strong commitment to improving the environmental quality of marinas. Echoing recent findings on the positive perceptions of coastal environments including ports [52–54,41], this high WTP confirms the place of marinas as specific urban coastal environments widely valued for their contribution to recreation, landscape and quality of life. In this perspective, the high WTP would be explained both by a strict environmental

Table 6
Knowledge and Responsibility NIS Indices.

	Residents	Boaters	Proportion comparison test (H_0 : Equal proportion) p-value	Sail	Motor	Proportion comparison test (H_0 : Equal proportion) p-value
Knowledge index						
Low (up to 1)	45 %	51 %	0.1468	46 %	62 %	0.0038
Medium (1.5)	22 %	18 %	0.2048	20 %	15 %	0.2178
High (from 2 to 3)	33 %	31 %	0.3501	34 %	23 %	0.0189
Responsibility index						
Low (0)	34 %	26 %	0.0433	26 %	26 %	0.3989
Medium (1)	43 %	49 %	0.1656	47 %	53 %	0.2107
High (2 and 3)	23 %	25 %	0.3053	27 %	21 %	0.1620

Table 7
Observed willingness to pay from boaters and residents.

	Boaters			Residents	All
	Average	Sail	Motor		
Zero willingness to pay (in %)	4.4	3.1	7.1	12.7	7.6
Average willingness to pay per household (in €)	34.4	37.3	29.0	28.8	32.3

Table 8
Estimates on the probability of having a positive WTP (Step 1 - Probit model).

Variables	Coef.	Pr > Chi²
Age (Reference: –40,60 years old)		0.0071***
Less than 40 years old	-0.3877	0.0017***
More than 60 years old	0.1873	0.0986*
Income (Reference: >€7500)		0.0008***
€1000 to €2000	-0.4789	0.0063***
€2000 to €3000	-0.4745	0.0016***
€3000 to €5000	0.2409	0.1718
€5000 to €7500	0.5284	0.0885*
Donations (Reference: Yes)		
No	-0.1714	0.0516*
Impact on the marine environment	0.0957	0.0150**
Intercept	1.0214	<0.0001***
LRT (Prob > Chi²)	<0.0001***	
Pseudo-R^2	0.1482	

* weakly significant (10 %).
** significant (5 %).
*** highly significant (1 %)

objective and by a more hedonic one, aimed at increasing the benefits of marinas for users and residents.

However, both the probability to contribute and the level of contribution are not evenly distributed among respondents. Probability and level of contribution are higher for relatively old respondents with high levels of education and income, in particular the over-60 age group. This age effect confirms the results of [55] but contradicts many articles in the literature that show a greater sensitivity of young people to environmental issues, including applications to coastal areas, such as [27] and [56]. This could be explained by a stronger appropriation of marinas by older and higher income generations, who use them more and for longer. As suggested by several authors including [57–59] or [60], this sense of appropriation could indeed be responsible for the motivation to preserve the environment. In our case study, this sense of appropriation would counterbalance the effect of age. As for the correlations

Table 9
Estimates on WTP levels – (Step2 – ln WTP).

Variables	Coef.	Pr > t
Gender (Ref. Female)	0.3644	<0.0001***
Number of years of post-secondary education	0.0816	<0.0001***
Relation to nature	0.0646	0.0014***
Donations (environnemental associations) (Ref. No)	0.1732	0.0017***
Knowledge index	0.0576	0.0887*
Infrastructure improving the capture of larvae and young fish[a] (Ref. No)	-0.1476	0.0380**
Intercept	2.3703	<0.0001***
Prob > F	<0.0001***	
R-squared	0.1737	
Adj R-squared	0.1649	

[a] Note that the positive, albeit controversial, role of marinas as a nursery or a refuge for fishes has a negative impact on WTP levels, meaning that respondents who defend this positive impact also have lower WTP.
* weakly significant (10 %).
** significant (5 %).
*** highly significant (1 %)

between environmental preservation and both income and education levels, these relationships are well documented [e.g. 61,62,36,63]. It should be noted, however, that the intensity of the relationship with education levels is high, with each additional year of education increasing WTP by 8.5 %.

In addition to the importance of socio-demographic profiles, we also find that those who are more environmentally aware have a higher propensity to contribute. In particular, WTP is higher the more respondents are willing to donate to environmental organizations and the more they believe that NIS have a strong impact on the marine environment. This positive relationship between environmental sensitivity and WTP is expected and frequently observed in the literature [e.g. 64,26]. More specifically concerning port areas, [22] note a positive correlation between frequentation, type of activity and length of residence in the vicinity of the port, on the one hand, with knowledge of the port environment and, on the other, with acceptance of public funding, through taxes, for ecological engineering works in favor of ports. In this logic, high WTP would then be explained by a sensitivity to the environment and the amenities offered by marinas, both of which being amplified by the use and appropriation of marinas in the long run. In contrast, but consistent with this line of argument, boaters who see marinas as refugees and nurseries for fishes are less willing to pay for marinas' environmental quality. This can be explained in two ways. The first is that these respondents have a positive view of the environmental impact of marinas, and that it is not necessary to pay to improve it more. The second is that these respondents do not value the environmental quality of marinas, and justify their choice not to pay by the controversial assertion that marinas have positive environmental virtues.

4.2. An unusual gender effect

While the literature in experimental economics generally shows that women are more sensitive to the provision of public goods and to environmental protection in particular [27,55,63,65], we obtained radically opposite results with much higher contributions from men (+44 %, this value is obtained from the coefficient associated to the gender dummy variable (Table 9) by the following computation: 100.[exp(0.3644)-1]). Because of the relative importance of men in the boating population - which is a widely shared characteristic within boating [21,66] - we performed additional tests (non-parametric Mann-Whitney U-tests) to check that the difference in WTP was not influenced by this characteristic (see Supplementary Material). Women's willingness to pay was significantly different (p-value <0.0001) from that of men, even in the residents group. This confirms the gender effect in WTP and highlights the singularity of marinas in terms of preference for

environmental preservation. The WTP were €26.9 for women and €38.3 for men. The level of knowledge of environmental issues in marinas and of NIS in particular does not explain this difference, with women having a better knowledge of the impact of NIS than men (51% of men have a low knowledge compared to 41 % of women[3]). On the other hand, the low presence of women in nautical activities and more generally in port activities, where they represent less than 2 % of jobs in France [67], could explain this gender effect. As documented by [68], there is a historical dominance of men in the marine world, whether as navigators or fishermen, but also in maritime law. Because of this domination, marinas are primarily a male object, which means that environmental preservation in these places could be interpreted as the production of a club good rather than a public good. Since women do not participate in this club, they would have less interest in contributing to it. This is in line with the findings of [69] or [70] on the influence of social and cultural context in contributing to the preservation of ecosystem services. The less directly involved one is, the less one contributes. To moderate this point, if marinas are seen as men's clubs to which women have little or no access, their level of contribution, although lower than that of men, is relatively high. This corroborates a recent result by [71] showing that women contribute significantly to non-local public facilities from which they do not benefit. Echoing the point made earlier about the place of harbors in urban coastal areas, this lower contribution of women brings us back to the question of how marinas are used and by whom. In order to preserve the environmental quality of marinas, but also to make the most of the amenities they offer, we need to consider broadening their uses and users, by including residents, particularly women and young people [72]. This requires urban policies that open these spaces to all and to multiple uses. It also requires participatory governance and a diversification of the actors mobilized, especially in terms of gender [73].

4.3. The role of environmental sensitivity and knowledge

Unsurprisingly, contribution levels are higher the closer respondents feel to nature [43] and the more they donate to environmental associations. As suggested by [74,75] or [76], these correlations fall under intrinsic motivations for nature. WTP is also positively correlated with the NIS knowledge index and negatively correlated with the respondent's attribution of marinas as having a positive impact on the development of larval and juvenile fish, being viewed ad refugees and nurseries for fishes. The respondents are therefore all the more willing to give when it comes to compensating for environmental damage caused by human activity and if this activity also has a positive impact on the environment, they deduct the amount of this impact from their contribution. The impact of the respondents' level of knowledge on their WTP has been widely highlighted in the literature, including with regard to the establishment of marine protected areas [32,61] or lagoon preservation [77,78]. One reason suggested is that the level of knowledge is correlated with the level of attendance and use [61]. Respondents with higher knowledge of environmental damage would therefore have a greater interest in contributing to limit it. Conversely, we show that knowledge of the positive environmental impact of marinas - in this case, their role as nurseries - have a negative effect on the WTP. This could be explained by the fact that it would justify the pointlessness of paying to limit a nuisance that is not really or totally a nuisance. If this result is original, the behavior of these respondents is no less unfounded in the present case, since as shown by [47], this nursery role would be more particularly beneficial to the establishment and proliferation of NIS than to native species.

5. Conclusion

In addition to the ambivalence and diversity of perceptions of marinas, this work showed that there is a strong and widely shared will to contribute to the improvement of the environmental management of marinas. Despite that many ecological studies showed the increasing prevalence of NIS in marinas and their impact on biodiversity [3,5,47,79,80], we showed that knowledge of NIS and their impact, as well as the responsibility of recreational boating for their establishment and spread, remains low. Yet, the WTP for improving the ecological quality of marinas is high. This is especially true as the respondents are older, male, with higher levels of education and income. In other words, the typical profile of people using marinas. Although they are less willing to pay for these spaces, which are probably too often considered as club goods, other socio-demographic profiles also have relatively high WTP, especially when they are aware of the negative impact of marinas on the environment. This suggests the need for greater awareness of environmental issues related to these areas, but also for greater appropriation of these areas by the population. As argued by [81,82] or [41] a wide range of the population admits a positive view of ports especially in the perspective of an urban coastal environment open to the sea. This calls for the promotion of a multifunctionality of marinas which would allow their appropriation. We see this multifunctionality as a way to enhance the WTP for an improvement of the environmental quality of marinas but also to accompany their restructuring in the coastal urban spaces.

The implications of this work for public policy are twofold. First, the need for information campaigns on the issues related to NIS in the marine environment, but also on the boating practices that can limit their impacts and spread. Awareness campaigns are currently entirely focused on water quality and it is critical to broaden their scope to include other environmental issues, including NIS. Complementing the work of [60] on the impacts of cleaning practices, voyage duration and boat size for the presence and spread of NIS, our work suggests that information campaigns would not only enable the appropriation of better practices but also greater sensitivity among these key users. Second, the opening up of marinas to other uses and other users, which will be accompanied by amenities but also by a greater acceptability of committing funds to improve environmental quality. The challenge is to strengthen the knowledge and appropriation of marinas as specific and multidimensional environments [52,53] in order to foster the commitment of a wider population to limit their environmental impacts [83,84]. These efforts should lead to the generalization of labelling policies specific to the prevention and management of NIS, which are beginning to develop not only for port areas, but also for other types of marine infrastructures [1] that accompany the recent boom in the blue economy [85] that participates in the proliferation of NIS [47,86].

Author Agreement Statement

We the undersigned declare that this manuscript is original, has not been published before and isnot currently being considered for publication elsewhere.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed.

We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We understand that the Corresponding Author is the sole contact for the Editorial process. He/she is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs

[3] The corresponding proportion comparison tests are provided in Appendix 2.

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CRediT authorship contribution statement

Frédérique Viard: Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Jean Michel Salles:** Conceptualization, Formal analysis, Methodology, Validation, Writing – original draft, Writing – review & editing. **Pierre Courtois:** Conceptualization, Formal analysis, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. **Thierry Blayac:** Formal analysis, Methodology, Writing – original draft, Writing – review & editing, Conceptualization. **Hélène Rey-Valette:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing. **Lucille Sevaux:** Conceptualization, Investigation, Project administration, Resources, Writing – original draft. **Nicole Lautrédou-Audouy:** Conceptualization, Data curation, Investigation, Project administration, Resources, Visualization, Writing – original draft, Writing – review & editing. **Anais Page:** Data curation, Formal analysis, Investigation, Methodology, Resources, Writing – original draft.

Data Availability

The authors do not have permission to share data.

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Appendix 1. Non-parametric tests for comparison of WTP mean

We work on the WTP obtained in step 2. The proportions of true zeros are modeled at step 1. This explains why the results are slightly different from those presented in Table 8 (Section 3.3). To find them again, simply multiply the WTP values in Table 11 by the share of non-zero WTP. Thus, at the aggregate level, the share of null WTP is 7.6 %, so we have WTP = (1–0.076) * 34.9 = 32.2 €

A preliminary test of the normality of the distribution of WTP allowed us to reject the null hypothesis for normal distribution of WTP for all the samples, and sub-samples. Therefore, we use non-parametric tests of comparison of means.

Table 10
Non-parametric tests for comparison of WTP mean

WTP (€)	**Samples**		
	Whole	Residents	Boaters
Female	**26.9**	**27.3**	**26.1**
[n1]	[169]	[109]	[60]
Male	**38.3**	**39.4**	**38.0**
[n2]	[405]	[97]	[308]
Total	**34.9**	**33.0**	**36.0**
[n1 + n2]	[574]	[206]	[368]
H_0: WTP F = WTP M	**No**	**No**	**No**
[p-value]	[< 0.0001]	[< 0.0001]	[< 0.0001]
Conclusion of the tests	Women's willingness to pay is substantially different from that of men. This is true for the whole sample, as well as for the subsamples of residents and boaters.		

Appendix 2. Gender differences in NIS knowledge index

Table 11
Proportion comparison test in NIS Knowledge Index

			Comparison test (H_0 : *Equal proportion*)	
	Female	Male	U-Statistic	p-value
Low Knowledge Index [Freq.]	41 % [70]	51 % [208]	-2.19	0.0360
Medium Knowledge Index [Freq.]	21 % [36]	19 % [75]	0.75	0.3004
High Knowledge Index [Freq.]	37 % [63]	30 % [122]	1.64	0.1040
Sample size	169	405		

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2024.106224.

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