Public awareness, concerns, and priorities about anthropogenic impacts on marine environments

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Public awareness, concerns, and priorities about anthropogenic impacts on marine environments

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Numerous international bodies have advocated the development of strategies to achieve the sustainability of marine environments. Typically, such strategies are based on information from expert groups about causes of degradation and policy options to address them, but these strategies rarely take into account assessed information about public awareness, concerns, and priorities. Here we report the results of a pan-European survey of public perceptions about marine environmental impacts as a way to inform the formation of science and policy priorities. On the basis of 10,106 responses to an online survey from people in 10 European nations, spanning a diversity of socioeconomic and geographical areas, we examine the public's informedness and concern regarding marine impacts, trust in different information sources, and priorities for policy and funding. Results show that the level of concern regarding marine impacts is closely associated with the level of informedness and that pollution and overfishing are two areas prioritized by the public for policy development. The level of trust varies greatly among different information sources and is highest for academics and scholarly publications but lower for government or industry scientists. Results suggest that the public perceives the immediacy of marine anthropogenic impacts and is highly concerned about ocean pollution, overfishing, and ocean acidification. Eliciting public awareness, concerns, and priorities can enable scientists and funders to understand how the public relates to marine environments, frame impacts, and align managerial and policy priorities with public demand.

ocean literacy | ocean impacts | Europe | attitudes | ocean health

With the Earth's population >7.5 billion people, humans are increasingly dependent on the oceans for resources and recreation and as a platform for the exchange of goods in a globalized world (1). This increasing use of marine environments poses a number of challenges, including the formulation of equitable and sound governance mechanisms, sustainable use of renewable resources, and the need to address the multiple drivers impacting ocean health. Marine environments are affected by multiple anthropogenic stressors, such as overfishing, aquaculture, pollution, climate change, ocean acidification, coastal erosion, habitat loss, and the introduction of invasive species, which impact the entire ocean (2–7).

The depleted and degraded state of oceans around the world and the consequent social, health, and economic impacts have prompted numerous international efforts to consider options for returning oceans to a healthy state. For example, the Secretary General of the United Nations (UN) recently announced the Oceans Compact initiative to accelerate progress in addressing the impacts and achieving the common goal of "Healthy Oceans for Prosperity" (www.un.org/depts/los/ocean_compact/). The World Bank has created its Global Partnership for Oceans, a "new and powerful approach to restoring ocean health' 'to activate proven solutions at an unprecedented scale for the benefit of communities, countries and global well-being" (www.globalpartnershipforoceans.org). In addition, the Global Ocean Commission recently released its report "From Decline to Recovery: A Rescue Package for the Global Ocean" (www.globaloceancommission.org; ref. 8). Efforts such as these typically rely heavily on experts providing information about the direct and indirect drivers of impacts and proposing policy options, but they usually do not seek rigorously obtained scientific information about public perceptions of the issues or solutions. Because public support is key to successful implementation of changes, ignoring public understanding and attitudes may well be short-sighted (9, 10).

Although human perceptions, understandings, and responses have been widely explored for some environmental problems, particularly climate change (e.g., refs. 11–14), much less attention has been given to anthropogenic impacts on marine environments (10, 15). The studies that have been conducted are enlightening, but typically have been at only a local or national scale, such as assessments of public perceptions of specific ocean problems as part of valuation of nonmonetary goods and services of coastal ecosystems like water quality (16) or recreation (17). Studies have also explored perceptions of wind and tidal energy (18, 19) and public reaction to carbon capture and storage (20). These studies illustrate strong personal connections to marine and coastal environments, affected by aesthetics, identity, practical considerations, livelihoods, assessment of impact on marine wildlife, and energy production.

Systematic global mapping efforts of multiple anthropogenic ocean impacts have been conducted by expert groups (21), but these

Significance

We report the results of a 10,106-person pan-European survey of public awareness, concerns, and priorities about marine anthropogenic impacts as a way to inform both science and policy initiatives in achieving marine sustainability. Results enable scientists and policymakers to understand how the public relates to the marine environment and how they frame impacts and can help make managerial, scientific, and policy priorities more responsive to public values.

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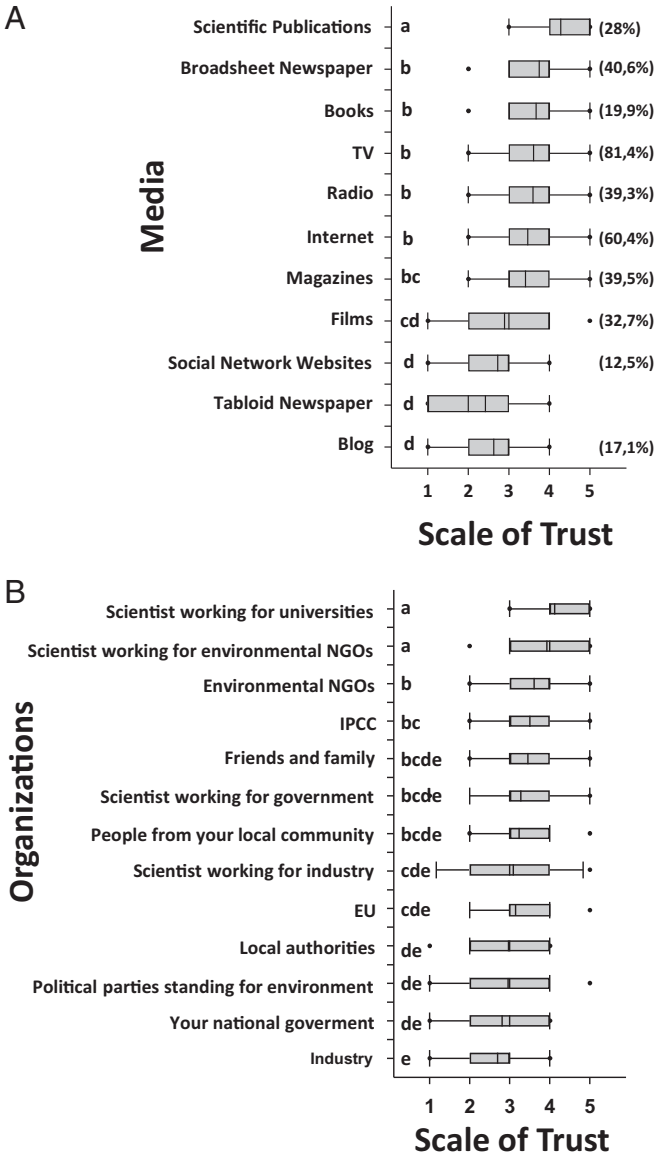

Fig. 1. (*A*) Public trust in different sources of information (bars) complemented by indication of main sources of information (percentage of respondents in parentheses). (*B*) Public trust in different individuals or organizations. Anchor points in the scale are 1, distrust a lot; and 5, trust a lot. Different letters represent decisive differences between sources by using a Bayesian discrete choice cumulative logit link model for multinomial responses (*SI Appendix*, Figs. S1, S4, and S5). For all box plots, the median is represented by line and dot, the box represents the interquartile range, the whiskers represent the data range, and dots are outliers.

studies have not assessed public awareness, concern, and priorities about these impacts. Understanding public awareness, concerns, and priorities with regard to marine impacts is important, firstly, to appreciate how people relate to the marine environments and the way they frame impacts (21); secondly, to identify science-based conceptions or misconceptions among the public that may arise from poor communication (22); and, thirdly, to understand societal perceptions with a view to making managerial and policy priorities more responsive and accountable to public values (10, 23).

Here we report results of a pan-European survey on public concerns and priorities regarding marine impacts. We do so on the basis of responses to an online survey by 10,106 citizens from 10 European nations spanning a diversity of sociopolitical and geographical areas. In particular, we examine information and concern regarding marine impacts and priorities for policy and funding actions according to various impacts. Because the European Union (EU) is one of the largest consumers of seafood in the world (24), many European nations champion global conservation issues, and the key role the EU plays in international ocean affairs, understanding European citizens' awareness, concerns, and priorities is of global importance.

Results

European citizens primarily rely on television (82%) and the Internet (61%) as sources of information about marine impacts, particularly those related to climate change. They respond that they trust scientific publications the most, followed by printed newspapers, books, television, and radio (not statistically different from one another; Fig. 1*A*; Bayesian hypothesis tests; *SI Appendix*, Figs. S1 and S4). When asked on a five-point Likert scale "To what

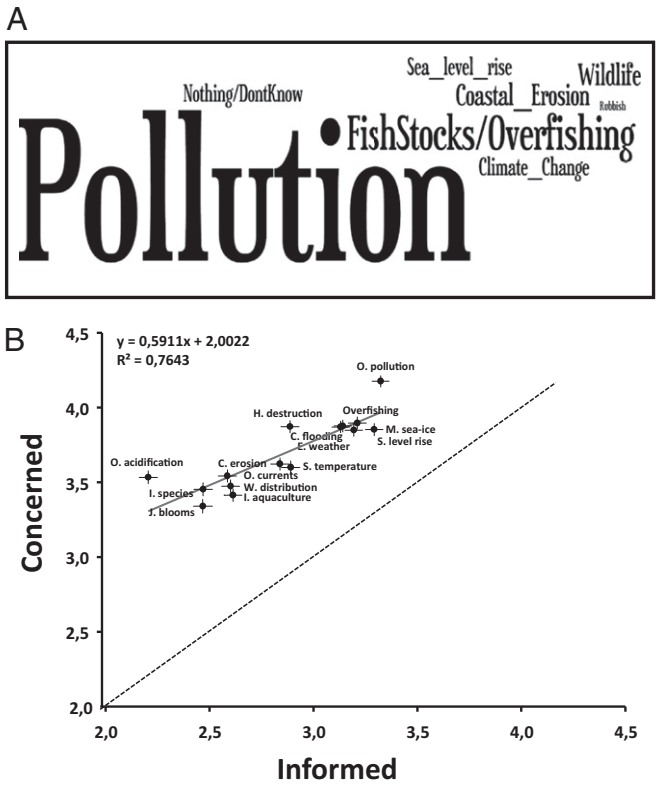

Fig. 2. (*A*) Responses to the survey question: "When you think about the coastline or the sea, what are the three most important environmental matters that come to mind?" (Aggregate responses for all 10 countries surveyed and all responses received; each respondent could provide up to three matters). In the word cloud the size of the word represents the percentage of responses. The term pollution combines mentions of "pollution," "water cleanliness," "sewage," "water pollution," "oil pollution," and "water quality." (*B*) Relationship between the public's perceived level of information and perceived concern regarding ocean impacts. The bold line is the regression, the dotted line the 1:1 line, and the error bars are 2 SEs. Legends in the figure represent impacts: 1, O. currents, ocean current changes; 2, M. sea-ice, melting sea ice); 3, S. level-rise, sea level rise; 4, C. flooding, coastal flooding; 5, E. weather, changes in the frequency of extreme weather events; 6, I. aquaculture, environmental impacts of aquaculture; 7, Overfishing; 8, I. species, effects of marine invasive species; 9, O. acidification, ocean acidification; 10, S. temperature, sea temperature changes; 11, H. destruction, destruction of the habitat at the coast or in the sea; 12, O. pollution, ocean pollution; 13, C erosion, coastal erosion; 14, W. distribution, changes in the distribution of marine wildlife; 15, J. Blooms, increased jellyfish marine blooms/swarms.

Table 1. Percentage of responses for the question, "When, if at all, do you think the following impacts of climate change on the coastline and seas of Europe become apparent?"

Impact	Impacts are already apparent, %	Impacts will be apparent in the next 20 y, %	Impacts will be apparent in the next 50 y, %	Impacts will be apparent over 50 years' time, %	These impacts will never become apparent, %	Don't know/didn't answer, %
Changes in the frequency of extreme weather events (e.g., storms)	54	22	10	4	2	9
Major economic impacts from coastal flooding	31	33	16	7	2	10
Extensive loss of land to the sea	24	28	21	13	3	11
Ocean current changes leading to sudden/abrupt climate change in Europe	26	30	19	9	3	13
Complete melting of Artic sea-ice in the summer	22	24	21	16	6	12
Oceans becoming more acidic impacting sea life and fisheries	16	33	19	8	2	19

Percentage calculation includes all responses (n = 10,106).

extent, if at all, do you trust the following organizations when providing information about climate change impacts on the coastline or the sea?", public trust in scientists working for universities and, to a lesser extent, in those working for nongovernmental organizations (NGOs), was significantly higher than that for scientists in government and industry (Fig. 1*B*; Bayesian hypothesis tests; *SI Appendix*, Figs. S1 and S5). In general, industry professionals and national governments were distrusted the most (Fig. 1*B*). The UN Intergovernmental Panel on Climate Change (IPCC), an intergovernmental body of independent scientists operating under the auspices of the UN, elicited less trust than university scientists and showed the same level of trust as scientists working for government and industry and asking friends and family about these issues, despite most IPCC authors being university scientists (25). This finding could point to a low awareness of the IPCC, a perceived lack of independence of scientists contributing to the IPCC, a distrust of the governance structures of the IPCC and its relationship with governments, or a lack of engagement with IPCC information and communications, leading to misconceptions about how the IPCC works.

When respondents were asked in the first marine-related (and open-ended) question of the survey to list the three most important marine environmental problems that spontaneously come to mind, the main responses identified pollution (33%), overfishing (8%), coastal erosion (5%), wildlife conservation (5%), and climate change (4%) as the most important problems (Fig. 2*A*). These open-ended questions provide insight into how the public actually frames their associations and concerns in terms of multiple issues and impacts.

European respondents felt only moderately informed about marine impacts; average values of informedness ranged between somewhat and slightly informed (scores between 2 and 3 on a Likert scale). Perceptions regarding the level of informedness differed across impacts (Bayesian hypothesis tests; *SI Appendix*, Fig. S2), with respondents claiming that they are most informed about ocean pollution (3.32), melting sea-ice (3.29), overfishing (3.21), sea level rise (3.19), coastal flooding (3.14), and extreme weather events (3.13) and least informed about ocean acidification (2.2), proliferations of invasive species (2.47), and jellyfish blooms (2.5) (Fig. 2*B*; *SI Appendix*, Fig. S2).

Concern about marine environmental issues varied significantly across impacts (Bayesian hypothesis test; *SI Appendix*, Fig. S3). European respondents reported the highest concern, on average, for the impacts of ocean pollution (4.18; *SI Appendix*, Fig. S3) and were "somewhat concerned or concerned" for all other impacts (scores between 3 and 4). The level of concern was closely related to the level of informedness for the various impacts (Fig. 2*B*). Respondents expressed a higher level of concern, relative to their perceived level of informedness, for three specific impacts: ocean pollution, habitat destruction, and ocean acidification (Fig. 2*B*). The level of concern was below their declared levels of informedness for the impacts of aquaculture and increased jellyfish blooms (Fig. 2*B*). Importantly, the level of respondents' informedness and concern on marine impacts increased with the frequency in which they visited the coast for all impacts assessed (*SI Appendix*, Fig. S6).

Despite some recognition of uncertainty regarding ocean acidification (19% of respondents did not know when effects would be apparent), the European respondents generally perceived marine anthropogenic impacts as having occurred or would occur within their lifespan (Table 1). This finding includes impacts whose primary effect may only become evident in the second half of this century, such as the complete Arctic ice melt in the summer (which 22% of respondents perceive has already occurred; Table 1). Results suggest a perceived immediacy and severity of all marine anthropogenic impacts assessed.

When respondents were asked to prioritize research funded by the EU on climate change and marine impacts, they tended to focus on melting of sea ice in polar regions, physical changes in the ocean, and impacts of climate change on marine organisms as their top three priorities, with the least priority given to understanding impacts of marine invasive species (Fig. 3). Our analysis indicates that, in general, responses were related to awareness of research performed on climate change marine impacts (Fig. 3). Main issues that stand out in the awareness/priority regression as research priorities include research on physical changes in the ocean (e.g., ocean currents, storms, and waves), marine diseases and pests that may become more common with climate change, and research on how human societies can cope with the impacts of climate change (Fig. 3). The issues that receive a lower research priority than expected from declared awareness include research on the impacts of invasive species, studies of long-term records of past climate change, and research on coastal erosion (Fig. 3). When respondents were asked to indicate which of 11 ocean-related policies should be prioritized by the EU, the majority of respondents preferred policies on regulating pollutants and overfishing; the lowest

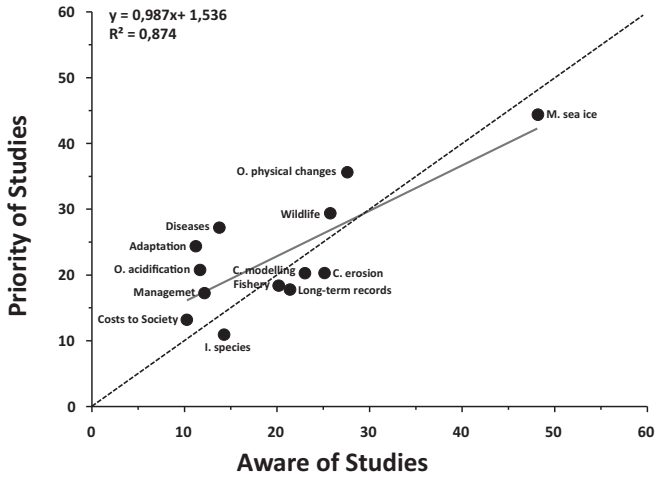

Fig. 3. Relationship between the public's perceived awareness and priorities regarding research on climate change impacts at the coastline or sea. The bold line is the regression, the dotted line the 1:1 line, and the short phrases represent the research priorities: 1, O. physical changes, studies of physical changes in the ocean (e.g., ocean currents, storms and waves); 2, Long-term records, studies of long-term records of past climate change; 3, M. sea ice, studies of melting sea ice in the Arctic and Antarctic; 4, Fishery, studies looking at climate impacts on commercial fish and shellfish; 5, Wildlife, studies looking at climate impacts on wildlife at the coastline or in the sea; 6, I species, studies looking at the impacts of nonnative species at the coastline or in the sea; 7, C. modeling, computer models that predict future changes at the coastline or in the sea; 8, C. erosion, studies of coastal erosion; 9, O. acidification, studies of what will happen if the ocean becomes more acidic; 10, Diseases, studies of diseases and pests that may become more common with climate change; 11, Costs to society, studies to estimate the costs to society of climate change impacts at the coastline or in the sea; 12, Adaptation, studies on how communities can cope with the impacts of climate change; 13, Management, studies on marine and coastal management practices.

priority was given to policies aimed at enabling the coastline to respond naturally to rising sea levels (Fig. 4). These results are within expectations, given respondents' concern scores and their framing of issues within the open-ended questions.

When respondents were asked about the effectiveness of different actors to tackle anthropogenic marine impacts, 59% of respondents indicated that NGOs were very effective or somewhat effective, whereas 46% indicated the EU and 42% pointed to individual citizens as being effective. Sixty-nine percent of respondents perceived that businesses and industry would not be effective at tackling marine anthropogenic impacts (Fig. 5).

Discussion

The results provide an overview of concerns of European citizens with regard to marine impacts and their priorities for funding and policy. European citizens respond that they are only moderately informed about marine impacts, with their level of personal experience and informedness related to their concerns and priorities. The relationship between informedness and concerns reported here is consistent with earlier reports on public perceptions about impacts from global warming (26).

Although significant relationships between informedness and concern are prevalent in our results, personal experience and informedness alone do not necessarily fully account for concern, and personal risk, interest, and moral values—not assessed here—can also play important roles (26). Indeed, our results show some exceptions to the direct relationship between informedness and concern, because respondents showed higher levels of concern, relative to their level of informedness, for marine pollution, habitat destruction, and ocean acidification. Ocean pollution and habitat destruction have been previously identified by individuals as pressing issues facing the world's oceans (27); however, ocean acidification is a relatively new and complex issue in science-policy circles (28). That ocean acidification has surfaced as an issue of public concern offers food for thought on how these scientifically new and complex impacts are being perceived and understood, while also raising optimism as to the capacity of the public to respond to new impacts on the ocean ecosystem.

Public views, in conjunction with expert opinion, can help focus international, national, and local initiatives in prioritizing the most important or most manageable marine impacts. Indeed, there is considerable consensus between the citizens' responses to the survey and the outcome of a systematic assessment of ocean threats performed by 135 experts (21). For instance, experts assigned the greatest impact scores to ocean warming, overfishing, and pollution, much like the outcome of the open-ended responses from the public. In addition, one of the lowest certainty scores of all threats identified by the experts concerns diseases in the oceans, an issue met with relatively low awareness but high priority for research by the public. Interestingly, although species invasions are commonly cited as a major threat to particular ecosystems (e.g., ref. 29), they rank low in the expert opinion survey as well as in the concerns and priorities of the European public. In addition, experts recommend that ocean acidification be allocated increased research effort, coinciding with the general public's perception of lack of information around this issue.

Marine ecosystems are affected by multiple impacts and are affected at some level by every identified threat (4). The public frames their concerns in terms of multiple, rather than isolated, impacts (22, 30), suggesting that scientists can capitalize on the public understanding of multiple stresses and focus on the combined effects of biodiversity loss, overfishing, climate change, and pollution as a comprehensive ocean health problem, thereby aligning scientific research efforts with public framing of these issues as collective inputs to ocean health. We infer, on the basis of the responses analyzed, that the European public is prepared to engage with multiple stressors in ocean impacts and their synergies, which should encourage scientists to avoid oversimplified approaches and tackle these new and complex research and management challenges (31). The same holistic, comprehensive approach is appropriate for crafting policy.

Marine impacts range broadly from those that have been reported in Europe for decades or even centuries, such as overfishing (32) and pollution (33), to impacts associated with

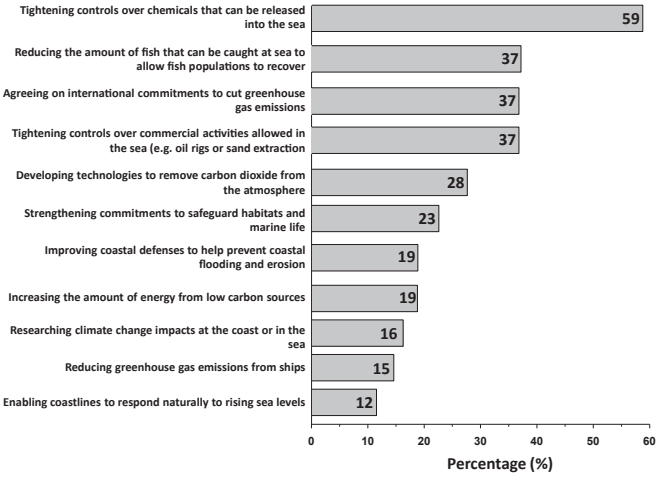

Fig. 4. Public's responses to question: "If you had to decide what climate change and marine policies should be prioritized by the EU, which three would you select from the list below?" Figure includes all responses (n = 10,106).

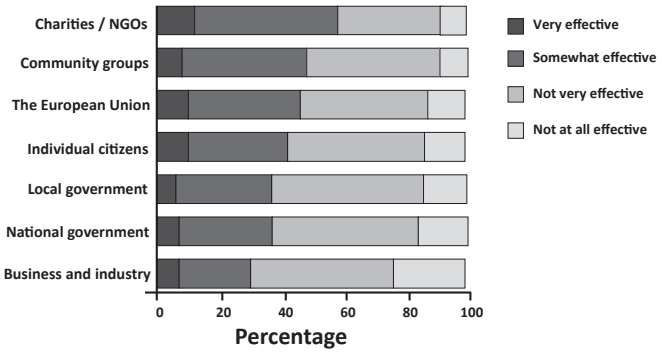

Fig. 5. Public's responses to question: "How effective are the following in tackling climate change impacts at the coastline or in the sea?" Figure includes all responses (n = 10,106).

climate change whose primary impacts are only beginning to be fully realized, such as ocean acidification impacting sea life and fisheries (34). Survey responses show a tendency by individuals to perceive the immediacy of all marine impacts, even those that have not yet materialized—a possible reflection of public concern about marine environmental risks. However, the survey also highlights a perceived lack of individual effectiveness in tackling marine impacts. In fact, 57% of respondents assert that individual citizens' actions are not effective. Research has shown barriers to behavioral change when individuals feel their actions are ineffective, if they perceive that individual change will be futile compared with the magnitude of the problem (35) and if they are not sure what to do (36). Without understanding the benefits of behavioral and attitudinal changes, individuals can be left feeling overwhelmed or opt to ignore the issue (37). Therefore, a key lesson from our results is the need to communicate how individual behavior and lifestyle choices can collectively help improve marine health (27) as a way to incentivize citizens to take greater personal responsibility for the oceans.

Despite the high degree of trust the public places on scientific reports and publications by independent academics, the main source of information for individuals remains the television and the Internet. These findings, coupled with others' (38), suggest that simply giving people scientific information is insufficient and that the most effective way to increase public acceptance of science could be when there is two-way engagement between scientists and citizens. To achieve effective communication, which can trigger increased concern and individual action, we suggest that it is necessary to engage the public through more concerted and transparent fora. In addition to targeting television and the Internet, presenting and discussing marine and climate sciences with the public through open discussions, or deliberative fora (e.g., science shops involving accessible dialogues free of jargon and prior framing) should be promoted (39, 40). Overall, communicating about marine impacts should be based on creating engagement, by being sensitive to peoples' own local circumstances, facilitating emotional involvement with the issue (41, 42), and guiding the public toward the range of personal actions they could take (27).

The development of periodic integrated and comprehensive global assessments (e.g., IPCC, the Millennium Ecosystem Assessment, the United Nations Environmental Programme Global Environmental Outlook, and the International Platform on Biodiversity and Ecosystem Services) is often conducted by scientists, with policymakers as an audience, and typically delivered as summary policy documents (43). Our results suggest that these efforts should take into account public perceptions and target the public as an audience, building on their already advanced level of understanding, their capacity to integrate impacts around synthetic concepts, such as ocean health (21), and triggering individual and collective action. As such, a marine assessment should bring together wide-ranging perspectives about marine impacts, including public perceptions and local knowledge (44), and initiate conversations with multiple policy actors at different scales (45, 46). It is by understanding how the public frames different dimensions of complex marine impacts that scientists and policymakers can become more knowledgeable about how to trigger and support individual and collective action to improve ocean health.

Methods

To assess public perceptions with regard to marine environmental impacts, we administered a survey across 10 European countries. The survey was designed by the research team together with TNS-BMRB, a large social research company with European-wide coverage and experience, commissioned to conduct the survey in January and February 2011. The survey was carried out online. The 10 countries involved in the survey were the United Kingdom, France, Italy, Germany, Spain, Norway, the Czech Republic, Ireland, the Netherlands, and Estonia. Countries were selected on the basis of their proximity to different European regional seas from the Arctic through to the Mediterranean and with high enough Internet-penetration rates to make the research feasible (i.e., this survey was not possible in Bulgaria and Romania).

Respondents were recruited from TNS-BMRB's country online panels, which are built to be representative of the national population and which are continuously updated. Panel respondents (adults, age 18 y and above) were invited to participate in the online survey via invitation emails. Invitations were repeated until hard quotas were met for age, sex, and geographical region to ensure a statistically representative sample based on these socio-demographic characteristics.

The questionnaire was designed to include the following: Likert-type scale responses and free elicitations of word associations. The latter were used at the beginning of the survey to allow participants to define relevant issues in their own terms. This method was designed to minimize bias by enabling personal, spontaneous, and relatively unfiltered responses, providing a unique means to accessing subjective associations and meanings. These open responses were translated into English by native speakers of each country surveyed and coded into key categories as part of the analysis. The 20-min survey was structured into five sections: the first section sought to explore what are the main ocean impacts that come to mind when people think about the coastline or the sea. In the second section, a set of 15 key marine impacts was compiled from the literature (4, 21). Respondents were asked to indicate how informed and concerned they were regarding these impacts on a five-point scale with anchor points (1) "not informed at all" or "not concerned at all" to (5) "very informed" or "very concerned". A third section of the questionnaire explored public trust in media and individuals or organizations that provide climate change information using a scale from 1 (distrust a lot) to 5 (trust a lot). In the same way, we analyzed the public's trust in different individuals and organizations that provide climate change and environmental impact information. The final section explored the public's research and policy priorities on a series of marine environmental issues the EU is currently funding. Respondents were asked to choose the three most important. To avoid a possible lack of independence between variables, we sought differences between the public perceptions by using a Bayesian discrete choice cumulative logit link model for multinomial responses in which country is included as a random factor (ref. 47; *SI Appendix*, Fig. S1). We used the software Winbugs (48, 49) and R (50).

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