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What are the major global threats and impacts in marine environments? Investigating the contours of a shared perception among marine scientists from the bottom-up.

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1. Introduction

A large body of scientific work has described the "litany" [14] of global changes that deteriorate the sustainability and resilience of marine environments, including habitat loss, global warming, ocean acidification, overfishing, coastal sprawl, eutrophication, species redistributions, etc. (e.g. [14,11,6]). Collectively, these impacts can be considered as a single *"interlinked, higher-order syndrome of global marine change"* that is constituted through multiple mechanisms and feedbacks [6]. This syndrome of global (marine) change is historically unique because it is the largest environmental change that is primarily driven by anthropogenic factors. Several scholars now use the term 'anthropocene' [25] to mark this distinctive phase in earth's historical development.

However, Duarte et al. [7] warn that the recital of marine environmental collapse associated with the anthropocene can become self-perpetuating and biased. The occurrence of new *"ocean calamities"* is too readily accepted into the above-mentioned litany, even when evidence for them is weak. This lack of (self-)criticism often stems from miscitations, selective citations and citation errors, which, according to the authors, are rooted in a confirmation bias, i.e. the human tendency to confirm prior beliefs and opinions

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([7], 136). This critique has already produced some counter-reactions,[1] which may hopefully lead to an interesting debate about the role of perceptions in performing and communicating scientific research.

Duarte et al.'s criticism lends support for more explicit focus on scientists' perceptions of global marine change and solutions to mitigate its impact (see also [20]). This resonates with many recent attempts that aim to distil 'major challenges' or 'big questions' from the marine scientific community directly through so-called bottom-up, participatory surveys or exercises [18,21,23,8,9]. A particular objective of these efforts is to take stock of the variety of perceptions and opinions of marine scientists from different academic disciplines to better understand research priorities.

Elucidating dominant and marginalized viewpoints can help to identify self-confirmation biases, and 'bandwagon fallacies' i.e. assuming things because most people do ('argumentum ad populum' or 'appeal to the majority'). Moreover, these exercises can also provide information if dominant perceptions cross disciplines. Indeed, awareness of the contours of dominant perceptions and priorities shaping current scientific agendas [19] can help to identify strengths and weaknesses that enable or impede the development towards greater interdisciplinarity [5].

The objective of this paper is to use a bottom-up approach to take stock of the shared understanding among leading marine scientists in academia of the most pertinent, worldwide threats and impacts that currently affect marine environments. Results from an email survey are used to identify a shared research agenda of global change in marine environments. The assessment is structured using two assumptions derived from Wilen [27] who suggests that natural scientists predominantly focus on symptoms while social scientists focus on causes of environmental change. These suggestions were reformulated into two assumptions: (a) because of a dominance of natural scientists in marine science a tendency exists to focus on investigating the symptoms of global change in marine environments instead of the causes that induce impacts; (b) natural and social academics in marine science likely differ in their focus on symptoms or causes of global marine change. To investigate the validity of these assumptions answers were needed to the following questions: (a) Do marine scientists emphasize symptoms or causes; and b) who mentions what? Do social scientists indeed mention causes more often than natural scientists?

2. Method and materials

To find answers to the above questions a survey was conducted under leading international academics in marine science. These scientists were identified from a literature search that included journals from the social and natural sciences that published marine science. To limit the number of potential respondents 10 target journals were selected with the highest five-year Impact Factor ranking from Thomson Reuters 2010 Journal Citation Reports (JCR) and containing more than fifty articles per year. Five journals were selected from the category 'Ecology' from the JCR Science Edition to represent academics from natural science disciplines; and another five from the category 'Environmental Studies' from the JCR Social Sciences Edition to represent the academics from social science disciplines (Table 1). For each of the selected journals, articles were extracted related to marine topics and published between 2007 and mid-2012. The list of academics in marine science who were asked to participate in the survey was compiled by extracting the names of the first and last authors of each of the selected publications. Through this exercise, a total of 1131 academics were identified as potential respondents. There were 352 authors identified from articles published in the category Environmental Studies (from now on referred to as 'social scientists'); 779 were identified as authors from articles published in the category Ecology (from now on referred to as 'natural scientists'). These academics were contacted through email with the request to identify what they considered the five greatest global impacts and threats in marine environments. The exact question was formulated as follows: *"Could you tell us which five topics represent the greatest global threats or potential impacts in marine environments?"* By phrasing the question in terms of 'threats' and 'impacts' it was left it open to respondents to focus on causes (which the authors associate with 'threats') or symptoms (which the authors associate with 'impacts').

Table 1
The top five journals in marine science for 'Ecology' in the 2010 JCR Science Edition and 'Environmental Studies' in the 2010 JCR Social Science Edition, their impact factors, and the number of authors per journal identified as marine scientists.

Category	Journal name	5-Year Impact Factor	Authors contacted
Ecology	Ecology Letters	14.261	429
	Frontiers in Ecology and the Environment	7.931	52
	Global Change Biology	7.814	216
	ISME Journal	6.813	32
	Trends in Ecology and Evolution	17.735	50
Environmental studies	Ecological Economics	3.232	90
	Ecology and Society	4.644	92
	Energy Policy	3.035	31
	Global Environmental Change	7.840	63
	Tourism Management	3.415	76

A total of 45 responses from social scientists (a response rate of 12.78%), and 126 responses from natural scientists were returned (a response rate of 16.17%). Only the first five topics mentioned were included in the survey analysis, also for those instances when academics replied with more than five answers. The replies were categorized through integrative coding [1], an inductive coding process by which items were merged into subcategories (secondary level), and then further into seven main categories (first level) to arrive at a shortlist of topics that marine scientists consider significant for better understanding the impacts and threats associated with global change in marine systems (see Fig. 1).

3. Results

Our respondents listed "overfishing" (80.1%); "elevated temperature" (69.0%); "contamination and waste" (50.3%); and "ocean acidification" (49.7%) as major threats impacting marine environments (Fig. 2). These results indicate that a broad consensus exists among marine scientists, be they from the social or the natural sciences. The consensus is also visualized as a 'commonality cloud' (Fig. 3), highlighting the replies that were most often mentioned by the academics in our survey.

However, upon closer investigation the responses of natural and social scientists differ markedly on the following aspects. Firstly, social scientists more often mention "societal failures" than

[1] [7] are critical of the publishing practices of high-impact journals such as *Science* and *Nature*, which, as they say, tend to publish work that fits with the prevailing scientific paradigms. The editor-in-chief of *Nature* already responded to this charge (http://www.nature.com/news/ocean-calamities-oversold-say-researchers-1.16714).

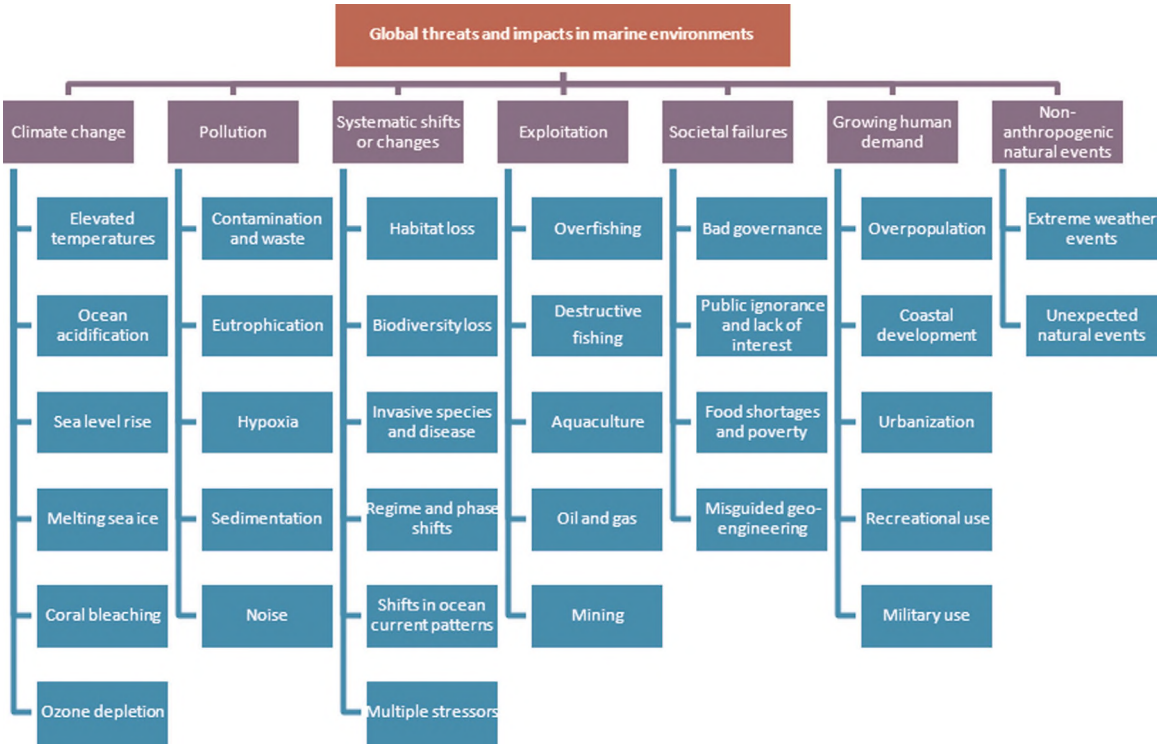

Fig. 1. Bottom-up conceptualization of respondents' replies through integrative coding.

natural scientists (13.8% versus 3.0% respectively, two-sample proportions test: $P < 10^{-7}$). Secondly, natural scientists more often regarded "invasive species and disease" and "overfishing" as important than social scientists ($P=0.013$ and $P=0.032$ respectively, two-sample proportions test). Thirdly, social scientists emphasized "bad governance" and "food shortage, poverty", while natural scientists regarded these as less significant ($P < 10^{-5}$ and $P=0.020$ respectively). These differences are captured in a 'comparison cloud' (Fig. 4) which highlights the differences between the two disciplines.

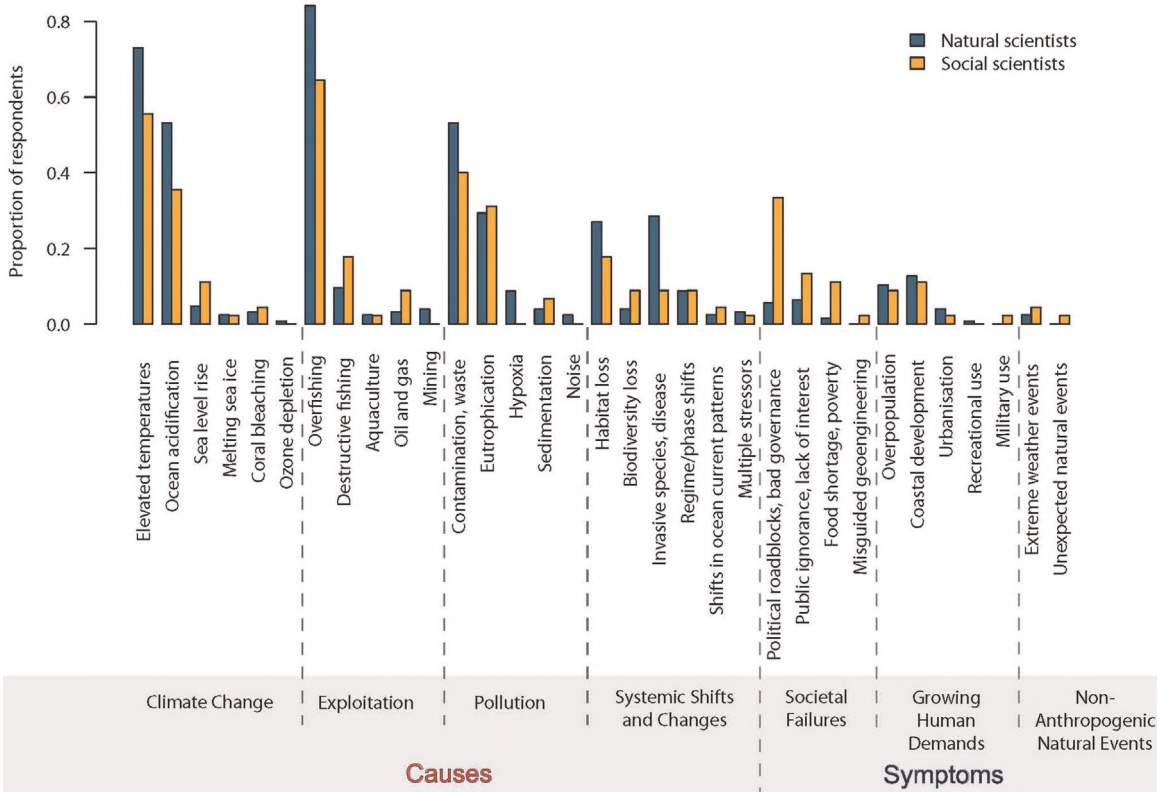

Fig. 2. Proportion of natural and social scientists in the results of the survey.

Fig. 3. Commonality cloud. The size of the individual categories indicates their relative frequency, i.e. how frequently items were mentioned by all respondents in the survey.

Fig. 4. Comparison cloud. The size of the words indicates relative differences between the rates that an item is mentioned by natural scientists (green) and social scientists (red) (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).

4. Discussion and conclusion

Several studies have recently assessed and ranked marine management priorities [11,15]. This study builds on earlier attempts, but differs in its bottom-up approach. Information on the contours of scientific consensus is often lost in conventional assessments, which typically start from a predetermined list of items that are then prioritized. Through the bottom-up approach this article highlighted the extent to which academics in marine science share a common understanding of the symptoms and causes of global change in marine environments.

Based on the survey it was concluded that a shared understanding among marine scientists about the symptoms and causes of global change in marine environments exists. As shared understandings accommodate interdisciplinary research, opportunities for interdisciplinary initiatives within marine science seem positive. Interdisciplinary collaboration on temperature elevation, ocean acidification, overfishing and eutrophication already exists, or is likely easy to establish.

According to our interpretation of the results, however, the scientific consensus predominantly refers to symptoms of global change, i.e. phenomena that impact marine systems. This overall tendency consequently 'backgrounds' some crucial dimensions of global marine change related to anthropogenic drivers, such as the malfunctioning of governance or social institutions. The reason seems due to the dominance of natural scientists in marine science (which is mirrored in our sample). Comparing the replies of natural and social scientists shows some apparent differences in focus. The largest discrepancies were in replies that list "bad governance", mostly by social scientists, and "invasive species", mostly by natural scientists. From this comparison it seems valid to conclude that social scientists more often highlight phenomena that cause the deterioration of marine environments.

These findings thus reinforce our prior assumptions, as well as results of earlier, similar investigations (see [23]), that: (a) there is a tendency in marine science, due to the dominance of natural scientists in this field, to focus on investigating the symptoms, or 'impacts', of global change in marine environments; (b) natural and social scientists likely differ in their focus on symptoms or causes of global change in marine environments.

Many recent studies of global environmental change make clear that interdisciplinary perspectives are needed to identify priorities for policy and management [16,22,24,26]. However, despite important efforts [10,12,17,3], interdisciplinary research continues to be a challenge. It is certainly hopeful that marine scientists share to a large extent the perception that impacts and threats in marine environments are integrated parts of a large syndrome of global marine change [13,2]. Nevertheless, as our findings indicate, disciplinary boundaries remain clearly distinguishable especially when processes of global marine change are perceived in terms of causes and effects.

An important step needed to move towards an interdisciplinary marine science with the aim to help mitigate and/or adapt to the impact of global change is to become aware of the contours of consensus and shared understanding, and where this consensus disintegrates. Such knowledge is necessary to reach a certain level of tolerance and mutual understanding needed for interdisciplinary marine science to progress.

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