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Communicating about marine disease: The effects of message frames on policy support

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ABSTRACT

Oceans are suffering from the dual climatic pressures of warming temperatures and acidification, increasing the presence of disease risks that affect marine organisms and public health. Through a randomized field-based experiment, this study examines the effects of communicating about risks to marine organisms and public health on people's support for policies aimed at mitigating those risks as a function of different message frames. To maximize the salience of these issues, participants were recruited from ferry passengers ($N=543$) in the San Juan Islands of Washington State in the summer of 2013 and randomized to read one of four fictitious news articles detailing the increased incidence of deadly bacteria (*Vibrio*) in oysters in the Pacific Northwest. Depending on condition, the article attributed the causes to global warming *or* climate change and the consequences primarily to oyster health *or* public health—frames that recent research suggests can influence how the public responds to environmental messages. Results showed high levels of support for marine policy and high concern about the prevalence of marine disease risks across the sample (i.e., irrespective of framing condition). Analysis of individual differences suggested that participants with lower biocentric (i.e., environmental) values were more supportive of marine policy when exposed to the article highlighting consequences to oyster health from global warming, an effect that was fully mediated (or explained) by level of self-reported concern. The results demonstrate the importance of communication about marine disease in showing how subtle changes in message frames can elicit differential support for marine policy.

1. Introduction

Marine disease risks and ocean health threats are forecast to change significantly with the dual climatic pressures of rising ocean temperatures and acidification [5,12,35]. Addressing these disease threats will require greater collaboration across diverse scientific fields to better elucidate human dimensions of marine disease. This includes exploring how the public perceives marine disease risks that have been linked to climate change and the factors that shape support for actions to mitigate them. Ultimately, such efforts can aid in the development of comprehensive solutions to promote environmental stewardship and encourage sustainable actions that protect ocean health and human health.

The present study builds on emerging research into the framing of environmental issues and its effects on human judgments, including beliefs, perceived risks, and policy preferences (e.g., [17]). Framing theory recognizes that the words chosen to convey a given issue can exert a powerful effect on how audiences process and perceive messages by bringing certain considerations to mind over others (e.g., [10,9]). Empirical studies of framing typically expose audiences to different versions of the same core message (by varying wording or some other feature) and take any observed differences in stated attitudes, beliefs, or preferences as evidence that a framing effect has occurred (e.g., [7,15,34]). These effects are theorized to operate through basic principles of human cognition, such that frames in their operationalized forms (e.g., variants in wording) increase the accessibility or salience of previously stored knowledge structures in the minds of an audience ("priming" in psychological terms), thereby increasing the likelihood that *that* knowledge – as opposed to other relevant considerations – will be brought to bear on subsequent judgments (e.g., [6], Higgins and Brendl, 1995, [39]).

In this vein, research in climate change communication has begun to explore how the different ways of framing climate change and related issues may influence the public's climate-related beliefs and concerns. To date, two lines of climate framing research have garnered the most attention from scholars. One line considers how highlighting the public health consequences of climate change as opposed to its more traditional environmental consequences affects audience perceptions and suggests that a public health frame can

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bolster concerns and support for climate-mitigating actions (e.g., [24,25]). Another line explores the influence of framing the issue through the use of different labels that are commonly applied to it—including global warming, climate change, global climate change, and so on (e.g., [1,30,31,36]).

Evidence suggests that, despite their interchangeable usage in many mainstream media outlets and everyday public discourse, these terms are perceived differently by the public. Whereas global warming has been found to carry stronger associations with human causes (e.g., pollution) and heat-related consequences (e.g., melting polar ice), climate change may evoke stronger thoughts related to natural causes and broader, more wide-scale climatic alterations (see [2,37,9]). These patterns may partly account for the observation that U.S. survey respondents report weaker belief in the existence of global warming than climate change and other effects of these frames on survey responses [17,18,28]. Among other findings, research suggests that global warming is a more politicized frame than climate change, invoking greater skepticism from individuals who may be predisposed to challenge the existence of the phenomenon (e.g., Republicans and conservatives in the United States; [7]). Thus, rejecting the view that messages have the same effects on all audiences, researchers have shown that when exposed to messages, audiences' predisposed values and ideological orientations may perform as a perceptual filter, leading them to engage in motivated reasoning, whereby they actively select a subset of considerations that are consistent with and support their pre-existing attitudes and ideologies [6,33]. In this manner, audiences' environmental values may influence their responses to messages (e.g., [20,29,30,38]).

Further, although climate change is commonly framed in terms of its consequences for environmental and ecosystem health (by highlighting threats to species survival or shifts in wildlife habitats), framing the issue in terms of its possible public health impacts may evoke stronger emotional responses and help mobilize support for climate mitigation ([21,24]). Although this notion is bolstered by previous work suggesting that apathy and inaction on climate issues may be due, in part, to many people's abstract and distant construal of the threats (e.g., [19,35]), limited research has explored whether emphasizing the public health versus environmental health consequences of emerging climate-related issues shapes how audiences perceive indirect effects of climate change, such as infectious disease or loss of biodiversity. Moreover, little is known about the possible combined effects of different health frames (environmental vs. public) and label frames (global warming vs. climate change), which routinely co-occur in mass media that inform the public about marine disease outbreaks linked to a changing climate. For instance, does the effect of public health versus environmental health framing depend on whether the threat is attributed to "global warming" or "climate change"? On one hand, given past research suggesting that both public health and climate change framing promote stronger climate-related beliefs and concern, it may be reasonable to predict that, in general, the most pro-environmental attitudes and beliefs would be observed when these frames co-occur. On the other hand, any given marine disease context likely evokes unique thoughts and considerations that may themselves interact with these frames. In the specific case of *Vibrio* outbreaks in oysters, for example, "global warming" might prove a more impactful frame, given the negative connotations that pairing "warm" and "oysters" is likely to evoke. Thus, outbreaks like that of *Vibrio*, which poses a serious risk to human health through the consumption of raw oysters and other routes of infection, represent ideal cases for studying the intersection of these different climate frames, in addition to providing insight into the public's awareness and concern about marine disease—a topic receiving little attention in recent social scientific work on perceptions of biodiversity and species conservation (e.g., [4,11,16]).

After a brief overview of the study context, this paper reports on an experimental survey in which participants read differing versions of a fictitious news article about diseases in oysters that was designed to address some of these gaps. Specifically, the experiment explored the effects of different ways of framing risk communication messages on people's support for marine policy to mitigate the causes and consequences of diseases in the ocean.

2. Materials and methods

2.1. Study context: Oysters in the Pacific Northwest

The context for this study is the recent increase in disease vulnerability of oysters due to ocean warming and acidification. Oysters provide important economic and ecosystem services in estuaries worldwide. The Northeast Pacific Coast, particularly the U.S. West Coast and Pacific Northwest, is an important oyster growing area, accounting for $73 million in oyster harvest annually [27]. In addition to threatening the health of oysters and oyster larvae in particular [3], ocean warming has increased both the geographic distribution and number of cases of human illness due to *Vibrio* bacteria (including cases from the Pacific Northwest) through both the ingestion of raw oysters and wound infections (for a review, see [5]).

2.2. Data collection procedure

Over the course of two weeks in July 2013, passengers riding the Washington State Ferries in the San Juan Islands were recruited to participate in the experiment. Passengers were approached by undergraduate research assistants wearing university name tags and asked if they would be interested in participating in a social science survey. Those who agreed[1] ($N=543$) were handed iPads© preloaded with the experimental materials using Qualtrics survey software and given brief instructions about how to operate the device if necessary.

Participants were randomly assigned to one of the five different conditions: four message conditions and a no message, control condition. Participants in the message conditions were presented with a fictitious news article modeled after local media coverage of *Vibrio* outbreaks and ocean acidification affecting the Pacific Northwest oyster industry, which was reviewed prior to the study for scientific accuracy. Depending on the experimental condition, the article highlighted consequences either for public health or oyster health; in addition, effects were attributed either to *climate change* or *global warming*. These treatments were crossed to create the following four message conditions: oyster health × global warming, oyster health × climate change, public health × global warming, and public health × climate change. Besides these variations, the articles were similar across conditions (see the Appendix for all message conditions). After reading their assigned article, participants completed a series of survey items containing key measures and demographics; participants in the control condition advanced immediately to the survey items.[2] Upon completion of the survey, participants were debriefed and given the opportunity to ask questions about the study. On average, the study took 15 minutes to complete.

[1] Response rates, including number of refusals, were not tracked systematically since the intent was not to obtain a random sample or generalize to a population, e.g., all ferry passengers. Even so, most passengers who were approached were willing to participate.

[2] Participants were oversampled in the control (no message) condition relative to the message conditions in order to establish reliable baseline measures of the outcome variables of interest (support for marine policy and concern about marine disease).

2.3. Measures

The dependent variable was support for marine policy to mitigate diseases in the ocean. This variable was measured using responses to the following three statements, which were presented in a random order for each participant to control for any unintended order effects: (a) *The United States should protect coastal industries from harmful bacteria or disease in the ocean*, (b) *The United States should reduce threats to marine life from harmful bacteria or disease in the ocean*, and (c) *The United States should limit public health risks from harmful bacteria or disease in the ocean* (response scale endpoints: 1=strongly support and 6=strongly oppose). These items were reverse-scored and averaged to compute the main dependent variable (Cronbach's α=.88), with higher values indicating greater support (M=5.14, SD=.91).

The survey also measured biocentric values, which reflect a belief that all biological life has intrinsic value [8,26,32]. In light of prior work suggesting that framing effects may vary as a function of environmental values (e.g., [25,31]), biocentric values were expected to moderate the effect of the different message frames on marine policy support. Biocentric values were measured by agreement with the following six statements drawn from previous research [4,22], which were again randomly ordered for each participant: (a) *Losing one species will have far-reaching effects on the ecosystem as a whole*, (b) *The Earth's remaining ecosystems should be conserved at all costs*, (c) *As humans, we have a moral obligation to ensure that we do not cause the extinction of other species*, (d) *The Earth's fragile ecosystems can be disrupted by very small changes in the balance of species*, (e) *All animals have a right to live*, and (f) *Every species has equal value and an equal right to exist* (response scale endpoints: 1=strongly agree and 6=strongly disagree). These items were reverse-scored and averaged to compute into a single composite index of biocentric values (α=.92, M=4.85, SD=1.07), with higher values indicating greater biocentrism.

Concern about marine disease was also measured because it may serve as a potential mediator of any effect of message framing on marine policy support. To measure concern, participants were asked the extent to which they would be "bothered by" the scenarios depicted in the following three statements: (a) *Diseases among marine life may occur more frequently*, (b) *Diseases among marine life may be getting more severe*, and (c) *Diseases may result in declines in marine life populations* (response scale: 1=not at all, 2=a little, 3=somewhat, 4=a great deal). These items were again averaged to create a single variable, with higher values indicating greater concern (α=.90, M=3.56, SD=.60).

Finally, demographic variables (including gender, age, education, ethnicity, and distance between the study area and participants' primary residence) were also measured [Table 1].

None of these demographic variables differed across message conditions, suggesting that the experimental randomization was successful[3].

Table 1
Descriptive statistics of study participants (N=543).

	Proportion (N)
Randomized experimental condition	
Public health with climate change	.16 (89)
Public health with global warming	.16 (89)
Oyster health with climate change	.17 (91)
Oyster health with global warming	.16 (89)
Control group (no message condition)	.34 (185)
Female	.58 (316)
Age (mean and standard deviation)	45.9 (.65)
Highest level of education completed	
High school diploma or less	4.97 (27)
Completed some college	13.81 (75)
College graduate	81.22 (441)
Race/ethnicity	
White or Caucasian	90.06 (489)
Other	9.94 (54)
Political party	
Republican	13.08 (71)
Democrat	51.38 (279)
Independents	26.34 (143)
Distance between study area and primary residence	
Less than 20 mi	17.68 (96)
More than 20 but less than 100	25.41 (138)
More than 100 but less than 500	20.81 (113)
More than 500 mi	36.10 (196)

Note: All sample characteristics are proportions with sample sizes in parentheses, except for age.

3. Results

3.1. Main effects of messages

A comparison of mean values for support for marine policy showed no significant differences across the five conditions (F<1, ns). Overall, high levels of support for marine policy were observed across conditions (M=5.14, SD=.91, with 6 representing the highest level of support), with values ranging from relatively low in the climate change/oyster health message condition (M=5.08, SD=.88) to relatively high in the global warming/public health message condition (M=5.24, SD=.85). However, mean values of concern for marine disease revealed a marginally significant difference across conditions, F(4, 538)=2.31, p=.06. Although concern for marine disease was also generally high across conditions (M=3.56, SD=.60, with 4 representing the highest level of concern), the global warming/public health combination elicited the highest concern (M=3.71, SD=.47) whereas the climate change/oyster health condition yielded the lowest (M=3.46, SD=.71), a marginally significant difference (post-hoc contrast with Bonferroni correction; 95% CI: −.003 to .496, p=.06). Level of concern in the control condition did not differ significantly from that observed in any of the message conditions (ps>.13).

3.2. The interaction effect of framing and biocentric values on marine policy support

To explore the effect of different frames on people with different biocentric values, Ordinary Least Squares (OLS) multiple regressions were used. Specifically, policy support was regressed onto the cause frame (global warming or climate change, dummy-coded with the climate change as the referent group), the consequence frame (oyster health or public health, dummy coded with the oyster health condition as the referent group), biocentric values (mean-centered), and all second- and third-order interaction terms. For simplicity, these analyses excluded the control group (which was not exposed to any experimental message), decreasing the number of participants used in the analysis to N=348[4].

The regression yielded a number of significant findings. First, the term representing the three-way interaction between the cause frame, consequence frame, and biocentric values was significant, b=−.39, t (3 5 0)=−2.58, p=.01 [Model 1 of Table 2][5]. To better understand

[3] As a check of message equivalence (aside from the framing treatments), participants also rated their randomly assigned message in terms of being *informative*, *persuasive*, *clear*, and *realistic*. No significant differences were observed.

[4] In addition, the functions that underlie some regression models reported here (i.e., mediated moderation) can become difficult to interpret in analyses including additional conditions, further supporting the decision to exclude the control group (for a discussion, see [23]).

[5] An analysis of variance on biocentric values across the experimental conditions indicated that the message manipulation had no effect participants' biocentric values, F<1.

this conditional effect of causal frames, estimated values of marine policy support at the 10th, 25th, 50th, 75th, and 90th percentiles of biocentric values were analyzed separately across the four message conditions with contrast analyses using the linear combinations of coefficient ("lincom") algorithm in Stata. Although the effect of global warming/climate change framing did not vary across biocentric values of those reading the public health version of the article ($|b|$s = .20, $|t|$s < 1.17, ns), for the oyster health version of the article, global warming framing raised support for marine policy relative to climate change framing among participants reporting lower biocentric values in particular (i.e., the 10th percentile on the biocentric values scale), b = .48, CIs = .14 and .81, t = 2.81, p < .01 ($M_{\text{Global Warming}}$ = 5.10, $M_{\text{Climate Change}}$ = 4.62). In contrast, this effect was not observed for participants reporting higher biocentric values (i.e., the 90th percentile) ($M_{\text{Global Warming}}$ = 5.23, $M_{\text{Climate Change}}$ = 5.50), b = −.27, CIs = −.61 and .06, t = −1.62, p = .11, nor among those with biocentric values at the 25th, 50th, and 75th percentiles, $|b|$s < .23, $|t|$s < 1.86, ns [Fig. 1].

Complementing this spotlight analysis, a simple slopes analysis revealed a significant positive relationship between biocentric values and marine policy support among participants who read about consequences for oyster health from climate change, b = .88, CIs = .51 and 1.25, t = 4.69, p < .001. In contrast, no such relationship was observed when the consequences for oyster health were instead attributed to global warming, b = .13, CIs = −.19 and .45, z = .79, ns.

3.3. The interaction effect of framing and biocentric values on concern about marine disease

Further analysis explored how the messages influenced concern about marine disease when accounting for biocentric values [Model 2 of Table 2]. As with the analysis of support for marine policy reported above, the term representing the three-way interaction between cause frame, consequence frame, and biocentric values was again significant, b = −.36, t (3 5 0) = −3.57, p < .001.

This three-way interaction was probed using the same techniques as above. Consistent with the results on marine policy support, no effect of the global warming/climate change framing was observed in the public health condition regardless of biocentric values $|b|$s < .12, $|t|$s = 1.48, ns. However, in the oyster health condition, global warming framing raised concern for marine disease relative to climate change framing among participants with weaker biocentric values (the 10th and 25th percentiles) in particular bs > .27, ts > 3.25, ps < .01. In comparison, participants with stronger biocentric values (the 75th and 90th percentiles) reported significantly *less* concern under the global warming frame, bs < −.20, ts < −2.07, ps < .05, and no significant effects were found among participants reporting moderate biocentric values (50th percentile), b = .03, t = .41, ns [Fig. 2].

Complementing the above spotlight analysis, simple slopes analysis revealed a significant positive relationship between biocentric values and concern in the oyster health and climate change condition, b = 1.09, CIs = .84 and 1.34, z = 8.68, p < .001, a pattern not observed when these oyster health consequences were instead attributed to global warming, b = .21, CIs = −.004 and .42, z = 1.92, ns.

3.4. Testing for mediated moderation

Given the significant correlation between marine policy support and concern (r = .46, p < .001, two-tailed), further analysis explored whether concern about marine disease was a potential mediator of the observed relationships between the message frames, biocentric values, and support for marine policy [28]. To establish this form of mediated moderation, two conditions must be met: (1) the effect of the treatment on the mediator depends on the moderator, and (2) the moderation of the residual direct effect of the treatment is reduced when controlling for the indirect effect of the mediator, whether or not this effect is moderated. If the 95% confidence interval (CI) surrounding the estimated indirect effect does not include zero, the finding is interpreted as evidence for mediated moderation.

The PROCESS macro for SPSS was used to examine these conditions [28]. Regression models 1 and 2 showed that the effect of message frames on the mediator (i.e., concern for marine disease) depended on the moderator (biocentric values), thus establishing condition 1. When controlling for the indirect effects of concern, the three-way interaction between the two treatments and biocentric values on marine policy support became non-significant, thus establishing condition 2. Finally, when controlling for concern for marine disease, the residual direct effect of the three-way interaction on marine policy support was no longer significant, b = −.24, p = .10 (reduced from b = −.39, p = .01). Using a 95% CI and 5,000 bootstrap resamples, the CIs indicated that the overall indirect effect of concern for marine disease was significant (i.e., did not include zero), b = −.14, CI: −.32 to −.05, p < .05.

4. Discussion

4.1. General discussion

This study sought to extend current dialogue about framing effects and climate change to the context of marine disease and ocean health. In particular, it explored effects of framing the causes of marine disease in terms of either global warming or climate change and the consequences in terms of either environmental or public health on support for marine policy. The specific topic focused on the health of oysters in the Pacific Northwest, which are suffering from the dual climatic pressures of warming oceans and ocean acidification. The oyster context provided an opportunity to emphasize the risks or consequences as primarily to oysters (e.g., loss of larvae) or public health (e.g., increased levels of deadly *Vibrio* bacteria in raw or undercooked oysters). The guiding question was whether different ways of framing the issue would lead to different levels of concern about marine disease and support for marine policy to mitigate those risks, while holding constant the core information conveyed by the message.

The results showed no main effect of message framing on support for marine policy and only a marginal effect on concern for marine disease, with the global warming/public health combination eliciting the highest level of concern and the climate change/oyster health combination eliciting the lowest[6]. Overall, the sample – ferry passengers traveling between different locations in the San Juan Islands in Washington State – reported high policy support and concern (near the top of the scales' ranges), which may help explain why participants who read a news article did not exhibit significantly greater support or concern than control participants, on average (i.e., a possible ceiling effect). The messages may also have conveyed information already familiar to many in this sample, many of whom may visit and make their homes on islands where such marine issues are commonly discussed[7].

Further analysis explored the potential for differential effects of the messages as a function of participants' biocentric (or environmental) values. It was expected that participants with stronger or weaker beliefs about the importance of biodiversity in the ecosystem might respond differently to the global warming/climate change and oyster health/public health frames. As this research was exploratory, it was posed as a question rather than as a

[6] While speculative, the marginally greater concern observed in the global warming/public health condition may partly owe to global warming's relatively strong connotations of warmth [36] and the widespread knowledge that oysters must be kept cold (on ice) for public safety reasons.

[7] Even so, over half of participants stated that they lived more than 100 mi from where they were completing the survey on the ferry, with over a third more than 500 mi from home, suggesting some geographic diversity and topic familiarity among the sample.

Table 2
OLS regression models testing interactions between frames and biocentric values.

	Model 1: support for marine policy			Model 2: concern about marine disease		
	b (SE)	*t*	beta	*b* (SE)	*t*	beta
Global warming frame (ref=climate change frame)	.10 (.12)	.84	.06	.11	1.47	.10
Oyster health frame (ref=public health frame)	−.02 (.12)	−.20	−.01	−.10	−1.31	−.09
Biocentric values	.35 (.09)	4.15***	.46	.19	3.30***	.35
Global warming frame × biocentric values	.09 (.11)	.78	.09	.01	.10	.01
Oyster health frame × biocentric values	.00 (.11)	−.02	.00	.25	3.25***	.35
Global warming frame × oyster health frame	−.02 (.16)	−.15	−.01	−.03	−.26	−.02
Global warming frame × oyster health frame × biocentric values	−.39 (.15)	−2.58**	−.29	−.36 (.10)	−3.57***	−.38
Constant	5.12 (.08)	62.45***		3.58	65.48	
Number of observations		358			358	
% Explained R^2		18.1%			24.9%	

** $p < .01$.
*** $p < .001$.

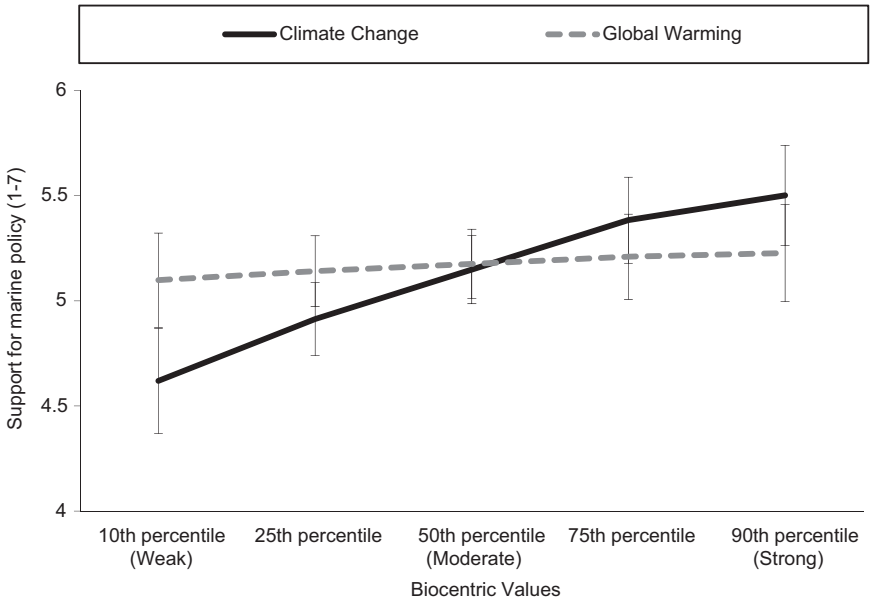

Fig. 1. Graph depicting the interaction between oyster health frame and biocentric values on support for marine policy. Error bars represent 95% confidence intervals.

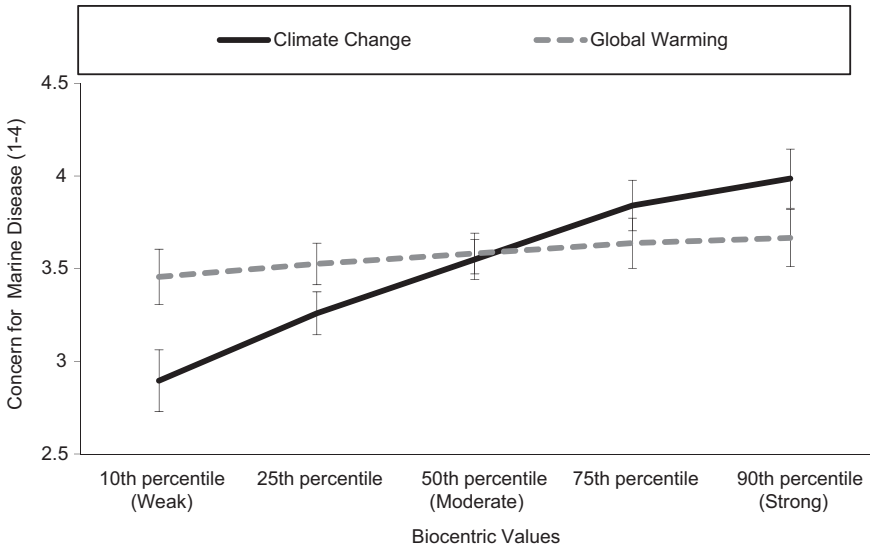

Fig. 2. Graph depicting the interaction between oyster health frame and biocentric values on concern for marine disease. Error bars represent 95% confidence intervals.

hypothesis. The results did indeed show that, depending on a participant's biocentric values, different message frames relating to oyster health influenced concern and support for marine policy in varying ways. Specifically, while participants who were high in biocentric values were generally supportive and unmoved by any particular message condition, participants who were lower in biocentric values were significantly more supportive and concerned after being exposed to the message that emphasized the consequences for oyster health resulting from global warming. Additional analysis explored the relationship between these variables and found that support for marine policy was moderated by participants' biocentric values and mediated by their concern for marine disease. Thus, even among this sample of ferry passengers who were generally highly supportive of marine policy, significant differences were present when individuals' biocentric values were considered. Interestingly, the results also found that among participants with the highest biocentric values, the global warming/oyster health condition resulted in significantly less concern than the climate change/oyster health condition. It may be that these participants, who have the strongest beliefs about the value of all living creatures and the importance of biodiversity, preferred the climate change label as it captures the overall complexity of the phenomenon, including its impact on ocean acidification; however, this explanation is speculative and would benefit from further research. It is important to note that these changes were shown only for the oyster health frame and no differential effects among participants were found for the public health frame.

Along these lines, when viewing the results, it is important to consider study limitations. First, because the messages were focused on the consequences of changing oceans on oysters, caution is warranted against generalizing the findings to other marine organisms or marine disease more broadly. Another potential limitation is the study sample: ferry passengers in the San Juan Islands. It may be that, given the acute location (the Pacific Northwest) and the topic of the study (disease outbreaks in endemic oysters), these riders represented a unique and also biased population. Indeed, the results confirm that participants were generally quite concerned about marine disease and supportive of policy to mitigate them, irrespective of receiving a message. Although the study location and topic were purposefully chosen, future work may wish to explore whether similar results might be obtained in another location that has less direct sensory, geographic, or economic connection to the topic.

4.2. Conclusion

Overall, the study presents evidence that messages focusing on public health consequences of marine disease resonate more than messages focusing on marine organism health, which in this study was oyster health. In this manner, the results speak to previous research that has suggested public health frames as an avenue toward increasing support for policies that mitigate the effects of climate change (e.g., [23,24]). For those who communicate about these issues, it also suggests that linking marine disease to public health could increase concern and support for marine policy that can protect not only public health but also reduce risks to marine organisms. Not every disease that sickens marine organisms has public health implications, however, or at least the more obvious or direct ones such as *Vibrio* in oysters; this point may be disheartening to those seeking to galvanize support for other diseases in marine organisms. To address these other circumstances, further research is needed to examine the effects of other types of message frames on concern and policy support. Anecdotal evidence suggests several possibilities. For example, the recent outbreak of sea star wasting syndrome along the West Coast and the resulting media attention it received may suggest that other aspects, such as the organism's iconicity, may resonate with audiences and policy makers (see, [13], on H.R. 5546, the Marine Disease Emergency Act of 2014). Diseases that affect charismatic marine mammals, such as sea otters or whales, already protected under the Marine Mammal Protection Act, also receive attention in policy arenas (see, e.g., [7], on California's required warning labels on cat litter to protect sea otters: CA Fish and Game Code sections 4500–4501). Finally, the economic impacts of diseases, including those on tourism or fishery management, may resonate with audiences and policy makers (see, e.g., [14], on the influence of wastewater treatment on coral reef health in the Caribbean).

This study also provides evidence that relatively minor changes in wording may shift responses to messages about marine disease, including levels of concern and policy support. Namely, among participants lowest in biocentric concern, the global warming frame led to greater policy support and concern than the climate change frame when focusing on oyster health. Previous research has shown that people tend to associate global warming with human causes and climate change with natural causes [2,37,31]. It may be that the global warming frame triggered such associations among participants, suggesting the need for human action to address a human-induced problem. The climate change frame, in comparison, might have led to an association of natural changes in the ocean that have less need for human response. Further data are needed to determine whether using the global warming frame leads to greater policy support when discussing other consequences of marine disease on marine organisms.

In conclusion, as scientists raise the alarm about emerging marine diseases that are linked to climate change and may impact human health (e.g., [35]), multiple environmental frames that communication scholars have studied (e.g., [25,29]) are bound to interact in related messaging efforts, presenting a need to understand not only framing in this context but also how different climate frames interact more broadly. In this vein, the present data highlight the importance of considering how the multiple words and frames that are commonly used in scientific and popular discourse can lead to different responses, which is both a cautionary message and a recommendation for future inquiry into these possible effects.

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Appendix. Message conditions

Climate change/public health

Bacteria on the half shell? Climate change may increase threats to public health

Scientists are studying links between climate change, oysters, and public health risks in the Pacific Northwest. Carbon emissions are causing increases in water temperatures and the ocean's acidity, and these increases contribute to diseases that affect human and marine life. Carbon dioxide in the atmosphere lowers the pH of oceans, turning waters more acidic. The Northwest is home to some of the most corrosive waters on the planet. Warmer waters lead to more disease-causing pathogens in the ocean that can threaten both public and marine animal health.

Although oysters are just one of many ocean creatures affected by climate change, the evidence for links between climate change, oysters, and human disease risk is particularly strong. As Kelly Thompson, a staff scientist with the Ocean Disease Institute, explained,

> "Warmer ocean temperatures lead to more disease-causing pathogens in the ocean that are concentrated by oysters. These bacterial and viral pathogens can make people sick when they eat raw or undercooked oysters."

All these factors lead to public health risks and pose a significant economic threat to the oyster industry.

Global warming/public health

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Climate change/oyster health

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Although oysters are just one of many ocean creatures affected by climate change, the evidence for links between climate change and oyster disease risk is particularly strong. As Kelly Thompson, a staff scientist with the Ocean Disease Institute, explained,

> "Higher acidity hurts oysters' ability to form, build, and maintain their shells and can kill the baby shellfish. The combination of increased acidity and warmer water temperatures might also lead to more disease-causing pathogens in the ocean that make oysters sick."

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Global warming/oyster health

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