

Building support for carbon emissions mitigation: can we use an ocean acidification frame to promote support?

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## **Abstract**

Increasing public support for carbon emissions mitigation is crucial for solving global issues like climate change and ocean acidification (OA). Yet carbon emissions mitigation policies are typically discussed in the context of climate change and hardly ever in the context of OA. In this paper, we present carbon emissions in five different contexts (climate change, global warming, carbon pollution, air pollution, and ocean acidification) and use an online survey tool—with a politically diverse sample of the US population—to measure support for mitigation policies. Though air pollution mitigation receives the highest amount of policy support overall, OA mitigation receives higher levels of support than carbon pollution, climate change, and global warming from conservatives who have heard of ocean acidification. This finding, coupled with other trends in OA perceptions has interesting potential for future risk communication and carbon emissions mitigation policies; OA may offer a new way to engage conservatives in carbon mitigation policy.

## Introduction

At his inaugural address in January 2013, environmentalist and newly minted Washington State Governor Jay Inslee invoked the spirit of paternalism when he stated: “As a parent and grandparent, I cannot consciously accept the dangers of climate change for my family or yours.” He continues, encouraging Washingtonians to embrace the “responsibility and opportunity of climate change;” Inslee then affirms that “Climate change [science is] settled” and wants to see Washington lead the way towards “economic solutions to climate change.”

Inslee went on to use the term “climate change” a few more times in that speech, but he has been much choosier in his wording of late. In his official speeches made public on the Governor’s website, he has slowed his use of “climate change” over time and has called for action to mitigate “carbon pollution” instead (data comes from public statements made during the first three years in office from 2013 to 2016).

It appears that Inslee has started framing climate change policies as “carbon pollution” policies. For example, a 2014 executive order titled, “*Washington Carbon Pollution Reduction and Clean Energy Action*” paved the way for a state carbon tax bill titled, “*The Carbon Pollution Accountability Act*.”

### Pollution as a climate change frame

Air pollution carries a strong negative connotation and is often perceived as a major cause of environmental and public health problems (McDaniels, Axelrod, and Slovic 1996; Bickerstaff and Walker 2001; Pfister and Böhm 2001). However, the description of CO<sub>2</sub> as a pollutant is a more recent phenomenon, having gained currency with the 2007 U.S. Supreme Court ruling, *Massachusetts v Environmental Protection Agency* (EPA) allowing the EPA to regulate CO<sub>2</sub> and other greenhouse gasses as pollutants. However, it is unclear if people can make a distinction between air pollution (as traditionally thought about; for example, particulate matter, nitrogen oxides, etc) and carbon pollution. Air pollution is one of the most highly cited causes of climate change and “pollution” holds a strong negative association (Kempton 1991; Bostrom et al. 1994; Read et al. 1994; Brechin 2003; Bickerstaff 2004, Bostrom et al. 2012). It seems Governor Inslee is trying to take advantage of this association by describing carbon as pollution.

### Framing Climate Change

Framing is the attempt to set a particular train of thought in motion in order to communicate an issue, place responsibility, and/or offer solutions (Nisbet 2009a). Climate change frames typically emphasize particular aspects of climate change, like causes or effects, in order to highlight an appealing outcome (in Inslee’s case, reduction of Washington State carbon emissions). Many scholars and climate change activists have called for this kind of climate change reframing (Nisbet 2009a; Nisbet 2009b) as a strategy

for advancing an emissions-reduction agenda. Researchers have tested many different climate change frames—usually to discover the effects of frames on people’s perceptions of climate change and, most relevant to this study, their subsequent support for climate change mitigation.

Spence and Pidgeon (2010) demonstrated that positive support for climate change mitigation was stronger when participants were exposed to “gain-framed information” as opposed to “loss-framed information.” People felt more positively about mitigation policies when they were framed with gains that would be made from climate change mitigation as opposed to losses from the effects of climate change. Similarly, Morton et al. (2011) showed that under conditions of high uncertainty, negative frames that stressed possible losses decreased participants intentions to act pro-environmentally relative to positive frames. However, both Spence and Pidgeon (2010) and Morton et al. (2011) attribute their results to activation of self-efficacy, or feelings that change is possible. In other words, when climate change information is communicated in a gain frame/positive way, people feel like they can make a difference, which results in support for mitigation.

Spence and Pidgeon (2010) also showed that framing climate change impacts as spatially distant resulted in those impacts being perceived as more severe. The authors indicate that an “optimism bias” is behind the perception, as people feel more optimistic about climate change effects in their local area. Scannell and Gifford (2013) tested people’s engagement when presented with local versus global climate change mitigation frames. They found that engagement was higher in the local mitigation frame. Evans, Milfont, and Lawrence (2014) examined local climate change adaptation frames. They demonstrated that a local adaptation frame seemed to increase support for mitigation and pro-environmental behavior.

Myers et al. (2012) demonstrated that climate change framed as a public health concern elicited more positive emotional responses and probable support for mitigation policy. This suggests that people are more “hopeful” about climate change when it is framed as a public health issue.

### **Framing and political ideology**

However, the study also showed that when climate change is framed as a national security risk, it is more likely to incite anger and backlash toward mitigation amongst people (generally conservatives) who doubt or dismiss anthropogenic climate change—essentially causing a ‘boomerang’ effect (Hart and Nisbet 2012; Myers et al. 2012). Bain et al. (2012) also examined differences between climate change believers and deniers under different climate frames. Those that denied the existence of man-made climate change (again, mostly conservatives) were more likely to act pro-environmentally when outcomes “increased consideration for others” or “improved economic and technological advancements” as opposed to avoiding environmental risk. Believers showed no difference between frames,

though each one motivated pro-environmental behavior. Recently, Hine et al. (2016) showed that *not* mentioning climate change and emphasizing local impacts were more likely to motivate climate change adaptation in those dismissive of climate change. Across all audiences, messages containing specific adaptive advice motivated more climate adaptation (Hine et al. 2016). Most relevant to this study, framing the issue as either “global warming” or “climate change” has also been tested in the United States (Schuldt, Konrath, and Schwarz 2011). The terms had distinctive effects on different political affiliations; Democrats (liberal party) show no difference in beliefs when presented with either term while Republicans (conservative party) show more belief in “climate change.”

### **The role of climate change perceptions, knowledge, and demographics**

Climate change framing is meant to manipulate perception in hopes of altering an outcome, be it pro-environmental behavior, climate change belief, or climate change policy support like Gov. Inslee is likely attempting to do. Many studies demonstrate that people’s perception of climate change influences their policy support for mitigation. For example, Dietz et al. (2007) showed that personal values and future orientation predicted support for mitigation via worldviews. Concern has also been shown to be an important predictor of mitigation effort (Semenza et al. 2008). However, perception is just one component of climate change outcomes; knowledge and demographics also play a role in predicting climate change policy support and policy support proxies like concern (O’Connor, Bord, and Fisher 1999; O’Connor et al. 2002; Lorenzoni and Pidgeon 2006; Whitmarsh 2011; Brulle, Carmichael, and Jenkins 2012; Bostrom et al. 2012).

Knowledge of climate change science is a good indicator of policy support for mitigation. Research has shown that specific knowledge (as opposed to self-reported or measures of knowledge by proxy) can have an effect on perception and policy support. For example, Guy et al (2014) demonstrated that knowledge of climate change causes significantly reduced the effect of ideology on climate beliefs. Causal knowledge has also been shown to predict concern (Shi et al. 2016), with further evidence that concern is one of the first perceptions activated by knowledge (Milfont 2012). Though causal knowledge is typically a good predictor of support, it usually has a much smaller effect than perceptions or demographics (Lorenzoni and Pidgeon 2006; Semenza et al. 2008). Demographics--like education level, income, age, and political party--are some of the strongest drivers of policy support and its proxies (McCright and Dunlap 2011; Lee et al. 2015). Demographics are generally less malleable than other cofactors, and, coupled with knowledge, can obfuscate the role that perception plays in climate mitigation policy support—a recent paper highlights this well. In contrast to much of the framing literature cited above, Bernaur and McGrath (2016) ran two comprehensive studies involving multiple climate change frames and found no significant differences between like-minded people. Those that reported climate change as a “serious” problem had high policy support regardless of frame, while those that see climate change as “not a problem” had lower policy support regardless of

frame. Their results indicate that a simple reframing of climate change is unlikely to increase support for mitigation; people who believe climate change is a problem already support mitigation policy and those that do not believe climate change is a problem will not change their policy position based on a climate change frame.

### **The case for ocean acidification as a carbon emissions frame**

Experiments framing climate change have mainly focused on climate change consequences (e.g. a health frame highlights health impacts of climate change). Gov. Inslee's use of "carbon pollution" is one of the few ways to reframe climate change's main cause. But carbon emissions are also the main cause of a different, global, environmental problem: ocean acidification.

Ocean acidification (OA) is the anthropogenic reduction in ocean pH (Gattuso and Hansson 2011). When CO<sub>2</sub> in the atmosphere chemically reacts with seawater, it generates carbonic acid, and makes the water more acidic (i.e., lowers ocean pH, although the ocean remains basic overall) (Orr et al. 2005). Since pre-industrial times, the ocean has gotten ~30% more acidic and will continue to acidify until CO<sub>2</sub> flux between the atmosphere and ocean reaches equilibrium (Royal Society (Great Britain) 2005). In other words, the concentration of CO<sub>2</sub> in the atmosphere directly determines the ocean's pH.

However, not many people have heard of OA. In 2010, Leiserowitz, Smith, and Marlon (2010) reported that only 23% of the American public had heard of ocean acidification. A 2012 survey by the Ocean Project reported only 14%. Capstick and Corner et al. (2016) conducted two surveys in the UK in 2013 and 2014 and found that roughly 20% of people had heard of OA. Though, in Alaska, a state highly dependent on fisheries and other oceanic resources—76% of the population has heard of OA, with 63% of those correctly identifying carbon emissions as the cause (Frisch et al. 2015).

Lower-pH water primarily hurts calcifying organisms as the change in chemistry makes it more difficult to build calcium carbonate shells or skeletons (Gattuso and Hansson 2011). This threatens many important ecosystems, like coral reefs (Hoegh-Guldberg et al. 2007). More than half of those in the West-coast shellfish industry report already feeling negative impacts of OA on their businesses and personal lives (Mabardy et al. 2015).

In Alaska, a conservative leaning state where much of the economy is dependent on fishing, ocean acidification is perceived as a larger threat than climate change, despite climate change having a significantly higher (and potentially catastrophic) impact on fisheries than ocean acidification (Frisch et al. 2015; Muñoz et al. 2015). This result seems to indicate that OA is not as politicized as climate change, even when awareness of OA is high. Could it be that OA is easier to understand than climate change? OA chemistry is replicable with any home carbonation device—the formula for carbonated water is consistent from the ocean

to cola (Thaler 2014). Like pollution, OA also has a strong, negative connotation (Capstick and Corner et al. 2016).

In this study, we examine how presenting carbon emissions in different contexts affect support for carbon emissions reduction. We compare an ocean acidification frame to climate change, global warming and two pollution frames: air pollution and carbon pollution.

## **Hypothesis**

**H<sub>1</sub>: Support for carbon emissions reduction is higher when the policy is presented in the context of ocean acidification than when the policy is presented in the context of climate change or global warming.**

People are unlikely to support something they are unaware of (Stern et al. 1999), so our hypothesis should be constrained to those who have heard of OA. Policy support could also follow a similar political pattern as seen in other framing papers (like Bain et al. 2012) where framing effects are only seen in conservatives due to ceiling effects for liberals (i.e., they are already so supportive of CO<sub>2</sub> emissions abatement that they cannot increase their support). Additionally, support for a particular environmental policy tends to be higher when it directly affects a person's local community (Hart, Stedman, and McComas 2015). With OA awareness disproportionately skewed to coastal areas where impacts are highest, we expect H<sub>1</sub> to be contingent on awareness and location in a coastal state.

## **Methods**

We used a survey containing an experimental manipulation to test our hypothesis. Participants were asked questions regarding their policy support and concern for one of five, randomly assigned, carbon emission contexts (frames): air pollution, carbon pollution, climate change, global warming, and ocean acidification. We tested for the influence of frames by comparing mean policy support across different variables for each frame. After the experimental manipulation, each participant received questions measuring various aspects of ocean acidification perceptions.

### **Participants**

The survey was implemented using Qualtrics research software provided by the University of Washington's Foster School of Business. We collected data from 1013 participants recruited through Amazon's Mechanical Turk (MTurk) service. Though MTurk's population is not representative of the United States (Levay, Freese, and Druckman 2016; Paolacci and Chandler 2014), it is more diverse than student samples that often comprise audiences for similar surveys; our sample varies substantially among several demographic and political variables (Table 1). Most importantly, the data confirm we recruited a diverse pool of subjects in terms of political ideology, a key study variable.

## Method and Measures

Participants were randomly assigned one of five carbon emission mitigation frames. Questions meant to measure policy support and concern were asked specifically of each participant's assigned frame. The questions used in this study were part of a larger survey meant to pilot a forthcoming efficacy study.

Two different kinds of policy support were measured using a different question for each. The first had no specific mention of carbon emissions and simply asked a general policy support question: *How much do you support or oppose policies or actions meant to reduce [frame]?* A five-point response scale went from *strongly support* (2) to *strongly oppose* (-2) with *Neither support nor oppose* (0) in the center and an additional option for "don't know." It should be noted that this was the first question asked in the entire survey. Later in the survey, after a series of questions asking participants about their perceptions of climate change, a second policy support question was asked that included the specific mechanism (reducing carbon emissions) for mitigating the frame: *How much do you support or oppose reducing [frame] by reducing carbon emissions?* This response scale was identical to that in the other policy support question. Support for the second question was significantly lower than the first, however, responses correlate highly (Pearson's  $r = 0.89$ ), so the average is used as the main dependent variable.

Our research goals specifically focus on three predictors: concern, political ideology and causal knowledge, because their relationship to climate change mitigation policy support is well documented and makes for a good comparison to other carbon emissions contexts.

Concern was measured using the question: *How concerned, if at all, are you about [frame]?* The 0-4 response scale went from "not at all" to "a great deal" and included an option for "don't know."

Political ideology was self-reported on a 7-pt scale from extremely liberal (1) to extremely conservative (7). Though political party affiliation was also collected, we did not include it in our analysis due to historically low political party affiliation in the United States (Gallup 2016) and record high dislike for each of the two major party candidates in the 2016 presidential election (Roper Center 2016).

We define those that have "heard of OA" as those that answered "yes" to the question, *"Before taking this survey, had you ever hear of Ocean Acidification?"*

Causal knowledge of ocean acidification was measured by coding open-ended responses to the question, *"What do you believe is causing ocean acidification?"* Seven different levels of thinking/causal understanding were identified and scored (see Table 2). These scores were the basis of measurement. One researcher coded the whole dataset, though it was checked for consistency with an outside coder.

It was determined if participants lived in a coastal state by using longitude and latitude coordinates collected by Qualtrics from ip addresses of participants. Due to the relative ease in which ip addresses can be manipulated, this measurement should be considered imprecise.

Climate change perceptions were also collected and consisted of two different questions. One question asked: *“Is the global climate changing?”* with response options being, “yes,” “no,” or “unsure.” Another question, on the same page, asked: *“Have humans caused any of this change?”* with response options being the same as above. Though MTurk samples tend to have more accurate beliefs about climate change (Levay, Freese, and Druckman 2016), our sample tends toward the extreme: 87% of participants answered “yes” to the question, *“Is the global climate changing?”* with 92% of those participants then answering “yes” to the question, *“Have humans caused any of this change?”* This equates to roughly 80% of the entire sample that climate change has an anthropogenic cause.

## **Analysis**

Simple linear regression was used to examine differences in policy support by frame. Linear mixed-effects models were used to explore predictors of policy support across frames. As framing aims to set a particular train of thought in motion, holding frame as a random effect allows us to see how influential the supposed train of thought is on the given answers (using ICC score). The mixed-effect models also correct for differences between frames in order to fairly compare overall predictors of policy support. All analysis was done in R (R Core team); lme4 (Bates et al. 2015) was used to create the mixed-effect models while sjPlot (Lüdtke 2016) was used to tabulate the models.

## **Results**

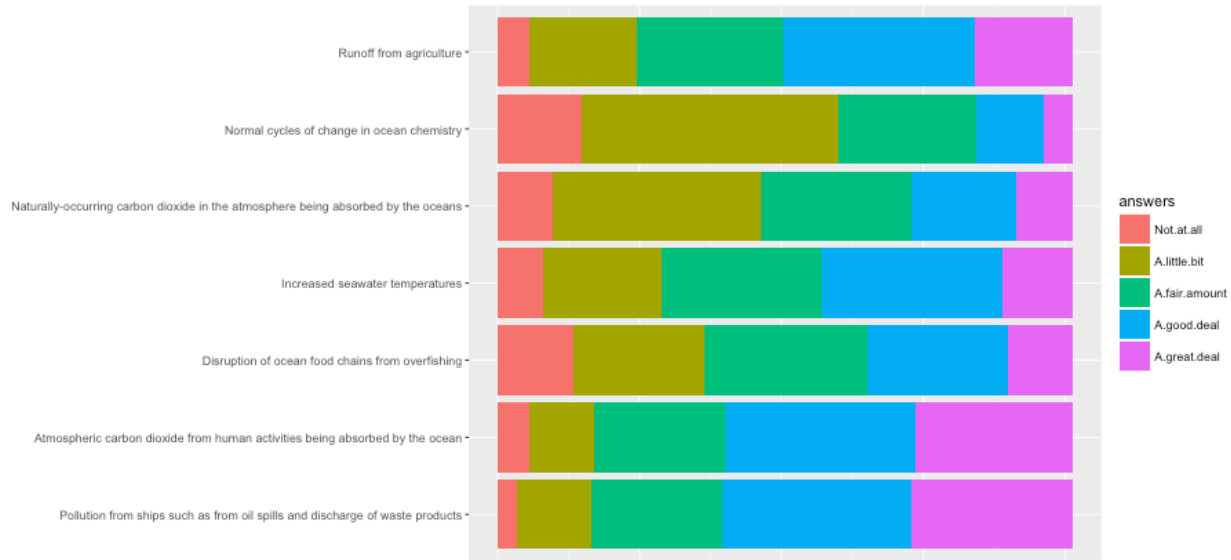
### **OA Causal Knowledge**

From 1013 open-ended responses to the question, *What do you believe is causing ocean acidification?* 864 people cited at least one cause (see Appendix table 3). 149 people indicated that they did know or denied ocean acidification’s existence. 168 different people (16.7%) listed CO<sub>2</sub> as a cause; of those, 52 (30%; 5.1% of total) also described the mechanism.

Close-ended responses to the question, *“How much do you believe each of the following contributes to ocean acidification?”* are reported below in Figure 1 and discussed in the appendix. Participants were then asked which of the possible causes is the “main” cause of OA (Table 1). Increased awareness and knowledge of OA indicated more correct responses. Though only 37% of participants correctly identified anthropogenic CO<sub>2</sub> as the main cause of OA, over half of those that had heard of OA before taking the survey and over two-thirds of those that self-report more than “a little bit” of knowledge did so (table X). It should be noted that there is evidence that other atmospheric compounds and some kinds of fertilizer

runoff have an effect on acidification (Doney et al. 2007). This can have large effects in coastal areas with localized runoff issues, however, on a global scale, an overwhelming percent of the acidification (~97-99%) is due to atmospheric CO<sub>2</sub> (Doney et al. 2007).

Participants were also asked about potential consequences of OA; close-ended responses to the question, “Based on what you know about ocean acidification, would you say that ocean acidification has direct effects on each of the following?” are reported in Figure 2 and discussed in the appendix.

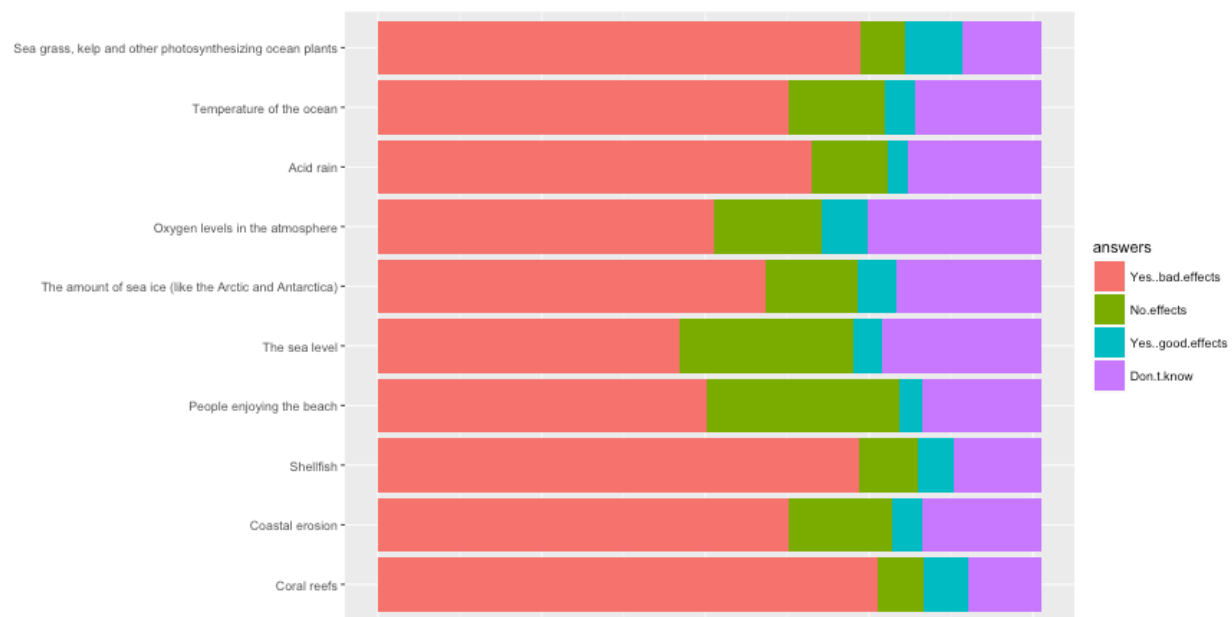


**Figure 1.** Responses to the question, “How much do you believe each of the following contributes to ocean acidification?” Explanation of answers can be found in the appendix.

**Table 1:** Responses to the question: *Which, if any, do you think is the main cause of ocean acidification?* Increased awareness and knowledge of OA indicated more correct responses. “Heard of OA” indicates only those that had heard of OA before taking the survey; “self-report knowledge” indicates those that had heard of OA and also self-reported more than “a little” knowledge. The correct answer is *Atmospheric carbon dioxide from human activities being absorbed by the ocean*.

Possible Cause	Percent Responding		
	All Participants	Heard of OA	Self-report knowledge
Pollution from ships such as from oil spills and discharge of waste products	32.0	16.4	12.2
<b>Atmospheric carbon dioxide from human activities being absorbed by the ocean</b>	37.0	53.4	67.1

Normal cycles of change in ocean chemistry	5.4	4.1	3.7
Increased seawater temperatures	8.1	7.6	7.3
Disruption of ocean food chains from overfishing	1.5	0.9	1.2
Runoff from agriculture	8.6	10.6	4.9
Naturally-occurring carbon dioxide in the atmosphere being absorbed by the oceans	6.1	6.2	2.4
Other	1.3	0.9	1.2
<b>N</b>	<b>1013</b>	<b>341</b>	<b>82</b>



**Figure 2.** Responses to the question, “Based on what you know about ocean acidification, would you say that ocean acidification has direct effects on each of the following?” Explanation of answers can be found in the appendix.

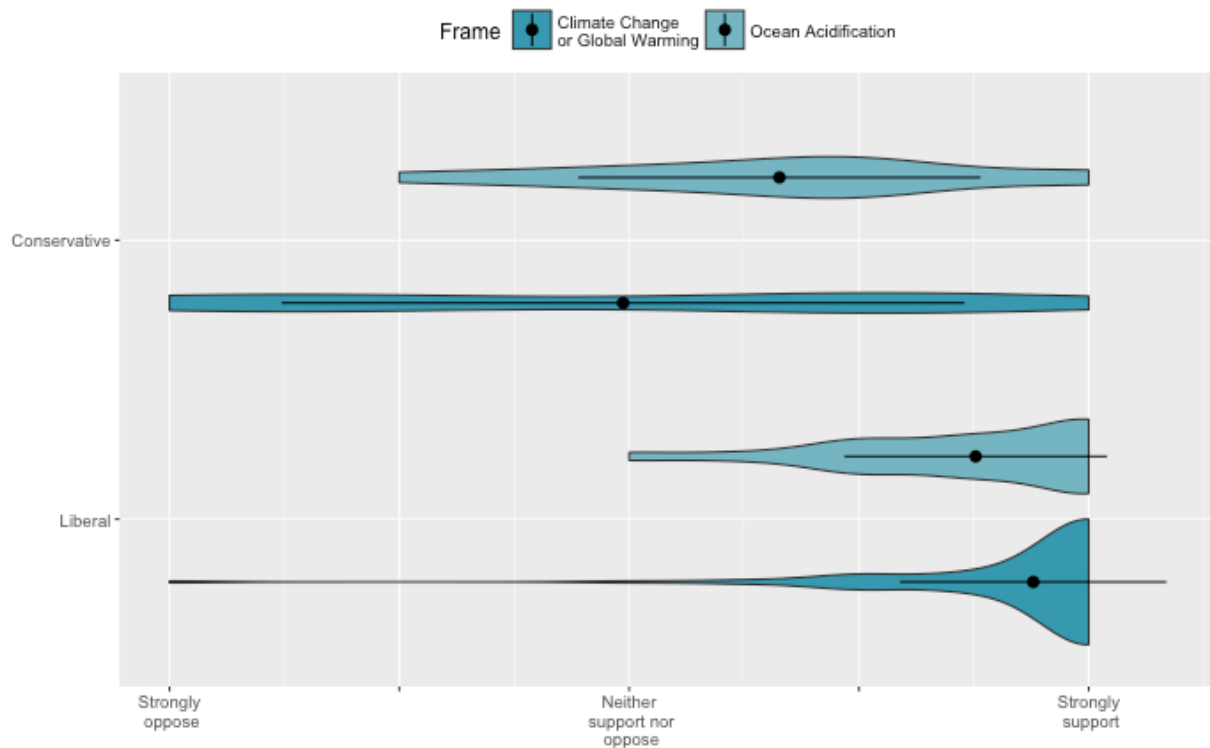
### Policy Support

Participants were highly supportive of mitigation policy overall: mean = 1.164, se = 0.033 (scale from -2 to 2 with 0 as midpoint). Across frames, those that had heard of OA before taking the survey were more supportive of mitigation than those who had not. When separated by frame, policy support for air pollution mitigation showed to be significantly higher across all demographics (Table 2). However, amongst conservatives who had heard of OA before taking the survey, support for OA was higher than for climate change or global

warming, supporting our hypothesis (Figure 3); though the difference between OA and climate change was not statistically significant. Support for OA mitigation was also significantly higher than for carbon pollution.

**Table 2.** Policy support for mitigation in the context of five different carbon emissions frames. Policy support measured on a 5-point likert scale from strongly oppose (-2) to strongly support (2), thus a negative mean indicates opposition and a positive mean support.

	All participants			All participants who have heard of OA			All conservatives			Conservatives who have heard of OA		
	Mean (error)	p	N	Mean (error)	p	N	Mean (error)	p	N	Mean (error)	p	N
<b>Air pollution (Intercept)</b>	1.41 (0.073)	<b>&lt;.001</b>	202	1.6 (0.118)	<b>&lt;.001</b>	66	0.79 (0.199)	<b>&lt;.001</b>	39	0.81 (0.352)	<b>0.026</b>	13
<b>Carbon Pollution</b>	1.15 (0.103)	<b>0.013</b>	207	1.36 (0.165)	0.15	68	0.42 (0.273)	0.171	44	0 (0.534)	0.137	10
<b>Climate Change</b>	1.14 (0.104)	<b>0.011</b>	199	1.46 (0.172)	0.411	58	0.25 (0.271)	<b>0.048</b>	45	0.22 (0.551)	0.293	9
<b>Global Warming</b>	1.18 (0.103)	<b>0.023</b>	206	1.35 (0.165)	0.126	68	0.51 (0.264)	0.298	51	-0.25 (0.534)	0.053	10
<b>Ocean Acidification</b>	0.83 (0.104)	<b>&lt;.001</b>	199	1.36 (0.158)	0.13	81	0.2 (0.263)	<b>0.025</b>	52	0.65 (0.498)	0.759	13
<b>Observations</b>			1013			341			231			55
<b>R<sup>2</sup> / adj. R<sup>2</sup></b>	.030 / .026			.010 / -.002			.027 / .010			.099 / .027		



**Figure 3.** Distribution of policy support between climate change and global warming or ocean acidification frames amongst liberals and conservatives that had heard of OA before taking the survey.

### Predictors of policy support

Linear mixed-effect models explored predictors of policy support across frames, see Table 5. Building on concern and political ideology, both of which are consistent, significant predictors across all models; OA awareness and knowledge also play an important role in predicting policy support. OA awareness is significant in model 3, but OA causal knowledge, added in model 4 and beyond, is a much better predictor. Interestingly, coastal state shows no influence on policy support. Belief in climate change also did not show any significant influence on policy support, however, belief in *anthropogenic* climate change nearly matched concern in effect size.

**Table 5.** Linear mixed-effect models

Predictors	Policy Support																	
	Model 1			Model 2			Model 3			Model 4			Model 5			Model 6		
	Estimate	Conf. Int.	p-value	Estimate	Conf. Int.	p-value	Estimate	Conf. Int.	p-value	Estimate	Conf. Int.	p-value	Estimate	Conf. Int.	p-value	Estimate	Conf. Int.	p-value
<b>Fixed Parts</b>																		
(Intercept)	-0.54	-0.70 – -0.37	<.001	0.28	0.05 – 0.52	.017	0.24	0.00 – 0.48	.046	0.19	-0.05 – 0.43	.119	0.17	-0.10 – 0.44	.225	-0.28	-0.69 – 0.14	.191
Concern	0.46	0.42 – 0.50	<.001	0.38	0.34 – 0.42	<.001	0.38	0.34 – 0.42	<.001	0.37	0.33 – 0.41	<.001	0.37	0.33 – 0.41	<.001	0.36	0.32 – 0.40	<.001
Political ideology				-0.16	-0.20 – -0.13	<.001	-0.16	-0.19 – -0.12	<.001	-0.16	-0.19 – -0.12	<.001	-0.16	-0.19 – -0.12	<.001	-0.16	-0.19 – -0.13	<.001
Heard of OA							0.13	0.02 – 0.24	.018	0.07	-0.05 – 0.18	.233	0.06	-0.05 – 0.18	.279	0.07	-0.04 – 0.18	.230
OA causal knowledge										0.09	0.04 – 0.15	.001	0.10	0.04 – 0.16	.001	0.10	0.04 – 0.16	.001
Coastal state													0.01	-0.08 – 0.09	.886	0.00	-0.08 – 0.09	.968
Climate change beliefs																-0.10	-0.25 – 0.04	.170
Anthropogenic climate change beliefs																0.34	0.22 – 0.46	<.001
<b>Random Parts</b>																		
N <sub>frame</sub>	5			5			5			5			5			5		
ICC <sub>frame</sub>	0.007			0.009			0.011			0.013			0.014			0.016		
Observations	1004			1003			1003			1003			995			995		

## Discussion

Our results indicate that framing carbon emissions as an ocean acidification problem can build support for mitigation policy among a particularly salient segment of the electorate: conservatives who are aware of OA. Additionally, policy support for OA mitigation is higher than it is for climate change, global warming, and carbon pollution—suggesting that, among conservatives that have heard of it, OA is a better way to frame carbon mitigation policy. OA education and awareness campaigns could play a crucial role in building support for carbon mitigation policies.

Liberals show high policy support across frames, even amongst those that have not heard of OA. This result is consistent with many other framing studies that show that liberals have higher, unwavering support for carbon emissions mitigation, regardless of frame (e.g. Bain et al. 2012).

This study was inspired by Washington State Governor Jay Inslee and his noted change in policy verbiage from global warming and/or climate change to “carbon pollution.” Conversations with members of his team confirmed this as a calculated move, and further conversation with senior management at NOAA and the Monterey Bay Aquarium indicate that unpublished focus group research has been circulating in policy circles and pushed the change.

Our results show that carbon pollution as a policy frame commands about the same mitigation support as climate change and global warming across demographics. These results support Bernauer & McGrath (2016)’s assertion that a simple reframing is unlikely to increase policy support for carbon emissions mitigation.

Air pollution received the highest amount of mitigation policy support across all political demographics; however, carbon dioxide is not regulated as an air pollutant under the

United States Clean Air Act. Using air pollution as a policy frame to reduce carbon in the atmosphere could be legally ineffective. Furthermore, many of the toxic air pollutants that are regulated by the EPA actually have a global cooling effect and act as a climate change buffer (at the cost of human health). Reducing the amount of those pollutants would likely have a net warming effect and exacerbate climate change (IPCC 2014).

### **Predictors of policy support**

The largest predictor of policy support is, unsurprisingly, concern. The more concerned a person is about a given frame, the higher the mitigation policy support. In each model, concern has the largest coefficient, typically followed by political ideology (more liberal people show higher support for mitigation). Having heard of OA before taking the survey (OA awareness) showed some importance in Model 3, but when other variables are added to the model, the significance of having heard of OA disappears. However, OA causal knowledge has a significant impact on a person's policy support of carbon emissions mitigation. The more knowledgeable a person is about OA, the more likely they are to support carbon emissions mitigation across all frames. Though smaller than the effect of concern and political ideology, OA causal knowledge explains about the same amount of variance in every model.

Unexpectedly, location has no influence on policy support. Even when examining only those who received the OA frame, policy support did not vary between coastal and inland inhabitants. However, it should be noted that the measure used to judge location is imprecise.

Though belief that the climate is changing has little bearing on policy support, belief in *anthropogenic* climate change is actually the largest predictor of mitigation policy support in addition to concern. This raises the question of how belief in anthropogenic climate change is related to OA causal knowledge. Our data indicates some sort of a relationship between climate change beliefs and OA knowledge, but more work needs to be done to better understand it. A mental models would be a good first step as layperson climate change mental models have been thoroughly documented and comparing them to OA mental models would be revealing (Bostrom et al. 1994; Read et al. 1994; Reynolds et al. 2010; Bostrom et al. 2012; Bruin and Bostrom 2013).

### **OA Understanding**

As seen in Figures 1 & 2, misperceptions about the causes and consequences of OA are plentiful. Comparing these results to people's understanding of the causes and consequences of climate change is difficult without any understanding of OA mental models, however, the spread and unevenness of OA misperceptions is similar to climate change—see figures in Reynolds et al. (2010). Though the high amount of causal understanding amongst those that have heard of OA offer some evidence, the main idea

behind our hypothesis, that OA is easier to understand than climate change, needs to be explored further.

Though climate change awareness is near universal in the U.S., public understanding has, overall, remained low for the past few decades (Reynolds et al. 2010; Leiserowitz et al. 2016). Much of the blame for the persistent lack of public understanding of climate change can be attributed to mass media's wrongful portrayal of climate science having "two sides" despite the scientific consensus (Boykoff and Boykoff 2007). This communication error fueled the political polarization of climate change and lack of policy action in the United States (McCright and Dunlap 2003; Boykoff and Boykoff 2004). Scientists, educators and communicators have a great opportunity at a do-over with OA. Coupled with Frisch et al. (2015)'s sample of Alaska, our results support the notion that OA is not politically polarized and can offer a new way to engage conservatives in carbon mitigation policies. For example, highlighting the threat to shellfish farming livelihoods could make OA more salient to rural conservatives who are typically less engaged in climate change (Kelly, Cooley, and Klinger 2013; Howe et al. 2015). Rural America has a deep economic history in farming (Tickamyer and Duncan 1990) and has a disproportionate amount of political influence in the U.S (Gamm and Kousser 2013); a high-profile media story about a shellfish farm's struggle with OA has already led to policy action in Washington State (Kelly, Cooley, and Klinger 2013).

### **Moving forward**

We made the case that, due to OA's relative simplicity, OA causal knowledge and OA awareness go hand in hand and would make OA a good carbon mitigation policy frame. Though our results do indicate this, it should be emphasized that the OA frame only appears effective amongst those with OA awareness. Increasing awareness should be a priority for environmental policy advocates, science educators and communicators. Best practices for increasing OA awareness will emerge with further research, as there is currently only one empirical examination of OA communication. Capstick and Corner et al. (2016) gave participants two separate passages to read that explained OA. One passage explained OA by itself, the other linked OA to climate change. Participants given the passage discussing OA by itself reported a significantly higher amount of concern for OA. These findings reinforce our inference that OA is a better mitigation policy frame than climate change, though more empirical studies are needed before definitive conclusions are made. We would like to see OA communication develop its own body of literature as climate change communication has done over the past few decades.

### **Conclusion**

This study presented carbon emissions reduction policies in five different contexts, or frames (air pollution, carbon pollution, climate change, global warming and ocean

acidification) to assess the effects of frames on mitigation policy support. The study was motivated by a recent upward trend in the usage of “carbon pollution” in policy proposals, and by a desire to explore the potential of ocean acidification (OA) as a carbon mitigation frame. Though air pollution mitigation received the highest amount of policy support overall and across all demographics, OA mitigation receives higher levels of support than carbon pollution, climate change, and global warming mitigation from conservatives who have heard of ocean acidification. OA may offer a new way to engage conservatives in carbon mitigation policy. Though concern, political ideology and belief in anthropogenic climate change are perhaps better predictors of policy support, OA causal knowledge is also a significant predictor. However, awareness of OA is low and best practices for OA communication are mostly unknown. OA communication deserves investigation in its own right, as there are many gaps in understanding to fill.

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## Appendix

Appendix table 1: Demographic and political characteristics of participants along with relevant national data for comparison.

	Frequency	Percent	National Comparison
<b>Sex</b>			
Male	520	0.51	
Female	493	0.49	
<b>Age</b>			
Average Age =36.6			
<b>Race</b>			
Nonwhite	230	0.23	
White	783	0.77	
<b>News</b>			
How often do you read the newspaper (online or on paper)?			
Once a week or less	339	0.33	
A few times a week	352	0.35	
Daily	321	0.32	
<b>Political Party Affiliation</b>			
Republican	193	0.19	
Democrat	462	0.46	
Independent	273	0.27	
Unaffiliated	72	0.07	
Other	13	0.01	
<b>Political Ideology (n=1012)</b>			
In general, do you think of yourself as...			
Extremely liberal (1)	135	0.13	
Liberal	288	0.28	
Slightly liberal	167	0.17	
Moderate, middle of the road	191	0.19	
Slightly conservative	107	0.11	
Conservative	92	0.09	
Extremely conservative (7)	32	0.03	
Total Liberal	590	0.58	0.24
Moderate	191	0.19	0.35
Total Conservative	231	0.23	0.37
Average = 3.25			
Note: n = 1013 unless otherwise specified			

**Appendix table 2.** Identification and scoring of causal thinking in response to the question *What do you believe is causing ocean acidification?*

<b>Level</b>	<b>Description</b>	<b>Example</b>	<b>Score</b>
<b>0</b>	I don't know or denial	"I don't know" or "I don't think it is being acidified"	0
<b>1</b>	Specific, but fully incorrect causes of OA	"Overfishing"	
<b>2</b>	Large scale generalizations about human causes that are not necessarily wrong, but not close to a fully explained cause	"Human activity"	
<b>3</b>	Pollution-related causes: shows an understanding of anthropogenic cause, though too unspecific to justify giving a correct score	"Air pollution, water pollution"	1
<b>4</b>	Fossil fuel-related answers that do not specifically mention CO <sub>2</sub>	"Greenhouse Gas Emissions"	
<b>5</b>	Factually correct responses that do not mention the main cause.	"Fertilizer runoff."*	2
<b>6</b>	CO <sub>2</sub> as the cause of OA	"CO <sub>2</sub> "	3

\*Note: Fertilizer is a cause of OA, but only in small, localized contexts  
 Other measures meant to explore other aspects of carbon emissions mitigation policy support included distance from coast and climate change perceptions.

**Appendix table 3.** List of different kinds of causes coded from responses to the question, “*What do you believe is causing ocean acidification?*” and their frequencies.

<b>Response</b>	<b>Frequency of Cause</b>	<b>Percent of Causes</b>	<b>Percent of People</b>
<b>Level 0: I don't know or denial of existence</b>			
I don't know/incoherent	NA		13.7
Deniers/Skeptics	NA		1.1
<b>Level 1: Specific and fully incorrect answers</b>			
Acid Rain	56	5.0	
Nuclear radiation	7	0.6	
Physical change - Biotic	22	2.0	
Physical change - abiotic	34	3.0	
Plastic	6	0.5	
ice/glacial melt	13	1.2	
Natural	17	1.5	
Total: Level 1	155	13.9	
<b>Level 2: Large scale generalizations about human causes</b>			
Humans	52	4.7	
Specific human artifact (boat/ship/cars etc.) or construct (carelessness)	32	2.9	
Total: Level 2	84	7.5	
<b>Level 3: Pollution-related</b>			
Non-specific/Not categorized/"from humans"	180	16.1	
Oil, oil spills and related concepts	53	4.7	
Industry/Factory	39	3.5	
Litter/garbage/trash	42	3.8	
Chemicals/Toxic	39	3.5	
Air	49	4.4	
Water/Dumping/waste	161	14.4	
Runoff: non-specific/chemical/factory/pollution	19	1.7	
Total: Level 3	582	52.1	
<b>Level 4: Fossil fuel-related answers that do not specifically mention CO2</b>			
Climate Change/Global Warming/Temperatures	63	5.6	
Fossil-fuels/GHG/"Emissions"	38	3.4	
Carbon monoxide	6	0.5	
Total: Level 4	107	9.6	
<b>Level 5: Factually correct responses that do not mention the main cause</b>			
Fertilizer/Agricultural runoff	14	1.3	
Other factual (e.g. "reduction of pH")	4	0.4	
Total: Level 5	18	1.6	
<b>Level 6: CO2 as the cause of OA</b>			
Carbon Emissions/CO2/deforestation	169	15.1	16.7
Mechanism (e.g. "absorbed" or "dissolved")	NA		5.1
Total	1117		

## Discussion of OA knowledge questions

### q14.3 How much do you believe each of the following contributes to ocean acidification? (order of items randomized)

The following six items were taken or modified from (Corner, Capstick, and Pidgeon 2014). Anthropogenic carbon dioxide emissions are the principle cause of ocean acidification (Doney et al. 2009)—all other items are meant as distractors and draw on common perceptions of ocean issues (Dropkin and Ludemann 2015; Corner, Capstick, and Pidgeon 2014).

- Pollution from ships such as from oil spills and discharge of waste products **[not at all]**
- Atmospheric carbon dioxide from human activities being absorbed by the ocean **[a great deal]**
- Disruption of ocean food chains from overfishing **[not at all]**
- Increased seawater temperatures **[not at all]**
- Naturally-occurring carbon dioxide in the atmosphere being absorbed by the oceans **[not at all]**
- Normal cycles of change in ocean chemistry **[not at all]**

The following item was added to this set of questions as there is evidence that runoff from agriculture can contribute to localized ocean acidification (Feely et al. 2010). However, of the total, causal amount of ocean acidification, runoff is responsible for only a few percent of acidification, though localized impacts are much higher (Doney et al. 2007).

- Runoff from agriculture **[a little bit]**

### q14.5 Which, if any, do you think is the main cause of ocean acidification?

[Atmospheric carbon dioxide from human activities being absorbed by the ocean]  
For example see (Corner, Capstick, and Pidgeon 2014; Doney et al. 2009)

### q15.1 Based on what you know about ocean acidification, would you say that ocean acidification has direct effects on each of the following? (order of items randomized)

The following 2 items are directly impacted by ocean acidification in a negative way. Ocean acidification makes it harder for calcifying organisms to grow (Orr et al. 2005). Direct, negative effects on coral and shellfish have already been observed (Mabardy et al. 2015; Albright et al. 2016)

- Coral reefs **[Yes, bad effects]**
- Shellfish **[Yes, bad effects]**

The following 6 items are common misperceptions of ocean acidification consequences as shown in Corner et al. (2014).

- Coastal erosion **[No effects]**

- The sea level **[No effects]**
- The amount of sea ice (like the Arctic and Antarctica) **[No effects]**
- Oxygen levels in the atmosphere **[No effects]**
- Acid rain **[No effects]**
- Temperature of the ocean **[No effects]**

Large marine autotrophs (plants) are expected to benefit from ocean acidification (Koch et al. 2013) so the following item was included. This question parallels the benefits of land plants to additional carbon dioxide in the atmosphere.

- Sea grass, kelp and other photosynthesizing ocean plants **[Yes, good effects]**

The following item is a subjective measure included to gauge people's perception of ocean acidification on human wellbeing.

- People enjoying the beach