Title: **Indexing Ocean Acidification Vulnerability among the U.S. Coastal States**

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Background/Introduction:

Ocean Acidification is changing today's ocean with huge implications for sea-life and humans who depend upon the ocean for food, income, and the production of goods and services. A balanced, healthy ocean is important for the health and wellbeing of all people, but has special relevance for coastal communities and developing countries. The observed change in carbonate chemistry occurs because of well-understood processes as increasing amounts of carbon dioxide in the atmosphere dissolve in seawater. This natural process helps regulate atmospheric levels of CO2, but the unprecedented growth of fossil fuel use by humans is disrupting the balance, causing extreme changes to ocean chemistry that may result in the extinction of many marine organisms, especially since ocean acidification is taking place in an ocean experiencing temperature changes, reduced dissolved oxygen and increased pollution. Together, these pressures could overwhelm the coping ability of many organisms. Even if all fossil fuel burning ceased tomorrow, the ocean will experience significant acidification before reaching equilibrium in thousands of years. Today's surface waters become tomorrow's bottom waters, separated from the atmosphere for a long time before upwelling to the surface decades from now and bathing sea-life in a chemical mix that will threaten their survival. In fact, the acidic waters upwelling now were in equilibrium with an atmosphere much less saturated with CO2 than today's atmosphere, so scientists expect the rate of acidification to continue accelerating.

Most of the research in ocean acidification has been conducted in the past decade. Key questions about ecosystem and economic effects are still unanswered. Scientists have largely conducted single-species, laboratory-based experiments to test reactions to the expected changes. Researchers have been challenged by technological limitations in monitoring sensors, missing baseline data for most costal areas, and the inherent complexity in measuring the carbonate system and controlling it in experiments. There are now international guides to best practices in acidification research that should make it easier to standardize and compare experimental data, but the field still faces issues with using datasets that were not prepared with this area of study in mind and in devising new research designs to allow for more complete study of the effects on the marine food web. As the literature has evolved, the list of physical and biological effects keeps growing.

Although some effects are well-understood, like the threat posed to shellfish in areas subject to strong upwelling, the complexity in measuring and predicting the impacts of decreasing pH/carbonate saturation has made it difficult for people and governments to judge the appropriate level and types of mitigation and adaptation

efforts needed to head off the worst effects. Ocean acidification uniquely challenges government institutions because it is multi-sector and multidisciplinary; urgent, yet information is still coming out; requires international, national, state, and local government engagement; and is taking shape during a time of increasing political pressure to reduce government spending. Since the Federal Ocean Acidification Research and Monitoring Act of 2009, the U.S. Federal Government has invested in further scientific research and prepared a multi-agency strategic plan intended to direct federal investments and prepare a program to spearhead the U.S. response.

Purpose:

I became interested in ocean science and policy because this area represents one of few remaining frontiers on the planet and I place a high value on preserving a healthy ocean for the good of today's sea-life, for humanity and for future generations. Ocean acidification and climate change are the most serious threats to ocean ecosystems and they share an anthropogenic origin. While climate change is widely discussed and researched, acidification is relatively unknown to the public and policymakers that will soon be dealing with its effects. This issue represents an opportunity to reach people with information before their positions are ossified and the facts obscured. Ocean acidification differs from climate change in that it arises from clearly understood chemical interactions; is unambiguously connected to fossil fuels; represents an obvious deviation from the geological record, with its nearest analog showing massive extinctions despite a much slower rate of change; and finally, it has a short time horizon for observable and severe impacts – by midcentury. All of these characteristics make it both extremely important and perhaps a more convincing case for the need to address fossil fuel emissions.

This is a critical time in U.S. federal ocean acidification work. Some of the momentum from 2009, when the issue really came to the attention of the broader scientific community, the media and policymakers, has ebbed and the Federal Ocean Acidification Research and Monitoring Act (FOARAM) will expire September 30, 2013. Advocates will need to justify the continued prioritization of this policy area, the research spending and the continued interagency approach. Otherwise, the program could be subsumed into the research enterprise, where individual agencies may not have the broader vision required to serve stakeholder needs, especially if the program comes into competition with other areas of research for funding. Although some states like Washington, Oregon, and California are moving quickly to plan their own Ocean Acidification response, it is not clear that most states are giving adequate attention to this issue or that most policymakers are even reasonably aware of the problem.

I would argue that there has been a failure to translate the developing scientific results into a form that describes the relative risk to important political jurisdictions like the states in the United States. There is no uncertainty about the occurrence or seriousness of ocean acidification. And yet, when the issue is discussed, the focus goes to a non-existent argument about whether it is happening instead of the more

useful conversation about how much it will affect people and to whom it poses the greatest threat, questions that are relevant to state policymakers. Although acidification is a global problem, early research suggests that different localities will experience its impacts in different ways, due to their unique geological, economic, cultural and environmental characteristics. The rate of change will require policy-makers to begin taking action on the issue before the full contours of its projected impacts are clear. How then can the science be communicated in a way that aids their understanding of the issue and helps them weigh the risks to their constituents?

Indexing the factors that make coastal states vulnerable is a preliminary step that would allow state policymakers to shift perspective from seeking certainty to judging the relative risk and designing timely policy intervention. Increasingly, policymakers use the formulation and updating of Bayesian prior probabilities as a way to deal with complexity and uncertainty. This project would inform their perception of the problem and allow for integration of new findings as the research continues to progress and forecasts are refined. In summary, if ocean acidification has an extremely negative impact on the state's interests, variation in the final amount of the damage or the timetable when it is already an unacceptably large risk shouldn't stop governments from investing in the problem.

Approach/Method:

I propose to index the relative risks of ocean acidification to the U.S. coastal states, using the existing scientific literature of acidification impacts, including expert elicitation studies, and publicly available statistical data on the U.S. states. First, I'll develop a list of characteristics that make a state particularly vulnerable to acidification's effects, like strong seasonal upwelling; economic dependence on fishing, especially shellfish (recreational and/or commercial); importance of biological products of the ocean e.g. fertilizer; dependence on ocean tourism; and existing water quality problems (which exacerbate species response to changing pH). Then, I'd assign scores for the characteristics and come up with a total number that expresses the risk to each state according to what we already know about ocean acidification. I will also express the results visually i.e. on maps, in graphics, and ranked lists. Finally, I will consider how the results could be combined to reflect the ecosystem regions described in the U.S. ocean policy.

My emphasis is on creating an index that could be easily updated as new scientific and statistical information becomes available. One important weakness of this method is that it does not address the many other good reasons a policymaker might want to address acidification: including placing a value on environmental stewardship; concern about disproportionate effects on the developing world and social justice; a particular connection to vulnerable species; and prioritizing other oceanic resources like biodiversity for intrinsic or other uses, like the development of new drugs. However, I think it is important to begin providing some a framework

for policymakers to rationally evaluate the issue in a way that speaks to their responsibilities to their specific constituents.

After the development of my framework and materials, I will pursue publication in academic journals and especially in magazines and on websites that might reach a broader audience. I would also use my own experience as a federal lobbyist to share the results with as wide a policy-making audience as possible. Finally, time permitting, I would like to conduct a few interviews with state policymakers (likely New Jersey and Maryland) and issue specialists to find out their reaction to the index.

Key Reference List:

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Gattuso et al., "Ocean acidification and its impacts: an expert survey," *Climatic Change*, 2013.

Kelly and Caldwell, "Ten Ways States Can Combat Ocean Acidification (And Why They Should)," *Harvard Environmental Law Review*, 2013.

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Washington State Blue Ribbon Panel on Ocean Acidification (2012): *Ocean Acidification: From Knowledge to Action, Washington State's Strategic Response*. H. Adelsman and L. Whitely Binder (eds). Washington Department of Ecology, Olympia, Washington. Publication no. 12-01-015.

Target Journals:

1.) Marine Policy – www.journals.elsevier.com/marine-policy/
2.) Ocean and Coastal Management – www.journals.elsevier.com/ocean-and-coastal-management/

Tasks:

- Literature review and methods research

- Examine expert elicitation studies of ocean acidification experts to determine consensus impacts
- Develop a list of principle factors of vulnerability for U.S. states using consensus acidification impacts as guide, consider how to weigh the relative importance of each factor and how to measure varying degrees of vulnerability for each factor
- Look for statistical resources that measure the states in terms of principle factors
- Determine each state's score
- Consider whether it makes sense to divide the states into various categories of vulnerability in order to allow for comparison beyond the general score
- Develop graphic presentations of the material
- Test materials with state officials and acidification policy experts
- Draft and write AP
- Defend
- Submit AP to academic journals, websites, conferences and share with advocates, policymakers etc.

Due dates:

September – finalize proposal and committee; literature review, especially expert elicitation studies and metadata on acidification research
October – develop list of factors of vulnerability for states and determine whether the available information allows for quantitative or categorical weights for each state on each factor
November – share idea with acidification policy researchers and officials to see if factors seem reasonable
December – collect statistical information on states
January – analysis of data set, make decision about whether and how to categorize states in groups; work on ranked lists and graphical presentation of material
February – interviews with officials and experts; first draft of AP
March – final draft of AP
April – AP defense

Committee Composition:
Willett Kempton, Chair
Biliana Cicin-Sain
Jonathan Sharp

APPENDIX – FULL LIST OF REFERENCES

POLICY

Center for Biological Diversity petition to EPA for additional water quality criteria and guidance under Sec. 304 of CWA 33 U.S.C. 1314 to address ocean acidification; April 17, 2013

Center for Ocean Solutions (2012) *Why Ocean Acidification Matters to California and What California Can Do About It*

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Committee on Metrics for Global Change Research, Climate Research Committee, National Research Council (2005) *Thinking Strategically: The Appropriate Use of Metrics for the Climate Change Science Program.*

EPA Ocean Acidity document

Federal Ocean Acidification Research and Monitoring Act of 2009

IWGOA 2nd Report on Federally Funded Ocean Acidification Research and Monitoring Activities and Progress on a Strategic Research Plan

National Research Council (2012): *Best Practices in Assessment of Research and Development Organizations*

NSF Solicitation 10-530 (2010)

Peter Silva, EPA, letter to Center for Biological Diversity dated April 15, 2012

Summary from symposium – *Ocean Acidification: A Summary for Policymakers from the Second Symposium on the Ocean in a High-CO2 World (2008)*

Washington State Blue Ribbon Panel on Ocean Acidification (2012): *Ocean Acidification: From Knowledge to Action, Washington State's Strategic Response*. H. Adelsman and L. Whitely Binder (eds). Washington Department of Ecology, Olympia, Washington. Publication no. 12-01-015.

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EPOCA Guide to best practices for Ocean Acidification research and data reporting (2010)

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Dupont and Portner (2013). "*Get ready for Ocean Acidification*," Nature.

Feely, R.A., T. Klinger, J.A. Newton, and M. Chadsey (2012): *Scientific Summary of Ocean Acidification in Washington State Marine Waters*. NOAA OAR Special Report.

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C.J. Gobler and S.C. Talmage (2013): *Short- and long-term consequences of larval stage exposure to constantly and ephemerally elevated carbon dioxide for marine bivalve populations*, Biogeosciences

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Ryan P. Kelly and Margaret R. Caldwell (2013) *Ten Ways States Can Combat Ocean Acidification (And Why They Should),* Harvard Environmental Law Review

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Narita et al. (2012): *Economic costs of ocean acidification: a look into the impacts on global shellfish production*, Climatic Change

NOAA Ocean Acidification Steering Committee *NOAA Ocean and Great Lakes Acidification Research Plan* (2010)

NOAA PMEL Primer on pH (website)

NOAA State of the Science Fact Sheet 2013

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Pespeni et al. (2013): *Evolutionary change during experimental ocean acidification*, PNAS

Teck et al. (2010) *Using expert judgment to estimate marine ecosystem vulnerability in the California Current*, Ecological Applications

Waldbusser et al. (2013) *Ecosystem effects of shell aggregations and cycling in coastal waters: an example of Chesapeake Bay oyster reefs,* Ecology

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