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INTRODUCTION

The objective of the Clean Water Act (CWA) is to “restore and maintain the chemical, physical and biological integrity of the nation’s waters.” 33 USC §1251(a). Section 101(a)(2) of the CWA establishes as a national goal “water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water, wherever attainable.” 33 USC 1251 (a)(2).

The phenomenon known as “ocean acidification” (OA) poses a serious risk to the chemical, physical, and biological integrity of the coastal waters of the United States and in particular to the productivity of the fish and shellfish industries.¹ When carbon dioxide (CO₂) is absorbed by seawater, chemical reactions occur that reduce seawater pH and saturation states of biologically-important calcium carbonate minerals, which are the building blocks for the skeletons and shells of many marine organisms. Rising atmospheric CO₂ changes ocean chemistry and harms shelled organisms in a direct manner. When shelled organisms are at risk, the entire food web may also be at risk.

This case arises in the broader context of the dramatic changes in ocean chemistry that are occurring globally. Since the beginning of the Industrial Revolution, the pH of surface ocean waters has fallen by 0.1 pH units largely due to anthropogenic sources of CO₂ emissions and deforestation.² Since the pH scale is logarithmic this change represents approximately a thirty

¹ Washington fisheries generate \$1.7 billion a year, and sustain 42,000 jobs. Nationally, the economic value of commercial fishing amounts to \$70 billion and 1 million jobs. Washington State Blue Ribbon Panel on Ocean Acidification, *Ocean Acidification in Washington State From Knowledge to Action*, 3(Dec 19, 2012); accessed on 8/16/14

http://www.ecy.wa.gov/water/marine/oa/20121219_OA_Presentation.pdf

² NOAA, PMEL Carbon Program, *What Is Ocean Acidification?* Accessed 8/17/14

<http://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F>

1 percent increase in ocean acidity.³ If CO2 emissions continue on their current path the surface
2 waters of the ocean could be nearly one hundred and fifty percent more acidic by the end of this
3 century, resulting in a pH that the oceans have not experienced for more than twenty million
4 years.⁴ There is no question that these unprecedented changes are attributable to anthropogenic
5 sources of CO2.⁵

6 The central issue here is whether the Environmental Protection Agency's (EPA) decision
7 not to list any of the coastal waters of Washington and Oregon as either "impaired" or
8 "threatened" under section 303(d) of the CWA is based on a complete and adequate review of
9 the best available science on the effects of OA. Amici respectfully disagree with EPA's
10 assessment that no listing is warranted and offer the following information to assist the court in
11 evaluating the available evidence within the framework of the CWA.

13 I. INTEREST OF AMICI

14 Dr. Ken Caldeira, whose CV is attached as Exhibit A, is one of the world's foremost
15 experts on climate change and ocean acidification. He is a senior member of the Carnegie
16 Institution's Department of Global Ecology staff and a professor in Stanford University's
17 Environmental Earth System Sciences department. He studies the global carbon cycle; marine
18 biogeochemistry and chemical oceanography, including ocean acidification and the
19 atmosphere/ocean carbon cycle; land-cover and climate change; the long-term evolution of
20 climate; and geochemical cycles. Dr. Caldeira is a member of the Intergovernmental Panel on
21

22 ³ *Id.*

23 ⁴ *Id.*

24 ⁵ International Geo-sphere Biosphere Program *Ocean Acidification, Summary for Policymakers,*
25 *Third Symposium on Oceans in a High CO2 World*, (2013); available at
http://igbp.sv.internetborder.se/download/18.30566fc6142425d6c91140a/1385975160621/OA_spm2-FULL-lorez.pdf

1 Climate Change and a lead author of the most recent climate assessment (AR5).

2 Dr. Jane Lubchenco, whose CV is attached as Exhibit B, is a world renowned marine
3 ecologist. She is the University Distinguished Professor and Advisor in Marine Studies at
4 Oregon State University. Dr. Lubchenco served as Under Secretary of Commerce for Oceans and
5 Atmosphere and Administrator of the National Oceanic and Atmospheric Administration from
6 2009 to 2013. Dr. Lubchenco is one of the “most highly cited” ecologists in the world, and eight
7 of her publications are recognized as “Science Citation Classics.” Dr. Lubchenco has served as
8 president for the American Association for Advancement of Science (AAAS), the International
9 Council for Science, and the Ecological Society of America, and was a board member for 10
10 years on the National Science Board. She is an elected member of the National Academy of
11 Sciences, the American Philosophical Society, and the Royal Society.
12

13 **II. EPA RULES AND GUIDANCE REQUIRE THE LISTING OF WATERS**
14 **THREATEND WITH IMPAIRMENT BASED ON THE BEST AVAILBLE**
15 **INFORMATION**

16 In compiling their 303(d) lists of water quality limited segments states must “assemble and
17 evaluate all existing and readily available water quality-related data and information.” 40 CFR
18 §130.7(5). All forms of reliable data and information must be considered. This includes monitoring
19 data, modeled predictions, laboratory analysis, field studies, visual observations and commercial
20 harvest data. EPA’s guidance acknowledges that precise information is not always available, that
21 data gaps frequently exist, and that scientific certainty is not the standard:

22 The intent of this policy is to protect against dismissing valuable information
23 when evaluating aquatic life use attainment, particularly in detecting impairment.
24 EPA’s policy on independent application is based on the premise that any valid,
representative dataset indicating an actual or projected water quality impairment
should not be ignored when one is determining the appropriate action to be taken.
(Emphasis added)⁶

25 ⁶ See *Consolidated Assessment and Listing Methodology: Toward a Compendium of Best*

1 More recently, EPA issued special guidance advising that states “should list waters not
2 meeting water quality standards, including marine pH WQC, on their 2012 303(d) lists...when data
3 is available.”⁷ EPA also acknowledged that “information is absent or limited for OA parameters and
4 impacts at this point in time and, therefore, listings for OA may be absent or limited in many
5 States.” Importantly, however, the guidance also stresses that lack of information about the precise
6 causes of impairment is not a reason to avoid a 303(d) listing:

7 EPA reminds states that if designated uses are not supported and the segment is
8 impaired or threatened the fact that the specific pollutant is not known does not
9 provide a basis for excluding the segment from being listed as impaired.
10 Therefore if marine pH exceeds the state’s criterion but the source stressor is
unknown (e.g., carbon deposition, nutrient enrichment, industrial discharge,
natural background) then EPA expects the segment to be listed.⁸

11 Further, EPA guidance recognizes that impairment of water quality can result from
12 multiple factors and stressors, some of which are natural and some the result of human activity.
13 Regardless, where the potential for impairment exists, and anthropogenic sources of pollutants
14 are present, EPA expects that States will list the affected waters:

15 When a State evaluates whether a potential designated use impairment is the
16 result of natural conditions, the State should consider all sources of the pollutant
17 being evaluated. If the pollutant concentrations do not meet the EPA-approved
18 water quality standards, and anthropogenic sources of the pollutant are present,

19 *Practices* First Edition, Ch3 Water Quality Standards Attainment Decisions 3-9 (July 2002);
20 accessed on 8/15/14

21 http://water.epa.gov/type/watersheds/monitoring/upload/2003_07_02_monitoring_calm_calm_co
22 [ntents.pdf](http://water.epa.gov/type/watersheds/monitoring/upload/2003_07_02_monitoring_calm_calm_co) EPA also acknowledges the need for further investigation where there are conflicting
23 results.

24 ⁷ Memorandum from Denise Keehner, Director Office of Wetlands, Oceans, and Watersheds to
25 Water Division Directors Regions I-10, *Information Concerning 2014 Clean Water Act Sections*
26 *303(d), 305(b), and 314 Integrated Reporting and Listing Decisions* September 3, 2013
(Hereafter “OA Memo”); accessed on 8/15/14

27 <http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/2014-memo.cfm>

28 ⁸ *Id.* at 9 (Emphasis added).

1 the water is considered impaired and should be included on the State's Section
2 303(d) list even if natural sources of the pollutant are present.⁹

3 Two conclusions can be drawn from this review of the legal framework of the 303(d) listing
4 process. First, the decision to list or not to list must be based on the best available scientific
5 evidence, recognizing that science is an iterative process where ideas are constantly tested and
6 inferences are drawn from observable facts. Second, the policy is to err on the side of caution in the
7 face of scientific uncertainty in order to effectuate the statutory objective to “maintain” existing high
8 quality waters and prevent degradation before it is too late to halt or reverse the damage.

9 As discussed below EPA failed to fairly consider the cumulative weight of the available
10 scientific evidence on OA and did not follow its own guidance in critical respects.

11 **III. THE BEST AVAILABLE SCIENTIFIC EVIDENCE INDICATES THAT**
12 **OCEAN ACIDIFICATION IS IMPAIRING THE CHEMICAL, PHYSICAL**
13 **AND BIOLOGICAL INTEGRITY OF THE COASTAL WATERS OF**
14 **WASHINGTON AND OREGON.**

15 **A. The Pacific Northwest is Especially Vulnerable to OA.**

16 The report of the Washington State Blue Ribbon Panel on Ocean Acidification provides a
17 comprehensive review of the state of the science on OA on the Northwest. One of its key
18 findings is that:

19 Washington State is particularly vulnerable because of its location and regional
20 oceanography. Atmospheric CO₂ is indisputably the most important driver of
21 ocean acidification in the open-ocean waters of the North Pacific, and unless
22 carbon emissions are rapidly brought under control, it will dominate at the local
23 level as well within the coming decades.¹⁰

24 The report identifies several contributing factors including:

25 ⁹ *Information Concerning 2014 Clean Water Act Sections 303(d), 305(b), and 314 Integrated*
26 *Reporting and Listing Decisions* September 3, 2013; accessed on 8/15/14
27 <http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/2014-memo.cfm>

28 ¹⁰ Washington State Blue Ribbon Panel on Ocean Acidification, *Scientific Summary of Ocean*
Acidification in Washington State Marine Waters, November 2012 (hereafter, “Blue Ribbon
Panel”); accessed 8/15/14 <https://fortress.wa.gov/ecy/publications/publications/1201016.pdf>

- 1
- 2 • Upwelling of cold CO₂-rich waters from the ocean depths to flow onto the continental
 - 3 shelf and eventually into Puget Sound and coastal estuaries. These waters have naturally
 - 4 low pH from respiration processes and, combined with the added contribution of the
 - 5 anthropogenic CO₂, become corrosive to shell-forming organisms such as oyster larvae,
 - 6 clams, mussels, crabs, abalone, and pteropods.
 - 7 • Nutrients such as phosphorous and nitrogen from runoff, atmospheric deposition and
 - 8 other sources. These nutrients can stimulate the growth of marine algae, thus serving to
 - 9 temporarily decrease seawater CO₂ and increase pH of the surface waters.
 - 10 • Freshwater from rivers and stormwater runoff that often has pH values and calcium
 - 11 carbonate saturation states lower than seawater.¹¹

12 These findings have been broadened by the West Coast Ocean Acidification and Hypoxia

13 Science Panel that covers California, Oregon, Washington and British Columbia. This Panel has

14 released a fact sheet containing these salient findings:¹²

- 15 • Ocean acidification has been well documented through global observations
- 16 conducted over several decades by hundreds of researchers. It has been definitively
- 17 attributed to anthropogenic (human-generated) CO₂ in the atmosphere that has been
- 18 released primarily by fossil fuel combustion and deforestation.
- 19 • Anthropogenic CO₂ is the largest human-derived source of acidifying pollution in
- 20 Pacific Northwest waters.
- 21 • Significant losses in Pacific oyster production have been observed in shellfish
- 22 hatcheries in Washington and Oregon under slightly saturated conditions, because
- 23 shell formation in developing larvae requires supersaturated conditions.
- 24 • Small changes in the environment can cause large responses among living
- 25 organisms.
- 26 • The current rate of acidification may be unprecedented in the Earth's history. The
- 27 rate of acidification is estimated to be 10 to 100 times faster than any time in the past
- 28 50 million years. An acidification event that occurred 55 million years ago (at the
- Paleocene-Eocene Thermal Maximum) was associated with a mass extinction of
- some marine species, especially deep-sea shelled invertebrates.

What is clear from this review is that a combination of natural and human sources is responsible for the increasing acidification of the coastal waters of Washington and Oregon. We

¹¹ Id at 3-4

¹² Ocean Acidification in the Pacific Northwest May 2014; accessed 8/28/14
<http://www.noaa.gov/factsheets/OA18PNWFacts14V4.pdf> (hereafter "OA in the PNW")

1 know that rising atmospheric CO2 changes ocean chemistry and harms shelled organisms like
2 oysters, clams, mussels, crabs, and corals.¹³ We know that shellfish in Pacific Northwest marine
3 waters are particularly vulnerable to ocean acidification-driven effects because Pacific Northwest
4 waters are colder and fresher than the global average ocean, which means CO2 gas dissolves
5 more effectively in these waters and because upwelling brings corrosive waters to the surface.¹⁴
6 We know that anthropogenic contributions to ocean acidification are detectable and have
7 increased the frequency, intensity, and duration of harmful conditions.¹⁵ We know that Pacific
8 oysters in aquaculture facilities in Washington and Oregon have shown clear negative responses
9 to low saturation states of aragonite, a key calcifying mineral that is vulnerable to OA.¹⁶ Studies
10 of the Olympia oyster, native to Washington, showed that survival and growth of larvae and
11 juveniles decreased with exposure to low pH and low saturation rates of aragonite in both the
12 laboratory and field.¹⁷

14 Finally, we know that human contribution to acidification in the Pacific Northwest is
15 quantifiable and has increased the frequency, intensity, and duration of harmful conditions. For
16

17 ¹³ IPCC, *Climate Change 2007: Synthesis Report*. Contributions of Working Groups I, II, and III
18 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

19 ¹⁴ Doney, S. C., V. J. Fabry, R. A. Feely, and J. A. Kleypas. 2009. *Ocean acidification: The*
20 *other CO2 problem*. *Annual Review of Marine Science*, 1: 169–192; Feely, R. A., S. C. Doney,
and S. R. Cooley. 2009. *Ocean acidification: Present conditions and future changes in a high-*
CO2 world. *Oceanography*, 22(4): 36–47.

21 ¹⁵ Feely, R. A., C. L. Sabine, J. M. Hernandez-Ayon, D. Ianson, and B. Hales. 2008. *Evidence*
for upwelling of corrosive “acidified” water onto the continental shelf. *Science*, 320: 1490-1492.

22 ¹⁶ Barton, A., B. Hales, G. G. Waldbusser, C. Langdon, and R. A. Feely. 2012. *The Pacific*
oyster, Crassostrea gigas, shows negative correlation to naturally elevated carbon dioxide
levels: Implications for near-term ocean acidification effects. *Limnology and Oceanography*,
23 57(3): 698-710.

24 ¹⁷ Hettinger, A., E. Sanford, T. M. Hill, E. A. Lenz, A. D. Russell, and B. Gaylord. 2013. *Larval*
carry-over effects from ocean acidification persist in the natural environment. *Global Change*
25 *Biology*, 19: 3317-3326.

1 example, in Hood Canal, 24-49% of the total increase in CO₂ in subsurface waters since the
2 industrial revolution is linked to human activity.¹⁸ Off the Oregon coast, under-saturated
3 conditions of aragonite, once rare, now occur 30% of the time during the summer upwelling
4 season.¹⁹ Anthropogenic CO₂ is the largest human-derived source of acidifying pollution in
5 Pacific Northwest waters, adding an amount of CO₂ that can significantly worsen naturally-low
6 saturated aragonite conditions for shelled organisms.²⁰

7 **B. Acidification in Puget Sound and the Strait of Juan de Fuca is well-**
8 **documented**

9 OA in these waters is strongly influenced by oceanic input when corrosive water moves
10 in from the coast at depth and resides in the subsurface basin layers.²¹ Inputs of nutrients and
11 organic matter can further reduce pH and carbonate saturation state by stimulating microbial
12 respiration. Subsurface waters in many parts of Puget Sound are under-saturated with respect to
13 aragonite throughout the year. OA accounts for 24–49% of the dissolved inorganic compounds
14 (DIC) increase in the subsurface waters of Hood Canal.

15 Under Washington’s water quality standards (WQS), Puget Sound and the Strait of Juan
16 de Fuca must provide “extraordinary” water quality for aquatic life. WAC 173-201A-612. Such
17 waters must support “[e]xtraordinary quality salmonid and other fish migration, rearing, and
18 spawning; clam, oyster, and mussel rearing and spawning; crustaceans and other shellfish (crabs,
19 shrimp, crayfish, scallops, etc.) rearing and spawning.” *Id.* 173-201-210(1)(a)(i). The pH
20 standard for marine waters of extraordinary quality requires that “pH must be within the range of
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22 _____
23 ¹⁸ Feely et al *The combined effects of ocean acidification, mixing, and respiration on pH and*
carbonate saturation in an urbanized estuary, Coastal and Shelf Science 88, 442e449(2010)

24 ¹⁹ *OA in the PNW* supra n 14.

25 ²⁰ *Id.*

²¹ *Blue Ribbon Panel*, supra n 13, Ch. 3.

1 7.0 to 8.5 with a human-caused variation within the above range of less than 0.2 units.” *Id.* 173-
2 201A-210(1)(f).

3 Some marine ecosystems already experience natural declines in pH approximating those
4 predicted with future anthropogenic ocean acidification (OA), the decline in seawater pH caused
5 by the absorption of atmospheric CO₂. A study by Timothy Wootton and colleagues at Tatoosh
6 Island at the mouth of the Strait of Juan de Fuca found that the pH in the Strait has changed by
7 substantially more than the 0.2 unit limit under Washington’s WQS.²² The Wootton study
8 analyzed 24,519 measurements of seawater between 2000 and 2008. The study found: (1) the pH
9 value declined a total of 0.36-units—well over the .02 limit in the WQS and greater than
10 previously predicted by models.²³ EPA found methodological and other problems with the
11 Wootton study but did not contest the fact that the pH in the Strait has declined. Rather, EPA
12 asserts that “it is unclear whether the pH changes observed over time in the Wootton et al. 2008
13 study are due to natural or anthropogenic drivers.”²⁴ EPA explicitly acknowledged that
14 “atmospheric CO₂ may explain a portion of the [pH] decline;” and suggested that “[f]urther
15 work is needed in identifying the dominant factor driving the declining pH at Tatoosh Island.”
16 Yet EPA chose to entirely discount this evidence as indicating that the waters of the Strait are at
17 least threatened with impairment.
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20

21 ²² J. Timothy Wootton, Catherine A. Pfister, and James D. Forester, *Dynamic patterns and*
22 *ecological impacts of declining ocean pH in a high-resolution multi-year dataset* Proceedings of
the National Academy of Sciences Vol. 105, No. 48 (Dec. 12 2008) (hereafter “Wootton et al”)

23 ²³ *Id.*

24 ²⁴ EPA also discounted the results because the study was conducted in “tribal” as opposed to
25 “state” waters.” While this distinction seems questionable as a legal proposition it is entirely
irrelevant as a scientific matter. Political boundaries have no relevance to how ecosystems
function.

1 This conclusion is at odds with the guidance discussed above directing that: “If the
2 pollutant concentrations do not meet the EPA-approved water quality standards, and
3 anthropogenic sources of the pollutant are present, the water is considered impaired and should
4 be included on the State's Section 303(d) list even if natural sources of the pollutant are
5 present.”²⁵ EPA also ignored its recently issued OA guidance which directs that “if marine pH
6 exceeds the State’s criterion, but the source-stressor is unknown (e.g., carbon deposition, nutrient
7 enrichment, industrial discharge, natural background), then EPA expects the segment to be
8 listed.”²⁶

9
10 Moreover subsequent studies have linked atmospheric CO₂ and low pH in the coastal
11 waters of the PNW. A study in the intertidal waters at the mouth of Fogarty Creek in Oregon
12 used high-frequency measurements of environmental variables to develop a 104-day time series
13 of pH, temperature, wind and sea level pressure demonstrated that offshore upwelling
14 dramatically alters pH in this near-shore environment.²⁷ The goal of this study was to explore
15 whether populations are adapted to local pH regimes and tolerant of the seasonal changes in
16 seawater chemistry associated with strong upwelling on the Oregon coast. Seasonal upwelling is
17

18 ²⁵ *Information Concerning 2014 Clean Water Act Sections 303(d), 305(b), and 314 Integrated*
19 *Reporting and Listing Decision*, supra, n. 11

20 ²⁶ *OA Memo*, supra, n 9

21 ²⁷ Tyler G. Evans et al, Transcriptomic responses to ocean acidification in larval sea urchins
22 from a naturally variable pH environment, *Molecular Ecology* (2013) 22, 1609–1625.; accessed
23 8/28/14 <http://www.ncbi.nlm.nih.gov/pubmed/23317456>. This study was published after EPA’s
24 listing decision .Amici are aware of the general rule against supplementation of the record but
25 would note that courts have made exceptions in some cases. Specifically courts have ruled that:
26 “Extra record evidence is admissible in cases where evidence arising after the agency action
27 shows whether the decision was correct or not.” *Esch v. Yeutter*, 876 F.2d 976, 991 (D.C. Cir.
28 1989). In that case the DC Circuit noted that: “The applicability of the exception, however, is at
its zenith when extra- record evidence is needed to facilitate examination of the procedural
soundness of an agency decision. 876 F.2d at 991.

1 a dominant oceanographic process in the Northeastern Pacific Ocean that mixes deep, CO₂-rich
2 waters with surface layers causing significant declines in seawater pH. Using high frequency pH
3 sensors, the study demonstrates that upwelling events off the coast of Oregon strongly influence
4 pH dynamics in a near-shore intertidal habitat.

5 **C. OA Has Been Linked to Massive Oyster Die-offs in Washington and**
6 **Oregon**

7 For the past six years, wild oysters in Willapa Bay, Washington, have failed to reproduce
8 successfully.²⁸ Wild oysters in Puget Sound and off the east coast of Vancouver Island also have
9 experienced reproductive failures. Other wild oyster beds in the Pacific Northwest have
10 sustained losses in recent years. As these events have unfolded there has been a steady rise in the
11 acidity and corrosivity of the coastal waters in which the oyster beds are located.

12 The collapse of the Whiskey Creek Oyster Hatchery in Netarts Bay, Oregon in 2006 -
13 2008 has been conclusively linked to OA.²⁹ The researchers found that increased seawater
14 carbon dioxide (CO₂) levels, resulting in more corrosive ocean water, inhibited the larval oysters
15 from developing their shells and growing at a pace that would make commercial production cost-
16 effective.

17
18 Science may not yet be able to establish a definitive causal connection between
19 atmospheric CO₂ and the deaths of literally billions of oyster larvae over the past several years

20 _____
21 ²⁸ Elizabeth Grossman, *Northwest Oyster Die-offs Show Ocean Acidification Has Arrived* Yale
22 Environment 360 November 21 2011; accessed 8/17/14
http://e360.yale.edu/feature/northwest_oyster_dieoffs_show_ocean_acidification_has_arrived/2466/

23 ²⁹ George G. Waldbusser et al, *A developmental and energetic basis linking larval oyster shell*
24 *formation to acidification sensitivity*, Geophysical Research Letters Vol. 40, Issue 10, pages
25 2171–2176, 28 May 2013; Phys. Org, *Ocean acidification killing oysters by inhibiting shell*
formation, study finds Jun 12, 2013; accessed 8/17/14 <http://phys.org/news/2013-06-ocean-acidification-oysters-inhibiting-shell.html>

1 but the circumstantial evidence is strong enough to warrant precautionary actions by EPA. At a
2 minimum these observed conditions indicate that the ability of these high quality waters to
3 continue supporting their designated and existing uses are seriously threatened and listing under
4 303(d) is warranted as a first step in addressing the problem.

5 **D. Laboratory Data Clearly Shows the Corrosive Effects of OA on a**
6 **Number of Marine Organisms**

7 Laboratory studies suggest that some oceanic plankton are highly sensitive to changes in
8 CO2 concentrations in sea water. A recent synthesis of 228 studies examining biological
9 responses to OA found “reductions in survival, calcification, growth, development and
10 abundance in response to ocean acidification across a broad range of marine organisms.”³⁰
11 Calcifying organisms that may be affected include the coccolithophores, pteropods, gastropods
12 and foraminifera, all of which are major food sources for fish and some whale species. Research
13 has already found that pteropods experience reduced calcification when exposed to elevated
14 CO2.³¹ Early life stages of many molluscs (larvae and juveniles) as well as adults have shown
15 reduced calcification, growth and survival.³²
16

17 EPA acknowledged the number of laboratory experiments demonstrating these effects but
18 concluded that lab studies alone could not demonstrate non-attainment of WQS; however, proof
19 of actual non-attainment is not the test required under the listing guidance discussed above.

20 Similarly, EPA discounted the hatchery data because hatchery populations are not sufficient to

21 _____
22 ³⁰ Kroecker et al, *Impacts of ocean acidification on marine organisms: quantifying sensitivities*
23 *and interaction with warming*, Global Change Biology (2013) 19, 1884–1896; accessed 8/28/14
<http://onlinelibrary.wiley.com/doi/10.1111/gcb.12179/abstract>

24 ³¹ Orr J. C., et al., *Anthropogenic ocean acidification over the twenty-first century and its impact*
25 *on calcifying organisms*. Nature 2005;437:681-686

26 ³² Wittmann, A.C., Pörtner, H.-O., *Sensitivities of extant animal taxa to ocean acidification*,
27 Nature Climate Change 2013

1 determine the condition of natural populations. However, neither EPA's 303 (d) rules nor its
2 guidance distinguishes between natural and wild populations, and the available information
3 shows that both are negatively affected by human caused OA. Indeed aquaculture is one of the
4 designated uses that must be protected under the water quality standards for Washington and
5 Oregon.³³

6 CONCLUSION

7 The cumulative weight of the best available evidence indicates that ocean acidification is
8 impairing the coastal waters of Washington and Oregon and threatening beneficial uses protected
9 by the CWA. EPA did not synthesize this large body of information. Rather EPA examined each
10 of the component parts in isolation and failed to connect the dots. EPA failed to follow the
11 precautionary approach prescribed by its rules and guidance. Amici therefore suggest that this
12 matter be remanded to EPA for further analysis.
13

14 Respectfully submitted this 28th day of August, 2014.
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24 ³³ Scott Doney, *Oceans of Acid: How Fossil Fuels Could Destroy Marine Ecosystems*, Nova
25 Next 12 Feb 2014

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s/ Patrick Parenteau

Patrick Parenteau (*Pro Hac Vice*)*
Environmental and Natural Resources Law Clinic
Vermont Law School
South Royalton, VT 05068
(802) 485-6412 | Phone
(802)831-1630 | Fax
pparenteau@vermontlaw.edu

s/ Todd D. True

TODD D. TRUE (WSB #12864)
Earthjustice
705 Second Avenue, Suite 203
Seattle, WA 98104
(206) 343-7340 | Phone
(206) 343-1526 | Fax
ttrue@earthjustice.org

Attorneys for Proposed Amici Scientists

*The contributions of Zhengzhi Wang, student clinician, and Rachel Stevens, clinic fellow, are gratefully acknowledged.

1 **CERTIFICATE OF SERVICE**

2 I hereby certify that, on August 28, 2014, I electronically filed the foregoing with the
3 Clerk of Court using the CM/ECF system which will send notification of such filing to the
4 following:

5 **Counsel for parties participating in electronic service via the CM/ECF**
6 **system for Case No. 2:13-cv-01866-JLR.**

7
8
9 Dated August 28, 2014

s/ Patrick Parenteau
Patrick Parenteau (*Pro Hac Vice*)
Environmental and Natural Resources Law Clinic
Vermont Law School
South Royalton, VT 05068
(802) 485-6412 | Phone
(802)831-1630 | Fax
pparenteau@vermontlaw.edu

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26 CENTER FOR BIOLOGICAL DIVERSITY v. EPA
27 PROPOSED BRIEF OF PROPOSED AMICI SCIENTISTS
28 No. 2:13-cv-01866-JLR

*Env't'l and Nat'l Resources Law Clinic
Vermont Law School
PO Box 96; 164 Chelsea Street
South Royalton, VT 05068
(802) 831-1630*

EXHIBITS

Curriculum Vitae of Amici Scientists

KEN CALDEIRA, PH.D

JANE LUBCHENCO, PH.D

Curriculum Vitae for Ken Caldeira

PRESENT POSITION

Senior Scientist
Department of Global Ecology
Carnegie Institution
260 Panama Street
Stanford, CA 94305 USA
kcaldeira@ciw.edu
(650) 704-7212; fax: (650) 462-5968

Professor (by courtesy)
Department of Environmental Earth System Sciences
Stanford University
450 Serra Mall
Stanford, California 94305 USA
kcaldeira@carnegie.stanford.edu

EDUCATION

Ph.D., 1991, New York University, Atmospheric Sciences, Department of Applied Science
M.S., 1988, New York University, Atmospheric Sciences, Department of Applied Science
B.A., 1978, Rutgers College, Philosophy

PRIOR RESEARCH EXPERIENCE

Physicist/Environmental Scientist (Lawrence Livermore National Laboratory, 1995 to 2005) Research ocean carbon cycle, atmospheric CO₂, ocean/sea-ice physics, climate, and energy systems
Post-Doctoral Researcher (Lawrence Livermore National Laboratory; 1993 to 1995) Research the ocean carbon cycle, atmospheric CO₂ and climate
NSF Earth Sciences Postdoctoral Fellow (Earth Systems Science Center & Dept. of Geosciences, The Pennsylvania State University; 1991 to 1993) Role of the carbonate-silicate cycle in long-term atmospheric CO₂ content and climate

GENERAL RESEARCH INTERESTS

Ocean acidification; climate/carbon-cycle interactions; numerical simulation of climate and biogeochemistry; marine biogeochemical cycles; global carbon cycle; long-term evolution of climate and geochemical cycles; intentional intervention in the climate system; energy technology and policy

ADVISORY PANELS / DISSERTATION COMMITTEES / ETC

Fellow of the American Geophysical Union (2010)
National Academy of Sciences, America's Climate Choices Panel Member (2009)
UK Royal Society Geoengineering Report Panel Member (2009)
Global Carbon Project, Steering Committee Member (2009-present)
European Project on Ocean Acidification (EPOCA), Advisory Board Member (2008-2012)
Intergovernmental Oceanographic Commission, Representative at International Maritime Union Negotiations (2008, 2009)
UK Royal Society Ocean Acidification Report Panel Member (2007)
IPCC Special Report on CO₂ Capture and Storage, Oceans Chapter, Coordinating Lead Author (2005)
US Delegation to climate-related negotiations leading up to G8 Summit, Technical Support (2005)
UNESCO International Oceanography Commission CO₂ Panel of Experts (2002-2004)
US Global Carbon Cycle Scientific Steering Group (2001-2004)
Dissertation Committees of students at Stanford, MIT, and University of Illinois

PRINCIPAL PUBLICATIONS

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- Rampino, M.R., K Caldeira (1992) *Episodes of terrestrial geologic activity during the past 260 million years: A quantitative approach*. **Dynamics and Evolution of Minor Bodies with Galactic and Geological Implications**. doi: 10.1007/978-94-011-2743-1_10
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- Caldeira, K., MR Rampino (1990) *Carbon dioxide emissions from Deccan volcanism and a K/T boundary greenhouse effect*. **Geophysical Research Letters**, 17, 1299-1302. doi: 10.1029/GL017i009p01299

- Caldeira, K., MR Rampino, T Volk, JC Zachos (1990) *Biogeochemical modeling at mass extinction boundaries: Atmospheric carbon dioxide and ocean alkalinity at the K/T boundary*. **Extinction Events in Earth History**. doi: 10.1007/BFb0011156
- Caldeira, K (1989) *Evolutionary pressures on planktonic production of atmospheric sulphur*. **Nature Publishing Group**, 337, 732-734. doi: 10.1038/337732a0

The Honorable Dr. JANE LUBCHENCO

Curriculum Vitae

University Distinguished Professor and Advisor in Marine Studies Oregon State University

Recent Positions:

Mimi and Peter Haas Distinguished Visitor in Public Service and Visiting Fellow,

Center for Ocean Solutions, Stanford University, March-June 2013 (on leave from OSU)

Under Secretary of Commerce for Oceans and Atmosphere and Administrator of the National Oceanic and Atmospheric Administration (NOAA), March 20, 2009 to February 27, 2013; (on leave from OSU). Nominated by Barak Obama December 20, 2008; confirmed by U.S. Senate March 19, 2009, resigned February 27, 2013.

Education: **B.A.** 1969, Colorado College (Biology; Ford Foundation Independent Study Program); **M.S.** 1971, University of Washington (Zoology); **Ph.D.** 1975, Harvard University (Ecology).

Previous Positions:

Assistant Professor, 1975-1977, Harvard University.

Assistant Professor 1977-1982, **Associate Professor** 1982-88, Oregon State University (OSU).

Research Associate, Smithsonian Institution, 1978-1984.

Professor 1988-2009; **Chair,** Department of Zoology 1989-92; **Distinguished Professor** 1993-2009, OSU (2009-2013 on leave while serving as NOAA Administrator), 2013-present.

N.B.: From 1977-1989, Dr. Lubchenco worked part-time, by choice, so she could spend more time with her two young sons. She held a 0.5 FTE tenure-track, then tenured appointment for ten years, followed by a 0.75 FTE appointment for two years; in 1989, she returned to full-time.

Wayne and Gladys Valley Professor of Marine Biology 1995-2009, 2013-2014, OSU.

University Distinguished Professor and Advisor in Marine Studies 2014-present, OSU.

Visiting Professor: University of the West Indies, Kingston, Jamaica, 1976; Smithsonian Tropical Research Institute, Panama, 1975-1984; Universidad Catolica, Santiago, Chile, 1986; Institute of Oceanography, Academica Sinica, Qingdao, P.R. China, 1987; University of Canterbury, Christchurch, New Zealand, 1994-95, 1999-2000, 2002-2003.

National Science Board, member 1996-2000, 2000-2006, twice nominated by President William Jefferson Clinton and twice confirmed by the U.S. Senate.

Interests/Expertise:

Science, the environment, climate and other global changes and human well-being; social responsibilities of scientists; sustainability science; biodiversity and conservation biology; communication of science to the public, private sector, and policy makers; state of the oceans, rocky intertidal shores, and coastal upwelling ecosystems; ecosystem services; marine reserves; hypoxia ('dead zones') and ocean acidification; evolutionary community ecology; plant-herbivore interactions; biogeography; mollusks; echinoderms; seaweeds.

AWARDS and HONORS are listed below in four categories: Honorary Societies, Honorary Doctoral Degrees, Recognition from Professional Scientific Societies, and Major Awards and Other Honors

AWARDS and HONORS part 1: Honorary Societies (3 national, 4 international; year elected, history, size)

- **American Academy of Arts and Sciences,** 1993; founded 1780 by John Adams, John Hancock et al.; around 4,000 members.

- **National Academy of Sciences**, 1996; founded 1863, charter signed by President Abraham Lincoln; about 2000 members.
- **American Philosophical Society**, 1998; founded 1743 by Benjamin Franklin et al.; around 1,000 members.
- **European Academy of Sciences**, 2002-2014; founded 1990; ca 1500 members; resigned 2014.
- **The Royal Society**, Foreign Member, 2004; founded 1660 by Christopher Wren et al.; around 1450 members.
- **The World Academy of Sciences (TWAS)**, 2004; founded by Abdus Salam ‘to advance science and engineering for sustainable prosperity in the developing world’; around 1100 members, around 90% of whom live and work in developing countries.
- **Academia Chilena de Ciencias (Chilean Academy of Sciences)**, Corresponding Member, 2007; founded 1964; 39 members, 48 corresponding (foreign) members.

AWARDS and HONORS part 2: *Honorary Doctoral Degrees (19):*

Drexel University, 1992; Colorado College, 1993; Bates College, 1997; Unity College, 1998; Southampton College, Long Island University, 1999; Princeton University, 2001; Plymouth State College, 2002; Michigan State University, 2003; Georgetown University, 2008; Augsburg College, 2009; Dartmouth College, 2009; University of Copenhagen, Denmark, 2009; Loyola University New Orleans, 2011; State University of New York (SUNY) Stony Brook University, 2011; Western Washington University 2011; University of South Carolina, 2012; University of Puget Sound, 2012; Yale University, 2012; Rutgers University, 2013.

AWARDS and HONORS part 3: *Recognition from Professional Scientific Societies- PARTIAL LIST*

1979: George Mercer Award, Ecological Society of America, (co-recipient Bruce A. Menge);
 outstanding paper published anywhere in the world by a young ecologist

1990: Fellow, American Association for the Advancement of Science Fellow

1997: AWIS Fellow, Association for Women in Science

1997: Distinguished Service Award, Ecological Society of America

2001: Honorary Member for Life, British Ecological Society

2003: Distinguished Service Award, Society for Conservation Biology

2004: Distinguished Scientist Award, American Institute of Biological Sciences

2005: Public Understanding of Science and Technology Award, American Association for the Advancement of Science (the first woman to receive this award)

2012: Presidential Citation for Science and Society, American Geophysical Union

2012: Inaugural Fellow of the Ecological Society of America

2013: Honorary Lifetime Member, American Society of Naturalists. (The total number of living Fellows is limited to 12.)

2014: Eminent Ecologist Award, Ecological Society of America

AWARDS and HONORS part 4: *Major Awards and Other Honors – PARTIAL LIST*

Cumulative: 8 ‘Science Citation Classics’ or ‘Top 0.25%’ Papers, ISI (Institute for Scientific Information) Current Contents

1986: Outstanding Teacher Award, OSU Alpha Lambda Delta (freshman honor society)

1992: Pew Scholar in Conservation and the Environment, Pew Charitable Trusts, 1992-1995

1993: Distinguished Professor, Oregon State University, 1993-present

1993: MacArthur Fellow, John D. and Catherine T. MacArthur Foundation, 1993-1998

2002: The Heinz Award for the Environment, Heinz Family Foundation

- 2003: ISI Highly Cited Researcher in Ecology/Environment**
- 2003: Nierenberg Prize for Science in the Public Interest**, Scripps Institution of Oceanography
- 2004: Environmental Law Institute Award** (the first scientist to receive this honor)
- 2008: The Zayed International Prize for the Environment**, for Scientific and Technological Achievements, Dubai, United Arab Emirates
- 2010: Peter Benchley Ocean Award for Excellence in Policy**, Blue Frontier
- 2010: Nature Magazine's Newsmaker of the Year**, cover photo and feature article on activities during 2010
- 2011: Blue Planet Prize**, Asahi Glass Foundation, Tokyo, Japan
- 2011: Department of Commerce Gold Medal Award to NOAA** for extraordinary service during the Deepwater Horizon Oil Spill
- 2012: U.S. Coast Guard Academy Hedrick Fellow**, Coast Guard Foundation, 'honors citizens whose distinguished public service shaped the course of our nation'; 'brings world-renown political, military and industry leaders to the Coast Guard Academy to share their wisdom with cadets.'
- 2012: Women in Science and Technology Hall of Fame, inductee**, Women in Science and Technology International (WITI) Foundation, 'to recognize, celebrate and publicize women's exceptional contributions to science and technology'.
- 2012: Inaugural Ocean Hero, Sailors for the Sea** (along with Charlie Rose and Sir Russell Coutts).
- 2013: Distinguished Public Service Award, U.S. Coast Guard.** (The highest award the Coast Guard gives to a civilian.) '...for her extraordinary vision, leadership and commitment to maritime stewardship...'
- 2013: Lifetime Achievement Award, National Marine Sanctuaries Foundation.**
- 2013: Frontiers of Knowledge Award in Ecology and Conservation Biology, BBVA Foundation**, 'for experimentally characterizing marine ecosystems and providing the science behind the design of protected areas'.
- 2013: Prince Albert II of Monaco Foundation, Climate Change Award**
- 2014: Seattle Aquarium Medal**, 'for leadership and longstanding commitment to issues facing the environment, oceans and our climate, and for inspiring many, especially the next generation.
- 2014: TWAS Medal**, every year The World Academy of Sciences (TWAS) 'honors three of its members for their outstanding achievements in their fields of research'.
- 2014: Miguel Alemán Medal** commemorating the delivery of the XX Miguel Alemán Lecture, Mexico City, Universidad Nacional Autónoma de México.

Major Elected Offices Held (reverse chronological order):

International Council for Science (ICSU), Past-President 2005-2007, President 2002-2005, President-Elect 1999-02;

National Academy of Sciences, elected to Council 1999-2002, Executive Committee 2000-2002;

American Association for the Advancement of Science, President-Elect, President, Chair of Board of Directors 1995-98;

Ecological Society of America: Vice-President, President-Elect, President, Past President 1988-94;

ICSU's Scientific Committee on Problems of the Environment, SCOPE, Executive Committee, 1992-95.

Editorial Boards: (Lubchenco resigned from all editorial boards when she became NOAA Administrator in 2009 to avoid any real or perceived conflicts of interest.)

American Naturalist, 1978-81; ***Oecologia***, 1985-88; ***Journal of Phycology***, 1987-90; ***Ecological Applications***, 1989-93; ***The Northwest Environmental Journal***, 1991-93; ***Trends in Ecology &***

Evolution, 1991-2006; *Conservation Ecology*, 1995-2001; *Issues in Ecology*, 1995-2002, 2003-2005; *Ecosystems*, 1997-99; *Environmental Conservation*, 1998-99; Advisory Editor, *Ecological Studies*, Springer-Verlag, 1993-2000; Associate Editor, *Encyclopedia of Biodiversity*, Academic Press, 1997-2000; International Advisory Board, *Encyclopedia of Global Environmental Change*, Wiley, 1998-2001; Editor for *Special Issue on Marine Reserves, Ecological Applications*, 1999-2002; *Ad hoc* Editor, *Proceedings of the National Academy of Sciences*, 1998-2009; *Frontiers in Ecology*, Advisory Board, 2001-2004; *Human-Environment Interactions* (U. Michigan book series), 2003-2009; *Faculty of 1000*, 1 of 3 Inaugural Heads of Faculty for Ecology and Evolution, 2003-2009; *Marine Ecosystems and Management*, 2007-2009.

Advisory Services:

1. Boards of Directors or Trustees - Recent and Current (Lubchenco resigned from all but one board in 2009 when she became Administrator of NOAA to avoid any real or potential conflict of interest. Because the Smithsonian is partly governmental, government officials may serve on Smithsonian boards without conflicts.)

World Resources Institute, 1993-2000; **Environmental Defense Fund**, Trustee 1995-2009, 2013-2016, Science Advisory Committee, 1995-2009, 2014-2016; Co-chair of Oceans Committee, 1997-2009; Vice-Chair 2005-2009; Oceans Committee 2014-2016; Ecosystem Committee 2014-2016; **Monterey Bay Aquarium**, 1995-2007, Program Committee, 1995-2007; **Royal Swedish Academy of Sciences**, **Beijer Institute for Ecological Economics**, 1999-2004; **SeaWeb**, 2000-2007; **David and Lucile Packard Foundation** Trustee, 2001-2004, Trustee Emerita 2004-2009, Trustee 2013-2016; **Monterey Bay Aquarium Research Institute**, Trustee 2007-2009; **Smithsonian Institution's National Museum of Natural History**, Board of Advisors 2007-present; **The Nature Conservancy**, Director, 2014-present; **Union of Concerned Scientists**, 2014-present.

2. Advisory Boards and Panels – Current

Leonardo DiCaprio Foundation Advisory Committee, 2013-present; **Union of Concerned Scientists Center for Science and Democracy**, Inaugural Steering Committee, 2013-2014; **X-Prize Foundation Energy and Environment** Advisory Committee 2013-present; **Department of Global Ecology, Carnegie Institution**, Advisory Committee, 2013-present; **MomentUs** Leadership Council, 2013-present; **Georgetown University Environmental Initiative**, Advisory Committee 2013-present.

3. International Committees – Current:

Inclusive Wealth Center, Science Advisory Committee, 2013-present; **World Bank's Global Partnership for Oceans, Blue Ribbon Panel**, 2013-present; **UN Sustainable Development Solutions Network**, advisor to the UN Secretary General, Ban Ki-moon, 2013-present.

Invited Presentations (recent)

2014:

City Club of Portland, rebroadcast on **Oregon Public Broadcasting radio**; **Seattle Aquarium** keynote remarks after receipt of Seattle Aquarium Medal at Awards Ceremony and Chairman's Dinner; **Gulf of Mexico Oil Spill and Ecosystem Science Conference**, panel on 'Role of Academia in Environmental Disaster Response', Mobile, AL; **United Nations**, Open Working Group on Sustainable Development Goals, Keynote Address on Oceans and Seas, Biodiversity and Forests; **Salem City Club**, Salem, Oregon; **World Ocean Summit, The Economist Magazine**, Governance within National Jurisdictions, Half Moon Bay, CA; **Public Interest Environmental Law Conference, University of Oregon**, Eugene, OR; **University of Alaska, Fairbanks, Irving-Scholander Lecture, Institute of Arctic Biology and Institute**

of Marine Science, and technical lecture; **NatureServe Annual Awards Dinner**, New Orleans, LA; **Edwin Way Teale Lecture**, University of Connecticut; **Linnemann Lecture**, Colorado College; **Aldo Leopold Lecture**, University of Wisconsin, Madison; **Commencement Address**, Colorado College; **Climate Science**, MomentUs Leadership Summit, Chicago; **Opportunities for Ocean Conservation**, Benchley Bay to Sea Symposium, Aquarium of the Bay, San Francisco; **Miguel Aleman Foundation, XXth Lecture in Ecology and the Environment**, ‘Opportunities for economic, environmental and social wins’, National Autonomous University of Mexico, Mexico City.

Research Grants, Select: (Extramural; Lubchenco is PI unless otherwise indicated; Lubchenco resigned from all grants in 2009 when she became Administrator of NOAA, turning over responsibility to co-PIs)

- 1973-75 **National Science Foundation** Doctoral Dissertation Grant "The Community Role of Intertidal Herbivorous Gastropods" \$4,000.
- 1976-78 **National Science Foundation** "Experimental studies of community organization in tropical and temperate rocky intertidal regions" B.A. Menge, Co-PI, \$126,000.
- 1978-80 **National Science Foundation** "Experimental studies of community organization in a tropical rocky intertidal community." B.A. Menge, Co-PI, \$196,000.
- 1980-85 **National Science Foundation** "Heterogeneity and Community Organization in a temperate and tropical rocky intertidal community." B.A. Menge, Co-PI, \$488,000.
- 1986-88 **National Science Foundation** "Bromophenols in a temperate red alga: variability and anti-herbivore effects." D.J. Carlson, Co-PI, \$209,910.
- 1987 **National Academy of Sciences**, Visiting Investigator Program, People's Republic of China, "Rocky intertidal community structure and Marine Reserves along temperate Chinese shores."
- 1989-91 **Andrew W. Mellon Foundation** "A Strategic Plan for Ecology for the 1990's," \$125,000.
- 1990-91 **National Science Foundation** "The Sustainable Biosphere Initiative: Research Agenda for the Nineties Workshop," \$35,025.
- 1991-93 **National Science Foundation** "The Sustainable Biosphere Initiative Project," P.G. Risser, Co-PI. \$554,600.
- 1992-95 **Pew Charitable Trusts, Scholar in Conservation and the Environment Program** "Marine Conservation Biology and the Sustainable Biosphere Initiative: National and International Challenges," \$150,000.
- 1993-95 **National Science Foundation**, Supplement to SBI grant, P.G. Risser, Co-PI. \$60,000.
- 1992-96 **Andrew W. Mellon Foundation** "Rocky Intertidal Communities: Opportunities for Linking Ecological Studies at Different Scales," B.A. Menge, Co-PI. \$300,000.
- 1993-95 **National Science Foundation** "Inter-American Institute Program for Temperate Terrestrial Ecology: Workshops to Develop Scientific and Implementation Plans," P.I.: G. Bradshaw, Co-PIs: T. Strub, W. Winner. \$101,350.
- 1993-97 **John D. and Catherine T. MacArthur Foundation Fellowship**, \$280,000.
- 1994-95 **National Science Foundation**, Supplement to SBI grant, P.G. Risser, Co-PI. \$140,000.
- 1994-95 **Andrew W. Mellon Foundation** "The Sustainable Biosphere Project, Amazon Basin Case Study." P.G. Risser, Co-PI. \$180,000.
- 1995-98 **Andrew W. Mellon Foundation** "Rocky Intertidal Communities: Integration of Pattern-Process Linkages Across Expanding Scales," B.A. Menge, Co-PI. \$320,000.
- 1996-97 **Andrew W. Mellon Foundation** "Marine Ecosystem Dynamics: Planning for Comparisons of North and South America," \$19,900.
- 1997-98 **David and Lucile Packard Foundation** "The Spring Green Project: Training for Science-Advocates," \$110,829.

- 1997-2001 **National Science Foundation, National Center for Ecological Analysis and Synthesis**, “Developing the theoretical basis for marine protected areas.” \$120,000.
- 1998–2013 **Robert and Betty Lundeen Marine Biology Fund** “Frontiers in Marine Ecology,” \$750,000.
- 1998–2001 **Andrew W. Mellon Foundation** “Nearshore Marine Ecosystem Dynamics,” B.A. Menge, Co-PI. \$380,000.
- 1998–2003 **David and Lucile Packard Foundation** “The Aldo Leopold Leadership Program: Leadership and Communication Training For Science-Advocates,” \$1,437,940.
- 1999-2002 **Environmental Defense** “Siting Marine Reserves in Temperate Coastal Ecosystems” Co-PIs H. Leslie, B. Menge; in support of research of Heather Leslie.
- 1999–2004 **David and Lucile Packard Foundation** “Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO): A Long-Term Ecological Consortium,” Co-PIs: B. Menge, S.D. Gaines, R. Warner, G. Somero, M. Denny, P. Raimondi, M. Carr. \$17,711,742.
- 1999-2004 **David and Lucile Packard Foundation** “COMPASS: The Communication Partnership for Science and the Sea”, PI: Chuck Savitt (Island Press); Co-PIs: Vikki Spruill (SeaWeb), Chris Harrold (Monterey Bay Aquarium); \$2,136,425.
- 2000–2003 **Andrew W. Mellon Foundation** “The Mellon Marine Ecosystem Dynamics Consortium: An Infrastructure Plan to Provide Inter-hemispheric Links among Research Groups” Co-PI, with B. A. Menge, \$220,000.
- 2000-2004 **David and Lucile Packard Foundation** “Augmentation for PISCO”, Co-PIs: B. Menge, S.D. Gaines, R. Warner, G. Somero, M. Denny, P. Raimondi, M. Carr. \$2,285,098.
- 2000-2003 **Andrew W. Mellon Foundation** “Structuring processes in temperate marine nearshore reefs: parallel studies in New Zealand and Oregon” Co-PIs: D. Schiel, B.A. Menge, \$329,000.
- 2001-2002 **David and Lucile Packard Foundation** “Evaluating The Aldo Leopold Leadership Program.” \$63,388.
- 2002-2003 **David and Lucile Packard Foundation** “Communicating the Science of Marine Reserves”, Co-PIs B. Simler, S. Airame, R. Warner and S. Gaines. \$246,428.
- 2002-2008 **David and Lucile Packard Foundation** “The Aldo Leopold Leadership Program” Co-PIs: C. Robinson and D. Wall. \$1,500,000.
- 2004-2005 **David and Lucile Packard Foundation:** “PISCO Realizing the Potential of a Unique Model to Understand Coastal Marine Ecosystems.” Co-PIs: B. Menge, J. Barth, M. Carr, P. Raimondi, M. McManus, G. Somero, M. Denny, S. Palumbi, S. Gaines, B. Warner, L. Washburn, G. Hofmann. \$3,920,205.
- 2003-2006 **Andrew W. Mellon Foundation** “Closing the Loop: Linking Pelagic and Benthic Communities Through larval Production and Transport Mechanisms” PI: B. Menge. \$330,000.
- 2003-2004 **Andrew W. Mellon Foundation** “Researching Sites in South Africa: Travel Grant.” Co-PI: B. Menge. \$25,000.
- 2004-2006 **David and Lucile Packard Foundation** “Communication Partnership for Science and the Sea (COMPASS): 2004-2005; PI: Chuck Savitt; co-PIs V. Spruill, C. Harrold. \$2,000,000.
- 2004-2005 **David and Lucile Packard Foundation.** A Symposium on “Managing for Resilience: An Integrated Approach to Coastal Marine Science and Conservation”; P.I.: A.O.D. Willows, co-PIs: K. McLeod, M.P. Morse; \$45,000.
- 2005-2009 **David and Lucile Packard Foundation.** Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO): 2005-2009. Co-PIs: B. Menge, J. Barth, P. Raimondi, M.

- Carr, M. McManus, G. Somero, M. Denny, S. Palumbi, S. Gaines, B. Warner, G. Hofmann, L. Washburn. \$11,000,000.
- 2005-2009 **Gordon and Betty Moore Foundation.** PISCO (see above). \$13,543,700.
- 2004-2007 **Andrew W. Mellon Foundation.** “Dynamics of Nearshore Marine Ecosystems: Complementary Studies on Temperate Shores,” P.I. Dave Schiel; co-PI B. Menge. \$330,000.
- 2005-2006 **Andrew W. Mellon Foundation.** “The Marine Ecosystems Dynamics Consortium: Integration of the science, training and outreach missions across the consortium.” P.I.: B. Menge, Co-PIs: S. Gaines, S. Navarrete, J.C. Castilla, D. Schiel, G. Branch. \$76,000.
- 2005-2007 **David and Lucile Packard Foundation.** “Communicating the Science of Marine Reserves to Latin American Audiences. Co-PIs: Sally Hacker, Brooke Simler. \$249,969.
- 2006-2008 **David and Lucile Packard Foundation.** “Communication Partnership for Science and the Sea (COMPASS),” Co-PI: Brooke Simler. \$2,159,960.
- 2006-2008 **Gordon and Betty Moore Foundation.** “Science for Ecosystem-Based Management: COMPASS, Co-PI: Brooke Simler. \$350,022.
- 2006-2008 **The Marisla Foundation.** “Communication Partnership for Science and the Sea (COMPASS),” Co-PI: Brooke Simler. \$60,000.
- 2006-2008 **The Resource Legacy Fund Foundation.** “Communicating Marine Conservation Science along the West Coast of the U.S.” PI: Brooke Simler. \$393,010.
- 2006-2008 **Meyer Memorial Trust.** “Communicating Marine Conservation Science in Oregon,” PI: Brooke Simler. \$90,825.
- 2006-2008 **David and Lucile Packard Foundation.** “New Advances in the Science of Marine Reserves, Second Edition of “Science of Marine Reserves” Booklet. Co-PIs: Steven Gaines, Satie Airame, Brooke Simler. \$249,946.
- 2006 **Hanlon Venture Fund.** PI: F. Chan; co-PIs: B Menge, J. Barth. \$9,600.
- 2007 **Flora Family Foundation.** “Closing the Gap between Science and Action on Climate Change.” PI: Steve Pacala. \$125,000
- 2007 **Kingfisher Foundation.** “Consequences of New Low Zones of Low Oxygen along the Oregon Coast” Co-PIs F. Chan and J. Barth, \$39,059.
- 2007-2010 **Andrew W. Mellon Foundation.** PI: B. Menge. "Collaborative Research: Mechanisms Underlying Patterns of Recruitment on an Interhemispheric Scale" \$200,000; JL recused from all responsibilities as of March 2009.
- 2008 **The Marisla Foundation.** “Communication Partnership for Science and the Sea (COMPASS),” PI: Brooke Simler. \$75,000.
- 2007-2009 **The Resource Legacy Fund Foundation.** “Communicating Marine Conservation Science along the West Coast of the U.S.” PI: Brooke Simler. \$512,990.
- 2008-2009 **The David and Lucile Packard Foundation.** “PISCO Organizational Effectiveness Project: Securing the future for an integrated large marine ecosystem research program.” Co-PIs: K. Milligan and S. Gaines. \$150,000.
- 2008-2010 **The David and Lucile Packard Foundation.** “Communication Partnership for Science and the Sea (COMPASS),” PI: Brooke Simler. \$2,000,000; JL recused from all responsibilities as of March 2009.
- 2008-2009 **The David and Lucile Packard Foundation.** "Effectively communicating the science of marine reserves to a global audience" Co-PI: K. Grorud-Colvert, S. Gaines, and S. Airame. \$100,000.
- 2008 **The United Nations Foundation.** “Workshop: Global Changes in Hypoxia and Anoxia in Eastern Boundary Current Large Marine Ecosystems.” PI: P. Bernal. \$36,100.

- 2008-2010 **The Gordon and Betty Moore Foundation.** “Science for Ecosystem-Based Management: COMPASS, Co-PI: Brooke Simler. \$710,000; JL recused from all responsibilities as of March 2009.
- 2008-2011 **The Gordon and Betty Moore Foundation.** Microbial diversity and activity in the seasonal hypoxic coastal waters off Central Chile and Oregon: A comparative study” PI R. Letelier, co-PIs S. Giovannoni, O. Ulloa, J. Barth, F. Chan, C. Lange, L.Farias, A. Mix, S. Pantoja, O. Pizzaro. \$5,000,211; JL recused from all responsibilities as of March 2009.

Principal Publications¹: (Does not include abstracts or technical reports. Professional name changed from Menge to Lubchenco in 1977. Dr. Lubchenco's philosophy has been to encourage her graduate students to publish their thesis research papers independently, as opposed to co-authoring them with her. These publications are listed separately in a subsequent section.)

- 1 P 1974 **Menge, J. Lubchenco.** Prey selection and foraging period of the predaceous rocky intertidal snail, *Acanthina punctulata*. *Oecologia* 17: 293-316.
- 2 P 1974 **Menge, J. Lubchenco.** and B.A. Menge. Role of resource allocation, aggression and spatial heterogeneity in coexistence of two competing starfish. *Ecological Monographs* 44: 189-209.
- 3 P 1978 **Lubchenco, J.** and B.A. Menge. Community development and persistence in a low rocky intertidal zone. *Ecological Monographs* 48: 67-94. **Mercer Award Winner, 1979; Science Citation Classic Paper, ISI.**
- 4 P 1978 **Lubchenco, J.** Plant species diversity in a marine intertidal community: importance of herbivore food preference and algal competitive abilities. *American Naturalist* 112: 23-39. **Science Citation Classic Paper, ISI.**
- 5 P 1979 **Lubchenco, J.** Consumer terms and concepts. *American Naturalist* 113: 315-317.
- 6 P 1979 **Lubchenco, J.** Causes of zonation patterns on rocky intertidal shores. pp. 219-221 in: "Symposium on regularities of distribution and ecology of coastal marine biocoenoses." **Proceedings of the Soviet Academy of Science.**
- 7 P 1980 **Lubchenco, J.** Algal zonation in the New England rocky intertidal community: experimental analysis. *Ecology* 61: 333-344.
- 8 P 1980 **Lubchenco, J.** and J. Cubit. Heteromorphic life histories of certain marine algae as adaptations to variations in herbivory. *Ecology* 61: 676-681.
- 9 P 1981 **Lubchenco, J.** and S.D. Gaines. A unified approach to marine plant-herbivore interactions. I. Populations and Communities. *Annual Review of Ecology and Systematics* 12: 405-437. **Science Citation Classic Paper, ISI.**
- 10 P 1981 Menge, B.A. and **J. Lubchenco.** Community organization in temperate and tropical rocky intertidal habitats: prey refuges in relation to consumer pressure gradients. *Ecological Monographs* 51(4): 429-450.

Publications are listed chronologically.

Categories of publications:

P Peer-reviewed publication.

Δ Book review, commentary, editorial or opinion.

± National Academy of Sciences, National Research Council, National Science Board, or international scientific assessment reports for which Lubchenco was a primary author.

⊠ U.S. Congressional or State of Oregon testimony, U.S. Presidential briefing, or *Amicus Curiae* for the U.S. Supreme Court or State of Oregon Supreme Court.

- 11 P 1982 Gaines, S.D. and **J. Lubchenco**. A unified approach to marine plant-herbivore interactions II. Biogeographic Patterns. *Annual Review of Ecology and Systematics* 13: 111-138.
- 12 P 1982 **Lubchenco, J.** Effects of grazers and algal competitors on fucoid colonization in tide pools. *Journal of Phycology* 18: 544-550.
- 13 P 1983 **Lubchenco, J.** *Littorina* and *Fucus*: Effects of herbivores, substratum heterogeneity and plant escapes during succession. *Ecology* 64: 1116-1123.
- 14 P 1984 **Lubchenco, J.**, B.A. Menge, S.D. Garrity, P.J. Lubchenco, L.R. Ashkenas, S.D. Gaines, R. Emler, J. Lucas and S. Strauss. Structure, persistence and role of consumers in a tropical rocky intertidal community (Taboguilla Island, Bay of Panama). *Journal of Experimental Marine Biology and Ecology* 78: 23-73.
- 15 P 1985 Menge, B.A., **J. Lubchenco** and L.R. Ashkenas. Diversity, heterogeneity and consumer pressure in a tropical rocky intertidal community. *Oecologia* 65: 394-405.
- 16 P 1986 **Lubchenco, J.** Relative importance of competition vs. predation: early seaweed colonization in New England. *in* J.M. Diamond and T.J. Case (eds.) *Community Ecology* pp. 537-555. Harper and Row, New York.
- 17 P 1986 Menge, B.A., **J. Lubchenco**, L.R. Ashkenas and F. Ramsey. Experimental separation of effects of consumers on sessile prey in the low zone of a rocky shore in the Bay of Panama: direct and indirect consequences of food web complexity. *Journal of Experimental Marine Biology and Ecology* 100:225-269.
- 18 P 1986 Menge, B.A., **J. Lubchenco**, S.D. Gaines and L.R. Ashkenas. A test of the Menge-Sutherland model of community organization in a tropical rocky intertidal food web. *Oecologia* 71: 75-89.
- 19 Δ 1986 **Lubchenco, J.** Rocky shore ecology. (Review of Moore P.G. and R. Seed (eds.) *The Ecology of Rocky Coasts: essays presented to J.R. Lewis.*) *Ecology* 67: 1699.
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Teaching and Advising at OSU:

Courses:

Ecology, Marine Biology, Marine Conservation Biology, Marine Ecology, Community Ecology, Environmental Controversies, Invertebrate Zoology, Human Ecology, Marine Reserves, Marine Conservation Science and Policy and various graduate seminars. Guest lectures in various OSU courses, for example in 2003-2007: FOR-365, GEO-308, Bi-450/451.

2013-14: Z507: Science and Policy

Degrees Awarded to Graduate Students (advised jointly with B.A. Menge) (29 Ph.D.s; 10 MS.s)

(Name, degree, date, current position):

William R. Rice, Ph.D. 1980, Professor; University of California at Santa Barbara; **Dianna K. Padilla**, M.S. 1981; Ph.D., University of Alberta; Professor, State University of New York at Stony Brook; **Kenneth R. Yates**, M.S. 1982; Ph.D., 1989; Vice President of Husbandry and Life Support Systems, Long Beach Aquarium of the Pacific; unknown; **Teresa Turner**, Ph.D. 1982; Professor, College of Virgin Islands, St. Thomas, V.I.; **Steven D. Gaines**, Ph.D. 1982; Professor, Dean, Bren School for the Environment, U.C. Santa Barbara; National Graduate Advisor of the Year, 2009; **Carla M. D'Antonio**, M.S. 1982; Ph.D., U.C. Santa Barbara; Professor, U.C. Berkeley; Professor, U.C. Santa Barbara; **Christopher P. Marsh**, Ph.D. 1984; Director, Spring Island Trust, South Carolina; **Alice F. Brown**, M.S. 1985; Ph.D. Brown University; local activist; **Annette M. Olson**, M.S. 1985; Ph.D., 1992; Independent scientist; **Lani West**, Ph.D. 1986; Research Associate, University of Queensland; **Terence M. Farrell**, Ph.D.; 1987, Professor, Stetson University; **Cynthia D. Trowbridge**, Ph.D., 1989; Research Associate, Hatfield Marine Science Center, OSU; **Denise Idler**, M.S. 1992; Ph.D. University of Medicine and Dentistry of New Jersey, 2002, voluntarily unemployed; **Peter van Tاملen**, Ph.D., 1992; private consultant; **Deborah R. Brosnan**, Ph.D., 1994; Co-Founder and President, Sustainable Ecosystems Institute, Lake Oswego, Oregon, now private consultant; **Carol A. Blanchette**, Ph.D., 1994; Associate Professor, Research, U.C. Santa Barbara; **Sergio A. Navarrete**, Ph.D., 1994; Associate Professor, Catholic University, Santiago, Chile, and Director, Coastal Station of Marine Investigations (ECIM), Universidad Catolica, Las Cruces, Chile; **Deirdre Roberts**, M.S., 1995; middle school science teacher, Salinas, CA; **Eric Berlow**, Ph.D., 1995; Director, Sierra Nevada Research Institute, Wawona Field Station, Yosemite National Park (UC Merced); TED Global Fellow ; **Gary Allison**, Ph.D., 1997; Assistant Professor-Research , Ohio State University; **Karina Nielsen**, Ph.D., 1998; Associate Professor Sonoma State University; **Eric Sanford**, Ph.D., 1999; Associate Professor, University of California at Davis; **Jen Burnaford**, Ph.D., 2001; Assistant Professor, California State University at Fullerton; **Tess Freidenberg**, Ph.D. 2002; Senior Scientist, Marine Protected Areas Monitoring Enterprises, Oakland, CA.; **Matt Bracken**, Ph.D., 2003; Assistant Professor, Northeastern University; **Heather Leslie**, Ph.D. 2004; Assistant Professor, Brown University; **Roly Russell**, Ph. D. 2005; Independent Scholar; **Maria Kavanaugh**, M.S. 2005; PhD Student OSU; **John Howieson**, M.S. 2006, retired; **Anne Guerry**, Ph.D., 2006; Lead Scientist, the Natural Capital Project's Marine Conservation Initiative, Stanford University, Woods Institute; **Elise Granek**, Ph.D., 2006, Assistant Professor, Portland State University; **Chris Krenz**, Ph.D., 2007, Staff Scientist, Oceana; **Laura Petes**, Ph.D., 2007, Ecosystem Science Advisor, Climate Program Office,

NOAA; A. **Paulina Guarderas**, M.S., 2007, Instituto NAZCA de Investigaciones Marinas (a marine NGO), Ecuador; **Luis Vinueza**, Ph.D. 2009, Assistant Professor, Universidad de Ecuador; **Dafne Eerkes-Medrano**, Ph.D., 2011, Research Associate, British Antarctic Survey, Cambridge, UK; **Joe Tyburczy**, PhD. 2011, PISCO Policy Coordinator, Oregon State University.

Graduate Students initially co-advised with B.A. Menge; then advised solely by B.A. Menge when Lubchenco was at NOAA:

Alison Iles (NSERC Fellow), Ph.D. 2012; Sara Close, (NSF Fellow), Ph.D. 2013
Jeremy Rose, (NSF Fellow).

Former Postdoctoral Students (Advised jointly with Bruce Menge; 15)

1. **Elizabeth Dahlhoff**, 1993-1995; Ph.D. Scripps Inst. of Oceanography; Mellon Post Doc; Professor University of Santa Clara; **Cynthia Trowbridge**, 1993-9; Ph.D., OSU; Research Faculty, Hatfield Marine Science Center, OSU; **Sergio Navarrete**, 1994-5; Ph.D. OSU; Associate Professor and Director of Marine Laboratory, Catholic University, Santiago, Chile; **Eric Berlow**, 1995-96, Ph. D., OSU; Director, Wawona Field Station, University of California Merced; **Patricia Halpin**, 1995-2001, Ph.D., Instructor, University of California at Los Angeles; **Gary Allison**, 1997-98, Ph.D. OSU; Ohio State University Research Faculty; **Brian Grantham**, 1997-2003, Ph.D., Stanford University; Coordinator, Aquatic Research-AQUATIC Research and Development Section, Natural Resources, Government of Ontario, Peterborough, Ontario, Canada; **George Leonard**, 1998-1999; Ph. D., Brown University; Director, Aquaculture Program, Ocean Conservancy; **Carl Schoch**, Ph.D., Oregon State University; Affiliate Associate Research Professor, Alaska Ocean Observing System, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks; **Karina Nielsen**, 2000-2003; Ph. D., OSU; Associate Professor, Sonoma State University; **Francis Chan**, 2001-2004, Ph.D., Cornell University; Assistant Professor, Senior Research, OSU; **Michael Webster**, 2001-2004; Ph. D., OSU; Executive Director, The Coral Reef Alliance, Oakland, CA; **Tess Friedenborg**, 2002-2004; Ph. D., Senior Scientist, Marine Protected Areas Monitoring Enterprise, California Ocean Science Trust, Oakland CA; **Kimberly Heiman**, 2006-2008; Ph.D., Stanford; Instructor, Muhlenberg College, 2008-present; **Gil Rilov**, 2005-2007; PhD. Tel Aviv University; Senior Scientist, Department of Biology and Biotechnology, National Institute of Oceanography, Israel Oceanographic and Limnological Research, Haifa, Israel; **Karen McLeod** 2003-2007; PhD. OSU; Director of Science, COMPASS; **Sarah Dudas**, 2005-2009; Ph.D.; Canada Research Chair, University of Vancouver Island, Nanaimo, BC; **Kirsten Grorud-Colvert** 2006-2010; Ph.D. University of Miami; Schmidt Research Vessel Initiative Postdoctoral Fellow, 2010-2012.

Currently enrolled Graduate Students - :

Jessie Reimer

Professional Memberships:

American Association for the Advancement of Science
American Institute of Biological Sciences
British Ecological Society (honorary member for life)

Ecological Society of America
Association for Women in Science
American Society of Naturalists (Honorary Member for life)