Exhibit 14

http://today.oregonstate.edu/archives/2015/feb/study-outlines-threat-ocean-acidification-coastal-communities-us

Study outlines threat of ocean acidification to coastal communities in U.S.

Feb 23, 2015

CORVALLIS, Ore. - Coastal communities in 15 states that depend on the $1 billion shelled mollusk industry (primarily oysters and clams) are at long-term economic risk from the increasing threat of ocean acidification, a new report concludes.

This first nationwide vulnerability analysis, which was funded through the National Science Foundation's National Socio-Environmental Synthesis Center, was published today in the journal Nature Climate Change.

The Pacific Northwest has been the most frequently cited region with vulnerable shellfish populations, the authors say, but the report notes that newly identified areas of risk from acidification range from Maine to the Chesapeake Bay, to the bayous of Louisiana.

"Ocean acidification has already cost the oyster industry in the Pacific Northwest nearly $110 million and jeopardized about 3,200 jobs," said Julie Ekstrom, who was lead author on the study while with the Natural Resources Defense Council. She is now at the University of California at Davis.

George Waldbusser, an Oregon State University marine ecologist and biogeochemist, said the spreading impact of ocean acidification is due primarily to increases in greenhouse gases.

"This clearly illustrates the vulnerability of communities dependent on shellfish to ocean acidification," said Waldbusser, a researcher in OSU's College of Earth, Ocean, and Atmospheric Sciences and co-author on the paper. "We are still finding ways to increase the adaptive capacity of these communities and industries to cope, and refining our understanding of various species' specific responses to acidification.

"Ultimately, however, without curbing carbon emissions, we will eventually run out of tools to address the short-term and we will be stuck with a much larger long-term problem," Waldbusser added.

The analysis identified several "hot zones" facing a number of risk factors. These include:

- The Pacific Northwest: Oregon and Washington coasts and estuaries have a "potent combination" of risk factors, including cold waters, upwelling currents that bring corrosive waters closer to the surface, corrosive rivers, and nutrient pollution from land runoff;
- New England: The product ports of Maine and southern New Hampshire feature poorly buffered rivers running into cold New England waters, which are especially enriched with acidifying carbon dioxide;
- Mid-Atlantic: East coast estuaries including Narragansett Bay, Chesapeake Bay, and Long Island Sound have an abundance of nitrogen pollution, which exacerbates ocean acidification in waters that are shellfish-rich;
- Gulf of Mexico: Terrebonne and Plaquemines Parishes of Louisiana, and other communities in the region, have shellfish economies based almost solely on oysters, giving this region fewer options for alternative - and possibly more resilient - mollusk fisheries.

The project team has also developed an interactive map to explore the vulnerability factors regionally.

One concern, the authors say, is that many of the most economically dependent regions - including Massachusetts, New Jersey, Virginia and Louisiana - are least prepared to respond, with minimal research and monitoring assets for ocean acidification.

The Pacific Northwest, on the other hand, has a robust research effort led by Oregon State University researchers, who already have helped oyster hatcheries reboundfrom near-disastrous larval die-offs over the past decade. The university recently announced plans to launch a Marine Studies Initiative that would help address complex, multidisciplinary problems such as ocean acidification.

"The power of this project is the collaboration of natural and social scientists focused on a problem that has and will continue to impact industries dependent on the sea," Waldbusser said.

Waldbusser recently led a study that documented how larval oysters are sensitive to a change in the "saturation state" of ocean water - which ultimately is triggered by an increase in carbon dioxide. The inability of ecosystems to provide enough alkalinity to buffer the increase in CO_2 is what kills young oysters in the environment.

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Exhibit 15

Vulnerability and adaptation of US shellfisheries to ocean acidification

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Vulnerability and adaptation of US shellfisheries to ocean acidification

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Ocean acidification is a global, long-term problem whose ultimate solution requires carbon dioxide reduction at a scope and scale that will take decades to accomplish successfully. Until that is achieved, feasible and locally relevant adaptation and mitigation measures are needed. To help to prioritize societal responses to ocean acidification, we present a spatially explicit, multidisciplinary vulnerability analysis of coastal human communities in the United States. We focus our analysis on shelled mollusc harvests, which are likely to be harmed by ocean acidification. Our results highlight US regions most vulnerable to ocean acidification (and why), important knowledge and information gaps, and opportunities to adapt through local actions. The research illustrates the benefits of integrating natural and social sciences to identify actions and other opportunities while policy, stakeholders and scientists are still in relatively early stages of developing research plans and responses to ocean acidification.

The ocean has absorbed about 25% of anthropogenic atmospheric CO_2 emissions, progressively increasing dissolved CO_2, and lowering seawater pH and carbonate ion levels[1]. On top of this progressive global change in oceanic carbon conditions, local factors such as eutrophication[2,3], upwelling of CO_2-enriched waters[4] and river discharge[5] temporarily increase anthropogenic ocean acidification (OA)[6] in coastal waters[7–9]. Ocean acidification could primarily affect human communities by changing marine resource availability[1]. Studies have shown that, in general, shelled molluscs are particularly sensitive to these changes in marine chemistry[10–12]. Shelled molluscs comprise some of the most lucrative and sustainable fisheries in the United States[13]. Ocean acidification has already cost the oyster industry in the US Pacific Northwest nearly $110 million, and directly or indirectly jeopardized about 3,200 jobs[13]. The emergence of real, economically measurable human impacts from OA has sparked a search for regional responses that can be implemented immediately, while we work towards the ultimate global solution: a reduction of atmospheric CO_2 emissions. Yet there is little understanding about which locations and people will be impacted by OA, to what degree, and why, and what can be done to reduce the risks.

Here, we present the first local-level vulnerability assessment for ocean acidification for an entire nation, adapting a well-established framework and focusing on shelled mollusc harvests in the United States; for other evaluations of OA social vulnerability, see refs 14–16. We explored three key dimensions—exposure, sensitivity and adaptive capacity (Fig. 1, Supplementary Fig. S1)—to assess the spatial distribution of vulnerable people and places to OA. The underlying assumption guiding this assessment is that addressing existing vulnerability can reduce future vulnerability to OA, sometimes called 'human-security vulnerability'[15].

Exposure of marine ecosystems addresses acidification driven by global atmospheric CO_2 and amplified by local factors in coastal waters. We divided the coastal waters around the United States into existing National Estuary Research Reserve System bioregions[17] (Supplementary Fig. S7), and for each bioregion, examined: (1) projected changes to ocean chemistry based on a reduction in aragonite saturation state (Ω_{Ar}) (Supplementary Fig. S2), and (2) the prevalence of key local amplifiers of OA, including upwelling, eutrophication and input of river water with low-aragonite saturation state [**AU: OK?**], for each bioregion (Supplementary Figs S4–S6). Aragonite saturation state (Ω_{Ar}) is a measure of the thermodynamic stability of this mineral form of calcium carbonate that is used by bivalve larvae and other molluscs, which is also commonly used to track OA[1]. Declining Ω_{Ar} makes it more difficult and energetically costly for larval bivalves to build shells even before Ω_{Ar} becomes corrosive [**AU: is it Ω_{Ar} that becomes corrosive, or should this be OA?**], and Ω_{Ar} seems to be the important variable for the most sensitive early stage of bivalve larvae[18]. We evaluated relative exposure to anthropogenic OA as the time [**AU: i.e. 'time until', or 'the**

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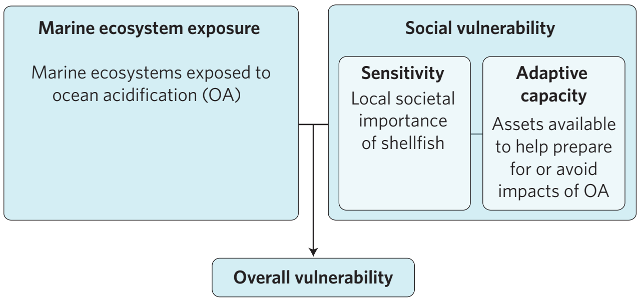

Figure 1 | Conceptual framework structuring the analysis of vulnerability to ocean acidification. Vulnerability analyses can focus on three key dimensions (exposure, sensitivity and adaptive capacity): (1) the extent and degree to which assets are exposed to the hazard of concern; (2) the sensitivity of people to the exposure; and (3) the adaptive capacity of people to prepare for and mitigate the exposure's impacts. These three dimensions together provide a relative view of a place's overall vulnerability. Adapted conceptual model components from refs 16,52–55.

extent of time for which'?] mean annual surface seawater exceeds an empirically informed absolute Ω_{Ar} threshold for several species of bivalve larvae. This indicator for disruption to the biological processes of calcification and development in larval molluscs was favoured over alternatives (for example time until the historic range of Ω_{Ar} is exceeded) because the biological mechanism was clear[19] and empirical evidence exists[20]. For comparison purposes, the Supplementary Information includes the time until the historic range of Ω_{Ar} is exceeded (Supplementary Fig. S3), but below we document the outcomes based on the Ω_{Ar} threshold projections and local amplifiers of OA.

Sensitivity of social systems was evaluated at the scale of 'clusters of coastal counties' around the United States, using three indicators of community dependence on shellfish, adapted from the National Marine Fisheries Service's fishing community vulnerability and resilience index[21]: (1) the 10-year median landed value of shellfish (including both wild and aquaculture harvests); (2) the 10-year median proportional contribution of shellfish to total value of commercial landings; and (3) the 5-year median number of licences (representing jobs) supported by shelled mollusc fishing (Supplementary Information). Sensitivity indicators were re-scaled and combined into a single index (Supplementary Information and Supplementary Fig. S8).

Adaptive capacity of social systems to cope with and adapt to OA is represented by three classes of indicators: status of state government climate and OA policies, local employment alternatives and availability of science. We examined a total of six indicators representing adaptive capacity that are derived largely from the broader economic and policy landscape, yet are directly relevant for dealing with the threat of OA (Supplementary Fig. S9). This is a deliberate departure from studies conducted at broader and finer geographic scales that use general demographic indicators (see Supplementary Information). We assessed 'potential government support for adaptation' through measures of: (1) the status of state legislative action on OA and (2) the status of state climate adaptation planning. These indicators reflect social organization and assets at the state jurisdictional level that could be used by communities to adapt to, cope with, or avoid the impacts of lost shellfish harvests. We examined aspects of employment alternatives through: (3) the diversity of shelled mollusc harvests, suggesting potential alternative shellfish that could be harvested and (4) the diversity of non-shellfish-related employment industries. These reflect the likelihood of job alternatives for shellfish harvesters and those in the aquaculture industry. Finally, we captured 'access to and availability of science' through (5) a score for marine laboratories developed to take into account the high local influence that such laboratories can have as well as the potential contribution beyond their immediate vicinity. For each county cluster, a metric based on the number of university marine laboratories (on-campus and satellite laboratories) in that county cluster was averaged with a metric based on the total number of university marine laboratories in that state (see Supplementary Information for more information) and (6) Sea Grant state budgets normalized by shoreline length. These indicators represent the availability of local scientific capacity, the potential for troubleshooting assistance, and the possibility of access to a range of tools and data products, such as available early warning information. We attributed each county cluster (as used in Sensitivity) to each variable score of the six indicators. We then combined into a single index by averaging re-scaled (0–1) overall component scores for sensitivity and adaptive capacity (Supplementary Information Fig. S9). Coincidence of high marine ecosystem exposure to OA with high sensitivity and low adaptive capacity of social systems reveals the areas at highest overall vulnerability to OA.

Places vulnerable to ocean acidification

Our results show that 16 out of 23 bioregions around the United States are exposed to rapid OA (reaching Ω_{Ar} 1.5 by 2050) or at least one amplifier (Fig. 2; Supplementary Table S1); 10 regions are exposed to two or more threats of acidification (note that Alaska and Hawaii are missing local amplifier data; Fig. 2). The marine ecosystems and shelled molluscs around the Pacific Northwest and Southern Alaska are expected to be exposed soonest to rising global OA, followed by the north-central West Coast and the Gulf of Maine in the northeast United States. Communities highly reliant on shelled molluscs in these bioregions are at risk from OA either now or in the coming decades. In addition, pockets of marine ecosystems along the East and Gulf Coasts will experience acidification earlier than global projections indicate, owing to the presence of local amplifiers such as coastal eutrophication, upwelling and discharge of low-Ω_{Ar} river water (see Supplementary Figs S4–S6, Supplementary Table S1).The inclusion of local amplifiers reveals more coastline segments around the United States that are exposed to acidification risk than when basing exposure solely on global models.

Combining sensitivity and adaptive capacity reveals that the most socially vulnerable communities are spread along the US East Coast and Gulf of Mexico (Fig. 2), yet the sources of high social vulnerability are very different between these two regions (see Supplementary Information for breakdown separated by sensitivity and adaptive capacity, Figs S8 and S9). Specifically, the East Coast is dominated by high levels of sensitivity, or economic dependence, from strong use of shellfish resources. For example, southern Massachusetts measures as having the highest sensitivity. This county cluster ranks in the top four for all three sensitivity indicators (Supplementary Fig. S8), meaning that this area has the highest mollusc harvest revenues of any coastal area in the United States, second highest number of licences and fourth highest proportion of seafood revenues coming from molluscs. In contrast, the Gulf of Mexico region is socially vulnerable from low adaptive capacity, owing to social factors such as low political engagement in OA and climate change, low diversity of shellfish fishery harvest and relatively low science accessibility (Supplementary Fig. S9).

Importantly, our visually combined overall vulnerability analysis reveals that a number of socially vulnerable communities lie adjacent to water bodies that are exposed to a high rate of OA or at least one local amplifier, indicating that these places could be at high overall vulnerability to OA (Fig. 2). The areas that are exposed to OA (including local amplifiers) and high and medium–high social vulnerability coincide include southern Massachusetts, Rhode Island, Connecticut, New Jersey and portions around the

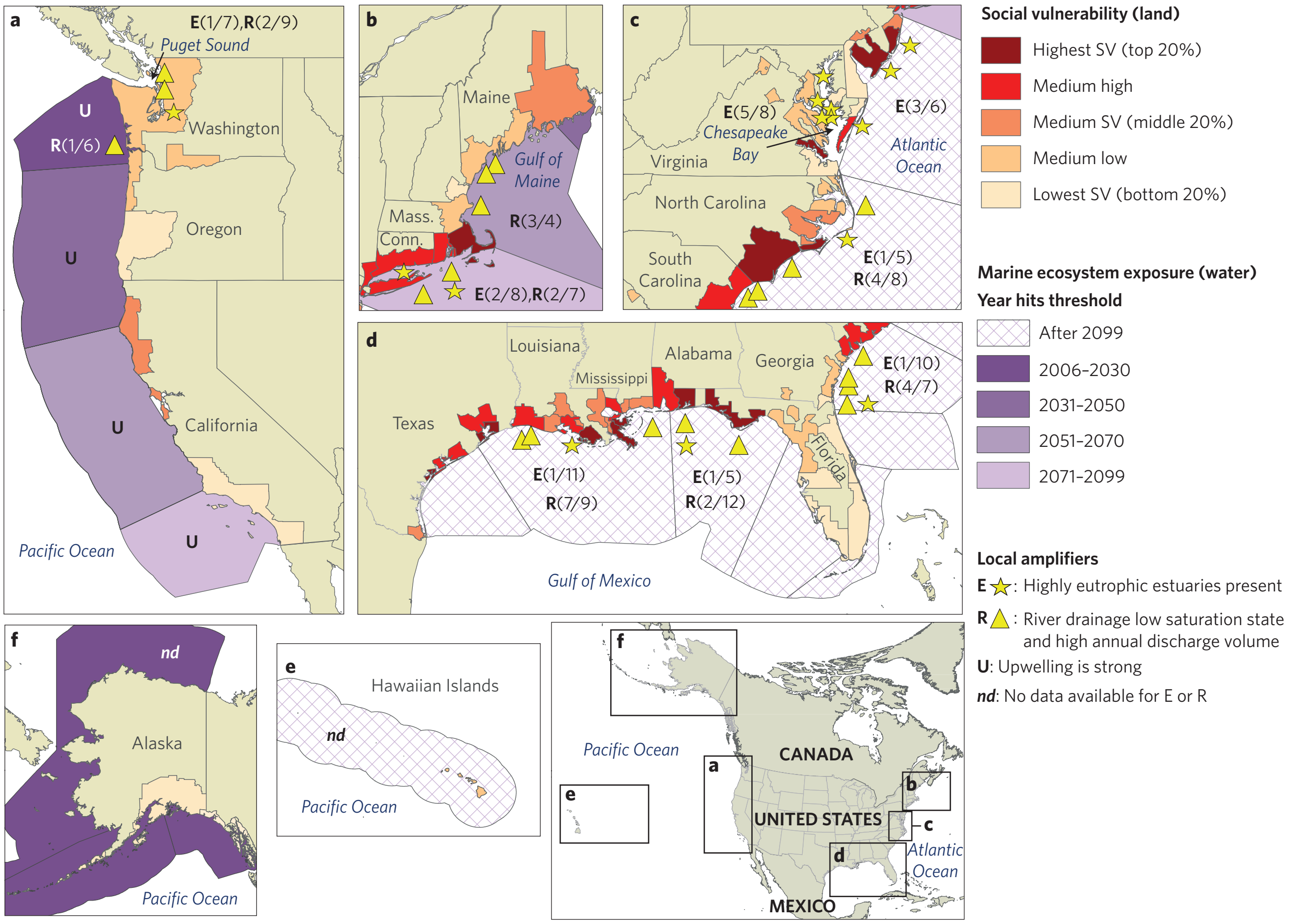

Figure 2 | Overall vulnerability of places to ocean acidification. Scores of relative social vulnerability are shown on land (by coastal county cluster) and the type and degree of severity of OA and local amplifiers to which coastal marine bioregions are exposed, mapped by ocean bioregion: (a) contiguous US West Coast; (b) Northeast; (c) Chesapeake Bay; (d) Gulf of Mexico, and Florida and Georgia's coast; (e) Hawaii Islands; and (f) Alaska. Social vulnerability (red tones) is represented with darker colours where it is relatively high. Exposure (purple tones) is indicated by the year at which sublethal thresholds for bivalve larvae are predicted to be reached, based on climate model projections using the RCP8.5 CO_2 emission scenario[27]. Exposure to this global OA pressure is higher in regions reaching this threshold sooner. Additionally, the presence and degree of exposure to local amplifiers of OA are indicated for each bioregion: E(*x*/*y*) marks bioregions [**AU: OK?**] in which highly eutrophic estuaries are documented, *x* is the number of estuaries scored as high, and *y* is the total number evaluated in each bioregion (source: ref. 56), locations of highly eutrophic estuaries are marked with a star; R(*x*/*y*) marks bioregions in which **sampled river water draining into bioregion scored** [**AU: this description is not clear grammatically: should it be 'bioregions in which... water was scored', or is something missing here? Also, does 'scoring in the top quintile' here mean top quintile of discharge volume only? Please clarify phrasing**] based on very low saturation state and high annual discharge volume (top quintile, calculated by authors from US Geological Survey[57]), *x* is the number of rivers scoring in the top quintile of those evaluated, and *y* is the total number evaluated in this study. Approximate locations of river outflows of those rivers scoring in the top quintile are marked with a delta [**AU: a yellow triangle?**]; and U marks bioregions where upwelling is very strong in at least part of the bioregion (source: ref. 58).

Chesapeake Bay, the Carolinas, and areas across the Gulf of Mexico (Fig. 2b–d). Interestingly, global ocean models that project the advance of OA, primarily as a result of atmospheric CO_2, do not reveal these areas as exposed to global OA until after 2099, based on our study's Ω_{Ar} threshold (Table 1). The marine ecosystem exposure in the areas located along the Atlantic coast and the Gulf of Mexico is from low-Ω_{Ar} conditions caused primarily by the addition of river water and eutrophication, local factors that have only more recently been considered major amplifiers of nearshore acidification[6,7]. These coastal processes are likely to tip coastal oceans past organism thresholds as atmospheric CO_2 uptake continues in the future (see ref. 22). Although the Pacific Northwest, northern California and Maine exhibit only medium and medium–low social vulnerability (Fig. 2a,b), these areas are particularly economically sensitive and lie adjacent to marine ecosystems highly exposed to global OA[23,24] (sensitivity, Supplementary Fig. S8). This profile of relatively high dependency and high exposure in these three regions has already activated significant research and local action/engagement among local scientists, government and shellfish growers (see for example refs 25,26). This engagement has driven up adaptive capacity (based on our study's indicators) in these areas, which reduces their social vulnerability relative to other regions across the United States. In comparison, the lower level of OA-related action in other regions such as the Gulf of Mexico (Fig. 2d), Massachusetts (Fig. 2b) and Mid-Atlantic (Figs 2c,d) with high overall vulnerability profiles might be partly because their marine ecosystem exposure is dominated by the presence of local OA amplifiers rather than global OA (Supplementary Fig. S2, Supplementary Table S1). At the same time, some of these areas (for example Maryland) do have strong advocates for addressing water quality which could provide an opportunity to address locally driven acidification as awareness of the issue grows.

[AU: Please indicate where Table 2 should be cited in the text.]

Table 1 | Indicators of drivers and amplifiers of ocean acidification, and the criterion for each used in this study.

Factors causing and amplifying OA (reducing Ω_{Ar})	Indicator	Scoring scale	Criterion for ranking the risk factor as 'high'
Rising atmospheric CO_2 reduces Ω_{Ar} causing chronic stress to shelled mollusc larvae	Projected year that surface water will reach 1.5Ω_{Ar} (ref. 27)	Continuous scale from current year to 2099	1.5Ω_{Ar} threshold reached by 2050
Eutrophication increases pCO_2 locally via respiration, leading to reduced Ω_{Ar}	Degree of eutrophication[56]	Eutrophication scored on a five-point scale: low to high	Presence of a high-scoring eutrophic estuary in bioregion
River water can reduce Ω_{Ar} locally in coastal waters	Combined metric of river's aragonite saturation state and annual discharge volume	Rivers scored on a five-point scale: low to high	Presence of high scoring river (for low aragonite saturation and high discharge volume) in bioregion
Significant seasonal upwelling delivers water rich in CO_2 to shallow waters, leading to reduced Ω_{Ar}	Degree of upwelling[58]	Coastal zones scored on a five-point scale: low to high	Presence of high upwelling zone in bioregion

Table 2 | Indicators representing 'sensitivity' (people's dependency) on organisms expected to be affected by ocean acidification (in this study, shelled molluscs).

Indicator or measure	Source	Raw format	Processing for subindex
Landed value (median of 10 years)	Regional fisheries databases (ACCSP, GulfBase, PacFIN), and States of Alaska and Hawaii	US dollars, annual	Calculated median for years 2003–2012 Winsorized the top 10%
Percentage of shellfish by value **[AU: i.e. as percentage of all fish caught?]** (median of 10 years)		For each year: shelled molluscs value/total commercial landed value	Divided landed value of shellfish by landed value of all fish Winsorized the top 10%
Number of licences as proxy for jobs (median over 5 years)		Number of commercial licences, annual	Winsorized the top 10%

All indicators are in units of county clusters.

Robustness of analysis

To examine the robustness of these spatial patterns of vulnerability, we varied the index aggregation methodology and the selection of indicators. To test the difference in index aggregation methods for social vulnerability, we compared the output of adding and multiplying sensitivity and adaptive capacity indices and found little difference; the same set of county clusters made up the top 10 most socially vulnerable places using either aggregation method.

To explore the effect of indicator selection on adaptive capacity (and thus social vulnerability), we compared a set of commonly used generic indicators for adaptive capacity relating to income, poverty, education and age with the set of threat-specific indicators developed for this study (see Table 3 and Supplementary Figs S10 and S11). Using the generic capacity measures to calculate social vulnerability, we found that six of the same county clusters measured within the top 10 highest socially vulnerability places in the United States as those found using the threat-specific indicators (see Supplementary Information for analysis and maps). This is considerable overlap given that the two sets of variables indicate entirely different notions of adaptive capacity. Because the sensitivity indicators were developed and vetted by fisheries social science researchers[21] and alternative potentially appropriate data were not available nationwide, we did not have a useful comparison for this element from which to draw.

To explore the criterion for Ω_{Ar}, we examined one alternative for disruption of biological processes with respect to rising atmospheric CO_2: the time until average surface waters move outside the present range of Ω_{Ar} (that is, exceeding a historic envelope)[27]. The map generated by this 'historic envelope' approach shows that southern areas experience potential OA exposure earlier, which is nearly an inverse pattern to our chosen criterion of a chemical threshold when calcification and development of larval molluscs may decrease (Supplementary Fig. S3). This difference in patterns is because natural variability is much smaller in southern regions, although evidence of greater sensitivity in populations of bivalves that live in tropical and subtropical waters is lacking. This discrepancy underscores the need for targeted research integrating a physiological, ecological and evolutionary perspective on the potential and limitations of strong local biological adaptation to different carbonate regimes for commercially valuable shelled mollusc populations.

Overall, we found that variable selection has stronger effects than aggregation methods, which provides high confidence in our aggregation methods for social vulnerability. The differences found in variable selection identify research needs relating to what factors underlie vulnerability on the ground that are relevant to OA; this conversation has only just begun.

Opportunities to reduce vulnerability to ocean acidification

Social–environmental syntheses, including vulnerability analyses, can help to identify opportunities for actionable solutions to address the potential impacts of ocean acidification. Our analysis reveals where and why the overall vulnerability from OA varies among the many coastal areas of the United States, and thus identifies opportunities to reduce harm.

One way to tackle OA is by reducing marine ecosystem exposure to it. Several portions of the east coast are highly exposed to OA from high levels of eutrophication (Fig. 2b–d). In addition to releasing extra dissolved CO_2 and enhancing acidification, eutrophication can also decrease seawater's ability to buffer further acidification[3]. People in these regions are uniquely positioned to reduce exposure to OA through regional actions by curtailing eutrophication (as compared, for example, with regions exposed to upwelling). Although a significant challenge, reducing nutrient loading to the coastal zone in these areas could provide multiple benefits, making it a no-regrets option. Reducing eutrophication can decrease hypoxia and harmful algal blooms, in addition to reducing risk from fossil-fuel-derived OA at the local and regional level. Policy

Table 3 | Threat-specific indicators used to assess capacity of fishing communities to deal with impacts of ocean acidification.

Group	Indicator	Source	Raw format	Processing for subindex
Access to scientific knowledge	Budget of Sea Grant programmes	National Sea Grant	State-level total funds of budget (state and federal contributions combined, 2013)	• Re-scaled (0–1) • Attributed normalized scores to each county cluster
	Number of university marine laboratories	Direct count from registries and Internet	Latitude/longitude location of laboratories	• Combined score of laboratories per state/ shoreline length and labs per county cluster
Employment alternatives	Shelled mollusc diversity	Regional fisheries databases (ACCSP, GulfBase, PacFIN), and States of Alaska and Hawaii	Ratio of landing revenues for each taxon by county cluster	• Calculated Shannon Weiner Diversity Index
	Economic diversity	ACS Census	Proportion of county population employed in each industry	• Calculated Shannon Weiner Diversity Index for county clusters
Political action	Legislative action for OA	Keyword searches on legislature websites and follow-up calls	Established five-point scale for state's legislative progress on OA	• Re-scaled 0–1 • Attributed score to county clusters
	Climate adaptation planning	Georgetown Law School Climate programme website	Status of climate adaptation plan for state	• Re-scaled 0–1 • Attributed score to country clusters

See Supplementary Information for discussion and presentation of alternative indicators and measures.

instruments to reduce eutrophication exist in the United States[28] and can be leveraged to facilitate efforts to reduce OA[8].

Another important way to combat the effects of OA will be by reducing social vulnerability. In regions where high sensitivity (one component of social vulnerability) arises from the structure of the fishing industry, an entirely different approach to adaptation may be more appropriate than those geared to reduce marine ecosystem exposure. For example, where fishery harvest portfolios are dominated by a single species, such as in the Gulf of Mexico where mollusc production is limited to the eastern oyster (*Crassostrea virginica*), diversification of the species harvested might be a beneficial strategy.

A further way to reduce social vulnerability may be by increasing adaptive capacity of people and regions. Access and availability to science already has helped shellfish aquaculturists in the Pacific Northwest to identify and avoid some of the consequences of OA[20]. Working with local scientists, hatcheries have implemented several strategies to adapt and mitigate OA effects on bivalve seed production. Through local industry–research partnerships in the Pacific Northwest, implementation of real-time monitoring of saturation state, chemical buffering of water, changes in timing of seasonal seed production and use of selectively bred lines of oyster broodstock, this collaboration has prevented collapse of the regional oyster industry.

In every case, when developing a broader array of adaptation strategies, it is critical to work directly with the coastal communities in each region so they can develop context-appropriate and feasible adaptation options. Targeted projects to develop local adaptation plans may even require developing further regionally relevant indicators of adaptive capacity and community resilience that this nationwide study does not capture. In fact, zooming in to assess particular regions at a higher resolution would enable regional stakeholders to provide input into a possible different set of variables that defines vulnerability in their particular region based on values and social or economic context.

Barriers to and path forward for addressing OA

This study offers the first nationwide vulnerability assessment of the spatial distribution of local vulnerability from OA focusing on a valuable marine resource. But it is just a first step to understanding where and how humans and marine resources are at highest risk to OA and its local amplifiers. Another key finding of this assessment is that significant gaps in the scientific understanding of coastal ocean carbonate dynamics, organismal response and people's dependence on impacted organisms limit our ability to develop a full suite of options to prepare for, mitigate and adapt to the threats posed by OA, and these can be considered in a structured way using the framework (Fig. 3). The types of gaps identified—as commonly classified in information science and other disciplines[29,30]—range from data inaccessibility to knowledge deficiencies.

Marine ecosystem exposure. Key gaps remain in understanding how global and local processes interact to drive nearshore OA, and how this will affect marine organisms and ecological systems. Recent studies suggest that the biogeochemical interaction between global OA and local amplifiers is additive[3,22,31]; however, most ocean models used to project future OA cannot adequately resolve these processes, which are also increasingly affected by human activity[7,32]. Even though direct measurements incorporate an ever-growing global network of monitoring instruments, they are often located offshore and remain too sparse in space and time to resolve the dynamics of seawater chemistry near shore, where most shellfish live. Historically, OA monitoring has focused on offshore regions, where long-term, high-accuracy and precise measurements enabled detection and attribution of the rising atmospheric CO_2 acidification signal. But many commercially and nutritionally important organisms live in the coastal zone where they experience the combined effects of multiple processes that alter the carbonate chemistry[7]. This results in greatly variable 'carbonate weather' for a given location[33]. Characterizing this variation, including modelling how rising atmospheric CO_2 will increase the frequency, duration and severity of extreme events **[AU:OK?]**, would provide a fuller picture of how OA is unfolding within the dynamic coastal waters.

To improve our understanding of which marine ecosystems and organisms are most susceptible to ocean acidification, additional information on the Ω_{Ar} thresholds below which reproduction and survival are disrupted is needed. In the US context, the

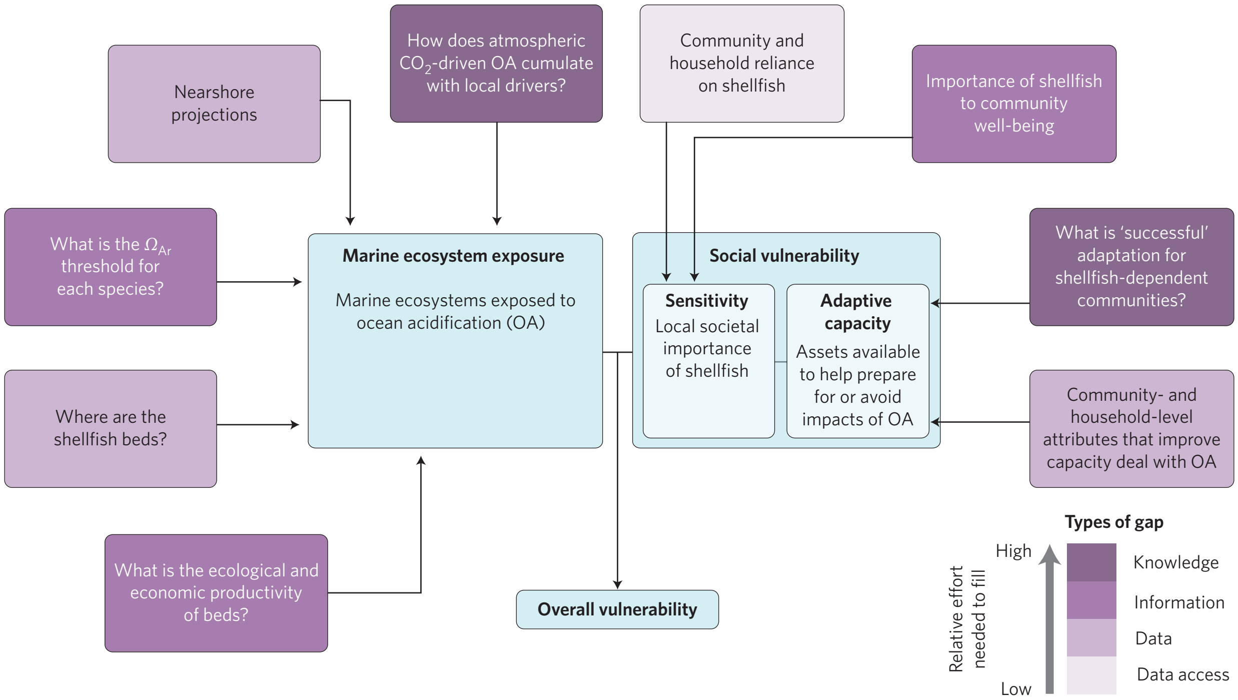

Figure 3 | Sample of gaps in knowledge related to OA vulnerability, information and data organized around components of the framework. Different types of gaps are classified by the level of effort that is required to fill them (gaining knowledge is the most challenging, whereas data access tends to be the most straightforward).

concentration of value in a limited number of shellfish species means that the identification of biologically susceptible and resistant species and populations is both prudent and feasible. Based on total landed value from 2003 to 2012, approximately 95% of shelled-mollusc revenues in the United States come from only 10 species (and 80% from five). These species include sea scallop (52.9%), eastern oyster (11.3%), Pacific geoduck (5.8%), Pacific oyster (5.2%) and six species of clam (that range from 5% to 2.6% of total value)[34]. There is some evidence of local biological adaptation of other marine taxa to varying carbonate chemistry regimes[35–37]. This potential genetic variation, if present, could be documented to aid in the development of resistant strains of cultured or other organisms.

Social vulnerability. Our study also revealed large gaps in information about mollusc-dependent communities to inform measures of social vulnerability. We do not have high-resolution nationwide data on the full cultural and societal significance of shelled molluscs. Even data on the contributions of shellfish to human nutrition, shoreline protection, and water filtration were inadequate nationwide. Incorporation of these other ecosystem services provided by molluscs could alter the social vulnerability landscape. For the commercial fisheries data that we did obtain, confidentiality constraints forced us to aggregate our analysis into county clusters, preventing county-specific or port-level analyses of social vulnerability that might have revealed more spatial heterogeneity. We also lack social science data that describe use at species-, human community-, port- or household levels. We lack data on the value chain that links threatened organisms to harvesters, processors and end-users. Finally, empirically tested adaptive capacity measures could contribute to a more rigorous evaluation of social vulnerability. This includes data on scientific spending and infrastructure directly relevant to end-users, as well as social and demographic data that are reflective of end-users (for this study, fishing and aquaculture communities) and not the general population (for example generic indicators quantifying education and income).

Beyond helping in prioritizing and developing adaptation strategies, social science is also useful to inform and guide planning for social adaptation and mitigation. As with climate change adaptation, preparing for and adapting to the impacts of OA is a social process[1,38,39]. Implementation does not occur automatically once strategies are developed, but instead must often overcome a suite of institutional (including legal), political, psychological and other types of barriers[40]. As learned from climate change initiatives, the 'softer side' of adaptation (such as coordination among stakeholders, industry and scientists) is the first step towards preparing for a threat like OA[41]. Despite its fundamental importance, this type of effort is often overlooked and remains underfunded. Social science can also help practitioners even in early stages of adaptation figure out how to engage public and policy-makers effectively in OA issues[42–44]. Farther along in adaptation processes, social science can inform the development of strategies by accounting for social values[45,46] and existing property rights in use and norms[47,48] and even helping to work out what type of information is salient for and trusted by decision-makers[49,50]. Although important for reducing its risks, social science relevant for understanding OA has been minimal thus far. A budget assessment conducted by the Interagency Working Group on Ocean Acidification reported that federal research in fiscal year 2011 allocated $270,000 of Federal funds for social science research related to OA, which represents 0.9% of the entire OA spending for that year's budget[51].

Conclusions

As with other global environmental changes, acidification of the oceans is a complex and seemingly overwhelming problem. Here we have focused only on OA (and nearshore amplifiers) as the threat to coastal species. Although other stressors also threaten coastal ecosystems, our single-threat assessment allows us to tease out where OA in isolation could hit people and organisms the hardest, which can inform research agendas and decision-making geared specifically to address OA. A vulnerability framework helps to structure our thinking about the ways in which ocean acidification will affect ecosystems and people. The framework also helps to identify and organize the opportunities and challenges in dealing with these problems. But this study is the beginning; adaptation to OA and other global environmental change is an iterative process that requires both top-down and bottom-up processes. Our analysis of OA as it relates to [**AU: OK**?] US shelled mollusc fisheries makes clear just how much the pieces of the OA puzzle vary around the country. Marine ecosystem exposure, economic dependence and social capacity to adapt create a mosaic of vulnerability nationwide. An even more diverse set of strategies may be needed to help shellfish-dependent coastal communities adapt to OA. Rather than create and apply a nationwide solution, decision-makers and other stakeholders will have to work with fishing and aquaculture communities to develop tailored locally and socially relevant strategies. Meaningful adaptation to OA will require planning and action at all levels, including regional and local levels, which can be supported with resources, monitoring, coordination and guidance at the national level.

Over the past decade, scientists' understanding of ocean acidification has matured, awareness has risen and political action has grown. The next step is to develop targeted efforts tailored to reducing social and ecological vulnerabilities and addressing local needs. Tools like this framework can offer a holistic view of the problem and shed light on where in the social–ecological system to begin searching for locally appropriate solutions.

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Author contributions
All authors provided input into data analysis and research design, and participated in at least one SESYNC workshop; J.A.E. led the drafting of the text with main contributions from L.S., S.R.C., L.H.P., G.G.W. and J.E.C.; R.v.H. contributed projections of ocean acidification; J.A.E., L.S., S.R.C., J.R. and C.D. collected the data; J.A.E. carried out data analysis and mapping.

Additional information
Supplementary information is available in the online version of the paper. Reprints and permissions information is available online at www.nature.com/reprints. Correspondence should be addressed to J.A.E.

Competing financial interests
The authors declare no competing financial interests. [**AUTHORS: OK?]**

Exhibit 16

https://newfoodeconomy.org/ocean-acidification-oysters-dungeness-crabs/

The ocean is changing faster than it has in the last 66 million years. Now, Oregon oysters are being farmed in Hawaii. That fix won't work forever.

November 28th, 2017
by H. Claire Brown

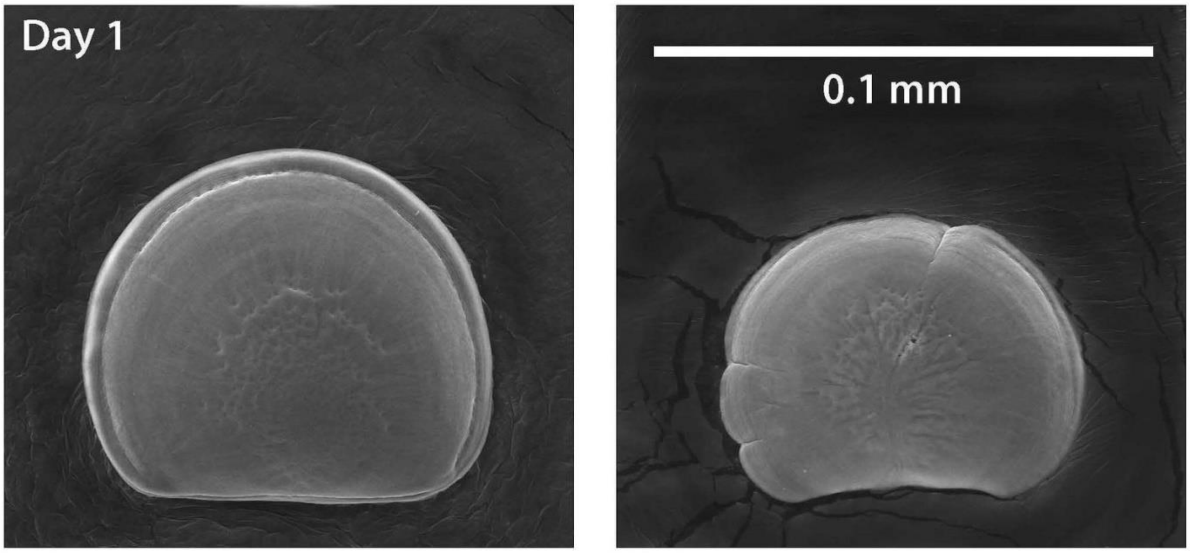
A little more than ten years ago, a mysterious epidemic wiped out baby oyster populations. It started in 2006, when Whiskey Creek shellfish hatchery in Oregon lost 80 percent of its cultured larvae. Around the same time, 200 miles north in Washington, Taylor Shellfish saw similarly high mortality rates. And oysters in the wild weren't faring much better: Oystermen who usually sourced larvae from Washington's Willapa Bay, one of the largest natural oyster-producing estuaries in the country, weren't finding enough stock to seed their beds.

It wasn't long before the epidemic migrated to the East Coast. In the Gulf of Maine, hatchery owner Bill Mook began to notice larval die-offs and slowed growth rates following big storms that pumped fresh water into his hatchery starting in 2009. Sometimes, the surviving organisms were severely deformed. No one knew exactly what had gone wrong.

> After two years of massive losses, scientists discovered what was really wrong.

Suspecting bacterial infection or a problem with the feed, Whiskey Creek and Taylor Shellfish invested in machines that kill *vibrio tubiashii,* a bacteria that is a common culprit in oyster larvae die-offs. Survival rates didn't improve.

But after two years of massive losses and no answers, scientists testing the waters discovered what was really wrong: the ocean water flowing into the hatcheries had changed, and the oysters weren't able to build their shells. Without shells, they couldn't survive.



Flickr / Oregon State University

Oyster larvae in normal conditions (left) versus oyster larvae in acidified conditions (right)

Larval oysters experience a crucial phase in their life cycle where they morph from a form not unlike free-floating dust particles into lentil-sized bivalves with the beginnings of a shell. In order to start building that shell, the larvae need to use carbonate ions from their surroundings. But seemingly all of a sudden, the ocean waters flowing into the hatcheries on the Pacific Coast had a lower concentration of carbonate ions than usual, meaning the larvae missed the dust-to-lentil growth phase that turns them into tiny oysters. As a result, most of them died.

But why had the carbonate ions dipped in the first place? Researchers discovered that the underlying cause was more than a couple years of bad luck or a minor disturbance in tidal patterns. In the mid-aughts, a global shift, which had been quietly altering the ocean's chemistry for hundreds of years, had finally washed up on the shores of the Pacific Coast. And oyster larvae, some of the most vulnerable, valuable, and closely-monitored creatures in the sea, were the first recognized victims of a process that had already started to affect aquatic life across the globe: ocean acidification, a climate change-related process that is gradually lowering pH levels in the water that covers 97 percent of the earth.

> It took a human story to get the public and local representatives to pay attention to the problems at hand.

The Whiskey Creek hatchery story made the front page of the *Seattle Times* in 2009. Several years later, in 2013, the Royal Swedish Academy of Sciences published a report analyzing the media's treatment of the Whiskey Creek oyster die-offs. In that paper, the authors took a look at the relationship between the hatcheries, the media, and scientific research. What they found was that, at the time of the die-offs, a "landmark" paper had already been published by researchers at Seattle's Pacific Marine Environmental Library showing that ocean acidification was impacting the Pacific Northwest. Which means scientists *knew* the problem was a real threat, but the public hadn't yet caught on. It wasn't the authoritative research paper that got people to pay attention. It was the loss of the seed stock for an entire sector of the economy.

The researchers found that it took a human story—a $136 million industry in the United States, employing thousands of people, turned on its head—to get the public and local representatives to pay attention to the problems at hand. Years of scientific papers couldn't accomplish what the Whiskey Creek story demonstrated in short order: When people's lives are affected, legislators hear about it. Washington's then-governor Christine Gregoire soon formed a Blue Ribbon Panel on Ocean Acidification. The panel made policy recommendations, ultimately positioning Washington State as a national leader in ocean acidification research and planning.

Flickr / Louisiana Sea Grant College Program Louisiana State University

Oyster hatcheries raise larvae into seed oysters, pictured above, then sell them to farmers. Once an oyster as reached this size, it can survive in acidified conditions

But despite one state government's proactive stance on changing seas, ocean acidification-related problems have continued to creep toward other parts of the seafood industry. And now, researchers find themselves racing to grasp the implications of a tangled underwater web that includes global warming, ocean acidification, natural seawater patterns, long-term weather events like El Niño and La Niña, and changing fishery management practices.

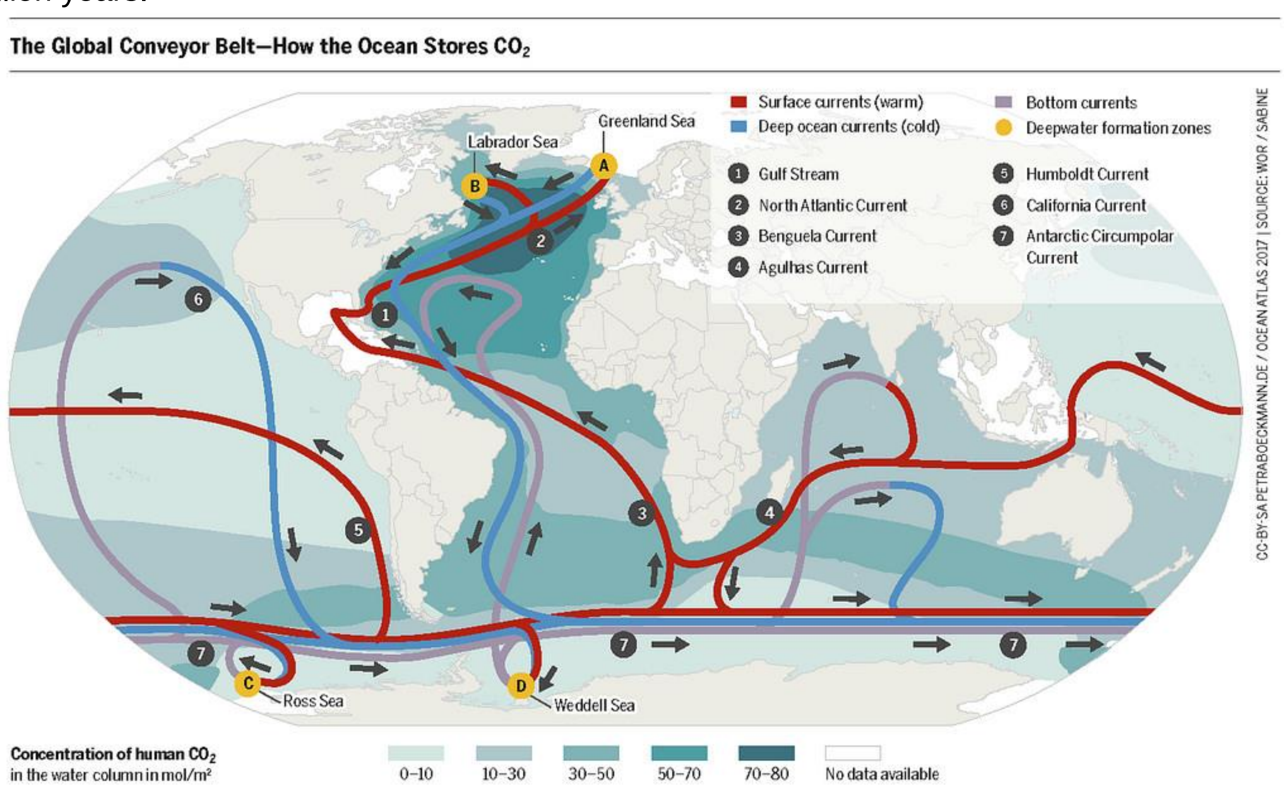
Ocean water has a birth place. It begins as melting ice somewhere in the North Atlantic, where the newly-formed cold water sinks to the bottom and floats slowly past the equator. It then falls into a rhythm, flowing along the depths and rising to the surface in a global "conveyor belt" that has carried water on the same path for millennia. It takes ten thousand years for a droplet to make its way to the end of the belt, where it emerges, marked with chemical signposts dating further back than written language, off the coast of Washington and Oregon.

As we know, the ocean itself is also changing. It absorbs about a quarter of the carbon dioxide that humans release into the atmosphere and most of the heat from human activities. Scientists have been studying the *warming* ocean for a while—that's how we learned about sea-level rise and coral bleaching—but until the mid-1990s, no one really understood that the chemical content of the ocean was being altered, too.

The change in ocean water pH levels likely has a million different effects on marine life.

The term "ocean acidification" refers to a change in oceanic pH. Whereas the pH of the ocean used to be 8.2, it's now hovering around 8.1. And even though that doesn't *sound* like a big difference, pH is measured on a logarithmic scale—which means, for those of us who haven't thought about logs since the SATs, that the ocean is actually about 30 percent more acidic than it used to be. It's expected to hit pH 7.8 by the end of the century.

Here's another way to look at it: The ocean is currently acidifying faster than it has in the last 66 million years.



CO_2 entrapment is made possible by large oceanic currents. Working like conveyor belts, they carry warm surface water, which absorbs CO_2, from the tropics in the Atlantic towards the colder poles.
On the way, the water slowly cools and becomes saltier. When it arrives in the Greenland Sea (A), the Labrador Sea (B), and at the Antarctic coast in the Ross Sea (C) and the Weddell Sea (D), the heavy surface water sinks into the depths, taking the CO_2 with it. The CO_2-rich water then flows back towards the tropics. As it travels, the cold water slowly mixes with the warmer layers above and rises—very slowly—back to the surface.

Flickr / Heinrich-Böll-Stiftung Follow

Water moves between the surface and the ocean floor as it advances along the conveyor belt

It helps to think about pH in human terms. A healthy human body typically has a pH of around 7.4, and it fluctuates very little. A change of 0.3 or 0.4—the same amount the ocean is expected to change by the end of the century—can induce a coma. If body pH rises or falls by 0.5 or more, the results are deadly. So while we don't know exactly what's happening to the organisms that live in the ocean, we know that their environment is changing more rapidly than ever, at rates that would cause serious problems for the human body.

(It's important to note that the ocean isn't actually going to turn to acid by 2100. Shallin Busch, a scientist at NOAA, explains it this way: "The North Pole is a fundamentally cold place, but we say that it's warming. Not that it's going to get warm, but that it's warm*ing.* So you can say the same thing about ocean waters: they're acidifying or becoming more acidic, but they are not acidic themselves.")

But why did ocean acidification appear in the Pacific Northwest before it showed up in Maine?

> The change in ocean water pH levels likely has a million different effects on marine life.

As I described, water moves between the surface and the ocean floor as it advances along the conveyor belt. In the Pacific Northwest, for instance, the water that welled up during the summer the oyster larvae were dying off had last seen the surface about half a century before, north of Hawaii, where it absorbed some of the atmospheric carbon being released at that time. So it's not as though the waters off Seattle are just carrying carbon emissions from the Amazon headquarters they flowed past two days ago—rather, they're carrying the carbon from all the times they welled up to the surface since the Industrial Revolution. "We know that even if all carbon dioxide emissions ceased today, the waters off the Pacific Northwest would continue to acidify for at least another 50 years, so the train is already coming," says Busch.

The water in the Pacific near Washington is at the end of the conveyor belt, and because it's so old it contains a lot of carbon dioxide from the natural decomposition of the organisms that have been dying in it for thousands of years. So when the *added* carbon dioxide from human emissions is mixed with this already-carbon-rich environment during upwelling events, the combination is enough to kill oyster larvae.

Flickr / Louisiana Sea Grant College Program Louisiana State University

The decrease in concentration of carbonate ions—the change that prevented oysters from building their shells—is the most concrete and observable effect of ocean acidification so far

Here's another way to think about it: If the waters in a hatchery are normally somewhere around pH 8.1, they may dip down to pH 7.8 during annual upwelling events when old, carbon-rich water naturally rises to the surface, as happens every summer. But when that old acidic water is mixed with *new* acidic water (the latter being the surface waters impacted by human-released carbon dioxide 50 years ago), the combination can nudge the pH down to, say, 7.7. And it's that small added difference that kills oyster larvae. The human-generated carbon nudges the water across the threshold.

The change in ocean water pH levels likely has a million different effects on marine life, most of which we still know nothing about. The decrease in concentration of carbonate ions—the change that prevented oysters from building their shells—is the most concrete and observable effect of ocean acidification so far. But scientists and fishermen are now trying to tease out all the other, subtler changes. For instance, how a negative impact on one species could affect an entire food chain, or whether or not a change in pH can alter a fish's ability to make decisions. The predictions are all over the place—remember that *Washington Post* story about "super crabs" invading the Chesapeake Bay? (Probably not gonna happen.) But research has advanced rapidly in the last few years. Here's what we know now.

Oysters on the West Coast

Once the West Coast hatcheries—which shepherd the larvae through the first stage of life before selling them to farmers as hardy juveniles—diagnosed the problem, they moved quickly to organize a response. The Pacific Coast Shellfish Growers Association recommended that NOAA establish water monitoring systems that give industry players real-time information about the quality of the water flowing into their farms. Hatcheries then used that information to manipulate the water flowing onto their properties—block it when it's too rich in carbon, open the floodgates when the upwelling is over. Many hatcheries have also installed pricey buffering systems that automatically add sodium carbonate to the seawater to balance its chemistry.

> "I was afraid if I didn't do something, then our business would just slowly die."

But manipulating the incoming water can only work for so long. To escape the West Coast upwelling events, some hatcheries are moving operations as far south as Hawaii.


Flickr / Louisiana Sea Grant College Program Louisiana State University

The oyster industry was the first to be affected by ocean acidification, and it has adapted quickly

Taylor Shellfish—one of the first farms to be impacted by the die-offs—expanded its existing Hawaii hatchery, growing seed oysters and Manila clams. The shellfish are hatched in tropical waters, then shipped northward to mature in places like the Puget Sound.

In 2012, Willapa Bay's Dave Nisbet followed suit. Unlike Taylor Shellfish, which had always relied on its own hatchery for seed oysters, Nisbet's company had depended on harvesting wild oyster seed. He took NOAA's warnings about ocean acidification to heart and decided to build his hatchery in Hawaii, even though it would have been much less expensive to build one in Washington. "I just got nervous," Nisbet told the *Seattle Times* in 2012. "I was afraid if I didn't do something, then our business would just slowly die."

Even though shellfish represent some the most vulnerable populations, they're also the easiest to fix.

Once shellfish pass through the crucial early development stages where they grow their shells, they're more impervious to changes in ocean water. Adolescent oysters, for instance, can thrive in conditions that kill larval clams. West Coast oystermen haven't yet seen acidification-triggered damage to older shellfish.

The oyster industry was the first to be affected by ocean acidification, and it has adapted quickly. In many ways, even though shellfish represent some the most vulnerable populations, they're also the easiest to fix: The infrastructure to hatch farmed shellfish was in place long before ocean acidification became a concern, and individuals can survive the trip from Hawaii to Seattle. But other species—like Dungeness crabs, which aren't farmed, and Alaskan salmon, which migrate—don't have such a simple life cycle.

California's Dungeness crabs

If larval oysters die-offs were the earliest indicator of the coastal arrival of ocean acidification, then Dungeness crabs are the species researchers and fishermen worry may struggle next. They represent the most valuable fishery on the West Coast, generating $167 million in ex-vessel value in California in 2011. Like oysters, Dungeness crabs are a key driver of the fishing industry, so lucrative that many fishermen rely on them to guarantee an annual income.

Flickr / California Department of Fish and Wildlife

Like oysters, Dungeness crabs rely on carbonate to build their shells. But carbonate isn't the primary molecule they use

Paul McElhany, a researcher at NOAA, has been testing potential impacts of lowered pH levels on Dungeness crabs. In 2016, his Seattle-based team collected egg-laying female crabs and hatched their young in treated water with varying levels of carbon dioxide.

The researchers' results would concern any fisherman. At an acidified pH level of 7.5, which has *already* been observed during upwelling events in the Puget Sound, only about a third of the Dungeness crabs survived into the juvenile stage as compared to those that survived in waters with a normal pH. (Remember, the open ocean is at about pH 8.1 now. It's expected to hit pH 7.8 by the end of the century.)

McElhany says scientists aren't quite sure *why* the acidified conditions led to such a big drop in crab survival rates. Like oysters, Dungeness crabs rely on carbonate to build their shells. But carbonate isn't the *primary* molecule they use. Which means the lower survival rate was probably caused by something other than what killed the larval oysters, something scientists have not yet identified.

> Ocean acidification *could* be impacting Dungeness crab life cycles already.

And this experiment only manipulated pH levels in a controlled environment. The results, though stark, don't even come close to mimicking conditions in the wild. "Out in the field you've got multiple things going on at the same time because you've got ocean acidification, you also have temperature, climate change, and changes in fishery practice," McElhany explains. If two-thirds of Dungeness crabs are dying inside a tank that doesn't contain predators, fluctuating temperatures, or hard-to-find food, the results in the open ocean could be much worse.

Out in the field, fisherman John Mellor has been keeping an eye on the impossibly complex oceanic patterns that swirl through the crabs' habitat. And while he doesn't think he's witnessed ocean acidification impacting crab populations first hand, he's seen warming waters directly affect the crab catch.

To be clear, ocean acidification *could* be impacting Dungeness crab life cycles already. But because they aren't farmed and because their West Coast habitat has been so abnormal for the last few years—we'll get to that in a second—it's impossible to separate ocean acidification from everything else that's happening along their migration routes.

Flickr / Oregon Department of Fish & Wildlife

Unlike shellfish, which can start their lives in Hawaiian hatcheries to avoid being damaged by a bit of bad water, Dungeness crabs only grow in the wild

But there *have* been recent events that have impacted the Dungeness crab fishery, and they show how a small environmental change (in this case, so small the crabs didn't even notice) can affect the industry as a whole. It's these types of indirect impacts—problems that involve organisms far down the food chain, not the crabs themselves—that researchers like McElhany can't yet predict in a lab. But that doesn't mean they're insignificant.

Between 2014 and 2016, a mass of warm water known as "The Blob" was hanging out along the West Coast. It hasn't been proven that the blob was a direct result of climate change, though Mellor says many people assume it was. Regardless, scientists expect blob-like conditions to become more common as ocean waters continue to warm.

The blob disrupted local environments, causing die-offs of sea lions and fur seals. It also made a certain type of algae really, really happy. That algae, *Pseudo-nitzschia australis,* produces a toxin called domoic acid. (It has "acid" in its name, but that's where its relationship to ocean acidification ends.) Humans can't eat too much domoic acid without getting sick.

The Dungeness crabs aren't bothered by domoic acid. They can eat a lot of the affected algae and it won't impact their survival rates. But when they eat the algae, the domoic acid stays in their bodies. And it can cause real problems for humans eating cooked crabs—think short-term memory loss, comas, and seizures.

Crabs are a reminder that our knowledge of this phenomenon is far from complete.

Regulators in California don't let fishermen catch Dungeness crabs if the crabs have eaten too much algae—no one wants to pass domoic acid poisoning off on some unsuspecting diner. But those restrictions are hard on fishermen. A few years back, Mellor's season was delayed by five months as he waited for the crab tests to come back clean.

"You can't really go drive for Uber," he says, adding that he had to be ready to start fishing at any moment.

To recap: The crabs hadn't gone anywhere. They were healthy and thriving, and they hadn't moved from their normal stomping grounds. But warmer-than-usual waters meant higher-than-normal levels of algae, and that algae made the crabs poisonous to humans. This is the kind of butterfly effect that will likely impact Dungeness populations long before pH levels drop down to 7.5, and it's this type of phenomenon scientists are hoping to predict by running computer simulations of entire food webs in acidified conditions.

Jessica Fu

This year, crab fishing season in Oregon has already been delayed because of domoic acid

Shallin Busch, the scientist at NOAA who studies ocean acidification and fisheries, has been working to predict the effects of ocean-wide change on specific populations. "Basically we created a model of the West Coast food web in the computer and we put in this scenario of ocean acidification from the chemistry change," she explains. "We looked to see what might happen to fish populations that we harvest under acidification. The take-home answer is that the Dungeness crab harvest was most impacted by our scenarios," she says. "What this model work was showing was that there's also likely to be some indirect effect, kind of a food web effect of acidification as well."

It'll take years for the gap between lab-generated conclusions and the natural world to narrow.

Unlike shellfish, which can start their lives in Hawaiian hatcheries to avoid being damaged by a bit of bad water, Dungeness crabs only grow in the wild. "The crabs walk in and out of the canyons, and then they'll walk up onto the shelf, and they feed on the clam beds and the worm beds and whatever they can eat, and then they typically will mate in February, March, April—and then after they're done mating, they eat a little more and then molt," Mellor says. All the while, they're migrating throughout different parts of the ocean floor.

This year, Mellor's fishing season started on time. Crab fishermen in Oregon weren't so lucky—their season has already been delayed because of domoic acid.

If oysters show the most direct and observable link between ocean acidification and survival rates, the crabs are a reminder that our knowledge of this phenomenon is far from complete. It'll take years for the gap between lab-generated conclusions and the natural world to narrow. In the meantime, crab populations will continue to live in a changing habitat.

Elsewhere

Though we have the most data about oysters and Dungeness crabs, researchers are also focusing on the potential impacts of ocean acidification on other commercially-valuable species. McElhany says there's some preliminary evidence that shows elevated acidity may impact the part of a salmon's brain that helps it avoid predators—another incidence of a subtle change that could have catastrophic consequences. Earlier this month, biologists began sounding the alarm bells about Alaska's red king crabs, warning that they could be extinct in the next century. King crabs struggle to build their shells in acidified conditions, and researchers hypothesize that they simply can't generate enough energy to maintain a survivable internal pH as external pH levels continue to fall.

Unsplash / Charlotte Coneybeer

There's a little hope, though: In the king crab trials, a few of the juveniles made it out alive in lab conditions that simulated Alaskan waters a hundred years from now. Those crabs may be able to pass their traits onto their young, creating a new generation of crustaceans that can survive in changing waters.

What can we do about the impact of ocean acidification right now? "We don't have that answer for you," Busch says. "We're hoping in the future that we will. There's this massive global effort to better understand species sensitivity, better understand ecosystem changes, do better monitoring. That's one thing."

ENVIRONMENT, **FARM**, **HEALTH**, **POLICYDUNGENESS CRABSOCEAN ACIDIFICATIONOYSTERSSHELLFISHWASHINGTON STATE**

H. Claire Brown

A North Carolina native, Claire Brown joins The New Food Economy after working on the editorial team at *Edible Manhattan* and *Edible Brooklyn.* She won the New York Press Club's Nellie Bly Cub Reporter award in 2017. Follow her at @hclaire_brown.

Exhibit 17

http://kcby.com/news/local/coos-county-sheriffs-office-turns-to-social-media-for-recruitment

Coos County Sheriff's Office turns to social media for recruitment

by KCBY / Sept 13, 2016 -

(SBG photo/Jessica Waite)

COQUILLE, Ore. -- The Coos County Sheriff's Office has taken to social media in search of new recruits.

The office has created a Facebook page and recruitment video.

Officials say their short term goals include building up manpower that would help open up the jail facility to house a few more prisoners.

They say they are currently down about five positions.

Their long term goals depend heavily on the Jordan Cove Project.

Officials say if the plant is completed in the next couple years the sheriff’s office may need up to 30 new employees.

"We've been shorthanded for quite some time and our ability to hire good employees has just been in the tank,” explained Sgt. Pat Downing. “We're in this situation because the lack of money … and that our budget has been very, very minimal compared to what we've had in years past."

Officials say they hope to reach a whole different group of people who rely on social media, especially younger prospects.

Jordan Cove officials supplemented the cost of the recruitment video.

http://theworldlink.com/news/local/crime-and-courts/sheriff-talks-jail-levy-staffing-drone-use-in-thursday-presser/article_91545d92-1600-5ae6-a0d8-5adc792db025.html

Sheriff talks jail levy, staffing, drone use in Thursday presser

Department hopes to recruit more deputies

SAPHARA HARRELL and JILLIAN WARD - The World
Sept 9, 2016

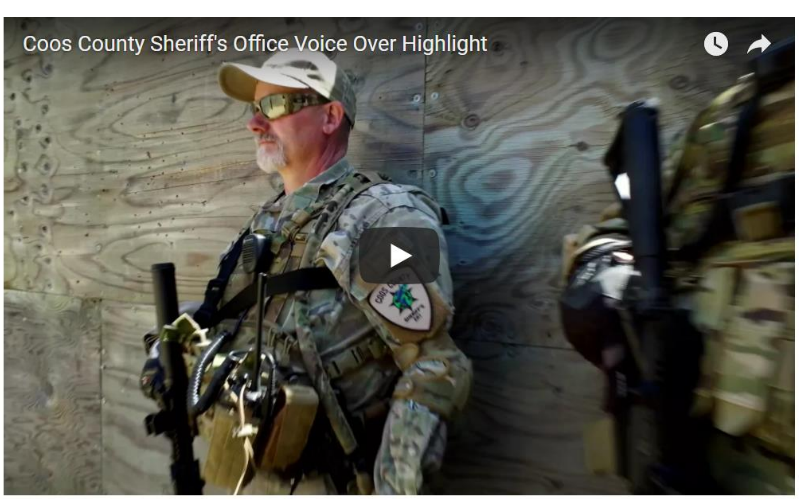
COQUILLE — Keeping more criminals in jail is the goal at the Coos County Sheriff's Office. On Sept. 9, Sheriff Craig Zanni held a press conference to discuss strategies to do just that, even if it means going after new taxes.

Zanni said he is trying to fill five open deputy positions in order to help staff the Coos County jail and increase the available occupancy from 49 to 98. Zanni said he is even exploring the possibility of a tax levy.

"This press conference was called because, at this time of year, it's a good time to start thinking about what services the government provides, because it impacts all of us," Zanni said, and referred back to 2015 when the department was required to reduce jail space due to staffing shortages. The jail is capable of holding 250 inmates, but due to lack of funding it can't run at full capacity. Not only that, but the department is struggling to fill what open positions it has.

"We've gained some staff, but lost them to other agencies for greater pay or retirement," Zanni said. "We're in competition with every other agency in the state, and the current forecast is that there will be a shortfall of 500 law enforcement positions in the next year throughout the state. With what's going on nationally, people think twice before they to go into law enforcement."

Zanni said the sheriff's office once advertised open positions in the newspaper, but has now turned to social media outlets like Facebook. To help encourage potential applicants, the Jordan Cove Energy Project funded something akin to an Army recruitment video featuring squad cars set against scenic backdrops while a deep-voiced narrator and theatrical trailer music play in the background.



Jordan Cove paid for the video, as well as training and overtime pay, as a way to help compensate for the potential crime increase that would enter the county if its project to build a liquefied natural gas export plant were ever approved. The company has given roughly $300,000 to the sheriff's department to cover additional costs its project would incur, as well as new equipment.

One audience member suggested staffing corrections officers instead of patrol deputies, who cost the department more due to higher qualifications. Zanni explained that the department would rather hold all personnel to the higher standard than eventually pay someone who is less qualified the same amount later in their career.

Another audience member raised concern about what criminals do once they're let out of jail.

"I know some of these people at the Devereux Center who laugh because they will never have a job and know they aren't ever going to pay for anything," one man said. "It's all a joke to them. It seems we need chain gangs, maybe take these guys out instead of letting them sit on their butt in a jail cell and think they're in Mayberry."

The department used to take inmates on work release projects, but Zanni said the staffing levels now make that prohibitive.

Zanni also announced the addition of drones, which will help officers carry out search and rescue missions. The drones are especially helpful in inclement weather, because officers are able to operate the machines from the truck.

Zanni said the drone would've come in handy a few years ago when a Bandon woman with dementia went missing and officers weren't able to find her because the weather had turned bad. When the weather got better, Zanni and others went searching in the woods with a canine, but were blocked by a ten-foot ravine filled with water. The next week, Zanni said he went on the other side of the ravine and found the woman's body. He explained that if he had a drone at the time, they might've been able to find the woman before she died.

"If we were an NFL team, we'd be starting the season short," Zanni said. "We are very aware of the current state of crime in our area and are actively looking for a way to stop those activities. If we're able to obtain a levy to allow us to hire a sufficient amount of deputies to reopen the jail, it would create the ability to hold all suspects who may pose a danger to the community and help reduce crime rates and make criminals fully accountable by keeping them incarcerated. It would go a long way to make Coos County safer, as well as the surrounding areas."

Interested applicants can apply here.

Reach Saphara Harrell at (541) 269-1222 ext. 239 or by email at saphara.harrell@theworldlink.com

Exhibit 18

http://theworldlink.com/news/local/jordan-cove-has-its-own-division-in-the-sheriff-s/article_fd7cddb2-fb52-527a-8f8d-d3507922c06a.html

Jordan Cove has its own division in the sheriff's office

Nicholas A. Johnson - The World
Mar 5, 2018

This is an aerial view of the North Spit, the proposed site for Jordan Cove pipeline.
Alex Derr | OSCC

COOS BAY — The Coos County Sheriff's Office plans to hire nine new employees starting in July to fill out its combined service unit with Jordan Cove LNG.

At preliminary budget hearings last week, the sheriff's office purposed its LNG division budget, which is just over $3 million for the 2018-2019 fiscal year. The division is completely funded through Jordan Cove LNG, no county dollars are used to fund this combined service unit.

The combined service unit was approved well before Coos County Sheriff Craig Zanni was elected to his position. When he took office he agreed to continue to work with Jordan Cove to develop the LNG division.

"When I became sheriff they asked if I'd be willing to work with this program, and I told them I'm willing to provide security with law enforcement officers, I am not willing to give security people law enforcement powers," Zanni said.

LNG division deputies, although funded by Jordan Cove LNG, will be employed by the Coos County Sheriff's Office.

"They will be paying for full-time deputies that part of their jobs will be providing the security around the facility out there since obviously it would be a high target area for terrorists or others," Zanni said.

One of the everyday security responsibilities of the LNG division will be providing security for boats coming in or out of the facility.

"When they're not doing that, they'll be working on regular deputy jobs," Zanni said.

Even though the Jordan Cove LNG facility has not yet been approved, finding qualified applicants and getting them trained does take a lot of time. According to Zanni, it could take between three and five years to get the LNG division fully staffed and trained.

If the facility is not approved most of those hired to the LNG division will lose their jobs, as the county can't afford to pick up the cost of the eventual 20 to 25 LNG division deputies they hope to hire. Although it would be unfortunate for those deputies to have to find new work the sheriff is confident they will quickly find another job in law enforcement because they will have already been trained.

"When that facility opens we can't start training them then. They have to be ready to do that task as soon as the facility opens. We foresee that if something should fall through, or this facility is not approved, both through attrition and availability of other jobs we wouldn't end up with much of a liability if any," Zanni said.

When the Jordan Cove LNG pipeline was purposed it was stated in its charter that if the project created an additional cost to Coos County, that company would have to pay for it.

"This is one of the ways that they're making sure they aren't increasing the cost for the county by having us respond to more call out there if they have threats or whatever. So they're really just paying for it up front," Zanni said.

The LNG division is not the only combined service unit the sheriff's office has. Their Marine division is partially funded by the Oregon State Marine board. The Dunes division is partially funded through the United States Forest Service and the Oregon Department of Transportation.

"It's also similar to our timber deputies who are partially paid through the private land owners to patrol forest areas," Zanni said.

However, the LNG division is the only Coos County combined service unit that is completely funded by a private company.

Deputies who are part of the LNG division will receive all the training of normal deputies as well as advanced vessel operations.

According to Zanni, LNG division deputies will serve the community first, and public safety will not be sacrificed to meet the needs of Jordan Cove LNG.

"If they're going to wear a sheriff's uniform their first responsibility is still to the citizens of Coos County," Zanni said.

Exhibit 19

Scientists say public safety hazards at Jordan Cove LNG terminal in Coos Bay are underestimated

403 Forbidden

By **Ted Sickinger| The Oregonian/OregonLive**
Email the author | **Follow on Twitter**
on January 16, 2015 at 5:00 AM, updated January 16, 2015 at 4:50 PM

A pair of scientists **told federal regulators** this week that safety measures incorporated in a proposed liquefied natural gas terminal in Coos Bay actually increase the chance of a catastrophic failure and present far more serious public safety hazards than those regulators have analyzed and deemed acceptable.

Jerry Havens, a chemical engineering professor at the University of Arkansas, and James Venart, an emeritus professor of mechanical engineering at the University of New Brunswick, filed a public comment Wednesday outlining their concerns with hazard modeling for the proposed Jordan Cove Energy Project.

Those results were summarized in the project's **draft environmental impact statement** that the Federal Energy Regulatory Commission issued in November.

The modeling addresses the project's **most fundamental public safety question** – what will happen in the event of an accident, natural disaster or terrorist attack at the facility that results in a leak of natural gas or other chemicals.

FERC staff have concluded that since there are no homes within a mile of the facility, the resulting hazard would be minimal. But the question took center stage at public meetings following the release of FERC's draft analysis. And it's one that politicians say must be adequately addressed.

COOS BAY LNG

Jordan Cove LNG terminal gets environmental stamp of approval from feds

Colorado governor pushing for approval of Coos Bay gas export project

Federal decision on Jordan Cove LNG in Coos Bay delayed again

Labor leader recuses himself from state decision on Jordan Cove LNG project after ethics complaint

Wyden asks regulators for more information on hazards of proposed LNG facility in Coos Bay

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Regulators acknowledge that such leaks could lead to flammable and potentially explosive vapor clouds, liquid pool fires and other knock-on effects. So they require applicants to model various scenarios and demonstrate that they wouldn't pose any risk outside the facility's property line.

Havens and Venart have both researched and published extensively on the fire and explosive risks of LNG and other materials during the last 40 years. Indeed, Havens authored two of the models that the FERC formerly used to model LNG spills and vapor cloud dispersion.

In their public comments, they conclude that Jordan Cove's hazard modeling provides inadequate safety exclusion zones due to the ballooning size of LNG facilities in general, and export facilities in particular due to their use of other chemicals. Those include propane and ethylene used to purify and refrigerate natural gas. Those gases are more flammable than natural gas and subject to high order explosions.

They also contend that the facility design proposed at Jordan Cove would actually increase such risks during a leak. The design includes impermeable barriers as high as 40 feet designed to retain vapor clouds within the facility's property line during a spill.

Yet their read of the modeling results is that vapor clouds would be concentrated by the barriers, enveloping the facility's liquefaction equipment, its massive storage tanks and much of its shipping berth, potentially including a tanker full of LNG docked there. In the event of ignition, the knock-on effects could be disastrous, they contend.

"We believe the hazards attending the operations at the Jordan Cove export facility could have the potential to rise, as a result of cascading events, to catastrophic levels that could cause the near total and possibly total loss of the facility, including any LNG ships berthed there," their comment said. "Such an event could present serious hazards to the public well beyond the facility boundaries."

Havens said Thursday that the risk of such an event is probably very, very low. But in the last decade alone, he said, there have been four major international incidents involving explosions that destroyed facilities using similar gases as Jordan Cove.

Havens and Venart are also concerned that regulators -- primarily the U.S. Department of Transportation -- have switched from using open-source hazard modeling software, where the underlying code was freely available for independent scientific review and verification, to proprietary models developed by private companies.

Activists have also complained that hazard modeling data filed with regulators is often submitted under the designation of "Critical Energy Infrastructure Information," which means it isn't immediately available for outside review.

"I can't accuse them of using models that are wrong, but I can't get inside to even check them," Havens said. "If you can't, as a member of the public, satisfy yourself that these things are being calculated right, it undermines confidence in the entire procedure."

Jordan Cove declined to address specific critiques on Thursday, but a company spokesman, Michael Hinrichs, sent a statement via email.

"We understand that people are likely going to have concerns and that's what the public comment period is all about. Jordan Cove submitted safety information to FERC, DOT, PHMSA and other agencies per regulations and for their review. We believe our data satisfies applicable regulations to meet FERC review standards. The FERC will determine if added regulation or additional modeling is needed."

FERC project manager Paul Friedman said Friday that the agency will address specific issues raised in public comments in its final environmental impact statement.

Oregon Sen. Ron Wyden has expressed strong support for Jordan Cove based on the potential for the $7 billion project to create much needed jobs and tax revenue in Coos County and other locales along the pipeline route . But he has told residents repeatedly that the federal analysis on the project will be done right, and he will insist that community members be provided with full answers to legitimate questions.

Wyden's office sent out a statement indicating that he intends to follow up. "It's unacceptable for FERC to rely on anything o than the most up-to-date modeling when it comes to evaluating safety risks at Jordan Cove. Senator Wyden plans to write to FERC and to ask why the modeling cannot be made public and to make clear FERC needs to make sure it is using the best information available to approve or deny that facility."

-- tsickinger@oregonian.com

503-221-8505; @tedsickinger

Exhibit 20

Jordan Cove LNG Tanker Hazard Zones (FEIS Page 4.7-3)

Zone 1 (yellow) - No one is expected to survive in this zone. Structures will self ignite just from the heat.
Zone 2 (green) - People will be at risk of receiving 2nd degree burns in 30 seconds on exposed skin in this zone.
Zone 3 (blue) - People are still at risk of burns if they don't seek shelter but exposure time is longer than in Zone 2.
Map does not include the hazard zones for the South Dunes Power Plant and the Pacific Connector Gas Pipeline.

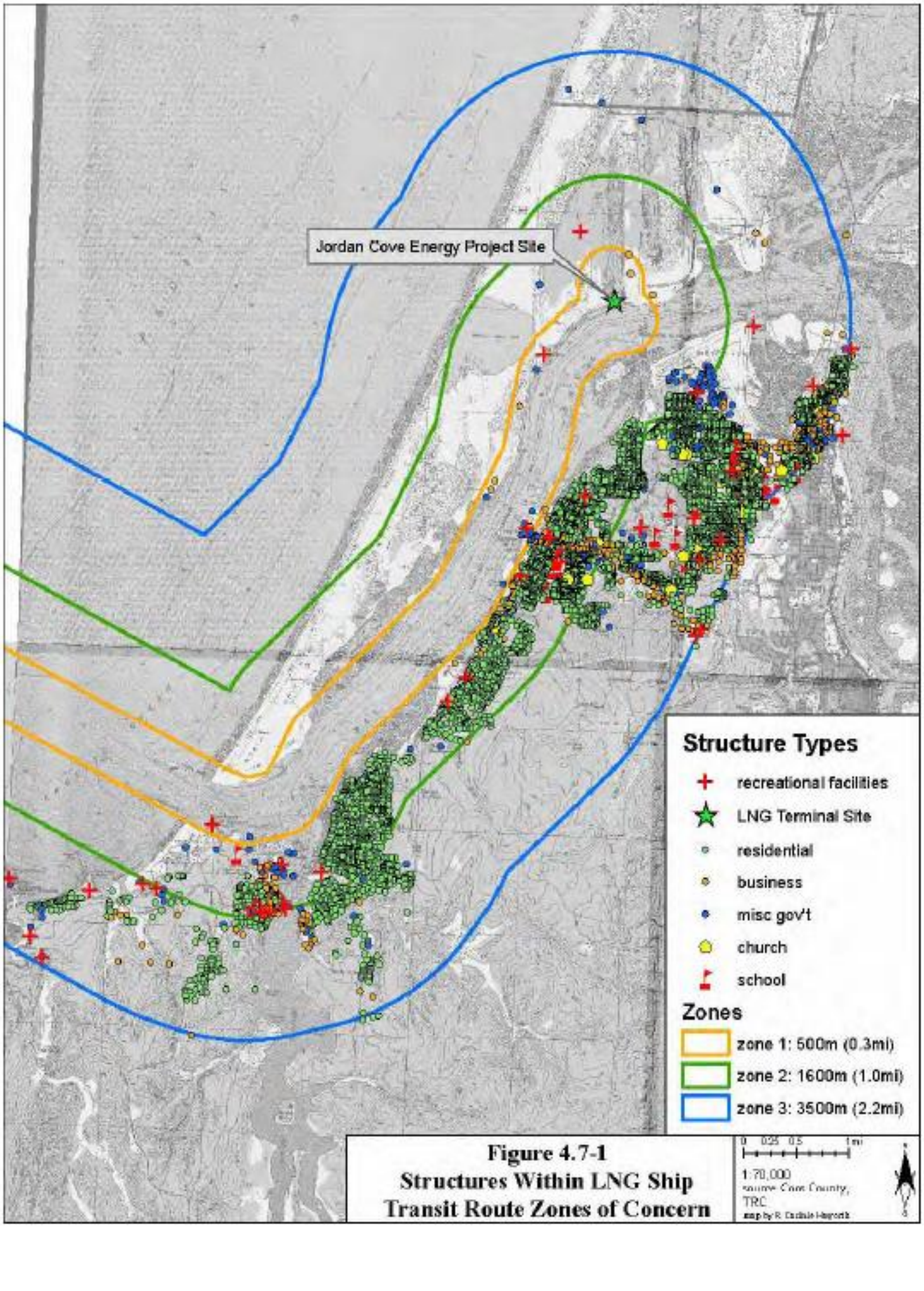

Figure 4.7-1
Structures Within LNG Ship
Transit Route Zones of Concern