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Ocean Acidification

California MPA Threats Assessment: Legal and Policy Gap Analyses

I. Executive Summary

A. Ocean acidification and its potential impacts to California's nearshore ecosystems and MPAs

California's waters have acidified by 26% during the last century and will become 3-4 times more acidic by 2100, driven by a combination of local and global forces.[1] Evidence for strong potential impacts on California's marine species and habitats exists (see figure 1).[2] As ocean acidification (OA) continues to intensify, projections indicate that ecosystem and socioeconomic impacts may be considerable.[3] However, the significance of OA impacts on California's ocean ecosystems and economy, and its MPAs, *compared to other coastal stressors* remain unknown. Given what we do know about acidification's trajectory, drivers, and potential ecosystem impacts, there are a number of 'minimum-regret' opportunities to address and mitigate acidification's deleterious impacts to California's ocean and coastal resources using existing state law, while serving to protect these resources against more certain coastal threats.

The primary direct drivers of OA in California waters are increasing global atmospheric concentrations of CO_2 from burning fossil fuels[4] and coastal upwelling. Scientists expect the acidity of upwelling zones to increase in the next few decades, as the upwelled waters continue to reflect increasing atmospheric CO_2 from the last 50 years.[5] Additional direct drivers of OA conditions in coastal waters may include local atmospheric deposition of SOx and NOx.[4] Indirect drivers of OA include nutrient runoff[6] and freshwater inputs.[7] There is no scientific evidence directly attributing coastal OA to a particular local driver. Natural pH variability, which confounds our ability to decipher the extent of human-caused pH change in coastal waters, is most extreme in bays and estuaries, where rapid fluctuations are driven by tides, freshwater input, photosynthesis, shell formation, and respiration, among other factors.[8]

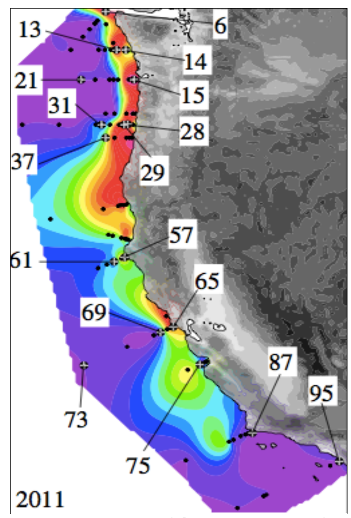


Figure 1: Percent of the upper 100m of the California Current water column estimated to be 'corrosive' to shell-forming organisms in 2011 (Bednarsek et al. 2014). See endnote for more detail.[140]

There is growing evidence of OA impacts—such as the loss of calcereous species[9] that are both commercially and culturally important and reduced growth among species integral to marine food webs—that will directly threaten species and habitats within California's MPAs.[10] For example, pteropods are an important prey group for an array of economically and ecologically important species in state waters and evidence shows their shells are significantly corroded due to greater nearshore acidity in recent decades. How these impacts on one type of plankton (pteropods) will have long-term consequences for our marine food webs is unknown. Research in other geographies has uncovered direct impacts of higher pH on corals and abalone,[11] two species that California's Marine Protected Areas (MPAs) are designed to explicitly protect (e.g., purple hydrocorals and red, black, green, pink or white abalone in the South Coast Region MPAs).[12]

B. Recommendations to address the threat of OA

Although preliminary scientific research in California may inform initial policy directions for mitigating and adapting to OA, the current state of knowledge regarding (1) the extent and severity of acidification; (2) the relative impact of local drivers, as compared to natural variation and global drivers; and (3) effective policies for addressing those drivers, remains nascent. The findings of the West Coast Ocean Acidification and Hypoxia Panel ("OAH Panel") will be critical for: identifying appropriate monitoring protocols and locations, evaluating projected OA impacts along the California Current, and surfacing key management challenges and opportunities for the coming decade. In this report, we identify potential steps for addressing OA in California, with the understanding that the choice of actions should be informed by forthcoming scientific findings by the OAH Panel and the broader scientific community.

Existing MPAs in California provide place-based mechanisms for managers to (a) coordinate and promote strategies to mitigate potential local drivers of OA, such as nutrient inputs and local acidifying air emissions; and (b) provide adaptive protections by serving as "sentinel sites" for monitoring and protecting species and habitats that have been identified as critically important for long-term ecosystem resilience and function.[13] We also outline legal and policy recommendations to address potential drivers of OA—both direct and indirect—and enhance protection of the state's network of MPAs against its impacts. For all of the recommendations, state policymakers and managers may need incentives to act in the face of poorly understood OA impacts and drivers.[14]

The recommendations below would yield a number of "co-benefits"—likely outcomes of the policy or legal action that will positively impact coastal resources or help address other coastal threats—that increase their return on investment regardless of the extent to which they directly address OA (see table 1). Consequently, we conclude this report by highlighting six "low-hanging fruit" strategies designed to improve the state's capacity to proactively address and respond to impacts by incorporating OA into its planning processes and increase our collective understanding of OA patterns, impacts, and attribution.

II. Findings

A. Leading practices and strategies for addressing the threat

Ocean acidification research is a relatively new field. To date, only preliminary policy discussions for federal—let alone state—action have occurred. However, a number of critical policy and legislative steps have built momentum around the issue, namely the 2009 Federal Ocean Acidification Research and Monitoring Act (FOARAM)[15] and Washington State's 2013 Senate Bill creating the Marine Advisory Council.[16] These initial actions are paving the way for further scientific research and public awareness. In California, the Ocean Science Trust, as directed by the Ocean Protection Council, is supporting the West Coast Ocean Acidification and Hypoxia Panel ("OAH Panel"), a comprehensive initiative currently underway to inform state and regional OA policy and management.[17] Future actions to address OA on the state level should be developed and implemented with consideration to the OAH Panel's findings and recommendations.

Federal Action
Primarily stemming from the FOARAM Act, a number of federal actions have promoted research on OA and coordinated federal programs to better understand its causes and impacts. Such actions include publication of the Strategic Plan for Federal Research and Monitoring on Ocean Acidification.[18] The FOARAM Act is now pending reauthorization, at which time Congress can re-work the bill's agenda (e.g., to support state-level initiatives) and re-appropriate funding.[19] Additionally, the National Marine Sanctuaries (NMS) generated a series of resolutions on OA, which summarize recommendations to NOAA's Office of National Marine Sanctuaries on behalf of the 13 Sanctuary Advisory Councils.[20] Stemming from the OA resolutions, the West Coast OA Task Force drafted the NMS OA Action Plan of 2011. The NMS OA Action Plan includes seven strategies for addressing OA through the sanctuaries network, including recommendations to: (1) monitor, (2) research, (3) conduct education and outreach, (4) mitigate damages to sanctuary resources, (5) influence regional and national policy; (6) demonstrate leadership by reducing carbon emissions; and (7) coordinate OA actions internally.[21] Prioritizing and funding these strategies rests with the regional sanctuaries; thus far no sanctuary has begun implementing action.[22,23]

Meanwhile, the Center for Biological Diversity (CBD) sued the U.S. Environmental Protection Agency (USEPA) for approving Washington State's 303(d) list because the list did not include coastal waters as "impaired" for marine pH under the Clean Water Act.[24] CBD and USEPA settled the litigation, and, as part of the settlement, USEPA solicited comments and initiated studies on how it should address OA under the 303(d) program (including use of TMDLs).[25] Based on comments received explaining the lack of clear scientific evidence on whether local management action can directly influence local pH levels to achieve compliance with the Clean Water Act, USEPA now encourages, not requires, regional authorities to list waters as pH impaired in order to gather more information about the use of the 303(d) program to address OA.[26] The agency encourages states to focus on coastal ecosystems and resources especially vulnerable to OA, such as shellfish resources, marine fisheries and coral reefs.[27] Thus far no state has listed a marine water body as impaired for pH.

Most recently, Senators Begich and Cantwell have announced their intention to introduce a new bill on OA. The legislation would create a national strategy to address ocean acidification and deploy additional sensors to monitor OA impacts to the nation's commercial fishing industry.[28]

State-Level Action
(1) Washington State's Blue Ribbon Panel on Ocean Acidification was a model effort in summarizing the science on and policy options for addressing OA in state waters.[29] The Blue Ribbon Panel's outputs helped catalyze plans to update monitoring platforms at hatcheries and in key coastal locations and secure funding for continued research on forecasting OA trajectories as well as the direct effects of OA on coastal marine species.
(2) The OAH Panel consists of 21 scientists across California, Oregon, Washington, and British Columbia.[30] The OAH Panel seeks to synthesize available and relevant science on OA, specifically investigating spatial and temporal variability, the degree to which the region's coastal systems have deviated from naturally occurring coastal OA, the relative attribution of

local drivers, the consequences of OA for resource use within the region, and what additional research and monitoring is necessary to fill critical information gaps.

(3) The California Ocean Science Trust's MPA Monitoring Enterprise has begun to develop monitoring plans for each region of the coast to track the changing condition of ocean ecosystems and performance of the MPA network in California,[31] including identification of indicator species that may be used to detect climate change effects.[32]

(4) The California Current Acidification Network (C-CAN) is a collaborative effort to track and coordinate OA monitoring and data sharing on the US west coast.[33] Universities have launched similar monitoring networks, such as the Bodega Ocean Acidification Research (BOAR) consortium.[34]

(5) Washington State Senator Kevin Ranker is working with colleagues in Oregon, California, and Alaska to develop and introduce in each state's legislature parallel legislation designed to address climate change and ocean acidification sources and their impacts on coastal and marine resources.[35]

(6) Maine has recently passed legislation to fund a Commission to study the effects of OA, specifically on commercial shellfish.[36]

B. Approaches in California for addressing the threat

As evident above, various public bodies have begun to coordinate state action to address OA. However, California still lacks a targeted legal or policy framework for monitoring OA and addressing relevant drivers. To the extent that locally generated sources of pollution (water discharges or air emissions) may act as local drivers of coastal OA (and as the trajectories of such drivers may increase over time), existing water and air quality management frameworks under California and federal law can be applied to mitigate potentially significant drivers of OA.[37] Relevant authorities include the California Porter-Cologne Water Quality Control Act,[38] Clean Water Act,[39] California Coastal Act,[40] California Ocean Protection Act,[41] Clean Air Act,[42] and the Coastal Zone Management Act.[43] Presently, however, no mechanisms under these laws, such as criteria and standards in the State Ocean Plan, have been used to address OA specifically.

Nor does California currently use place-based marine and coastal designations to address drivers of OA or explicitly protect against its impacts. However, protections that may be used to improve water quality include: (1) Areas of Special Biological Significance and other State Water Quality Protection Areas (ASBS and SWQPAs; managed by the State Water Resources Control Board or "SWRCB"),[44] (2) Critical Coastal Areas (CCAs; Coastal Commission and SWRCB),[45] (3) Environmentally Sensitive Habitat Areas (ESHAs; Coastal Commission), and (4) Marine Protected Areas (MPAs; Department of Fish and Wildlife and Ocean Protection Council). Each of these designations could potentially trigger water quality protections (e.g., ASBS,[46] CCAs,[47] ESHAs[48]), but lack of incentives, prioritization, and agency capacity limitations appear to have constrained rigorous implementation of such existing water quality protections as well as additional designations.[49] State MPAs and SWQPAs likely present the greatest opportunity for improving coastal water quality given strong statutory language in the Marine Life Protection Act (MLPA) around ecosystem protection and recent agency efforts to revitalize SWQPA protections within the California Ocean Plan.

Climate change drivers and impacts were not considered in designating state MPAs.[50] Designating authorities include the Ocean Protection Council (OPC), which coordinates MPA policy,[51] and the Department, which is charged with identifying measures to mitigate adverse impacts to MPAs[52] and using MPA designations to improve our understanding of those impacts.[53] The MLPA could serve as a tool for revisiting MPA designations and/or adaptively managing the existing network in light of emerging science on OA and its effects on marine ecosystems.[54] For example, MPAs can be used as "control sites" to understand the effects of non-fishing stressors, including OA and its direct and indirect causes.[55]

C. *Feasible strategies for addressing OA through law and policy changes in California*

i. Mitigate potentially significant sources of OA

The suggested strategies outlined below would use existing California legal and policy provisions to address potential drivers of coastal OA, including point and nonpoint source pollution and atmospheric deposition of SO_x, NO_x, and CO_2 emissions. See Table 1 for an analysis of the financial investment, existing institutional capacity, scientific support, and potential co-benefits associated with each of these recommendations. See Figure 2 for a map visualizing how these recommendations may help California mitigate or adapt to OA.

Nonpoint source nutrient pollution, often entering the ocean through runoff from irrigation, rainfall, or snowmelt, can increase the acidity of coastal aquatic ecosystems and can cause hypoxia.[56] The below strategies to curb nonpoint source pollution should be considered in concert with the state nonpoint source pollution program's upcoming actions.[57]

1. **Use the Clean Water Act to enhance water quality regulations**. At present, there is insufficient scientific evidence attributing local acidification to nonpoint sources. If nonpoint source pollution controls were scientifically linked to a meaningful change in OA measures (e.g., aragonite saturation state or pH), state water quality managers would be well positioned to establish the administrative record to justify intensified regulation of the local drivers of OA. Failing action on their own initiative, strategic litigation could compel the State and Regional Water Quality Control Boards (SWQCB and RWQCB) to act. Enhancing water quality management to address nonpoint pollution found to cause, at least in part, coastal OA could include:
    a. **Strengthen existing water quality standards** to reflect our understanding of how monitoring for nutrients and carbonate chemistry indicators, such as pH, can be used to track and control coastal OA sources.[58] Strengthening standards could include the RWQCBs updating Basin Plans[59] to reinforce protections for existing beneficial uses that may be impaired due to OA (e.g., recreational or commercial shellfish harvesting).[60] Strengthening standards could also include the SWRCB amending the Triennial review of the Ocean Plan with additional water quality criteria[61] that can be measured easily and accurately in the field (e.g., aragonite saturation state and dissolved inorganic carbon).[62] Such criteria would trigger nonpoint source pollution protections within existing NPDES (administered by SWRCB)[63] and TMDL[64] (administered by RWRCBs)[65] programs and improve the state's ability to observe and regulate coastal fluxes in acidification. TMDLs do present a regulatory burden on

State and Regional Water boards due to their large data and administrative requirements, such as detailed information characterizing pollutant loading and linking those inputs with impacts on beneficial uses.[66] However, TMDLs may be effective for pollutants with existing water quality criteria (such as pH[67], NO_3, dissolved oxygen, and sediment[68])[69] in zones particularly affected by OA; additional criteria (e.g., total alkalinity, NO_x, and SO_x)[70] could be developed.[71] Moreover, development of water quality standards, such as SWRCB's effort to develop Nutrient Numeric Endpoints—measures to assess eutrophication in state estuaries—could incorporate the potential biological impacts of OA and OA-relevant water quality thresholds.[72]

b. **Use Waste Discharge Prohibitions and Waste Discharge Requirements** to limit nonpoint source pollution that contributes to OA conditions.[73] Beyond TMDLs, the SWRCB may use waste discharge requirements (WDRs), waivers of WDRs, and basin plan prohibitions to limit nonpoint source pollution. WDRs may be used to limit discharges into waters that fall below a particular acidity and waivers allow dischargers to sidestep requirements by adhering to best management practices, such as requiring water quality monitoring of receiving waters.[74]

2. **Use state water quality protections for commercial shellfish growers** to designate waters particularly impacted by coastal sources of OA around shellfish operations as "threatened."[75] The California Shellfish Protection Act of 1993[76] provides the RWRCB broad authority to order remediation and abatement of point or nonpoint source pollution where such pollution threatens the health of commercial shellfish.[77] Moreover, through legislative amendments, this Act could be expanded to other fisheries that may also be impacted by OA, such as urchin fisheries,[78] and could also be strengthened by limiting or eliminating its agricultural exemptions.[79]

Point source pollution, largely from sources such as sewage outfalls,[80] contributes to coastal OA through the same mechanisms as nonpoint source pollution. Strategies to address point source pollution include:

1. **Strengthen water-quality-based controls on National Pollutant Discharge Elimination Systems (NPDES)** permits for Publicly Owned Treatment Works (POTW).[81] POTWs must meet requirements more stringent than those of other NPDES permittees, such as heightened reporting requirements and discharge limitations. If sewage is found to be a significant contributor to coastal OA, the Regional SWRCBs possess the authority to tighten NPDES requirements on POTWs by strengthening the state technology-based standards (e.g., standards for pH).[82] Such action could have wide-reaching co-benefits for marine and coastal resources adversely affected by OA as well as by various individual pollutants contained in treated sewage.[83] Alternatively, strengthened site-specific standards where point sources may disproportionately contribute to coastal OA, such as discharges to estuaries, may be more efficient and cost effective (e.g., permitting restrictions for specific POTWs in vulnerable estuaries).[84]
2. **Upgrade Municipal Separate Storm Sewer Systems (MS4s)** to reduce potentially harmful discharges. The relative contribution of stormwater runoff to coastal OA remains unknown in California geographies where stormwater runoff contributes significantly to local water quality degradation. Even so, MS4 upgrades in some geographies may help mitigate coastal

OA. MS4s are subject to NPDES permitting[85] and more stringent standards would trigger treatment upgrades. USEPA has published recommendations for how to fund such upgrades,[86] although upgrade requirements are unlikely to be pursued unless direct linkages between OA and MS4 discharges are made.

Sulfur oxides and nitrogen oxides (SO_x and NO_x) are gases that form acids when dissolved in seawater, lowering the pH of receiving waters.[87] These gases have short residence times in the atmosphere and, therefore, may contribute to OA proximate to emission sources. Conspicuous sources of SOx and NOx emissions along the coastline include petroleum refineries and automobiles.[88] Potential strategies to address atmospheric deposition of SO_x and NO_x include:

1. **Amend California Ambient Air Quality Standards (AAQS) to include secondary standards for environmental protection**. The California Air Resources Board may set air quality standards[89] and is required to review the state AAQS whenever substantial new scientific information becomes available or every five years, whichever comes first.[90] However, AAQS are established to protect public health (the most recent amendment was a revision to the NO_2 standard in 2008),[91] so the state would need to adopt regulatory requirements equivalent to *secondary* National AAQS[92] in order to restrict criteria pollutants on the basis of environmental impact. If state secondary standards were adopted, the state could implement standards for SO_2, NO_x, or CO_2 where scientific evidence demonstrates their relative contribution to nearshore acidification.[93] However, it is important to note that such revisions require "substantial evidence" in the record and there is tremendous deference to the administrative agency determining whether such evidence exists. In addition, strengthening California AAQS[94] for SO_2, NO_x, or CO_2 to be consistent with or stronger than federal 1-hour standards would ensure proactive protection in the near term.[95] Standards could be more stringent in coastal areas where significant SO_x and NO_x are emitted from coastal refineries (e.g., San Francisco Bay and Los Angeles regions), provided local emissions are found to be important in driving coastal acidification.
2. **Include OA within the funding priorities of the California Global Warming Solutions Act (AB 32) General Fund.[96]** AB 32, in addition to forcing reductions of state CO_2 emissions that directly contribute to atmospheric deposition and acidification of marine waters, also established a general fund to invest in near-term emissions reductions, resource assessments, and infrastructure developments for sustainable communities. The General Fund Investment Plan could be updated to include (a) wetland restoration projects to sequester carbon and reduce local pH variability and (b) emissions reduction programs within coastal counties where SO_2, NO_x, or CO_2 deposition is found to be increasing the acidity of local marine waters.

ii. Strengthen state habitat protections

Marine Protected Areas (MPAs) reduce fishing stressors on coastal and marine ecosystems and sustain key ecological functions and services.[97] Although some areas of California's coast, and thus some MPAs, appear to be more impacted by OA than others (see Figure 1), there is limited science on how MPAs may be differentially affected in the near-term. Existing, updated,[98] or new MPA designations[99] could afford important spatial and temporal protections for mitigating and adapting to OA impacts. Such protections could serve as a mechanism to 1) reduce coastal stressors that exacerbate OA; (2) protect vulnerable marine communities against other coastal stressors given projected OA impacts, particularly in cases where such species and habitats co-occur with areas naturally prone to lower pH;[100] and/or (3) shelter species and habitats with high adaptive capacity to current and future OA impacts.[101] Conversely, depending on scientific findings, adaptive management of and investment in the MPA network could entail avoiding species, habitats, or areas that will be the most stressed by OA in order to consolidate and strategically allocate limited resources. Regardless, MPAs can be used to establish a monitoring framework for understanding and tracking the drivers and impacts of OA, which is arguably the first and most important step toward tackling OA in California and throughout the California Current.[102]

Recommendations for addressing OA in the course of future reviews of and decisionmaking about the state MPA network include:

1. **Designate new SWQPAs over or around existing Marine Protected Areas** to strengthen water quality protections for MPAs and the ecological, economic, recreational and cultural services they support that may be harmed by local OA conditions.[103] The 2012 California Ocean Plan amendment directed SWRCB to designate new SWQPAs based on the existing siting process for ASBS. In the Ocean Plan, it states that "all water bodies draining to MPAs and SWQPAs that appear on the State's CWA Section 303(d) list shall be given a high priority to have a TMDL developed and implemented."[104] As a place-based policy tool that has recently received agency attention, SWQPA designations could be used to strategically address OA drivers in areas particularly hard hit by pH variability, such as estuaries.
2. **Consider where species have exhibited high adaptive capacity to projected OA impacts**. Both MPAs designated under the California Fish and Game Code and SWQPAs designated under the Porter-Cologne Act[105] may help to protect highly adaptive species and habitats. Recent studies identify species that have particularly high or low adaptive potential in low pH waters.[106] Future reviews of the MPA network should consider the best available science on such matters.
3. **Consider where MPA species and habitats are highly impacted or vulnerable to degraded water quality; use MPA designations to facilitate reduction of coastal water quality stressors.** In the absence of strong science demonstrating the relative impacts of OA on stressed species and habitats, (including evidence of MPAs differentially impacted), locating MPAs in areas most threatened by water quality degradation serves the dual purpose of limiting non-OA water quality impacts of coastal pollution (e.g., eutrophication, inorganic pollutant, and toxicity impacts) and addressing a potentially important driver of local acidification (see above for levers to limit coastal pollution near or within MPAs). MPA designations could aim to preserve the genetic and functional diversity of important ecosystem components by spreading spatial and temporal risk of OA impacts (in species or habitat representation, redundancy, or distribution), and maintaining overall ecosystem function.
4. **Monitor OA in MPAs to determine pH thresholds at which policy actions should be triggered**.[107] Using MPAs as 'sentinel sites' for OA monitoring can provide valuable, long-term datasets for understanding oceanographic change. There are substantial efforts underway in California to track OA, including the data-sharing collaborative C-CAN, which has published a set of core principles for nearshore OA monitoring.[108] MPA monitoring programs and research,[109] stakeholder engagement, and long-term synthesized condition

reports are required under the MLPA[110] and the MPA Master Plan.[111] State managers can use these programs to improve our understanding of OA and its impacts. MPA monitoring efforts can build upon and spatially complement monitoring by marine labs along the California coast, as documented by the Global Ocean Acidification Observing Network (GOA-ON).[112] State resource agencies and policymakers will need to help the Ocean Science Trust, Ocean Protection Council, and other partners operationalize the OAH Panel's pending recommendations for nearshore OA observing. Monitoring efforts improve our scientific understanding of where critical pH thresholds exist in order to link those threshold changes to management or policy action.

5. **Consider where habitat connectivity is critical for economically or culturally important species vulnerable to OA or where species may need to emigrate on account of OA impacts**.[113] The MLPA is particularly suited to consider habitat connectivity for species vulnerable to OA impacts, given its goal to design a coherent network for marine life protection.[114] Precisely where California marine species will be able to move to adapt to changing pH conditions remains unknown.[115] Nonetheless, requiring the best available science around projected species emigration on account of OA will ensure MPAs are mutually replenishing and capable of addressing future species range shifts.
6. **Use MPAs to help educate the public about OA**. MPAs are valuable tools for raising public awareness and educating local communities about ocean issues. The MLPA Master Plan includes a number of guidelines for public education.[116] Future public education and outreach could include information about what California scientists are learning about OA sources and effects through the state's MPA network and coordinated monitoring efforts.

iii. Increase adaptive management capacity and scientific understanding of OA

The above recommendations may be critical steps for mitigating and adapting to OA in California. However, those strategies are contingent upon additional source attribution science and/or improved scientific understanding of OA impacts. The following recommendations are 'low-hanging fruit' that will enhance the state's ability to mitigate OA sources that prove to be significant in the future and to adapt to economic and social impacts in the near term.

Recommendations for building adaptive management capacity through planning include:

1. **Secure federal and state resources for enhancing protection of water bodies vulnerable to OA impacts**. The National Estuarine Research Reserve System (NERRS) is a research and monitoring program administered by NOAA whereby designated water bodies are set aside for long-term protection.[117] Enrolling additional estuaries in the National Estuary Program—such as Humboldt Bay, Half Moon Bay, Monterey Bay, and San Diego Bay[118]—would provide targeted funding for integrated plans to address nonpoint source pollution at the watershed level and for creation of monitoring programs for estuaries with OA-related water quality concerns.[119] Additionally, the EPA Climate Ready Estuaries Program provides existing National Estuaries—including San Francisco Bay, Morro Bay, Elkhorn Slough, and Santa Monica Bay—with tools to plan for adaptation. The program provides additional funding to these estuaries for planning efforts, particularly around addressing nonpoint source pollution.[120] The State Coastal Conservancy's Climate Change Program also provides funding to coastal communities that are located near OA hot spots or that may be particularly vulnerable to the economic impacts of OA.[121]

2. **Incorporate OA considerations into state fisheries management.** Although the impacts of OA on California's fisheries are relatively unknown, consideration of OA impacts could be included within Fishery Management Plan development. For example, fishery plans could include built-in harvest reduction rules if a particular threshold of OA impacts on a fish species is detected.
3. **Amend County and Municipal General Plans** in coastal regions to include goals for minimizing direct and indirect stressors that may contribute to localized OA, including local sources of SO_x, NO_x, and CO_2. OA has not yet been explicitly incorporated into such planning, but is a natural candidate for inclusion in new and updated plans. Amendments may include stricter compliance criteria for stormwater management,[122] transit-friendly plans,[123] and erosion control.[124] Strategic litigation under the California Environmental Quality Act (CEQA) to ensure General Plan amendments do not significantly contribute to coastal OA could create a statewide precedent for incorporating OA considerations in planning efforts.[125]
4. **Amend existing CEQA guidelines to include ocean acidification** as a specific example of the environmental impacts that project proponents must analyze. There is room for additional language within CEQA guidelines to incorporate the direct and indirect impacts of projects on coastal OA through nutrient enrichment and greenhouse gas emissions.[126]
5. **Support the Coastal Commission in using its existing legal authority** to prevent or limit land-use practices that aggravate nonpoint source pollution in coastal areas,[127] incentivize sustainable development,[128] and coordinate monitoring of nearshore discharges that may contribute to OA. The Commission, through Local Coastal Program (LCP) amendment updates and approval, could work with local governments to adopt more proactive policies that minimize the direct and indirect drivers of coastal OA, including nutrient runoff from nonpoint sources. Such policies include Low Impact Development and stormwater best management practices. The Commission could apply such policies directly in areas where LCPs have not been certified and where it retains primary regulatory authority. Additionally, the Commission could require permittees whose development contributes to point source pollution in areas of high pH variability, such as estuaries, to monitor those activities and the coastal and marine resources that are likely impacted by local acidity, such as estuarine shellfish.[129] In addition or in the alternative, the Commission could require those permittees to contribute in lieu fees to support existing OA and source identification monitoring programs. To improve the State's understanding of how much point source pollution may contribute to coastal acidification, the Commission should coordinate any monitoring requirements with other coastal monitoring programs, such as those developed or coordinated by the MPA Monitoring Enterprise, C-CAN, and SCCWRP,[130] to contribute to a more complete understanding of linkages among permitted activities, coastal OA, and marine and coastal resource conditions.

Recommendations to increase scientific certainty around particular management actions and general understanding of OA patterns and impacts include:

6. **Fund OA science, such as source attribution research, long-term monitoring, cumulative effects, and socio-economic impacts.** All of the strategies outlined above require additional science to evaluate their efficacy in addressing the drivers or impacts of OA, their feasibility, and their potential feedback with and co-benefits for other coastal threats. For instance, research on the relative contribution of natural upwelling and nutrient

cycling vs. anthropogenic point and nonpoint source nutrient pollution to nearshore water quality will help determine which MPA-related protections or pollution controls will limit nearshore acidification. In order to operationalize pollution controls, funding must be directed toward the development of easily measurable and accurate OA measures (e.g., water quality criteria) to inform short-term forecasts of changing water quality.[131] Consortia particularly able to conduct such research include SCCWRP, C-CAN, MBARI, and several research universities (see Appendix A). Long-term monitoring is also chronically underfunded and necessary to inform effective management response. Research on how OA may exacerbate the cumulative effects of other coastal threats, as well as if there are thresholds in the biological response of species and habitats to OA, is critical for setting appropriate policies and management targets. Finally, supporting research on the socio-economic impacts of OA is also critical for highlighting these impacts and focusing attention to OA at the state level.[132]

7. **Fund OA communication efforts.** As the OAH Panel and other knowledge producers highlight additional science needs, it will be important to translate these findings for the public and policy and management decisionmakers. Whether the findings—in conjunction with other state science efforts—inform regional or state resolutions and planning; agency priorities, planning, or regulation; state legislation; or all of the above, all credible knowledge brokers must trumpet these efforts to build momentum and awareness around addressing OA. Communications funding can support researchers and NGOs to weave the narrative of OA's impacts on California's communities in order to motivate appropriate policy action.[133]
8. **Develop and implement monitoring requirements for major dischargers**—such as MS4s, POTWs, and refineries—on temporal and spatial scales that will detect changes in pH, nitrogen, and related OA parameters.[134] The Ocean Plan triennial review has identified a coordinated, standard monitoring procedure as a key need for future water quality planning efforts by the SWRCB and RWRCB.[135] New standardized monitoring requirements could include factors critical for tracking the influence of point source dischargers on coastal OA.

III. Supplemental material

A. List of key groups working and charged with working on these issues in California, as identified during research

The California Current Acidification Network (C-CAN) is a collaboration dedicated to advancing the science around OA along the U.S. west coast.[136] C-CAN has helped coordinate a community of interested scientists and decisionmakers, elevate the discussion around OA in the California Current, and communicate the most recent OA science to stakeholders.

There are a number of public and private laboratories in California that are investigating OA and its impacts. These include**:** Stanford University, Rob Dunbar, William Gilly, Fiorenza Micheli, Giulio De Leo, Steve Palumbi; University of California Santa Barbara, Hoffman Lab; California State University San Marcos, Fabry Lab; Scripps Institution of Oceanography, Dickson and Send Labs; Marine Conservation Biology Institute; University of California, Davis, Bodega Marine Laboratory, Hill and Largier Labs; San Francisco State University, Romberg Tiburon Center; National Marine Fisheries Service, Southwest and Northwest Fisheries Science Centers. This list was adapted from the National Marine Sanctuaries OA Action Plan. A few of these labs are working in partnerships with the shellfish industry to identify trends in and consequences of OA for coastal communities. For example, Bodega Marine Laboratories is working with Hog Island Oyster Farm to monitor OA and its impacts on its farmed oysters.

The 2009 California Climate Change Adaptation Strategy identifies OA as a threat to California marine waters. The strategy calls for the preparation of "climate strategies, indicators, and thresholds that respond to [a] changing ocean."[137] The strategy called for the creation of the Coastal and Ocean Resources Working Group for the Climate Action Team (CO-CAT), hosted by OPC, to execute these recommendations. The CO-CAT is comprised of state agencies with marine responsibilities and is a venue for members to coordinate climate adaptation.[138]

B. Tables and Figures

Table 1: A coarse estimate of the financial investment, existing authority, scientific support, and co-benefits associated with each of the recommendations.

1. **Financial Investment Required:** "Low" ($) means limited financial resources needed to achieve management goals, with costs approximately below $1 million. "Moderate" ($$) means the action could take several forms, some of which would require substantial financial resources, with costs ranging between $1 million and $5 million. "High" ($$$) means that significant resources are required, with costs likely above $5 million. Cost ranges are based on cost ranges from Washington's Blue Ribbon Panel on Ocean Acidification: Washington State Blue Ribbon Panel on Ocean Acidification (2012): *Ocean Acidification: From Knowledge to Action, Washington State's Strategic Response*. H. Adelsman and L. Whitely Binder (eds). Washington Department of Ecology, Olympia, Washington. Publication no. 12-01-015.

2. **Institutional Capacity:** "High" indicates there is significant NGO presence, state and federal agency attention and staff capacity, and political will to commit to the opportunity. "Medium" indicates there is partial NGO, state and federal agency, and

political capacity to commit to the opportunity. "Low" indicates there is very limited NGO, state and federal agency, and political capacity to commit to the opportunity.

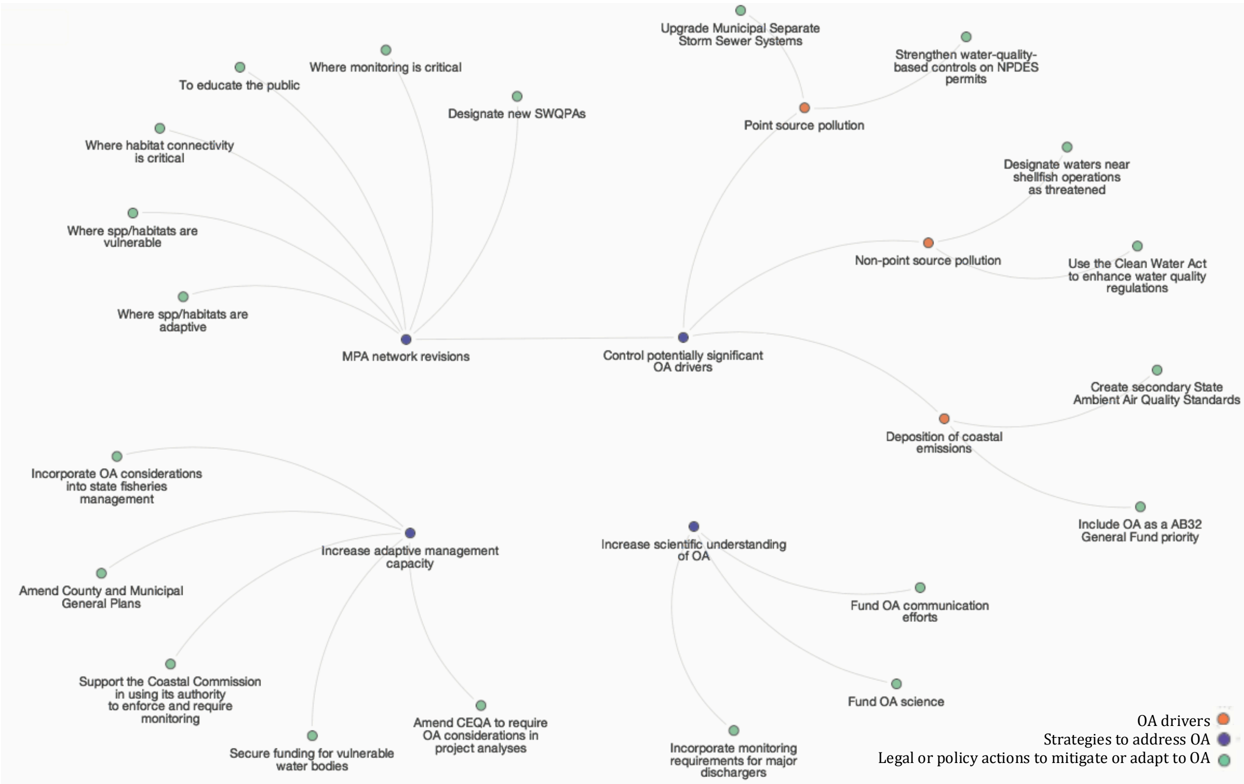
3. **Scientific Support:** "High" (or green) indicates there is sound scientific consensus that the recommendation will lead to a reduction in nearshore acidification or improve our understanding of OA. "Medium" (or yellow) indicates there is science that indicates the recommendation *may* lead to a reduction in coastal acidification or improve our understanding of OA. "Low" (or red) indicates there is limited scientific understanding of the linkage between the recommendation and a marked decrease in coastal acidification, and it may improve our understanding of OA. This metric does not evaluate how the action may be effective in addressing other coastal threats (e.g., strengthening NPDES permit requirements will improve water quality irrespective of its impact on OA-related parameters).

4. **Co-benefits:** Regardless of the science supporting the link between the recommendation and reductions in coastal OA, many of these actions address other threats to California's MPAs and coastal resources.[139] The degree to which these actions represent 'no-regret' options, insofar as they address other coastal stressors, is noted here.

OA Driver	Recommendation	Financial Investment	Institutional Capacity	Scientific Support	Co-benefits
Nonpoint Source Pollution	Use the Clean Water Act to enhance water quality regulations	$$	Medium	● (yellow)	Reduce nonpoint source pollution, trigger monitoring requirements, improve measurable water quality standards
	Use state water quality protections for commercial shellfish growers	$$	Medium	● (green)	Reduce nonpoint source pollution, protect key fisheries
Point Source Pollution	Strengthen water-quality-based controls on National Pollutant Discharge Elimination Systems (NPDES)	$$	Medium	● (yellow)	Reduce point source pollution, reduce site-specific water quality concerns
	Upgrade Municipal Separate Storm Sewer Systems (MS4s)	$$$	Low	● (yellow)	Reduce point source pollution
Deposition of coastal emissions	Amend California Ambient Air Quality Standards (AAQS) to include secondary standards for environmental protection	$	Low	● (green)	Reduce human health impacts of local emissions, reduce regional environmental impacts of NO_x and SO_x deposition
	Include OA within the funding priorities of the California Global Warming Solutions Act (AB32) General Fund	$	Medium	● (yellow)	Reduce human health impacts of local emissions, reduce environmental impacts of CO_2 emissions through deposition or global climate change
Strengthen state habitat protections	Designate MPAs in areas where species and habitats are highly vulnerable to OA and disproportionately affected; use these designations to reduce other stressors	$$	Medium	● (yellow)	Increase protections for California's marine and coastal resources, protect species and habitats co-located in areas of poor water quality
	Designate MPAs where species have exhibited high adaptive capacity to projected OA impacts	$$	Medium	● (yellow)	Increase protections for California's marine and coastal resources, enhance the connectivity and resiliency of the MPA network
	Consider where reporting and monitoring is most critical for tracking OA when designating new MPAs	$$$	High	● (green)	Increase protections for California's marine and coastal resources, increase monitoring capacity and coordination
	Designate MPAs where habitat connectivity is critical for species vulnerable to OA or where species may need to emigrate on account of OA impacts	$$	Medium	● (yellow)	Increase protections for California's marine and coastal resources, enhance the connectivity and resiliency of the MPA network
	Use MPA designations to help educate the public about OA	$	Medium	● (green)	Increase public awareness of California's marine and coastal resources
	Designate new SWQPAs over or around existing MPAs	$$	Medium	● (yellow)	Reduce nonpoint source pollution, trigger TMDL prioritization

OA Driver	Recommendation	Financial Investment	Institutional Capacity	Scientific Support	Co-benefits
Increase adaptive management capacity	Secure federal and state resources for enhancing protection of water bodies vulnerable to OA impacts	$	Low	●	Reduce coastal pollution, secure federal funding for addressing watershed level water quality concerns and building adaptive capacity
	Incorporate OA considerations into state fisheries management	$$	High	●	Build regional adaptive capacity, proactively manage environmental and socio-economic impacts
	Amend County and Municipal General Plans	$$	High	●	Reduce point and nonpoint source pollution and deposition of air pollutants into the coastal zone
	Amend existing CEQA guidelines to include ocean acidification	$$	Low	●	Reduce point and nonpoint source pollution and deposition of air pollutants into the coastal zone
	Support the Coastal Commission in using its authority to enforce and require monitoring	$	Medium	●	Increase monitoring requirements for coastal dischargers, increase inter-agency coordination of nearshore monitoring
Increase scientific understanding of OA	Incorporate monitoring requirements for major dischargers	$$	High	●	Increase monitoring of coastal point source pollution to understand drivers of poor water quality and associated stressors
	Fund OA science	$$$	High	●	Increase scientific understanding of cumulative impacts to ocean resources, build awareness among policymakers, build long-term scientific capacity
	Fund OA communication efforts	$	High	●	Build public awareness around climate change impacts to ocean resources

Figure 2: Map of the proposed recommendations to address coastal OA in California.



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[1] Orr J, Fabry V, Aumont O, et al. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature* 437: 681-686.
[2] Bednarsek N, Feely R, Reum J, et al. 2014. *Limacina helicina* shell dissolution as an indicator of declining habitat suitability owing to ocean acidification in the California Current Ecosystem *Proceedings of the Royal Society of Biology* 381:20140123.
[3] For research on the projected economic impacts of OA, *see* Cooley S. and Doney S. 2009. Anticipating Ocean Acidification's Economic Consequences for Commercial Fisheries. *Environmental Research Letters* 4: 024007; for an overview of potential ecosystem impacts *see* Doney, S, Fabry V, Feely R, and Kleypas J. 2009. Ocean acidification: The other CO_2 problem. *Annual Review of Marine Science* 1:169-192, *See also* NOAA's MPA Program website on Climate Change Impacts: http://marineprotectedareas.noaa.gov/sciencestewardship/climatechangeimpacts/
[4] CO_2 is the primary driver of ocean acidification; lowering pH and increasing carbonic acid. The deposition of SO_x and NO_x into coastal waters may also contribute to local acidification of coastal waters, however the degree of contribution is unknown (*see* S.C. Doney, S, et al., 2007. Impact of Anthropogenic Atmospheric Nitrogen and Sulfur Deposition on Ocean Acidification and the Inorganic Carbon System, 104 Proceedings of the National Academy of Sciences 14580, 14583). SO_x and NO_x emissions are primarily sourced from heavy industry using fossil fuels, such as locomotives, ships, and non-road equipment. *See* Environmental Protection Agency website: http://www.epa.gov/airquality/urbanair/
[5] Upwelling brings nutrient-rich waters high in carbon dioxide to the surface in coastal zones. Waters corrosive to calcifying organisms are among the most shallow in the world along the North Pacific coasts, making the coastal ocean particularly vulnerable to OA in upwelling zones. The lower pH waters in upwelling zones are driven by atmospheric CO_s concentrations 50 years ago. Thus, the rate of acidification will increase in the next few decades in parallel with the rate at which atmospheric CO_2 has risen in the last 50 years. *See* Feely R, Sabine C, Hernandex-Ayon J, et al. 2008. Evidence for upwelling of corrosive "acidified" waters into the continental shelf. *Science* 320(5882): 1490-1492.
[6] Increased nutrient concentrations drive greater biological productivity, which in turn causes decomposition and oxygen respiration. Oxygen depletion and carbon dioxide production in these zones of nutrient runoff lead to "dead zones", acidifying waters.
[7] Such as freshwater with low carbonate ion concentrations and terrestrial organic carbon inputs.
[8] Wootton J, Pfister C, and Forester J. 2008. Dynamic Patterns and Ecological Impacts of Declining Ocean pH in a High-Resolution Multi-Year Dataset. *Proc. Natn'l Acad. Sci*. 105:18848.
[9] Such as corals, calcareous phytoplankton, mussels, and urchins. *See* Wootton J, Pfister C, and Forester J. 2008. Dynamic Patterns and Ecological Impacts of Declining Ocean pH in a High-Resolution Multi-Year Dataset. *Proc. Natn'l Acad. Sci*. 105:18848.
[10] OA impacts include those on phytoplankton (reduced production of calcifying phytoplankton and possible extinction), zooplankton (reduced production of calcifying organisms if unable to form skeleton and possible extinction), benthos (lower growth and decrease in shell strength of benthic calcifiers), and fish (little change in growth or mortality, but reduced ability to settle on coral reefs and avoid predators). Doney, S, Fabry V, Feely R, and Kleypas J. 2009. Ocean acidification: The other CO_2 problem. *Annual Review of Marine Science* 1:169-192, *See also* NOAA's MPA Program website on Climate Change Impacts: http://marineprotectedareas.noaa.gov/sciencestewardship/climatechangeimpacts/
[11] Kroeker K, Kordas RL, Crim RN, et al. 2013. Impacts of ocean acidification on marine organisms: Quantifying sensitivities and interaction with warming. Global Change Biology 19: 1884-1896; Crim RN, Sunday JM, Harley CDG (2011) Elevated seawater CO_2 concentrations impair larval development and reduce larval survival in endangered northern abalone (Haliotis kamtschatkana). Journal of Experimental Marine Biology and Ecology, 400, 272–277.
[12] *See* Regional Profile of the South Coast Study Region, http://www.dfg.ca.gov/marine/pdfs/rpsc/body_part2.pdf, Appendix C pp.217, 222
[13] McLeod E, Salm R, Green A, and Almany J. 2009. Designing marine protected area networks to address the impacts of climate change. *Frontiers in Ecology and Environment* 7

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[14] Thomas, Michael. MARINE Seminar Talk. "Implementing Ocean Acidification Research: Strategies and Perspectives". December 7, 2011.
[15] The FOARAM Act of 2009 (FOARAM Act, 33 U.S.C. § 3703)
[16] Engrossed Washington State Senate Bill 5603 Section 4. *See* Washington Department of Ecology Ocean Acidification page *available at* http://www.ecy.wa.gov/water/marine/oceanacidification.html. *("*The 2013 Legislature enacted Engrossed Washington State Senate Bill 5603 Section 4 creating the Washington Marine Resources Advisory Council, within the Office of the Governor. The Marine Resources Advisory Council's membership includes legislative, executive, and elected officials, nongovernmental organizations, and private sector.")
[17] The OAH Panel is a joint effort by California, Oregon, Washington, and British Columbia. For more information, see the OAH Panel website: http://westcoastoah.org. The Panel's efforts were amplified in 2013 when the West Coast Collaborative, led by the governors of the west coast states, sent a letter to President Obama and the Prime Minister of Canada calling for federal support of state level action on OA. The letter is available at: http://www.ecy.wa.gov/water/marine/oa/20131212_PacificCoastCollaborative_letter.pdf
[18] Strategic Plan for Federal Research and Monitoring on Ocean Acidification, prepared by Interagency Working Group on Ocean Acidification, the Subcommittee on Ocean Science and Technology, the Committee on Environment, Natural Resources, and Sustainability, and the National Science and Technology Committee. *Available at* http://www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC/iwg-oa_strategic_plan_march_2014.pdf
[19] The FOARAM Act of 2009 (FOARAM Act, 33 U.S.C. § 3703) set out a coordinated process for monitoring of and research on OA, and precipitated the development of NOAA's OA Program and the Interagency Working Group on OA. Major federal research reports that have been completed to inform OA planning include those by the National Oceanographic Partnership Program's OA Task Force (completed policy recommendations in 2012) and the National Research Council report on OA.
[20] Ocean Acidification Resolutions: Sanctuary Advisory Council Recommendations to NOAA 2008-2010. http://sanctuaries.noaa.gov/management/pdfs/oareso_summary2.pdf. These resolutions were originally prompted by an OA report released by the Channel Islands Marine Sanctuary. Conservation Working Group, Channel Islands National Marine Sanctuary. Ocean Acidification and the Channel Islands National Marine Sanctuary: Cause, effect and response. Adopted by the CINMS Advisory Council September 19, 2008. Prepared by S. Polefka and J. Forgie, Environmental Defense Center, Santa Barbara, CA.
[21] Lott D, Bowlby E, Howard D, et al. 2011. National Marine Sanctuaries of the West Coast: Ocean Acidification Action Plan. *Available at* http://sanctuaries.noaa.gov/about/pdfs/wc_onms_plan.pdf
[22] Although no action has been taken as a result of the Action Plan, there was one follow-up workshop in September 2012 to identify effective messages and tools to communicate about OA impacts and "foster public action". A summary of this workshop can be found *at* ftp://ftp.oar.noaa.gov/OA/OA%20Workshop%20Summary_12_17_12.pdf
[23] President Obama's proposed expansion of the Pacific sanctuaries could serve to protect species and habitats from other stressors that may be threatened by OA, thus reducing the cumulative effect of OA on species and habitats within or near California's sanctuaries. President Obama announced these potential new protections on June 17, 2014, as part of a broader declaration to protect U.S. marine waters. The White House press release is available at: http://www.whitehouse.gov/the-press-office/2014/06/17/fact-sheet-leading-home-and-internationally-protect-our-ocean-and-coasts
[24] The Center for Biological Diversity's most recent complaint was filed October 16, 2013 and asked EPA to disapprove of Oregon and Washington State's impaired water lists in part, and add water bodies impaired with OA (Ctr. For Biological Diversity v. EPA et al. Case No. 12-1238, 13 (U.S Court of Appeals, filed May 27, 2014). . Listing would require Washington to include marine waters on its impaired waters list and, if approved by EPA, establish pollution limits (Total Maximum Daily Loads or "TMDLs") for those water bodies (33 U.S.C. § 1313(d)). Previous litigation on behalf of CBD included requests to the Washington Department of Ecology to include pH impaired water bodies on their 303(d) list (2007) and to the EPA to forego certifying Washington's 303(d) list (2009).
[25] Clean Water Act Section 303(d): Notice of Call for Public Comment on 303(d) Program and Ocean Acidification, 75 Fed. Reg. 13, 537, 13,537-40 (Mar. 22, 2010).
[26] For a summary of EPA's actions, see "Questions and Answers on Ocean Acidification and the Clean Water Act

303(d) Program November 15, 2010" *available at* http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/qa_oa_memo_nov2010.pdf ("EPA has concluded that States should list waters not meeting water quality standards, including marine pH WQC, on their 2012 303(d) lists, and should also solicit existing and readily available information on OA using the current 303(d) listing program framework." The Memorandum entitled "Integrated Reporting and Listing Decisions Related to Ocean Acidification" is *available at* http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/oa_memo_nov2010.pdf

[27] Memorandum from Denise Keehner, Dir. of EPA Office of Wetlands, Oceans and Watersheds, Integrated Reporting and Listing Decisions Related to Ocean Acidification 4 (Nov. 15, 2010), *available at* http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/oa_memo_nov2010.pdf.

[28] For a press release on the announcement, *see* http://www.cantwell.senate.gov/public/index.cfm/press-releases?ID=69297373-195e-4338-97f0-0df69cec9f90

[29] In 2012, Washington State created the Blue Ribbon Panel on Ocean Acidification (" Blue Ribbon Panel"), largely in response to the large loss of oyster hatcheries between 2005 and 2009. The Blue Ribbon Panel sought to summarize the best available science on OA in Washington State and deliver policy recommendations for addressing OA in state waters. Born out of the Panel's findings, the state legislature created the Marine Resources Advisory Council ("Council") within the Office of the Governor to coordinate research and action around ocean acidification in the state. As of March 2014, the Council was investigating next steps for research, as well as for management, including 1) ensuring water quality monitoring at hatchery sites and the deployment of monitoring equipment at post-hatchery sites, 2) investigating water treatment methods or hatchery designs that may protect shellfish larvae from harmful pH levels, and 3) incorporate indicators and threshold for OA into management. Washington State Blue Ribbon Panel on Ocean Acidification (2012): *Ocean Acidification: From Knowledge to Action, Washington State's Strategic Response*. H. Adelsman and L. Whitely Binder (eds). Washington Department of Ecology, Olympia, Washington. Publication no. 12-01-015.

[30] West Coast Ocean Acidification and Hypoxia Panel. http://westcoastoah.org

[31] MPA Monitoring Enterprise. http://monitoringenterprise.org

[32] Monitoring climate effects in temperate marine ecosystems. MPA Monitoring Enterprise, California Ocean Science Trust, Oakland, CA. February 2012.

[33] For more information, see the C-CAN website: http://c-can.msi.ucsb.edu

[34] Bodega Ocean Acidification Research Consortium. UC Davis Bodega Marine Laboratory. http://bml.ucdavis.edu/research/research-programs/climate-change/oceanacidification/

[35] Personal communication with WA State Senator Kevin Ranker, June 28, 2014.

[36] LD 1602 (HP 1174). Sponsored by Michael Devin. Bill info *available at* http://www.mainelegislature.org/LawMakerWeb/summary.asp?ID=280050738. Commission Website *at* http://www.maine.gov/legis/opla/oceanacidificationmtgmatrls.htm

[37] Kelly R and Caldwell M. Center for Ocean Solutions. 2012. Why Ocean Acidification Matters to California, and What California Can Do About It: A Report on the Power of California's State Government to Address Ocean Acidification in State Waters. Stanford Woods Institute for the Environment, Stanford University, California.

[38] See, in particular, Water Code § 13181 (water quality monitoring), § 13241 (water quality objectives), § 13263.6 (effluent limitations).

[39] See, in particular, 33 U.S. Code § 1311-1315 (water quality standards). Taking action to address OA under the CWA is supported by the California Coastal Commission, yet the State Water Resources Control Board has not yet done so. *See* California Coastal Commission, Comments on U.S. Environmental Protection Agency (EPA) Mar. 22, 2010 Federal Register Notice on Clean Water Act Section 303(d) Program/Ocean Acidification (May 13, 2010) ("The Commission believes that using the Clean Water Act to reduce ocean acidification is both appropriate and necessary.").

[40] Pub. Res. Code §30231 ("The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored through, among other means, minimizing adverse effects of waste water discharges and entrainment, controlling runoff, preventing depletion of ground water supplies and substantial interference with surface water flow.").

[41] Publ. Res. Code § 35500-35650 ("Moneys deposited in the fund may be expended, upon appropriation by the Legislature, for both of the following….Improve coastal water quality.").

[42] Clean Air Act (42 U.S.C. 7409); California Health & Safety Code **§** 39606

[43] Coastal Zone Act Reauthorization Amendments (CZARA) Section 6217, which addresses nonpoint source pollution in state waters.
[44] Publ. Res. Code § 36700 ("A nonterrestrial marine or estuarine area designated to protect marine species or biological communities from an undesirable alteration in natural water quality, including, but not limited to, areas of special biological significance that have been designated by the State Water Resources Control Board.").
[45] For a description of the program and existing CCAs, see the State Water Quality Control Boards' program overview http://www.waterboards.ca.gov/northcoast/water_issues/programs/wpc/24appendixc-ccas.pdf
[46] Publ. Res. Code § 13142.5(a) ("Wastewater discharges shall be treated to protect present and future beneficial uses, and, where feasible, to restore past beneficial uses of the receiving waters. Highest priority shall be given to improving or eliminating discharges that adversely affect any of the following: (1) Wetlands, estuaries, and other biologically sensitive sites; (2) Areas important for water contact sports; (3) Areas that produce shellfish for human consumption; (4) Ocean areas subject to massive waste discharge.").
[47] The CCA program was designed to address water quality holistically by engaging the agencies responsible for upland watersheds and the marine environment. However, despite the fact that several pilot locations were selected for CCAs in 2002, this program is largely dormant on account of budget constraints. *See* Protecting Coastal Waters: State of California 2002 Critical Coastal Areas Draft Strategic Plan. http://www.coastal.ca.gov/nps/cca-strategy.pdf.
[48] Fish & Game Code § 2855(c)1 ("Environmentally sensitive habitat areas shall be protected against any significant disruption of habitat values.").
[49] Lack of political will and state agency capacity to implement water quality regulations that may apply to MPAs presents a challenge to many of the recommendations we propose within this white paper. Moreover, lack of agency capacity to ensure enforcement of existing standards, restrictions, and protections may be a concern. Although we did not research evidence of inadequate enforcement within California water quality programs, improving or supporting rigorous enforcement of water quality standards and permits may be an important first step in limiting point and nonpoint source pollution. For further discussion, *see* Kelly R and Caldwell M. Center for Ocean Solutions. 2012. Why Ocean Acidification Matters to California, and What California Can Do About It: A Report on the Power of California's State Government to Address Ocean Acidification in State Waters. Stanford Woods Institute for the Environment, Stanford University, California.
[50] Saarman E and Carr M. 2013. The California Marine Life Protection Act: A balance of top down and bottom up governance in MPA planning. *Marine Policy* 41:41-49.
[51] Fish and Game Code § 2850.5
[52] Fish and Game Code § 2862 ("The department, in evaluating proposed projects with potential adverse impacts on marine life and habitat in MPAs, shall highlight those impacts in its analysis and comments related to the project and shall recommend measures to avoid or fully mitigate any impacts that are inconsistent with the goals and guidelines of this chapter or the objectives of the MPA.").
[53] Fish and Game Code § 2851
[54] Fish and Game Code § 2851 ("Understanding of the impacts of human activities and the processes required to sustain the abundance and diversity of marine life is limited. The designation of certain areas as sea life reserves can help expand our knowledge by providing baseline information and improving our understanding of ecosystems where minimal disturbance occurs.").
[55] The North Coast MPA Monitoring Plan includes the use of MPAs as control sites for evaluating coastal stressors as a potential strategy for building a foundation of knowledge about MPA ecosystem baselines. *See* North Central Coast Monitoring Plan. 2010. MPA Monitoring Enterprise. *Available at* http://monitoringenterprise.org/pdf/NCC_Monitoring_Plan_and_Appendices.pdf
[56] Cai W, Hu X, Huang W, et al. 2011. Acidification of Subsurface Coastal Waters Enhanced by Eutrophication. *Nature Geoscience* 4: 766.
[57] Section 6217 requires states and territories with approved Coastal Zone Management Programs to develop Coastal Nonpoint Pollution Control Programs—which CA has done and NOAA and the EPA have approved. California received $10.6 million in 2013 to begin implementation. The most recent announcement in June, 2014, indicated the State and Regional Water Quality Control Boards and EPA is currently co-creating a Six-Year Plan (2014-2020). For more details, see the State Water Resources Control Board website *at* http://www.waterboards.ca.gov/water_issues/programs/nps/

[58] In 2010, EPA published a MOU stating that states should list waters as impaired for pH when there is data available to do so. The EPA MOU is *available at* http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/oa_memo_nov2010.pdf

[59] The RWRCBs adopt amendments to the Basin Plan. The Basin Plans can be found on the California Environmental Protection Agency website, *available at* http://www.waterboards.ca.gov/plans_policies/ ("Each proposed amendment to the Basin Plan is subject to an extensive public review process. The Water Board must then adopt the amendment, which is then subject to approval by the State Water Board.").

[60] Expanding the range of beneficial uses in this manner could broaden the Regional Water Quality Control Boards' authority to protect water bodies from new OA-related dischargers and limit pollutant inputs from existing dischargers whose actions exacerbate OA conditions in receiving waters. Water quality standards, including beneficial uses for California water bodies, are contained in the regional Water Quality Control Plans. *See* http://www.waterboards.ca.gov/mywaterquality/water_quality_standards/ and California Water Code § 13050. New beneficial use categories may be added by individual regional control boards and requires a Basin Plan Amendment.

[61] For marine waters, current criteria can be found in the California Ocean Plan. *See* Water Code § 13170.2; State Water Resources Control Board, California Ocean Plan 2009, *available at* http://www. waterboards.ca.gov/water_issues/programs/ocean/docs/2009_cop_adoptedeffective_ usepa.pdf.

[62] C-CAN, NOAA, and the Integrated Ocean Observing System have moved towards using aragonite saturation state as an effective measure of the biological impact of OA, although other, more accurate or easily measurable metrics may be discovered. Additionally, a pH standard could be developed, in accordance with EPA's national recommendations. For a list of the national recommended water quality criteria, *see* http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm. *See also* Caldwell, M. and Kelly, R. 2012. The Limits of Water Quality Criteria. The Policy Journal of the Environmental law Institute 29(6).

[63] National Pollution Discharge Elimination System, 33 U.S.C. § 1342

[64] 33 U.S.C. § 1313(d)(1)(C).

[65] Total Maximum Daily Load; 33 U.S.C. § 1313(d)(1)(C).

[66] For a detailed analysis of TMDLs, their requirements, and their history, *see* Copeland, Claudia. 2012. "Clean Water Act and Pollutant Total Maximum Daily Loads". *Congressional Research Service.* http://fas.org/sgp/crs/misc/R42752.pdf

[67] A pH TMDL does exist in the Tygart Valley River Watershed, West Virginia, and others have been proposed in freshwater systems, such as Walla Walla, Washington and Savanna River, Georgia. A list of approved pH TMDLs can be found on the EPA website. http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/ph.cfm. Additional TMDLs for p(CO_2) and NO_2/SO_x would give the State useful tools for combating atmospheric acidification drivers.

[68] Increased sediment loads from land use changes can lead to increased acidity in coastal marine waters, as soil pH can be less than 7. Soil can carry absorbed nutrients, which can contribute both directly and indirectly to coastal acidification. Moreover, coastal erosion can lead to a decrease in CO_2 absorbing organisms, contributing to global and local CO_2 emissions and sedimentation.

[69] Existing water quality criteria provide parameters sufficient for designating OA-relevant TMDLs and do not require agencies to expend additional effort designating new criteria. This reduces the burden of TMDL implementation, though TMDLs for other OA parameters may be more effective in restricting drivers of coastal OA as our understanding of such proximate causes develops.

[70] Upwelling zones, where colder ocean waters quickly take up CO_2 and therefore acidify, are coastal regions amenable to protection via TMDLs. Additionally, TMDLs could be developed for pollutants that exacerbate OA through deposition, such as NO_x and SO_x.

[71] New TMDLs can be developed alongside efforts to streamline and speed the TMDL establishment and implementation process. Recently, Oregon has introduced "implementation-ready" TMDLs to address management capacity challenges; California could follow a similar approach. After a number of delayed and complicated management efforts to implement TMDLs in the mid 2000s, Oregon introduced "implementation-ready" TMDLs to meet water quality goals and standards within the Mid-Coast Basin. This pilot approach requires less agency staff time and will ensure the Department of Environmental Quality has and uses its legal authority to meet load allocations and water quality standards. *See* Oregon Department of Environmental Quality website: http://www.deq.state.or.us/wq/tmdls/midcoast.htm and Oregon's TMDL rule, OAR 340-042-0025 to 0080. For a description of California's current TMDL implementation requirements, *see* http://www.waterboards.ca.gov/water_issues/programs/tmdl/background.shtml.

[72] The Southern California Coastal Water Research Project (SCCWRP) and the State Water Quality Control Boards are developing the Nutrient Numeric Endpoint Framework (NNE) for the state's estuaries to mitigate coastal eutrophication. It is an effort to identify ecological thresholds relevant to beneficial uses, rather than pre-defined numerical limits, to better assess impairment. Linking the potential impacts of OA on beneficial uses with nutrient numeric endpoints may make these thresholds more conservative. Although identifying thresholds in biological responses to OA will inform actionable management targets, the development of these criteria may be challenging due to significant nearshore variability in acidity from upwelling. For a description of the Nutrient Numeric Endpoint Framwork *see* Sutula M, Creager C, and Wortham G. 2007. Technical approach to develop nutrient numeric endpoints for California estuaries. Southern California Coastal Water Research Project.
[73] Kelly R and Caldwell M. Center for Ocean Solutions. 2012. Why Ocean Acidification Matters to California, and What California Can Do About It: A Report on the Power of California's State Government to Address Ocean Acidification in State Waters. Stanford Woods Institute for the Environment, Stanford University, California. ("The states have three tools with which to control nonpoint source pollution outside of the Clean Water Act's TMDL provision: waste discharge requirements (WDRs), waivers of WDRs, and basin plan prohibitions. The boards can issue WDRs for general or specific discharges, for example, barring discharges outside of a particular pH range or having a particular nutrient content. Alternatively, boards can agree to waive WDRs in exchange for the discharger's application of best management practices or for other assurances; many of the coastal nonpoint source plan's management measures are administered in this way. WDR violations may trigger abatement, cease- and-desist orders, or similar remedies including civil liability. Fees associated with WDRs defray the costs of implementation and secondarily discourage avoidable discharges."). For the Nonpoint Source Pollution Control Program policy *see* http://www.waterboards.ca.gov/water_issues/programs/nps/
[74] For more information about the California WDR program, *see* See: http://www.swrcb.ca.gov/water_issues/programs/agriculture/
[75] Water Code § 14954(d). Primarily applicable to regions where shellfish harvesting operations exist, which include Morro Bay, Tomales Bay, and Humboldt Bay.
[76] Water Code § 14956(a)
[77] Water Code § 14956(b) ("If agricultural sources of pollution have been identified as contributing to the degradation of shellfish growing areas, the regional board shall invite members of the local agricultural community ... and affected shellfish growers to develop and implement appropriate short- and long-term remediation strategies that will lead to a reduction in the pollution affecting the commercial shellfish growing area.")
[78] Early research indicates that OA reduces the early stages of development of urchins, as well as mollusks. Kroeker K, Kordas RL, Crim RN, et al. 2013. Impacts of ocean acidification on marine organisms: Quantifying sensitivities and interaction with warming. Global Change Biology 19: 1884-1896.
[79] Agriculture is not defined in the law or case law, thus the agricultural exemptions may be far-reaching. Legislative history indicates that dairy ranchers were opposed to the Act. *See* Kelly R and Caldwell M. Center for Ocean Solutions. 2012. Why Ocean Acidification Matters to California, and What California Can Do About It: A Report on the Power of California's State Government to Address Ocean Acidification in State Waters. Stanford Woods Institute for the Environment, Stanford University, California.
[80] Sewage treatment plants are particularly challenging due to the absolute volume of water they discharge: in California, 43 plants discharge 1.32 billion gallons of wastewater daily. *See* Heal the Bay. 2010. California Ocean Wastewater Discharge Report and Inventory. http://healtheocean.org/images/_pages/research/HTO_COWDI.pdf
[81] 33 U.S.C. § 1370 (expressly reserving the right of states to adopt or enforce "any standard or limitation respecting discharges of pollutants," so long as these restrictions are no less stringent than those provided by the Clean Water Act.)
[82] Nationally, technology-based effluent limitations are based on secondary treatment standards (e.g., total suspended solids). Technology-based requirements may also be imposed on a case-by-case basis. 44 CFR § 122.44(a). California can also implement more stringent technology-based standards on the state or local level, including "best conventional pollutant" control technology standards (BCT). These are more limiting as they are set by establishing the standard based on the best performing technology available, rather than the "average" technology available. 33 U.S.C. § 1314(b)
[83] Tightening NPDES technology-based standards would establish a more stringent minimum level of treatment for POTWs. These standards define limits on biochemical oxygen demand, total suspended solids (TSS), and pH, all of which are water quality indicators linked to broader ecosystem impacts and function. For example, TSS, and

corresponding turbidity, have been shown to have a range of impacts on salmonids (*see* Bash, J and Berman, C. 2001. “Effects of turbidity and suspended solids on salmonids”. Research Project T1803, Task 42 for the Washington State Transportation Commission and U.S. Department of Transportation.).

[84] Targeted permitting restrictions may reduce the economic impacts of such limitations and protect estuarine waters most impacted by point source discharges, depending on attributional research on point source pollution and sensitive receiving waters. California has adopted more stringent NPDES permit standards for particular facilities in the past. For example, the Central Valley Regional Water Quality Control Board recently required N-DN for the Sacramento Regional Wastewater Treatment Plant. Order R5- 2010-0114 (NPDES Permit CA0077682) (Dec. 1, 2011), *available at* http://www.swrcb.ca.gov/centralvalley/board_decisions/adopted_orders/sacramento/r5-2010-0114-01.pdf

[85] 33 U.S.C. §1342(p)(3)(B)

[86] EPA Region 3, Factsheet: Funding Stormwater Programs. 2008. http://www.epa.gov/npdes/pubs/region3_factsheet_funding.pdf.

[87] Doney, SC, Fabry VJ, Feely RA, and Kleypas JA. 2009. Ocean acidification: The other CO_2 problem. *Annual Review of Marine Science* 1:169-192.

[88] The largest stationary sources of SOx near the coast are petroleum and related industries. The largest sources of NOx are automobiles. EPA’s National Emissions Inventory, http://www.epa. gov/ttn/chief/net/2008inventory.html.

[89] The regulation of SO_x, NO_x and CO_2 primarily falls under the Clean Air Act (CAA), which directs public agencies to regulate sources of air pollution and set standards for ambient concentrations of air pollutants. California may also set AAQS under the Children’s Environmental Health Protection Act, California Health & Safety Code **§** 39606

[90] California Health & Safety Code **§** 39606

[91] For more information, see the California Air Resources Board summary of nitrogen dioxide amendments *at* http://www.arb.ca.gov/research/aaqs/no2-rs/no2-rs.htm

[92] The Environmental Protection Agency (EPA) regulates three criteria pollutants that directly influence the acidity of coastal acidification: SO_x, NO_x, and, most recently, CO_2. The EPA can set two types of National Ambient Air Quality Standards (NAAQS) to control these pollutants: primary NAAQS to protect human health and secondary NAAQS to protect the environment. In 2008, the EPA established secondary NAAQS for SO_2 and NO_x to address the potential impacts of acidifying deposition on terrestrial systems, but acknowledged that there was insufficient scientific evidence to set standards protective of aquatic systems. In 2011, the EPA determined that NO_x and SO_2 deposition contribute to the acidification of aquatic ecosystems, and called for further research to inform more protective secondary NAAQS. At present, EPA has initiated a five-year pilot program to evaluate the contribution of SO_2 and NO_x deposition to regional, aquatic ecosystem acidification (Secondary National Ambient Air Quality Standards for Oxides of Nitrogen and Sulfur, 77 Fed. Reg. at 20,264.). However, the EPA has not set secondary air quality standards to protect aquatic systems from the acidification impacts of SO_x and NO_x because these standards are regulated nationally, while the deposition of these pollutants impacts ecosystems regionally. Moreover, there is inconclusive evidence identifying a “critical load” of criteria pollutant deposition that negatively impacts aquatic ecosystem through acidification.

[93] State standards for emissions that impact ecosystems within the state internalize the costs of these emissions. Often, regional emissions reductions result in high financial costs to state industry, with only partial return on investment because the reductions contribute to global environmental benefits. If local emissions are linked to local impacts, tightening air quality standards would be an economically rational management decision.

[94] http://www.arb. ca.gov/research/aaqs/caaqs/caaqs.htm (California Ambient Air Quality Standards).

[95] 75 Fed Reg 6474 (Feb. 9, 2010); 75 Fed Reg 35520 Because the state is required to meet or exceed the federal standard, CARB will be treating the federal standard as if it were the state standard until the next state rulemaking on the matter. Clean Air Act (42 U.S.C. 7409)

[96] Health and Safety Code § 38500 or “California Global Warming Solutions Act of 2006”.

[97] Lester S, Halpern B, Grorud-Colvert K, et al. 2009. Biological effects within no-take marine reserves: a global synthesis. *Mar Ecol Prog Ser* 384: 33–46.

[98] Periodic reviews of the state MPA network are required under the MLPA. These reviews offer an opportunity to incorporate OA considerations into the MPA Master Plan, in addition to building OA considerations into the regional monitoring plans.

[99] Under Fish and Game Code § 2861(a), new MPA designations can be proposed. (“The commission shall, annually until the master plan is adopted and thereafter at least every three years, receive, consider, and promptly act upon

petitions from any interested party, to add, delete, or modify MPAs, favoring those petitions that are compatible with the goals and guidelines of this chapter."). For new SWQPA designations, State and Regional Water Quality Control Boards, as well as any person, may nominate areas for designation. *See* California Ocean Plan, Appendix IV. State Water Resources Control Board. 2012. *Available at* http://www.swrcb.ca.gov/water_issues/programs/ocean/docs/cop2012.pdf

[100] See note 5 and 8.

[101] Commission for Environmental Cooperation. 2012. *Guide for Planners and Managers to Design Resilient Marine Protected Area Networks in a Changing Climate*. Montreal, Canada. ("Some of these properties [mitigation and adaptation to OA] can be supported through the size and placement of protected areas (e.g., abundance and size structure of upper trophic levels, species richness), and the reduction of other stressors such as fishing pressure. Some ecosystem properties may not be amenable to MPAs but can be used to predict their vulnerability to climate change (e.g., phenological matches, flexibility of migration routes, dependence on critical habitats, functional redundancy, response diversity and community evenness).")

[102] Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean. 2010. Committee on the Development of an Integrated Science Strategy for Ocean Acidification Monitoring, Research, and Impacts Assessment; National Research Council. *Available at* http://www.mbari.org/earth/mar_chem/ocean_acid/OceanAcidification_1-14.pdf

[103] The State Water Quality Control Board may designate SWQPAs to prevent the undesirable alteration of natural water quality within MPAs. These designations may include either SWQPA- ASBS or SWQPA-GP or in combination. In considering the designation of SWQPAs over MPAs, the State Water Quality Control Board will consult with the affected Regional Water Quality Control Board, the Department of Fish and Game and the Department of Parks and Recreation. *See* California Ocean Plan. State Water Resources Control Board. 2012. *Available at* http://www.swrcb.ca.gov/water_issues/programs/ocean/docs/cop2012.pdf

[104] Following SWRCB Resolution 2010-0057, new SWQPA-GP designations over existing wastewater outfalls would not require new limiting conditions or prohibitions on those outfalls. However, new wastewater outfalls or an increase in nonpoint source pollution into the SWQPA would be prohibited.

[105] See note 103.

[106] Kroeker K, Kordas RL, Crim RN, and Singh GG. 2010. Meta-analysis reveals negative yet variable effects of ocean acidification on marine organisms. Ecology Letters 13: 1419-1434; Kroeker K, Kordas RL, Crim RN, et al. 2013. Impacts of ocean acidification on marine organisms: Quantifying sensitivities and interaction with warming. Global Change Biology 19: 1884-1896.

[107] Monitoring has been identified as the first step towards addressing OA by a number of governmental and nongovernmental scientific bodies. Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean. 2010. Committee on the Development of an Integrated Science Strategy for Ocean Acidification Monitoring, Research, and Impacts Assessment; National Research Council. *Available at* http://www.mbari.org/earth/mar_chem/ocean_acid/OceanAcidification_1-14.pdf

[108] McLaughlin K, Weisberg SB, Dickson A, Hofmann G[E], Newton J. 2013. Core Principles for Development of a West Coast Network for Monitoring Marine Acidification and Its Linkage to Biological Effects in the Nearshore Environment. California Current Acidification Network.

[109] California Fish & Game Code § 2856. (The MPA Master Plan must contain "recommendations for monitoring, research, and evaluation in selected areas of the preferred alternative, including existing and long-established MPAs, to assist in adaptive management of the MPA network, taking into account existing and planned research and evaluation efforts.").

[110] California Fish & Game Code § 2850-2963

[111] Master Plan for Marine Protected Areas. Department of Fish and Wildlife. January 2008. *Available at* http://www.dfg.ca.gov/marine/pdfs/revisedmp0108.pdf

[112] Global Ocean Acidification Observing Network. http://www.pmel.noaa.gov/co2/GOA-ON/

[113] National Center for Marine Protected Areas. http://marineprotectedareas.noaa.gov; CEC. 2012. *Guide for Planners and Managers to Design Resilient Marine Protected Area Networks in a Changing Climate*. Montreal, Canada. Commission for Environmental Cooperation.

[114] Fish and Game Code § 2857 c(5) ("The MPA network and individual MPAs shall be of adequate size, number, type of protection, and location to ensure that each MPA meets its objectives and that the network as a whole meets the goals and guidelines of this chapter.").

[115] McLeod E, Salm R, Green A, and Almany J. 2009. Designing marine protected area networks to address the impacts of climate change. *Frontiers in Ecology and Environment* 7

[116] One of the MLPA's goals for the Marine Life Protection Program is: "To improve recreational, educational, and study opportunities provided by marine ecosystems that are subject to minimal human disturbance, and to manage these uses in a manner consistent with protecting biodiversity." FGC 2853(b). Master Plan for Marine Protected Areas. Department of Fish and Wildlife. January 2008. *Available at* http://www.dfg.ca.gov/marine/pdfs/revisedmp0108.pdf

[117] After an evaluation process, including environmental impact analysis, sites that are included in the system are "protected for long-term research, water-quality monitoring, education and coastal stewardship". California's NERRS sites include Elkhorn Slough, a portion of San Francisco Bay, and the Tijuana River slough. NOAA Website. http://www8.nos.noaa.gov/reserves/

[118] There are 2 MPAs in or adjacent (within 10 kilometers) of Humboldt Bay, 2 MPAs in or adjacent to Half Moon Bay, 14 MPAs in or adjacent to Monterey Bay, and 2 MPAs in or adjacent to San Diego Bay.

[119] 33 U.S. Code § 1330. The program provides federal funds for creating and implementing comprehensive management plans for nationally significant bays and estuaries. (Research funding for "a comprehensive water quality sampling program for the continuous monitoring of nutrients, chlorine, acid precipitation dissolved oxygen, and potentially toxic pollutants (including organic chemicals and metals) in estuarine zones"). For example, the San Francisco National Estuary Program has initiatives around the bay area to implement Low Impact Development designs and improve stormwater management, both of which help mitigate nonpoint source pollution. Estuaries particularly vulnerable to OA because of existing pH variability can be prioritized. High swings in pH exacerbated by coastal OA may be reduced by mitigating local anthropogenic drivers of coastal pH, including point and nonpoint sources.

[120] The federal Climate-Ready Estuaries Program provides funding to National Estuary Programs and coastal communities to adapt to climate change impacts, including ocean acidification. EPA Climate Ready Estuaries Program, information *available at* http://www2.epa.gov/cre/about-climate-ready-estuaries-program

[121] The State Coastal Conservancy climate change program specifically mentions OA as a climate change impact of interest and identifies projects the include the following elements as ones eligible for funding: "*Conservation, Restoration and Enhancement of Habitats that Sequester Carbon,* including forests, tidal wetlands, and estuarine scrub/shrub habitats" and "*Adaptive Management and Monitoring* of ecosystem and physical processes to support implementation of management actions to achieve project objectives under rapidly-changing climatic conditions". State of California Coastal Conservancy. http://scc.ca.gov/2009/01/21/coastal-conservancy-climate-change-policy-and-project-selection-criteria/.

[122] Gov't Code § 65302(d)(3). Counties and municipalities can support low impact development (LID) standards. *See* http://www.coastal.ca.gov/nps/lid_workshops.html for explanation of low impact development approaches and California Coastal Commission regional workshops held to promote their adoption, http://www.centralcoastlidi.org/Central_Coast_LIDI/General_Resources.html for zoning and land use planning LID recommendations, and http://cityofwatsonville.org/download/Public%20Works/Low%20Impact%20Dev%20BMP%20Design%20Guidance.pdf for the City of Watsonville's Low Impact Development Best Management Practice Design Guidance. *See* the California Low Impact Development Portal for other resources on urban runoff controls. https://www.casqa.org/resources/california-lid-portal

[123] Gov't Code § 65302(b)(2)(A)

[124] Gov't Code § 65302, 65596(f), 66411

[125] In 2007, the California General Attorney sued Bernardino County under CEQA for failing to adequately analyze adverse effects of their General Plan on air quality and climate change, and properly mitigate local air emissions to ensure good air quality for county citizens. Litigation on the contribution of local air emissions and point and nonpoint source pollution to coastal water quality and OA would force municipalities and counties to consider such impacts under CEQA and within their planning processes. *See* People ex. rel. Attorney Gen. Brown v. County of San Bernardino, No. CIVSS 0700329 (Cal. Super. Ct. Aug. 28, 2007) (Order Regarding Settlement).

[126] For specific language that would require projects to consider OA within proposal analysis, *see* Kelly R and Caldwell M. Center for Ocean Solutions. 2012. Why Ocean Acidification Matters to California, and What California Can Do About It: A Report on the Power of California's State Government to Address Ocean Acidification in State Waters. Stanford Woods Institute for the Environment, Stanford University, California, page 34.

[127] The Coastal Act authorizes the Commission to maintain and restore marine resources, including coastal water quality and biological productivity. *See* Publ. Res. Code § 30230 ("Marine resources shall be maintained, enhanced, and where feasible, restored"); § 30231("The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored.")
[128] Such as providing fee structures that incentivize development applicants to reduce coastal pollutant emissions that directly deposit into marine receiving waters. For example, the California Coastal Commission provides permit application fee reductions for energy efficient development. *See* http://www.coastal.ca.gov/climate/feereduction.html.
[129] The Commission can require coastal permit applicants to monitor coastal resources; monitoring requirements could scale with the size of the project or proposed development. For example, procedural guidance for the review of wetland projects requires monitoring in order to accurately evaluate project impacts. *See* California Coastal Commission. "Procedural Guidance for the review of wetland projects in California's coastal zone". Appendix C. ("The monitoring plan should include… Monitoring of water quality. Repetitive sampling of various chemical and physical constituents such as salinity, pH, nutrient concentration, dissolved oxygen, temperature, and turbidity throughout the year."), *available at* http://www.coastal.ca.gov/web/wetrev/wetappc.html.
[130] *See* the Southern California Coastal Water Research Project's regional monitoring program website: http://www.sccwrp.org/researchareas/RegionalMonitoring/BightRegionalMonitoring.aspx
[131] Developing these measures is challenging given the short spatial scales (e.g., water quality and local pH can vary hourly) and small spatial scales (e.g., around a hatchery intake pipe) that may be required to adequately inform proactive management.
[132] Although nascent, there is a growing body of research detailing the existing and potential socio-economic impacts of OA (for a repository of this research, see NOAA's website *at* http://oceanacidification.noaa.gov/AreasofFocus/SocioEconomicImpacts.aspx). The need for research on the social and economic impacts of OA is also referenced in Washington State's Senate Bill 5603 *available at* http://apps.leg.wa.gov/documents/billdocs/2013-14/Pdf/Bills/Senate%20Bills/5603.E.pdf.
[133] *See* Kelly R, Cooley S, and Klinger T. 2014. Narratives can motivate environmental action: the whiskey creek ocean acidification story. *Ambio* 43(5):592-599.
[134] 33 U.S.C. § 1341(d) (NPDES permits may include "monitoring requirements necessary to assure that any applicant for a Federal license or permit will comply with any applicable effluent limitations.").
[135] State Water Quality Resource Control Board. California Ocean Plan Triennial Review Workplan. 2011. http://www.waterboards.ca.gov/water_issues/programs/ocean/docs/trirev/wrkpln2011_13.pdf
[136] California Current Acidification Network. http://c-can.msi.ucsb.edu
[137] 2009 California Climate Change Adaptation Strategy. 2009. California Department of Natural Resources. *Available at* http://resources.ca.gov/climate_adaptation/docs/Statewide_Adaptation_Strategy.pdf ("Prepare climate strategies, indicators, and thresholds that respond to changing ocean temperatures, air temperatures, predator-prey interactions, and ocean acidification. These strategies should include alternative management strategies that could be employed, such as alternative fisheries management approaches dependent upon temperature regimes, alternative marine protected areas for stressed species, or changes to aquaculture and fishing practices under lower pH conditions.")
[138] The CO-CAT website details membership and its mission. *See* http://www.opc.ca.gov/2010/07/coastal-and-ocean-climate-action-team-co-cat/.
[139] Thomas, Michael. MARINE Seminar Talk. "Implementing Ocean Acidification Research: Strategies and Perspectives". December 7, 2011.
[140] Percent of the upper 100m of the California Current water column estimated to be under-saturated with aragonite during August and September in 2011. The numbers indicate sampling locations for pteropods, which were collected to measure the degree of shell dissolution damage, as correlated with undersaturation, within the California Current. Aragonite, a more soluble form of $CaCO_3$, is used by calcifying organisms to form shells. The saturation horizon ($\Omega ar=1$) has been associated with significant shell dissolution within the California Current. The numbers indicate sampling locations for pteropods, which were collected to measure the degree of shell dissolution damage, as correlated with undersaturation, within the California Current. *See* Bednarsek N, Feely R, Reum J, et al. 2014. *Limacina helicina* shell dissolution as an indicator of declining habitat suitability owing to ocean acidification in the California Current Ecosystem *Proceedings of the Royal Society of Biology* 381:20140123.