April 16, 2014

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Re: Comment Concerning Ocean Acidification on Public Review Draft Staff Report for the 2012 Integrated Report for the Clean Water Act Section 305(b) Surface Water Quality Assessment and the 303(d) List of Impaired Waters

In response to the draft 2012 integrated report, the North Coast has failed to identify waters impaired by ocean acidification.

In previous comments, the Center has provided significant information about the impacts of ocean acidification on the California coast. As shown in the record for this draft integrated report, on February 27, 2007, the Center for Biological Diversity submitted scientific information supporting the inclusion of ocean waters on California's 303(d) list to each of the coastal regional water boards. I was informed that the regional board deferred action on ocean acidification to the State Water Resources Control Board. Missing from the region's record therefore, are letters dated June 11, 2008; February 4, 2009, May 28, 2010; and August 27, 2010 in which the Center submitted additional information and comments on ocean acidification to the State Water Resources Control Board. Those comments are incorporated here by reference and are available upon request.

Since then, it has only become more apparent that ocean acidification poses a serious threat to seawater quality with adverse effects on marine life. There is a significant body of scientific information that has developed since the 2007 letter which is in the record. This letter will describe some of the most important new studies on ocean acidification in the region, yet the region must evaluate all readily available information on ocean acidification to inform its 303(d) list.

1. California Must Evaluate its Own Data and Solicit it From Research Organizations

California has an independent duty to evaluate ocean acidification during its water quality assessment (Environmental Protection Agency 2010). Specifically, EPA directed states to evaluate ocean acidification data for their 2012 integrated reports (Environmental Protection Agency 2010). The Clean Water Act provides that states must "evaluate all existing and readily available water quality-related data and information to develop the list." 40 C.F.R. § 130.7(b)(5); *see also Sierra Club v. Leavitt*, 488 F.3d 904 (11th Cir. 2007). Beyond reviewing the information submitted by the Center, California must also evaluate pH, biological information, and other monitoring data that is available to it and seek out ocean acidification data from state, federal, and academic research institutions. EPA's 2010 memo and Integrated Report Guidance discussed several sources, including the National Oceanic and Atmospheric Administration data (EPA 2010: 7-9; EPA Guidance 30-31). There are now several sources for high resolution ocean acidification data. California must obtain and evaluate data from research institutions, including but not limited to:

- PMEL NOAA http://www.pmel.noaa.gov/
- National Ocean Data Center http://www.nodc.noaa.gov/
- Integrated Ocean Observing System http://www.ioos.noaa.gov/
- Central & Northern California Ocean Observing System http://www.cencoos.org/
- Monterey Bay Aquarium Research Institute
- Scripps Institution of Oceanography
- West Coast Ocean Acidification and Hypoxia Science Panel http://westcoastoah.org
- California Current Acidification Network http://c-can.msi.ucsb.edu/

California has failed to meet these requirements. To correct its integrated report, the North Coast Region needs to obtain and evaluate all relevant parameters of ocean acidification data available from these sources that serve as clearinghouses for ocean acidification data, especially those that are specific to California's waters.

2. The North Coast Should List Ocean Waters as Impaired

This comment letter focuses on research since 2010 that is particularly relevant to California and the California Current ecosystem, but it is only a glimpse into the research that exists on ocean acidification. This information and data highlight that Northern California is particularly vulnerable to ocean acidification and its aquatic life impacts. California is already experiencing levels of CO_2 that were not expected until the end of the century.

a. Corrosive Waters Warrant Listing

The oceans are becoming more acidic faster than they have in the past 300 million years, a period that includes four mass extinctions (Honisch et al. 2012). Researchers looked at the geologic record and found that that the Paleocene-Eocene Thermal Maximum was the closest event to what we're experiencing now by adding carbon dioxide to the oceans. At that time, the climate warmed by about 5˚C, yet the rate of carbon dioxide increase was only about 10% of what the earth is experiencing now. This means that the ocean chemistry changes that are occurring due to ocean acidification are unprecedented and are cause for concern that the oceans may face mass extinctions of many species that we care about including California's shellfish. Friedrich et al. concluded that anthropogenic ocean acidification already exceeds the natural variability on regional scales and is detectable in many of the world's oceans (Friedrich et al. 2012).

The California Current ecosystem is already experiencing adverse impacts of ocean acidification. A survey of the Pacific off the coasts of Washington, Oregon, and California revealed that the effects of ocean acidification are occurring more rapidly there than predicted (See figure 3) (Feely 2008). Researchers found seawater undersaturated with respect to aragonite upwelling onto large portions of the continental shelf, reaching shallow depths of 40 to 120 meters (Id.). As a result, marine organisms in surface waters, in the water column, and on the sea floor along the West Coast of the United States are already being exposed to corrosive water during the upwelling season. According to the study, "the upwelled water off northern California (line 5) was last at the surface about 50 years ago, when atmospheric CO_2 was about 65 ppm lower than it is today" (Feely et al. 2008: 1492).

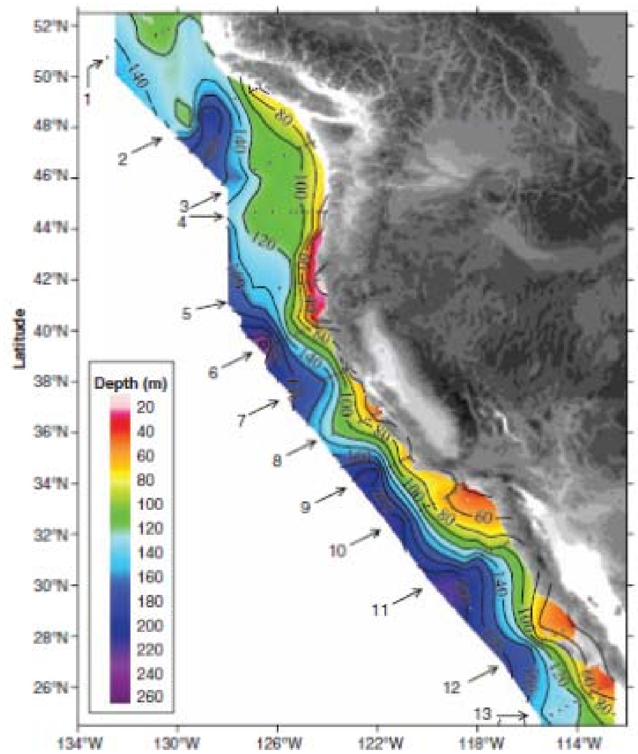

Figure 3. Distribution of the depths of the undersaturated water (aragonite saturation < 1.0; pH < 7.75) on the continental shelf of western North America from Queen Charlotte Sound, Canada, to San Gregorio Baja California Sur,Mexico. On transect line 5, the corrosive water reaches all the way to the surface in the inshore waters near the coast. The black dots represent station locations (Feely et al. 2008).

Time series monitoring shows that the aragonite saturation state along the California coast is much lower than would be expected in the North Pacific (Harris, DeGrandpre et al. 2013). Surface ΩAr values ranged between 0.66 and 3.9 compared to an estimated pre-industrial range of 1.0 to 4.7. While some areas are already exhibiting undersaturated conditions (Feely et al. 2012; Reum et al. 2014), scientists predict that most shallow shelf areas along the West Coast will become undersaturated with respect to aragonite within the next 20-30 years (Capone and

Hutchins 2013; Gruber et al. 2012). Modeling of the California Current System demonstrates that the area is rapidly approaching near-permanent undersaturation with respect to aragonite and it is departing significantly from natural variability (Hauri et al. 2013).

Moreover, California must consider that waters off the California Coast are already experiencing CO_2 levels not expected until the end of the century. Off the West Coast in upwelling waters during August 2011, pCO_2 measured 850 to 950 μatm near the continental shelf break with higher values inshore (Feely 2012). Accordingly, many of the studies consider this CO_2 range to predict end of the century levels, but here off the California coast these levels are already occurring in surface waters.

b. Ocean Acidification Impairs Shellfish and Aquatic Life Uses

California's shellfish are adversely impacted by ocean acidification, or will be in the near future. Oregon and Washington have already experienced massive oyster mortality as a result of ocean acidification. Since 2005, oysters have failed to reproduce in Willapa Bay, Washington (Feely 2012, Panel 2012). A few years later, shellfish hatcheries in Washington and Oregon witnessed massive die-offs of oyster larvae—nearly causing the industry to collapse and causing panic in the nation's top oyster producing region (Id.). Barton et al. have now definitively linked the devastating oyster mortalities in the Pacific Northwest to ocean acidification. The study found that oyster larvae had difficulty with growth and production in waters with elevated CO_2 . The researchers observed oyster response to ocean acidification from the Whiskey Creek Hatchery on Netarts Bay, Oregon in the summer of 2009 (Barton et al. 2012). Notably, this study analyzed calcifying organism responses to ambient water in the coastal upwelling system, a study reaching beyond the laboratory to actual observation. Subsequent studies confirm the link between ocean acidification and impaired growth and survival of Pacific oysters (Waldbusser, Brunner et al. 2013). Studies of Pacific oysters from the wild also demonstrated developmental problems (Timmins-Schiffman et al. 2012).

Similarly, research on the Olympia oyster showed that with reduced pH levels the juvenile oysters exhibited a 41% decrease in shell growth rate (Hettinger et al. 2013; Hettinger et al. 2012). Notably the negative impacts of exposure to low pH early in the life history of the oysters persisted even when juveniles were returned to higher pH levels. Olympia oysters also demonstrated 20% increase of predation by invasive snails due to ocean acidification in studies (Sanford et al. 2014). And ocean acidification can impair the ability of mollusks to escape predators (Watson et al. 2014).

A study on northern abalone, which is endemic to the West Coast, found it was sensitive to ocean acidification (Crim, Sunday et al. 2011). Northern abalone (*Haliotis kamtschatkana*), or pinto abalone, has declined throughout its range and is considered endangered by the IUCN. The study on the impacts of ocean acidification on northern abalone found that a doubling of CO_2 levels reduced larval survival by 40% and increased shell abnormalities by 40% (Id.). Because of the upwelling system along the California coast, the levels of CO_2 that were used in this experiment may be reached much sooner than earlier predictions and northern abalone spawns at the peak of the upwelling season. The study indicates that it does not tolerate ocean acidification, which may contribute to population level impacts (Id.).

Research has also shown negative impacts on bivalves (Talmage and Gobler 2011, White, McCorkle et al. 2013). Newer studies show that these early growth impacts in larval bivalves continue to impair the bivalves at later life stages (Gobler and Talmage 2013). Researchers have also found that the combination of hypoxia and acidification act synergistically to elevate the negative impacts on metamorphosis of bivalves, bay scallops and hard clams (Gobler et al. 2014).

Echinoderms have also proven sensitive to ocean acidification. In a review of studies on sea urchins, 13 species demonstrated impaired growth for sea urchin larvae for levels of 800 µatm pCO_2, whereas at future levels all species of urchins had growth problems (Byrne, Lamare et al. 2013). Notable here in California, ocean acidification delays purple sea urchin (Strongylocentrotus purpuratus) larvae growth (Stumpp, Dupont et al. 2011).

A review of the sensitivity of five taxa to ocean acidification reveals the severity of the threat in species composition of the marine ecosystems (Wittmann and Pörtner 2013). Although different species had different responses, overall corals, echinoderms, molluscs, and fish showed sensitivity to ocean acidification at 936 ppm pCO_2, with crustaceans less sensitive (Id.). Another meta-analysis of the biological responses to ocean acidification confirms these results with impacts seen on the survival, growth, reproduction, and other functions of species (Kroeker et al. 2013). The chart below shows the sensitivity of each taxa to varying degrees of pCO_2 (Wittmann and Pörtner 2013). These studies predict severe changes in ecosystem composition and negative impacts on most marine animals. Seasonal conditions in California already reach extreme pCO_2 levels not expected until the end of the century.

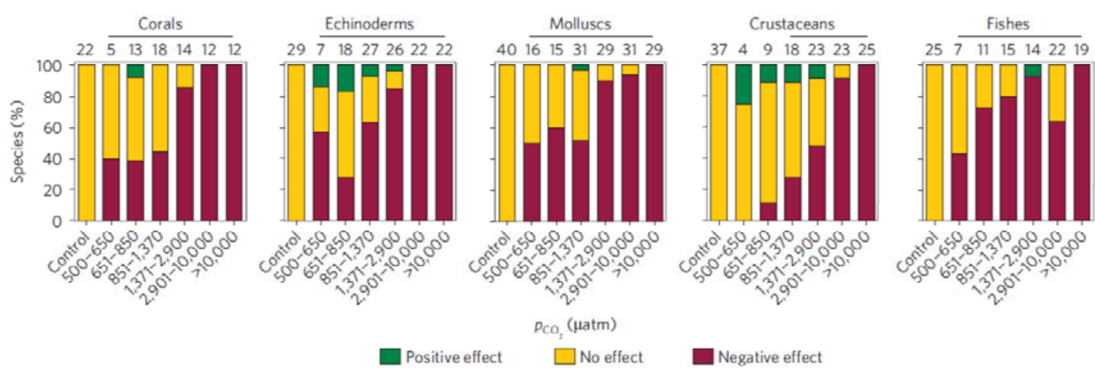

Figure 1 Sensitivities of animal taxa to ocean acidification. Fractions (%) of coral, echinoderm, mollusc, crustacean and fish species exhibiting negative, no or positive effects on performance indicators reflecting individual fitness (see text) in response to the respective *p*CO2 ranges (_atm). Note that it was not possible to determine the response of each species for each CO2 range, such that variable species numbers (on top of columns) result, even though the following assumptions were used to compensate at least for some of the missing information: species that exhibit negative effects at low *p*CO2 will exhibit negative effects at the higher *p*CO2 levels as well; if a species exhibits a positive/negative/no effect at both, a low and a high *p*CO2 , it will exhibit the same effect at a medium *p*CO2 (see also Supplementary Table S2). Bars above columns denote count ratios significantly associated with *p*CO2 (according to Fisher's exact test, *p*<0:05, used to analyse species counts of pooled groups of negatively affected species versus not negatively affected species (sum of positively affected and unaffected species); see Supplementary Table S3 for exact *p* values). (Wittmann and Pörtner 2013).

A review of ocean acidification studies on fish and shellfish describes impacts in many commercially targeted species (Branch et al. 2012). Studies show impacts to many seafood species impairing their senses, function and survival (Id.). Predicted impacts to fisheries are expected to be substantial (Id.). Tanner crabs are sensitive to ocean acidification (Long et al. 2013). They exhibited decreased survival at lower pH, slower growth in pH 7.5 water, and impaired calcification in acidified water (Id.). The impacts on fisheries from ocean acidification will be substantial. Narita et al. suggest that the costs for the world could be over $100 billion USD in production losses of mollusks alone by 2100 if CO_2 emissions are unabated (Narita et al. 2011).

Ocean Acidification Intensifies Toxicity

The toxicity of harmful algal blooms increases with ocean acidification. Research suggests that ocean acidification conditions can increase toxins as much as five-fold in harmful algae that can poison shellfish, marine mammals, fish, and even cause paralytic shellfish poisoning in people (Fu et al. 2012; Tatters et al. 2013a; Tatters et al. 2013b; Tatters et al. 2012). The neurotoxin domoic acid in diatom *Pseudo-nitzschia* increased under these experiments with acidification as did the toxicity of *Alexandrium catenella* (Id.). The experiments done in these studies were at levels of CO_2 that are already occurring in California, and the increase in the toxicity of harmful algal blooms in Southern California may be consistent with ocean acidification (Id.)

Additionally, research shows that under conditions of ocean acidification sediments become more toxic (Roberts, Birchenough et al. 2013). Ocean acidification makes sediment-bound metals more available and thus more toxic for aquatic life (Id.)

California is vulnerable to having its fisheries and seafood industry severely impacted by increasing toxicity of ocean habitats.

* * *

In conclusion, California and the North Coast Region must thoroughly evaluate ocean acidification data and identify undersaturated waters and others that are not meeting water quality standards as threatened or impaired. It is imperative that the state take action now on ocean acidification to address this important water quality problem before it has devastating consequences on its fisheries and ecosystems.

Sincerely,

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enclosure

Barton A, Hales B, Waldbusser GG, et al. (2012) The Pacific oyster, Crassostrea gigas, shows negative correlation to naturally elevated carbon dioxide levels: Implications for near-term ocean acidification effects. Limnol Oceanogr 57:698–710. doi: 10.4319/lo.2012.57.3.0698

Branch T a., DeJoseph BM, Ray LJ, Wagner C a. (2012) Impacts of ocean acidification on marine seafood. Trends Ecol Evol 1–9. doi: 10.1016/j.tree.2012.10.001

Byrne, M., M. Lamare, D. Winter, S. A. Dworjanyn and S. Uthicke (2013) "The stunting effect of a high CO2 ocean on calcification and development in sea urchin larvae, a synthesis from the tropics to the poles." Philos Trans R Soc Lond B Biol Sci 368(1627): 20120439.

Capone DG, Hutchins D a. (2013) Microbial biogeochemistry of coastal upwelling regimes in a changing ocean. Nat Geosci 6:711–717. doi: 10.1038/ngeo1916

Crim, R. N., J. M. Sunday and C. D. G. Harley (2011) "Elevated seawater CO2 concentrations impair larval development and reduce larval survival in endangered northern abalone (Haliotis kamtschatkana)" Journal of Experimental Marine Biology and Ecology 400(1-2): 272-277.

Environmental Protection Agency (2010) Memo: Integrated reporting and listing decisions related to ocean acidification.

Feely RA, Klinger T, Newton JA (2012) Scientific Summary of Ocean Acidification in Washington State Marine Waters.

Feely RA, Sabine C, Hernandez-Ayon JM, et al. (2008) Evidence for upwelling of corrosive “acidified” water onto the continental shelf. Science (80-) 320:1490. doi: 10.1126/science.1155676

Feely, R. A. (2008) "Evidence for Upwelling of Corrosive Acidified Waters." Science(320): 1490.

Feely, R. A. (2012) "Scientific Summary of Ocean Acidification in Washington State."

Friedrich, T. et al., (2012) Detecting regional anthropogenic trends in ocean acidification against natural variability. *Nature Climate Change*, 2(2), pp.1–5.

Fu F, Tatters A, Hutchins D (2012) Global change and the future of harmful algal blooms in the ocean. Mar Ecol Prog Ser 470:207–233. doi: 10.3354/meps10047

Gobler CJ, Depasquale EL, Griffith AW, Baumann H (2014) Hypoxia and acidification have additive and synergistic negative effects on the growth, survival, and metamorphosis of early life stage bivalves. PLoS One 9:e83648. doi: 10.1371/journal.pone.0083648

Gobler, C. J. and S. C. Talmage (2013) "Short- and long-term consequences of larval stage exposure to constantly and ephemerally elevated carbon dioxide for marine bivalve populations." Biogeosciences 10(4): 2241-2253.

Gruber, N. et al., (2012) Rapid progression of ocean acidification in the California Current System. *Science (New York, N.Y.)*, 337(6091), pp.220–3.

Harris, K. E., M. D. DeGrandpre and B. Hales (2013) "Aragonite saturation state dynamics in a coastal upwelling zone." Geophysical Research Letters 40(11): 2720-2725.

Hauri C, Gruber N, Vogt M, et al. (2013) Spatiotemporal variability and long-term trends of ocean acidification in the California Current System. Biogeosciences 10:193–216. doi: 10.5194/bg-10-193-2013

Hettinger A, Sanford E, Hill T (2012) Persistent carry-over effects of planktonic exposure to ocean acidification in the Olympia oyster. Ecology In press:

Hettinger a., Sanford E, Hill TM, et al. (2013) The influence of food supply on the response of Olympia oyster larvae to ocean acidification. Biogeosciences 10:6629–6638. doi: 10.5194/bg-10-6629-2013

Hönisch, B. et al., 2012. The geological record of ocean acidification. *Science*, 335(6072), pp.1058–63.

Kroeker KJ, Kordas RL, Crim R, et al. (2013) Impacts of ocean acidification on marine organisms: quantifying sensitivities and interaction with warming. Glob Chang Biol n/a–n/a. doi: 10.1111/gcb.12179

Lischka S, Riebesell U (2012) Synergistic effects of ocean acidification and warming on overwintering pteropods in the Arctic. Glob Chang Biol 18:3517–3528. doi: 10.1111/gcb.12020

Long WC, Swiney KM, Harris C, et al. (2013) Effects of ocean acidification on juvenile red king crab (Paralithodes camtschaticus) and Tanner crab (Chionoecetes bairdi) growth, condition, calcification, and survival. PLoS One 8:e60959. doi: 10.1371/journal.pone.0060959

Meinvielle M, Johnson GC (2013) Decadal water-property trends in the California Undercurrent, with implications for ocean acidification. J Geophys Res Ocean 118:6687–6703. doi: 10.1002/2013JC009299

Narita D, Rehdanz K, Tol RSJ (2011) Economic Costs of Ocean Acidification : A Look into the Impacts on Shellfish Production.

Panel, W. S. B. R. (2012) "Ocean Acidification: From Knowledge to Action, Washington State's Strategic Response."

Reum JCP, Alin SR, Feely R a., et al. (2014) Seasonal Carbonate Chemistry Covariation with Temperature, Oxygen, and Salinity in a Fjord Estuary: Implications for the Design of

Ocean Acidification Experiments. PLoS One 9:e89619. doi: 10.1371/journal.pone.0089619

Roberts, D. A., S. N. Birchenough, C. Lewis, M. B. Sanders, T. Bolam and D. Sheahan (2013) "Ocean acidification increases the toxicity of contaminated sediments." Glob Chang Biol 19(2): 340-351.

Sanford E, Gaylord B, Hettinger A, et al. (2014) Ocean acidification increases the vulnerability of native oysters to predation by invasive snails. Proc Biol Sci 281:20132681. doi: 10.1098/rspb.2013.2681

Stumpp, M., S. Dupont, M. C. Thorndyke and F. Melzner (2011) "CO2 induced seawater acidification impacts sea urchin larval development II: gene expression patterns in pluteus larvae." Comp Biochem Physiol A Mol Integr Physiol 160(3): 320-330.

Talmage, S. C. and C. J. Gobler (2011) "Effects of elevated temperature and carbon dioxide on the growth and survival of larvae and juveniles of three species of northwest Atlantic bivalves." PLoS One 6(10): e26941.

Tatters AO, Flewelling LJ, Fu F, et al. (2013) High CO2 promotes the production of paralytic shellfish poisoning toxins by Alexandrium catenella from Southern California waters. Harmful Algae 30:37–43. doi: 10.1016/j.hal.2013.08.007

Tatters AO, Fu F-X, Hutchins D a (2012) High CO2 and silicate limitation synergistically increase the toxicity of Pseudo-nitzschia fraudulenta. PLoS One 7:e32116. doi: 10.1371/journal.pone.0032116

Tatters, A.O. et al. (2013) Diatom community to acidification and warming Short- and long-term conditioning of a temperate marine diatom community to acidification and warming.

Timmins-Schiffman E, O'Donnell MJ, Friedman CS, Roberts SB (2012) Elevated pCO2 causes developmental delay in early larval Pacific oysters, Crassostrea gigas. Mar Biol 160:1973–1982. doi: 10.1007/s00227-012-2055-x

Waldbusser GG, Brunner EL, Haley B a., et al. (2013) A developmental and energetic basis linking larval oyster shell formation to acidification sensitivity. Geophys Res Lett 40:2171–2176. doi: 10.1002/grl.50449

Waldbusser, G. G., E. L. Brunner, B. A. Haley, B. Hales, C. J. Langdon and F. G. Prahl (2013) "A developmental and energetic basis linking larval oyster shell formation to acidification sensitivity." Geophysical Research Letters 40(10): 2171-2176.

Watson S, Lefevre S, Mccormick MI, et al. (2014) Marine mollusc predator-escape behaviour altered by near-future carbon dioxide levels Marine mollusc predator-escape behaviour altered by near-future carbon dioxide levels.

White, M. M., D. C. McCorkle, L. S. Mullineaux and A. L. Cohen (2013) "Early exposure of bay scallops (Argopecten irradians) to high CO(2) causes a decrease in larval shell growth." PLoS One 8(4): e61065.

Wittmann AC, Pörtner H-O (2013) Sensitivities of extant animal taxa to ocean acidification. Nat Clim Chang 3:1–7. doi: 10.1038/nclimate1982