Dynamic MPAs ver.0.0: Protecting Cowcods From Potential Climate-Forced Hypoxia in Southern California

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Summary

Dynamic marine protected areas (MPAs) are areas with a range of dormant management responses that turn on only when conditions warrant them. This new tool has the potential to allow resource managers to respond to impending but highly uncertain future environmental harms, such as the effects of climate change, in a timely fashion without abridging existing public participation processes. The creation of a dynamic MPA would require careful integration of science, law, and policy. Dynamic MPAs would have three components: (1) management goals; (2) substantive responses; and (3) triggering indicators. This Article applies the challenge of managing developing climate-driven mid-water hypoxia to the protection of an overexploited fish species in southern California and creates a hypothetical dynamic MPA based on an existing MPA.

Government administrators need flexibility to account for uncertainties when managing natural resources.[1] At the same time, administrators must comply with procedural legal mandates when they take management actions.[2] These mandates can significantly lengthen the time managers need to put regulatory responses into effect.[3] Such delays can easily hamper the effectiveness of management responses. Minimizing delays in the context of managing marine resources is especially important, since the ocean is a dynamic environment and conditions can change rapidly.

Preemptive administrative actions can ensure timely regulatory responses. However, creating and implementing preemptive responses is difficult when complex uncertainties that would severely hamper a resource manager's ability to project future conditions still exist.[4] For managers in charge of California's marine resources, accounting for the complexity of over 800 miles of coastal ecosystem in an increasingly volatile climate is a challenging endeavor. This Article proposes the use of dynamic marine protected areas (MPAs) as a potential tool for managers to efficiently manage a dynamic system in the face of substantial uncertainties. By synthesizing a range of solutions ahead of time, managers can implement those solutions in a timely manner, comply with existing procedural mandates, and take into account any significant lack of information.

This Article proposes a new management tool, the dynamic MPA, which resource managers can use to manage complex environmental problems. Part I discusses what a dynamic MPA is, why it is preferable to traditional MPAs under certain circumstances, and the pertinent California statutes it can be implemented under. Part II analyzes the process of creating a dynamic MPA using an emerging environmental issue currently facing southern California MPAs as the context. Part III uses the process and issue discussed in Part II to create a hypothetical dynamic MPA.

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1. *See* James William Merrill, *Trawling for Meaning: A New Standard for "Best Scientific Information Available" in the Magnuson-Stevens Fisheries Conservation Act*, 60 Cath. U. L. Rev. 475 (2011).
2. *See infra* note 14.
3. *See infra* note 16.
4. *See infra* note 18.

I. Dynamic MPA and the Marine Life Protection Act

MPAs are "clearly defined geographical space [in the marine environment], recognized, dedicated, and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values."[5] Simply put, MPAs restrict human disturbances within a given area of the ocean.[6] When MPAs are properly designed and managed, ecosystems within them are generally healthier than unprotected areas due to insulation from human disturbances.[7] MPAs can confer specific benefits to local communities under the right conditions, such as more fish for local fishermen.[8] However, MPAs primarily serve to provide diffused ecosystem services that are difficult to capture with hard numbers.[9] For example, the 25-Year Strategic Document of the Australia Great Barrier Reef Marine Park mainly emphasizes the value of nonextractive uses of its MPAs.[10]

An MPA's effectiveness ultimately depends in large part on the quality of its design.[11] An MPA's design should reflect the conditions of the surrounding natural environment. An MPA designed to protect a specific population of fish is effective only if the fish stay inside the MPA boundary most if not all of the time.[12] Environmental conditions, however, can change. Resource managers can have a hard time keeping up with constant changes in the environment under the existing administrative system, especially changes that are complex and difficult to predict. The dynamic MPAs proposed here offer resource managers a tool that can keep pace with an ever-changing environment. And with the power conferred by the Marine Life Protection Act (MLPA), resource managers in California should have the authority to implement this new tool.

A. *Managing Changing Environment With Dynamic MPAs*

Dynamic MPAs as envisioned in this Article are areas with a range of built-in response mechanisms that alter the MPAs and agency management efforts automatically in response to changing ocean conditions.[13] For instance, a set of MPA regulations may alter the level of protection for a vulnerable fish population based on the amount of new fish the population receives each year. These regulations would undergo documentation and public scrutiny like any other regulation. Once the regulations are finalized, they would lie dormant within the regulations and require automatic agency response when triggering environmental conditions occur. This ability to turn specific regulatory responses on only when they are needed confers an important advantage: it gives resource managers the ability to respond to volatile future changes on time without sacrificing the accuracy of the responses.

Procedural environmental statutes like the California Environmental Quality Act (CEQA) require California agencies to explain any significant environmental decision, memorialize it in the public record, and open it to public scrutiny.[14] Such additional public processes are designed to help prevent managers from taking shortcuts or skipping important analyses, but they can also impact the timeliness of regulatory responses.[15] A 2005 finding published in the *Administrative and Regulatory Law News* suggests that new federal regulations can take anywhere from just under one year when no public comment is made to over one year when comments are made, and that does not include

5. *See* International Union for Conservation of Nature (IUCN), Guidelines for Applying the IUCN Protected Area Management Categories to Marine Protected Areas (IUCN 2012), *available at* https://cmsdata.iucn.org/downloads/iucn_categoriesmpa_eng.pdf.
6. *See* Elizabeth R Selig & John F. Bruno, *A Global Analysis of the Effectiveness of Marine Protected Areas in Preventing Coral Loss*, 5 PLoS One e9278 (2010); *but see* Monica Montefalcone et al., *Legal Protection Is Not Enough:* Posidonia oceanica *Meadows in Marine Protected Areas Are Not Healthier Than Those in Unprotected Areas of the Northwest Mediterranean Sea*, 58 Marine Pollution Bull. 515 (2009).
7. *Id.*
8. *See* R. Quentin Grafton et al., *The Economic Payoffs From Marine Reserves: Resource Rents in a Stochastic Environment*, 82 Econ. Rec. 469 (2006); *see also* James N. Sanchirico & James E. Wilen, *A Bioeconomic Model of Marine Reserve Creation*, 42 J. Envtl. Econ. & Mgmt. 257 (2001).
9. *See* Grafton et al., *supra* note 8; *see also* Cal. Fish & Game Code §§853(3), (4) (2013).
10. Great Barrier Reef Marine Park Authority, The Great Barrier Reef, Keeping It Great—A 25-Year Strategic Plan for the Great Barrier Reef World Heritage Area 13 (Great Barrier Reef Marin Park Authority 1994), *available at* http://www.gbrmpa.gov.au/__data/assets/pdf_file/0004/5476/the-25-year-strategic-plan-1994.pdf.
11. *See* Martin D. Smith & James E. Wilen, *Economic Impacts of Marine Reserves: The Importance of Spatial Behavior*, 42 J. Envtl. Econ. & Mgmt. 183 (2003); *see also* Ronald J. Maliao et al., *A Survey of Stock of the Donkey's Ear Abalone,* Haliotis asinina L., *in the Sagay Marine Reserve, Philippines: Evaluating the Effectiveness of Marine Protected Area Enforcement*, 66 Fisheries Res. 343 (2004).
12. James B. Lindholm et al., *Modeling the Effects of Fishing and Implications for the Design of Marine Protected Areas: Juvenile Fish Responses to Variations in Seafloor Habitat*, 15 Conservation Biology 424 (2001).
13. *See* Robin Kundis Craig, Ocean Governance for the 21st Century: Making Marine Zoning Climate Change Adaptable (2012); *see also* Stanford Law School Symposium: Emerging Perspectives on the Law, Science, and Policy of Dynamic Marine Conservation (2013), *available at* http://blogs.law.stanford.edu/dynamic-ocean/2013/02/01/home/; *see also* Robin Kundis Craig, Comparative Ocean Governance: Place-Based Protections in an Era of Climate Change 163 (Edward Elgar Publ. 2012) (the concept of managing the ocean with a dynamic system is an ongoing area of research).
14. 42 U.S.C. §§4321 et seq. (2013); Cal. Pub. Res. Code §§21000 et seq. (2013); *see* Western States Petroleum Association v. Superior Court, 9 Cal. 4th 559 (1995); *see also* Marsh v. Oregon Natural Resources Council, 490 U.S. 360, 373, 19 ELR 20749 (1989).
15. *See* Natural Resources Defense Council v. Kempthorne, 506 F. Supp. 2d 322, 352-54 (2007); *see also* Kern v. U.S. Bureau of Land Management, 284 F.3d 1062, 1073, 32 ELR 20571 (9th Cir. 2002) (BLM improperly tiered NEPA documents to avoid analysis); *see also* NRDC v. U.S. Army Corps of Engineers*,* 457 F. Supp. 2d 198, 233-34 (S.D.N.Y. 2006).

the time it takes to conduct environmental assessments.[16] Moreover, recent MPA designation history in California suggests that any significant regulatory change would lead to litigation, which would impact the timeliness of any new regulatory response even further.[17]

At a time when the ocean environment is becoming more and more volatile and unpredictable due to climate change, resource managers cannot always afford to delay regulatory responses.[18] Effects associated with larger climate can be cumulative through time, and every month of administrative delay can lead to increasingly dire consequences.[19] Marine organisms would not wait for rulemaking processes; they would either wither or leave when an MPA become inhospitable.[20]

While the effects climate change can have on the ocean are potentially catastrophic, the sheer complexity of the phenomenon makes responses based on "most likely" scenarios impractical. Climate scientists can make predictions regarding the future climate impacts with sophisticated climate models, but different models tend to create different results.[21] The differences can be significant in some instances.[22] Resource managers hoping to pin down a single future scenario around which to develop a management strategy may find themselves jostling between several likely scenarios that require drastically different management approaches.[23] Under the dynamic MPA framework, time-consuming decisions are front-loaded, and a full range of responses would be synthesized to account for multiple possible future scenarios that incomplete scientific knowledge cannot eliminate. Decisionmakers would develop the management responses based on different future scenarios, shepherd them through any essential public process, and embed them into regulations before the impending environmental harm takes place.

B. *The Legality of Dynamic MPAs and the California MLPA*

Resource managers in California can implement dynamic MPAs only if either the state constitution or a state law gives them the power to do so.[24] Right now, this power would come from the MLPA.[25] The Act was first passed in 1999 in an effort to consolidate then-existing state MPAs and to create new ones.[26] The state legislature subsequently passed the Marine Managed Areas Improvement Act (MMAIA) in 2000 to further complement the administration of the MLPA.[27] MLPA regulations are promulgated through the California Department of Fish and Wildlife.[28] The job of designating the MPAs, however, falls to the California Fish and Game Commission (Commission).[29] Designations process, in turn, provides for a strong public participation mechanism.[30]

Under the MLPA as amended by the MMAIC, State Marine Reserves (SMRs), State Marine Parks (SMPs), and State Marine Conservation Areas (SMCAs) are considered as MPAs.[31] SMRs are the most protective form of MPAs under the MLPA. Extracting marine organisms for any reason other than state-approved scientific research in an SMR is prohibited.[32] SMPs similarly restrict most, if not all, destructive human activities, but emphasize giving public access for low-impact recreation.[33] SMCAs often allow recreational and commercial extraction of living organisms, but the state generally bans the most-destructive forms of disturbances in these areas, such as bottom-trawling.[34]

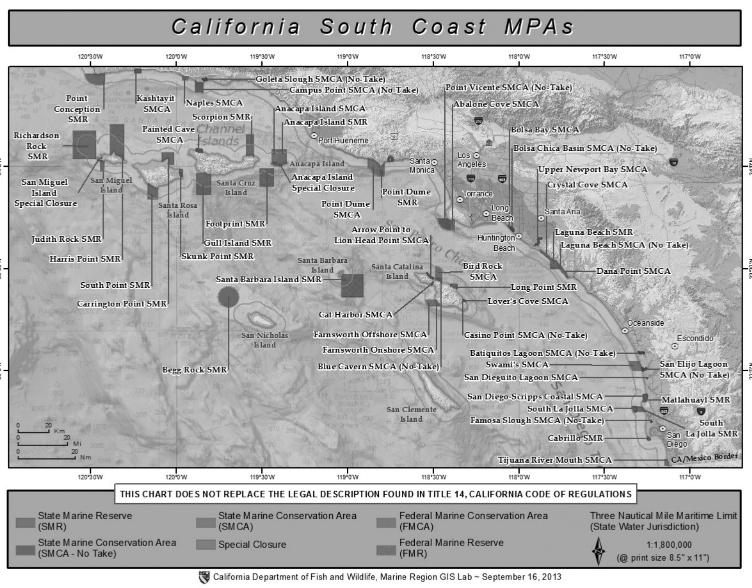
The state's initial attempt in MPA designations was based on a comprehensive master plan synthesized at the state level and only provided for limited public input.[35] Unfavorable public opinion convinced the state to revise its effort.[36] Under a new approach, the state-level master plan no longer delineates specific MPAs and regulations; instead, it sets forth guidelines for regional planning groups to follow when designating MPAs within their respective regions.[37] The program divides the state's coastline into

16. Stuart Shapiro, *Two Months in the Life of the Regulatory State,* 30 Admin. & Reg. L. News 12, 15 tbl. 5 (2005).
17. *See* Coastside Fishing Club v. California Resources Agency, 158 Cal. App. 4th 1183 (2008).
18. Working Group I—Intergovernmental Panel on Climate Change, Climate Change 2007—The Physical Science Basis (Susan Soloman et al. eds., 2007); *see also* Myles R. Allen et al., *Quantifying the Uncertainty in Forecasts of Anthropogenic Climate Change*, 407 Nature 617 (2000); Mort Webster et al., *Uncertainty Analysis of Climate Change and Policy Response*, 61 Climatic Change 295 (2003).
19. *See* Francisco P. Chavez et al., *From Anchovies to Sardines and Back: Multidecadal Change in the Pacific Ocean*, 299 Science 217 (2003) (fisheries can be impacted by the ocean's temperature on a very small time scale); *see also* John E. Dore et al., *Physical and Biogeochemical Modulation of Ocean Acidification in the Central North Pacific*, 106 Proc. Acad. Sci. 12235 (2009).
20. *See* Leif Pihl et al., *Effects of Periodic Hypoxia on Distribution of Demersal Fish and Crustaceans*, 108 Marine Biology 349 (1991).
21. *See* Working Group I, *supra* note 18; *see also* Elizabeth Mcleod et al., Designing Marine Protected Area Networks to Address the Impacts of Climate Change, 7 Frontiers Ecology & Env't 362 (2008).
22. *Id.*
23. *See* Andrew Bakun et al., *Greenhouse Gas, Upwelling—Favorable Winds, and the Future of Coastal Ocean Upwelling Ecosystems*, 16 Global Change Biology 1213 (2010); *but see* Ryan R. Rykaczewski & John P. Dunne, *Enhanced Nutrient Supply to the California Current Ecosystem With Global Warming and Increased Stratification in an Earth System Model*, 37 Geophysical Res. Letters L21606 (2010) (climate change may cause central California coast to be much more productive or much less productive).
24. *See* Turlock Irrigation Dist. v. Hetrick, 71 Cal. App. 4th 948, 951 (1999); Koponen v. Pacific Gas & Elec. Co. 165 Cal. App. 4th 345, 355 (2008); Wallace Berrie & Co. v. State Bd. of Equalization, 30 Cal. 3d 60, 65 (1985); Agricultural Relations Bd. v. Superior Court, 16 Cal. 3d 392, 411 (1976).
25. Cal. Fish & Game Code §§2850 et seq. (2013).
26. *Id.*
27. Cal. Pub. Res. Code §§36700 et seq. (2013).
28. *See* 14 Cal. Code Regs. §632 (2013) (filed under Division I: Fish and Game Commission—Department of Fish and Game).
29. Cal. Pub. Res. Code §36602(b) (2013) (State Park and Recreation Commission and State Water Resources Control Board also have power to designate managed areas in the marine environment).
30. Cal. Fish & Game Code §2853(b) (2013).
31. Cal. Pub. Res. Code §36602(d) (2013).
32. Cal. Pub. Res. Code §36710(a) (2013).
33. *Id.* at (b).
34. *Id.* at (c).
35. *See* Christopher Weible et al., *A Comparison of a Collaborative and Top-Down Approach to the Use of Science in Policy: Establishing Marine Protected Areas in California*, 32 Pol'y Stud. J. 187 (2004).
36. *Id.*
37. *See* California Department of Fish & Game, California Marine Life Protection Act—Master Plan for Marine Protected Areas 31-59 (2008).

five geographical regions with different stakeholder groups drawn from each of the five regions.[38]

Since the state relaunched its MLPA effort in 2002, California has established a statewide system of over 100 MPAs.[39] Southern California alone accounts for 50 MPAs, spanning from Point Conception in the north to the Mexican-U.S. border in the south (Figure 1).[40] However, the designations are not set in stone. Any entity can propose to amend, add, or remove MPAs by petitioning the Commission.[41] The Commission must respond to these requests every three years.[42] The statute also commands any entity that may designate MPAs, such as the Commission, to promulgate regulations detailing how such proposals can be made. The Commission has not yet promulgated these regulations as of summer 2013.

Figure 1: Map of the MPAs in Southern California



Available at https://www.dfg.ca.gov/marine/images/mpamaps/scmpas.jpg.

On top of the power to amend existing MPA regulations, the MLPA also gives the Commission power to regulate all commercial, recreational, or any other taking of wildlife within the MPAs.[43] Moreover, the MLPA grants the Commission broad power "to ensure that California's MPAs have clearly defined objectives, effective management measures, and adequate enforcement, and are based on sound scientific guidelines."[44] Here, the managers are facing a fluctuating environment that threatens to undermine the conservation value of MPAs. It is wholly within the Commission's power to not only set or amend the management goal of each MPA, but also to set or amend management measures to be flexible enough to meet the challenge of managing a dynamic, ever-changing system.

II. Process of Constructing a Dynamic MPA

Creating the right management measures for a dynamic MPA is a technical process. Dynamic MPAs require resource managers to front-load difficult decisionmaking when significant uncertainties still exist. Furthermore, managers are not contemplating just one response, but an entire set of responses, as well as the proper triggering mechanism for each response. As such, resource managers must be able to incorporate complex scientific information with pertinent legal requirements and desired policy goals.

All dynamic MPAs as defined by this Article would contain three basic components. First, a dynamic MPA must be designed with a set of management goals in mind. Second, the regulations must contain substantive responses. Third, a dynamic MPA must contain triggering mechanisms that determine when the regulatory responses would turn on. The effectiveness of the final MPA regulations would depend on the government's ability to merge expertise from multiple disciplines, as well as an ability to exercise independent expert judgments. This Article will use the protection of an overexploited southern Californian rockfish species from climate-induced, regionwide oxygen decrease (hypoxia) as the context for the construction process of a hypothetical dynamic MPA.

A. Setting Management Goals

Dynamic MPAs as envisioned here are regulatory tools designed to manage an uncertain future harm. Thus, the first step in designing any dynamic MPA is to determine what the uncertain harm is, and what the MPA is protecting from that harm. In other words, a dynamic MPA must first have a management goal. Because the MLPA does not specify any particular management goal for individual MPAs, the Commission and the public have significant flexibility in tailoring management goals for each MPA.[45] Designating an MPA as an SMR, an SMP, or an SMCA would allow the Commission to tailor regulatory prohibitions in pursuit of a broad range of regulatory objectives.[46]

Recent publications suggest that the oxygen concentration within the Southern California Bight (SCB) has steadily decreased for the past three decades (Fig. 2).[47]

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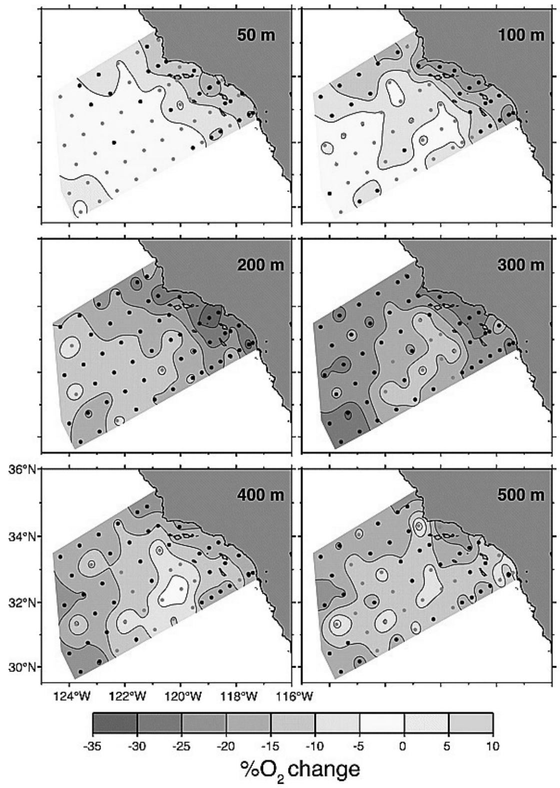
38. *Id.* at 18.
39. 14 Cal. Code Regs. §632(b) (2013).
40. *Id.*
41. Cal. Fish & Game Code §2861(a) (2013).
42. *Id.*
43. Cal. Fish & Game Code §2860(a) (2013).
44. Cal. Fish & Game Code §2853(b)(5) (2013).
45. Cal. Pub. Res. Code §§36710(a)-(c) (2013); *see also* Lands Council v. McNair, 537 F.3d 981 (9th Cir. 2008) (courts are generally deferential toward agencies exercising expert judgments).
46. Cal. Pub. Res. Code §§36710(a)-(c) (2013).
47. Steven J. Bograd et al., *Oxygen Declines and the Shoaling of the Hypoxic Boundary in the California Current*, 35 Geophysical Res. Letters L12607, at 4, fig. 3 (2008); Sam McClatchie et al., *Oxygen in the Southern California Bight: Multidecadal Trends and Implications for Demersal Fisheries*, 37 Geophysical Res. Letters L19602 (2010) (Southern California Bight is the marine environment between Pt. Conception and the U.S.-Mexico border

This drop in oxygen concentration, or hypoxia, has been corroborated by climate forecasting models as well as observations made in other comparable regions of the world.[48] However, the details of the expansion or whether the expansion would even continue to take place is subject to debate.[49] But if the oxygen concentration along the southern California Coast does continue to drop, the worsening condition would eventually impact bottom-dwelling fishes residing in the region and thus the management of the area's MPA.

Figure 2: Percentage Change in Oxygen Concentration in SCB in Past 30 Years



Source: Bograd et al., 2008, *available at* http://onlinelibrary.wiley.com/doi/10.1029/2008GL034185/abstract.

1. Potential Adverse Environmental Impact and Associated Uncertainties: Hypoxia in the SCB

Climate change-related effects such as stronger or weaker upwelling, rising sea level, ocean layer stratification, acidification, and hypoxia each involves extremely complex natural processes.[50] This Article focuses on hypoxia in southern California for two reasons. First, the California Cooperative Oceanic Fisheries Investigations (CalCOFI) program has monitored oceanographic conditions in California for decades, with data spanning over 50 sampling locations at multiple depths.[51] Second, the expansion of mid-water hypoxia within the SCB involves relatively localized causes and effects.[52] The relative lack of complication allows for the construction of a relatively simple dynamic MPA.

Using the CalCOFI time series, Steven Bograd et al. demonstrated a declining trend for dissolved oxygen concentration inside the SCB.[53] Data suggest that the existing Oxygen Minimum Zone (OMZ) off the California coast, which generally occurs at between 500-1,000 meters (m) depth, is thickening as well as shoaling (angling up toward the surface) near the coast.[54] Hypoxic condition naturally occurs at these depths when photosynthesis cannot take place and the diffusion of oxygen from the ocean surface cannot offset local respiration.[55] However, the 2008 article showed that a significant relative oxygen decline is occurring in areas outside of the traditional boundary of the offshore OMZ off California.[56] In particular, the study detects moderate decrease in relative oxygen concentration north and west of Point Conception, where the California Current System (CCS) enters the region.[57]

Though the decline of oxygen concentration has been corroborated, the details of the decline are far from clear. Recent CalCOFI data suggest that the SCB has yet to see the type of large-scale catastrophic hypoxic events observed in Louisiana and Oregon.[58] Furthermore, oxygen concentrations at the 200-300m depth range have not dropped

where the coastline abruptly curves landward, in contrast to the relatively straight north-south coastline of California's central coast).

48. *See* Richard J. Matear et al., *Changes in Dissolved Oxygen in the Southern Ocean With Climate Change*, 1 Geochemistry, Geophysics, Geosystems 2000GC000086, fig. 1a (2000); *see also* Anthony C. Hirst, *The Southern Ocean Response to Global Warming in the CSIRO Coupled Ocean-Atmosphere Model*, 14 Envtl. Modelling & Software 227 (1999); *see also* Richard J. Matear & Anthony C. Hirst, *Climate Change Feedback on the Future Oceanic CO_2 Uptake*, 51 Tellus B 722 (1999); Brian A. Grantham et al., *Upwelling-Driven Nearshore Hypoxia Signals Ecosystem and Oceanographic Changes in the Northeast Pacific*, 429 Nature 749, 751 (2004); Bograd et al., *supra* note 47, at 5.
49. Curtis Deutsch et al., *Climate-Forced Variability of Ocean Hypoxia*, 333 Science 336 (2011).
50. *See, e.g.*, Ryan R. Rykaczewski & David M. Checkley, *Influence of Ocean Winds on the Pelagic Ecosystem in Upwelling Regions*, 105 Proc. Nat'l Acad. Sci. 1965 (2008) (coastal wind can become stronger in the future climate, which helps bring more nutrients from the bottom of the ocean to the surface through a process known as upwelling) (warmer water is less dense and tends to float above cooler water, and the ocean is segregated into multiple layers through this mechanism; as the surface warms, this "stratification" becomes more pronounced and nutrients have a harder time reaching the surface from the bottom); *see also* James C. Orr et al., *Anthropogenic Ocean Acidification Over the Twenty-First Century and Its Impact on Calcifying Organisms*, 437 Nature 681 (2005); *see also* Daniel M. Sigman et al., *Polar Ocean Stratification in a Cold Climate*, 428 Nature 59 (2004); *see generally* Working Group I—Intergovernmental Panel on Climate Change, *supra* note 18.
51. *See* Scripps Institution of Oceanography, Data Report—Physical, Chemical, and Biological Data, CalCOFI Cruise 9602, 29 Jan. 29-Feb. 16, 1996 & CalCOFI Cruise 9604, Apr. 15-May 3, 1996; *see also* CalCOFI website, http://www.calcofi.org/.
52. *See infra* Part III.B. (managers would not have to consider the global ocean circulation in depth).
53. Bograd et al., *supra* note 47.
54. *See* Henry T. Mullins et al., *Oxygen-Minimum Zone Edge Effects: Evidence From the Central California Coastal Upwelling System*, 13 Geology 491 (1985).
55. *See* Klaus Wyrtki, *The Oxygen Minima in Relation to Ocean Circulation*, 9 Deep Sea Res. & Oceanographic Abstracts 11 (1962).
56. Bograd et al., *supra* note 47, at 4, fig. 3.
57. *Id.*
58. *See* Scripps Institution of Oceanography, Data Report—CalCOFI Cruise 0707 (2008); *see also* Scripps Institution of Oceanography, Data Report—CalCOFI Cruise 0808 (2009); *see also* Scripps Institution of Oceanography, Data Report—CalCOFI Cruise 0907 (2010); *see also* Scripps Institution of Oceanography, Data Report—CalCOFI Cruise 1008 (2011); *see also* Scripps Institution of Oceanography, Data Report—CalCOFI Cruise 1108 (2012).

significantly in some parts of the state territorial water.[59] There is also evidence suggesting that worsening hypoxia is part of the ocean's natural cycle, and the planet's natural processes have the ability to counteract the trend over a longer time scale.[60] Lastly, even if the mid-water hypoxia does expand, how it would develop is still far from certain.[61]

2. Protecting Cowcods From Encroaching Hypoxia

The potential expansion of low-oxygen condition carries serious ramifications for MPA management. Almost all organisms, including those within the southern California coastal marine ecosystems, require oxygen for respiration.[62] However, spatial protection is not suitable for every marine species. MPAs in general are not well-suited to protect highly mobile species like sardines.[63] Likewise, benthic invertebrates may not need protection from encroaching hypoxia due to their high tolerance toward hypoxia.[64] Furthermore, the depths where many commercially important benthic invertebrates such as abalones reside are not facing significant impact from an expanding mid-water hypoxia.[65]

In contrast, mid-water hypoxia in the SCB would play a much bigger role in the management of demersal (bottom-dwelling) fishes, which tend to stay within a limited range after they mature.[66] Normally, establishing MPAs in these species' prime habitats could protect productive adult populations from human disturbances. These protected populations could in turn bolster recruitments during normal years and provide resilient seed populations during difficult ones.[67]

Effective spatial protection for productive adults is especially important for demersal fishes that are recovering from past overexploitation. The southern California cowcod population is one example. These fish were once an important species to the California groundfish fishery. Unchecked harvest has since depleted the population, and the species is now listed as a "species of concern" by the National Oceanic and Atmospheric Administration.[68] Properly constructed and managed MPAs can protect the recovering cowcod stock from incidental mortalities by preventing human disturbances from taking place within the fish's habitat.

The developing mid-water hypoxia in SCB, however, can threaten the cowcod conservation value of the region's MPAs. Juvenile cowcods tend to first settle near the 100m depth range when they exit the larval stage.[69] As the fish mature, they gradually move into the 200-300m depth range.[70] As recent data indicate, this prime habitat depth within the SCB has experienced a 25-35% drop in oxygen concentration in the last 30 years.[71] While no literature is available on cowcods' oxygen tolerance, study on a similar deep-sea fish suggests that adverse physiological reactions begin to occur below oxygen concentrations of around 2.0 milliliters to liter (mL/L).[72] This level of oxygen concentration also corresponds to general macrofaunal mortality events.[73] Even if the cowcods are able to withstand the current level of oxygen saturation, which already dips below the 2.0mL/L threshold during the summer, a continuous decline in oxygen will eventually overwhelm the fish's physiological adaptation.[74]

As condition deteriorates, the SCB cowcod population will begin to exhibit responses. Fishes like the cowcods have the ability to migrate relatively long distances when adverse conditions arise.[75] A static MPA with a fixed boundary cannot protect a resident fish population if the fish leave the boundary of the MPA. Traditional regulatory process may not generate management responses fast enough to track the pace of hypoxia development and the cowcods' behavioral responses. Furthermore, expending public resources by immediately moving or expanding existing MPAs without solid scientific support is anathema to good management practice. Using dynamic MPAs, the Commission can con-

59. *Id.*
60. Deutsch et al., *supra* note 49.
61. Bograd et al., *supra* note 47.
62. *See* Robin N. Gibson & R.J.A. Atkinson, *Oxygen Minimum Zone Benthos: Adaptation and Community Response to Hypoxia*, 41 Oceanography and Marine Biology, An Annual Review 1 (2003).
63. P. Dee Boersma & Julia K. Parrish, *Limiting Abuse: Marine Protected Areas, A Limited Solution*, 31 Ecological Econ. 287, fig. 1 (1999).
64. Robert J. Diaz & Rutger Rosenberg, *Marine Benthic Hypoxia: A Review of Its Ecological Effects and the Behavioural Responses of Benthic Macrofauna*, 33 Oceanography and Marine Biology—An Annual Review 245 (1995); *see also* Wen Xiong Wang & J. Widdows, *Physiological Responses of Mussel Larvae* Mytilus edulis *to Environmental Hypoxia and Anoxia*, 70 Marine Ecology Progress Series 223 (1991).
65. Bograd et al., *supra* note 47, at 4, fig. 3; *see also* Alistair J. Hobday et al., *Over-Exploitation of a Broadcast Spawning Marine Invertebrate: Decline of the White Abalone*, 10 Rev. Fish Biology & Fisheries 493 (2000) (abalones are algae grazers and are found in shallower water of less than 100m where photosynthesis can take place).
66. *See, e.g.*, Phillip S. Levin, *Fine-Scale Temporal Variation in Recruitment of a Temperate Demersal Fish: The Importance of Settlement Versus Post-Settlement Loss*, 97 Oecologia 124 (1994).
67. *See* Will J.F. Le Quesne & Edward A. Codling, *Managing Mobile Species With MPAs: The Effects of Mobility, Larval Dispersal, and Fishing Mortality on Closure Size*, 66 ICES J. Marine Sci.: J. du Conseil 122 (2009); *see also* Boersma & Parrish, *supra* note 63, fig.1.
68. *See* NOAA website, http://www.nmfs.noaa.gov/pr/pdfs/species/cowcod_detailed.pdf.
69. Korie A. Johnson et al., *Recruitment of Three Species of Juvenile Rockfish (*Sebastes spp.*) on Soft Benthic Habitat in Monterey Bay, California*, 42 Cal. Cooperative Oceanic Fisheries Investigations Rep. 153, tbl. 1 (2001).
70. Mary Yoklavich et al., *Habitat Associations of Deep-Water Rockfishes in a Submarine Canyon: An Example of a Natural Refuge*, 98 Fishery Bull. 625, tbl. 1 (2000).
71. Bograd et al., *supra* note 47, at 4, fig. 3.
72. Alexander A. Soldatov & I.A. Parfenova, *The Methemoglobin Blood Level and Stability of Circulating Erythrocytes of the Rockfish* Scorpaena porcus *to Osmotic Shock Under Conditions of Experimental Hypoxia*, 37 J. Evolutionary Biochemistry & Physiology 622 (2001); *see also* McClatchie et al., *supra* note 47 (choosing 1.5mL/L as a threshold for cowcods based on knowledge regarding general marine fish physiology).
73. Diaz & Rosenberg, *supra* note 64, at 250; *see also* Raquel Vaquer-Sunyer & Carlos M. Duarte, *Thresholds of Hypoxia for Marine Biodiversity*, 105 Proc. Nat'l Acad. Sci. 15452 (2008).
74. McClatchie et al., *supra* note 47; *see also* Ralph F. Keeling et al., *Ocean Deoxygenation in a Warming World*, 2 Ann. Rev. Marine Sci. 199, 202-03 (2010); *see also* Scripps Institution of Oceanography, Data Report—CalCOFI Cruise 0707 (2008); *see also* Scripps Institution of Oceanography, Data Report—CalCOFI Cruise 0808 (2009); *see also* Scripps Institution of Oceanography, Data Report—CalCOFI Cruise 0907 (2010); *see also* Scripps Institution of Oceanography, Data Report—CalCOFI Cruise 1008 (2011); *see also* Scripps Institution of Oceanography, Data Report—CalCOFI Cruise 1108 (2012).
75. Denise L. Breitburg, *Episodic Hypoxia in Chesapeake Bay: Interacting Effects of Recruitment, Behavior, and Physical Disturbance*, 62 Ecological Monographs 525, 543 (1992).

struct a range of initially dormant regulatory responses based on available science and complete the public process for the new regulations before the responses are needed. When mid-water hypoxia encroaches upon an MPA, it would respond automatically to the change to protect its resident cowcods.

B. *Regulatory Response Mechanisms: Expanding or Moving the SMR*

Once a management goal is identified, resource managers would then decide on the substantive regulatory responses for the possible future changes. These responses would correspond to the types of substantive mandates already found within existing MPA regulations. All existing California MPAs contain two substantive components: (1) a spatial component delineating the boundary of an MPA; and (2) a substantive component enumerating the specific regulatory prohibitions in place for that MPA.[76] Dynamic MPA regulations could be designed to alter one or both of these components to match changing conditions. For example, if a region is experiencing climate-driven hypoxia expansion, the Commission could amend the spatial component of the affected MPAs by expanding their boundaries to include better oxygenated water or move them to account for cowcods' migration. Alternatively, managers could amend substantive protection by imposing further fishing restrictions to reduce overall cowcod mortality.

The detail of a substantive response should depend on the specific nature of the harm managers seek to avoid. Since the Commission here would be dealing with mid-water hypoxia, it should first identify the various scenarios through which hypoxia could develop. Climate change can cause a decrease in dissolved oxygen concentration at mid-depth through several mechanisms. Most of these mechanisms either reduce the amount of oxygen that reaches mid-water from the surface or decrease the oxygen concentration of the water that enters mid-water from the bottom. The effects of these mechanisms can manifest in two forms: (1) a uniform decrease of mid-depth oxygen concentration across the region; or (2) the expansion of hypoxia from several "hot spots" within the SCB. The different developmental paths would in turn warrant two different forms of response.

A reduction in the amount of oxygen diffusing into mid-depth directly from the surface above would impact the entire SCB in a relatively uniform fashion. Most of the new dissolved oxygen that mid-depth waters receive comes from the surface layer directly above it.[77] As the surface water warms due to climate change, it becomes more stratified and less able to transport oxygen downward.[78] Furthermore, as the ocean surface warms, oxygen molecules generally have a harder time staying in dissolved form.[79] Because the climate-driven increase of the air temperature in southern California is a regionwide phenomenon, moving an MPA to another location within the SCB would not provide the cowcods any additional respite from lower oxygen.[80] However, the Commission could compensate for the increased stress by reducing other sources of cowcod moralities. For example, the Commission could expand the MPAs in the region and provide cowcods with further protections from existing anthropogenic stresses such as bycatch.

Climate change can also drive down the oxygen concentration along the southern California coast by modifying the upwelling processes in the region.[81] Upwelling is a phenomenon in which deep water is brought to the surface through a combination of physical forces.[82] These events bring high-nutrient water to the surface and are responsible for the rich productivity of the California coast.[83] Climate change can create stronger seasonal hypoxia by intensifying upwelling along the coast and create massive boom-and-bust cycles similar to the events observed off Oregon.[84] It can also reconfigure the north Pacific's circulation pattern, which causes older (water that has remained out of contact with the surface for a longer period of time) and/or more hypoxic water to be upwelled into the region.[85] Both mechanisms can exacerbate hypoxic conditions in southern California near major upwelling centers.[86] The Commission could respond to this type of hypoxia by moving the MPAs away from these hypoxia hotspots.

Lastly, there are other climate change-related pathways through which mid-water hypoxia in the SCB can

76. Cal. Fish & Game Code §§2852(d), 2860, 2861 (2013).
77. *See* Plattner, *infra* note 87; *see also* Zbigniew S. Kolber et al., *Bacterial Photosynthesis in Surface Waters of the Open Ocean*, 407 Nature 177 (2000); *see also* Matear et al., *supra* note 48 (the rest of the oxygen would be the oxygen that was in the water before the water loses contact with the surface).
78. Ralph F. Keeling & Hernan E. Garcia, *The Change in Oceanic O_2 Inventory Associated With Recent Global Warming*, 99 Proc. Nat'l Acad. Sci. 7848 (2002); *see also* Laurent Bopp et al., *Climate-Induced Oceanic Oxygen Fluxes: Implications for the Contemporary Carbon Budget*, 16 Global Biogeochemical Cycles 1022 (2002).
79. Keeling & Garcia, *supra* note 78, at 7848; *see also* Jinlun Zhang & Mike Steele, *Effect of Vertical Mixing on the Atlantic Water Layer Circulation in the Arctic Ocean*, 112 J. Geophysical Res.: Oceans (1978-2012) C04S04 (2007); *see also* Paul C. Fiedler et al., *Pycnocline Variations in the Eastern Tropical and North Pacific, 1958-2008*, 26 J. Climate 583 (2013) (pycnoclines are boundaries that separate the ocean into distinct depth ranges characterized by strong difference in temperature and salinity; due to the difference in temperature and salinity, molecules such as oxygen have a harder time exchanging through these "layers").
80. Working Group I, 767, *supra* note 18; Gilberto Jeronimo & Jose Gomez-Valdes, *Mixed Layer Depth Variability in the Tropical Boundary of the California Current, 1997-2007*, C5 J. Geophysical Res.: Oceans (1978-2012) 115 (2010) (variation of the depth of mixed layer in the region would not impact the uniformity of surface-associated hypoxia; entire mixed layer ends much shallower than hypoxic region).
81. *See* Keeling & Garcia, *supra* note 78; *see also* Frank A. Whitney et al., *Persistently Declining Oxygen Levels in the Interior Waters of the Eastern Subarctic Pacific*, 75 Progress Oceanography 179, 180 (2007); *see also* David M. Checkley Jr. & John A. Barth, *Patterns and Processes in the California Current System*, 83 Progress Oceanography 49 (2009).
82. *See* Adriana Huyer, *Coastal Upwelling in the California Current System*, 12 Progress Oceanography 259 (1983).
83. *Id.*
84. *See* Checkley & Barth, *supra* note 81.
85. *See* Bograd et al., *supra* note 47, at 3-4; *see also* Keeling & Garcia, *supra* note 78, at 209.
86. Bograd et al., *supra* note 47, at 5.

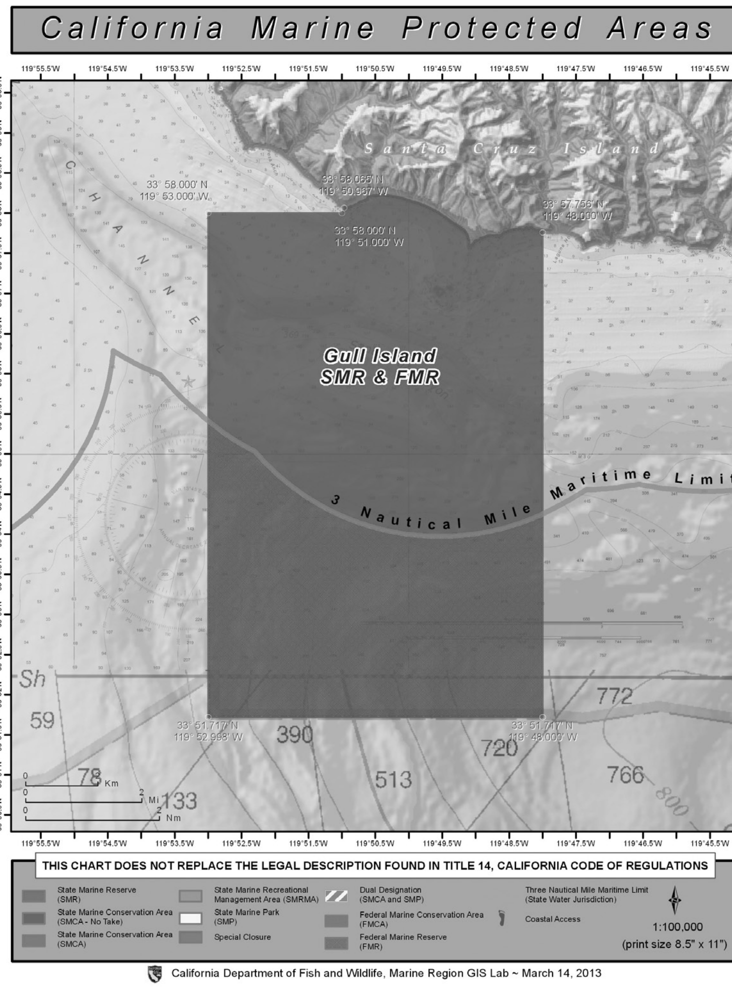
expand. However, they may not warrant regulatory responses. For instance, the oxygen level in mid-water can decrease simply due to organisms consuming more oxygen in a warmer environment, but models generally suggest that increased respiration would not contribute substantially to mid-water hypoxia in the SCB.[87]

C. *Triggering Indicator*

Once the substantive regulatory responses are determined, they must be attached to triggering mechanisms so that a response would activate only when the condition warrants it. This is where the concept of an "indicator" could prove useful. The International Union for Conservation of Nature (IUCN) defines an MPA indicator as "a unit of information measured over time that will allow [managers] to document changes in specific attributes of [an] MPA."[88] Such indicators can be used as metrics for measuring the effectiveness of MPAs, but they could also be used to trigger regulatory responses.[89] Indicators can be biological, such as the abundance of key indicator species, or they can be physical, such as the concentration of dissolved organic matters within a given MPA.[90] Each response mechanism could be attached to its own triggering indicator.

Triggering indicators must be able to reflect potential environmental changes contemplated by the management goal, and they must comport to the responses chosen. The current monitoring plan for southern California MPAs uses mostly biotic indicators to quantify an MPA's effectiveness, such as mussel bed coverage, prevalence and size of specific fishes, and nearby landing of commercial.[91] However, since the dynamic MPAs contemplated here are designed to adapt to expanding hypoxic conditions, measuring oxygen concentration directly would arguably detect the targeted adverse changes more efficiently than waiting for biotic responses.

Figure 3: Gull Island SMR



Source: California Department of Fish & Wildlife, *available at* https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=65090&inline=true.

Analysis on SCB mid-water hypoxia in the previous section yields two possible regulatory responses: expand the MPAs if the mid-depth is receiving less oxygen from the surface; or move them if a changing upwelling pattern is at play. Resource managers can create indicators using the difference in the rate of oxygen decrease between the shallow end and the deep end of the mid-depth water. MPAs should expand only when the SCB is experiencing decreasing oxygen concentration due to warming sea surface. As such, the associated triggering indicators should be a proportionally faster decrease in oxygen concentration at the shallow end of mid-depth compared to the deep end. Alternatively, a move is warranted when mid-water hypoxia is developing from the upwelling centers. The associated triggering indicator would be a sharper decrease in oxygen concentration at the deep end of mid-depth water compared to the shallow end. If none of the scenarios occurs, the triggering indicators and their associated responses would remain dormant and the MPAs would retain their current boundaries.

III. Hypothetical Dynamic MPA Based on an Existing SMR

The Commission can apply the analyses from the previous part to any existing California MPA and turn it into a dynamic MPA that can protect cowcods from future hypoxia. This Article would use the Gull Island SMR as an

87. *See* Lawrence R. Pomeroy & William J. Wiebe, Bacterial Responses to Temperature and Substrate Concentration During the Newfoundland Spring Bloom 75 (Marine Ecology Progress Series, Oldendorf 1991); *see also* Gian-Kasper Plattner et al., *Revision of the Global Carbon Budget Due to Changing Air-Sea Oxygen Fluxes*, 16 Global Biogeochemical Cycles 43-1 (2002).
88. Pomeroy & Wiebe, *supra* note 87, at 8, box 5.
89. *See generally* IUCN, *supra* note 5.
90. *Id.* at 49 (also discusses an "aerial" category, which measures how pristine an MPA is; however, human disturbance is not part of the conservation goal in this test case).
91. MPA Monitoring Enterprise, South Coast California MPA Monitoring Plan, 36-47 (D. Oregon 2011).

Figure 4: Move

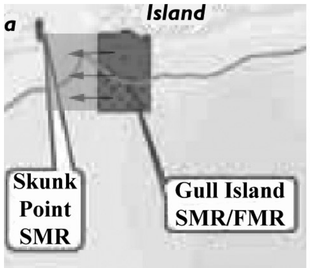


Figure 5: Expansion

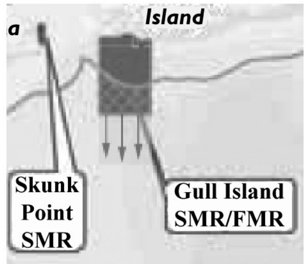
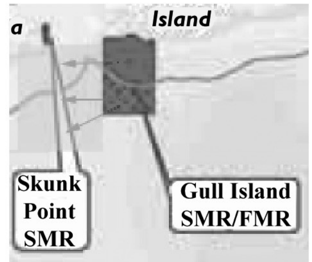


Figure 6: Move & Expansion



example to construct a hypothetical dynamic MPA. The SMR is located on the southwestern corner of Santa Rosa Island (Figure 3); its regulation prohibits the extraction of living organism within the SMR.[92] Based on previous analyses, the SMR may see an appreciable drop of oxygen concentration at depths greater than 100-200m.[93]

The previous part only contemplates two types of responses (move or expand). In reality, the modified MPA would contain four actual responses: (1) move; (2) expand; (3) move and expand; and (4) not change (Appendix). If the oxygen concentration at the 200m depth of the reference point between the Gull Island SMR and the nearest upwelling center (i.e., the coast) is dropping faster than it is at 100m, the region is assumed to be impacted by upwelling-associated mid-water hypoxia, and the SMR would move away from the nearest upwelling region (Figure 4). Alternatively, if the oxygen concentration is dropping faster at the 100m depth than at 200m at the reference point, surface temperature-associated hypoxia is presumed to be impacting the region. In which case, the SMR would expand to offset the impending regionwide cowcod mortality (Figure 5). If both types of hypoxia are detected, the SMR would both move and expand (Figure 6). Lastly, if the oxygen concentration at the reference point remains consistent at both the 100m and 200m depths, the SMR would not move.

IV. Conclusion

The hypothetical dynamic Gull Island SMR illustrated here is simplified. It does not consider other factors that might be relevant to cowcod conservation such as the amount and quality of suitable habitats in the area that the MPA is moving or expanding to.[94] More sophisticated experimental designs may be warranted depending on the precise management goals and the amount of information available.[95] Nonetheless, the MPA does showcase how dynamic MPAs could be used to confront uncertainties and to achieve management responses in line with rapidly changing conditions. Like traditional MPAs, the dynamic MPA is built with a specific management goal in mind. The management goal and available information would in turn determine what the appropriate substantive regulatory responses are and when they should be implemented. The embedded regulatory responses would then spring into action when the need arises.

Dynamic MPAs have the potential to become more sophisticated than the hypothetical one presented here if resource managers are willing to invest the effort to develop the tool. For example, resource managers may wish to protect an MPA containing the last viable white abalone population from multiple potential environmental harms, not just one. In which case, the MPA would incorporate multiple sets of responses arrayed against different potential environmental harms. These sets of responses would need to be compatible with each other. Aside from incorporating more sophisticated response structures, dynamic MPAs can also adopt more sophisticated designs. A set of dynamic regulations may not need to delineate the specific location of a future move. Instead, the regulation can simply move an MPA a certain length away from a source of disturbance up or down the coast indefinitely. The mechanism would operate very similarly to computer programming, and in a sense making the MPAs closer to being "alive."

Ultimately, the concept of a dynamic MPA rests on the notion that our society and government administrative apparatus can rise to meet increasingly dynamic environmental problems without succumbing to the paralyzing effects of complex uncertainties. Even in the face of great uncertainties, society can still draw on its pool of technical experts and modern computing power to synthesize sophisticated and comprehensive solutions. With an expanding population and finite resources, society must be willing to engage and to solve difficult environmental issues now and in the future.

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92. 14 Cal. Code Regs. §632(b)(109)(B) (2013).
93. Bograd et al., *supra* note 47, at 4, fig. 3.
94. *See* Southern California Coastal Ocean Observation System website, http://www.sccoos.org/data/bathy/?r=2 (last visited Apr. 25, 2014).
95. *See* Antony James Underwood, Experiments in Ecology: Their Logical Design and Interpretation Using Analysis of Variance (Cambridge Univ. Press 1997).

Appendix

Gull Island State Marine Reserve (Dynamic):

Boundary:

(a) This area is bounded by the mean high-tide line and the following points in the order listed:

33° 58.065' N. lat. 119° 50.967' W. long.;
33° 58.000' N. lat. 119° 51.000' W. long.;
33° 58.000' N. lat. 119° 53.000' W. long.;
33° 51.717' N. lat. 119° 53.000' W. long.;
33° 51.717' N. lat. 119° 48.000' W. long.; and
33° 57.756' N. lat. 119° 48.000' W. long.

(b) When oxygen concentration at 33° 49.300' N. lat. 118° 37.700 W. long at 200m depth drops below 0.86 ml/L and oxygen concentration at 100m depth remains above 1.85 ml/L, the area becomes bounded by mean high tide and the following points:

33° 58.000' N. lat. 119° 58.650' W. long.;
33° 56.530' N. lat. 119° 58.650' W. long.;
33° 51.717' N. lat. 119° 58.650' W. long.;
33° 51.717' N. lat. 119° 53.000' W. long.; and
33° 58.000' N. lat. 119° 53.000' W. long.

(c) When oxygen concentration at 33° 49.300' N. lat. 118° 37.700 W. long at 100m depth drops below 0.86 ml/L and oxygen concentration at 200m depth remains above 1.85 ml/L, the area becomes bounded by mean high tide and the following points:

33° 58.065' N. lat. 119° 50.967' W. long.;
33° 58.000' N. lat. 119° 51.000' W. long.;
33° 58.000' N. lat. 119° 53.000' W. long.;
33° 45.000' N. lat. 119° 53.000' W. long.;
33° 45.000' N. lat. 119° 48.000' W. long.; and
33° 57.756' N. lat. 119° 48.000' W. long.

(d) When oxygen concentration at 33° 49.300' N. lat. 118° 37.700 W. long at 200m depth drops below 0.86 ml/L and oxygen concentration at 100m depth drops below 1.85 ml/L, the area becomes bounded by mean high tide and the following points:

33° 58.000' N. lat. 119° 58.650' W. long.;
33° 56.060' N. lat. 120° 00.800' W. long.;
33° 45.000' N. lat. 120° 00.800' W. long.;
33° 45.000' N. lat. 119° 53.000' W. long.; and
33° 58.000' N. lat. 119° 53.000' W. long.

This set of regulations uses a threshold of 1.85mL/L oxygen concentration for the 100m depth and the threshold of 0.86mL/L oxygen concentration for the 200m depth. The number was computed using available CalCOFI data from the same location since 1955.[96] Two normal distributions were drawn based on the level of oxygen observed at the two depths in the past. Assuming that the distributions are actually normal, there is only a 1% chance in the next given year that the reference point would experience an oxygen concentration of 1.85mL/L at 100m and an oxygen concentration of 0.86mL/L at 200m if the oxygen level is fluctuating as part of a natural cycle and the perceived decrease in oxygen does not actually exist.[97] Furthermore, if the data next year do not trigger a regulatory response, there is less than a 1% chance that the non-triggering is caused by the threshold not being set low enough.[98]

96. *Available at* http://data.calcofi.org/component/content/article/37-cat-bottle-data/52-calcofi-data-reports-pdf.html & http://data.calcofi.org/bottle-data/calcofi-data-reports.html.
97. This is essentially an inverted t-test. The null hypothesis is that the fluctuation of oxygen is part of natural variation, and is not exhibiting any particular trend. Since the Article is assuming that the trend observed in Bograd et al. is part of the natural variation, data from that time period, namely 1984 to early 2000s, would form part of the data that give rise to the normal distribution. Once a normal distribution is obtained, the threshold is set at $\alpha = .01$. Distribution is one-tailed because the regulation is only concerned with oxygen concentration being lower than a certain threshold. *See* Jerrold H. Zarr, Biostatistical Analysis 678 (Deirdre Lynch ed., Prentice Hall 2010) (1974).
98. *See* Jacob Cohen, Statistical Power Analysis for the Behavioral Sciences 54 (Psychology Hall 1988) (1977).