CALIFORNIA INITIATIVE TO DEFINE "OCEAN HEALTH"

WORKSHOP REPORT: September 17, 2015, Oakland, CA

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ABSTRACT

Despite the existence of numerous laws that articulate a goal of "ocean health," our coastal and marine ecosystems face ongoing degradation. This occurs in part because our laws fail to define "ocean health" or set measurable objectives for achieving it. Ocean health accordingly has been the topic of increasing discussion among California marine scientists, including at a September 2015 workshop organized by Earth Law Center. Among other findings, this workshop and related background research resulted in the following conclusions:

- "Ocean health" must be considered and achieved from the context of the ocean's own, intrinsic well-being, rather than primarily from the context of the ocean's utility to humans.
- "Healthy" ocean ecosystems are those exhibiting "normal form and function"; that is, demonstrating sufficient organization, vigor and resilience to allow the ecosystem to exist, thrive and evolve as a natural system. "Normal" need not necessarily be "pristine" to allow for natural functioning. Conversely, "normal" refers to a higher level of functioning than merely the "absence of disease or infirmity," which unfortunately is the goal of many marine protection laws today.
- A definition of ocean health is ultimately a policy decision, but it must be based in the best science in order to be effective policy.
- Modern science describes the ocean environment as a complex web of relationships with significant temporal and spatial variability. By contrast, management agencies and laws isolate elements of the ocean systems and minimize the significance of relationships and variability. A shared, holistic vision of ocean health will help integrate agency operations toward "ecological policymaking," to better reflect the complexity of marine systems.
- Monitoring and reporting are necessary to track progress toward ocean health and to adjust its definition (associated metrics, indicators and thresholds) as needed.

The paper concludes with recommendations regarding the scientific research and policy changes needed to advance progress toward realizing healthy ocean and coastal ecosystems.

WHAT IS THE PROBLEM?

The concept of "ocean health" appears frequently because it is an attractive vision – we inherently prefer "healthy" ecosystems and reject degradation. The challenge emerges in deciding what exactly we are managing towards – what is "health"? While "health" is often cited as a goal of environmental laws, the term is defined nowhere in statute, leaving policymakers in need of guidance to effectively implement such laws and policies.

In part because of a lack of clear, science-based principles for achieving ocean health, we currently receive mixed and incomplete messages about the state of the ocean. For example, a 2012 report states that the California Current Ecosystem (CCS) is in "relatively" good shape; that is, it is doing better than other marine systems around the country for which people have been around longer and caused more sustained damage.[1] This, however, does not mean the system is doing *well*. Indeed, the report itself later observes that the CCS is at the "35-45% level," a "2.5 on scale of 1-5," "depleted," and likely not in "good shape."

Without clear information about what is needed to achieve ocean health, regulations designed to manage human use of the ocean fall short. Regulations particularly fall short by minimizing protection the ocean's *own* needs, as opposed to (for example) the services the ocean provides to humans. At least one NOAA fisheries scientist, for example, found that as a result of provisions that "maximize" sustainable fishery yields to humans, fishing rates are far more than is actually sustainable. As he summarizes, "harvested [fish] populations should be maintained at levels from 60-100% larger than what is often considered desirable in conventional [fishery] management," and "harvest rates commonly need to be less than 10% of the magnitude of those used in much of today's management."[2]

California's Ocean Protection Council (OPC) was established in part to begin to redress these gaps and limitations in our protection of ocean health. The OPC mission statement calls for "healthy, resilient and productive ecosystems. The question remains, however, *how do we operationalize this?* California law calls for "healthy" ocean ecosystems, but the state has not defined "healthy" – leaving management without appropriate goals or benchmarks. Moreover, the management policies and approaches that do exist do not reflect the complexity of ecosystems as actual systems (or, further, "evosystems,"[3] which considers the *co-evolutionary* web of ecological interactions).

As noted above, "health" is often cited as a goal of environmental laws, but as with the OPC mission, this term remains to be defined. Examples of calls for ocean health in California laws include the following:

- The California Ocean Protection Act (COPA) states that California decisions affecting coastal waters and the ocean environment "should be designed and implemented to conserve the *health* and diversity of ocean life and ecosystems"[4] and "conducted in a manner consistent with protection, conservation, and maintenance of *healthy* coastal and ocean ecosystems …."[5]

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[1] California Environmental Associates, "California Current Ecosystem Assessment: Summary of current condition, pressures, and opportunities for the conservation community – January-July 2012," pp. 17-20 (2012), available at: http://www.ceaconsulting.com/CaseStudyFiles/California%20Current%20Ecosystem%20Assessment%20-%20Summary%20Findings.pdf (CEA 2012).
[2] C.W. Fowler, "Pattern-Based Control Rules for Fisheries Management," NMFS-AFSC-268 (2014).
[3] *Id*., n. 3.
[4] Public Resources Code § 35510(b)(1) (emphasis added).
[5] Public Resources Code § 35510(b)(5) (emphasis added).

COPA further finds that "[a] *healthy* ocean is part of the state's legacy, and is necessary to support the state's human and wildlife populations."[6]

- The Marine Life Management Act lists its top objective as: "Conserve the *health* and diversity of marine ecosystems and marine living resources" (Fish and Game Code 7050(b)1))
- The California Coastal Act states that "Uses of the marine environment shall … maintain *healthy* populations of all species of marine organisms" (Pub. Res. Code 30230)
- The Marine Life Protection Act (MLPA) advances protection of the ocean and coast generally, aiming for overall ocean ecosystem health. For example, Fish and Game Code Sec. 2853(b)(1) notes that the goals of MLPA include "protect[ing] the natural diversity and abundance of marine life, and the structure, function, and integrity of marine ecosystems"; the MLPA Master Plan interprets this goal as emphasizing the "*health* of marine ecosystems."[7]
    - The MLPA specifically recognizes the importance of protecting marine habitats for their own "intrinsic value."[8] In other words, "health" in the MLPA context refers to "health" from the perspective of the affected ecosystems, as opposed to an anthropocentric perspective of ocean utility to humans.
- Fish and Game Code 1801 ("Conservation of Wildlife Resources") articulates the "policy of the state" is to "perpetuate all species of wildlife *for their intrinsic and ecological values*, as well as for their direct benefits to all persons." The section adds that "management shall be consistent with the maintenance of *healthy* and thriving wildlife resources…."
- The Porter-Cologne Water Quality Control Act mandates tracking of the effectiveness of water quality projects based on their success in "achieving clean water and *healthy* ecosystems."[9]
- The federal Marine Mammal Protection Act states that the primary objective of marine mammal management "should be to maintain the health and stability of the marine ecosystem."[10]

In light of these mandates, the California Ocean Science Trust (OST) has begun to address the meaning of "ocean health." The OST held a workshop specifically on ocean health in June 2014, and expanded the discussion in a public forum in August 2014. OST staff have expressed strong interest in examining and applying this concept further, consistent with the OPC's mission to advance "healthy" ecosystems.

To advance this discussion of ocean health further, on September 17, 2015 Earth Law Center (ELC) and its consultant Dr. Brock Bernstein convened an all-day meeting in Oakland of top scientists from around the state. Participants included those with the California Ocean Science Trust, UC Santa Barbara, California Department of Fish and Wildlife and UCLA. The results of this meeting are discussed in more detail below, along with additional research and recommendations for next steps.

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[6] Public Resources Code § 35505(a) (emphasis added).
[7] CA DFG, "Master Plan for Marine Protected Areas," pp. iii, 12 (Jan. 2008); available at: http://www.dfg.ca.gov/marine/pdfs/revisedmp0108.pdf (emphasis added).
[8] Fish and Game Code Sec. 2853(b)(4).
[9] Water Code §13181(a) (emphasis added).
[10] 16 U.S.C. 1361, Sec. 2(6).

BACKGROUND INFORMATION

In advance of the September 2015 workshop in Oakland, ELC conducted a review of the literature regarding strategies for assessing the "health" of aquatic and marine ecosystems. Key findings include the following:

1. There is no single, agreed-upon definition of "ocean health."

Scientists last debated "ocean health" in some detail roughly 20 years ago as ecosystem-based management approaches became more widely adopted, in order to help provide scientific input into related policy questions.[11] No agreement, however, was reached on a single definition of "health" for use in the marine management arena. Recent advancements in modeling technology , better understanding of ecosystem processes and dynamics,[12] and expanding management challenges have since ripened the time to reinvigorate this discussion, which will affect implementation of the growing number of laws calling for ecosystem "health."

2. There are at least three basic approaches to examining "ocean health." Clarity on which approach is being applied or discussed is important before moving forward.

(a) "Health" as relative to humans' continued use of the oceans; that is, health in the context of the ecosystems' services to humans. From this anthropocentric perspective, "healthy" is seen as "not so degraded by human activity that the ecosystem cannot be used by humans." Here, nature here is seen as separate from humans (*i.e*., a "resource"). The majority of assessment methodologies today focus on measuring the impacts of human activities to continued ecosystem use; that is, the degree to which such impacts lessen the delivery of "ecosystem services." This model is less effective in challenging "traditional economic and consumer values," which ocean scientists now assert "are not sustainable."[13]

(b) "Health" as relative to "pristine" conditions, without human impacts. In this perspective, "healthy" is seen as "untouched by humans," or very close to that condition. This approach can be useful for comparison purposes (*e.g*. in establishing a reference site) and on occasion as a policy goal. However, it is not broadly applicable as a management approach (though it can come into play in prioritizing actions or setting targets for restoration). Not only can "pristine" be difficult to define, it leaves no room for a practical definition of health that includes human interactions as a sustainable element of natural systems.

(c) "Health" as relative to achieving harmonious relations between humans and nature. This perspective includes the possibility for humans to live in an integrated and interdependent way with nature. This was a key message of the 1992 United Nations Earth Summit, which called for "harmony with nature."[14] This broader, more holistic concept of health considers

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[11] *See, e.g*., a review of past discussions at Scrimgeour and Wicklum, "Aquatic ecosystem health and integrity: problems and potential solutions." *J. N. Am. Benthol. Soc*. 15(2): 254-261 (1996).

[12] For example, when the earlier discussions were being held, scientists had only a limited understanding of what El Niño involved and meant.

[13] IUCN, International Programme on the State of the Ocean, and World Commission on Protected Areas, "International Earth System Expert Workshop on Ocean Stresses and Impacts" (June 2011), at: http://www.stateoftheocean.org/pdfs/1906_IPSO-LONG.pdf.

[14] United Nations, Report of the United Nations Conference on Environment And Development (Rio de Janeiro, 3-14 June 1992); available at: http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm.

and incorporates humans' complex relationship with natural systems. Rather than the one-way relationship we assume now, with humans consuming nature's corpus and services, **this approach incorporates nature's *own* need to maintain its "normal form and function"** (as described below), as well as nature's ability to support human needs. This approach accounts for a human presence within and as part of natural systems, and so it sets a higher bar for human co-existence with nature. The potential for a successful, complex ("harmonious") relationship with the ocean has been under-examined in part because relatively little work has been done to explore "ocean health" from the perspective of the ocean itself.

3. **To date, scientists have attempted to observe "ocean health" in large part through measures of ecosystem *status*;** that is, through generally static indicators that have yet to represent dynamic, complex, and holistic ecosystem processes. For the most part, these indicators do not reference back to progress toward a specified goal for overall ocean well-being.

4. **Even where more holistic goals for ecosystem health have been developed, it has been difficult to operationalize them to date.** This is due in part to:
   - Our increased understanding of the complexity of ecosystems;
   - The associated lack of specific benchmarks, baselines, thresholds and standards;
   - The difficulty of defining common criteria for selecting indicators and scoring metrics; and
   - The sensitivity of outcomes to the differing management objectives that have precipitated the selection of indicators and efforts to track status.

5. **Evolving understanding of the complexity of ocean systems calls now for a deliberate reexamination of "ocean health" that includes both perspective and science, in order to increase clarity of purpose and result.** As noted in #2 above, there are at least three perspectives for understanding ecosystem "health"; each involve considerations of policy in addition to science. The scientific research undertaken and applied will depend on the policy perspective selected; conversely, the policy perspective selected must be grounded in the science of its implications. For example, Fowler (2009) states: "Key to . . . achieving the objectivity of consonant pattern-based [*i.e*., science-based] management is **overcoming our tendency to undermine sustainability and health with values, such as economics, that we believe trump sustainability** (in conventional thinking) – even to the point of assuming that there is sustainability in the unsustainable (*e.g*., 'sustainable' economic growth or development)." The policy perspective should be chosen to best achieve ocean health in light of the most current scientific understandings of ocean system dynamics (*i.e.,* evolution toward increasing complexity, dynamism on a range of temporal and spatial scales, and interrelationships among key components).

HOW HAS "OCEAN HEALTH" BEEN EXAMINED IN CALIFORNIA TO DATE?

To date, California ocean law and policy has *de facto* defined "health" as "slower degradation," and the ocean is suffering as a result.[15] As noted above, even the California Current Ecosystem, largely viewed as doing better than other, similar systems worldwide, has "changed dramatically in … terms of biological diversity" in recent years, prompting scientists to describe it as "not natural" and a "system that is not healthy."[16]

A measureable vision of "healthy" will more effectively guide agencies to develop common metrics that help us permanently improve marine ecosystem states, rather than observe their slow decline. The Ocean Protection Council's Science Advisory Team (OPC-SAT) took up the effort to begin to define "ocean health" in two 2014 workshops, in June[17] and August[18] 2014. Earth Law Center submitted detailed comments[19] in June to the OPC-SAT in support of this ocean health initiative. As noted by panelist Dr. Brendan Kelly with the Monterey Bay Aquarium, this discussion of "ocean health" is important not only for the substantive results of these two workshops, but also for its illustration of the gap between the holistic nature of ecosystems and the operations of agencies, which continue to regulate in a siloed fashion.

Recent scientific work in California on integrating metrics across media to assess the status of ecosystems and species can provide important avenues of inquiry into further discussions of this topic. Examples include California's Healthy Streams Partnership[20] (and associated pilot efforts in San Diego[21] and along the Central Coast[22]), Heal the Bay's Malibu Creek Watershed Stream Health Index,[23] and U.S. EPA's recent report on California integrated watershed assessment.[24] As to the last, U.S. EPA found that:

> the biological, chemical, and physical health of a stream are fundamentally connected to one another and to the maintenance of natural watershed processes… [By] integrating information on multiple ecological attributes at several spatial and temporal scales, a systems perspective on watershed health is provided.

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[15] As observed by Dr. Jane Lubchenco, "[o]ur "ocean-based and land-based activities together are… literally changing the chemistry, the physical structure and the biology of our oceans in unprecedented ways . . . [a]nd we are suffering the consequences." Dr. Jane Lubchenco, Testimony before the U.S. Commission Ocean Policy (Wash. D.C., Nov. 13, 2001).

[16] CEA 2012, *supra* n. 1.

[17] http://www.opc.ca.gov/2014/05/california-ocean-protection-council-scientific-advisory-team-meeting-opc-sat-topic-ocean-health/.

[18] http://www.opc.ca.gov/2014/07/ocean-protection-council-meeting-and-ocean-health-workshop-august-27th-2014/.

[19] http://www.opc.ca.gov/webmaster/_media_library/2014/05/OPC-SAT-Ocean-Health-cmts-ELC.pdf.

[20] http://www.mywaterquality.ca.gov/monitoring_council/healthy_streams/.

[21] http://www.mywaterquality.ca.gov/monitoring_council/healthy_streams/docs/sdrw_reportcard.pdf.

[22] http://www.mywaterquality.ca.gov/monitoring_council/healthy_streams/docs/healthywatersheds_krw.pdf.

[23] Heal the Bay, "Malibu Creek Watershed: System on the Brink," pp. 21, 124-130, available at: http://bit.ly/1ptG01P.

[24] The Cadmus Group, for U.S. EPA, "California Integrated Assessment of Watershed Health: A Report on the Status and Vulnerability of Watershed Health in California" (Nov. 2013), available at: http://www.mywaterquality.ca.gov/monitoring_council/healthy_streams/docs/ca_hw_report_111213.pdf.

These evolving forms of integrated aquatic ecosystem assessments provide critical tools to help policymakers and scientists define and track what ecosystem "health" means to California. The first steps of this conversation have begun, and the full hearing room at the August 2014 OPC-SAT workshop[25] attests to the broad interest in this conversation. Creating a shared vision of "health" is consistent with COPA's mandate that the state "integrate and coordinate" its "laws and institutions responsible for protecting and conserving [the] ocean," including by "[p]rovid[ing] a set of guiding principles for all state agencies to follow."[26]

As observed by one agency representative at the June 2014 OPC-SAT workshop, **"[w]hat we need is a broad, conceptual, aspirational goal and statement that we could all point to and drive towards as a shared vision for ocean health, even in the context of our own agency mandates, jurisdictions and policies."**[27] Efforts toward a statewide policy vision to help us move away from the default of "degradation avoidance" and towards ocean well-being have begun. With support, these efforts can result in a shared vision that solidifies California's leadership in ocean policy and protection.

SEPTEMBER 2015 OCEAN HEALTH WORKSHOP

INTRODUCTION

Marine scientists from around California met at the California Ocean Science Trust office in Oakland in September 2015 to discuss development of a consistent definition of ocean health that could help guide ocean policy. Specific uses for such a definition include improved implementation of laws protecting the coast and ocean, creation of a model for developing new legislative mandates, enhancement of the effectiveness of restoration efforts, and targeting of scientific research toward holistic regulatory and restorative management strategies that better reflect the complexities of ecosystems. The intended audience for the discussion includes all marine professionals – scientists, policymakers, decisionmakers – as well as the interested public.

Workshop participants noted that a holistic understanding of the dynamic and interconnected behavior of ocean systems has yet to fully penetrate policymaking and management decisionmaking, in part because scientists cannot always articulate clearly this fundamental understanding of complex ecosystems to policy makers. One outcome of a more refined definition of ocean health would therefore be a clearer rationale for more holistic policymaking that is based on current scientific understanding of the nature of ocean systems. This would in turn lead to clarified policy priorities, more integrated agency operations, better metrics by which to resolve conflicts among interest groups and overcome agency silos, enhanced scientific bases for setting policy and research goals, closer tracking of successes and setbacks, and improved (including more holistic) strategies to protect natural systems.

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[25] http://www.cal-span.org/cgi-bin/archive.php?owner=COPC&date=2014-08-27.
[26] Pub. Resources Code § 35515.
[27] Ocean Protection Council Science Advisory Team (OPC-SAT) "Exploring Ocean Health as a Scientific Concept and Management Goal (June 11, 2014)" – Workshop Proceedings; available at: http://www.opc.ca.gov/webmaster/ftp/pdf/SAT/OPC-SAT%20FULL%20Workshop%20Proceedings%206.11.14.pdf.

It was also noted that ocean policy today is generally not ecological policy, which considers humans as a part of natural systems rather than separate users of such systems. NOAA fisheries scientist Chuck Fowler observes that "[a]ll species are confined by the limits imposed by their environments and empirical patterns display the balance among the systemic forces involved." [28] Workshop participants believe that this balance needs to be better tracked and managed to ensure that we live sustainably within the limits of marine systems. In undertaking this task, however, we face a significant obstacles in our human "tendency to undermine . . . health with values, such as economics, that we believe trump sustainability…."[29] Without clarity in our objectives, our ability to rationalize in favor of short-term economic gain has tended to lead us astray from our higher goals.

While numeric objectives provide the most clarity, the difficulty in developing truly holistic numeric metrics should not limit our efforts. Workshop participants felt that a narrative health "objective," with associated scientific guidance to be developed later, would be a reasonable start.

Another reason to accelerate this effort now arises out of the benefits of de-siloing agency operations, a point noted above by Dr. Brendan Kelly of the Monterey Aquarium. Multiple agencies have responsibility over coastal and ocean issues, but the agencies exist and operate in silos, the antithesis of holistic natural systems**. The act of developing an ocean health definition itself provides an opportunity to help bring agencies together, through the joint creation of a new perspective that assumes planning and action must occur across existing management boundaries.** Given its mandate for ecosystem-based management, the OPC could play a significant role in leading this effort.

The Concept of Ocean Health

The term "ocean health" is widely used in law and policy to establish overarching principles and goals. However, the absence of a formal and holistic definition has left us with competing recommendations that: reflect different perspectives, are often at odds, do not necessarily reflect the most recent scientific understandings, and (most importantly) fail to effectively protect natural systems. This is a fundamental challenge for implementing California laws and policies that highlight ocean health.

The definition of ocean health is ultimately a policy decision, but it is one that must be informed closely by the best science. For a number of people, the term "ocean health" reflects the ocean's ability to provide services for humans, primarily but not exclusively focused on harvest of ocean "resources." This policy approach runs counter to the science of our human integration with ocean systems, and the longer-term impacts of our unsustainable use of the ocean. For example, an arguably unhealthy ocean can provide abundant services to humans in the short term. An Arctic

[28] C.W. Fowler and L. Hobbs, "Are We Asking the Right Questions in Science and Management?" NOAA Technical Memorandum NMFS-AFSC-202 (Dec. 2009).
[29] *Id.*

Ocean devoid of ice as a result of climate change can provide cheaper navigation routes or access to previously unavailable oil and gas resources, which in turn creates more greenhouse gas emissions. In other examples, invasive species can provide the basis for a valued sport fishery (striped bass in the San Francisco estuary), and altered marine food chains can produce larger quantities of commercially important species. The question here becomes – for how long, and at what cost to the marine environment and ourselves, can we continue to exploit the ocean's intrinsic well-being? It is critical now to incorporate the best science into the development of a concept of health that will help prevent further degradation of marine systems, and that will begin to turn the tide toward greater ocean well-being.

Analogies with Human Health and Well-Being

At the outset, workshop participants noted that analogies with human health appear attractive because human health is a holistic concept that is intuitively and readily understood. The Constitution of the World Health Organization (WHO) **defines human health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity**." The WHO Constitution adds that "enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being ...."[30]

The utility of this definition is somewhat limited by its lack of clarity around the meaning of "well-being." Some useful lessons can be gleaned from the WHO efforts, however. Based on the WHO definition, we see "health" as the *integration* of various attributes – here, human physical, mental and social states. "Well-being," in turn, is the parameter by which each state is judged before being integrated into the measure of overall health. In other words, well-being refers to the separate components (*e.g.*, physical well-being, social well-being), while health refers to the aggregate across all three metrics. Human health, then, is a holistic concept – a lesson readily applied to the examination of ocean health.

Although the structure of separate components (or attributes) aggregated into an overall measure of health is familiar to marine scientists, the specific components of the WHO definition do not always map neatly onto separate features of ocean ecosystems.[31] Analogies can be drawn, though, that help us move closer to a workable definition of ocean health. For example, the social component of the WHO definition can be analogized to what scientists now understand is a complex web of relationships across space and time that contribute to the health of ecosystem structure and function. Humans are a part of that complex network of relationships, not outside of it. Accordingly, back-and-forth interactions among humans and marine ecosystems should be incorporated into a holistic concept of ocean health and strategy for achieving it.

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[30] As a side note, many have taken issue with the goal of "complete" health across physical, mental, and social dimensions because this appear essentially unachievable, which results in virtually all people being classified as unhealthy.

[31] For example, humans' acceptable range of physical conditions tends to be narrower than those under which an ecosystem might be considered "healthy." Comparative mental and social well-being also merits deeper examination. However, important work has started, such as in the area of cetacean emotional/social intelligence and associated social well-being.

Workshop participants agreed that humans' connection to the ocean must not be conceived as simply the ocean's ability to provide services. This "ecosystem services to humans" perspective posits, incorrectly, that there is primarily a one-way relationship between humans and the ocean. That is, it assumes that humans can somehow take from the ocean without concern for ocean health except to the extent continued take is sustainable – a questionable result in light of the fundamentally flawed conception of our complex relationship with the sea.

A conception of social well-being (and ultimately, ocean health) as achieved through care for relationships aligns with the modern scientific understanding of ecology, which includes humans as part of the natural world. It further prompts consideration of the "human services" we should give back to ecosystems as part of our human contribution to the well-being of the network of relationships. For example, we could conduct significantly more restorative activities than currently undertaken, and on a more affirmative basis (that is, restoration that is not necessarily tied to a recent destructive activity). We could also develop forward-looking systems of interaction with the natural world that give back at least as much, or more than, we receive (*e.g*., prioritizing water-friendly permaculture over industrial agriculture that drains inland waterways needed to support connected marine life).[32]

Finally, the WHO definition importantly suggests that health is a state more positive than merely the "absence of disease or infirmity," a much more limited concept. Unfortunately, "absence of disease or infirmity" appears to often be the default conception of a healthy ecosystem today.

Other Considerations in Defining and Measuring Ocean Health

Workshop participants agreed that ocean health means more than simply the "absence of disease or infirmity." Health requires goals or targets more protective than current law generally allows, although without necessarily a goal of pristine conditions. From this starting point, participants began to develop a set of more specific considerations needed to both define and measure ocean health for scientific and policy purposes.

First, participants noted that traditional equilibrium concepts of health, especially related to ecological climax communities and stability, are outmoded. Scientists now understand that ecosystems are dynamic and characterized by a variety of disturbances and complex, nonlinear interactions that can lead to a variety of alternative conditions or states that can be quite different from the original state. Fluctuations or cycles in status are a normal part of natural ocean conditions, and not all species can do well at the same place or time because of competing physical and biological requirements. Examples of this that were noted include the cycles of the California Current System, warm and cold phases of the Bering Sea ecosystem, and cycles in sea urchin population abundance in Nova Scotia, Canada. Each of these, and similar spatially or temporally heterogeneous systems, include states that could be considered unhealthy if viewed in

[32] *See, e.g*., NOAA, "NOAA Biological Opinion Finds California Water Projects Jeopardize Listed Species; Recommends Alternatives" (June 4, 2009); available at: http://www.noaanews.noaa.gov/stories2009/20090604_biological.html.

isolation or as a snapshot, from the perspective of species or communities in the impacted state(s).

Accordingly, participants noted, ocean health is probably best understood as context dependent, including change over time.[33] A definition of ocean health should encompass the dynamic nature of ocean systems across multiple spatial and temporal scales. However, participants emphasized that acknowledgement of natural disturbance, cycles, or other shifts in system state should *not* be used to rationalize destructive human practices or to subvert the goal of minimizing human impacts on ocean health. Climate change is the most obvious example of this type of rationalization, with policymakers avoiding needed action in the face of clear scientific evidence that far more than natural variability is at play. The human tendency to rationalize calls for even more attention to clarity in defining ocean health to ensure that scientific research is appropriately targeted in order to distinguish between natural and human disturbances and their effects.

Given the gaps in needed marine science research to date, a second observation by participants was that a useful starting point in the near term could be examination of localized well-being. Improved knowledge of ecosystem behavior under a range of local conditions could provide a starting point for an operational definition of ocean health as the integration of various aspects of well-being. Here, researchers and policymakers would ideally select metrics for local measurement that could be consistently aggregated at the attribute level for larger system scales (measurement is discussed further below).

Finally, in light of the gaps in knowledge identified by participants, participants noted that **additional consideration should be given to updating precautionary approaches in marine law and policy**. Needed precautionary measures will help avoid further degradation and potentially allow for a reversal of condition toward health.[34] They will also help buy time needed to create and implement improved management strategies, and to identify emerging patterns of degradation that need to be swiftly addressed.

Operationalizing a Definition of Ocean Health

Considering "Normal Form and Function" as a Descriptor of Ocean Health

Operationalizing a definition of ocean health that (a) encompasses the dynamic nature of ocean systems across multiple spatial and temporal scales and (b) provides input to and feedback on evolving human policies presents significant challenges. NOAA fisheries scientist Fowler's call to ensure all marine ecosystems exhibit "normal form and function"[35] is a useful starting point for this effort. Specifically, Fowler (2009) addresses the popular concept of "sustainability" by defining it as "what works in natural systems," adding that **the term sustainable "links directly to the**

[33] M.J. Allen, R.W. Smith, E.T. Jarvis, V. Raco-Rands, B.B. Bernstein, and K.T. Herbinson, "Temporal trends in southern California coastal fish populations relative to 30-year trends in oceanic condition," *Southern California Coastal Water Research Project Biennial Report 2003-2004*, pp. 264-285 (2004).
[34] *See, e.g.*, Fowler (2014), pp. 12-19.
[35] *Id.*, p. 1.

concept of doing what is possible to ensure that all systems (e.g., ecosystems, evosystems, and fisheries) exhibit normal form and function (Fowler 2003, 2009)."[36] Stream ecologists use the analogous concept of normal or intact structure and function. Both concepts refer to those features expected to be present in a natural state and include the sorts of complex dynamism and interactions described above.

The concept of "normal form and function" is similar to the idea of "reference" that is frequently used to benchmark assessments of ecosystem condition, with two important differences. First, in practice reference sites or conditions typically capture only a snapshot in time, and thus do not always or necessarily reflect ecosystems' normal range of temporal heterogeneity. Second, reference sites or conditions often refer to individual attributes or even specific metrics (a subset of attributes), rather than the larger and more complete set of ecosystem features encompassed by the more holistic concept of normal form and function.

While stream ecologists have made substantial progress in defining normal form and function,[37] defining "normal" is a more noteworthy challenge for the ocean because of the scope of spatial and temporal variability, which is usually poorly characterized, and the complexity of interrelationships at a number of scales. In addition, "normal" can imply a fixed temporal component that may be inconsistent with natural shifts among system states over time.

Defining "normal" then could start with what it is *not* – for example, *not* merely the absence of disease or infirmity, as outlined in the WHO definition of human health, which calls for a higher state of being. This conclusion calls into question the baseline impacted condition that current environmental laws generally permit today, prompting consideration of changes to those laws to make them stronger (as recommended by Fowler, for example). In other words, **our environmental laws aim too low: they generally seek to avoid disease or infirmity, rather than aim for a higher state of well-being, as is the goal for human health policymakers.**

How high, then, should our environmental laws aim above "absence of disease or infirmity"? We can draw initial lessons from the recent work of stream ecologists. Stream ecologists have formalized "distance from reference state or condition" as the observed vs. expected (or O/E) ratio, which measures how close any particular stream is to its expected (*i.e*., "normal") structure and function. Workshop participants agreed on the value of developing the ability to similarly measure O/E for marine ecosystems, even if the expected is no longer attainable everywhere, and use that information in developing a policy decision on ocean health.

Another lesson from stream ecologists is that an operational definition of ocean health should account for "abnormal" circumstances, in when incomplete knowledge prevents the full description of the expected system state. Stream scientists have already considered this challenge. For example, when natural events (*e.g*., natural floods, wildland fires) create conditions for which

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[36] *Id.*

[37] *See, e.g*., A.M. Milner *et al*., "Detecting Significant Change in Stream Benthic Macroinvertebrate Communities in Wilderness Areas," *Ecological Indicators* 60: 524-537 (2016); *see also* Charles Hawkins *et al*., "The reference condition: predicting benchmarks for ecological and water-quality assessments," *J. N. Amer. Benthol. Soc.* 29(1): 312-343 (2010).

it is not possible to set expectations or to separate human and natural impacts, stream scientists and managers have chosen to suspend assessments in the affected areas until a certain amount of recovery has occurred. They do so because they believe it is not possible to clearly detect or distinguish signals of human impact after such large events. In these instances, the time since the disturbance can be an important input to any assessment of health, because the expected condition will change depending on this context and the state of the system before the event.

Addressing Natural Variability

Setting expectations for ocean health in a given habitat context requires adequate data or a model, conceptual or otherwise. Because species and conditions are not static over time, information needed to set expectations could come from such sources as sites free of human disturbance in the same or similar habitat, historical data, historical ecology studies, and/or modeling. However, as noted above, there is a particular danger in using the observed range of natural variability to set specific, local expectations of normal form and function. If policymakers select the lower end of the range of natural variability as the expectation (the "normal" state of being), they could continue or even accelerate the slide toward degradation.

Participants accordingly focused particular attention on the role natural variability in space and especially in time plays in defining health. Such variability is a central feature of the natural behavior of marine systems, but measuring such variability poses a significant challenge to current monitoring and assessment practices. Nevertheless, participants felt that consideration of variability is crucially important, because system status measured at separate snapshots in time is insufficient for a complete assessment of health. In other words, knowing what is "normal" temporally requires longer-term data. One approach might be to look at longer time frames (*e.g.*, 50-year increments) and ask, "What it is across all of these snapshots that is consistent?" This might be possible in some cases. For instance, data extending back several hundred years are available for some pelagic species, and longer-term history for some systems can be generated with other methods (*e.g.*, fish scales preserved in anoxic sediments in deep basins off the California coast).

Another approach might be to characterize the rate of change over time, rather than only ecological health at single points of time. Change in the rate of change can provide important information and should be considered in policymaking and preventive action. We manage primarily with respect to current conditions, but impacts lag and last. A more holistic ocean health policy would consider the impacts of our actions on both current and future generations (for example, Australia's Great Barrier Reef Act calls for intergenerational equity). It is notable that the rates of change in marine systems are faster now than previously seen in recorded human history, but there is not a clear place in our governance systems to account for this. In particular, our siloed laws and management agencies make swift adjustments in the face of change extraordinarily difficult to accomplish (again, climate change provides an important example of this). Participants accordingly identified improved understanding of temporal and spatial variability in ocean systems as a key area for future research funding and policy action.

Measuring Ocean Health through the Attributes of Organization, Resilience, and Vigor

In their seminal paper, Costanza and Mageau write that **a "healthy ecosystem is one that is sustainable – that is, it has the ability to maintain its structure (organization) and function (vigor) over time in the face of external stress (resilience)."** As with the WHO definition for human health, which measured physical, social and mental well-being and then folded those results into an overarching, integrated understanding of health, Costanza and Mageau propose "fold[ing organization, vigor and resilience data] into a comprehensive assessment of ecosystem health."[38] Examination of the extent to which scientists and policymakers are considering the attributes of organization, vigor and resilience will help inform necessary next steps towards a working definition of ocean health.

Workshop participants found that most studies and monitoring activities currently focus on organization, or status, with little or no attention to vigor or resilience. This gap illustrates the limits of our understanding of the normal form and function of ecosystems. With regard to next research and monitoring steps, vigor could be assessed by tracking such variables as food web structure, primary production, or energy flow models. Resilience similarly is often left out of current ecosystem health indices, in part because it can be challenging to measure or estimate, especially in a nonequilibrium context.

Despite these gaps, participants agreed on the value of defining an ideal monitoring approach that includes all three attributes, even if it cannot be fully implemented immediately. They noted the example of the first Heinz Center report on the nation's coastal ecosystems, which defined needed indicators even where data were lacking or could not be accessed and integrated at a national scale.[39] This initial effort helped stimulate U.S. EPA's program to create periodic national reports on the nation's ecosystems.[40]

Summary

Workshop participants agreed that a holistic and ecologically appropriate definition of "ocean health" refers to ecosystems' "normal form and function," where "normal" refers to a higher level of form and functioning than merely the absence of disease or infirmity (the default of many environmental laws today). As to what is "normal," Fowler (2009) observed that "[t]he terms normal and abnormal bring to management the matter of definition: **sustainability is defined as what works in natural systems." "Normal" thus is not necessarily "pristine," but instead refers to "natural" functioning. This implies a level of impact that allows for sufficient organization, vigor and resilience to allow the ecosystem to exist, thrive and evolve as a natural system**. For the moment, this relatively broad observation is sufficient to guide us toward higher system functioning that current laws provide for.

Participants additionally agreed that the ocean system is dynamic over space and time, a realization that enhances the significance of longer-term patterns of behavior as opposed to static

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[38] Robert Costanza and Michael Mageau, "What Is a Healthy Ecosystem," *Aquatic Ecology* 33:105-115 (1999).

[39] The Heinz Center, *The State of the Nation's Ecosystems* (Cambridge Univ. Press 2002).

[40] U.S. EPA, "Report on the Environment"; available at: http://cfpub.epa.gov/roe/index.cfm.

observation. Again, more research is needed to further define our understanding of ocean dynamics, but that need not prevent action now. At a minimum, this realization leads to a recognition of the importance of building in precautionary actions and standard buffers in order to avoid continued harm through ignorance of the longer-term impacts of our actions.

With regard to lessons from the WHO definition of human health, participant observations were mixed as to their direct applicability. However, the WHO structure of understanding health as an integrative concept echoes the findings of Costanza and Mageau, and the work by WHO reinforces the fact that "health" encompasses more variables than are being measured today. Additional research and analysis is needed to flesh out potential contributions from experts on social well-being (given the relationships among humans and the marine environment) and mental well-being (an area even less studied to date, but which may provide important clues about patterns of behavior of marine species that could be relevant to policymaking).

Finally, participants noted that ocean health could be measured using a roll-up of the system attributes of organization, vigor, and resilience. Participants then turned to how these attributes might be measured in order to help further inform a policy definition of ocean health.

Measuring Ocean Health: Components of an Index

Strategies

As Costanza and Mageau (1999) observe, "**Ecosystem health represents a desired endpoint of environmental management, but it requires adaptive, ongoing definition and assessment**." Assuming policymakers settle on a definition for regulatory purposes of "normal form and function," monitoring will be needed to track progress toward this goal and adjust it as needed. There are numerous ways by which this information can be presented, but it is generally accepted that policymakers welcome scientific information in summary form, such as an index or report card. Workshop participants accordingly discussed how such a report should be structured, building on Fowler's (2009) question, "What kind of ecological data are required for ecosystem health assessment?"

First, participants noted that it is useful to structure a report card around the same top-level **attributes** (*e.g.*, organization, vigor, resilience) applied across all systems and habitats, and then identify lower-level **metrics** (*e.g.*, biodiversity, mean trophic level, total productivity, community structure, abundance of key species, quality of essential habitat, amount and frequency of specific disturbances, etc.) specific to each system or habitat. This enables the top-level attributes to be rolled up across different systems and habitats if desired, allowing different systems to be compared in meaningful ways. At the same time, this approach avoids the problem of forcing all systems to be assessed with the same metrics.

Report cards could be structured to also allow for scores related to the attributes and metrics to be rolled up or aggregated into a single, overall number, permitting even easier communication of assessment results to non-technical audiences. Report cards with the ability to aggregate scores to

different degrees (*e.g.*, rollup across habitat types) can also be useful for different audiences. At the same time, they noted that it is important to have the ability to disassemble an overall score into its component sub-scores for closer examination.

Participants emphasized that metrics for all three attributes (organization, vigor, resilience) should be developed. As noted above, most assessments currently focus on the organization attribute at the expense of vigor and resilience, which can be more effective measures of ecosystem process or function.

An additional major challenge for all metrics is to convert a vision of health to specific, measurable **indicators**, with some statement that identifies the desired characteristics of normal form and function and provides guidance for human behavior to achieve that goal. In other words, measurement strategies must address the questions: what are we moving toward, and how far have we come? Indicators of our expectations (as targets, references, or model results) are available for some but not all metrics currently. Participants expected that initial versions of an ocean health report card may be able to define expectations only in narrative terms for many metrics.

Thresholds that mark meaningful change points or levels of concern are another important feature of most assessment and report card approaches. However, defining ecologically meaningful thresholds can require substantial research and iterative pilot applications. In one recent example related to California streams, the state spent considerable effort defining expectation and thresholds for a number of ecoregions across the state.[41] In light of this, participants discussed an alternative to such quantitative development in the form of best professional judgment approaches (*e.g.*, Biological Condition Gradient),[42] which can be useful if carefully and rigorously applied.

With regard to report card structure, participants noted that **the three attributes that measure ocean health (organization, vigor, resilience) should be maintained on a separate axis**, with stressors, vulnerability, uses, and other interactions with the human system on other axes. This will prevent the confounding that stems from integrating stressors and vulnerability with health, and thus make it easier to separate out human impacts. Avoiding the conflation of health with other factors also allows researchers to better identify and examine different situations with similar levels of human activity/stress but different conditions or health. For example, high stress could result in higher or lower levels of vulnerability depending on system resilience. Embedding services or stressors in the core health index can therefore lead to artificially lower or higher results that are not really reflective of health. For example, the Santa Monica Bay Restoration

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[41] *See, e.g.*, Andrew Rehn *et al*., "The California Stream Condition Index (CSCI): A New Statewide Biological Scoring Tool for Assessing the Health of Freshwater Streams," SWAMP Technical Memorandum SWAMP-TM-2015-0002 (September 2015); available at: http://www.waterboards.ca.gov/water_issues/programs/swamp/bioassessment/docs/csci_tech_memo.pdf.

[42] *See, e.g.*, E. Shumchenia *et al*., National Health and Environmental Effects Research Laboratory, "A Biological Condition Gradient Model for Historical Assessment of Estuarine Habitat Structure" (2015); available at: http://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=307134.

Commission report card[43] includes vulnerability as a part of the overall measure of health while California's Integrated Assessments of Watersheds[44] measures vulnerability on a separate axis. This separation allows for results that include: healthy and not vulnerable, healthy and vulnerable, unhealthy and vulnerable, etc. This helps define targets for protection, restoration, and other management action. The Healthy Reefs Initiative report card[45] also separates health and stressor axes, as does the Australia Great Barrier Reef Outlook report.[46]

Challenges

One challenge to tracking progress toward normal form and function involves accounting for how species and habitats interact over time, rather than simply combining multiple separate elements of a system in an additive way. For example, the California Current system exhibits normal shifts on multi-year and decadal scales related to El Niño and the Pacific Decadal Oscillation, respectively. During different phases of these processes, some species will rise and others will fall in abundance, and their distributions will shift sometimes dramatically. As a result, information on single species in isolation will be difficult to interpret; this is particularly true where we have only a few replicates for ecosystem trends (such as El Niños). The significant gaps in our current ability to define the context across space and time for individual metrics once again calls for additional precautionary requirements to be inserted into governance strategies.

Participants identified additional measurement challenges and opportunities related to ocean health reporting that should be considered in order to most accurately assess progress toward normal form and function, and adjust actions as needed. These include the following:

- Defining temporal and spatial scales, given the importance of natural variability at multiple scales in ocean systems;
- Defining trajectories, given that similar outward appearances can actually be different system states;
- Deciding whether or not to combine scoring across habitats, assessing the validity of assumptions of linearity in response, addressing different scales of response, applying metrics on different scales, establishing thresholds, and deciding whether to use best professional judgment (BPJ) in cases where no thresholds existed or no quantitative metrics were available (noting that humans can tend to see the patterns they want to see rather than those that exist).[47]

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[43] Santa Monica Bay Restoration Commission, "State of the Bay 2010"; available at: http://www.smbrc.ca.gov/docs/sotb_report.pdf.
[44] Available at: http://www.epa.gov/sites/production/files/2015-11/documents/ca_hw_report_111213_0.pdf.
[45] Healthy Reefs Initiative, "Mesoamerican Reef: An Evaluation of Ecosystem Health" (2015); available at: http://www.healthyreefs.org/cms/wp-content/uploads/2015/05/MAR-EN-small.pdf.
[46] Australian Great Barrier Reef Marine Park Authority, Great Barrier Reef Outlook Report (2009); available at: http://www.gbrmpa.gov.au/managing-the-reef/great-barrier-reef-outlook-report/outlook-report-2009. See also Great Barrier Reef Outlook Report (2014); available at: http://www.gbrmpa.gov.au/managing-the-reef/great-barrier-reef-outlook-report.
[47] Santa Monica Bay Restoration Commission, "State of the Bay 2010," at: http://www.smbrc.ca.gov/docs/sotb_report.pdf.

Focusing on patterns in space and time, and patterns among ecosystem components, will be immensely helpful because scientists and policymakers are faced with extraordinarily complex information. The large spatial and variability scales make this a daunting task; scientists currently understand processes across this range of scales only in smaller and well-studied systems. Spatial heterogeneity in particular can be a critical important factor that can be addressed relatively well on the local level, but is more challenging on a wider scale. For example, spatial variability and connectivity in the ocean is much larger than what is captured by the state's network of marine protected areas. Because all spatial and temporal scales cannot be covered without a large expenditure of effort, participants felt that the design of any report card and accompanying monitoring effort should be tied to the spatial and temporal scales most relevant to management audiences.

Finally, as mentioned above, characterizing integrated change over time may provide more useful decisionmaking information than capturing numerous isolated aspects of ecosystem condition. Sites with little variability are good for this purpose, but the tradeoff is losing the potential for understanding of variability at local scales. This argues for well thought-out, hybrid monitoring designs that measure both local variability and longer-term trends and signals in areas with low local variability.

Summary

The overarching goal of an ocean health report card is to assess progress toward ocean health (as defined by policymakers and informed by science), support adjustments to the definition as needed, and offer a sound scientific foundation for robust, flexible, adaptive, and holistic management philosophies and responses. That is, **we need to ensure we apply science in a way that allow us to move toward "ecological policymaking," rather than linear, cause-and-effect activity**. This system-based governance would mimic key features of the natural systems, thereby better reflecting our relationship with it. System based, holistic governance seeks to avoid overly simplistic assumptions about cause-and-effect linearity in the marine system, and instead supports the scientific perspective of ecosystems as webs of interactions, allowing for more direct routes to action than the finger-pointing that linearity creates. System-based governance thus potentially would allow for swifter adjustments to governance strategies as needed to respond effectively to ecosystem changes.

One example of this that the participants noted was management of the Bering Sea pollock fishery, which uses integrated ecosystem research to help adjust fishery management to reflect shifting ecosystem states.[48] Combined with the North Pacific Fishery Management Council's policy of viewing humans as a predator in the system, and controlling human take to allow sufficient prey

[48] *See, e.g.*, http://www.nprb.org/news/detail/benefits-of-integrated-research.

for other predators, this approach exemplifies the way in which holistic ocean health assessment and tracking can inform more proactive ocean management.

NEXT STEPS

Workshop participants agreed that significant attention needs to be paid to conducting research that will better articulate the temporal and spatial variability associated with marine ecosystems, beginning with those ecosystems most critical to policy decisions. Given the scope of this task, pilot projects on a localized level may be the needed first step. In accomplishing this effort, participants noted the increasing development and value of historical ecology in filling data gaps and/or extending expectations of condition further back in time. They offered that a pilot project or proof of concept linked to marine protected areas might be one study option, as it would provide an opportunity to consider network and connectivity effects over larger scales.

Participants also agreed on the significance of assessing all three potential attributes of ocean health – organization, vigor and resilience – noting the dearth of information on vigor and resilience to date. They emphasized that metrics for understanding and evaluating vigor and resilience are particularly important areas for further scientific inquiry. Also with respect to monitoring, participants observed that indicators and thresholds for comprehensively assessing ocean health also need to be developed. Once again, the scope of the task will require prioritization to those variables most relevant to critical policy initiatives.

While participants felt that the work to develop a definition of human health was only partially related to that for ocean health, they nonetheless saw value in additional research and analysis on defining the social and mental well-being of marine systems. These are little-studied areas that may provide important clues about relationships among humans and marine species that warrant heightened policy action.[49]

While additional scientific research is needed to better understand ocean dynamics and live within the limits of marine dynamics and ocean needs, that gap need not prevent action now. At a minimum, the gap in needed data signifies the importance of adding precautionary measures and buffers to ocean laws and policies. There is much we can do now to avoid continued harm through ignorance of the longer-term impacts of our actions.

Other policy changes that could be made now involve assessing the extent to which existing laws affirmatively and measurably improve ocean health, *versus* merely avoid the absence of disease or

[49] For example, cetacean scientists at the 2012 AAAS conference presented a "Declaration of Rights for Cetaceans: Whales and Dolphins" that called for rights for whales and dolphins to "basic needs." Legal rights cited included rights "to stay alive, to not be confined, to make choices and travel, and … to engage in social interaction." The scientists added that it is "ethically indefensible" to kill, injure, or keep cetaceans in captivity in light of their high emotional and social intelligence. "Declaration of Rights for Cetaceans: Ethical and Policy Implications of Intelligence" (AAAS Annual Meeting, Vancouver, Feb. 19, 2012); available at: https://aaas.confex.com/aaas/2012/webprogram/Session4617.html.

infirmity. Laws that aim for absence of disease rather than health will more likely than result in degradation, and should be strengthened to aim for a higher state of well-being.

Finally, participants strongly agreed on a description of ocean ecosystems as involving extraordinarily complex, constantly interacting sets of relationships. Our siloed governance models almost could not be further from this scientific fact. At a minimum, the state should invest in strengthening the role and authority of the California Ocean Protection Council to bring agencies with ocean responsibilities together, with the goal of more actively and jointly managing human use of marine systems across existing management boundaries.