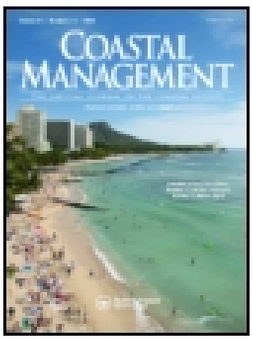

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A Comprehensive Method for Assessing Marine Resource Governance: Case Study in Kāne'ohe Bay, Hawai'i

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ABSTRACT

A recent metaanalysis identified certain management attributes that are associated with successful management of threshold-based systems. However, high variance among case studies indicates that these attributes do not guarantee good conservation outcomes, suggesting that additional factors may be at play. To better understand these additional factors, we compiled a list of effective governance attributes from the literature, and developed guidance for systematically evaluating their presence, absence, and the extent to which each attribute is actually manifested in a given case study. We also examine the distribution of rights and responsibilities within a system, and the resulting impacts on stewardship incentives. Here we present the results of this analysis as applied to Kane'ohe Bay, Hawai'i. Our results confirm that absent or incomplete effective governance attributes can negatively impact conservation outcomes. In Kane'ohe Bay, a public-private partnership temporarily compensated for gaps and weaknesses in the governance system, thereby creating conditions conducive to successfully reducing populations of invasive algae. However, this partnership has since dissolved and current capacity to address this and other issues in this system is again lacking. Failure to fix governance weaknesses may compromise the continued health and functioning of the Kane'ohe Bay system.

KEYWORDS

coral reef management; governance; institutions; rights and responsibilities; thresholds

Introduction

Improving the effectiveness of common-pool resource management requires an understanding of the key differences between successful and unsuccessful examples of such management. Kelly et al. (2014) conducted a meta-analysis that explored the relationships between management system attributes and outcomes in ecosystems that can exist in alternative states separated by thresholds, where a transition across the threshold significantly compromises management goals. Fifty-one case studies were evaluated for the presence of 19 "input attributes," which included items such as "ability to control or influence all system drivers" and "use of adaptive management." Each case was then given an outcome score based on the ecological condition of the system after management efforts were implemented.

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Kelly et al. (2014) revealed that certain attributes are significantly correlated with successful achievement of intended ecological outcomes, including spatial scale (smaller systems tended to have higher success scores), explicit management of ecosystem thresholds, and robust monitoring systems. However, for a handful of cases, biophysical and management conditions did not seem to sufficiently explain ecological results, implying that factors not captured in the list of management attributes examined are driving the conservation outcomes. The coral reefs of Kāneʻohe Bay, Hawai'i are one such case. The Kāneʻohe Bay case study received similar scores to a variety of other cases across many of the biophysical and management attributes examined in Kelly et al. (2014); however, efforts to restore the system after a shift to algal domination have been significantly more successful, and ecological outcomes significantly better, over the time period examined in Kelly et al. than in other seemingly similar cases (Kelly et al. 2014; Bahr, Jokiel, and Toonen 2015).

One explanation for these differences in outcomes is that lower-level structural and institutional factors that impact management outcomes were not assessed in Kelly et al. (2014). To examine these more subtle factors, we systematically evaluated the Kāneʻohe Bay case using a more comprehensive, finer-scale list of governance and institutional characteristics that multiple authors have suggested are associated with successful conservation practices worldwide (Table 1). While these attributes may not be additive, it seems likely that the more of these attributes a system has, and the more fully they are realized, the more positive the outcomes will be for conservation and sustainability objectives, and conversely, that items lacking or not fully realized in a given system will reduce management effectiveness. While there are a multitude of legitimate goals attached to most marine resource management regimes (e.g., economic gains, food security), we focus here on conservation goals. In this article, we evaluate in detail the relationships between governance attributes, the distribution of rights and responsibilities, and the incentives created as a result, in Kāneʻohe Bay, Hawai'i, and discuss those attributes that seem most important for explaining the successes and failures throughout the course of marine resource management in this system. The product is an in-depth look at an important case study wherein a novel public-private partnership succeeds in compensating for weaknesses in the formal governance structure to achieve conservation goals with respect to invasive species, while failing to achieve goals related to non-commercial fishing access.

Case study: Coral versus algal dominance in Kāneʻohe Bay, Hawai'i

Located on the northeast coast of Oahu, Kāneʻohe Bay is the largest bay in the Hawaiian Islands. It includes a well-developed barrier reef, as well as patch reefs, and a broad fringing reef system ("Kane'ohe Bay, O'ahu" 2011). Governance of Kāneʻohe Bay is complex and multilayered (Figure 1). A state-level management entity (Hawai'i's Department of Land and Natural Resources [DLNR] and its Division of Aquatic Resources [DAR]) is the main agency responsible for reef management in Kāneʻohe Bay (Gombos et al. 2010), augmented by a range of institutional arrangements including international agreements (the International Coral Reef Initiative [ICRI] and the Global Coral Reef Monitoring Network [GCRMN]) and programs established through a national statute (the Coral Reef Conservation Act of 2000) (Gombos et al. 2010; "Laws Protecting the Oceans" 2012). DAR engages in several interagency programs, state-federal agency partnerships, and partnerships with The Nature Conservancy (TNC) and the University of Hawai'i (University of Hawai'i) ("NOAA's

Table 1. Master list of effective governance attributes, with definitions and sources.

	Attribute	Amended definition	Sources
Structural attributes	Regulatory authority	• The authority (granted by statute) to develop, adopt, and implement rules and regulations within a given management jurisdiction or over a particular resource or set of resources, evaluate the efficacy of those decisions, and adjust them over time.	2; 14; 15
	Efficient enforcement mechanisms	• Mechanisms to enforce compliance with rules should be available to those tasked with monitoring those rules. • Sanctions should increase with repeat offenses and in congruence to the severity of the offences.	2; Ostrom, as cited in 4; 15
	Governance goals aligned with conservation objectives	• Ecosystem values are identified, including ecosystem connections, conservation status, state of ecosystem integrity and critical habitat for utilized and non-utilized species. • Rules are developed that limit resource use, with a focus on maintaining the natural structure and function of the ecosystem.	2; Ward et al. as cited in 12
	Science-based decision-making	• Decision-making under established policy must be based on the best available science. • Where significant scientific uncertainty exists, the precautionary principle should guide decision-making. • Local knowledge should be integrated • All sources of understanding need to be mobilized- management may benefit from the combination of different knowledge systems. • Social incentives for ecological knowledge generation need to be in place.	Ostrom, as cited in 4; 5; 10; 14; 13
	Agency flexibility	• Institutions should be capable of adapting to new situations in ways that are appropriate to the relevant respects in which the situation has changed. • Institutions should not change fundamentally when a situational change is not really relevant to the system.	Wollenberg et al. (2008) as cited in 3; Ostrom, as cited in 4; 5; 7; 8; 10; Ward et al. as cited in 12; 14
	Explicit recognition of tradeoffs	• Agencies must have formalized mechanisms to make choices if and when goals or values conflict with each other.	3
	Dependable funding	• State (or other legal authority) must guarantee sufficient and dependable funding to the effort. • Credit opportunities should be provided to local organizations for creation and maintenance of cooperative services. • Aid should be provided to local users in exchange for conservation services.	1; 10; 14; 16
	Participation	• Stakeholder engagement must be institutionalized, incorporated as early as possible, carried out consistently throughout the management and rule-making process. • Engagement must include rapid dissemination of information, materials, public comments, etc. • All individuals affected by rules must be able to participate in changing them (collective choice arrangements).	Wollenberg et al. (2008) as cited in 3; Ostrom, as cited in 4; 9; 10; 13; 14;
	Systematic representation	• Relevant stakeholders need to be identified, analyzed, and represented systematically. • Institutions should have formal mechanisms for "leveling the playing field" during negotiations.	Wollenberg et al. (2008) as cited in 3; 7; 9; 13; 15

(*Continued on next page*)

Table 1. (*Continued*).

Attribute	Amended definition	Sources
Deliberation	• A process of open communication, discussion, and reflection among actors who have alternative political viewpoints and understandings should include debate, decent, mediation, and negotiation. Highly skilled facilitation is necessary. • Conflict resolution mechanisms must exist.	Ostrom, as cited in 4; 7; 9; 13
Clear decision-making rules	• Decision-making rules should be established up front, leaving no ambiguity regarding how decision outcomes will be achieved.	7; 14
Clear objectives and directives	• Management system should set forth overarching principles, clear tasks, deadlines for completing tasks, directives explaining the standards by which decisions will be measured and made, and the processes for making those decisions. • Objectives should be developed among stakeholders to represent shared vision. • Objectives and directives should be agreed on at the outset in order to inform participatory process. • Periodic review should be carried out to determine progress. • System (biophysical) and institutional boundaries should be clearly defined.	Ostrom, as cited in 4; 7; Ward et al. as cited in 12; 13; 14
Accountability and Transparency	• Managing agents should be accountable to both local communities and higher authorities. • Mechanisms for transparency and accountability such as independent monitoring, clear milestone deadlines, linking funding with achievement or performance, issuing performance reports for public consumption, polycentricity, separation of powers, legal recourse, budget control, and a free media should be incorporated into all levels of the governance hierarchy. • Management systems should provide for maximum transparency so that the basis for data analysis and decision-making is unambiguous and the process by which decisions are made is obvious as the decisions are under consideration. • Management decisions should be publicly defensible. • Accurate information about the condition of the resource and the expected flow of benefits and costs should be available at low cost. • Management decisions should be independent of political and/or special interest agendas to reduce the potential for "agency capture" or political gridlock. • Institutions should be sensitive to the complex (sometimes self-serving) motivations of social actors.	2; Wollenberg et al. (2008) as cited in 3; Ostrom, as cited in 4; 7; 8; 9; 11; 14; 15
Appropriate scale	• Scale of appropriation rules (restricting time, place, technology, and/or quantity of resource available for use) and provision rules (requiring labor) should be congruent with local conditions and scaled to local system. • Institutional arrangements should be variable across spatial and temporal scales, and should encourage experimentation in different places as well as take lessons learned elsewhere into account.	Wollenberg et al. (2008) as cited in 3; Ostrom, as cited in 4; Ward et al. as cited by 12
Social Justice and empowerment	• Managing entities should engage in proactive efforts to address inequities in the distribution of rights, benefits, and involuntary risks. • Institutions must have mechanisms to *actually respond* to feedback provided during participatory process.	2; 7; 9;

	Organizational features designed to allow transfer of authority	• Multilayered (nested) and/or polycentric governance hierarchies must allow for authority to be transferred to different levels to prevent corruption and improve efficiency. • Institutional relationships/ interactions/ power sharing should be formalized and transparent. Coordination among agencies should be designed to reduce the bureaucratic burden. • Attributes of larger scale institutions (i.e., federal government agencies) should be designed to facilitate smaller scale, more local institutions to achieve their goals. • Smaller scale institutions should be designed to foster leadership and social capital.	2; Wollenberg et al. (2008) as cited in 3; Ostrom, as cited in 4; 5; 6; 8; 9; 14; 15; 16
Societal enabling conditions	Capacity for self-organization	• Strong local leadership that must be familiar with local traditions and changing external conditions. • High capacity and self-organization exists to free the system from the need to be continually invested in, subsidized, or replenished from outside. • Participants should have the autonomy to make many of their own operational rules which if made legitimately, will not be interfered with, and even potentially will be supported and enforced by, external authorities. • Participants should use collective-choice rules that fall between the extremes of unanimity or control by a few (or by bare majority) and thus avoid high transaction or high deprivation costs. • Participant groups should be small enough to enable ease of cooperation. • Users should be located close to the resource. • User group boundaries should be clearly defined.	1; 2; Ostrom, as cited in 4; 9; 10; 11; 15
	Capacity for adaptation and learning	• The system is enabled to cope with nonlinearities or other forms of surprise and uncertainty; to detect hard-to-reverse thresholds in a timely manner; and improve fit between rules and ecosystems even as they go through dynamic cycles. • Participants can develop relatively accurate and low-cost monitoring and sanctioning arrangements.	9; 11
	Preexisting local/ traditional organizations	• Local and traditional organizations should serve as the foundation for more formalized management organizations. • Participants should share generalized norms of reciprocity and trust, based on past successful experiences in group functioning that can be used as initial social capital. • Participants must not discount the future at a high rate.	1; 11; 15; 16
	Social support and agreement	• Participants should be relatively homogenous in regard to information and preferences about the use of the resource. • Interdependence should exist among group members. • Participants must share a common understanding about the potential benefits and risks associated with the continuance of the status quo as contrasted with changes in norms and rules that they could feasibly adopt. • The group using the resource should be relatively small and stable.	1; 11; 15

Citations: 1: (Baland and Platteau 1996); 2: (Basurto and Ostrom 2009); 3: (Campbell, Sayer, and Walker 2010); 4: (Cinner et al. 2011); 5: (Folke et al. 2005); 6: (Fujita et al. 2010); 7: (Fung 2003); 8: (Goodin 1998); 9: (Lebel et al. 2006); 10: (Olsson, Folke, and Berkes 2004); 11: (Ostrom and Schlager 1996); 12: (Pitcher et al. 2009); 13: (Reed 2008); 14: (Sivas and Caldwell 2008); 15: (Wade 1988); 16: (Wielgus et al. 2014).

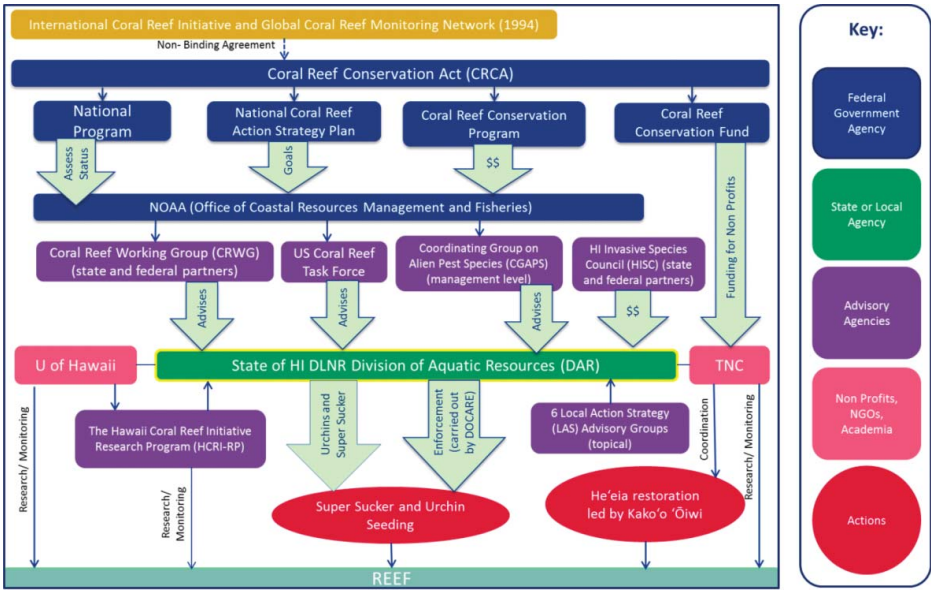

Figure 1. International, national, state, and local governance network of Kaneohe Bay, Hawai'i.

Coral Reef Conservation Program" 2013; Gombos et al. 2010; "Division of Aquatic Resources" 2014; "About the Hawaii Coral Reef Strategy" 2013; "Memorandum of Understanding between The Division of Aquatic Resources of Department of Land and Natural Resources and The University of Hawaii for the Establishment of Hawaii Coral Reef Initiative Research Program" 1998).

In recent years, a variety of invasive algae (including *Kappaphycus alvarezii, K. striatum, Eucheuma denticulatum*, and *Gracilaria salicornia*) that were introduced for commercial purposes in the 1970s have spread throughout Kāneʻohe Bay, damaging corals and threatening the tourism industry (Conklin and Smith 2005; "Invasive Algae" 2014). These algae form thick mats that out compete corals and other reef organisms (DLNR/ Division of Aquatic Resources 2014; Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014; Cynthia L. Hunter, Associate Professor, Biology Department; Director, Marine Option Program University of Hawai'i at Manoa, personal communication by phone, January 30, 2014). This invasion came on the heels of a previous system shift to a state dominated by an invasive *native* algae that was spurred by sewage being discharged directly into the Bay from the 1950s through 1977 (S. V. Smith et al. 1981; Pastorok and Bilyard 1985; Hunter and Evans 1995). After the sewage was diverted out of Kāneʻohe Bay in 1977 and 1978, the system began a rapid recovery back to coral domination (Bahr, Jokiel, and Toonen 2015). However, as the non-native algae were introduced before the sewage diversion they were likely able to take advantage of the compromised benthic biological composition in the Bay (S. V. Smith et al. 1981). In addition, some researchers believe that excess nutrients from the sewage runoff remain in the sediments in Kāneʻohe Bay, and are being cycled through the system by the invasive algae (John Stimson, Larned, and McDermid 1996; J. Stimson, Larned, and Conklin 2001; Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication on phone, January 22, 2014). Furthermore, between 1937 and 1944 large portions of the coral reefs in Kāneʻohe Bay were

damaged in the dredge and fill operations that were part of construction of the Kāneʻohe Naval Air Station, and recent research shows that parts of the reefs have yet to recover from these impacts (Jokiel, Kuʻulei, and Farrell 2005; Bahr, Jokiel, and Toonen 2015). Finally, Kāneʻohe Bay has faced heavy pressure from recreational and, to a lesser degree, commercial fisheries for decades, which keeps numbers of native herbivores low, reinforcing and strengthening the algal invasion (Jono Blodgett, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii, contracted by the State of Hawai'i, Division of Aquatic Resources, personal communication by phone, April 15 and May 6, 2014; Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014; Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication by phone, January 22, 2014; "Super Sucker Saves Reefs" 2014). Bahr et al. (2015) gives an excellent, comprehensive account of the myriad pressures that have impacted this system throughout the past eight centuries.

The rapid spread of exotic algae in Kāneʻohe Bay was first documented by Rodgers and Cox (1999). In the early 2000s, a group of scientists and managers from the University of Hawai'i, TNC, and DAR came together to form the Hawai'i Island Marine Algae Group (HIMAG) to respond to this threat to their local coral reef system (Cynthia L. Hunter, Associate Professor, Biology Department; Director, Marine Option Program University of Hawai'i at Manoa, personal communication by phone, January 30, 2014). This group first implemented a small-scale experiment that showed reef recovery was still possible, and then participated in larger-scale, community clean-up efforts. When these efforts fell short, HIMAG explored other options including the idea of using a giant underwater vacuum with a venturi-style pump (the "Super Sucker") designed to protect any non-target species sucked up along with the algae (Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014; Cynthia L. Hunter, Associate Professor, Biology Department; Director, Marine Option Program University of Hawai'i at Manoa, personal communication by phone, January 30, 2014; Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014; Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication by phone, January 22, 2014; "Super Sucker Saves Reefs" 2014).

The Super Sucker is the single most effective tool in Hawai'i for removing exotic invasive algae. It can remove as much as 3,000 lbs per day and clears about seven acres of reef per year ("Hawaii's Secret Weapon Against Alien Algae" 2006; "Questions and Answers: Super Sucker Junior" 2007; "Super Sucker Saves Reefs" 2014). The algae is given to local farmers to use directly on their fields as soil amendment ("DAR Super Sucker Invasive Algae Removal Process" 2014; Cynthia L. Hunter, Associate Professor, Biology Department; Director, Marine Option Program University of Hawai'i at Manoa, personal communication by phone, January 30, 2014; Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014). In 2007 a second Super Sucker barge was created, and managers now have sufficient capacity to clear the Bay of the invasive algae species fast enough to prevent them from overtaking the area (Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014; "Super Sucker 2.0" 2014). However, the rapid growth and dispersion of these algal species allows them to quickly repopulate cleared areas (Conklin and Smith 2005; "Super Sucker Saves Reefs" 2014). In 2009, the Super Sucker operation was supplemented by introducing native herbivorous urchins, based on experimental studies showing that enhanced urchin populations

could stem repopulation of cleared areas (Stimson, Cunha, and Philippoff 2007; Conklin and Smith unpublished).

Both the initial Super Sucker project and the more recent urchin interventions have followed a common trajectory: after each passed out of the proof-of-concept and into the implementation phase, DAR took over day-to-day operations ("Aquatic Invasive Species: Ongoing Projects" 2011; "Super Sucker Saves Reefs" 2014; Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014; Cynthia L. Hunter, Associate Professor, Biology Department; Director, Marine Option Program University of Hawai'i at Manoa, personal communication by phone, January 30, 2014). These efforts to restore the reefs have been remarkably effective over a limited spatial scale ("Sea Urchins to the Rescue" 2011; Jono Blodgett, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii, contracted by the State of Hawai'i, Division of Aquatic Resources, personal communication by phone, April 15 and May 6, 2014; Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014; Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014), and managers speculate that if they could secure continued funding the Bay's northern section could be cleared of harmful algae in a matter of months ("Super Sucker 2.0" 2014).

Evidence from the small-scale experiments in algal removal and urchin seeding shows that ecological recovery is possible (Barlow et al. 2011; "Restoring a Reef: Innovative Solution Helps Coral Reefs Recover from Invasive Alien Algae" 2010; "Sea Urchins to the Rescue" 2011). However, while this coordinated program to eradicate exotic algae has been successful, it fails to address other drivers of ecosystem change in the Bay that could compromise success. For example, non-commercial (recreational and subsistence) fishing pressure on herbivorous fish, which are severely depleted, is contributing to the invasiveness of exotic algae and retarding the return of coral dominated states (J. Stimson, Larned, and Conklin 2001; Conklin and Smith 2005; Vermeij et al. 2009; "HI Reef Revival" 2014). Scientists and managers widely acknowledge that reducing this fishing pressure could provide sustained algal control at a lower cost than the Super Sucker program (Cynthia L. Hunter, Associate Professor, Biology Department; Director, Marine Option Program University of Hawai'i at Manoa, personal communication by phone, January 30, 2014; Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014; Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication by phone, January 22, 2014). However, managers and policymakers have failed to limit non-commercial fishing pressure on herbivorous fish. Thus, managers in Kāneʻohe Bay face challenges common to coral reef systems worldwide, experiencing mixed success in political and ecological battles against invasive algae and other ecosystem impacts. Furthermore, although the coral reefs in Kāneʻohe Bay have thus far proven to be fairly resilient to anthropogenic pressures, this system (like others) will face continued and increasing pressures from climate change that may exceed the limits of that resilience (Bahr, Jokiel, and Toonen 2015). Based on this context, we asked what institutional and structural governance factors and sociocultural attributes outside the level of the direct system management might be impacting the ability of managers to address the algae problem. We implemented a three step analysis process: first, we examined the over-arching governance attributes and societal enabling conditions within the system; second, we evaluated the distribution of rights and responsibilities for resource users generated by these governance constructs; and third, we briefly discuss the potential incentives to conserve that may result from this distribution of rights and responsibilities.

Methods

Good governance attributes

We compiled a "master list" of attributes that are important for effective governance, as well as certain societal attributes that may augment the management of resilience, drawing particularly from the literature on institutional design and governance characteristics associated with sustainable common property resource management (e.g,, MacCay and Acheson 1987; Wade 1988; Berkes et al. 1989; Ostrom 1990; Ostrom, Gardner, and Walker 1994; Baland and Platteau 1996; Goodin 1998; Fung 2003; Olsson, Folke, and Berkes 2004; Folke et al. 2005; Lebel et al. 2006; Ward et al. 2006; Sivas and Caldwell 2008; Reed 2008; Pitcher et al. 2009; Basurto and Ostrom 2009; Cinner et al. 2011). We limited our search to studies that drew from real-life cases of natural resource management. While we acknowledge that "effectiveness" has multiple dimensions—including the achievement of social and economic goals—here we are focused on conservation outcomes (e.g., reduction of overfishing, protection of threatened species, removal of invasive species, prevention or removal of pollution).

We then slightly amended the definitions and explanations advanced by the reviewed authors so that each attribute could pertain to all sectors involved in marine conservation and management. This step was necessary because many of the original guidelines were written with a specific sector of marine resource management in mind (e.g., implementation of a marine protected area); however, we took care not to change the thrust of the original definitions (Table 1).

Rights, responsibilities, and incentives

Governance attributes affect the distribution of rights, responsibilities, and rewards among the stakeholders affected by resource management decisions (Schlager and Ostrom 1992), an observation that is particularly salient for cooperative fisheries management (Moxley, Markham, and Fujita 2011; Wielgus et al. 2014; Yandle 2006; 2007). The most relevant analyses center on the distribution of rights of Access (the right to enter a defined physical property), Withdrawal (the right to obtain the "products" of a resource), Management (the right to regulate internal use patterns and transform the resource by making improvements), Exclusion (the right to determine who will have an access right, and how that right may be transferred), and Alienation (the right to sell or lease either or both of the above collective-choice rights) among institutions ranging from central governments to small groups of local fishermen. Previous discussions of rights-based management of common-pool resources such as fish stocks have been criticized for failing to explicitly lay out the responsibilities that come with each of the given rights (Lam and Pauly 2010). Most formal rights come with some minimal responsibilities and common understandings that are intended to prevent infringement on the rights of others. If rights are allocated without accompanying responsibilities that explicitly prevent rights holders from infringing on the rights and assets of others (which is often the case) there is a risk that individual actors will pursue their rights to the point of reducing the benefits associated with other people's rights. We have attempted to address this issue by creating, through reference to the literature, a list of potential responsibilities that could accompany these rights (Table 2). We explore the distribution of rights and related responsibilities, with a focus on how governance structures have impacted these distributions.

Well-designed governance structures will facilitate an appropriate and relatively even distribution of rights, and of the associated responsibilities, tailored to specific circumstances of the system

Table 2. Potential list of responsibilities to be associated with rights.

Operational-level rights holders
• Adhere to all rules and regulations pertaining to access and withdrawal disseminated by higher authorities (i.e., respecting temporal and spatial closures, obtaining fishing permits, staying within catch limits, using sanctioned gear, not taking snorkel tours to closed areas, etc.).
• Use the resource that they withdraw (to ensure that whoever's extracting the resource that was once a common good is using it for the benefit of society).
Collective-choice rights holders
• Create and implement Management Plans.
• Provide for day to day upkeep of the system.
• Implement conservation and restoration projects.
• Carry out data collection, reporting, and system monitoring, as well as conduct ecological risk assessments.
• Monitor and enforce all rules and regulations.
• Account for all sources of resource withdrawal.
• Host conflict resolution mechanisms for resource users.
• Ensure users have safe space to organize.
• Train resource users and managers, and disseminate all relevant rules.
• Clearly define guidelines laying out which individuals are included in, or excluded from, the system.
• Clearly define and demarcate the boundaries of the system (prepare maps at appropriate scales).
• Establish an organizational structure for system management, including different stakeholders (this group will decide on and implement allocation of access and withdrawal rights).
• Incorporate current best available science into management to facilitate maximization of benefits (includes setting standards for water quality, discards, etc.).
• Establish research and information needs and priorities.
• Design operational rules to ensure best practices in management (i.e., mechanisms for data collection, monitoring, incorporation of science, adaptive management, etc.); includes laying out Spatial, Temporal, and Quantitative dimensions of rights.
• Design technical rules and regulations pertaining to all aspects of use and management of the system (i.e., catch limits, spatial and temporal closures, etc.) with the aim of perpetuating resource use over the long term (sustainable management).
• Secure funding for management efforts, including day-to-day upkeep, monitoring and enforcement, and conservation or restoration projects.
• Select penalty or sanction amounts to be applied to varying degrees of violations (graduated sanctions).
• Ensure that organizations do not become so complex that they cannot be managed (ensuring appropriate scale).
• Identify partners and their interests and responsibilities (identifying stakeholders).
• Establish ecosystem values.
• Establish objectives and targets, as well as strategies for achieving targets.
• Design and implement performance assessments and review process.

being managed (Ostrom 1990). Such a distribution should function to internalize externalities that accompany use of the natural resource, and generate an effective array of incentives to conserve and sustainably manage the resource. For example, the rights of Management and Exclusion allow participants to capture future benefits of conservation actions taken currently, arguably creating incentives for conservation actions. A recent analysis shows a positive association between the existence of such rights and the implementation of conservation regulations by fisheries cooperatives (Ovando et al. 2013). The right of Alienation creates additional incentives to invest in the long-term welfare of the system because all "rent" can be captured by the rights holder (Schlager and Ostrom 1992; Ostrom and Schlager 1996). Of course, it is important to carefully consider the initial allocations of the various rights and accompanying privileges, and to recognize that there are limits and challenges associated with the creation and allocation of private property rights (Hilborn, Parrish, and Litle 2005).

We apply three levels of evaluation to the Kāneʻohe Bay case study. First we examine the quality and completeness of the effective governance attributes (Table 1) through the systematic approach described above, then we evaluate the distribution of rights and responsibilities created and influenced by those attributes, and lastly we consider the incentives to

conserve that may be present in the system based on the structure of governance attributes and the distribution of rights and responsibilities. We use the UNEP categories of incentives (economic, interpretative, knowledge, legal, and participatory; see Jones et al. 2011 and 2013 for full list) to explore the incentives that may exist in Kāneʻohe Bay.

Evaluating the management system in Kāneʻohe Bay

We aimed to evaluate the relevant governance attributes—and the degree to which these attributes are realized in practice—by means of a literature review, supplemented by interviews with key respondents in the Kāneʻohe Bay region. We note that only seven interviews were completed (Appendices 4 and 5), and as a result the information provided does not represent all expert opinions for the case; however, we endeavored to corroborate respondent claims wherever possible.

We evaluated the governance attributes in this system with respect to the master list of effective governance attributes (Table 1). Using the compiled definitions for each item on the list as a standardized metric, we gave each case a score of "low" (1), "medium" (2), or "high" (3) for each attribute (see Appendices 1 and 2 for scoring metric, scores, and totals). These scores were assigned by a single analyst (WB) based on an interpretation of the data and information gathered through research and interviews, and then reviewed by the other authors. These scores provided us with a heuristic through which we could systematically explore the quality and completeness of each attribute as it presents in this case. If all components of a given attribute's definition were fully realized, the attribute was assigned a score of 3; if some components were missing or we felt that they were incomplete, we assigned that attribute a score of 2; and if the system presented none of the components of the attribute's definition we assigned a score of 1. We then explored how the fully realized, partially realized, and missing attributes might be impacting the achievement of conservation goals in Kāneʻohe Bay.

It is important to note that these scores, and the resulting cumulative score for the system as a whole, were only used as a tool for conducting a systematic and uniform analysis that can be applied to any given case study. The scores help ensure that our results are transparent and repeatable, and that no important components (as identified by authors across many disciplines) were left out of the analysis. The ultimate goal of the analysis was to identify strengths and weaknesses in the governance and institutional structures in this system that may be differentially helping or hindering the achievement of management goals. Thus, the interpretation of the reasons why a given attribute may be incomplete or missing, the effects of those gaps on outcomes, and the mechanisms through which other more complete attributes may be acting alone or in concert are significantly more important to the findings than the numerical scores themselves.

Here we provide a summary of the most important governance factors identified, discussing only the structural components that have a significant impact on management success. For a detailed discussion of each item on the master list as it presents in this case study see Appendix 3.

Case study analysis and results

Structural governance attributes

Scores for Kāneʻohe Bay are generally high for the governance attributes we examined (Table 1), with just a few items receiving "low" scores. Closer inspection of some of the

attributes as they present in this case reveals important clues as to why managers have so far been successful in their restoration efforts, and point to important issues that may hinder continued success into the future (see Appendix 3 for all scores and detailed analysis).

One of the attributes influencing reef restoration outcomes in this case is regulatory authority—the authority (in this case, granted by statute) to develop, adopt, and implement rules and regulations, evaluate the efficacy of those decisions, and adjust them over time (Table 1). In Kāneʻohe Bay, the state government operating through the DLNR's DAR has full authority to develop and implement reef management programs and fisheries regulations (Gombos et al. 2010; Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014). This has allowed DAR managers to implement a sophisticated system of adaptive management for reef restoration whereby new projects are applied on a patch by patch basis and scaled up slowly as new information is gathered (Jono Blodgett, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii, contracted by the State of Hawai'i, Division of Aquatic Resources, personal communication by phone, April 15 and May 6, 2014; "Aquatic Invasive Species: Ongoing Projects" 2011). While regulatory authority may not be a sufficient condition to ensure management success, our research suggests that it may be necessary—without it, implementation of the Super Sucker and urchin seeding programs would have been significantly more difficult, as every innovation and decision would have had to pass through some kind of approval process, potentially delaying or obstructing implementation.

Furthermore, the lack of formal support for science-based decision making (another item on our list of effective governance attributes; Table 1) made regulatory authority even more important to the success of the Super Sucker program. Science is consistently used in DAR's adaptive management effort despite the lack of a formalized mechanism in Hawai'i to facilitate this process. To do so, DAR managers must reach out to scientists on a project-by-project basis to gather data necessary for management decisions (Jono Blodgett, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii, contracted by the State of Hawai'i, Division of Aquatic Resources, personal communication by phone, April 15 and May 6, 2014; Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014). There is ample scientific research on the reefs in Kāneʻohe Bay where, in addition to the studies carried out by the University and TNC, the Hawai'i Coral Reef Initiative - Research Program (HCRI-RP) funds research efforts and hosts quarterly project review meetings and workshops ("Governance" 2013). However, this research is infrequently used in the design of formal regulations (Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014; Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014). In the case of the Super Sucker, organizations such as the University of Hawai'i and TNC have aided DAR's efforts to incorporate science into management, stepping in to help fill capacity gaps with monitoring and data gathering programs, and by engaging the local community in reef monitoring ("HI Reef Revival" 2014; Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014; Cynthia L. Hunter, Associate Professor, Biology Department; Director, Marine Option Program University of Hawai'i at Manoa, personal communication by phone, January 30, 2014; Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014; Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication by phone, January 22, 2014).

This public-private partnership between DAR, TNC, and the University of Hawai'i is an excellent example of a governance structure that is effectively organized to allow for the transfer of authority (an important effective governance attribute; Table 1). Interestingly, however, this structure arose outside of the more formal marine resource governance structure in the state, and such partnerships are not supported or facilitated by the official institutional structure in any way (Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014; Cynthia L. Hunter, Associate Professor, Biology Department; Director, Marine Option Program University of Hawai'i at Manoa, personal communication by phone, January 30, 2014). The success of the Super Sucker project relies in equal parts on the research capacity of the University of Hawai'i, the funding and community organization capacity of TNC, and the invasive species management expertise of DAR (Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014; Cynthia L. Hunter, Associate Professor, Biology Department; Director, Marine Option Program University of Hawai'i at Manoa, personal communication by phone, January 30, 2014). Each of the three institutions involved in this partnership plays a pivotal role. However neither TNC nor the University of Hawai'i has the regulatory authority to create or enforce new regulations. That authority lies solely in the hands of the state (Jono Blodgett, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii, contracted by the State of Hawai'i, Division of Aquatic Resources, personal communication by phone, April 15 and May 6, 2014; Alton Miyasaka, Biologist, Aquatic Resources Division, Division of Land and Natural Resources, Hawai'i, e-mail message to author, May 9, 2013; Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014). Unfortunately, as this public-private partnership was not formalized it has now dissolved to a large extent (Cynthia L. Hunter, Associate Professor, Biology Department; Director, Marine Option Program University of Hawai'i at Manoa, personal communication by phone, January 30, 2014; Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014; Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication by phone, January 22, 2014), leaving behind a clear gap between science and regulatory design.

This disconnect is apparent in the lack of restrictions on non-commercial (recreational, traditional, and subsistence) fishing in Kāne'ohe Bay. Despite ample scientific evidence that pressure from these fisheries has been a significant factor in the depletion of herbivores which would otherwise help to keep the algae in check, DAR managers and policymakers have failed to significantly reform fishing regulations (Cheroske, Williams, and Carpenter 2000; Vermeij et al. 2009; Barlow et al. 2011; Jono Blodgett, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii, contracted by the State of Hawai'i, Division of Aquatic Resources, personal communication by phone, April 15 and May 6, 2014; Cynthia L. Hunter, Associate Professor, Biology Department; Director, Marine Option Program University of Hawai'i at Manoa, personal communication by phone, January 30, 2014; Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication on phone, January 22, 2014). Non-commercial fishing is practically unrestricted throughout the state of Hawai'i (exceptions include a small number of poorly enforced gear restrictions and minimum size limits, a handful of marine protected areas, and a recently passed recreational bag limit for a small number of species) ("Division of Aquatic Resources" 2014; "Regulated Marine Fishes and Vertebrates" 2014; Jono Blodgett, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii,

contracted by the State of Hawai'i, Division of Aquatic Resources, personal communication by phone, April 15 and May 6, 2014; Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication on phone, January 22, 2014). Moreover, non-commercial fishers are not required to obtain permits or licenses for marine fishing, and there is no required reporting for most species ("Licenses and Permits" 2013). Non-commercial fishing is the main source of fishing pressure in Kāneʻohe Bay, and the single small no-take area there (around Coconut Island) was not designed to address this pressure ("Regulated Fishing Areas on O' ahu" 2013; Jono Blodgett, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii, contracted by the State of Hawai'i, Division of Aquatic Resources, personal communication by phone, April 15 and May 6, 2014). Heavy pressure on herbivorous fish from these small-scale fisheries has removed nearly all grazing pressure on the algae, allowing it to proliferate throughout the system (Barlow et al. 2011; Cheroske, Williams, and Carpenter 2000; Cynthia L. Hunter, Associate Professor, Biology Department; Director, Marine Option Program University of Hawai'i at Manoa, personal communication by phone, January 30, 2014; Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication on phone, January 22, 2014). Scientists and managers are now attempting to replace the missing grazing pressure through the urchin seeding program. They have shown that these native urchins will eat the invasive algae, but so far the urchins have not permanently established, and may not be reproducing, in the Kāneʻohe Bay waters (Jono Blodgett, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii, contracted by the State of Hawai'i, Division of Aquatic Resources, personal communication by phone, April 15 and May 6, 2014; Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014; Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication by phone, January 22, 2014). TNC has focused significant resources in the area on fostering community involvement in this issue, and helping the communities to propose fishing regulations that might alleviate the problem. However, these groups must convince the state agency to pass these rules, which has proven challenging. Even if passed, these rules must be effectively enforced if they are to maintain continued community support and effectively reduce fishing pressure (Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014; Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014; Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication by phone, January 22, 2014).

There are many reasons for DAR's failure to create stronger non-commercial fishing regulations in Kāneʻohe Bay. Among them are shortcomings related to four effective governance attributes: a lack of explicit recognition of tradeoffs, insufficient accountability and transparency, and a lack of community support for such regulations, which is exacerbated by inefficient funding and enforcement mechanisms (Table 1). Unfortunately, the public-private partnership that coalesced to facilitate the creation and implementation of the Super Sucker project was not powerful enough to address these pervasive problems. The clearly defined goals and objectives (another attribute associated with effective governance, Table 1) for aquatic invasive species management laid out by DAR in coordination with TNC and the University of Hawai'i have facilitated some reef management decisions in favor of conservation and restoration, providing a counter-point to short-term economic considerations (Shluker 2003; Gombos et al. 2010; "About the Hawaii Coral Reef Strategy" 2013). However, non-

commercial fishing regulation reform has remained controversial. There is little doubt that the recreational value of the reefs is very high, but the costs associated with their degradation are difficult to quantify (Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014). Although studies exist that reveal the high value of the reefs to the state economy (e.g., (Cesar and Van Beukering 2004), they are all at a fairly large scale, which makes it difficult to calculate the value locally (Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014). Presumably the costs of strong fishing regulation are highly salient to non-commercial fishers, much more so than the benefits. As a result, opponents of reform have prevailed (Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication by phone, January 22, 2014).

In Kāneʻohe Bay (as in many systems), draft management plans are subjected to a lengthy public review and comment process and publicly funded actions are regularly audited by the funding agencies (Shluker 2003; Alton Miyasaka, Biologist, Aquatic Resources Division, Division of Land and Natural Resources, Hawai'i, e-mail message to author, May 9, 2013). Moreover, the structure of governance agencies in Kāneʻohe Bay is both multilayered and polycentric (see Figure 1), with agencies up and down the hierarchy partnered to share responsibilities and capacity and to serve as a system of checks and balances. However, there may also be important weaknesses in the mechanisms for accountability and transparency in this case. DAR carries out its own monitoring, and published results of these reviews are infrequent due to lack of funding and staff capacity (Jono Blodgett, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii, contracted by the State of Hawai'i, Division of Aquatic Resources, personal communication by phone, April 15 and May 6, 2014; Alton Miyasaka, Biologist, Aquatic Resources Division, Division of Land and Natural Resources, Hawai'i, e-mail message to author, May 9, 2013). Furthermore, the recreation and tourism industries are extremely valuable to the state of Hawai'i (Gombos et al. 2010), and their interests tend to be especially influential in the rule-making process. The state's legislative and regulatory processes are often not completely independent of these pressures, and at times these short-term interests have prevented the passage of initiatives that may have been beneficial to both stakeholders and ecosystem over the long term (Jono Blodgett, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii, contracted by the State of Hawai'i, Division of Aquatic Resources, personal communication by phone, April 15 and May 6, 2014).

The Super Sucker has been successful in part because it was developed and implemented outside of this complex, bureaucratic process, and the public-private partnership between TNC, the University of Hawai'i, and DAR allowed each of these agencies to facilitate different aspects of the project, depending on their specific capacities and capabilities (Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014). In this case, the innovation, research, and development aspects of the project were developed and efficiently completed by the nongovernmental actors. Once the benefits became clear, management of the Super Sucker project was transferred to DAR who could better handle the day-to-day operations. Now that the project has moved from the development stage to the long-term maintenance and management stage, the public-private partnership between TNC, the University of Hawai'i, and DAR has largely dissolved (Cynthia L. Hunter, Associate Professor, Biology Department; Director, Marine Option Program University of Hawai'i at Manoa, personal communication by phone, January 30, 2014; Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30,

2014; Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication by phone, January 22, 2014). However, because the underlying drivers of system change (e.g., the overfishing of herbivores) have not been addressed, the Super Sucker and urchin seeding programs will require continued input and support to be successful. Unfortunately, nothing in the state resource management legislation encourages the continuation of such a partnership, or the creation of any other agency or body capable of addressing the governance gaps left behind by its dissolution. This may prove to be a significant obstacle to the sustainability of the Super Sucker and urchin seeding programs, and to the long-term success of restoration in this system (Cynthia L. Hunter, Associate Professor, Biology Department; Director, Marine Option Program University of Hawai'i at Manoa, personal communication by phone, January 30, 2014).

Societal enabling conditions have also had a large impact on the ecological outcome of resource management in Kāneʻohe Bay. Some of Kāneʻohe Bay's highest scores are for attributes related to societal enabling conditions, including the capacity for self-organization and preexisting traditional organizations (Table 1). Social agreement and support, however, is mixed in this case. In general, all users of the Bay agree that the invasive algae should be removed (Jono Blodgett, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii, contracted by the State of Hawai'i, Division of Aquatic Resources, personal communication by phone, April 15 and May 6, 2014; Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014). Traditional groups support the removal of the algae because they have seen the changes in the Bay over the past four decades (Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication by phone, January 22, 2014; Gombos et al. 2010). Furthermore, the traditional cultural heritage in Kāneʻohe Bay—including the *ahupuaʻa* concept, which considers the entire watershed as one area to be managed by one group governed by one chief, and the *kapu* system of temporary spatial and temporal fishing closures and species restrictions—is especially well suited to conservation and sustainable management of resources (Gombos et al. 2010), making these concepts appealing to, and easily understood by, local community members. However, there has been disagreement among stakeholders over the impact of non-commercial fishing on the health of the Bay, and conflict over the passage of stricter non-commercial fishing regulations that do not distinguish native and subsistence fishers from tourists and recreational fishers (Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication by phone, January 22, 2014). This is another reason that DAR managers have only been able to design and implement reef restoration and algae removal programs that do not impact fishing, and hence do not generate conflict. However, in order to achieve restoration success over the long term, all of the drivers of system change, including all sources of herbivore mortality, will need to be addressed and brought into alignment with ecological outcomes. One of the main reasons that societal support for fisheries regulations is so low in Kāneʻohe Bay is a lack of confidence that any such regulations, if passed, would be enforced. Efficient enforcement mechanisms for marine resource regulations (another important attribute of effective governance—Table 1) are sorely lacking in Kāneʻohe Bay (Jono Blodgett, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii, contracted by the State of Hawai'i, Division of Aquatic Resources, personal communication by phone, April 15 and May 6, 2014; Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014; Gombos et al. 2010). The Division of Conservation and

Resource Enforcement (DOCARE) is responsible for enforcing all state and federal terrestrial and marine resource management rules and regulations, as well as for enforcing against a variety of other types of criminal activities on the Hawaiian islands (Gombos et al. 2010; "About the Division of Conservation and Resource Enforcement (DOCARE)" 2014). DOCARE is understaffed and underfunded, which leaves significant gaps in the enforcement of reef management regulations (Jono Blodgett, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii, contracted by the State of Hawai'i, Division of Aquatic Resources, personal communication by phone, April 15 and May 6, 2014; Gombos et al. 2010; "About the Division of Conservation and Resource Enforcement (DOCARE)" 2014). Furthermore, because violations of fishing and other marine resource use regulations are treated as criminal cases, violators must be tried in the general court system, which requires extensive time and resources ("About the Division of Conservation and Resource Enforcement (DOCARE)" 2014; Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014). When juxtaposed against serious and violent criminal cases, fisheries violations may not be taken seriously, and judges may dismiss them too easily (Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014). The result of this situation is that existing regulations often go unenforced, and community members and resource users are incentivized to ignore them. Moreover, it is especially difficult to garner community support for new regulations limiting resource use when there is an assumption that violators will go un-punished (Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014; Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014; Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication by phone, January 22, 2014). A potential solution to this problem would be to issue civil penalties for violations of marine resource regulations. In addition to alleviating the prosecutorial burden, these fines would also generate revenue that could be channeled back into marine resource management and enforcement. DLNR is currently working to implement such a solution through the creation of a new "civil resource violations system," which allows for violations to be prosecuted through the civil rather than criminal courts. However, this system is currently only in effect for commercial fisheries reporting and boating registration delinquencies (Alton Miyasaka, Biologist, Aquatic Resources Division, Division of Land and Natural Resources, Hawai'i, e-mail message to author, May 9, 2013).

The greatest barrier to continued sustainable management of reefs in Kāneʻohe Bay is the lack of dependable funding to support the manpower and resources needed to implement management efforts (including the Super Sucker and urchin seeding programs), to develop scientifically sound management plans, and to effectively enforce regulations that prevent overfishing and help keep algae in check. Coral reef management is mainly funded by the Hawai'i State Legislature on an annual basis and is subject to budget fluctuations each fiscal cycle. Additional grants from a variety of funding sources sometimes fill gaps in capacity left by the state budget, but many of these agencies have faced budgetary shortfalls in recent years ("Super Sucker Saves Reefs" 2014; Gombos et al. 2010). Uncertainty about consistent funding from one year to the next has made it very difficult for DAR managers to invest in long-term projects, or to set long-term management goals, and funding for monitoring and enforcement of existing regulations is especially deficient (Gombos et al. 2010; Jack Kittinger, Director, Conservation International, Hawai'i Fish Trust, Betty and Gordon Moore Center for Science and Oceans, personal communication by phone, April 2, 2013). The Super

Sucker and urchin seeding programs were initially funded through earmarked federal research grants from NOAA (Celia Marie Smith, Professor of Botany, University of Hawaii at Manoa, personal communication by phone, January 22, 2014). This funding was supplemented with short-term grants from the Hawai'i invasive Species Council and other state agencies, generated through lobbying efforts by TNC. Once Super Sucker ownership and operations transitioned fully to DAR, TNC raised private funds for the creation of a second, more mobile "Super Sucker Junior" (Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014; "Invasive Algae Mobile Rapid Response Vacuum (HI)" 2005). Managers are now seeking a dependable source of funding to keep the two Super Suckers operating consistently (Jono Blodgett, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii, contracted by the State of Hawai'i, Division of Aquatic Resources, personal communication by phone, April 15 and May 6, 2014; Matthew Parry, NOAA Fisheries Biologist, personal communication by phone, January 30, 2014).

This analysis reveals that the structure of governance attributes in Kāneʻohe Bay has changed in the years since the initial formation of the Hawai'i Island Marine Algae Group. The creation of this public-private partnership between TNC, the University of Hawai'i, and DAR allowed each agency to exercise their strengths in addressing the invasive algae problem. The University was well equipped to handle the research and development project aspects and to seek grant funding, TNC was well equipped to seek private funds and to organize community participation and provide expert support where necessary, and the broad authority of DAR allowed the successful Super Sucker innovation to move quickly into regular use. This partnership maximized or fulfilled many of the effective governance attributes and societal enabling conditions that were incomplete before its formation, including science-based decision-making, governance goals aligned with conservation objectives, governance structures organized to allow for the transfer of authority, the societal capacity for self-organization, societal capacity for adaptation and learning, and societal agreement on the problem and its solution. When combined with DAR's full regulatory authority, clear objectives and directives, and the strong preexisting cultural traditions for conservation, the Kāneʻohe Bay governance system was well situated to address the spread of invasive algae on the local reefs. Unfortunately, this partnership dissolved before managers could successfully execute the urchin-seeding program, or address continued overfishing of the herbivorous reef species which may be compromising success. Thus this governance system was able to create a short-term fix to the problem, while longer-term strategies may be needed to create a durable solution. Furthermore, the Super Sucker project itself is at risk of discontinuation if funding for continued operations cannot be secured.

Distribution of rights and responsibilities and resulting incentives

The existing governance structure creates a distribution of rights and responsibilities in Kāneʻohe Bay that does little to incentivize long-term thinking and sustainable use of the resources. There are no restrictions on entry to Kāneʻohe Bay, and because there are no permits or licenses required for non-commercial fishing, everyone has the operational-level rights of access and withdrawal. There are also no formalized responsibilities (such as those listed in Table 2) associated with these rights. While managers have been able to implement the Super Sucker and urchin seeding program to address and contain the algae problem in

the short term, the longer-term solution would require an overhaul of non-commercial fishing regulations to generate a distribution of rights and responsibilities that is aligned with conservation and long-term sustainability.

Furthermore, the state government of Hawai'i holds the rights of management, exclusion, and alienation, and is expected to act as a steward of the resource, making management choices that benefit the greater good. Local reef users lack the rights of exclusion, alienation, and collective-choice, creating incentives for maximizing short-term gains at the expense of long-term sustainability. Furthermore, while various agencies are undertaking efforts to improve interpretative, knowledge-based, legal, and participative incentives to conserve ("HCRI-RP: About" 2014; "Working with Communities" 2011; Gombos et al. 2010; Jono Blodgett, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii, contracted by the State of Hawai'i, Division of Aquatic Resources, personal communication by phone, April 15 and May 6, 2014; Eric J. Conklin, TNC's Hawai'i Director of Marine Science, personal communication by phone, February 4, 2014), the gaps in effective governance attributes outlined above would be expected to limit the impact of these efforts.

Summary

A public-private partnership involving DAR, TNC, and the University of Hawaii successfully removed invasive algae from areas within Kāneʻohe Bay by overcoming several significant governance problems: lack of dependable funding, lack of a formal mechanism to incorporate science into management decisions, and a distribution of rights and incentives that is not aligned with conservation outcomes. Managers continue to successfully implement the adaptive Super Sucker and urchin-seeding program with support from the local community; however, dissolution of the public-private partnership and remaining gaps in capacity threaten this continued success.

In contrast, efforts to reduce non-commercial fishing pressure on grazing fishes—important for keeping invasive algae in check and more generally for maintaining coral reef ecosystem resilience and integrity—have not been successful to date. The distribution of rights, incentives, and responsibilities within the governance system—with the state holding most of the rights and responsibilities, and with resource users holding the right of withdrawal without reporting or stewardship responsibilities, and lacking the right of exclusion—appears to be generating substantial barriers to such efforts. A more even, multipolar distribution of rights and responsibilities could potentially improve outcomes.

Discussion and conclusions

Our analysis suggests that systems with similar management and biophysical attributes (as assessed in Kelly et al. 2014) may have different conservation outcomes because of the influence and differential realization of certain governance attributes that were not analyzed in that manuscript. A public-private partnership in Kāneʻohe Bay was able to overcome several significant governance gaps (and realize effective governance attributes more fully) in order to successfully remove invasive algae. Strong regulatory authority, clear goals aligned with conservation, and organizational features designed to allow for transfer of authority have allowed managers to work around insufficient or absent mechanisms for efficient enforcement, formal recognition of tradeoffs, insufficient and unstable funding, and a formal

process for science-based decision-making. However, as this partnership has now dissolved, sustainable management is again hindered by these governance gaps, as evidenced by the lack of regulations designed to curb non-commercial overfishing.

It may be that the relationships between certain governance attributes (i.e., where failings in one attribute worsen or alleviate failings in another) are more important for achieving management objectives than any given selection of individual attributes. For example, in Kāneʻohe Bay, funding deficiencies are partially mitigated by the direct actions of the managers in reaching out to researchers to ensure science is incorporated into management, as well as the monitoring and implementation assistance of The Nature Conservancy and the University of Hawai'i. This public-private partnership allowed managers to effectively address the significant problem of invasive species despite severely limited resources and limitations faced by each individual member of the partnership when trying to act alone. Although DAR had the authority necessary to manage invasive species, they were funding- and capacity-limited, preventing them from being able to carry out the necessary research to design, test, and implement a new solution. The University of Hawai'i had this research capacity, but lacked the ability to organize the community (crucial to pilot phases of the project) and to secure private funds. TNC had these capabilities, but not the authority to implement the project on a large scale or to run and manage it once it moved out of the experimental stages. The experts we interviewed for this analysis referred to a significant amount of "luck" and "good timing" as the enabling conditions for this advantageous partnership. However, we point instead to the initiative on the part of conservation-minded individuals who had regulatory authority (DAR managers) to seek out and infuse management efforts with strong scientific support, and to legal and administrative conditions favorable to the transfer of authority at key points in the project's lifespan. Unfortunately these relationships were not codified in any formal way to prevent their dissipation over time. The result is that continued Super Sucker operations, as well as additional measures to combat the problem of invasive species and threats to the sustainability of success (e.g., overfishing of herbivores), are threatened.

Finally, this case illustrates a common distribution of rights and responsibilities, where a centralized governing body holds all of the collective-choice rights of Management, Exclusion, and Alienation while important classes of resource users hold only the operational-level rights of Access and Withdrawal with very few restrictions or accompanying responsibilities. Although commercial fishing is regulated to limit access and withdrawal in Kāneʻohe Bay, there is still substantial pressure from the large non-commercial fishing sector, which is nearly unregulated. Local reef users do not have the right to manage this sector, or to exclude users to limit overuse. Transference of these rights from centralized governments to local-level resource users is associated with increased conservation actions (Ovando et al. 2013) and higher compliance levels (Grimm et al. 2012). Thus, there are important opportunities to improve the incentives to conserve through the redistribution of rights and responsibilities, as well as through modification of the governance structures examined in this article.

The situation in Kāneʻohe Bay, Hawai'i is not unique. Managers and scientists around the world struggle to protect and restore marine systems with complex drivers and characteristics, where future impacts are uncertain, but are likely to be more frequent and severe with climate change (Harley et al. 2006; Bernhardt and Leslie 2013; Bahr, Jokiel, and Toonen 2015). The stakes are especially high in marine systems such as coral reefs where relatively small changes in drivers can result in large changes in ecosystem structure and function (Folke et al. 2004;

McClanahan, Polunin, and Done 2002; Karr et al. 2015). Understanding the governance and institutional attributes of a social-ecological system, identifying missing and incomplete attributes that may be limiting effectiveness, and examining the effects of the distribution of rights and responsibilities on incentives and behavior can provide valuable information for guiding system reform in order to improve management outcomes, both in terms of ecosystem functioning and of community wellbeing. Our method of assessing a system against each item on the master list of effective governance attributes offers a systematic and robust approach to gaining this understanding. This method can be applied to any social-ecological system.

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Appendix 1: Scoring system

Score	Translation
1	Low: Meets none of the qualities listed in attribute definitions.
2	Medium: Meets some, but not all qualities listed in attribute definitions.
3	High: Meets all of the qualities listed in attribute definitions.

Appendix 2: Case Study Scores, Reasoning, and Totals

	Attribute	Score	Notes
Structural Attributes	Regulatory Authority	3	DAR has full authority over reef management, and fisheries regulations.
	Efficient Enforcement Mechanisms	2	DOCARE responsible for monitoring and enforcement of all natural resource management rules and regulations, which include graduated sanctions. However, DOCARE is underfunded and over extended, making enforcement less efficient than it could be.
	Governance Goals Aligned with Conservation Objectives	3	Conservation goals explicitly specified in DAR's mission statement and in legislation at all levels of the hierarchy. Written goals are supported through management actions.
	Science- Based Decision Making	2	No formal, institutional mechanism, but DAR staff tries to incorporate science into management themselves.
	Agency Flexibility	1	Institutional relationships inflexible.
	Explicit Recognition of Trade-Offs	1	No formal recognition and no restrictions on recreational fishing.
	Dependable Funding	1	Funded by state on year to year basis. Seek grants to fill gaps.
	Participation	2	Public comment periods for all legislation, but little actual community involvement in implementation.
	Systematic Representation	2	Many agencies work together but recreational fishers and tourism overly influential.
	Deliberation	3	There are several agencies/actors in charge of making decisions pertaining to the reefs in Hawaii and each of these bodies has its own explicit deliberative process.
	Clear Decision Making Rules	3	The CRWG works with LAS advisory groups and DAR biologists to develop and rank reef management and project goals which then serve as a guide for decision making.
	Clear Objectives and Directives	3	CRWG explicitly lists over-arching goals and objectives for reef management in Hawai'i, prioritized through consultation with LAS. DAR sets shorter term goals and deadlines than the CRWG because they are funded on a year-to-year basis.
	Accountability and Transparency	2	DAR monitors itself and reports are not published regularly due to lack of funding and capacity.
	Appropriate Scale	2	Reef restoration and invasive species management are designed and implemented at the scale of the Bay, fisheries management, however is regulated at the State level.
	Social Justice and Empowerment	2	All reef management regulations take subsistence fishers into account, however social justice for the indigenous people remains among the main concerns.
	Organizational Features Designed to Allow Transfer of Authority	2	Multilayered and fairly polycentric, but too many agencies results in unnecessary complexity.
Societal Enabling Conditions	Capacity for Self-Organization	2	Users in three groups: local subsistence fishers; commercial fishers; and locals or tourists who fish recreationally and/or dive at the reef. Boundaries clearly defined, but not very strong community leadership. DAR and TNC are currently working with groups across the state to move towards community-based management.
	Capacity for Adaptation and Learning	3	UH, TNC, and HCRI-RP doing profuse research there, including extensive monitoring of the reefs.
	Preexisting Local/ Traditional Organizations	3	*Ahupua'a* resource management system involved a single group, led by a single chief, managing an entire watershed.
	Social Agreement	2	High agreement on need to remove invasive algae, but low on need to regulate fisheries.
	Total (possible 60):	44	

Appendix 3: Full list of Kāneʻohe Bay Governance Attributes with analysis and scores

Total Score: 44 out of 60

Structural Governance Attributes

Regulatory Authority

Score: 3

DAR has full authority over establishment and implementation of reef management and restoration initiatives, and can adjust them over time if need be.

The DLNR DAR has the full authority to carry out any reef management programs it sees fit. It may be required to complete certain programs by the federal government, or advised to do so by one of the advisory bodies (Gombos et al. 2010). DAR is also the agency with the authority to regulate all fishing (both commercial and non-commercial) within state waters (which includes all of Kāneʻohe Bay) (Parry, Personal Communication, January 30th, 2014), however very few such regulations have been passed on non-commercial fishing, which is the larger pressure on this system (Blodgett, Personal Communication, April 15th and May 6th, 2014).

Recreational and subsistence fishers are not required to obtain permits or licenses for marine fishing, and there is no required reporting of this type of catch ("Licenses and Permits" 2013). There are minimum size regulations for recreational fishing, but given DOCARE's capacity gaps (see below) these regulations often go unenforced. Commercial fisheries are only a very small actor in Kāneʻohe Bay, whereas recreational fishing is perhaps the largest factor impacting reef health (Blodgett, Personal Communication, April 15th and May 6th, 2014).

Efficient Enforcement Mechanisms

Score: 2

DOCARE responsible for monitoring and enforcement of all natural resource management rules and regulations, which include graduated sanctions. However, DOCARE is underfunded and over extended, making enforcement less efficient than it could be.

Violations of state laws are subject to criminal, civil, and administrative penalties, and sanctions increase with the severity and/or frequency of the offense. The use of chemicals, electrofishing, and explosives are considered Class C felonies (Miyasaka, Personal Communication, May 9, 2013). Additionally, damaging or removing the corals or live rocks is illegal to all fishers or tourists (Gombos et al. 2010; "Regulated Marine Fishes and Vertebrates" 2014).

The enforcement agency within DLNR is the Division of Conservation and Resource Enforcement (DOCARE), which is responsible for monitoring and enforcing all rules and regulations put forth by DLNR in the State of Hawaiʻi (Gombos et al. 2010; "About" 2014). DLNR promulgates state laws, while the NMFS Office of Law Enforcement (OLE) Pacific Islands Division promulgates federal fishing laws, but DOCARE enforces both federal and state laws in exchange for funding from NMFS OLE ("About Us" 2013). In addition,

DOCARE is charged with enforcing terrestrial land and natural resource management legislation. They are responsible for vast geographic regions and also respond to other types of criminal activities on the islands. Due to this situation, and also to a shortage of funding, DOCARE is understaffed, which leaves significant gaps in the enforcement of reef management regulations (Gombos et al. 2010; Blodgett, Personal Communication, April 15th and May 6th, 2014; Parry, Personal Communication, January 30th, 2014).

Organizations such as the University of Hawai'i and TNC carry out monitoring, data gathering, and scientific study of the reefs, and are also involved with efforts to engage the local community in reef health monitoring ("Science and Stewardship" 2011; "Working with Communities" 2011; Jokiel et al. 2001). However none of these agencies have the regulatory authority to police the reefs or enforce regulations (Blodgett, Personal Communication, April 15th and May 6th, 2014; Miyasaka, Personal Communication, May 9, 2013; Conklin, Personal Communication, February 4th, 2014).

Governance Goals Aligned with Conservation Objectives

Score: 3

Conservation goals explicitly specified in DAR's mission statement and in legislation at all levels of the hierarchy. Written goals are supported through management actions.

DAR's mission is "to manage, conserve and restore the state's unique aquatic resources and ecosystems for present and future generations." They go on to describe coral reefs as "some of the most biologically diverse and economically valuable ecosystems on earth [which provide] food, jobs, recreational opportunities, coastal protection and other important services to billions of people world-wide" ("Coral Reefs" 2013). Additionally, the goals and objectives cited by the CRWG, the USCRTF, and the ICRI all indicate inherent high valuation of coral reefs, and the desire to restore and preserve them over the long term (Gombos et al. 2010; "About the U.S. Coral Reef Task Force" 2013; "ICRI at a Glance" 2013), implying that governance goals are aligned with conservation objectives at all levels of the hierarchy. DAR is currently working towards an ecosystem-based management system for their reefs, and away from single sector regulations (Blodgett, Personal Communication, April 15th and May 6th, 2014).

Science-based Decision Making (including local knowledge)

Score: 2

No formal, institutional mechanism, but DAR staff tries to incorporate science into management themselves.

The Hawai'i Coral Reef Initiative Research Program (HCRI-RP) was created to support research and monitoring efforts in the near-shore reefs across the state of Hawai'i. The HCRI-RP funds research efforts and hosts quarterly project review meetings and workshops where scientists, managers and stakeholders have the opportunity to interact and discuss priorities. They also host community events to promote better understanding of reef issues, and provide educational materials to schools and public audiences ("HCRI-RP: About" 2014).

Unfortunately, however, there are no institutionalized mechanisms for incorporation of science into management of the reefs at Kāne'ohe Bay (Parry, Personal Communication, January 30th, 2014; Conklin, Personal Communication, February 4th, 2014), and managers must take the initiative, on a project by project basis, to reach out to the University of Hawai'i

or agencies such as HCRI-RP, or to conduct the scientific data gathering and monitoring required for responsible management on their own (Blodgett, Personal Communication, April 15th and May 6th, 2014). Furthermore, DAR does not currently have a full time biostatistician on staff (Gombos et al. 2010), although they are working to remedy this situation in the near future (Blodgett, Personal Communication, April 15th and May 6th, 2014).

Despite the lack of institutionalized communication between DAR managers in Kāneʻohe Bay and scientific research programs such as the HCRI-RP, managers have implemented a system of adaptive management for reef restoration efforts throughout the Bay. New projects are applied on a patch by patch basis and scaled up slowly as details are adjusted (Blodgett 2013). The urchin seeding effort is an excellent example of this principle. Because there are a variety of different reef and algae types throughout the Bay, different areas respond differently to application of the urchins. The project has begun with a constant application of two urchins per square meter, but managers expect that as they gather project monitoring data this number will change for some areas ("About the Hawaii Coral Reef Strategy" 2013; Blodgett, Personal Communication, April 15th and May 6th, 2014). Additionally, DAR will implement regular reassessment of project status and reef health across the Bay once the project is fully functional. Managers will identify optimal urchin densities for the initial algae reduction period, and for the subsequent maintenance period, as well as determine an appropriate restocking schedule that allows a slow increase in urchin density over time ("About the Hawaii Coral Reef Strategy" 2013; Blodgett, Personal Communication, April 15th and May 6th, 2014).

Native Hawaiian communities managed their environment through the traditional *ahupua'a* concept, which considers the entire watershed as one area to be managed by one group governed by one chief. These management methods included the *kapu* system of temporary spatial and temporal fishing closures and species restrictions (Gombos et al. 2010). These traditional techniques, by which the reefs were effectively managed for efficient, long-term use for centuries (Kittinger, Ayers, and Prahler 2012), have unfortunately been eroded through modern political, cultural, and economic drivers(Cesar et al. 2002; Gombos et al. 2010; Friedlander, Shackeroff, and Kittinger 2013).

Agency Flexibility

Score: 1

Institutional relationships are inflexible.

At an agency structure/ governance level, there is not a great deal of flexibility or room for adaptation. Reef management in Hawaiʻi will most likely always be the purview of DAR, and is unlikely to transition to a different agency or body regardless of any situational changes that my happen (Blodgett, Personal Communication 2013).

Explicit Recognition of Trade-Offs

Score: 1

No formal mechanism for recognizing trade-offs and no restrictions on recreational fishing.

In our research we found no explicit mechanism for choosing between contrasting goals and values within the institutional framework around reef management in Hawaiʻi (Parry, Personal Communication, January 30th, 2014).

Dependable Funding

Score: 1

Funded by state on year to year basis and state has budgetary problems. DAR applies for grants to fill gaps.

Coral reef management is mainly funded by the Hawai'i State Legislature on a year to year basis and is subject to budget fluctuations each fiscal cycle. Additional grants from a variety of funding sources including NOAA (DAR applies to NOAA's Coral Reef Management Grant Program each year), the National Fish and Wildlife Foundation, the National Sea Grant Program, the Hawai'i Community Foundation, and HISC fill gaps in capacity left by the state budget ("Division of Aquatic Resources" 2014; Gombos et al. 2010). Many of these funding agencies (especially the Hawai'i Legislature) have been struggling with budget cuts in recent years, which has resulted in funding gaps for the Super Sucker and other reef restoration programs in Kāne'ohe Bay. Uncertainty about consistent funding from one year to the next has made it very difficult for DAR managers to invest in long term projects, or to set long term management goals. This system has also resulted in the loss of experienced employees and perpetually unfilled positions (DAR has not had an administrative head since 2009) as funding sources must be approached each year to re-negotiate contracts (Gombos et al. 2010; Kittinger, Personal Communication, April 2, 2013).

The Super Sucker and urchin seeding programs were initially funded through earmarked federal research grants from NOAA via then-Senator Inouye to Dr. Smith's lab at the University of Hawai'i (approximately $600 thousand per year for three years) (Smith, Personal Communication 2014). This funding was supplemented with short term grants from the Hawai'i invasive Species Council and other state agencies, generated through lobbying efforts by TNC. Once the Super Sucker was past the "proof of concept" phase, ownership and operations transitioned fully to DAR, and meanwhile TNC raised private funds for the creation of a second, more mobile "Super Sucker Junior" (*Invasive Algae Mobile Rapid Response Vacuum (HI)* 2005; Parry, Personal Communication, January 30th, 2014). Managers are now seeking a dependable source of funding to keep the two Super Suckers operating consistently (Blodgett, Personal Communication 2013; Parry, Personal Communication, January 30th, 2014).

In addition to funds from the state legislature, HISC gets funding for invasive species removal programs through a tax on home sales across the state, and is working to obtain a more consistent source of funding, such as an increase in oil barrel taxes. Additionally, they are working with the Hawai'i Tourism Authority to create a program to gather voluntary donations from Hawai'i's many visitors each year (Blodgett, Personal Communication 2013). HISC divides all of their limited available funds between terrestrial and aquatic invasive species removal and prevention programs throughout Hawai'i (Blodgett, Personal Communication 2013).

Participation

Score: 2

Public comment periods for all legislation, but little actual community involvement in implementation.

DAR's Coral Program and reef management efforts follow guidelines laid out in the Hawai'i Coral Reef Strategy document created by CRWG after multiple stakeholder

interviews, public meetings, and workshops with resource managers, biologists, and advisory groups ("About the Hawaii Coral Reef Strategy" 2013). This document and all reef management plans prepared by DAR are subject to periods of public comment, which are advertised online and in local papers in an effort to reach affected communities (Shlucker 2003; "About the Hawaii Coral Reef Strategy" 2013).

In spite of these formal arrangements encouraging public comment on management plan design, efforts to encourage participation of local community members in the implementation of management activities are still largely undeveloped. Such efforts have thus far focused mostly on education, and on raising awareness about the problem of invasive algae and the importance of healthy coral reefs to the community. There is no formalized mechanism for community based management in the Bay at this time. To initiate this process DAR has been working with TNC to reach out to community groups to raise awareness and talk about potential co-management options. DAR and TNC helps host "Community Days" in the wetlands, where links between the health of the reefs and activities on land are highlighted, as well as events on the reefs, where volunteers learn first-hand about the problem of invasive algae and work to remove it manually (Blodgett, Personal Communication 2013).

In addition to these efforts, TNC has recently partnered with the He'eia community in Kāneʻohe Bay to implement a project aimed at restoring the health of the local wetlands and reefs through traditional *ahupua'a* (mountains-to-sea) management. This project aims to reduce the sediment flowing into the bay through wetlands restoration and the reclamation of 400 acres of ranchland, which will be transformed back into traditional taro fields. TNC is employing co-management to complete this project, engaging with community members, scientists, and other stakeholders to design project guidelines, and supporting long-term community-based sustainable management through traditional practices ("Working with Communities" 2011; Conklin, Personal Communication, February 4th, 2014).

Systematic Representation

Score: 2

Many agencies work together but recreational fishers and tourism overly influential.

Implementation of the Super Sucker and urchin seeding in Kāneʻohe Bay is done through an ongoing collaboration of DAR, the University of Hawaiʻi, and TNC("Kane'ohe Bay, O'ahu" 2011; "Sea Urchins to the Rescue" 2011). Both the CRWG and the HCRI-RP (which directly advise DAR) include representatives from federal, state, and non-governmental agencies, however local community members do not participate in these advisory groups (Gombos et al. 2010; "About the Hawaii Coral Reef Strategy" 2013). The Aquatic Invasive Species Management Plans, developed by the Aquatic Invasive Species LAS and DAR, are informed by comments received at stakeholder scoping meetings held on various islands early on in the plan development process, as well as during the public comment period held after a draft of the plan is complete. Federal, State, county, industry, science, and community representatives present their interests during this process (Shlucker 2003). Although all comments received during public comment periods are considered, and many are included in final plan documents, there is currently no formal mechanism to ensure a "level playing field" for all stakeholders in the negotiation and management plan design process (Shlucker 2003; Gombos et al. 2010).

Because the recreation and tourism industries are so economically valuable to the state of Hawaiʻi their interests tend to be especially influential in the rule-making process.

Subsistence and recreational fishermen hold a lot of "clout" in the state legislature because of their long-standing presence in Kāneʻohe Bay, and regulatory decisions are often not completely independent of these pressures (Blodgett, Personal Communication 2013).

Deliberation

Score: 3

There are several agencies/actors in charge of making decisions pertaining to the reefs in Hawaii and each of these bodies has its own explicit deliberative process.

There are several agencies/actors in charge of making decisions pertaining to the reefs in Hawaii: the Governor's office, the DLNR Chairperson, the DAR administrator, and the Hawaiʻi State Legislator. Each of these bodies has its own explicit deliberative process (Miyasaka, Personal Communication, May 9, 2013). In addition, CRWG acts in an advisory role to DLNR through the process described below.

Clear Decision Making Rules

Score: 3

The CRWG works with LAS advisory groups and DAR biologists to develop and rank reef management and project goals which then serve as a guide for decisionmaking.

The CRWG works with LAS advisory groups and DAR biologists to develop and rank reef management and project goals (Gombos et al. 2010). Creation of the Hawaiʻi Coral Reef Strategy document involved interviewing a variety of stakeholders and experts, studying coral reef management plans from around the world, and reviewing comments from public meetings on marine protected areas held around the state(Gombos et al. 2010). CRWG develops all reef management goals and objectives for the state of Hawaiʻi and sends them to the LAS advisory groups, DAR staff, and NOAA consultants for further refinement (Gombos et al. 2010). DAR designs its reef management plans with reference to the CRWG strategy document and stated goals and objectives (Blodgett, Personal Communication 2013).

Clear Objectives and Directives

Score: 3

CRWG explicitly lists over-arching goals and objectives for reef management in Hawai'i, prioritized through consultation with LAS. DAR sets much shorter term goals and deadlines than the CRWG because they are funded on a year-to-year basis.

CRWG explicitly lists four over-arching goals and thirty objectives for reef management in Hawaiʻi. They have prioritized these goals based on consultation with LAS advisory groups, and identified the top five objectives as priorities to be addressed by 2020 (Gombos et al. 2010).

The goals of The Hawaiʻi Coral Reef Strategy are:

GOAL 1: Coral reefs undamaged by pollution, invasive species, marine construction and marine debris.

GOAL 2: Productive and sustainable coral reef fisheries and habitat.

GOAL 3: Coral reef ecosystems resilient to climate change, invasive species and marine disease.

GOAL 4: Increased public stewardship of coral reef ecosystems.

The five priority objectives for the next ten (2010–2020) years are:

1. Reduce key anthropogenic threats to two priority near-shore coral reef sites (Kaʻanapali-Kahekili, Maui and Pelekane Bay-Puako-Anaehoʻomalu Bay, Hawaiʻi) by 2015 and five by 2020 using *ahupua'a* based management.
2. Prevent new AIS introductions and minimize the spread of established AIS populations by 2020.
3. Increase the abundance and average size of ten targeted coral reef fisheries species critical to reef health and ecological function by 2020.
4. Designate a sufficient area of marine waters under effective conservation by 2020 to ensure sustainable and resilient coral reef ecosystems.
5. Reduce anchor damage and trampling on coral reefs through the implementation of no-anchor zones, utilization of day-use mooring buoys and other means by 2020.

("About the Hawaii Coral Reef Strategy" 2013; Gombos et al. 2010)

DAR, in coordination with TNC and the University of Hawaiʻi, developed the Aquatic Invasive Species Management Plan (and all other reef management plans) independently of CRWG, although they do reference the Hawaiʻi Coral Reef Strategy goals and objectives during the process (Shlucker 2003; Blodgett, Personal Communication 2013). They tend to set much shorter term goals and deadlines than the CRWG because they are funded on a year-to-year basis. In the Super Sucker program, DAR sets goals for clearing a certain number of reef patches, and restoring the coral ecosystems in those patches, each year (Blodgett, Personal Communication 2013).

Accountability and Transparency

Score: 2

DAR monitors itself and reports are not published regularly due to lack of funding and capacity.

Draft management plans are posted on the DAR website (with hard copies on request) for a three week period of public and agency review. Comment periods are advertised through press releases to local papers, and on electronic list-servers. The draft is also sent directly to all individuals involved with its creation, and federal agencies may be granted extended review periods if necessary. All comments submitted during this process are reviewed and considered for incorporation into the final management plan (Shlucker 2003).

State and federal funds are audited by the agencies that provide them, and justification for funding requests are published in the DLNR budget and presented at public meetings. Progress reports on projects funded by federal agencies are generally required, and must be made publicly available. Private funds are subject to the DLNR chairperson's discretion unless their use is specified in a contract, and are generally subject to less scrutiny than public funds (Miyasaka, Personal Communication, May 9, 2013).

Despite claims by the HCRI-RP that that agency will provide a "mechanism through which management practices can be evaluated and modified as necessary in order to maximize their effectiveness" ("Hawaii Coral Reef Initiative Research Program" 2011), DAR carries out its own monitoring of all of its projects and operations, and is not subjected to oversight by NOAA or any independent bodies. DAR also sets its own deadlines and issues reports detailing the results of its projects (Blodgett, Personal Communication 2013). These

reports are not published on a regular basis as there is no funding or staff assigned to carry them out (Miyasaka, Personal Communication, May 9, 2013). This situation is not ideal for ensuring agency accountability, however reports and results of this monitoring are all disclosed to NOAA and to the public through DAR's website or through special request (Blodgett, Personal Communication 2013), and independent agencies or individual researchers occasionally publish their own reports on the status of the reef (Miyasaka, Personal Communication, May 9, 2013).

Appropriate Scale

Score: 2

Reef restoration and invasive species management are designed and implemented at the scale of the Bay, fisheries management, however is regulated at the State level.

Individual restoration, invasive species management, and conservation projects are developed and implemented at a local level by local DAR staff and are therefore generally designed at the appropriate scale. Recreational fisheries regulations, however, were set at the scale of the whole state of Hawai'i ("Division of Aquatic Resources" 2014) and are therefore less sensitive to specific issues that might be present in an individual bay or reef. Commercial fishing is managed on an island by island basis, as each island is considered to be a "fishing community" under the MSA ("About Us" 2013). Returning to the traditional *ahupua'a* resource management technique, in which each island is divided into smaller segments based on the topography of the land, would be an improvement on this situation, although it would require some significant preparatory work and would not remedy the problems with low capacity currently faced by DAR. DAR has begun efforts to move reef management back towards this traditional system (Friedlander, Shackeroff, and Kittinger 2013; Blodgett, Personal Communication 2013).

Social Justice and Empowerment

Score: 2

All reef management regulations take subsistence fishers into account, however social justice for the indigenous people remains among the main concerns.

All rules and regulations pertaining to reef management in Kāne'ohe Bay go through a number of different public comment periods, as described above. During this process the public is encouraged to voice any concerns with potential rules and restrictions. One of the most vocal groups commenting on reef regulations, especially on any efforts to implement spatial closures or no-take areas, are the local people who depend on fishing the reefs to feed themselves and their families. All rules and regulations promulgated to manage the reefs take subsistence fishers into account (Blodgett, Personal Communication 2013). Nevertheless social justice for the indigenous Polynesian people remains among the main concerns for communities in Hawai'i (Kittinger, Personal Communication, April 2, 2013).

Organizational Features Designed to Allow Transfer of Authority

Score: 2

Multilayered and fairly polycentric, but too many agencies results in unnecessary complexity.

Reef management in Hawai'i can be described as "multilayered", with state agencies nested within federal agencies, which are in turn nested within international agreements. It also has some features of polycentricity, as DAR collaborates with TNC, and the University of Hawai'i, and receives input and advice from a variety of agencies and organizations, as described above. However DLNR is the only agency with regulatory and enforcement authority, and because they carry out all their own monitoring and performance evaluations there are few formalized mechanisms to address accountability within this agency (Blodgett, Personal Communication 2013). The success of the Super Sucker project relied in equal parts on the research capacity of the University of Hawai'i, the funding and community organization capacity of TNC, and the invasive species management expertise of DAR (Conklin, Personal Communication, February 4th, 2014; Hunter, Personal Communication, January 30th, 2014).

A major drawback of the governance system in Hawai'i is the potential for inefficiencies between so many natural resource management organizations and agencies. Many of the advisory bodies, including the CRWG, the CGAPS, and the HCRI were created in an effort to address these inefficiencies and improve coordination between the various agencies managing Hawai'i's marine resources (Gombos et al. 2010; "About the Hawaii Coral Reef Strategy" 2013; "Coordinating Group on Alien Pest Species (CGAPS)" 2013; "HCRI-RP: About" 2014), however it seems that thus far these groups have only added to the complexities and have failed to consistently communicate with Bay managers (Blodgett, Personal Communication 2013). Additionally, the six LAS management plans (Climate Change and Marine Disease, Lack of Public Awareness, Coral Reef Fisheries, Land-Based Sources of Pollution, Recreational Impacts to Reefs, and Aquatic Invasive Species) were each developed independently of each other. This has resulted in several redundancies and gaps in their implementation. DAR and the CRWG have been working to address these issues through the development and prioritization of goals and objectives (embodied in the Hawai'i Coral Reef Strategy document) for the short and long terms (Gombos et al. 2010).

Societal Enabling Conditions

Capacity for Self-Organization

Score: 2

Users in three groups: local subsistence fishers; commercial fishers; and locals or tourists who fish recreationally and/or dive at the reef. Boundaries clearly defined, but no strong community leadership.

Changes to the state constitution made in 1978, followed by enabling legislation passed in 1994, made fishery co-management systems possible in Hawai'i (Kittinger, Personal Communication, April 2, 2013). DAR is currently in the process of reorganizing their operations to facilitate community-based management of the reefs, especially with regards to subsistence fishing regulations (Gombos et al. 2010; Blodgett, Personal Communication 2013). Such efforts should increase community capacity for self-organization as it will result in greater autonomy and authority for communities to make and enforce their own rules and regulations. There is already some interest in self-governance among the local community in Kāne'ohe Bay. DAR and TNC have made efforts to reach out to community members

and groups to discuss the issues facing their reefs and the potential community management options, and they have received favorable responses from many of these members, especially those who have lived and fished in the Bay for a number of years, and who have seen the declines in reef health and fish abundance ("Division of Aquatic Resources" 2014; Gombos et al. 2010; Blodgett, Personal Communication 2013; "Working with Communities" 2011).

Users of the marine resources within Kāneʻohe Bay generally fall into three groups: local communities who fish in the Bay for subsistence or recreational purposes; commercial fishers who come from nearby or elsewhere in Hawaiʻi to fish for food fish, bait fish, and/or aquarium fish; and locals or tourists who fish recreationally and/or dive at the reef (Blodgett, Personal Communication 2013; Kittinger, Personal Communication, April 2, 2013). According to our master list of good governance characteristics, users who live close to the Bay are more likely to care about the welfare of the resources therein, and those users coming from farther away may be more likely to behave in ways that jeopardize that welfare.

Capacity for Adaptation and Learning

Score: 3

UH, TNC, and HCRI-RP doing profuse research there, including extensive monitoring of the reefs.

Extensive capacity for adaptation and learning exists in Kāneʻohe Bay. DAR, the University of Hawaiʻi, TNC, and the HCRI-RP all work to ensure reliable data is consistently available for use in reef management efforts, and would almost certainly be willing to coordinate and share information with any community management groups in an effort to ensure sustainable reef management.

Preexisting Local/Traditional Organizations

Score: 3

Traditional ahupua'a resource management system involved a single group, led by a single chief, managing an entire watershed.

DAR and TNC's efforts to encourage local groups to become involved in reef management have reached more than 30 different communities, many of which are now involved in coastal and marine stewardship projects across the state. Many of these groups have also incorporated traditional knowledge and management techniques into their efforts (Gombos et al. 2010). The native Hawaiian *ahupua'a* resource management system involved a single group, led by a single chief, managing an entire watershed. In some parts of Hawaiʻi, remnants of these groups still exist which could be built on as a basis for cooperative, community-based management. While community-based management has not currently been implemented in Kāneʻohe Bay, DAR managers are interested in doing so in the near future (Blodgett, Personal Communication 2013).

Social Agreement

Score: 3

High agreement on need to remove invasive algae, but low on need to regulate fisheries.

In general local communities in Hawai'i support efforts to remove invasive species and restore native ecosystems (Kittinger, Personal Communication, April 2, 2013; Smith, Personal Communication, January 22nd, 2014). In Kāne'ohe Bay, support for removal of the invasive algae is fairly widespread. DAR has reached out to subsistence fishers to discuss the issue, and they generally acknowledge that they have noticed a decline in the health of the bay and the abundance of native fish (Gombos et al. 2010). However a limit to this support seems to be at the implementation of MPAs or other such initiatives that might restrict access to the bay and use of its resources (Blodgett, Personal Communication 2013; Kittinger, Personal Communication, April 2, 2013). In so far as efforts remain largely focused on manual removal of the algae community support is not a problem. However, if and when attempts are made to reform fisheries practices- the underlying issue responsible for the out of control algae in the Bay- managers may be met with significant resistance.

Appendix 4: Experts consulted to complete analysis

- **Jono Blodgett**, Aquatic Invasive Species Program Leader, Research Corporation of the University of Hawaii, contracted by the State of Hawai'i, Division of Aquatic Resources. Interviewed by phone on April 15th, 2013 and May 6th, 2013.
- **Dr. Eric Conklin**, Hawai'i Director of Marine Science at The Nature Conservancy. Interviewed by phone on February 4th, 2014.
- **Dr. Cynthia Hunter**, Associate Professor, Biology Department; Director, Marine Option Program University of Hawai'i at Manoa. Interviewed by phone on January 30th, 2014.
- **Dr. John N. (Jack) Kittinger**, Director, Conservation International, Hawai'i Fish Trust, Betty and Gordon Moore Center for Science and Oceans. Interviewed by phone on April 2nd, 2013.
- **Alton Miyasaka**, Biologist, Aquatic Resources Division, Division of Land and Natural Resources, Hawai'i. Interviewed by email on May 9th, 2013.
- **Dr. Matthew Parry**, Fisheries Biologist with the National Oceanic and Atmospheric Administration (NOAA). Interviewed by phone on January 30th, 2014.
- **Dr. Celia Smith**, Professor of Botany, University of Hawaii at Manoa. Interviewed by phone on January 22nd, 2014.

Appendix 5: Questions used to guide interviews

Note: All interviews were somewhat free-form, such that if an interviewee had more to say about one topic than another he or she was allowed to guide the conversation. However all of the below questions were addressed at least briefly with each interviewee.

Questions:

1. Tell me about your role in the Super Sucker program/ Kāne'ohe Reef restoration in general.
2. What is the current status of the reefs at Kāne'ohe Bay? Is the alga under control? Any quantitative measurements (i.e. percent cover)? What's holding back success (if anything) in your opinion?

3. What agency holds regulatory authority over marine resource management in the Bay? Describe the extent of this authority- do they issue permits? Do they have to discuss new regulations with any other bodies? Etc.
4. What agency is responsible for enforcing rules and regulations about use of resources in the Bay? Describe the enforcement process. What kinds of mechanisms exist for ensuring compliance (i.e. sanctions, fines, revocations of permits, etc.)? Are fines/sanctions graduated, such that penalties increase with severity of infractions?
5. What are the (stated or unstated) governance goals of the regulatory agency?
6. What kinds of formal/ institutionalized mechanisms exist for incorporating science and/or local knowledge into management?
7. How flexible are the management agencies in structure and function? If corruption was discovered at one level of the governance hierarchy, what mechanisms exist to move power to other levels?
8. Is there a dependable funding source for management/restoration efforts and enforcement of regulations?
9. Is there an explicit recognition of trade-offs that might need to be made? (I.e. restricting fishing which people depend on to improve the health of the environment)
10. What kinds of formal or institutionalized mechanisms exist for encouraging participation of local communities in the design and/or implementation of management efforts? Is there a formal process for soliciting public comments on policy or management plan drafts? Are these comments considered/ utilized? Are there efforts to facilitate stakeholder participation/ negotiation, and if so are these negotiations mediated by a third party?
11. What are the operational rules that govern the decision making process? Are objectives and directives laid out clearly ahead of time? Are stakeholders involved in development of overarching objectives and principles? Are timelines, deadlines, and measurement standards stated explicitly and used effectively?
12. What kinds of mechanisms to ensure accountability and transparency exist? How is the management agency held accountable, both to the local communities and the higher levels of authority? Are there any other organizational features (such as nested or polycentric agencies) designed to minimize corruption?
13. In your opinion, are management decisions/ actions on an appropriate scale to that of the resource?
14. What kinds of mechanisms exist to ensure social justice and empowerment of local communities?
15. Regarding the structure of the local communities, is there an existing capacity for self-organization and for adaptation and learning?
16. Is there a general sense of agreement or understanding among community members that the reefs/fisheries are in trouble and that something needs to be done about it? If not, are there any agencies or organizations working to raise awareness about the issues? Do the users of the resource tend to live relatively close to it? Or do they come from farther away?
17. Distribution of Rights and responsibilities:
    a. Who holds the right to Access the resource? Are there any explicit responsibilities or rules that go along with this right?

b. Who holds the right to Withdrawal the resource? Are there any explicit responsibilities or contingencies on this right?
c. Who holds the right to Management of the resource? Are there any explicit responsibilities or rules that go along with this right?
d. Who holds the right to Exclusion from the resource? In other words, who decides who is/isn't allowed to access/withdraw the resource? Are there any explicit responsibilities or rules that go along with this right?
e. Who holds the right to Alienation from the Bay? In other words, who has the right to sell the Management and Exclusion rights to the resource?

Do any of the above rights come with spatial, temporal, or quantitative restrictions?