UNIVERSITY OF CALIFORNIA
Santa Barbara

Navigating Fragmented Ocean Law in the California Current: Tools to Identify and Measure Gaps and Overlaps for Ecosystem-Based Management

A Dissertation submitted in partial satisfaction of the requirements for the Degree of
Doctor of Philosophy

in Marine Science

by

Julia Anne Ekstrom

Committee in charge:

Professor Oran R. Young, Chair
Professor Steven Gaines
Professor Susan Stonich
Research Professor Paul A. Berkman
Professor Bonnie J. McCay, Rutgers University

June 2008

The dissertation of Julia Anne Ekstrom is approved.

Paul A. Berkman
University of California, Santa Barbara

Steven Gaines
University of California, Santa Barbara

Bonnie J. McCay
Rutgers University

Susan Stonich
University of California, Santa Barbara

Oran R. Young, Committee Chair
University of California, Santa Barbara

May 2008

Navigating Fragmented Ocean Law in the California Current:
Tools to Identify and Measure Gaps and Overlaps for
Ecosystem-Based Management

by

Julia Anne Ekstrom

ACKNOWLEDGEMENTS

I am very grateful for receiving support from so many people and entities to produce this dissertation. First, in 2001 the Interdepartmental Graduate Program in Marine Science was the only such program in the United States that provided a rigorous background in ocean sciences, but allowed students to design cross-disciplinary social science research projects. My experience in an interdisciplinary program taught me the value of communicating with people from all sorts of expertise and backgrounds to produce well-informed science. I appreciate the support of Alice Alldredge and Mark Brzezinski, the graduate program chairs, for their advice, continuous support, and accessibility.

I am grateful for the support of my entire committee throughout the project. Though trained within his/her respective disciplines, each member has an incredible ability and willingness of collaborating across disciplines. In addition to the committee's research expertise, each member's had a unique contribution to the project. My dissertation committee chair Oran Young has an amazing talent to see and communicate the bigger picture, especially when I am stuck in the details. I thank him for relaying this bigger picture and using it to keep me on track in our regular update meetings but also, more importantly, in my dissertation as a whole. I am grateful to Steve Gaines for meeting me consistently with enthusiasm and positive reinforcement. Our discussions about analyzing and interpreting data and his advice on how to frame papers have been extremely valuable to me. I thank Susan Stonich for helping me build a solid foundation in social sciences at UCSB and for her support throughout the project despite the changes. I thank Bonnie McCay for thoroughly editing and providing feedback on drafts, and for her reassurance that my research still indeed relates to the questions of the commons. I would like to thank Paul Berkman for encouraging me to explore laws in the California Current and for hiring me as a Research Assistant, which introduced me to insights about data management. I am indebted to Maria Gordon for her generous support in advising me on how tactfully to overcome the obstacles presented in this project, building my confidence, and assisting in the writing and editing of proposals and dissertation chapters.

The National Center for Ecological Analysis and Synthesis (NCEAS) was incredibly vital to my project in many ways. I participated in the Ocean Zoning Working Group (guided by Principal Investigators Gail Osherenko, Oran Young, Satie Airame, and Larry Crowder). The Working Group's in-depth discussions about ecosystem-based management (EBM) provided an invaluable foundation for my dissertation work. Beyond the Working Group, NCEAS generously provided me with server space and access to run analyses on my large dataset. In addition, the EBM program provided technical advice and supported the conceptual development of the project.

This dissertation research required that I receive feedback at all stages of the project from ocean management practitioners. I appreciate the feedback during the early stages of this project from the Social Science Branch of Northeast Fisheries Science Center in Woods Hole, Massachusetts. Although I cannot list them by name here due to the project's Human Subjects Protocol at U.C. Santa Barbara, I am grateful to all those working in the California Current who took the time to meet with me. Their feedback at each stage shaped the development of the analysis.

Many people assisted me in the technical development aspects of the project. I wish to acknowledge the following individuals who made this study possible: Dan Spiteri for coding and data management support throughout the project, George Morgan for lengthy discussions in the early stages of this project about text mining and information retrieval, Alex Villacorta for an introduction of text analysis and related statistics in Matlab, Jim Regetz at NCEAS for lessons on multivariate analysis, and Tihomir Kostadinov, Wil Black, and Mike Springborn at UCSB for their programming assistance. Jonathon Gurish at the California Coastal Conservancy for answering many law questions and assisting my collection endeavors for California State statutes and regulations. I appreciate the assistance and feedback from the following people on constructing the ocean acidification ecosystem model: Shiva Polefka (Environmental Defense Center), Matt Kay (UCSB), Dan Reed (UCSB), Peter Brewer (Monterey Bay Aquarium Research Institute), Jono Wilson (UCSB), and Carla Guenther (UCSB).

The following entities directly financially supported this dissertation project: The California Environmental Quality Initiative Graduate Fellowship through the UC Marine Council, the California Sea Grant and Ocean Protection Council, NCEAS Ecosystem-Based Management Program, and the UCSB Interdepartmental Graduate Program in Marine Science. I wish to acknowledge EvResearch

Incorporated, which donated server space for the project website and use of the DigIn Pro Version software. In addition, I would like to acknowledge the National Science Digital Library funding for its support through a Research Assistantship.

The acknowledgements are not complete without conveying my gratitude to my family and friends for their love and support: My parents for encouraging me to pursue my dreams and patiently supporting me through six more years in school, especially to my mom who listened with an open ear nearly every morning about the trials and tribulations of every part of graduate school; Dan Spiteri for his love, patience, and compassion; Elisa Echeverria for meliorism-enriched conversations and tons of editing; Sarah Henkel for introducing a much-needed hobby into my life, for discussions about how we were going to complete our dissertations (within days of one another!), and for editing at critical times; Sara Hughes for life and governance discussions, bluff walks, and chapter editing; Stephanie Oakes and Mark Zegler for our "finishing lunches," and Carla Guenther for stress-relieving beach walks and always helping me understand challenges from a different perspective.

I dedicate this project to two professors who inspired me to pursue graduate school: Barney Nietschmann and Arnold Schultz. From completely different disciplines (cultural geography and ecology, respectively), their courses taught me about the interconnectedness that exists in every facet of our world. They introduced me to the powerful insights revealed from examining connections among cultures, shifting paradigms, societal values, ecological systems, and different academic

disciplines. I aspire to follow in their footsteps to train others about the important connections between disciplines, the importance of social and ecosystem thinking, and how to think outside of the box, all the while having fun.

JULIA ANNE EKSTROM

EDUCATION

2008 Ph.D. Marine Science, University of California at Santa Barbara (expected June)

2000 B.S. Conservation and Resource Studies, Minor in Geography, University of California at Berkeley

FELLOWSHIPS, GRANTS, AWARDS, AND HONORS

2008-2009 David and Lucile Packard Foundation, Ecosystem-Based Management Tools Initiative Fund

2008 Society for Conservation Biology Conference Student Paper Award Finalist

2006-2007 UC Marine Council Coastal Environmental Quality Initiative (CEQI) Graduate Fellowship

2006 National Center for Ecological Analysis and Synthesis (NCEAS) Ecosystem-Based Management Graduate Support

2006 UC Santa Barbara Marine Science Summer Fellowship

2005-2006 UC Santa Barbara Marine Science Tuition Fellowship

2005 UC Santa Barbara Robert Alldredge Marine Science Travel Fellowship

2004 UC Santa Barbara Department of Anthropology Travel Grant

2003 UC Santa Barbara Marine Science Block Grant

2000 UC Regents President's Undergraduate Fellowship

2000 UC Berkeley California Alumni Leadership Honor and Scholarship

2000 UC Berkeley Horace Albright Scholarship

RESEARCH PROJECTS

2004-2008 **Navigating Ocean Law in the California Current LME**
Dissertation research project to find priority areas for implementing ecosystem-based management. Compiled all national and state marine-related laws for California Current.

2005-2007 **Ocean Zoning Working Group, NCEAS**, Participant

2003 **Preliminary Site Visit to Mesoamerican Barrier Reef System**
Conducted a preliminary site visit to potential field sites in Mexico and Belize. During this visit I interviewed fishermen, collected census data, and identified a prospective study site (Xcalak, Mexico).

2001 ***Costa Rica's Beaches* (Costa Rica)**
Conducted field research to continue book manuscript on the cultural and natural history of Costa Rica's coastline (Manuscript begun by Bernard Nietschmann and Don Melton, both deceased). Funded by the Horace Albright and James Parsons Scholarships.

2000 **Stream Run-off Influence on Damselfish Behaviors Study (Moorea, French Polynesia)**
Designed fish behavior project; created proposal; conducted field work in Moorea, French Polynesia; analyzed data; wrote final report and presented project methods and results at U.C. Berkeley symposium.

2000 **Traditional Fisheries Management Project (Costa Rica)**
As project leader and coordinator, designed study of river and coastal community fisheries management, researched background, applied for and received project funding (President's Undergraduate Fellowship), carried out field work in Tortuguero, Costa Rica. Reported project findings to the Costa Rican National Park Administration and to the Geographic Institute.

1999 **Tortuguero Wildlife and Community Project (Costa Rica)**
Monitored wildlife, tested river water quality, assisted community mapping, volunteer staff for EarthWatch project under Prof. Bernard Nietschmann, led and instructed EarthWatch volunteers in daily fieldwork.

EMPLOYMENT

2007-2008 California Sea Grant Trainee, Principal Investigator: Dr. Oran Young, Project: Facilitating Ecosystem-Based Management through Evaluation of Institutional Interplay

2006 Graduate Research Assistant National Center for Ecological and Analytical Synthesis (NCEAS), Ocean Zoning Working Group

2004-2005 Graduate Research Assistant UC Santa Barbara, National Science Digital Library project, Constructing the Digital Library of the Marine Mammal Commission Compendium; advised by Drs. Paul Berkman and Oran Young

2005 Social Scientist Contractor, Northeast Fisheries Science Center, National Marine Fisheries Service, Woods Hole, Massachusetts.

2004 Contract Researcher, Marine Life Protection Act Initiative, California Resource Legacy Foundation

2004 Social Science Intern, Northeast Fisheries Science Center, National Marine Fisheries Service, Woods Hole, Massachusetts.

2003 Graduate Research Assistant (under Dr. Susan Stonich)

2002-2004 Graduate Student Instructor, UCSB Environmental Studies Courses: Introduction to Environmental Studies, Sustainable Development, Third World Environments, People and Poverty in Central America

2001 Administrative Assistant, Coral Reef Alliance (CORAL), Berkeley, California

1998-2000 Research Assistant San Francisco Estuary Institute, Richmond, California

PUBLICATIONS

Ekstrom, J. (in review). Measuring Gaps in Ocean Management for Ecosystem-Based Management.

Young, O., G. Osherenko, J. Ekstrom, L. Crowder, J. Ogden, J. Wilson, J. Day, F. Douvere, C. Ehler, K. McLeod, B. Halpern, and R. Peach. 2007. Solving the Crisis in Ocean Governance: Place-Based Management of Marine Ecosystems. *Environment* 49:8-19.

Ekstrom, J., and G. Lau. 2008. Exploratory Text Mining of Ocean Law to Measure Overlapping Jurisdictions. *Proceedings of the 9th Annual International Conference on Digital Government Research (dg.o2008)*, Montreal, Canada, May 18-21, 2008.

CONFERENCE PRESENTATIONS

July 2008 "Measuring Gaps in Ocean Law for Ecosystem-Based Management" Society for Conservation Biology Conference, Chattanooga, Tennessee.

May 2008 "Exploratory Text Mining of Ocean Law to Measure Overlapping Jurisdictions" Digital Government Research, Montreal, Canada.

July 2007 "Measuring Fragmentation in Ocean Law for Ecosystem-Based Management" Coastal Zone Conference, Portland, Oregon.

Dec. 2006 "Quantifying Institutional Interplay for Ecosystem-Based Management" International Development for Governing Environment Change (IDGEC) Conference, Bali, Indonesia. Presented work on methodology developed for dissertation project.

Sept. 2006 "A Tool to Improve Understanding of Marine Governance in California" California and the World Ocean 2006 Conference. Long Beach, California. Presentation about digital library tool of laws and regulations.

Mar. 2006 *co-author Satie Airame* "Ocean Management in Southern California" Society for Conservation Biology, San Jose, California. Based on case study conducted with NCEAS Ocean Zoning Working Group.

Apr. 2005 "Evaluation of United States Fishing Community Profile Projects" Society for Applied Anthropology (SfAA). Albuquerque, New Mexico. Presented comparative analysis of fishing community profile project based on summer work at NOAA Fisheries Northeast Fisheries Science Center.

Mar. 2004 "Local Response to Marine Protected Areas: Comparison of Costa Rican Villages" Society for Applied Anthropology (SfAA), Dallas, Texas. Presented findings from undergraduate and post-graduate fieldwork.

OTHER SKILLS

Extensive knowledge of the following programs and languages: Microsoft Office (Word, Excel, Access, Powerpoint, and Visio), Adobe Illustrator and Photoshop, MATLAB, UCINET, NetDraw, Pajek, MySQL, and JMP. Moderate knowledge and experience in the following computer languages: SQL, UNIX, and HTML. Proficient in Spanish. NAUI Open Water Diving; NAUI Advanced Diving; NAUI Rescue Diving; U.C. Research diving; YMCA after-school teen program (1998-2000); Facilitator and Member, Outdoor Connection, UC Berkeley "Decal" class facilitator (1997-2000); Swim Team (1983-1996).

ABSTRACT

Navigating Fragmented Ocean Law in the California Current:
Tools to Identify and Measure Gaps and Overlaps for Ecosystem-Based Management

by

Julia Anne Ekstrom

Fragmented ocean management contributes significantly to the declining health of the world's oceans. The sector-based piecemeal approach to management has produced a governance system filled with gaps and overlaps. These inefficiencies impede effective mitigation and confrontation of major environmental stressors. Historically, industries such as mining, fishing, and shipping, have driven management decisions for ocean-related uses. Government agencies, scientists, and other natural resource stakeholders are moving toward a management approach based on the relevant ecosystem, in order to resolve problematic fragmentation in ocean management. Transitioning into an ecosystem-based management approach requires comprehensive and systematic evaluation of the problems created by fragmented decision-making and of the landscape of the current governance system. In an effort to contribute to the shift toward ecosystem-based management efforts, this dissertation explores and develops text mining techniques that identify and evaluate gaps and overlaps. Two institutional theories frame the development of gaps and overlaps analyses: the problem of fit and institutional interplay, respectively. The gaps analysis uses conceptual ecosystem models and term counts from laws to identify situations in which management fails to acknowledge ecosystem relationships. From the gaps analysis, two measures indicate the degree to which governance (referring to the whole cross sectoral system of law) reflects the relationships and functionality of the ecosystem it aims to manage. The overlaps analysis uses term counts of laws combined with agency authority data to provide information about potential hubs of regulatory activity for a given topic (Overlap Index), and the degree of agency involvement in a particular topic. To develop such techniques, the project first compiled a comprehensive set of state and federal statutes and regulations to represent ocean and coastal management in the California Current Large Marine Ecosystem. This dissertation also highlights the utility of analyses in the context of a real world environmental problem by presenting a case study applying the analyses to ocean acidification and its projected impacts on the California Channel Islands waters. Overall, this dissertation demonstrates the immense application potential of computer science to provide baseline data about fragmented ocean management. This dissertation shows that text mining can provide a quantitatively and systematically generated starting point for further investigation and identifying research priorities.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1 Introduction

RESEARCH PROBLEM

Fragmented ocean management

Fragmented management contributes significantly to the declining health of the world's oceans (Crowder et al. 2006). The United States has traditionally divided management of the marine environment into individual sectors, such as transportation, mining, and fishing (USCOP 2004). Government bodies have typically written laws to address symptoms of problems on a case-by-case basis, which has resulted in a piecemeal approach to management (Knecht et al. 1988, Miles 1989, Agardy 1997, NRC 2001). This approach functioned reasonably well at the levels of human use of the oceans prior to the technological advances of the 1970s and 1980s that led to skyrocketing rates of marine resource exploitation and extraction (Weber 2002). Increased coastal populations combined with improved technology lie behind the dramatic rise in impacts on the marine environment seen over the last two decades (USCOP 2004, Kildow and Colgan 2005). Forced to apply to oceans facing increased stressors and use, the piecemeal approach to management has led to a fragmented system of ocean-related governance (Sutinen et al. 2000).

A wide range of problems can derive from fragmented management (Pew Oceans Commission 2003, USCOP 2004, Crowder et al. 2006). Sector-based decision-making commonly results in two problematic issues of an institutional nature: gaps and overlaps. Effective management necessitates that institutions[1] match the functionality and nature of the relevant ecosystem (Young 2002, Wilson 2006, Folke et al. 2007). *Gaps* arise when management (or governance as a whole) does not reflect the key properties and interactions of an ecosystem. This project aims to identify where gaps occur because no law or management action exists to address linkages critical for maintaining ecosystem services[2] (Millennium Ecosystem Assessment 2005). For example, orcas (killer whales) resident in Puget Sound feed primarily on salmon. Consequently, ecosystem research shows that in order to maintain the orca population and ecosystem resilience, management decisions regarding an activity that degrades salmon populations in the area should reflect (or at least acknowledge) this key whale-salmon interaction (Ford and Ellis 2006). If there is no law or regulatory process in the region's governance system that acknowledges the linkage between the species, the absence constitutes a *gap*.

---

[1]Definition of *institution* used here and throughout the dissertation: "rules, clusters of rights, and decision-making procedures" that guide human behavior. As such, *environmental institution* refers to a management system that guides human use and responds to abuse of the environment. *Environment regime*, on the other hand, refers to an institution or set of institutions that has a particular environment-related scope, such as fisheries management, minerals management, water quality control, etc. (Young 1999). *Governance* is used in this dissertation to refer to management in general and also the system of interdependent (though fragmented) institutions that exist for the management of coasts and oceans.

[2] Defined by the Millennium Ecosystem Assessment (2005): "Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth. . . Biodiversity is the source of many ecosystem goods, such as food and genetic resources, and changes in biodiversity can influence the supply of ecosystem services" (http://www.millenniumassessment.org/documents/document.300.aspx.pdf).

The second institutional problem frequently occurring as result of fragmentation is *overlap*. Overlap arises when multiple agencies have jurisdiction over the same resource and/or activity. Overlaps also occur when agencies have jurisdiction over incompatible activities. Both types of overlap can benefit agencies or multiple sectors when they coordinate and/or when they follow similar mandates. Without coordination or alignment, when an agency makes a decision for one sector, it can result in unintended negative consequences for other sectors (Sutinen et al. 2000, Young 2002). For instance, permitting salmon aquaculture without appropriate management can lead to the spread of disease and weakening of the genetic stock of near-by wild salmon populations, jeopardizing the region's commercial and recreational fisheries - sectors managed by other agencies (Naylor et al. 2000).

Transition to holistic management

An excellent opportunity now exists to address and resolve or mitigate problematic gaps and overlaps. Resolution of regulatory mismatches would naturally produce more holistic management – governance of all components as united rather than independent aspects of the same system. Government agency representatives, scientists, and other natural resource stakeholders are pushing for a paradigm shift in ocean management from the historically fragmented approach to one that reflects and considers the ecosystem (USCOP 2004, Watkins 2007). Such an approach, inherently holistic, has gained support as shifting baselines for calculating the status of populations and ecological communities have increased scientific understanding of the depth of crisis in the oceans. Resulting scientific reports about the loss of predator fish, and the increasing frequency and size of dead zones have heightened public concern and awareness (Ludwig et al. 1993, Pauly 1995, Steele 1998, Myers and Worm 2003). Findings on the state of marine ecosystems inspired the formation of two commissions to review ocean policy in the United States. Results of the commissions (Pew Oceans Commission 2003, USCOP 2004) were surprisingly similar: both called for an integrated placed-based ecosystem approach to management. Implementing such an approach would require management agencies to consider the short and long-term effects of human activities on the whole marine system where conventional management has focused only on individual populations or species (McLeod et al. 2005). Riding on the coattails of land use management advances realized several decades ago (Leopold 1949, Van Dyke 1969) and applied throughout the past half century, the time has come for ocean governance to transition from the sector and single-species approach to an ecosystem based direction (Pew Oceans Commission 2003, USCOP 2004).

Trailing behind governance in a handful of coastal states and nations, the U.S. Congress has begun in recent years to show concern for ocean health and climate change impacts. The emerging impacts of climate change and other severe multi-scale environmental problems will be especially difficult to mitigate and adapt to within the existing fragmented and uncoordinated governance (Watkins 2007). To effectively mitigate and overcome global environmental problems, governance related to natural resources and industry needs to become more coordinated and integrated (Knecht et al. 1988, Golley 1996, Young 2002). Realizing the goal of a coordinated system of ocean management requires analysis of gaps and overlaps beyond partial or single case and single sector diagnosis and assessment. Full analysis entails quantitative, objective, and comprehensive evaluation of existing governance (as a whole) across sectors and geopolitical jurisdictional boundaries. As gaps and overlaps arise in the legal and regulatory systems governing ocean and coastal resources, it follows that dedicated analysis of the laws covering different sectors can help to identify such gaps and overlaps. Since laws represent an important aspect of formal institutions, legal analysis can be used to help identify and evaluate both the overlaps and the gaps in marine management (USCOP 2004). A formal assessment of laws, however, as a step toward holistic management, raises the problem of ensuring the use of quantitative analysis in the evaluation of governance. This project provides a quantitative tool to map gaps and overlaps, one that could augment full legal analysis.

Ecosystem-based management (EBM)

Recognizing the strongly negative effect of fragmented management on ocean and coastal health, the United States and Pew ocean commissions, among others, called for the implementation of ecosystem-based management (EBM). A large group of scientists has conceptually defined EBM as:

"… an integrated approach to management that considers the entire ecosystem, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors." (McLeod et al. 2005)

According to the Millennium Ecosystem Assessment (2005), “An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment, interacting as a functional unit. Humans are an integral part of ecosystems,” (Millennium Ecosystem Assessment 2005). Therefore, the linkages among humans (in terms of activities, uses, and impacts), other species, and biophysical processes inherently constitute an ecosystem.

Government agency representatives, non-governmental organizations (NGOs) and other stakeholders also articulate the need for the ecosystem-based management approach, but sometimes in different terms. For example, the National Oceanographic and Atmospheric Administration (NOAA) regards it as the “ecosystem approach to management,” or “EAM” and “ecosystem management” (Barnes and McFadden 2008).

The necessity of holistic management conducted in the context of an ecosystem is not a new concept (see (Leopold 1949, Van Dyke 1969, Christensen and et al. 1996, Slocombe 1998). Land use managers and terrestrial ecologists have advocated the approach for over 50 years. Despite the clear need for marine EBM, marine management still occurs within sectors (Pew Oceans Commission 2003, USCOP 2004). Implementation of EBM requires the integration of existing decision-making systems so that ocean-related activities can be managed under an overarching holistic goal to consider the entire ecosystem rather than the individual sector (McLeod et al. 2005). Easier to discuss conceptually than to operationalize, integration presents a major obstacle to implementing EBM (Slocombe 1993, Juda 2003b).

The transition to EBM cannot occur without greatly improved knowledge of the extant institutions involved in governance (Imperial and Hennessey 1996, Cortner et al. 1998, Sutinen et al. 2000, Juda and Hennessey 2001, Rosenberg and McLeod 2005). Knowledge of the linkages among institutions is as fundamental to EBM as understanding the relationships among ecological components, such as those among species, their habitats, and stressors (Sutinen et al. 2000, Olsen et al. 2006). A better understanding of the type and degree of interplay among management systems can help set priorities for EBM programs in filling gaps and preventing unhelpful overlaps in coordination. Unfortunately, the institutional component has received much less attention than non-human ecosystem aspects in scientific research and management (Cortner et al. 1998), most likely due to the relatively recent incorporation of human dimensions in the environmental sciences (Cordell and Bergstrom 1999).

Interest in EBM is rapidly growing among marine managers, NGOs, and academics along the west coast of the United States. The programs emerging in this region could benefit from a rigorous coastal and ocean dataset to facilitate analysis of the nature and extent of management fragmentation. EBM initiatives specifically need baseline data about gaps and overlaps in order to coordinate marine management decisions strategically among sectors and government agencies (Imperial 1996, McLeod 2005, Slocombe 1993, Underdal 1980).

In the task of restructuring the existing fragmented management system towards an ecosystem-based approach (Grumbine 1994), the following questions arise:

- What are the overlapping jurisdictions?
- What are the gaps in management?
- Which of the gaps and overlaps should take priority?

Answering these questions naturally entails asking also: Across which agencies? At what level of jurisdiction? Concerning what object(s) of regulation?

Thus far, these questions have only been answered anecdotally. To progress the discussion and the field of EBM, this project develops tools to identify and measure types of management fragmentation for systematic evaluation. Answering the above questions quantitatively and systematically would provide data for use in order to: 1. establish a baseline for monitoring improvements over time; 2. measure the impact of fragmentation on ecosystem health; and 3. prioritize problems based on location, state of resources affected, and severity of fragmentation.

Producing such information comprehensively across sectors sets a daunting task, even if focused only on laws. This project used approximately 60 federal statutes (nearly 4000 sections of law) to represent ocean management across sectors. The compilation as combined with ocean and coastal-related statutes and regulations from three states totals 75,286 documents (in the form of legal sections). Analysis of such a large dataset is greatly facilitated by digitization and sophisticated information retrieval techniques developed by computer scientists. Such techniques include mining of structured and unstructured data - data mining and text mining respectively (Feldman and Sanger 2007). This project explored a range of such techniques applied in order to identify and measure gaps and overlaps in ocean management. Prior to this research project, no methods existed to systematically generate such quantitative information. This dissertation sets out the development of a text mining tool that provides baseline data and its application in the mapping of fragmentation in governance.

RESEARCH FOCI AND HYPOTHESIS

This dissertation describes the development of a tool that facilitates quantitative analysis and the generation of baseline data useful for understanding problems of fragmented ocean management. The project's central hypothesis holds that quantitative information useful in determining the existence, extent, and type of gaps and overlaps in ocean management can be gleaned from text analysis of laws and regulations. As such, the main product of this thesis constitutes the analytical methods to identify and measure gaps and overlaps contributing to the larger effort to integrate necessary social science into ecosystem-based management.

This dissertation focuses on *gaps* and *overlaps* as two problems that frequently appear in ocean management (Young 2002, Crowder et al. 2006). Gaps and overlaps receive separate analysis, employing, respectively, the institutional theories of the problem of fit between institutions and ecosystems (Costanza and Folke 1996, Young 2002, Wilson 2006, Folke et al. 2007) and the theory of institutional interplay (Young 2002).

Gaps and the problem of fit

Background

The problem of fit centers on the idea that management systems need to reflect the structure, properties, and processes of the ecosystem within their scope in order to achieve sustainable use of related resources. Recognition of the importance of fit goes back to Garrett Hardin's 1968 *Science* article, "Tragedy of the Commons." Hardin articulated the perspective of many governments and scholars before him. He saw the lack of top-down control (government regulation) or of private property as the causes of over-exploitation by users of the very resources on which they depended (Hardin 1968). Publication of Hardin's paper triggered a surge of research in anthropology, political science, sociology, and human ecology contesting Hardin's assertion that sustainability of natural resource systems necessitates formal top-down regulation or privatization. The tremendous efforts to examine the commons, which continue today, showed that in the absence (or distance) of top-down regulation on the one hand or privatized rights on the other, people who share the use of a "commons" or jointly held resources may design and enforce their own sets of rules, rights, and decision-making procedures (institutions) for management of the resources involved. The scholars of commons research soon turned to investigate: 'Why are some communities able to develop institutions for sustainable management of their commonly held resources and others are not?' (McCay and Jentoft 1998).

Investigation reveals no cookie cutter design; an institution that performs well in one place does not necessarily transfer well to another (Young et al. 2007).

Patterns of success and failure, however, have been identified across cases worldwide, leading to a set of institutional design principles for common property management (Ostrom 1990). This set of principles includes the importance of congruency between institutions and the common pool. The idea of congruency has become the problem of fit (Wilson 2006), where the latter focuses on the mismatches between a relevant ecosystem and management of it. The problem of fit is now an internationally recognized topic of importance in natural resource management (Folke et al. 2007).

There are several ways in which an institution may or may not fit an ecosystem. Institutions often fail to encompass spatial or temporal scales or functional ecosystem processes (Ostrom 1990, Young 2002, Wilson 2006). Spatial mismatches occur, for example, when the migratory scope of a species spans political borders. Such difference in scale prevents any effective control over human behavior outside the institutional jurisdiction unless there is substantial effort to coordinate the authoritative entities (Wilson 2006). Temporal mismatches appear typically through disconnection in time scales between ecosystem functionality and voting cycles and other decision-making procedures that drive political processes. Impacts on marine systems can occur faster or slower than rigid institutional time scales, leading to a lack of policy response to adapt management adequately and effectively (Crowder et al. 2006).

A third aspect of the problem of fit less documented in literature concerns the failure of governance (or some institution within it) to relate adequately to the functionality and nature of the ecosystem in which it is embedded (Costanza and Folke 1996, Young 2002, Folke et al. 2007). Situations in which governance as a whole does not take into account the key properties and interactions of an ecosystem are regarded as *gaps* in this dissertation. While land management somewhat implements this concept of fit, major mismatches between the management and ecosystems exist for the ocean environment (Fowler and Treml 2001, Young 2002, Wilson 2006).

Ecosystem in natural sciences

Since the mid-1900s, natural scientists concerned with resource management have conducted a parallel dialogue over similar issues. Tansley coined the 'ecosystem' concept in 1935, which caught on as the focus of the ecology discipline. Rather than focus on species in isolation of one another or in isolation of biophysical factors (e.g. climate, relief, parent material, time), ecology adopted a systems approach to explore relationships among living and non-living components (Golley 1996). In 1962, Rachel Carson's *Silent Spring* documented how human actions could destroy the environment on which we depend. Focused on agriculture and pesticide application, her work demonstrates how the vulnerability of species (including humans) can increase when people do not act as a subset within ecosystem functions and structures. The growing public awareness of the 1960s gave ecologists strength in their conviction of the need to improve our understanding of the structure, function, and dynamics of the natural world, using ecosystems as the fundamental building block.

In 1969, a group of ecologists published the book *Ecosystem Concepts in Natural Resource Management*, whose message bears striking similarity to that of the commons literature from social science research (Van Dyke 1969). The book emphasizes that management needs to consider ecosystem components and properties. Van Dyke, Arnold Schultz and others examined the importance of managing resources in the context of the ecosystem even as scientific understanding of ecosystems was still in its early days. Furthermore, the authors defined an ecosystem to include humans as a significant component. Despite recognizing the importance of humans within ecosystems, discussion in ecology often overlooks the capacity of people to develop institutions appropriate to the resource on which they depend.

Combining disciplines

After decades of separate but similar research agendas within social and natural sciences, the two branches reached the same conclusion: institutions need to fit better with the ecosystems in which they are embedded if we are to sustain natural resources and ultimately ourselves (Costanza and Folke 1996, Young 2002, Wilson 2006, Folke et al. 2007). The branches of social and natural science have now begun to join forces to work together to report this message, as well as to continue clarifying what it entails. One large and growing community of researchers from both social and natural sciences investigates what are referred to as *social-ecological systems* (SES), (see e.g. (Berkes et al. 1998). Many visionaries have arrived at parallel insights, all of growing significance given the increase in environmental problems seen in recent decades. As a result, the paradigm of resource management and science has shifted to acknowledge that sustainability can be obtained only through management that acknowledges and reflects the relevant SES (Norton 1992). How to accomplish this has become the major question. Responses include a wealth of examples, from community-based conservation, to market-based approaches, and top-down governance. To progress and apply our understanding of SESs, however, requires objective identification and measurement of fit between institutions and the ecosystems they address.

This dissertation presents a quantitative technique that can be used at any scale and across any set of political jurisdictions in order to capture misfits between institution and ecosystem. The results can help to pinpoint priority areas in need of attention. The data will also advance our understanding of the degree to which fit plays a role in institutional performance and effectiveness.

Gaps as misfits

As discussed above (Background), several types of misfit[3], principally functional, spatial, and temporal, can occur between institutions and ecosystems (Wilson 2006, Folke et al. 2007). Problems of fit can stem from imperfect knowledge, institutional constraints, rent-seeking behavior, or any combination of the three (Young 2002). No previous method has existed for identifying mismatches in any rigorous, quantitative, and cross-sectoral way. Thus, this dissertation project

---

[3] Following the literature (Young 2002, Crowder et al. 2006, Wilson 2006, Folke et al. 2007), this dissertation uses the terminology of *mismatch* and *misfit* interchangeably, and thus *match* is used interchangeably with *fit*.

initiated a systematic investigation of mismatch through the identification of gaps – discovering ecosystem properties and critical linkages not covered by existing management institutions in the form of laws and regulations. Because the definition of an ecosystem is flexible, examining this type of fit between governance and ecosystems allows the incorporation of shifting values and improved knowledge about important components and linkages in the system. However, also because the ecosystem definition is subjective, one has to make decisions about scales (such as tropic levels, scale of management) and societal values in order to generate an ecosystem model for the analysis of ecosystem linkages in law (and associated gaps). Identifying gaps as a functional form of mismatch can serve as a foundation for future investigation of the problem of fit particularly as stemming from fragmented management.

Overlaps and institutional interplay

Overlapping jurisdictions are the more widely recognized problem resulting from fragmented management (Fowler and Treml 2001, USCOP 2004, Crowder et al. 2006). An *overlap* occurs when two or more agencies have the same jurisdiction or influence over the same area, activity, and/or resource. Agencies involved in an overlap often do not coordinate or consult one another adequately to ensure permitted activities are compatible with one another. The resulting institutional interplay can sometimes prove beneficial rather than problematic (Young 2002). As a result of sector-based management, however, a decision made by one agency often results in unintended negative consequences for other sectors. Negative interplay of this kind results from redundancy, conflicting mandates, inconsistent regulations, and other actions causing inefficiencies and preventing effective management. Cases of institutional interplay can present major obstacles to the implementation of ecosystem-based management (Crowder et al. 2006).

Institutional interplay until now has been identified only on a case-by-case basis and investigated only in a qualitative, often descriptive manner (Ebbin 2002, Young 2002, Oberthur and Gehring 2006). While qualitative case studies are important and necessary to understand situations thoroughly, quantitative assessment of institutional dimensions could facilitate evaluations across sectors and beyond the knowledge domains of the investigator. Furthermore, quantitative evaluation could support comparison across political jurisdictions in a comprehensive manner not achievable by qualitative research. It will allow prioritization of cases of interplay for follow-up with qualitative assessment to improve the depth of understanding.

How to quantify institutional interplay? For this dissertation, I developed a method to identify and map interplay using indicators that reveal potential functional overlap among institutions, thus pinpointing where coordination should occur among the agencies responsible for institutional enforcement and compliance. Accurate information about coordination efforts cannot be gleaned from laws and regulations. An overlap analysis can, though, identify likely cases of overlap and institutional interplay, contributing baseline data indicating areas where coordination needs to occur.

TEXT ANALYSIS

Text analysis rationale

Recent immense growth of data, including laws and regulations, requires intelligent techniques to generate usable information. This has become feasible thanks to the increasingly routine production of data in digital formats (Moore et al. 1998, Unwin et al. 2006). A growing number of scientists turn now to information retrieval science to solve a wide variety of problems (Jones et al. 2006). Text analysis has become a valuable tool in many disciplines to quantify relationships between documents (Krippendorff 2004).

Classic document analysis techniques use variations of keyword or term frequency counts for the purposes of text mining (Baeza-Yates and Ribeiro-Neto 1999). At the core of analyses on a static collection of text is a *term-document matrix*, which organizes terms in a table according to the frequency of occurrence in each document (Zeimpekis and Gallopoulos 2006). Once generated, this type of matrix can be analyzed, or mined, using various manipulations and statistics, including term count weightings, latent semantic analysis, vector space modeling, and various clustering algorithms (Berry 2003).

In exploring these advanced forms of text analysis of laws in the field of ocean management, I found the most useful mining methods involved raw term counts. Term counts of basic data allow transparent methods for interpretation by and presentation to various stakeholders. Document analysis using term counts can answer questions about fragmented management because it identifies and calculates certain types of relationships between the laws based on any given terms or phrases. For example, if two terms representative of species in an ecosystem co-occur in a document, this indicates the document potentially acknowledges the ecosystem linkage. The Engineering Informatics Group at Stanford University conducts research through the Regnet Project to address problems caused by the "complex, diverse and extensive" amount of US Federal and State business domain law. Their project focuses specifically on the effects of fragmented laws on business management (Lau et al. 2006). With comparable proposed outcomes, my project used U.S. Federal and State laws regarding marine regulation and management. By providing an objective map of regulatory gaps and interplay, text analysis can supplement and help guide comprehensive legal analysis as well as a broader review of management issues from various agency and other stakeholder perspectives. (See chapters 4, 5, and 6 for text analysis experiments used in this project.)

Geographic scope of text

The project explored several text mining methods and consistently gathered feedback from ocean management experts. To explore various methods, I applied text analysis methods to a compilation of codified statutes and regulations (relating to ocean and coasts) as the expression of the apex of management within the California Current Large Marine Ecosystem (CCLME).

To improve management of the marine environment, international organizations, and national and state governments have adopted the large marine ecosystem (LME) concept. On the magnitude of 200,000 km^2, LMEs "are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves, enclosed and semi-enclosed seas, and the outer margins of the major current systems," (Sherman 2005). LMEs spatially cover the most economically, politically, and ecologically important portions of the oceans worldwide (Wang 2004).

The CCLME consists of one of the most well-documented marine ecosystems in the world (Lluch-Belda et al. 2003). This makes it a useful test bed for developing algorithms to measure management system gaps and overlaps in relation to the ecosystems in which the institutions are embedded. Located from the Washington State-Canada border to just south of Baja, the CCLME extends seaward to approximately 300-600 nautical miles from the continent. This project could have been performed using any LME or another type of delineation. As I have been based at the University of California, however, the CCLME made sense as the focus of my research for ease of access to stakeholders for interviews and meetings as necessary for consultation and corroboration. Political jurisdiction over the CCLME area is held by international policy, the United States and Mexico national laws, as well as State laws of Washington, Oregon and California. Mexico marine waters are under the jurisdiction of the national government, therefore no Mexican state laws were compiled for this project.[4]

[4] Mexico national laws were part of the compiled dataset. However, National Mexico laws could not be included owing to the linguistic complications they would introduce.

While statutes and regulations do not provide a complete representation of ocean and coastal management, they neatly articulate multiple geopolitical jurisdictions across all marine relevant sectors. (Chapters 4, 5, and 6 present experiments testing the utility of text analysis in generating relevant data.)

ORGANIZATION OF THESIS

This dissertation develops the central thesis that text analysis can reveal gaps and overlaps in ocean management in the following sequence: Introduction (this chapter), Development of Concept to Technique, Materials & Methods, Results (case study application), and Conclusion.

Development of concept to technique

Chapter 2

Chapter 2 presents the conceptual development of the thesis. This research project involved a complex research problem that required multiple exploratory and ground-truthing stages. To adequately define the problem so that I could develop a useful solution for policy-makers, I followed an iterative methodology (Figure 1.1). I revisited and improved multiple times on the following main components of the project:

- Define problem
- Determine utility of information retrieval (IR) applied to the problem
- Structure the data appropriately for IR
- Design application

- Test analysis
- Test presentation

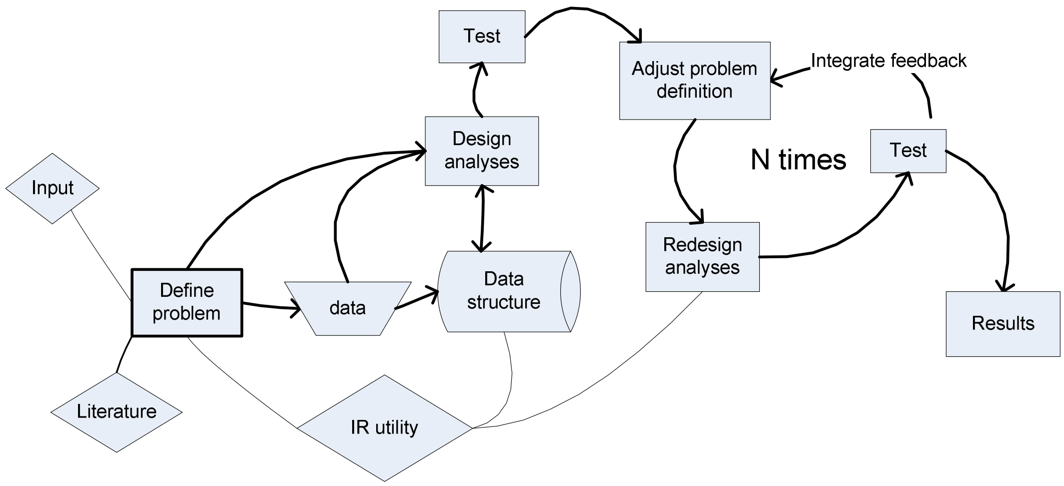


Figure 1.1. Methodology followed from concept to technique development. (IR = Information Retrieval)

I interviewed and met with a variety of stakeholders throughout all stages of the dissertation project. These included academic and government agency scientists (in the fields of ecology, oceanography, network analysis, anthropology, economics, political science, and law), resource managers, government administrators, and non-governmental organization representatives (e.g. COMPASS, Marine Conservation Biology Institute (MCBI), The Nature Conservancy (TNC), Point Reyes Bird Observatory (PRBO), and San Luis Obispo Science and Ecosystem Alliance (SLOSEA)).

Materials & methods

The Materials & Methods chapters make up the majority of this dissertation, consisting of four chapters: dataset, gaps analysis, and two papers about the overlaps analysis. Although slightly adjusted for the formatting and flow of the dissertation, each chapter exists as a stand-alone article. As a result, each chapter contains some repetitive background and descriptive information.

Chapter 3: Dataset

Chapter 3 provides a detailed account of the dataset. First, I selected and compiled laws and regulations. For the gaps analysis, I then cleaned, divided, re-cleaned, and finally parsed the documents to convert them into a term-document matrix as a standard and very useful format for text analysis. This chapter reports summary statistics about the term-document matrix, and lastly, discusses potential uses for the dataset.

Chapter 4: Gaps concept and technique

Chapter 4 presents the technique developed to identify and measure gaps in ocean management. This technique combines ecosystem ecology with information retrieval science and social network analysis. Two outputs resulted from the analysis: 1. specific gaps; and 2. two metrics for the degree of fit between a modeled ecosystem and laws. One metric evaluates the correlation between networks (ecosystem and laws) using the quadratic assignment procedure (Mantel Test), while the other measurement evaluates the ratio of gaps to ecosystem linkages. The gaps analysis focuses primarily on the notion of functional fit rather than the temporal and spatial types. The first metric represents only the first step of many to quantitatively and comprehensively answer questions about the problem of fit across sectors and political jurisdictions.

I used a generic estuarine ecosystem, composed of species, habitats, and stressors commonly found in the Northern California Current Large Marine Ecosystem, to demonstrate the gap analysis technique. The methodology presented, with its capacity to identify and measure legal gaps in specific locations, provides decision-makers with a tool to tackle fragmentation as a major obstacle to ecosystem-based management.

Chapter 5: Overlaps concept and technique (technical)

The first overlaps paper presents technical details about generating useful information about overlaps as written for the Digital Government Research Conference in 2008. I developed a metric of overlap indicating the degree of “complexity,” which essentially locates relative hubs of legal and agency activity through a calculation of the number of laws and agencies involved in a given topic. A selection of 46 topics relevant to ocean management spanning across sectors demonstrates this preliminary overlaps index. Of these topics, those most fragmented are related to marine transportation, which corresponds to findings of expert legal research (US Commission on Ocean Policy Report, USCOP 2004). Perhaps more important in this exploration, I found that information about overlaps is most useful to decision-makers and other stakeholders in the format of diagrams rather than numerically in tables.

Chapter 6: Overlaps concept and technique (broad audience)

Second, citing the work detailed in Chapter 5, Chapter 6 introduces the concept of text analysis of laws to find overlaps and the need for baseline quantitative data about overlapping jurisdictions. Written for a diverse audience in the form of a short paper articulates what can and cannot be answered through text analysis in regard to management issues. The paper emphasizes the utility of agency authority network diagrams, and also briefly describes an experiment testing the basic function of term and phrase counts to represent the involvement of a law in any given issue.

Case study -- Application of tools to ocean acidification

CHAPTER 7: Evaluation of management related to ocean acidification (Channel Islands, CA)

I applied the gaps and overlaps analyses as set out in the previous chapter to management related to ocean acidification for the final case study of this dissertation. The chapter includes an overarching introduction followed by two main sections. Part A presents the gaps analysis and interprets the major findings. Part B shows the overlaps analysis used to generate baseline data about complexity of issues and agency involvement related to ocean acidification.

Part A: Gaps in ocean law related to ocean acidification

Part A demonstrates the potential of the gaps analysis for policy making and ocean management. In collaboration with the Environmental Defense Center, I am assisting in a report to the Channel Islands National Marine Sanctuary Advisory Council about the emerging threat of ocean acidification on the area. Since this report must include the description of existing governance for the issue, it provided an opportunity for an application-oriented experiment to run analyses and gather user feedback. This chapter presents and interprets the analysis, the summary of which I will present to various stakeholder groups (Environmental Defense Center, Conservation Working Group, fishermen, and Sanctuary Advisory Council) Summer 2008.

Part B: Filling the gaps using overlap analyses

Part B of this chapter presents an application of the overlaps analysis to reveal how the gaps in management related to ocean acidification can be filled using the extant network of jurisdictional agencies.

Conclusion Chapter

The concluding chapter of the dissertation includes a discussion of the dissertation's main findings, the relevance of these findings to the policy community and academia, and future directions of work that have grown out of the project.

Chapter 2 From Concept to Technique

INTRODUCTION

This chapter describes the progression from the original proposed dissertation concept to the execution of analytical techniques and discussion of applications developed for the dissertation. The dissertation topic is unconventional in its focus on a complex research problem requiring multiple exploratory and verification stages. I followed an iterative process for two reasons: to accurately define the problem and, within a theoretical framework, to develop a set of tools for policy-makers (Figure 2.1). I revisited and improved multiple times upon the following main components of the project:

- Define problem
- Determine utility of information retrieval (IR) applied to the problem
- Structure the data appropriately for IR
- Design application
- Test and implement analysis
- Test and implement presentation

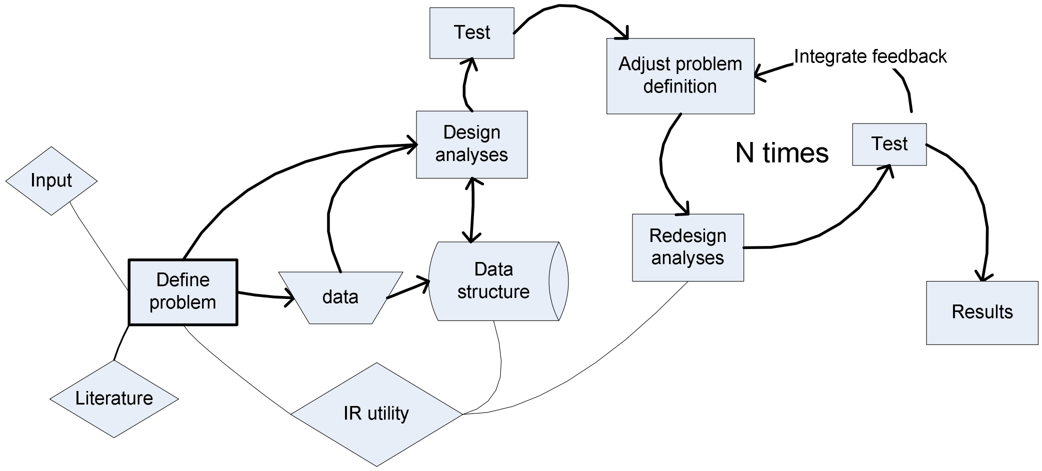


Figure 2.1. Methodology followed from concept to technique development, beginning with "Define problem" based on stakeholder input and literature, to "Results," which are a product of testing, redesigning analyses, and adjusting the problem definition. (IR = Information Retrieval)

At each step and iteration of processes, I interviewed and met with a variety of stakeholders. These included academic and government agency scientists (from the fields of ecology, oceanography, network analysis, anthropology, economics, and political science), resource managers, and representatives of government administration and non-governmental organizations. A timeline (Figure 2.2) presents the chronology of steps taken. Two important current events occurred during the project development, and are referenced on the left of the timeline. The meetings and events together greatly influenced the project thesis. The box on the upper right side of the figure gives a summary of how the project concept transformed.

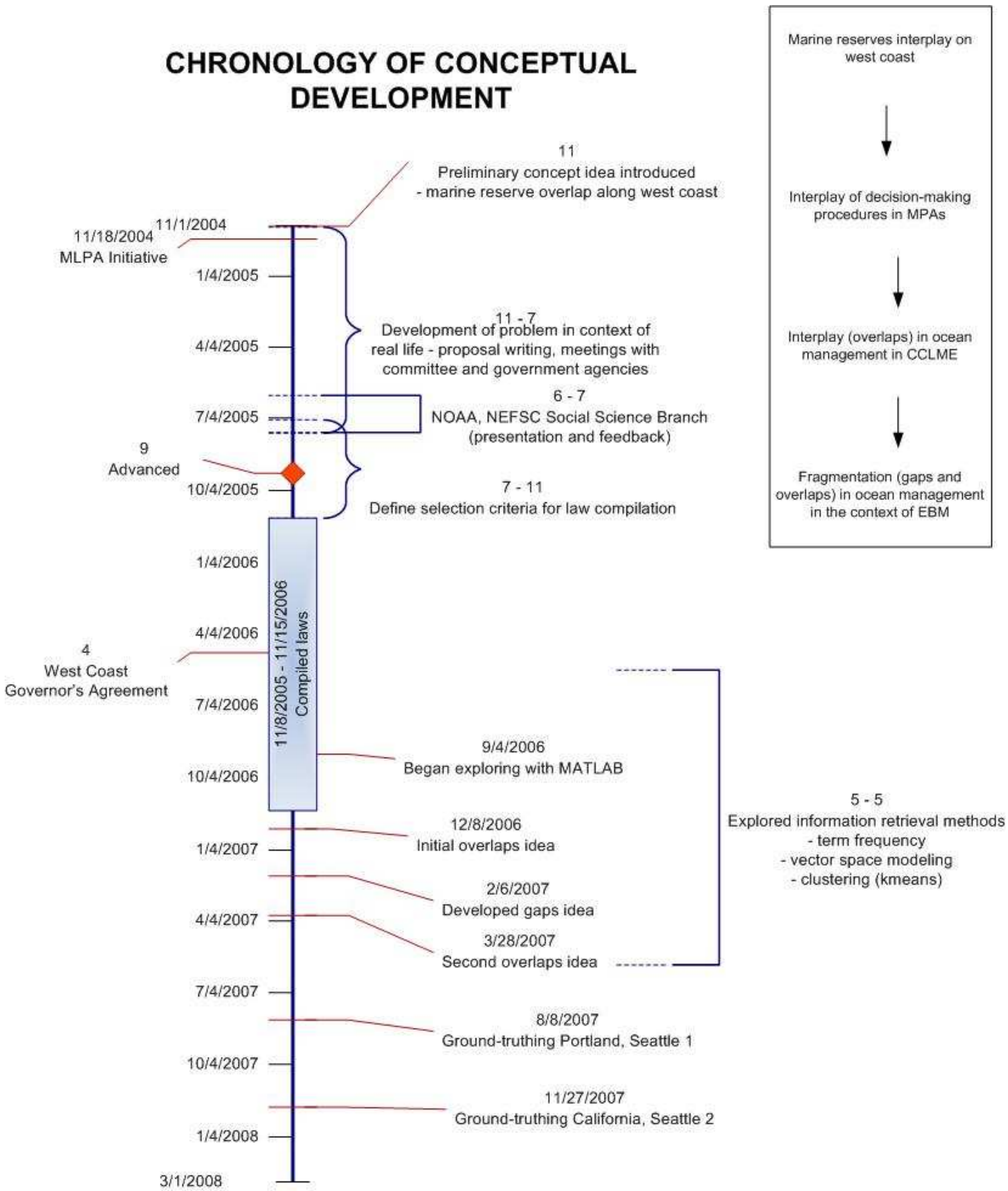


Figure 2.2. Timeline of from the development of the project's conceptual research problem through development of the methods to analyze this problem

PROBLEM DEFINITION

Original project

My original interest lay in examining marine protected areas in lesser developed nations, specifically the impacts of conservation efforts on local communities and their response to those efforts. The inspiration for this line of research inquiry first sparked as a result of lessons in cultural geography from the late Dr. Bernard Nietschmann. Dr. Nietschmann's research explored the relationship between community participation, or lack of it, and the success of conservation initiatives in Central America (see (Lovell 2002)). This led me to theories of political ecology and the critical relationships between hard science and social science playing out in current environmental predicaments. My project trajectory moved toward larger scale institutional dimensions of ocean management as I gained a perspective on the urgent need for more proactive and tactical policy-making methodology in the US. At the Social Science Branch of the Northeast Fisheries Science Center of NOAA Fisheries in Woods Hole, Massachusetts, I assisted in work to guide fisheries decision-making by generating social science data. Following this introduction to national efforts to integrate science fields, I gained experience in text mining as a research assistant for a digital library project. A surge of publications on marine EBM, from scientific articles to government memoranda, and NGO declarations, reignited my interest in the subject. I realized that, although social science findings would be critical in the transition from sector and species-based management to EBM, they could well become marginalized. This led to the idea that the provision of tools to quantify social science findings could confirm their value and facilitate their necessary inclusion in EBM.

Although the focus of my project has dramatically transformed, I hope still that it contributes to understanding the human dimensions of environmental decision-making. Ultimately, my dissertation aims to provide hard data for the complex task of producing scientific findings that help to create institutions that provide protection equal to the dire environmental conditions we face today.

Initial idea

After interning with NOAA, my project shifted gears considerably. I accepted a Research Assistantship (RA) under Drs. Paul Berkman and Oran Young to help build a digital library from the Marine Mammal Commission Compendium (Wallace 1996). While my project still focused then on marine protected areas in Central America and Mexico, the RA job came with the expectation that I would apply a digital library technology to my dissertation project. Constructing the library introduced me to techniques employed in sophisticated document analysis and expanded my project to include formal institutional dimensions at the higher level of policy.

At NOAA, I discovered the rich history of ocean management in the United States. My prior focus on tropical marine and coastal studies meant I was completely unfamiliar with domestic issues and surprised to find similarly ineffective ocean governance in the US. Back in Santa Barbara, I took up the suggestion to use policy documents to conduct quantitative analysis about institutional interplay among marine protected areas (MPA) in the California Current. Because interplay had been examined only through case studies, text analysis could potentially bring a quantitative dimension to future research.

Current affairs

Ocean management came to the fore through two events that underscored the value of a line of inquiry about MPA interplay. By 2003, the piecemeal designation of MPAs had become problematic. The federal MPA Science Advisory Board intended to create a marine management area (MMA) inventory and had plans to do the same for MPAs as a subset of MMAs. In California, private donors had bolstered the State's commitment to initiate the Marine Life Protection Act Initiative process. The State had failed in its past two attempts, due first to a lack of stakeholder participation and later from a lack of funds (Weible et al. 2004, Avasthi 2005). The Act mandates that California review all MPAs in State waters, utilizing the best available science, and adjust them to reflect a conservation network reflective of the ecosystem.

The Pew Ocean Commission released its report in 2003 cautioning that the problem associated with fragmented MPA designation also existed within and among all sections of ocean management, not just MPAs. These two developments put critical issues associated with MPA overlap in the limelight. Incidentally, research was underway to confront fragmentation of MPAs. In fact, lawmakers in California developed the Marine Life Protection Act essentially to de-fragment the State's MPAs. In the interest of contributing to a broader scope beyond a conservation-centric inquiry, I expanded my research problem to include all sectors of ocean management.

This decision increased the range of law and therefore the density of the data bed that I would have to compile and analyze. Despite this challenge, the criteria for selection of laws became simpler. A more general range allowed generic selection all ocean and coastal relevant laws without having to decipher which ones pertained to MPAs (what a relief!).

Returning to Woods Hole in 2005, I presented my research ideas to gather suggestions about which aspects of fragmentation posed problems in government/management. Resounding feedback indicated that the lack of coordination in sector-based decision making presented a major obstacle to effective management. The NOAA research scientists also conveyed a sense of frustration concerning the magnitude of the undertaking required to wade through all the pertinent laws and other management documents in order even to begin to uncover the complexity of overlapping jurisdictions. I also learned of the latest large marine ecosystem (LME) book (Hennessey and Sutinen 2005) in which the authors reiterated the problem of fragmentation, and the need for a systematic review of institutional dimensions to move towards an ecosystem approach to ocean management. This work and the feedback from NOAA researchers confirmed that my research problem needed a quantitative investigation. Despite criticism that my project should focus on a single sector, I maintained the overarching perspective based on the advice of my dissertation committee chair that institutional interplay is not only problematic within –sectors but also across them. Rather than limit the application of findings to one sector, the project would move forward with the aim of developing tools to identify and prioritize gaps and overlaps across all sectors of ocean management.

Ecosystem-based management

As an attempt slightly to narrow the problem definition, I proposed to investigate fragmentation (gaps and overlaps) within EBM. This resulted from my involvement in the National Center for Ecological Analysis and Synthesis (NCEAS) ocean zoning working group as well as the EBM recommendations by the two ocean commissions (Pew Oceans Commission 2003, USCOP 2004). Furthermore, the Sutinen et al. 2005 LME book specified the necessity to address institutional fragmentation in order to shift to Ecosystem Approach to Management (EAM), which is equivalent to EBM for the purposes of this project. The literature clearly supported my conclusion that an investigation in the context of EBM would generate the most relevant analysis.

The NCEAS working group initially intended to focus solely on ocean zoning. However, the working group fully recognized zoning as just one tool. Group discussions tended to revolve around the broad concept and challenge of EBM implementation. I began to grasp fully that identifying and evaluating the obstacles in the implementation of EBM could provide a roadmap for overcoming the complexities and intangibles of the theory.

By late summer 2005, I had defined the overall research problem and main project objectives: to quantitatively identify overlaps in law, and gaps in agency coordination for the purpose of implementing EBM in the ocean management for the California Current Large Marine Ecosystem. With this goal and a general sense of how I could accomplish the objectives using text analysis of ocean laws, I defended my proposal to my committee and advanced to candidacy. I then began creating a list of laws to compile as the dataset. Although the project no longer required a search for all MPA related laws, the increased scope encompassing all sectors of ocean management nevertheless involved a much larger task than originally anticipated. The effort of selection alone required consultation with legal experts. Thanks to the Ocean Commission and the encouraging shift toward EBM and recognition that it must address fragmentation in law, I was able to draw on assistance from several existing efforts. The NOAA Coastal Services Center had developed the Ocean Planning Information System, now called the Digital Legislative Atlas. The Atlas provides spatial jurisdictions of statutes and documents what agencies have authority to implement these laws for ocean and coastal related management. I compiled codified versions of the federal statutes using the Atlas list, with a few additions. For Oregon, I used the Territorial Sea Plan and recent amendments as my base selection list (Oregon Ocean Policy Advisory Council 1994). I continued to add all other statutes relevant to ocean and coasts found along the way. As a result of the Ocean Protection Council (OPC), then newly designated under the California Ocean Protection Act, California had drafted a list of all ocean-related laws. I am also grateful for the generosity of Jonathon Gurish, OPC staff member and attorney with the California Coastal Conservancy, in providing access to his list of ocean-related law, which I expanded to include acts and additional sections. Although I could not find a comparable list for the State of Washington, by this point I knew how to develop my own list thanks to conversations with staff at the Department of Ecology and information found at the Revised Code of Washington website.

The compilation of regulations proved more challenging than creating the list of statutes. After discussions with various legal experts and ocean management practitioners, I created selection criteria using the key terms: “marine”, “ocean”, and “coast” to search the large bodies of administrative code for each geopolitical jurisdiction. Chapter 3 details the methodology for selecting and compiling both laws and regulations.

ANALYSIS DESIGN

Once I had a representative dataset, I began exploring avenues of analysis using techniques common to text and data mining. These procedures use the power of computer programming languages to reveal patterns among documents or data. Text mining borrows from data mining, but requires substantial preprocessing because text is inherently unstructured relative to other data types (Feldman and Sanger 2007). Because of the rapid growth of digital information, investigations to develop mining techniques have spawned an entire sub-discipline within computer science referred to as “Knowledge Discovery” (International Association for Artificial Intelligence and Law, Feldman and Sanger 2007). A plethora of potential techniques now exists for application to document collections, such as my compilation of ocean laws, for purposes of discovering relationships within and among documents (Feldman and Sanger 2007).

The collection of laws and regulations was completed in December 2006, ending the essential initial preparation phase for institutional analysis relating to management of the CCLME. Explorations then began in Matlab® of advanced text analysis techniques, applying the Text to Matrix Generator, a free toolbox provided by Drs. Dimitrios Zeimpekis and E. Gallopoulos from the University of Patras in Greece. The Generator produces a term-list dictionary for a collection of documents and automatically creates a term document matrix (TDM) from the user’s collection of text files (Zeimpekis and Gallopoulos 2006). Commonly used to develop text mining techniques (Feldman and Sanger 2007), a TDM organizes terms in a table on the basis of frequency of occurrence in each document in a collection. The necessary organization of the TDM, enabled my next step of exploration of various advanced methods, including latent semantic analysis (LSA) as applied in vector space modeling and kmeans clustering (Baeza-Yates and Ribeiro-Neto 1999).

Analyses on the entire dataset took several months. Initially, patterns in the resulting clusters and their associated dominant terms looked promising. At this stage, the clustering of laws (including statutes and regulations) by kmeans clustering (with cosine)[5] and vector space analysis was tested as a dual process method to identify gaps and overlaps. However, the inverse document frequency weighting entailed in the process often generated clusters based on the occurrence of words around a term, but included laws without the original term. This may appear to be a matter requiring only a simple fix. However, for a non-statistician, it poses considerable algorithmic obstacles and involves extreme density of code. Not only did this method require lengthy and cumbersome accuracy checking and challenging ground-truthing, its refinement would have needed dedicated statistical expertise. The dissertation at this point could have moved into the realm purely of statistical analysis and away from the production of a tool useful for stakeholders.

At this point, it made sense to test analysis at more basic levels of text mining. This brought the added benefit of more transparent presentation. I had become convinced of the need for transparency. Several interviews with legal practitioners, government agency scientists, and NGO representatives had made the importance of transparency and interpretability clear.

Gaps

Developing the concept

The development of the concept for the gaps analysis was quite serendipitous. I first intended to investigate "gaps" in management to address the lack of coordination between overlapping agencies. Although this aspect of overlaps still lies within the investigation boundaries of my dissertation, I hit on an

[5] See Feldman and Sanger (2007)

alternative concept of a *gap* particularly useful in the context of ecosystem-based management. The idea came from reading theoretical institutional literature (Young 2002), the Pew Oceans Report (2003), the US Ocean Commission Report (2004), and the transcription from my dissertation oral exam. At the crux of gap analysis is the notion of a "gap" as merely the absence of something that should exist. Statements by EBM proponents illuminate particular aspects not covered by existing management practices as a result of a sector-based approach:

> *"The goal of EBM is to maintain the health of the whole as well as the parts. It acknowledges the connections among things,"(Pew Oceans Commission 2003)*
>
> *"EBM looks at all the links among living and nonliving resources, rather than considering single issues in isolation . . . Instead of developing a management plan for one issue, . . . EBM focuses on the multiple activities occurring within specific areas that are defined by ecosystem, rather than political, boundaries," (USCOP 2004).*

The research clearly indicates that decisions need to be made that acknowledge the connections within any given ecosystem. Two questions arose from this line of reasoning:

- Could text analysis of the laws reveal the failure of management to acknowledge ecosystem linkages?

The definition of a *gap* for the purposes of my dissertation became "a critical linkage in the ecosystem that is unacknowledged by management." I use laws to represent management at its apex, providing the equivalent of a high altitude aerial view of institutions in place with responsibility for the upkeep of resources. Ideally, this analysis can and will be extended to other types of management documents such as court cases, management plans, budget allocations, and meeting transcriptions, giving pictures of management at different resolutions and from different angles.

When exploring the utility of the advanced text analysis techniques, I began conducting experiments to test the accuracy of the relative results for cluster output and raw term frequency for finding gaps in law. I determined that the clustering and LSA algorithms yielded inaccurate information for my purposes. (Cluster data actually reflected more documents than pertained to the topic of interest.) It may prove valuable in the future to delve further into the more advanced techniques. The raw term counts, however, proved surprisingly useful for the purpose of establishing a baseline of gaps and overlaps. In keeping with the project goal of incorporating EBM, the algorithm constructed to investigate gaps used an ecosystem model (with linkages among components) to determine which of the modeled linkages were missing in the relevant law.

Assessment

I validated the basic approach with practitioners in academia, government agencies, and non-governmental organizations. I presented the gaps concept in a series of meetings, and quickly learned that the basic idea matched the concerns and interests of a wide variety of ocean management stakeholders, especially those working to implement EBM. Not only did I build confidence in the trajectory of my research but, with each meeting, I learned how to communicate the research problem more articulately.

To maximize the value of the meetings, I tailored the articulation of the problem and the method to find gaps based on relevancy for the stakeholder. For example, stakeholders interested in the institutional "big picture" appreciated an explanation of the theoretical basis of the analysis. These individuals responded positively to a discussion of the fundamental problem of fit, which is the concept that management systems "should fit properties of the ecosystems with which they interact" (Young 2002). Stakeholders with an ecology background value the use of matrices to represent ecosystem components and linkages. Stakeholders' questions and critiques guided me at every stage (Figure 2.1) because I made it a point to integrate their feedback into both the way I performed the analysis, and the way I presented the material. Notably, in fall 2007, my use of the matrix containing different types of components (species, habitat, and stressors), puzzled a few interviewees. Reorganizing each ecosystem component into a series of categories helped me explain what the ecosystem model matrix represented. This new organization of categories also helped me further synthesize results of the gaps analysis and address the major criticisms from agency and NGO personnel about the need to synthesize the results I received in summer 2007. (I refer to this method of categorical synthesis as "block-based" analysis in the case study presented in Chapter 7 on gaps in governance related to ocean acidification.)

Discussions with my committee member Dr. Steve Gaines, spurred my exploration of statistical methods that could be applied to this technique. As recommended by an ecosystem network analysis expert, I began by measuring the correlation between my two networks (ecosystem and legal) and then tested the significance by running the correlation against multiple random matrix permutations. After further investigation, I discovered that ecologists and geographers refer to this common technique as the Mantel Test, and in social networking analysis it is the Quadratic Assignment Procedure (QAP). Since my networks did not represent spatial data, I use the term QAP to describe this metric of my gap analysis. Fortunately, social network analysis software (UCINET) provided this statistical test with a user defined number of random permutations (Borgatti et al. 2002). The QAP correlation measure essentially represents the degree to which the linkages modeled in the ecosystem match up to language in the management documents.

Besides the correlation, I developed another metric, "G", to indicate how many modeled links were absent in the law compared with the ecosystem model. In addition to revealing missing links, the G metric also indicates misfit between the modeled ecosystem linkages and the laws. This second metric is a ratio of legal gaps to modeled links, enabling the comparison of the "degree of misfit" between laws and an ecosystem across various ecosystem models and across various geopolitical jurisdictions.

After more meetings and interviews with stakeholders, this method of analysis did not alter substantially. Indeed, it prompted many ideas for future applications. Feedback emphasized a need to look at other management documents such as court cases, local law, tribal law, meeting transcripts, and agency or area management plans and to use synonyms and phrases to represent ecosystem components. Analyses incorporated this feedback in the later analyses. Several interviewees suggested that I could expand my analysis to present solutions rather than just defining a problem. This could be achieved through analyses tailored specifically to identify how to filling the gaps (through what laws and through what agencies), such as is demonstrated in Part B of the Case Study about ocean acidification (Chapter 7).

Overlaps

Concept development

The development of the overlaps analysis went through a series of changes in response to stakeholder feedback. More abstract than the concept of gaps, the definition itself of overlaps changed several times. Initial explorations included simple term counts to compare the involvement of various laws. Using analysis of the counts, I then ran an exploratory clustering analysis to test the utility of kmeans clustering and vector space modeling to identify and measure overlaps. This exploration was based on the assumption that the terms most frequently referenced in a cluster of documents represented accurately the most frequent words of each document in the cluster. I then measured similarities among sections using "pairwise distance (with cosine)," a common text analysis procedure (Baeza-Yates and Ribeiro-Neto 1999, Feldman and Sanger 2007). Theoretically, taking the most similar sections derived from different source documents should have revealed potential cases of redundancy. Although this technique will likely be investigated in the future using more powerful applications, the vector space modeling and clustering were not sufficiently accurate for purposes of this dissertation. Seeing the complexities arising, I had to step back and reassess the concept of overlaps and its significance to institutional interplay.

As with the gaps analysis, I returned to the simple raw term counts. Through interviews in summer 2007, I received feedback on progress. Each scientist, lawyer, and government agency member interviewed clarified that although the problem derived from overlapping laws, the real problem involved which agencies overlap through which laws and whether or not agencies coordinate with one another. Following this line of inquiry, I generated an "agency-authority-to-laws" table by reading through every law and regulation in the collection to determine the agency authority. I followed the methods of the NOAA Coastal Services Center Digital Legislative Atlas as NOAA had conducted a similar exercise for the federal statutes (pers. comm. Hamilton Smillie).

Adding the agency dimension to the overlaps analysis prompted a lot of favorable feedback. The next set of interviews showed that inclusion of the agency dimension made the results more tangible and explicable. I experimented with various metrics and diagrams to display the information, finding that "agency-to-law" diagrams where the law nodes were resized by frequencies of topic (e.g., "fish") were easiest to interpret. Chapters 5 and 6 discuss in more detail the current form of overlaps analysis and its benefit in generating a visual baseline of where and to what degree agencies overlap on a given issue. The overlaps output does not distinguish between positive and problematic overlaps nor does it reveal where coordination actually exists over ecosystem components for which each agency has some responsibility. The aim, however, has not been to tease out specific problems of agency coordination. The purpose instead has been to provide a map for further investigation of these questions. For example, baseline data can be used to locate where (among which agencies) coordination should occur, or to highlight agencies involved in management of certain activities and resources – both functions in high demand by the practitioners and researchers I have encountered. Policy-makers could benefit from the use of such data in law revision and making to remove and prevent redundant and conflicting regulations and mandates.

Testing

I interviewed over fifty stakeholders to develop the analyses. Some stakeholders assisted with statistical and ecosystem modeling, but most challenged me to fine-tune the concepts and research questions in order to make the results useful and reflective of information needed by practitioners. I chose contacts through "snowball sampling" (word of mouth suggestions from other experts with whom I spoke). Others I met at conferences, where I presented preliminary information from my investigations. Some found me through either my project website (http://www.cclme.org) or through recommendations from individuals familiar with my research. I am grateful to all those who met with me in person and on the phone.

The cycle of designing the analysis, testing the results with stakeholders, redefining the problem based on feedback, adjusting the analysis, and retesting the results with more stakeholders was potentially never-ending. My committee and I had determined that two revolutions of this cycle were necessary for the dissertation. The practice proved so valuable, however, that I went through many more testing cycles, sometimes casually over the phone, sometimes assisted by an explanatory PowerPoint presentation. I performed two series of interviews in the Pacific Northwest using Puget Sound as the basis for the conceptual ecosystem model. After the first testing series, I made major changes to the overlaps analysis. I integrated the feedback from the fall 2007 meetings into discussions of my dissertation, and included my findings in my recommendations for future work.

Challenges to testing

The main challenge to ground-truthing results lay in identifying the appropriate people to interview. Notably, in most meetings, the issue of problem definition dominated rather than the analysis of the results. I realized that this occurred in the instances where I failed adequately to define the problem or present the data. Interviewees with a vision of the larger picture across agencies, as well as those with some knowledge of ecology, tended to provide the most useful feedback. In general, those most critical of the problem definition and text analysis methods provided the most valuable feedback. I continue to learn how to best explain and present the data to different types of audiences based on their management, legal, and science expertise. So far, my presentation of the concept, methods, and results has produced an overall positive reception. It seems possible that they could indeed serve as a unifying tool for integrating management across sectors and agencies toward more strategic and cooperative relationships and policy-making.

CONCLUSION

The concepts developed for this project were not solely my own creation. My committee's expertise, the NCEAS working group discussions, statistics and computer programming knowledge, as well as advice from academic sources, and NGO and government agency experience were all instrumental in leading me to the concept, techniques and conclusions presented here. I am grateful for the opportunity to work with outstanding professionals from various disciplines and management sectors, all of whom have contributed elements essential to this dissertation.

Chapter 3 Dataset of Ocean Law

INTRODUCTION

Historically, uses of the marine environment has been managed within individual sectors, such as transportation, mining, and fishing (USCOP 2004). Coupled with increased uses, this fragmented approach has led to inconsistent management and a lack of coordination across political jurisdictions and between sectors (USCOP 2004, Kildow and Colgan 2005, Crowder et al. 2006). Ecosystem-based management can help alleviate environmental problems caused by this piecemeal approach (McLeod et al. 2005). But to operationalize this concept, place-specific legal overlaps and gaps must be better identified and measured. Recognizing the need to navigate through the complex ocean management, this paper presents a unique dataset that makes the exploration and construction of objective analyses of ocean laws possible across multiple jurisdictions and between sectors.

This chapter first emphasizes the need for an ocean law database. The following section summarizes text analysis efforts, especially with application to law. The Methods section discusses how I assembled the dataset. The Results section presents summary statistics about the dataset. The Discussion offers suggestions on developing techniques to measure and identify problems of fragmentation.

Need for an ocean law database

The time to rigorously and comprehensively assess problems in ocean management is long overdue. The Stratton Commission in 1969 recognized that fragmented ocean management threatened marine ecosystem health and resources (Stratton Commission 1969). Over two decades later, the US Commission on Ocean Policy Report (2004) and the Pew Ocean Commission Report (2003) reassessed ocean management and found the same problem, but with the oceans in a more dire condition.

Fragmented management

Management has not sufficiently adapted to the rapidly increased ocean uses. As a result when one ocean-related industry makes a decision, it can result in unintended negative consequences for other sectors (Young 2002). For instance, the shipping and transportation sector needs to regulate collision prevention, response to hazardous spills, traffic lanes, and port facilities as critical management components (USCOP 2004). Over time, this sector's activities have impacted and will increasingly continue to impact other marine-related uses, such as recreation, mining, and fishing. For example, impacts to the fishing sector occur when estuarine habitats are degraded by the dredging done to maintain shipping channel depth. This practice jeopardizes spawning and nursery habitat for commercially important species. The inter-relationships between sector-based activities and ecological systems must be managed comprehensively (Kennish 1992) with a body of regulations that take into account the linkages between the appropriate components (Imperial and Hennessey 1996).

Ecosystem-based management (EBM) is one approach to lessen detrimental impacts on the coast and oceans in the United States (Pew Oceans Commission 2003, USCOP 2004). However, the implementation of EBM requires alleviating the fragmented nature of ocean management by coordinating management decisions within and between levels of government (Underdal 1980, Slocombe 1993, Imperial and Hennessey 1996). Critical questions about problems in ocean management cannot be quantitatively answered without a comprehensive dataset that embodies how marine-related uses, activities and resources are managed. Quantitative evaluation could complement qualitative in-depth investigations to provide a better understanding of the extent of fragmentation in ocean management.

Opportunity for Ecosystem-Based Management

We are in an opportune time to confront and resolve problems of fragmentation. Unbiased, objective analyses of gaps and overlaps in management are essential to realizing this goal if people are to move forward in implementing EBM. It is most reasonable to begin with the laws that are used to guide and regulate use and abuse of ocean and coastal related activities. A manageable database containing all ocean-related laws for a given area is needed to begin developing techniques that quantitatively, objectively and comprehensively identify gaps and overlaps.

The collection and summary of a dataset composed of law that will allow us to start answering critical questions about fragmented ocean management. While the statutes and regulations only represent the formal institutions for how a resource or activity is managed, their compilation can provide a dataset that crosses sectors and geopolitical jurisdictions to represent governance of oceans as a whole.

Text analysis

Text analysis can provide a useful method in many disciplines to quantify relationships between documents. The recent immense growth of digital data requires more intelligent techniques to make sense out of the available information. Thus, much of the innovation in text analysis has occurred within university computer science and statistics departments, as well as technology-based companies. These researchers have strategic interests in perfecting data mining and information retrieval algorithms and technologies. Classic document analysis techniques use keyword or term frequency counts to identify relationships among documents (Baeza-Yates and Ribeiro-Neto 1999). More recently, structure has been woven into some content analyses (Wan and Peng 2005, Lau et al. 2006). Document analyses usually include probabilistic modeling, Boolean modeling, or Vector Space Modeling, all of which use keywords or index terms to represent each document in a given collection. The Boolean and probabilistic models only assign binary weights to index terms so that measures of similarity may result in either *similar* or *different* output to quantify relationships between documents. Conversely with the Vector Space Model, index terms in documents are assigned non-binary weights and each document is represented by a vector of term counts. This allows varying degrees of similarity between documents to be measured (Lau et al. 2006).

At the core of these analyses is a *term-document matrix*, which organizes terms in a table according to the frequency with which they occur in each document (Table 3.1). This type of matrix can be generated for a collection of text documents using Matlab®. Drs. Dimitrios Zeimpekis and E. Gallopoulos from the University of Patras in Greece provide a free add-on Matlab toolbox (Text to Matrix Generator) that generates a term document matrix and term-list dictionary for a collection of documents (Zeimpekis and Gallopoulos 2006). Users can choose local and global weighting schemes, remove common words from the matrix, and rely on term stemming to create the index of terms (using Porters Stemming Algorthim).

Table 3.1. Example of a sample term-document matrix. Cells represent the raw term frequencies for each document.

	crab	estuary	fishery	kelp	lobster	mussel
Document 1	2	1	6	0	1	0
Document 2	0	0	0	1	0	0
Document 3	0	3	2	0	0	6
Document 4	0	0	6	0	0	0

Resolution of text analysis

Text analysis is often performed on elements derived from larger documents (Krippendorff 2004, Zeimpekis and Gallopoulos 2006). Increasing the granularity of a set of documents enables a higher resolution of analysis (Krippendorff 2004). Documents are typically divided based on structure or size. For example, a corpus of text from a book may be divided into chapters, paragraphs, or sentences for more detailed analysis (Krippendorff 2004).

DigIn software, a product of EvResearch, formed the basis of my work as a Research Assistant on the construction of the digital library from the Marine

Mammal Commission Compendium. DigIn allows a user to divide documents into pieces of any size based on the formatted structure of a document or set of documents that is constructed in a parallel manner. After dividing the document the software renames all new pieces by adding a chronological numeric suffix to the original document name. With the Digin *Pro* version, a user writes a regular expression (code written to identify a pattern, such as that for a section heading, for the program to find (Friedl 2006)) to divide individual or sets of documents into sections. This allows the dividing of a diversely structured set of statutes and regulations (Berkman et al. 2006). I used DigIn software, license kindly donated by EvResearch, LTD to divide my compilation of ocean and coastal laws.

Text analysis applied to problem of fragmented law

Document analysis is useful to answer questions about fragmented management because it facilitates identifying and measuring certain types of relationships between the terms within the laws. The enormous (and growing) number of law texts has caused informational retrieval problems and inconsistencies in implementation in domains beyond the oceans, such as construction (Lau et al. 2006) and urban housing development (Koschinsky and Swanstrom 2001). In fact, an entire discipline is devoted to addressing this problem (International Association for Artificial Intelligence and Law). *Legal informatics* combines legal expertise with information technology and a variety of text analysis techniques, focusing on the needs of lawyers, managers, policy-makers, and the public.

For example, the Engineering Informatics Group directed by Dr. Kincho Law at Stanford University is conducting research to address problems caused by U.S. federal and state business domain law. Their project focuses specifically on untangling fragmented laws in the domains of business management and water quality (Lau et al. 2006). With comparable proposed outcomes, this dataset can contribute to identifying and quantifying the current inefficiencies of U.S. and State laws regarding marine regulation and management.

METHODS

Methods to create a database of ocean and coastal related laws relevant to the northern California Current LME are presented in this section. The following steps taken to create this dataset: 1. determine and collect useful set of laws; 2. divide documents into consistent elements; and 3. finally, generate term-document matrix to use for queries and text analysis (Figure 3.1).

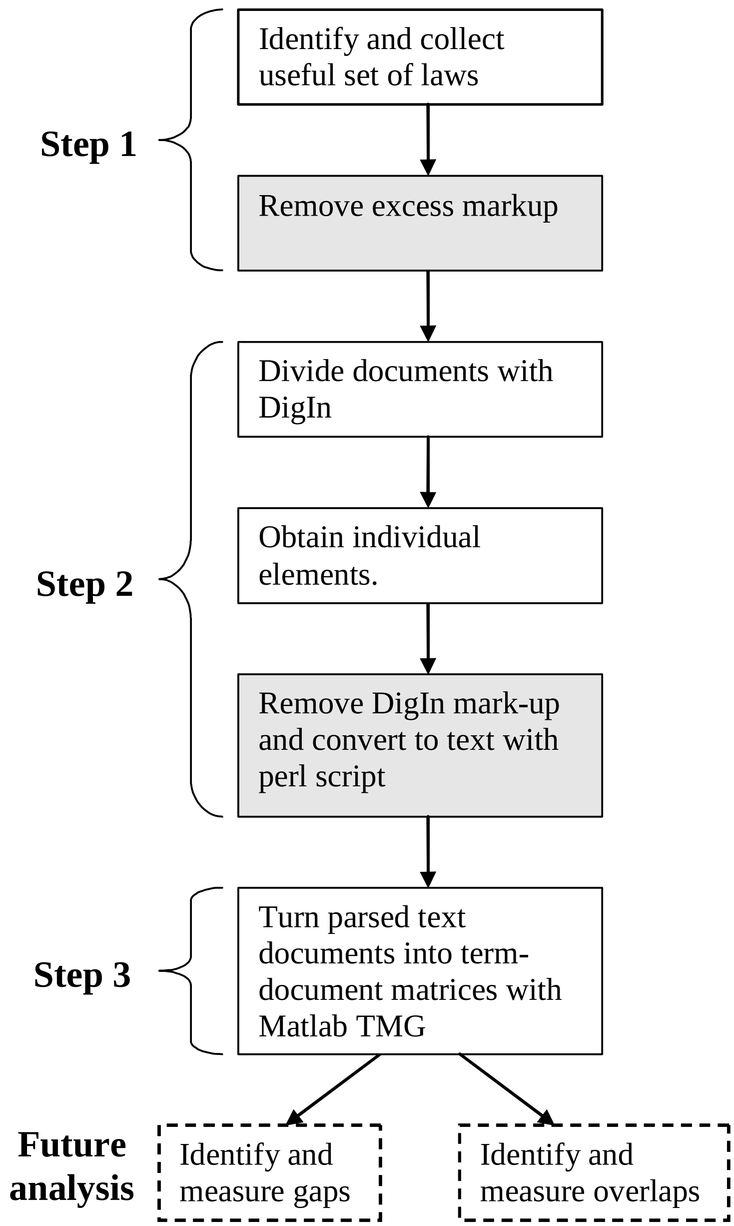


Figure 3.1. This figure illustrates the steps taken to create the dataset of laws. Gray boxes indicate necessary text cleaning stages. Step 1 included selection and collection of documents, for which necessary cleaning was performed to remove markup. Step 2 entailed divided documents into legal sections (referring to as "elements"), which were then cleaned for markup. Step 3 required parsing the term frequencies from the text of each element, generating a term-document matrix for data analysis. Future analyses (in dotted boxes) included developing algorithms to identify and measure gaps and overlaps using this dataset as a test bed.

Determine set of document collection

Choosing the set of laws first required identifying and applying a set of criteria. 1. geographic scope, 2. scale of social organization, and 3. type of document. Collecting within the defined criteria will produce a consistent collection of laws that can be examined quantitatively to answer fragmentation questions relevant to national and state levels, as well as between jurisdictions.

Geographic scope

In terms of geographic scope, these documents must have power or influence over managing the activities that affect resources in the California Current Large Marine Ecosystem. To improve management of the marine environment, the international organizations, and national and state governments have adopted the large marine ecosystem (LME) concept. On the magnitude of 200,000 km^2, LMEs "are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves, enclosed and semi-enclosed seas, and the outer margins of the major current systems," (Sherman 2005). LMEs spatially cover the most economically, politically, and ecologically important portions of the oceans worldwide (Wang 2004).

The California Current Large Marine Ecosystem consists of one of the most well-documented marine ecosystems in the world (Lluch-Belda et al. 2003). Located from the Washington State-Canada border to just south of Baja California, the California Current LME extends seaward to approximately 300-600 nautical miles from the continent (Figure 3.2).

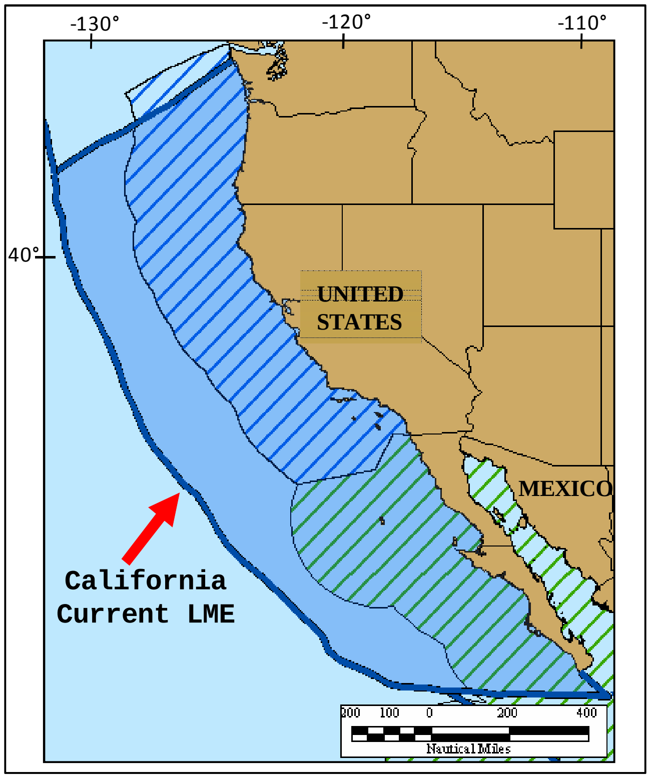


Figure 3.2. California Current LME. The solid line in the Pacific Ocean represents the boundary of the California Current LME. The blue hatching is the Exclusive Economic Zone (EEZ) of the United States, and the green hatching is the EEZ of Mexico (GIS data from University of Rhode Island for LME, NOAA Coastal Services Center for U.S. Exclusive Economic Zone, and Marine Conservation Biology Institute for Mexico Exclusive Economic Zone).

Political jurisdictions for this area include international policy, United States and Mexico national laws, as well as State laws from Washington, Oregon and California. Mexico's marine waters are under the jurisdiction of the federal government (Rivera-Arriaga and Villalobos 2001); therefore, no Mexican state laws were compiled for this project.

Scale of social organization

The second criterion was that the laws are limited to national and state levels. The inclusion of additional levels of management, such as county, regional, and city, would provide a finer scale of analysis, but there are thousands of localities within the geographic scope. Therefore, due to time constraints, it was not feasible to identify and gather laws from the smaller-scale jurisdictions.

Type of law

The third criterion was that laws must be codified statutes or administrative code (regulations) for state and federal levels. Codified versions of laws were used because these are the most accessible. Additionally, the publicly accessible digital format for each relevant jurisdiction is updated regularly. The aim of this collection was to gather relevant laws for one point in time, for which codified laws were the most appropriate. For documents at the international level, this criterion included treaties, agreements, or other relevant documents that are part of the Marine Mammal Commission Compendium (Wallace 1996). The specific routine used to collect for each jurisdiction is presented in the Results section.

Dividing laws into legal sections

The hierarchical structures in which the laws are codified vary. For example, the U.S. Code hierarchy includes Title/Chapter/Section, and *Chapters* were collected. The California Code of Regulations hierarchy includes Title/Division/Chapter/Section, for which *Division* was collected as the source document. Table 3.2 shows each jurisdiction's hierarchy, legal database web address and partition collected for text analysis. The larger partition was compiled to ensure compilation of any potentially relevant context that surrounds individual ocean-related sections.

Table 3.2. Hierarchy of codified laws for each jurisdiction pertaining to this study. Bold capitalized text indicates the level at which the law was collected (aka "source document"). These source documents were then divided into smallest consistently used unit of legal sections for text analysis (also referred to as "elements", see Figure 3.3).

Scale	Geopolitical jurisdiction	Law type	Codification hierarchy	Compiled document (Statutory/ Regulatory Unit)
National	Federal United States law	U.S. Code (statutes)	Title/Chapter/Section	Chapter
		U.S. Code of Federal Regulations	Title/Volume/Chapter/ Part/Section	Part
	Federal Mexico law	Ley	Ley/Section	Ley
		Regulaciones	Regulación/Section	Section
State	State of Washington	Revised Code of Washington (RCW)	Title/Chapter/Section	Chapter
		WA Administrative Code (WAC)	Title/Chapter/Section	Chapter
	State of Oregon	Oregon Revised Statutes (ORS)	Title/Chapter/Section	Chapter
		Oregon Administration Rules (OAR)	Chapter/Division/Section	Division
	State of California	California Code	Code/Division/Chapter /Article/Section	Article
		California Code of Regulations	Title/Division/Chapter/ Section	Division

Laws within the scope of this project shared the structure of *sections* as the smallest cohesive elements of law (Figure 3.3). I used DigIn Pro software to divide the large partitions of laws (referred to as *source documents*) into legal sections.

Each source document was divided into sections so the structural composition of the collection would be consistent. Because each jurisdiction's laws were written in a different format, I wrote regular expressions for each jurisdiction.

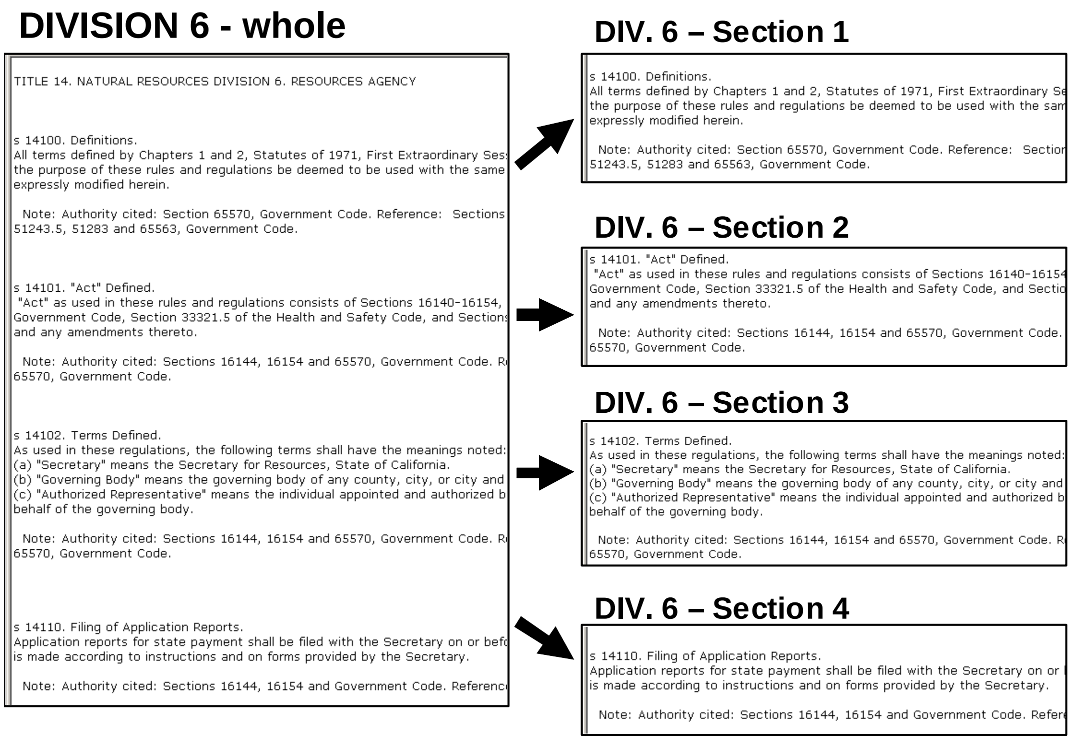


Figure 3.3. This diagram demonstrates the concept of dividing law documents, such as divisions (referred to as *source documents*), into smaller consistent sections of law (referred to as *elements*) for more revealing text analysis.

Generate Term-Document Matrix from law collection

To begin the text analysis, the sections of law collected from the U.S., Washington, Oregon and California were fed through the Text Matrix Generator in Matlab (Zeimpekis and Gallopoulos 2006), which produced a dictionary of all unique terms in the collection and then generated weighted term frequencies for each document. Common words were also removed using a stop list provided in the TMG toolbox. Terms were stemmed so that words such as "crab" and "crabs" were counted as the same term. In addition, the TMG toolbox allowed a user to easily change options without running through the entire two hour process. This gives the capability to compare how options, such as local and global weightings, affect the dataset. The results provide summary statistics about the term-document matrix, including a summary of the document sizes. Furthermore, results present summaries of the term frequency data to emphasize the future use of various weighting schemes for analysis of ocean management questions.

Error proofing

The large size of the dataset, coupled with the multi-step process, provided ample room for manual or systematic error in generating the term-document matrix. Once the term-document matrix was built in Matlab, I proofed the dataset for the following errors: duplicate source documents in the system, duplicate elements in the system, and misnamed source documents (e.g. space in the name, multiple periods in name). In addition, I tested the term-document matrix and associated metadata to ensure that there was associated source document metadata for each element. Also, I tested to make sure that all source documents in the metadata had associated elements in the collection.

To test for these potential errors, I exported the term-document matrix arrays as text documents and imported them as tables into a Microsoft Access database. Appropriate relationships were drawn between the tables so that I could run queries for each type of error (Figure 3.4). The most frequently occurring error was the mismatch between the elements and the source documents collection. Once discovered, the missing elements were generated from associated source documents and added to the system. The following results present the cleaned and error-proofed data.

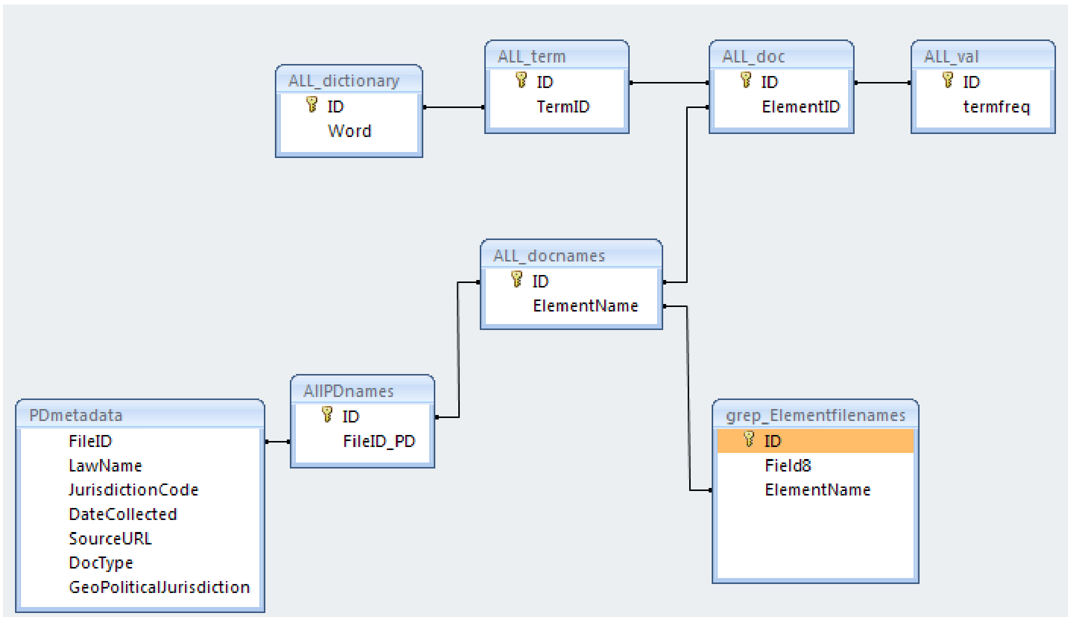


Figure 3.4. Architecture of database used to verify whether all the documents in the term-document matrix were accounted for in the metadata (and whether all the documents in the metadata were accounted for in the term-document matrix). Tables were exported from Matlab into Microsoft Access and relationships were drawn between each to check for errors between the dataset constructed in Matlab with the metadata tables.

RESULTS

A combination of informal interviews (to collect expert opinion), manual copy and paste, DigIn, perl script, and Term Matrix Generator in Matlab was used to generate the dataset. The results are presented as follows: (1) a description of laws gathered for each jurisdiction; (2) results of dividing laws into sections; and (3) summary statistics of the end goal term document matrix,

Law compilation

Digital versions of laws were manually collected for the international, national, and state level of the California Current LME, including laws from Washington, Oregon and California, as well as national level laws of the United States and Mexico. In additional, relevant international agreements and conventions were compiled. The identification and collection of this corpus was conducted from November 2005 through November 2006.

United States Federal

I used the list of marine laws from the NOAA Coastal Services Center's Digital Legislative Atlas to determine the United States Code portion of the document collection. These documents were downloaded off the internet from the U.S. Office of Law Revision. The national regulations were chosen from the Federal Code of Regulations with a search on "marine" and "ocean." There were 669 Parts that met the collection criteria.

California

To select the California State portion of our collection, I used a list of codified statutes produced by Jonathon Gurish for the Ocean Protection Council, which identified relevant codified statutes to the ocean and coast for the State of California. I gathered these documents from the California Code website (http://www.leginfo.ca.gov). To determine relevant California regulations, I searched the administrative code using the terms "marine," "ocean" and "coast" on the California Code of Regulations website (http://www.oal.ca.gov/). The California

Code of Regulations that contained one or more occurrence of these terms was marked for collection.

Oregon

Oregon Revised Code relevant to this project was identified through the updated list in the Oregon Territorial Sea Plan. Additionally, I searched for "marine," "ocean" and "coast" on the Oregon Revised Statutes website (http://www.leg.state.or.us/ors/). To determine the relevant Oregon regulations, the Oregon Administrative Code was searched using "marine," "ocean" and "coast" (http://arcweb.sos.state.or.us/banners/rules.htm).

Washington

Applicable Washington codified statutes were determined by searching "marine," "ocean" and "coast" on the Revised Statutes of Washington website (http://search.leg.wa.gov/pub/textsearch). To identify the pertinent State regulations, I searched the Washington Administrative Code using "marine," "ocean" and "coast" (http://apps.leg.wa.gov/wac/).

I skimmed each section individually to determine whether the term "marine" referred to the ocean or to rights associated with individuals involved with the U.S. Marines. The latter were discarded from the collection list. The remaining sections were collected within their larger partitions (Table 3.2).

Mexico

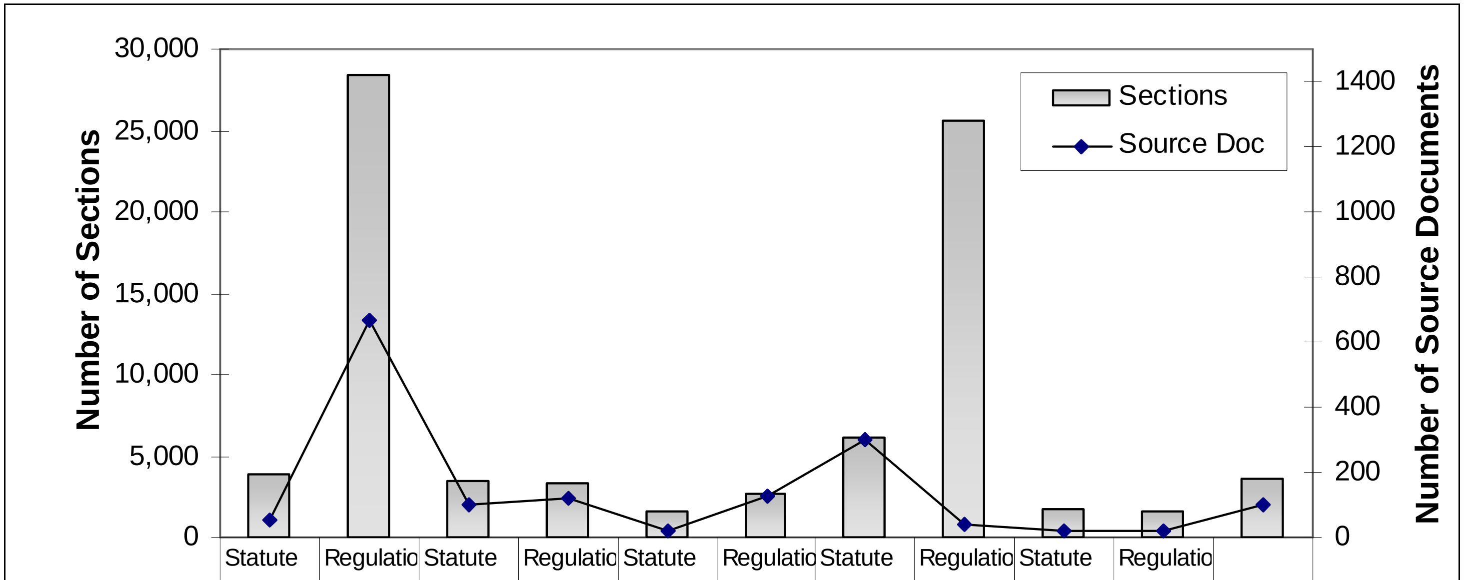
For the Mexico laws the terms "mar" "costa" "marina" and "navegación" and "Pacifico" were searched. These statute and regulation documents are downloadable in full document form from the internet (http://www.disputados.mx.gob).

Dividing source documents into law sections

For text analysis pre-processing, generating the smallest unit consistently used across jurisdictions required preparing the document collection at the scale of section. I used Digin Pro software package to divide source documents in the smaller legal sections to prepare for text analysis. For the majority of laws, the regular expressions had to be written for individual documents due to slight inconsistencies in the structure of many laws.

The resulting collection of laws included United States (federal), Mexico (federal), California, Oregon, and Washington codified statutes and regulations, and international agreements, totaling 1,567 source documents (unprocessed) which divided into 82,163 sections (Figure 3.5).

Figure 3.5. Number of codified statutes and regulations gathered for each jurisdiction. Black dots show number of source documents (scale along secondary y-axis). The bars show number of sections the divided source documents produced (scale along primary y-axis).



	UNITED STATES Statute	UNITED STATES Regulatio	WASHINGTON Statute	WASHINGTON Regulatio	OREGON Statute	OREGON Regulatio	CALIFORNIA Statute	CALIFORNIA Regulatio	MEXICO Statute	MEXICO Regulatio	XNAT'L
Sections	3,907	28,409	3,522	3,391	1,593	2,654	6,166	25,644	1,692	1,579	3,606
Source Doc	56	669	103	120	18	129	297	41	17	17	100

Data cleaning

With the complete, divided collection, a Perl script was written to convert the newly divided laws into ASCII text format. The dividing process introduced markup material into the element itself, occurring in three forms: html tags, header tags, and hyperlinks. The Perl script addressed this as part of the conversion to ASCII text.

Due to unforeseen formatting and translation complications, international agreements and Mexican laws were not included in processing past this cleaning phase. However, with only the national United States federal and state laws, the fully processed portion of the collection represents the northern sub-region of the California Current LME.[6] This portion included 75,286 sections of law.

Term-Document Matrix of law collection

Text Matrix Generator Specifications

To create a term document matrix, sections of law from the U.S., Washington, Oregon and California were fed through the Text Matrix Generator in Matlab. This produced a dictionary of all unique terms in the collection and then generated term frequencies for each document (Zeimpekis and Gallopoulos 2006). Table 3.3 presents the optional specifications chosen, such as the removal of common words using a stop list provided. This produced a matrix composed of documents (elements, sections of law) by stemmed terms, which contained the occurrences of all terms for each section of law in the collection.

---

[6] It is anticipated that this deficit will be addressed in the future by processing through Java applications.

Table 3.3. Table of specifics from the Term Matrix Generator toolbox in Matlab (TMG).

TMG options	Specifications
Stemming	Yes
Local weight	Yes (term frequency)
Min length	3
Max length	30
Min local frequency	1
Max local frequency	Infinite
Min global frequency	2
Max global frequency	Infinite
Normalization	No
Remove common words	Yes, (list of 421 terms provided by TMG)

The TMG produced the following output to summarize the dataset:

Number of documents = 75,286
Number of terms = 33,347
Average number of terms per document (before the normalization) = 310.609
Average number of indexing terms per document = 158.261
Sparsity = 0.182218%

Removed 421 stopwords...
Removed 21568 terms using the stemming algorithm...
Removed 989 terms using the term-length thresholds...
Removed 30194 terms using the global thresholds...
Removed 0 elements using the local thresholds...
Removed 0 empty terms...
Removed 68 empty documents...

Summary Statistics – Documents

There was a high range of words per document in the collection. After the removal of common words, the smallest element contained one word, and the longest document contained 152,447 words. However, the mean was 307.6, median was 117, and the mode was 18 words per document. The TMG toolbox identified 68 documents as empty because they only contained common words and numbers, both of which the toolbox removed, and thus omitted the empty documents. Because the standard deviation was so high (1348), quartiles were measured. These quartiles showed that 75% of the collection had 273 or less words per document. The box plot demonstrates the quartiles (Figure 3.7). The plot reveals that 50% of the data are between 50 and 273 words per document, producing an interquartile range of 223. The upper whisker is much longer than the lower whisker (note the Y axis is logarithmic scale to show the entire plot). The extreme values (outliers) are all above the upper whisker, reaching over 100,000.

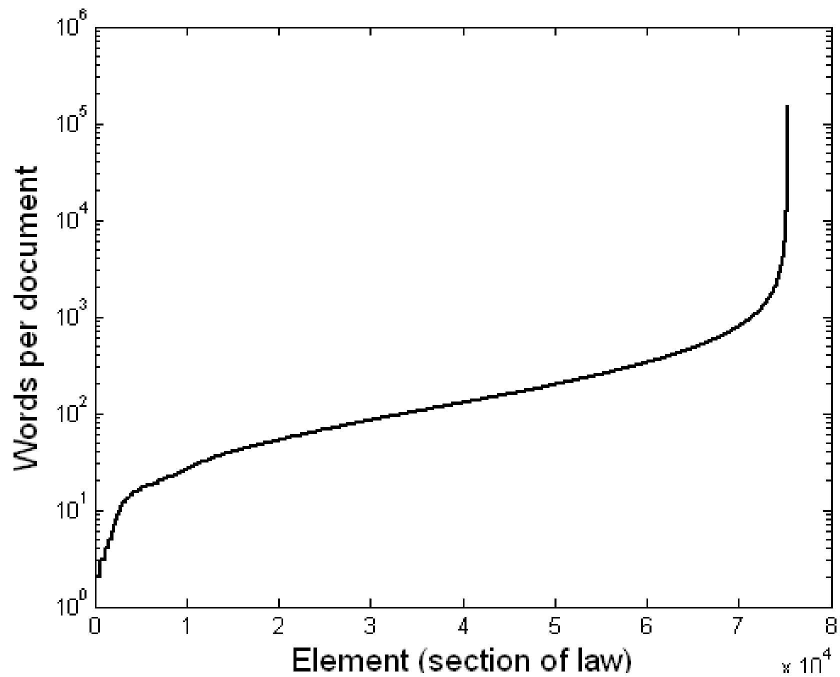


Figure 3.6 Words per document (legal section). Plot illustrates sum of words per section. Note the Y-axis scale.

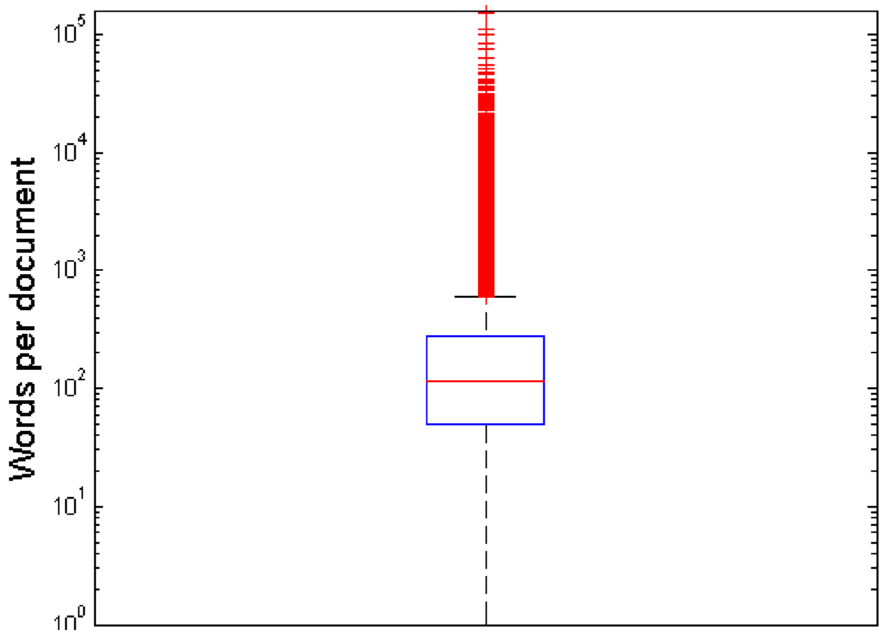


Figure 3.7 Box plot of the distribution of words per document. Note the Y-axis scale.

Table 3.4. Elements (documents, legal sections) per term.

	Words per document
Min	1
Max	152,447
Mean	310.6
Median	117
Mode	18
Std	1348
Range	1.52e+05

Quantiles for WPD
25% 50
50% 117
75% 273
97.5% 1647

Summary Statistics –Terms

According to the global frequencies of terms within the law collection, the majority of terms were relatively rare among the laws (Figure 3.8). Similarly, document frequency per term demonstrated that the majority of terms occurred in a small number of the laws (Figure 3.9). The box plot of quartiles in Figure 3.10 showed that 75% of the terms appear in 19 or less sections of law in the collection. The middle two quartiles (25% to 75% of the terms), which have a more representative distribution of the document frequencies, reveal that each of these terms occurs in only 3 to 20 sections of law. The high variability of term frequencies throughout the collection suites well for the application of weightings to the raw frequency counts. Various weightings, such as inverse document frequency and other global weightings should be explored in any future vector space modeling applied to this dataset.

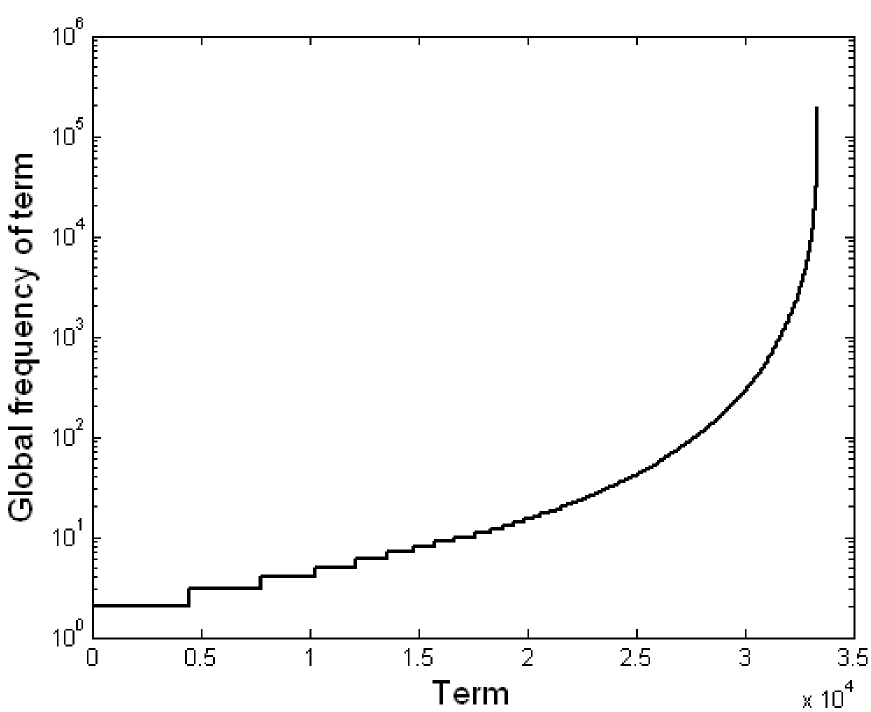


Figure 3.8. Law collection term frequencies. Note the Y-axis scale.

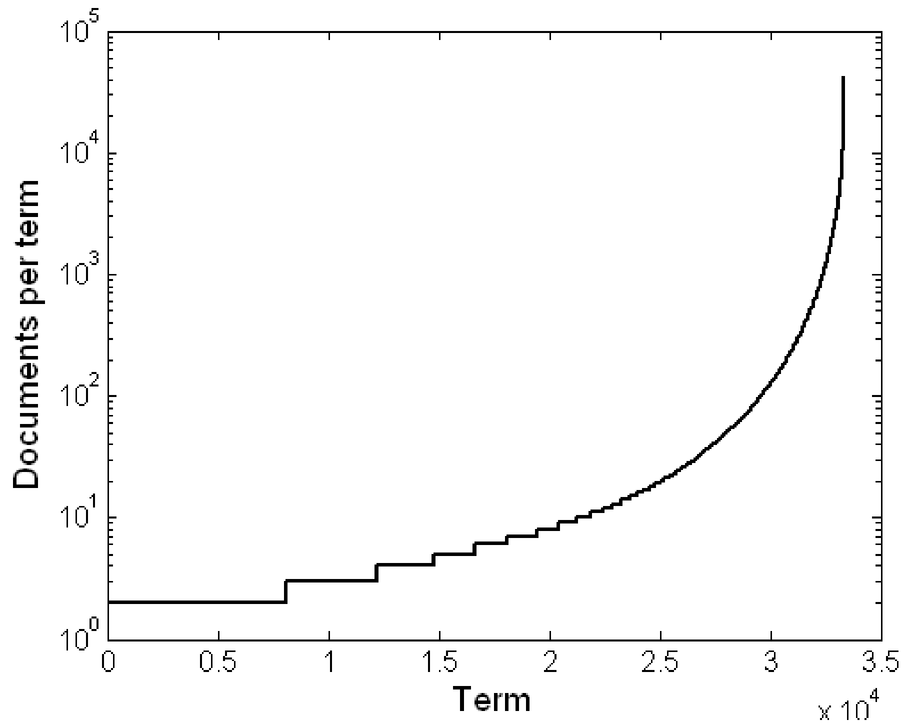


Figure 3.9. Number of documents containing each term. Note the Y-axis scale.

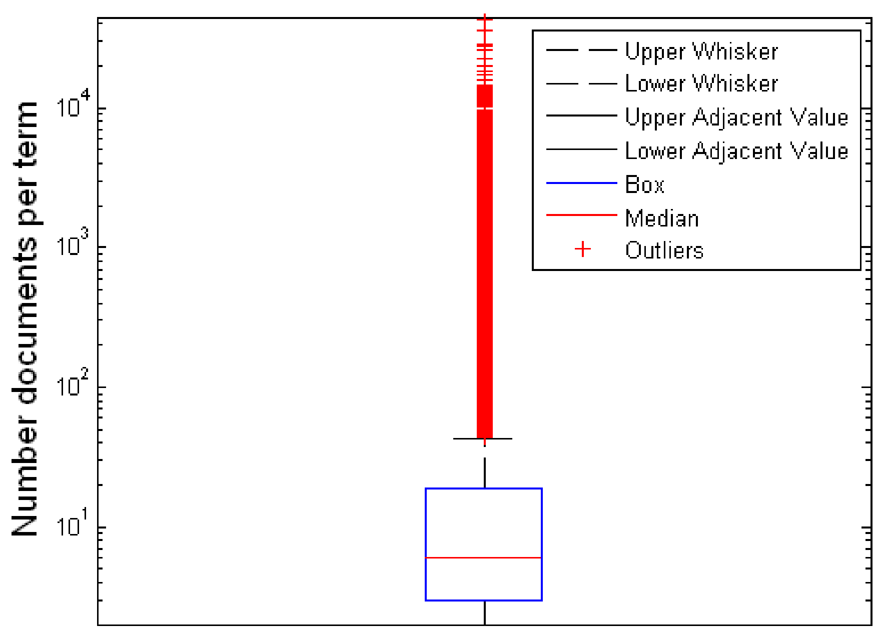


Figure 3.10. Box plot showing the distribution of term frequencies for collection. Note the Y-axis scale.

Quantiles for documents per term box plot.

25%	3
50%	6
75%	19
97.5%	1155.3

To present the summary statistics of this dataset, I documented the most frequently occurring terms in the collection. First the Top 20 stemmed words ranked in order of global frequency throughout collection are below in order of decreasing rank:

section requir oper applic code author includ provid water area depart person vessel part permit plan unit mean public determin

Second, the Top 20 stemmed words ranked in order of number documents they occur in, in decreasing order.

section author note requir top refer code cite provid applic includ part oper public person chapter determin purpos provis regul

DISCUSSION

Public access and data processing constraints

The documents of the California Code of Regulations were most challenging to compile. The only format they are available in digitally for the public is by sections. Considering there were over 28,000 sections of regulations, this was an arduous task.

Once compiled, these regulations contained a large amount of markup from the online legal database (Barclay/Westlaw). Each document was run through a list of several steps to remove the markup using search and replace functions in Microsoft Word and TextPad. Cleaned documents from all jurisdictions were converted into text from their original format (html or Microsoft Word). Additionally, three lines of text tags were added to each unprocessed document to indicate the source hierarchy for the sections. This step was taken in preparation so that DigIn could be used to convert this compilation into an online digital library. Each DigIn tag was composed of the first three lines for each document indicating the general level of law (e.g. State or National), specific jurisdiction (e.g. California), Title and Division number and name.

Final composition of dataset

The four included geopolitical jurisdictions cover the northern-most bioregion nested within the California Current LME (NOAA Regional Ecosystem Delineation Workgroup 2004) providing a useful set of laws for analysis in the context of ecosystem-based management between political boundaries.

Dataset statistics

Many of the summary statistics were typical of text corpora. The high sparsity is a reflection of the many subject matters that the laws cover. The term frequencies, both the global frequency and the documents per term, matched past document collections (unrelated to this project) that support Zipf's Law of rank frequency (Hill 1974). Zipf's Law demonstrates that the least occurring terms in any collection of documents occur in only a few documents, while few terms occur in most of the documents. Similarly, documents per term results followed the same pattern.

CONCLUSION

Creating a dataset of ocean related laws was one of the first critical steps to exploring the utility of information retrieval to provide baseline information about ocean governance. With this dataset scientists can develop new ways to objectively discover and measure management problems, which can assist decision-makers to overcome one of the major obstacles to implementing ecosystem-based management.

The constructed law database promises a new tool for marine EBM. The compilation of unprocessed and processed laws can facilitate the application of numerous types of text analyses to answer questions about the state of ocean management. Until now there has not been a comprehensive set of laws across all sectors and multiple jurisdictions. Consequently, no analysis has assessed interactions among marine management systems in a comprehensive, objective and quantitative way. Forthcoming analyses plan to develop techniques identify gaps in law and allow the examination of management issues within and between geopolitical jurisdictions along the Pacific coast.

As the next step in untangling fragmented ocean management, we can exploit this legal database with techniques deriving from information retrieval and social network analysis to study specific aspects of fragmentation, such as gaps and overlaps. Perhaps most straight-forward is the identification and measurement of legal gaps in the context of ecosystems. For example, a technique measuring gaps could demonstrate its utility by calculating the degree of congruency for an individual sector, such as Shipping and Transportation, and then compare this to a system of ecological components interconnected with human uses. If the technique is successful, the congruency would measure higher for the sector activities than for the ecological system. In addition, development of techniques can help decision-makers prepare for foreseen problems, such as new ocean uses and impacts of global climate change.

The collection of ocean relevant laws within a large ecosystem that spans political borders is a critical step to the task of comprehensively evaluating problems of fragmentation so that we may move forward with Ecosystem-Based Management. Although laws are publicly accessible, the identification and compilation of relevant laws that represent both national and multiple state jurisdictions is a substantial undertaking. As analyses prove useful, a more systematic corporate or government driven collection could be conducted in the future to update this collection, as well as to generate a similar compilation for other regions. But first we must prove the utility for this collection by developing techniques to measure fragmentation in ocean law.

Chapter 4 Gaps Analysis Concept and Technique

INTRODUCTION

In the United States, management of the marine environment traditionally has been divided into individual sectors, such as transportation, mining, and fishing (USCOP 2004). Historically, the government has regulated the marine environment through case by case lawmaking within these sectors, a reactionary and piecemeal approach to the management of marine resources (Knecht et al. 1988, Miles 1989, NRC 2001). The combination of growing coastal populations and advanced technology has resulted in a higher degree of ocean uses. The increased stress on ocean resources compounds the fragmented regulatory approach, leading to inconsistent management and a lack of coordination across political jurisdictions and between marine management sectors (USCOP 2004, Kildow and Colgan 2005, Crowder et al. 2006).

When one sector makes a decision, it can result in unintended negative consequences for other sectors (Young 2002). For instance, the shipping and transportation sector regulates critical management components such as collision prevention, response to hazardous spills, traffic lanes, and port facilities (USCOP 2004). Over time, the transportation sector's activities will increasingly impact other marine-related uses, such as recreation, mining, and fishing. Impacts to the fishing sector occur, for example, when the dredging done to maintain shipping channel depth degrades estuarine habitats. This practice jeopardizes spawning and nursery habitat for commercially important species. The inter-relationships between sector-based activities and ecological systems must be managed for comprehensively (Kennish 1992, Sutinen et al. 2000, Juda and Hennessey 2001), with a body of regulations that take into account the overlapping nature of marine sectors (Imperial and Hennessey 1996). However, as a result of the fragmented management, each sector has focused on its own interests without taking responsibility for the unintended side effects that result from its decisions. Thus, governance as a whole is filled with management gaps.

Both the U.S. Commission on Ocean Policy (USCOP 2004) and Pew Ocean Commission called for the implementation of ecosystem-based management (EBM) as a solution to mitigate detrimental impacts on the coast and oceans in the United States (Pew Oceans Commission 2003, USCOP 2004). However, the implementation of EBM requires the strategic coordination of marine management decisions within sectors and government agencies (Underdal 1980, Slocombe 1993, Imperial and Hennessey 1996, McLeod et al. 2005). In the task of restructuring the existing fragmented management system, the following questions arise:

- What systems are the most riddled with gaps?
- How do gaps vary by location and ecosystem?
- What issues cause the gaps for a specific location?

Answering these questions will give us data to: 1. use as a baseline for monitoring improvements over time, 2. measure the impact of fragmentation on ecosystem health, and 3. prioritize the problems to be solved based on location and severity of fragmentation.

BACKGROUND OF APPROACH

This paper addresses the fragmentation of ocean management, a significant source of deteriorating ocean health. Common to sector-based governance systems, two fundamental problems consistently appear in ocean management, *overlaps* and *gaps* (Young 2002). This paper focused on the *gaps* problem in ocean management systems.

Gap definition

To define this project's use of the term *gap*, I return to the idea of how one sector's actions can unintentionally impact the effectiveness of another sector. For example, the shipping and transportation sector's dredging activities, if conducted without proper constraints, can destroy habitat used by fish nurseries. Take the circumstance in which the shipping sector does not address the impact of dredging on fish nurseries, nor do the sectors of fisheries or conservation provide protection of this habitat from dredging. In this situation the failure of any management system to address this dredging-habitat relationship is a gap which can wreck havoc on the fisheries sector and ecosystem health.

For the scope of this project, a *gap* in management is when a *critical linkage* between two components of a system for a given place is not addressed in management (represented by statutes and regulations). *Linkages* refer to interactions among species, habitats, biophysical conditions, and human stressors. In the example above, the dredging that impacts fish nursery habitat (such as eelgrass) is a linkage. The concepts of system components and linkages are borrowed from the discipline of systems ecology (Kitching 1983, Odum 1994).

Systems ecology and conceptual modeling

The systems branch of ecology, which derived from a combination of systems theory and ecology, focuses on studying components and interactions (or linkages) between the components as a system (Odum 1994). Systems ecology emphasizes the importance of economic activity, societal values, and human stressors as logical components of an eco-system, along with the more conventional ecological components of species and habitats. For example, salmon depend on estuaries for safe nursery and spawning habitat along the coasts of California, Oregon, and Washington (NRC 1996). To understand salmon within the context of the ecosystem, the systems approach recognizes the relationship that exists between this species and the estuary habitat and also between human activities (i.e. dredging) and the nursery habitat (Nehlsen et al. 1991).

There are a variety of designs used to depict and develop ecosystems, ranging from illustrations to energy circuits (Huggett 1993). This project employs first an illustrated conceptual model, which is used to develop a box diagram (with defined components and linkages). Then this diagram is converted into a linear matrix of system components and relationship. This end interaction matrix is used by Sutinen et al. (2000) to organize ecosystem "activities and resources by listing them along each axis. Matrix cells represent potential interactions or linkages between the components listed in a particular column and row of the matrix. These matrices have the capacity to inventory, organize and explore relationships or linkages among human uses, ecological components and processes of the LME [Large Marine Ecosystem]," (Sutinen et al. 2000). This project uses the same organization for ecosystems of smaller scales for which data exists.

Conceptual models are used in practically all disciplines and walks of life to "help clarify loose thoughts about how components of a system are related to one another" (Thom et al. 2003). Modeling the conceptual relationships among components of an ecosystem is one of the first necessary steps for conducting ecosystem-based management or ecological restoration projects. Without at the very least a conceptual definition of the relationships between components of an ecosystem, decision-makers cannot strategically protect, maintain, or address the interactions that are critical to the functionality of ecosystem services (Thom et al. 2003).

Institutional fit (or misfit) to ecosystems

The legal gap analysis technique was developed based on the idea that environmental management systems "should fit properties of the ecosystems with which they interact" (Young 2002). This has been demonstrated through discussion of spatial and temporal types of misfit, as discussed by Crowder et al. 2006. However, combining Young's (2002) definition above with a systems ecology approach, another type of fit between institutions and an ecosystem – perhaps more basic – can be investigated. This other type of fit can be revealed by exploring the degree to which an ecosystem's components and linkages are reflected in management. The term “management” is used interchangeably with “institution,” both of which refer to rules, rights, and decision-making procedures that guide the behavior of human use of the coasts and oceans (Juda 1999, Young 2002). Within the traditional marine sector-based approach, incongruence between institutions and the ecosystem is common (Christensen and et al. 1996, Fowler and Treml 2001, Ebbin 2002). In trying to identify particular gaps objectively and quantitatively for any given ecosystem, the legal gaps analysis tests specifically for whether critical relationships between ecosystem components are reflected in management laws and regulations. Again I return to the linkage between dredging and estuary habitat, but now in terms of management. Ideally, this linkage should be reflected in the management system regulating the species, the habitat, and their interaction. In addition, if there are more components in the area that impact estuary habitat, such as dredging activities, then a relationship or linkage exists between this activity and the habitat. If management fails to take into account each linkage, the result is a *gap*.

Opportunity for filling management gaps

The time to rigorously assess and mitigate the gaps in ocean management is long overdue. The Stratton Commission in 1969 recognized that fragmented ocean management threatened marine ecosystem health and resources (Stratton Commission 1969). Over two decades later --in 2003 and 2004 -- the Pew Ocean Commission Report and the US Commission on Ocean Policy Report confirmed the problem of regulatory fragmentation, but also found the oceans in a more dire condition. With the present momentum, there is a major opportunity to actually fill the gaps and coordinate the overlaps opens to Policy makers (Pew Oceans Commission 2003, USCOP 2004, McLeod et al. 2005, Rosenberg and McLeod 2005). Realizing the goal of a coordinated system of ocean management requires objective analyses of gaps and overlaps in ocean management. A reasonable place to begin is with a dedicated analysis of the laws currently guiding and regulating use and abuse of ocean and coastal resources. This paper describes a technique to address gaps in management using a comprehensive set of ocean-related laws. While the statutes and regulations only represent part of the documents guiding marine management, they provide an essential first step to view the management of oceans as a whole. Ideally, other documents, such as government Memorandums of Agreement, management plans, meeting notes, and court case briefings, would be added to future analyses.

Analysis of all ocean-relevant laws, whether qualitative or quantitative, is no trivial task. The enormous number of laws alone reveals the challenge ahead in untangling regulatory fragmentation. Figure 4.1 represents a graphical depiction of a small sample of coastal and ocean management laws and their interrelationships. The diagram illustrates the complexity inherent in these large and fragmented sectors. The California Ocean Protection Council identified over 300 California State laws for qualitative study from the California Code pertaining to the ocean. This list compiled nearly 6,000 sections of law and does not include the administrative code (known as regulations). Any of these laws have the potential to interfere with one another, resulting in 44,850 combinations of possible interactions between laws. This represents over 10 million combinations of interactions between sections of law – a massive task to conduct qualitatively. While qualitative analysis of legal gaps can reveal detailed comparisons among a small collection of laws, it is important to conduct these studies utilizing a more objective assessment of laws.

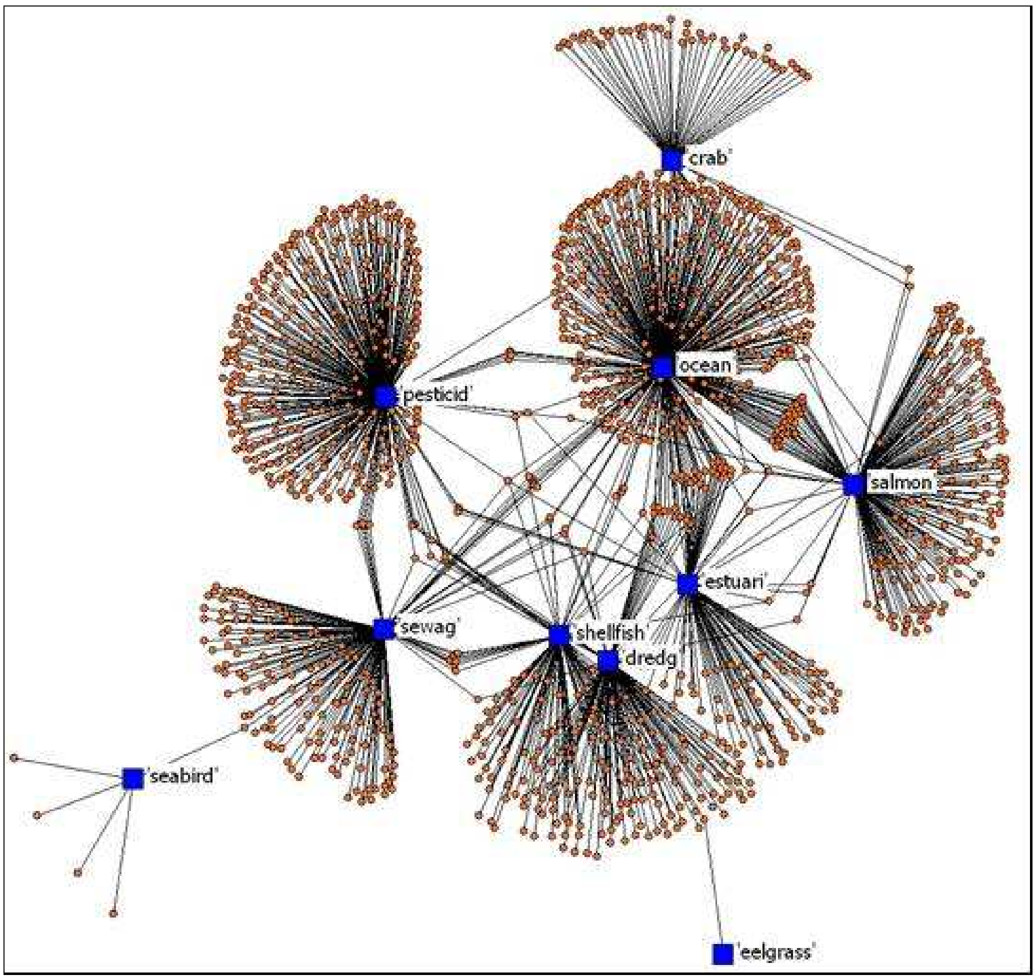


Figure 4.1. Graphical depiction of the complex entanglement of laws and regulations managing interlinked components of an estuarine system. Small circular nodes represent individual sections of California law and regulation. Each law connects to a square node representing an ecosystem component. Multiple laws connect many of these components to each other. Not all links in the ecosystem are addressed in the laws, such as the missing link between seabird and eelgrass.

Text analysis

Text analysis has provided a useful method in many disciplines to quantify relationships between documents (Bernard 1998, Baeza-Yates and Ribeiro-Neto 1999, Krippendorff 2004, Lau et al. 2006). Recent immense growth of digital data requires more intelligent techniques to make sense out of the available information. Thus, much of the innovation in text analysis has occurred within university computer science and statistics departments, as well as technology-based companies (Feldman and Sanger 2007). These researchers have strategic interest in perfecting text mining and information retrieval algorithms and technologies. Classic document analysis techniques use variations of keyword or term frequency counts to identify relationships between documents (Baeza-Yates and Ribeiro-Neto 1999). More recently, structure has been woven into some content analyses (Wan and Peng 2005, Lau et al. 2006). Classic document analyses usually include probabilistic modeling, Boolean modeling, and Vector Space Modeling, all of which can use keywords or index terms to represent each document in a given collection. The Boolean and probabilistic models only assign binary weights to index terms so that measures of similarity may result in either *similar* or *different* output to quantify relationships between documents. Conversely, the Vector Space Model assigns non-binary weights to index terms in documents to measure similarity between documents (Lau et al. 2006).

At the core of these analyses is a *term-document matrix*, which organizes terms in a table according to the frequency of occurrence in each document (Table 4.1). This type of matrix can be generated for a collection of text documents using Matlab®. Drs. Dimitrios Zeimpekis and E. Gallopoulos from the University of Patras in Greece provide a free add-on Matlab toolbox (Text to Matrix Generator) that generates a term document matrix and term-list dictionary for a collection of documents (Zeimpekis and Gallopoulos 2006). Users can choose local and global weighting schemes, remove common words from the matrix, and count stems of words (using Porters Stemming Algorthim).

Table 4.1. Example of a term-document matrix. The cells represent the raw term frequencies for each document.

Term	Doc 1	Doc 2	Doc 3	Doc 4
crab	2	0	0	0
estuary	1	0	3	0
fishery	6	0	2	6
kelp	0	1	0	0
lobster	1	0	0	0
mussel	0	0	6	0
tuna	0	0	0	7
upwelling	0	2	0	0
wave	0	1	0	0

Document analysis can be useful in answering questions about fragmented management because it identifies and calculates certain types of relationships between the terms within the laws. The Engineering Informatics Group at Stanford

University is conducting research through the Regnet Project, to address problems caused by the “complex, diverse and extensive” amount of US Federal and State business domain law. Their project focuses specifically on the effects of fragmented laws in construction and business management and water quality (Lau et al. 2006). With comparable proposed outcomes, this paper targets the current inefficiencies of U.S. and State laws regarding marine regulation and management.

Network Analysis

Social sciences such as anthropology, sociology, and psychology also apply text analysis to generate quantitative data (Bernard 1998). Systems of coding and survey response data can reveal answers about social values, socio-economic impacts and relatedness between individuals or groups. Analysis of networks in the social sciences enable researchers to understand how and why populations relate to one another, as well as to investigate communication and distribution of information (Carrington et al. 2005, Hanneman and Riddle 2005). The development of more robust statistical procedures, utilizing automated random permutations, has increased digital information capacity (Krippendorff 2004) and enables the processing of more rigorous statistical procedures on network data (Huisman and vanDuijn 2005). A variety of software packages are made solely to conduct social networking analyis, including Pajek, UCINET and NetDraw. UCINET, arguably the most comprehensive network software, allows the user to import network matrices and conduct various statistical procedures (Huisman and vanDuijn 2005). The user can perform network multiple regression, Quadratic Assignment Procedure (i.e.

correlations between networks), and ANOVA, all of which can be computed using network data (Borgatti et al. 2002).

Application of text analysis and social network analysis to EBM

This paper demonstrates a technique that identifies and measures legal gaps in ocean management by combining systems ecology, text mining, and social network analysis. An ecosystem can be modeled as a network comprised of a set of components and the linkages connecting those components to each other (Johnson and O'Neil 2001, Roloff et al. 2001). In fact, defining the ecosystem components, services, and stressors is one of the first necessary steps to implementing EBM (Huggett 1993, Thom et al. 2003, McGinnis 2006). Once the practitioner defines the ecosystem’s components and linkages, their model can be converted to a matrix (Borgatti et al. 2002, Carrington et al. 2005). The objective of this process is to identify the links in the ecosystem that are absent from the regulatory body of laws.

To demonstrate how this technique measures gaps in marine law, I must first model the components and linkages of a particular ecosystem. When modeling an ecosystem, the network consists of components that are connected, such as through energy transfer, within a defined, often arbitrary, spatial area (Huggett 1993). Components may include species, biophysical factors (i.e. habitat and processes) and other inputs (i.e. stressors) (Odum 1994). Modeling an estuary as a network illustrates the components of an ecosystem and the intuitive linkages connecting them (Kennish 1992). In the estuary example, each component is dependent on or has impacts on the health of another component (Table 4.2). These characteristics of estuarine ecosystem components are commonly found in estuaries throughout the northern coast of the California Current LME, including: Humboldt Bay in California (HBHRCD 2006), Tillamook, Yaquina and Coos Bays in Oregon, and Willapa Bay and Grays Harbor in Washington (Huppert et al. 2003, Parrish et al. 2003).

Table 4.2. Selection of interconnected components in estuaries throughout northern California, Oregon and Washington.

	Ecosystem Components
Species	Eelgrass Salmon Seabird Crab
Biophysical Habitat / Processes	Estuary Ocean
Human Stressors	Sewage outflow Pesticide run-off Dredging

Along the northern sub-region of the California Current coast, estuarine habitat is crucial for a diverse array of species. Numerous fish species, such as salmon, lingcod and tuna, depend on estuaries for nursery or spawning habitat (Parrish et al. 2003). Black Brant (*Branta bernicla*) and other seabirds rely on estuarine habitat for food and nesting (Colwell 1994, Moore et al. 2004). Estuaries also provide humans with safe shipping ports, especially along the U.S. Pacific coast, where few safe inlets exist naturally. Moreover, estuaries collect drainage from upland watersheds. They bear the brunt of non-point source pollution in the form of abundant nutrients, chemicals from sewage and agricultural runoff (Kennish 1992).

The components and linkages, illustrated in Figure 4.2a (as a network) and Figure 4.2b (as a matrix), originate from literature associated with the coastal northern California Current, including peer-reviewed literature (Huppert et al. 2003, Parrish et al. 2003, Moore et al. 2004), estuary management plans (HBHRCD 2006), a report from the Pacific Northwest Coastal Ecosystems Regional Study (Litle et al. 2000), and other works (Silliman 1941, Johnson and O'Neil 2001).

A.

B.

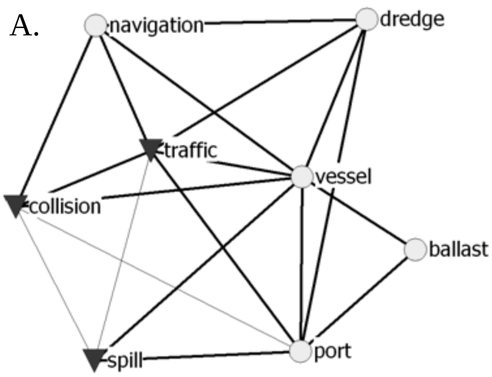
	SPECIES					HABITAT		STRESSOR		
	crab	seabird	eelgrass	salmon	shellfish	ocean	estuary	dredge	pesticide	sewage
crab		0	1	0.5	1	1	1	1	1	0.5
seabird			1	0.5	0.5	1	1	0.5	1	0
eelgrass				1	1	0.5	1	1	1	1
salmon					0.5	1	1	0.5	0.5	0.5
shellfish						1	1	1	1	1
ocean							1	0.5	0.5	0.5
estuary								1	1	1
dredge									0	0
pesticide										0

Figure 4.2. Ecosystem model demonstrating linkages between components (Table 2) that are found in estuarine systems in northern California, Oregon and Washington. A. Illustration of components and linkages; and B. Represents modeled linkages with value of 0, 0.5, and 1. Thick lines in A indicate a direct linkage (valued at 1 in the matrix B). Thin lines in A represent indirect linkages (valued at 0.5 in the matrix). The values represent different strengths in linkages, which could be expanded to more values in future ecosystem models. Direction of the representation of the linkages (energy transfer, dependence and stress) is not necessary for text analysis purposes.

Comparison to Model of Sector Management System

To test the strength of our modeling strategy, I applied the analysis technique to a primarily man-made sector-based system. I chose to study the Shipping and Transportation system because its interlinked components exist throughout California, Oregon, and Washington. Also, some of this sector's activities occur in estuaries. The Shipping and Transportation system was represented with the selection of following components: vessel, dredge, port, navigation, ballast, spill, collision, and traffic. Figure 4.3 illustrates the modeled linkages. Performing the gaps analysis on the models of a sectoral system such as Shipping and Transportation and an ecosystem model allowed testing of the analysis techniques. If the findings were to reveal a higher degree of mismatch (from gaps) for the ecosystem model compared to that of the sector model, this would verify the potential of the technique to depict information that corresponds to management. Conversely, if the sector and ecosystem models' output reveal similarly high correlation, these data would not reflect the substantiate difference between management of these systems. The central hypothesis of this paper is that all or most of the linkages in the sector model exist in the laws, demonstrating that a lesser degree of mismatch exists within laws managing a single sector's components than within the laws addressing components of an ecological system across various sectors. In addition, the hypothesis is that most of the linkages of the ecosystem model do not appear in law.

A.



B.

	COMPONENT/ ACTIVITY					IMPACT/ STRESSOR		
	vessel	dredge	port	navigation	ballast	spill	collision	traffic
vessel		1	1	1	1	1	1	1
dredge			1	1	0	0	0	1
port				1	1	1	0.5	1
navigation					0	0	1	1
ballast						0	0	0
spill							0.5	0.5
collision								1

Figure 4.3. Components of the Shipping and Transportation sector conceptually modeled system. A. Illustration of components and linkages; and B. Represents modeled linkages with value of 0, 0.5, and 1. Thick lines in A indicate a direct linkage (valued at 1 in the matrix B). Thin lines in A represent indirect linkages (valued at 0.5 in the matrix). The values represent different strengths in linkages, which could be expanded to more values in future ecosystem models. Direction of the representation of the linkages (energy transfer, dependence and stress) is not necessary for text analysis purposes.

DATASET

Text analysis was conducted on a collection of state and national laws for the U.S. portion of the California Current Large Marine Ecosystem (CCLME). To improve management of the marine environment, international organizations and national and state governments have adopted the large marine ecosystem (LME) concept. On the magnitude of 200,000 km^2, LMEs “are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves, enclosed and semi-enclosed seas, and the outer margins of the major current systems,” (Sherman 2005). LMEs spatially cover the most economically, politically, and ecologically important portions of the oceans worldwide (Wang 2004). The California Current Large Marine Ecosystem consists of one of the most well-documented marine ecosystems in the world (Lluch-Belda et al. 2003) providing a useful geographic scope to investigate ecosystem-based management issues. Because state and national government agencies have jurisdiction over marine waters in the U.S.A. portion of the California Current LME geographic scope, the collection contains laws from Washington, Oregon and California and the United States. Both state and national level laws are included. “Laws” refer to both codified statutes and codified administrative code (regulations).

I chose the laws by searching legal databases for each jurisdiction for the terms “marine” “coast” and “ocean.” I conducted the text analysis at the scale of “section” because it is the smallest unit consistently used across jurisdictions, enabling a higher resolution of analysis (Krippendorff 2004).

The selected collection, totaling 1,433 source documents included codified statutes and regulations from the Federal United States, California, Oregon and Washington. Using DigIn Pro Version 1 (http://tierit.com), I divided the source documents into legal sections.

To prepare for text analysis, the sections of law collected from the U.S., Washington, Oregon and California were fed through the Text Matrix Generator (TMG) in Matlab (Zeimpekis and Gallopoulos 2006). The result was a dictionary of all unique terms in the collection and a generation of weighted term frequencies for each document. Terms were stemmed so that words such as “crab” and “crabs” were counted as the same term. Additionally, the TMG toolbox removed common words using a stop list of common words provided in the TMG toolbox. The completed text processing generated a matrix composed of 75,286 documents (sections of law) by 33,347 terms and contained the occurrences of all stemmed terms for each section of law in the collection.

METHODS

The methodology to identify management fragmentation included the following steps: 1. creation of a term-document matrix of ocean laws to produce a law network in which components of the system are contained within a defined system model, 2. execution of a correlation test to measure the degree of statistically significant association (R) between the linkages in the ecosystem model and linkages in the laws, 3. calculation of the ratio of legal gaps to system linkages (G), and 4. identification of those *gaps* or specific modeled links absent from the law compilation.

Generating Law Networks of Modeled Components

Laws for Shipping and Transportation System Model

In an effort to focus the investigation, I produced a subset of the large term-document matrix for the laws containing terms representative of each component in the Shipping and Transportation model. This generated a smaller term-document matrix. The matrix was then divided into individual jurisdictions, producing four matrices of components (terms) by sections of law (documents) for the U.S. federal, Washington, Oregon and California. I manually imported these matrices into UCINET (Version 6.176, Borgatti et al. 2002)) from Matlab Version 7.1, and used the Affiliation Function in UCINET to calculate the number of laws co-occurring between each pair of components. For each imported term-document matrix, this function produced a square matrix of components, by components, so that the values of the cells are the number of laws shared between each pair of components. These affiliation matrices were structurally parallel to the modeled network.

Laws for Estuary Model

The steps performed for the Shipping and Transportation model were then repeated for the Estuary Ecosystem model. Congruent to the Shipping and Transportation model output, the Matlab query and UCINET conversion produced four affiliation matrices (one for each geopolitical jurisdiction) that were structurally parallel to the modeled estuary network. I then compared each affiliation matrix with the ecosystem model matrix to find the missing links in management. It was also critical to measure just how mismatched each jurisdiction is in relation to the ecosystem it is meant to manage.

Measuring gaps from fragmentation

The affiliation law matrices and their respective system models were used to measure fragmentation. I applied two approaches to measure the degree of mismatch from gaps; first, the correlation between networks (R) and second, the ratio of weighted gaps to links (G).

QAP Correlation (R)

A network analysis statistical procedure was first used to evaluate the overall mismatch of the laws for a given sector or ecological system. I calculated the degree of similarity between a law matrix and a system model utilizing the Quadratic Assignment Procedure (QAP) correlation. The Quadratic Assignment Procedure (QAP) computes the correlation between entries of two square matrices, "and assess[es] the frequency of random measures as large as actually observed" (Borgatti et al. 2002). The algorithm provided by UCINET software has two steps:

> *In the first step, it computes Pearson's correlation coefficient . . . between corresponding cells of the two data matrices. In the second step, it randomly permutes rows and columns (synchronously) of one matrix (the observed matrix, if the distinction is relevant) and recomputes the correlation and other measures.*
>
> *The second step is carried out [ten thousand] times in order to compute the proportion of times that a random measure is larger than or equal to the observed measure calculated in step 1. A low proportion (<0.05) suggests a strong relationship between the matrices that is unlikely to have occurred by chance. (Borgatti et al. 2002)*

Two types of QAP Correlation results exist for measuring fragmentation. First, high similarity (high correlation measurement) with high significance (low p-value) shows that linkages in the modeled system are addressed similarly in the laws. This result has two potential interpretations. It may reveal a good fit for the management of the system. Alternatively, a high correlation can reflect a different problem caused by fragmentation – overlapping jurisdictions. This problem occurs when too many agencies manage one issue or resource without sufficient inter-agency collaboration.

A second type of QAP Correlation results is a correlation value that is (or is close to) zero. This result demonstrates high legal fragmentation (or mismatch) for the modeled ecosystem, revealing policy-makers' lack of consideration for the modeled ecosystem linkages.

Additional QAP Correlation: Comparison of Jurisdictions

An additional set of QAP Correlation tests were performed to compare one jurisdiction's affiliation law matrix with that of another. A high correlation reveals that the two jurisdictions dealt similarly with linkages between modeled components (indicating a potentially good fit among the political jurisdictions). A zero correlation reflects that the two jurisdictions did not address linkages similarly, which indicates a lack of fit between the institutions. A negative correlation (p-value <0.05) indicates that one jurisdiction addressed linkages that the other did not (or some variation of difference).

Ratio of weighted gaps to links (G)

Following the QAP tests, a basic calculation of mismatch was performed based on the number of observed gaps relative to the number of modeled linkages. The strength of the ecosystem linkages, direct and indirect, was taken into account by weighting the associated gaps as primary vs. secondary, respectively. The different weighting of gaps in law was calculated by dividing the secondary gaps by two, so their existence was worth only half that of the primary gaps. The degree of fragmentation is the average weighted ratio of gaps to modeled links (Equation 1).

$$G = \frac{\frac{PG}{PML} + \frac{(0.5)SG}{SML}}{0.75}$$

Equation 1. "G" represents the proportion of legal gaps to modeled links. (PG = Primary gaps; PML = Primary Modeled Links; SG = Secondary gaps; SML = Secondary Modeled Links)

This measure *G* serves as an index of the degree of mismatch. A high score indicates a high number of gaps, while a lower score indicates a closer match between the institutions and the conceptually modeled system. This enables comparison across jurisdictions within the same system models, as well as comparisons across different modeled ecosystems. Even if a system resulted in high positive QAP correlations, this second test provides a useful evaluation of the number of specific linkages in a system absent from law.

Identifying Gaps

To determine specific legal gaps for each jurisdiction, I identified the modeled linkages that scored zero in each law matrix. These gaps reveal instances where two terms (that represent different components in a given ecosystem) did not appear together in the same section of law for a particular jurisdiction.

In addition, I identified region-wide legal gaps for each model using the sum of all four law matrices. An existing linkage scoring zero for the sum of matrices revealed gaps that are common to all four jurisdictions.

RESULTS

As described in the methodology above, a combination of Matlab and UCINET analyses were used to generate the linkages between laws for the two modeled systems. Results were reported first for the Shipping and Transportation modeled system and then for the estuarine ecosystem model. In summary, the sector model measured low mismatch for both metrics of fragmentation. In addition, zero legal gaps emerged. The ecosystem model measured high mismatch according to the QAP Correlation tests (ranging from -0.078 to 0.178) and the G ratio (ranging from 20% to 66%). Various legal gaps emerged for each jurisdiction.

Sector Model System (Shipping and Transportation)

Figure 4.4 indicated the sums of sections of law that contained each component of the transportation system model for each jurisdiction. A total of 1209 sections of law for Washington, 577 sections for Oregon, 2399 sections for California and 9367 sections for the United States refer to at least one component. For each jurisdiction, affiliation matrices were created using UCINET's affiliation function which calculates the number of laws co-occurring for each pair of components.

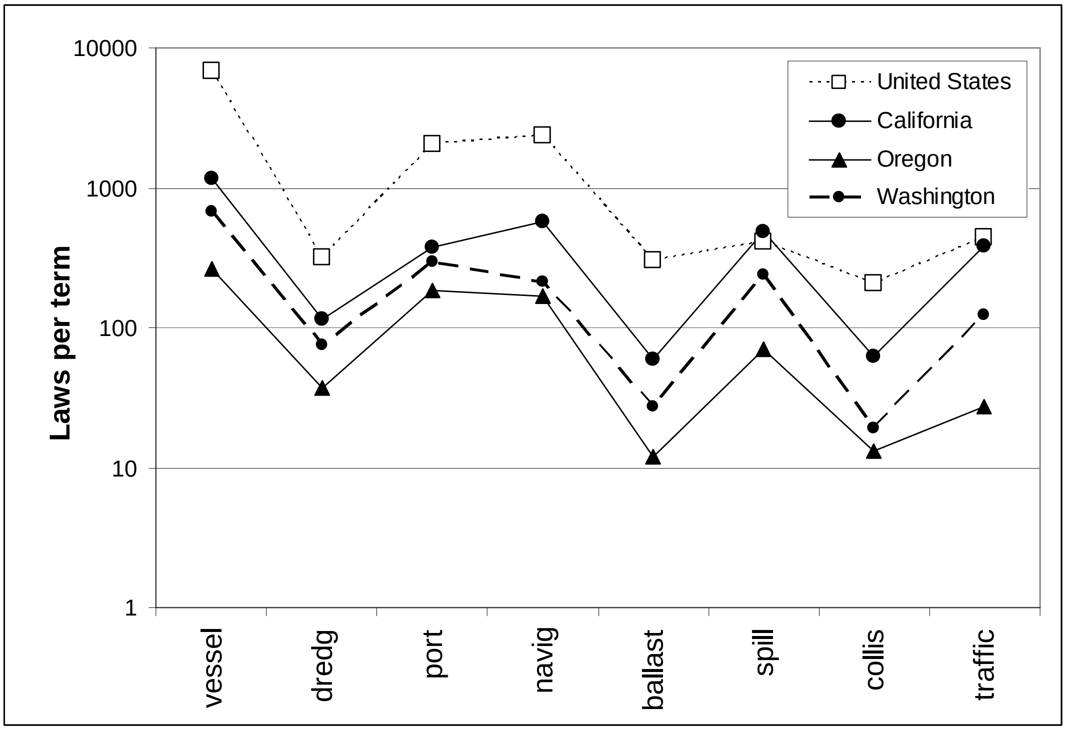


Figure 4.4. Number of law sections that contain each term (representing components of the modeled transportation system).

Measure of Fragmentation- QAP Correlation (R)

To apply the first method of measuring the degree of fragmentation, I used UCINET Version 6.176 (Borgatti et al. 2002) to test for similarity between the square affiliation matrix from each jurisdiction and the matrix representative of the transportation system model. QAP correlation tests produced a list of correlation coefficients and associated p-values (Table 4.3). A number of linkages between components of the transportation system surfaced in the laws for Washington, Oregon, California and the United States. Laws of each geopolitical jurisdiction showed strong statistical significance in their relationship to the modeled sector.

Table 4.3. QAP Correlation (R) results for links between the modeled Shipping and Transportation system components and section of laws.

Comparison of sector model with:	R	p-value
Washington	0.376	0.002
Oregon	0.452	0.002
California	0.389	0.044
United States	0.418	0.027

Additional QAP Correlation- Comparison of Jurisdictions

Following the fragmentation measurement, the QAP correlation procedure in UCINET was run to quantify the extent of similarity among the law data matrices of California, Oregon, Washington, and the U.S. Table 4.4 shows that the linkages between the laws of all four jurisdictions are slightly more similar to one another, more similar than any one jurisdiction is to the modeled linkages between modeled components. For each comparison, the probability that R occurred by random chance is, or is close to, zero. For example, Table 4.4 shows that the law affiliation matrix for Oregon laws was highly similar to that of California laws with a 0.941 correlation (p-value < 0.001).

Table 4.4. This table demonstrates the correlation between jurisdictions for how the transportation system model linkages are reflected in laws. Horizontal comparison refers to inter-state comparison, while the vertical comparison refers to relationship between federal and state levels of management.

Comparison type	Comparison between law matrices of:	R	p-value
Horizontal	Washington and Oregon	0.885	< 0.000
	Washington and California	0.928	< 0.000
	Oregon and California	0.941	< 0.000

Vertical	Washington and U.S. federal	0.885	0.002
	Oregon and U.S. federal	0.857	0.004
	California and U.S. federal	0.821	0.009

Measure of Fragmentation- Ratio of weighted gaps to links (G)

The second measure of fragmentation (G), calculated for each jurisdiction, resulted in zero percent for each jurisdiction because no missing linkages appeared among the relevant laws. This result indicates that there is no mismatch for this second method of measurement.

Legal Gaps Identified

For the laws of each jurisdiction all of the modeled links are greater than zero, indicating that this sector has no legal gaps between its modeled components.

Ecological System (Estuarine)

Figure 4.5 displays the composition of legal sections for the estuarine system. Sums of the number of law sections containing each term, and representing a component of the system, are given for each jurisdiction. Using UCINET's affiliation function I created affiliation matrices with the sum total of the laws for Washington (1061), Oregon (778), California (1338) and U.S. federal level laws (1848). This process generated sums of the number of laws in which each pair of components occurs.

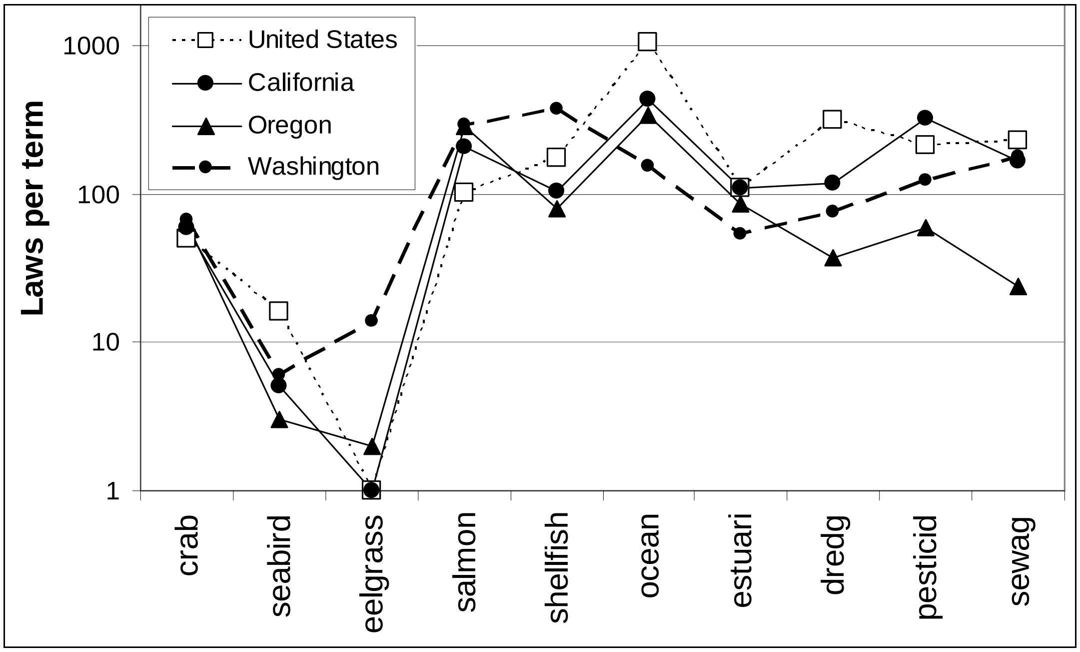


Figure 4.5. Number of law sections that refer to each term that represents a component in modeled ecosystem.

Measure of Fragmentation- QAP Correlation (R)

Using UCINET again (Borgatti et al. 2002), I conducted a test for similarities between the square affiliation matrix from the laws of each jurisdiction and the matrix representative of the estuarine system model. These QAP correlation tests generated a list of correlation coefficients (Table 4.5). Table 4.5 shows that linkages between components of the estuarine system are not recognized as statistically significant in the laws. All correlations are close to zero with the 18% to 34% probability that this result is no different than random.

Table 4.5. QAP Correlations (R) and statistical significance (p-value) between ecosystem model and law data.

Comparison of ecosystem model with:	R	p-value
Washington	0.16	0.23
Oregon	0.178	0.18
California	0.101	0.343
United States	-0.078	0.327

Additional QAP Correlation: Comparison of Jurisdictions

Next I ran the QAP correlation procedure in UCINET to quantify the extent of similarity between the law data matrices of California, Oregon, Washington, and the U.S. Table 4.5 indicates that the linkages between laws of all four jurisdictions highly correlate to one another relative to the correlations between the ecosystem and law data. Comparing Table 4.5 with Table 4.6 emphasizes the substantially higher correlation between laws in the four jurisdictions.

Table 4.6. QAP Correlation test results (R) and statistical significance (p-value) for estuarine ecosystem linkages reflected in laws across different jurisdictions.

	Comparison between law matrices of:	R	p-value
Horizontal comparison	Washington and Oregon	0.634	0.008
	Washington and California	0.469	0.031
	Oregon and California	0.772	0.001
Vertical comparison	Washington and U.S. national	0.306	0.104
	Oregon and U.S. national	0.284	0.096
	California and U.S. national	0.656	0.008

Measure of Fragmentation- Ratio of weighted gaps to links (G)

The degree of fragmentation was calculated for each jurisdiction, as shown in Table 4.7. For the estuarine model, California laws measured the highest G of 66%, while Oregon and the U.S. federal ranked second and third (61% and 56% respectively). Washington laws ranked the least fragmented for the tested jurisdictions, with only four links missing from the model's primary linkages (20%).

Table 4.7. This table presents the degree of mismatch (G) for the estuarine model for each jurisdiction. The table includes the primary and secondary links and gaps counted to calculate G.

Geopolitical jurisdiction	Measurement	Primary	Secondary	Degree of mismatch from gaps (G)
Washington	Gaps	4	1	19.94%
	Links modeled	27	13	
Oregon	Gaps	11	4	61.25%
	Links modeled	27	13	
California	Gaps	11	5	66.38%
	Links modeled	27	13	
United States	Gaps	11	3	56.13%
	Links modeled	27	13	

Legal Gaps Identified

Across all four jurisdictions there were two primary ecosystem links absent from law: eelgrass-pesticide and eelgrass-crab. There were no secondary ecosystem links missing for all jurisdictions. The majority of the legal gaps present in individual jurisdictions include eelgrass. Table 4.8 displays each modeled link missing from the law matrices for each jurisdiction (circle symbol). In addition, Table 4.8 contains the number of sections (if any) that refer to component dyads in the model.

Table 4.8. This table presents the dyads of components in the ecosystem model. Circle symbols (●) indicate relationships that are not linked in the legal system. For example, there is no section of law in the collection containing both the terms "crab" and "eelgrass," which was a primary linkage in the ecosystem model (Figure 4.2).

Interaction Type		Interaction	US	WA	OR	CA
species /habitat interactions	Primary	crab-eelgrass	●	●	●	●
		crab-shellfish	4	32	11	1
		salmon-eelgrass	●	2	●	●
		shellfish-eelgrass	●	12	●	●
		crab-ocean	12	11	34	11
		crab-estuary	1	5	7	2
		seabird-ocean	9	2	3	●
		seabird-estuary	●	2	●	●
		eelgrass-estuary	●	2	2	●
		salmon-ocean	23	36	66	35
		eelgrass-seabird	●	1	●	●
		salmon-estuary	5	11	8	6
		shellfish-ocean	53	29	14	12
		shellfish-estuary	16	11	6	6
		estuary-ocean	45	18	28	35
	Secondary	crab-salmon	9	23	17	5
		salmon-seabird	●	3	●	●
		shellfish-salmon	5	51	17	2
		eelgrass-ocean	●	2	1	●
Interactions between species/ habitats and stressors	Primary	dredge-crab	5	1	2	●
		pesticide-crab	●	●	1	1
		pesticide-seabird	●	2	●	●
		dredge-eelgrass	●	7	●	1
		pesticide-eelgrass	●	●	●	●
		sewage-eelgrass	●	2	●	●
		dredge-shellfish	28	19	2	5
		pesticide-shellfish	11	3	●	7
		sewage-shellfish	15	21	●	11
		dredge-estuary	12	15	7	10
		pesticide-estuary	7	●	3	5

		sewage-estuary	16	4	2	2
	Secondary	sewage-crab	●	●	1	●
		dredge-seabird	6	2	●	●
		dredge-salmon	5	4	2	2
		pesticide-salmon	2	5	●	2
		sewage-salmon	1	2	●	●
		dredge-ocean	99	12	7	18
		pesticide-ocean	23	1	2	7
		sewage-ocean	38	4	3	13

DISCUSSION

Results of the combined tests proved to have promise for measuring and identifying gaps in ocean law. The following discussion interprets the results for both modeled systems and examines ways to refine the technique to improve its utility in EBM efforts.

Interpretation of results

Sector-Based System

As predicted, the Shipping and Transportation system model measured zero fragmentation in both metrics. The QAP Correlations (R), comparing affiliation networks of law linkages and the model system network, showed positive correlation to the laws in each jurisdiction. Overall, laws representing the sector-based system were more consistent with the modeled system than the ecosystem law. Law networks from all jurisdictions were statistically significant when correlated with the model. The second measure of fragmentation from gaps (G) revealed no mismatch for any of the jurisdictions. Additionally, there were no legal gaps for any of the jurisdictions, further demonstrating the ability of the methodology to provide quantitative analysis of what has been generalized about ocean management. These findings affirm that this methodology can show the integration of laws within a sector.

It was also found that management of this sector was highly correlated across geopolitical jurisdictions relative to the other example. This illustrates that both emphasis on components and linkages between components were recognized similarly horizontally among the States of Washington, Oregon, and California, and also similarly vertically between each State and the federal level of law.

Ecological System

As predicted, the modeled estuarine ecosystem showed a high degree of legal fragmentation using the set of techniques presented in this paper. Indicative of fragmented management, the QAP correlations were approximately zero for each jurisdiction and lacked statistical significance when compared to the model run against 10,000 random permutations of the law matrices. Additionally, there were several gaps identified for each jurisdiction varying across jurisdictions. Eelgrass consistently emerges as a component lacking sufficient management within its ecosystem. This likely is due to the fact that the laws solely addressing eelgrass are disorganized and thus fail to provide a foundation for well-managed connections with other components. According to ecology literature and management plans, as a result of inadequate protection, eelgrass has been heavily degraded in the past century (Short and Wyllie-Echeverria 1996, Duffy 2006, Orth et al. 2006). While 14 sections (four divisions) in Washington law used for this analysis referred to eelgrass, only two sections (derived from the same source document) in Oregon law and one section in California law referred to the component. No reference to the species name (*Zostera marina*) exists in the law utilized for the analysis. U.S. federal law contained no reference to eelgrass; invariably all eelgrass links in the ecosystem were identified as gaps at the national level of management. On the other hand, this lack of emphasis on eelgrass may not reveal a problem, but rather this species and its linkages may be covered with broader terms in law, such as through the protection of “marine resources” in the California Coastal Act.

Beyond the disorganization within protective regulation of eelgrass in an estuarine system, there were a number of gaps that better management practices should address. California, Oregon, and the U.S. did not have any section of law referring to both the estuary and seabird components, an omission ignoring the well established dependency of seabirds on estuaries for refuge (Litle et al. 2000, Parrish et al. 2003).

Of even greater concern is that no section of State of Washington laws contains both the terms “pesticide” and “estuary”. The impact of pesticides on estuaries in Washington and throughout the Pacific Northwest has been scientifically established (Johnson and O'Neil 2001). The high number of sections dealing with the two components separately demonstrates significant management responsibility; this legal gap might be a major source of the environmental degradation of Washington estuaries. Another possibility is that federal level law covers this linkage; indeed seven sections of U.S. federal law contain both components. However, if this linkage were under the sole responsibility of national law and agencies, then those linkages would also not appear in Oregon and California analysis. Alternatively, the gap may be misleading because other different terms representative of the two components were not used in the text analysis. For example, the name of a specific pesticide could be queried to find if it is mentioned in any sections of law with the keyword "estuary," or a query could be done on like-terms, such as "bay," "brackish water," "inlet," tidal marsh," or "river mouth."

Improvements to the Technique

From the initial quantitative analysis of this technique, it is evident that ocean law is more fragmented in its management of ecosystems relative to its management of an individual sector/industry. Likewise, the statistical results reveal the legal gaps in ocean management that are not recognized in law. However, several aspects of the technique could be improved by the addition of terms to represent components, adjustment of models to be place-specific, and verification of results with government agencies. Perhaps most urgent is the analysis of alternative ecosystem models, to further test its performance.

Additional terms

For purposes of casting a wider net than possible from simply querying a single stemmed term, additional terms and phrases could be used to represent each component. However, while sometimes it may prove productive to apply alternative terms and rerun the analyses, in some cases a law's reference to a general term, such as *fish,* may not be sufficiently focused to address a specific linkage such as the *salmon* component.

Adjustment of Models

An additional improvement in the technique may be to utilize the expertise of ecologists and stakeholders to develop more accurate ecosystem models that focus on a particular place rather than span across three states. The generic models proved useful for illustrating comparisons across jurisdictions, but the application of this technique will be most valuable when applied to specific locations. That output will reveal the legal gaps in components, gaps that should be addressing the social values, activities, stressors, species and biophysical conditions of the place.

Verification

For maximized accuracy, these gaps need to be corroborated by interviews or focus groups with marine ecologists, NGOs, and resource managers. For purposes of determining how accurately the legal analysis of location-based case studies reflects management problems, interviews and surveys should be conducted with resource agencies, marine scientists and other stakeholders.

Obstacles

Ideally this gaps analysis would be conducted across a variety of representative ecosystems for the California Current. However, one of the main obstacles to performing this analysis on a range of ecosystems has been in obtaining accurate, systematically generated, and complete conceptual models. The technique to find gaps in management through this analysis approach would be most useful if a conceptual model, along with alternative models, was provided by a diverse group of stakeholders for a particular ecosystem or region. Matching the needs for diverse stakeholders in ecosystem-based management programs, it is critical to the performance of the gaps analysis that we work with physical, biological, and social scientists to create conceptual models of the ecosystem with best available science, which should also reflect societal needs and values.

Next Steps

Further research needs to be conducted on more models to test the usefulness and interpretability of the technique. These models should provide analysis on a variety of ecosystems and incorporate scales of biophysical processes and human activities. For example, an ecosystem involving seabirds, associated species, as well as upwelling and other biophysical components can be modeled together to create a subset ecosystem model, testable with this technique. In addition, models should be designed to exhibit real ecosystems for particular places, increasing the complexity of the model. These location-based ecosystem models also will require alternative models incorporating different words to represent the same components, or to include different linkages between components.

CONCLUSION

The methodology presented provides a way to measure and identify fragmentation in management with regard to ecosystems. Application of this technique has the potential to improve ecosystem-based management.

Fragmentation analysis grounded in quantitative, defined procedures extracts baseline information for the identification of linkages and gaps in management. Managers, ocean councils, NGOs and other EBM stakeholders can then promote and monitor the progress of “de-fragmentation.” Over the long term, the gaps analysis can be aligned with ecological and socio-economic data to gauge the impacts of implementing EBM. Improved consideration in law and by agencies of linkages among ecosystem components helps to meet ecological, economic and societal goals in a way that sustains the resources on which they depend.

At this initial stage, the legal gaps analysis tests only to see if the structural and functional properties of the ecosystem are reflected in formal institutions. It provides a step forward in understanding socio-ecological systems and the institutional dimensions of environmental change. Even in its initial stages, the analysis could provide useful baseline information about existing governance of the California Current. Gap analysis results may help in the design of EBM institutions that increase the likelihood of successful stewardship because the resulting governance comprehensively reflects system components, relationships, and functions.

This tool also highlights the importance of *place* in implementing EBM (Young et al. 2007). By focusing the analysis on a place, stakeholders and scientists can determine the core components of the location-based ecosystem. Naturally, scientific understanding of the area, as well as social, economic and cultural values of stakeholders will drive the selection of components. Combining scientific and local knowledge to understand stressors on an ecosystem produces multiple ecological and social benefits.

Ultimately, implementing and monitoring the long-term effectiveness of ecosystem-based management requires a quantitative assessment of existing ocean management across all sectors. The presented methodology, with its capacity to identify and measure legal gaps in specific locations, provides decision-makers with a tool to tackle the major obstacle of fragmentation through ecosystem-based management.

Chapter 5 Overlaps Concept and Technique (technical)

INTRODUCTION

In the United States, the large and growing number of laws related to any given issue or domain, such as building construction, water quality, emergency response, and oceans, is leading to inefficient and inconsistent management. The huge number of statutes and regulations can hinder decision-making involving both current activities and emerging uses. For example, in the early 1980s, while conducting mineral exploratory assessments, seismic survey vessels unintentionally cut lines of fishing traps set along the Southern California coast. This cutting resulted in derelict, lost traps scattered along the ocean floor, a loss causing direct economic impact on fishermen and threatening future fish populations since the traps continued to catch fish with no escape route (pers. comm. John Richards). Commercial fishermen had set these traps under the permission of the California Department of Fish and Game, and the survey vessels operated under the authorization of the California State Lands Commission. The shared spatial jurisdiction between the Department of Fish and Game and the State Lands Commissions became problematic when the two agencies' permitted activities functionally interfered with one another. Although the situation was eventually remedied through a collaborative process between the two agencies, cross-functional disasters such as this one could be avoided if decision-makers had information about management regulations of other agencies.

Regulatory measures permitting a new activity should be developed in the context of existing legislation. Up until now, decision-makers have depended on qualitative legal evaluations to provide information about existing legislation. While this may be sufficient for small-scale issues occurring in a manageable geographical area, such as within one or two counties, a tool to provide comprehensive and quantitative data is needed for larger scale issues. With the number of laws continuing to grow, a tool that addresses the scale and density of laws and regulations is necessary for future decision-making (Baron and Thompson 2007).

Locating all applicable laws and their authoritative agencies is no easy task. Still, to avoid inconsistent and conflicting law-making, government agencies and other stakeholders need objective baseline information about existing legislation. Additionally, these data must be transparently produced so that decision-makers unfamiliar with advanced information retrieval techniques can easily interpret critical information. This paper proposes to employ information retrieval techniques and social network graphical representations that reveal quantitative information about selected topics in the domain of ocean law.

Problem in context of oceans

As the health of Earth's oceans is pushed to its limits by increasing anthropogenic stressors, it is vital that we more effectively manage uses and abuses of the marine environment. Uncoordinated ocean management is a major source of deteriorating ocean health and will continue to be a problem under the current sector-based management system (Crowder et al. 2006). In the United States, decision-making for the marine environment is divided into sectors such as fishing, mining, and transportation, among others. Growing coastal populations, combined with technological advances, have greatly increased ocean use and led to the creation of a massive body of government ocean regulation. Coupled with the morass of law, the fragmented approach has resulted in overlapping jurisdictions, gaps in management, and inconsistent regulation (Young 2002). As a consequence of the sectoral divisions, the agencies with management authority often do not consult or cooperate with one another to ensure that permitted activities are compatible. Lacking sufficient coordination, the jurisdictional overlaps have become major culprits in damaging ocean health (USCOP 2004, Crowder et al. 2006). Policy-makers cannot begin to strategically fill problematic gaps in coordination or address jurisdictional overlaps without a comprehensive evaluation of the problem. Focusing on the challenge of overlap, this paper presents a simple but powerful use of text mining and social network analysis to systematically identify and characterize who manages what in the oceans. As the tool is further developed, the intended users are advisory boards of ecosystem-based management (EBM) programs along the west coast of the United States.

In recent decades, the problems of uncoordinated overlapping laws and agency jurisdictions have been highlighted by a number of actors, including proponents of ecosystem-based management (EBM) (Cortner et al. 1998, Crowder et al. 2006) and marine protected areas (McArdle 1997). For instance, EBM is a management approach developed to address problems of sectoral management (USCOP 2004). The implementation of this integrated approach requires tactical coordination between agencies when making marine management decisions. Thus far, advocates of EBM articulate fragmented management problems through a mix of cases. These cases thoroughly and qualitatively describe instances of uncoordinated overlaps, inconsistent regulations, incompatible activities, and cumulative impacts (USCOP 2004, McLeod et al. 2005, Crowder et al. 2006). However, for both marine protected area and EBM efforts, no comprehensive analysis has existed to compare the degree of overlap across sectors. Such an analysis of overlaps would equip decision-makers with baseline information so that they can identify gaps in coordination and incompatible regulations. Identification of key agency control and regulatory overlaps relating to any given management topic can assist effective stakeholder communication, participation, and decision-making.

This paper demonstrates a simple, but formal, analysis of ocean and coastal law that aims to answer the following questions:

- What ocean issues are the most fragmented in terms of overlap?
- A. What laws functionally overlap? B. What agencies are involved in implementing these laws?

Answering these questions provides data to: 1. determine the severity of fragmentation by geographic location and ecosystem type; 2. prioritize problems based on location and severity of fragmentation; 3. serve as a baseline for monitoring institutional performance; and 4. measure the impact of management changes on ecosystem health. More generally, the information generated from a comprehensive and quantitative analysis of ocean laws can assist decision-makers to define high priority areas more precisely. Moreover, empirical information provides a crucial baseline vantage point for improved government cooperation and future policy-making.

Exploration of text mining applications to answer questions about overlap required a collection of legal documents to represent ocean and coastal management. I used a compilation of laws that were manually collected in 2006 from publicly accessible websites from four geopolitical jurisdictions (federal and three states), which is described in Chapter 3 of this dissertation. The following Dataset section presents the data and the metadata used. The Preliminary Overlaps Analysis section presents the analysis methods used to explore the data. The results of the preliminary analysis are presented in the Results section. In the Discussion and Conclusion sections, I present interpretation of preliminary findings and suggested future work to fine tune the algorithm.

DATASET

Two sets of information were used in the overlaps analysis: 1. term and phrase frequencies extracted from a set of ocean and coastal laws; and 2. record of authoritative agencies for each law. These data and metadata were integrated for 46 topics representing various issues related to the marine environment along the Pacific coast of the United States (see Figure 5.4 key for list of topics). Analyzing laws to represent management constrains the analysis only to formal rules, rights, and decision-making procedures. However, until a dataset including non-governmental and informal institutions is compiled to represent all sectors across multiple jurisdictions, the laws provide a free and publicly available dataset to begin quantitative examination of fragmented management.

Data filtering

In order to generate term and phrase frequencies, I used a set of ocean and coastal laws representing the state and federal laws relevant to the west coast of the United States (Ekstrom 2008). Choosing a set of laws for analysis required identifying and applying a set of criteria. To be included in the analysis of this project, a law had to fulfill three criteria: geographic scope, scale of social organization, and type of document. Collecting within the defined criteria produced a consistent collection of laws for quantitative examination of overlap relevant to federal and state levels, as well as among multiple topics.

Geographic scope

The scope of this project was the Northern California Current Large Marine Ecosystem. Therefore, documents with power or influence over managing the activities that affect resources in this region were selected. International organizations and national and state governments have adopted the Large Marine Ecosystem (LME) concept to improve management of the marine environment. On the magnitude of 200,000 km^2, LMEs "are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves, enclosed and semi-enclosed seas, and the outer margins of the major current systems," (Sherman 2005). LMEs spatially cover the most economically, politically, and ecologically important portions of the oceans worldwide (Wang 2004).

The California Current Large Marine Ecosystem consists of one of the most well-documented marine ecosystems in the world (Lluch-Belda et al. 2003). Located from the Washington State-Canada border to just south of Baja California Sur, Mexico, the California Current LME extends seaward to approximately 300-600 nautical miles from the continent. The northern portion of this LME includes the coast and offshore regions of northern California, Oregon, and Washington (Sherman 1991).

Scale of social organization

The second criterion was that the laws were limited to national and state levels. The inclusion of additional levels of management, such as county, regional, and city, would have provided a finer scale of analysis, but there are thousands of localities within the geographic scope. Therefore, due to time constraints, it was not feasible to identify and gather laws from the smaller-scale jurisdictions.

Type of law

The third criterion was that laws were in the format of codified statutes or administrative code (regulations) for state and federal levels. Codified versions of laws were used because these were the most accessible. Additionally, the publicly accessible digital format throughout all relevant jurisdictions is updated regularly for codified versions of law. For example, the updated code does not include repetitive text from a reauthorized act that existed in the original version. The aim of this collection was to gather relevant laws for one point in time, for which codified laws were the most appropriate. For each jurisdiction, I included any law that mentioned at least one of the terms “ocean,” “coast,” or “marine.” Laws referring only to “marine” were manually filtered out if they only applied to issues relating to the United States Marines (i.e., insurance or retirement regulations, or other issues unrelated directly to uses of the ocean). The remaining list of laws was compiled in their hierarchical units to be as parallel as possible among each jurisdiction within the constraints of digital availability (Table 5.1). The number of laws meeting the criteria varied with jurisdiction (Figure 5.1).

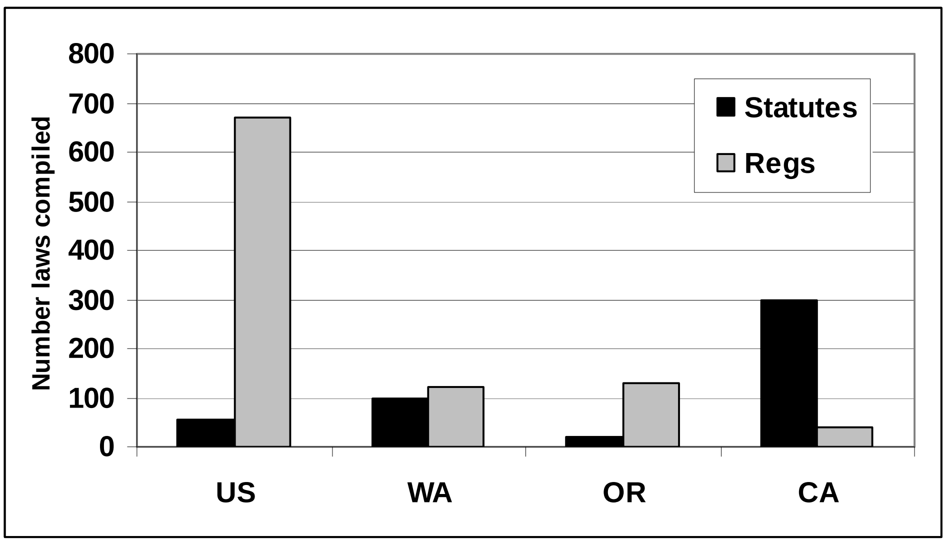


Figure 5.1. Number of ocean and coastal laws compiled for overlaps analysis (see Table 5.1 for hierarchical unit of law compiled for each geopolitical jurisdiction).

Table 5.1. Jurisdictions, format of law, and units collected for marine-related law dataset.

Geopolitical jurisdiction	Law type	Codification hierarchy	Compiled document (Statutory/ Regulatory Unit)
Federal United States law	U.S. Code (statutes)	Title/Chapter/Section	Chapter
	U.S. Code of Federal Regulations	Title/Volume/Chapter/Part/Section	Part
State of Washington	Revised Code of Washington (RCW)	Title/Chapter/Section	Chapter
	WA Administrative Code (WAC)	Title/Chapter/Section	Chapter
State of Oregon	Oregon Revised Statutes (ORS)	Title/Chapter/Section	Chapter
	Oregon Administration Rules (OAR)	Chapter/Division/Section	Division
State of California	California Code	Code/Division/Chapter/Article/Section	Article
	California Code of Regulations	Title/Division/Chapter/Section	Division

Ideally the legal units would have been compiled consistently, such as in chapters. However, the hierarchies varied slightly across geopolitical jurisdictions and the California code was more readily available at the Article level than the Chapter level. There were two types of legal units used in this analysis. Documents containing regulations are referred to as *Regulatory Units* (U.S. Code of Federal Regulations, Washington Administrative Code, Oregon Administrative Rules, and California Code of Regulations), and the codified statute documents are referred to as *Statutory Units* (U.S. Code, Revised Code of Washington, Oregon Revised Statutes, and California Code).

Metadata - Agency authority tables

The agency authority metadata for each law were in part supplied by the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center and in part compiled by me. The NOAA Coastal Services Center Digital Legislative Atlas Program (Willis 2006, NOAA) had the agency authority list for each federal ocean-related statute publicly available on its website. Their website listed authority to the most specific level of program or agency that was apparent from reading the law. For the state statutes, I obtained agency authority by skimming laws. These metadata were stored in the format of an agency by document matrix (Table 5.2).

Table 5.2. Excerpt of document-agency matrix metadata compiled for each law in dataset. Ones indicate where an agency has authority to implement the law. A full list of agencies and acronym definitions can be found in Figure 5.2.

Agency / Document	EPA	DOC	DHS	ACE
Clean Water Act (33 USC 1251 et seq.)	1	0	1	1
Magnuson Stevens Fisheries Management & Conservation Act (16 USC 1801-1883)	0	1	0	0
Invasive Species Act (16 USC 4701 et seq.)	0	0	1	0

To ensure consistency, the higher department level of the agency was recorded for the metadata. With this generalization, an agency was recorded as its parent department, in which it is embedded. For instance, the National Oceanic and Atmospheric Administration (NOAA) was recorded as the Department of Commerce, and the National Park Service was recorded as the Department of the Interior.

However, the more specific agency authority information will be used in forthcoming analysis to investigate needs for intra-agency coordination.

Agency authority for the national and state regulations was available on the U.S. Code of Federal Regulations website (http://www.gpoaccess.gov) and on the relevant State government administrative code (regulations) websites. Authorities were scaled up consistently in parallel of the statute authorities, as described above.

PRELIMINARY OVERLAPS ANALYSIS

Preliminary text analysis was performed to map overlapping functions among laws of relevant agencies. To demonstrate the technique's utility and test its accuracy, I selected 46 issues related to ocean and coastal management (see key to Figure 5.4) to represent key ocean topics. A topic for overlap analysis can be anything related to the marine environment, such as an activity, resource, species, or ecosystem stressor. Several of these topics were associated with well documented management arrangements (USCOP 2004), thus enabling verification of results. In addition, the 46 topics were selected as a representative sample of activities and resources that span all major marine-related sectors within the geographic scope of the laws investigated.

Data – Topic by document matrix

To establish the baseline analysis, the 46 topics are each represented by a term or a phrase (see Figure 5.4 for list of topics investigated). In the future, I plan to utilize multiple terms, synonyms, and related phrases to improve results. A script[7]

---

[7] The script was implemented by Daniel Spiteri.

was developed to identify and count any term (word or phrase) occurrence in the law collection. Querying the law collection with the selected term or phrase produced a topic by document matrix of raw frequencies for each legal unit (Table 5.3).

Table 5.3.Sample of topic-document matrix.

Document \ Topic freq	Transportation	Pollut*	Fishing	Ballast
Clean Water Act (33 USC 1251 et seq.)	102	986	2	1
Magnuson Stevens Fisheries Management & Conservation Act (16 USC 1801-1883)	32	5	726	0
Invasive Species Act (16 USC 4701 et seq.)	8	3	1	79

The frequencies were used to represent the degree to which a law is involved in managing issues related to each topic. Although the frequency, as used here, cannot precisely indicate a law's jurisdiction, it can reflect a law or agency's relative involvement. For example, if one law references 'fishing' two times and a different law references the term 700 times, it is evident the latter is more concerned with fishing activities. Alternatively, the fact that two laws contain a term 15 times does not necessarily reveal that they are equally involved in management relating to the topic.

To determine what agencies were involved in a given topic, the topic-document matrix (Table 5.3) was integrated with the document-agency matrix (Table 5.2) resulting in a topic by agency matrix (Table 5.4). The number of agencies associated with laws containing a topic represented a second dimension of overlap.

As such, a relatively high number of agencies involved in a topic indicated a likely complicated case for coordination.

Table 5.4. Excerpt of topic-agency matrix compiled from combination of document-agency and document-topic matrices. See Figure 5.2 for agency acronyms defined.

Agency / Topic	EPA	DOC	DHS	ACE
Transportation	1	1	1	1
Pollut*	1	1	1	1
Fishing	1	1	1	1
Ballast	1	0	1	1

Using the topic-document and topic-agency matrices, the following two subsections present preliminary variables developed to calculate the degree of overlap of laws and agencies.

What topics are most fragmented from overlapping jurisdictions?

We developed preliminary metrics to indicate the degree of overlap as a function of topic and geopolitical jurisdiction. The degree of overlap was calculated using the number of laws involved and the number of associated agencies that were linked to laws involved in each topic. The topics were then ranked for each geopolitical jurisdiction based on these variables.

We used three variables to indicate the degree of overlap that occurs for each given topic. The first variable was derived from the number of statutes that contain a given topic, referred to as Statute Overlap (SO). The topic with the highest number of laws ranked as having the highest overlap from this statute variable. To compare the variable across multiple geopolitical jurisdictions, I normalized the statute overlap variable by the total number of possible statutes in the ocean law compilation for the given geopolitical jurisdiction.

$$SO(T,GP) = \frac{SU(T,GP)}{\sum SU(GP)}$$

SO= Statute Overlap; T= Topic; GP = Geopolitical jurisdiction; SU= Statutory units

The second variable was derived from the number of regulations that contain a given topic, referred to as Regulation Overlap (RO). The topic with the highest number of laws ranked as having the highest overlap from this regulation variable. To compare the variable across multiple geopolitical jurisdictions, I normalized the RO variable by the total number of possible regulations in the ocean law compilation for the given geopolitical jurisdiction.

$$RO(T,GP) = \frac{RU(T,GP)}{\sum RU(GP)}$$

RO= Regulation Overlap; T= Topic; GP = Geopolitical jurisdiction; RU= Regulatory units

The third variable was derived from the agency authority metadata for each law. To calculate this agency overlap variable, referred to as Agency Overlap (AO), the agencies associated with the overlapping laws (statutes and regulations) for a given topic were summed. To compare the variable across multiple geopolitical jurisdictions, I normalized the AO variable by the total number of agencies represented in the ocean law compilation for the given geopolitical jurisdiction.

$$AO(T,GP) = \frac{A(T,GP)}{\sum A(GP)}$$

AO= Agency Overlap; T= Topic; GP = Geopolitical jurisdiction; A = Agencies

In our preliminary development of an overarching index of overlap, the three variables were averaged as the Overlap Index (OI). Within any geopolitical jurisdiction for any given topic, this Overlap Index demonstrates the legal and agency complexity involved in managing the topic. For each jurisdiction, the number of laws and the number of agencies were normalized by their corresponding total possible laws and agencies. Then the average sum of the normalized variables was calculated as follows:

$$OI(T,GP) = \frac{SO + RO + AO}{3}$$

OI= Overlap Index; T= Topic; GP = Geopolitical jurisdiction

This overlap measurement provides an index that allows the systematic comparison of overlap between topics within and among jurisdictions. The index can range from zero to 100%. A topic involving a high number of laws and a high number of associated agencies would result in a number closer to 100%. Alternatively, with zero number of laws and with consequently no agencies associated, the index result would be zero.

This basic calculation of OI adjusts appropriately for cases where one variable is high and the other is relatively low; however, the separate variables of SO, RO and AO provide a more detailed depiction of the overlapping information. For example, in cases where a topic has many laws that are implemented through one agency, the OI may be a high number only based on the high results of the SO and RO. Only by comparing the individual variables will the researcher see that the AO is low or null and therefore, the topic is not at risk of interagency overlap (though intra-agency overlap may be revealed through further investigation). The aggregated OI and more granular components are likely to be of interest to different users, and I plan to perform usability evaluations in the future to determine their usages.

What laws and agencies overlap?

To visualize ocean management overlaps, I demonstrate here a graphical representation of the previously defined data and metadata matrices. For this task, I used the social networking software UCINET version 6.170 ((Borgatti et al. 2002) and NetDraw version 2.064 (Borgatti 2002). The document-agency authority metadata matrix served as the primary data input (Table 5.2). Agencies and documents were displayed as individual nodes with agencies labeled and each document (legal unit) represented by a circular node. A line was drawn from each document to its associated agency (or multiple agencies) (Figure 5.2). For example, the National Environmental Policy Act (42 U.S.C. 4321 et seq.) was connected to its authority agency of the Council on Environmental Quality (CEQ) because this agency has jurisdiction to implement the statute. Some statutes are under the authority of multiple agencies, such as the Clean Water Act. This Act is under the authority of the Environmental Protection Agency (EPA), the Army Corps of Engineers (ACE), and the Department of Homeland Security (DHS). Regulation nodes were linked to the agency that wrote them. Lastly, the topic (represented by a term or phrase) frequencies were added as attributes. Document nodes were resized to reflect relative frequency of each topic. These diagrams visually demonstrate what laws overlap, and consequently what agencies overlap given their authority over the topic-associated laws.

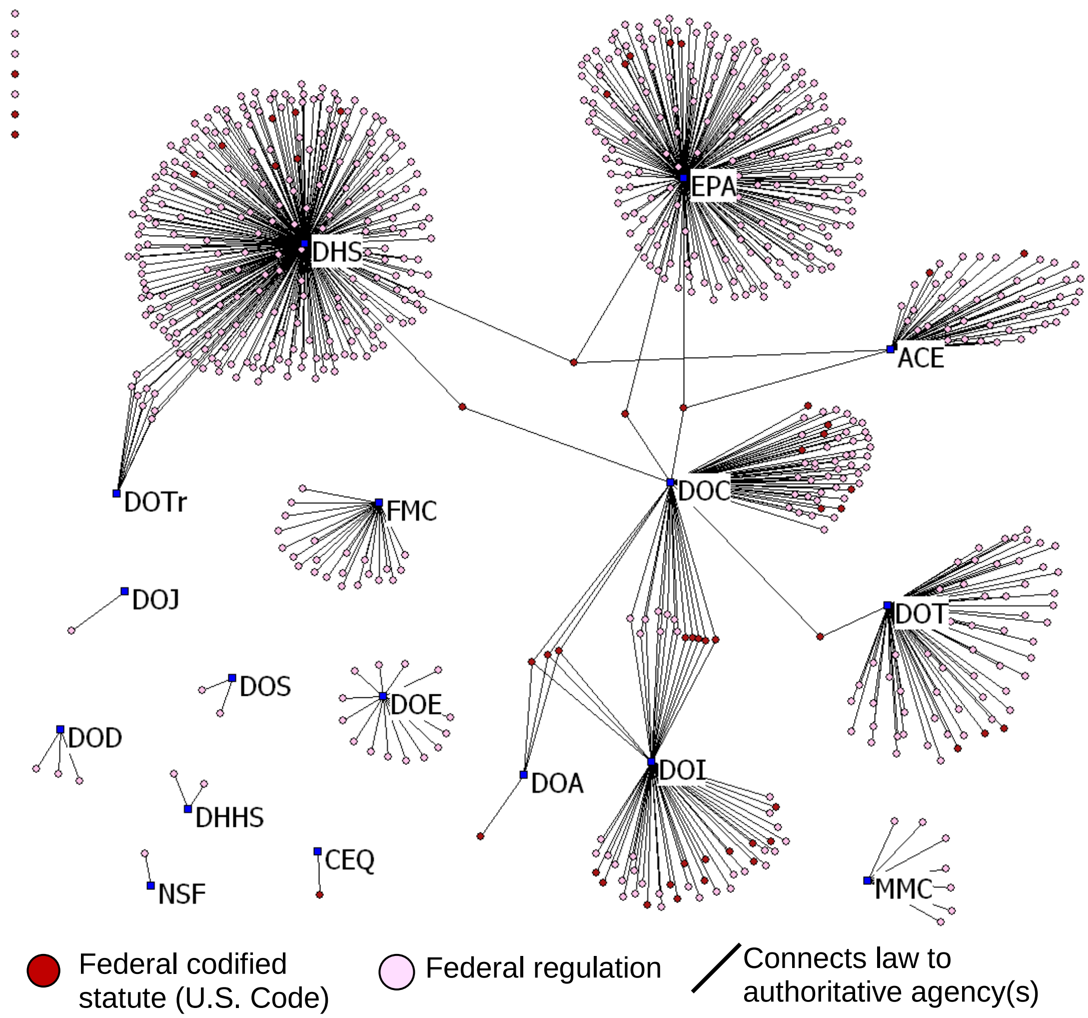


Figure 5.2. Metadata of agency authority for federal statutes and regulations. Laws (circular nodes) linked to their authoritative and/or implementing agencies (square nodes labeled with agency acronyms). The placement of agencies and length of lines are randomly generated. This is the foundational map from which the diagrams in Figure 5.8 were generated. Note that there are no term frequency data in this figure. In Figure 5.8, the law nodes are re-sized by the frequency in which a selected term occurs in the law. Acronym key: EPA= Environmental Protection Agency; ACE= Army Corps of Engineers; DHS= Department of Homeland Security; DOTr= Department of Treasury; DOE= Department of Energy; NSF= National Science Foundation; CEQ= Council of Environmental Quality; DOC= Department of Commerce; DOT= Department of Transportation; DOS= Department of State; DOI= Department of Interior; DOA= Department of Agriculture; FMC= Federal Maritime Commission; DOJ= Department of Justice; DHHS= Department of Health and Human Services; MMC= Marine Mammal Commission; DOD= Department of Defense.

RESULTS

This section first presents initial results justifying use of term and phrase counts to reveal a law's involvement in a given topic. Then the results present the measurements of overlap, followed by graphic display of overlaps using the laws, topic frequencies, and associated agencies in network diagrams.

Topic frequencies

Initial results showed that federal United States laws that ranked as most involved for each of the topics accurately corresponded to the descriptions of the recent U.S. Commission on Ocean Policy report (USCOP 2004). For example, the U.S. law containing the most references to the term 'fishing' (frequency = 726) was the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1866 et seq.). The laws that ranked second and third by their raw count of the same term were the regulations written by NOAA to implement the Magnuson-Stevens Act (50 CFR 600 et seq, 50 CFR 660 et seq.). Similarly, the authoritative agencies that ranked highest for each topic accurately corresponded to the USCOP report descriptions. For instance, the Department of Commerce (DOC), which in many cases then delegates authority to the NOAA, had authority over most of the laws for the topic of fishing (see Table 5.4, Figure 5.8c).

The general observation regarding a law's relative involvement provided sufficient justification that simple text analysis can be used to represent law and agency jurisdictions. As such, the following presents a summary of results for what topics ranked as the highest degree of overlap and a sample of what graphic display of these data can illustrate.

What topics are most fragmented from overlapping jurisdictions?

This subsection presents a summary of federal level results of the three individual variables (SO, RO, and AO) and then the results of the Overlap Index (OI). Results of the state levels of jurisdiction are briefly summarized for the Overlap Index. Table 5.5 provides excerpts of data used to calculate these three variables for the federal laws. For example, for the topic of 'fishing,' there were 31 statutory units. To obtain the Statute Overlap variable, I divided 31 by the total number of statutory units (55) for the geopolitical jurisdiction of the federal United States level.

Table 5.5. Sample of data used to calculate overlap variables for federal geopolitical jurisdiction

Units (federal only)	Units in collection	# units that refer to topic			
		Transportation	Pollut*	Fishing	Ballast
Statutes (USC)	55	43	35	31	5
Regulations (CFR)	670	265	260	114	86
Agencies	18	17	15	12	9

For the federal laws, the topics of 'transportation' (78%), 'fisher*' (69%), and 'pollut*' (64%) ranked as having the highest Statute Overlap. The top three topics ranked by Regulation Overlap were 'discharge' (48%), 'shipping' (43%), and 'navigation' (43%) for the federal laws. In terms of Agency Overlap, the topics of 'transportation' (94%), 'public health' (88%), 'pollut*' (83%), and 'discharge' (83%) measured the highest. To follow the examples of four topics of 'transportation', 'pollut*', 'fishing', and 'ballast', Figure 5.3 presents the variables measured for each for federal laws.

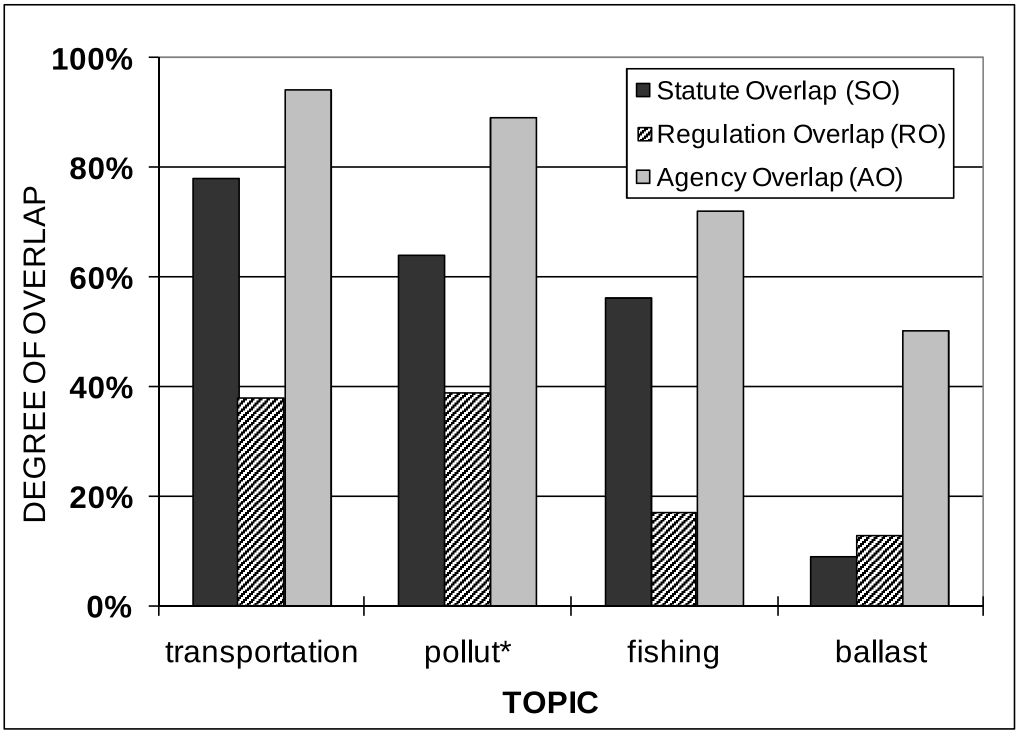


Figure 5.3. Three variables of overlap in U.S. federal law for a sample of four topics (transportation, pollut*, fishing, and ballast).

Based on the Overlap Index from the three combined variables of the number of statutes, regulations, and agencies per topic, the issue of 'transportation' measured as the highest overlap for the U.S. federal level and all three states examined (Figure 5.4). For 'transportation,' the U.S. had 43 statutes, 256 regulations and 17 agencies involved, which resulted in an OI of 72%. Following the same computation, the OIs of the states of Washington, Oregon and California are 50%, 55% and 66% respectively. The topic 'agricultur*' ranked second in the Overlap Index for the states of California and Oregon, while OIs that ranked second for federal level and Washington were 'pollut*' (64%) and 'discharge' (49%) respectively. Figure 5.4

presents Overlap Index for the 46 topics for each of the four geopolitical jurisdictions investigated.

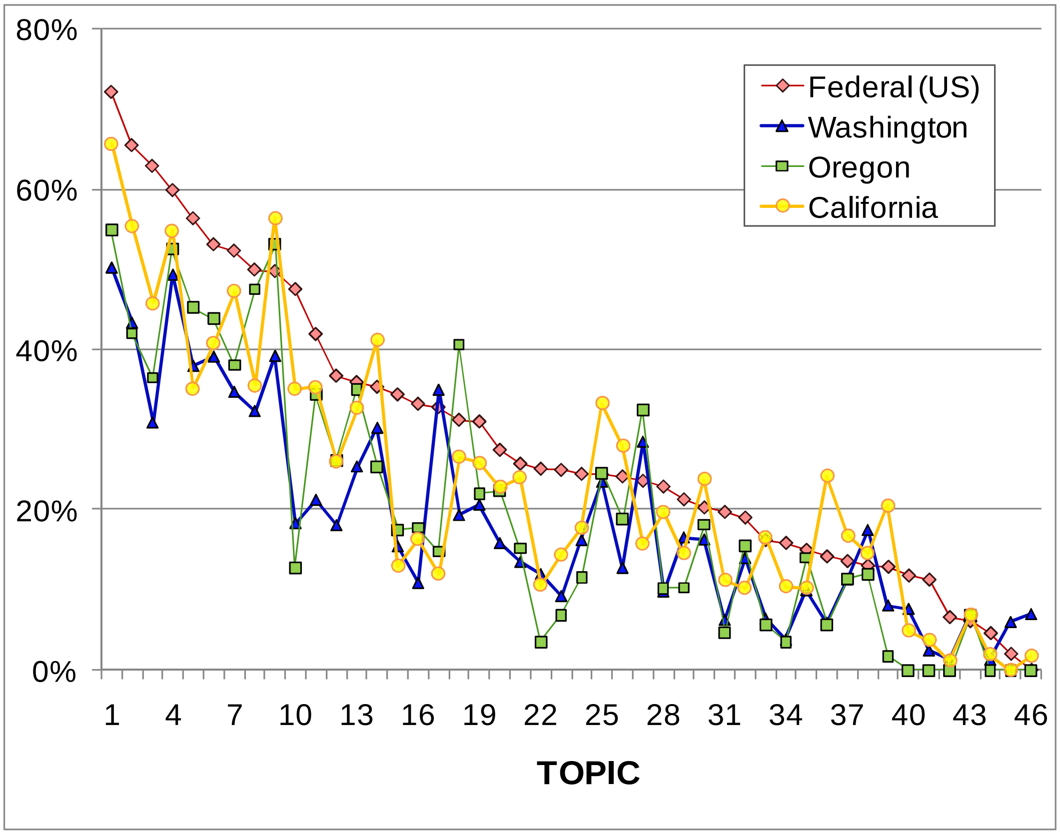


Figure 5.4. Overlap Index (OI) for topics investigated for each geopolitical jurisdiction. Key to topics: 1. transportation, 2. pollut*, 3. navigat*, 4. discharge, 5. fisher*, 6. port(s), 7. public health, 8. fishing, 9. agricultur*, 10. shipping, 11. mineral, 12. dredg*, 13. water quality, 14. contamina*, 15. ecosystem, 16. mammal, 17. shellfish, 18. estuar*, 19. bird, 20. sediment, 21. pesticide, 22. bulkhead, 23. ballast, 24. wastewater, 25. sewage, 26. climat*, 27. salmon, 28. oil spill, 29. aquaculture, 30. boating, 31. armor 32. spawn, 33. herbicid*, 34. sea level, 35. crab, 36. mercury, 37. nutrient, 38. oyster, 39. cattle, 40. invasive spec*, 41. sea otter, 42. algal bloom, 43. kelp, 44. nonindigenous spec*, 45. spartina, 46. geoduck.

Although the degree of overlap varied slightly for some topics, the results among jurisdictions were highly correlated. The topic of ‘discharge’ ranked within the five highest overlapping issues for each jurisdiction. Similarly, for all four jurisdictions investigated, the topics of ‘fishing’ and ‘fisher*’ ranked within the top ten. For California, Washington, and the U.S., the Overlap Index of ‘pollut*’ measured within the top five of each jurisdiction.

What laws functionally overlap, involving what agencies?

Numerical values of term frequencies revealed the laws overlapping for each topic. However, these long laundry lists of laws in tabular form are difficult and unpleasant to synthesize. As such, visual display of these data in network diagrams exposed multiple dimensions of the data, allowing for a more thorough and attractive interpretation. Diagrams were produced using the metadata table of “agency authority to laws” (see Figure 5.2). Labeled nodes represent federal government agencies and lines were drawn from agencies to laws, which are represented by circular nodes (pink = regulations, red = statutes). These law nodes were then sized by the frequency of topic contained in the law (see Table 5.3). A sample of four topics for the federal level is presented in Figure 5.8 to demonstrate the utility of the graphical display.

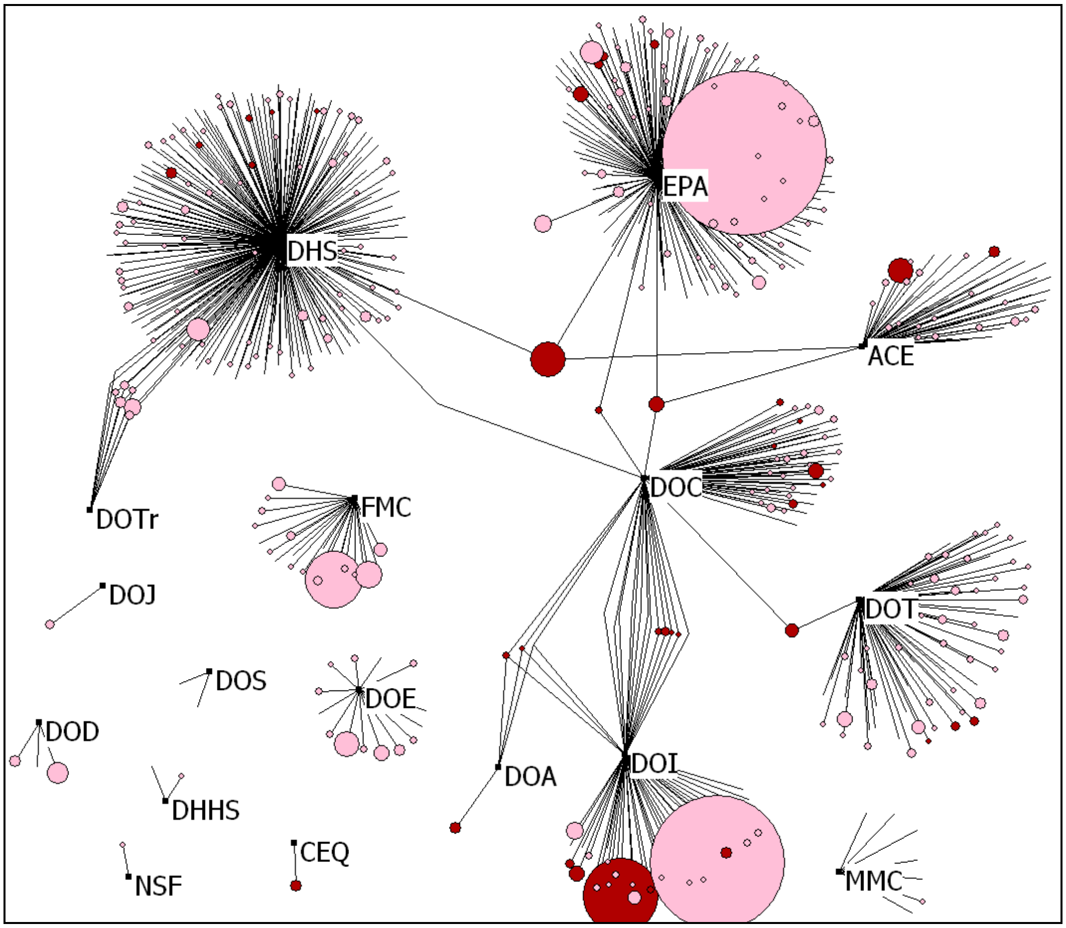


Figure 5.5. Overlapping United States federal laws and agencies for 'transportation', which measured 72% with the Overlap Index (OI). Relative frequency of term or phrase in each law (document node size varies with frequency). Refer to Figure 5.2 for legend.

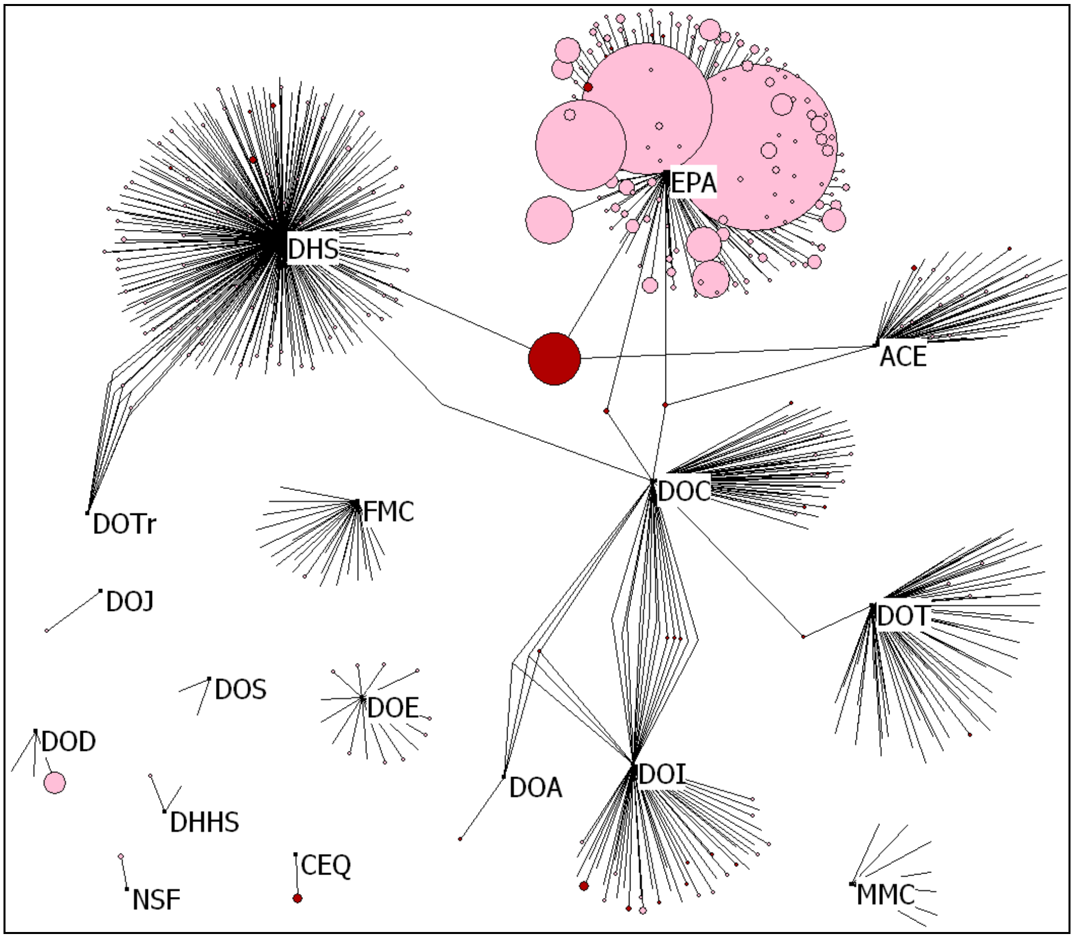


Figure 5.6. Overlapping United States federal laws and agencies for 'pollut*', which measured 64% with the Overlap Index (OI).Relative frequency of term or phrase in each law (document node size varies with frequency). Refer to Figure 5.2 for legend.

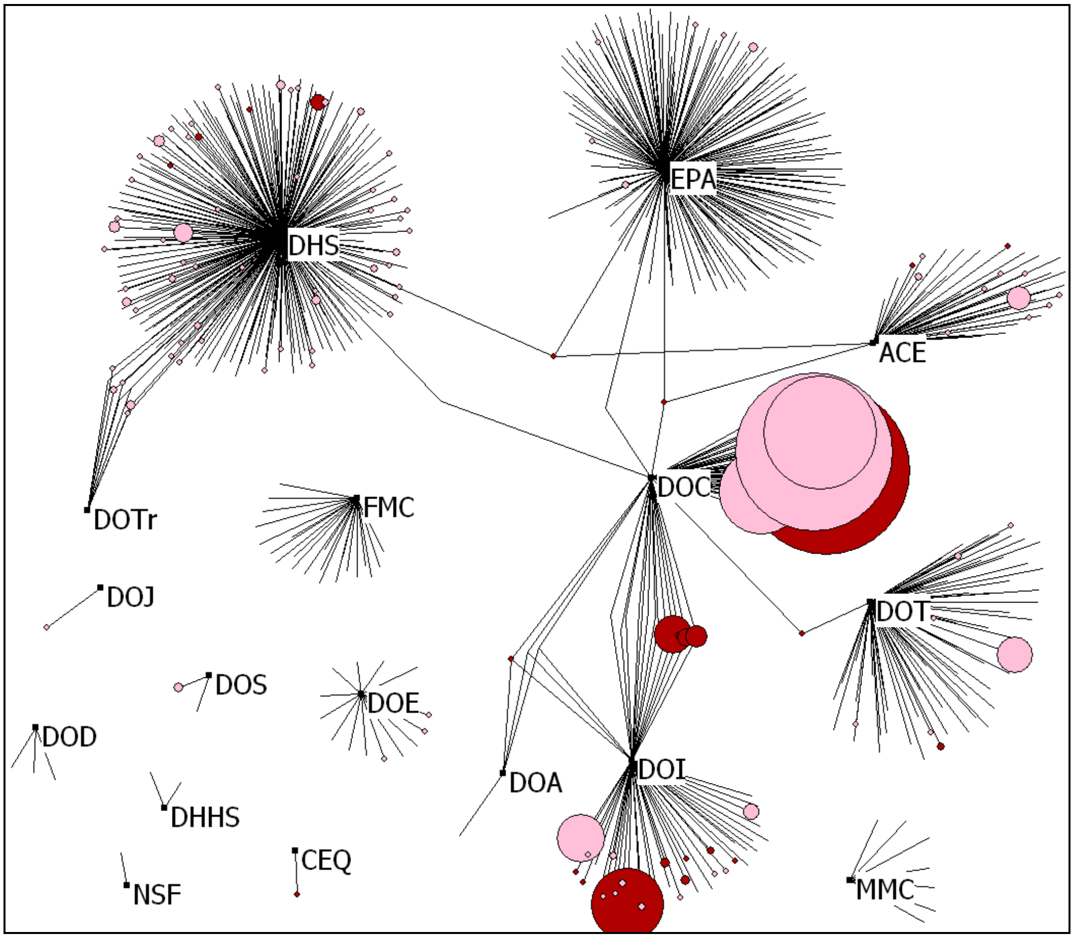


Figure 5.7. Overlapping United States federal laws and agencies for 'fishing', which measured 49% with the Overlap Index (OI). Relative frequency of term or phrase in each law (document node size varies with frequency). Refer to Figure 5.2 for legend.

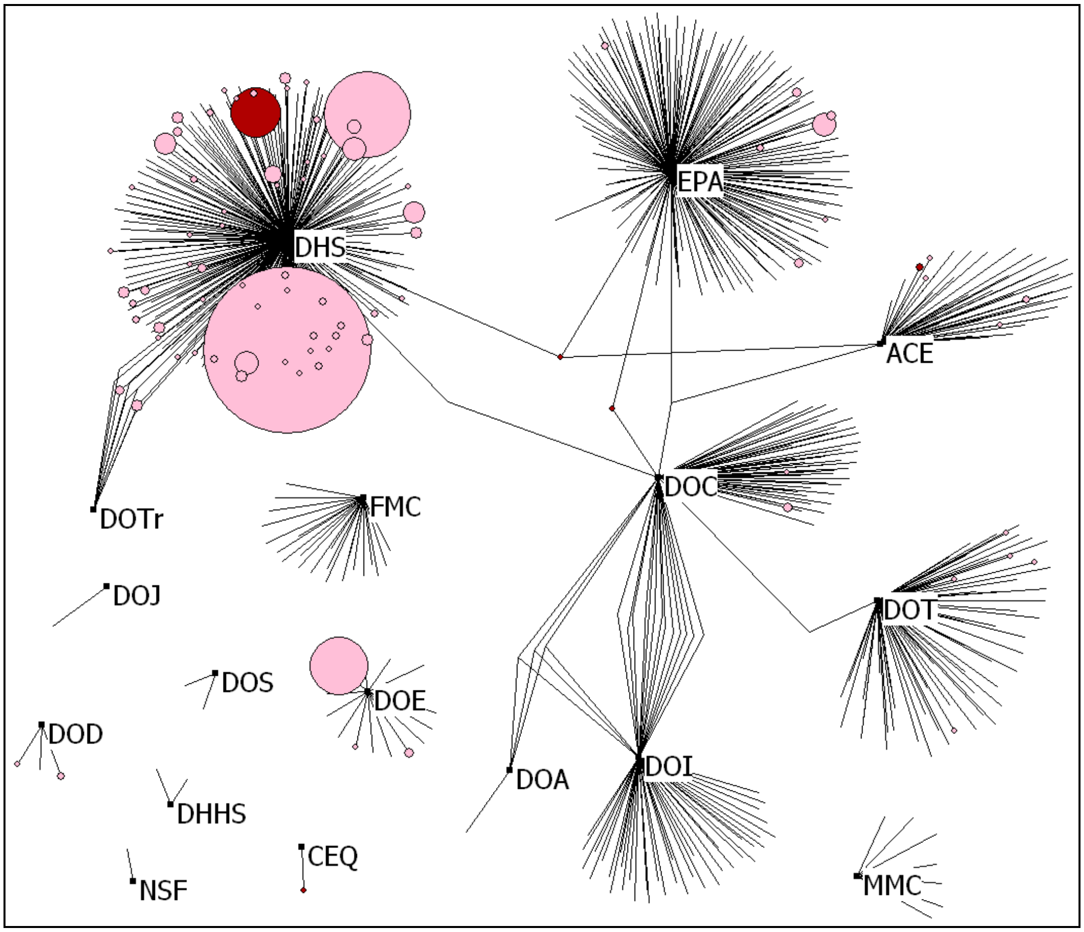


Figure 5.8. Overlapping United States federal laws and agencies for 'ballast', which measured 24% with the Overlap Index (OI). Relative frequency of term or phrase in each law (document node size varies with frequency). Refer to Figure 5.2 for legend.

In the network diagrams, relational patterns and multiple dimensions were revealed that cannot be easily captured from tables or bar charts. For instance, the diagrams reflected that the topic of ‘transportation’ appeared to be more complex in its management relative to the topics of ‘pollut*’, ‘fishing’, and ‘ballast’ (Figure 5.8). Large nodes point to laws that contain a high frequency of references to the topic (represented by a word or phrase). Similarly the laws with no reference to the topic are eliminated, but the lines remain. There were several laws containing high frequency of the term ‘transportation’. On the other hand, there were relatively few laws that refer to the term ‘ballast’ with high frequency. The complexity of each topic was revealed through the associated agencies that are linked to the laws. For example, the largest nodes in the ‘transportation’ diagram (Figure 5.5) were connected to the Environmental Protection Agency (EPA) and the Department of Interior (DOI). In addition, medium size nodes were connected to several more agencies. In contrast, the majority of laws containing high frequency of the term ‘pollut*’ are under the authority of the EPA, conveying a relatively low complexity in terms of agency overlap for this topic (Figure 5.6). The agency primarily involved in ‘fishing’ appeared to be the Department of Commerce (Figure 5.7) because the statute and regulations containing the highest frequency of the topic were linked to the DOC. Although there were relatively few document nodes for the topic ‘ballast’, the largest of these nodes were primarily connected to the DHS, which is the parent department of the U.S. Coast Guard (Figure 5.8). Although the relative complexity displayed in the diagrams accurately matched the Overlap Index measurement, the visual depiction of the raw data provided the results in a more transparent manner, which can be used by policy-makers and other ocean-related stakeholders.

DISCUSSION

The discussion section includes a brief interpretation of key results, our plan of evaluation of usability and accuracy for the overlaps metric, and related work.

Interpretation of results

Results demonstrate the utility of text mining, even in its simplest form, for untangling overlapping jurisdictions in ocean management. Although government agencies report on their policies, functions, and duties, etc., generation of a baseline understanding of ocean management requires an objective overview. Of the 46 topics investigated, the one that ranked as having the highest Overlap Index was 'transportation' for each of the four geopolitical jurisdictions. This result was consistent with the findings of the recent U.S. Commission on Ocean Policy. After a multi-year examination of ocean management by government-appointed experts, the Commission found that management of the Shipping and Transportation sector was so fragmented that it needs to be restructured: "Statutory, regulatory, and policy differences among federal agencies with roles in marine transportation lead to fragmentation, competition, and in some cases, an inability to work collaboratively due to conflicting mandates" (USCOP 2004).

The quantitative aspects of a baseline assessment enable objective comparison across sectors. Combining the Overlap Index measurement with the graphical display of the overlap provided a comprehensive picture of the data. In comparing these results, I was able to see discrepancies between the generically calculated Overlap Index, which does not take into consideration term frequency or the relative involvement of multiple agencies illustrated in the network diagrams.

The simple but comprehensive tool has enormous potential, for example, to assist ecosystem-based management initiatives in defining priorities from data collection to stakeholder communication. Present applications identified where jurisdictional relationships and functions dictate the need for management coordination. Even from the prototype text analysis with transparent methods, the lucid identification of the multiple agencies involved in management of various topics provides policy-makers with a roadmap for locating where (between whom) coordination should exist.

Evaluation

Initial testing of the accuracy of results has begun through a series of interviews with approximately 25 experts in ocean and coastal management. These experts included government agency representatives, academic scientists (both social and ecological disciplines), and non-governmental organizations. Conducted in 2007, these meetings were used to steer the line of inquiry to produce useful and accurate information about ocean management overlap. Based on the last set of interviews, suggestions for improvement will be woven into the analysis in future work, including a more thorough survey to evaluate accuracy of results. This future study could survey the degree to which each agency finds itself involved in the given topics. These survey results would be compared to the text analysis results to determine degree and patterns of error that text analysis reveals.

From the input of experts, it is also apparent that future work needs to include input of synonyms for topics investigated. Inclusion of multiple terms or phrases to represent a single topic could improve the accuracy of results. This improvement could also be intertwined with the verification of result survey to test how much inclusion of synonyms (and what rules are needed for synonyms) can increase the accuracy of results.

Once the algorithm is fine tuned to meet the needs of coastal and ocean management stakeholders, automation of the overlaps tool will require additional surveys to establish usability for the potential users.

Future and related work

The term-document matrix data yielded by this technique affords excellent opportunities to use information retrieval statistics and other advanced text analysis methods, such as the vector space model and other content analyses (Salmon et al. 1975, Krippendorff 2004). However, even raw frequencies provide information that pre-empts the need to read hundreds of documents to ascertain an extremely detailed, relative assessment of statutory and regulatory overlap. In addition, text analysis can be employed with any set of laws or policy documents on any subject. As already seen with work on construction and water quality law (Lau et al. 2006), the application of text analysis can help untangle management in different domains. Recognizing the growing problem of increasing legislation requiring review, a small group of computer scientists and engineers has been developing algorithms using information retrieval statistics and methodologies for navigating through legal documents (International Association for Artificial Intelligence and Law).

Future research also will further develop the technique to prioritize what agencies need to coordinate around any given topic. With more topics, graphic display through network diagrams of these data could provide a valuable teaching tool for marine policy courses. In addition, text analysis is being applied to the collection of ocean related legal documents to investigate gaps in management in the context of a given conceptually modeled ecosystem. Combining the overlaps analysis with gaps analysis may prove to be the most useful for marine management initiatives because it could be used to locate what agencies and through what laws gaps in management could be filled.

CONCLUSION

Text analysis of the laws has the potential to provide a thorough synopsis of which agencies and laws manage various topic issues in the ocean. The approach to measuring overlaps demonstrates how an interdisciplinary integration of methods and perspective can be used to illuminate the black box of ocean management. It is our expectation that by providing a systematic and repeatable technique, policy-makers and other stakeholders will be better equipped to make new laws consistent with existing ones. Rather than passing new legislation or writing new regulations that unintentionally conflict with existing ones, if necessary, policy-makers will be able to address the inconsistency in new law. With improved knowledge of management, policy-makers can implement and adapt future regulation of the marine environment, in particular for emerging uses, in a more integrated and consistent manner. Furthermore, this tool can be used to define high priority areas for alleviating uncoordinated ocean management overlaps.

Though contributing through the lens of ocean management, this prototype text analysis technique can be applied to any set of problems of legal and government agency overlap. With more and more regulations created and increased competition for agency authority, overlapping jurisdictions and the need for improved cooperation will continue to increase. By supplying policy-makers with cross jurisdictional information about overlaps, this information can assist them to begin untangling and alleviating not only overlapping jurisdictions, but also the subsequent inefficiencies and ineffectiveness in existing management.

Chapter 6 Overlaps Concept and Technique (broad audience)

INTRODUCTION

Scientific reports of irreversible fish stock declines, increased dead zones, and loss of marine biodiversity signal a global trend of deteriorating ocean health caused by anthropogenic impacts. In confronting these and other complex cross-scale environmental problems, policy experts, government agencies, scientists, and other ocean stakeholders are shifting to more comprehensive management approaches that consider characteristics of the ecosystem (Wilson and Wheeler 1997, Sutinen et al. 2000, Juda and Hennessey 2001, Juda 2003a, USCOP 2004, McLeod et al. 2005, Rosenberg and McLeod 2005, Sherman 2005). Historically, industries, such as fishing, mining, and shipping, have driven management decisions (Knecht and Cicin-Sain 1993, Weber 2002). One common problem that derives from fragmented management occurs when multiple agencies have jurisdiction over the same resource and/or activity, but do not coordinate. In some cases agencies also have jurisdiction over incompatible activities (Rosendal 2001, Young 2002). Both types of jurisdictional issues resulting from sector-based management can benefit agencies when they coordinate or have consistent mandates. However, when a governing body makes a decision for one sector, it can result in unintended negative consequences for other sectors (Pew Oceans Commission 2003, USCOP 2004). For instance, shipping routes along the Pacific and Atlantic coasts of the United States coincide with whale migration pathways (Channel Islands National Marine

Sanctuary Advisory Council 2008). The designation of shipping sector's route was not determined in the context of marine mammal migration routes. Thus, as cargo vessel traffic has increased, ship strikes have caused a high number of whale deaths because of the overlap (Channel Islands National Marine Sanctuary Advisory Council 2008). Unintentional and uncoordinated overlaps can exacerbate the threats to ocean ecosystems by creating obstacles to effective and efficient regulation of the marine environment (USCOP 2004, Crowder et al. 2006).

How do we move to an ecosystem-based approach without unintentionally further fragmenting the sector-based management system?

A baseline view of ocean management

A critical step to transition into an ecosystem-based management approach is to create baseline data that present a comprehensive picture of institutions that govern the ocean (Juda 1999). Baseline information about existing management would assist decision-makers to: 1. identify where coordination should exist between agencies, and thus reveal potentially problematic overlapping jurisdictions; 2. identify potentially incompatible and inconsistent regulations; 3. monitor regulatory impact on ecosystem health; and 4. ultimately track feedbacks between governance and ecosystem services that can improve our understanding of the complex interdependencies within social-ecological systems. Together these benefits of generating a governance synopsis could assist EBM initiatives in planning stages to understand existing management systems. In the long term, if baselines were generated over time, such data could support monitoring and evaluation efforts to measure the effectiveness of EBM's implementation.

Statutes, regulations, legislative histories, and other management documents contain useful information to generate this baseline. The utility of such documents is reflected in the *Review of U.S. Ocean and Coastal Law: The Evolution of Ocean Governance Over Three Decades* (Appendix 6 of (USCOP 2004)), which provided a detailed account of key federal governing statutes involved in a selection of ocean issues. Such legislative analyses are extremely valuable and irreplaceable; however, evaluating a comprehensive selection of topics would be expensive. Furthermore, the outcome will often be dynamic due to ever-changing regulation and mandates. To provide a path that avoids further fragmentation of the jurisdictional landscape regulating marine ecosystems, we need tools to generate a baseline picture of ocean governance that are rapid, cost effective, widely accessible, and provide new insight (Juda 1999). Such baseline data could inform stakeholders of regulatory and other management complexity, as well as possibly assist directing rigorous legal analysis.

Even with a focus only on the Pacific Coast of the USA, marine and coastal laws encompass over 30,000 sections of United States federal law and regulation (Ekstrom 2008), which exemplifies how overwhelming it can be for agency personnel, scientists, and other non-legal experts to navigate through documents that contain elements of marine management to answer questions about ocean governance. Exploring such a large number of documents to investigate even a single topic for jurisdictional overlaps would be a daunting task, as evidenced by the years of analysis the US Commission on Ocean Policy (USCOP) required to explore existing and historical legislation just in ocean related statutes.

Confronted with the rapid growth of digital information, scientists are increasingly turning to a range of information retrieval techniques to solve a wide variety of similarly complex data analysis problems (National Research Council 1995, Feldman and Sanger 2007). For example, interpreting satellite and aerial photography revolutionized our understanding of the oceans, terrestrial ecosystems, and atmosphere. Can information technology also assist in generating governance overviews so that new legislation can promote a more ecosystem based approach to ocean management?

Challenges and obstacles to text mining laws

There is ample reason for skepticism to an assertion that quantitative text analysis, especially based on simple term frequencies, could objectively reveal the complex functionality of a law in a way that provides insight to managers and legislators. First, word frequency may not equate to importance. One law may be concise. Others on the same issue may ramble and discuss every nuance of the issue. Second, laws and regulations vary in spatial jurisdiction. For example, the National Park Service's regulations on species protection only pertain to areas with delineated boundaries, whereas the Endangered Species Act pertains to any public and private actors alike independent of location. Third, different sections of a law play different roles. For instance, although a statute's preamble gives the context in which the law was written, this content does not necessarily define an agency's authority. To further complicate the challenge, different geopolitical jurisdictions not only fail to use a consistent vocabulary, but also follow different standards for regulating. For example, the majority of the California Coastal Commission's decisions are not reflected necessarily in its published regulations, but instead in documents such as Commission reports, meeting transcripts, case law, and certified Local Coastal Programs. Despite the obstacles, those familiar with ocean and any natural resource management cannot deny the enormous desire for an accessible and comprehendible way to systematically synthesize ocean management. Text mining, a sub-discipline of computer science, can reveal relationships between documents by analyzing the pattern and frequency of terms and phrases (Feldman and Sanger 2007). Thus, if developed strategically to tackle the challenges laid out above, text mining has the potential to accurately generate baseline synopses of ocean governance.

These potential obstacles may constrain the utility of simple text analyses, but many can be overcome through more encompassing datasets beyond law and advances in information retrieval (IR), such as xml tagging and generating hierarchical sets of synonyms that facilitate comparison of laws across jurisdictions. Using hierarchical synonyms or concept domains, for example, we could develop a system to understand that a reference to "marine resources" in the California Coastal Act encompasses all marine species and habitat off California. Additional approaches from organizations such as the International Association for Artificial Intelligence and Law (www.iaail.org), which investigates challenges involved in automatically generating accurate information from laws, also could assist in developing a useful tool.

Prior to undertaking more complicated analyses in IR, this paper first explores the insight that can be gleaned from simple text analysis through term frequencies.

Assessment

To explore the utility of information gleaned about ocean management from text analysis of laws, I set up an experiment to examine the ability of text analysis to match a set of well-documented categorizations of ocean laws. Results of term counts on laws were compared with the categorization of statutes described in the USCOP Appendix 6 (Table S1). Investigation of topics within three selected categories provided strong evidence that findings from our preliminary analysis closely correspond to the synthesis of long term expert legal analysis (USCOP 2004)(NOTE 1). Although quite basic, this general correspondence sets the stage for a broader exploration of ocean issues.

Mapping landscapes of ocean law

Our continued analysis on term count data for a range of ocean and coastal relevant topics produced long lists of laws, difficult to synthesize. For example, there were many laws that referred to 'pollut*' in addition to the Clean Water Act. Producing network diagrams using agency authority to law data (Ekstrom and Lau 2008) visually displayed multiple dimensions of the data simultaneously, allowing for a more thorough and insightful interpretation. Law nodes were resized by the frequency of term or phrase counts for each topic, as shown in Figure 1 for the example topics of ‘marine mammal’ and ‘shipping.’ Large nodes pointed to laws that contain a high frequency of references to the topic, while laws without reference to the selected term or phrase were eliminated. The resulting set of diagrams creates a graphical legislative landscape for any topic or combination of topics. Although the landscapes do not provide details about the complexities within the laws, they can offer a roadmap to potential overlaps. Essentially, they are general snapshots from a system perspective of what agencies are involved through what laws for management of any given issue.

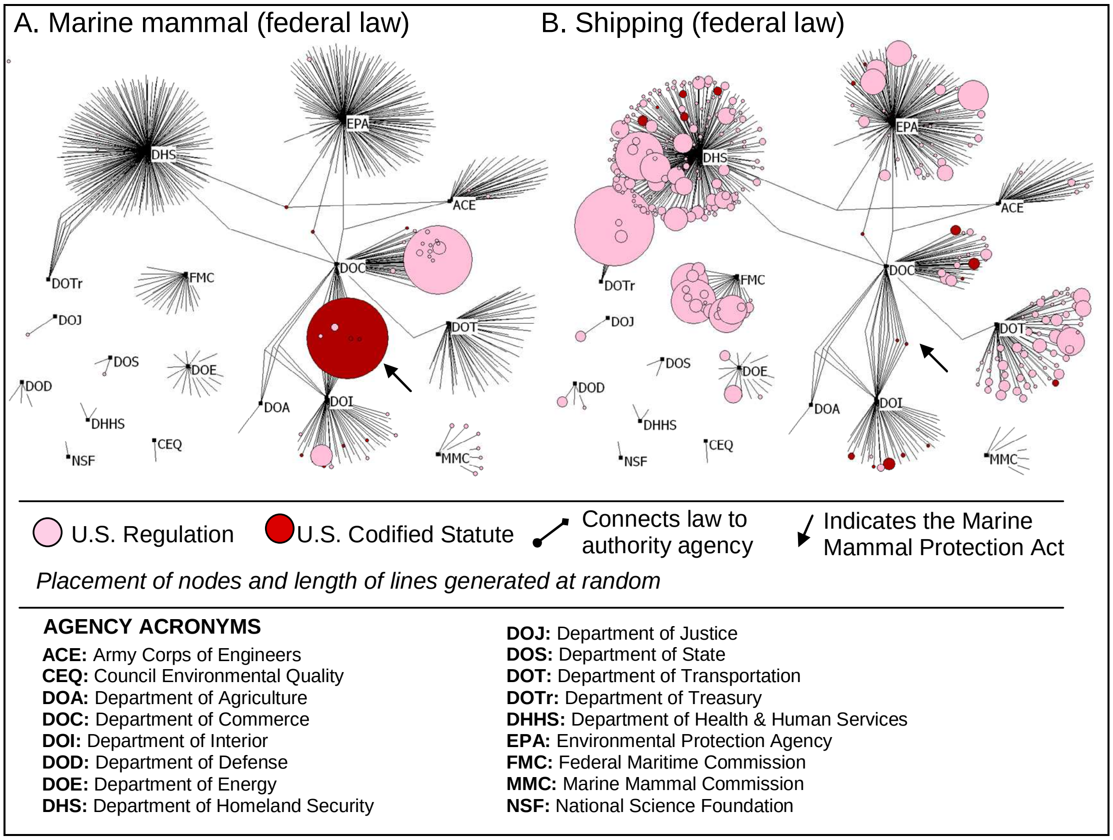


Figure 6.1. Overlapping United States federal laws and agencies directly involved in management of marine mammals (A) and shipping (B). Laws (red circular nodes) linked with lines to their statutory implementing agencies. Regulations (light pink circular nodes) are linked to their author agency. Relative frequency of term in each law is represented by varying node size. Arrow points to the Marine Mammal Protection Act in A and B, which is under the primary authority of the U.S. Department of Commerce and the U.S. Department of Interior.

The network diagrams revealed relational patterns and multiple dimensions that cannot be captured in a single table or bar graph (Ekstrom and Lau 2008). For instance, the diagrams reflected that the key statute involved in the topic of ‘marine mammal’ is the Marine Mammal Protection Act (Table S1), which is under the primary authorities of the Department of Commerce and the Department of Interior (see arrow Figure 6.1a,b). For this topic, there are few other federal agencies with regulations that are involved in managing marine mammals (Figure 6.1a). In comparison, it is apparent from Figure 1b that ‘shipping’ is under the regulatory authority of many agencies without an apparent key governing statute, which sets the stage for potentially far greater regulatory conflict.

Other topics could be added to the displays to reveal how each agency’s involvement differs or specifically overlaps with that of another in the context of a specific topic. For example, the problematic overlap between marine mammals and shipping activities has been of recent concern in Southern California due to the unusual high number of blue whales struck and killed by ships in 2007 (Channel Islands National Marine Sanctuary Advisory Council 2008). As with the continued crisis of Right Whales in the North Atlantic (Jensen and Silber 2003, Kraus et al. 2005), the overlapping geography of whale migratory routes and shipping traffic necessitates strategic management decisions to alleviate further impact on threatened cetacean populations (Channel Islands National Marine Sanctuary Advisory Council 2008). When combined, the two “legislative landscapes” expose one aspect of how sector-based decision-making has unintentionally produced problematic overlapping jurisdictions that can pose challenges for efforts to promote marine biodiversity and ecosystem health. There is an enormous body of regulation, under the multiple agencies, involved in shipping (Figure 6.1b). In some cases, involvement of many agencies indicates cohesion and coordination for management of an issue. In other cases, high involvement may reflect highly overlapping laws and agency jurisdictions. The latter is likely the case for shipping, considering the U.S. Commission on Ocean Policy (USCOP) noted the high degree of fragmentation in Shipping and Transportation sector (USCOP 2004). No matter the interpretation of how shipping is managed within the sector, its legislative landscape of term frequency counts (Figure 6.1b) relative to the marine mammal landscape (Figure 6.1a) demonstrates the large obstacles that the National Marine Fisheries Service (by way of the Department of Commerce) faces to protecting marine mammals from shipping practices.

Dimensions beyond law

We recognize that applying text mining operations is constrained in that the text of laws will not contain all information that is critical to understanding how the oceans are managed (NOTE 2). Other fundamental characteristics of management may include: 1. agency budget allocations; 2. Number and nature of Supreme Court and other court cases involving interpretation of a statute; 3. geographic scope of a law; and 4. whether the implementing agency has written and implemented regulations from a statute. Yet, quite conveniently, these characteristics can be directly linked to agencies and/or laws as additional attributes of a quantitative analysis. These added dimensions could help characterize the scope and influence of laws. Also, other documents in addition to laws can provide a more accurate picture about management, such as legislative histories, court case transcripts, meeting notes, management plans, Memorandums of Agreement, and other documents. Moreover, non-governmental organizations play a significant role in governance and thus baseline analysis should incorporate their contribution.

Other applications

Text analysis techniques can be applied to a broad set of problems involving agency jurisdictional overlap. It may help untangle management in different domains, as already seen with work on construction and water quality law (Lau et al. 2006). With more regulations created and increased competition for agency authority, overlapping jurisdictions and the need for improved cooperation will continue to increase. By supplying policy-makers with cross jurisdictional information about overlaps, this information can provide a starting point from which to begin untangling and alleviating not only overlapping jurisdictions, but also the subsequent inefficiencies and ineffectiveness in management.

CONCLUSION

In its rudimentary form, the governance analysis presented is only the tip of the iceberg in terms of developing tools to generate critically needed baseline governance data. There is enormous potential to combine information gleaned from the laws and additional management documents with other data sources, such as ecosystem relationships (see e.g. Newton et al. 2000) and human threats on oceans and coasts (see e.g. Halpern et al. 2008). Advancements in information technology are facilitating integration of data that could only be imagined in the past. Experts in all related fields need to conceive of the capabilities of these advancements and push for the tactical integration of social and natural science data. Implementation of efforts supporting such integration will equip us to effectively address complex and large scale environmental threats with informed and cohesive policy, facilitating the implementation of ecosystem-based management.

Table 6.1. Comparison of primary law for each topic identified by USCOP (Appendix 6) compared to law ranked highest from term frequency analysis.

Category	Topic within category (term/phrase used)	Law listed by USCOP App.6	Law from term count (ranked highest)	Term frequency	Success
Coastal management	coast	Coastal Zone Management Act (CZMA)	CZMA	454	Yes
	Coastal management	CZMA	CZMA	31	Yes
	Coastal development	CZMA	CZMA	4	Yes
	Coast* + management	CZMA	CZMA	711 (sum of terms)	Yes
Living marine resources	Living marine resources	Magnuson Stevens Act (MSA)	MSA	13	Yes
	Marine resources	MSA	MSA	37	Yes
	Fisher-	MSA	MSA	1407	Yes
	Fishing	MSA	MSA	726	Yes
	Endangered species	Endangered Species Act (ESA)	ESA	144	Yes
	Threatened species	ESA	ESA	91	Yes
	Critical habitat	ESA	ESA	34	Yes
	Marine mammal	Marine Mammal Protection Act (MMPA)	MMPA	621	Yes
Ocean and coastal pollution from land-based sources	Pollution	Clean Water Act (CWA)	CWA	986	Yes
	Water quality	CWA	CWA	287	Yes
	Nonpoint source pollution	CZARA	CZARA (sits within CWA doc)	67	Yes
	Air pollution	Clean Air Act (CAA)	CAA	287	Yes
	Atmospheric deposition	CAA	CAA	5	Yes
	Atmosphere(ic)	CAA	CAA	71	Yes

NOTE 1: The experiment initially was designed to determine if laws with the highest term count for each of the given categories could match those deemed "key statutes"

for a selection of the categories described in the USCOP (Table S1). I chose the three categories (coastal management, living marine resources, and ocean and coastal pollution) that appeared to have the most straight-forward set of topics. For example, the category of living marine resources contained topics of ‘fishing’ and ‘fisheries,’ which are under the primary authority of the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1866 et seq.); but this category also included the topic of ‘threatened species’ and ‘critical habitat’ which are under the primary authority of the Endangered Species Act. The laws that ranked as most involved for all three categories investigated accurately corresponded to the descriptions of USCOP Report (USCOP 2004). As an example of a topic accurately portrayed through term counts, the law containing the most references to the term ‘fishing’ (726 frequency) was the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1866 et seq.).

NOTE 2: Governance encompasses formal and informal institutions, as defined by Juda 1999. Analyzing laws to represent management constrains the analysis only to formal rules, rights, and decision-making procedures. However, until a dataset including non-governmental and informal institutions is compiled to represent all sectors across multiple jurisdictions, the laws provide a free, publicly available dataset to begin quantitative examination of fragmented management. Even the most advanced text mining techniques will not replace valuable legal knowledge or lawyers’ experience with and interpretation of the law. Nor will they capture any disconnect between *de facto* (law on paper) and *de juro* (management in practice) management. However, text analysis of laws could provide a useful tool to test the disparity between rules on paper and rules in use. In addition, without case law, local laws and regulations, and area management documents, results will not precisely portray the full suite of formal institutions in the oceans and coasts.

Chapter 7 : Application of Gaps and Overlaps Techniques to Evaluate Management Institutions Relating to Ocean Acidification[8]

CASE STUDY INTRODUCTION

Ocean Acidification

Over the next century, ocean acidification will likely cause larger ramifications for humans and ecosystems than global climate change. Scientists have shown with certainty that the pH balance of the ocean will decrease dramatically, "acidifying" or reducing alkalinity, as a result of the increased anthropogenic carbon dioxide in the atmosphere (Caldiera and Wickett 2003). In fact, since the beginning of the industrial revolution, humans have been responsible for more than 290 billion tons of carbon dioxide emitted into the atmosphere. This carbon effusion has largely been due to the burning of fossil fuels and cement manufacturing (Hanle et al. 2004, IPCC 2007). The increased concentration of atmospheric CO_2, coupled with other anthropogenic greenhouse gas emissions, cause climate change (Houghton et al. 2001). These CO_2 emissions distribute among three places: terrestrial biota through photosynthesis (and then partially into sediment), the atmosphere, and the ocean. Humans have been fortunate thus far that the severity of climate change has been buffered by the ocean's capacity to absorb a substantial portion of atmospheric CO_2

[8] NOTE TO READER: The methods section of this chapter contains portions taken directly from Chapters 4 and 5

(Raven and et al. 2005). Consistent with the law of Henry, the ocean draws down increased atmospheric CO_2 into the surface water by way of diffusion and into deeper water through currents (Caldiera and Wickett 2003, Portner 2008). Unfortunately, this buffering action is altering the chemistry of the ocean. In fact, the ocean's pH balance has already decreased by 0.1 pH units, which is a 30% increase in hydrogen ion activity in ocean surface waters. Based on the Intergovernmental Panel on Climate Change (IPCC) "business as usual" scenario of CO_2 emissions (IS92a), projections show that pH will decrease by an additional 0.3-0.4 units by the end of the century (Haugan and Drange 1996, Brewer 1997). Research has already shown that calcifying organisms, such as coral and plankton, may not be able to adapt to the reduced carbonate conditions (Feely et al. 2004). Increased levels of CO_2 in sea surface water may also substantially undermine the physiology of non-calcifying organisms, such as by undermining the respiratory systems of fish and marine mammals (Seibel and Fabry 2003, Portner 2008). In the big picture, the ocean's ability to sequester atmospheric carbon over geological time scales – known as the "biological pump" – will decline, exacerbating the problem of carbon dioxide build up in the atmosphere (Sarmiento et al. 1995). Perhaps most frightening is the realization that the cumulative impacts of these stressors may cause the breakdown of the ecosystem services (i.e., coral reefs providing nursery and refuge for commercially important food fish) on which humans depend on for health (Portner 2008).

Governance related to ocean acidification

Confronted with impending environmental catastrophes, the following question arises: how do humans reverse the trajectory of ocean acidification and ensure a sustainable balance between industry and environment? Ideally, we would simply develop regulations that reduce — until they eliminate — carbon dioxide emissions. Unfortunately, this proposition is not realistic because new regulatory systems cannot be implemented in a vacuum; they must be designed within existing governance structures and regimes. As such, detailed knowledge of existing institutions is critical to the design of a realistic and effective resolution to any environmental problem (Bromley 1992, Hanna et al. 1996). The chemical process for determining levels of ocean acidification is well established and straightforward (Raven and et al. 2005), so the knowledge of existing governance, and the ability to redress the lack of governance on this issue, becomes the essential element in reversing ocean acidification. The basis of this case study is our belief that an improved understanding of existing management and agency jurisdiction will illuminate the key agencies, regulatory standards and effective policymaking strategies necessary to develop a realistic resolution to the problem of ocean acidification.

Pending legislation -- FOARAM

While there are no existing laws specifically addressing ocean acidification, there is a pending bill in Congress to fund more research on the topic. The bill seeks funding to monitor and analyze biological and ecological impacts of ocean acidification (Federal Ocean Acidification Research and Monitoring, FOARAM, Act of 2007). This bill proposes to support further research on the process and impacts of acidification on marine ecosystems.

Existing water quality standards

Also on the forefront of ocean management discussions is the Environment Protection Agency's (EPA) marine water quality criteria for human-induced pH alterations and whether the findings by the IPCC's[9] best-case scenario of atmospheric CO_2 rises will be in violation (Caldeira et al. 2007). The EPA water quality standard established in 1976 states that: "For open ocean waters where the depth is substantially greater than the euphotic zone, the pH should not be changed more than 0.2 units outside the range of naturally occurring variation . . . " (U.S. Environmental Protection Agency 1976). Indeed 25 leading experts in ocean chemistry and atmospheric science found continued carbon emissions from fossil fuel burning would cause the ocean to violate this criterion (Caldeira et al. 2007). Dr. Ken Caldeira, scientist from the Carnegie Institution's Department of Global Ecology, asserted that "if atmospheric CO_2 goes above 500 ppm, the surface of the entire ocean will be out of compliance with EPA pH guidelines for the open ocean" (Carnegie Institution 2007).

---

[9] The Intergovernmental Panel on Climate Change (IPCC) is an international scientific body that evaluates the state of scientific understanding on climate change and its impacts (www.ipcc.ch/).

Related and overlapping governance

Despite the lack of any specific initiative to address ocean acidification, a tremendous quantity of formal and informal management systems exist that directly relate to various aspects of the problem. In order to give context to the issue in human terms, consider that humans rely heavily on activities and energy that emit CO_2 from basic necessities to recreational luxuries. For example, agriculture that produces most of the food consumed in the United States also uses a large amount of fossil fuels (Cleveland 1995). How do we manage for such tradeoffs? Institutions[10] support each of these carbon-emitting activities and products, so developing a new set of rules that aims to eliminate CO_2 emissions would overlap with the jurisdiction and priorities of the existing institutions. Likely, the status quo would override proposed regulation. The situation of unintended and/or problematic overlapping jurisdictions so commonly arises that social scientists have spent considerable effort on the topic, referring to it as *institutional interplay* (see e.g. Rosedal 2001, Young et al. 1999, 2005 IDGEC). Although institutional interplay is more widely researched on the international scale, the findings on the nature of institutional interplay, approaches and results can be applied at the national and local scales (Young 2002).

---

[10] The definition of an *institution* encompasses "rules, cluster of rights, and decision-making procedures" that guide human behavior (Young 2002). As such, *environmental institution* refers to a management system that guides human use and abuse of the environment. *Environment regime*, on the other hand, refers to an institution or set of institutions that have a particular target, such as fisheries management, minerals management, water quality control, etc. *Governance* refers to management in general and also the system of interdependent formal and informal institutions that exist for the management of coasts and oceans (Juda 1999).

Despite institutional challenges, confronting ocean acidification is not a lost cause. To move forward, it is crucial to recognize that no institution can be created as if it exists or will exist in a vacuum. As such, we can work within the context of the existing governance by either proposing to modify what exists or to develop entirely new institutions. It is critical that a new institution be created as a productive partner in the existing web of institutions and not cause unintended interplay among overlapping jurisdictions (Ebbin 2002). Thus, baseline data about existing institutions provides policymakers and stakeholders with a blue print of the regulatory environment in regard to ocean acidification, so they can determine the most effective strategies toward realistic resolution of the issue. For example, there are numerous laws pertaining to the regulation of carbon dioxide (CO_2) emissions, a causal factor in the problem of ocean acidification. Similarly, there are monitoring systems and regulations in place that pertain to pH balance of water. Although these laws were not written to address ocean acidification, they can still play a role in the institutional environment where, if reasonable, a new institution that directly tackles ocean acidification could be developed.

The amount of governing law as a whole that inherently, though peripherally, relates to ocean acidification is enormous as a consequence of sector-based management. Historically, in the United States and many other developed countries, management of the oceans has been conducted within sectors or industries, such as fishing, mining, shipping, and recreation (USCOP 2004, Elliott et al. 2006, Cao and Wong 2007). Government agencies, along with other ocean-related stakeholders, recognize that this approach is no longer effective. With the increases in coastal populations (and its associated development), ocean pollution, and technological advances, the human footprint left on the oceans and coasts is visible everywhere on earth (Halpern et al. 2008). With industry priorities leading regulation, marine and coastal uses (and abuses) were developed in a piecemeal manner within the sectors. As a result, sector-based management has created a governance system riddled with gaps and overlaps in ocean law and regulation (Knecht et al. 1988, USCOP 2004, Crowder et al. 2006).

Fragmented decision-making is fraught with problems. One problem is the negative consequences that result from overlapping jurisdictions, such as when one institution's regulation conflicts with the actions or objectives of another. Some of these overlaps can be mitigated through improved coordination or collaboration. Another common problem associated with fragmented management is the mismatch of institutions in the context of the ecosystem. This is referred to as "the problem of fit," which calls attention to the potentially harmful ecological implications of developing institutions without adequate consideration of the relevant ecosystem's properties (Young 2002, Folke et al. 2007). Clearly the fragmented nature of sector-based policy-making is no longer adequate for the complexity of modern ocean uses and the severity of poor management consequences (Pew Oceans Commission 2003, USCOP 2004). New methods for effective management call for a broader perspective and better use of information about the institutional environment (Sutinen et al. 2000, Juda and Hennessey 2001).

Ecosystem-Based Management (EBM)

There has been recent momentum in marine policy to shift away from the sector-based decision-making to a more holistic approach that considers the ecosystem. Policymakers commonly refer to this methodology as ecosystem-based management (EBM) or an ecosystem approach to management (EAM). For the sake of this project these concepts are the same in that they both require decisions to be made with consideration of *all* ecosystem components, rather than decisions made based on an activity, resource, stressor, species, or habitat as an isolated entity (McLeod et al. 2005). This approach, which should be tailored to the physical location's biophysical conditions and socio-cultural, economic, and institutional environment, can involved a vast number of policy instruments to implement it (Young et al. 2007). There is no cookie cutter institutional design for what EBM looks like (Young et al. 2007), but what is key to effective EBM is a scientific understanding of the existing institutional environment and how EBM can most seamlessly replace the fragmented system (Sutinen et al. 2000, Juda and Hennessey 2001, Olsen et al. 2006).

The holistic approach of EBM is especially effective for environmental problems that span multiple scales. Without EBM we really have no way in which to strategically address multi-scale issues such as hypoxic zones, climate change impacts, rising sea level, increased storm severity, and ocean acidification. Implementation of EBM provides a mechanism to tackle such issues through the strategic development of cross-scale institutional linkages (Berkes 2002). Cross-scale linkages may vary from global scale decision-making between nations (Young 2002) or bottom-up initiatives at the local level that influence national or international decision-making (Berkes 2002). A holistic approach is the only method that has the capacity to take into account all these factors.

It is critical to remember that human actions created our current environmental issues; these actions were guided and misguided from human-constructed rule, rights, decision-making procedures, and societal values (Hanna et al. 1996, Young 2002, Ostrom 2005). In human society, institutions play the role in mitigating and allowing harmful human actions to the environment, and preventing and facilitating multiple-scale environmental disasters (Ostrom 2005). But in order to strategically and effectively redesign or modify institutional systems so they consider ecosystem services and properties that guide human behavior, we must have a clear understanding of the existing complexity of governance (Cortner et al. 1998, Juda and Hennessey 2001, Olsen et al. 2006). It is critical that this management baseline reflect a comprehensive view of all sectors since the gaps and overlaps between and within sectors have produced many of the major roadblocks to effective management (Crowder et al. 2006).

Foci of this case study's institutional analysis

This case study aims to generate a comprehensive baseline view of governance relating to ocean acidification by performing quantitative analyses about gaps and overlaps in the laws and regulations of this issue. The problem of ocean acidification is analyzed within its broader cross-scale context. This *chain of explanation* is a tool borrowed from political ecology and was developed, and is employed in this case study, to place a specific problem in the broader framework (Vayda 1983, Sutinen et al. 2000, Belausteguigoitia 2004, Robbins 2007). The utility of a causal chain approach has also been stressed as a framework to integrate systematic and holistic analysis of sector-based management problems[11] (Juda and Hennessey 2001). My chain of explanation, as it relates to ocean acidification, is presented as a set of interdependent components that include human activities, species, habitats, and biophysical processes. Essentially, these components and relationships make up a system which can be regarded as a conceptual ecosystem (or even socio-ecological system).

The scale of this system spans from global to local. Increased CO_2 for example, is a global problem, but its impact on pH in the ocean surface layer will differ by region. And the organisms directly affected by the ocean acidification will differ by location. This case study encompasses the multiple scales for the system, but focuses on one particular locale for the direct and indirect impacts. The

---

[11] Quoted from Juda and Hennessey (2001:67): "Pernetta and Mee, *The Global International Waters Assessment*, supra note 8 emphasize the importance of causal chain analysis. According to them: "A causal chain is a series of statements that demonstrate and summarize, in a stepwise manner, the linkages between problems and their underlying or 'root' causes. Uncertainties accompanying each linkage should be clearly stated. The analysis also permits barriers to resolving the problems to be investigated. A causal chain presents the nature of the problem itself, including the effects and transboundary consequences, and then probes the linkages between problems and its societal causes. In its practical application, it can serve as a model into which regionally relevant information may be inserted."

geographic focus for this case study is the Channel Islands National Marine Sanctuary. The impact analysis considers the direct impact on calcifying organisms, the indirect impacts on dependent organisms, and a small representative sample of human system activities that depend on the impacted organisms. In future research, this approach can easily be applied to other regions, as well as include an expanded or modified version of the ecosystem model. While finer resolution to these analyses is possible, this project provides a starting point and foments discussions that will contribute to developing policy to tackle the emerging threat of ocean acidification.

In Part A, the gaps analysis measures and highlights the points of mismatch between state and federal governance and the modeled ecosystem. In Part B, the degree to which each agency is involved in each topic (and category) is presented. The second part of the case study also presents an overlaps analysis, which quantifies the complexity of governance related to each component of the modeled system. In addition, complexity is calculated for the grouped components in their respective categories.

In conjunction with demonstrating the utility and limitations for these analyses, these findings will provide preliminary information for policymakers about:

- Where the biggest gaps in management are that relate to ocean acidification;
- Within topics relevant to acidification, which of these involve the highest degree of overlap complexity, and therefore may present the biggest roadblocks against institutional change; and

- What agencies are involved in the relevant topics? Which agencies (empowered by which laws) would need to be involved in a coordination effort in order to effectively prevent or alleviate further ocean acidification scenarios?

Using the answers to these questions, the discussion in Part B presents policy recommendations in regard to what an agency (such as the Channel Islands National Marine Sanctuary) can do to initiate a solution from the bottom-up. The discussion then expands to a larger consideration of what needs to be done to tackle ocean acidification from the top-down. At the foundation of this analysis is the belief that understanding the institutional environment in the context of ecosystem-based management is the first step in proposing a solution to complex issues such as ocean acidification.

PART A – GAPS IN MANAGEMENT

GAPS ANALYSIS INTRODUCTION

As with nearly every other environmental problem, more research needs to be conducted to broaden our understanding of ocean acidification and its ecological repercussions; in the meantime, management agencies, Congress, and other stakeholders involved in decision-making can move toward developing a practical solution. Finding a realistic resolution depends upon a better understanding of existing management systems. Laws and regulations that relate to ocean acidification span across multiple sectors and scales. It is critical to identify the gaps in this complex web of governance in order to strategically address priority issues currently unresolved by existing laws. Confronted with impending environmental disaster and the task of designing a holistic resolution that integrates multiple sectors and scales, researchers and policymakers must ask themselves:

- What are the gaps in management related to ocean acidification?
- What institutions are involved in each aspect of this problem (from carbon emission sources to ecological impact)?

Identifying gaps and relevant institutions assists decision-makers, managers, scientists, and other stakeholders to perform the following: 1. prioritize problems to be resolved based on the severity of identified gaps, and then 2. determine which agencies, statutes, and regulations should be involved in mitigating ocean acidification. This paper focuses on analysis, interpretation, and discussion of gaps in management because the unresolved issues in regulation for ocean acidification could result in environmental disaster. Part B of this case study considers agency and jurisdictional authority and provides insight into how to fill the gaps in management in order to thwart the progression of ocean acidification.

This paper applies a technique that identifies and measures legal gaps in ocean management, combining approaches from systems ecology, information retrieval and social network analysis. The legal gap analysis technique was developed based on the idea that management institutions should reflect the nature and functionality of a relevant ecosystem (Young 2002). An ideal system of governance would take into account a conceptually modeled ecosystem, defined to include humans, and relate to the pieces of that modeled system. As explained in the case study introduction, an ecosystem refers to a system of interdependent components that relate directly or indirectly to a particular problem. This study quantitatively establishes that Federal and California State laws fail to specifically address the problem of ocean acidification. Additionally, the technique reveals where current laws address problem areas and where gaps exist. This information provides a baseline view of governance that peripherally relates to ocean acidification, and can be used to develop policy and management recommendations.

BACKGROUND

This section presents a background summary of gaps analysis. More information about this technique can be found in Chapter 4. This section provides a conceptual model of ocean acidification as a system of interrelated components and presents various aspects of the issue from carbon emissions to ecological impacts of the predicted ocean acidification. For the purposes of making manageable conclusions, the scope of this project is limited to a sample of predicted impacts as they may occur in the Southern California Channel Islands region.

Legal gap analysis

The legal gaps analysis generates baseline data revealing disconnects between the institutional management and the scientific components of an ecosystem. This technique was developed based on the idea that to sustain ecosystem services, management systems should "fit" or match the properties of a given ecosystem[12] (Costanza and Folke 1996, Young 2002, Folke et al. 2007). Within the traditional sector-based approach, mismatches between institutions and the ecosystem are common. For example, Crowder et al. (2006) categorizes two types of mismatches that commonly appear in ocean management: spatial and temporal. A spatial mismatch occurs, for example, when the migratory scope of a species spans political borders. This difference in scale prevents any effective control over human behavior outside the jurisdiction unless there is substantial effort in coordinating the authoritative entities (Wilson 2006). Temporal mismatch refers to situations in which there is a disconnect between time scales of an ecological or biological functional process and a human governing process. Impacts on marine systems can occur faster

---

[12] *Ecosystem* in this dissertation refers a system of interdependent components including humans, other species, and biophysical processes and entities (Millennium Ecosystem Assessment 2005). As such, an ecosystem, depending on the components, location, and scale, inevitably spans multiple sectors and industries.

or slower than rigid institutional time scales, leading to a lack of policy response to adequately adapt management effectively (Crowder et al. 2006, Wilson 2006). These mismatches, as well as others, often are unintended consequences of management based on industry priorities and not ecosystem realities (USCOP 2004). The gaps analysis performed in this dissertation evaluates mismatches between institutions and ecosystems at a more fundamental level. By focusing on relevant ecosystem components, and linkages between institutions and ecosystems, the analysis reveals whether regulation and law adequately address critical environmental issues such as ocean acidification. Law is the medium by which government agencies exercise their control across multiple atmosphere, ocean, and coastal sectors.

The task for identifying these mismatches objectively and quantitatively for any given ecosystem requires that the gaps analysis tests whether critical relationships between ecosystem components are found in law. The analysis generates two outputs: (1) two metrics for the degree of fit between a user-defined ecosystem and the laws of a geopolitical jurisdiction; and (2) specific ecosystem linkages missing from law, called *gaps* for purposes of this case study. A legal *gap* in ocean management is when laws and regulations do not address a critical linkage between two components of a system. *Linkages* can include interactions among species and/or habitats, or with biophysical conditions, or human stressors. The methodology of this analysis exemplifies ecology-based social science findings that conceptually modeling the interdependent components of an ecosystem facilitates effective and holistic environmental problem solving (Huggett 1993, Cordell and Bergstrom 1999).

Ecosystem approach for ocean acidification

This project applies an ecosystem-based perspective to analyzing ocean acidification-related governance for purposes of developing a policy resolution across sectors and ecosystems. The methodology first requires a succinct discussion of ocean acidification within the context of a larger system (see Figure 7.1 for conceptual diagram of modeled system). Next a presentation is made of the modeled components of the larger ecosystem, these occur within and between various scales. Appendix A explains the model construction in more detail.

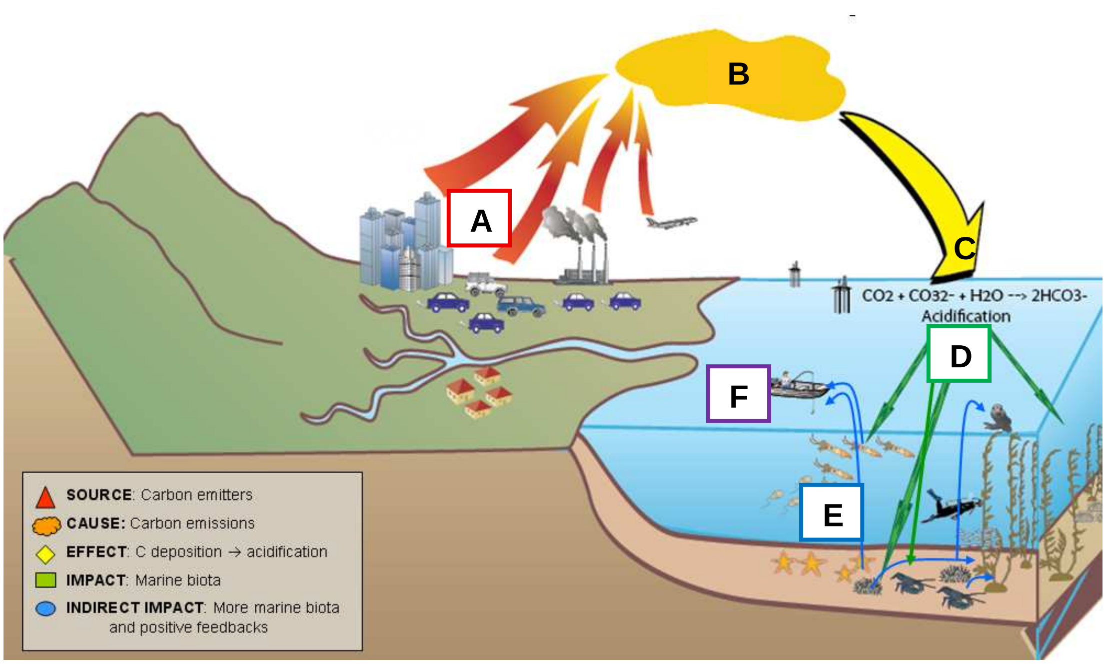


Figure 7.1. Conceptual diagram of ocean acidification problem. Diagram shows acidification process from the source of carbon emitters through the predicted ecological impacts, specifically on the kelp forest ecosystem of Southern California Channel Islands. Conceptual diagram of ecosystem relating to ocean acidification. A. Source; B. Cause; C. Effect; D. Direct Impact; E. Ecological

Impact; F. Human Systems Impact. Refer to Table 7.1 for definitions of each category. Illustration generated in Adobe Illustrator with Integrative Applications Network (IAN) Ecosystem toolbox, 2008.

Conceptual model

Full comprehension of the system and extent of the ocean acidification problem necessitates identification of components, linkages and a conceptual model of those species and human activities impacted by ocean acidification.

Categorization

The drawing of a conceptual diagram (Figure 7.1) utilizes six main categories to represent the chain of explanation related to acidification. Beginning with ocean acidification (OA) as the *Effect* (represented by a diamond in Figure 7.2), we can look backwards to the source of this problem (represented by circles in Figure 7.2), and then forwards to the anticipated impacts of OA in the future (Figure 7.2). Therefore, the boundaries delineating this system encompass both the sources of carbon dioxide and the indirect impacts of OA. The following categories explain this system: (A) Source; (B) Cause; (C) Effect; (D) Direct Impact; (E) Ecological Impact; and (F) Human Systems Impact (Figure 7.2). Each category is represented with multiple components (Table 7.1), each interacting with one or more other components in the defined system (Figure 7.1). This conceptual ecosystem model generates a symmetrical matrix of 40 components by 40 components with each cell indicating either the existence of a direct linkage (1) or no direct relationship between components (0) (Figure 7.3). Each component sits within one of the six categories so that additional cross-category analysis can be calculated.

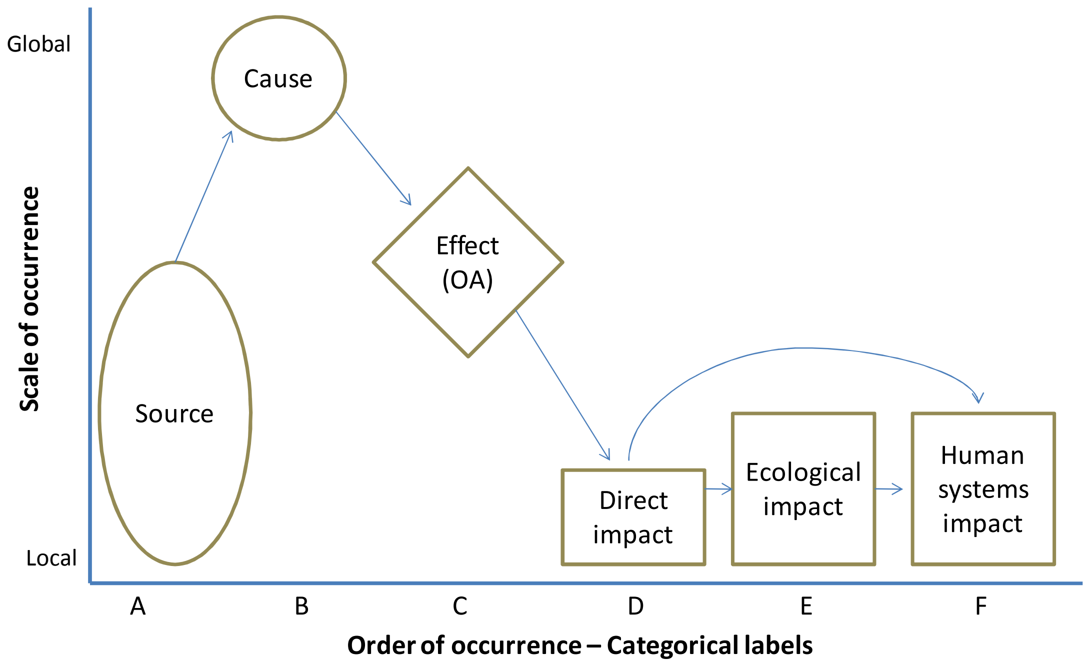


Figure 7.2. Categories selected to conceptually model the larger system surrounding ocean acidification (OA) and its interrelated components. Categories are represented by shapes in the order in which they occur. Each arrow indicates the direct linkage between these two components. For example, the Source (carbon emitters) directly impacts the Cause (atmospheric CO_2); or specifically, carbon emitters directly increase the amount of atmospheric CO_2.The two categories occur on different geospatial scales; as such, their position along the y-axis indicates scale. Refer to Table 1 for each category's description, components, and scale.

Table 7.1. Categories investigated as relevant components of the system (Source to Impacts) of ocean acidification for the Channel Islands National Marine Sanctuary. Scale varies from local to global, or specifically the carbon dioxide emitters occur on a local scale while their emissions impact the atmosphere on a global scale.

ID	Category	Component description	Scale	Component	Term used to represent component
A	Source	Transportation industry, carbon emitters	Local, regional	Fossil fuel	Fossil fuel
				Transportation	_transportation
				Shipping	_shipping_
				Cargo	Cargo
				Vehicle	Vehicle
				Car	_car_
				Truck	Truck
				Motor	Motor
		Energy production from power plants		Energy production	Energy produc*
				Power plant	Power plant
		Cement manufacturing		Cement manufacturing	_cement_
B	Cause	Physical cause of ocean acidification (atmospheric CO_2 increase)	Global	Carbon dioxide	Carbon dioxide
				Atmosphere	Atmosphere
				Carbon emission	Carbon emiss*
C	Effect	Atmospheric carbon deposition from the atmosphere to the ocean	Regional, global	Carbon deposition	Carbon + deposit*
				Sequestration	Sequest*
		Decrease in pH		Acidification	Acidification
				pH	_pH_
				Carbonate	Carbonate
D	Direct Impact	Selection of calcifying organisms and kelp in Channel Islands region	Local	Plankton	Plankton
				Kelp	Kelp
				Lobster	Lobster
				Squid	Squid
				Abalone	Abalone
				Urchin	Urchin
E	Ecological Impact	Species directly linked to one or more of the species listed in Direct Impact category	Local, regional	Sheepshead	Sheepshead OR sheephead
				Whale	Whale
				Otter	_Otter_
				Anchovy	Anchov*
				Sardine	Sardine
				Mackerel	Mackerel
				Starfish	Seastar
				Mackerel	Mackerel
				Rockfish	Rockfish
				Seabird	Seabird
F	Human Systems Impact	Recreational or economic activities common in the Channel Islands region that directly relate to components in the Direct Impact or Ecological Impact category	Local, regional	Fishing	Fishing
				Harvest	Harvest
				Whale watching	Whale watch*
				Scuba diving	Scuba div*
				Recreation fishery	Recreation fish*
				Commercial fishery	Commercial fish*

Linkages between components

Using the components listed in Table 7.1, this subsection summarizes the inherent linkages among categories that are presented broadly in Figure 7.2. Following the x-axis (from A to F), the first category is the principal *Source*, which refers to the burning of fossil fuels by the transportation and industry sectors, as well as other activities emitting CO_2. Emissions caused by fossil fuel consumption and the resulting increase in the concentration of atmospheric carbon dioxide are the physical *Cause* of the mounting uptake of inorganic carbon into the ocean. The *Effect* (the primary focus of this model) on the ocean is lower pH and reduced carbonate availability; a process scientifically known as 'acidification' (Caldiera and Wickett 2003). This sequestration changes the chemistry of the ocean surface water, eventually producing a decrease in carbonate concentration. Acidification has a *Direct Impact* on the physical oceans and the marine biota, especially for those organisms that use carbonate to develop shells, such as pteropods, foraminifera, and coccolithophores (Feely et al. 2004). These calcifying plankton are essential food to other commercially and aesthetically important species, such as salmon and baleen whales. Moreover, acidification raises the depth of the carbonate supersaturation horizon. This diminishes calcifying zooplankton habitat because waters saturated in carbonate dissolve their shells (Feely et al. 2004). Thus ocean acidification impacts the fitness of calcifying plankton in two major mechanisms – decreased availability of carbonate for producing shells and reduce habitat.

While many direct impacts of this chemical alteration threaten ocean health, the most studied concern is the effect of ocean acidification on calcifying organisms (Orr et al. 2005, Gazeau et al. 2007). Chemically speaking, the increasing uptake of carbon dioxide combines with water (H_2O) and carbonate (H_2CO_3), decreasing the ratio of the ocean's carbonate to bicarbonate ions (HCO_3^-):

$$CO_2 + CO_3^{2-} + H_2O \rightarrow 2HCO_3^-$$

(Orr et al. 2005)

If this process continues to diminish levels of carbonate then calcifying organisms in the Southern California Channel Islands region, such as pteropods, foraminifera, lobster, crab, and urchins, will have inadequate supplies of carbonate to form their shells (Orr et al. 2005). Scientists predict this will reduce the survivorship and likely the overall fitness of the populations. Recent studies have shown that lower pH levels will have a negative direct impact on kelp (Klinger and Kershner 2008), as well as the physiological functionality of many non-calcifying organisms (Portner 2008). Kelp has been included in the ecosystem model as a directly impacted organism, although other non-calcifying organisms have not been included in the model as directly impacted components because the science is less established on these system components. Calcifying plankton are also fundamental building blocks to marine food webs, providing sustenance to fish, marine mammals, and invertebrates (Hays et al. 2005). The reality is that whether we focus narrowly on the fitness impacts on calcifying organisms (Orr et al. 2005), or expand the scope to include non-calcifying organisms, ocean acidification still has a broad *ecological* and *human system impact* (Brewer 2007) that scientists have only begun to examine.

This synopsis of conceptual linkages vindicates the use of the components' categorization, which then leads to the development of a more detailed matrix of linkages between components within and between all categories (Figure 7.3).

	fossil fuel	_transportation	_shipping	cargo	vehicle	_car_	truck	motor	energy produc	power plant	_cement_	carbon dioxide	atmosphere_	carbon emiss_	carbon + depos	sequest_	acidification	_pH_	carbonate	plankton	lobster	squid	abalone	urchin	sheep(s)head	whale	_otter	anchov_	sardine	mackerel	seastar	rockfish	kelp	seabird	fishing	harvest	whale watch_	scuba div_	recreational fis	commercial fis
fossil fuel		1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
_transportation			1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
_shipping				1	1	0	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cargo					1	0	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
vehicle						1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
car							1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
truck								1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
motor									0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
energy produc										1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
power plant											0	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cement												1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
carbon dioxide													1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
atmosphere_														1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
carbon emiss_															1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
carbon + deposition																1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sequest_																	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
acidification																		1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
_pH_																			1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
carbonate																				1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
plankton																					0	1	0	0	0	1	0	1	1	1	0	1	1	1	1	0	0	0	0	0
lobster																						0	0	1	1	0	1	0	0	0	0	0	0	0	1	1	0	1	1	1
squid																							0	0	0	1	0	0	0	1	0	0	0	1	1	1	0	0	0	0
abalone																								1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
urchin																									1	0	1	0	0	0	0	0	1	0	1	1	0	1	0	0
sheep(s)head																										0	0	0	0	0	0	0	0	0	1	1	0	1	1	1
whale																											0	0	0	0	0	0	0	0	1	0	1	1	0	0
_otter																												0	0	0	0	0	1	0	1	1	0	1	1	1
anchov_																													0	1	0	1	0	1	1	1	0	0	1	1
sardine																														1	0	1	0	1	1	1	0	0	1	1
mackerel																															0	1	0	1	1	1	0	0	1	1
seastar																																0	0	0	0	0	0	1	0	0
rockfish																																	1	1	1	1	0	0	1	1
kelp																																		1	0	1	0	1	0	0
seabird																																			1	1	0	0	1	1
fishing																																				1	0	1	1	1
harvest																																					0	1	1	1
whale watch_																																						0	0	0
scuba div_																																							0	0
recreational fish_																																								1
commercial fish_																																								

Figure 7.3. Matrix of conceptual ecosystem model pertaining to the components of ocean acidification relative to the Southern California Channel Islands region. Cells indicate whether there is a linkage (1) or not (0) between the two corresponding components. Colors group components into their relevant categories (Table 7.1). PINK= Source (A); ORANGE= Cause (B); YELLOW= Effect (C); GREEN= Direct Impact (D); BLUE= Ecological Impact (E); PURPLE= Human Systems Impact (F).

Scale

Fundamentally, ocean acidification is a cross-scale problem. The location of the Source is not directly linked to where impact occurs. For example, CO_2 is emitted by individuals or entities, but it is the cumulative abuse of the individual emitters around the world that cause ocean acidification. That being said, emitters are a local to regional scale concern especially since certain regions, such as the United States, contribute more carbon dioxide emissions than most other parts of the world. The rising atmospheric CO_2 is a global issue because it causes worldwide changes in climate and ocean pH levels. The cross-scale nature of ocean acidification is also apparent in the fact that while increased carbon dioxide in the atmosphere and its effect on pH levels is a global problem, the degree of impact will vary by region based on temperature, upwelling, and other local or regional biophysical factors. Research has indicated that the variance in the effect of ocean acidification in a specific region will not necessarily correlate with the carbon emissions produced in that region (REF). The polar regions will experience the most severe and rapid impacts because of cold-water temperatures and the already limited habitat in which marine organisms can survive (Orr et al. 2005). The coastal waters of California will also experience more severe impacts than other regions because its waters are already low in oxygen and high in CO_2 due to upwelling (Childress and Seibel 1998). Therefore, the addition of CO_2 combined with warming will further decrease the oxygen concentration and thus be less able to support higher life than the coastal waters at the same latitude in the Atlantic (Peter Brewer, pers. comm.).

Caveat about modeled ecosystems

Some may argue that this analysis will be biased from the start because it relies upon a user-defined ecosystem. However true that observation might be, it is also true that the ecosystem itself is always a human-constructed entity delineated by arbitrary boundaries. For purposes of understanding species, habitats and other components as a system of interdependent parts, the ecosystem concept provides a theoretical and tangible foundation for analysis. In studying issues related to global environment change, it is far more useful to acknowledge the complexity of systems than to investigate the behavior and functionality of a single component in a vacuum (Golley 1996). The boundaries of an ecosystem may be based on biogeography or climate factors, but these scientific variables will always be social constructions. Thus at a fundamental level, while ecosystems may be a human construct, they provide us with an understanding of the world in which we live by systematically reducing complexity to manageable units with boundaries (Huggett 1993).

DATASET

Dataset

The dataset used for this gaps analysis includes two geopolitical levels of management, U.S. and California State laws, both of which are relevant to the impacted region of interest. A collection of codified statutes and regulations was utilized to represent management. While the majority of state and federal laws compiled in the dataset specifically relate to marine and coastal issues, a large number of state and federal documents in this compilation represent air quality regulation and pH monitoring. Chapter 3 of this dissertation describes the federal and state marine and coastal portions of the dataset. Appendix B contains more information on the selection criteria and a list of additional laws. In summary, a total of 33,405 sections of United States federal law and regulation and 32,820 sections of California State law and regulation were queried in the text analysis.

Constructing law matrices for analysis

The conceptual system model matrix in Figure 7.3 demonstrates how a term or phrase represents each modeled component. The frequency of the 40 relevant terms in each document was counted and organized into a term-document matrix. Two term-document matrices were generated for each level of management; federal and state. Utilizing the social networking software UCINET Version 6.182 (Borgatti et al. 2002), the affiliation function was employed on each term-document matrix to sum the co-occurrences of documents. For both state and federal levels of management, this produced a symmetric matrix of terms by terms—mimicking the structure of the modeled system (Figure 7.3)—except that each cell contained the number of documents that refer to the relevant terms. This produced a matrix that is structurally identical to the conceptually modeled ecosystem (Figure 7.3). Therefore, these two matrices enable a direct comparison between the model ecosystem and laws to determine whether the linked components in model occur in the law.

METHOD

The methodology to identify and quantitatively evaluate gaps in management requires the following actions: 1. Create a term-document matrix of ocean laws to produce a law network, where components of the modeled ecosystem are represented as terms in law; 2. Identify legal *gaps*, these being specific modeled links absent in a law collection; 3. Calculate two metrics that indicate the degree to which the management is riddled with gaps: first, a ratio of legal gaps to system linkages (G), and second, a quadratic assignment procedure test to measure the degree of statistically significant correlation (R) between the linkages in the ecosystem model and linkages in the laws; 4. lastly, the gap metric, G, is performed on subsets (blocks) of the matrices for a finer scale synthesis of the gaps.

Measuring gaps across whole networks

The affiliation law matrices and ecosystem model work in conjunction to measure the extent of mismatch (or gaps) in management. As described and demonstrated in Chapter 4, the two approaches measure the degree of mismatch from gaps; first, the correlation between networks (R) and second, the ratio of gaps to links (G).

QAP Correlation (R)

A network analysis statistical procedure was first used to evaluate the overall degree of misfit between the laws and the conceptualized ecosystem. The degree of similarity between a law matrix and a system model is calculable utilizing the Quadratic Assignment Procedure (QAP) correlation. The Quadratic Assignment Procedure (QAP) computes the correlation between entries of two square matrices, "and assess[es] the frequency of random measures as large as actually observed," (Borgatti et al. 2002). The algorithm provided by UCINET software has two steps:

> *In the first step, it computes Pearson's correlation coefficient . . . between corresponding cells of the two data matrices. In the second step, it randomly permutes rows and columns (synchronously) of one matrix (the observed matrix, if the distinction is relevant) and recomputes the correlation and other measures.*
>
> *The second step is carried out [ten thousand] times in order to compute the proportion of times that a random measure is larger than or equal to the observed measure calculated in step 1. A low proportion (<0.05) suggests a strong relationship between the matrices that is unlikely to have occurred by chance. (Borgatti et al. 2002)*

Two types of QAP correlation results exist for measuring fit of laws to an ecosystem. First, high similarity (high correlation measurement) with high significance (low p-value) shows that linkages in the modeled system are addressed similarly in the laws. This result has two potential interpretations. It may reveal a recognition of interdependencies among components by the management of the system. Alternatively, a high correlation can reflect overlapping jurisdictions, a different problem caused by fragmented decision-making. Overlapping jurisdictions typically arise when multiple agencies manage a single issue or resource without sufficient interagency collaboration (see Chapters 5 and 6). Overlaps in jurisdiction result from a lack of strategic coordination between institutions and often cause conflicts and/or inefficiencies.

A second type of QAP output results in a correlation value that is (or is close to) zero. This result demonstrates high legal fragmentation (or mismatch) for the modeled ecosystem and exposes a common policy-making pitfall in which ecosystem linkages have not been considered. A third type of correlation result value could be a negative value that is statistically significant. This output indicates that laws were made avoiding system linkages and linking unrelated modeled components.

Additional QAP Correlation: Comparison of Jurisdictions

An additional set of QAP Correlation tests were performed to compare one jurisdiction's affiliation law matrix with that of another. A high QAP correlation would reveal that the two jurisdictions dealt similarly with linkages between modeled components (indicating a potentially good fit). A zero correlation would reflect that the two jurisdictions did not address linkages similarly, or put inconsistent emphasis on components. A negative correlation (with p-value <0.05) would indicate that one jurisdiction addressed linkages that the other did not.

Ratio of weighted gaps to links (G)

Following the QAP tests, a basic calculation of mismatch was performed based on the number of observed gaps relative to the number of modeled linkages. Because there is no range of strengths in the links for the development of the ecosystem model in this paper, there was no weighting in place for the linkages. The degree to which management is riddled with gaps is the number of gaps divided by the total number of modeled system links (Equation 1). In effect, this is the ratio of the gaps in law to the total modeled links.

$$G = \frac{\#\,gaps}{\#\,linkages}$$

Equation 1. "G" represents the proportion of legal gaps to modeled links. (gaps = number of modeled links absent from law; linkages = number of total modeled links in the system)

This measure *G* serves as an index of the degree of mismatch. A high score indicates a high number of gaps, indicating high mismatch within the modeled system. Conversely, a lower score would demonstrate a closer match between the institutional management and the conceptually modeled system. The G index enables comparison across jurisdictions within the same system models, as well as comparisons across different modeled ecosystems. Even if a system resulted in high positive QAP correlations, this second test provides a useful evaluation of the number of specific linkages absent from the laws regulating that system.

Comparisons among subsets ("blocks") of modeled system and law matrices

Finer resolution of network comparison coupled with the G metric can quantitatively reveal the location (in the modeled ecosystem matrix) of any patterns of gaps in law compared to the ecosystem model. This methodology divided cells (representing individual linkages) in the ecosystem model matrix into interaction types corresponding with the categories of Source, Cause, Effect, Impact, and Ecological Impact, and Human Systems Impact (Table 7.1). The cells representing relationships between components of each category were sectioned into individual "blocks" (Table 7.2).

Table 7.2. Block identification numbers within ecosystem model matrix used for the block-based analysis. Letters represent each category in order of occurrence, according to Table 7.1. Blocks 1-6 represent linkages among components within a single category. Blocks 7-12 represent linkages between components of two categories. For example, Block 7 linkages in the modeled ecosystem matrix between categories of Source and Cause.

	Source (A)	Cause (B)	Effect (C)	Impact (D)	Eco Impact (E)	Human Impact (F)
A	1	7	12	16	19	21
B		2	8	13	17	20
C			3	9	14	18
D				4	10	15
E					5	11
F						6

The higher resolution of network comparison allows us to see patterns of gaps across the entire system. For example, is there a pattern of legal gaps within the matrix, or are gaps evenly distributed throughout the modeled ecosystem network? Our null hypothesis revealed the latter, that the gaps are evenly distributed. If the gaps are not evenly distributed, this suggests that some blocks are more severely mismatched with the ecosystem than others. In terms of policy, this would lead us to specific priorities within the system; blocks that show up displaying a higher proportion of gaps relative to modeled links should be tagged for policy review.

To test this hypothesis the G metric was employed to compare whole matrices against each other. This metric was calculated for each block, rather than on the matrices as a whole, so that both metrics are a function of block *n*. In addition, tests were performed as a function of management level, so that both metrics were a function of n and *j*, where *j* represents the geopolitical jurisdiction. Therefore, the new G measurement was calculated by:

$$G(n, j) = \frac{\#\, gaps(n, j)}{\#\, links(n)}$$

Equation 2. The metric indicating degree of mismatch between laws and the ecosystem (G) is performed on each block. Applied on the block-level (see Table 7.2), *j* is the jurisdiction or management level (federal or state); *n* is the block number; *gaps(n,j)* are the number of block *n* modeled links absent from the law matrix of jurisdiction *j*; and *links(n)* is the total number of modeled links for block n. Table 7.3 shows the number of links modeled per block.

	Source (A)	Cause (B)	Effect (C)	Impact (D)	Eco Impact (E)	Human Impact (F)
A	30	33	1	1	2	6
B		3	15	6	0	0
C			10	17	0	0
D				6	17	13
E					9	34
F						8

Table 7.3. Number of modeled linkages per block. Headers of rows and columns correspond to categories of the modeled ecosystem related to ocean acidification (see Table 7.1, Figure 7.3)

In addition to providing insight on distribution of gaps, the block-based analysis allows us to compare any patterns and possible differences in gaps within the state and federal bodies of law. If the block-based pattern between these two levels of law differs substantially, this could potentially reflect a multi-scalar incongruence between federal and state governance in relation to the relevant ecosystem. Alternatively, the difference may suggest that the federal government more thoroughly regulates certain issues, while other issues are left to the State. If patterns appear similar on the federal and state level, this may indicate that federal and state law is consistent in how it manages components and linkages in the modeled system.

Identification of specific legal gaps

In order to determine specific legal gaps for each scale of management, it was necessary to identify the modeled linkages that are zero in each law matrix. These gaps reveal instances where two terms, each representing different components in the modeled ecosystem, did not appear together in the same section of law for a particular jurisdiction. To facilitate interpretation, these gaps have been listed by their corresponding block. Additionally, system-wide legal gaps, in the context of the system model, could be identified using the sum of both law matrices. An existing linkage scoring zero for the sum of matrices revealed a gap common to all geopolitical levels of management investigated.

The following questions can be explored using this block-based analysis in combination with the list of specific gaps:

- Are gaps more severe in any particular blocks?
- How do the gaps vary across levels of management?
- Does the state law recognize links that federal law does not?

RESULTS

This section reports the results for the analysis of whole systems (by scale of management, state and federal), for the block-based results, and for the specific list of identified gaps. Although various legal gaps emerged for each jurisdiction, both metrics of fragmentation revealed that California State law and United States Federal law showed similar degrees of misfit in the context of the modeled ecosystem. According to the block-based synthesis and the G ratio, the gaps are highest in the blocks that involve modeled relationships within the categories directly related to ocean acidification (OA), as well as the linkages among living marine resources. Two other blocks in federal law and one block in state law also measured a high degree of mismatch but were completely irrelevant to OA, and therefore removed from the final interpretation.

Results have been presented in the following order: (1) frequency of documents within which the modeled components occurred referred to as the term-document matrix; (2) calculation of two metrics comparing modeled ecosystem matrix to law matrices, referred to as the R correlation and G ratio; (3) block-based G ratio analysis; and (4) identification of specific legal gaps.

Term-document matrix data

Figure 7.4 presented a summation of the total sections of law containing each component of the ocean acidification ecosystem model, for both federal and state laws. A total of 5,395 sections of law for California and 7,011 sections of federal law referred to at least one component. For each jurisdiction, matrices were created using UCINET's affiliation function for purposes of calculating the number of laws co-occurring for each pair of components. This process generated a total number of laws in which each pair of components occurs.

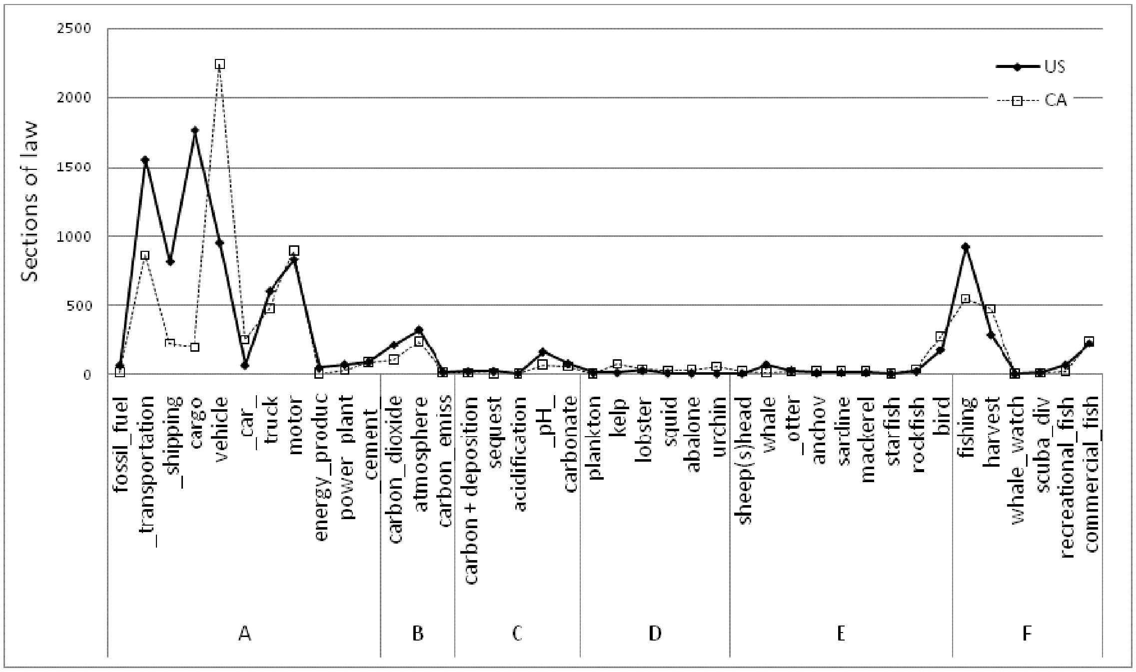


Figure 7.4. Number of law sections that contain each term. Each term represents a component of the modeled system involving ocean acidification (see Table 7.1).

Whole network comparisons

Measure of Fragmentation – QAP Correlation (R)

To apply the correlation method of measuring the degree of fragmentation (R), UCINET Version 6.187 (Borgatti et al. 2002) was employed to test for a similarity between the square affiliation matrix from each jurisdiction and the matrix representative of the ecosystem model. QAP correlation tests produced a list of correlation coefficients and associated p-values (Table 7.4). Although a number of linkages between components of the ecosystem surfaced in both state and federal law, many linkages were also absent. Laws of both geopolitical jurisdictions showed weak correlation (from 0.22 to 0.26), with strong statistical significance in their relationship to the modeled system.

Table 7.4. QAP Correlation results for linkages between the modeled system components and sections of laws.

Comparison of sector model with:	R	p-value
California	0.22	< 0.001
United States	0.263	< 0.001

Additional QAP Correlation- Comparison of Jurisdictions

Following the measure of fit between the ecosystem model and laws, the QAP correlation procedure in UCINET was run to quantify the extent of similarity among the federal and state law data matrices. In comparing the two geopolitical jurisdictions, the comparison calculated a 0.868 correlation demonstrating similar instances of linkages. The probability that this high correlation measure occurred by random chance is, or is close to, zero (p-value <0.001). Comparison of Table 7.4 values, with the state to federal correlation, accentuated the significantly higher correlation among the two geopolitical jurisdictions relative to the correlation between the ecosystem and each geopolitical jurisdiction. This finding quantitatively confirms that state and federal law acknowledge (or fails to acknowledge) linkages in the ocean acidification ecosystem model more similar to one another than either acknowledges the modeled ecosystem linkages.

Measure of mismatch- Ratio of weighted gaps to links (G)

The degree of mismatch was calculated for both jurisdictions, as shown in Table 7.5. For the ocean acidification ecosystem model, California State laws measured the higher G of 35%, while the United States measured a slightly lower degree of mismatch at 26% (Table 7.5).

Table 7.5. QAP correlation test results for ocean acidification ecosystem linkages reflected in laws across two geopolitical jurisdictions.

Geopolitical jurisdiction	Measurement	# gaps	Degree of mismatch from gaps (G)
California	Gaps	73	35%
	Links modeled	211	
United States	Gaps	55	26%
	Links modeled	211	

Block-based comparisons between subsets of modeled system and law matrices

Representation of the categorical relationships of the components required the division of each matrix (modeled ecosystem and two law matrices, all having the same structure) into subsets, or *blocks*, as shown in Table 7.2. Performing the G ratio of gaps to modeled links on these blocks provided a synopsis of gap patterns within, and between, each jurisdiction. The block-based analysis showed that for both state (Table 7.6) and federal law (Table 7.7), the blocks with the highest degree of mismatch from gaps were Block 13 (representing links between categories Cause and Impact, B and D), and Block 16 (links between categories Source and Impact, A and D). For state law, the G ratio measured 100% for both blocks 16 and 13. The federal law measured 100% for Block 16 and 83% for Block 13, indicating slightly less fragmentation for the latter. Block 9, which represents linkages between Effect and Impact (C-D), ranked third for both state and federal levels with 65% and 59% respectively.

Table 7.6. State law G proportion of #gaps/#links. Higher percentage indicates a higher degree of mismatch from gaps. Asterisks (*) point to blocks that involve linkages completely irrelevant to ocean acidification. Further analysis omitted these irrelevant linkages (Figure 7.5).

California	Source (A)	Cause (B)	Effect (C)	Impact (D)	Eco Impact (E)	Human Impact (F)
A	23%	27%	0%	100%*	50%*	0%
B		33%	60%	100%	0%	0%
C			60%	65%	0%	0%
D				33%	47%	8%
E					44%	21%
F						0%

Table 7.7. Federal law G proportion of #gaps/#links. Higher percentage indicates a relatively higher degree of mismatch from gaps. Asterisks (*) point to blocks that involve linkages completely irrelevant to ocean acidification. Further analysis omitted these irrelevant linkages (Figure 7.5).

United States	Source (A)	Cause (B)	Effect (C)	Impact (D)	Eco Impact (E)	Human Impact (F)
A	0%	18%	0%	100%*	0%*	17%
B		33%	33%	83%	0%	0%
C			30%	59%	0%	0%
D				33%	65%	31%
E					33%	6%
F						13%

Upon closer view of this block-based analysis, there were a few blocks that ranked as highly fragmented but had nothing to do with ocean acidification (indicated with asterisks in Table 7.6 and Table 7.7). For instance, a legal gap was found in California law between *plankton* and *power plant*. Since this modeled linkage was the only one in its block, its absence in state law produced a G of 100% for that block. While this linkage undeniably exists between the two system components, the relationship does not relate to the problem of ocean acidification. Therefore, Figure 7.5 displays a contour plot of the G measures for both jurisdictions and unrelated blocks were removed from this visual display of the block-based results.

A. State of California law   B. Federal United States law

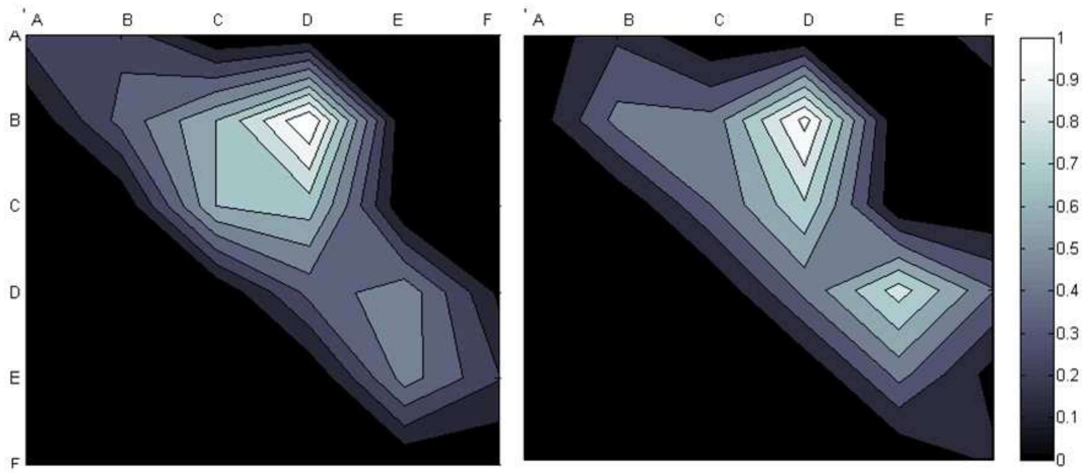


Figure 7.5. Contour plot of block-based gaps analysis for the system involving ocean acidification. Light color indicates high ratio of legal gaps to ecosystem linkages in the block (up to 1, as indicated on the legend color bar). Gaps irrelevant to ocean acidification system were removed from the contour plot (i.e., whales/shipping, power plant/plankton). Both federal and state laws have peak degree of gaps at the same areas: linkages between categories of Cause (carbon emitters) and Direct Impact (kelp and calcifying organisms), and between categories of Direct Impact and Indirect Ecological Impacts. The peak degree of gaps demonstrates that laws made for certain species have been written without ecosystem linkages (modeled for ocean acidification) taken into account.

The state and federal plots of the block-based analysis revealed two main peaks indicating mismatch (Figure 7.5). The most striking peak is in the upper middle of both diagrams. This peak demonstrates a high concentration of gaps between B-C (Cause and Effect), C-C (Effect and Effect), and C-D (Effect and Impact) and climaxes in B-D (Cause and Impact). This first peak relates to issues associated with ocean acidification. For example, Block 8 (interaction between Cause and Direct Impact, B-D) was the summit of this peak with 100% mismatch (G ratio) for state law and 83% mismatch for federal law. This block contains linkages between CO_2 (Category B) and several species (Category D), such as plankton, kelp, lobster, squid, abalone, and urchin. These modeled linkages compose the connection between the ocean acidification process and its projected impact on marine organisms. As such, the fact that these linkages are not found in law legitimizes the anecdotal concern of many scientists and other citizens about the lack of law to tackle the impending environmental catastrophe.

The second peak was in the lower right side of the contour plots, involving interaction types D-E, E-E, and slightly E-F. This peak contains linkages between living marine resources and human activities dependent upon them. The degree of mismatch was lower in state law at its summit than the federal law. The state law measured 44% for the interactions in E-E (Block 5), and D-E was 47% (Block 10). The latter peaked at D-E with 65% of mismatch from gaps (Block 10). These categories (D, E, and F) are all species or activities that depend on marine species. At first glance this peak in gaps appears to be irrelevant to ocean acidification; however, it may reflect a fragmented decision-making for all the impacted species. If not addressed strategically, this fragmentation could create an obstacle to monitoring and developing a united front to adequately confront ocean acidification.

Legal Gaps Identified

Across both the state and federal levels of management, there were 40 ecosystem links absent from law. While Table 7.8 provides the list of all gaps, a few noteworthy patterns emerged. State law had six gaps in the linkages among Source components (Block 1), five of which involved the component *fossil fuel*. Federal law had zero gaps in this block. Block 8 (B-C) contained gaps for both jurisdictions that involved *carbon emission* (B) and terms in reference to the process of ocean acidification (C). Six gaps emerged involving *carbon emission*, although 13 state sections and 14 federal sections of law referred to this phrase in the document collection investigated.

Table 7.8. This table presents the dyads of components in the ecosystem model. Circle symbols (●) indicate relationships not linked in the legal system. For example, no section of law in the collection contains both the terms "plankton" and "squid," a linkage specified in the ocean acidification ecosystem model (Figure 7.3). Relationships are organized according to Block ID, for which the corresponding interaction type is listed. Interaction type refers to the categories with which the modeled linked components are associated.

Block ID	Interaction Type	Jurisdiction / Interaction	US Federal	CA State
1	Source-source (A-A)	Fossil fuel-shipping	3	●
		Fossil fuel-cargo	2	●
		Fossil fuel-car	3	●
		Fossil fuel-truck	12	●
		Fossil fuel-energy production	8	●
		Energy production-power plant	3	●
2	Cause-cause (B-B)	Carbon dioxide – carbon emission	3	●
		Atmosphere-carbon emission	●	2
3	Effect-effect (C-C)	Deposition + carbon – sequest	3	●
		Deposition + carbon – acidification	●	●
		Deposition + carbon – carbonate	3	●
		Sequest* – acidification	●	●
		Sequest*-pH	3	●
		Sequest*-carbonate	●	●

4	Direct impact-direct impact (D-D)	Plankton-squid	●	●
		Plankton-kelp	**2**	●
5	E-E	Anchovy-bird	●	●
		Sardine-bird	**1**	●
		Mackerel-bird	**1**	●
		Rockfish-bird	●	●
		Mackerel-rockfish	●	**5**
6	F-F	Harvest-scuba diving	●	**2**
7	A-B	Fossil fuel-atmosphere	**14**	●
		Energy-produc*-carbon dioxide	**1**	●
		Power plant- carbon dioxide	**2**	●
		Energy produc*-atmosphere	**3**	●
		Fossil fuel – carbon emission	●	●
		Shipping-carbon emission	●	●
		Cargo-carbon emission	**1**	●
		Car-carbon emission	●	**2**
		Energy produc*-carbon emission	●	**1**
		Power plant-carbon emission	●	●
		Cement-carbon emission	●	●
8	B-C	Carbon emission-carbon + deposition	●	●
		CO2-sequest	**7**	●
		CO2-acidification	**1**	●
		Atmosphere-sequest	**4**	●
		Atmosphere-acidification	**3**	●
		Carbon emiss*-deposition + carbon	●	●
		Carbon emiss*-sequest	●	●
		Carbon emiss*-acidification	●	●
		Carbon emiss*-pH	●	●
		Carbon emiss*-carbonate	●	●
9	C-D	Acidification-plankton	●	●
		Acidification-kelp	●	●
		Acidification-lobster	●	●
		Acidification-squid	●	●
		Acidification-abalone	●	●
		Acidification-urchin	**1**	●
		pH-lobster	●	●
		pH-squid	●	●
		pH-abalone	●	**1**
		Carbonate-plankton	**1**	●
		Carbonate-lobster	●	●
		Carbonate-squid	●	**1**
10	D-E	Plankton-whale	●	●
		Plankton-anchovy	●	●
		Plankton-sardine	●	●
		Plankton-mackerel	●	●
		Plankton-rockfish	●	●
		Lobster-otter	●	●
		Squid-whale	●	●

		Squid-bird	●	**3**
		Abalone-otter	●	**2**
		Urchin-sheephead	●	**1**
		Urchin-otter	●	●
11	E-F	Harvest-scuba diving	●	**9**
12	A-C	*No gaps*	-	-
13	B-D	CO2-plankton	●	●
		CO2-kelp	●	●
		CO2-lobster	●	●
		CO2-squid	**1**	●
		CO2-abalone	●	●
		CO2-urchin	●	●
14	C-E	*No links modeled*	-	-
15	D-F	Sheep(s)head-scuba diving	●	**1**
		Whale-scuba diving	●	●
		Otter-scuba diving	●	●
		Otter-recreational fish*	**2**	●
		Anchov*-recreation fish*	**2**	●
		Sardine-recreational fish*	**2**	●
		Mackerel-recreational fish*	**3**	●
		Starfish-scuba diving	●	●
16	A-D	Energy produc*-plankton	●	●
17	B-E	*No links modeled*	-	-
18	C-F	*No links modeled*	-	-
19	A-E	Shipping-whale	**4**	●
20	B-F	*No links modeled*	-	-
21	A-F	Motor-whale watching	●	**1**

DISCUSSION

The following discussion presents an interpretation of results, preliminary policy implications of findings, next steps, and future work.

Interpretation of results

The results of this project demonstrate that a substantial degree of mismatch exists between the modeled ecosystem and relevant law relating to ocean acidification. In addition, two main patches of a relatively high degree of mismatch for both state and federal law emerge from the results.

Whole networks

When looking at the whole network analysis of state and federal law, in relation to the ecosystem model, the two jurisdictions have a similar degree of mismatch. The correlation value (R) was low between the laws and ecosystem model relative to the high R among the state and federal law matrices. This finding indicates that state and federal regulations are managing ocean issues in a similar manner but not in the context of the modeled system.

Block-based analysis

Overall, the block-based analysis proved to be quite useful for the synthesis of the gaps analysis as it revealed patterns within individual geopolitical jurisdictions and facilitated a comparison of patterns across the two management levels. The block-based results for state and federal collections showed clear areas of higher mismatch compared to other parts of the OA system. After irrelevant block data were removed, the two peaks of high mismatch directly and indirectly related to ocean acidification.

The larger peak of mismatch, directly associated with ocean acidification terminology (pH, acidification, carbon deposition, sequester, carbonate), demonstrates the absence of law to address this emerging environmental problem and its predicted biological and ecological implications. This data may appear to state the obvious but it is fundamental to verifying the accuracy of the entire analysis. In the best-case scenario five or ten years from now, repeat analysis ought to show that these gaps have been filled: assuming that management institutions make progress toward the mitigation of OA. Of course, the ecosystem model should continue to be improved with more robust scientific understanding of the impacts and feedbacks associated with temperature and climate change. In the meantime however, a statistical analysis that generates quantitative output of where gaps in law exist provides policymakers with a blue print for developing new legislation.

The second peak is likely a product of species specific decision-making within the living marine resources sector (LMR) (Pikitch et al. 2004), and may be depicting the species-specific strategy in law common for LMRs. This high degree of mismatch within a single sector poses an additional obstacle to the resolution of the ocean acidification problem because it exemplifies the lack of cohesion within the LMR regime. These findings demonstrate that myopic law does not adequately address important issues related to OA and other environmental problems, and substantiates the urgency of ecosystem-based fisheries management. Gaps analysis and a finer resolution block-based analysis provide a persuasive argument: why LMR management should evaluate the current regulatory strategy and consider multiple species and habitat interactions in fisheries management (Pikitch et al. 2004).

Legal gaps identified

Certain absent linkages in both state and federal management laws were especially noteworthy. For example, in Block 3 (C-C) the absence of a linkage between *carbon + deposit* and *acidification* is a severe gap. It indicates a lack of acknowledgement between the two components, and signifies that no formal institutional arrangement even recognizes the process of ocean acidification.

Potentially, absent linkages between *power plant* and *carbon dioxide*, and *power plant* and *carbon emission* are also gaps for California State law. This is surprising considering that California touts its climate change and greenhouse gas emission policies (Barringer 2006). The Intergovernmental Panel on Climate Change (IPCC) reported in 2005 that compared to any other sector, energy produced by power plants each year emits the largest proportion of CO_2 into the atmosphere (IPCC 2005). In 1999, California CO_2 emissions from the Energy Sector were over 350 million megatons (http://www.climatechange.ca.gov/policies/images/fig6a.jpg). Furthermore, as of 2005, California had 388 power plants dependent on gas and oil[13] (California Energy Commission 2007). In addition, those power plants that burn oil and gas produce 74% of the state's total capacity of energy used in California (California Energy Commission 2007). *The State of the Carbon Cycle Report* (2007) found that North America's carbon emissions from fossil fuels contribute 27% of global emissions (SOCCR 2007). Thus, the state burns a substantial amount of fossil fuels, contributing to the increased atmospheric CO_2 but appears to fail to acknowledge the interconnection between power plants and CO_2 emissions. The evidence of the link between power plants and CO_2 emissions is clear scientifically. The undeniable connection necessitates more investigation by policy experts to

---

[13] This number refers to power plants that produce at least 0.1 megawatts of energy (California Energy Commission 2005).

determine why this analysis identified a gap between these two critical components. The data output may truly be revealing a gap or it may be a case of different terminology used in the laws than was employed in this study.

Preliminary policy implications of findings

The gaps analysis results provide a springboard to future action. The next step involves investigating how to fill the existing gaps in management. As explained in the introduction of this case study, it is critical that new policies or laws are developed within the context of existing legislation in order to avoid creating more of the unintended overlaps already typical of the fragmented system of governance. Accordingly, Part B of the case study presents findings of the overlaps analysis and identifies the agencies involved in each of the modeled system components. This analysis has the potential to provide policymakers with a preliminary indication of institutional politics and existing strongholds that may hamper inter-agency collaboration and cohesion (see example of Shipping vs. Marine mammal agency involvement in Chapter 6). As an added benefit, overlaps analysis coupled with the gaps analysis generates baseline data for other qualitative and quantitative analyses.

With or without overlaps analysis, there are still important policy implications of this paper's findings. Foremost, the highest peak in Figure 7.5 indicates a striking disconnect between the scientifically established linkages directly associated with acidification process, and the biological and ecological implications. The results of this paper's findings should compel policymakers to address the mismatches and gaps in regulation with collaborative policies that acknowledge the complexity of the systems and institutional environment.

Next steps

Part B of this case study presents the results from the overlaps analysis, revealing existing laws that address the single modeled components, as well the degree to which various agencies manage these components. The overlaps analysis contains output that can be useful to policymakers interested in evaluating whether and to what degree a particular bill in U.S. Congress can fill a gap in federal law related to ocean acidification. In addition, the overlaps and agency involvement evaluation in Part B can be combined with the gaps analysis in Part A to predict where the current form of the FOARAM bill will effectively fill gaps in the context of the existing governance. This could help anticipate roadblocks and strategically prioritize and prepare for challenging coordination between institutions.

Future work

This analysis represents one utility for analyzing marine management with text mining of ocean law. Future work will involve automating the gaps analysis technique so that policymakers, managing institutions and other stakeholders may freely investigate their own ecosystem models. Automation will facilitate more profound analysis on large scope environmental problems. The capabilities of advanced text mining techniques and the statistical analysis of ocean management law are limitless if the interface is user-friendly. Future work could entail coupling law data with attributes shedding light on the importance and scope of a specific law.

For example, budget allocations of statutes linked to text analysis of laws could help expose the extent to which an agency implements a particular statute. Take the case in which a statute without funding contains the only sections of law that fulfill a modeled ecosystem linkage. The analysis would combine the economic and law data so that economic data would prompt a disregard for the unfunded statute, and therefore more accurately reveal a gap in management (rather than merely in law).

While analysis of law is constrained by the language of the law, the advantage of the ability to organize, manage and view patterns in gaps and overlaps in law has been investigated in this project. Now that a process for mining the enormous body of laws across the multiple jurisdictions has been initiated, we can add other data types to the analysis.

CONCLUSION

Though the findings of this analysis may appear to be logical to environmental policy experts, the contribution of these findings is twofold. First, the analysis brings a quantitative dimension to comprehensive legislative analysis and can be applied to any alternative conceptual ecosystem of interest to a researcher or decision-maker. For example, one may add components or even new categories to the system model related to ocean acidification, components such as temperature and other climate change-related feedbacks with role in ocean acidification. Second, the gaps analysis presented in this paper reveals accurate results that verify the utility of the approach. Perhaps the technique used in this paper may be even more instrumental in finding gaps in a system with less obvious gaps than those revealed for ocean acidification. Therefore, the hope for this technique is that it will be useful tool for management agencies, policymakers and proponents of ecosystem-based management. By assisting efforts in determining gaps in management and in defining priorities in the context of an ecosystem, this tool can promote and contribute to more effective management of uses and abuses related to ocean health.

But most urgently, findings from this gaps analysis reveal holes in existing federal and state law. In order to prevent the distressing scenario of ocean acidification and its toll on ocean health and organism survival as predicted by scientists across the world, we need institutions with better management strategies to address and fill the gaps at all scales and across sectors of governance.

PART B – Filling the gaps

OVERLAPS ANALYSIS INTRODUCTION

Part A of this case study defined the prominent gaps in federal and state legislation related to ocean acidification. To tackle the problem of ocean acidification, new policies must be developed that fill these holes in management; however, simply filling the gaps with new regulations does not guarantee implementation.

A critical dimension of baseline governance data relates to jurisdictional and agency authority and is essential in the development of an effective solution to ocean acidification (OA). Improving our understanding of existing legislation and associated agencies that relate to OA is imperative to the design of a new institution that will make effective policy and minimize overlaps and conflicts. As mentioned in the case study's introduction, one scheme to tackle OA would be to prohibit CO_2 emissions. However, common sense tells us that this proposition is logistically unfeasible because an outright prohibition conflicts with existing regulations and laws. It would create an overlapping jurisdiction, in a system of governance already riddled with overlaps. While it can be argued that overlapping jurisdictions can be beneficial when the laws are strategically consistent or/and coordinated (Young 2002, Cao and Wong 2007), when laws lack consistency or coordination overlaps can cause unintended negative consequences. Inconsistent regulation is often unenforceable (Grenade-Nurse 1998) and ineffective. Lack of enforcement is especially problematic for environmental protection or conservation efforts. An enormous amount of time can go into developing a new regime but a new institution or agency will only be as effective as its ability to coordinate with existing rules and regulations. If the existing overlapping regimes wield control of the issue of focus, the new regime can end up missing its aims.

The goal of the case study's Part B is to provide a baseline of legislative and agency jurisdiction for the modeled ocean acidification ecosystem presented in the gaps analysis. I applied two techniques first demonstrated in Chapter 5. Along with an additional measurement, these techniques produced three main results for each modeled topic: (1) the degree of agency involvement; (2) the relative complexity of legislation based on the proportion of agencies, regulations, and statutes; and (3) the legislative landscapes for each modeled topic. As utilized in the case study, a topic can be either an individual modeled component or a categorical group of components. Together, these techniques generate a baseline for determining methods and institutions that can resolve the problem of management gaps as they relate to OA.

Part B gives a short review about the case study and briefly describes the reformatted dataset used from Part A. The methods section presents the two metrics of overlap. First, the methods section describes the preliminary agency involvement measure (AIM), a new metric utilized for overlap analysis. Second, the degree of complexity, as identified by the overlap index and associated variables, is supported by an excerpt from Chapter 5. The method section concludes with an explanation of the data format used to produce these metrics and a brief summary of the legislative landscapes. The results section presents the conclusions of the analysis in the same order as the methods; first the two metrics and then the legislative landscapes. The discussion section interprets the results and puts into context the findings for the purpose of filling gaps in OA related policy. Part B concludes with a discussion about questions the results and analysis can and cannot address, as well as recommendations for future work.

BACKGROUND

Ocean acidification (OA) in brief

Over the next century, ocean acidification will likely cause larger ramifications for humans and ecosystems than global climate change. Scientists predict that increased levels of CO_2 in the atmosphere will be absorbed by ocean surface water causing acidification and seriously compromising the physiological health of both calcifying and non-calcifying organisms (Portner 2008). In the big picture, the ocean's ability to sequester atmospheric carbon over geological time scales – known as the "biological pump" – will decline, exacerbating the problem of carbon dioxide build-up in the atmosphere. Perhaps what is most frightening is that the cumulative impacts of these stressors may cause the ecosystem services on which humans depend for our own health to default (Portner 2008).

This case study applied an ecosystem perspective to analyze the governance related to ocean acidification in order to assist efforts toward a policy resolution. A conceptual ecosystem model related to ocean acidification was built by identifying components and linkages; this was a necessary step for understanding the full system and the extent of the problem. The conceptual diagram (Figure 7.7) draws upon six main categories to represent the chain of explanation related to acidification. Beginning with ocean acidification (OA) as the *effect* (represented by a diamond in Figure 7.6), we can look backwards to the source of this problem (represented by circles in Figure 7.6), and then forwards to the anticipated impacts of OA in the future (represented by rectangles in Figure 7.6). Therefore, the boundaries delineating this system encompass both the sources of carbon dioxide and the indirect impacts of OA. The following categories explain this system: (A) Source; (B) Cause; (C) Effect; (D) Direct Impact; (E) Ecological Impact; and (F) Human Systems Impact (Figure 7.6). Each category is represented with multiple components (Table 7.1), each interacting with one or more other components in the defined system (Figure 7.7).

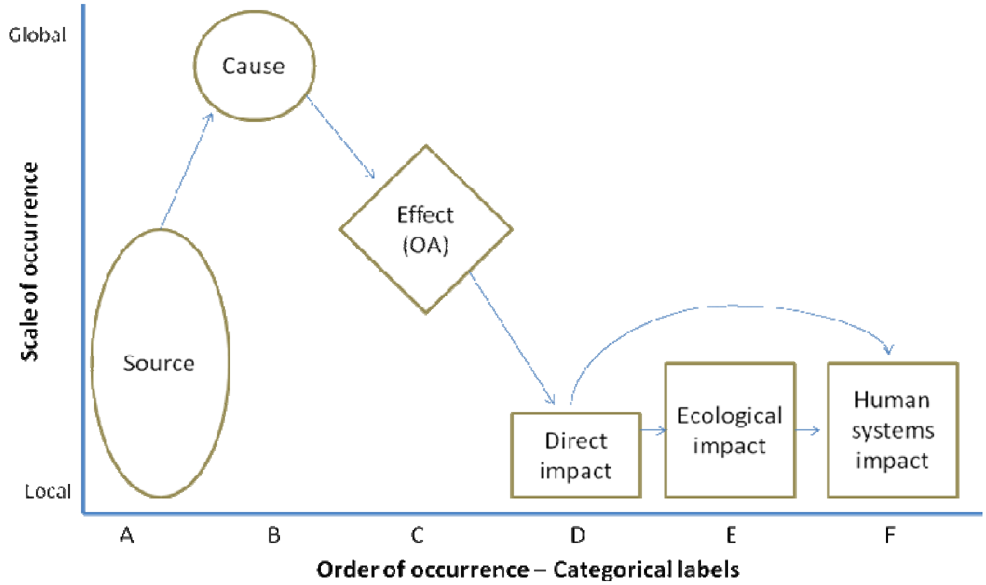


Figure 7.6. Categories selected to conceptually model ocean acidification and its interrelated components. Categories are represented by shapes in the order in which they occur. Each arrow indicates the direct linkage between these two components. For example, the Source (carbon emitters) directly impacts the Cause (atmospheric CO_2) or specifically, carbon emitters directly increase the amount of atmospheric CO_2. The two categories occur on different geospatial scales; as such, their position along the y-axis indicates scale. Refer to Table 7.9 for definitions of each category.

Gaps summary

Gaps analysis

In Part A of this case study, the legal gaps analysis provides baseline legal governance data about disconnects between the management institutions and the scientific understanding of the system related to ocean acidification. This technique was developed on the idea that in order to support ecosystem services, management systems should "fit" or match the properties of a related ecosystem (Costanza and Folke 1996, Young 2002, Folke et al. 2007). The ecosystem modeled for the purposes of this case study related to ocean acidification (Figure 7.7). The main entities responsible for OA included two categories: Source, which represented the

CO_2 emitters, and *cause*, indicating increase in atmospheric CO_2. Source and Cause lead to the *Effect*, which is ocean acidification for purposes of this project. The Effect is predicted to *directly impact* calcifying organisms, such as urchins, plankton, and lobsters, who reside in this study's area of interest: the California Channel Islands. The plight of calcifying organisms, due to OA, has an indirect *ecological impact* on other local organisms and an indirect impact on several human activities (*human system impact*).

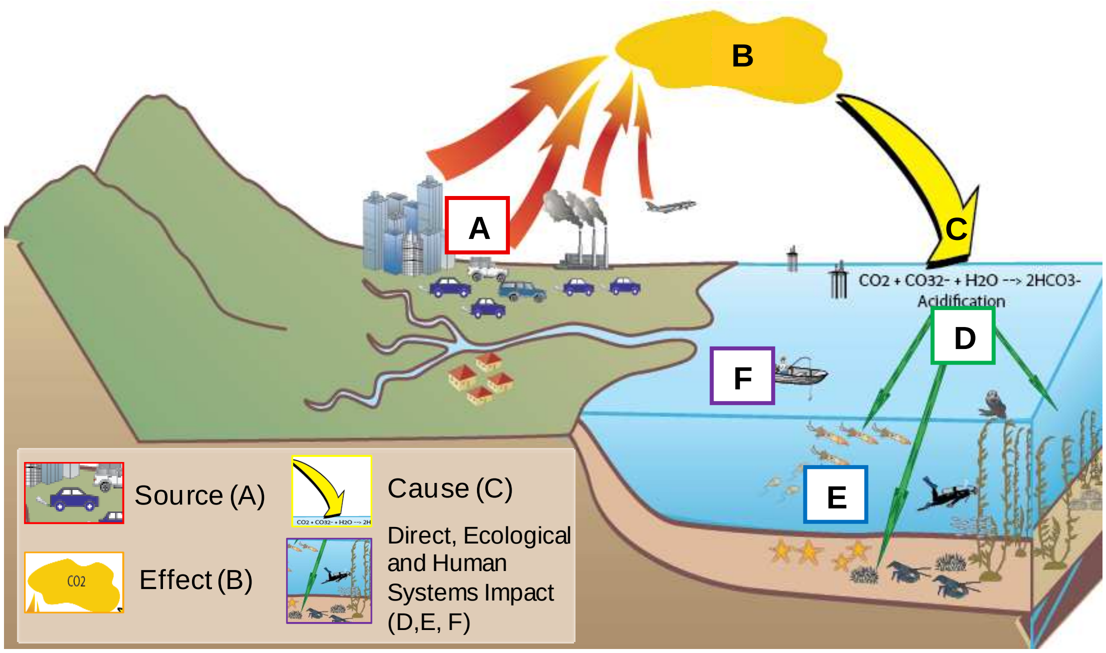


Figure 7.7. Conceptual diagram of ecosystem relating to ocean acidification. A. Source; B. Cause; C. Effect; D. Direct Impact; E. Ecological Impact; F. Human Systems Impact. Refer to Table 7.9 for definitions of each category.

Gaps found

According to the gaps analysis, there were two main patches indicating a relatively high degree of mismatch for both state and federal law. For both state and federal law, the peaks appeared similar. The most extensive peak illustrated that a striking disconnect exists between the scientifically-established linkages directly associated with the acidification process, and the biological and ecological implications. This discrepancy needs to be addressed in order to avoid the destructive potential of OA. The slightly smaller patch of gaps, related to linkages among the direct and indirect impacts of ocean acidification, indicates an obstacle of intra-sector fragmentation. While the nature of these two apparent gaps differs, they underscore the necessity for improved knowledge of legislative and agency authority and the goal to avoid producing new unintended overlaps that could stall OA problem-solving efforts.

Overlaps analysis

For purposes of identifying situations of potential institutional interplay, I have developed in this dissertation project three techniques to investigate overlapping jurisdictions. This interplay is characterized by regulations or mandates of one sector or agency influencing those of another sector or agency. In some situations this can benefit one or both agencies, such as in cases where resource sharing or coordination results from interplay. Conversely, interplay can also have negative consequences on the performance or effectiveness of one or both agencies.

The indicators of potential interplay are analyzed in this case study utilizing two aspects of this overlaps analysis and one additional measurement of the degree of agency involvement for any given topic. Chapter 5 provides a basic demonstration of this analysis.

The techniques performed in this paper were originally developed to identify existing overlaps. As added value, they can also be used to strategically avoid unintended overlaps when designing new legislation and regulations. The two metrics, in conjunction with the legislative landscape diagrams, provide insight into potential roadblocks and the urgency of coordination to confront the perils of ocean acidification. This added value came to light from feedback given by a handful of interviewees during the development of both the gaps and overlaps analyses. Apart from developing the tools to solely define and quantify the problem of gaps and overlaps respectively, interviewees suggested taking the analysis one step farther in the context of ecosystem-based management (EBM) initiatives. For instance, baseline information about agency involvement could define gaps and foment recommendations toward filling these gaps and the development of improved policy. Otherwise, managers and EBM initiatives are left without a way to implement the information produced from the gaps analysis.

In summary, Part B acknowledges the clear gaps identified in Part A and takes the next step to answer the following questions:

- What agencies are involved in the relevant topics? Which agencies (empowered by which laws) would need to coordinate in order to prevent or alleviate further ocean acidification scenarios?
- Within topics relevant to ocean acidification, which issues involve the highest degree of overlap complexity and could present the most challenging obstacles on the path to institutional change?

DATASET

The overlaps analysis uses two sets of informational output: 1. term and phrase frequencies extracted from a set of ocean and coastal laws; and 2. a record of authoritative agencies for each law. Chapter 5 provides more descriptive detail of the informational output of the overlaps analysis. These data and metadata were integrated for the 40 components modeled in the ocean acidification ecosystem. Table 7.9 displays the list of topics; these were the same terms and phrases queried for in Part A of this case study.

Table 7.9. Categories investigated as relevant components of the system (source to impacts) of ocean acidification for the Channel Islands National Marine Sanctuary. Scale varies from local to global. For instance, carbon dioxide emissions occur on a local scale but their impact on the atmosphere is on a global scale.

ID	Category	Component description	Scale	Component	Term used to represent component
A	Source	Transportation industry, carbon emitters	Local, regional	Fossil fuel	Fossil fuel
				Transportation	_transportation
				Shipping	_shipping_
				Cargo	Cargo
				Vehicle	Vehicle
				Car	_car_
				Truck	Truck
				Motor	Motor
		Energy production from power plants		Energy production	Energy produc*
				Power plant	Power plant
		Cement manufacturing		Cement manufacturing	_cement_
B	Cause	Physical cause of ocean acidification (atmospheric CO_2 increase)	Global	Carbon dioxide	Carbon dioxide
				Atmosphere	Atmosphere
				Carbon emission	Carbon emiss*
C	Effect	Atmospheric carbon deposition from the atmosphere to the ocean	Regional, global	Carbon deposition	Carbon + deposit*
				Sequestration	Sequest*
		Decrease in pH		Acidification	Acidification
				pH	_pH_
				Carbonate	Carbonate
D	Direct Impact	Selection of calcifying organisms and kelp in Channel Islands region	Local	Plankton	Plankton
				Kelp	Kelp
				Lobster	Lobster
				Squid	Squid
				Abalone	Abalone
				Urchin	Urchin
E	Ecological Impact	Species directly linked to one or more of the species listed in Direct Impact category	Local, regional	Sheepshead	Sheepshead OR sheephead
				Whale	Whale
				Otter	_Otter_
				Anchovy	Anchov*
				Sardine	Sardine
				Mackerel	Mackerel
				Starfish	Seastar
				Mackerel	Mackerel
				Rockfish	Rockfish
				Seabird	Seabird
F	Human Systems Impact	Recreational or economic activities common in the Channel Islands region that directly relate to components in the Direct Impact or Ecological Impact category	Local, regional	Fishing	Fishing
				Harvest	Harvest
				Whale watching	Whale watch*
				Scuba diving	Scuba div*
				Recreational fishery	Recreation fish*
				Commercial fishery	Commercial fish*

Data filtering and configuration

The generation of term and phrase frequencies utilized a body of ocean and coastal laws representative of state and federal laws relevant to the west coast of the United States. This represented the same collection of laws and regulations used in Part A, but in a different format. The overlaps technique analyzes coarser-sized documents, from which the sections of law were derived for the gaps analysis. The coarser grain of documents allowed for the examination of relationships between statutes rather than between sections of law within documents. In contrast, the gaps analysis required the finer granularity of documents because it sought co-occurrences of terms in the same section. For gaps analysis, larger documents likely would have produced false information. For instance, if the gaps analysis had been performed on statute-level documents (e.g., if *whale* occurred in section 1 of a statute and shipping occurred in section 220), the analysis would indicate that two topics occur in one document and therefore fulfill a modeled ecosystem linkage, despite the fact that the law-maker had not intended any relationship between the two terms. In contrast, the statute level of analysis and multiple sections of regulations lend themselves well to the needs of the overlaps technique performed in Part B. These laws were codified, and typically written, as somewhat cohesive units. They may be composed of many sections but are organized under a defined authority of one or more agencies. For purposes of expanding the scope of the project, it was important to first identify overlaps in relationship to entire legal units rather than within specific documents. However, future investigation of overlaps could pinpoint where the overlap occurs within the statute or regulatory unit by using section level of documents in the analysis.

This project investigates overlaps on the legal unit level, which is consistent with Chapter 5's presentation of the analysis. Ideally the legal units would have been compiled in a consistent manner, such as in chapters. However, the hierarchies varied slightly across geopolitical jurisdictions and some were more accessible than others. For example, the California Code was readily available at the article level, but not at the chapter level. Furthermore, the California Code of Regulations was available by section or division, but not by chapter. Therefore, these documents were compiled in divisions rather than in sections because a division was more consistent with the hierarchical unit of the rest of the collection's documents (Table 7.10). Two types of legal units are used in this analysis; documents containing regulations are referred to as *Regulatory Units* (U.S. Code of Federal Regulations and California Code of Regulations) and the codified statute documents are referred to as *Statutory Units* (U.S. Code and California Code).

Table 7.10. Jurisdictions, format of law, and units collected for marine-related law dataset.

Geopolitical jurisdiction	Law type	Codification hierarchy	Compiled document (Statutory/ Regulatory Unit)
Federal United States law	U.S. Code (statutes)	Title/Chapter/Section	Chapter
	U.S. Code of Federal Regulations	Title/Volume/Chapter/Part/Section	Part
State of California	California Code	Code/Division/Chapter/Article/Section	Article
	California Code of Regulations	Title/Division/Chapter/Section	Division

As described in Chapter 3, the majority of the collection was compiled based on a connection to ocean and coastal related laws and regulations. The additional documents were added to encompass federal and state statutory law concerning air quality, CO_2, pH, and chemical water quality because these issues relate to ocean acidification. The analysis was run on 385 and 742 legal units for the State of California and Federal United States, respectively.

Metadata - Agency authority tables

The agency authority metadata for each law was in part supplied by the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center and in part compiled by me. The NOAA Coastal Services Center Digital Legislative Atlas Program (http://www.csc.noaa.gov/legislativeatlas/) supplied the agency authority list for each federal ocean-related statute publicly available on its website. Their website listed authority to the most specific level of program or agency discernable from reading the law. For the state statutes, I obtained agency authority information by skimming laws. These metadata were stored in the format of an agency by document matrix. To ensure consistency in the metadata, an agency was recorded as its parent department. For instance, the metadata represented the National Oceanic and Atmospheric Administration (NOAA) as the Department of Commerce, and the National Park Service as the Department of the Interior.

However, more specific agency authority information will be used in future work analysis to investigate needs for intra-agency coordination.

Agency authority for the national and state regulations was available on the U.S. Code of Federal Regulations website (http://www.gpoaccess.gov/) and on the California State government codified regulations website (http://ccr.oal.ca.gov). Regulatory authorities were reported at the parent department level, consistent with the statute authorities described above. However in the case of the state agencies it was necessary to modify the authority specification because in the hierarchy of California (CA) state law, nearly all agencies fall under the California Resources Agency.

Although many departments, commissions, boards, and other entities are embedded within the CA Resources Agency, their authority is essentially decentralized (REF). Each of the agencies, departments, and commissions within the CA Resources Agency essentially operate under its own institution[14], with its own regulations and decision-making procedures (Gurish 2007). For this reason, the relevant entities under the CA Resources Agency were recorded when possible. Similarly, the agencies acting under the California Environmental Protection Agency (CalEPA) also were recorded as individual entities. This seemed to produce a somewhat even playing field in terms of agency size for comparison across agencies under state law. For example, the Department of Fish and Game, Coastal

[14] Note that *institution* refers to a system of rules, rights, norms, values, and decision-making procedures as defined earlier, while the agency itself is the actor guided by this institution.

Commission, and Coastal Conservancy were recorded as such rather than hiding these under the auspices of the CA Resource Agency. Nevertheless, some laws did not articulate a specific department, but rather the larger parent agency. Therefore, California "agency to law authority" data contains multiple levels of the agency hierarchy. In addition, some statutory codes clearly stated their implementation by federal agencies. Thus, the state landscapes contain some instances of state law tagged as under federal authority. In total, the metadata includes 70 agencies associated with the compiled state law and 20 agencies associated with the compiled federal law.

METHODS

Text analysis generated a map of relative functions among laws of relevant agencies. In order to examine issues related to ocean acidification, 40 topics represented components of the ecosystem model matrix related to ocean acidification (see Table 7.9). To establish the baseline analysis, the 40 topics were each represented by a term or a phrase (Table 7.9). The same script was used in Chapter 5 to identify and count any word or phrase occurrence in the law collection. Querying the law collection with the selected word or phrase produced a topic by document matrix of raw frequencies for each legal unit.

The frequencies represent the degree to which a law influences the management issues related to each topic. Although the frequency measurement generated here cannot precisely indicate a law's jurisdiction, it can reflect a law or agency's relative involvement. For example, if one law contains the term 'fishing' twice, while a different law refers to the term 700 times, clearly the latter is more concerned with fishing activities. However, in the case that two laws reference a term an equal number of times does not necessarily indicate that they are equally involved in management relating to the topic.

To determine what agencies were involved in a given topic, the topic-document matrix was integrated with the agency-document matrix resulting in a topic- agency matrix. The number of agencies associated with laws containing a particular topic represented a second dimension of overlap. As such, a relatively high number of agencies involved in a topic indicated a potentially complicated situation for coordination.

Using the topic-document and topic-agency matrices, the following two subsections present preliminary measures developed to calculate the degree of legal complexity associated with the modeled system topics. The graphical representations of these data are then presented. The first step describes a new metric, called the Agency Involvement Measure (AIM), which indicates relative degree of agency involvement in a topic or category. The second step mimics Chapter 5, presenting the Overlap Index (OI) as a measurement of regulatory, statutory, and agency complexity. As also described in Chapter 5, the third step generates the graphical network diagrams of the term frequency and agency authority data. By computing the sum of components within a category, this graphical network illustrates the legislation and agency authority for each topic. These diagrams utilize the same data used to calculate the Overlap Index of complexity (OI) and Agency Involvement

Measure (AIM). The goal of the metrics was to develop a tool to quantify the visual results of the data. Both metrics are still preliminary prototypes and will likely be advanced in the future.

Agency involvement measure (AIM)

Implementation purpose

The development and execution of the metric to quantify the degree of relative involvement of any agency in a topic helps to identify what agencies should be involved in a proposed policy addressing ocean acidification. Hypothetically speaking, if the Environmental Protection Agency (EPA) were the only agency involved in all of the topics associated with the modeled system of ocean acidification then, assuming the conceptual model developed encompasses all related issues, implementation of a new policy or statute should solely involve the EPA. However, in cases where one agency has exclusive authority over one topic and another agency is solely responsible for another topic, it behooves these two entities to coordinate for a more cohesive resolution to the ocean acidification problem. If one of these agencies is not involved from the inception of new policy measures, it may thwart the effectiveness of the new initiatives. This is especially likely if the uninvolved agency has a mandate in conflict with newly proposed legislation. The most probable situation is that multiple agencies are involved in all or nearly all of the topics associated with ocean acidification. In this case, a range of alternative coordination models are available to policy experts interested in problem-solving efforts for more effective decision-making.

Calculation

The preliminary metric of agency involvement was based on two variables: (a) proportion of agency-related documents; and (b) proportion of agency-related term frequency. The first variable derives from the number of documents associated with agency *A* that contain topic *T*. To compare the variable across multiple geopolitical jurisdictions, the number of agency documents was normalized by dividing it by the total number of documents associated with agency A. This proportion is referred to as Agency-associated Documents (AD).

$$AD(A,T,GP) = \frac{D(A,T,GP)}{D(T,GP)}$$

AD= Agency-associated documents; A=Agency; T= Topic; GP=Geopolitical jurisdiction; D= Documents

The second variable derives from the summed frequency of term *T* for those laws associated with agency *A*. To compare the variable across multiple geopolitical jurisdictions, I normalized the summed term frequencies by the total sum of term frequencies for term *T* in all the documents of the particular geopolitical jurisdiction.

$$AF(A,T,GP) = \frac{TF(T,D(A,T,GP))}{\sum TF(T,D(T,GP))}$$

AF= Agency term frequency; A=Agency; T= Topic; GP=Geopolitical jurisdiction; TF = Term frequency; D= Documents

In the preliminary development of an overarching index of agency involvement, the two variables were multiplied to generate the Agency Involvement Measure (AIM). Within any geopolitical jurisdiction and for any given topic, an agency's AIM demonstrates the degree to which it is involved in management of the topic. For each jurisdiction, the number of laws and the summed term frequency were normalized by their corresponding total possible laws and term frequencies. The two proportions were then multiplied as follows:

$$AIM(A,T) = (AD)(AF)$$

AIM= Agency Involvement Measure; A=Agency; T=Topic; Refer to equations above for definition of AD and AF.

The agency involvement index provides a measurement for the systematic comparison of involvement among agencies within and between topics. The index can range from zero to 100%. An agency that is associated with many laws containing high frequencies of reference to the topic would result in a higher percentage. A higher index identifies an agency as the primary entity involved in that topic relative to the other agencies. Alternatively, if an agency is associated with zero number of laws and consequently no term frequency, then its AIM index result would be zero.

The basic calculation of AIM adjusts appropriately for cases where one variable is high and the other is relatively low; however, the separate variables can provide more detailed depiction of agency involvement. For example, in cases where a topic has one agency managing many laws containing that topic, the AD will be high despite the high or low frequency of occurrence in these documents (as long as it is greater than zero). However, in the case that the term frequency for a topic is relatively low in these documents, the result would be an AF close to zero. The AIM adjusts appropriately to reflect a combination of the two variables. If another agency has one or just a few laws containing high frequencies of the same topic, this second agency will measure with a high AF relative to the first agency's AF. In other cases, agency involvement may be consistent among the variables and would be reflected by the AIM index. For example, if one agency manages most of the laws associated with a topic (measuring a high AD) and these laws contain relatively high frequencies of the topic (measuring a high AF), the resulting AIM for this agency would be high as function of topic. Therefore, depicting both of these pieces of information is important to the overarching index.

By category

The Agency Involvement Measure was performed on the 40 individual components. The AIM was also performed on groups of components for purposes of identifying patterns of agency involvement between the six categories of the modeled system and for creating a synthesis of results. To generate an AIM for each category, the AIM(A,T) of all components was averaged within each category so that this new category-based AIM still ranged from zero to 100%. Therefore, this metric indicates the average agency involvement that a particular agency has across the components of a given category.

Overlap Index (OI)

Implementation purpose

Chapter 5 demonstrates the Overlap Index (OI) which was developed to evaluate complexity for any given topic related to the ocean. In contrast to Chapter 5's application, this case study calculates the OI metric to expose potential obstacles due to complexity that may encumber holistic management resolutions to ocean acidification. For example, if a topic (represented by a single component or category in the modeled ecosystem) were to measure a high Overlap Index (or associated variables) relative to the other categories, it is likely that this category poses a potential obstacle in coordination among categories. Of course, this high complexity may also be an indication of high coordination for the given topic. And while current coordination could be a positive indicator, it could also pose another barrier because existing strongholds on issues and procedures often inhibit institutional change. On the brighter side, any cohesion could streamline decision-making toward a holistic resolution to the problem of ocean acidification.

Calculation

The following explanation of the variables and calculation of the Overlap Index also appears in Chapter 5.

The degree of overlap was calculated using the following variables: (1) the number of laws involved; and (2) the number of associated agencies linked to laws involved in each topic. The three variables were calculated to indicate the degree of overlap occurring for each given topic. The first variable, referred to as Statute Overlap (SO), was derived from the number of statutes that contain a given topic. Based on this statute variable, the topic with the highest number of laws ranked as the most severe overlap. In order to compare the variable across multiple geopolitical jurisdictions, I normalized the statute overlap variable by the total number of possible statutes in the ocean law compilation for the given geopolitical jurisdiction.

$$SO(T,GP) = \frac{SU(T,GP)}{\sum SU(GP)}$$

SO= Statute Overlap; T= Topic; GP = Geopolitical jurisdiction; SU= Statutory units

The second variable, referred to as Regulation Overlap (RO), derives from the number of regulations that contain a particular topic. The regulation variable indicated that the topic with the highest number of laws ranked as having the most instances of overlap. To compare the variable across multiple geopolitical jurisdictions, it is necessary to normalize the RO variable by the total number of possible regulations in the ocean law compilation for the given geopolitical jurisdiction.

$$RO(T,GP) = \frac{RU(T,GP)}{\sum RU(GP)}$$

RO= Regulation Overlap; T= Topic; GP = Geopolitical jurisdiction; RU= Regulatory units

The third variable derives from the agency authority metadata for each law. To calculate this agency overlap variable, referred to as Agency Overlap (AO), a summation was made of the agencies associated with the overlapping laws (both statutes and regulations) for a given topic. In order to compare the variable across multiple geopolitical jurisdictions, AO variable was normalized by the total number of agencies represented in the ocean law compilation for the given geopolitical jurisdiction.

$$AO(T,GP) = \frac{A(T,GP)}{\sum A(GP)}$$

AO= Agency Overlap; T= Topic; GP = Geopolitical jurisdiction; A = Agencies

In our preliminary development of an overarching measurement of overlap, the three variables were averaged to determine the Overlap Index (OI). For any geopolitical jurisdiction over a particular topic, this Overlap Index demonstrates the legal and agency complexities in management of that topic. For each jurisdiction, the number of laws and the number of agencies were normalized by their corresponding total possible laws and agencies. Then the average sum of the normalized variables was calculated as follows:

$$OI(T,GP) = \frac{SO + RO + AO}{3}$$

OI= Overlap Index; T= Topic; GP = Geopolitical jurisdiction

This overlap measurement provides an index that allows the systematic comparison of overlap between topics within and between jurisdictions. The index can range from zero to 100%. A topic involving a high number of laws and a high number of associated agencies would result in a number closer to 100%. Alternatively, with zero number of laws and with consequently no agencies associated, the index result would be zero.

The basic calculation of OI adjusts appropriately for cases where one variable is high and the other is relatively low; however, the separate variables of SO, RO and AO provide a more detailed depiction of the overlapping information. For example, in cases where a topic has many laws implemented through a single agency, the OI may be a high number only due to the high results of the SO and RO. Only by comparing the individual variables will the researcher recognize that the AO is low or null and be able to determine that the topic is not at risk of inter-agency overlap (though intra-agency overlap may be revealed through further investigation).

By category

The average Overlap Index per category was calculated to facilitate comparison between categories and geopolitical jurisdictions, and to synthesize the results. For example, this categorical-based complexity index information allows one to see whether there is a similar degree of complexity for state and federal law in any of the categories. To generate OI for each category, the OI(T,GP) average of all components within each category was calculated so that this new category-based OI still ranged from zero to 100%. Consequently, this metric demonstrates the hubs of activity or complexity of a particular category based on the average proportion of laws and agencies in relationship to the frequency of components occurring within that category.

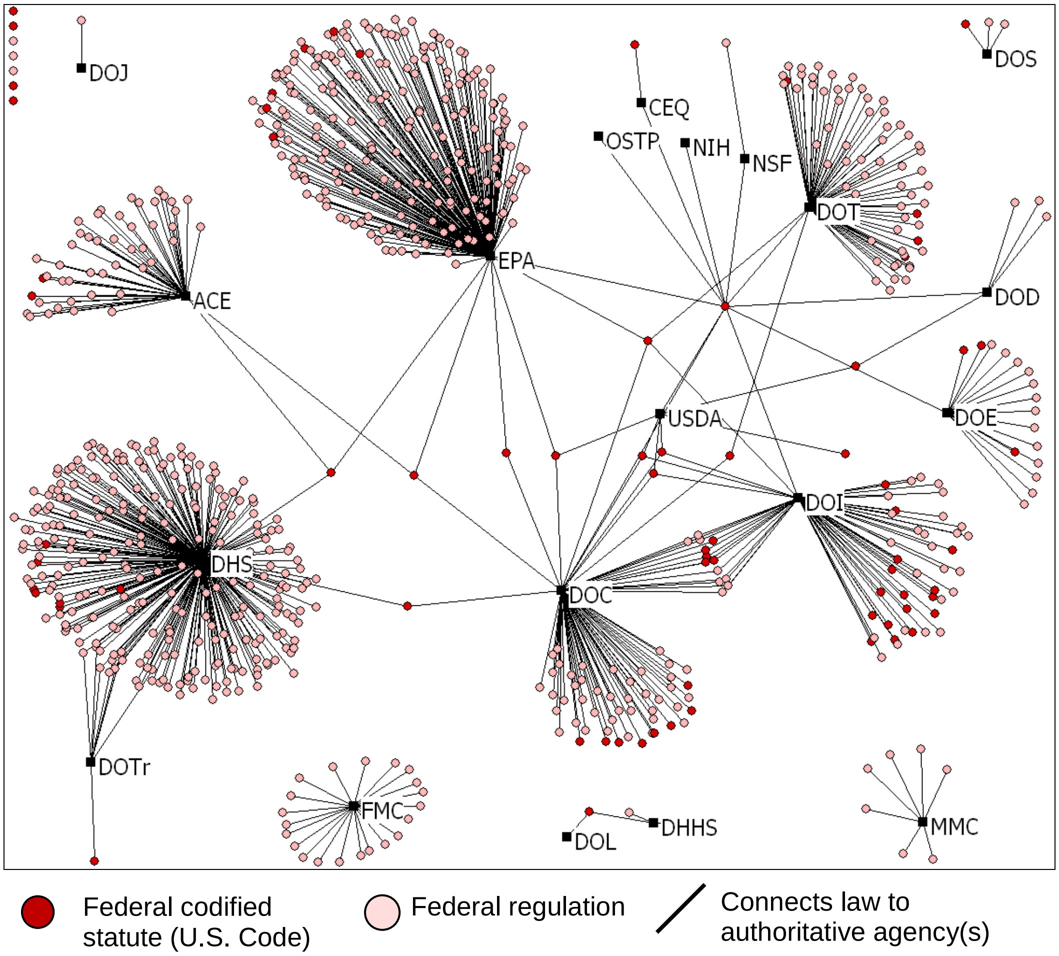
Legislative landscapes -- graphical depiction

Implementation purpose

To visualize legislative and agency jurisdiction for the modeled ecosystem components (Table 7.9), the following legislative landscapes provide a graphical representation of the previously defined data and metadata matrices. These diagrams visually illustrate what laws reference the various topics in the model, and consequently what agencies are involved in the topics given their authority over the topic-associated laws. The figures reflect the analysis performed on the six categories, listed in Table 7.9.

Construction

The task of creating visual analysis for the components and categories utilized the social networking software UCINET version 6.170 and NetDraw version 2.064 (Borgatti et al. 2002) . The document-agency authority metadata matrix served as the primary data input. Agencies and documents were displayed as individual nodes, with agencies labeled for clarity. Each document, or legal unit, is represented by a circular node with a line connecting each document to its associated agency or multiple agencies (Figure 7.8 and Figure 7.9). For example, the National Environmental Policy Act (42 U.S.C. 4321 et seq.) connects to its authority agency, the Council on Environmental Quality (CEQ), because CEQ has jurisdiction to implement the Act. Some statutes are under the authority of multiple agencies, such as the Clean Water Act. This Act is under the authority of the Environmental Protection Agency (EPA), the Army Corps of Engineers (ACE), and the Department of Homeland Security (DHS). Also, regulation nodes linked to the authoring agency. Lastly, terms or phrases were organized as topics, the frequency of these topics appear as attributes. The size of the document nodes (shown in the Results section) reflects relative frequency of each topic.



AGENCY ACRONYMS
ACE: Army Corps of Engineers
CEQ: Council on Environmental Quality
DHHS: Dept. of Health & Human Services
DOA: Department of Agriculture
DOC: Department (Dept) of Commerce
DOD: Dept of Defense
DOI: Dept of Interior
DOE: Dept of Energy
DOJ: Dept of Justice
DOL: Dept of Labor
DOS: Department of State
DOT: Dept. of Transportation
DOTr: Dept of Treasury
EPA: Environmental Protection Agency
FMC: Federal Maritime Commission
MMC: Marine Mammal Commission
NIH: National Institute of Health
NSF: National Science Foundation
OSTP: Office of Science & Technology Policy

Figure 7.8. Foundation maps of agency authority for federal statutes and regulations. Laws (circular nodes) linked to their authoritative and/or implementing agencies (square nodes labeled with agency acronyms). The placement of agencies and length of lines was randomly generated. It is important to understand first how federal governance of ocean law is organized by agency and second, how the laws implementing those agencies' goals cluster, interact or work autonomously. This is the foundational map with no term frequency data from which the diagrams in Figure 7.16 were generated. In Figure 7.16, the law nodes are re-sized by the frequency in which a selected term occurs in the law.

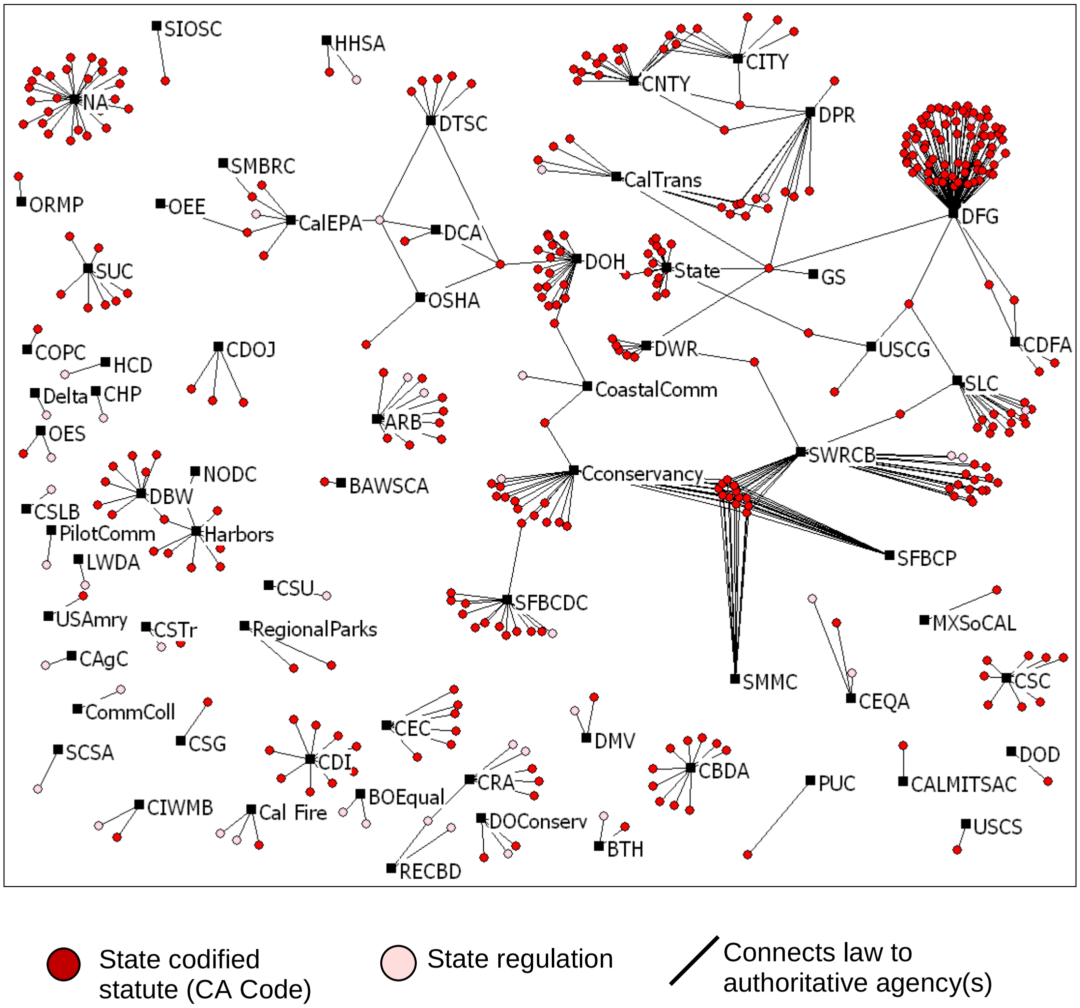


Figure 7.9. Foundation maps of agency authority for state statutes and regulations. Laws (circular nodes) linked to their authoritative and/or implementing agencies (square nodes labeled with agency acronyms). The placement of agencies and length of lines was randomly generated. It is important to understand first how state governance of ocean law is organized by agency and second, how the laws implementing those agencies' goals cluster, interact or work autonomously. This is the foundational map with no term frequency data from which the diagrams in Figure 7.17 were generated. In Figure 7.17, the law nodes are re-sized by the frequency in which a selected term occurs in the law. See following two pages for acronym definitions.

FIG 7.9 ACRONYMS	AGENCY NAME	EMBEDDED WITHIN
DTSC	Department of Toxic Substances Control	-
DCA	Department of Consumer Affairs	-
ARB	Air Quality Districts	ARB
BAWSCA	Bay Area Water Supply and Conservation Agency	-
BOEqual	Board of Equalization	-
BTH	Dept of Business, Transportation, and Housing	-
CAgC	County Agricultural Commission	DPestR
Cal Fire	Department of Forestry and Fire Protection	CRA
CalEPA	California EPA	-
CALMITSAC	California Marine and Intermodal Transportation System Advisory Council	MTSNAC
CalTrans	Department of Transportation	BTH
CBDA	Bay-Delta Authority	CRA
Cconservancy	California Coastal Conservancy	CRA
CDFA	CA Dept of Food and Agriculture	-
CDI	Department of Insurance	-
CDOJ	CA Department of Justice	-
CEC	Energy Commission	CRA
CEQA	CEQA	-
CHP	California Highway Patrol	BTH
CITY	City	-
CIWMB	Cal Integrated Waste Management Board	CalEPA
CNTY	County	CNTY
CoastalComm	California Coastal Commission	CRA
CommColl	Community Colleges	-
COPC	California Ocean Protection Council	-
CRA	California Resource Agency	-
CSC	CA Seafood Council	CDFA
CSG	California Sea Grant	-
CSLB	Contractors State License Board	DOCA
CSTr	Cal State Treasury	-
CSU	Cal State University	-
DBW	Department of Boating and Waterways	CRA
Delta	Delta Protection Commission	CRA
DFG	Dept of Fish & Game	CRA
DMV	Department of Motor Vehicles	-
DOConserv	Department of Conservation	CRA

ACRONYM (continued)	AGENCY NAME	EMBEDDED WITHIN
DOD	U.S. Department of Defense	FED
DOH	State Department of Health Services	-
DPR	Dept of Parks and Recreation	CRA
DWR	Dept of Water Resources	CRA
GS	Government Services	-
Harbors	Harbors and watercraft commission, or Harbor districts	CRA
HCD	Dept of Housing and Community Development	BTH
HHSA	Health and Human Services Agency	-
LWDA	Labor & Workforce Development Agency	-
MXSoCAL	Marine Exchange of Los Angeles-Long Beach Harbor	-
NA	Not Applicable	NA
NODC	Navigation and Ocean Development Commission	-
OEE	Office of Education and Environment	Department of Education
OES	Office of Emergency Services	-
ORMP	Ocean Resources Management Program	-
PFMC	Pacific Fisheries Management Council	FED, DOC
PilotComm	State Board of Pilot Commissioners for the Bays of San Francisco, San Pablo and Suisun	-
PUC	Public Utilities Commission	-
RECBD	California Reclamation Board	-
RegionalParks	Regional Park Districts	CRA
SCSA	State and Consumer Services Agency	SCSA
SFBCDC	San Francisco Bay Conservation and Development Commission	CRA
SFBCP	SF Bay Conservancy Program	CRA
SIOSC	State Interagency Oil Spill Commission	CRA
SLC	State Lands Commission	-
SMBRC	Santa Monica Bay Restoration Commission	-
SMMC	Santa Monica Mountains Conservancy	-
State	State	-
SUC	Sea Urchin Commission	CDFA
SWRCB	State Water Resources Control Board	CalEPA
USAmry	US Army	FED
USCG	US Coast Guard	DHS, FED
USCS	US Coast Survey	DOC, FED
OSHA	Occupational Safety and Hazards Administration	OSHA, FED

It is important to understand first how federal governance of ocean law is organized by agency and second, how the laws implementing those agencies' goals cluster, interact or work autonomously. Thus Figure 7.8 and Figure 7.9 provide foundational maps illustrating the mandate and authority connections between the agencies and documents for federal and state law. The Results section uses these foundational maps to generate the legislative landscape of topics associated with the conceptual ecosystem model of ocean acidification.

By category

Following the synthesis of the AIM and OI metrics, the generation of legislative landscapes by category facilitated the identification of patterns between categories and involving different geopolitical jurisdictions. A raw sum of the topic frequencies or an average sum across components produces an equivalent diagram because the nodes are sized relative to the minimum and maximum frequency of a given topic (see example Table 7.11). Thus, I used the raw sum of component term frequencies for each category.

Table 7.11. For a sample of five laws, this table contains the Sum of raw frequencies for modeled ecosystem components. The summation is made by category.

Law	SOURCE	CAUSE	EFFECT	DIRECT IMPACT	ECOL. IMPACT	HUMAN IMPACT
Clean Air Act (42 U.S.C. 7401)	1434	20	2	0	0	0
Energy Policy of 2005 (42 U.S.C. 15801)	366	21	18	0	0	4
Clean Water Act (33 U.S.C. 1251)	170	3	4	5	1	6
Global Climate Change Prevention Act of 1990 (7 U.S.C. 96 et seq.)	0	2	7	0	0	0
Magnuson Stevens Act (16 U.S.C. 1801-1883)	91	0	0	10	20	995

RESULTS

This section presents findings from the two measures of overlap, Agency Involvement Measure (AIM) and Overlap Index (OI), for both state and federal levels of law. Graphic displays present the findings for each category. Together these data provide a baseline illustration of the management entities and their authority as it relates to our conceptually modeled system of ocean acidification. In summary, federal agencies exhibited high cohesion among components by category. This cohesion is evident in that AIM results of individual components were similar within their associated categories. The impact-related categories displayed the most consistency among components in that the Department of Commerce (DOC) dominated nearly all of the components of Direct Impact, Ecological Impact and

Human Systems Impact categories. Graphic results for federal law confirmed this cohesion in that the majority of laws referencing impact-related category topics were under the authority agency of the Department of Commerce. In contrast, the graphic results for state law revealed fragmentation in management, where many agencies with minimal involvement in each component and category act independently. Management by the California Department of Fish & Game did exhibit cohesive controls of the impact-related categories more consistently within and between categories.

Based on the OI, it appears that both state and federal policy related to OA addresses issues of Source, Cause, and Human System Impact categories with the highest complexity. In some cases high complexity can mean that agencies are working together but it can also mean that two agencies are implementing redundant policy with potentially dangerous consequences. The categories of Effect, Direct Impact, and Ecological Impact measured lower OI, which indicates the components of these categories are more clearly managed by certain agencies and/or there are relatively few laws referencing the associated components. In some cases this low complexity may be because gaps exist.

Agency involvement

Federal Agency Involvement Measure (AIM)

Every federal agency was involved to some degree in one or more of the modeled system components investigated. Figure 7.10 presents the AIM results for each individual component, grouped by category. For example, Figure 7.10A contains the AIM results for each component of the Source category, and are presented as stacked area charts to facilitate identification of patterns within and across categories. Figure 7.11 illustrates the average component AIM results of each category in order to display patterns within and among categories. AIM results for federal departments ranked accordingly: the Department of Commerce (DOC) ranked as the most involved in the categories combined, with EPA at a close second, and the Department of Homeland Security ranked third (see Figure 7.11).

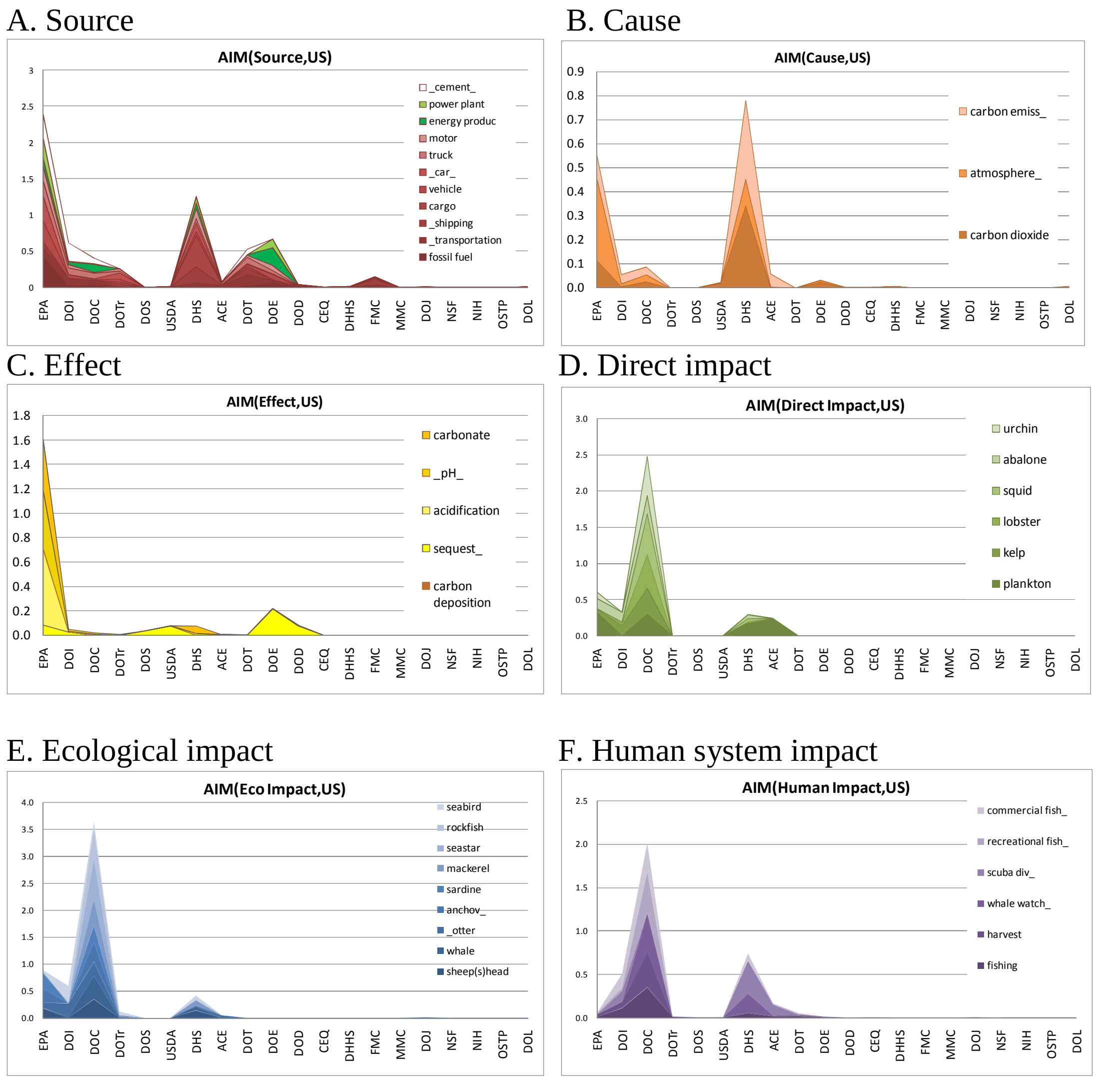


Figure 7.10. Agency Involvement Measure of federal law for each modeled component. Each chart contains the AIM of the components grouped into associated categories (A. Source; B. Cause; C. Effect; D. Direct impact; E. Ecological impact; and F. Human systems impact). Colors correspond to the categories, except cement, power plant, and energy production not colored in a shade of red to facilitate differentiation between them and the other Source components. In other situations, shading allows interpretation of the differences and similarities among components within each category. (Color key: RED and variations = Source; ORANGE = Cause; YELLOW = Effect; GREEN = Direct Impact; BLUE = Ecological Impact; PURPLE = Human System Impact.)

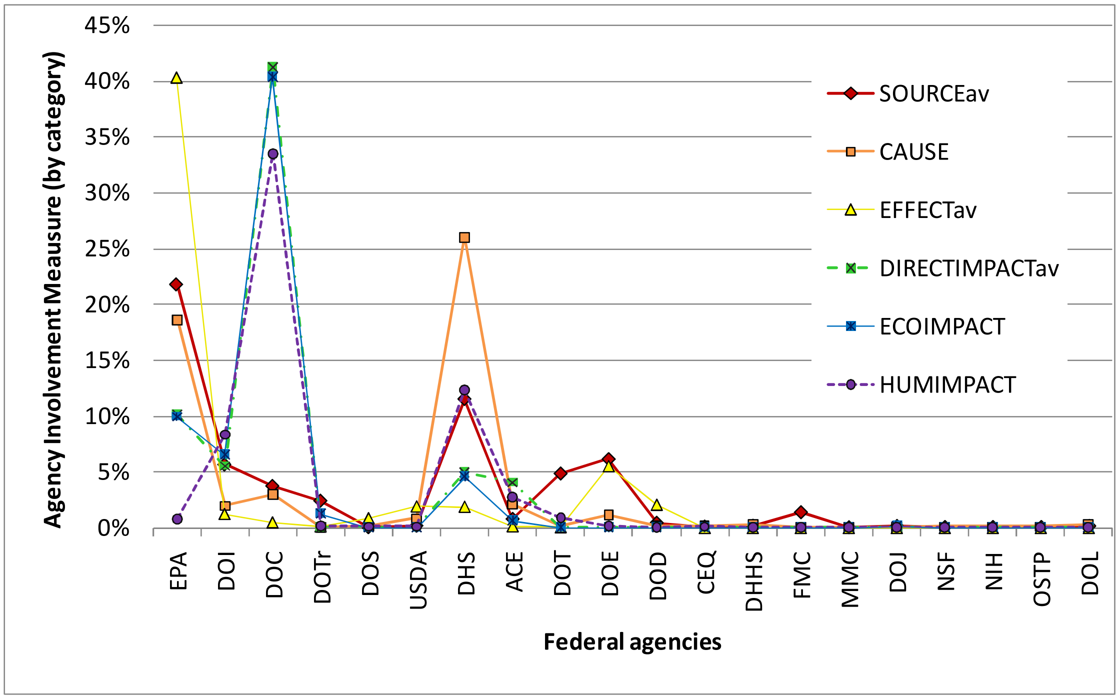


Figure 7.11. Figure shows the average agency involvement for each category. Colors correspond to key in Figure 7.10.

There were two primary and two secondary agencies involved in Source components. The Environmental Protection Agency (EPA) ranked as the most involved for the combined AIM of the Source components. The AIMs of each component summed to 2.39 for the EPA and 1.26 for the Department of Homeland Security (DHS). The Source component average of the EPA and DHS were 21.5% and 11.5% respectively. The secondary agencies involved in the Source category were the Department of Energy (DOE) and Department of Transportation (DOT), according to the Agency Involvement Measurement.

Within the Cause category, two highly involved agencies emerged: the DHS and EPA displayed categorical averages measuring 26.0% and 21.8%, respectively

(Figure 7.11). In contrast, the Effect category revealed EPA as the primary agency involved, measuring an average 40.2% for this category. The Department of Energy (DOE) ranked at a distant second for the Effect category, with an average of 6.1%.

The impact-related categories (Direct Impact, Indirect Ecological Impact, and Indirect Human System Impact) showed similar patterns for agency involvement. Within all three categories, the Department of Commerce (DOC) ranked as the most involved agency, with averages ranging from 33.5% to 41.3%. The DHS ranked second in each category, with average involvement (AIM) ranging from 1.2% to 4.9%.

State Agency Involvement Measure (AIM)

Results showed a range of state agency involvement across and within the categories, especially in comparison to the cohesion seen in the federal law. Overall results show that the Department of Fish & Game (DFG) is the agency most involved in OA related management across all categories. However, according to the components investigated, DFG measured zero involvement in the categories of Effect and Cause.

While there may be many agencies managing the modeled components, agency involvement of components is not consistent within categories. Out of the total 70 agencies identified as being associated with the laws investigated, only 58 had relationships to the laws containing one or more occurrence of a model component. In other words, results indicate agencies have either potentially overlapping jurisdictions or potential for common goals or outcomes.

Following the description of federal agency involvement, Figure 7.12 presents the AIM results for each individual component grouped by category. For example, Figure 7.12A contains the AIM results for each component of the Source category, but they are stacked area charts to facilitate identification of patterns within and across categories. Figure 7.13 illustrates the AIM results of each category (average component AIM) to presenting patterns within and among categories.

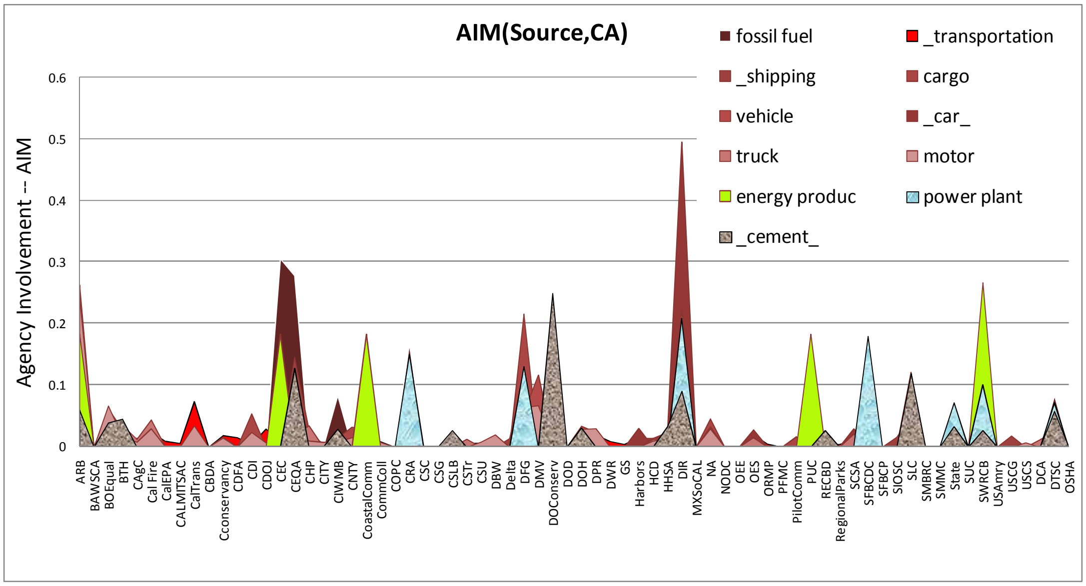


Figure 7.12(a). Agency Involvement Measure of state law for each modeled component. Each chart contains the AIM of the components grouped into associated categories (A. Source; B. Cause; C. Effect; D. Direct Impact; E. Ecological Impact; and F. Human Systems Impact). Colors correspond to the categories, except cement, power plant, and energy production not colored in a shade of red to facilitate differentiation between them and the other Source components. In other situations, RED= Source; ORANGE=Cause; YELLOW=Effect; GREEN=Direct Impact; BLUE=Ecological Impact; PURPLE=Human System Impact. Shading allowed interpretation of the differences and similarities among components within each category.

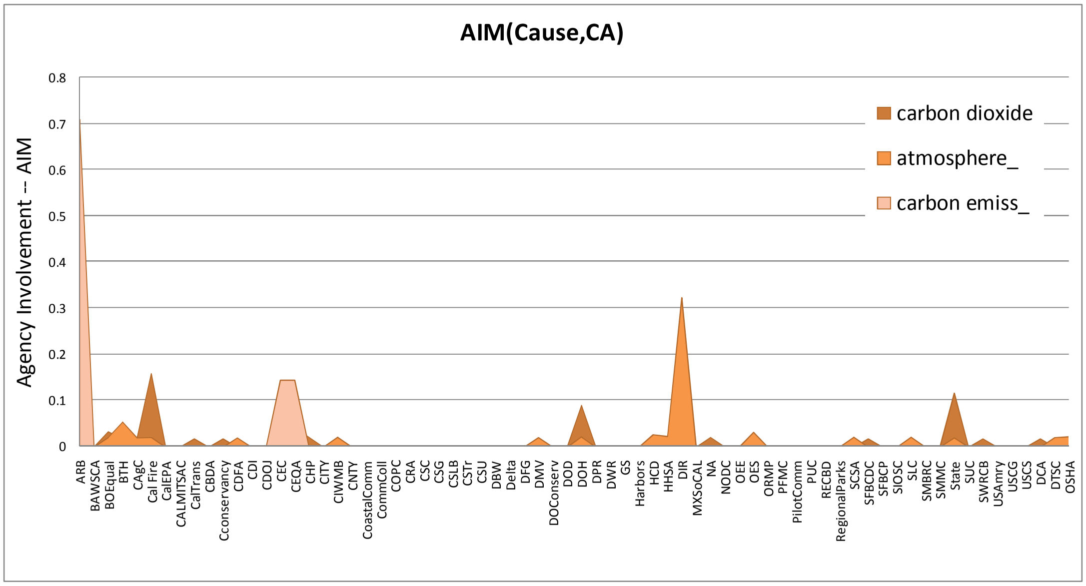


Figure 7.12b. See caption for Figure 7.12a.

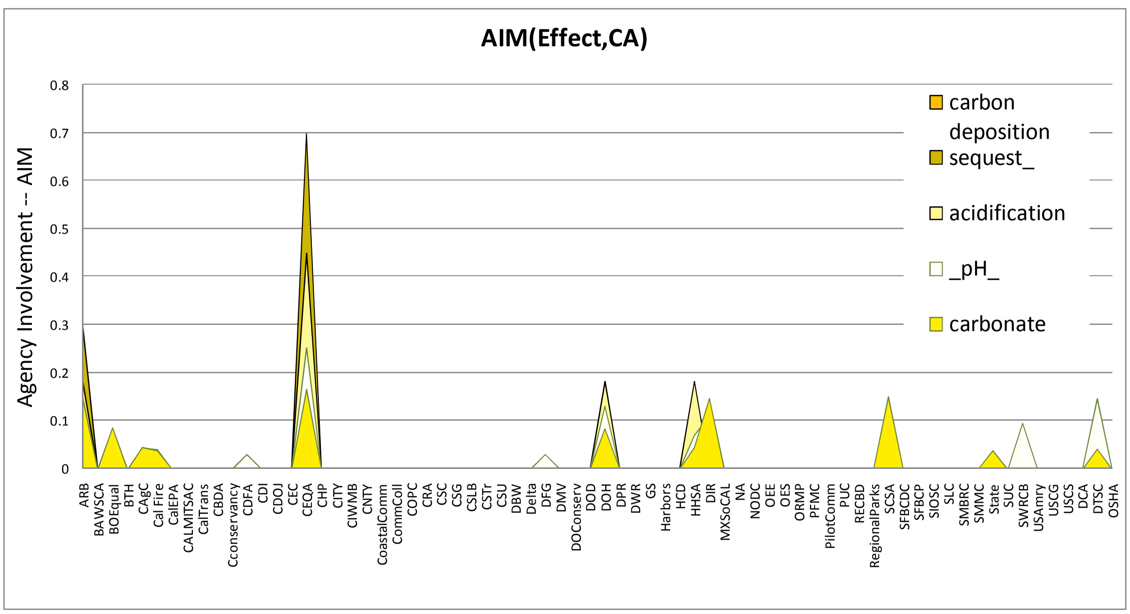


Figure 7.12c. See caption for Figure 7.12a.

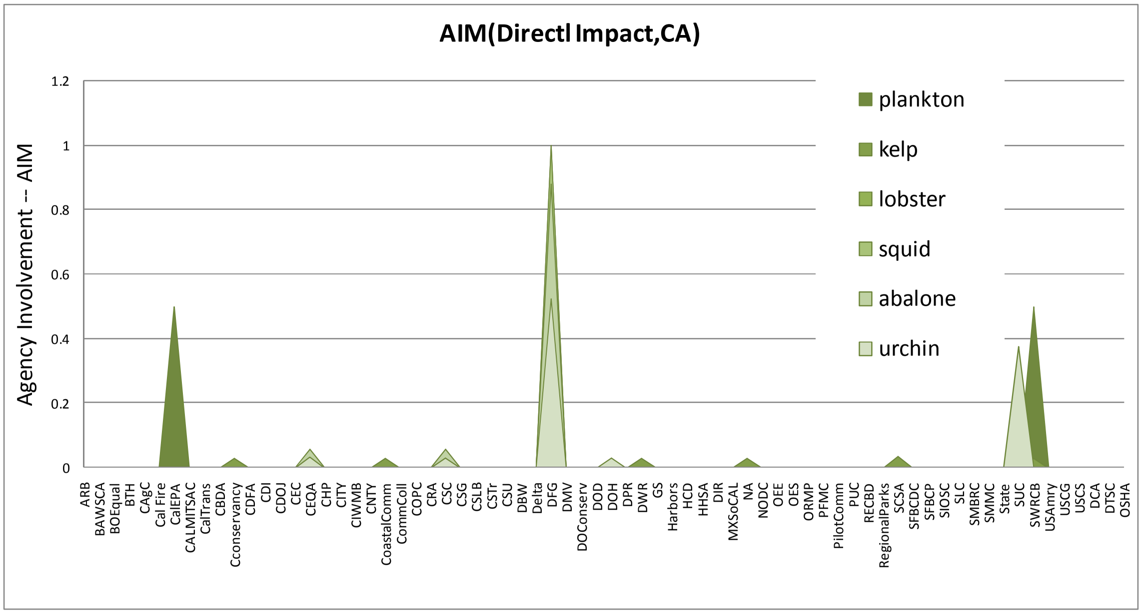


Figure 7.12d. See caption for Figure 7.12a.

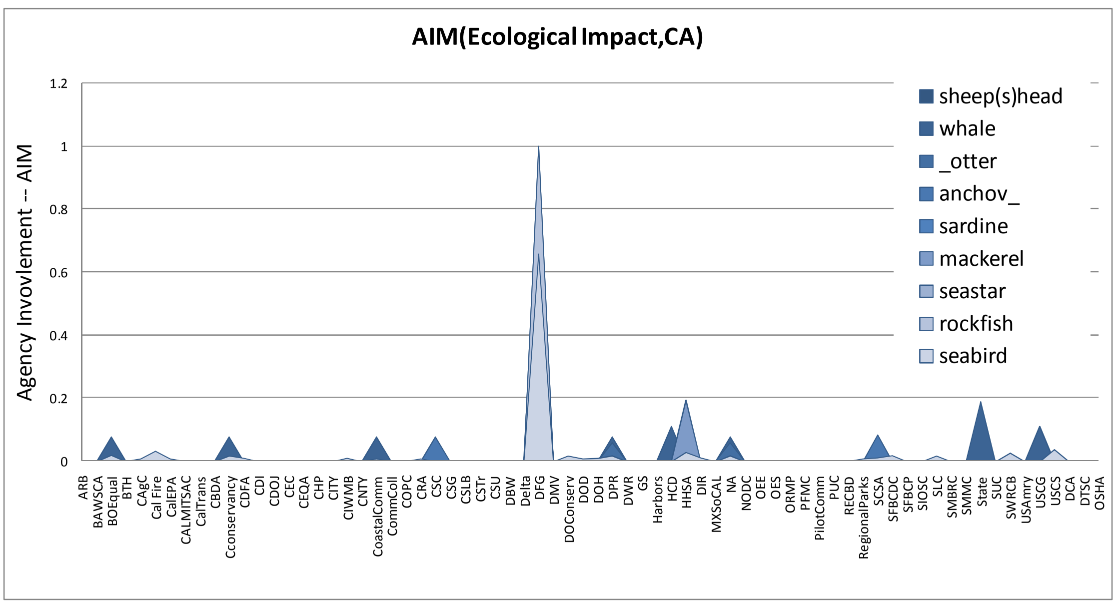


Figure 7.12e. See caption after Figure 7.12a.

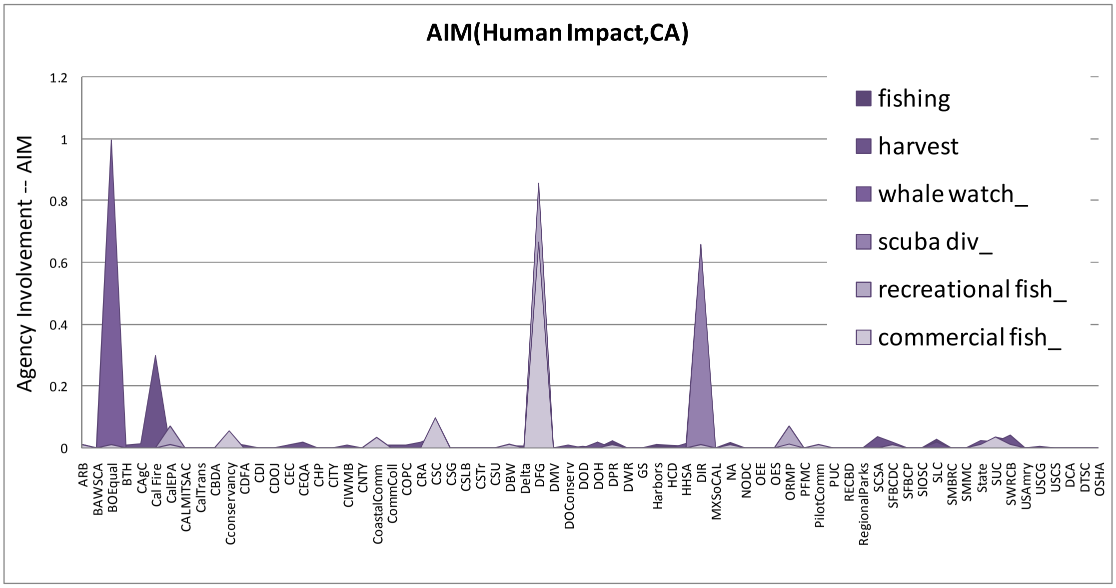


Figure 7.12f. See caption after Figure 7.12a.

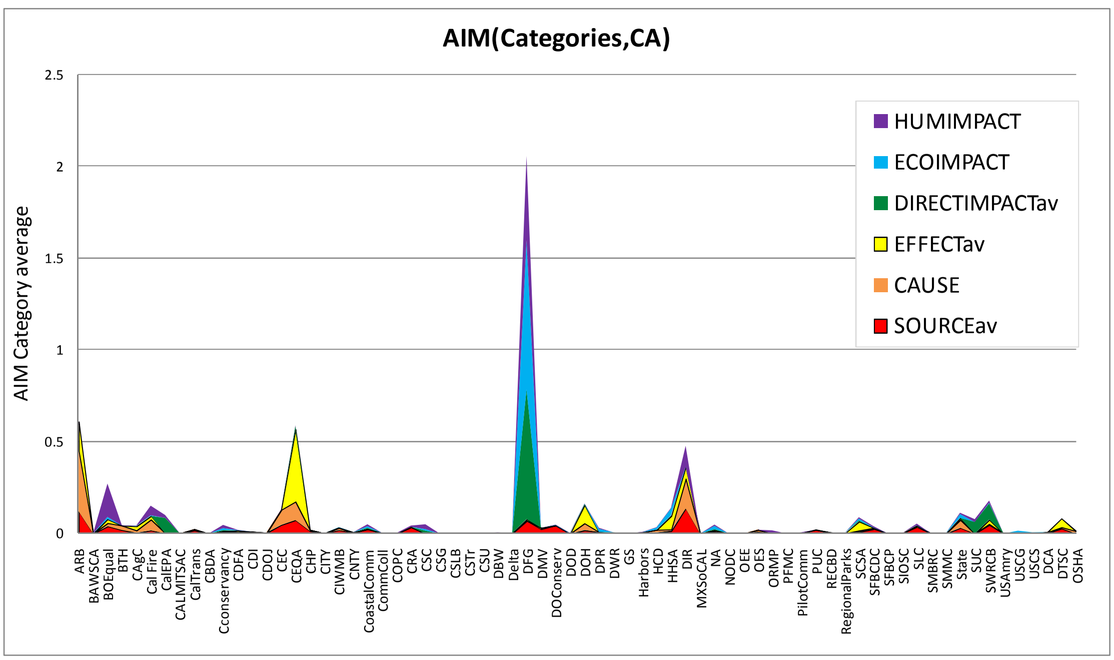


Figure 7.13. Figure shows the average agency involvement for each category in California State law. Color scheme followed accordingly: RED= Source; ORANGE=Cause; YELLOW=Effect; GREEN=Direct Impact; BLUE=Ecological Impact; PURPLE=Human System Impact.

Within the Source category, the agency involvement was spread across many agencies and displayed no clear cohesion among the components. The Department of Industrial Relations (DIR) measured the highest relative involvement for the Source category, with California Energy Commission (CEC) and California Environmental Quality Act (CEQA) ranking second and third respectively. The DIR ranked highest by its involvement in the components of *car*, *power plant*, and *cement*. Averaging across the Source category, the only agencies that measured an AIM above 10% were the DIR (13%) and Air Resources Board (ARB, 12%).

As with the Source, the Cause category reflected a clear lack of cohesion among the components for the agencies involved. The Air Resources Board (ARB) had the highest AIM relative to the other agencies, but this was solely due to its involvement in *carbon emiss**. For the specific component, *atmosphere*, the Department of Industrial Relations ranked highest in its involvement. Averaged across the whole category of Cause, the Air Resources Board (ARB) ranked as exhibiting the highest involvement (with 33% AIM), followed by the DIR (16%), CEQA (10%), and CEC (8%).

Within the Effect category, there were only three agencies measuring average involvement over 10%. The highest ranking agency was the California Environmental Quality Act (CEQA), which was involved in all three of the category's components with an average of 39% AIM (Figure 7.13c). The Air

Resources Board (ARB) ranked second with 15.8% and the Department of Health (DOH) ranked third with 10.0%, for the Effect category AIM.

For state law, the Direct Impact category showed higher cohesion than the other categories. The Department of Fish & Game ranked as the highest involved agency with over 70% average AIM (Figure 7.12d), and emerged as the only agency with an average involvement measuring over 10%. This ranking was due to DFG management and controls on lobster, squid, abalone, and urchin. The California Environmental Protection Agency (CalEPA) and State Water Resources Control Board (SWRCB) both ranked second but with a minimal average of 8.8%, attributed to their involvement in two laws exclusively associated with *plankton*.

The Ecological Impact category also showed higher cohesion relative to the other categories for state law. The Department of Fish & Game (DFG) ranked by far the highest with 81.3% of the average AIM per component. No other agency measured more than 4%. Notably, the DFG also ranked highest for the Human Impact category with 45.9% of the average AIM per component. The Board of Equalization ranked second with 18.2% due to the agency's association with the one state regulation mentioning *whale watch* a single time.

Degree of complexity (Overlap Index), function of topic/category

This subsection presents a summary of federal and state level results of the three individual variables (SO, RO, and AO) and then results of the Overlap Index (OI) by component. Then the OI of the components is averaged for each category to show normalized categorical complexity, and to see if a pattern emerges between the state and federal levels of law. The results of these overlap measures provide insight into ocean acidification-related management issues where coordination is most needed.

Federal

As evident in Figure 7.14, large fluctuations appeared in the Overlap Index between topics. Even so, aside from three components, the variables of SO, RO, and AO aligned closely in the federal law. The components of *car*, *carbon dioxide*, and *atmosphere* appeared to have the largest difference between the degree of agency overlap and the other two variables. The Agency Overlap (AO) consistently measured higher than either the Statutory or Regulatory Overlap.

Among categories, there was a clear difference in Overlap Index measurements (Figure 7.15). The Source (A) and Cause (B) categories ranked highest in complexity with 35% and 27% respectively, while the Human System Impacts (F) category ranked third with an OI of 19%. The categories of Effect (C), Direct Impact (D), and Ecological Impact (E) measured considerably lower Overlap Indices with 9%, 6%, and 9% correspondingly.

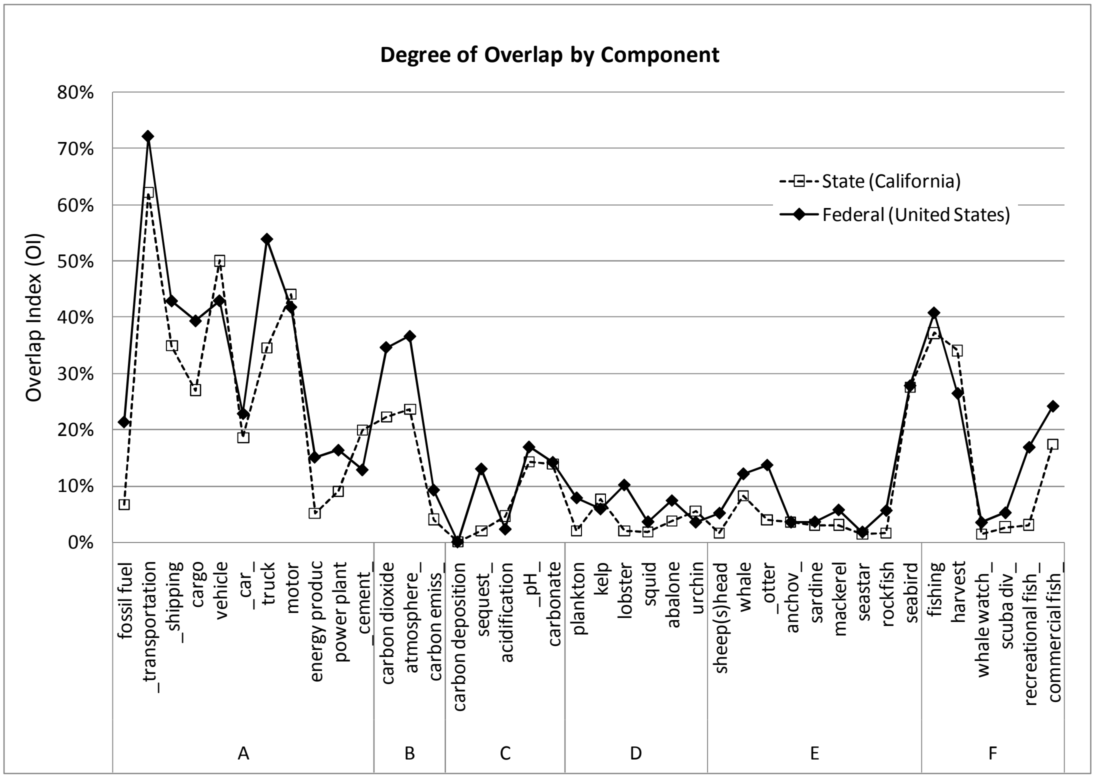


Figure 7.14. Degree of overlap (OI) by topic. The x-axis represents topics investigated, which are organized into their relevant categories as defined in Table 7.9. Categories are as follows: A= Source; B = Cause; C = Effect; D = Direct Impact; E = Ecological Impact; F = Human Systems Impact.

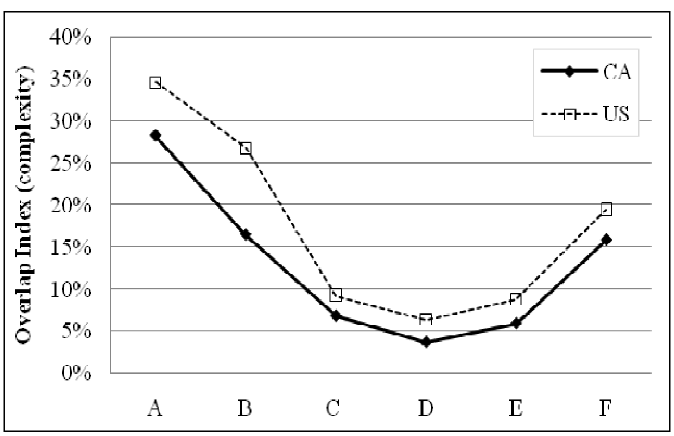


Figure 7.15. Degree of overlap (OI) by category (summed topics). Categories are as follows: A= Source; B = Cause; C = Effect; D = Direct Impact; E = Ecological Impact; F = Human Systems Impact.

State

There was a clear difference in Overlap Index measurements on average among categories in state law (Figure 7.15). Following the federal law pattern (Figure 7.14), the Source (A) and Cause (B) categories ranked highest in complexity with 28% and 17% respectively, while the Indirect human system impacts (F) category ranked third with an OI of 16%. The categories of Effect (C), Direct impact (D), and Indirect ecological impact (E) measured considerably lower Overlap Indices with 7%, 4%, and 9% correspondingly.

Law networks of modeled components

The graphic displays are presented for each category (Figure 7.16 and Figure 7.17). In combination with the metrics indicating agency involvement and issue complexity, these landscapes depict the baseline of which agencies manage what laws related to our conceptually modeled system of ocean acidification. Patterns among components that demonstrated similarity or difference of complexity are noted in the Discussion section.

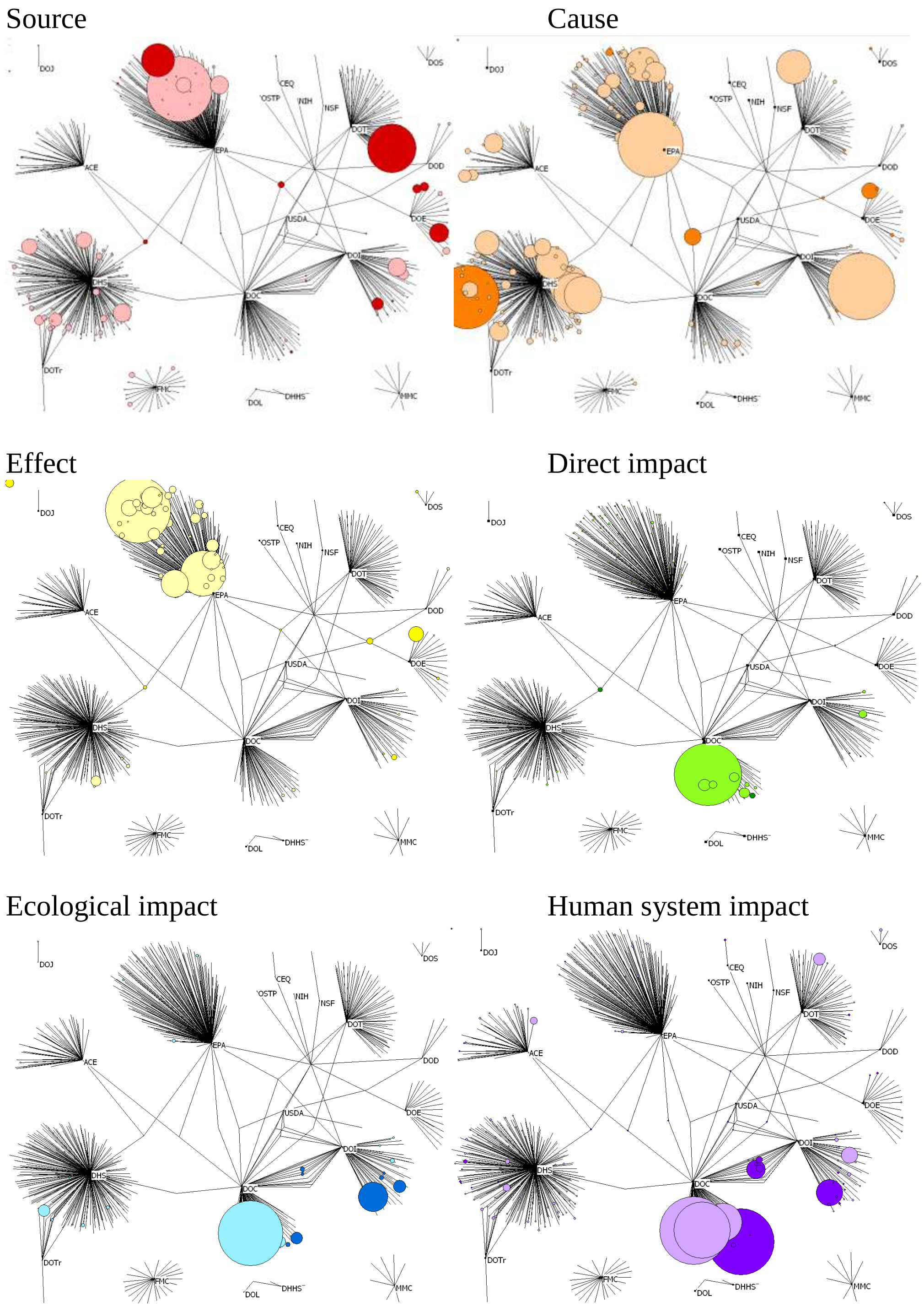


Figure 7.16. Federal legislative landscapes related to each category of components in the ecosystem model for ocean acidification. The color scheme follows accordingly: RED= Source; ORANGE=Cause; YELLOW=Effect; GREEN=Direct Impact; BLUE=Ecological Impact; PURPLE=Human System Impact. Refer to Figure 7.8 for enlargement of foundation map and agency key.

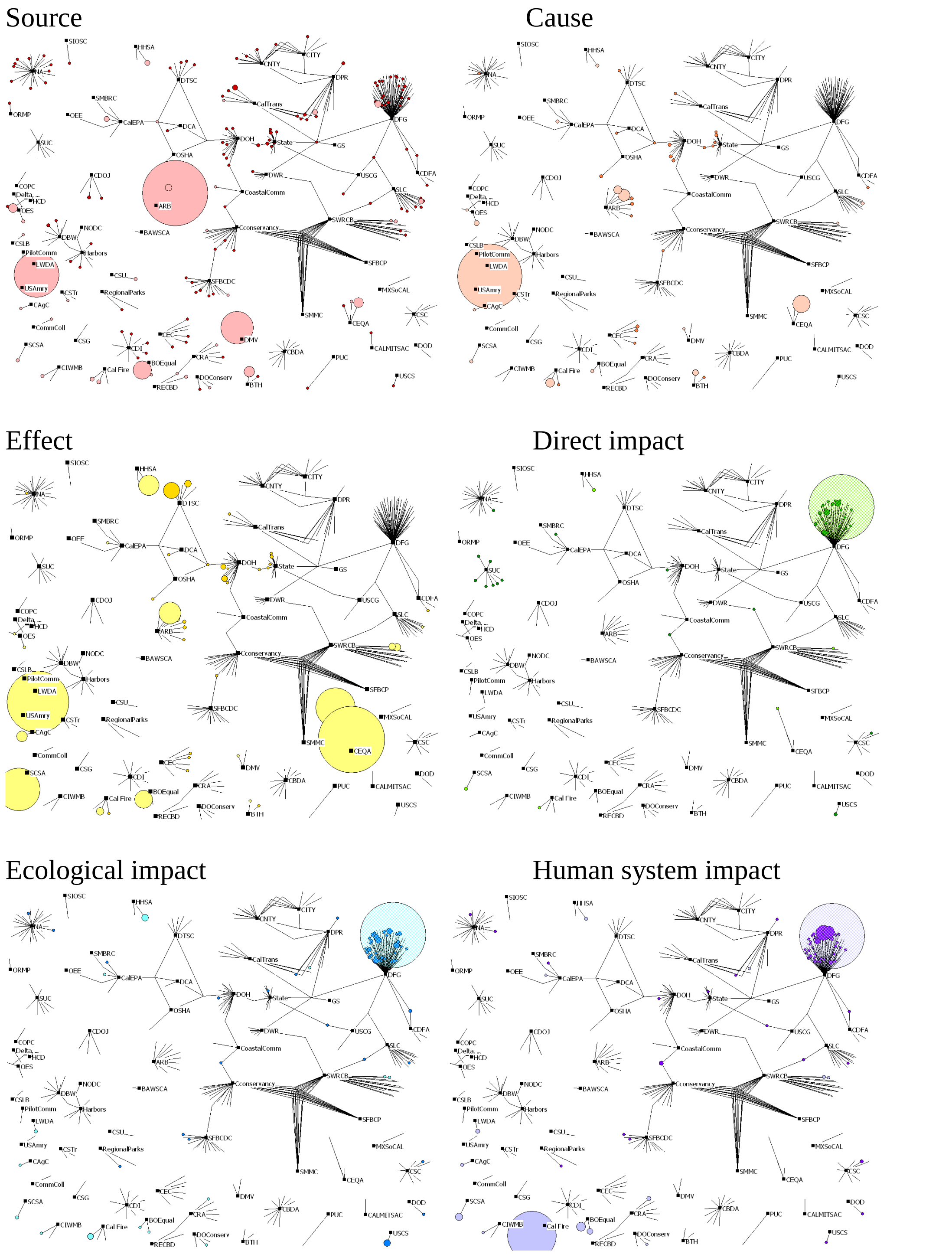


Figure 7.17. State legislative landscapes related to each category of components in the ecosystem model for ocean acidification. The color scheme consistent with key in Figure 7.16. Refer to Figure 7.9 for enlargement of foundation map and agency key.

DISCUSSION

Interpretation of results

The visual and quantitative Results showed a range of agency involvement across the categories. However, while federal law displayed relatively high cohesion among components within the categories, state law lacked comparable cohesion. In the context of this case study, cohesion was expected because most of the components making up each category are associated with a single sector. Since lawmaking has been conducted primarily within sectors it should follow that the components within each category be managed consistently by a single or small group of relevant agencies. Notably, for the categories of Source, Cause, and Effect, the state law did not exhibit as much cohesion between agencies that were involved in each category's components as much as federal. For state law however, the three categories relating to impact AIM analysis showed slightly more cohesion between components within the categories, as well as between categories. This inter-category consistency, which primarily revolves around the dominant involvement of the California Department of Fish & Game, is analogous to the Department of Commerce's role in the same three categories.

Findings from this case study suggest that the most challenging situation for both geopolitical jurisdictions is that the agency in most danger of impact on its resources currently has minimal, if any, involvement in the categories of Source, Cause, and Effect controlling the supply of ocean acidification. As such, the policies necessary to effectively confront the threat of ocean acidification will rely upon coordination among all relevant agencies.

Federal results

Combining the three analyses, the modeled system categories can be summarized together. To begin, the Environmental Protection Agency (EPA) emerged as the primary agency involved in the Effect category due to its prominence as a regulatory entity. The Department of Energy (DOE) was involved through statutory authority. The complexity of agencies and laws involved in the Effect category was relatively low. In contrast, the Source and Cause categories showed high overlap index, indicating a higher number of laws and agencies associated with the relevant components of the categories. This was expected for the Source category because it contained so many components. And while the Cause category only contained three components, *atmosphere* and *carbon dioxide* are multi-scale issues (Figure 7.6) that inherently cross sector and jurisdictional boundaries. This diversity in characteristics is evident through the many laws and many agencies associated with the components of these two categories (Fa and b).

The categories related to impact in federal law were highly consistent with one another in that the Department of Commerce was the agency showing the highest involvement. This was expected considering these categories contained components related to living marine resources, which are generally regulated by the

National Oceanic and Atmospheric Administration (NOAA, an agency within the DOC).

The consistency within the Effect category and within the impact categories may indicate an encouraging policy development in terms of monitoring the impacts of ocean acidification. The EPA has primary involvement in chemical water quality standards, this is apparent from its high involvement in the Effect category which contained components of *carbonate*, *pH*, *sequester*, *carbon deposition*, and *acidification*. Also, according to the AIM analysis, the DOC has the primary authority over the species and human activities that will be directly and indirectly impacted by the change in water quality. Clearly, the EPA and DOC need to be in coordination in their efforts to monitor water quality as it relates to impacts on marine organisms and ecosystems. And given the serious implications of ocean acidification, these two agencies should be at the forefront of federal policy addressing the issue.

State results

Beginning with the primary focus of the case study, there was no clear single or even small group of agencies that dominated the Effect category. The California Environmental Quality Act (CEQA) by itself did demonstrate substantial involvement, a logical result considering that the statute enforces the environmental quality standards for any activity in California. At the same time, this finding was surprising because the parallel federal law, the National Environmental Quality Act, NEPA, did not demonstrate the same degree of involvement for the Effect category. Considering that the California Environmental Protection Agency (CalEPA) was created to implement the regulations at the state level for the national EPA, so the lower level involvement of CalEPA in the Source, Cause, and Effect categories versus that of EPA was surprising. However, in the state law analysis, the CalEPA showed no prominence in these or any of the modeled categories. It is recommended that further investigation of state law be made considering the questions that arise from this analysis.

The components in categories of Source and Cause exhibited obvious lack of cohesion. For example, AIM for components in the Source category appeared chaotic because many singular agencies exhibited a small degree of involvement but no cohesion among grouped components. Furthermore, the analysis revealed only slight consistency between the Source and Cause relative observations made in federal law.

The Department of Fish & Game measured as the most involved for the Direct Impact, Ecological Impact, and Human System impact categories. The emergence of a primary agency for impact categories relating to living marine resources was parallel to federal law results. However, among the other categories the analysis showed a low degree of involvement from many agencies with the impact categories, both on average and by individual component. Interpreting the chaos produced by the state law findings proves challenging and will require further analysis.

Filling the gaps

Federal United States

The gaps analysis showed two main patches in federal law relating to the ocean acidification ecosystem model. The primary patch related directly to ocean acidification (see Part A, Figure 7.5). To fill this gap, in the context of existing legislative information, this patch can be broken down into linkages within the Effect category, linkages between the Effect and Cause, and the Effect and Direct Impact categories. For analysis of the Effect category, the gaps should be relatively straightforward because this category has one primary agency, the EPA. However, it is more complicated to strategically close the gaps between Cause and Effect since multiple agencies will need to remove themselves from current regulatory bottlenecks.

Note that according to the gaps analysis, the living marine resources-associated categories were part of the second patch of major mismatch. The data demonstrated that this mismatch sits within one agency, the Department of Commerce (DOC)—a situation in which intra-agency coordination can facilitate needed changes. In fact, the National Marine Fisheries Service been charged with a mandate to implement an Ecosystem Approach to Management (EAM) since 2006 (Barnes and McFadden 2008). A demonstration that fragmented species-based regulations hinders effective monitoring of ocean acidification could impel NOAA to also move forward in its implementation of EAM.

State of California

The gaps analysis of state law showed two main patches pertaining to the ocean acidification ecosystem model. The primary patch related directly to ocean acidification (Figure 7.5). To fill this gap in the context of existing legislative information, this patch can be broken down into linkages within the Effect category, linkages between the Effect and Cause, and the Effect and Direct Impact categories. Within the Effect category for state law, the gaps are more complex than federal law because several agencies are involved in the components of this category. Perhaps many of the laws that refer to the terms *acidification*, *pH*, and *carbonate* are irrelevant to the ocean acidification problem. For example, the Department of Industrial Relations regulation contains the term *carbonate* 33 times, indicating a relatively high involvement of the agency in the category. However, *carbonate* is discussed in the context of industrial specifications, which is an irrelevant use for this project. It is recommended that further research be performed to fine-tune investigation of the state law. This research should be done in collaboration with lawyers who can identify and remove unrelated laws from the collection so they do not interfere with the analysis. Furthermore, text mining (computer science) experts could assist in developing algorithms that recognize the context in which a given term is used. For instance, term-sensitive text mining could prevent counting *carbonate* unless it is only used in the context of marine chemistry. In summary, no policy recommendations can be made on how to fill this Effect category gap without suggested further investigation.

The second patch of gaps that resulted from the gap analysis involved the impact-related categories, which include components associated with living marine resources. Similar to that of the federal level, the agency involvement in these categories was more consistent. This indicates that the gap derives primarily from a single agency's lack of ecosystem-based decision-making. Consequently, this conclusion underscores the problem of species-based management paralleled at the federal level. Of course, congruent species-based decision-making in federal and state levels may be indicative of a policy structure built to mimic itself across geopolitical jurisdictions.

To fill this major gap within the living marine resources sector, other agencies besides the Department of Fish & Game must be involved. Analysis revealed that the Coastal Commission, Coastal Conservancy, and the State Water Resources Control Board (SWRCB), and several others play some role in the components of these categories, although no agency appears dominant. Relatively speaking, the California Environmental Protection Agency measured as having substantial involvement in the Direct Impact category because of one law containing a single occurrence of the term *plankton* (California Public Resources Code 28000-28007). The law mentioning plankton designates Morro Bay and San Diego Bay as state estuaries. Moreover, Morro Bay and its watershed are combined as a State Estuary planning area, reflecting a policy shift toward a holistic ecosystem-based management approach.

Further investigation should be conducted to determine whether this law or type of law could be expanded or used as a model to manage more of the California coast with an ecosystem-based approach.

What we can and cannot obtain from this text analysis

This case study introduces a gaps and overlaps analysis heretofore unexplored by governance entities and applies it to an emerging global environmental problem. The coupling of the gaps and overlaps text analysis techniques shows high promise for providing useful information, even in terms of using a simple array of terms and linkages to produce a visual representation of the modeled system-related ocean acidification. It is significant that the data output for the gaps analysis makes logical sense in the context of governance literature and in the experience of policy experts. The overlaps analysis supplements the gap analysis by providing baseline governance data about agency involvement and legal complexity. Notably, the results for the geopolitical jurisdictions drew different conclusions. For instance, the California State law was difficult to interpret because frequencies of some documents' modeled components were misleading. For both state and federal findings, exploration by researchers will be critical in understanding the true nature of the findings because of the complexities and potential explanations. It is important to consider that misleading results could originate from quality assurance problems related to the following:

- Different terminology in state law than federal law

- Different level of management/focus by state agencies versus federal agencies
- Inconsistent document collections between state and federal levels
- More fragmented decision-making than imagined
- Laws appear fragmented, but only a few of the laws are implemented

The first three issues could be tested by a team of experts in California law and computer scientists adept in advanced text mining algorithms. The last two issues could be investigated through strategic discussions between policymakers about a select group of topics, with a researcher present to record and analyze complexities of the various agencies' involvement. Further expansion of this analysis could involve the comparison of the budget allocations of these agencies to the Agency Involvement Measures, for purposes of exploring the benefits of economic and law data integration.

Policy recommendations for the CINMS Advisory Council

A look at The Channel Islands National Marine Sanctuary (CINMS) provides insight into what a single agency can do to systematize itself to better confront ocean acidification. CINMS acts under the authority of NOAA within the federal Department of Commerce. As mandated under the National Marine Sanctuary Act, the objective of the Sanctuary is "to comprehensively conserve and manage special areas of the marine environment," (http://sanctuaries.noaa.gov)[15]. Although CINMS enforces few regulations and labors to achieve its goals under budget pressures, by maintaining protection of species and ecosystems from additional stressors within the Sanctuary, it plays a critical role in mitigating impacts of ocean acidification. Scientists predict that changes in ocean chemistry, a result of increased atmospheric carbon, will make marine organisms and ecosystems more vulnerable to other environmental impacts such as climate change, water quality, fisheries, and pollution. Raven et al (2005) asserted that "the increased fragility and sensitivity of marine ecosystems needs to be taken into consideration during the development of

---

[15] Eight of the nine purposes and policies of the National Marine Sanctuary Act (16 U.S.C. 1431) quoted below:

- To provide authority for comprehensive and coordinated conservation and management of these marine areas, and activities affecting them, in a manner which complements existing regulatory authorities;
- To maintain the natural biological communities in the national marine sanctuaries, and to protect, and, where appropriate, restore and enhance natural habitats, populations, and ecological processes;
- To enhance public awareness, understanding, appreciation, and wise and sustainable use of the marine environment, and the natural, historical, cultural, and archeological resources of the National Marine Sanctuary System;
- To support, promote, and coordinate scientific research on, and long-term monitoring of, the resources of these marine areas;
- To facilitate to the extent compatible with the primary objective of resource protection, all public and private uses of the resources of these marine areas not prohibited pursuant to other authorities;
- To develop and implement coordinated plans for the protection and management of these areas with appropriate Federal agencies, State and local governments, Native American tribes and organizations, international organizations, and other public and private interests concerned with the continuing health and resilience of these marine areas;
- To create models of, and incentives for, ways to conserve and manage these areas, including the application of innovative management techniques; and
- To cooperate with global programs encouraging conservation of marine resources

any policies that relate to their conservation, sustainable use and exploitation, or the communities that depend on them," (Raven et al. 2005: page vii). This policy recommendation epitomizes the role the Sanctuary's existing management plan already plays in combating ocean acidification impacts in its role of maintaining the resilience of the ecological system. In addition, it also underscores the need for collaboration with other agencies and sanctuary programs. As such, the following discussion proposes further recommendations on how one agency can work within its mandate and jurisdiction to help confront ocean acidification.

Formal recognition of ocean acidification

For purposes of establishing a foundation for support and recognition of ocean acidification, the CINMS Sanctuary Advisory Council should formally pronounce the threats of ocean acidification and its commitment to addressing the issue. Consequently, the Manager of CINMS should formally declare approval of this commitment to combating ocean acidification. An additional piece of this declaration would be the Sanctuary's intention to take the initiative to join forces with other agencies and strategically confront ocean acidification. To leverage collaboration with other agencies, other Sanctuaries along the west coast should sign onto this declaration, eventually developing a nation-wide conservation policy issued by the Director of the National Marine Sanctuary Program[16]. Such a policy could attract the collaboration of NOAA Fisheries Science Centers and the Fisheries

[16] For further information the process of establishing conservation policy in the National Marine Sanctuary Program see http://sanctuaries.noaa.gov/management/conservation_faq.html.

Management Councils, and with bottom-up momentum spur the creation of unified front in NOAA to confront ocean acidification.

Public awareness

Once the Channel Islands National Marine Sanctuary makes a declaration recognizing ocean acidification, the Sanctuary can play a role in disseminating this message through public education. One of the major strengths of the Sanctuary Program is its successful public awareness and education efforts (Morin 2001). Prioritizing ocean acidification in the CINMS public education plan would spread awareness of the issue. Recognizing that the only effective remedy to ocean acidification is to stop carbon emissions, public education around this issue should focus on methods to minimize carbon emissions and the burning of fossil fuels in order to protect marine ecosystem health.

Interagency coordination

Another major strength of the National Marine Sanctuary Program has been the facilitation of interagency communication (Suman 1997). By nature of their geography and mandate, sanctuaries exist within the jurisdictions of other agencies (e.g., see Figure 7.18). Given the role of sanctuaries as collaborative partners, it is recommended that the Sanctuary Advisory Council (SAC) add a new member to represent air quality, since the SAC brings together the primary actors in their waters. Now that the role of carbon emissions has been firmly established as the culprit in marine water acidification, issues of air quality should have a voice on the Advisory Council. As seen with the Sanctuary Advisory Councils nationwide, representation by experts in crucial issues have facilitated coordination and communication among other government agencies and interest groups. As such, the inclusion of an air quality council member would encourage coordination among all agencies and stakeholders with an interest in the health of species and water of the Sanctuary.

From this starting point, perhaps a more formal agreement between the Sanctuary and the state and federal air quality agencies could be developed. For example, the Sanctuary could propose a goal to reduce carbon emissions released within the boundaries of the Sanctuary. Together with the air quality agencies, the CINMS could develop a voluntary monitoring program, which could be evaluated biannually and encourage new emission standards and compliance. Although the release of carbon into the atmosphere is a global problem, the collaboration between NOAA and air quality agencies would raise awareness and establish a constructive model of coordination for other agencies to follow.

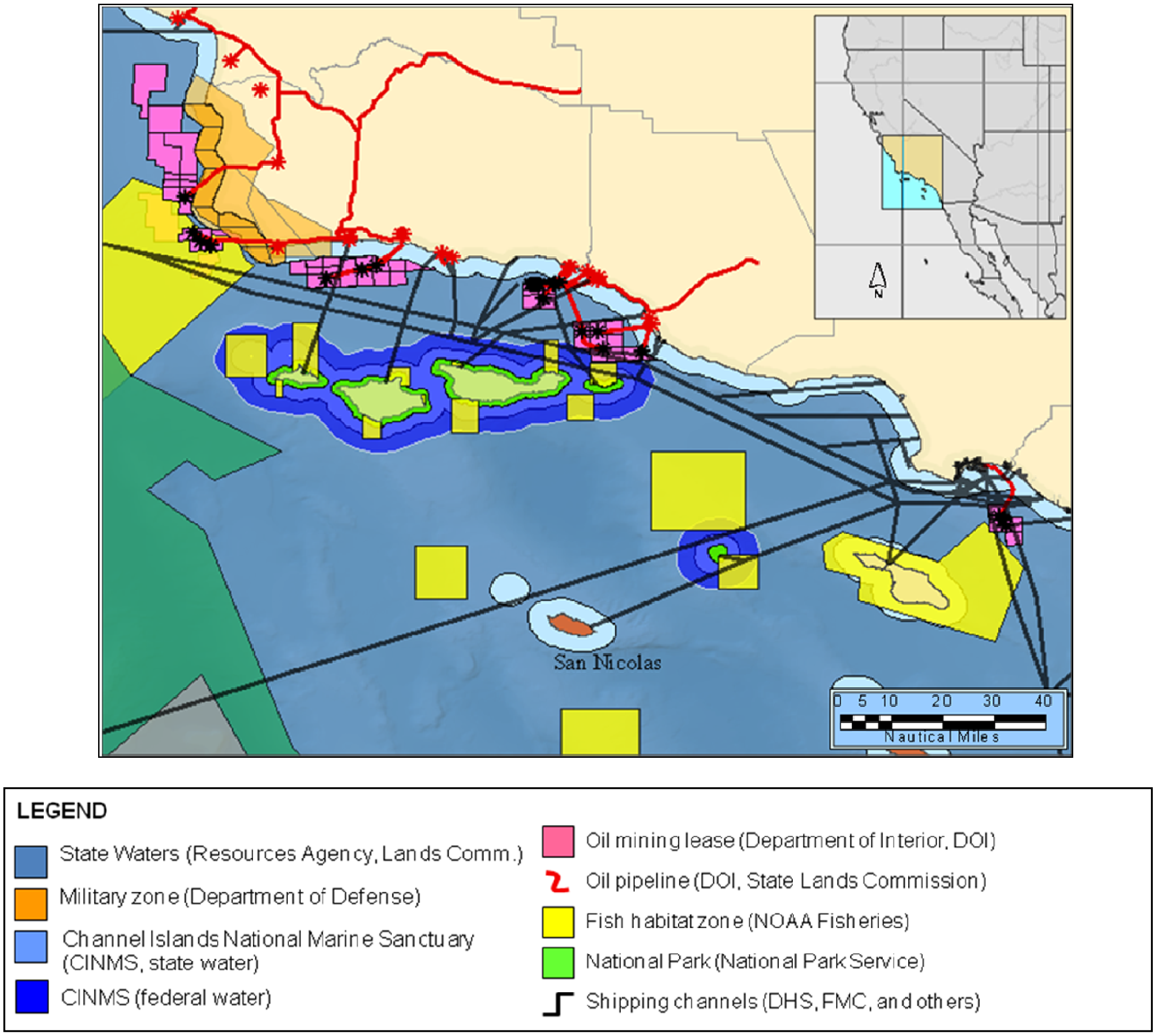


Figure 7.18. Map of California Channel Islands region and coast of Southern California. This map contains the spatial jurisdictions of activities and associated agencies in the area, demonstrating the inherent potential for overlapping jurisdictions.

Future work

Future work will explore more advanced text mining techniques for better analysis and more conclusive findings. Additional datasets will be generated to represent management, as well as alternative models reflecting additional or different components of ocean acidification.

Exploration of advanced text mining

The collection of laws compiled to develop the gaps and overlaps techniques provide a comprehensive dataset deserving of more advanced information retrieval techniques for greater exploration. As discussed in Chapter 6, text mining applications such as hierarchical organization of synonyms or tagging preambles could assist in accurate and critical information retrieval from the massive dataset. It is also recommended that additional datasets be integrated with law analysis for purposes of accurately deciphering the enforcement of rules in real life and their description in the written law. Overall, further quantitative and qualitative evaluation of accuracy and conclusions of the experiments will enable future work.

Exploration of addition ecosystem models

Future work needs to involve gaps and overlap analysis on other conceptual models. For purposes of this case study, the model used for ocean acidification was a simplistic model in that it was isolated from the known feedbacks such as temperature, sea level rise, and other factors associated with climate change. Furthermore, research is emerging that quantifies the physiological impacts on all marine organisms from projected pH decent. With this information, more non-calcifying components found to be directly impacted, as well as other components for the other categories, could be included in a modified system model.

In addition, the application of this analysis could be applied to other locations, such as the other National Marine Sanctuaries. This analysis would provide data to test whether similar gaps exist among categories for both state and federal law, in the context of differing local impacts. Analysis could also be performed for different costal states to see if they exhibit a lack of cohesive governance similar to that of California.

CONCLUSION

Ocean chemistry confirms what will happen if we continue on our business-as-usual path of fossil fuel burning and other carbon emitting activities. A holistic ecosystem-based approach is crucial to tackling the multi-scale and multi-sector environmental problem of ocean acidification. The analysis performed in this case study demonstrates the power of text mining a massive collection of laws, in order to generate baseline information about gaps in agency management and legal jurisdiction in relation to ocean acidification. The output showed that more cohesion exists in federal law among individual issues relating to ocean acidification, which made term frequency data transparent to interpret. Understanding this output in the context of governance, it is clear that the Environmental Protection Agency and the Department of Homeland Security need to coordinate with the Department of Commerce to develop a policy and enforcement structure to limit carbon emissions. If top-down policy is unfeasible due to the political environment, bottom-up initiatives are critical for generating the public awareness and consequently policy momentum to confront ocean acidification. A sample of ideas was provided for the Channel Islands National Marine Sanctuary, these recommendations can be tailored to another agency. With or without new federal or state legislation, it is important that individual agencies initiate progress toward recognizing and confronting ocean acidification through internal declarations and commitments. Another key factor in progress toward solutions to global environmental issues such as ocean acidification is that individual agencies will initiate relationships and collaborations between sectors and relevant agencies. The future success of the holistic management approach will likely be demonstrated in the context of multi-sector environmental problems, such as ocean acidification, because the scale, complexities and stakes are so great.

The gaps analysis of state law resulted in patches of mismatch between the laws and ecosystem akin to federal law. However, the overlaps of agency involvement analysis looked nothing like the federal results. The state law results involved many agencies working unilaterally and chaotically. The convoluted output was thus difficult to interpret and begs further examination. A range of tools can be used to investigate this lack of cohesion found in the state law and can help determine whether these results are accurately depicting highly overlapping jurisdictions among state agencies, or a need to reconfigure the agency authority metadata.

Despite the challenges of interpreting agency involvement for the state, this analysis powerfully illustrated the complexity of the issues and the range of government agencies at multiple jurisdictional levels that relate to ocean acidification. No simple solution emerges from the finding. However, a baseline perspective on the management systems, related to ocean acidification or any other multi-scale environmental problem, can be especially useful to develop strategic policy and avoid redundancy and disastrous situations from regulatory overlaps. In their rudimentary form, the gap and overlap analyses presented in this case study are only the tip of the iceberg in terms of developing tools to generate critically needed baseline governance data. There is enormous potential to combine data gleaned from the laws with other data sources, such as budget allocations, spatial delineation of relevant laws and regulations, court cases, meeting notes, management plans, memorandums of agreement, and many others. Once text analysis techniques go beyond just counting terms in laws, baseline governance data could be generated as a time series and integrate with other marine, terrestrial, and atmospheric biophysical data, such as ecosystem monitoring results and satellite sea temperature data. This integration would begin to truly break down barriers for understanding feedbacks and causal drivers between governance and biophysical systems. Furthermore, socio-cultural and economic data could be intertwined with the governance and biophysical information to understand and examine the whole system and its linkages. A holistic approach such as this overturns outdated methodologies commonly divided by disciplines and unequipped to confront global, multi-scale issues. Advancements in computer science and digital information are facilitating integration of data that could only be imagined in the past. Experts in all related fields need to conceive of the capabilities of these advancements, push for the tactical integration of data and support systems that seek to address large scale environmental threats such as ocean acidification with informed and cohesive policy.

This case study stimulates discussion on the development and potency of robust tools for understanding governance in the context of any ecosystem or multi-scale environmental problem. As demonstrated by the baseline data, understanding the governance in which we function is no simple task. However, the tools for understanding governance are at our fingertips, and with development and further analysis they can empower us to envision and implement ecosystem-based management strategies necessary to address global issues.

Chapter 8 Conclusion

MAIN FINDINGS

Research goal

This dissertation aims to develop quantitative analysis tools to generate baseline conclusions drawn from empirical data. The tools are designed to guide an ecosystem-based management approach to problems of fragmented ocean law. The research focuses on two problems commonly associated with fragmented decision-making: mismatch between governance and a relevant ecosystem (gaps) and institutional interplay (overlaps). The investigation combines theoretical institutional frameworks (Young 2002) with feedback from professionals in the field of natural resource management. The research in this way not only contributes to academic theory but also introduces a tool for use by practitioners.

The definitions of the two key concepts of gaps and overlaps evolved over the span of the project as they produced terminological challenges. In hindsight, the terms "gap" and "overlap" may not be sufficient without qualification to cover one or two of the concepts identified in the output of the research. An "overlap" in institutional theory typically refers to a form of institutional interplay where different institutions govern the same function(s) (see Young 2002). The output of analysis for this dissertation also included an overlap of different functions as managed by different institutions. This type of interplay is unintentional: the institution for one or more sectors or "functions" causes unintended effects on the institutional arrangements for another function in the environment (Young 1999). Because ships sometimes collide with whales, for example, the rules governing shipping in the Santa Barbara Channel off the coast of California unintentionally affect the rules in place for the protection of whales. This type of overlap might usefully be termed a “functional overlap.” This conceptualization may serve, but additional conceptualization may be needed to cover the aspect here of a type of “disconnect.” In the case of a functional overlap, the institutional interplay is problematic when there is an underlying absence of management of the conflicting factors. An unintended functional overlap of this kind needs untangling in order clearly to identify the management missing for conflicting functions in the environment. It follows that a possible term for such underlying missing institutional provision could be “institutional disconnect” or “functional disconnect.” In theory, identification of institutional disconnects before implementation of governance measures would prevent functional overlaps assuming the agencies (or other actors) involved in the overlapping institutions were willing to collaborate. In reality, however, identification is likely to proceed the other way around due to failure to anticipate conflict among and changes within or to separate subjects of management by separate institutions.

On the other hand, it is also possible that government agencies will begin to adopt a precautionary approach as the movement shifting governance toward implementing EBM continues. With the growing interest of EBM, we will have a baseline of ecosystem data (to include human activities as well as biophysical components and functions). This ecological baseline can provide a roadmap for where the overlapping functions occur or will occur. Integrating this ecological baseline data with the institutional dimensions of overlap can reveal where the subsequent where institutional disconnects and unintended institutional interplay likely occur.

Contributions

Principal

The principal finding of this dissertation, consistent with the thesis and objective of the project, is that useful knowledge about gaps and overlaps in ocean management can be gleaned from text analysis of laws and regulations. Running basic text mining techniques on a document collection I compiled to represent ocean management on the West Coast, I demonstrate the value of quantitatively identifying and evaluating fragmentation in ocean law. Although I developed the techniques using a document collection bounded by the California Current LME, it is critically advantageous that these tools and analyses transfer easily to other geographies. Equally exciting is the capacity of this methodology to generate insights for any scale of governance, from local to international.

Dataset

In addition to the principal finding, this project makes other important contributions to the field of ocean management. A crucial step in the development of this dissertation was the creation of a dataset of ocean and coastal related laws. This collection provided a vital test bed for the exploration and development of text mining algorithms. The identification and compilation of relevant documents representing both national and multiple state jurisdictions is a substantial undertaking. I recommend government or industry updates and maintains of the collection for the California Current LME and for other regions. As described in Chapter 3, I have archived the term frequency data generated from this document collection (in the form of a term-document matrix), in the Knowledge Network for Biocomplexity (KNB) data repository through NCEAS. The KNB Project, "is a national network intended to facilitate ecological and environmental research on biocomplexity," (http://knb.ecoinformatics.org/). Storage of law data in the format developed by NCEAS ecoinformatics programmers is key because it ensures consistency and access for scientists who need the dataset to explore advanced techniques and EBM implementation.

Case study findings

Experts and/or literature have corroborated the real-life examples of gaps and overlaps in management presented in this dissertation. Chapter 4 results, for example, revealed a major gap in management surrounding the protection of eelgrass in federal and Oregon and California state law. The absence of protective laws for eelgrass was surprising given the wide acknowledgement of the importance of eelgrass in the coastal ecosystem (Short and Wyllie-Echeverria 1996, Duffy 2006, Orth et al. 2006). Reflection on the deteriorating populations of this critical species makes it clear that policy-makers have dropped the ball. Future work is needed to determine the extent and reliability of gaps of this kind as identified using the tools developed. This will require more rigorous examination for each ecosystem modeled.

Relative to the other 45 topics investigated, Chapter 5 results include measurements for transportation that show high levels of fragmentation due to overlapping legal and agency jurisdictions. This corresponds with the findings of the recent U.S. Commission on Ocean Policy (USCOP 2004).

Research for Chapter 7 (case study) yielded both a methodological and technical contribution in the use of *Agency Involvement Measure* and the Block Analysis (to synthesize information into understandable units) respectively. Inclusion of agency regulations proved essential for full representation of institutional factors. The case study presented in Part A (gaps analysis) revealed a complete absence of law at every scale to deal directly with ocean acidification. This is consistent with Congressional testimonies (Watkins 2007) and scientific articles (Caldeira et al. 2007).

Although each of these findings confirm previous qualitative assessments and anecdotal knowledge, the tools developed to identify gaps and overlaps generate quantitative, evidence of real-life situations in governance and facilitate its visual representation. The objective nature of the output supports both prioritization of strategies and the coordination needed to address where management in ocean governance is missing or conflicting.

RELEVANCE OF FINDINGS

The development of tools to evaluate problems related to fragmentation contributes substantively to EBM efforts. At a basic level, the gaps and overlaps revealed by term counts assist the progression of EBM into mainstream management practices. The overlaps analysis, for example, both as a quantitative metric and in the associated graphical display of the legislative landscapes, objectively calls attention to management aspects in need of inter-agency coordination. Decision-makers need these kinds of objective tools to support development of overarching, coordinated policies that reflect the shift towards an EBM approach that itself reflects the Earth's inherently overlapping marine, atmospheric, and terrestrial ecosystems.

In addition to strengthening EBM and assisting in its adoption, this project also helps to bridge the ideological distance between social and natural sciences through its use of systems thinking. The project results support the assessment that interdisciplinary research is essential to environmental problem solving (Clark 1999, Ewel 2001). The development of techniques used natural science concepts, such as ecosystem modeling, to answer governance related questions. The baseline data generated by the research facilitates interdisciplinary thinking and conversations among disciplines. The organization of laws and ecosystems into a test bed for quantitative analysis provides a powerful model for the systematic integration of social and natural science datasets. The integration of these disciplines and datasets will enable holistic identification, evaluation, and resolution of environmental problems.

The findings of this dissertation present an introduction to the potency of technical tools for EBM implementation. As techniques that integrate social and natural science theories and facilitate communication between disciplines, they can also be further applied and developed to assist more broadly in the study of the human dimensions of global environmental change.

FUTURE DIRECTIONS

The project's findings naturally generate more research questions than could be answered in the scope of this dissertation. The potential for future discovery through the development of interdisciplinary tools to identify and measure the notion of fragmentation is energizing. The techniques I present in this project are only the tip of the iceberg in terms of the utility and concurrent application in this field of computer science, ecosystem ecology, and governance theory. I envision future research advancing the techniques and expanding applications in the following directions:

- creation of more ecosystem models representing a variety of geographical locations;
- exploration of advanced text mining methods beyond keyword frequencies;
- assimilation of the remaining portion of the law collection that represents Mexico ocean management and international policy;
- compilation of new collections representing management in other regions and the employment of explorative techniques on these datasets ; and

- further verification of results by experts and practitioners in the context of environmental issues.

Upon completion of this dissertation and under the guidance of legal informatics experts at Stanford University, my post doctorate focus is the automation of the gaps analysis into a free, open source software package. I will also fine-tune the basic algorithm of the overlaps analysis, continue to verify accuracy of the results, and automate the tool to make it more practical for use by natural resource management practitioners. Automation of the techniques will create a user-friendly system for EBM efforts, and assist informed decision-making for natural resource management.

I anticipate four primary benefits of automation. First, and to occur in the short term, is accessibility for government agencies and other stakeholders involved in existing EBM programs within the California Current. Second is the future provision of a framework functional for other regions that incorporates the relevant laws and management-related documents. Third, automation facilitates the exercise of fine-tuning the algorithms because it supports a wider spectrum of text mining tools and will ultimately allow the integration of other data types. Last, and essential to capacity building of the text mining analysis of environmental law, an automated tool will attract a user base for survey in order to test the accuracy, utility, and interpretability of other techniques.

Additional ecosystem models

The process of designing ecosystem models needs to be tested for usefulness and interpretability. Such models are powerful in that they provide an overarching perspective on ecosystem relationships and incorporate human activities and scales of biophysical processes Defensible construction of these models is essential. An example of a generic ecosystem model involving seabirds, eelgrass, associated species as well as general biophysical components is presented in detail in Chapter 4. This model provided a testable dataset utilizing my project techniques. I recommend that future models should be designed with increasing complexity in order to reflect real ecosystem components unique to geographic locations, such as upwelling and other biophysical processes and conditions that drive seasonal and annual species fluctuations. Location-based ecosystem models must reflect complexities by incorporating different words to represent the same components and different linkages between components.

Automating the techniques developed in this dissertation project will allow scientists, non-governmental organizations, managers, and other EBM practitioners to input ecosystem models at the desired level of complexity or simplicity.

More advanced text mining methods

My project findings lead to the conclusion that raw frequencies, coupled with agency authority data, obviate the need to review hundreds of legal documents to identify statutory and regulatory overlap. I have been encouraged by the work of the International Association for Artificial Intelligence and Law (IAAIL) who share my concern about the problem of a growing body of legislation and its inherently cumbersome complexities. This small group of computer scientists and engineers has begun researching and developing algorithms that use information retrieval statistics and methodologies to navigate legal documents. I will conduct my next research phase in collaboration with an affiliate of the IAAIL in joint exploration of advanced algorithms that expand upon the gaps and overlaps analyses developed thus far.

Verification

I recommend a more thorough survey process and greater evaluation of output in order to determine accurately what issues these analyses can and cannot address. A future study is in order, for example, to evaluate the *agency involvement measure (AIM)*, presented in Part B of the Chapter 7 Case Study. I envision an agency survey in which the researcher qualitatively investigates the degree of involvement for each agency within the given topics. The survey results would then be compared to the text analysis results to determine consistency and/or patterns of error in the data findings, and also to move in real-time toward resolving agency overlaps.

Integration with other data types

Further research of text mining operations should expand the collection of laws to include all documents relevant to the management of the oceans. Other fundamental ocean management materials and information may include: 1. agency budget allocations; 2. number and nature of Supreme Court and other court cases involving interpretation of a statute; 3. geographic scope of a law; and 4. whether an agency has written and implemented regulations from a statute. Conveniently, these materials can be directly linked to agencies and/or laws as additional attributes of a quantitative analysis. Such added dimensions help characterize the scope and importance of laws. A relatively high agency budget to implement a certain statute, for example, could be correlated with a visual cue to indicate to a researcher that the statute has been assigned greater management importance than statutes with little or no budget allocation.

Moreover, because EBM is an inherently location-based approach, other types of datasets containing information about a place could be integrated into the analysis. Halpern et al. (2008), for example, recently mapped by location the degree of impact of a variety of human activities on coastal and marine ecological habitats and ecosystem services. Expanding on this work, these findings could be integrated with conceptual development of ecosystem models for the California Current region. For such purposes, analysis could, for instance, use the study's data demonstrating that nutrient loading has a relatively high impact relative to invasive species on a particular area along California's coast. Based on the technique presented by Halpern et al. 2008, if stakeholders generated an ecosystem model for the gaps analysis that contained components related to both nutrient loading activities and invasive species, these modeled components and their associated linkages could be tagged by the degree of impact they have in the area. As such, if the analysis revealed gaps associated with both components they could be prioritized based on data from Halpern et al. (2008). An advanced gaps analysis such as this could rank gaps not only by severity in category, but also incorporate another dataset to consider the degree of impact or value a particular component has on the ecosystem's functionality.

Additional document collections

In addition to integrating other types of data, future research will rely on the compilation of document collections relevant to other regions as well as on expansion and maintenance of the California Current region collection. In addition, Mexico's federal laws could be incorporated into the analyses through more sophisticated processing to address language translation. These collections enable the use of the technical tools to answer questions about governance across scales and geography, a combined contribution to an interdisciplinary effort to tackle problems associated with fragmented management in a holistic manner.

Last words

In conclusion, implementation of adaptive and holistic management is essential to restore and sustain the ecosystem services on which humans depend. Global, multi-scale environmental problems can be strategically addressed with the support of modern data management and programming based on algorithms developed from interdisciplinary input. The technical tools presented in this dissertation are novel in their application of information technology to integrate social and natural science data. Addressing fragmentation based on all relevant laws is overarching in its scope, and thus can reflect of even global-scale environmental issues or any management topics that require a system-wide perspective of both the natural world and of its governance. The complexities of these systems have largely still to be explored, but research tools like those developed for this dissertation enable directed, organized, and sustained inquiry, particularly in support of continued efforts toward EBM and holistic management in general of Earth's resources.

References

Agardy, T. 1997. Marine Protected Areas and Ocean Conservation. R. E. Landes, Academic Press, Austin, TX.

Avasthi, A. 2005. California Tries to Connect Its Scattered Marine Reserves. Science **308**:487-488.

Baeza-Yates, R., and B. Ribeiro-Neto. 1999. Modern Information Retrieval. ACM Press, New York.

Bailey, R. G. 1983. Delineation of ecosystem regions. Environmental Management **7**:365-373.

Barnes, C., and K. W. McFadden. 2008. Marine ecosystem approaches to management: challenges and lessons in the United States. Marine Policy **32**:387-392.

Baron, J. R., and P. Thompson. 2007. The Search Problem: Posed by Large Heterogeneous Data Sets in Litigation: Possible Future Approaches to Research. Pages 141-147 *in* Proceedings of the 11th international conference on Artificial Intelligence and Law, June 04-08, Stanford, CA.

Barringer, F. 2006. Officials Reach California Deal to Cut Emissions. Pages http://www.nytimes.com/2006/2008/2031/washington/2031warming.html *in* The New York Times, New York.

Becker, B. H., and S. R. Beissinger. 2006. Centennial Decline in the Trophic Level of an Endangered Seabird after Fisheries Decline. Conservation Biology **20**:470-479.

Belausteguigoitia, J. C. 2004. Causal Chain Analysis and Root Causes: The GIWA Approach. AMBIO: A Journal of the Human Environment **33**:7-12.

Berkes, F. 2002. Cross-Scale Institutional Linkages: Perspectives from the Bottom Up. Pages 263-292 *in* E. Ostrom, T. Dietz, N. Dolsak, P. Stern, S. Stonich, and E. U. Weber, editors. Drama of the Commons. National Academy Press, Washington, D.C.

Berkes, F., J. Colding, and C. Folke, editors. 1998. Linking social and ecological systems: management practices and social mechanisms for building resilience. Cambridge University Press, Cambridge, UK.

Berkman, P. A., G. J. Morgan, R. Moore, and B. Hamidzadeh. 2006. Automated granularity to integrate digital information: the "Antarctic Treaty Searchable Database" case study. Data Science Journal **5**:85-99.

Bernard, H. R. 1998. Research Methods in Anthropology. AltaMira Press, Walnut Creek.

Berry, M. W., editor. 2003. Survey of Text Mining: Clustering Classification, and Retrieval. Springer, New York.

Blaikie, P., and H. Brookfield. 1987. Land Degradation and Society. Methuen, London & New York.

Borgatti, S. P. 2002. NetDraw: Graph Visualization Software. *in*. Analytic Technologies, Inc., Harvard, Massachusetts.

Borgatti, S. P., M. G. Everett, and L. C. Freeman. 2002. Unicet for Windows: Software for Social Network Analysis, Version 6.182. *in*. Analytic Technologies, Inc., Harvard, Massachusetts.

Brewer, P. G. 1997. Ocean chemistry of the fossil fuel CO_2 signal: the haline signal of "business as usual". Geophysical Research Letters **24**:1367-1369.

Brewer, P. G. 2007. Carbon dioxide, Carbon sequestration, and the Oceans. *in* Inaugural Solutions Summit, San Francisco, CA: November 15, 2007.

Bromley, D. W., editor. 1992. Making the Commons Work: Theory, Practice, and Policy. Institute for Contemporary Studies, San Francisco.

Caldeira, K., D. Archer, J. P. Barry, R. G. J. Bellerby, P. G. Brewer, L. Cao, A. G. Dickson, S. C. Doney, H. Elderfield, V. J. Fabry, Richard A. Feely, J.-P. Gattuso, P. M. Haugan, O. Hoegh-Guldberg, A. K. Jain, J. A. Kleypas, C. Langdon, J. C. Orr, A. Ridgwell, C. L. Sabine, Brad A. Seibel, Y. Shirayama, C. Turley, A. J. Watson, and R. E. Zeebe. 2007. Comment on ‘‘Modern-age buildup of CO2 and its effects on seawater acidity and salinity’’ by Hugo A. Loa´iciga. Geophysical Research Letters **34**:doi:10.1029/2006GL027288.

Caldiera, K., and M. E. Wickett. 2003. Anthropogenic carbon and ocean pH. Nature **425**:365.

California Energy Commission. 2007. California's Electricity Market. *in*. California Energy Commission, Sacramento.

Cao, W., and M. H. Wong. 2007. Current status of coastal zone issues and management in China: A review. Environment International **33**:985-992.

Carnegie Institution. 2007. Carbon Emissions Could Violate EPA Ocean-quality Standards Within Decades. ScienceDaily Retrieved March 27, 2008, from http://www.sciencedaily.com/releases/2007/09/070919175542.htm.

Carrington, P. J., J. Scott, and S. Wasserman, editors. 2005. Models and Methods in Social Network Analysis. Cambridge University Press, Cambridge.

Channel Islands National Marine Sanctuary Advisory Council. 2008. Reducing Ship Strikes on Large Cetaceans in the Santa Barbara Channel and Channel Islands National Marine Sanctuary. CINMS, Santa Barbara.

Childress, J. J., and B. A. Seibel. 1998. Life at stable low oxygen levels: adaptations of animals to oceanic oxygen minimum layers. The Journal of Experimental Biology **201**:1223-1232.

Christensen, N., and et al. 1996. The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management. Ecological Applications **6**:665-691.

Clark, T. W. 1999. Interdisciplinary problem-solving: Next steps in the Great Yellowstone Ecosystem. Policy Sciences **32**:393-414.

Cleveland, C. J. 1995. The direct and indirect use of fossil fuels and electricity in USA agriculture, 1910-1990. Agriculture, Ecosystems & Environment **55**:111-121.

Colwell, M. A. 1994. Shorebirds of Humboldt Bay, California: Abundance Estimates and Conservation Implications. Western Birds **25**:137-145.

Cordell, H. K., and J. C. Bergstrom, editors. 1999. Integrating Social Sciences with Ecosystem Management: Human Dimensions in Assessment, Policy, and Management. Sagamore Publishing, Champaign, IL.

Cortner, H. J., M. G. Wallace, S. Burke, and M. A. Moote. 1998. Institutions matter: the need to address the institutional challenges of ecosystem management. Landscape and Urban Planning:159-166.

Costanza, R., and C. Folke. 1996. The Structure and Function of Ecological Systems in Relation to Property-Rights Regimes. Pages 13-34 *in* S. S. Hanna, C. Folke, and K.-G. Maler, editors. Rights to Nature: Ecological, Economic, Cultural, and Political Principles of Institutions for the Environment. Island Press, Washington, D.C.

Cowen, R. K. 1983. The effects of sheephead (Semicossyphus pulcher) predation on red sea uchin (Strongylocentrotus franciscanus) populations: an experimental analysis. Oecologia **58**:249-255.

Crowder, L., G. Osherenko, O. Young, S. Airame, E. A. Norse, N. Baron, J. C. Day, F. Douvere, C. N. Ehler, B. S. Halpern, S. J. Langdon, K. L. McLeod, J. C. Ogden, R. E. Peach, A. A. Rosenberg, and J. A. Wilson. 2006. Resolving Mismatches in U.S. Ocean Governance. Science **313**:617-618.

Croxall, J. P., and P. A. Prince. 1996. Cephalopods as prey. I. Seabirds. Philosophical Transactions: Biological Sciences **351**:1023-1043.

Dietrich, K., and E. Melvin. 2004. An Annotated Bibliography: Seabird Interactions with Trawl Fishing Operations and Cooperative Research. Pages http://wsg.washington.edu/mas/pdfs/seabirdbibliography.pdf *in* W. S. G. Program, editor. University of Washington.

Duffy, J. E. 2006. Biodiversity and the functioning of seagrass ecosystems. Marine Ecology Progress Series **311**:233-250.

Ebbin, S. A. 2002. Enhanced fit through institutional interplay in the Pacific Northwest Salmon co-management regime. Marine Policy **26**:253-259.

Ekstrom, J. 2008. Database of coastal and marine law for the California Current Large Marine Ecosystem. NCEAS KNB Data Repository.

Ekstrom, J., and G. Lau. 2008. Exploratory text mining of ocean law to measure overlapping agency and jurisdictional authority *in* Proceedings of the Digital Government Research Conference, Montreal, Canada.

Elliott, M., S. J. Boyes, and D. Burdon. 2006. Integrated marine management and administration for an island state -- the case for a new Marine Agency for the UK. Marine Pollution Bulletin **52**:469-474.

Estes, J. A., and J. F. Palmisano. 1974. Sea Otters: Their Role in Structuring Nearshore Communities. Science **185**:1058-1060.

Ewel, K. C. 2001. Natural Resource Management: The Need for Interdisciplinary Collaboration. Ecosystems **4**:716-722.

Feely, R. A., C. L. Sabine, K. Lee, W. Berelson, J. Kleypas, V. J. Fabry, and F. J. Millero. 2004. Impact of Anthropogenic CO2 on the CaCO3 System in the Oceans. Science **305**:362-366.

Feldman, R., and J. Sanger. 2007. The Text Mining Handbook: Advanced Approaches to Analyzing Unstructured Data. Cambridge University Press, Cambridge.

Fisher, E. M. 1939. Habits of the Southern Sea Otter. Journal of Mammalogy **20**:21-36.

Folke, C., L. Pritchard, F. Berkes, J. Colding, and U. Svedin. 2007. The Problem of Fit between Ecosystems and Institutions: Ten Years Later. Ecology and Society **12**:30.

Ford, J. K. B., and G. M. Ellis. 2006. Selective foraging by fish-eating killer whales Orcinus orca in British Columbia. Marine Ecology Progress Series **316**:185-199.

Fowler, C., and E. Treml. 2001. Building a marine cadastral information system for the United States -- a case study. Computers, Environment and Urban Systems **25**:493-507.

Friedl, J. E. 2006. Mastering Regular Expressions. O'Reilly Media, Sebastopol, CA.

Gaines, S. D., and J. Roughgarden. 1987. Fish in Offshore Kelp Forests Affect Recruitment to Intertidal Barnacle Populations. Science **235**:479-481.

Gazeau, F., C. Quiblier, J. M. Jansen, J.-P. Gattuso, J. J. Middleburg, and C. Heip. 2007. Impact of elevanted CO_2 on shellfish calcification. Geophysical Research Letters **34**.

Golley, F. B. 1996. A History of the Ecosystem Concept in Ecology: More than the Sum of the Parts. Yale University Press, New Haven, CT.

Grenade-Nurse, F. 1998. Decentralized Agencies with Overlapping Jurisdictions -- A Problem for Enforcement. *in* INECE, editor. International Network for Environmental Compliance and Enforcement (INECE) Conference Proceedings, Monterey, California.

Grumbine, R. E. 1994. What is Ecosystem Management? Conservation Biology **8**:27-38.

Hall, C. A. S., and J. W. Day. 1977. Ecosystem Modelling in Theory and Practice. John Wiley & Sons, New York.

Halpern, B. S., S. Walbridge, K. A. Selkoe, C. V. Kappel, F. Micheli, C. D'Agrosa, J. F. Bruno, K. S. Casey, C. Ebert, H. E. Fox, R. Fujita, D. Heinemann, H. S. Lenihan, E. M. P. Madin, M. T. Perry, E. R. Selig, M. Spalding, R. Steneck, and R. Watson. 2008. A Global Map of Human Impact on Marine Ecosystems. Science **319**:948-952.

Hanle, L. J., K. R. Jayaraman, and J. S. Smith. 2004. CO2 Emissions Profile of the U.S. Cement Industry. *in* E. P. Agency, editor. 13th International Emission Inventory Conference: "Working for Clean Air in Clearwater", Clearwater, FL.

Hanna, S. S., C. Folke, and K.-G. Maler, editors. 1996. Rights to Nature: Ecological, Economic, Cultural, and Political Principles of Institutions for the Environment. Island Press, Washington, D.C.

Hanneman, R. A., and M. Riddle. 2005. Introduction to Social Network Methods. University of California, Riverside, Riverside, California.

Hardin, G. 1968. The Tragedy of the Commons. Science **162**:1243-1248.

Haugan, P. M., and H. Drange. 1996. Effects of CO_2 on the ocean environment. Energy Conservation Management **37**:1019-1022.

Hays, G. C., A. J. Richardson, and C. Robinson. 2005. Climate change and marine plankton. Trends in Ecology and Evolution **20**:337-344.

HBHRCD. 2006. Humboldt Bay Management Plan: Final Environmental Impact Report. *in*. Humboldt Bay Harbor, Recreation and Conservation District.

Hennessey, T., and J. Sutinen, editors. 2005. Sustaining Large Marine Ecosystems: The Human Dimension. Elsevier, Boston.

Hill, B. 1974. The Rank-Frequency Form of Zipf's Law. Journal of American Statistical Association **69**:1017-1026.

Hines, A. H., and J. S. Pearse. 1982. Abalones, Shells, and Sea Otters: Dynamics of Prey Populations in Central California. Ecology **63**:1547-1560.

Houghton, J. T., Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, X. Dai, K. Maskell, and C. Johnson, editors. 2001. Climate Change 2001: The Scientific Basis: Contributions of Working Group I to the Third Assessment Report of the Intergovernment Panel on Climate Change. Cambridge University Press, Cambridge, UK.

Huggett, R. 1993. Modeling the Human Impact on Nature. Oxford University Press, Oxford.

Huisman, M., and M. vanDuijn. 2005. Software for social network analysis. Pages 270-316 *in* P. J. Carrington, J. Scott, and S. Wasserman, editors. Models and Methods in Social Network Analysis. Cambridge University Press, Cambridge.

Huppert, D., R. L. Johnson, J. Leahy, and K. Bell. 2003. Interactions between Human Communities and Estuaries in the Pacific Northwest: Trends and Implications for Management. Estuaries **26**:994–1009.

Imperial, M. T., and T. M. Hennessey. 1996. An Ecosystem-Based Approach to Managing Estuaries: An Assessment of the National Estuary Program. Coastal Management **24**:115-139.

International Association for Artificial Intelligence and Law. Available at http://www.iaail.org.

IPCC. 2005. Special Report on Carbon dioxide Capture and Storage. Cambridge University Press, Cambridge.

IPCC. 2007. Cambridge University Press, New York.

Jensen, and Silber. 2005. Large Whale Ship Strike Database. *in* US Department of Commerce, editor. NOAA Technical Memorandum, NMFS-OPR.

Jensen, A. S., and G. K. Silber. 2003. Large Whale Ship Strike Database. U.S. Department of Commerce, NOAA Technical Memorandum **NMFS-OPR**.

Johnson, D. H., and T. A. O'Neil, editors. 2001. Wildlife-Habitat Relationship in Oregon and Washington. Oregon State University Press, Corvallis.

Jones, M. B., M. P. Schildhauer, O. J. Reichman, and S. Bowers. 2006. The New Bioinformatics: Integrating Ecological Data from the Gene to the Biosphere.

Juda, L. 1999. Considerations in Developing a Functional Approach to the Governance of Large Marine Ecosystems. Ocean Development and International Law **30**:89-105.

Juda, L. 2003a. Changing National Approaches to Ocean Governance: The United States, Canada, and Australia. Ocean Development and International Law **34**:161-187.

Juda, L. 2003b. Obstacles to Ecosystem-Based Management. Pages 67-71 *in* UNESCO, Paris.

Juda, L., and T. Hennessey. 2001. Governance profiles and the management of the uses of large marine ecosystems. Ocean Development and International Law **32**:43-69.

Kennish, M. J. 1992. Ecology of Estuaries: Anthropogenic Effects. CRC Press, Boca Raton, Florida.

Kildow, J., and C. Colgan. 2005. California Ocean's Economy: A Report to the California Resources Agency. NOAA Economic Program, Monterey.

Kitching, R. L. 1983. Systems Ecology. University of Queenland Press, New York.

Klinger, T., and J. Kershner. 2008. Low PH reduces growth rates in kelp gametophytes. *in* 2008 Ocean Sciences Meeting. March 2-7, Orlando.

Knecht, R. W., and B. Cicin-Sain. 1993. Ocean Management and the Large Marine Ecosystem Concept: Taking the Next Step. *in* K. Sherman, Alexander, and B.

Gold, editors. Large Marine Ecosystems: Stress, Mitigation, and Sustainability. AAAS, Washington, D.C.

Knecht, R. W., B. Cicin-Sain, and J. H. Archer. 1988. National Ocean Policy: A Window of Opportunity. Ocean Development and International Law **19**:113-142.

Koschinsky, J., and T. Swanstrom. 2001. Confronting policy fragmenation: a political approach to the role of housing nonprofilts. Policy Studies Review **18**:111-127.

Kraus, S. D., M. W. Brown, H. Caswell, C. W. Clark, M. Fujiwara, P. K. Hamilton, R. D. Kenney, A. R. Knowlton, S. Landry, C. A. Mayo, W. A. McLellan, M. J. Moore, D. P. Nowacek, D. A. Pabst, A. J. Read, and R. M. Rolland. 2005. North Atlantic Right Whales in Crisis. Science **309**:561-562.

Krippendorff, K. 2004. Content Analysis. Sage Publications, Thousand Oaks.

Lau, G. T., K. Law, and G. Wiederhold. 2006. A Relatedness Analysis of Government Regulations using Domain Knowledge and Structural Organization. Information Retrieval **9**:657-680.

Leighton, D. L. 1966. Studies on food preferences in algivorous invertebrates of southern California kelp beds. Pacific Science **20**:104-113.

Leighton, D. L., and R. A. Boolootian. 1963. Diet and growth in the black abalone, *Haliotis crachereodii*. Ecology **44**:227-238.

Leopold, A. 1949. A Sand County almanac and sketches here and there. Oxford University Press, New York.

Litle, K., S. Breslow, and J. K. Parrish. 2000. PNCERS 2000 Report. Submitted to Coastal Ocean Programs, NOAA. *in*.

Lluch-Belda, D., D. B. Luch-Cota, and S. E. Luch-Cota. 2003. Interannual Variability Impacts on the California Current Large Marine Ecosystem: Trends in Exploration, Protection, and Research. *in* G. Hempel and K. Sherman, editors. Large Marine Ecosystems of the World. Elsevier, Boston.

Lovell, G. 2002. Bernard Q. Nietschmann, 1941-2000 requiem for a friend. The Geographical Review **92**.

Ludwig, D., R. Hilborn, and C. Walters. 1993. Uncertainty, Resource Exploitation, and Conservation: Lessons from History. Science **260**:17,36.

McArdle, D. A. 1997. California marine protected areas. California Sea Grant, University of California, La Jolla.

McCay, B. J., and S. Jentoft. 1998. Market or community failure? Critical perspectives on common property resea. Human organization **57**:21-29.

McGinnis, M. V. 2006. Negotiating ecology: Marine bioregions and the destruction of the Southern California Bight. Futures:1-24.

McLeod, K. L., Jane Lubchenco, S. R. Palumbi, and A. A. Rosenberg. 2005. Scientific Consensus Statement on Marine Ecosystem-Based Management. *in* Communication Partnership for Science and the Sea.

Miles, E. L. 1989. Concepts, Approaches, and Applications in Sea Use Planning and Management. Ocean Development and International Law **20**.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, D.C.

Montevecchi, W. A., and R. A. Myers. 1995. Prey harvests of seabirds reflect pelagic fish and squid abundance on multiple spatial and temporal scales. Marine Ecology Progress Series **117**:1-9.

Moore, J. E., M. A. Colwell, R. L. Mathis, and J. M. Black. 2004. Staging of Pacific flyway brant in relation to eelgrass abundane and site isolation, with special consideration of Humboldt Bay, California. Biological Conservation **115**:475-486.

Moore, R., T. A. Prince, and M. Ellisman. 1998. Data-Intensive Computing and Digital Libraries: How to automate management of the flood of scientific data being collected in astronomical and neuroscience projects. Communications of the ACM **41**.

Myers, R. A., and B. Worm. 2003. Rapid worldwide depletion of predatory fish communities. Nature **423**:280-283.

National Research Council. 1995. Finding the Forest in the Trees. National Academy Press, Washington, D.C.

Naylor, R. L., R. J. Goldburg, J. H. Primavera, N. Kautsky, M. C. M. Beveridge, J. Clay, C. Folke, J. Lubchenco, H. Mooney, and M. Troell. 2000. Effect of aquaculture on world fish supplies. Nature **405**:1917-1924.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific Salmon at the Crossroads: Stocks at Risk from California, Oregon, Idaho, and Washington. Fisheries **16**:4-21.

Newton, J., T. Mumford, J. Dohrmann, J. West, R. Llanso, H. Berry, and S. Redman. 2000. A Conceptual Model for Environmental Monitoring of a Marine System: Puget Sound Ambient Monitoring Program (PSAMP). PSAMP.

NOAA. 2007. Digital Coast: Legislative Atlas. NOAA Coastal Services Center, Available at http://www.csc.noaa.gov/legislativeatlas/.

NOAA Regional Ecosystem Delineation Workgroup. 2004. Report on the Delineation of Regional Ecosystems Produced by the NOAA Regional Ecosystem Delineation Workgroup as a result of the Regional Ecosystem Delineation Workshop. Charleston, South Carolina.

Norton, B. G. 1992. A New Paradigm for Enviromental Management. Pages 23-41 *in* R. Costanza, B. G. Norton, and B. D. Haskell, editors. Ecosystem Health: New Goals for Environmental Management. Island Press, Washington, D.C.

NRC. 1996. Upstream: Salmon and Society in the Pacific Northwest. National Academies Press.

NRC. 2001. Marine protected areas: tools for sustaining ocean ecosystems. National Academy Press, Washington, D.C.

Oberthur, S., and T. Gehring. 2006. Institutional Interaction in Global Environmental Governance: Synergy and Conflict among International and EU Policies. The MIT Press, Boston, MA.

Odum, H. T. 1994. Ecological and General Systems: An Introduction to Systems Ecology. University Press of Colorado, Niwot, Colorado.

Olsen, S. B., J. G. Sutinen, L. Juda, T. M. Hennessey, and T. A. Grigalunas. 2006. A handbook on governance and socioeconomics of large marine ecosystems. University of Rhode Island, Coastal Resources Center.

Orr, J. C., V. J. Fabry, O. Aumont, L. Bopp, S. C. Doney, R. A. Feely, A. Gnanadesikan, N. Gruber, A. Ishida, F. Joos, R. M. Key, K. Lindsay, E. Maier-Reimer, R. Matear, P. Monfray, A. Mouchet, G. Raymond, R. G. Najjar, G.-K. Plattner, K. B. Rodgers, C. L. Sabine, J. L. Sarmiento, R. Schlitzer, R. D. Slater, I. J. Totterdell, M.-F. Weirig, Y. Yamanaka, and A. Yool. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature **437**.

Orth, R. J., T. J. B. Carruthers, W. C. Dennison, C. M. Duarte, J. W. Fourqurean, K. L. Heck, A. R. Hughes, G. A. Kendrick, W. J. Kenworthy, S. Olyarnik, F. T. Short, M. Waycott, and S. L. Williams. 2006. A Global Crisis for Seagrass Ecosystems. BioScience **56**:987-996.

Ostrom, E. 1990. Governing the Commons. Cambridge University Press, Cambridge, UK.

Ostrom, E. 2005. Understanding Insitutional Diversity. Princeton University Press, Princeton.

Paine, R. T., and R. L. Vadas. 1969. The Effects of Grazing by Sea Urchins, Strongylocentrotus SPP., on Benthic Algal Populations. Limnology and Oceanography **14**:710-719.

Parrish, J., R. Bailey, A. E. Copping, and J. E. Stein. 2003. The Pacific Northwest Coastal Ecosystems Regional Study. Estuaries **26**:991-993.

Pauly, D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology and Evolution **10**:430.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese, and F. Torres. 1998. Fishing Down Marine Food Webs. Science **279**:860-863.

Pew Oceans Commission. 2003. America's Living oceans: Charting a Course for Sea Change. Pew Foundation.

Pikitch, E. K., C. Santora, E. A. Babcock, A. Bakun, R. Bonfil, D. O. Conover, P. Dayton, P. Doukakis, D. Fluharty, B. Heneman, E. D. Houde, J. Link, P. A. Livingston, M. Mangel, M. K. McAllister, J. Pope, and K. J. Sainsbury. 2004. Ecosystem-Based Fishery Management. Science **305**:346-347.

Poornima, E., M. Rajadurai, V. N. R. Rao, S. V. Narasimhan, and V. P. Venugopalan. 2006. Use of coastal waters as condenser in electric power plants: Impact on phytoplankton and primary productivity. Journal of Thermal Biology **31**:556-564.

Portner, H.-O. 2008. Ecosystem effects of ocean acidification in times of ocean warming: a physiologist's view. draft from Peter Brewer.

Raven, and et al. 2005. Ocean acidification due to increasing atmospheric carbon dioxide. The Royal Society Policy Document **12/05**.

Rivera-Arriaga, E., and G. Villalobos. 2001. The coast of Mexico: approaches for its management. Ocean & Coastal Managment **44**:729-756.

Robbins, P. 2007. Political Ecology: A Critical Introduction. Blackwell Publishing.

Roloff, G. J., F. F. Wilhere, T. Quinn, and S. Kohlmann. 2001. An Overview of Models and Their Roles in Wildlife Management. *in* D. H. Johnson and T. A. O'Neil, editors. Wildlife-Habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis.

Rosenberg, A. A., and K. McLeod. 2005. Implementing ecosystem-based approaches for its management. Ocean & Coastal Managment **44**:729-756.

Rosendal, G. K. 2001. Impacts of Overlapping International Regimes: The Case of Biodiversity. Global Governance **7**:95-117.

Salmon, G., A. Wong, and C. S. Yang. 1975. A vector space model for automatic indexing. Comm. ACM **18**:613-620.

Sarmiento, J. L., C. L. Quere, and S. W. Pacala. 1995. Limiting Future Atmospheric Carbon Dioxide. Global Biogeochemical Cycles **9**:121-137.

Seibel, B. A., and V. J. Fabry. 2003. Marine biotic response to elevated carbon dioxide. Advanced Applied Biodiversity Science **4**:59-67.

Sherman, K. 1991. The Large Marine Ecosystem Concept: Research and Management Strategy for Living Marine Resources. Ecological Applications **1**:349-360.

Sherman, K. 2005. The Large Marine Ecosystem Approach for Assessment and Management of Ocean Coastal Waters. *in* T. M. Hennessey and J. Sutinen, editors. Sustaining Large Marine Ecosystems: The Human Dimension. Elsevier, Boston.

Short, F. T., and S. Wyllie-Echeverria. 1996. Natural and human-induced disturbance of seagrasses. Environmental Conservation **23**:17-27.

Silliman, R. P. 1941. Fluctuations in the Diet of the Chinook and Silver Salmons (Oncorhynchus tschawytscha and O. kisutch) off Washington, as Related to the Troll Catch of Salmon. Copeia **1941**:80-87.

Slocombe, D. S. 1993. Implementing Ecosystem-Based Management: development of theory, practice and research for planning and managing a region. BioScience **43**:612-622.

Slocombe, D. S. 1998. Lessons from experience with ecosystem-based management. Landscape and Urban Planning **40**:31-39.

Smith, S. C., and H. Whitehead. 2000. The Diet of Galapagos Sperm Whales Physeter Macrocephalus as Indicated by Fecal Sample Analysis. Marine Mammal Science **16**:315-325.

SOCCR. 2007. The First State of the Carbon Cycle Report (SOCCR) - The North American Carbon Budget and Implications for the Global Carbon Cycle.

Steele, J. H. 1998. Regime Shifts in Marine Ecosystems. Ecological Applications **8**:S33-S36.

Stratton Commission. 1969. Our Nation and the Sea: A Plan for National Action. Report of the Commission on Marine Science, Engineering and Resources. United States Printing Office, Washington, D.C.

Suman, D. O. 1997. The Florida Keys National Marine Sanctuary: A case study of an innovative federal-state partnership in marine resource management. Coastal Management **25**:293-324.

Sutinen, J. G., P. Clay, C. L. Dyer, S. F. Edwards, J. Gates, T. A. Grigalunas, T. M. Hennessey, L. Juda, A. W. Kitts, P. N. Logan, J. J. Poggie, B. P. Rountree, S. Steinback, E. M. Thunberg, H. F. Upton, and J. B. Walden. 2000. A Framework for Monitoring and Assessing Socioeconomics and Governance of

Large Marine Ecosystems. *in* N. T. M. NMFS-NE-158., editor. NOAA Technical Memorandum NMFS-NE-158. Northeast Fisheries Science Center. Northeast Fisheries Science Center, Woods Hole, MA.

Tegner, M. J., and P. Dayton. 2000. Ecosystem effects of fishing in kelp forest communities. ICES Journal of Marine Science **57**:579-589.

Tegner, M. J., and P. K. Dayton. 1981. Population Structure, Recruitment and Mortality of Two Sea Urchinsw (Strongylocentrotus franciciscanus and S. purpuratus) in a Kelp Forest. Marine Ecology Progress Series **5**:255-268.

Thom, R. M., G. D. Williams, and A. B. Borde. 2003. Conceptual Models as a Tool for Assisting, Restoring, and Managing Puget Sound Habitats and Resources. *in* PSP. www.psat.wa.gov/Publications/03_proceedings/PAPERS/ORAL/9e_thom.pdf

U.S. Environmental Protection Agency. 1976. Quality Criteria for Water EPA 440/PB-263 943 (Red Book). National Technical Information Service, Springfield, VA.

Underdal, A. 1980. Integrated Marine Policy: What? Why? How? Marine Policy:159-169.

Unwin, A., M. Theus, and H. Hofmann. 2006. Graphics of Large Datasets: Visualizing a Million. Springer, New York.

USCOP. 2004. An Ocean Blueprint for the 21st Century Final Report of the U.S. Commission on Ocean Policy.

Van Dyke, G. M., editor. 1969. The Ecosystem Concept in Natural Resource Management. Academic Press, New York.

Vayda, A. P. 1983. Progressive contextualization: Methods for research in human ecology. Human Ecology **11**:265-281.

Wallace, R. 1996. The Marine Mammal Commission compendium of selected treaties, international agreements, and other relevant documents on marine resources, wildlife and the environment. Biological Conservation **76**:211-212.

Wan, X., and Y. Peng. 2005. A Measure Based on Optimal Matching in Graph Theory for Document Similarity. Pages 227-238 *in* S. H. Myaeng, M. Zhou, K.-F. Wong, and H.-J. Zhang, editors. Information Retrieval Technology: Asia Information Retrieval Symposium (AIRS) 2004, Beijing, China, Revised Selected Papers (LNCS 3411), October 2004. Springer-Verlag, Berlin.

Wang, H. 2004. Ecosystem Management and Its Application to Large Marine Ecosystems: Science, Law, and Politics. Ocean Development and International Law **35**:41-74.

Watkins, J. D. 2007. Effects of Climate Change and Ocean Acidification on Living Marine Resources, Testimony of Admiral James D. Watkins. Pages 4 *in* Committee on Commerce, Science, and Transportation, Subcommittee on Ocean, Atmosphere, Fisheries, and Coast Guard, U.S. Senate. U.S. Senate Committee on Commerce, Science & Transportation, Washington, D.C.

Weber, M. L. 2002. From Abundance to Scarcity: A History of U.S. Marine Fisheries Policy. Island Press, Washington, D.C.

Weible, C., P. A. Sabatier, and M. Lubell. 2004. A Comparison of a Collaborative and Top-Down Approach to the Use of Science into Policy: Establishing Marine Protected Areas in California. Policy Studies Journal **32**:187-207.

Willis, C. 2006. Digital Coast: Legislative Atlas for the Gulf of Mexico. *in* paper presented at the 25th Annual International Submerged Lands Management Conference, Redbank, New Jersey.

Wilson, J. A. 2006. Matching Social and Ecological Systems in Complex Ocean Fisheries. Ecology and Society **11**:9.

Wilson, P., and D. P. Wheeler. 1997. California's Ocean Resources: An Agenda for the Future. Year of the Ocean (YOTO) Discussion Papers, Sacramento.

Young, O., G. Osherenko, J. Ekstrom, L. Crowder, J. Ogden, J. Wilson, J. Day, F. Douvere, C. Ehler, K. McLeod, B. Halpern, and R. Peach. 2007. Solving the Crisis in Ocean Governance: Place-Based Management of Marine Ecosystems. Environment **49**:8-19.

Young, O. R. 1999. Governance in World Affairs. Cornell University Press, Ithaca.

Young, O. R. 2002. The Institutional Dimensions of Environmental Change: Fit, Interplay, and Scale. MIT Press, Cambridge.

Zeimpekis, D., and E. Gallopoulos. 2006. TMG: A MATLAB Toolbox for generating term-document matrices from text collections. *in* J. Kogan, C. Nicholas, and M. Teboulle, editors. Grouping Multidimensional Data: Recent Advances in Clustering. Springer-Verlag, New York.

APPENDIX A.
A conceptual ecosystem model on ocean acidification

INTRODUCTION

Similar to many other environmental problems, placing ocean acidification in its larger context is a useful approach for developing a solution to mitigate or obviate its impacts. Comprehending the problem of ocean acidification requires an examination within its broader context. This project uses a chain of explanation approach to place the environmental problem of ocean acidification into a broader framework (Vayda 1983, Blaikie and Brookfield 1987, Sutinen et al. 2000, Belausteguigoitia 2004, Robbins 2007). Governance literature has stressed the utility of integrating the broader perspective as a framework to integrate systematic and holistic analysis of sector-based management problems[17] (Juda and Hennessey 2001).

The ocean acidification chain of explanation is a set of interdependent categories that include human activities, species, habitats, and biophysical processes. Each category is composed of several components that represent specific aspects of each category. Many of the components within and between categories inherently relate to one another. Essentially the components and interdependencies make up a system which can be developed into conceptual ecosystem (or even socio-ecological system).

Systems analysis provides a structured manner to analyze interconnected components. Many disciplines use network modeling to evaluate a system, such as engineering, ecology, and social sciences. For example, social network analyses can answer question about who relates to whom and who does business with whom to understand if there are specific key players in different aspects of the community, as well as to understand how a community functions (Carrington et al. 2005). Thus, development of the conceptual ecosystem model for this case study employs frameworks from both political ecology and systems analysis.

---

[17] Quoted from Juda and Hennessey (2001:67): "Pernetta and Mee, *The Global International Waters Assessment*, supra note 8 emphasize the importance of causal chain analysis. According to them: "A causal chain is a series of statements that demonstrate and summarize, in a stepwise manner, the linkages between problems and their underlying or 'root' causes. Uncertainties accompanying each linkage should be clearly stated. The analysis also permits barriers to resolving the problems to be investigated. A causal chain presents the nature of the problem itself, including the effects and transboundary consequences, and then probes the linkages between problems and its societal causes. In its practical application, it can serve as a model into which regionally relevant information may be inserted.""

Steps to build conceptual model of any system

There is a set of commonly applied steps to build a model of any system (Hall and Day 1977). First, drawing an illustration of the system is typical to conceptualize the system's boundaries and define what components to include. Second, a black box diagram may serve to better define the components and linkages. Third, the blackbox diagram can be interpreted into a conceptual, but quantitative, matrix of the system's components and linkages. The matrix is usually composed of components by components with cells indicating whether a linkage exists between the paired components. Following the matrix, there are several more advanced options to developing a more quantitative model of a system. Many ecosystem models continue to more complex modeling; for example, of energy transfer between species. However, our end goal for this project is to use a matrix of components and conceptual direct linkages. In this case study I stop after the stage of developing a two-dimensional matrix that conveys linkages between each component in the defined system boundaries.

The following are three general steps to create an ecosystem model:

- Establish boundaries of system
- Identify components within boundaries
- Define relationships between components within a set of rules

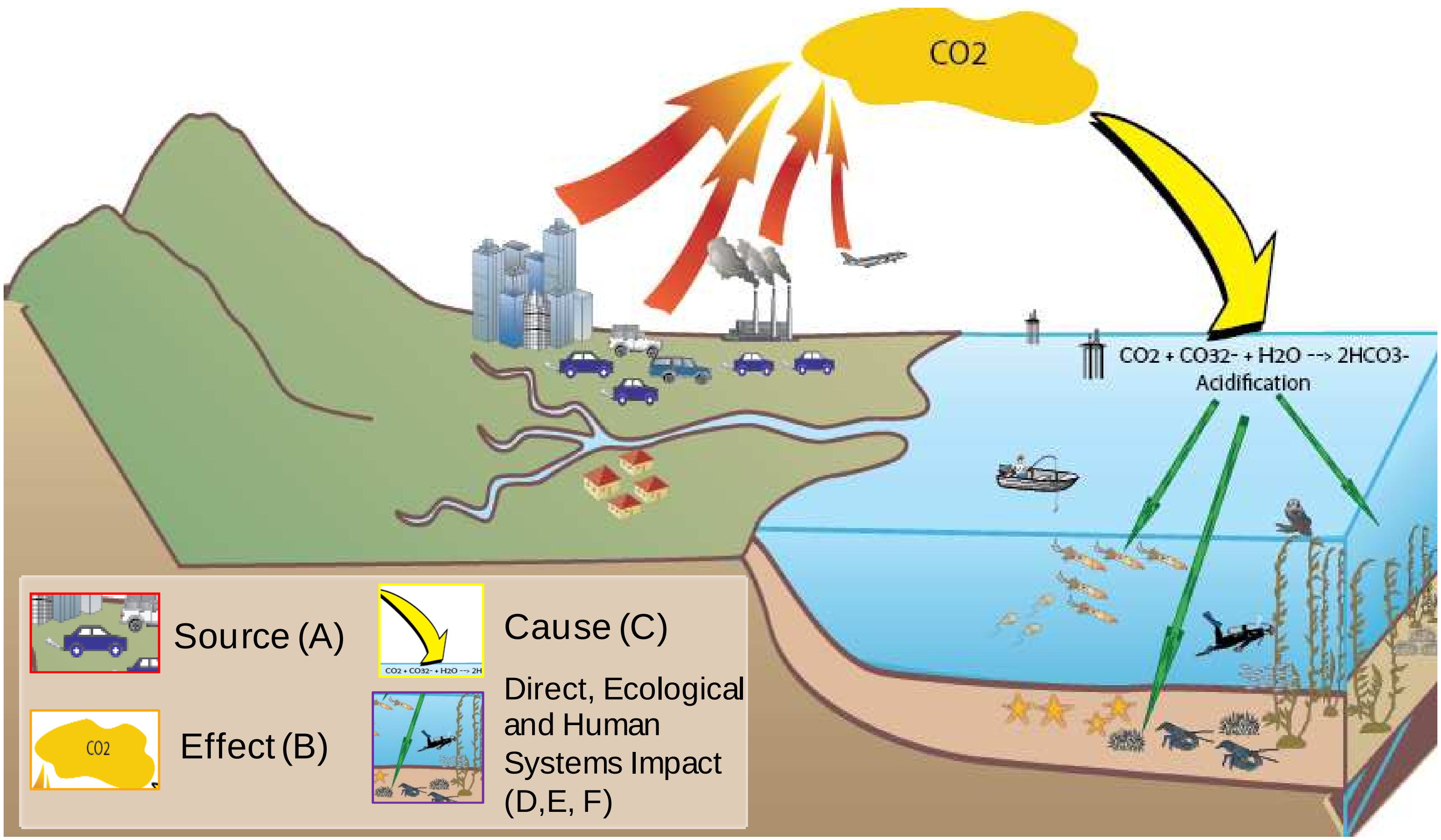
SYSTEM BOUNDARIES

The first step of modeling a system is to define the boundaries. Boundaries can be delineated by a plethora of frameworks. Natural science, for example, often bounds a system using biogeographical data (Bailey 1983). Conversely, an anthropologist may bound their system of focus using family ties data (Bernard 1998, Carrington et al. 2005). Scientists often define boundaries of ecosystems based on whatever information is available, or based on whatever allocation is feasible for the study purposes (Hall and Day 1977, Huggett 1993, Odum 1994). Therefore, one may define a puddle in the middle of a dirt road as an ecosystem, while another person may define the boundaries of an ecosystem to be the waterfowl migratory route that includes the thousands of little puddles. Both constitute an ecosystem with interdependent components. However, inclusion of components depends on the investigator's focus and scale of interest. Scales can range from microbial and vial levels (e.g. the microbial loop) to the species or larger biogeographic level (e.g. large marine ecosystem). Thus, ecosystems are socially-constructed even when the parameters used to define them are biological or physical. Taking a step back from our own "scientific system," one may find that all organization defined using biological and physical data are also socially-constructed, but we leave that philosophical discussion to post-modernists.

For the system involving ocean acidification, we chose categories to help delineate the boundaries in which our system is defined. Ocean acidification is an ecosystem problem requiring an ecosystem approach to the solution. This means that rather than an analysis of governance of the physical/chemical problem, we need to look at the source of the problem, as well as the predicted ecological and socio-economic indirect impacts. This is the same line of thinking referred to as “causal chain” by Sutinen et al. (2000) and similar to chains of explanation in political ecology (Vayda 1983). Thus, through a systems perspective of ocean acidification, the following categories to delineate the boundaries of our system: Source, Cause, Effect, Impact, Ecological Impact, Human Systems Impact. The surface water ocean acidification is the “effect”. But if we take the political ecology lens that has been valuable for resolving environmental problems (REF), the researcher must examine multiple scales and spaces to illuminate where the source of the given problem comes from, as well as where and through what mechanisms the given problem will impact. This framework is referred to by political ecologists as the “chain of explanation” (Blaikie and Brookfield 1987).

Figure A.1 graphically illustrates of the conceptual model that includes the main pieces that make up the chain of explanation for this case study.

Figure A.1. Conceptual diagram of ecosystem relating to ocean acidification. A. Source; B. Cause; C. Effect; D. Direct Impact; E. Ecological Impact; F. Human Systems Impact. Refer to Table A.1 for definitions of each category.



The following diagram (Figure A.2) contains the six categories used to delineate the ecosystem boundaries. The linkages between (indicated with lines) categories represent the conceptual chain of causation in the ecosystem model.

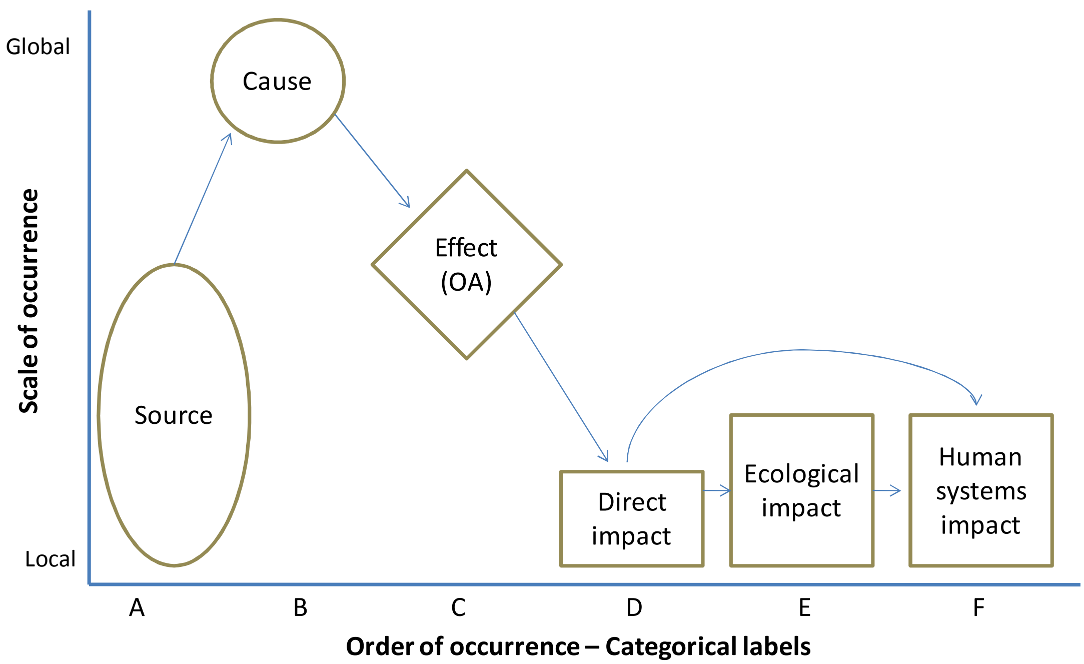


Figure A.20. Categories selected to conceptually model the larger system surrounding ocean acidification (OA) and its interrelated components. Categories are represented by shapes in the order in which they occur. Each arrow indicates the direct linkage between these two components. For example, the Source (carbon emitters) directly impacts the Cause (atmospheric CO_2) or specifically, carbon emitters directly increase the amount of atmospheric CO_2. The two categories occur on different geospatial scales; as such, their position along the y-axis indicates scale. [SOURCE = Carbon emitting activities and entities; CAUSE = Increase in atmospheric CO_2 from carbon discharge; EFFECT = Ocean acidification process; DIRECT IMPACT = Calcifying organisms in the area of study (Channel Islands) and kelp; ECOLOGICAL IMPACT = Organisms that directly affect or are affected by fitness of species in the Direct Impact category; HUMAN SYSTEMS IMPACT = Human activities that directly affect or are affected by fitness of species in Ecological Impact and/or Direct Impact categories.]

SYSTEM COMPONENTS

The categories in Figure A.20 delineate the system's boundaries; thus, a sampling of components represented each category. For example, to represent the Effect category, which embodies the physical process of ocean acidification, components included *acidification*, *carbonate*, and *pH*. Selecting a category's components is a function of the scope and scale (trophic, geographic, geopolitical, etc) combined with the defined boundaries. For this project the scope was to include components that could or should be reflected in management within the confines of our six categories. Therefore, something obscure and clearly not critical to the system's functionality would not be included. Societal and economic values, as well as ecological (ie. foodweb) importance were strongly taken into consideration. The model does not include some particular species of fish, such as surfperch, because (at least to my knowledge) they do not play a significant role in the functionality of the conceptually modeled ecosystem for ocean acidification.

Each category in the modeled ecosystem consists of individual components. For example, 11 components form the Source category, all of which account for the anthropogenic release of CO_2. This category's components include *transportation* and *cement manufacturing* because these activities contribute a large proportion of the world's carbon emissions (Hanle et al. 2004, IPCC 2005). The following sections apply the components to explain the concept of each category.

Source

Components representative of entities and activities that contribute a large proportion of carbon dioxide fill the Source category. These encompass cement manufacturing and fossil fuel consumers, the latter of which includes the transportation industry from the mass scale (e.g. shipping cargo) to the individual scale of vehicles or any other entity that runs a motor or combusts oil.

Cause

The Cause category is more straight-forward because it is represented by carbon emissions that increase the carbon dioxide concentration in the atmosphere.

Effect

The Effect category is also straight-forward because the components are directly derived from the physical/chemical effect caused by increased atmospheric carbon dioxide. These include the absorption of CO_2 into ocean surface water, the reduced availability of carbonate, the decrease in pH, the terminology "acidification" coined by Ken Caldeira (Caldeira and Wickett 2003), and the reduced capacity to sequester atmospheric CO_2 for the long term.

Direct Impact

The impact category is made up of components that are directly impacted by either the reduced ocean pH, the narrowing supersaturation horizon (Raven and et al.

2005), or the decreased availability of carbonate. From current scientific evidence it seems there will be an undeniable impact on the survivorship of organisms that use carbonate to create calcium carbonate. In the Channel Islands kelp forest, these calcifying organisms include zooplankton (foraminifera, pteropods), lobster, urchin, abalone, and squid. See (Orr et al. 2005) for information about impacts on fitness of calcifying organisms, and (Klinger and Kershner 2008) on predicted direct impacts on kelp.

Ecological Impact

The Ecological Impact category was less straight-forward to populate with components. I chose a representative selection of species that could be directly impacted by a shift in population of the species in the impact category. These include salmon, sheephead, anchovy, sardine, mackerel, starfish, rockfish, otter, whale, and seabird.

Human Systems Impact

The impact analysis considers the direct impact on calcifying organisms, the indirect impacts on dependent organisms, and a small representative sample of human system activities that depend on the directly and indirectly impacted organisms. The selection of components representing the Human Systems Impact category includes economic and recreational activities common in the Southern California Channel Islands region: whale watching, fishing, SCUBA diving, and commercial and recreational fisheries.

Table A.1. Components used to represent each category of the conceptual system model of ocean acidification in the Channel Islands National Marine Sanctuary.

ID	Category	Component description	Scale	Component	Term used to represent component
A	Source	Transportation industry, carbon emitters	Local, regional	Fossil fuel	Fossil fuel
				Transportation	_transportation
				Shipping	_shipping_
				Cargo	Cargo
				Vehicle	Vehicle
				Car	_car_
				Truck	Truck
				Motor	Motor
		Energy production from power plants		Energy production	Energy produc*
				Power plant	Power plant
		Cement manufacturing		Cement manufacturing	_cement_
B	Cause	Physical cause of ocean acidification (atmospheric CO_2 increase)	Global	Carbon dioxide	Carbon dioxide
				Atmosphere	Atmosphere
				Carbon emission	Carbon emiss*
C	Effect	Atmospheric carbon deposition from the atmosphere to the ocean	Regional, global	Carbon deposition	Carbon + deposit*
				Sequestration	Sequest*
		Decrease in pH		Acidification	Acidification
				pH	_pH_
				Carbonate	Carbonate
D	Direct Impact	Selection of calcifying organisms and kelp in Channel Islands region	Local	Plankton	Plankton
				Kelp	Kelp
				Lobster	Lobster
				Squid	Squid
				Abalone	Abalone
				Urchin	Urchin
E	Ecological Impact	Species directly linked to one or more of the species listed in Direct Impact category	Local, regional	Sheepshead	Sheepshead OR sheephead
				Whale	Whale
				Otter	_Otter_
				Anchovy	Anchov*
				Sardine	Sardine
				Mackerel	Mackerel
				Starfish	Seastar
				Mackerel	Mackerel
				Rockfish	Rockfish
				Seabird	Seabird
F	Human Systems Impact	Recreational or economic activities common in the Channel Islands region that directly relate to components in the Direct Impact or Ecological Impact category	Local, regional	Fishing	Fishing
				Harvest	Harvest
				Whale watching	Whale watch*
				Scuba diving	Scuba div*
				Recreation fishery	Recreation fish*
				Commercial fishery	Commercial fish*

SYSTEM LINKAGES

Rules

This model contains only direct linkages between components. For example, if species A could be greatly affected by the population reduction in species B, then there is a direct linkage between species A and B. Similarly for non-species interactions, if an activity directly causes a certain effect, then these two components of the system are directly linked. Feedbacks are not included as part of the modeled ecosystem for the sake of simplicity and time feasibility. Figure A.3 contains the matrix form of the linkages and Table A.2 contains the list of linkages.

Gathering linkages

Depending on the needs and confines of the party of interest, there are a variety of processes to construct a conceptual system model. Since the main goal was to construct this model to apply the gaps and overlaps management analysis, I constructed this conceptual model by first getting familiar with the topic of ocean acidification through scientific literature and the Congressional Testimonies provided on the web. Then I defined my system boundaries based on the scientific literature about the problem – listing categories from source to indirect impacts. Then I drafted a list of logical components within each category (again based on the literature) and drafted linkages. With the draft matrix of linkages, I sought feedback from scientists based on their knowledge of particular categories or between multiple categories. For example, marine ecologists assisted in defining the components to use and the associated linkages within and between the Direct Impact and Ecological Impact categories. These linkages are essentially related to food web dynamics. Appropriately, ocean chemists validated linkages between the Effect and Cause categories and between the Effect and Source categories.

The purpose of this case study was to use a conceptual model of the system to the best of my ability within the time constraints. Future will include alternative models to test the utility of changing the rules of defining linkages (e.g. by adding indirect linkages to the system) and testing to see if results vary significantly with the use of alternative models for the system.

Figure A.3. Matrix of conceptual ecosystem model pertaining to the components of ocean acidification relative to the Southern California Channel Islands region. Cells indicate whether there is a linkage (1) or not (0) between the two corresponding components. Colors group components into their relevant categories (Table A.1). PINK= Source (A); ORANGE= Cause (B); YELLOW= Effect (C); GREEN= Direct Impact (D); BLUE= Ecological Impact (E); PURPLE= Human Systems Impact (F). Refer to Table A.2 for desciription of individual relationships.

	fossil fuel	_transportation	_shipping	cargo	vehicle	_car_	truck	motor	energy produc	power plant	_cement_	carbon dioxide	atmosphere_	carbon emiss_	deposition	sequest_	acidification	_pH_	carbonate	plankton	kelp	lobster	squid	abalone	urchin	sheep(s)head	whale	_otter	anchov_	sardine	mackerel	seastar	rockfish	seabird	fishing	harvest	whale watch_	scuba div_	fish_	fish_
fossil fuel		1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
_transportation			1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
_shipping				1	1	0	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
cargo					1	0	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
vehicle						1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
car							1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
truck								1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
motor									0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
energy produc										1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
power plant											0	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cement												1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
carbon dioxide													1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
atmosphere_														1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
carbon emiss_															1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
carbon + deposition																1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sequest_																	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
acidification																		1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
_pH_																			1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
carbonate																				1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
plankton																					1	0	1	0	0	0	1	0	1	1	1	0	1	1	1	0	0	0	0	0
kelp																						0	0	1	1	0	0	1	0	0	0	0	1	1	0	1	0	1	0	0
lobster																							0	0	1	1	0	1	0	0	0	0	0	0	1	1	0	1	1	1
squid																								0	0	0	1	0	0	0	1	0	0	1	1	1	0	0	0	0
abalone																									1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
urchin																										1	0	1	0	0	0	0	0	0	1	1	0	1	0	0
sheep(s)head																											0	0	0	0	0	0	0	0	1	1	0	1	1	1
whale																												0	0	0	0	0	0	0	1	0	1	1	0	0
_otter																													0	0	0	0	0	0	1	1	0	1	1	1
anchov_																														0	1	0	1	1	1	1	0	0	1	1
sardine																															1	0	1	1	1	1	0	0	1	1
mackerel																																0	1	1	1	1	0	0	1	1
seastar																																	0	0	0	0	0	1	0	0
rockfish																																		1	1	1	0	0	1	1
seabird																																			1	1	0	0	1	1
fishing																																				1	0	1	1	1
harvest																																					0	1	1	1
whale watch_																																						0	0	0
scuba div_																																							0	0
recreational fish_																																								1
commercial fish_																																								

Table A.2. Table of linkage definitions between components in modeled ecosystem related to ocean acidification.

Block ID	Type	Modeled link	Justification/link description	Reference, if applicable
1	A-A	Fossil fuel-transportation	The transportation industry relies on fossil fuel	NA
		Fossil fuel-shipping	The shipping industry relies on fossil fuels	NA
		Fossil fuel-cargo	Cargo vessels rely on fossil fuels	NA
		Fossil fuel-vehicle	Most vehicle run with fossil fuel.	NA
		Fossil fuel-car	Most cars use fossil fuel	NA
		Fossil fuel-truck	Trucks use fossil fuels.	NA
		Fossil fuel-motor	Most motor run on fossil fuels.	NA
		Fossil fuel-energy produc*	The majority of energy produced in the US is derived from fossil fuel combustion	IPCC 2005
		Fossil fuel-power plant	Many power plants use fossil fuels to produce energy	IPCC 2005
		Transportation-shipping	Shipping is a transportation medium.	NA
		Transportation-cargo	Cargo shipping is part of the transportation sector.	NA
		Transportation-vehicle	Vehicles are one mechanism of transporation.	NA
		Transportation-car	Cars are one mechanism of transporation.	NA
		Transportation-truck	Trucks are one mechanism of transporation.	NA
		Transportation-motor	Motor are one mechanism of transporation.	NA
		Shipping-cargo	Much of cargo is shipped.	NA
		Shipping-vehicle		NA
		Shipping-truck		NA
		Shipping-motor		NA
		Cargo-vehicle		NA
		Cargo-truck		NA
		Cargo-motor		NA
		Vehicle-car	Cars are a type of vehicle.	NA
		Vehicle-truck	All trucks are vehicles.	NA
		Vehicle-motor	All vehicles have a motor.	NA
		Car-truck	Cars and trucks are vehicles.	NA
		Car-motor	All operating cars have a motor.	NA
		Truck-motor	All trucks have a motor.	
		Energy production-power plan	Power plants produce energy.	NA
2	B-B	Carbon dioxide-	Concentration of carbon	NA

		atmosphere	dioxide is increasing in the atmosphere.	
		Carbon dioxide-carbon emission	"Carbon emission" relates to the release of carbon dioxide into the atmosphere	NA
		Atmosphere-carbon emission	Carbon emissions affects the concentration of carbon dioxide in the atmosphere	NA
3	C-C	Carbon deposition-sequestration		(Caldiera and Wickett 2003)
		Carbon deposition-acidification		(Caldiera and Wickett 2003)
		Carbon deposition-pH		(Caldiera and Wickett 2003)
		Carbon deposition-carbonate		(Caldiera and Wickett 2003)
		Sequestration-acidification		(Caldiera and Wickett 2003)
		Sequestration-pH		
		Sequestration-carbonate		(Caldiera and Wickett 2003)
		Acidification-pH	Ocean acidification refers to the decrease in ocean pH driven by anthropogenic atmospheric CO_2	(Caldiera and Wickett 2003, Orr et al. 2005, Caldeira et al. 2007)
		Acidification-carbonate		(Orr et al. 2005)
		pH-carbonate		(Orr et al. 2005)
4	D-D	plankton-kelp	Plankton find refuge in kelp	
		Plankton-squid	Squid eat plankton	find literature or contact Briana Brady at DFG SB office: bbrady@dfg.ca.gov
		Kelp-abalone	Abalone eat kelp	(Leighton and Boolootian 1963, Leighton 1966)
		Kelp-urchin	Urchin eat kelp	(Paine and Vadas 1969)
		Lobster-urchin	lobster eat urchin	(Tegner and Dayton 1981)
		Abalone-urchin	Urchin provide habitat for abalone.	Tegner and Dayton 1976
5	E-E	Anchov*-mackerel	"Small jack mackerel taken off southern California and northern Baja California eat large zooplankton, juvenile squid, and anchovy"	PFMC, http://www.pcouncil.org/cps/cpsback.html, Accessed 3/26/2008
		Anchov*-rockfish	Diet of Boccaccio includes mainly fishes such as sardine	DFG website, accessed 2/19/08

			and anchovy.	
		Anchov*-seabird	Seabird, such as pelicans, cormorants, and albatross, eat little coastal pelagic finfish, such as anchovy	PFMC, http://www.pcouncil.org/cps/cpsback.html, Accessed 3/26/2008
		Sardine-mackerel	Mackerel eat sardine	PFMC, http://www.pcouncil.org/cps/cpsback.html, Accessed 3/26/2008
		Sardine-rockfish	Diet of Boccaccio includes mainly fishes such as sardine and anchovy	DFG website, accessed 2/19/08
		Sardine-seabird	Seabird eat little coastal pelagic, such as anchovy	PFMC, http://www.pcouncil.org/cps/cpsback.html, Accessed 3/26/2008
		Mackerel-rockfish	"The diet of bocaccio [a rockfish] includes mainly fishes such as surfperch, jack mackerel, sablefish, anchovies, sardines…"	DFG website, accessed 2/19/08
		Mackerel-seabird	Seabird eat little coastal pelagic, such as mackerel	PFMC, http://www.pcouncil.org/cps/cpsback.html
		Rockfish-seabird	Seabirds (ie. comorants) eat rockfish	(Becker and Beissinger 2006)
6	F-F	Fishing-harvest	Fishing activities harvest fish.	NA
		Fishing-scuba div*	Scuba diving is one way to fish.	NA
		Fishing-recreational fish*	Fishing is a major part of recreational fisheries.	NA
		Fishing-commercial fish*	Fishing is a major part of commercial fisheries.	NA
		Harvest-scuba div*		
		Harvest-recreational fish*	Fishing activities harvest fish.	(Pauly et al. 1998)
		Harvest-commercial fish*	Fishing activities harvest fish.	(Pauly et al. 1998)
		Recreational fish*-commercial fishi*	Recreational and commercial fisheries often directly compete with one another.	
7	A-B	Fossil fuel-carbon dioxide		(IPCC 2005)
		Fossil fuel-atmosphere		(IPCC 2005)
		Fossil fuel-carbon emission		(IPCC 2005)
		Transportation-		(IPCC 2005)

		carbon dioxide		
		Transportation-atmosphere		(IPCC 2005)
		Transportation-carbon emission		(IPCC 2005)
		Shipping-carbon dioxide		(IPCC 2005)
		Shipping-atmosphere		(IPCC 2005)
		Shipping-carbon emission		(IPCC 2005)
		Cargo-carbon dioxide		(IPCC 2005)
		Cargo-atmosphere		(IPCC 2005)
		Cargo-carbon emission		(IPCC 2005)
		Vehicle-carbon dioxide		(IPCC 2005)
		Vehicle-atmosphere		(IPCC 2005)
		Vehicle-carbon emission		(IPCC 2005)
		Car-carbon dioxide		(IPCC 2005)
		Car-atmosphere		(IPCC 2005)
		Car-carbon emission		(IPCC 2005)
		Truck-carbon dioxide		(IPCC 2005)
		Truck-atmosphere		(IPCC 2005)
		Truck-carbon emission		(IPCC 2005)
		Motor-carbon dioxide		(IPCC 2005)
		Motor-atmosphere		(IPCC 2005)
		Motor-carbon emission		(IPCC 2005)
		Energy produc*-carbon dioxide	Energy production sector releases a large amount of carbon dioxide into the atmosphere	(IPCC 2005)
		Energy produc*-atmosphere	Energy production sector releases a large amount of carbon dioxide into the atmosphere	(IPCC 2005)
		Energy produc*-carbon emission	Energy production sector releases a large amount of carbon dioxide into the atmosphere	(IPCC 2005)
		Power plant-carbon dioxide	Power plants release a high amount of carbon dioxide into the atmosphere	(IPCC 2005)
		Power plant -atmosphere	Power plants release a high amount of carbon dioxide into the atmosphere	(IPCC 2005)

		Power plant -carbon emission	Power plants release a high amount of carbon dioxide into the atmosphere	(IPCC 2005)
		Cement-carbon dioxide		(Hanle et al. 2004)
		Cement-atmosphere		(Hanle et al. 2004)
		Cement -carbon emission		(Hanle et al. 2004)
8	B-C	Carbon dioxide-carbon + deposition		(IPCC 2005)
		Carbon dioxide-sequest*		(IPCC 2005)
		Carbon dioxide-acidification		(Caldiera and Wickett 2003)
		Carbon dioxide-pH		(Orr et al. 2005)
		Carbon dioxide-carbonate		(Orr et al. 2005)
		Atmosphere-carbon + deposition		(Orr et al. 2005)
		Atmosphere-sequest*		(Orr et al. 2005)
		Atmosphere-acidification	Ocean acidification refers to the decrease in ocean pH driven by anthropogenic atmospheric CO_2 (from carbon emissions). This reduces the balance of carbonate in surface waters.	(Orr et al. 2005)
		Atmosphere-pH	Ocean acidification refers to the decrease in ocean pH driven by anthropogenic atmospheric CO_2 (from carbon emissions).	(Orr et al. 2005)
		Atmosphere-carbonate	Ocean acidification refers to the decrease in ocean pH driven by anthropogenic atmospheric CO_2 (from carbon emissions). This reduces the balance of carbonate in surface waters.	(Orr et al. 2005)
		Carbon emiss*-carbon + deposition	Ocean acidification refers to the decrease in ocean pH driven by anthropogenic atmospheric CO_2 (from carbon emissions). This reduces the balance of carbonate in surface waters.	(Orr et al. 2005)
		Carbon emiss*-sequest*	Ocean acidification refers to the decrease in ocean pH driven by anthropogenic atmospheric CO_2 (from carbon emissions). This	(Orr et al. 2005)

			reduces the balance of carbonate in surface waters.	
		Carbon emiss*-acidification	Ocean acidification refers to the decrease in ocean pH driven by anthropogenic atmospheric CO_2 (from carbon emissions)	(Orr et al. 2005)
		Carbon emiss*-pH	Ocean acidification refers to the decrease in ocean pH driven by anthropogenic atmospheric CO_2 (from carbon emissions)	(Orr et al. 2005)
		Carbon emiss*-carbonate	Ocean acidification refers to the decrease in ocean pH driven by anthropogenic atmospheric CO_2 (from carbon emissions). This reduces the balance of carbonate in surface waters.	(Orr et al. 2005)
9	C-D	Acidification-plankton	Acidification (reduced pH) impacts calcification required for making calcium carbonate shells, which some species of plankton have (pteropods, coccolithophores, krill, etc.).	(Orr et al. 2005)
		Acidification-kelp	Reduced pH (ocean acidification) impacts kelp gametophytes	(Klinger and Kershner 2008)
		Acidification-lobster	Acidification (reduced pH) impacts calcification required for making calcium carbonate shells.	(Orr et al. 2005)
		Acidification-squid	Acidification (reduced pH) impacts calcification required for making calcium carbonate shells.	(Orr et al. 2005)
		Acidification-abalone	Acidification (reduced pH) impacts calcification required for making calcium carbonate shells.	(Orr et al. 2005)
		Acidification-urchin	Acidification (reduced pH) impacts calcification required for making calcium carbonate shells.	(Orr et al. 2005)
		pH-plankton	Reduced pH impacts calcification required for making calcium carbonate shells	(Orr et al. 2005)
		pH-kelp	Reduced pH impacts kelp gametophytes	(Klinger and Kershner 2008)
		pH-lobster	Reduced pH impacts calcification required for	(Orr et al. 2005)

			making calcium carbonate shells	
		pH-squid	Reduced pH impacts calcification required for making calcium carbonate shells	(Orr et al. 2005)
		pH-abalone	Reduced pH impacts calcification required for making calcium carbonate shells	(Orr et al. 2005)
		pH-urchin	Reduced pH impacts calcification required for making calcium carbonate shells	(Orr et al. 2005)
		Carbonate-plankton	Reduced available carbonate impacts calcification required for making calcium carbonate shells	(Orr et al. 2005)
		Carbonate-lobster	Reduced available carbonate impacts calcification required for making calcium carbonate shells	(Orr et al. 2005)
		Carbonate-squid	Reduced available carbonate impacts calcification required for making calcium carbonate shells (mouth of squid)	(Orr et al. 2005)
		Carbonate-abalone	Reduced available carbonate impacts calcification required for making calcium carbonate shells	(Orr et al. 2005)
		Carbonate-urchin	Reduced available carbonate impacts calcification required for making calcium carbonate shells	(Orr et al. 2005)
10	D-E	Plankton-whale	Baleen whales feed on plankton	
		Plankton-anchov*	Anchovy feed on plankton	http://www.pfeg.noaa.gov/research/climatemarine/cmffish/cmffishery4.html
		Plankton-sardine	Sardine feed on plankton	http://www.pfeg.noaa.gov/research/climatemarine/cmffish/cmffishery4.html
		Plankton-mackerel	Mackerel feed on plankton	http://www.mi.mun.ca/mi-net/fishdeve/mackerel.htm
		Plankton-rockfish	Kelp forests harbor juvenile rockfish	(Gaines and Roughgarden 1987)
		Plankton-seabird	Seabirds, such as storm	

			petrales and gulls, feed on large plankton (such as krill)	
		Kelp-otter	Kelp provides refuge for otters.	
		Kelp-rockfish	Kelp provides refuge for rockfish.	
		Kelp-seabird	Kelp provides refuge for seabirds	
		Lobster-sheephead	Sheephead eat little lobster	Matt Kay pers. comm.
		Lobster-otter	Otter eat lobster	No documentation (Matt Kay pers. comm.)
		Squid-whale	Sperm whales eat squid	(Smith and Whitehead 2000)
		Squid-mackerel	Mackerel feed on squid	http://www.dfg.ca.gov/marine/mspcont1.asp
		Squid-seabird	Seabirds eat squid	(Montevecchi and Myers 1995, Croxall and Prince 1996)
		Abalone-otter	Otters eat abalone	(Fisher 1939, Estes and Palmisano 1974, Hines and Pearse 1982)
		Urchin-sheephead	Sheephead eat urchin	(Tegner and Dayton 1981, Cowen 1983)
		Urchin-otter	Otter feed on urchin	(Fisher 1939, Estes and Palmisano 1974)
11	E-F	Sheephead-fishing	"Intense fishing has affected the abundance and size distribution of spiny lobsters and sheephead"	(Tegner and Dayton 2000)
		Sheephead-harvest	Consumptive fishing impacts (harvest) sheephead populations	(Tegner and Dayton 2000)
		Sheephead-scuba div*		
		Sheephead-recreational fish*	Recreational fishery depend on sheephead populations	
		Sheephead-commercial fish*	Commercial fishery depends on (and impacts) sheephead population	(Tegner and Dayton 2000)
		Whale-fishing	Whales have gotten caught in various types of fishing gear	
		Whale-whale watch*		
		Whale-scuba div*		
		Otter-fishing		
		Otter-harvest		

		Otter-scuba div*		
		Otter-recreational fish*		
		Otter-commercial fish*		
		Anchov*-fishing		
		Anchov*-harvest		
		Anchov*-scuba div*		
		Anchov*-recreational fish*		
		Anchov*-commercial fish*		
		Sardine-fishing		
		Sardine-harvest		
		Sardine-scuba div*		
		Sardine-recreational fish*		
		Sardine-commercial fish*		
		Mackerel-fishing		
		Mackerel-harvest		
		Mackerel-scuba div*		
		Mackerel-recreational fish*		
		Mackerel-commercial fish*		
		Seastar-scuba div*	People see sea stars when SCUBA diving	
		Rockfish-fishing	Fishing practices have reduced rockfish populations	
		Rockfish-harvest	Fishing practices (harvesting) have reduced rockfish populations	
		Rockfish-scuba div*	SCUBA divers can view rockfish	
		Rockfish-recreational fish*	Some recreational fisheries depend on rockfish	
		Rockfish-commercial fish*	Some commercial fisheries depend on rockfish	
		Seabird-fishing		(Dietrich and Melvin 2004, Becker and Beissinger 2006)]
		Seabird-harvest		(Dietrich and Melvin 2004)
		Seabird-scuba div*		
		Seabird-recreational fish*		(Becker and Beissinger 2006)
		Seabird-commercial fish*		(Becker and Beissinger 2006)
12	A-C	Cement-carbonate		(Hanle et al. 2004)

14	B-D	Carbon dioxide-plankton		(Orr et al. 2005)
		Carbon dioxide-kelp		(Klinger and Kershner 2008)
		Carbon dioxide-lobster		(Orr et al. 2005)
		Carbon dioxide-squid		(Orr et al. 2005)
		Carbon dioxide-abalone		(Orr et al. 2005)
		Carbon dioxide-urchin		(Orr et al. 2005)
15	D-F	Plankton-fishing		
		Kelp-harvest	Kelp is harvested commercially in California State waters.	
		Kelp-scuba div*	Kelp forests make the SCUBA diving experience for California waters	Personal observation
		Lobster-fishing	"Intense fishing has affected the abundance and size distribution of spiny lobsters and sheephead"	(Tegner and Dayton 2000)
		Lobster-harvest	"Intense fishing has affected the abundance and size distribution of spiny lobsters and sheephead"	(Tegner and Dayton 2000)
		Lobster-scuba div*	Lobster are a highlight of night diving.	Personal observation
		Lobster-recreational fish*	"Intense fishing has affected the abundance and size distribution of spiny lobsters and sheephead"	(Tegner and Dayton 2000)
		Lobster-commercial fish*	"Intense fishing has affected the abundance and size distribution of spiny lobsters and sheephead"	(Tegner and Dayton 2000)
		Squid-fishing		
		Squid-harvest		
		Urchin-fishing		
		Urchin-harvest		
		Urchin-scuba div*		
16	A-D	Plankton-power plant		(Poornima et al. 2006)
17	A-E	Transportation-whale		(Jensen and Silber 2005, Kraus et al. 2005)
		Shipping-whale		(Jensen and Silber 2005, Kraus et al. 2005)
18	A-F	Motor-fishing		

		Motor-harvest		
		Motor-whale watch*		
		Motor-scuba div*		
		Motor-recreational fish*		
		Motor-commercial fish*		

Appendix B. Selection and compilation of laws for ocean acidification case study

Running the gaps and overlaps analyses for the case study of ocean acidification required additional laws in order to fully represent the spectrum of management relevant to this issue. In addition to those that were already collected for as part of this dissertation (see Chapter 2 Dataset of Ocean Law), the focus of the case study required compilation of air quality law. Laws on the federal and state level needed to be added to this marine collection to represent management of air quality, monitoring of pH, carbon emissions, and the problem of acidification.

Additional State law

For the State of California Code, I searched the leginfo.ca database for the following terms:

- carbon dioxide
- emission
- pH
- carbon + deposition
- carbonate
- alkalinity
- acidification
- mollusk

Laws containing the majority of these terms typically pertain to air or freshwater quality regulation; therefore, many were not in my existing collection. Although some laws containing these terms were already in my collection, there were 42 additional source documents added (

Table B.2). Additions included Global Warming Solutions Act of 2006 and the Atmospheric Acidity Protection Act of 1988, and the Waste Heat and Carbon Emissions Reduction Act, in addition to others (

Table B.2, Table B.2). These documents were collected in articles of sections as provided by the State of California. This format was compiled consistent to the source documents of the CCLME collection. Also, these source documents were divided into individual sections, as described in Chapter 2, creating smaller section-size text documents (elements) that were consistent with the rest of the collection for the gaps analysis. There were a total of 1,008 sections added, which resulted in the performing the analysis on 32,818 sections of law for the State of California.

I did not compile additional administrative code from the California Code of Regulations for this case study due to the complicated process necessary to collect these.

Table B.2.California Code added to CCLME collection for gaps analysis of ocean acidification.

FileID	Description or Name of Law
2-cabpc_1200-1214.txt	BUSINESS AND PROFESSIONS CODE SECTION 1200-1214
2-cabpc_1740-1777.txt	BUSINESS AND PROFESSIONS CODE SECTION 1740-1777
2-cabpc_19560-19578.txt	BUSINESS AND PROFESSIONS CODE SECTION 19560-19578.1
2-cabpc_8500-8519.txt	BUSINESS AND PROFESSIONS CODE SECTION 8500-8519.5
2-cafac_14511-14564.txt	FOOD AND AGRICULTURAL CODE SECTION 14511-14564
2-cafac_38391-38401.txt	FOOD AND AGRICULTURAL CODE SECTION 38391-38401
2-cagc_53060-53087.txt	GOVERNMENT CODE SECTION 53060-53087.5
2-cahsc_111070-111198.txt	HEALTH AND SAFETY CODE SECTION 111070-111198
2-cahsc_112650-112680.txt	HEALTH AND SAFETY CODE SECTION 112650-112680
2-cahsc_113728-113941.txt	HEALTH AND SAFETY CODE SECTION 113728-113941
2-cahsc_114057.txt	HEALTH AND SAFETY CODE SECTION 114057-114057.1
2-cahsc_114130-114145.txt	HEALTH AND SAFETY CODE SECTION 114130-114145
2-cahsc_114419-114423.txt	HEALTH AND SAFETY CODE SECTION 114419-114423
2-cahsc_116775-116795.txt	HEALTH AND SAFETY CODE SECTION 116775-116795
2-cahsc_125292-10.txt	HEALTH AND SAFETY CODE SECTION 125292.10
2-cahsc_25110-25124.txt	HEALTH AND SAFETY CODE SECTION 25110-25124
2-cahsc_25140-25145.txt	HEALTH AND SAFETY CODE SECTION 25140-25145.4
2-cahsc_25159.txt	HEALTH AND SAFETY CODE SECTION 25159.10-25159.25
2-cahsc_25200-25205.txt	HEALTH AND SAFETY CODE SECTION 25200-25205
2-cahsc_25208.txt	HEALTH AND SAFETY CODE SECTION 25208-25208.17
2-cahsc_38500etseq.txt	HEALTH AND SAFETY CODE SECTION 38505
2-cahsc_39010-39060.txt	HEALTH AND SAFETY CODE SECTION 39010-39060
2-cahsc_39900-39905.txt	HEALTH AND SAFETY CODE SECTION 39900-39905
2-cahsc_40910-40930.txt	HEALTH AND SAFETY CODE SECTION 40910-40930
2-cahsc_41500-41514.txt	HEALTH AND SAFETY CODE SECTION 41500-41514.10
2-cahsc_44010-44025.txt	HEALTH AND SAFETY CODE SECTION 44010-44025
2-cahsc_44030-44045.txt	HEALTH AND SAFETY CODE SECTION 44030-44045.6
2-calc_7965-7985.txt	LABOR CODE SECTION 7965-7985
2-capc_0369-402.txt	PENAL CODE SECTION 369a-402c
2-capc_0830-832.txt	PENAL CODE SECTION 830-832.17
2-caprc_12210-12211.txt	PUBLIC RESOURCES CODE SECTION 12210-12211
2-caprc_19515-19519.txt	PUBLIC RESOURCES CODE SECTION 19515-19519
2-caprc_00600-615.txt	PUBLIC RESOURCES CODE SECTION 600-615
2-capuc_2840-2845.txt	PUBLIC UTILITIES CODE SECTION 2840-2845
2-capuc_2860-2867.txt	PUBLIC UTILITIES CODE SECTION 2860-2867.4
2-capuc_8340-8341.txt	PUBLIC UTILITIES CODE SECTION 8340-8341
2-cartc_6351-6380.txt	REVENUE AND TAXATION CODE SECTION 6351-6380
2-cashc_0163-164.txt	STREETS AND HIGHWAYS CODE SECTION 163-164.56
2-cauic_9700-9702.txt	UNEMPLOYMENT INSURANCE CODE SECTION 9700-9702
2-cavc_27700.txt	VEHICLE CODE SECTION 27700
2-cavc_28060.txt	VEHICLE CODE SECTION 28060

Additional Federal law

For the Federal United States Code, I searched the U.S Code online database (http://uscode.house.gov/download/download.shtml) for the following terms:

- carbon dioxide
- emission
- pH
- carbon + deposition
- carbonate
- alkalinity
- acidification
- mollusk

Laws containing the majority of these terms typically pertain to air or freshwater quality management; therefore, many were not in the existing collection. Although some laws containing these terms were already in the original collection, I added another 18 additional source documents (Table B.2). Additions included Energy Policy of 2005 and the Clean Air Act, in addition to others (Table B.2). I collected these documents in chapters of sections as provided by the U.S. Code, consistent to the format of source documents in the CCLME collection. Combined with the federal source documents of the CCLME compilation, there were 742 source documents for federal level used in the overlaps analysis of this case study. Also, I divided these source documents into individual sections, as described in Chapter 2, creating smaller section-size text documents (elements) consistent with the rest of the collection for the gaps analysis. There were a total of 1,020 sections added, which resulted in the performing the analysis on 33,405 sections of law for the U.S. federal level of management.

I did not compile additional administrative code from the U.S. Code of Federal Regulations for this case study due to the complicated process necessary to collect these.

Table B.3. Federal law (U.S. Code) added to CCLME collection gaps and overlaps analyses of law for the case study on ocean acidification.

FileID	Description or Name of law
1-07_usc_096etseq.txt	Global Climate Change Prevention Act of 1990
1-10_usc_2701etseq.txt	CHAPTER 160 - ENVIRONMENTAL RESTORATION
1-15_usc_2901etseq.txt	Global Change Research Act of 1990
1-15_usc_2953etseq.txt	National Climate Program Act
1-16_usc_1601etseq.txt	FOREST AND RANGELAND RENEWABLE RESOURCES PLANNING
1-16_usc_2101etseq.txt	COOPERATIVE FORESTRY ASSISTANCE
1-22_usc_7901etseq.txt	CLIMATE CHANGE TECHNOLOGY DEPLOYMENT IN DEVELOPING COUNTRIES
1-23_usc_001etseq.txt	FEDERAL-AID HIGHWAYS
1-25_usc_3500etseq.txt	INDIAN ENERGY
1-26_usc_4600etseq.txt	ENVIRONMENTAL TAX
1-30_usc_181etseq.txt	Coal Market Competition Act of 2000, Mineral Revenue Payments Clarification Act of 2000, etc.
1-30_usc_801etseq.txt	Federal Mine Safety and Health Act
1-42_usc_15801etseq.txt	Energy Policy of 2005
1-42_usc_8901etseq.txt	ACID PRECIPITATION Act of 1980
1-42_usc_13201etseq.txt	Energy Policy Act of 1992
1-42_usc_6201etseq.txt	Energy Policy and Conservation Act of 1975, 'Energy Act of 2000'
1-42_usc_6901etseq.txt	Storage Tank Compliance Act, Medical Waste Tracking Act of 1988', Hazardous and Solid Waste Amendments of 1984', Waste Disposal Act'
1-42_USC_7401etseq.txt	Clean Air Act

Appendix C. Glossary of terms

Block – Used in case study (Chapter 7) to refer to a partition of the matrix that represents a conceptually modeled ecosystem. The model matrix was partitioned according to the modeled *categories*.

Category – Groupings used to delineate the conceptually modeled ecosystem boundaries. Each category represented a set of ecosystem *components*. The case study uses six categories to represent the chain of explanation related to *ocean acidification*: Source, Cause, Effect, Direct Impact, Ecological Impact, and Human Systems Impact.

Component – Refers to the elements that make up an *ecosystem*, including species, human activities, habitats, and biophysical processes.

Data mining - Application of computer science techniques to discover patterns in data and between datasets that would not have otherwise been possible without the processing power of computer programming languages. The term "data" assumes some type of structure that can be used to analyze the information.

EAM – see *Ecosystem Approach to Management*

EBM – see *Ecosystem-based management*

Ecosystem - An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment, interacting as a functional unit. Humans are an integral part of ecosystems," (Millennium Ecosystem Assessment 2005). Therefore, the *linkages* between humans (activities, uses, and impacts) and other species and biophysical processes inherently constitute an ecosystem.

Ecosystem Approach to Management (EAM) – same as ecosystem-based management for this dissertation (see below). The National Oceanic and Atmospheric Administration (NOAA) uses this terminology in law.

Ecosystem service - Defined by the Millennium Ecosystem Assessment (2005): "Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth. . . Biodiversity is the source of many ecosystem goods, such as food and genetic resources, and changes in biodiversity can influence the supply of ecosystem services" (http://www.millenniumassessment.org/documents/document.300.aspx.pdf)

Ecosystem-based management – "an integrated approach to management that considers the entire ecosystem, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors." (McLeod et al. 2005)

Gap – For this project a *gap* is a critical linkage in the ecosystem that is absent from management

Gaps analysis – *Text mining* analysis developed in this dissertation project to identify *gaps* in management and measure the degree of mismatch between management institutions and a relevant ecosystem.

Ground-truth – Refers to verification meetings and interviews conducted to get feedback from ocean management practitioners and scientific experts for developing and verifying the data analysis techniques created in this dissertation.

Institution – Used throughout the dissertation with Oran Young's definition of an *institution*. Encompasses "rules, cluster of rights, and decision-making procedures" that guide human behavior. As such, *environmental institution* refers to a management system that guides human use and abuse of the environment (Young 1999, 2002).

Institutional interplay - Agencies involved in the overlap often do not coordinate or consult one another adequately to ensure permitted activities are compatible with one another. The resulting institutional interplay can be either beneficial or problematic (Young 2002). Negative interplay can be seen in examples of redundancy, conflicting mandates, inconsistent regulations, and other actions causing inefficiencies and preventing effective management. These problematic cases of institutional interplay are often major obstacles in implementing *ecosystem-based management* decisions. Institutional interplay until now has only been identified on a case-by-case basis and investigated in a qualitative, often descriptive manner

Knowledge discovery – A sub-discipline of Computer Science that investigates developing data and text mining techniques. This field spawned from the rapid growth of digital information (Feldman and Sanger 2007).

Linkage - *Linkages* can include interactions among species and/or habitats, or with biophysical conditions or human stressors (Young 1996).

Misfit – Incongruence between institutions and the ecosystem. There are several ways in which an institution may fit (or not fit) a common pool resource or ecosystem. Problems may derive from any type of misfit, such as when institutions often do not fit with or encompass the spatial or temporal scales or functional processes of the relevant ecosystem in which they play a role (Ostrom 1990, Young

2002, Wilson 2006). Spatial mismatches occur, for example, when the migratory scope of a species spans political borders. This difference in scale prevents any effective control over human behavior outside the jurisdiction unless there is substantial effort in coordinating the authoritative entities (Wilson 2006). Temporal mismatches appear typically through disconnect in time scale between ecosystem functionality and voting cycles and other decision-making procedures that drive political processes. Impacts on marine systems can occur faster or slower than rigid institutional time scales, leading to a lack of policy response to adequately adapt management effectively (Crowder et al. 2006). Used interchangeably with *mismatch*

Mismatch – Incongruence between institutions and the ecosystem. Used interchangeably with *misfit*.

Natural science – Group of academic disciplines such as astronomy, physics, chemistry, and biology that traditionally have investigated questions about the world using laws of nature for a basis of theory. Historically, scientists sought to conduct natural science separate from human dimensions.

Ocean acidification – The chemical process of ocean surface water reducing in alkalinity, referred to as 'ocean acidification' because waters are becoming essentially less basic (Caldiera and Wickett 2003). As water becomes less basic, it is essentially acidifying even though ocean water pH measures higher than 7.0. As the ocean absorbs atmospheric carbon dioxide, in the surface water carbonate bonds with the added anthropogenic CO_2 becoming carbonate (HCO_3^{2-}), which decreases the pH in this water. This chemical change disrupts calcification rates and growth of calcifying organisms, such as coral, some species of plankton, urchins, and probably lobster. However, the chemical impacts will likely have larger repercussions on the physiology of all marine life. In the larger context, the ocean's acidification will reduces the ocean's capacity to effectively sequester CO_2 out of the atmosphere into the deep ocean for hundreds of thousands of years. Thus this means ocean acidification will lead to more rapid buildup of carbon dioxide in the atmosphere, increasing rates of global warming.

Overlap - occurs when multiple agencies have jurisdiction over the same resource and/or activity. Overlaps also occur when agencies have jurisdiction over incompatible activities. Both types of overlap can benefit agencies or multiple sectors when they coordinate or have consistent mandates. However, when an agency makes a decision for one sector, it can result in unintended negative consequences for other sectors (Sutinen et al. 2000, Young 2002).

Overlap Index (OI) - Within any geopolitical jurisdiction for any given topic, the Overlap Index demonstrates the complexity of managing the topic as a function of the combined number of laws and agencies in the topic's management.

Problem of fit – The problem of fit relies on the idea that to achieve sustainable use management systems need to reflect the structure, properties, and processes of the relevant ecosystem. See Young 2002, Folke et al. 2007, Ebbin 2002.

Sector – Refers to tradition divisions of management, such as mining, fisheries, and shipping and transportation, which historically have been driven by industrial use of the ocean.

Sectoral management –Historically government agencies and Congress made decisions within sectors to manage for uses and abuses of the marine environment.

Social science – Group of academic disciplines, such as anthropology, sociology, political science, human ecology, and cultural geography, that use qualitative and quantitative methods to answer questions about human behavior and other human-related aspects of the world.

Species-based management – Regulating fisheries and other natural resources based on individual organisms or populations of species, such as salmon, without stock assessment models including the organism's ecological linkages with other species and habitats.

TDM – see Term Document Matrix

Term Document Matrix (TDM) - A *term-document matrix* (TDM), commonly used to explore text mining techniques (Feldman and Sanger 2007), organizes terms in a table according to the frequency of occurrence in each document in a collection.

Text mining - Application of computer science techniques to discover patterns between documents that would not have otherwise been possible without the processing power of computer programming languages. Text documents are essentially unstructured data when they have no markup and thus require additional preprocessing techniques before they can be analyzed systematically.