Modeling for policy change: a feedback perspective on improving the effectiveness of coastal and marine management

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MODELING FOR POLICY CHANGE: 
A FEEDBACK PERSPECTIVE ON IMPROVING THE EFFECTIVENESS OF 
COASTAL AND MARINE MANAGEMENT 

by 

Donald D. Robadue, Jr., 

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Modeling For Policy Change:
A Feedback Perspective On Improving The Effectiveness Of Coastal And Marine Management

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ABSTRACT

Those advocating for effective management of the use of coastal areas and ecosystems have long aspired for an approach to governance that includes information systems with the capability to predict the end results of various courses of action, monitor the impacts of decisions and compare those results predicted by computer models in order to suggest alterations in the actions needed if the goals are not being achieved. This dissertation draws on system dynamics modeling, content analysis and professional experience to explore four decades of experience in the United States as well as international cases to reveal lessons and strategies for putting into practice the systematic approach sought by advocates of ecosystem-based management of the nation’s, and the world’s coasts and marine areas. Simulations are used to examine the implications of program structure and policy choices in state-level coastal regulatory programs, decisions on a controversial use of marine areas: offshore fish farming, and the ongoing quest for more effective approaches to attaining local success in the sustainable use of coastal resources in poor countries.

Business applications of system dynamics modeling and simulations are relevant for coastal and marine management and policy. The models presented here draw upon structures used in variety of business management cases. These reveal the impacts of delay, the value of acting early on to set policies, and the danger of taking half-measures. Sufficient effort must be mobilized to enforce policies and change behavior patterns before coastal resource scarcity drives up the price of protection as well as the resistance to stringent rules. Development assistance places great emphasis on short term, high impact projects, but local success depends on steady long term support to overcome the
barriers to attaining better management. Fish farming is controversial for environmental reasons, but seemingly stable operations such as bluefin tuna ranching in Mexico are highly sensitive to market fluctuations, the migration patterns of juvenile bluefin tuna and dependent on the abundance of sardine stocks. Plans for greatly expanding operations in Mexico were prepared at the same time the businesses began to decline in production.

Examining long term experiences in coastal management reveals that we already know a great deal about the practice and limitations of adaptive and ecosystem-based management concepts. The concerns of critics of some coastal and marine uses can be incorporated into concept maps of coastal resource use problems. The policy proposals of entrepreneurs and advocates of coastal development can just as easily be tested using insight-oriented models or more detailed and carefully validated simulations. Many management failures can be traced to policy resistance and problems of informatics whose solutions include endogenous strategies. Walt Kelly’s famous Earth Day paraphrase, spoken by Pogo---we have met the enemy and he is us --- remains true. Our failures are often generated by ourselves, not by outsiders or by big, surprising shocks to our governance system. We need the eye-opening, wider view that a systems approach brings, to help us better understand what is holding problems into place, the implications of no action or wrong action, and the formulation and testing of strategies to accelerate evaluation, learning, conservation and an equitable sharing of nature’s bounty and services.

Key words: fish farming, development assistance, integrated coastal management, marine policy, policy informatics, public policy analysis, policy change, policy process, sustainable development, system dynamics, simulation modeling
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Colleagues at the University of Rhode Island and elsewhere have been supportive throughout this effort. Pam Rubinoff made my residency possible by arranging and collaborating in work assignments compatible with Chapters 2 and 3, including funding by the Sea Grant Program, the Packard Foundation and the Rhode Island Coastal Resources Management Council (CRMC). Grover Fugate and Jeff Willis of the CRMC provided data and ongoing reflections on the Rhode Island case in Chapter 2. Raul del Moral-Simanek was a key early collaborator on the tuna ranching model found in Chapter 3. Elin Torell helped draw lessons from the USAID-funded Tanzania Pwani project as well as apply ideas on the local coastal management success model in Chapter 4. Lynne Hale made the first step possible, the sabbatical at MIT, where the notion of pursuing a Ph. D. took root, as well as led early work with Don Seville in 2002 that became the seed of Chapter 4.
DEDICATION

This dissertation is dedicated to the memory of my parents Donald and June, and sisters Patricia and Carolyn, none of whom lived to participate in my graduation day but all of whom believed that I would be able to reach this goal, knowing that I had been infused with the family values of persistence, endurance, adaptability, love of knowledge and optimism. We lost my parents and Carolyn at different times in 2008, which meant putting research and writing on hold for a while, but not set aside, to be finished when the time was right.
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Chapter 1: Introduction

An information-feedback system exists whenever the environment leads to a decision that results in action which affects the environment and thereby influences future decisions.

Jay Forrester, 1961:14

Natural systems evolve and coevolve with management and change. Surprises are inevitable; hence policies must always be adaptive. Some surprises come from the outside...But other surprises are generated inside the system as vulnerabilities grow because both the natural system and people evolve as a consequence of myopic development.

Lance H. Gunderson, C.S. Holling and Stephen S. Light, 1995:491

1.1 Feedback thinking and information flow in integrated coastal resources management

What is it going to take to make coastal and marine management more effective? Those advocating for effective management of the use of coastal areas and ecosystems have long aspired for an approach to governance that includes information systems with the capability to “predict the end results of various courses of action”, monitor the impacts of decisions and compare those results predicted by computer models in order “to suggest alterations in the actions needed if the goals are not being achieved”. As recently as 2009, The President’s Interagency Ocean Policy Task Force notes that after nearly forty years of federal coastal management policy and implementation we are still missing “a more integrated, comprehensive, ecosystem-based, flexible, and proactive approach planning and managing these uses and activities.”

In its newly released proposal, “A Blueprint for Ocean and Coastal Sustainability” a UN interagency group states that after 20 years, “we still find the ocean in peril, coastal communities unable to cope with existing and emerging issues, and all levels of government unable to effect the institutional change required to address these
issues “(IOC/UNESCO, IMO, FAO, UNDP 2011:4) The Global Ocean Forum, a broad-based group of experts, assessed progress since the influential 1992 Earth Summit held in Rio de Janeiro, Brazil, finds that, despite ‘commendable efforts’, the situation for oceans and coasts has gotten worse:

…the conditions of oceans and coasts have continued to deteriorate—marine ecosystems are significantly degraded by a wide range of anthropogenic stressors, exposed to adverse impacts of pollution, overfishing, unsustainable coastal development, impacts from oil, gas, and minerals extraction. (Cicin-Sain, Balgos, Appiott, Wowk, Hamon, 2011: 9)

Both reports contain messages with a great sense of urgency. The Global Ocean Forum declares that “…coastal communities continue to suffer, and the action needed to mitigate these impacts becomes more costly and difficult.” (Cicin-Sain et al., 2011:2) The **Blueprint** emphasizes that “Adequate governance structures and institutional coherence are therefore crucial to effectively respond to growing pressures” (IOC/UNESCO, 2011: 22). This concept extends to economic issues related to its recommended transition to a ‘blue-green economy’ in coastal areas. Governments and the private sector need to address the fact that, at the national level “weak institutional systems can also create barriers to growth. Lack of transparency in permit systems for fisheries, aquaculture, coastal forests, tourism, and oil or gas production” are just a few of the things that need to be addressed through better monitoring and enforcement. Unfortunately, as the Global Ocean Forum warns, “there is no regular collection and assessment of information on the social and economic well-being of coastal communities”(Cicin-Sain et al., 2011:7) making it difficult to track the benefits of the progress that has been made since 1992.
The much prescribed concept of adaptive environmental management requires that society “allow change in practice over time as scientific evidence increases” (IOC/UNESCO, 2011:41) with the aim of reducing the lag time between detection of deteriorating environmental conditions and remedial actions. Taking a science-based approach also is aimed at balancing the competing influence on decisions by resource users, citizens and municipalities:

Together with those responsible for providing information and equitable governance arrangements, science and technology are critical for creating tools to assist in mitigating potential negative impacts. The role of science will include continuing and increasing monitoring and reporting, as well as ‘proving the case’ for changing economic and social behaviours, providing the basis for adaptive ecosystem management, and developing solutions for existing and future challenges. (IOC/UNESCO, 2011:19)

The endeavor of managing the use of coastal areas and ecosystems has long aspired for information systems that offer the ability to “predict the end results of various courses of action”, monitor the impacts of decisions and compare those results predicted by computer models in order “to suggest alterations in the actions needed if the goals are not being achieved”. This view was articulated early on in the MIT- publication The Water’s Edge, which summarized the conclusions of the 1972 Coastal Zone Workshop that helped spark legislative action leading to the 1972 Coastal Zone Management Act in the United States. This view is also relevant today, promoted by the U.S. Commission on Ocean Policy (2004); recommended for coastal land use (Kleppel, Devoe and Rawson, 2006); viewed as an essential element of ecosystem-based management of the coasts and oceans (McLeod and Leslie, 2009) and proposed as a national priority for ocean and coastal policy, (White House Council on Environmental Quality, 2009). It is also the
core of the strategies that will be offered up in 2012 by the ocean and coastal community participating at the Rio+20 Conference.

The system dynamics modeling approach of Jay Forrester was considered by the 1972 Coastal Zone Workshop as a promising direction that could “take into account a multiplicity of inputs in order to assess the impacts of various alternative social actions” over the very long term (Ketchum et al., 1972:346). Forrester had just recently published *World Dynamics* and had stated in an article in MIT’s Technology Review titled “Counterintuitive Behavior of Social Systems” that “until we come to a much better understanding of social systems, we should expect that attempts to develop corrective programs will continue to disappoint us.” (Forrester, 1971:52).

The Stratton Commission, which a few years earlier issued the catalyzing report “Our Nation and the Sea” (Commission on Marine Science, Engineering and Resources, 1969), envisioned cooperative research including modeling, so that “a complex computer simulation model developed for one estuary may have more general applicability to others.” Science and technology was so important in the view of the panel that “The full potential of the coastal zone will be realized only when science and technology are coupled with imagination and sound management to make existing uses more efficient and to introduce new beneficial uses.”

Forty years later, the future has arrived, but not the integrated models that can account for the dynamic among coastal ecosystems, human uses and their impacts, and governance mechanisms that moderate uses in light of an understanding of and valuation of ecosystem conditions. By now, the advocates of a systems view of coastal zone management in the 1970s would have expected to see a mature systematic approach
generating and tracking many “practical management improvements.” They would be pleased with advances in engineering and physical sciences and geographic information systems, and impressed with the expansion and refinement of policies and plans, but disappointed in how little information is generated and utilized to make, implement and track the results of decisions. McLeod and Leslie point out that “there are few examples where ecosystem-based management in coastal and marine areas has been fully implemented” and that “the time has come to move more quickly and efficiently from planning to implementation.” (2009:350) The U.S. Interagency Ocean Policy Task Force declared that: “A broad program of basic and applied disciplinary and interdisciplinary scientific research, mapping, monitoring, observation, and assessment, coupled with development of forecasts, models, and other decision-support tools, is required to build knowledge of ocean, coastal, and Great Lakes ecosystems and processes and ensure that management and policies are based on sound science.”

This finding is echoed in 2011 by the Global Ocean Forum. “It is widely recognized that an integrated approach to the governance, ecosystem science and decision making is required to undertake complex management requirements of EBM/ICM (ecosystem based management/ integrated coastal management)” (Cicin-Sain et al., 2011:19). The Forum report’s authors find several major obstacles in the way of accomplishing this at both the international and national levels:

“Insufficient data on marine ecosystem structure and function
Low national capacity to apply the technical aspects of EBM and ICM
Institutional and sectoral resistance, inertia and inappropriate decision frameworks
Poorly documented economic and social values of coastal areas and oceans, resulting in low political will
Low funding levels for ecosystem science and management institutions
Low adoption rate for integrated ecosystem assessments as the main tool for governance”

Sound science is not the only limiting factor in the way of progress in ocean and coastal management, according to the Interagency Ocean Policy Task Force created by the White House Council on Environmental Quality. A fully integrated approach is required that combines ecological, social, economic and security goals and addresses the reality of conflicting uses, misunderstandings, uncertainty in the decision making process and accumulating impacts. The governance regime for ocean, coasts and land needs “an approach that balances competing uses, including traditional, new, and expanding uses (e.g., energy, aquaculture), minimizes impacts on coastal and ocean ecosystems, ensures sustainable uses under reasonable changes in environmental conditions, and minimizes costs.” (White House Council on Environmental Quality, 2009: 31) Understanding ecosystem resilience needs to be matched by understanding policy resistance. A statement aimed directly to the authors of the Blueprint for Ocean and Coastal Sustainability by Institute for Sustainable Development and International Relations reinforces this point:

Pretending things have been moving in the right direction, although too slowly, would not only be misleading: it would be a strategic dead-end. The only way forward is to recognize the overall failure with regard to ocean governance, to study the few successes at hand, and to develop strategies that seriously take both into account. This means also acknowledging the conflictual dimension of ocean governance and the widespread reluctance – if not active resistance – to make it more sustainable as soon as it comes at a cost. (Billé, Druel, and Rochette, 2011:8)

In brief, society needs to provide governance services up to the job of insuring that our terrestrial, coastal and ocean ecosystems can continue to provide their services. We ought to be able to understand and model the governance service capacity of a given
locality, state or region sufficiently to simulate not only the extent to which ecosystems and their services are lost, protected or restored, assuming perfect implementation, but also what the governance regime is likely to do.

1.2 Research Design

The research presented here uses a system dynamics perspective to examine the ways in which coastal management planning and implementation recognize and address feedback related gaps in information flow, response time delays, and the dynamics of the “balancing act” that characterizes coastal management policy and decision making and problems in the coordination required to slow or reverse use patterns that create mismatches between natural processes and the built environment. Models of three key policy areas where long term implementation experience exists: state level coastal management in the U.S., offshore fish farming (bluefin tuna) in Mexico, and community based coastal management in a developing country setting Tanzania are formulated and tested as part of this exploration.

The research starts with that fact U.S.-based coastal management programs that have direct state-level regulatory authority have been using adaptive, ecosystem-based management approaches since the 1970s, as have some of the earliest international examples of coastal management such as the island nation of Sri Lanka, and some of the more than 100 other countries that have created coastal management programs since the Earth Summit of 1992 (Cicin-Sain et al., 2011:19). In briefing members of the Ocean Policy Task Force during a field trip to Rhode Island in 2009, Grover Fugate, executive director of the state’s Coastal Resources Management Council, “told Jane Lubchenco, executive director of the National Oceanic and Atmospheric Administration, and others at
the University of Rhode Island’s Bay Campus about 26 years of work using special area maps to plan and regulate the state’s coastal waters. ‘You are living in one of the most densely populated areas of the world, but look how pristine that shoreline is — that’s the result of ocean zoning’. (Fugate, 2009) He was referring to the fact that Rhode Island has already been using marine spatial planning and an ecosystem based approach for nearly three decades, including Special Area Management Plans for specific coastal ecosystems that take an integrated, science based approach, and most recently the first ocean zoning plan for a State that includes policy priorities for the use of adjacent Federal waters.

Much can be learned by examining the structure and experience taking a feedback perspective. Rissmiller (2000) notes that “system dynamics might still be the best approach for moving beyond a journalistic diary of political personality and history toward a social science of politics.” He points to the advantage of using historical data and events for understanding policy change, as many modelers do, as well as examining how shocks to the system, as represented by a simulation model, can reveal new aspects of system performance. Small models are strongly recommended as an important way to convey dynamic insights on important policy matters to decision makers and the public. Ghaffarzadegan, Lyneis and Richardson (2010) clearly set out the features of small, insight based models that can shed light on some of the main characteristics of public policy problems, which include:

The policy environment, where feedback within the system generates significant policy resistance
The potentially high cost of undertaking policy experiments, which could benefit greatly from diagrams of the structure of the problem as well as simulations of a wide range of scenarios.

Stakeholder engagement and persuasion, which can be facilitated by diagrams and discussion of simulations.

Policymaker bias and confidence in particular solutions whose repercussions may not be well-understood.

Grasping the endogenous dimensions of policy dynamics rather than erroneously attributing the problem solely to external factors beyond control of stakeholders and decision makers.

The examples provided by Ghaffarzadegan et al., are small, which the authors define as “models that consist of a few significant stocks and at most seven or eight major feedback loops” (2010:23) but represent effective representations of the selected problems and are sufficient for testing scenarios and capable of generating meaningful model outputs that contribute to policy discussions.

The remainder of this chapter traces the origins of a systems approach to coastal management from the early 1970s, which drew on the field of system dynamics and systems oriented information science. This discussion reviews the extent to which systems thinking concepts and models have been incorporated into the design of federal and state coastal management policy, institutions, and information systems or utilized in the literature analyzing this accumulating experience. It characterizes the extent and ways in which documented implementation experience employs feedback concepts to address problematic gaps in information flows, resource use and environmental effects.
(for example Ketchum, 1972; Clark, 1996; Cicin-Sain and Knecht, 1998; Ruth and Lindholm, 2002; Olsen, 2003; Chua, 2006, Kleppel et al., 2006).

The three cases which form the main body of the research are all coastal and marine policy issues with which the author has had direct professional involvement. In the cases of coastal management in Rhode Island and local success for donor-assisted coastal plans in developing countries, the models are based on fairly simple stakeholder conceptualizations of problem definition and situation structure elicited by the author during the preparation of policy and project design documents. For the case of fish farming along Mexico’s Baja Peninsula coast, the author was affiliated with a research team conducting a scientific assessment of the sustainability of the bluefin tuna ranching activity centered in the State of Baja California.

1.3 Overview of Cases

Chapters 2 and 3 present simulation models of intermediate complexity to explore two broad areas of practice noted as priority concerns of the U.S. Ocean Commission. The first is U.S. based state level coastal management planning and regulation which examines the dynamics of the balancing act designed into the legal framework and decision-making approach that has to accommodate and deal with the demand a wide range of private and public uses of the physically and ecologically dynamic coastal zone. Setting and enforcing clear spatial use policies early on, prior to the burst of development pressure in a coastal area can make a big difference. Secondly, the question of sustainability of a single use of coastal waters, offshore fish farming, draws upon the experience of bluefin tuna 'ranching' in Baja California, Mexico. This is a supply chain with a number of important feedback loops involving the decisions of ranching operators,
regulators, the market for sushi grade tuna, as well as important elements of the supply chain out of the control of the fish farming businesses: the migration patterns of juvenile bluefin tuna and the productivity of the sardine fishery. Chapter 4 explores a third area of practice of great international interest, the viability of locally-led coastal management in rural and rapidly urbanizing areas in developing countries. Poor coastal residents endure the fluctuating attention of donors, centralized decision making of national governments, the frustrations and misery of poverty in the midst of private wealth, and rampant overexploitation of the natural systems that make even subsistence living possible.

The inquiry in U.S. state level coastal management in Chapter 2 and the international issues explored in Chapter 4 regarding achieving local success in coastal management in poor nations are core areas of professional practice by the author through his employment at the University of Rhode Island’s Coastal Resources Center. The Joint Ocean Commission Initiative recognizes that: “The same challenges facing our oceans and coasts—fisheries decline, pollution, habitat loss, invasive species, and climate change—are prevalent around the world. Efforts by the United States to address these challenges at home need to be extended beyond our borders” (JOCI, 2009, p. 19).

The tuna ranching study presented in Chapter 3 is related to an international assessment funded by The Packard Foundation involving Dr. Barry Costa-Pierce, the director of the Rhode Island Sea Grant Program, as well as an associated grant from Packard for the author and a large group of others to develop approaches for reducing the impacts of recreational boating and mariculture in Mexico’s Gulf of California (Sea of Cortez). The object in each example is to identify key feedback structures through a review and revision of model structure, and validation, and calibration and testing in
specific settings in the cases of coastal management and offshore aquaculture in chapters 2 and 3. More broadly, the case of local coastal management success for developing countries in examines the interplay of national and local actors to achieve social, economic and environmental results based on a conceptual model elicited from project managers involved in the Coastal Resource Center’s international portfolio, examines the use of systems thinking in the ongoing Tanzania Coastal Management Partnership.

The simulation models presented here are somewhat more complex than “small models”. The models range in complexity from 8 to 19 stocks and dozens to hundreds of causal loops. However each is presented as 6 to 7 small sub-models linked to each other by one or more feedback loops. The advantage of the somewhat more complex models is in the ability to test scenarios specified by stakeholders because sufficient structure is included. In addition to lacking the characteristics of small models, disadvantages include the necessity of being more fully familiar with the entire model to grasp how the parts are connected together, and the larger number of equations that need to be tested and parameters that need to be adjusted as part of a scenario. With too many critical variables, designing and testing meaningful scenarios is made more confusing and difficult. Some powerful feedback loops may remain obscured and unrecognized because of the detail and size. Models rich in feedback loops can also be much harder to troubleshoot. Even so, for all three cases some very simple combinations of policy and parameter tests generate substantially distinct, meaningful responses.
1.4 Research questions

Chapter 2 addresses the question of how a U.S.-based coastal management program with direct state level regulatory authority can function in the much prescribed mode of adaptive management, which requires reducing the lag between detecting environmental conditions and the previous policy formulations implemented to address those conditions while also balancing the competing influence on decisions by resource users, citizens and municipalities. Several relevant prior doctoral dissertations have addressed aspects of these questions and applied other methods. Laverty (1980, University at Albany) focused on citizen participation in the Rhode Island coastal program. Cunningham (1995, Clemson University) utilized permit data base records, staff rosters, council membership and a sample of permits to analyze the South Carolina coastal program, which is similar in structure to the Rhode Island program. Belfiore (2005, University of Delaware) provides a detailed critique of the U.S. and international models of coastal management, focusing on identifying indicators to evaluate coastal program process and outcomes. Imperial (2001, Indiana University) utilizes institutional analysis and development framework to examine Narragansett Bay, and Rhode Island Salt Pond watershed management experiences. Davis (2003, University of Rhode Island) studied 15 special area management plans including Rhode Island's.

The case for which the dynamic model has been calibrated is the program led by the Rhode Island Coastal Resources Management Council (CRMC). It exemplifies a state program that exercises direct state regulation, land and water planning, has long utilized spatial zoning of marine and shore areas and is one of the longest running coastal management programs in the U.S. (Robadue, 2005). The CRMC also extensively
employs special area plans in order to work more closely with stakeholders concerned about a specific ecosystem or coastal economic resource, as well as to mesh local and state decision-making.

Chapter 3 addresses the question of how marine and coastal management might deal with a specialized and controversial form of mariculture in coastal areas: offshore fish farming, specifically the practice of fattening or 'ranching' wild bluefin tuna in pens near shore for sale mainly to Japan. (Robadue and del Moral-Simanek, 2007) Fish farming for high value species such as bluefin tuna is practiced extensively in Mexico, Australia, Japan and the Mediterranean, and has been studied for the U.S., as part of the emerging national ocean policy debate. A detailed content analysis of the result of a science assessment of the Mexican industry is used to refine the original model and to test scenarios for helping the faltering operations recuperate.

Chapter 4 examines the dynamics of local coastal management program success in developing country settings, where the productivity of coastal resources are often a matter of family survival and the capability to govern their use to provide sustained benefits highly constrained. This model is an operationalized simulation of a causal loop diagram of how donor-assisted projects can contribute to local success in coastal management in the context of poor, developing coastal nations created in 2002 during a group modeling exercise with a group of international field level project managers employed by the Coastal Resources Center in projects in Ecuador, Sri Lanka, Thailand, Indonesia, Tanzania and Mexico. (Robadue, D., L. Hale and D. Seville, 2003) The conceptual model, which is operationalized as a working insight-oriented simulation, is utilized to explore the use of systems thinking in the Tanzania Coastal Management
Partnership’s Pwani (coast) Project. The partnership is unusual in its scope since it addresses coastal biodiversity conservation in conjunction with human health and population issues. (Torell et al., 2006; De Souza, 2008) The selection and monitoring of coastal management activities is based upon a dynamic understanding of the links among the social, economic and environmental aspects of local community life, however reporting on progress has to match the strategy and structure of the donor’s results reporting framework, which spans a wide range of investments.

The motivation for selecting these three particular facets of coastal management practice is in the light of the recent and renewed calls for ecosystem based management and integrated planning of coasts and marine areas. The Working Group on Ocean and Coastal Management, in preparation for the 2002 World Summit on Sustainable Development, proposed the ambitious goal that 20% of the 173 national coastlines should be under management by 2012 and 60% by 2022. (Global Conference, 2001). The world is far off from meeting the modest 2012 goal, which is renewed in the proposals being submitted for the Rio+ 20 Conference mentioned above. Both US and international leaders continue to pursue integrated approaches to development assistance in addressing marine and coastal management problems in places that are ready to engage in tackling coastal issues, even if the scope of coverage of programs cannot be easily attained. Renewed interest at the federal level through the President’s Ocean Policy Task Force is putting the spotlight on U.S. states with experience in marine spatial planning and ecosystem based approaches and there is a need as well as to encourage integrated approaches in international development assistance, which, from a coastal management practitioner perspective is plagued by 'stove-piped' programs that fund programs to meet
either biodiversity conservation or economic development or community health and sanitation needs, based upon Congressional 'earmarks', but are unable to take an integrated approach. As noted above, leaders in the ocean and coastal management community continue to advocate for integrated approaches that tie together local, national, and international efforts to implement policies based on the concepts of ecosystem-based management.

Chapter 5 summarizes the aspects of feedback thinking and response that are at work, or absent in some cases, related to coastal and marine management situations that the cases in Chapters 2 through 4 exemplify. Each is formulated based on group discussions and content analysis, and partially validated with empirical information, however none have yet been re-introduced and explored by a client group. The chapter assesses the relative ability of the simulations to capture the key dynamics that affect and can improve the match with environmental conditions, program design and program performance. The informatics needed to incorporate the model structure, parameters and results as part of policy making and management decision making are set out. The chapter concludes with guidance on how elements of each model can contribute to the need for moving past global statements of principles and aphorisms that allude to system dynamics and the pursuit of half-hearted strategies that fail to lead to implementation and scaling up of promising approaches to ocean and coastal management concerns.

1.5 Feedback thinking in coastal and ocean management: a historical perspective

System dynamics concepts and methods are rarely referenced directly in the field of coastal resources management, even though coastal systems and decision-making are dynamically complex and the SD literature offers a rich and relevant body of theory,
practice and models. Recent work in the theory of ecosystem management calls for the use of modeling and is becoming of increasing interest to coastal managers. However, feedback thinking is embedded in the earliest efforts to establish a national coastal management program in the U.S. The Coastal Zone Workshop held in 1972 set out to help “develop, improve, and refine both the factual information and the understanding needed for the wise and effective use of the coastal zone” (1972: xi), setting out the issues which needed to be addressed, the quality of the knowledge base and tools for decision support, and the institutional capacity to manage. The closing chapter is titled “A Systems View of Coastal Zone Management”, and draws upon the ideas of Jay Forrester, Eugene Odum and others from the operational research tradition to set out how coastal management should be functionally organized, as well as the stream of decisions needed to effectively govern complex environmental components.

In operation, the controller implements one policy from a predetermined set of allowable policies. He also senses the effect of a given policy implementation, and, as appropriate, may subsequently select and implement an alternative policy to reduce deviation from the optimum pathway. Even nonlinear and noisy environments may be handled by such means. Memory of past effective policy performances is incorporated into the system. Within the limits of knowledge and program capability, the model may be adapted to new circumstances on the basis of previous experience. (1972:359)

Figure 1.1 is a reformatted version of the nested coastal management process envisioned by the Coastal Zone Workshop participants. The center of the diagram shows the flow of authority and decision-making from federal to state to local, with blue lines and arrows featuring the elements of planning and exercising authority. The left side has an equivalent number of upward pointing variables and arrows representing the role of feedback in formulating, applying and revising guidelines, standards and policies.
Notes for Figure 1.1: The idea put forward by the Coastal Zone Workshop envisioned a tiered or “nested” system for setting policy, making decisions on projects, and monitoring both the health of the governing system and the results and impacts of decisions made on projects through a case-by-case process.

- **The national level** enables the entire system through legislation and the articulation of federal policy, including how state programs should be created as well as standards and regulations.
- **State programs** do the majority of information gathering and monitoring work as well as more detailed standards and guidelines and negotiating what is called “federal consistency” in the 1972 Coastal Zone Management Act.
- **Local programs** have a symmetrical function to play, creating guidelines and policies for their specific jurisdictions within the framework of the state program.
- **Case-by-case decision making** refers to the specific development proposals which the coastal management program reviews, and is mainly envisaged as handling permits or land acquisition. This should not be interpreted as all decisions being made at the local level.
Figure 1.1 A feedback view of the coastal management decision-making system

**Green lines** are explicit information feedback loops to the multi-tiered decision process. **Blue lines** are flow of decision authority.
The language of *The Water's Edge* is not directly from the system dynamics glossary. A content analysis of the full text of the document finds no use of terms such as causal loop, feedback loop, downward spiral, endogenous, exogenous, leverage, positive or negative feedback. On the other hand, terms such as delay, equilibrium, effect, and feedback (only 8 times), flow (72 times), goal (52 times), growth, impact, solution interval, stable, and structure are prevalent. Figure 1-2 illustrates the association analysis for the concepts of stock and flow. Systems thinking concepts and metaphors are present in coastal management legislation, policies, plans and operations even though the expression of the ideas does not follow system dynamics conventions.

The treatment of the core ideas on how to make and track the outcomes of decisions made in the complex environmental setting of the coast is not as clear, in SD terms, however it is prescient of the currently popular representation of systems thinking alternately labeled Pressure- State- Response, (PSR) or Driving Forces- Pressures-States- Impacts- Responses (DPSIR). This approach has been adopted by the Organization of Economic Cooperation and Development (OECD) and the European Environmental Agency as its framework for mapping the relationships of society and environment.

The original graphic from *The Water's Edge* depicting how the process and information flows in coastal management are combined to create what is now called adaptive ecosystem management is shown in Figure 1.3. Some annotations have been added to clarify its meaning. The area at the top, Level C, is where goals are set and modified, and continuous, ever-improving systems analysis and modeling takes place. Level B corresponds to management and decision-making, and can be interpreted as
containing a glossed-over version much of the multi-tiered decision process shown in
Figure 1.1. The “use-impact level”, Level A, is the trouble spot for this representation of
the systems thinking.

**Figure 1.2** Frequency of appearance of terms associated with the term “stock” and
“flow” or representing other system dynamics concepts

Frequency of appearance of terms associated with the term “stock” and “flow” or representing other system dynamics concepts in “The Water's Edge” (Ketchum, 1972). The terms “stock” and “flow” are not used in the document in the system dynamics sense.
**Figure 1.3** The Integrated Model from the Coastal Zone Workshop

**A: Impact Level.** Decisions are made that change the combination of environmental conditions from one “state”, S1, to another, such as a graph or set of graphs of the levels of resource stocks over time.

**B: Managerial level.** A nested system of decision processes (the blue lines in Figure 1.1) operates at the managerial level to insure that good information is being used, and that the nature and consequences of the decisions are recorded and tracked.

**C: Referee (goal) level:** Knowledge from a variety of sources, including scientific research and decision monitoring is assembled, synthesized and fed back into the management system.

Much of the text of *The Water's Edge* reflects a clear and sophisticated understanding of the functioning of ecosystems, along with a deep sense of the inadequacy of then existing methods and decision making procedures. Its representation
in this diagram is not very clear. The National Environmental Policy Act had been
adopted only three years earlier and is represented as “A: Impact Level”. The
environmental impact assessment (EIA) was viewed at the time as both as fundamentally
important as well as flawed in its execution.

The major impediment to thorough analysis lies in the identification and
evaluation of impacts. Shortsighted planners have perhaps been reticent to pursue
identification of secondary and lower-order impacts because the difficulties of
evaluation are so well recognized. Quantification, or at least qualification, of
many types of impacts has as yet been largely ignored. We all know that wetlands
have significant value to the coastal ecosystem, but these values have yet to be
expressed in terms that fit the present decision-making system. (Ketchum,
1972:201)

The depiction of “A: Impact Level” is attempting to capture the idea that society, if it
uses the methods and information prescribed for coastal management, can choose
between desired and unwanted outcomes, or future states of coastal resources. This belief
characterizes the most recent US statements of commitment to ocean and coastal policy,
and underlies the urgent pleas for more resources and faster action at the global level. It
points correctly to the fact that it is human actions that are being managed, not the state of
the environment directly, and further, that monitoring of both management and
environmental processes is important. The diagram, unfortunately, has a break in logic,
shifting from a representation of a continuously flowing system to one that shows a single
instance of a shift in the environment from State S1 (right now) to one of two possible
States S2 in the future, with the result dependent on the quality of decisions society
makes. The arrows pointing downward in Figure 1.3 represent the control system, the
same as in Figure 1.1, and the two upward pointing gray arrows added by the author
show how the diagram depicts a continuous upward flow of information both on human activities, and environmental conditions.

Figure 1.4 attempts to rectify this diagrammatic confusion with a causal loop diagram representation of “A: Impact Level” utilizing a basic bathtub model structure. The State of the Coastal Environment is shown as a single stock, which would change in value over time, rather than showing each new state as a separate box in sequence S1, S2 etc. Keeping with stock and flow diagramming convention, there is both regeneration of the environment stock and damage to the stock. Information flow, shown as dashed lines, out of the top of this stock is part of what defines the gap between its condition or level, and what is desired. The other component is the desired state of the environment, or goal, which is generated by C: Referee system. The result is a simple, combined representation of physical and information flows.
Figure 1.4 incorporates a time delay as well as imperfections in the quality of environmental information, and these generate the “perceived gap”, which is all that managers can know about. Translators feed information to the managerial decision process, which is not shown in detail here, rather it is found in Figure 1.1. Management is also monitored at Level C and contributes to the ongoing systems analysis. The aim is to reduce human damaging activity, or to explicitly decide that a planned State S is going to be based upon a trade-off that “represents, in essence, balancing the preliminary version of the planned state with socioeconomic conditional constraints through the
mechanisms of the marketplace, government administration, and the courts with judicious input through public information media.” (Ketchum, p. 355)

Understanding environmental systems better was seen as the main success factor for management and the Workshop was optimistic. “The primary goal of the discussion of a systems approach has been to demonstrate both the necessity and feasibility of developing a model for evaluating the potential effects of conceived alternate courses of action as a component of the necessary decision-making processes....At best, systems approaches can establish the framework for handling the entire coastal zone management job” (p. 362). The expectation was in fact for an “electronic oracle” (Meadows and Robinson, 1985) or answer-machine, the need was to generate the information needed to create, evaluate and use such models, and “development of the managerial and technological framework within which the society-ecosystem relationship may successfully be controlled” (Ibid).

1.6 Coastal management program progress and prospects since 1972

The Working Group on Ocean and Coastal Management, in preparation for the 2002 World Summit on Sustainable Development, proposed the ambitious goal that 20% of the 173 national coastlines should be under management by 2012 and 60% by 2022 (Global Conference, 2001). The optimism of these goals is counterpoised by the observation of a long-standing expert in the field who perhaps speaks for many of his peers by drawing the dismal conclusion that “The practice of Integrated Coastal Management (ICM) is learning relatively little from its 35 years of experience involving approximately 698 ICM efforts at all levels of governance, in all parts of the world, in all
types of political regimes, in all types of environments, and at all levels of national
economic development. ICM practitioners appear to have little time (and often facilities)
for information searches and reading to find answers to specific questions they have [in
order] to design or improve their program” (Sorensen, 2000.)

The United States has long since exceeded these targets, and has been a pioneer in
coastal management policy and program development since the adoption of the federal
Coastal Zone Management Act in 1972. The voluntary program now covers 34 states
and territories.

State Programs take three basic forms:

(A) Local Programs: State establishment of criteria and standards for local
implementation, subject to administrative review and enforcement.

(B) Direct State land and water use planning and regulation.

(C) Networked Programs: State administrative review for consistency with the
management program of all development plans, projects, or land and water
use regulations proposed by any State or local authority or private
developer.

Virtually the entire national shoreline, encompassing 95,376 miles including the
Great Lakes region are managed through state programs approved by the federal Office
Ocean and Coastal Resources Management. State coastal management programs in the
United States that directly regulate uses in the marine and shore area frequently utilize
“special area plans” as a complementary approach for addressing issues and promoting
effective implementation for environmentally or economically important areas where no
single actor or agency has sufficient jurisdiction, influence or resources.
Tracking and evaluating the decisions made through the coastal management process has not been the strength of U.S. coastal management at the federal or state levels. Cicin-Sain and Knecht lament:

However, because base-line data on the condition of the coasts were not collected at the outset of the program, it is difficult to assess on-the-ground improvements such as acreage of wetlands protected and miles of coastal public access acquired or protected or to evaluate whether management of coastal development has resulted in the maintenance of coastal ecological and human amenity values. (1998, p. 296)

The Heinz Center (2004) examined the learning and information needs of U.S. coastal managers. Their report observes that

Coastal managers are keenly aware that the problems their predecessors were addressing in the 1970s and 1980s were only the obvious ones—curbing the physical destruction of coastal habitats, treating industrial and municipal wastes, providing for greater public access to the shore, and so on. Today, there is greater scientific understanding and documentation of the complexities and interrelationships of coastal problems, and as layers are peeled away, there is also an appreciation for what we do not know. (Heinz Center, 2004: 19)

Despite this sense that “obvious” problems are being handled, development pressures appear to be overwhelming current capacity acknowledging that studies of the Pew Oceans Commission and the U.S. Commission on Ocean Policy “clearly document the continued ecological decline—indeed crisis—facing our coasts and oceans. Our management principles, institutions, practices, capacity, and political will to squarely face the problems are all insufficient to reverse the decline”.

The U.S. Commission on Ocean Policy (2004) completed a thorough review of marine and coastal programs and concluded that there is much more to be done in coastal management in the U.S. context:
To more effectively manage coasts, states need a stronger capacity to plan for and guide growth---one that incorporates a watershed approach to govern coastal and ocean resources. In addition, to assist states in such development and support the move toward an ecosystem-based management approach, federal area-based coastal programs should be consolidated to better integrate and capitalize on the strengths of each. [2004:109]

The vision of the U.S. Commission on Ocean Policy has the nation moving toward an ecosystem approach that will encompass coastal watershed management and coordinated, policies across agencies and levels of government and a seamless implementation approach that eliminates duplication and fosters synergy including in trans-boundary and international situations. In addition:

Social and natural resource assessment and planning at the watershed scale should become a high priority in each state’s program...The Coastal Zone Management Act can be strengthened by developing strong, specific, measurable goals and performance standards that reflect a growing understanding of ocean and coastal environments, the basic tenets of ecosystem-based management, and the need to manage growth in regions under pressure from coastal development. [2004:112]

The Heinz Center points out, however, that we are not in good shape in terms of sustained information collection and analysis for an integrated understanding and reporting on the state of the environment to decision makers at the top tiers. Noting that “it is important to foster a broad view of a “system,” from management and policy choices to end user—and to involve a wide range of parties in the oversight of this enterprise” (Heinz Center, 2008:29), there remains a large gap between requirements and the current state of affairs. Coastal information is among the weak areas, suffering from “Data gaps constrain reporting on the extent of key aquatic habitats, including coral reefs, submerged aquatic vegetation, coastal wetlands, rivers, streams, riparian areas, lakes, and reservoirs”, and “time trends cannot be reported for many extent and pattern indicators,
including shoreline types, the percentage of cropland in the farmland landscape, the size of "natural" patches, riparian area and land use type, and the extent of grasslands and shrublands, as well as housing density, impervious area and overall extent of urbanized areas.” Just as forty years ago, the Heinz Center concludes that “decision makers and the public need timely, reliable, unbiased, scientifically rigorous information about changes and trends in the state of the nation’s ecosystems—that is, a clear window through which we can see where we are and where we are heading.”

The Report Card produced in 2011 by the Global Ocean Forum on progress since 1992 and 2002 is not any more complicated than Figure 1.4. The score card is summarized as Table 1.1. Information flow problems are a key problem, with continuing limits on scientific understanding and monitoring on the one hand, and little effort to collect information on local social and economic conditions or the capacity for ocean and coastal governance. Billé et al., (2011:2) are not much concerned about some of the constraints: “We argue that significant progress has been made on science – not a limiting factor at this stage, on the diagnosis of threats and governance gaps, and on legal and policy proposals.” Instead of worrying about broad generalizations of the global situation, they propose a focus on very specific problems, for example land based sources of pollution to the marine environment by improving regional approaches to pollution control (focused on international water-bodies such as the Mediterranean Sea or other large marine ecosystems) specific investments in sewage treatment (most developing countries treat little or none of the waste from their fast growing, sprawling urban areas) and using economic measures including reducing subsidies for harmful practices in
agriculture, industry, mining and tourism, and using economic measures to create incentives for waste treatment by the public and private sectors.
### Table 1.1 A Report Card on Global Progress in Meeting Commitments on Oceans, Coasts, and Island States

<table>
<thead>
<tr>
<th>Element</th>
<th>Extent of effort</th>
<th>Extent of progress</th>
<th>Timing-goals reached</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Ecosystem based ocean, coastal management</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protect marine environment from land based pollution</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrated water resources management</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biodiversity, marine protected areas</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Small island developing states</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustainable fisheries and aquaculture</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Marine environment and climate change</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UN coordination on oceans</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reporting on the state of marine environment</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity development</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Source: Global Ocean Forum, 2011 pp. 19-40
1.7 Is coastal management becoming ecosystem management?

There is an element of “It's like déjà vu all over again” (Berra, 1998) in the continual rediscovery of environmental or ecosystem management as a core element of coastal management. Although prescribing it, the U.S. Commission on Ocean Policy does not define what ecosystem-based management means nor does it specifically declare what it considers to be standards of good practice or examples to follow.

Grumbine provides a robust definition that is a good place to start and consistent with the ideas of the Coastal Zone Workshop:

Ecosystem management integrates scientific knowledge of ecological relationships within a complex sociopolitical and values framework toward the general goal of protecting native ecosystem integrity over the long term. (Grumbine, 1994:31)

Although this definition arises from the field of conservation biology, it explicitly places humans and their institutions at the center of the discussion.

A contemporary, consensus definition from the recent book by McLeod and Leslie Ecosystem – based management for the Oceans is as follows:

Ecosystem-based management is 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 and Leslie, 2009:4)

Ecosystem-based management (EBM) is claimed to be new and curative of “current management practices that tend to focus on the short-term provision of single services and under which individual sectors are often working at cross-purposes” and aimed at
conserving “the long term potential of systems to sustain the delivery of a broad suite of ecosystem service”.

The Global Ocean Forum makes a detailed comparison of EBM and ICM approaches, finding similarities and key differences. The most important conclusion they draw is that:

The implied principle may be that ecosystem health is a priority for the reason that without it, ecological services and resources cannot meet human economic and social needs. In comparison, ICM sources more clearly and consistently regard sustainable development as a key goal – assuming a balance of the three elements of environment, economy, and social values. (Murawski, Davidson, Hart, Balgos, Wowk, and Cicin-Sain, 2008)

Grumbine found ten dominant themes in his review of the ecosystem management literature up to the early 1990s. The first is: “A systems perspective: focusing on any one level of the biodiversity hierarchy is not sufficient”.

If this were true in the case of coastal resources management we would expect to find a burgeoning literature on systems approaches that could help explain what states should do as they reexamine their programs, but that turns out not to be the case. The broad vision of the 1972 Coastal Zone Workshop to bring an integrated systems approach and modeling capacity to fruition might be seen as a disappointment in view of such recent declarations and conclusions.

A full text search for feedback thinking and system dynamics terms in the issues of the two major coastal management journals Coastal Management Journal (CMJ) and Ocean & Coastal Management (O&CM) generates seemingly few returns, keeping in mind that the term “system dynamics” itself returned only 11 articles in O&CM (1992 to 2010) and none in CMJ (1973 to 2010). “Feedback” returned 145 articles in O&CM and
45 in CMJ. “Balancing” returned 71 and 21 articles respectively. A scan of the articles that employed some use of the concept “feedback” finds that an author might include a causal arrow or loop in an explanatory diagram describing a process, or the description of a participatory approach either in concept or in a case example, where the term is used in a communication sense. Neither journal has many articles that explicitly show causal loop or stock and flow diagrams of the kind used in the SD literature and practice. Several of these articles mention the term in the context of discussing participatory approaches and the policy process but none explicitly utilize SD concepts or methods. Terms such as feedback (48), flow (49), capacity (57), stock (75), cumulative (81), dynamics (129) models and modeling (259) are far more common in the book by McLeod and Leslie than in the coastal management literature in general.

Perhaps the most well-known text in the field: Integrated Coastal and Ocean Management (Cicin-Sain and Knecht, 1998) contains no references, indexed terms or content sections relating to feedback thinking. A more recent text (Brown et al. 2002) has no references or examples of causal loop or stock and flow models, but does include three indexed references to feedback, one relating to the social dimension, as well as numerous citations to the ecological economics literature and the concept of ecological resilience. Richard Burroughs book Coastal Governance (2011) also makes no use of systems concepts, although he cites The Water’s Edge in alluding to the dynamic interactions among coastal uses. The low utilization of SD concepts and techniques stands in contrast to the importance of scientific information and extensive use of physical and ecosystem modeling of specific issues in ICM to understand shore processes, storm hazards, estuary and bay dynamics and water quality, for example.
Although the recent national commissions and the coastal management literature have not pursued the management dimensions from a feedback thinking perspective, the ecosystem management literature offers coastal management some clarity and guidance. Coastal ecosystems located within or near urban settlements and are actively utilized. Within the broad scheme of ecosystem management, these can be called social-ecological systems, or SES. Drawing again on the ecosystem management literature, a principal concern is resilience, which has two main meanings. *Engineering resilience* is the notion that a system will return to a global equilibrium following a disturbance such as environmental pollution or over-harvesting, so the focus of environmental management is to restore the balance and maintain efficiency. *Ecological resilience*, on the other hand, is the recognition of the ability of ecosystems to shift their functions in response to perturbations, often irreversibly, thus the main management concern is maintaining the existence of a system’s functioning. [Gunderson et. al, 2002]

Social-ecological systems, which combine engineered and natural system components, are complex in ways that make them especially unpredictable, thus “limit the usefulness of forecasting methods for the scientific study and management of regions in transition. Given these limits to understanding, we must focus on learning to live within systems rather than ‘control’ them”. The goal then is “to prevent an SES from moving into undesirable configurations. It depends on the system being able to cope with external shocks in the face of irreducible uncertainty” (Walker, et. al, 2002) Resilient pathways cannot be computed, they are discovered in a process which has elements that are not entirely unfamiliar to coastal managers.
The recommended four steps are:

1. Answer the question “resilience of what?” by conducting a system modeling exercise with strong stakeholder involvement.

2. Answer the question “resilience to what?” by developing visions and a limited set of plausible future scenarios including trajectories that the stakeholders might want to drive the system toward.

3. Conduct a resilience analysis, with “discussions among stakeholders, policy makers, other local experts and scientists aimed at examining how the system will respond and change under the various scenarios”. This is done “using a combination of modeling and non-modeling techniques.”

4. Draw implications for management, having identified the processes that determine critical levels of the system’s important control variables, and the corresponding set of actions that can enhance or reduce resilience.

The authors only offer stylized examples of how to do this analysis but the steps are familiar to the SD community as part of the standard modeling process (Sterman, 2000:86) and in particular drawing upon group modeling (Vennix, 1996; Richardson, Andersen and Luna-Reyes, 2004; Richmond, 1997), and certainly echo the anticipated developments expressed in the 1972 Coastal Zone Workshop.

Yaffee (1999) describes a range of approaches to thinking systematically about coastal resources and their management. He proposes an idealized form, eco-regional management, that involves restoring and maintaining ecosystem function while allowing sustainable human uses, with “the ecosystem as an integrated spatial unit, fitting within a nested hierarchy of geographic units; ...collaborative decision making decentralized to the
eco-region level;...reorganization of management along eco-regional lines.” While he cautions that “one of first steps in collaborative decision making...the development of a shared definition of the problem”, this formulation is actually very familiar to coastal managers and is more in line with the concepts advanced by the Global Ocean Forum.

McLeod and Leslie (2009) address the broader marine and coastal audience with their focus on ocean as well as coastal management issues, much in the tradition of the Stratton Commission and the Coastal Zone Workshop. They pose a key question at the end of their book: “How can we move from management systems designed to consider each sector of human activity in isolation to management systems that embrace the inherent connections among activities and explicitly deal with trade-offs among activities and ecosystem services?” (2009:341). Their view is that the focus in ocean and coastal management has to shift from planning to implementation. McLeod and Leslie identify five areas where this change has to occur:

• create a constituency for marine and coastal stewardship,
• build upon some of the small successes within sectoral programs that they document;
• use area-based management tools that are scaled up and address multiple issues;
• make trade-offs explicit and avoiding optimizing one ecological service over others, and
• obtain new mandates for working across agencies to improve efficiency, not add-on.

Their key research questions for moving forward parallel these concerns (2008:345):

1. What can we learn from how humans have interacted with coastal and marine environments in the past?

2. How do we translate knowledge developed at the local scale to broader geographic scales?
3. What are the cumulative impacts of human activities on ecosystem health and human well-being?

4. How can trade-offs among ecosystem services and sectors be more systematically assessed?

5. How do we evaluate the success of ecosystem-based management efforts?

Three of these questions are addressed in part in the following chapters of this dissertation. Looking back into human history as recommended by Question 1 has been usefully done by many authors, for example Costanza, Graumlich, and Steffen’s recent book *Sustainability or Collapse?: An Integrated History and Future of People on Earth*. Instead, this research effort examines what can be learned from an example of what has happened since the inception of US coastal management at the federal level in 1972, the focus of Chapter 2 is on the case of the Rhode Island Coastal Resources Management Program, which has employed many ecosystem-based management tools. The issue of trade-offs is examined in Chapter 3, which explores the likely sustainability of a new and expanding use of the oceans, fish farming, by examining the case of bluefin tuna ranching in Mexico. The broad reach of Question 5 on evaluating success, is at the core of the *local coastal management success* model presented in Chapter 4, drawing upon a group modeling exercise that identified factors related to success that incorporate social, economic and institutional dimensions in addition to ecological factors. This is combined with a description and discussion of the systems thinking approach used in the Tanzania Coastal Management Partnership to carry out an ecosystem oriented management program for the Northern Tanzania and Zanzibar seascapes.
1.8 The possibility of transformation in fostering a feedback perspective on policy making

Donella Meadows and Jenny Robinson directly challenge modelers trying to address social and policy issues, wondering if: “instead of seeing themselves as scientific adjuncts to the policy process, [they] could shift to seeing themselves as experimental, and even compassionate, their practice would be turned inside out. ...They could participate in experiments, publicize and learn from their mistakes, work closely and honestly with people, communicate clearly” (Meadows and Robinson, 1985: 428) Their notion of wisdom cuts against the grain of the positivist spirit that characterizes the aspiration for a rational system of governing human uses of ocean and coastal ecosystems. This idea points to a seeming paradox of the aspirations of an increasingly scientific management of human use of ecosystems which requires at the same time a necessary humility, compassion and open-mindedness that allows for the possibility of transformation.

Schwarzer et al. (2001) in reporting out the conclusions of their portion of the Dahlem Workshop on Science and Integrated Coastal Management, held in Berlin in 1999, show an unusual awareness of this apparent dilemma. They interpret “wisdom” as effective use and communication of science in the ICM process (Schwarzer et al., 2001:166). The panel recognizes how uncertainty in scientific information leads to having it ignored, yet the ability to express and deal with uncertainty is an essential element of the scientific process. Researchers can be much more tuned in to decision maker and stakeholder concerns but the latter groups have a big responsibility to become
educated enough to work effectively with scientists, perhaps with the aid of 'information brokers' or extension agents. This is particularly the case in coastal management, where risk to humans and their businesses, residences and infrastructure, are high, and the risks posed by humans to the integrity of these coastal systems is likewise high.

Much of the management of shoreline development is directed towards minimizing and mitigating risk of natural processes on human activity, and of human activity on natural systems. Effective communication of science could assist in making the decision-making realm more objective and “less individual”, as explicit knowledge becomes internalized by decision-makers. At the same time, increased emphasis on the needs of managers for scientific research could make science more relevant and responsive to social goals. (Schwarzer et al., 2001:182).

Meadows and Robinson, in essence speaking to all coastal management researchers, warn that “modelers may enter their profession in hopes of becoming oracles, of knowing all there is to know and of seeing clearly into the future. But if they let it do so, the profession itself will nudge them in the direction of becoming sages, questioning conventional wisdom, examining the ultimate purposes that should guide decisions, and shaping the future rather than predicting it.” (Meadows and Robinson, 1985:437). The Dahlem Workshop panel on shoreline management could not help but adopt this spirit by questioning conventional practices, highlighting a strong concern about the impacts of delay on policy success, drawing the analogy of the opportunity costs of delay (including delay in getting coastal permits issued) in business. “If the response-delay time is too long, then the results will be a catastrophic collapse of coastal economy or natural systems...[for example] tourism development due to increased resort development while the coastal landscape is becoming less attractive to tourists.”

The problem of delay is particularly worrisome in developing country settings where “suffering from fragile economics, only a few actions can be taken before there is
a drastic reduction of environmental capital.” (Schwarzer et al., 2001:176) In considering
the broader question of carrying capacity, which needs to have a scientific basis, and
requires ongoing investments in the technology to reduce and treat waste discharges and
other impacts they note: “Assimilative capacity is an integral part of the carrying
capacity and is a finite resource that, when exhausted, impairs the economic functioning
of the environment.” (Ibid., 175)

Knowing when such collapses in capacity might occur (the oracle role) is one
pathway, and scientific progress continues to be made in understanding the dynamics of
shoreline systems. Another path perhaps is simply being able to generate plausible
simulations that indicate the possibility of their occurrence and the potential to avoid
them (the transformation role), especially in data poor areas where high quality localized
information is not going to be collected. “A learning-by-doing policy works only if
learning is fast enough”, the panel warns. “Otherwise, shoreline development will
continue to be ruled by crisis management.” In practice, ad hoc shore management
policies and actions are inherently difficult to predict and decisions have to be made
driven by values and an eye to future generations. “Human interference rarely produces
linear and straightforward reactions or interrelations. Synergistic and antagonistic
reactions, and different stages of ecosystem development and maturity play an important
role in determining the degree and critical level of assimilative capacity in systems
simultaneously receiving physical (e.g. land development), chemical and biological
inputs (e.g., industrial wastes, domestic sewage). These synergies make it difficult to
forecast how systems will adapt to changes in their carrying capacity.” (Ibid., 177) The
Dahlem panel concluded that “Successful communication between different interest
groups activities should result in some transformation of ideas and convergence of
mindsets. It may promote synergy of policies and resources between groups. It should,
also, allow for conflicts to be identified so that resources can be focused on their
resolution.” (Ibid, 187)

The aim of this study is to use feedback thinking and modeling as a way to
explore some examples of at least slow to moderate paced learning in coastal
management, drawing in part upon the author's own professional engagement in the effort
to transform his own profession of coastal management. Echoing Meadows and
Robinson, “If computer modelers can think of transformation as a possibility, if they can
learn the principles of creating it, and if they can bring about a transformation of their
own profession, they will have done more than reform social systems analysis. They will
have found and demonstrated a key, maybe the key, to solving the problems of social
systems.” (Meadows and Robinson, 1985:416) Developers and regulators struggling to
review individual cases decisions will demand specific, accurate predictions from the
coastal management science answering-machine. The focus here instead is to take a
modeling approach in examining recent experiences to shed light on what actually
happens on the social and institutional side as we try to put a plan into action.
Chapter 2: The dynamics of coastal resources management in Rhode Island

“Visioning, networking and truth-telling are useless if they do not inform action. There are many things to do to bring about a sustainable world.”

Donella Meadows, Jorgen Randers, Dennis Meadows, 2004:279

2.1 Introduction

Rhode Island adopted a state coastal management law in 1971, a year before the federal Coastal Zone Management Act, and state program leaders are proud of the fact that the federal statute drew upon concepts and language. As a state program with direct regulatory control of the state's coastal waters, coastal features and a 200 foot wide primary jurisdiction inland of the high water mark, it has been innovative, if not transformative during its first four decades. The author has been involved in developing plans, regulations, policy studies and information systems for the Rhode Island program throughout these four decades, as well as drawing from this unfolding experience to train hundreds of international mid-career professionals using case studies from this setting, and adapting methods and policies to a variety of international settings including Sri Lanka, Thailand, Ecuador, Mexico, Fiji, Tanzania, and Ghana. Most of the information and analysis presented in this chapter was developed between 2005 and 2010.

Of particular importance during this period was the preparation of Rhode Island's Marine Resources Development Plan (MRDP) (Robadue et al., 2006), mandated by the Rhode Island General Assembly (RI Office of the Governor, 2004):

(A) Marine resources development plan. (1) The purpose of the marine resources development plan shall be to provide an integrated strategy for: (a) improving the
health and functionality of Rhode Island’s marine ecosystem; (b) providing for appropriate marine-related economic development; and (c) promoting the use and enjoyment of Rhode Island’s marine resources by the people of the state.” (RI G.L. 2004, Chapter 145. 2004-S 3028A codified as section 46-23-6 (v)(A)(1)).

The MRDP was one of Rhode Island's responses to the call for strengthening by the U.S. Commission on Ocean Policy. The State is focusing on four strategic areas: improving the health and functionality of Rhode Island’s marine ecosystems; providing for appropriate marine-related economic development; promoting the use and enjoyment of Rhode Island’s marine resources by the people of the state; and coastal resources management program leadership and coordination roles, responsibilities and capabilities.

The Marine Resources Development Plan, MRDP, was prepared using unconventional strategic planning techniques emphasizing reflective assessments of economic, social and environmental trends and a design oriented prospective examination of simple scenarios over the course of 2005 by a working group including the author in conjunction with interviews of key stakeholders and public workshops. Key elements of the simulation model and the data on coastal trends and the CRMC shown in this chapter were initially developed during this period. The unusual plan was adopted by the CRMC in January, 2006, won local and regional awards, and has been accompanied by a five year effort to implement many of its provisions and reforms. These include preparing an updated special area management plan (SAMP) for the metropolitan Providence shore, called the “Metro Bay SAMP” (see http://seagrant.gso.uri.edu/metrosamp/). The metropolitan waterfront is the expected locus of commercial and residential growth in the
state over the next decade, along with the western shore of Aquidneck Island and Newport Harbor, stimulated in part by the imminent transfer of selected Navy properties for non-military uses. In addition, the Ocean SAMP was launched to address a key issue of the potential for offshore wind energy development including expanded use of marine spatial zoning in state waters.

The strategic areas are placed within the much larger context of the evolving relationship of the state with its marine resources, in three broadly defined eras: The Era Endless Harvest: Post Civil War to Post World War II The Era of the Suburbs: Post-WWII to the 1980s The Era of Recovery: 1990s to present. (Figure 2.1, Table 2.1) The working group developed a characterization of each strategic area, set out a brief vision statement and desired scenario for the future, and set out several strategic actions to achieve the vision. An important issue in preparing the MRDP was recognizing and finding appropriate ways to adapt the role of the core components of the program, which has direct regulatory jurisdiction over coastal waters and the shoreline.

The dynamics that gave rise to the establishment of the Coastal Resources Management Council (CRMC) in 1971 have changed. The pressures on the CRMC as an institution comprising the Council, staff, consultants, and partners, are different than they were even as recently as a half decade ago...The CRMC finds that uses of marine resources in Rhode Island are intensifying; that optimizing the potential of this intensification will require intentional action—i.e. it will happen by design, not by accident... (RI CRMC, 2006: 1).
Figure 2.1  Eras in Rhode Island development. Rhode Island income was well above the U.S. average until WW II, when its economy was a leading in terms of industry and natural resources.

Figure 2.2  Population dynamics in Rhode Island. The growth of cities, in particular Providence peaked in the 1950s, followed by a wave of suburbanization and now stagnation. Source: US Bureau of the Census, Rhode Island State Planning Program
### Table 2.1: Eras in recent Rhode Island coastal development

<table>
<thead>
<tr>
<th>Era</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The Era of the Endless Harvest: Post Civil War to Post World War II</strong></td>
<td>The industrial revolution bore its most significant results. The City of Providence was the economic and demographic hub of the state due to waves of immigration that built the economy and generated settlement patterns including rural to urban migration. It witnessed successive booms and busts in inshore commercial fisheries and aquaculture. The Bay was the dominant transportation route, as well as the processor of industrial and urban wastes (its assimilative capacity stressed beyond limits). At the same time a regionally important producer of seafood and as playgrounds for rich and poor alike. Governance of coastal resources was ad-hoc and oriented to addressing immediate problems through a profusion of boards and commissions and a few pioneering public officials. Upper Bay water pollution that had killed off oyster beds and fisheries was addressed by building the first municipal sewage treatment plant in the US. Salt marshes and freshwater wetlands were considered wastelands and were filled. Public health, not environmental quality was considered the only concern that might reasonably modify the trajectory of economic growth. Citizens decried the notorious contamination of upper Narragansett Bay before the onset of WW II, mobilizing statewide pressure to get urban wastewater treated.</td>
</tr>
<tr>
<td><strong>The Era of the Suburbs and the White Collar Economy: Post-WWII to the 1980s</strong></td>
<td>Rhode Island’s economy declined prior to WW II. The bay had been transformed, in many ways devastated, by events of mid-century including the Hurricanes of 1938 and 1954. The construction or expansion of military facilities in Quonset Point, Davisville, Melville and Newport industrialized large stretches of shoreline. Discharges of raw sewage to the upper estuary were controlled by massive investments of federal funds in public water treatment facilities. Hurricane barriers across the mouth of the Bay were designed but ultimately rejected. Massive dredging projects were completed to provide a 40ft channel to the harbor of Providence. Bay fisheries stabilized at a new, but far less abundant level. Public support remained high for state spending on pollution control, land conservation and acquisition. It was widely accepted that unregulated economic growth and neglect of environmental impacts resulting from activities at every scale had produced unacceptable consequences. Large scale development proposals were rejected (an oil refinery in Tiverton, nuclear power stations at Rome Point and in Charlestown, an LNG terminal on Prudence Island, additional dredging and, most recently a major port at Quonset-Davisville). However, the cumulative impact of many small development decisions – largely related to suburbanization – proved difficult or impossible to control. The massive investments in water quality treatment, pre-treatment of industrial wastes began to produce major improvements in the condition of the Bay. Remaining wetlands were protected but little progress was made in regulating fisheries. DEM catalyzed efforts at the state and municipal level to conserve remaining open space.</td>
</tr>
<tr>
<td><strong>The Era of Recovery of the Ecosystem and the Information Economy: 1990s to present</strong></td>
<td>Institutional and planning investments and regulatory programs of the 1980s, combined with public funding for construction and operation of waste treatment and management facilities, to yield significant pollution reductions. Urban revitalization became a source of coastal development in addition to continued housing sprawl. Historic preservation, brownfield cleanup and designs that opened up access to the waterfront, occurred in small coastal towns as well as Newport and Providence. These generated new conflicts over shifting purposes for the coastal waterfront, pitting port users against multi-purpose waterfronts favored by planners. Infrastructure projects that had been years in planning now came to pass: dredging the Port of Providence, the realignment of I-195, the Capital Center District, the Jamestown-Verrazano Bridge all take place along the coast. Governance success is characterized by collaboration, vertical and horizontal integration and adaptability. Municipalities are adding more environmental controls to their land use decisions; harbor management plans and special area plans for coastal ecosystems are adopted and revised, watershed councils and strategies are formulated in the sub-basins feeding coastal waters. However, at the state level there remains little integration among the policies and actions of DEM, CRMC, and EDC.</td>
</tr>
</tbody>
</table>
The reflection on eras enabled the working group to take a design-oriented stance both to the institutional and environmental aspects of coastal development, especially since trends showed that use intensification, rather than new development in previously unaltered landscapes and parcels, was the dominant form, generating different issues and policy needs.

The goal of this little vignette is to draw attention to the similarity in structure and functioning of the RI coastal program with the feedback thinking ideas of the Coastal Zone Workshop as well as its striking similarity to ideas about ecosystem-based management today. Rhode Island is one of the first states (1971) to adopt a coastal management law creating a program that engages in direct state regulation of marine and coastal resources, predating the federal law by a year. The state’s Coastal Resources Management Council, was created to perform a balancing act.

It shall be the policy of this state to preserve, protect, develop, and, where possible, restore the coastal resources of the state for this and succeeding generations through comprehensive and coordinated long range planning and management designed to produce the maximum benefit for society from these coastal resources; and that preservation and restoration of ecological systems shall be the primary guiding principle upon which environmental alteration of coastal resources will be measured, judged, and regulated. (General Laws of Rhode Island, § 46-23-1)

Rhode Island's program is approved and funded in part by NOAA's Office of Ocean and Coastal Resource Management as well as permit fees, state funds and other grants. Unlike a number of other state programs, Rhode Island has a fair degree of vertical integration, from addressing federal and state policies, research, planning,
regulatory decision making on routine and environmental monitoring. To carry out its mandate and meet requirements for transparency, for example a strict state open meetings law, it also has to reach out horizontally to engage development and conservation oriented stakeholders, municipalities and several state agencies that have jurisdiction in areas often required to solve a coastal management problem. Information flow for planning, regulatory policy, issue analysis, case by case decision making and monitoring both environmental change and management operations is important. The combined roles of planning and implementation put the CRMC staff in a uniquely knowledgeable position in terms of the kinds of development taking place, the impacts likely to occur, and the conditions in the coast at a given time. It maintains relationships with university partners to influence the direction of scientific research and to carry out a wide range of special projects that engage these combined talents. It played these roles for nearly 40 years, creating a rich and still emerging record of decisions and actions, parts of which are examined in this chapter.
All coastal developments occur in or adjacent to one of the six water use types, which is a simple zoning scheme that sets clear priorities for allowable uses, a policy adopted in 1983 in a major reform of the coastal program called the “Red Book”. It is a little tricky to summarize these policies, since one extended part of the shore is Type 4, and the Sakonnet River, shown on the lower right hand of Figure 2-3, is entirely classified as Type 2, while the shore is Type 1. Otherwise most of the shore area, about 80 percent, is Type 1 Conservation or Type 2 Low Intensity Use. Looked at a bit differently, 5000
acres total area assigned to port and industrial uses, and most of this area is the dredged channels serving the Port of Providence; 650 acres is assigned to commercial waterfront; and about 2000 acres is set aside for recreational marinas and small harbors.

The “Red Book” reforms were transformational in several additional respects. In effect, the CRMC had adopted a paper-based “answer-machine” that embodied a prior decade of learning by the regulatory staff, the Council members, and the Coastal Resources Center at the University of Rhode Island, which had prepared the majority of planning documents and policies up to that point. The water area zoning scheme was the outcome of more than 200 local meetings to gather the ideas and preferences of people down to the neighborhood level. Not surprisingly most people preferred to keep their part of the coast in the condition it already was and to keep commercial and industrial uses where they already were. In effect, the water area zoning scheme which guides all regulatory decisions is a snapshot of Rhode Island in the early 1980's, and as we will see later on, this three-decade-old reality has largely, and surprisingly, remained intact. One other crucial piece of feedback was incorporated into the moment---impending major funding cuts from NOAA. One of the key arguments made for making such a fundamental revision to the program's procedures was that the current, inefficient way of making decisions was too expensive and could not be sustained by a reduced staff.

The second important part of the transformation was to set out as many specific decision criteria for routine development proposals and greatly reduce the number of applications for permits that were decided directly through the elaborate procedures required when the full CRMC met publicly to hear testimony for and against the project. Mailboxes and porches did not require the same scrutiny as a port facility or nuclear
power plant, yet the case-by-case decision procedures were about the same. The “Red Book” created a set of six tables, one for each water zone type, that specified whether 27 different types of common uses were prohibited (P), permitted if the applicant met routine technical requirements specified by the staff (A level decisions) or if the proposed use of an area required the more complex review and hearing by the full CRMC (B level decisions). Many uses in sensitive areas simply were prohibited, and the technical requirements for most others were spelled out in the pages of the “Red Book” or by the evaluations of the CRMC staff. Any applicant could use the “Red Book” to get a good idea whether their development proposal was even allowed, and if so, where, and under what conditions.

**Figure 2.5** Excerpt from decision making tables of the “Red Book”

<table>
<thead>
<tr>
<th>Type 2 Waters</th>
<th>Total Waters</th>
<th>Beaches and Dunes</th>
<th>Undeveloped Barrier</th>
<th>Moderately Developed Barrier</th>
<th>Developed Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filling, Removal, and Grading of Shoreline Features</td>
<td>n/a</td>
<td>P</td>
<td>F</td>
<td>A¹</td>
<td>A¹</td>
</tr>
<tr>
<td>Residential Structures</td>
<td>r</td>
<td>P</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Commercial/Industrial Structures</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>B</td>
</tr>
<tr>
<td>Recreational Structures</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>B</td>
</tr>
<tr>
<td>Recreational Mooring Areas</td>
<td>B</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Marinas</td>
<td>P²</td>
<td>P</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Launching Ramps*</td>
<td>P</td>
<td>P</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type 5 Waters</th>
<th>Total Waters</th>
<th>Beaches and Dunes</th>
<th>Undeveloped Barrier</th>
<th>Moderately Developed Barrier</th>
<th>Developed Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filling, Removal, and Grading of Shoreline Features</td>
<td>n/a</td>
<td>B</td>
<td>P</td>
<td>A¹</td>
<td>A¹</td>
</tr>
<tr>
<td>Residential Structures</td>
<td>r</td>
<td>B</td>
<td>P</td>
<td>P</td>
<td>A</td>
</tr>
<tr>
<td>Commercial/Industrial Structures</td>
<td>B</td>
<td>B</td>
<td>P</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Recreational Structures</td>
<td>B</td>
<td>B</td>
<td>P</td>
<td>P</td>
<td>B</td>
</tr>
<tr>
<td>Recreational Mooring Areas</td>
<td>B</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Marinas</td>
<td>B</td>
<td>B</td>
<td>P</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Launching Ramps*</td>
<td>B</td>
<td>B</td>
<td>P</td>
<td>B</td>
<td>B</td>
</tr>
</tbody>
</table>

For example, Type 2 low-intensity waters prohibit the establishment of recreational structures, marinas and launching ramps in tidal waters and on beaches or dunes. Type 5 commercial waterfront requires a Category B full CRMC review but does not prevent the use. Increasing the specificity of the requirements and showing what is acceptable and unacceptable use, and reforming the decision procedures by allowing for
many more administrative decisions reduced procedural uncertainty and outcome uncertainty for project developers, and increased the certainty that coastal environments would stay the same or possibly even improve in quality.

To complete the transformation, at the same time the “Red Book” was being adopted, another innovation was being put into place, the special area plan, for the urban area of Port of Providence, and the fastest growing and one of the highest environmental quality regions, the Salt Ponds Region along the southern shore of Washington County. One alternative approach that has already proven highly successful in the U.S. (Goss, 2003; NOAA, 1999), and especially in Rhode Island, is the use of special area plans. (Davis, 2004; Davis, Lopez and Finch, 2004) These are the equivalent of copies of the simple coastal world applied to a geographically and ecologically sensible subset of the available plus developed plus conserved sites. Rhode Island has adopted five such plans, and already revised three of them. (Dillingham, 1989; Imperial, 1999; Imperial and Hennessey, 2000) Each special area zone is located in an ecologically sensible and contiguous area, for example the chain of coastal lagoons along the state’s south shore, or Greenwich Bay, located in the mid-section of the encompassing Narragansett Bay. Most special area management zones contain many different coastal features, and multiple types of officially sanctioned uses, but have a common set of stakeholders willing to engage in an ecosystem planning process. Today, as Figure 2.5 shows, about half of the shore area is incorporated into special area management plans, which set out much more detailed scientific and technical information, policies, regulations, and actions using an intensive local participation process, targeted scientific research and detailed technical
studies. All of the special areas are environments of high ecological importance, even though they may also support commercial and industrial uses.

2.2 Research Questions

In 1983, having acted strongly at the “Referee Level”, and having created a road map, if not a blueprint for attaining desired environmental impacts, no one could say for sure what would happen next at the “Managerial” and “Impact” levels. Would the new managerial structure work? Would the policies be implemented? Would the program survive budget cuts and controversy? Would the policies be effective even if they were implemented? How would we even know? These questions will be explored, and partially answered in the next sections, from two perspectives. The first is through a simple system dynamics simulation of some core elements of a typical coastal management program based upon the premise of a “balancing act”, calibrated to the Rhode Island case. The second is by examining a range of data sets that characterize relevant facets of the Rhode Island program over time. Some of this analysis contributed to the preparation of the Marine Resources Development plan, and some is presented here for the first time. Almost thirty years has passed since work began on the 1983 transformation, and forty years since The Coastal Zone Workshop set out its bold if not awkwardly formulated vision for a decision support system that seamlessly, organically blended science, politics, social needs, ecology and economics.

To be more specific:

RQ 1.1: How does a coastal management program with direct state level authority influence decisions by resource users, citizens and municipalities
functions to achieve integration and to balance competing interests and policy objectives?

H 1.1: Plan formation is triggered by a delayed response to rapid coastal land development. Increased policy specificity and pre-allocation of coastal areas to conservation or water dependent use greatly increases the likelihood that both will be sustained over the long term compared to case-by-case approaches.

R.Q 1.2: How is the balancing act achieved over time?

H 1.2: Local preferences for the balance between conservation and development differ and may tend to favor development, accompanied by the expectation that state decision-makers will take on tough choices favoring conservation.

R.Q 1.3: What are the implications of capacity and performance on program sustainability?

H 1.3. Program performance can be tracked using simple information and improved over time and this makes an important difference in long term stability

R.Q. 1.4: What are the links and implications of information about policy impact on program sustainability?

H 1.4. Poor information flow on the normal benefits of coastal management as well as the quality of management effort will likely have a negative effect on program sustainability
The model structure of the simulation necessarily simplifies the coastal management program structure. Some of the key learning occurs during the process of choosing what to keep in and leave out, and how to formulate an equation or piece of model structure that is essential but proves to be a neglected subject. Simple analysis of some of the data can raise questions that need to be addressed in the model, and also reveal patterns that the model captures as well.

2.3 Review of literature and research methods

Three related bodies of literature are immediately relevant to the questions surrounding modeling coastal management planning and decisions. These are: the use of social science research methods in modeling of dynamic decision making; the dynamics of state and local interactions surrounding the metaphor of a balancing act that occurs in plans and decisions; and finally, research on modeling of coastal land development. Each is reviewed briefly below in terms of the methods employed and key insights regarding research questions and variables.

Social science research and modeling dynamic decision making

Rouwette, Grosler, and Vennix (2004) surveyed and classified 51 published papers using computer based simulators in experiments. The domains ranged from environmental studies on deer herd management to running an airline (the defunct People Express). The authors note that “In many simulation studies the focus is on how and when people achieve as optimally as possible, and increases in task performance are seen as indicators of learning” (2004: 356). In examining the characteristics of the models that affect performance, the authors observe that providing feedback can be negative, that is,
model users often ignore feedback information in making their decisions. Computer based decision support was not always effective in experimental settings, since results depend on the decision making styles of individuals and teams. Rouwette et al. did find one study that showed that “...reasoning by analogy is found to decrease performance in teams using decision support, but to increase performance in those teams that do not use decision support” (2004: 365).

Moxnes (1998) was puzzled to find that in his simulator of a cod fishery, when given full control, knowledge and ownership of the fishery, commercial fishermen still over fished. Moxnes was even more struck by the fact that all participants in the study failed to achieve sustainable stocks in the simulated fishery. The failure extended to both professional fisheries managers and scientists. “Since the researchers and advisers who participated in the experiment did no better than the others, it seems important that they improve their intuitive understanding of the stock nature of fisheries resources” (1998:1246).

Deegan presents a model on flood hazard response, stating: “The model represents the researcher’s mental model of the problem, which is based on the natural hazards literature reviewed for this project” (Deegan, 2005:26). Luna and Andersen (2005) point out the many similarities between grounded theory methods and aspects of system dynamics modeling.

In applying the technique, the researcher develops a set of categories or concepts that emerge across the texts (and these texts can be the transcripts of interviews, focus groups or observations). These categories could become stocks and flows for a system
dynamics model, or ratings of a particular variable (e.g., very difficult to very easy) that could be quantified by the modeler” (2005:285).

These studies all indicate the potential for using multiple methods of social research in model formulation and validation.

Research on the balancing act in land use decisions
Norton (2005a, 2005b, 2005c) examines the case of state and local relationships in the formulation of local coastal management plans in North Carolina. Much of the focus of research is on the dynamics of the balancing act in decisions, however without the use of system dynamics modeling. Norton notes that in North Carolina there is:

... a preference on the part of local elected officials for making decisions on a case-specific basis and not constraining their discretion to do so in the future; a fear that following a plan might diminish their chances of re-election; a concern that economic growth was needed to provide local jobs; ... and a tendency to rely on the state to provide adequate environmental protection (2005a:198).

There also has been some use of content analysis of public documents to understand coastal decision making. Laurian, Day, Backhurst, Berke, Ericksen, Crawford, Dixon and Chapman (2004) examined coastal permit decisions of local governments in New Zealand to detect the degree of strictness and effectiveness in applying storm water discharge rules. Norton (2005a) also used content analysis to examine the plans prepared by county governments under North Carolina’s coastal resources management program. An important dependent variable in his analysis was ‘plan policy emphasis’ which he operationalized as “Clear evidence of an emphasis in plan policies favoring economic development over environmental protection or vice versa” (Norton, 2004:183). Norton (2005c) found that 13 counties favored the economy, 4 favored the environment and 23 showed no tendency.
Healey and Shaw (1994) look at the balancing act by tracing the changing way in which the concept ‘environment’ has been utilized in British planning since World War II. They conclude “there can be no doubt that the postwar history of the planning system has seen the dominance of economic over environmental considerations, just as a narrow environmental conservationism allied with economic emphases allowed the sidelining of social distribution concerns” (1994:434). Wood and Becker (2004) found that 77 of 97 British local planning authorities could be characterized as minimalist or moderate in their selection of development projects for further screening and more intensive review, compared to 20 that showed precautionary tendencies. Laurian et al. (2004) explored the implementation of mandated local comprehensive plans in 86 district councils in New Zealand. The authors apply a self-developed “Plan Implementation Evaluation” methodology that attempts to predict the degree of plan implementation by considering the quality of the plan, the capacity of the planning agency, project scale, developer commitment and capacity, and enforcement style.

Norton (2005a) offers considerable insight into agency-developer interactions in North Carolina by employing a multi-method approach that included participant observation of 20 meetings of a stakeholder group convened by the state, the Land Use Planning Review Team. Norton also attended a number of meetings of the Coastal Resources Commission during the time frame of his study and conferences of different environmental groups involved in the evaluation process. Norton (2005b) distinguishes between the attitudes and willingness of counties and municipalities to comply with the procedures to create a local plan that would meet state approval, and the way these same officials make trade-offs between environment and economy in case by case decisions.
Since state government makes the decisions in areas of environmental concern, which comprise a small fraction of all coastal land in North Carolina. Further environmental regulation is viewed as encroachment by the state on local prerogatives, to the extent that coalitions have formed to resist the state.

**Land use modeling and planning**

The history of land use modeling since the 1970s is nested in the overarching quest to incorporate scientific methods in planning, including simulation. Batty (1994) summarizes this unfolding story from his perspective as the editor of one of the field’s leading journals: “The last 30 years have seen planning move from grandiose strategic thinking to small-scale parochialism, and both styles seem to have failed us in countless ways” (1994:15). Three limiting factors are the quality of models and associated data, the integration of urban and transportation theory into models, and the problem of time dynamics. Xiang and Clarke (2003) propose that scenarios be used as the bridge between modeling and planning on the one hand and decision making on the other. The authors offer three criteria for good land development scenarios. “Plausible unexpectedness” stretches thinking to help overcome the flaw of overconfidence. “A winning plan or correct decision is often the one that uses standard strategies unprecedentedly or even unpredictably” (p. 891). Careful decisions are required on the number and kind of themes addressed in scenarios, how many should be offered, and how far into the future scenarios should extend.

An overarching theme of specific land use modeling techniques is the interplay between model spatial accuracy and parameter choices made by modelers. Pettit and Pullar (2004) compare three different modeling approaches to the coastal region of
Hervey Bay in Queensland, Australia. The authors utilized ongoing consultative process while conducting the study to create the scenarios and employed three different models to forecast the implications of each scenario over a 20 year period. These results were compared using a goals achievement matrix. All three tested models produced scenarios that include a spatial distribution of predicted development, and offer visually and statistically distinct pictures that are meaningful at the regional scale.

By way of contrast; Pontius and Malanson (2005) compare two distinct micro-level modeling approaches (Markov and Geomod) for Worcester, Massachusetts in order to understand forecasting future development of the urban region. The authors compare the output of each model prediction of 1999 land use from a 1985 base line. Both Markov and Geomod can produce vivid forecasts at a very small scale and high level of detail, where a single pixel represents a grid of land 30 by 30 square meters. However each uses a different method to accomplish this. It turns out that the choice of options used by modelers contributes far more to accuracy that the fundamental difference in method between the two models. Both models produced useful and accurate only at pixel sizes greater than 2 square kilometers, which is in essence a regional scale. Pontius and Malanson found in essence that only at very coarse scales did the models prove more accurate than just leaving the 1999 map on the wall and pretending it was 2021.

In the Baltimore – Washington, D.C. area, Jantz, Goetz & Shelley (2003) test a third micro-level model. The SLEUTH model was calibrated and validated for the time period 1986 – 2000. Runs of the SLEUTH model made predictions 30 years into the future for three scenarios for the Baltimore and Washington, D.C. metropolitan area that surrounds Chesapeake Bay. The authors raise a number of concerns about SLEUTH’s
ability to generate spatially accurate forecasts. Jantz, Goezt, and Shelley found that the SLEUTH model performed best at a coarse scale of resolution but did poorly in rural areas, underestimating the amount of isolated rural development that has taken place in the region. The authors conclude that SLEUTH is best used at a regional scale, and that “visualization of potential land-use change has proven to be a powerful tool for raising public awareness and facilitating discussion” (p. 267). In sum, the value of developing general insights at a regional scale by models such as the simple coastal management model are in line with the conclusions being reached by investigators creating far more sophisticated geographic information system simulations.

A hybrid approach that combines ideas about landscape and ecological conditions with information flow for management, in the spirit of The Coastal Zone Workshop and ecosystem-based management is presented by Kleppel, Devoe and Rawson in 2006. This offers one of the few examinations of the actual ecological impacts of regional coastal land use development patterns in a rapidly growing area, and compares the terrestrial and marine impacts of two different forms of land development in South Carolina. Kleppel, Porter and Devoe (2006a) broaden their analysis to focus attention on the role of information, including quality and timeliness, in the dynamic between human uses and coastal ecosystems. The situation featured in Figure 2.6, taken from a content analysis of their book, highlights information flow in decisions on factors that cause impacts (see Figure 1.4 for the Coastal Zone Workshop version), focusing on the agenda-setting function of perceptions of environmental trends and the impact of changed perceptions on creating pressure to balance decisions more in the direction of conserving landscape. Figure 2.7 offers a more elaborate depiction of the importance of timely information in
influencing several components of the “Referee” and “Management” levels. Both of these causal loop diagrams are drawn from a content analysis of the text, and are approximately reflective of the complete arguments made by the authors.

**Figure 2.6** Specific impacts on terrestrial and coastal ecosystems in South Carolina from two forms of land development in coastal watersheds (information flow in dashed red arrows) (based on content analysis of Kleppel, Porter and Devoe, 2006a)

Figure 2.7 also illustrates a powerful surrogate variable that integrates consideration of the dynamics of coastal landscapes, the amount of impervious surface created by coastal development. Impervious surface data for RI is presented in a later section.
Figure 2.7 The role of information flow in the decision making “balancing act” in coastal watersheds (information flow in dashed red arrows) (based on content analysis of Kleppel, DeVoe and Rawson, 2006)

Both Rhode Island and South Carolina have similar coastal governance regimes, with a strong role played by local decision makers, but also a central coastal agency with jurisdiction over shore and marines, and both also use “special area management plans” which are integrated approaches that focus on natural or heavily urbanized coastal ecosystems, much in line with the type of ecosystem based, adaptive approach being proposed by current thinking and national policy reform.
2.4 Using an SD approach to guide inquiry on the future of coastal ecosystem management

To gain some clarity on what coastal ecosystem management entails, the Rhode Island coastal management program’s legislative purpose is used to create a simple dynamic model of the balancing act involved in allocating coastal resources, called “sites” for simplicity. In this model, coastal management involves nothing more than deciding what sites in the coast are to be developed and which are to be preserved. A coastal site could be a beach, wetland, lagoon, tidal flat, sand dune, bluff, or a parcel of dry, buildable land. One of many key simplifications is that technology and money can produce some kind of development from any available sites.

There are four important loops at work in this simple coastal ecosystem management world (Figure 2.8). In balancing loop B1, pressure to conserve coastal resources leads coastal decision-makers, whomever they might be, to remove sites from the inventory of available sites. In balancing loop B2, the decision makers allow certain sites to be developed under a set of stipulations. Both conservation and development reduce the stock of available sites. This sets two additional dynamics into motion. As development takes place, the coastal area’s economy grows, demand for sites increases, and the increasing scarcity of those sites is noticed, generating pressure to relax conservation policies and allow more sites to be developed, shown in balancing loop B3. Similarly, any increase in development, combined with the perception of declining availability of sites, generates pressure on the coastal management decision makers to conserve more sites, shown as balancing loop B4. This in stark form is the classic balancing act embodied in Rhode Island’s 1971 coastal management law and program.
What can we ask such a simple conceptual model that might offer some insight into the ongoing challenges of managing a real coastal ecosystem and help prompt reflection on experience to date? Brunner and Clark (1997) emphasize that ecosystem managers “are not omniscient, these and other practitioners must make interpretations and judgments that function as maps for self-orientation in the decision context...When practitioners act on such maps, the consequences of their actions unfold in a much more complex world that provides a reality check.” In their view, “the priority is to evolve improvements in principles of ecosystem management through reflection on the experience that follows action”.
One question derived from real world experience in Rhode Island is whether planning matters. Concepts such as adaptive ecosystem management seem to eschew any kind of pre-planning. In fact, not all researchers agree that the ecological concept of resilience, which refers to self-organizing systems, applies equally to a system with significant engineering-designed components like most SES. The concept of robustness has been proposed as more useful in characterizing how their productivity and flow of services are being maintained despite disturbances, since “the majority of components are self-organizing (ecological systems, social networks), very few are designed (rules of

Figure 2.8: A causal loop depiction of the simple coastal ecosystem management model
interaction), and uncertainty is high” (Anderies, Jannsen and Ostrom, 2004) At a minimum, six elements of an SES have to be taken into account in ecosystem management:

- the natural resource;
- the resource users;
- the public infrastructure providers (public decision makers);
- the public infrastructure itself;
- institutional rules; and
- the external environment.

Strategic interactions take place among these entities.

The robustness of a particular social-ecological system must take into account both the collective choice making and operational (implementation) aspects.

The stock and flow model that derives from the conceptual model can accommodate these recommendations.

**Figure 2.9:** The stock and flow structure of the simple coastal ecosystem management model

The model consists of three main stocks and five processes that represent what can happen to a site at different times, reflecting the real world decisions of coastal
management. Initially, all sites are available, and coastal decision-makers can decide to permit them to be (1) developed or (2) conserved. Over time, developed sites might be (3) redeveloped, or in rare cases (5) rehabilitated so they can be conserved. Finally, conserved sites can be (5) reallocated into the pool available for development. The decision-maker is not specified in the simple model, it could represent the result of an arbitrary decision by a local, state or federal authority, a collective choice process in the case of implementing a plan, or the private negotiation of property owners.

A simple example for a pristine, undeveloped coastal beach site illustrates the different possible stocks where the site could be located in the world of the model.
<table>
<thead>
<tr>
<th>SITE DECISION</th>
<th>EXAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Developed</td>
<td>A wharf is constructed in an existing small harbor along with offloading equipment, fish processing and cold storage facilities to meet the needs of near-shore fishing operations.</td>
</tr>
<tr>
<td>(2) Conserved</td>
<td>A government agency declares that no structures or physical modifications such as dredging are allowed to a specific coastal salt marsh located in the innermost portion of the harbor.</td>
</tr>
<tr>
<td>(3) Restored</td>
<td>A hurricane storm surge generates severe beach erosion on the barrier beach of a coastal lagoon. Sand that washed into the lagoon is returned to nourish and reestablish the damaged beach.</td>
</tr>
<tr>
<td>(4) Redeveloped</td>
<td>An obsolete and abandoned fuel off-loading and storage facility in the small harbor is removed and remediated and redeveloped as a time-share condominium with the option of a boat slip.</td>
</tr>
<tr>
<td>(5) Reallocated</td>
<td>A state agency obtains a large parcel of undeveloped land adjacent to a popular recreational beach which had previously been set aside for conservation. The agency establishes a new public beach facility with 500 parking spaces, a large pavilion with concessions, lockers and showers, and life guard stations.</td>
</tr>
</tbody>
</table>

Table 2.2 Decisions that can affect which stock contains the site

The working model described below moves a site between stocks 1, 2, 3 and 5. A separate stock uses information from (1) Developed level to track decisions to intensify existing uses of a site. The model is very general and allows testing of a variety of parameters to create very different coastal ecosystem management situations, and to try out a range of coastal management policies.
<table>
<thead>
<tr>
<th>COASTAL SITUATION PARAMETER</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950 demand for coastal sites</td>
<td>This sets the initial demand rate per person for coastal sites. The model start year can of course be changed</td>
</tr>
<tr>
<td>Initial population</td>
<td>This sets the population at the beginning of the model run</td>
</tr>
<tr>
<td>Total sites</td>
<td>This sets the number of sites remaining to be developed</td>
</tr>
<tr>
<td>Pre-existing developed sites</td>
<td>Any coast with population will have sites already utilized. This parameter is added to the ‘cumulative decisions allowing development of sites” so that site intensification decisions can be computed</td>
</tr>
<tr>
<td>Net census population growth rate</td>
<td>We can change how fast the population of the model world grows by a fraction. The parameter is phrased this way because in the Rhode Island case, managers believe that official census data undercounts the number of people living on a temporary or permanent basis in coastal municipalities.</td>
</tr>
<tr>
<td>Net extra population growth rate</td>
<td>This allows the model to account for growth in the number of people not counted by the census</td>
</tr>
<tr>
<td>Year to test extra population</td>
<td>This allows for choosing a time period in which non-census population increases</td>
</tr>
<tr>
<td>normal demand for intensifying sites</td>
<td>This parameter sets a rate of requests for permits to intensify use of a site per existing developed site</td>
</tr>
<tr>
<td>normal restoration fraction</td>
<td>This parameter allows for aging structures to be demolished and returned to the available sites stock</td>
</tr>
<tr>
<td>Long term growth in median income</td>
<td>This parameter allows for prosperity in the world of the model, and increases the 1950 demand for coastal sites</td>
</tr>
</tbody>
</table>

**Table 2.3 Key Model Parameters**

The policy test variables are also general, but their selection very much reflects the history of the Rhode Island coastal resources management program.
<table>
<thead>
<tr>
<th>POLICY TEST VARIABLE</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>conservation goal</td>
<td>The model run can attempt to set aside from 0 to 100 per cent of remaining available sites through case by case decisions</td>
</tr>
<tr>
<td>initial conservation year</td>
<td>the time to begin the conservation policy can be set</td>
</tr>
<tr>
<td>initial plan allocation policy</td>
<td>The model run can attempt to set aside from 0 to 100 per cent of remaining available sites by declaring them conserved in a plan. We can decide to conserve a large quantity of sites all at once, setting the initial year for implementation, and allocating the number of sites to conserved.</td>
</tr>
<tr>
<td>initial plan year</td>
<td>the time to implement the plan can be chosen</td>
</tr>
<tr>
<td>Year to implement the site decision program</td>
<td>this sets the time when a coastal program will begin to implement the permit system</td>
</tr>
<tr>
<td>Year to implement site intensity decision policies</td>
<td>This allows for the application of regulatory review of activities that change the intensity of use of sites that have already been developed</td>
</tr>
<tr>
<td>Rate of enforcement</td>
<td>This is a fraction applied to conserved sites that can return them to the status of sites available for development</td>
</tr>
<tr>
<td>Time to reallocate sites due to enforcement</td>
<td>This smooths the return of conserved sites to available status</td>
</tr>
</tbody>
</table>

**Table 2.4 Key Policy Test Variables**
This structure allows development to occur regardless of the presence of a decision making process by government, and that creating a decision process and providing it with enough resources to function are choices to be made, not assumptions. “Availability” can be interpreted broadly to mean parcels on the market, land and shore areas that have the necessary physical characteristics, locations that are both suitable and legally available given the current policies and effectiveness of the State's regulatory system.
This portion of the model captures the policy process, and treats “conserved site” broadly. A parcel or portion of a parcel might be conserved simply because it is not physically suitable for the use at a given willingness-to-pay, or it may not be legally available due to regulatory restrictions, easements. The model allows setting a very simple-minded policy which is a gloss for all of these conditions, and it also incorporates the “balancing act” in terms of pressure to increase the amount of area conserved, and the counterpoising pressure to develop. In addition, the model allows setting the time to implement the policy, both on the case-by-case approach (the amount of a site to 'conserve' is determined on a case-by-case basis, the default application of the environmental impact method for decision making) or a plan that changes the availability
of sites to be developed. Unfortunately, the coastal decision digital data base does not include information about the area or resources used or conserved in individual decisions. Records would have to be analyzed individually to generate this data.

To maintain simplicity, the economic component of the model acts exogenously at present, however a common sense view would be that the condition and attractiveness of coastal ecosystems would have an effect on property values and in-migration. This is accounted for in some way by the “net extra population” variable, which has to be set as a parameter rather than a feedback loop. The model contains a demographic structure similar to Meadow's World 3, however it is not switched on. In fact it is questionable
whether land and shore development in Rhode Island should be considered driven endogenously by population at all. Demand for coastal sites is regional and global in nature, and coastal development patterns appear in fact to be unpredictable and 'leap-frog' in nature. This model does not have any way to address demand in a realistic way.

The main equations for intensifying use of sites are based mainly on parameters such as normal demand for intensification, plus pressure generated endogenously from the deficit of coastal sites. This component is also somewhat isolated from the rest of the model, and serves mainly to capture the coastal decision maker’s work load without itself generating feedback into the economic or population models, for example. As shown in

Figure 2-13 Intensifying use of sites
the next section, the Rhode Island coastal development decision data base is able to fully capture this aspect of model, indeed, the model findings inspired the data analysis.

Selected parameters and policy variables are combined in a screen that allows immediate viewing of parameter results.

![Figure 2.14 Interface for setting case parameters and policy tests](image-url)
**Base Rhode Island Run: No Conservation Policies or Coastal Plans**

Two runs are presented here, the first serves as a baseline by using parameters from Rhode Island case without coastal management, and the second tests the results of a conservation policy backed by a conservation plan.

The base run uses these parameters: Sites = 20000; Existing Developed Sites = 20000. There is also a base assumption that 0.1 sites is conserved for every site developed, that base demand for sites in 1950 is 113 sites/million people/year, and that the 1950 Population = 791896

![Available, New, Total, Intensified, Conserved Sites](image)

**Figure 2.15** Available and conserved sites in the model

In Figure 2.15, the number of available sites drops considerably over the model run, and a small fraction of sites is conserved due to the minimum conservation set-aside assumptions of the run.
Figure 2.16 Accumulated decisions to allow intensified, new uses of sites in the model

Figure 2.16, shows the accumulation of new sites and intensified sites as a result of the model run. Intensification (blue line), which captures changes to existing developed parcels grows exponentially. The accumulated number of developed sites begins to level off by 2050, as the stock of available sites is depleted.

Implementation Runs with a Conservation Plan

A plan that sets aside a fraction of sites early on is much more effective than a policy that is initiated later on in the development process, when sites are scarcer and pressure to develop more acute. This model run shows the results of both planning and case by case decision making.

The parameters tested are for a generalized version of the Rhode Island case

Goal is to conserve 50 per cent of sites, Plan implemented in 1985
Policies to control site intensification becomes effective in 1981

Base demand is for 113 sites/million people/year

Enforcement effectiveness is 90%

Permitting efficiency is 90%

Figure 2.17 shows the result of implementing the plan and backing it up with case by case decisions. The amount of available sites is reduced, and the amount of conserved sites increases. Remaining available sites decline more slowly than in the base run, but conserved sites also decline due to weak enforcement. In practice enforcement issues in Rhode Island and the U.S. probably do not have such a dramatic effect, so the parameter needs to be revisited.

![Available, New, Total, Intensified, Conserved Sites](image)

**Figure 2.17** The impact of the 1985 plan on conservation of coastal zone sites in the model
**Figure 2.18** Accumulation of decisions to allow intensification and development of new sites in model

Figure 2.18 shows the cumulative results. Fewer available sites are developed, but many more existing sites are subjected to intensified use. Figure 2.15 shows how a plan reduces the availability of sites. Figure 2.19 shows that conserving sites reduces the supply of sites for development.
Figure 2.19 Comparison of sites available for development, with and without 1985 plan

Summary of Model Run
Without a plan, development continues steadily until site scarcity and expense limit further growth. Intensification of uses continues.

**Figure 2.20** Summary of typical model run without any plan
With a plan set into place about 1985, the amount of conserved area is much higher but subject to attrition if enforcement is weak and conserved sites are in practice placed back into the pool of available sites.

### 2.5 Actual Performance of coastal management in Rhode Island

The model structure and outputs have been developed simultaneously with analysis of program are inspired by two key coastal use decisions in the Rhode Island
program. First, the program can decide whether available coastal sites can be used (uses sites, red line) and whether a used site can be further modified or rehabilitated (Rehabs existing, blue line). Figure 2.22 presents annual data from actual program experience, and Figure 2.23 shows cumulative data.

In general, we are looking to see if the model is able to generate similar results when reasonable parameters taken from the Rhode Island case are used. There is no data set for Rhode Island as simple as the one used in the model, so two indicators were formulated from attributes of the CRMC permit data base. It classifies each of the approved applications by general type of use.

The following kinds of projects are related to decisions to use available sites:

<table>
<thead>
<tr>
<th>Aquaculture/Water Based</th>
<th>Marinas New</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Structure</td>
<td>Mosquito ditches</td>
</tr>
<tr>
<td>Docks Piers Floats Commercial</td>
<td>Petroleum/chemical</td>
</tr>
<tr>
<td>Docks Piers Floats Residential</td>
<td>Power and Energy</td>
</tr>
<tr>
<td>Dwelling/ISDS</td>
<td>Private Recreation Structure</td>
</tr>
<tr>
<td>Dwelling/Sewered</td>
<td>Public Recreation Structure</td>
</tr>
<tr>
<td>Filling Removing Grading</td>
<td>Shoreline Protection New</td>
</tr>
<tr>
<td>Industrial</td>
<td></td>
</tr>
</tbody>
</table>

The following kinds of activities are related to rehabilitating or intensifying a coastal site:

<table>
<thead>
<tr>
<th>Accessory structure</th>
<th>ISDS Repairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffer zone alteration</td>
<td>Landscaping</td>
</tr>
<tr>
<td>Commercial Alteration</td>
<td>Maintenance of Docks, Piers, Floats</td>
</tr>
<tr>
<td>Dredging Improvements</td>
<td>Maintenance of Residential/Commercial/Recreation</td>
</tr>
<tr>
<td>Dredging Maintenance</td>
<td>Marinas Alterations</td>
</tr>
<tr>
<td>Dwelling Additions</td>
<td>Non Structural Shore Protect</td>
</tr>
<tr>
<td>Dwelling Alteration</td>
<td>Right of Way improvements</td>
</tr>
<tr>
<td>Fuel tanks</td>
<td>Shoreline Protection Repair</td>
</tr>
<tr>
<td>Industrial Alteration</td>
<td></td>
</tr>
</tbody>
</table>
Figure 2.22 Approximation of new site development and site intensification, Rhode Island

This classification scheme produces a very similar pattern as the model simulations.
The pattern for accumulated new and intensified sites also follows the model pattern.

**Figure 2-23** Accumulated decisions (assents) to use (new sites) and rehabilitate (intensify) sites in Rhode Island
Figure 2.24 shows the actual data from the Rhode Island coastal program between 1970 and 2004 compared to the base and plan runs. The annual decision making data is noisy...the number of applications received each month varies considerably, as does the time it takes to process each of the kinds of site projects listed above. These factors could be included in another version of the model, allowing coastal managers to test different combinations of projects and utilize parameters on the time it take to issue permits in combination with bottlenecks generated by an overload of work, in order to address the regulatory efficiency question. The main point is that the simple model is able to
reproduce the behavior of the program using guesses at how many sites remain to be
developed and what the 1950 baseline was. The key fact is that the simple assumptions
about demand for site, and the use of population and economic parameters drawn from
Rhode Island historical trends combined with educated guesses goes a long way toward
simple model validation.

Figure 2.25 shows the results of matching actual Rhode Island data on decisions
to intensify sites with model output. A similar story holds here. In fact, we don't know
how many existing developed sites existed at the inception of the CRMC in 1971. The
graph shows data between 1970 and 1985 exhibiting a shallower slope than afterward. In
fact the coastal program did not have policies that would capture many of the site
intensification actions until after 1985. A smoothing function and program start time of
1981 produces the model result. Some additional structure would be needed to better
match the transition, but this perhaps would unnecessarily focus too much attention on
modeling to the situation rather than validating the overall approach.
Combined together, the site and intensification of use graphs and data produce the graph in Figure 2.26, which is a projection of the total annual workload in the future using the parameters and assumptions in the model. The overall fit of the line to data shows that the loops in the model act together to generate actual program behavior, thus merit further analysis and testing.
The main insight, however, is that the model forecasts an intensification in coastal program decision making due to the intensification of sites and the expectation that demand for remaining available new sites will stay steady.

Figure 2.26 Forecast of future coastal management program work load, compared with historical CRMC case load
2.6 What can a simple model suggest for meeting the coastal management challenges of the 21st century?

Coastal management programs at the beginning of the process

In the simple world of the model, conservation policies remove land from the market place, and this puts further pressure to develop remaining sites. Plans help a great deal, but only if there is strong enforcement. Over the long run, sites will continue to be redeveloped, and as well some sites become obsolete, are destroyed and placed back into the Available Sites stock.

The simple model cannot say how many coastal sites need to be conserved in order for the people and the economy to be successful. Should it be 10,000 sites if the system contains 20,000? We cannot say even though the aspiration for forty years has been such prescience.. Nor does the simple model also does not address the question of how “resilient” the remaining number of available sites plus conserved sites is. It's focus is mainly on WHETHER there will be any sites left. However, a resilience estimate component could be added, with feedback loops tied to both pressure to conserve in case by case negotiations, and in the fraction of the system to include when a system level plan is implemented. The coastal ecosystem may need to “flip” its configuration more than once before enough pressure is built up to motivate action and by then the list of potentially effective actions may change and get more expensive.

Finally, the simple model does not tell us about another key concern, which is the pollution generated from the development process in the way recommended by Kleppel et al. (see Figures 2.6 and 2.7). Conserving sites may create a buffer to pollution (the model does not address this) but a separate stock and set of processes is needed to identify and act on those factors, taking into account the same need for setting goals,
maintaining pressure to implement, and addressing both the perception of the problem and signals that reveal when the pollution problem is solved. These ideas are equally valid for developed and developing coastal countries however many of the parameters in the simple model might need to take on very different values.

Coastal management programs at the mature stages of the process

The closer we become to build out in the world of the simple model, the fewer options we have and the less effective they are. It is never too late to implement a coastal conservation plan, however it can become too late to expect to get the same results as before. In a world with many fewer conserved sites, our expectations of what configurations are possible will have become reduced. Ecosystem management theorists recommend that we try to discover resilient pathways, since we cannot compute them. A mature situation seems to be more heavily dominated by human engineered components, and the notion of being able to design a desirable configuration seems entirely plausible, especially given the successes in resource conservation and pollution control experienced in Rhode Island and many other U.S. states.

The simple model cannot answer our concerns about a specific configuration that is both desired and practicable but it offers us some additional processes that were not very important in the earlier stages but could make a difference now.

Even when the model is pushed to the extreme---the cap on sites is lifted and demand doubles, and no plan was ever put into place to conserve sites, there are 1012 sites remaining, including some available sites in addition to the relatively few conserved sites that were negotiated at the beginning of the development process. In reality, there are many irregular, hard to develop sites that also have high conservation value. In
addition, development will be driven toward those areas where higher densities are allowed, in other words urban areas. Here, developed sites can be redeveloped or restored and conserved and trades can be made between strategically important conserved and available sites. In addition, if the model had a pollution creation and control component, it is easy to imagine additional tradeoffs that make new, previously unusable sites, available to the simple coastal model.

Carrying out these more complex assessments of conserved and developed sites is difficult to do for a large area. Rhode Island’s coastal sites, for example, include the following features:

<table>
<thead>
<tr>
<th>FEATURE</th>
<th>ACRES</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Salt Marsh</td>
<td>2,708</td>
<td>0.413</td>
</tr>
<tr>
<td>Beaches</td>
<td>1,450</td>
<td>0.221</td>
</tr>
<tr>
<td>Rocky Shores</td>
<td>573</td>
<td>0.087</td>
</tr>
<tr>
<td>Tidal Flats</td>
<td>568</td>
<td>0.087</td>
</tr>
<tr>
<td>Low Salt Marsh</td>
<td>443</td>
<td>0.068</td>
</tr>
<tr>
<td>Brackish Marsh</td>
<td>427</td>
<td>0.065</td>
</tr>
<tr>
<td>High Scrub-Shrub Marsh</td>
<td>159</td>
<td>0.024</td>
</tr>
<tr>
<td>Eelgrass Beds</td>
<td>99</td>
<td>0.015</td>
</tr>
<tr>
<td>Pannes &amp; Pools</td>
<td>46</td>
<td>0.007</td>
</tr>
<tr>
<td>Dunes</td>
<td>43</td>
<td>0.007</td>
</tr>
<tr>
<td>Artificial Jetties &amp; Breakwaters</td>
<td>23</td>
<td>0.004</td>
</tr>
<tr>
<td>Oyster Reefs</td>
<td>9</td>
<td>0.001</td>
</tr>
<tr>
<td>Stream Beds</td>
<td>3</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Table 2.5 Important Rhode Island coastal features, by area. Source: RI Department of Environmental Management, 2000.

These features are scattered throughout the coastline in many different sites. As explained earlier in Figure 2.3, the Rhode Island Coastal Resources Management Council has afforded protection to five main types of coastal areas in addition to open water. Each of these areas might include several of the coastal environmental features listed
above, but the polygons are too small to be the subject of a useful mini-modeling exercise
to determine resilience and create a set of policies that will be robust. For example, it
might make sense to reallocate industrial waterfront to commercial or recreational use.
However, it may not make economic sense to expect that investors based in Providence,
at the head of Narragansett Bay, to incorporate newly designed commercial waterfront in
Newport Harbor, at the mouth of the bay.

<table>
<thead>
<tr>
<th>DESIGNATED USE</th>
<th>TYPE CODE</th>
<th>PERCENT OF COASTAL AREAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservation</td>
<td>1</td>
<td>0.27</td>
</tr>
<tr>
<td>Low intensity conservation and recreational use</td>
<td>2</td>
<td>0.57</td>
</tr>
<tr>
<td>High intensity recreation and marinas</td>
<td>3</td>
<td>0.04</td>
</tr>
<tr>
<td>Commercial and recreational waterfront</td>
<td>5</td>
<td>0.01</td>
</tr>
<tr>
<td>Industrial waterfront</td>
<td>6</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Table 2.6 Important Rhode Island coastal use policies, by fraction of shore zone. Source: Rhode Island Geographic Information System, taken from the policies of the Rhode Island Coastal Resources Management Council.

How can the simple model help us ask questions and seek the right kind of information we need to better manage coastal social-ecological systems?

The model structure, its stocks, flows and auxiliary variables, gives us a simple but complete picture of what needs to be known to manage the model world. The model also allows us to estimate the effects of faulty perception of some of this picture. We can also track the results of decision making by using the model as a guide for collecting and analyzing available data. For example, while there have been only a few, infrequent studies of coastal land and water use in Rhode Island, the state coastal agency has a complete record of decisions made. Combining spatial data with decision trends data on
specific kinds of development could be the basis for fairly fine-tuned forecasting and scenario testing. Information on the location and other attributes of remaining sites would also prove invaluable in calibrating and further validating a somewhat more sophisticated version of the model.

For this research I prepared a set of GIS maps using information from the most recent and in fact only available time period to address the issues raised by Kleppel's work and the overall insistence on environmental facts as part of the ongoing management and implementation project. It is the kind of information, that if collected continuously and systematically, would help address basic questions about whether the accumulated policies of the “Red Book” and the special area plans, along with municipal zoning and other state and local actions, make any difference. Figure 2.27 shows that demand and issuance of coastal permits of all types corresponding to the rapid growth of the area in the 1980s and 1990s.
Figure 2.27 Permits for coastal development of most types issued in the south shore ponds region. Type F are minor permits for activities with no impact.
Special area planning allowed the CRMC to identify areas according to carrying capacity and set policies to address the impacts of overdevelopment.

**Figure 2.28** Critical areas in the Salt Ponds region based on carrying capacity analysis

Data created by the Rhode Island Environmental Data Center in 2004 provides a one-time snap-shot of how local zoning and CRMC policies have keep shore areas relatively less developed than interior lands.
Figure 2-29  Land use, impervious surface in 2004 in area of critical concern
A band incorporating the first 200 feet inland from the shoreline, roughly corresponding to the CRMC's primary jurisdiction, is about 14.9 impervious surface, compared to 25.6 percent for a 300 foot wide band just inland of this. Not surprisingly, about 73.5 percent of beaches within coastal towns are found in the first 200 feet, but less of medium and high density residential, commercial, and industrial use than the next 300 feet, except a higher fraction of terminals and docks, and less vacant land.

Economy

The simple model has a single economic sector that has a single variable, and knowing its value is crucial to the model. Rhode Island’s coastal economy has many sectors, remains dynamic and somewhat difficult to define precisely. Two important ones for the coast are housing and port/commercial and recreational waterfront. A recent study in 2010 (Becker et al, 2010) finds that only 1,078 acres of the coast is being used for all types of water dependent use (ports, marine industry, marine recreation) and that 59 percent of Type 5 commercial waterfront zones are being used for not-water-related purposes, and 46 percent of Type 6 industrial port designated areas had not-water-related uses. Conflicts over the direction of future use of developed coastal sites continues, which is one of the reasons for the effort to create and revise special area plans for urban as well as rural areas. Information is not currently available in a form useful for projecting future demand for coastal sites. One of the values of developed sites, particularly in the coast, is the tax revenue they generate from the very high property values found in most shore areas. Such data is available in parcel maps for individual towns but not aggregated in a useable format.
Demography

The simple model has a single net growth variable, while the Rhode Island population shows S-shaped growth and is leveling off at about 1 million people. It has a growing deficit of working age residents and a rapidly increasing population of over-65. There are important coastal populations that are not included in demographic models and census data, including daily visitors and summer residents, college students who compete for rental housing with workers, owners of primary and second homes who have declared their primary resident elsewhere.

Figure 2.30 Public interest in coastal development trends
Pressures to conserve or develop

The simple model ties these pressures to perceptions of the rates or levels of key flows and stocks. The pressures involved in the balancing act carried out in the Rhode Island Coastal Program are generated from many sources and have their expression in case by case decisions, the overarching policies and regulations adopted to guide administrative decisions, and the ongoing process of creating and amending special area plans. The simple model can be extended to show the effect of public support and continuing involvement, but it would also have to show that as the conditions of the coast change (new configurations of available, developed and conserved sites) what the population wants from the coast is likely to change, adjusting downward to an era of scarce sites, or upward in a scenario where sites are redeveloped, restored and reallocated. Baumgartner and Jones (2009, 2002) take a feedback perspective in understanding how policy making occurs. They use the perhaps inapt metaphor of “punctuated equilibrium” to describe the pulses of pressure to create new policy, although in system dynamics terms they are describing the functioning of an integral controller that generates a policy correction based on the accumulated errors and failures of the past and thus pulses upward to give the needed push. This functioning could be better incorporated into the model, as well as Kingdon's concept of policy streams, since interest and pressure for economic development, conservation and housing come from somewhat different sources and windows of opportunity are not open permanently. The timing of special area planning reflects this. Major waterfront redevelopment projects in the metropolitan Providence area drove the revision of the out of date plan for Providence Harbor, a massive offshore wind energy proposal prompted the preparation of the largest
scale effort to prepare a SAMP for ocean areas. The increasing scarcity and development pressure should mean than better deals can be negotiated and modeling perhaps can better capture this. However, Rhode Island is not collecting data that can be shared to provide state and local decision-makers with independent assessments of the value of remaining coastal sites to guide the negotiation process.

A Cap on Permits

In an earlier version of the simple model, I tested a cap on the number permits processed per year to represent the effect of bureaucratic inefficiency as well as an intentional policy to reduce the pace of development. Lifting the cap, that is, creating a decision making system that has low transaction costs and few delays, does indeed let development happen faster, but as noted earlier, also has no long term benefit in the conservation of sites. Tightening the cap, to impose a moratorium on development in the model, actually delays conservation decisions as it creates increased opposition to conservation (which of course reduces the availability of sites further). Current discussions about the Rhode Island Coastal Program also urge improved regulatory efficiency, a need which extends well beyond the CRMC as an agency, which is seen as relatively efficient, however little is known about the true nature and cost of delays. A system modeling exercise would be a useful step in that direction.

Program Efficiency

The analysis of the CRMC permit data allows for examining the efficiency of the coastal program over time. One of the big concerns in 1983 was how the program could manage with impending funding cuts. Over the long term, the CRMC consolidated its dispersed staff into a single office under its leadership, increased application fees and
continued to compete effectively for grants to sustain the program. Figure 2.31 shows the annual number of permits (called assents by the CRMC) for the period of this study, 1970 to 2004. Since 1983 when the transformational policies of the CRMC were adopted, work load has actually tripled. The number of permits handled by the CRMC nearly doubled by 1988 (Figure 2.32) and the cumulative number of “B” permits reversed direction, nearly doubling as well for several years. (Figure 2.33) The average time to issue a “B” permit increased from 150 days in 1983 to nearly 700 in 1992 (Figure 2.34). The average time to process an administrative permit continued to increase as well, peaking at 200 days in 1992. It was not until 1994 that permit issuance times improved over those of 1983. (Figure 2.35)

Several factors are at play here, some of which are captured in the model, but more could be if elements of a system dynamics project model were added. By clarifying policies in 1983 the full regulatory reach and responsibility of the CRMC was made clear, greatly increasing permit applications. The full CRMC increased the number of cases it handled as a result, and also because of a considerable lag in allowing the staff to carry out its expanded role. It took time for the CRMC staff to become consolidated and expanded to meet the new work load, as well as to clear prior backlog of decisions. This was aided by creating several new categories of applications, in particular Type F, which meant that a property owner carrying out a trivial activity of patently no impact or relevance to the CRMC could not be challenged by an angry neighbor. The improved performance, although it took a long time, made it possible to hand the great increase in permit applications. As the model predicted, the amount of work required to keep up with the rehabilitation of coastal properties, in some cases by the construction of McMansions
where a small cottage once stood, as well as the number of urban redevelopment projects that followed upon progress in improving water quality in the metropolitan areas.

**Figure 2.31** Annual permits issued by CRMC by application type
Figure 2.32 Number of full CRMC review (B) decisions per year
Figure 2.31 Annual permits issued by CRMC by application type

Cumulative proportion of permits issued by CRMC by application type:

- A administrative
- B full CRMC review
- D preliminary determination
- F finding of no impact
- M maintenance of existing structure
- W freshwater wetland
- P: freshwater wetlands in the City of Warwick
Figure 2.34 Average processing time in days of permits: full CRMC review (B) compared to all permits

Figure 2.35 Total annual assents (permits) issued per year, and average days to process permit
2.7 Conclusion

The challenge facing the U.S. in coastal management in the next two to three decades is great, and that of the world’s coastal countries greater and more urgent still. Until now, the more than three decades of world experience and writing on coastal management has drawn very little on the most basic of systems dynamics concepts despite being one of the most obvious arenas where dynamic complexity in its natural, social and governance dimensions. The SD field itself, by contrast has not neglected the environmental management challenge. (Ford, 2010; van den Belt 2004; Moxnes, 1998, 2004) The simple model presented here, drawn upon the statutory balancing of uses requirements of the Rhode Island coastal law, is able to incorporate a great many facets of the coastal management challenge and suggest fruitful areas of inquiry and extension, both in practice and for the model itself as a tool to educate and guide the emerging practice of coastal ecosystem management.

To return briefly to our initial questions:

RQ 1.1: How does a coastal management program with direct state level authority influence decisions by resource users, citizens and municipalities functions to achieve integration and to balance competing interests and policy objectives?

The simple model and the actual Rhode Island experience shows that plan formation is triggered by a delayed response to rapid coastal land development.
Increased policy specificity and pre-allocation of coastal areas to conservation or water-dependent use greatly increases the likelihood that both will be sustained over the long term compared to case-by-case approaches, by increasing public support and scientific credibility of the regulations and through the special area planning process.

R.Q 1.2: How is the balancing act achieved over time?

Local preferences for the balance between conservation and development differ and may tend to favor development, accompanied by the expectation that state decision-makers will take on tough choices favoring conservation. This occurred in some localities in Rhode Island, who would approve a permit application and then expect the State to reject it. The water area zoning exercise used to create the 1983 transformational “Red Book” involved every waterfront community to have a voice in the determination of its future “state”, and special area planning reinforced this further by examining carrying capacity and working to align state and municipal policies to attain results. A preliminary examination of the evidence in the coastal landscape broadly supports the idea that land use and impervious cover are lower in shore than inland areas, and lower in locations designated for conservation, and low-intensity use than in areas adjacent to water zones for recreational ports, commercial waterfronts and industrial areas. Much more can be done with available data sets to examine this.

R.Q 1.3: What are the implications of capacity and performance on program sustainability?
Program performance can be tracked using simple information and improved over time and this makes an important difference in long term stability. The model does this by incorporating some aspects of the project cycle, and could be much expanded in this way. The permit data sets available, when analyzed carefully, reveal many patterns that show the effects of changes in policies and internal procedures, creating seemingly counter-intuitive results, for example the fact that the 1983 reforms actually greatly increased workload and were accompanied by worsening internal conditions, but resolved over the longer term by increased capacity and public support.

R.Q. 1.4: What are the links and implications of information about policy impact on program sustainability?

Poor information flow on the normal benefits of coastal management as well as the quality of management effort will have a negative effect on program sustainability. The aspiration of the Coastal Zone Workshop to have equally good information on environmental and management quality has not been attained. However, the simple model exercise points in a number of directions where this can be improved, and the available data sets assembled by the author indicate that many useful insights can be gained by examining the scarce, infrequently information collected in ways that link decision making, management processes and landscape and ecological change together. Doing better seems well within grasp.
Chapter 3: A system dynamics perspective on a global fishing enterprise: the case of tuna ranching in Mexico

“Our conventional language relates us to a world of linear relationships, simple cause and effect, and separate circumstances, be they events, individuals causes or effects. But that is not the world we live in.”

Donald N. Michael, 1995:463

3.1 Introduction

Tuna ranching is a value-added economic activity along the coast of Baja California in Mexico involving the live capture and transport of migrating juvenile bluefin tuna to pens located near shore, where they are fed for a period of months then harvested and shipped fresh or frozen to Japan for the high-end sashimi market, as well to emerging markets in the USA and Mexico. Capture-based tuna aquaculture (CBTA) as it is more formally described is nested within the global business of tuna fishing and processing for the fresh seafood, in particular sashimi market, is centered in Japan but expanding elsewhere. This is turn is nested within the international fishery and global business of bluefin tuna farming. Until recently, little was known about the functioning of Mexican tuna ranching, which is considered to be relatively sustainable by experts (Zertuche-González et al., 2008) compared to its Australian, Japanese and controversial Mediterranean counterparts. This is due to unique factors of geography, climate, expertise and a business strategy that draws upon Mexican entrepreneurship and the maquiladora system (Del Moral-Simanek and Vaca Rodríguez, 2009b). However, neither the tuna ranching industry nor experts are complacent about its future. There are several factors and issues, most of which are not the typical concerns found in popular
descriptions and critiques of tuna ranching that need to be taken into account in helping
determine whether Mexican tuna ranching activities have the potential to become sustainable.

The dynamic, information-rich nature of capture-based tuna aquaculture suggests the
need for an approach to planning and decision-making supported by a robust policy
informatics. This chapter employs multiple methods including system dynamics based
conceptual mapping and content analysis to create a policy-level simulation to help explore
the strengths and vulnerabilities of CBTA as a use of marine and coastal resources. It is also
formulated with an eye toward the information requirements of the growing interest in
ecosystem based management and coastal and marine spatial planning (CMSP) as discussed
in Chapter 2. Tuna ranching is a dynamic use of the coastal zone which requires onshore and
offshore facilities and areas, as well as depends on the sustainable management of two
different fisheries. It depends on management decisions by national and international
governments and firms regarding the availability of juvenile tuna, access to markets, feed
sources and new technology. It requires making rapid decisions throughout the production
cycle in response to continuous change in environmental conditions, ranch operations and
market conditions in order to remain profitable. Taken with too narrow a view,
uncoordinated policy choices by government combined with poor investment and operating
choices by tuna ranchers can have unanticipated consequences that undermine achieving the
desired economic and social outcomes for the industry.

There are additional reasons for taking a modeling-based approach to marine and
coastal spatial planning. Policy and management for complex, sophisticated uses of
scarce natural resources and areas are increasingly couched in terms of employing an
“ecosystem-based approach” that applies “adaptive management” principles so that good
results are produced by public policy. In practice, this would require policy makers to
take joint responsible for the financial success of the business enterprises they regulate. For example, Mexican planners are largely concerned about removing bottlenecks in the way of the nation’s fish farming production goals. Fisheries are subject to the phenomenon of “Ludwig’s Ratchet” where fishers continually create innovative ways to continue exploiting a fishery faster than regulators can set policy and controls for the previous innovation (Hennessey and Healey, 2000). Aquaculture and fish farming enterprises also need to innovate rapidly to address production challenges and take advantage of new opportunities. As discussed in subsequent sections, regulators need to be concerned about whether enough bluefin tuna arrives in Mexican waters, whether enough feed in the form of fresh sardines are available and the implications of tuna ranchers using feed from other regions and countries, whether tuna ranching operations maintain low environmental impacts so as not to impact on each other, whether ranchers are functioning efficiently as businesses and have enough information to make good operational decisions, and whether market conditions and regulations favor or impede the sale and transport of Mexican products. While conventional marine and coastal management policies usually incorporate some broad objective such as achieving a “balanced use” of resources, an endogenous, feedback perspective challenges policy makers to address the knock-on effects of policy choices and regulatory operations for the businesses they are charged with regulating and supporting.
3.2 Fish farming and mariculture as high value uses of marine and coastal resources

Global importance of aquaculture

Fin and shellfish aquaculture is a major and growing use of the world's coastal and marine zones, with species cultivated to meet protein needs for local populations including the poor, for export to global mass markets (salmon, shrimp) as well as species such as blue fin tuna, highly prized fish for sashimi in Japan and other Asian countries. A NY Times article covering the United Nations Food and Agriculture (FAO) report "State of World Fisheries and Aquaculture 2010" notes: “Aquaculture now makes up 46 percent of the world's food-fish supply in volume terms, up from 43 percent in 2006, according to the report, and appeared to have overtaken wild fisheries in dollar value, at $98.4 billion in 2008 compared with $93.9 billion” (Jolly, 2011) In the past decade, aquaculture has increased fish supply while capture of marine and inland fish has actually declined. (FAO Fisheries Department, 2010: 3)

Aquaculture is expected to continue increasing in its contribution to the world food supply as a larger fraction of world fisheries reach or exceed their sustainable yield. Numerous issues accompany the aquaculture supply chain, including the environmental impacts of siting and operating fish and shellfish farms, adequacy of sources of larvae, fingerlings or juvenile fish used in the grow-out process, disease outbreaks that can destroy harvests, health and nutrition of farmed fish and seafood, the distribution of economic benefits from aquaculture activities and the sanitation and safety of imported aquaculture products. Questions are raised at broader level about the wisdom and efficiency of converting large quantities of edible protein such as poultry, grains and fish
into feeds into high export value products such as shrimp, salmon and fattened tuna that provide only a fraction of the nutrition in return.

The FAO finds that aquaculture product producing countries are aware of these issues and committed to the challenge of establishing sustainable operations. There are two sides to the sustainability equation. “Sustainability requires environmental neutrality and social acceptability of the industry. It also requires, for the industry as a whole, revenues that, on the one hand provide compensation for risks associated with aquaculture and, on the other, ensure long-run profitability of aquaculture activities.” (FAO, 2010:84)

In an earlier global assessment of fisheries and aquaculture by the FAO, Subasinghe (2006), notes that “It is apparent that the aquaculture sector continues to intensify and diversify, is continuing to use new species and is modifying its systems and practices.” He argues, however, that this is being achieved with the growing awareness that the resources upon which it and society in general depend must be used responsibly. Effective regulation is only possible with an effective information system." Zertuche-González et al., conclude that even in the specialized case of bluefin tuna ranching presented in this chapter “Presently, there is insufficient information for the comprehensive planning needed to assure an orderly sustainable development of aquaculture.” (Zertuche-González, et al., 2008: 81) Aquaculture systems such as offshore fish farming are expected to play an increasingly important role in replacing wild caught fish. Concurring with the authors of the assessment of Mexican bluefin tuna ranching, the FAO warns that “aquaculture governance is already facing serious limitations in marine waters under national jurisdiction” (FAO, 2010: 86). Governance
improvements are seen as a critical success factor if sustainability is going to be achieved.

**Bluefin tuna ranching**

Bluefin tuna is a prized fish in Japan, consumed raw as sashimi and incorporated with other ingredients and as sushi. The red flesh of bluefin tuna, especially with the highest percentage of fat, is the most desired and thus is the costliest sashimi. (Del Moral-Simanek and Vaca-Rodríguez, 2009b) Annually in the Tsukiji market in Tokyo, one of the buyers will pay a spectacular price for a single fish, generating global headlines. (Bestor, 2004) News of this event then prompts a flurry of disparaging commentary that highlight many of the issues of fish farming mentioned above. In 2011, a 340 kg tuna caught off the coast of Japan sold at auction for $395,000 or $1,200 per kg. (Willacy, 2011) The normal market does not see such prices, but they are high nonetheless. In mid-2008, the wholesale price of some imported fresh tuna at the Tokyo Central Wholesale Market ranged from $12.19 to $61.93 per kg (Table 3.1).

**Table 3.1** Prices for bluefin tuna in Tokyo Central Wholesale Market. (Sonu, S. 2008)

<table>
<thead>
<tr>
<th>Date</th>
<th>Sales volume</th>
<th>Origin</th>
<th>Price per kg $US</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/8/2008</td>
<td>4 fish</td>
<td>Boston, MA (wild caught)</td>
<td>$40.34 to $61.93</td>
</tr>
<tr>
<td>9/8/2008</td>
<td>48 fish</td>
<td>Mexico (farmed)</td>
<td>$14.07 - $18.76</td>
</tr>
<tr>
<td>9/19/2008</td>
<td>28 fish</td>
<td>Mexico (farmed)</td>
<td>$12.19 - $16.89</td>
</tr>
</tbody>
</table>

The price difference relates to the quality of the fish. Bluefin tuna imported from ports in Boston can be large, ranging from 100 to 140 kg, wild-caught Atlantic Bluefin which
have superior qualities from the market perspective, while the juvenile Pacific Bluefin fattened for a few months in Mexican ranches just off the coast of Baja California, are smaller, averaging 15 kg and fed with sardines during their captivity. The global visibility, high value and notoriety of the bluefin tuna fishery and fish farming makes it an interesting candidate for a modeling approach to exploring the governance and policy informatics needed to address the challenges of mariculture sustainability in spite of its overall small size in terms of biomass of landings and production. In 2007, Japan imported a total of 11,390 tonnes of fresh and frozen, gilled, gutted and tail-off bluefin tuna, the type produced by Mexico, with a wholesale value of USD $ 221.3 million. (Table 3.2)

Table 3.2 Japanese imports of fresh and frozen blue fin tuna, gilled, gutted and tail-off, all species from all sources. (Sonu, 2007, Sonu, 2008)

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh Bluefin tuna</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metric tonnes</td>
<td>9,966</td>
<td>9,882</td>
<td>7,395</td>
<td>5,108</td>
</tr>
<tr>
<td>Million US Dollars</td>
<td>201.5</td>
<td>164.1</td>
<td>125.5</td>
<td>98.1</td>
</tr>
<tr>
<td>Frozen Bluefin tuna</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metric tonnes</td>
<td>6,626</td>
<td>4,220</td>
<td>5,355</td>
<td>6,282</td>
</tr>
<tr>
<td>Million US Dollars</td>
<td>102.6</td>
<td>65.2</td>
<td>93.6</td>
<td>123.2</td>
</tr>
<tr>
<td>TOTAL Million US</td>
<td>304.1</td>
<td>229.3</td>
<td>218.1</td>
<td>221.3</td>
</tr>
</tbody>
</table>

Bluefin tuna ranching is practiced at a large scale in the Mediterranean, especially in Spain and Morocco, as well as in Australia in the Port Lincoln region, in addition to Japan itself. In effect there are three separate global stocks (*Thunnus thynnus*, or the Atlantic Blue Fin Tuna; *Thunnus maccoyii*, the Southern Bluefin Tuna, and *Thunnus*
*thynnus orientalis,* the Pacific Bluefin Tuna), which are managed under different legal regimes, but all serving the Japanese fresh and frozen sushi grade tuna market.

The contribution of bluefin tuna ranching in Mexico

As recently as 2007 Mexico was the leading supplier to Japan of fresh bluefin in gilled, gutted and tail-off form (Sonu, 2008). The size and value of Mexican bluefin tuna ranching is not entirely clear. Table 3.3 shows estimates from four difference sources for the weight and dollar value of Mexican bluefin production. The values for 2006 range between 3,108 tonnes to 6,500 tonnes, and $32 to $74 million. While calendar year reporting seems to show great divergence, the production values for sources representing ranch production for the period 2000 to 2006 are 12,700, 16,946 and 17,400 tonnes from FAO, Zertuche-González and Tzoumas respectively (see Table 3.4 below). The estimated cumulative value for the same period is reported as $142 million by FAO and $279 million by Zertuche-González et al.

Table 3.3 Variations in reporting on Mexican tuna ranch production (fresh and frozen), metric tonnes and value, USD $ 000.

<table>
<thead>
<tr>
<th>Source</th>
<th>2006 Metric tonnes</th>
<th>2007 Metric tonnes</th>
<th>2006 USD $ 000</th>
<th>2007 USD $ 000</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAO, 2011</td>
<td>3,552</td>
<td>734</td>
<td>32,323</td>
<td>5,325</td>
</tr>
<tr>
<td>Sonu, 2008</td>
<td>3108</td>
<td>2549</td>
<td>51,360</td>
<td>47,687</td>
</tr>
<tr>
<td>Zertuche-González, 2008</td>
<td>4,350</td>
<td>NA</td>
<td>74,000</td>
<td>NA</td>
</tr>
<tr>
<td>Tzoumas, 2011*</td>
<td>6500*</td>
<td>3800*</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

As mentioned above, the question for aquaculture globally, and bluefin tuna ranching in Mexico in particular is whether it is sustainable. Does the Mexican industry and government have all the policy tools and levers at its disposal to insure this? What
kind of information system could be helpful in contributing to adequate planning, regulation and monitoring of mariculture so it can provide sustained benefits? Marine and coastal mariculture is diverse and complex in terms of the species utilized, technology employed, locations selected, ecosystems affected, governmental authorities potentially involved and markets served. A policy modeling approach based upon system dynamics methods is presented here as a way to consolidate the ideas and proposals of experts and tuna ranchers. This case is on its face simple enough, and of strong current interest, to allow for developing and validating a policy level model drawing upon the mental models of a variety of actors presently engaged from a business and public policy viewpoints.

Table 3-4 Reported annual production of fresh tuna from offshore "ranches" in Mexico.

<table>
<thead>
<tr>
<th>Species</th>
<th>Scientific name</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific bluefin tuna</td>
<td>Thunnus orientalis</td>
<td>0</td>
<td>521</td>
<td>517</td>
<td>517</td>
<td>4,193</td>
<td>3,402</td>
<td>3,552</td>
<td>734</td>
<td>2,919</td>
<td>2,987</td>
</tr>
<tr>
<td>1 Tonnes</td>
<td>USD 000</td>
<td>0</td>
<td>7,014</td>
<td>7,281</td>
<td>6,985</td>
<td>57,821</td>
<td>30,815</td>
<td>32,323</td>
<td>5,325</td>
<td>19,557</td>
<td>16,281</td>
</tr>
<tr>
<td>2 Tonnes</td>
<td>USD 000</td>
<td>9,000</td>
<td>10,000</td>
<td>12,000</td>
<td>35,000</td>
<td>59,000</td>
<td>80,000</td>
<td>74,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Tonnes</td>
<td>USD 000</td>
<td>700</td>
<td>800</td>
<td>5000</td>
<td>4400</td>
<td>6500</td>
<td>3800</td>
<td>1900</td>
<td>1500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Tonnes (fishery)</td>
<td>USD 000</td>
<td>3019</td>
<td>963</td>
<td>1708</td>
<td>3211</td>
<td>8880</td>
<td>4542</td>
<td>9806</td>
<td>4147</td>
<td>4392</td>
<td>3019</td>
</tr>
<tr>
<td>5 Tonnes</td>
<td>USD 000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The tuna ranching industry in Mexico was inspired in part by the early experience in Australia, and in turn may be affected in a variety of ways by developments in both regions. Globally there is a high level of concern over the status and sustainability of the wild tuna stocks and the activity of tuna ranching. Greenpeace (2005) and the WWF (Tudela and Garcia, 2004; ATRT, 2006) among many other critiques have decried the ineffectiveness of fishing quotas and tuna export restrictions in preventing the imminent collapse of both the ranching industry and the Atlantic Blue Fin fishery itself. The Australian tuna fishery reportedly was on the verge of collapse in the early 1990s, with tuna ranching introduced and now tightly regulated as part of overall Australian initiative to maintain sustainable fisheries and fish export businesses. (PIRSA Aquaculture, 2003).

Popular articles on tuna ranching sometimes take a skeptical perspective, conjuring up the exaggerated imagery of a lawless maritime Wild West with ranchers, fishers, and the government embroiled in rough-and-tumble conflict. (Montgomery, M. 2005). Such a metaphor widely misses the mark when applied to Mexican tuna ranching in our view, although perhaps the use of purse seines to capture juvenile tuna and transport them to pens close to the coast has something in common with a "round-up", and perhaps the divers who inspect and collect the fattened tuna are "wranglers". In fact, the Discovery Channel broadcast a two part series in August, 2007, on the Australian tuna ranching industry titled "Tuna Wranglers" and more recently tuna ranching was criticized in “Looting the Seas” produced by the International Consortium of Investigative Journalists and Television for the Environment (ICIJ. 2010)

Sasha Issenberg's journalistic account of world trade in fish for raw consumption "The Sushi Economy" (Issenberg, 2007), offers a different metaphor, placing tuna
ranching at the center of the global fishing industry. In describing Australian tuna ranching he points out: "The most successful of Port Lincoln’s (Australia) ranchers have made their money by identifying the optimal level of investment. They need to know when to stop feeding and to kill, the point at which they have created the highest value fish (per weight) as possible, and their investment begins to exceed the return" (Issenberg, 2007). The results of our work to date also suggest that tuna ranching is a sophisticated and well organized economic activity, and tuna ranching in Mexico also contains an element of *maquila*, the value-added production of goods with technical and material inputs from foreign investors, in this case principally the Japanese, with some local economic benefit, but organized mainly to serve the needs of the investing nation. Anthropologist Theodore Bestor's multifaceted study of Tokyo's Tsukiji fish market, broadens the perspective of Japan's system for providing fish to its population even further: "The structure of a commodity chain – the links, stages, phases, and hands through which a particular product passes…is a highly contingent social formation….Tsukiji serves as a central node—a command and control center--- for this global trade, and the market’s activities have wide influence…” (Bestor, 2004).

### 3.3 Key Research Questions

The core question guiding the research reported in this chapter from a policy perspective is whether and at what level tuna ranching in Mexico is sustainable, and from a methodological perspective, can a policy level SD modeling point the way toward an information system robust enough to serve as a bridge among scientific assessments, public dialogue among stakeholders, and the enterprises engaged in this complex activity? Is Mexican tuna ranching utilizing Pacific bluefin tuna a uniquely resilient
operation, when compared to its highly criticized Mediterranean counterpart based on overexploited Atlantic stocks, and higher-cost Australian ranching based on southern Pacific stocks? What policies are suggested when all aspects of the value chain of the industry are taken into account, including variability in migrating stock, limitations on coastal siting, alternative technologies, and local economic impacts? How vulnerable are management decisions to information flow problems within the ranching industry, and what might be the advantages of more transparent information practices? Are there important dynamics or knock-on effects among the three regional businesses that can create exogenous threats to the Mexican situation? Can a policy model be useful in guiding research questions? What approach is required to create and apply a model that draws upon the mental models and research findings from stakeholders who are not fully cooperative but reveal key facts and dynamics about their activities in speech and publications?

More specifically:

RQ: 3.1: What factors and dynamics, internal and external, affect the sustainability of export based fish ranching operations and what is their relative importance?

H 3.1a: Endogenous (internal operational) factors play an important role in the profitability of tuna ranching season to season

H 3.1b: External factors are important, in fact may be dominant and include access to juvenile tuna, global pricing, the situation in other bluefin tuna fisheries and farming (Mediterranean and Southern Pacific) and the emergence of closed-cycle bluefin and other sushi-type tuna that require high technology.
RQ: 3.2: Can a policy level SD modeling serve as a bridge between scientific assessments and policy dialogue among stakeholders?

H 3.2: SD modeling and the similar modeling undertaken by Anderson and Shamshak first can serve as a bridge among scientific assessments.

RQ: 3.3: Is Mexican tuna ranching utilizing Pacific Bluefin resilient, compared to the highly criticized Mediterranean based on Atlantic stocks, and higher-cost Australian ranching based on southern Pacific stocks?

H: 3.3 Mexican tuna ranching utilizing Pacific Bluefin is uniquely resilient, however it is far from immune to a large number of exogenous factors in addition to internal challenges.

RQ: 3.4: What policies are suggested when all aspects of the value chain of the industry are taken into account, including variability in migrating stock, limitations on coastal siting, alternative technologies, local economic impacts?

H: 3.4 Tuna ranching is highly susceptible to fisheries related variability as well as the investment behavior and markets of consuming countries, led by Japan. International agreements are an important aspect of several aspects of the ranching enterprise.
RQ: 3.5 How vulnerable are management decisions to information flow problems within the ranching industry, and what might be the advantages of more transparent information practices?

H: 3.5 Information flow problems pose issues within the ranching industry to the extent operators are independent, regulatory schemes are not functioning and information flow is low. An information system guided by a modeling approach can contribute toward addressing the broad concerns raised by the FAO on aquaculture.

3.4 Research Approach

In this chapter, a multi-method approach is employed to capture the structure and policy dynamics of capture-based Bluefin tuna aquaculture in Mexico. The opportunity to address this question initially arose in 2006 when the Packard Foundation commissioned a bi-national scientific team to assess the environmental impacts and sustainability of the emerging tuna ranching enterprise along the coast (Zertuche-González et al., 2008). The author, supported in part with funding from a complementary Packard Foundation grant, offered to participate in the activities of the scientific team to explore whether a policy model could be formulated and tested in the context of their project. In the end, a direct contribution to that study’s methodology and findings did not materialize.

Causal loop diagramming and simulation

However, an independent collegial relationship emerged with Dr. Raul Del Moral- Simanek, one of the research team members, who agreed to a series of interviews and work sessions held at the University of Rhode Island and in Ensenada, Mexico with
funding from the science assessment grant. It combines the elicitation, simulation and refinement of the evolving mental model of the scientist with content analysis of the limited literature on the Mexican case, and generalized data that is used to calibrate and validate the various builds of the model. In this sense, a modeling exercise can be viewed within the framework of action research. The results of this first phase of work included a working simulation that was reported on in Robadue and Del Moral-Simanek (2007) and presented at the 2007 System Dynamics Society conference.

Analysis of available literature at that time also provides useful input and raises important questions about dynamics of parts of the value chain that require interviews with key actors to verify, as well as interaction with the project team, representatives of the tuna industry, as well as government and NGO actors to specify and test model scenarios. For example, content analysis approach is fruitful in revealing structure and in some cases reference mode data on behavior over time as well as predictions of behavior in the future for major feedback loops. For example, one environmentalist warns that tuna ranching is unsustainable because of the risk of overproduction driving prices lower, which has happened in both shrimp and salmon farming. (Dalton, 2004) By contrast, an interview with the largest tuna rancher in Mexico addresses this price fluctuation as well, noting that it occurred early on during the emergence of tuna ranching, threatening the financial feasibility of the new business. (Panorama Acuicola, 2005). However, the issue related to price that each stakeholder is concerned with differs. The environmentalist is interested in slowing the growth of new sites and seeks to avoid higher levels of tuna fishing, while the businessman is concerned about having a stable regulatory climate, few new restrictions, and getting all blue fin tuna allocated to the ranching industry.
Content analysis of science assessments

The second phase of work reported on here is based upon a content analysis of the results of the science assessment, all of which were produced without the editorial participation of the author. This corpus includes three articles generated as part of del Moral-Simanek’s PhD dissertation (Del Moral-Simanek, Raúl Jesús; Vaca-Rodríguez, Juan Guillermo. 2009a, 2009b, and reprinted 2010 and Del Moral-Simanek, Raúl Jesús; Vaca-Rodríguez, Juan Guillermo, and Alcalá Álvarez, María del Carmen. 2010). Equally important is the report of the science assessment team itself. A marine science assessment of capture-based tuna (Thunnus orientalis) aquaculture in the Ensenada region of northern Baja California (Zertuche-González José A., Sosa-Nishizaki Oscar, Vaca Rodriguez Juan G., Del Moral-Simanek Raul, Costa-Pierce Barry A., Yarish Charles, Guzman-Calderon Jose Manuel, Chong-Robles Jennyfers, Leyva-Garcia Ivan Abiut, Robadue Don, Heupel Eric, 2008). This corpus was coded and analyzed using content analysis software (Atlas Ti version 6) to create in effect a searchable database and ontological representation of these studies. It includes complementary work by Dr. Gina Shamshak, who began her dissertation work at the same time as the author and del Moral-Simanek, collaborating with Dr. James Anderson of the University of Rhode Island on the economics of bluefin tuna ranching in the Atlantic coast in Shamshak and Anderson, (2009)

Revised simulation and scenario testing

The third phase of work presented here presents a revised version of the bluefin tuna ranching model to represent and explore different scenarios proposed by critics,
industry members and Mexican planners. The model revisions include limited changes to equations and parameters, drawing from knowledge in the coded corpus, while retaining the model boundaries. These changes improve the logic and performance of the model. Replication of the main scenarios presented in the scientific assessment and other discussions of the Mexican tuna ranching case helps illustrate the conclusion by the science assessment that the business of bluefin tuna ranching using a *maquiladora* system is stable under the unique current conditions present in the northwestern Pacific coast of the Baja Peninsula. However, both critics and industry leaders point out that moderate changes in any one of the conditions, or moderately changed combinations of conditions, can make the business unprofitable for some producers. Various Mexican government policies have changed in response to some of these concerns, while the industry itself is pressing forward with technological and operating innovations to address the dynamics of the bluefin tuna ranching value chain. There are a number of areas at the edge of the model boundary where the available research and documentation of industry structure, characteristics and behavior is deficient and model-guided information collection would be useful. Some of these are already addressed by more technically complex models that have the advantage of addressing economic and optimization issues that the simple tuna ranching cannot. However those require sophisticated programming capabilities and unlike the tuna ranching model presented here, require proprietary software to run.

In the following sections the exposition begins with a comparison of textbook and mental model versions of Mexican tuna ranching. It is followed by a brief comparison of variations on the basic textbook model that appears through content analysis of the few popularly available descriptions of the industry. A formal simulation model was then
developed, based on both these sources in order to explore some simple scenarios of the future development of the industry. This simulation was substantially improved as a result of the content analysis of research findings, not in terms of overall structure, which proved robust, but in parameters, equation formulation and the specification of scenarios by both the science assessment team and more recently by entrepreneurs and experts seeking more profitable operating methods to counter some of the Mexican industry dynamics which the revised model portrays. To the degree possible I have preserved the iterative, detective-like nature of this exploration in the narrative.

3.5 What is tuna ranching in Mexico and its issues?

A mental model

This investigation begins with this simple question that was answered in story-like form in 2006 and recorded by the author in the following causal loop diagram shown in Figure 3-1. Tuna ranching nests within other, larger fisheries and economic activities, including the overall tuna fishing industry and the sardine fisheries in Mexico. Bluefin tuna are merely visitors to the northern Pacific coast of Mexico and the western United States. They travel in schools as juveniles from the stock located off the Japanese coast, arriving around May and departing Mexican waters in August. The tuna arrive to feed on a large local sardine population located along the coast of Baja California and the State of California to the north. The presence of this large sardine stock also makes it relatively easy and economical to feed the captured tuna fresh sardines. The object of bluefin tuna ranching is fairly straightforward: capture, hold and feed tuna for several months until they increase in weight and in the proportion of fat to the preference of the Japanese
buyers, in other words, a marbled effect, so that a higher price can be obtained, somewhat closer to the large, wild-caught bluefin tuna noted in Table 3- above, that command a much higher price.

Figure 3-1  Simple mental model overview of tuna ranching in Mexico (Robadue and del Moral-Simanek, 2007)

Since Mexican tuna ranching occurs around the City of Ensenada, less than two hours by truck from the U.S. border city of San Diego, it is quite feasible to select, kill, process, pack and ship fresh chilled tuna to Los Angeles, where it boards an air cargo flight to Japan. Fresh blue fin tuna is also available from wild fisheries and to some degree from the Atlantic, Australian and Mediterranean fisheries. Current freezing technology is so efficient that it allows for comparatively good prices for frozen blue fin tuna, although the Japanese market offers a price premium for fresh and fillet forms of the tuna.
The model has one main positive, reinforcing loop (R1) that leads to increasing production from tuna ranching, driven by investment in ranches and fishing effort, and one main balancing loop (B1), which is the effect of tuna fishing on the stock. The boundaries of this mental model are at the fishery and the market place, both of which exist outside Mexico and thus are taken to be largely exogenous. Since the tuna themselves are not a local stock, there is no real endogenous fisheries management opportunity. Since the market for bluefin tuna is global, and largely controlled by Japan, tuna ranchers have to be price-takers, except for the fact that there is flexibility in their operations on how long to hold the tuna and pens, and the fact that Japanese buyers require samples and data in advance on every single fish that is sent to market so that its fat content and other qualities are known.

*The expert view of tuna ranching*

A more elaborate conceptual model of tuna ranching was developed for comparison, depicted using stock and flow notation in Figure 3.2. This conceptual model is in fact a supply chain, drawn from a content analysis of a recently published comprehensive text book on aquaculture (Pillay and Kutty, 2006) This concept map elaborates considerably on a few key aspects of the simple mental model elicited from del Moral-Simanek. While more detailed and complex in structure, it is also noteworthy for treating tuna ranching as a supply chain with no explicitly described feedback loops. This and subsequent model diagrams and simulations were created using Vensim DSS.
Moving from left to right in the diagram, key stages in the supply chain include:

- Bluefin tuna stock entering coastal waters
- Fishing for tuna
- Towing caught tuna to fixed pens in sites
- Feeding tuna in cages
- Processing tuna in fresh and frozen forms for sale to market

Pillay and Kutty imply there is a feedback loop between catching juvenile tuna and the need for fishing quotas, although in the case of Mexico, tuna is a migrating stock from the western Pacific, in particular Japan. In practice, Australia also closely manages the southern bluefin tuna stock. Fishing for tuna is done using purse seines, and the fish are transferred and carefully towed to fish pens located in open water near the coast. A number of practical issues come into play in terms of finding schools of tuna, the towing process, the siting of ranches, which are comprises of collections of pens near shore. It is also at this point that research on closed cycle tuna ranching is noted, which would substitute wild caught tuna with juveniles spawned in captivity. Once placed in pens, the tuna must be fed continuously in order to gain the fat content that increases their value in the fish market, for example with fresh or frozen sardines. Managers then determine when to begin selecting tuna to be processed, packed and shipped by air freight in the case of fresh tuna, or by ship in the case of frozen, not unlike wild caught tuna. Since both are important, the conceptual framework of Pillay and Kutty addresses issues unique to each.

A noteworthy aspect of Pillay and Kutty’s exposition is the identification of key areas for technological improvement and research. In many other types of aquaculture the industry is trying to eliminate dependence on wild caught larvae, fingerlings or juveniles, so they including that component. In the past five years since this research
project was initiated, Japan, Australia and European tuna ranchers have announced progress or success toward closed cycle production. A second area of needed improvement is in tuna ranching operations at every stage to reduce stress on the tuna, increase the efficiency of feeding, upgrading harvesting and handling techniques all toward improving the quality of farmed tuna to increase its price.
Figure 3-2 Generic tuna ranching conceptual model extracted from content analysis of Pillay and Kutty, 2006.
Critiques of tuna ranching

By way of comparison, and to indicate the potential of modeling exercises which incorporate detailed analysis of document content, I have annotated Pillay and Kutty’s view of the tuna ranching supply chain using a highly critical piece written by John Volpe in BioScience (Volpe, 2005). His critique is depicted in Figure 3.3 as an annotated version of the stock and flow diagram. Volpe's major criticisms are shown moving from right to left on the supply chain diagram in the form of major feedback loops. His main idea is that a high price differential between ranched and wild caught tuna is required to make a ranching operation viable. He predicted that price drops from oversupply of ranched tuna will lead to an industry collapse. A second major feedback loop created by price drops relates to Volpe's other principal claim is that a concentration of firms in tuna ranching will lead to weaker regulation and low compliance. This way of expressing the issue presumes that governance is presently strong and will be degraded, while the FAO views governance as weak and needing to be strengthened in view of the predominant resistance to better policy. Volpe draws from the example of the concern over an impending collapse of the Atlantic bluefin tuna fishery and tuna ranching industry to highlight problems with policy informatics issues such as poor documentation of catch, known as IUU or "illegal, unreported, unregulated" tuna fishing, which has plagued Mediterranean tuna ranching and the bluefin tuna fishery in general. This criticism is echoed strongly by Greenpeace and WWF which have been strong opponents of existing fisheries and tuna ranching policies in the Atlantic Ocean and the Mediterranean where
tuna ranches operate. More broadly the stock assessment study group of the International Commission for the Conservation of Atlantic Tuna (ICCAT) found recently that:

the available information strengthens the opinion held by the Group that harvests of bluefin tuna from the eastern Atlantic and Mediterranean have been seriously under reported in recent years, particularly those from the Mediterranean. The volume of catch taken in recent years likely significantly exceeds the current TAC (total allowable catch) and is likely close to the levels reported in the mid-1990s, i.e. about 50,000 t in the East Atlantic and Mediterranean. (ICCAT, 2006)

The researchers agree with Volpe, noting that accurate catch data is essential for managing the bluefin fishery, "our inability to obtain reliable information on catch and catch at age seriously undermines the credibility of conducting analytical evaluations of stock status which rely on this information." The ICCAT researchers also point out that fishing technology is changing rapidly in the Mediterranean as a consequence of blue fin tuna ranching, in particular the modernization of fleets using purse seines for live capture of juvenile tuna. "This worrying development in a context of overexploitation potential has further led to a tremendous spatial expansion of the PS fleets in the Mediterranean, ...Consequently, the Mediterranean nowadays supports BFT (blue fin tuna) fishing over its entire surface; a situation that has never been encountered in the past and that is of high concern since there appears to no longer exist any refuge for BFT in the Mediterranean during the spawning season."
Notes to Figure 3.3:

Balancing Loop 1 "Mediterranean ranches are flooding world markets, resulting in a decline in value of ranch tuna by 50 percent from 2003 to 2004. Tuna ranching is viable only as long as the premium price of its product is protected, which in turn demands scarcity of supply. The industry is showing every sign of becoming a victim of its own success. If present rates of growth are maintained, an industry wide collapse is imminent."

Reinforcing Loop 1 "As companies approach collapse, motivation to offload production costs will grow, resulting in more violations of the emaciated regulation regime. This is sure to make the current bad situation worse. From the ashes, a handful of large multinational players will most likely emerge to supply markets in an OPEC-like quota supply model."

Balancing Loop 2 "Ranched tuna eat a lot of fish—so much, in fact, that the local environment can rarely keep pace, necessitating the import of feed fish from other regions.... this potentially opens a Pandora’s box of epidemiological problems."

Variables added to Pillay and Kutty generic tuna ranching model

V1 Subsidy from nature's inputs

V2 Profit from frozen tuna

V3 Industry contraction (from profit drop due to oversupply of tuna)

V4 Fish used for feeding

V5 Imported feed fish

V6 Local food fish stocks

V7 Biosecurity Risk

V8 Concentration of firms (leads to weakened regulation)

Figure 3.3 Critique of Tuna Ranching by Volpe, 2005, in stock and flow format. Red arrows and box outlines indicate areas of criticism, <concepts in brackets> identify new concepts.
Fisheries and aquaculture policy perspective

In sharp contrast to the Mediterranean and Australian cases, very little is written or disseminated about the Mexican tuna ranching industry. This is first of all reflected in official publications of the Mexican government itself. At the time this research project and the science assessment funded by the Packard Foundation began, The Mexican Diario Oficial (August 25, 2006) published the policies and analyses of the Instituto Nacional de Pesca. Tuna aquaculture received two pages, with a simple bar graph acknowledging the growth of blue fin tuna capacity to 11 ranches and production increasing from virtually nothing in 1997 to nearly 3000 tonnes in 2003. The document also notes that there are no regulations for tuna aquaculture, and that at some point it might be useful to have an official guideline published on the correct treatment of the live tuna fishery. At the time the two main issues requiring research were the need for a "balanced" feed to supplement natural foods (such as sardines) and sanitation, for example parasites and infections. In terms of management policies, the national policy notes that it might be good in the future to separate out the management of yellowfin from bluefin tuna, given that the latter are an extremely small fishery. Also, the tuna fishing fleet in general should not be allowed to increase. Finally, the bluefin tuna stocks were categorized as "overexploited". Current analysis and policy are discussed below, and represent an evolution in two main regards. The Mexican government has adopted restrictions on bluefin tuna fisheries and actively monitors operations, but also is seeking a ten-fold expansion of marine fish farming in Northwestern Mexico.
León and Ruiz (2006) added little to this discussion except to suggest that it might be worthwhile to require that all blue fin tuna be assigned exclusively to tuna ranching, since "using the captured blue fin tuna in any other process would be to lose its economic potential, especially given its scarcity".

The OECD (2006) conducted a comprehensive study of Mexico's fisheries policies including marine, aquaculture and inland, striking the theme of the globalization of fisheries and its impact on Mexico. Tuna ranching did not figure very prominently in the overall set of reforms required to place Mexican fisheries on the path to sustainability, greater political visibility and a range of administrative reforms to strength enforcement, cooperation and research, and reduce unhelpful subsidies and overinvestment on the other. The OECD pointed out that "there is very little work done in Mexico on the economic and social aspects of fisheries management policies and the literature in this area is very small" (2006:230). It goes on to note that "the interest in these studies at the policy level appears slight, yet it is these types of studies which will provide essential information on the socio-economic impacts of fisheries policy changes".

A new general fisheries law was in fact adopted in Mexico in 2006 and Mexico has been actively engaged in international discussions, including the effort to create a code of responsible fisheries. It also successfully negotiated a trade agreement with Japan in 2005, including the reduction of tariffs for fresh tuna imports among many other products. An article at the time quoted Philippe Charat, the largest tuna rancher, as saying "Sure, if Japan removes tariffs on it (blue fin tuna), we will export 50% more" (Asia Pacific News, 2004).
Among the specific concerns, the OECD found that "there is limited information on the economic profitability of commercial fisheries" (2006:312). As part of creating greater certainty in the aquaculture sector, the study recommends "maintenance of long term concessions for aquaculture and tuna ranching", which are transferable. Overall, the OECD urged Mexico to create longer term plans for fisheries, and draw on concepts of self-regulation and market mechanisms, including individual transferable quotas rather than limited entry schemes that allow for over-exploitation through "technological creep". The OECD concluded that "...it is important to recall that fisheries are a dynamic system with many integrated components. Changing one component of the system will have consequences for other parts of the system; some consequences will be anticipated and well understood, while others will be unexpected" (2006:318).

3.6 A modeling approach to the question of sustainability of Mexican bluefin tuna ranching

The original simulation based on textbook and mental models of bluefin tuna ranching

The first version of stock and flow working model that emerged in November 2006 during work sessions with the author and del Moral-Simanek is reported in Robadue and Del Moral-Simanek (2007), and summarized here. Its structure preceded the preparation of the graphical representations of the exposition of Pillay and Kutty, and the critique by Volpe shown in Figures 3.2 and 3.3.

We evaluated four “scenarios” using the original formulation of the model to demonstrate the viability of the approach. To avoid repetition, structural details of the
revised version of the model and findings from scenarios based on the science assessment and more recent proposals for improving tuna ranching are presented in Section 3.8 below.

A glimpse of the core structure of the Mexico tuna ranching value chain model developed so far is presented in Figure 3.4. It differs in a few key details about how tuna ranchers make decisions in the operation of ranches related to annual fishing effort and deployment of additional pens to hold and feed the tuna, and the issue of feeding juvenile tuna. This is consistent with the aquaculture literature on tuna ranching, as represented by Pillay and Kutty in Figure 3.2, but without reference to closing the cycle and spawning blue fin tuna, nor to freezing the fattened tuna. While the critic Volpe (Figure 3.3) uses feedback thinking by discussing larger feedback loops that he believes pose a challenge to the tuna ranching industry, these were not included in the original running model. A simple price feedback loop influences the rate of processing, since market prices do vary (in a way described by Bestor (2004) that is far more complex than represented here) as well as influences ranch size.
**Figure 3-4** Overview of the initial build of the Mexico Tuna Ranching model

The working stock and flow model captures the basic value adding production chain of tuna ranching within the Mexican context, and appears to have a measure of face validity. It simplifies various aspects of each stage, since it is not the goal at the outset to simulate the activities and financial situations of the constituent firms rather to prepare an aggregate model that captures overall behavior and dynamics of importance to industry sustainability.

The boundaries of the working model are set at the stock of the Pacific Bluefin tuna *Thunnus thynnus orientalis*, that in this version is assumed to be in equilibrium and unaffected by fishing in Mexico and the Pacific. It is also limited at the sardine fishery,
which is assumed to be unaffected by fishing or sales of sardine to the tuna ranches. The economics and support industry, as well as financial transactions and pricing of the tuna, are not incorporated in this version. All of these components and possible additions are discussed in more detail for the revised model in Section 3.8, below.

The core scenario and basic parameters are drawn from the known and estimated characteristics of the industry in Mexico, however the model runs shown in Table 3.5 are presented to illustrate the functionally and plausibility of the structure and emphasize creative inquiry as to the sustainability of the activity from economic, social and environmental perspectives.

To examine the potential usefulness in asking questions about sustainability, several scenarios were formulated. Table 3.5 shows the variations in a few parameters that are used to set up 10 year runs, and the final outcome in terms of tonnes of Bluefin tuna to the market.
Table 3.5 Original simulation output from model runs analogous to the Mexican tuna ranching case

*Original Scenarios*

Scenario 1 The Base Case: The first question was whether the model could simulate fishing for tuna, placing it in pens, and feed the tuna enough to add weight for sale. Scenario 1 manages to do this. The industry was assumed to have enough pens on hand to raise 3600 tonnes of tuna, and the model sent enough tuna to Mexico to more than accommodate the fishing effort needed to have 40 tonnes per pen. The model successfully fed the tuna enough so they gained 9.4 percent in net weight after processing, however this growth rate would be considered low and unprofitable.
Figure 3.5 The original model output for capturing and processing bluefin tuna.

Figure 3.6 Creating added value in the tuna ranching supply chain.
Original Scenario 2 simply reduced the assumed size of the overall Western Pacific tuna stock, keeping all else equal, with the result that a lower stock, even if very large, will reduce the amount of tuna fattened. This might be the equivalent of events such as poor year classes in the Western Pacific, or offshore bluefin fishing increasing greatly, intercepting the juvenile tuna before they reach Mexico. The model does this with a lookup graph that has fishers become less efficient as the end of the bluefin tuna season in Mexico approaches so that at a certain point it is no longer worth setting nets.

Original Scenario 3 assumed that ranchers can decide to double their fishing effort to get as many tuna as possible, and assumes either the pens can accommodate the extra tuna or more pens are quickly deployed. The intuition is that because there are fewer tuna overall, each setting of the nets will be less and less productive. The model employs very simple structure to generate this effect. So while the capacity to accommodate tuna is present, the restriction on bluefin tuna stock produces a disappointing production result.

Original Scenario 4 represented the optimistic view of tuna ranching that does not recognize any internal or external constraints, and thus supports the assumption that tuna ranching is sustainable in the Eastern Pacific. Since the bluefin tuna stock is not local to Mexico, and literature shows that the juveniles that swim to Mexico must leave the Western Pacific waters in search of food and they do not form as part of the spawning stock, Mexico might as well catch and ranch them all.

*Limits of the original model and knowledge of tuna ranching*

Key uncertainties exist throughout the tuna ranching supply chain, including the tonnage of tuna actually captured and transferred to pens, the number of pens put into
operation each year, the amount of juvenile tuna in pens, the feeding rate practices of different ranchers, the conversion factor for transforming a kg of sardines into added fat. The amount of tuna fattened in ranches and sold and exported from Mexico is accurately tracked by the supply chain but real data for model validation on the exact production levels, as noted in Section 3.2 was not consistent with information obtained to date on the fattening process. The original base case used general parameters suggested by key informants, but which require verification and validation, as small changes in some of these parameters cause large behavior changes in the model output. The assumed goal of tuna ranching is to add enough weight and fat to tuna to maximize market value of the processed product.

Additional key assumptions include: each ranch has 6 pens, each pen holds 80 tonnes of tuna, and all pens are filled each year, with the implication that currently the tuna ranchers seek to acquire 4320 tonnes of juvenile tuna. The model includes approximate information on the number of ranches put into operation since 2001, up to 9 total ranches.

A second set of key assumptions in the original model are feeding and food conversion rates. It is assumed that each pen in operation requires \( (80 \text{ tonnes fish/pen} \times 80\text{kg/ton/day}) = 6.4 \text{ tonnes of sardines per day per pen}, \) or 192 tonnes per pen per month or 31104 tonnes per season for 54 pens. The base run assumed that one tonne of sardines is 5 % efficient in adding weight to tuna, that is per month each tonne of juvenile tuna gains 120 kg of weight from eating 2.4 tonnes of sardines.
Overall, just doing simple spreadsheet math, if tuna ranchers had purchased 4320 tonnes of tuna in a given season, and fed their tuna on average for three months before harvesting, they would have been able to ship 5875 tonnes of fresh tuna to Japan, having operated 54 pens for 3 months. The value added as determined by fat content gained, is in this example 1555 tonnes or 35%. The amount shipped should also be corrected to account for the weight loss from removing gills and guts. If the tuna are held on average for 6 months, then using this logic the gain would be 3110 tonnes for a total of 7,430 tonnes of product. However model runs do not produce this optimistic result because it takes months to capture 4,320 tonnes of tuna, the tuna are not raised in one giant batch for six months nor are they sold all at once. Tuna ranchers closely follow market trends and carefully time their feeding and processing rates.

In sum, this first build of the model, derived mainly from co-author Simanek's mental model of the industry, generates plausible results for key aspects of the Mexico portion of the Pacific bluefin tuna supply chain.

*Formulating policy scenarios for bluefin tuna ranching in Mexico*

The discussion of role of aquaculture in the global food supply in Section 3.2 raises questions about its sustainability at several levels. Linear diagrams of the supply chain such as the representation of the textbook view shown in 3-2 show the breadth of issues an entrepreneur must attend to in order to operate a profitably business and thus suggest the need to expand the number of elements included in any model of the industry. The feedback view that is implied by many of the criticisms of tuna ranching, and fish
farming more generally, suggests concerns as broad as the economics of the global industry as well as local such as the biological, economic and ethical aspects of using a food fish to fatten a luxury good.

Figure 3.7 shows global farmed bluefin tuna production for the period 2002 to 2010. (Tzoumas, 2011) This graphic (an interpolation of the data for Mexico is shown in Table 3.4 and below.) In stark contrast to the optimism noted in the model and earlier discussions, including Mexico’s own plan for expanding fish farming, bluefin tuna ranch production has steadily declined since 2006, not just in Mexico but in Australia, and the Mediterranean. Japan, on the other hand, has more than doubled its farmed bluefin tuna output, and in addition has closed the bluefin tuna production cycle including marketing bluefin raised entirely in captivity based on technology developed at Kindai (Kinki University). (Green, 2010; Haraguchi, 2010). Could it be that Japan has decided to wind down its support for the bluefin maquiladora in Mexico? Is it possible that Volpe is right and that the marketplace for ranched bluefin tuna is a victim of overproduction and price collapse? On the other hand, can tuna ranchers develop new technology and procedures to meet the apparent changing conditions and stabilize, if not attain sustainability in their operations?
**Figure 3.7** Global Farmed Bluefin Tuna Production (Estimated W/R equivalent sales weight at farm gate)  Source: Tsoumas, 2011

![Graph showing global farmed bluefin tuna production](image)

<table>
<thead>
<tr>
<th>Species</th>
<th>Scientific name</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific bluefin tuna</td>
<td>Thunnus orientalis</td>
<td>0</td>
<td>521</td>
<td>517</td>
<td>517</td>
<td>4,193</td>
<td>3,402</td>
<td>3,552</td>
<td>734</td>
<td>2,919</td>
<td>2,987</td>
</tr>
<tr>
<td>3</td>
<td>Tonnes</td>
<td>700</td>
<td>800</td>
<td>5000</td>
<td>4400</td>
<td>6500</td>
<td>3800</td>
<td>1900</td>
<td>1500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Tonnes (fishery)</td>
<td>3019</td>
<td>963</td>
<td>1708</td>
<td>3211</td>
<td>8880</td>
<td>4542</td>
<td>9806</td>
<td>4147</td>
<td>4392</td>
<td>3019</td>
</tr>
</tbody>
</table>

**Table 3-6** Production of farmed bluefin tuna and fished bluefin in Mexico. Sources: 1: FAO - Fisheries and Aquaculture Information and Statistics Service - 09/12/2011; 3: Tzoumas, 2011; 4: IATTC, 2010
What was a merely scenario at the time of the science assessment and the original report on the Mexico Bluefin Tuna Ranching Model now appears to have become the reference mode which a model would need to reproduce as part of demonstrating validity and to help test ideas that could address the various challenges identified by experts and the industry. Section 3.7 describes the findings of a content analysis of the corpus of documents generated by the Mexico tuna ranching science assessment and a few more recent statements by Mexican tuna ranchers and other experts. A series of corrections to the model are made based on this information, as well as scenarios formulated based upon issues raised by experts and ranchers. These are used in the exposition and testing in Section 3.8.

3.7 A knowledge base for bluefin tuna ranching in Mexico: a content analysis approach

Content analysis is a set of techniques “for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use.” (Krippendorf, 2004) Text analysis is a frequently used part of system dynamics teaching problem sets and exercises where a portion of model structure, parameters, reference modes and feedback loops need to be discerned and added, drawing from descriptive texts, newspaper articles, or interviews. Some researchers begin with document analysis to define and describe problem structure and feedback loops. For example, Vennix suggests the use of preliminary models to prepare for a group model building exercise. “In this case the project team examines a number of relevant reports and extracts a preliminary model from it [which] implies the use of content analysis as a research technique” (Vennix, 1996, p. 102) Deegan follows this procedure in coding texts to understand problem
formulation and decision making in flood management (Deegan, 2009) The reverse
procedure is applied here. In the present case, the original tuna ranching model was
elicited verbally during extended interviews, extended by close examination of textbook
and critical texts using content analysis, and partially validated to data from the actual
case (Robadue and Del Moral-Simanek, 2007). Meanwhile a series of key research
reports were prepared about the Mexican case and the larger question of offshore fish-
farming. A corpus of these documents was assembled, acting as a knowledge base for
model validation, scenario identification and calibration of parameters based on scientific
assessments. (Table 3.7)

Table 3.7 Documents included in tuna ranching corpus (data base) for content analysis

<table>
<thead>
<tr>
<th>Primary Doc #</th>
<th>Document reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>P4</td>
<td>Del Moral-Simanek, Raúl Jesús del; Vaca Rodríguez, Juan Guillermo. (2009a). Administración de la pesquería del atún aleta azul en Baja California. Una visión global</td>
</tr>
<tr>
<td>P3</td>
<td>Del Moral-Simanek, Raúl Jesús; Vaca-Rodríguez, Juan Guillermo. (2009b). Captura de atún aleta azul en Baja California, México: ¿pesquería regional o maquiladora marina</td>
</tr>
<tr>
<td>P1</td>
<td>Del Moral-Simanek, Raúl Jesús; Vaca-Rodríguez, Juan Guillermo, Alcalá Álvarez, María del Carmen. (2010). Análisis socioeconómico e interrelación de las pesquerías de sardina y atún aleta azul en la región noroeste de México.</td>
</tr>
<tr>
<td>P6/7</td>
<td>Robadue, D., and del Moral-Simanek, R. (2007). A system dynamics perspective on a global fishing enterprise: The case of tuna ranching in Mexico. NOTE: this document was analyzed in two parts due to an error in preparing the primary document.</td>
</tr>
</tbody>
</table>
The coding scheme for text pages and data is in essence a topic map or thesaurus of the topic of bluefin tuna ranching. The initial scheme was comprised of the topic map prepared as background for creating the original model (Robadue and del Moral-Simanek, 2007) then expanded in two ways. Nearly all of the variable names used in the 2007 model became codes. Whenever a phrase or passage was encountered that offered specific information that would help validate, correct or calibrate the model, it was coded with that variable. In addition, open coding was used to capture additional information about the topic of bluefin tuna ranching that was not within the boundaries of the model or was relevant to the model but not specific to Mexico. As a result, ten unique model variables used by Shamshak and Anderson (P2) were added to the coding scheme, 101 codes were related specifically to the bluefin tuna model, and 91 codes pertained to bluefin tuna ranching in general, many of which were related to the Mexico ranching model. This generated about 5800 coded quotations (excluding general categories such as country, region, and species, for example). This was accomplished using Atlas Ti 6.2, a content analysis software package.

A word count was done across the primary documents P1 to P7, which pointed out the differences in use of terminology among the authors. Three of the documents are in Spanish, but co-authored by the same two individuals, so the vocabulary use was consistent. Zertuche-Gonzalez et al. utilized a set of unique terms in their science assessment that made sense to adopt in the Mexico Bluefin Tuna Ranching Model, for example WPO referring to the Western Pacific Ocean (Japan region) and EPO referring to the Eastern Pacific Ocean (including Mexican waters). They also coined the phrase
Capture-Based Tuna Aquaculture, CBTA, which is used 147 times only by them; however the coding scheme was revised to accommodate it. Another pair of terms used in the corpus are farming and ranching to refer to CBTA. Variations on ranch, rancho, rancheros and so on was used 252 times, compared to 184 references to farms and farmers, so the term ranch is mainly used in this chapter and in the model. Finally pen or pens is used 67 times compared to cage or cages used 87 times, so terminology in the model has been adjusted to the use of cages.

More important than word usage is the content of the coding. Table 3.8 summarizes the main topics (code families) the number of specific codes and quotation associated with each topic. The first three summarize by broad categories. There are 91 general or context related codes, 101 related specifically to the model, and 10 unique codes related to the bio-economic model proposed by Shamshak. The remainder of the table lists topics and the number of codes tied to each, as well as the number of quotes. Very little information is provided on the closed cycle aspect of bluefin tuna ranching, although it helps explain the growth of Japanese tuna ranching, since mainly juveniles, not adult spawning tuna migrate to the Eastern Pacific Ocean.
Table 3.8 General categories of codes, and related quotations. See Appendix II

<table>
<thead>
<tr>
<th>Code Family</th>
<th>Codes</th>
<th>Quotation(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BFT (Bluefin Tuna) Context</td>
<td>91</td>
<td>2185</td>
</tr>
<tr>
<td>BFT (Bluefin Tuna) _Model</td>
<td>101</td>
<td>849</td>
</tr>
<tr>
<td>BFT (Bluefin Tuna) _Shamshak</td>
<td>10</td>
<td>126</td>
</tr>
<tr>
<td>BFT (Bluefin Tuna) _farming Closed Cycle :</td>
<td>1</td>
<td>37</td>
</tr>
<tr>
<td>BFT Fish Farming Feeding BFT (Bluefin Tuna)</td>
<td>23</td>
<td>321</td>
</tr>
<tr>
<td>BFT Fish Farming site operations</td>
<td>42</td>
<td>1665</td>
</tr>
<tr>
<td>Economic aspects BFT (Bluefin Tuna) Fish Farming</td>
<td>21</td>
<td>446</td>
</tr>
<tr>
<td>Efficiency of Conversion of Sardines to Tuna Fat</td>
<td>6</td>
<td>91</td>
</tr>
<tr>
<td>Environmental aspects BFT (Bluefin Tuna) Fish Farming</td>
<td>19</td>
<td>324</td>
</tr>
<tr>
<td>Fishing BFT (Bluefin Tuna)</td>
<td>50</td>
<td>605</td>
</tr>
<tr>
<td>Governance</td>
<td>9</td>
<td>349</td>
</tr>
<tr>
<td>Information</td>
<td>14</td>
<td>465</td>
</tr>
<tr>
<td>Marketing BFT (Bluefin Tuna)</td>
<td>23</td>
<td>434</td>
</tr>
<tr>
<td>Processing BFT (Bluefin Tuna)</td>
<td>22</td>
<td>239</td>
</tr>
<tr>
<td>Sardine Fishery</td>
<td>26</td>
<td>404</td>
</tr>
<tr>
<td>Social aspects BFT (Bluefin Tuna) Fish Farming</td>
<td>2</td>
<td>32</td>
</tr>
</tbody>
</table>

For detailed listing of codes. Social aspects are hardly discussed at all, only 2 codes and 32 quotes. Environmental aspects are largely discussed only by Zertuche-González et al. More attention is given to fishing, sardines and feed, operations, marketing and economic aspects.
A detailed network diagram illustrating the relationship among code families (topics) and codes is provided in Appendix III and not discussed further here. A similar diagram illustrating the relationship among codes in the three main groups is provided in Appendix IV. Some of the bio-economic model variables are unique to Shamshak and do not link much to the other codes. The codes representing the Mexico Bluefin Tuna Ranching Model are linked together approximately in a causal set of relationships, although feedback loops are difficult to portray without a more extensive amount of diagram development that would create a more robust ontology of bluefin tuna ranching. Some of the topics covered by the general treatment of bluefin tuna ranching, such as environmental factors, do not have many ties to the variables in the bluefin tuna ranching model as most of those details are kept exogenous.

Figure 3.8 provides a simple example of the use of content analysis to aid in refining the bluefin tuna ranching model. The discovery of the table through the content analysis provided a consolidated source of information about a key variable in the bluefin tuna ranching model, the rate of conversion of food, mainly sardines, into weight and fat gain. Similarly in Figure 3.9, the content analysis and code network located quotations from different sources allow for a comparison of viewpoints and recommendations on feeding rates. Codes with an _ as a prefix are from the model and refer specifically to Mexico, other codes pertain to general information about fish farming or tuna ranching. Finally, Figure 3.10 locates some proposals that link recommendations for best practices in tuna ranching with public policy proposals. A code appears between the two initially
selected codes related to research sharing and extension, adding quotes of ideas that otherwise would have been missed in the search.

A number of issues with different components of the model were addressed by selecting codes and then reviewing the content of the quotes for potential clarifications and solutions. This included identifying scenarios to evaluate using the revised model, which is discussed in Section 3.9.

**Figure 3.8** A summary of the literature on feed conversion rates needed to calibrate the Mexico Bluefin Tuna Ranching Model (Atlas Ti screenshot)

Table 3. Feed conversion rates in CBTA

<table>
<thead>
<tr>
<th>Species</th>
<th>Dry Basis FCR</th>
<th>Wet Basis FCR</th>
<th>Sizes</th>
<th>Food Types</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>T. orientalis</td>
<td>1.9</td>
<td>7</td>
<td>45 kg</td>
<td>S. sagax</td>
<td>Sylvia et al. (2003)</td>
</tr>
<tr>
<td>T. orientalis</td>
<td>2.6-4.1</td>
<td>10-14</td>
<td>&lt;=40 kg</td>
<td>Mix Sm Pelagic</td>
<td>Ikeda (2003)</td>
</tr>
<tr>
<td>T. orientalis</td>
<td>3.6</td>
<td></td>
<td></td>
<td></td>
<td>Smart et al. (2003)</td>
</tr>
<tr>
<td>T. orientalis</td>
<td>4.1-5.9</td>
<td>14-20</td>
<td>&gt;60 kg</td>
<td>Mix Sm Pelagic</td>
<td>Ikeda (2003)</td>
</tr>
<tr>
<td>T. thynnus</td>
<td>3.8</td>
<td>13</td>
<td>50-300 kg</td>
<td>Mix Sm Pelagic</td>
<td>Perc. Z. (2003)</td>
</tr>
<tr>
<td>T. thynnus</td>
<td>4.8</td>
<td>15-38</td>
<td>32 kg</td>
<td>Mix Sm Pelagic</td>
<td>Aagado et al. (2006)</td>
</tr>
<tr>
<td>T. thynnus</td>
<td>7.8</td>
<td>24-87</td>
<td>219 kg</td>
<td>Mix Sm Pelagic</td>
<td>Aagado et al. (2006)</td>
</tr>
<tr>
<td>T. thynnus</td>
<td>8.0</td>
<td>25.6</td>
<td>180 kg +</td>
<td>Mix Sm Pelagic</td>
<td>Aagado et al. (2005)</td>
</tr>
<tr>
<td>T. maccogii</td>
<td>2.7-4.9</td>
<td>10-17</td>
<td>17 kg</td>
<td>S. neoplanchards</td>
<td>Fernandes et al. (2007)</td>
</tr>
<tr>
<td>T. maccogii</td>
<td>3.2-3.8</td>
<td>11-13</td>
<td></td>
<td>Mix Sm Pelagic</td>
<td>Smart (1996)</td>
</tr>
</tbody>
</table>

Dry FCR was computed from reported wet FCRs. For Ikeda (2003) and Smart (1994) a 71% moisture composition for a mixed, small pelagic diet was used from a survey of literature including articles cited in the table and Bunce (2001), Fernandes et al. (2007) and Norita (2003). Besides species, individuals size and food composition, water temperature is a contributing factor to FCR (Ikeda 2003; Smart et al. 2003; Graham and Dickson 2004).
Figure 3.9 A portion of the code network that identifies the specific quotations in different parts of the corpus related to recommended feeding rates as well as the efficiency of conversion of feed to increased weight and fraction of fat in juvenile bluefin.
Figure 3.10 The discovery of quotations and linking concepts between best practices and public policy approaches to improving bluefin tuna ranching.
3.8 Evaluating Scenarios using the Mexico Tuna Ranching Model

Summary of scenarios

The tuna ranching science assessment and recent proposals by tuna ranching entrepreneurs are aimed at addressing different issues related to the sustainability of tuna ranching in Mexico, which in turn offer ideas for the global enterprise to consider. The Mexican Government, on the other hand, is assuming that tuna ranching is sustainable and seeks to dramatically expand it over the next decades. In this section ten scenarios are examined. The first group addresses the question of whether the model has face validity and can plausibly reproduce the general depictions of the functioning and results of Mexican tuna ranching since its inception. The second group is used to assess the implications of proposals made by entrepreneurs to cope with some of the difficulties, indeed the decline being experienced by the Mexican industry. Suggestions are made on how a modeling approach could be used to examine the feasibility of the Mexican proposal to expand tuna and other forms of fish farming in the country. In brief, the model is surprisingly robust in depicting the overall patterns of industry development and confirms the potential effectiveness of sustainability proposals by entrepreneurs. A small number of parameters and policy choice variables were sufficient to generate the scenarios. Many other potentially interesting issues and detailed testing of parameters and structures within the model could be tested and used to refine the result, but are not pursued further here since they are not central to the general question being addressed.
Table 3.9 briefly names and describes the scenarios that are examined. Table 3-10 shows the main parameters and policy choices that are used to set up the scenario runs used in this section and to estimate the final outcome in terms of tonnes of bluefin tuna to the market. Views of each of the eight panels that comprise the model showing the dramatically different base and S9 scenarios can be found in Appendix V. A listing of the model variables, equations and comments is in Appendix VI, and the text version of the Vensim Model (without sketch details) is located in Appendix VII.
Table 3.9 Named scenarios presented in this section

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Description</th>
<th>Insight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S-base Standard Mexico Scenario, average “fattening”</strong></td>
<td>Standard Mexico Scenario from Zertuche-Rodríguez et al.: Mid-point of range, 4140 mt are captured and spend on average 24 weeks ‘fattening’ time in cages.</td>
<td>Mid-range fish capture yields slightly higher than expected production of tuna, with low range consumption of sardines</td>
</tr>
<tr>
<td><strong>S1 Fast “fattening” in the standard case</strong></td>
<td>Del Moral-Simanek and Vaca-Rodriguez: Same as based case except only average of 12 weeks ‘fattening’ in cages</td>
<td>Mid-range fish capture yields lower production of tuna, with low range consumption of sardines: bad strategy</td>
</tr>
<tr>
<td><strong>S2 High range fish catch for the Standard Mexico Scenario</strong></td>
<td>5000 tonnes are fished, put in cages and fed. Average 24 weeks ‘fattening’ time in cages.</td>
<td>Generates highest revenues of any scenario, but not realistic in terms of available fish</td>
</tr>
<tr>
<td><strong>S3 Slow “fattening” in the standard case</strong></td>
<td>Standard Mexico Scenario with average 36 weeks ‘fattening’ time in cages.</td>
<td>Generates very high revenues with same amount of fish by using more sardines: good approach</td>
</tr>
<tr>
<td><strong>S4 Atkinson Strategy: Very Low catch and long “fattening”</strong></td>
<td>Atkinson Proposal: 2000 mt are captured, average 52 week ‘fattening’ time in cages</td>
<td>Generates very high revenues with half the amount of bluefin tuna by using more sardines, twice the sardines of S3: great strategy. Possible model error because all stocks not cleared at end of year</td>
</tr>
<tr>
<td><strong>S5 Umami Strategy: Low catch and ultra-long “fattening”</strong></td>
<td>Umami Proposal: 230 mt per ranch, Average 78 week ‘fattening’ time in cages, plus pressure to harvest</td>
<td>Similar to S4: Could generate very high revenues with a little more than half the amount of bluefin tuna, using more sardines, twice the sardines of S3. Potential error as in S4</td>
</tr>
<tr>
<td><strong>S6 Slow “fattening” in the standard Mexico scenario with reduced pressure to process</strong></td>
<td>Standard Mexico Scenario, 36 weeks of ‘fattening’, and less pressure to process (0.45)</td>
<td>Generates much more revenue than S-base, S1 or S3 with the same amount of tuna, but requires much more sardines for feed: good approach</td>
</tr>
<tr>
<td><strong>S7 Declining juvenile fish supply standard Mexico scenario, average 36 weeks ‘fattening’ time in cages + pressure to harvest</strong></td>
<td>Declining Fish Supply to 30000 mt (only 20% available for migration to Mexico, supply in Mexico cut to 50% by year 10) 36 weeks ‘fattening’, price and schedule pressure to harvest</td>
<td>Less than 5000 mt of juvenile tuna in Mexican waters reduces potential catch, offset by longer ‘fattening’.</td>
</tr>
<tr>
<td><strong>S8 Declining juvenile fish supply, standard Mexico scenario, average 52 weeks ‘fattening’ time in cages, less pressure to harvest</strong></td>
<td>Declining Fish Supply 30000 mt with only 20% available for migration to Mexico, tuna supply in Mexico cut to 50% by year 10, Applies S4 strategy and reduced pressure to harvest from schedule.</td>
<td>The Atkinson strategy (S4) plus lower pressure to harvest generates twice the revenues as S7, but requiring huge amounts of feed. Possible model error because all stocks not cleared at end of year: good approach</td>
</tr>
<tr>
<td><strong>S9 Severe decline in juvenile fish supply balanced by Atkinson strategy (see S4)</strong></td>
<td>Declining Fish Supply 10000 mt plus only 50% migrating to Mexico by Year 10, counterbalanced by the S4 scenario of 52 weeks ‘fattening’, reduced pressure to harvest from schedule.</td>
<td>Fish catch starts at 3551 mt per year but forced to drop to 486 by last year due to crisis in fishery. The Atkinson strategy keeps revenues relatively high for the few farms left.</td>
</tr>
<tr>
<td>Variable</td>
<td>S-base</td>
<td>S1</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>--------</td>
<td>-----</td>
</tr>
<tr>
<td>43. Industry Objective for Fishing Tuna, mt</td>
<td>4140</td>
<td>4140</td>
</tr>
<tr>
<td>68. Cumulative tuna in mobile cages, mt</td>
<td>4139</td>
<td>4139</td>
</tr>
<tr>
<td>92. Cumulative Ranched Tuna per season, mt</td>
<td>5302</td>
<td>4598</td>
</tr>
<tr>
<td>95. Cumulative Processed Gutted Tuna Per Season, mt</td>
<td>4768</td>
<td>4135</td>
</tr>
<tr>
<td>99. Revenues per year (hypothetical price $16.50/kg) millions of dollars</td>
<td>78.6</td>
<td>68.2</td>
</tr>
<tr>
<td>44. Fishing Season Length, weeks</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>45. Capacity Per Cage, mt</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>50. Cages Per Ranch</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>65. Expected Minimum Required Weeks in Cage</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>76. Efficiency of Conversion of Sardines to Tuna Biomass</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>80. Fraction Sardines Fed Per Tonne of Tuna in Fixed Pen per Week</td>
<td>0.56</td>
<td>0.56</td>
</tr>
<tr>
<td>90. Weight on schedule pressure to process</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>101. Breakeven price per kg of Mexican bluefin tuna, dollars</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>103. Standard Return on Investment</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>82. accumulated added biomass to tuna, mt</td>
<td>1162</td>
<td>458</td>
</tr>
<tr>
<td>115. Accumulated sardines fed to tuna per season, mt</td>
<td>23235</td>
<td>9155</td>
</tr>
<tr>
<td>3. Bluefin Tuna Juveniles in Mexico, mt</td>
<td>31241</td>
<td>31241</td>
</tr>
</tbody>
</table>

mt: metric tonnes
Table 3.11 helps explain some of the reasons for taking a feedback oriented modeling approach to formulating and evaluating scenarios. Overall, using simple spreadsheet math, if tuna ranchers had purchased 4,140 tonnes of tuna in a given season to fill up 54 pens at 80 tonnes per pen, and fed their tuna on average for three months before harvesting, they would have been able to produce 5,630 tonnes of fresh tuna ready to be processed and flown to Japan (S1 xls). The value added as determined by weight content gained, is in this example 1490 tonnes or 36%. The amount shipped would have to be adjusted to account for the weight loss from removing gills and guts. If the tuna are held on average for 6 months (S-base xls), then using this computation, the biomass gain would be 2,980 tonnes for a total of 7,120 tonnes of product before processing.

However, the tuna ranching model runs do not produce these optimistic results. It takes a few months to capture 4,140 tonnes of tuna, the tuna are not raised in one giant batch for three to six months nor are they sold all at once. If 4,140 tonnes were captured, only 458 tonnes of added biomass would be possible by holding them for three months (S1). Tuna ranchers closely follow market trends and carefully time their feeding and processing rates to maximize revenue. Holding the tuna on average for six months, according to the base model run, would increase the amount of added weight to 1,162 tonnes and the total ranched tuna to 5,302 tonnes (S-base), much less than the spreadsheet ‘batch’ calculation.

The only exception to this is comparing scenario S4 with S4 xls. The model run for this special scenario produces a better result than the otherwise exaggerated spreadsheet method, for reasons explained in Table 3.9 and discussed in more detail.
below. In all cases, the non-linear behaviors captured in the model offer food for thought about important factors and structures that influence outcomes in the real world and help explain the disappointing results, in essence the vulnerabilities, of tuna ranching in Mexico in recent years.

<table>
<thead>
<tr>
<th>Variable</th>
<th>S-base</th>
<th>S base xls</th>
<th>S1</th>
<th>S1 xls</th>
<th>S2</th>
<th>S2 xls</th>
<th>S3</th>
<th>S3 xls</th>
<th>S4</th>
<th>S4 xls</th>
</tr>
</thead>
<tbody>
<tr>
<td>43. Industry Objective for Fishing Tuna, mt</td>
<td>4140</td>
<td>4140</td>
<td>4140</td>
<td>4140</td>
<td>5000</td>
<td>5000</td>
<td>4140</td>
<td>4140</td>
<td>2070</td>
<td>2070</td>
</tr>
<tr>
<td>68. Cumulative tuna in mobile cages, mt</td>
<td>4139</td>
<td>4140</td>
<td>4139</td>
<td>4140</td>
<td>5748</td>
<td>5000</td>
<td>4139</td>
<td>4140</td>
<td>2069</td>
<td>2070</td>
</tr>
<tr>
<td>92. Cumulative Ranched Tuna per season, mt</td>
<td>5302</td>
<td>7121</td>
<td>4598</td>
<td>5630</td>
<td>7346</td>
<td>8600</td>
<td>6344</td>
<td>8313</td>
<td>6409</td>
<td>5092</td>
</tr>
<tr>
<td>65. Expected Minimum Required Weeks in Cage</td>
<td>24</td>
<td>24</td>
<td>12</td>
<td>12</td>
<td>24</td>
<td>24</td>
<td>36</td>
<td>36</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>76. Efficiency of Conversion of Sardines to Tuna Biomass</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>82. accumulated added biomass to tuna, mt</td>
<td>1162</td>
<td>2981</td>
<td>458</td>
<td>1490</td>
<td>1596</td>
<td>3600</td>
<td>2205</td>
<td>4173</td>
<td>4343</td>
<td>3022</td>
</tr>
<tr>
<td>115. Accumulated sardines fed to tuna per season, mt</td>
<td>23235</td>
<td>59616</td>
<td>9155</td>
<td>29808</td>
<td>31914</td>
<td>72000</td>
<td>44090</td>
<td>83462</td>
<td>86866</td>
<td>60444</td>
</tr>
</tbody>
</table>

**Table 3.11** Comparison of spreadsheet calculations and selected model results.

Except in S4, spreadsheet (back-of-the-envelop) calculations are always higher than model results.
Baseline Scenario: The Mexico Standard Scenario from the tuna ranching science assessment

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Description</th>
<th>Insight</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-base Standard Mexico Scenario, average “fattening”</td>
<td>Standard Mexico Scenario from Zertuche-Rodriguez et al.: Mid-point of range, 4140 mt are captured and spend on average 24 weeks 'fattening' time in cages.</td>
<td>Mid-range fish capture yields slightly higher than expected production of tuna, with low range consumption of sardines</td>
</tr>
</tbody>
</table>

A generalized scenario is suggested by the tuna ranching science assessment:

“Farming northern bluefin tuna (NBT) in the Ensenada region involves feeding 3,000 to 5,000 MT of tuna and producing between 2,000 to ~3,000 MT of fish biomass per season, in the CBTA facilities of 11 companies (only 9 currently operating). During the 6 to 9 month growth-out period, the NBT are primarily fed fresh Pacific sardine (Sardinops sagax caerulea), amounting to between 20,000 to 30,000 MT” Zertuche-González et al., 2008:45.

The base case run for the tuna ranching model tests this range of values by incorporating a stylized scenario of the construction of tuna ranches, with ranch capacity increasing in steps. Cage capacity, which is a generalized depiction of the development of bluefin tuna ranching in Mexico over the decade of the 2000s, varies in the base model from 1200 to 3600 tonnes, corresponding to 1307 to 4139 tonnes fished. The scenario specified by Zertuche-González et al. doesn’t clearly indicate how many ranches or pens are included, feed rates or assumptions of rates of conversion of sardines to tuna biomass.
Table 3.12 Scenarios built in to the base run, from Zertuche-González et al., 2008

<table>
<thead>
<tr>
<th>46. Total Cage Capacity</th>
<th>43. Industry Objective for Fishing Tuna</th>
<th>82. accumulated added biomass to tuna, mt</th>
<th>92. Cumulative Ranched Tuna per season, mt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200</td>
<td>1307</td>
<td>321</td>
<td>1525</td>
</tr>
<tr>
<td>2000</td>
<td>2283</td>
<td>635</td>
<td>2840</td>
</tr>
<tr>
<td>2800</td>
<td>3211</td>
<td>864</td>
<td>3963</td>
</tr>
<tr>
<td>3600</td>
<td>4139</td>
<td>1162</td>
<td>5302</td>
</tr>
</tbody>
</table>

The average duration for an individual tuna in the ranch is set by the model is 24 weeks or six months. These model run produces added-biomass estimate somewhat lower than the general case suggested by Zertuche-González, a 36 week run produces closer results but is not reported as the norm for the Mexico case (see Scenario S3). Estimates for the conversion ratio of sardines to biomass range vary as does descriptions of feeding practices, that is, the weight of sardines fed to a tonne of tuna per week, which are presented in simplistic form in the model. Clarification of these assumptions with researchers might produce runs that fit their expectations more closely. The base scenario is portrayed in Figure 3.11, which assumes 9 ranches with 10 pens per ranch, each with a capacity of 40 metric tonnes of tuna. Once all 9 ranches are online, they fished 4139 tonnes of bluefin tuna, fed them 23,235 tonnes of sardines, added 1,162 tonnes of biomass, produced 4,768 tonnes of processed gutted tuna which earned hypothetical revenues of $78.6 million.
Figure 3.11 Overview of base model run.

OVERVIEW

0 29 58 87 116 145 174 203 232 261 290 319 348 377 406 435 464 493 522
0 1,500 3,000 4,500 6,000

"92. Cumulative Ranched Tuna per season" : S-base tonnes
"95. Cumulative Processed Gutted Tuna Per Season" : S-base tonnes
"43. Industry Objective for Fishing Tuna" : S-base tonnes
"68. Cumulative tuna in mobile cages" : S-base tonnes
**Figure 3.12** Variables that interact to trigger and complete tuna processing

**Figure 3.13** Sardines are fed to tuna continually in the model, this is converted to biomass. Tuna are harvested continually, on average residing in cages for 24 weeks.
**S1 Fast “fattening” in the standard case**

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Description</th>
<th>Insight</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 Fast “fattening” in the standard case</td>
<td>Del Moral-Simanek and Vaca-Rodríguez: Same as based case except only average of 12 weeks ‘fattening’ in cages</td>
<td>Mid-range fish capture yields lower production of tuna, with low range consumption of sardines: bad strategy</td>
</tr>
</tbody>
</table>

Del Moral-Simanek and Vaca-Rodríguez suggest one practice of harvesting ‘fattened’ tuna after three months in cages. As a global policy within the model it produces very low revenue and production compared to other scenarios, however it might have been suggested to reflect the fact that harvesting might begin within 3 months of arriving in fixed cages. This policy is not tested further.

**S2 High range fish catch for the Standard Mexico Scenario**

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Description</th>
<th>Insight</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2 High range fish catch for the Standard Mexico Scenario</td>
<td>5000 tonnes are fished, put in cages and fed. Average 24 weeks 'fattening' time in cages.</td>
<td>Generates highest revenues of any scenario, but not realistic in terms of available fish</td>
</tr>
</tbody>
</table>

Zertuche-Rodríguez et al. suggest 5000 tonnes of juvenile tuna fished as an upper range for the Mexican industry. It produces the most spectacular production 7,346 tonnes and hypothetical revenues of $108.9 million, but historical total production by the industry (see Table 3-4) is considerably lower. This policy is not tested further.

**S3 Slow “fattening” in the standard case**

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Description</th>
<th>Insight</th>
</tr>
</thead>
<tbody>
<tr>
<td>S3 Slow “fattening” in the standard case</td>
<td>Standard Mexico Scenario with average 36 weeks 'fattening' time in cages.</td>
<td>Generates very high revenues with same amount of fish by using more sardines: good approach</td>
</tr>
</tbody>
</table>

An upper range of average time for holding and feeding juvenile tuna is 9 months (36 weeks in the model). This requires the same amount of tuna fished as the base case, but generated twice as much biomass (2205 tonnes compared to 1162 in the base case) and much higher revenues. It does require more feed and more costs (44,090 tonnes of sardines compared to 31241 in the base case) as shown in Figure 3-14. The model does not compute the fixed or variable costs of production such as the added labor, operations or acquisition of sardines. Formulations for harvesting based on price and schedule pressure are illustrated for Scenarios S6 to S9.
Figure 3.14 Comparing revenue generation from base scenario and S3 strategy of holding tuna in pens longer, up to 36 months.

*S4 Atkinson Strategy: Very Low catch and long “fattening”*

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Description</th>
<th>Insight</th>
</tr>
</thead>
<tbody>
<tr>
<td>S4 Atkinson Strategy: Very Low catch and long “fattening”</td>
<td>Atkinson Proposal: 2000 mt are captured, average 52 week 'fattening' time in cages</td>
<td>Generates very high revenues with half the amount of bluefin tuna by using more sardines, twice the sardines of S3: great strategy. Possible model error because all stocks not cleared at end of year</td>
</tr>
</tbody>
</table>

Atkinson (2011) has developed a much more sophisticated modeling approach, Optimal Aquaculture System Investment and Siting Model, OASIS, for siting future fish farms. He applies this to a general scenario for bluefin tuna ranching (see section 3.9), similar to work by Bronstein (2007), whose “Tuna Assist” software is specifically designed for managing the supply chain and operations of tuna ranching. The basic proposal is to catch much less tuna, use larger cages (100mt), maintain a one-year grow out cycle, keep ranches separated from each other by more than 2 km to address the environmental impacts of tuna and feeding waste, and to stagger the fishing and filling of the pens. The Mexico Tuna Ranching Model presented here is far simpler in structure and cannot
perform the detailed analyses of OASIS or Tuna Assist. However, two key ideas: use fewer fish and ‘fatten’ them longer, are important concepts that address the basic fact that ranch production has declined (Table 3.4, Figure 3.7) and fishing of juvenile tuna in the EPO has declined (Table 3.6).

**Figure 3.15** Atkinson strategy (S4): Reduce the amount of bluefin tuna fishing, and hold for one year on average
Figure 3.16 Atkinson strategy (S4): Biomass is maintained throughout the year, and processing is continuous.

The result of the policy generates much higher added biomass (4343 tonnes/yr) and revenue (a hypothetical cash flow of $95 million/yr). However, tuna stocks are driven by annual migration pulses, fishing is banned in certain months, and the model incorporates price as well as schedule pressure, so the annual saw-tooth pattern is
maintained. Model structure might need to be revised to more fully explore how decisions to process based on market price considerations would occur in this scenario. For example, the S4 strategy worked better when the variable “90. weight on schedule pressure to process” was relaxed. Schedule pressure is included in the model to force all tuna to be processed cleared out of cages before the end of the year, which is not a requirement for the S4 strategy. (See Appendix V, panel F.) In addition, the Atkinson strategy utilizes far more feed (sardines) per year than other tested, which might prove to become a new constraint and is a clear concern by the experts in the science assessment team. (Del Moral-Simanek and Vaca-Rodríguez, 2010; Zertuche-González et al., 2008)

**S5 Umami Strategy: Low catch and ultra-long “fattening”**

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Description</th>
<th>Insight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S5 Umami Strategy: Low catch and ultra-long “fattening”</strong></td>
<td>Umami Proposal: 230 mt per ranch, Average 78 week ‘fattening’ time in cages, plus pressure to harvest</td>
<td>Similar to S4: Could generate very high revenues with a little more than half the amount of bluefin tuna, using more sardines, twice the sardines of S3. Potential error as in S4</td>
</tr>
</tbody>
</table>

Tuna ranching entrepreneurs from Umami Sustainable Seafood, who operate Baja Aqua Farms, propose a similar approach to Atkinson among their new ideas for sustaining tuna ranching (Pederson and Ito, 2010). The concept is described and tested in terms of a single ranch but is scalable. A single ranch requires 230 tonnes of bluefin tuna per year, and produces 477 tonnes of processed tuna because harvesting is continuous, as shown in Figure 317. As in S4, the model does not appear to handle the overlap among years correctly, and in fact performs better when “90. weight on schedule pressure to process” is increased to 1.
Figure 3.17 S5 Umami Seafood’s concept of very long feeding of bluefin tuna in cages (78 weeks on average).

Figure 3.18 S5 The effect of schedule pressure on processing tuna. Increasing the pressure slightly forces the model to process more tuna, however since the average time to hold and feed tuna in cages is 78 months, which overlaps model years, this may not properly represent the benefits or disadvantages of the strategy.
S6 Slow “fattening” in the standard Mexico scenario with reduced pressure to process

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Description</th>
<th>Insight</th>
</tr>
</thead>
<tbody>
<tr>
<td>S6 Slow “fattening” in the standard Mexico scenario with reduced pressure to process</td>
<td>Standard Mexico Scenario, 36 weeks of ‘fattening’, and less pressure to process (0.45)</td>
<td>Generates much more revenue than S-base, S1 or S3 with the same amount of tuna, but requires much more sardines for feed: good approach</td>
</tr>
</tbody>
</table>

This scenario modifies the base by incorporating aspects of S4, the Atkinson approach, including reducing pressure to process from schedule, but holding tuna for only 36 weeks. It also adds pressure to process from price, which is generated through “noise” that randomly adjusts the market price above and below (“101. Breakeven price per kg of Mexican bluefin tuna, dollars” multiplied by “103. Standard Return on Investment”).

The effects of the Atkinson strategy plus price variation are shown in Figure 3.19. While the results in terms of revenues are excellent, approaching S2, the amount of tuna required per year is 20 per cent less (4,063 tonnes). The price effect is strong enough to influence weekly harvest decisions (64. Actual Processing Tuna). In addition the model incorporates a simple loop to create a modest long term price trend effect on “43.

Figure 3.19 S6 Modified S-base scenario following Atkinson strategy (S4)
Industry Objective for Fishing Tuna”, which is set higher than cage capacity (“41. effect of price trend on capacity utilization” is set to affect fishing by 10% in response to price), so that while total capacity remains at 3,600 tonnes, the industry objective for fishing shows a long term variation, which in turn affects how much tuna is kept in the ranches and processed per year. This random price effect could be replaced by retrospective data on pricing (such as the type shown in Table 3.1), as well as a prospective economic analysis or scenario.

The remaining scenarios in this section, S7 to S9, explore the impact of scenarios of declining fish stocks or fish migration to Mexico on the performance of the tuna ranching industry. In scenarios S-base to S5, the stock of juvenile tuna is set in the model far above biological reality so as to not impose any constraints. Constraints are gradually imposed in S7 to S9, accompanied by some of the more effective strategies explored above.

*S7 Declining juvenile fish supply standard Mexico scenario, average 36 weeks 'fattening' time in cages + pressure to harvest*

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Description</th>
<th>Insight</th>
</tr>
</thead>
<tbody>
<tr>
<td>S7 Declining juvenile fish supply standard Mexico scenario, average 36 weeks 'fattening' time in cages + pressure to harvest</td>
<td>Declining Fish Supply to 30000 mt (only 20% available for migration to Mexico, supply in Mexico cut to 50% by year 10) 36 weeks 'fattening', price and schedule pressure to harvest</td>
<td>Less than 5000 mt of juvenile tuna in Mexican waters reduces potential catch, offset by longer ‘fattening’.</td>
</tr>
</tbody>
</table>

The stock of juvenile bluefin tuna in the Western Pacific Ocean is reduced from a hypothetical 100,000 tonnes to 28,875, which reduces the stock in Mexico to a peak of
9,331 tonnes. In addition, a scenario is introduced beginning in Year 6 to steadily reduce the amount to 50% of the peak level by Year 10. The results are shown in Figure 3-20. Price variation (noise) affects both short term processing and longer term fishing objectives, but the declining availability of juvenile stock in Mexico has a stronger impact in reducing production.

**Figure 3.20** Scenario 7: Reduced bluefin tuna stock scenario, combined with declining migration to Mexico after Year 5.
**S8 Declining juvenile fish supply, standard Mexico scenario, average 52 weeks 'fattening' time in cages, less pressure to harvest**

The same decline in S8 bluefin tuna stocks and a reduced fish migration to Mexico is tested in S8, with full application of the S4 (Atkinson) strategy. This doubles revenue and substantially increases production compared to S7 (Figure 3.21).

### Scenario name | Description | Insight |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S8 Declining juvenile fish supply, standard Mexico scenario, average 52 weeks 'fattening' time in cages, less pressure to harvest</strong></td>
<td>Declining Fish Supply 30000 mt with only 20% available for migration to Mexico, tuna supply in Mexico cut to 50% by year 10, Applies S4 strategy and reduced pressure to harvest from schedule.</td>
<td>The Atkinson strategy (S4) plus lower pressure to harvest generates twice the revenues as S7, but requiring huge amounts of feed. Possible model error because all stocks not cleared at end of year: good approach</td>
</tr>
</tbody>
</table>

**Figure 3.21** Scenario 8: Application of S4 (Atkinson strategy) to Scenario 7. By extending the holding time in cages and relaxing the pressure to harvest from schedule, revenues are kept very high, but so are costs and massive requirement for feed (sardines). The model does not calculate net profit.
Figure 3.22 Comparing Revenues from scenarios S7, S8 and S9 (S7a and S8a assume a population of bluefin tuna in Mexico at Year 10 of 4,965 tonnes. S9 is reduced much further to 1,198 tonnes)

*S9 Severe decline in juvenile fish supply balanced by Atkinson strategy (see S4)*

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Description</th>
<th>Insight</th>
</tr>
</thead>
<tbody>
<tr>
<td>S9 Severe decline in juvenile fish supply balanced by Atkinson strategy (see S4)</td>
<td>Declining Fish Supply 10000 mt plus only 50% migrating to Mexico by Year 10, counterbalanced by the S4 scenario of 52 weeks ‘fattening’; reduced pressure to harvest from schedule.</td>
<td>Fish catch starts at 3551 mt per year but forced to drop to 486 by last year due to crisis in fishery. The Atkinson strategy keeps revenues relatively high for the few farms left.</td>
</tr>
</tbody>
</table>

This scenario reduces the stock of bluefin tuna available in Mexico at Year 10 from 4,965 tonnes in S8 to 1,198 tonnes in S9 (Figure 3.23). Severely reducing the stock in the Western Pacific Ocean and limiting the juveniles migrating to Mexican waters has a basis in biology, as poor year classes in the Western Pacific Ocean reduce the number of juveniles needing to migrate to seek food in the EPO, and alternately it corresponds to a potential policy choice in Japan to further expand its own tuna ranching efforts and retaining as many juveniles as possible. The S9 scenario tests the S4 Atkinson strategy is applied to this dire situation, with good results.
The fraction Mexico is catching of the total stock varies significantly by year. Matsukawa (2006) finds an evolutionary response in that "the population excess over the carrying capacity (in the Western Pacific) causes the migration in each life stage". Furthermore, "migration of the tuna into the eastern Pacific increased in years when the abundance of sardines was declining". These sources of variation are normal.

Figure 3.22 above shows that the Atkinson strategy is able to improve on the S7 response, giving results that are about twice the output of S7 for the same constraint in the fishery. It is also able to do the same when an extreme shortfall occurs in local stocks. The requirement, and potential next bottleneck for tuna ranching, is the abundance of feed for the bluefin tuna in cages. More than twice as many sardines are required in order to make up for the shortfall in juvenile tuna. The model cannot provide an economic explanation for this nor can it compute the net profit from the different scenarios.

![3. Bluefin Tuna Juveniles in Mexico](image)

**Figure 3.23** S9 Extreme scenario test with greatly reduced bluefin tuna stock
Figure 3.24 Comparing Revenues from scenarios S7 and S9 (S7a assumes a stock of bluefin tuna in Mexico at Year 10 of 4,965 tonnes. S9 is reduced much further to 1,198 tonnes)

Figure 3-24 shows revenues between the S7 and S9 scenarios remain similar even though the latter is largely deprived of bluefin stock. The dependence on abundance of sardines should not be taken for granted, as Figure 3-25 indicates. The Atkinson strategy depends heavily on the availability of feed year-round. The model incorporates some structure for testing the impact of reduced availability of sardine stocks in the Pacific coast as well as the Gulf of California stock.
Figure 3.25 A reason for the success of the Atkinson strategy under the extreme conditions of S9: holding fish in pens for 52 weeks on average, with corresponding need for feeding.

*Other modeling efforts and scenarios for bluefin tuna ranching*

A Tasmanian firm, Aqua Assist, developed sophisticated decision support tools for individual tuna ranchers and other types of ranching operations and is reported to be used in both Australia, Mexico and the United States. Figure 3-26 indicates that the software author (Bronstein, 2007) incorporates many features of the broader, text book model as represented by Pillay and Kutty. The Mexican Tuna Ranching Model presented in this chapter operates at an aggregate level, glossing over individual ranch differences, while Aqua Assist is entirely focused on the dynamics of operating nearly every aspect of a tuna ranch. From an information system perspective, Aqua Assist represents a major step forward, since it includes specific modules related to public policy topics such as tuna fishing quotas.
Figure 3.26 Decision making software for tuna ranchers by Aqua Assist (Bronstein, 2007, reproduced by permission.)

‘Tuna Assist’ caters for Tuna Farmers requiring total consolidation of data across all areas of their farm.
More recently, Atkinson presented the outline of Inforsim’s Offshore Aquaculture System Investment and Siting Model, OASIS. The model components are shown in Figure 3.27, and indicate its broad scope as an approach for siting, business planning and impact assessment, covering the physical, biological, ecological, economic and operations dimensions of fish farming.

**Figure 3.27** Offshore Aquaculture System Investment and Siting Model, OASIS. Source: Atkinson, 2011
A missing piece in the Mexican tuna ranching model is the closed cycle, although it is mentioned by both Atkinson and Pederson and Ito. The abundance of fresh sardines arriving just at the time when the bluefin tuna arrive off the coast of Baja California makes tuna ranching simpler than in the Mediterranean or Australia. The life cycle of the bluefin tuna had been reported as successfully closed since the mid-2000s. The aim is to spawn and raise juveniles with little concern for the dynamics and uncertainty of the ocean fishery. Sawada, Okada, Miyashita, Murata and Kumai (2005) reported that Japan successfully closed the cycle. Australian ranchers also claim to have closed the cycle for Thunnus maccoyii, including one highly publicized operation with several adult females placed in a special environment in anticipation of spawning. (Treadgold, 2005). Umami Sustainable Seafood, which operates Baja Aqua Farms, is pursuing the closed cycle in Croatia, where there is access to spawning female tuna.

The Mexican government aspires to scale up fish farming as a source of income and food ten-fold in the next twenty years. Mexico has already looked far ahead in its plan for capture based aquaculture, proposing 50,000 metric tons per year production of bluefin tuna and related species by 2030, a ten-fold increase over the highest recent production levels in the region. This would be distributed among numerous new coastal and marine areas in five Mexican states along its northwestern Pacific coast and the Gulf of California. (Centro de Investigaciones Biologicas del Noroeste CIBNOR, S.C. 2008)

Mexico recognizes a number of bottlenecks to this growth. In addition to the limited availability of capital, especially to small producers, many of the limitations belong to the realm of policy informatics, in terms of improving then monitoring the quality of policy, industry capability to understand and apply appropriate technology at
every stage of the value chain and to understand the dynamics of the markets for
products. Increasing the capacity to locate, operate, manage, and govern fish farming
activities are among the highest priorities for putting the vision into place. However, the
dynamics and risks of the fish farming industry as a use of marine and coastal resources
seem not to be fully appreciated by planners. Even the simple model of tuna ranching as
presented in this chapter is able to capture some of the most important dynamics and to
help portray in vivid relief the concerns raised by critics, analysts and the industry itself.
The plan calls for doubling the production of tuna (species not specified) to 10,000 mt per
year in the Baja California –Ensenada area alone, without clearly addressing the
dynamics of feed supply or juvenile tuna supply raised by entrepreneurs and experts. The
modeling approaches outlined by OASIS could potentially produce important, detailed
and careful analyses of siting, environmental and business issues raised by the Mexican
plan. However, even the simple policy model presented in this chapter, extended to
examine the risks and dynamics of such an ambitious plan, might be helpful in clarifying
the public policy questions that need to be addressed as regulatory, development and
investment decisions are made.

3.9 Conclusions and a look ahead

This chapter set out to use system dynamics modeling approaches and tools to
examine the factors and dynamics, internal and external, affect the sustainability of
export based fish ranching operations. Policy level SD modeling can serve as a bridge
between scientific assessments and policy issues raised by stakeholders. The modeling
presented here reveals some of the details of the extent to which Mexican tuna ranching
utilizing Pacific Bluefin tuna is resilient and sustainable, compared to the much criticized
Mediterranean practice based on Atlantic bluefin tuna stocks, and Australian tuna ranching based on southern Pacific stocks. As long as sardine supplies are abundant, and at least some bluefin tuna juveniles make it to Mexican waters, a few firms will be able to continue fish farming in Mexico. The limited available data show a recent decline in farm operations and productions, as well as in fishing, prompting entrepreneurs to propose and test ways to engage in profitable fish farming with less reliance on a high level of abundance of juvenile stock. These proposals require fewer, larger operations with the ability to manage and finance all aspects of the value chain in continuous production cycles and sustain fluctuations in market price.

Mexico has already acted in ways consistent with the findings of the tuna ranching science assessment, the model and suggestions from entrepreneurs. It is capping the issuance of tuna ranch licenses and has set a restriction on bluefin tuna fishing, albeit at the close of the period when bluefin migrate further north to US and Canadian waters and then return to the Western Pacific Ocean. On the other hand, the proposal by CIBNOR (2008) to increase by ten-fold the amount of bluefin and other tuna farming in the Pacific Coast, compared to its peak level in the mid-2000s raises some serious questions. Their analysis of the limits to such a proposal center on expanding technical and financial capacity and improving technology such as closed cycle production, rather than environmental, market, fish stock and feed availability issues raised by the science assessment, entrepreneurs and this modeling exercise. The CIBNOR plan does address the need for greatly improved information flow on all aspects of aquaculture and fish farming. Problems in informatics do pose issues within the ranching industry to the extent operators are independent, regulatory schemes are not
functioning and information flow is low. The data on price, fisheries, and ranch production are limited, inconsistent and intermittent.

The simple model presented and tested in this chapter is derived entirely from mental modeling and content analysis, which demonstrates the promise of these techniques, but misses out on the key role of client feedback and testing. While completely a derivative product of the knowledge of the entrepreneurs and experts cited, it is not “owned” emotionally or intellectually by any of them. Each individual likely would want to see improvements in equations, adjustments in structure, and selection of different parameters. To ease the presentation of the main policy issues raised by the model, many much debated parameters were chosen and kept constant to keep attention on the handful of policy choices and exogenous trends that clearly have a dramatic effect on the sustainability of the industry.

Further extension of the modeling effort would not be aimed at analyzing individual firms within the industry, rather the hope is to generate better information to confirm or contradict output from model runs under reasonable sets of assumptions, in the spirit of the OECD proposals for future improvements in fisheries and aquaculture management in Mexico and to evaluate bold proposals for dramatically expanded fish farming and mariculture by the government and researchers. In addition to equation, structure and parameter improvements, the model boundary needs to be examined in order to see the extent of what should be considered exogenous structure has to change. Also, dormant structures such as the sardine component need to be elaborated and tested. This in turn will build confidence in using both the specific tool, and more broadly the frame of reference the systems thinking perspective can add to both determine and assure
sustainability of Mexican tuna ranching in the face of a larger set of challenges based not on metaphors but on a deeper understanding of its structure and dynamics.
Chapter 4: Embracing Policy Dynamics in The Design And Monitoring Of Development Assistance: The Tanzania Coastal Management Partnership

Only from a more distant perspective in which events and decisions are deliberately blurred into patterns of behavior and policy structure will the notion that “behavior is a consequence of feedback structure” arise and be perceived to yield powerful insights.


4.1 Introduction

Villages and communities along the Tanzanian coast that depend for their well-being on the functioning of natural systems and coastal resources, are collaborating with assistance organizations such as the Tanzania Coastal Management Partnership (TCMP) to reach their development goals by trying to address their complex problems in an integrated, systematic way, weighing the advantages and consequences of actions upon both people and environmental systems. However, policy frameworks and funding for coastal community development, from government, non-governmental organizations and donors, is seldom structured in a way that guarantees a good, smooth and timely fit between local needs and priorities and donor or government priorities and mandates. This is a particular challenge in coastal areas where the interaction of human uses with the dynamic characteristics of tidal aquatic systems, shorelines, estuaries, watersheds and coastal landscapes make problem diagnosis, policy formulation and effective implementation are hard to predict and results hard to assure.

This chapter takes a feedback perspective on the factors required to achieve local project success in coastal areas in developing countries. The first section is a retrospective on a group model building exercise conducted with the involvement of the author in 2002 to capture the mental model of leaders of several coastal management assistance programs. (Robadue, Hale and Seville, 2003). This local coastal management success model drew on lessons learned by project staff in six countries. The model is compared to how a new project in Tanzania called Pwani (kiswahili for “coast”) was designed and is being implemented and monitored. The Tanzania Pwani project proposal uses diagrams created by the author capturing ideas of the project team in order to help explain how the project’s activities represent important leverage points on the problems
being addressed. These diagrams, and the project’s monitoring and evaluation system (that is, the informatics used to track and report progress and make adjustments to program activities) do not explicitly take into account a number of the dynamics identified in the *local coastal management success model*. This chapter describes how the concept map was translated into a working simulation. A range of scenarios are then tested to see if such an insight-oriented simulation could capture some of the insights generated in the original mental model exercise. The chapter concludes with reflections on the how an understanding of local project success dynamics might be applied to the Tanzania *Pwani* program.

The design of the TCMP emerged in 1997 when the need was recognized for creating a national framework to orient and build upon several community-oriented coastal management projects in different districts (Torell, Amaral, Bayer, Daffà, Luhikula and Hale, 2003). The initial aim of the project, funded in large measure by a long term commitment by the U.S. Agency for International Development, was to help formulate and implement Tanzania’s National Integrated Coastal Environmental Management Strategy (NICEMS) for the country’s coastal landscapes and seascapes. This included formulating national policy, establishing intersectoral approaches to guide emerging economic opportunities and demands for coastal resources, and supporting effective local implementation beyond the areas where pioneering projects were in place. A total of four phases of multi-year funded projects were carried out within this framework, supported by complementary global program support by USAID Washington through long term cooperative agreements with the University of Rhode Island.

In 2010 TCMP entered a fifth phase through its four-year *Pwani* initiative, an integrated coastal management effort aimed at

- protecting critical coastal forests, wildlife, and freshwater resources,
- protecting critical marine ecosystems and endangered species and
- addressing key human dimensions of the coastal ecosystem.

This effort concentrates on the Northern Tanzania seascape, incorporating two mainland districts, Pangani and Bagamoyo, Saadani National Park and the island of
Unguja in Zanzibar including the Menai Bay Marine Conservation Area, as well as remaining engaged in national coastal management and fisheries policy.

The design responds to at least three streams of interest in the coast:

*USAID/ Tanzania’s Country Strategic Plan* (USAID/Tanzania, 2005) has an evolved set of Strategic Objectives and desired Intermediate Results, supported by a changing mix of funding sources, that establishes priorities. The Pwani project supports USAID/Tanzania’s Environment/Natural Resources SO: Biodiversity Conserved in Targeted Landscapes through a Livelihood Driven Approach. It also contributes to the HIV/AIDS Strategic Objective – Enhanced Multisectoral Response to HIV/AIDS. These objectives and supporting intermediate results are measured by a standard set of performance and outcome indicators.

The Coastal Resources Center has its own long term approach and body of international experience, expressed in assessments such as *Crafting Coastal Governance in a Changing World* (Olsen et al., 2003) and the ongoing SUCCESS cooperative agreement that provides targeted support across the organization’s international portfolio of USAID funded efforts. In addition to complying with donor reporting requirements for standard indicators, the Center has utilized a wide range of approaches to tracking progress in coastal governance (Olsen, 2003b; Olsen, 2009); value chain analysis for economic activities (Mkama et al., 2011), health and environment (The BALANCED Project, 2010); marine protected areas (Crawford and Kasmidi, 2004), and community resilience to hazards (U.S. Indian Ocean Tsunami Warning System Program, 2007).
Figure 4.1 Location of coastal regions and districts in Tanzania
The Government of Tanzania has its own approach, guided by the National Integrated Coastal Environmental Management Strategy, the recently adopted Environmental Management laws, the poverty alleviation program MIKUPIA, the Millenium Development Goals and especially the World Bank’s Global Environment Facility funded Marine and Coastal Environment Management Project (MACEMP), a $63 million effort from 2005 to 2011 that was aimed in part in sustainable management of mainland coastal resources, implementing some important components of the NICEMS.

The Pwani project design also utilizes a simple framework favored by USAID called “Nature- Wealth-Power”. The foundation document explaining the approach states that “Experience demonstrates that programs that integrate nature (environmental management), wealth (economic concerns), and power (good governance) have promising results” (International Resources Group, 2002). To do this, projects focusing on natural resources are urged to put more emphasis on monitoring. “Monitoring should be of sufficient depth to capture information needed for adaptive management and social learning. The tendency to amass huge volumes of data of little relevance to decision making should be avoided” (IRG, 2002: 8).

The Pwani project monitoring plan requires fewer than 20 indicators to capture the entire range of the project’s activities in terms of project reporting. These indicators include specific environmental outcomes such as the number of hectares of biological significance under improved management (nature), process indicators such as an enumeration of the number of policies, laws and agreements reached (power) and social and economic indicators such as changes in access to financing (wealth).

However, this type information does not capture much about the decisions and process that the project team itself must pay attention to in order to generate the desired changes in the donor-required indicators. These processes are internal to the project but reflect as well an acute awareness of external conditions of the system that a project is trying to influence or change to get better results for the society receiving donor
assistance. The responsibility to keep in close touch with external political, social and economic developments rests squarely with project leaders, just as they are obligated to guide the functioning of the internal realm of organizations and their project related behavior.

4.2 Projects, programs and policy reform for coastal resources management in a development context

The informatics required to guide a complex endeavor such as the Pwani Project needs to span external and internal realms, be continuous over long periods of time, cope with two, three or more frameworks for assessing progress, as well as several layers of implementing agents and institutions from international agreements and national governments, to states or districts, municipalities, parks and protected areas, organized as well as informal stakeholder groups, villages and even sub-village levels of organization. One approach explored by the Coastal Resources Center was “outcome mapping” (Earl, Carden and Smutylo, 2001), a systematic approach to project design and performance monitoring that distinguishes among direct and indirect causality in setting performance targets, as well as the indirect influence that projects have over “boundary partners”, who are the actors in a country that will actually carry out intended reforms. (Kerr et al., 2003) This method emphasizes an endogenous stance in being realistic and explicit about the relationships among a project team and its partners and the entities it is trying to influence, as well as the extent to which the project has the means to directly generate the impacts it is seeking, versus the fact that many other external factors may be equally if not more important. At the same time, the Coastal Resources Center was reflecting on its initial decades of experience in developing countries. Another approach combined a profile of local issues with a maturity model for coastal management programs based on steps in the policy cycle. (Torell, Mmochi and Spierling, 2006)

A frequently used metaphor within the Coastal Resources Center is that projects need to interact with and help strengthen a “nested” system for governing coastal resources. “We have learned that good coastal governance functions best when it exists as part of a nested system—that is, one that operates simultaneously at scales ranging
from the local to the global.” (Sugrue, 2003) Local, regional and national levels needed to interact smoothly and support each other, each contributing resources as well as communicating results that might inspire more widespread adoption of the ideas and actions being piloted in a few selected locations. During a week-long retreat to reflect on and development messages on lessons from 18 years of experience in international projects through a cooperative agreement with USAID, a day was devoted to having field level managers, those who were charged with attaining project outcomes and building ‘nested systems’ have their say about what it takes to attain local success. (Robadue, Hale and Seville, 2003).

The picture that emerged of the structure and dynamics of creating and operating within a nested system at work proved relevant across the several country cases represented at the exercise (Ecuador, Sri Lanka, Thailand, Indonesia, Mexico, Tanzania). This visual portrait is rich in feedback loops and causal connections, and sets out how the seemingly indirect relationships between national policy and local project were in fact tightly coupled. Progress at one level was not fully possible without activity at another. Sometimes elements at different levels, often far removed from each other, need to move together simultaneously to prevent bottlenecks and deliver resources and decisions at the right time. At other times, word of local success in a ‘pilot’ area would spread quickly, perhaps faster than results perhaps might justify, increasing demand for similar policies or projects elsewhere. This type of diffusion of a good coastal resource use practice might be more effective than a declaration of national policy that does not have stakeholder support or any tangible means to carry out the mandate.

Figure 4.2 portrays the very simplest outline of this idea. Local projects or activities identify problems, seek solutions and carry out actions, but these do not occur in isolation. A donor or program might identify the location as a good or deserving place to work and appear as if from nowhere to provide needed resources to generate some kind of success. Inspired by the need, or the positive example, some type of regional or national effort is mobilized to aid such local projects. Good ideas, or even hints at the likelihood of beneficial effects might be captured by, and reinforce the regional or national support efforts, but these also might be bypassed by social communication where
word spreads that an idea is offering the promise to solve a problem, or that resources might be available in some way from a donor or government entity, increasing the visibility of the program as well as demand for support and services. The increasing number of initiatives at the local level places additional pressure on regional and national entities to respond and support the local efforts.

**Figure 4.2** The basic reinforcing relationship among local, national and other factors that contribute to the success of a local coastal management effort. (Robadue, Hale, and Seville, 2003)

![Diagram of the basic reinforcing relationship among local, national, and other factors contributing to the success of a local coastal management effort.](image)

A regional entity could take advantage of this structure in promoting new policy or problem solution by intentionally restricting its effort to carefully selected locations that have the right “enabling conditions” to insure just the kind of practical success and word of mouth transmission of the benefits of a policy or practice, rather than rolling out a new program in so many areas that implementation could not be supported and the policies, practices or ideas become discredited due to poor implementation effort, not to the nature of the actions. This basic structure can just as easily produce a “backfire” or failed outcome, since word of mouth from poor execution or poor design will spread just as quickly as success.
A broad application of this fundamental idea generated by coastal management project leaders is shown in Figure 4.3, using Tanzania as the example.

1. USAID / URI experience in Sri Lanka, Thailand, and Ecuador informs the design of Tanzania project in the mid-1990s. The initial premise of the Tanzania Coastal Management Partnership was that there was a great deal of local experience and projects addressing coastal management issues, but little communication among them nor much support or guidance from the national level. (Torell, Amaral, Bayer, Daffa, Luhikula, and Hale, 2003)

2. While the early years of the TCMP involved preparing national issue papers and convening national working groups to articulate coast-wide issues and propose national policy, USAID funding was also used to start pilot activities in three Tanzania District in early 2000s. This was also a way to build local support for the emerging National Integrated Coastal Environment Management Strategy (NICEMS)

3. Initial success in preparing coastal management action plans in the pilot coastal Districts of Bagamoyo, Pangani and Mkuranga in the early 2000s drew national attention and the concept was adopted as an element of the national program along with guidelines that specify how the plans should be prepared.

4. After adoption of the NICEMS, the World Bank Global Environmental Facility funded the design and implementation of the Marine and Coastal Environment Management Project, MACEMP, with the aim to scale-up district action plans and other proposals to all coastal Districts by the late 2000s.

5. Tanzania’s coastal districts completed the coastal action plans under MACEMP. However these were completed just as the program was ending, so relatively few resources became available for implementation. The Pwani Project, with USAID funds, is following-up in two original sites (Pangani and Bagamoyo) plus expanding efforts in Zanzibar in 2010s.
Figure 4.3 A simple representation of the Tanzania Coastal Management Partnership efforts over fifteen years of engagement with national, district and local coastal management activities.

4.3 Reflections on the dynamics of program success

Reflecting on the first several years of experience in Tanzania and the East Africa region, encompassed in Phases I and II of the partnership, Torell et al. conclude that “the TCMP’s greatest achievement is its proven ability to build relationships and promote collaborative behavior between national government agencies, district government, and private interests. Part of what contributed to this success was the great care the TCMP took from the very start of its efforts to balance local and national interests.” (Torell, et al., 2003: 199) Strengthening this nest of relationships implied increasing the effectiveness of the TCMP at the District and local level, which became the agenda for Phases III, IV and V (the current Pwani project). “Over the next two to three years, it will be essential to shift the program’s emphasis from planning and the development of enabling conditions to implementation of tangible on-the-ground actions.” (Torell, et al., 2003:201)
The general guidance offered by field program managers on insuring local success proved relevant mainly to the TCMP, which was the only country out of the Coastal Resources Center’s entire original international portfolio (Ecuador, Sri Lanka, Thailand, Mexico, Indonesia, and Tanzania) to continue on in Phase III as a full scale national and local program after 2003.

Figure 4.4 shows a key section of the local coastal management success model, a much more detailed set of relationships that field program managers identified as critical for local success, corresponding to the circle “local project or initiative” on the left side of Figures 4.2 and 4.3. Several of these are expressed as causal loops, most of them self-reinforcing, that promote further success. (A) working on problems that are of compelling importance or offer a potential benefit to the community increases local participation, which in turn improves the quality of local problem identification and deepens the degree of shared vision. For the TCMP, this occurred at the District and village levels. (B) Engaged local teams that are skilled enough to build a plan (C) based on reliable knowledge are helped by improved local governance arrangements and better leadership. While leadership helps insure compliance and behavior consistent with any local plans adopted by communities, (D), learning must occur as attempts are made to insure that behavior is consistent with local plans, and failures in this regard are likely to occur. The best way to insure that plans are carried out is to demonstrate early successes that have measureable impacts on local environmental quality and economic and social dimensions as well. As indications of improvement are perceived, local commitment with coastal management will increase.

The virtuous cycles shown in (D) and (E) (also frequently called “success to the successful”) is what donors and national authorities are looking to invest in. However, just as local citizens can be fatigued and discouraged when ambitious, good sounding plans fall flat, national governments and donors can tire of pilot projects or programs that fail to live up to their promises. This can become a vicious cycle that reduces external resources and dampens support for local efforts just when it is most needed.
Figure 4.4 Factors contributing to local success in coastal management projects Source: Robadue, Hale and Seville, 2003.

(A) Salience: work on problems that are of compelling importance or offer a potential benefit,

(B) Engagement: Form a local team that is skilled enough to build a plan based on reliable knowledge; seek capable local participation through local forums; build capacity and leadership to help support actions consistent with a plan or strategy.

(C) Local strategy: address perceived threats to resources in good condition as well as address concerns that resources and quality of life are degraded to such an extent that something must be done to prevent further loss.

(D) Behavior change: A project aimed at assisting the village to accomplish this must inevitably promote behavior that is consistent with the plan and discourage behavior that does not.

(E) Virtuous cycle (success to the successful): Through changed behavior, a village or site can claim local project success --- healthier, productive lives for their residents, and the sustained flow of natural and economic goods and services this requires.
4.4 Strengthening the “nested system”

Phases III and IV of the TCMP, spanning 2003 to 2009, took these and other concerns much to heart in their design and execution. In addition to working in Mkuranga, Bagamoyo and Pangani Districts, the TCMP targeted villages surrounding Saadani National Park, one of the newest and the only combined terrestrial and marine national park, as well as the Wami River sub-basin, and villages adjacent to the Menai Bay Conservation Area on Unguja Island in Zanzibar. The range of local activities expanded to include watershed management, environmental management systems for large water-consuming industries, collaborative fisheries management, environmental sanitation, livelihoods development, small scale financing, and HIV/AIDS prevention in coastal areas. Local outreach and capacity building became a much larger focus of program activities as well.

During this time, the TCMP reported on a wide range of indicators spanning process, capacity, and tangible outcomes, including several that reached beyond the districts of immediate focus. For example, the district action planning guidelines that were used to prepare and then implement, were revised to shape how MACEMP conducted its scaled-up program of completing action plans for all 11 coastal districts. In Phase IV, the TCMP reported training 1,166 people, nearly half of whom are women, in topics related to landscape and sea-scape conservation. Early efforts to carry out community based fisheries management showed promising results and were extended. The Wami-Ruvu Water Basin Commission and its staff received specialized training and participated with expert teams in developing a water allocation for the environmental systems supported by fresh water flow through the river basin to the Wami River estuary that is part of the Saadani National Park. Sanitation and water supply projects benefited 8,552 school children as well as demonstrated the need for sanitation facilities at schools, especially to retain female students. HIV/AIDS communication programs reached 44,000 coastal village residents in Pangani District. Nearly 500 microenterprises were formed, and 182 entrepreneurs joined project-assisted locally managed savings and loans associations. Tree planting for land care and mangrove conservation also took place in
coastal and Wami River watershed locations. (Tanzania Coastal Management Partnership, 2010)

These detailed indications of progress matched the intermediate results set by USAID/Tanzania for the project and work plan designs. The scope of TCMP’s program expanded considerably in Phase IV, with funding doubling to $3.1 million from an original anticipated level of $1.5 million. This included more funding for biodiversity activities, HIV/AIDS through the President’s Emergency Program for AIDS relief, PEPFAR, and water and sanitation due to a successful proposal for Water and Development Alliance funding in conjunction with The Coca-Cola Company. As noted earlier, overall resources for coastal management in Tanzania increased much more with the advent of the MACEMP program supported through the Global Environment Facility.

The reflections of field program managers in 2003 extended to the dynamic between levels of action. An extended depiction of what needs to happen among levels is shown as Figure 4.5, which is an elaboration on Figure 4.2 above. Actors and institutions at the regional and national level can create a variety of enabling conditions and channels that support success in scaling up including

(1) inspiring other communities,

(2) creating national awareness of issues and efforts and

(3) creating pressures for policy reform and program implementation.

Branching out from local experience are a number of channels for communicating news about local success (or failure), to national authorities but also to non-governmental organizations and international donors who can exert pressure on the national government to act. In addition local success in pilot areas can inspire other communities with similar problems to seek help in carrying out similar processes. Combined with national leadership, information and tangible results from local successes can inspire if not force a realignment of national policy with local efforts. In unitary or highly centralized states, a number of roadblocks or bottlenecks might need to be removed to allow for plans and strategies that emphasize local participation, planning, decisions and
implementation. That is why interest and support from outside the tight world depicted in Figures 4.2 and 4.3 is necessary.

The TCMP program was revised in 2007 to reflect the fact that while solid accomplishments were taking place at the local level in an expanded portfolio of practical actions, the role of TCMP at the national and district levels remained challenging. While technical and policy contributions continued to be welcomed, the TCMP by itself could no longer shape the main direction of national policy and decision-making, for example in creating a proposed specific administrative unit for coastal management within the National Environmental Management Council. This in turn was due partly to the overshadowing influence of the large MACEMP program. In broad terms, the nation was strengthening its ability to reach many more coastal areas through these new funds, as the strategy map of Figure 4.5 recommends. However, the TCMP did not expand its geographic scope or maintain its position as the principal driver of policy reform, instead it has concentrated on building up more local successes, a way to leverage greater national commitment and capacity.
Figure 4.5 The local coastal management success model. Elaboration of the reinforcing relationships among levels of program implementation.
Notes for Figure 4.5 The local coastal management success model

<table>
<thead>
<tr>
<th>Factors contributing to local success</th>
<th>Regional and national factors contributing to local success</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Compelling problem or benefits</td>
<td>F. National leadership</td>
</tr>
<tr>
<td>B. Engaged local teams</td>
<td>G. National budget availability</td>
</tr>
<tr>
<td>C. Local action plans and strategies</td>
<td>H. Policy alignment with integrated coastal management at the local level</td>
</tr>
<tr>
<td>D. Behavior consistent with the plans</td>
<td>I. Local participation in regional policy making</td>
</tr>
<tr>
<td>E. Local project successes</td>
<td>J. Decision making at the national level (permitting) consistent with local efforts and desires</td>
</tr>
<tr>
<td></td>
<td>K. Regional and national coastal management capacity increasing and made available to the local level</td>
</tr>
<tr>
<td></td>
<td>L. Regional and national knowledge made available to support local efforts</td>
</tr>
</tbody>
</table>

4.5 The Pwani Project approach to design and monitoring

In its current phase as the Pwani Project, the TCMP addresses the challenges of maintaining an integrated program design through the innovative use of a project design, annual work plans and performance monitoring. This complies with USAID requirements but is also guided by integrated concept maps and causal models that expand the number of variables which program managers seek to track, either qualitatively or in some cases quantitatively. Figure 4.6 presents a summary view of the project monitoring variables, organized using the simple but useful nature-wealth-power idea that ties together natural resources, economic outcomes and the strengthening of governance required to achieve results. The structure shown in Figure 4.6 is clearly and simply linked to USAID/Tanzania’s country strategic plan and ongoing program requirements. The indicators themselves give strong clues as to the kind of project activities that Pwani is undertaking. Annual and quarterly monitoring results for a selection of the indicators is shown in Table 4.1. Indicators span biological, social and governance topics. Some tracked items, such as leveraged funds, have no specific targets but shed light on the local and national acceptance of and desire to invest further in project activities. For example, the project has collared a number of elephants to better understand their use of certain critical habitats. Tourists and some tour operators and lodges have made substantial contributions to cover the costs of maintaining the tracking program.
**Project Goal:** to sustain the flow of environmental goods and services; reverse the trend of environmental destruction of critical coastal habitats; and improve the well being of coastal residents in the Bagamoyo-Pangani and Menai Bay Seascapes.

**Result Area 1.** Sound natural resource management (Nature)

- 1.1 Hectares in areas of biological significance showing improved biophysical conditions for selected parameters
- 1.2 Hectares in areas of biological significance under improved management
- 1.3 Local policies, plans, and co-management agreements adopted to manage natural resources and endangered ecosystems
- 1.4 Leveraged funding for project activities

**Result Area 2.** Strengthened resilience and assets (Wealth)

- 2.1 Number of coastal inhabitants with increased adaptive capacity and reduced vulnerability to harm from actual or expected climatic changes or their impacts
- 2.2 Number of individuals with increased economic benefits from project interventions
- 2.3 Number of households with improved access to finance, including those receiving community credit and start up grants
- 2.4 Number of persons reached through community outreach that promotes HIV/AIDS prevention
- 2.5 Number of the targeted population reached with individual and/or small group level HIV prevention interventions
- 2.6 Number of

**Result Area 3.** Improved governance (Power)

- 3.1 Number of local organizations strengthened to manage endangered ecosystems, and to support sustainable livelihoods and cross-cutting issues such as HIV/AIDS and gender
- 3.2 Number of individuals reached through community outreach and planning that promotes biodiversity conservation and improved gender equity
- 3.3 Number of individuals trained and/or certified in coastal governance, MPA management, HIV/AIDS action planning, and other cross-cutting issues
- 3.4 Number of success stories documenting key actionable findings about best practice approaches and lessons learned published in local media reports, radio shows, conference papers, and research studies
Table 4.1 Excerpts from Pwani Project reporting system for selected indicators

<table>
<thead>
<tr>
<th>INDICATOR</th>
<th>Data Source</th>
<th>Baseline data, 2009</th>
<th>FY 10 Results</th>
<th>FY 11 Target</th>
<th>FY 11 Results</th>
<th>FY 11 Q4 results</th>
<th>% of FY 11 target reached in Q4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2 Number of hectares in areas of biological significance under improved management</td>
<td>project records, secondary records</td>
<td>180,117</td>
<td>56,414</td>
<td>104,000</td>
<td>102,046</td>
<td>0</td>
<td>0%</td>
<td>On target.</td>
</tr>
<tr>
<td>1.1 Number of hectares in areas of biological significance showing improved biophysical conditions for selected parameter(s)</td>
<td>project records, survey reports</td>
<td>26,734</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0%</td>
<td>No results expected until year 3</td>
</tr>
<tr>
<td>1.3 Number of policies, laws, agreements, or regulations promoting sustainable natural resource management and conservation implemented.</td>
<td>project records, secondary records</td>
<td>5</td>
<td>1</td>
<td>8</td>
<td>5</td>
<td>0</td>
<td>0%</td>
<td>On target</td>
</tr>
<tr>
<td>1.4 Dollar value of funds leveraged</td>
<td>project records</td>
<td>0</td>
<td>189,471</td>
<td>No target</td>
<td>149,473</td>
<td>27,377</td>
<td>No Target</td>
<td>Elephant tracking</td>
</tr>
<tr>
<td>2.1 Number of stakeholders implementing risk reducing practices/actions for resilience to climate change</td>
<td>project records</td>
<td>0</td>
<td>-</td>
<td>400</td>
<td>563</td>
<td>74</td>
<td>19%</td>
<td>On target</td>
</tr>
</tbody>
</table>
The project road map perspective of the Pwani project

The project road maps used to design the Pwani project help show critical interactions among environmental, social and economic components of the target region, including the dimensions of gender inequity, population dynamics, and climate change. The actions undertaken during the life of the project are explicitly represented as leverage points within the overall systematic concept of how communities and ecosystems interact. As a result of this deeper understanding of social and ecological system dynamics, the program supports a broad mix of actions, including HIV/AIDS prevention and it is introducing the population-health-environment approach to meet family planning and health needs of villages while also addressing environmental problems.

A section of the project road map is shown in Figure 4.7, and the complete road map in Figure 4.8. In terms of the ideas presented earlier from field managers on what contributes to coastal management success at the local level, the substantive focus of the Pwani program is on the variables immediately tied to attaining behavior consistent with plans and policies (Section D) and the virtuous cycle of implementation (Section E) of Figures 4.4 and 4.5. Initial successes and tangible outcomes reinforce local commitment, leading to greater success.

Figure 4.7 builds off this basic notion of reinforcing success with success by highlighting the key stocks or components of the coastal situation that need to be maintained, restored or increased. For example, abundant terrestrial wildlife, such as elephants need intact coastal forests and landscapes and whose presence influences the extent the local workforce is employed in non-extractive activities such as the eco-tourism industry. The capacity of coastal communities to adapt is thought to be influenced by several factors, such as the condition of the local economy, food security, exposure and sensitivity to climate impacts and hazards such as flooding and drought.

The Pwani Project is not taking responsibility for 100 percent of the problems in each village, nor for the quality of life in all coastal villages where it works. Instead it has selected some actions it believes are high leverage, such as communication work on HIV/AIDS, vulnerability assessments for local villages, family planning, energy
technology improvements and the formation of local savings and loans groups. The performance monitoring plan tracks both the effort and effectiveness put into these actions on a periodic basis. The TCMP has also conducted more in-depth assessments of its interventions, for example behavior monitoring surveys to examine the effectiveness of its HIV/AIDS communication programs (see the series of studies including BALANCED Project, 2010; Tobey, Thaxton et al., 2005; Torell and Tobey, 2006; Torell, Kalangahe, et al., 2006).

Figure 4.8 presents the entire Pwani project road map. In addition to the human dimension elements shown in Figure 4.7, the full depiction of the road map covers two other core elements: biodiversity conservation in marine ecosystems, and in coastal forests, wildlife habitats and associated water resources such as the Wami and Ruvu rivers.

The road map for biodiversity conservation remains site specific, and centers on work in environments of critical concern such as Lazy Lagoon, Saadani National Park, the Wami River estuary associated with the park, and local populations of sea turtles. The roadmap remains schematic, as locations in Zanzibar in the Menai Bay Conservation Area, and the coastal villages of Paje and Jambiani suffering from coastal erosion and climate impacts are not specifically mentioned in the diagram. The road map exhibits a high degree of situational awareness on leverage points to address problems. Many other factors influencing project success are noted. Some elements such as the economic trends in tourism, shipping, transportation, and agro-industry are identified but there is relatively little a small program such as Pwani can do to directly affect these trends. On the other hand, national agencies are specifically included, such as park management, fisheries, and watershed management agencies, as well as the agency managing Menai Bay, in addition to the District and local governments in Pangani, Bagamoyo and Zanzibar.
Figure 4.7 A Section of the Pwani Project road map. Project activities are shown in boxes. Tan colored actions are aimed at the human dimension, strengthening community resilience (capacity to adapt) from economic, health, environmental and climate related shocks and impacts. Green boxes focus on biodiversity conservation and show policies aimed at environment. Blue actions are focused on livelihood options, in this case ecotourism as a result of protecting nesting areas. A number of causal links have been omitted for clarity.
The road map does not contain much detail in tracking national governance trends, however the program of work contains several national level actions that pertain to Result Area 3 and its related indicators (Figure 4.6). Pwani is more situationally aware of what national government is doing because of the inclusion of national policy results, but it is not attempting to track all the programs that are in place to produce the needed national and regional support to localities.

The USAID results framework (USAID/TANZANIA 2005) is based on an national assessment of the country’s economic, health and environment situation as well as prior USAID experience in project design and implementation. The strategic objective (SO) it chose that guides most of the work carried out under Pwani is “Biodiversity Conserved in Targeted Landscapes through a Livelihood Driven Approach”, which requires three intermediate results:

(IIR1) improved policies and laws,

(IIR2) the practice of participatory, landscape scale conservation and

(IIR3) “Conservation enterprises generate increased and equitable benefits from sustainable use of natural resources.”
Figure 4.8 Schematic view or road map of the Pwani Project Design. Project interventions shown in colored boxes coded by program element.
Outcomes for the Strategic Objective (SO) are measured using the following indicators:

<table>
<thead>
<tr>
<th>Year</th>
<th>Area under conservation management:</th>
<th>Biophysical trends:</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>Baseline: 1,500,000 hectares (ha)</td>
<td>2005 Baseline: stable or deteriorating</td>
</tr>
<tr>
<td>2009</td>
<td>Target: 2,750,000 ha</td>
<td>2009 Target: improving or stable</td>
</tr>
<tr>
<td>2014</td>
<td>Target: 4,000,000 ha</td>
<td>2014 Target: improving or stable</td>
</tr>
</tbody>
</table>

Well – aware that Tanzania does not lack for laws and policies, USAID/TANZANIA is focusing its attention instead on practical action. “Practically speaking, this will mean that for a given landscape, NRM actors will collaborate in developing and implementing their land or resource management activities.” Complementing this, IR 3 is opportunity-seeking: “Several types of conservation enterprises are poised to take off and/or continue growth, which can be enhanced with appropriate facilitation and investment. These opportunities include: community wildlife management; ecotourism; mariculture; non-timber forest products; NRM-based small and medium-size enterprises” and others.”

Figure 4.8 in essence is a both project and coastal management policy informatics road map. In addition to highlighting Pwani’s contributions to the results sought by USAID and the Tanzanian government, it sets out the project team’s beliefs about how the social, ecological and governance elements of the coastal management situation in the northern coastal seascape are interrelated. It would be immensely beneficial to government entities, donors and non-government organizations, as well as Tanzanian stakeholders to know, year by year, what is happening inside of each of the boxes and along each of the arrows in the road map. Instead planners and policy makers have to settle for a few assessments of trends in a selected few issue themes and geographic areas and to at least be aware and explicit about their understanding of the functioning of the system where measurement is difficult or elusive.

For example, in Phase IV, the TCMP monitored coral cover and fish abundance in managed (no-take) portions of reefs off the Bagamoyo coast, along with fee collection for
tourists visiting these zones. The importance of clarifying the dynamics of the problem, and identifying the appropriate levels of intervention are illustrated in TCMP’s reflections on the activities in support of fisheries management:

“The small sized no-take reserves in Bagamoyo are a good start but insufficient to fully address overfishing issues in the district. Unless other issues of overfishing and illegal fishing (including extensive use of beach seine nets) are addressed, improvements in the fishery are unlikely to materialize. This may require changes in national fisheries policy to provide districts more authority to manage levels of effort and implement other means of managing the fishery.” (TCMP, 2010)

The emphasis on high leverage actions and capacity building to carry out practical measures at the local level in Pwani and other poses a challenge related to project informatics. The monitoring and evaluation systems TCMP utilizes have to be effective in meeting the specific needs of the individual sources of funding, as well as addressing the need collect and analyze information in ways that are meaningful for policy development and implementation at village and district levels. Dashed lines in the lower right hand corner of Figure 4-8 connect several key areas of important interventions in fisheries which Pwani is no longer tasked to address, although the topics remain present in discussions with District and community stakeholders. For example, a value chain analysis prepared by the Pwani Project team includes several strong feedback loops showing that fisheries management remains a weak link. (Figure 4.9) On the one hand actions that favor fisheries management (blue boxes) are weakened by declining support to local fisheries committees and use of funds collected from visitor fees for purposes other than fisheries management. At the same time strongly counter-productive subsidies to overfishing by the national government and the MACEMP project confound the carefully set groundwork for local fisheries management in Bagamoyo and Pangani Districts. If the Pwani project only reported on the successes encountered in fisheries management activities, donors would end up being surprised because negative loops such as subsidies to increase fishing are at work erasing any gains on the side of good governance.
Figure 4.9 A value chain perspective on local fisheries management in Bagamoyo District, incorporating positive and negative feedback loops. Source: Mkama, Mposo, Mselemeu, Tobey, Kajubili, Robadue and Daffa, 2011. This elaborates on the treatment of fisheries in the Pwani Project roadmap. Efforts to manage fisheries locally (blue boxes) are undermined by subsidies for fishing, leading to overharvesting (pink boxes).
4.7 A modeling approach to informatics useful in tracking and improving local project success

The Tanzania Coastal Management Partnership maintains a holistic perspective that spans five project cycles, international to sub-village level action, and the social, economic, biological and governance dimensions of the areas it works in. For a number of these dimensions it has carried out assessments, sometimes as snapshots and other times as longitudinal assessments of trends and progress. The Pwani Project monitoring plan and the detailed data on social and environmental factors, collected as part of carrying out the work plan, includes variables in the conceptual model of the project design, but does not look as attentively at many of the factors that are addressed by the local coastal management success model presented as Figure 4.5. To explore the potential for incorporating some aspects of the dynamics of local project success into the traditional monitoring and evaluation framework, the local coastal management success model was translated into a computer simulation model, drawing on the system dynamics modeling tradition used in Chapters 2 and 3. The model presented in this section is set up to operationalize and test relationships among the ideas expressed in the concept map developed by international coastal management practitioners. It is not specifically calibrated to a particular case such as the Pwani Project and its work in Zanzibar and the northern Tanzania seascape. However, the logic of the model, and the scenarios tested, have a more than accidental resemblance to the challenge faced in Tanzania in terms of scaling up the individual, isolated local projects into a successful, sustained nation-wide coastal management program.

Model overview

Views of the key sections of the simulation version of the local coastal management success model sketch shown in Figure 4.5 are included as Appendix VIII. Figure 4.10 is a highly simplified sketch of the simulation version of the model. This section reports on the results from a test of twelve scenarios using the model. The tested scenarios are aimed at exploring one of the questions constantly facing donors, implementors, national and local governments: how to move from isolated local successes that rise and fall with donor interest and attention, to a sustained effort with
enough resources to support local projects and to build sufficient long term commitment to continue this support. Is it actually possible to engineer a smooth transition between pilots funded by donors, some increase in national commitment, followed by sustained local effort?

Figure 4.10 Schematic view of simulation version of local coastal management model
The simulation model is set to start initiatives in 100 locations, create action plans, then carry out actions that will generate an average of 100 improved behaviors, which in turn will improve the condition of coastal resources. As Figure 4-11 shows, all of the scenarios were able to generate 66 to 76 out of 100 plans.

![21. Places with Completed action plans](image)

**Figure 4.11** The results of seven scenarios: Even the base case was able to complete most projects and deliver completed action plans. None of the scenarios can deliver production of 100% of action plans, thus limiting the possibility for implementation.

The twelve scenarios are briefly described in Table 4.2. Seven of the twelve scenarios (marked with an * in the table) were selected for further examination.
<table>
<thead>
<tr>
<th>Scenario Name</th>
<th>Description</th>
<th>Insight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S-base</strong> Planning success, implementation failure</td>
<td>100 locations need plans, 100 behaviors to do per plan to reach a condition of 100% of coastal resources in good shape, over 50 years. Only 14% of goal is reached in base run</td>
<td>Planning is not enough to gain donor, national support and get locals past initial discouragement</td>
</tr>
<tr>
<td>S1 Boost National awareness and local leadership (+20%)</td>
<td>National variables 50, 54, and 55 increased by 20%; produces 61% improvement in behaviors aligned with plans (36), 23% of goal</td>
<td>A national-only approach gives a boost to implementation</td>
</tr>
<tr>
<td>S2 Boost Local leadership and local projects (+20%)</td>
<td>Local leadership increased in variables 4, and 5, while 10 starts more local projects. It produces no improvement over base</td>
<td>Local approach alone generate little traction</td>
</tr>
<tr>
<td>S3 Improve efficiency: faster plans, faster actions (+20%)</td>
<td>Efficiency variables 18, 42 help by producing a 53% improvement, reaching 22% of goal for improved resource use behavior.</td>
<td>Getting plans done faster is not enough help in boosting action, no better than S1</td>
</tr>
<tr>
<td><strong>S4</strong> Efficiency and big implementation effort (+20%)</td>
<td>Variables 18, 42, 65w are directly related to implementation and produce a 315% improvement over the base, 59% of goal</td>
<td>Concentrating on key implementation factors gradually gets plans and more actions done</td>
</tr>
<tr>
<td>S5 Combined strategy: local leadership and improved efficiency (+20%)</td>
<td>Increasing 4,5,10, 18, 42 produce only a 55% improvement, 22% of goal</td>
<td>Focusing on local process aspects adds little to scenario S3</td>
</tr>
<tr>
<td>S6 Combined strategy: national leadership, local projects (+20%)</td>
<td>Increasing variables 4, 5, 50, 54, 55 generates a 213% improvement over the base, 45% of goal</td>
<td>Local leadership, national attention gets quicker, better results but plateaus at 45%</td>
</tr>
<tr>
<td><strong>S7</strong> Improve all main factors by 10%</td>
<td>Increasing local, implementation and national variables by 10% creates an improvement of 338%, 63% of goal</td>
<td>S7 performs well in long run, slower than S10 or S11 in reaching goals</td>
</tr>
<tr>
<td>Scenario Name</td>
<td>Description</td>
<td>Insight</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------</td>
<td>---------</td>
</tr>
<tr>
<td><strong>S8</strong> Test just initial local effort and implementation effectiveness by 10%</td>
<td>Variables 10, 65w generate 23% improvement over the base, 18% of goal</td>
<td>S7 performs better in combination</td>
</tr>
<tr>
<td><strong>S9</strong> Test all but S8 variables by 10%</td>
<td>Variables 4, 5, 18, 42, 50, 54, 55 together generate 102% improvement, 29% of goal.</td>
<td>S7 performs better in combination</td>
</tr>
<tr>
<td><strong>S10</strong> Improve all factors by 20%</td>
<td>An across the board approach improves performance by 510%, 87% of goal</td>
<td>This all – out approach generates fastest, best result</td>
</tr>
<tr>
<td><strong>S11</strong> Improve all factors by 15%</td>
<td>An across the board approach improves performance by 420%, 74% of goal</td>
<td>This generates fast, very good result compared to S4 which has 20% increase in some variables</td>
</tr>
</tbody>
</table>
Figure 4.12 The results of seven scenarios with dramatically different results in aligning behaviors with plans. S10 achieves the highest number of improvements and does so much more quickly than other scenarios.

Figure 4.12 shows how the scenarios listed in Table 4.2 play out over time. Not only is S10 (blue line) able to produce the highest amount of desired behaviors, it does so rapidly and in a sustained pattern. It was generated by changing the parameters listed at the bottom of Table 4.2 a total of 20%. For example the average time to implement a behavior (for example, building sanitation facilities or organizing fisheries enforcement committees) was reduced by 20%, and the effectiveness of local teams was increased by
20%. A similarly dramatic pattern was attained with a 15% improvement (S11). The more modest 10% across-the-board improvement scenario, S7, generates a proportionally better than expected result, but the process is much slower. Scenario S4, which improves a small set of variables by 20% generates nearly the same long term result, but it is slower still. Since the model does not have any biological representation of coastal resources built in, unlike the Pwani Project conceptual model, the question has to be raised whether there would be any coastal resources left under S4 by the time the plans were prepared and slowly implemented.

Dynamics of implementation in two scenarios

Figure 4.13 shows scenario S7 and is stacked on top of the most successful scenario, S10 (Figure 4.14). The blue line at the top represents the ideal, desired goal of 10,000 actions or good behaviors, variable 39. These could be permits issued, micro-enterprises formed and functioning, membership in savings and loans associations, fishers complying with no-take zones, children with access to water and sanitation at school and so on. The red line, variable 46a, represents the maximum amount of good behaviors that can in practice take place because plans are adopted that set out what behaviors are required. The green line is the results of implementing the plans, in this case it begins to approach to the maximum possible by Year 36. The grey line shows that there is a remaining gap between plan and reality, but that the trend is in the right direction, which is downward. However, it only reaches 5000 improved behaviors by around year 30. By contrast, the best scenario, S10, attains 5,000 good behaviors by around Year 12, with local success on a trajectory to do better than the expected “total potential good behaviors”.

Figures 4.15 and 4.16 shows an important reason for the relative success of scenario S7 (10% boost) and the much greater success of scenario S10 (20% boost). The fractions of support from local actors and national government increase steadily over time and the role of donors was primarily in the beginning to jump start the process. However the peak of effort occurs very late, and the application of national resources dominates local throughout. This is reverses in Figure 4.16. Scenario 10 (20% boost) reaches its peak of resources much sooner, donor involvement drops relatively quickly, and the
proportion of local resources overtakes national resources midway through the run. Note in both cases that the model run drives resources for local ICM to 2, or 200% of requirements. The model does not have a way of computing the exact effort required to achieve the number of plans or desired behaviors so some aspects can be over-driven. Ideally, the model should be set up so that a proportion of 1 or 100% for all variable factors would generate a perfect result of 100 plans completed and 10,000 behaviors put into action.

Figure 4.13 Key elements of a modestly successful scenario, S7, based on a 10% improvement strategy. It takes S7 three times as long to attain 5,000 behaviors as S10 (see Figure 4.14)
Figure 4.14 Key elements of the most successful scenario, S10, based on a 20% improvement strategy. It attains 5,000 desired behaviors in just 12 years.

Figure 4.15 The shifting proportions of support from donors, national government and local actors in Scenario S7 (10% boost)
The importance of early implementation, local commitment, and quality of plans

Scenarios S10, S11 and even S6 do a better job in getting implementation of action plans started early, as shown in Figure 4.17. Also, as Figure 4.18 shows, the more successful scenarios have a much higher proportion of resources coming from local sources. They also have the lowest fraction derived from donor support. (Figure 4.19). While higher levels of national awareness are important in the beginning, the best scenarios see declines in this component over time as local leadership, knowledge and resources increase. (Figure 4.20) Finally, the quality of action plans increases over time in the most successful scenarios (Figure 4.21).
**Figure 4.17** Peak times when scenarios show a push for implementation (aligning behaviors with plans) S10 and S11 jump start implementation in a dramatic way.

**Figure 4.18** Proportion of local resources is higher in best scenarios.
**Figure 4.19** Donor contribution fraction is negatively related to scenario success

**Figure 4.20** The importance of early, high level of national awareness in jumpstarting local success. The most successful scenario sees national awareness decline over time.
Additional model details

The simulation version of the local coastal management success model allows for a much more fine-scaled exploration of the factors raised in Figure 4.5 and the notes which accompany the figure than will be presented here. Appendix 3 contains a table of all the variables including their mathematical definition and comments. The discussion in the next section considers some of the implications of the local coastal management success model for coastal management work in general and potential additions to the Pwani Project approach. It is important to recognize that the modeling exercise is based on a mental model developed in part by the early leaders of the Tanzania Coastal Management Partnership, but also that it is an amalgam of experiences in very different country settings. It is possible that important structure relevant to Tanzania has been left out. The parameters and look-up tables used for this exercise need to be adjusted to better fit the case. A test of the simulation using 11 coastal districts as places (Figure 4.22), rather than the arbitrary 100 places, generates somewhat different results. Scenario 10, giving a 20% boost to key parameters and policies, still does well, however Scenario 7, a 10% percent boost, is mediocre. Local resources applied to coastal management is lower, and donor involvement remains higher.

Figure 4.21 The quality of action plans increases over time in the most successful scenarios
Figure 4-22 Model simulation for Tanzania-like case, with 11 places (districts)
4.8 Discussion

**Linking project design and the local coastal management success model**

The Pwani Project roadmap depicted in Figures 4.7 and 4.8 constitutes only a small, generalized portion of the *local coastal management success model* shown in Figure 4.5 and Appendix VIII. As noted earlier, Pwani project managers wanted to depict their concept of how the social, economic and physical systems of the northern Tanzanian landscape and seascape can be improved through selected project actions. This fully recognizes that many other forces are at play that reinforce as well as resist these efforts. The example of local fisheries production in Bagamoyo district (Figure 4.9) is representative of this tug of war between efforts at reform and efforts that merely hasten the decline of fish stocks and the economic value chain it supports. The Pwani project cannot by itself collect relevant detailed time series data on all of the stocks of resources or the rates of change contributing to depletion or replenishment, however, the project roadmap makes clear its hypotheses about the nature of these relationships.

The *local coastal management success model* encompasses many elements beyond the variables shown in the Pwani Project road map. Many of these are addressed in project strategy, design and program management components and reported to USAID in narrative form to help explain the movement and progression (or absence of) the main indicators of project success. Pwani maintains a results framework and progress monitoring system that is closely coupled to USAID/TANZANIA, and more broadly, the US Government’s policies, priorities and standard indicators for reporting on and helping interpret the impacts of programs carried out in remote, rural coastal areas.

The fundamental challenge of aligning resources to meet local needs and address coastal management concerns at the level of the village or geographic site depicted in Figures 4.5, 4.9 and Appendix VIII are broadly played out in the five phases of the Tanzania Coastal Management Partnership since 1997. It can be seen in other parallel efforts such as the recently completed Marine and Coastal Environment Management Project (MACEMP) and earlier efforts such as the Tanga project funded by IUCN and Irish Aid and the Mafia Island Marine Park supported by WWF and Norwegian assistance (Torell, 2000). While the Pwani project draws upon the insights of field
program managers in several countries to set out a picture of how social, environmental and governance elements are at work in coastal locations in order to select appropriate actions, it is not in a position to track or be directly engaged in all of them. A moderately well-funded project such as Pwani has sufficient resources to collect both performance data and carry out some in-depth studies of the nature of coastal problems and the trends and likely effectiveness of actions. However, it is very difficult and costly to keep detailed records of every intermediate variable and causal link between the project’s actions and its impacts.

Instead, by using a concept modeling approach, the Pwani project team is able to clarify its own ideas about how problems, conditions and the results of project activities interact to generate results that can be measured. The visual depictions of both the world of the project, and the more general understanding of the dynamics of donor, national and local resources attempting to foster and spread local success provided in this paper are not comprehensive. The diagrams, and perhaps the thinking of any project team tends to emphasize the drivers of success, that is, the positive links and loops that are thought to follow from project interventions.

Simulation results and Pwani project strategy

The strength of the simulation version of the local coastal management model is the limitation of the feedback thinking in the causal loop diagrams and intervention maps representing the Pwani Project approach to the Northern Tanzania seascape. The simulations show the specific impact and importance of decisions made by donors, national constituencies and leaders, and how in turn those are affected by results and struggles at the project level. It suggests that a focus exclusively on pilot projects and small scale interventions cannot lead to the widespread adoption of better coastal management.

On the other hand, the concept maps used in the Pwani Project closely tie the specific actions aimed at making life better in coastal villages and areas in specific ways. The simulation has the simplest possible structure for representing this reality and socio-ecological structure and dynamics: a single arrow ties variable 36, “Local success:
Resource Use Behavior aligned with plan” to variable 40: “local coastal resources quality & abundance”, linking the number of behaviors in a completely linear way to their social, environmental and economic result. The grand result generated by scenario 10 would in reality need to be pruned considerably to take into account the slippages and dynamics that cause the best executed actions to miss their ultimate aim. In addition, the time frame of the simulation is decades. The simulation completely fails to account for the fact that local coastal resource quality and abundance, while degraded, is still relatively high and will continue to degrade while the governance system struggles to put plans into place and build the capacity and assemble the resources to implement needed actions and behaviors. A plan that takes ten or twenty years to even partially execute is going to see, as in the case of Chapter 2, the accelerating loss of those resources.

Some of these deficiencies can be remedied fairly simply in the model to set the resource base at a high level, add a rate of degradation, and then let the scenarios do their best to rectify the situation. Far better would be to identify and model specific aspects of the coastal economy, environment and social conditions, for example by incorporating the fisheries value chain shown in Figure 4.9, a similar representation of the use of mangrove ecosystems, and so on. These deficiencies do not diminish the result of this chapter, which is to demonstrate what an insight-oriented simulation can contribute to strategy formulation in a specific program.

Modeling Policy Resistance

An equally rich story exists and remains to be told in the realm of policy resistance, in other words, the accumulated effects of negative feedback loops and causal links that work against implementation. Some negative feedback loops have been made explicit in the Pwani case, such as public or private opposition to conservation of a marine protected area, mangrove forest or conservation of elephant habitat and the contradictory policies pursued in the fisheries value chain. Other sources of policy resistance are not so easy to discern or depict, such as conflict among political parties, low capacity to perform assigned tasks, economic trends that favor investments in resource-consuming businesses rather than resource-dependent or conserving enterprises.
The *local coastal management success model* features a few of these negative feedbacks in a generalized form and are represented in the simulation, for example as local contributions to coastal management increase, the donor contribution decreases, reducing overall resource availability and pressure to start new initiatives. Also, as local coastal resource abundance and quality improves, NGO pressure to keep coastal management on the national agenda diminishes, reducing the overall flow of resources to maintain improvements.

Further work on mapping out these parts of the coastal management road map could generate deeper insights and highlight additional types of information that could be collected or tracked as part of a more robust approach to project informatics, and thus project design, monitoring and management. The roadmap exercises initiated by the Pwani team provides valuable examples of the detail involved in converting projects into plans into desired behaviors. Similar detail for this and other cases in terms of the donor-national-local resources dynamic would lead to better insight-oriented models that can add the lessons learned during the Pwani program to the growing global repertoire and knowledge of how-to as well as what-not-to-do in at the different levels of a complex nested system that tries to match local needs with national and international resources.
Chapter 5: Modeling for Policy Change and Coastal Management Success

“To give satisfaction, your life will have to be lived in a family, a neighborhood, a community, an ecosystem, a watershed, a place, meeting your responsibilities to all those things to which you belong.”

Wendell Berry, 2007

5.1 Introduction

This dissertation explores three facets of marine and coastal management from a system dynamics perspective: a state government level regulatory program in the U.S., the controversial, rapidly expanding use of marine waters for fish farming, and the quest for sustainable development of coastal resources to benefit the poor. It is motivated in part from the author’s career-long concern that ‘everyone likes to complain about myopic, short-sighted decision-making but nobody wants to do anything about it’. It is also motivated by the belief that evidence of the need for and value of systems thinking and simulation is hiding in plain sight, permitting us to move beyond a marginal improvement in the quality of decisions toward a transformation of how society allocates and uses natural resources for social good.

So, what is it going to take to make coastal and marine management more effective? We should rephrase this question to ask, “what have we learned about what it has taken to achieve the progress we have made so far, and what are coastal resources users and stakeholders now confronting that an endogenous, feedback perspective can help overcome?” Our aspiration for an “electronic oracle”, or answer-machine, a computer that would tell the policy makers what to do, where, when and how, is only partially met. Environmental modeling and geographic information systems have made remarkable strides since the 1970s and are actively utilized in coastal and marine decision
making. Yet in 2012, the ocean and coastal policy community is more frantic and concerned about the urgency of their cause than ever before. The information we are collecting does not necessarily answer important, that is, the right questions raised by even the simple models presented in this research. Much of the information we are gathering, in monitoring, assessments and program evaluations are not answering questions that coastal citizens, resource users and those most adversely affected by deterioration of economic, social and environmental conditions are asking. The mental models and knowledge of a wider range of people involved in the resource use system have not been mapped out in a critical, collaborative way, even though the tools to do so are in ready reach.

The electronic oracles we have today are technically demanding and data hungry but not necessarily set up to create a consensus on the right path forward or to build the capacity we need to make the journey. Part of the transformation we need in marine and coastal management is to be able to test out what it will take to get a plan over the finish line, not just to the decision stage, but well into implementation at a level that overcomes willful and structural resistance long enough so that its benefits (and limitations) can be seen and heard. We already have abundant information about past policy experience that could shed light if we mined and analyzed the experience with content analysis and system dynamics techniques. The Coastal Zone Workshop of 1972 challenged the first generation of coastal managers to sift through and reconstruct the past record of experience. My colleagues and I did just that. We prepared retrospectives of a century of environmental policy making history in Rhode Island. It is this mindful sense of history, continuity and trajectory that distinguishes an effective culture of practice in the marine
and coastal community from mindless bureaucracy and collective amnesia. Even so, the limits of past reflections are seen in this study. We can portray a merely rudimentary view of some of this rich experience, in part because key data and records, and the memory of the principle actors have not been assembled in a way that preserves, or gives a chance to improve understanding.

The Stratton Commission’s 1969 report “Our Nation and the Sea” was intended as a wake-up call mainly to the untapped economic potential of developing ocean and coastal resources but also to promote more effective stewardship of those resources. The Coastal Zone Workshop was convened in 1972 out of concern that the U.S. would fail to carry through on the stewardship dimension, not that coastal management should be used as a driver for economic development. Ecosystem-based management today is not much concerned about supporting the economic development of the coastal and marine zone. The assumption is that pace of economic and population growth or change remains beyond the ability of existing institutions to handle it.

5.2: A summary of the three modeling efforts in Chapters 2, 3, and 4

Table 5.1 compares the approach, methods and results of the three simulation models prepared and described in Chapters 2, 3, and 4. This section looks across the three modeling exercises, ending with a consideration of the value of models in mapping out and testing strategies for advancing policy change in the face of resistance.

Role of the researcher

In all cases the researcher has been directly involved in the programs or studies described in the models. This combined action research and professional practice inspiring research. The most direct and ongoing involvement has been with the Rhode
Island Coastal Resources Management Program, and the least contact with decision-makers is in the tuna ranching case, where the role of the research was as a secondary member of a research team, not as an advisor to other actors, and unable to influence future Mexican policy in some way. The dilemma for the engaged modeler is no different than in a facilitated modeling situation. Successful stakeholder engagement can lead to pressure to include each of “their” parts of a model. In the case of Rhode Island presented in Chapter 2, the researcher had developed a larger version of the coastal management model but chose not to present or utilize it since it did not actually do a better job at showing some of the key insights than the simplest version. In the tuna ranching case, the details of the model are derived entirely from the publications of the science assessment team and published reports of the innovative ranch operators, and has not been reviewed by any individual inside the industry or the assessment team. The models presented in Chapter 4 which capture some of essence of a quest for local coastal management success, are central to the activities of the Coastal Resources Center at the University of Rhode Island, so the author continues to be actively engaged in applying systems thinking and policy informatics ideas into the design and management of the work in Tanzania.

*Endogenous variables and model boundaries*

A continuing challenge is to resist the temptation to insert all the structures and incorporate all the stocks and flows that a client or audience for the concept diagram or simulation can think of, even if they do not pass the test of 'differences that make a difference'. The coastal management model in Chapter 2 should probably be expanded to differentiate at least among housing, waterfront dependent operations and unrelated
commercial and industrial operations on the coast. It also should include at least some 
structure to factor in current environmental conditions and the feedbacks to pressure to 
conserve, as well as the impacts of natural hazards and climate change. However, it is 
not clear that a highly disaggregated model that accounts for every land use and every 
sector's uses of the coast would add insights or be capable of predicting future growth in 
the coastal region. In tuna ranching, proprietary commercial models already exist for 
making economic and biological decisions to manage ranching the operations. By way of 
contrast, the model presented in Chapter 3, and other studies such as that by Shamshak 
are aimed at public policy audiences. More aspects of the environmental impacts might 
have been included, but the science team has already done a thorough assessment of these 
questions. The range of model formulations shown in Chapter 4 related to local program 
success, from concept maps to working simulations, replicate structures commonly seen 
in business dynamics studies. The brief exposition of the model does not make this 
sufficiently clear, indeed all three models include a certain amount of modularity and 
replication of SD structures. It should be somewhat clearer from the comparison in Table 
5.1 is a step toward showing that many interchangeable pieces of model structure are 
shared across the chapters, and this would make a stronger case for connections among 
the three views of coastal management offered in this research.

A generalized comparison of the models and situations presented in Chapters 2, 3 
and 4 appears as Table 5.1.
Table 5.1 A comparison of simulation models from Chapters 2, 3 and 4

<table>
<thead>
<tr>
<th>Item</th>
<th>Coastal Management Program: Rhode Island (Chapter 2)</th>
<th>Offshore Tuna Fish Farming (Chapter 3)</th>
<th>Local Coastal Program Success (Chapter 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Role of researcher</td>
<td>Involved in program design and implementation in Rhode Island case, facilitation of decision process (except no role in permit decisions), advocate and policy entrepreneur</td>
<td>No role in policy or advocacy, however, associated with researchers whose reporting contains recommendations. Neutral stance toward case.</td>
<td>--In HIV/AIDS case, provided analysis for final reporting to assist project manager --Program design and implementation of TCMP and PWANI, advocate and policy entrepreneur, --organization of local process in variety of RI and international settings as project manager or as technical assistance or training</td>
</tr>
<tr>
<td>Endogenous variables</td>
<td>-Stocks of coastal land; -site allocation mechanism, -pressure on decision makers, -effects of change in one stock on decisions to develop or conserve, -operation of regulatory and planning mechanisms</td>
<td>-Decisions by tuna ranchers to deploy pens, obtain fish, feed fish, harvest and sell fish - stocks of juvenile bluefin, tuna in pens, fattened tuna, harvested and sold tuna -profits from ranching effect on deploying pens -food source for tuna -effect of timing sale of tuna on tuna price</td>
<td>--generalized effect of project on natural resources --local capacity to plan and implement --national capability to aid local level --effect of manager health on conservation efforts --effect of local project success on future external resources --word of mouth generating demand for local level projects and capability --effect of local and donor decisions on funding to national willingness to fund --impact of local discouragement</td>
</tr>
<tr>
<td>Exogenous variables</td>
<td>-plan goals for conservation -timing of plan implementation -initial availability of sites</td>
<td>-allocation of sites for tuna ranching -allocation of tuna for use in ranches -price of tuna based on demand</td>
<td>-initial interest in local project -initial investment by donors, government -initial support of national government for local efforts -condition of environmental stocks</td>
</tr>
<tr>
<td>Item</td>
<td>Coastal Management Program (Chapter 2)</td>
<td>Offshore Tuna Fish Farming (Chapter 3)</td>
<td>Local coastal program success (Chapter 4)</td>
</tr>
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<td>-------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Excluded variables</td>
<td>--allocation of sites to competing uses (residential and non-waterfront commercial vs. ports)</td>
<td>--effects of global tuna ranching (Mediterranean, Japan, Australia) behavior on local price for tuna, acceptability of tuna ranching</td>
<td>--global trends and fads in donor funding priorities</td>
</tr>
<tr>
<td></td>
<td>--natural hazards impacts on uses</td>
<td>--effects of management efforts of Pacific bluefin tuna on migrating stocks to Mexico</td>
<td>--specific sectors of coastal economy</td>
</tr>
<tr>
<td></td>
<td>--climate change impact on uses and sites</td>
<td>--governance of Mexican fishery</td>
<td>--non-project impacts on natural resources, project success</td>
</tr>
<tr>
<td></td>
<td>--asset specificity: the unique values of particular sites</td>
<td>--impacts of tuna on environment and acceptability of ranching activity</td>
<td>--distraction of national government and donors to other goals and priorities</td>
</tr>
<tr>
<td></td>
<td>--environmental impacts of site use on decisions to conserve</td>
<td>--taxation policies and actual revenue streams</td>
<td></td>
</tr>
<tr>
<td></td>
<td>--effect of site use on population growth and migration</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>--specific sectors of coastal economy either locally or regional</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Key positive (reinforcing) loops</td>
<td>--demand for rehabilitation of existing sites</td>
<td>--profitability and pen deployment</td>
<td>--word of mouth of project success (failure)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>--pen deployment and fishing for tuna, and fishing for feed species (sardines)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Key negative (balancing) loops</td>
<td>--core model structure is balancing among stocks of sites in different forms of use</td>
<td>--tuna fishing on tuna stock</td>
<td>--local effort and donor $ on national spending</td>
</tr>
<tr>
<td></td>
<td></td>
<td>--feed fishing (sardines) on sardine stock</td>
<td>--local success and future donor interest</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy resistance</td>
<td>--pressure to develop against pressure to conserve sites</td>
<td>--pressure to sell based on accumulating cost per tuna versus market price</td>
<td>--national spending to sustain local effort when donor spending is high, local commitment is high</td>
</tr>
<tr>
<td></td>
<td>-decision to initiate regulatory program, plan; enforcement effort</td>
<td></td>
<td>--donor fatigue</td>
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<td></td>
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</tr>
</tbody>
</table>
Exogenous variables

One of the advantages of simpler models is that the number of policy leverage points turns out to be rather few and the effect of adjustments can be seen rather easily. The models in all three chapters have reached, if not shot past to some degree, the limit of where parameters start to dominate the model setup, making the book-keeping of running scenarios unwieldy and unattractive to clients and colleagues who otherwise want to engage in the quest for insight. The policy tests represent shocks to the systems to some degree, but for the most part the aim was to find policies that can prevent resource degradation or practices that can improve the quality of management.

Excluded variables

When models are robust as guides to understanding, as these all were during their preparation, it is hard not to leap ahead and think that bringing into the model some major global factor would be beneficial. For the author, keeping eyes away and hands off from the global bluefin tuna situation, which includes the market place, fisheries, ranching and consumer demand was frustrating but necessary in order to contain the study to within the remaining lifespan of the researcher. However, no matter how obvious the links are, the question has to be answered: will incorporating this additional structure actually make any differences for the purposes of the modeling exercise? Perhaps unfortunately, the researcher has been, more often than not, responding with an enthusiastic ‘you don’t know until you try’.
Key positive (reinforcing) loops and negative (balancing) loops

Ecosystem-based management emphasizes stability in terms of desired levels of stocks of nature, and ability to respond to shocks, that is, remain in or close to equilibrium. Miller and Page (2008) make a helpful observation about model structure pointing out that models which are mainly all balancing loops tend to overemphasize stability as a characteristic rather than emergence. The balancing act incorporated in Chapter 2 does not have this, as positive loops are included, sites are irreversibly depleted and the amount of human re-engineering of the build coast has no apparent limit. The tuna ranching model runs the risk of being only a supply or value chain representation and ignore feedback altogether, since key loops and stocks are exogenous or excluded. The local success model has the opposite problem, it was only comprised of positive loops in its original formulation, and the learning for me was to incorporate some of the tacit balancing loops.

Policy resistance

In working with the groups to prepare the concept maps that led to the simulations in this study, it is interesting to see how many kinds or forms of opposition or policy resistance are identified, usually in the “Fears” portion of a hopes and fears exercise. It is equally interesting to see how hard it is for groups to incorporate policy resistance as part of the structure, perhaps because resistance is a painful subject so remains tacit, and also that it can be subtle and systematic. Part of policy agenda setting is to ratchet up the pressure for change to such an extent that it overcomes, or out-competes opposing forces,
but these appear in pulses because the intensity of the effort required and the nature of the
cycle of attention in a garbage can model world. Overcoming policy resistance by
whatever means is the mission of a change oriented policy reformer. The modeling
exercises should, and do, give one pause. Is the leader or analyst simply trying to find
ways to promote a pet policy, or is there a genuine search for higher leverage, lower cost
strategies?

To the extent that coastal and marine management is a project, the rework cycle is
relevant. It may appear to be the same as policy resistance but its nature is mundane.
Errors, overt or hidden, are introduced partly because enough information is never
available or preferences remain hidden until late in a process, which means the process
was handled so badly, unexpected resistance is encountered, once it is woken, and the
earlier policy options won't meet the new requirements.

Policy resistance sometimes appears more clearly in hindsight, after decisions are
made and attempts begin to implement. It could turn out that by the time a program is
taking shape, the original shape of the issue has changed, so that the choices prove to be
wrong. Or execution is poor, angering the constituency, or the system that is put into
action, like the earliest version of the Rhode Island coastal program, gave too much
leeway to appointed decision makers, increasing the uncertainty for project developers
and increasing pressure against a strong program.
5.3 Conclusions from the three modeling exercises

Each of the models presented in this study has features or emphasizes a facet of coastal management that the others lack. Utilizing these advantages and remedying the deficiencies will be part of the author’s future agenda of model analysis, improvement and practical application.

Coastal management: the Rhode Island case

The model of the coastal management balancing act calibrated to the Rhode Island case in its current form addresses a few simple points such as the effect of decisions to allocate the coastal zone to different uses on precluding future possible uses for conservation or development. The model shows that coastal programs will continue to need to handle a high volume of decisions as issues shift from guiding development to urbanization of the coast and the need to upgrade, relocate and redevelop shore areas. The model does not shed much light on the specific environmental impacts or benefits of overall plans or individual management decisions, but provides numerous entry points for elaboration and testing of these issues. The model can be used as a way to orient research in quantifying the past benefits of coastal management policies and implementation, explore the feasibility and nature of adaptive management and ecosystem based policies and approaches. The coastal management model, as applied to Rhode Island has a very simple formulation that generates coastal development as a fraction of existing development. In fact it is regional demand for coastal property and access to shipping channels that drives demand for coastal sites and sets up the dilemma of balancing
demand for port and waterfront related businesses with the pressure for mixed use and housing oriented development and the need to conserve coastal sites and natural features.

Special area management is the technique some U.S. and international programs use that has many facets in common with the community based approach to economic development. It is not likely in the U.S. that a coastal program would take on the responsibility for municipal level economic development, provision of basic services and mitigation of all natural hazards. However, special area plans in Rhode Island do address all of these concerns and several have been motivated by concern, and state interest in the future development of economic sectors, such as wind energy for the Ocean SAMP, port and mixed use development in the MetroBay SAMP, redevelopment of former military property in the Aquidneck Island West Side SAMP, and commercial fishing and recreational boating in the Salt Ponds Region SAMP.

*Fish farming in marine waters*

In the United States, fish farming faces stiff policy resistance from a variety of quarters for impacts ranging from pollution, feed supplies, the ethics of using (wasting) fish protein for raising animals with high cash value to niche markets that won't do anything to solve the global need for fish protein, to adverse impacts on fisheries such as the notorious destruction of the Atlantic bluefin stock in the Mediterranean Sea. Fish farming is not necessarily a good starting point for local coastal resource management in developing country settings, where nutrition, income and family health and well-being
are expected outcomes and the use of marine resources is generally left to the national government.

One primary way to deal with the pace of exploitation and its inevitable tendency to over-exploit resources is to place controls in every stage of the value chain of production, in effect using an understanding of how a business or industry works. In fisheries this could include limits on gear, fishing methods, vessels, trips, timing and catch of species as well as monitoring of fishers and research to better understand stocks. As Dudley (2008) explains from a feedback perspective, the fishing industry is ingenious at finding technical means to subvert the regulatory strategies, through a phenomenon known as “Ludwig's Ratchet”. Presently, regulators are testing strategies long recommended by economists that involve setting outcome targets, issuing individual shares of catch, or setting individual quotas, and allowing fishers to internalize the costs of control through self-regulation of how a fishery is governed, as long as the desired ecological result occurs. There are distributional impacts of any fisheries policy, and this is part of the current controversy, as the most efficient fishers will acquire the majority of quotas or shares and others may have to leave the industry.

The information generated by the scientific assessment of bluefin tuna ranching focused on three main issues related to the sustainability of the maquiladora-style system to add value to the raw material (fish) as though it were a manufacturing operation. The supply of juvenile bluefin tuna is crucial, and needs to be made endogenous to the model, which means that Mexico should negotiate with other countries that exploit the resource,
including Japan. The environmental impacts of fish farming operations need to be kept low, according to the science assessment, including by pursuing a multi-species farming operation but this is not treated directly in the bluefin tuna model. Thirdly, the supply of feed for the tuna, in this case sardine populations, that are at their peak stock size coincidently to the arrival of the juvenile tuna, cannot be taken for granted. While not a constraint in the model runs shown in Chapter 3, any scaling up plans for the industry, have to take food supply or feed alternatives into account. The biggest issue to actually diminish the sustainability and reduce production levels is the dynamics of the market and the cost structures of individual farmers. Several suspended operations during and after the time of the science assessment, with new operating practices not directly tied to the three main issues mentioned above the main focus of proposals for sustainability. The fish farming model was able to test these new ideas, at the level of an insight-oriented model, to show the promise of the innovations.

Mexico has developed plans to dramatically scale up fish farming throughout the Baja peninsula and the Gulf of California. A modeling approach would be highly beneficial in helping to temper these ambitions with the operational realities faced by bluefin tuna ranchers and firms working on related species such as Yellowfin Tuna and multi-trophic farming operations that might combine fish, seaweed and shellfish.

*Local coastal management success in developing countries*

Local coastal management programs in developing country settings share some of the concern for effective economic strategies raised by the Mexican fish farming case,
partly because overexploited local fisheries are a major concern in many coastal locations and mariculture not as rapid growing or successful as desired. Coastal managers are not all equally prepared to deal with some of the social and economic facets required to attain desired economic outcomes. Chapter 4 suggests that the number of parts that have to be coordinated to boost local success is considerable, and the amount of donor and government patience and financial support needed to help local communities difficult to attain. In order to build trust and credibility at the local level, and to demonstrate that coastal plans and projects will produce tangible benefits, projects might need to address specific expressed local needs even if they are not the primary mission of the donor or assistance organization. Strategies that optimize only a few key variables, don’t necessarily produce as much local and national support or local benefits, as approaches that aim at across the board improvements in key leverage points. Although this is an insight-oriented model, not calibrated directly to a case, it raises broader questions about the wisdom of donor and national government strategies that might seek shorter term results ‘spikes’ that can be attributed to a limited intervention but don’t do enough for long enough to overcome resistance.

5.4 If not an oracle, perhaps an auricle?

The Rhode Island Marine Resources Development Plan that is partly an outcome of work presented in Chapter 2 (the research was the lead author) tapped into the need for better quality information and monitoring by making a pitch for design-oriented “listening posts” around the state and the region. A generation ago, the Stratton
Commission called for the establishment of coastal “laboratories” around the country, whose function in part was to translate science for policy makers. The Coastal Resources Center at the University of Rhode Island was established by Dr. John Knauss, one of the Stratton Commission members, just for that purpose, but once in place we realized that the job was much more than translation, it was transformation. “Listening posts” are needed everywhere, and feedback thinking has to be their core activity. This listening-leading-to-modeling can start with a single key informant, a group modeling exercise, content analysis of the work of experts or stakeholder pronouncements and statements in the press, or a thought experiment which extends and explores concept maps and causal loop diagrams generated by others.

Listening augmented with feedback analysis must start early, occur often, and be woven into the way coastal management is organized and carried out. Models simpler than those presented here are capable of producing the kind of dynamic ‘surprises’ that are often attributed to the mysteries of complexity, but have their source in the structure where the problem is located. ‘External’ events that cause further damage to coastal community well-being or ecosystem productivity may seem to come from an unknown direction at an unexpected time in an unprecedented degree of intensity. They may be the result of the choices of unseen actors or the result of the accumulating force of undetected past trends. Being well-braced for the onslaught of external attacks and prepared to adapt quickly to surprising new circumstances is at the heart of the adaptive management strategy. However, gaining a grasp of the unremarkable, small, continuous streams of
change that eventually undermine natural, social economic and human capital might in many cases may be more effective and stave off such seemingly event-driven or ‘tipping point’ connected failures, using a forward looking feedback strategy. As a society we desperately need to become “surprising successful” at anticipating, dodging, turning around or fending off crises as well as the accelerating downward slide of nature-dependent coastal livelihoods and quality of coastal community life. The essence of doing this is an empowered, informed, alert and active citizenry and society that navigates and nudges a sufficient number of actors at the right levels, expanding the endogenous view just enough to make sure that all important players are in the room, prepared to take responsibility at the right moment, which is right now. A modeling approach to problem definition and solution testing has been in plain sight all along, we need simply to pick up the tools, and learn to use them well.
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Appendices

Appendix I  List of codes used in content analysis (see Section 3.7)

Economic model variables unique to Shamshak and Andersen, 2009.

1. --obft farming: cost of feeding ABT
2. --obft farming: harvest schedule
3. --obft farming: variable costs
4. --obft farming: water temperature
5. --obft: cost acquisition BFT
6. --obft: cost harvesting
7. --obft: cost vessel trip
8. --obft: discount rate

Mexico Bluefin Tuna Ranching Model variables, based on Robadue and Del Moral-Simanek, 2007

1. _-NBT farming: cost of NBT
2. _-NBT farming: total annual value of NBT shipped
3. _accumulated added fat to tuna
4. _Accumulated sardines per tonne of tuna
5. _accumulating processed tuna
6. _accumulating tuna in mobile cages
7. _accuracy of feeding effort
8. _Actual Processing Tuna
9. _added fat to tonne of tuna per week
10. _adding fat
11. _available tuna minus tuna in cages
12. _Baja California Sardines Stock
13. _Bluefin Juveniles Migrating to Mexico
14. _Bluefin Juveniles Returning to Western Pacific
15. _BlueFin Season Duration
16. _Bluefin Tuna Juveniles in Mexico
17. _Breakeven price per kg of Mexican bluefin tuna
18. _Capacity Per Pen
19. _Catching Juvenile Tuna
20. _Clear Duration
21. _clearing fat
22. _clearing processed tuna
23. _clearing sardines
24. clearing tuna in mobile cages
25. container shipments of fresh tuna crossing border from Mexico per week
26. Cumulative Processed Gutted Tuna Per Season
27. Cumulative tuna in mobile cages
28. Decision to feed
29. delay in returning to Mexico
30. Delay in Transporting to Pens
31. Desired wholesale price per kg of Mexican Bluefin Tuna
32. difference between market and breakeven price
33. effect of price trend on capacity utilization
34. Efficiency of Conversion of Sardines to Tuna Fat
35. Effort based on remaining seasonal tuna stock
36. Equilibrium juvenile stock
37. Expected Minimum Required Weeks in Pen
38. fishing BC sardines
39. fishing GoC sardines
40. Fishing GoC Sardines per Month
41. Fishing Season
42. Fishing Season Length
43. Fishing Season Start Time
44. Fishing Tuna Effort Delay
45. fishing Western Pacific juvenile stock
46. fraction juvenile bluefin fished on their way to WP
47. fraction of juvenile bluefin fished locally in Western Pacific
48. fraction of juvenile stock migrating
49. fraction of juveniles returning to Mexico
50. Fresh tuna arriving in Tokyo Tsukiji fish market
51. Fresh Tuna departing LAX
52. fresh tuna per trailer container
53. Gulf of California Sardines Stock
54. Increasing Juvenile Bluefin Tuna Stock
55. Industry Objective for Fishing Tuna
56. Initial BC Sardine Stock
57. Initial GoC Sardine Stock
58. Juveniles Returning to Mexico
59. market/desired price difference
60. Migration Back to Pacific Pattern
61. Migration Back to Pacific Season Length
62. Migration season start week
63. Migration to Mexico Pattern
64. Migration to Mexico season Length
65. moving tuna to Fixed Pens
66. _Net Yield Gutted Tuna
67. _normal fraction of migrating juvenile bluefin
68. _Normal Total Sardines for Tuna
69. _Pacific Migration Season Starting Time
70. _Pen Capacity Utilization Factor
71. _Pens Per Ranch
72. _Perceived Adding Fat to Tuna in Pens per week
73. _Perceived Tuna in Mobile Cages
74. _perceived tuna in pens error
75. _Perceiving Tuna To Be Fattened
76. _Planned Fishing Effort Per Week
77. _pressure to process tuna from price
78. _pressure to process tuna from schedule
79. _price trend
80. _putting pens into operation
81. _rate of loss during transit
82. _removing pens from operation
83. _replacement rate of bluefin tuna
84. _replacing BC sardines
85. _replacing GoC sardines
86. _sardines required per tonne of tuna per day
87. _Sardines Required Per Week
88. _Simulated weekly market price
89. _Standard Return on Investment
90. _Tonnes of sardines required for fattening one tonne of tuna per week
91. _Total Pen Capacity
92. _Total Pens
93. _Total Perceived Fattening Tuna in Fixed Pens
94. _Total Perceived Juvenile Tunas in Fixed Pens
95. _tuna migrating out of Mexico
96. _Tuna Out of Mexican Waters to the Eastern Pacific
97. _tuna pens in operation
98. _Tuna Ranch Construction
99. _Tuna Ranches
100. _weight of price difference on processing rate
101. _weight on schedule pressure to process
102. _Western Pacific Juvenile Bluefin Tuna Stock
103. _WP bluefin fished during return

Open coded variables on bluefin tuna ranching
1. bluefin tuna biology: general
2. bluefin tuna biology: spawning
3. bluefin tuna biology: spawning: location
4. bluefin tuna market: price
5. bluefin tuna market: product qualities
6. bluefin tuna market: products
7. bluefin tuna ranching system: BFT mortality
8. bluefin tuna ranching system: capture-based
9. bluefin tuna ranching system: closed
10. bluefin tuna ranching: annual production
11. bluefin tuna ranching: BFT handling
12. bluefin tuna ranching: business
13. bluefin tuna ranching: equipment
14. bluefin tuna ranching: fattening rate
15. bluefin tuna ranching: feed
16. bluefin tuna ranching: feeding rate
17. bluefin tuna ranching: feeding: method
18. bluefin tuna ranching: harvest duration
19. bluefin tuna ranching: harvesting technique
20. bluefin tuna ranching: international management policy
21. bluefin tuna ranching: investment
22. bluefin tuna ranching: Management agency
23. bluefin tuna ranching: management decision
24. bluefin tuna ranching: management policy/regulation
25. bluefin tuna ranching: operations management
26. bluefin tuna ranching: processing at sea
27. bluefin tuna ranching: profit margin
28. bluefin tuna ranching: ranch size
29. bluefin tuna ranching: scenarios
30. bluefin tuna ranching: seabed clearance cages
31. bluefin tuna ranching: sites
32. bluefin tuna ranching: siting distance
33. bluefin tuna ranching: stocking density
34. bluefin tuna ranching: stocking rate
35. bluefin tuna: climate and natural hazard impact
36. bluefin tuna: processing facility
37. bluefin tuna: processing technology
38. bluefin tuna: stakeholders
39. Country
40. economic issue fish ranching
41. economic model fish ranching
42. economic outcome FR fish ranching
43. economic outcome FR: employment
44. economic outcome FR: wages
45. environmental conditions affecting bluefin tuna
46. environmental conditions affecting sardines
47. environmental issue FR fish ranching
48. environmental issue FR: BFT waste
49. environmental issue FR: disease
50. environmental issue FR: exotic species
51. environmental issue FR: killing mammals or birds
52. environmental issue FR: pollution
53. environmental outcome fish ranching
54. environmental policy and regulation
55. fishing BFT
56. fishing BFT: Compliance & enforcement
57. fishing BFT: fish handling
58. fishing BFT: gear
59. fishing BFT: issue
60. fishing BFT: location
61. fishing BFT: Mexico season
62. fishing BFT: policy and regulations
63. fishing BFT: price to ranch
64. fishing BFT: resistance to regulation
65. fishing BFT: towing
66. fishing BFT: vessels
67. fishing port
68. Japan
69. Region
70. Region: California USA
71. sardines biology: spawning
72. sardines: biology
73. sardines: feed quality
74. sardines: fishing
75. sardines: fishing vessels
76. sardines: importing
77. sardines: location
78. sardines: market
79. sardines: price
80. sardines: processing
81. sardines: scenarios
82. seaweed aquaculture
83. Social issue fish ranching
84. Social outcome fish ranching
85. species
86. subnational location
Appendix II  Code Families, Codes and Quotation Count

Code Families

Code Family: BFT farming: ClosedCycle

Codes (1): [bluefin tuna ranching system: closed]

Quotation(s): 37

Code Family: BFT Fish Farming Feeding BFT

Codes (23):

[--obft farming: cost of feeding ABT] [accumulated added fat to tuna]
[Accumulated sardines per tonne of tuna] [accuracy of feeding effort] [added fat to
tonne of tuna per week] [adding fat] [clearing fat] [Decision to feed] [Efficiency of
Conversion of Sardines to Tuna Fat] [Normal Total Sardines for Tuna] [Perceived
Adding Fat to Tuna in Pens per week] [Perceiving Tuna To Be Fattened] [sardines
required per tonne of tuna per day] [Sardines Required Per Week] [Tonnes of sardines
required for fattening one tonne of tuna per week] [bluefin tuna market: product qualities]
[bluefin tuna ranching: fattening rate] [bluefin tuna ranching: feed] [bluefin tuna
ranching: feeding rate] [bluefin tuna ranching: feeding: method] [environmental issue FR:
BFT waste] [sardines: feed quality] [sardines: market]

Quotation(s): 321
Code Family: BFT Fish Farming site operations

Codes (42):

[--obft farming: modeling management decision] [Capacity Per Pen] [clearing tuna in mobile cages] [Delay in Transporting to Pens] [Expected Minimum Required Weeks in Pen] [moving tuna to Fixed Pens] [Pen Capacity Utilization Factor] [Pens Per Ranch] [Perceived Tuna in Mobile Cages] [perceived tuna in pens error] [putting pens into operation] [removing pens from operation] [Total Pen Capacity] [Total Pens] [Total Perceived Fattening Tuna in Fixed Pens] [Total Perceived Juvenile Tunas in Fixed Pens] [tuna pens in operation] [Tuna Ranch Construction] [Tuna Ranches] [bluefin tuna ranching: annual production] [bluefin tuna ranching: BFT handling] [bluefin tuna ranching: equipment] [bluefin tuna ranching: investment] [bluefin tuna ranching: ranch size] [bluefin tuna ranching: seabed clearance cages] [bluefin tuna ranching: sites] [bluefin tuna ranching: siting distance] [bluefin tuna ranching: stocking density] [bluefin tuna ranching: stocking rate] [Country] [environmental issue FR: BFT waste] [environmental issue FR: disease] [environmental issue FR: exotic species] [environmental issue FR: killing mammals or birds] [environmental issue FR: pollution] [environmental monitoring: frequency] [environmental monitoring: general] [environmental monitoring: location] [environmental monitoring: system] [environmental monitoring: variable] [Region] [subnational location]

Quotation(s): 1665
Code Family: Codes_BFT_Context

Codes (91):

[bluefin tuna biology: general] [bluefin tuna biology: spawning] [bluefin tuna biology: spawning: location] [bluefin tuna market: price] [bluefin tuna market: product qualities] [bluefin tuna market: products] [bluefin tuna ranching system: BFT mortality] [bluefin tuna ranching system: capture-based] [bluefin tuna ranching system: capture-based best practice] [bluefin tuna ranching system: closed] [bluefin tuna ranching: annual production] [bluefin tuna ranching: BFT handling] [bluefin tuna ranching: business] [bluefin tuna ranching: equipment] [bluefin tuna ranching: fattening rate] [bluefin tuna ranching: feed] [bluefin tuna ranching: feeding rate] [bluefin tuna ranching: feeding: method] [bluefin tuna ranching: harvest duration] [bluefin tuna ranching: harvesting technique] [bluefin tuna ranching: international management policy] [bluefin tuna ranching: investment] [bluefin tuna ranching: Management agency] [bluefin tuna ranching: management decision] [bluefin tuna ranching: management policy/regulation] [bluefin tuna ranching: operations management] [bluefin tuna ranching: processing at sea] [bluefin tuna ranching: profit margin] [bluefin tuna ranching: public awareness] [bluefin tuna ranching: ranch size] [bluefin tuna ranching: scenarios] [bluefin tuna ranching: seabed clearance cages] [bluefin tuna ranching: sites] [bluefin tuna ranching: siting distance] [bluefin tuna ranching: stocking density] [bluefin tuna ranching: stocking rate] [bluefin tuna: climate and natural hazard impact] [bluefin tuna: processing facility]
Quotation(s): 2185
**Code Family: Codes_BFT_Model**

Codes (101):

[_accumulated added fat to tuna] [_Accumulated sardines per tonne of tuna]

[_accumulating processed tuna] [_accumulating tuna in mobile cages] [_accuracy of feeding effort] [_Actual Processing Tuna] [_added fat to tonne of tuna per week]

[_adding fat] [_available tuna minus tuna in cages] [_Baja California Sardines Stock]


[_Clear Duration] [_clearing fat] [_clearing processed tuna] [_clearing sardines]

[_clearing tuna in mobile cages] [_container shipments of fresh tuna crossing border from Mexico per week] [_Cumulative Processed Gutted Tuna Per Season] [_Cumulative tuna in mobile cages] [_Decision to feed] [_delay in returning to Mexico] [_Delay in Transporting to Pens] [_Desired wholesale price per kg of Mexican Bluefin Tuna]

Western Pacific] [fraction of juvenile stock migrating] [fraction of juveniles returning to Mexico] [Fresh tuna arriving in Tokyo Tsukiji fish market] [Fresh Tuna departing LAX] [fresh tuna per trailer container] [Gulf of California Sardines Stock] [Increasing Juvenile Bluefin Tuna Stock] [Industry Objective for Fishing Tuna] [Initial BC Sardine Stock] [Initial GoC Sardine Stock] [Juveniles Returning to Mexico] [market/desired price difference] [Migration Back to Pacific Pattern] [Migration Back to Pacific Season Length] [Migration season start week] [Migration to Mexico Pattern] [Migration to Mexico season Length] [moving tuna to Fixed Pens] [Net Yield Gutted Tuna] [normal fraction of migrating juvenile bluefin] [Normal Total Sardines for Tuna] [Pacific Migration Season Starting Time] [Pen Capacity Utilization Factor] [Pens Per Ranch] [Perceived Adding Fat to Tuna in Pens per week] [Perceived Tuna in Mobile Cages] [perceived tuna in pens error] [Perceiving Tuna To Be Fattened] [Planned Fishing Effort Per Week] [pressure to process tuna from price] [pressure to process tuna from schedule] [price trend] [putting pens into operation] [rate of loss during transit] [removing pens from operation] [replacement rate of bluefin tuna] [replacing BC sardines] [replacing GoC sardines] [sardines required per tonne of tuna per day] [Sardines Required Per Week] [Simulated weekly market price] [Standard Return on Investment] [Tonnes of sardines required for fattening one tonne of tuna per week] [Total Pen Capacity] [Total Pens] [Total Perceived Fattening Tuna in Fixed Pens] [Total Perceived Juvenile Tunas in Fixed Pens] [tuna migrating out of Mexico] [Tuna Out of Mexican Waters to the Eastern Pacific] [tuna pens in operation]
Code Family: Codes_BFT_Shamshak

Codes (10):  

Quotation(s): 126

Code Family: Economic aspects BFT Fish Farming

Codes (21):

--NBT farming: cost of NBT] --NBT farming: total annual value of NBT shipped]  
Desired wholesale price per kg of Mexican Bluefin Tuna] [--difference between market and breakeven price] [--effect of price trend on capacity utilization] [--pressure to process tuna from price] [--price trend] [--weight of price difference on processing rate] [bluefin
tuna ranching: profit margin] [economic issue fish ranching] [economic model fish ranching] [economic outcome FR fish ranching] [economic outcome FR: employment] [economic outcome FR: wages] [sardines: price]

Quotation(s): 446

**Code Family: Efficiency of Conversion of Sardines to Tuna Fat Code Family**

Codes (6):

[_added fat to tonne of tuna per week] [Efficiency of Conversion of Sardines to Tuna Fat] [Perceived Adding Fat to Tuna in Pens per week] [sardines required per tonne of tuna per day] [Tonnes of sardines required for fattening one tonne of tuna per week] [bluefin tuna ranching: feeding rate]

Quotation(s): 91

**Code Family: Environmental aspects BFT Fish Farming**

Codes (19):

[bluefin tuna ranching system: BFT mortality] [bluefin tuna ranching: seabed clearance cages] [bluefin tuna ranching: siting distance] [bluefin tuna: climate and natural hazard impact] [environmental conditions affecting bluefin tuna] [environmental conditions affecting sardines] [environmental issue FR fish ranching] [environmental issue FR: BFT waste] [environmental issue FR: disease] [environmental issue FR: exotic species] [environmental issue FR: killing mammals or birds] [environmental issue FR:}
pollution] [environmental monitoring: frequency] [environmental monitoring: general] [environmental monitoring: location] [environmental monitoring: system] [environmental monitoring: variable] [environmental outcome fish ranching] [environmental policy and regulation]

Quotation(s): 324

**Code Family: Fishing BFT**

Codes (50):

[--obft: cost vessel trip] [accumulating tuna in mobile cages] [available tuna minus tuna in cages] [Bluefin Juveniles Migrating to Mexico] [Bluefin Juveniles Returning to Western Pacific] [BlueFin Season Duration] [Bluefin Tuna Juveniles in Mexico] [Catching Juvenile Tuna] [Cumulative tuna in mobile cages] [delay in returning to Mexico] [Delay in Transporting to Pens] [Effort based on remaining seasonal tuna stock] [Equilibrium juvenile stock] [Fishing Season] [Fishing Season Length] [Fishing Season Start Time] [Fishing Tuna Effort Delay] [fishing Western Pacific juvenile stock] [fraction juvenile bluefin fished on their way to WP] [fraction of juvenile bluefin fished locally in Western Pacific] [fraction of juvenile stock migrating] [fraction of juveniles returning to Mexico] [Increasing Juvenile Bluefin Tuna Stock] [Industry Objective for Fishing Tuna] [Juveniles Returning to Mexico] [Migration Back to Pacific Pattern] [Migration Back to Pacific Season Length] [Migration season start week] [Migration to Mexico Pattern] [Migration to Mexico
season Length] [_normal fraction of migrating juvenile bluefin] [_Pacific Migration Season Starting Time] [_Planned Fishing Effort Per Week] [_rate of loss during transit] [_replacement rate of bluefin tuna] [_tuna migrating out of Mexico] [_Tuna Out of Mexican Waters to the Eastern Pacific] [_Western Pacific Juvenile Bluefin Tuna Stock] [_WP bluefin fished during return] [fishing BFT] [fishing BFT: fish handling] [fishing BFT: gear] [fishing BFT: issue] [fishing BFT: location] [fishing BFT: Mexico season] [fishing BFT: policy and regulations] [fishing BFT: price to ranch] [fishing BFT: resistance to regulation] [fishing BFT: towing] [fishing BFT: vessels]

Quotation(s): 605

**Code Family: Governance**

Codes (9):

[bluefin tuna ranching system: capture-based best practice] [bluefin tuna ranching: international management policy] [bluefin tuna ranching: Management agency] [bluefin tuna ranching: management policy/regulation] [bluefin tuna ranching: public awareness] [environmental issue FR fish ranching] [fishing BFT: issue] [fishing BFT: policy and regulations] [fishing BFT: resistance to regulation]

Quotation(s): 349
**Code Family: Information**

Codes (14):

[--obft farming: bioeconomic model biology] [--obft farming: modeling management decision] [bluefin tuna ranching system: capture-based best practice] [bluefin tuna ranching: public awareness] [environmental monitoring: frequency] [environmental monitoring: general] [environmental monitoring: location] [environmental monitoring: system] [environmental monitoring: variable] [feedback loop/ model] [research findings] [research method] [research requirement/ question] [research sharing: extension]

Quotation(s): 465

**Code Family: Marketing BFT**

Codes (23):

[_-NBT farming: total annual value of NBT shipped] [_Breakeven price per kg of Mexican bluefin tuna] [_container shipments of fresh tuna crossing border from Mexico per week] [_Desired wholesale price per kg of Mexican Bluefin Tuna] [_difference between market and breakeven price] [_effect of price trend on capacity utilization] [_Fresh tuna arriving in Tokyo Tsukiji fish market] [_Fresh Tuna departing LAX] [_fresh tuna per trailer container] [_market/desired price difference] [_pressure to process tuna]
from price] [price trend] [Simulated weekly market price] [weight of price difference on processing rate] [weight on schedule pressure to process] [bluefin tuna market: price] [bluefin tuna market: product qualities] [bluefin tuna market: products] [bluefin tuna ranching: annual production] [bluefin tuna ranching: business] [bluefin tuna ranching: investment] [bluefin tuna ranching: profit margin] [fishing BFT: price to ranch]

Quotation(s): 434

**Code Family: Processing BFT**

Codes (22):

[--obft farming: harvest schedule] [--obft farming: variable costs] [--obft: cost harvesting] [accumulating processed tuna] [Actual Processing Tuna] [clearing processed tuna] [Cumulative Processed Gutted Tuna Per Season] [difference between market and breakeven price] [Net Yield Gutted Tuna] [pressure to process tuna from price] [pressure to process tuna from schedule] [removing pens from operation] [weight of price difference on processing rate] [weight on schedule pressure to process] [bluefin tuna market: price] [bluefin tuna market: product qualities] [bluefin tuna ranching: BFT handling] [bluefin tuna ranching: harvest duration] [bluefin tuna ranching: harvesting technique] [bluefin tuna ranching: processing at sea] [bluefin tuna: processing facility] [bluefin tuna: processing technology]

Quotation(s): 239
**Code Family: Sardine Fishery**

Codes (26):

- [Accumulated sardines per tonne of tuna]
- [Baja California Sardines Stock]
- [clearing sardines]
- [Efficiency of Conversion of Sardines to Tuna Fat]
- [fishing BC sardines]
- [fishing GoC sardines]
- [Fishing GoC Sardines per Month]
- [Gulf of California Sardines Stock]
- [Initial BC Sardine Stock]
- [Initial GoC Sardine Stock]
- [replacing BC sardines]
- [replacing GoC sardines]
- [sardines required per tonne of tuna per day]
- [Sardines Required Per Week]
- [Tonnes of sardines required for fattening one tonne of tuna per week]
- [sardines biology: spawning]
- [sardines: biology]
- [sardines: feed quality]
- [sardines: fishing]
- [sardines: fishing vessels]
- [sardines: importing]
- [sardines: location]
- [sardines: market]
- [sardines: price]
- [sardines: processing]
- [sardines: scenarios]

Quotation(s): 404

**Code Family: Social aspects BFT Fish Farming**

Codes (2): [Social issue fish ranching] [Social outcome fish ranching]

Quotation(s): 32
Appendix III  Code families and codes network
The following diagram is included to illustrate that code families are a way of organizing the topic of bluefin tuna ranching. A number of codes belong to different families or topics, since concepts overlap. A main purpose of the codes is to provide organized access to the content of the corpus of documents. This is done quickly using the tools provided by Atlas Ti 6.2, and is difficult to portray visually.
Appendix IV  Code network representing the links between variables in the system dynamics model and general context of fish farming

This view of the network of codes shows variables associated with Shamshak’s bio-economic modeling on the left side in the orange box. These are unique concepts not tied to the main part of the bluefin tuna ranching corpus. The middle section is a crude representation of the model causal loop structure using the codes that are variables in the model. On the right is a similarly organized set of topics on tuna ranching and fish farming in general, with lines connecting the general topic to the model variables. Some topics are exogenous to the modeling, and thus are located to the far right of the code network, for example the extensive coverage of environmental factors by Zertuche-Gonzalez et al., is barely mentioned by other authors. Drawing these links makes it easier for Atlas Ti to pull out the quotations tied to the codes. Again, the diagram is merely indicative of the fact that technical knowledge can be coded and combined in ways that represent the structure of the bluefin tuna ranching enterprise as well as its impacts and governance issues.
Appendix V  The Mexico Bluefin Tuna Ranching Model

The following are views of the model panels, showing behavior from the base case and the most extreme scenario, S9, which shows greatly reduced bluefin tuna availability in Mexican waters.

Panel A.  Model overview

Panel B.  Bluefin tuna stock in Mexico

Panel C.  Fishing bluefin tuna in Mexico

Panel D.  Putting bluefin tuna into fixed cages

Panel E.  Feeding bluefin tuna

Panel F.  Processing and shipping tuna

Panel G.  Sardines for feeding bluefin tuna

Panel H.  Price noise for testing market forces
Panel A.  Model overview

Bluefin Tuna Ranching Industry in Mexico Overview

1. Equilibrium juvenile stock
2. Migration to EPO Pressure
3. Bluefin Tuna Juveniles in Mexico
4. Industry Objective for Fishing Tuna
5. Noise Standard Deviation
6. Noise Correlation Time
7. NOISE SEED TUNA
8. Fraction Sardines Fed Per Tonne of Tuna in Fixed Pen per Week
9. Actual Processing Tuna
10. Total Perceived Biomass of Tuna in Fixed Cages
11. Cumulative Processed Gutted Tuna Per Season
12. normal fraction of migrating juvenile bluefin
13. Expected Minimum Required Weeks in Cage
14. Migration to Mexico scenario
15. Bluefin Juveniles Migrating to Mexico
16. Planned Fishing Effective Weeks
17. 68. Cumulative tuna in mobile cage
18. 75. Total Perceived Biomass of Tuna in Fixed Cages
19. 64. Actual Processing Tuna
20. 92. Cumulative Ranched Tuna per Season
21. 31. Fishing for Juvenile Tuna in Mexican Waters
22. 56. tuna cages in operation
23. 76. Efficiency of Conversion of Sardines to Tuna Biomass
24. 92. Cumulative Ranched Tuna per Season
25. 35. Planned Fishing Effective Weeks
26. 43. Industry Objective for Fishing Tuna
27. 50. Cages Per Ranch
28. 9. Equilibrium juvenile stock
29. 52. NOISE SEED TUNA
30. 33. Noise Correlation Time
31. Fishing for Juvenile Tuna in Mexican Waters
32. 45. Capacity Per Cage
33. 51. Noise Standard Deviation
34. 12. normal fraction of migrating juvenile bluefin
35. 42. Industry Objective for Fishing Tuna
36. 65. Expected Minimum Required Weeks in Cage
Panel B. Bluefin tuna stock in Mexico

BLUEFIN TUNA JUVENILES IN MEXICO WATERS

1. Fishing Western Pacific Juvenile Stock

2. Western Pacific Juvenile Bluefin Tuna Stock

3. Bluefin Tuna Juveniles in Mexico

4. Tuna Out of Mexican Waters to the Eastern Pacific Ocean

5. Fraction of juvenile bluefin fished locally in Western Pacific

6. Fraction of juvenile bluefin fished on their way to WP

7. Replacement rate of juvenile tuna

8. Equilibrium juvenile stock

9. Increasing juvenile bluefin stock

10. Increasing juvenile bluefin stock

11. Bluefin juveniles returning to Western Pacific

12. Normal fraction of migrating juvenile bluefin

13. Fraction of juvenile tuna stock

14. Migration to Mexico scenario

15. Bluefin juveniles returning to WP

16. Migration season start week

17. Migration to WP pressure

18. Migration to Mexico season length

19. Tuna migrating out of Mexico to the EPO

20. Tuna leaving Mexico to the EPO

21. Tuna leaving Mexico to the EPO then WP

22. Fraction of juveniles leaving Mexico to the EPO then WP

23. Seasonal pressure to migrate to EPO

24. Weeks after migration to WP

25. Seasonal pressure to migrate to EPO then WP

26. Fraction of juveniles returning to Mexico

27. Fraction of juveniles returning to Mexico from EPO

28. Migration to the Western Pacific Ocean WP Season Starting Week

29. Migration to the Western Pacific Ocean WP Season Ending Week

30. Migration Back to Western Pacific Ocean

Season Length

<FINAL TIME>

<FINAL TIME>

<TIME STEP>
Panel C.  Fishing bluefin tuna in Mexico
Panel D. Putting bluefin tuna into fixed cages
Panel E. Feeding bluefin tuna

FEEDING SARDINES TO FATTEN TUNA

74. Adding fished juvenile tuna to fixed cages

75. Total Perceived Biomass of Tuna in Fixed Cages

76. Efficiency of Conversion of Sardines to Tuna Biomass

78. Sardines Fed to Tuna in Fixed Cages

80. Fraction Sardines Fed Per Tonne of Tuna in Fixed Pen per Week

77. Adding Biomass to Tuna in Pens per Week

79. Accuracy of Feeding Effort

81. Adding Biomass to Tuna

82. Accumulated Added Biomass to Tuna

83. Clearing Added Biomass

<FINAL TIME>
Panel F. Processing and shipping tuna

84. pressure to process tuna from schedule

85. weighted price difference in processing rate

86. weighted price per kg of tuna

87. residual value of fixed assets

88. bulk weight of canned tuna

89. pressure to process tuna from schedule

90. pressure to process tuna from schedule

91. bulk weight of canned tuna

92. net yield of gutted tuna

93. cumulated ranched tuna per season

94. clearing ranched tuna

95. cumulative processed gutted tuna

96. accumulating processed gutted tuna

97. weighted price of canned tuna

98. pressure to process tuna from schedule

99. clearing processed gutted tuna

100. desired wholesale price per kg of Mexican bluefin tuna

101. breakeven price per kg of Mexican bluefin tuna

102. pressure to process tuna from schedule

103. standard return on investment

104. container shipments of fresh tuna crossing border from Mexico per week

105. fresh tuna departing LAX

106. fresh tuna arriving in Tokyo Tsukiji fish market

107. total cage capacity

108. accumulated sardines per tonne of tuna

109. price pink noise

110. cumulative simulated weekly market price

111. noisy standard deviation

112. processing and shipping tuna

113. standard deviation

114. simulated weekly market price

115. weight of price difference on processing rate

116. simulated weekly market price
Panel G. Sardines for feeding bluefin tuna

62. Tuna Added to Fixed Cages to Be Fattened

107. Sardines Required Per Week

110. Baja California Sardines Stock

111. replacing BC sardines

116. Gulf of California Sardines Stock

117. replacing GoC sardines

118. fishing GoC sardines

119. Fishing GoC Sardines per Week

120. Initial GoC Sardine Stock

97. clearing processed tuna

113. fishing BC sardines

114. clearing accumulated sardines for season

115. Accumulated sardines fed to tuna per season

92. Cumulative Ranched Tuna per season

108. Accumulated sardines per tonne of tuna

<80. Fraction Sardines Fed Per Tonne of Tuna in Fixed Pen per Week>

<71. BlueFin Season Duration>

61. Total Perceived Juvenile Tuna to be Fattened

65. Expected Minimum Required Weeks in Cage

<93. clearing

<73. Clear Duration>

<75. Total Perceived Biomass of Tuna in Fixed Pen per Week>

<74. Processing Sardines>

<76. Total Required Sardines per Week>

93. clearing

<95. Cumulative Processed Gutted Tuna per Season>

99. clearing

<FINAL TIME>

<81. Forecasting Sardines>

<82. Clearing Sardines>

<83. Forecasting Clear Duration>

<84. Clear Duration>

<85. Forecasting BlueFin Season Duration>

<86. BlueFin Season Duration>

<87. Forecasting Total Perceived Biomass of Tuna in Fixed Pen per Week>

<88. Total Perceived Biomass of Tuna in Fixed Pen per Week>

<89. Forecasting Total Perceived Juvenile Tuna to be Fattened>

<90. Total Perceived Juvenile Tuna to be Fattened>

<91. Forecasting Processing Sardines>

<92. Processing Sardines>

<94. Forecasting Sardines Required Per Week>

<96. Sardines Required Per Week>

<97. Forecasting Clearing Processed Tuna>

<98. Clearing Processed Tuna>

<99. Forecasting Clear Duration>

<100. Clear Duration>

<101. Forecasting Forecasting BlueFin Season Duration>

<102. Forecasting BlueFin Season Duration>

<103. Forecasting Total Perceived Biomass of Tuna in Fixed Pen per Week>

<104. Total Perceived Biomass of Tuna in Fixed Pen per Week>

<105. Forecasting Total Perceived Juvenile Tuna to be Fattened>

<106. Total Perceived Juvenile Tuna to be Fattened>

<107. Forecasting Sardines Required Per Week>

<108. Sardines Required Per Week>

<109. Forecasting Forecasting Clearing Processed Tuna>

<110. Clearing Processed Tuna>

<111. Forecasting Forecasting Clear Duration>

<112. Clear Duration>

<113. Forecasting Forecasting Forecasting BlueFin Season Duration>

<114. Forecasting BlueFin Season Duration>

<115. Forecasting Total Perceived Biomass of Tuna in Fixed Pen per Week>

<116. Total Perceived Biomass of Tuna in Fixed Pen per Week>

<117. Forecasting Total Perceived Juvenile Tuna to be Fattened>

<118. Total Perceived Juvenile Tuna to be Fattened>

<119. Forecasting Sardines Required Per Week>

<120. Sardines Required Per Week>
Panel H. Price noise for testing market forces

123. Price Pink Noise

53. Noise Correlation Time

122. Change in Pink Noise

51. Noise Standard Deviation

<TIME STEP>

52. NOISE SEED TUNA
Appendix VI The Mexico Bluefin Tuna Ranching Model summary of variables, values and equations

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>DEFINITION</th>
<th>COMMENT</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. fishing Western Pacific juvenile stock</td>
<td>=&quot;5. fraction of juvenile bluefin fished locally in Western Pacific&quot;*&quot;2. Western Pacific Juvenile Bluefin Tuna Stock&quot;</td>
<td></td>
<td>Equation</td>
</tr>
<tr>
<td>2. Western Pacific Juvenile Bluefin Tuna Stock</td>
<td>= INTEG (+&quot;10. Increasing Juvenile Bluefin Tuna Stock&quot;+&quot;11. Bluefin Juveniles Returning to Western Pacific&quot; - &quot;15. Bluefin Juveniles Migrating to Mexico&quot;- &quot;1. fishing Western Pacific juvenile stock&quot; - &quot;8. WP bluefin fished during return&quot;, &quot;9. Equilibrium juvenile stock&quot;)</td>
<td>This is an arbitrary quantity based on the functioning of the model, not biological reality</td>
<td>Equation</td>
</tr>
<tr>
<td>3. Bluefin Tuna Juveniles in Mexico</td>
<td>= INTEG (&quot;15. Bluefin Juveniles Migrating to Mexico&quot;-&quot;21. tuna migrating out of Mexico to the EPO then WPO&quot; + &quot;20. Juveniles Returning to Mexico from EPO&quot; - &quot;31. Fishing for Juvenile Tuna in Mexican Waters&quot;)</td>
<td>Bluefin tuna juveniles are largely transient and are somewhat dispersed in the region.</td>
<td>Equation</td>
</tr>
<tr>
<td>4. Tuna Out of Mexican Waters to the Eastern Pacific Ocean EPO</td>
<td>= INTEG (+&quot;21. tuna migrating out of Mexico to the EPO then WPO&quot; - &quot;11. Bluefin Juveniles Returning to Western Pacific&quot; - &quot;20. Juveniles Returning to Mexico from EPO&quot;)</td>
<td>This would represent the stock of bluefin tuna that has left Mexican waters at the end of the season but is still in the Eastern Pacific Ocean EPO. Some may remain over the winter and return, the rest returns to the Western Pacific Ocean WPO, where they may be fished by other countries</td>
<td>Equation</td>
</tr>
<tr>
<td>7. replacement rate of bluefin tuna</td>
<td>=&quot;8. WP bluefin fished during return&quot;+&quot;1. fishing Western Pacific juvenile stock&quot;+&quot;15. Bluefin Juveniles Migrating to Mexico&quot; - &quot;11. Bluefin Juveniles Returning to Western Pacific&quot;</td>
<td>This is a completely arbitrary function that keeps the tuna stock in equilibrium. If spawning is reduced by overfishing or climatic conditions, then this rate could decline, and can be tested in scenarios</td>
<td>Equation</td>
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<tr>
<td>Equation</td>
<td>Description</td>
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</tr>
<tr>
<td>8. WP bluefin fished during return</td>
<td>&quot;=6. fraction juvenile bluefin fished on their way to WP&quot; * &quot;11. Bluefin Juveniles Returning to Western Pacific&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Increasing Juvenile Bluefin Tuna Stock</td>
<td>Sorry about the IF THEN ELSE</td>
<td></td>
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</tr>
<tr>
<td>11. Bluefin Juveniles Returning to Western Pacific</td>
<td>&quot;=4. Tuna Out of Mexican Waters to the Eastern Pacific Ocean EPO&quot;*&quot;1.&quot;26. fraction of juveniles returning to Mexico&quot;)</td>
<td></td>
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</tr>
<tr>
<td>12. normal fraction of migrating juvenile bluefin</td>
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</tr>
<tr>
<td>13. fraction of juvenile stock migrating</td>
<td>&quot;= &quot;14. Migration to Mexico scenario&quot;*(Time)**&quot;12. normal fraction of migrating juvenile bluefin</td>
<td></td>
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</tr>
<tr>
<td>14. Migration to Mexico scenario</td>
<td>One third of the stock are juveniles that migrate. Note...amount migrating cannot be more than 1-assumed fraction of juvenile stock fished locally. This is not a biological formulation</td>
<td></td>
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</tr>
<tr>
<td>15. Bluefin Juveniles Migrating to Mexico (week)</td>
<td>This function creates a movement of juvenile tuna stock to Mexico.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Migration season start week</td>
<td>The model is not based on a calendar year biological reality, rather starts the season when the Tuna move. Months do not correspond to actual calendar based chronology of events.</td>
<td></td>
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</tr>
<tr>
<td>17. Migration to Mexico Pattern</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. Migration to Mexico season Length</td>
<td></td>
<td></td>
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<tr>
<td>19. delay in returning to Mexico</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>20. Juveniles Returning to Mexico from EPO</td>
<td>Some juveniles leave Mexican waters but remain in the Eastern Pacific Ocean EPO and return the following year</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>21. tuna migrating out of Mexico to the EPO then WPO</strong></td>
<td>$=((&quot;3. Bluefin Tuna Juveniles in Mexico&quot;**&quot;22. fraction of juveniles leaving Mexico to the EPO then WPO&quot;) * &quot;23. Seasonal Pressure to Migrate to EPO&quot; * &quot;27. Migration Back to Pacific Pattern&quot;) * &quot;30. Migration Back to Western Pacific Ocean Season Length&quot;</td>
<td>CURRENT $=((Bluefin Tuna Juveniles in Mexico<em>fraction of juveniles leaving Mexico to the EPO then WPO)/Migration Back to Western Pacific Ocean Season Length) TRY (PULSE TRAIN( BlueFin Season Duration, Clear Duration , 52 , FINAL TIME )<em>Bluefin Tuna Juveniles in Mexico)/Clear Duration==Тuna head north as environmental conditions change. All tuna leave Mexican waters before the end of the season (Migration Pattern) and spend some time in USA, Canadian Waters, the EPO, before returning to the WPO ORIGINAL EQUATION((Bluefin Tuna Juveniles in Mexico</em>fraction of juveniles leaving Mexico to the EPO then WPO)/Migration Back to Western Pacific Ocean Season Length)</em>(1+Time/Migration Back to Western Pacific Ocean Season Length)*Migration Back to Pacific Pattern</td>
<td><strong>Equation</strong></td>
</tr>
<tr>
<td><strong>23. Seasonal Pressure to Migrate to EPO</strong></td>
<td>&quot;23A. Migration to EPO Pressure&quot; * &quot;25. Seasonal pressure to Migrate to EPO scenario&quot;</td>
<td>This equation needs to put pressure so that all bluefin tuna leave Mexican Waters at the end of the season</td>
<td><strong>Equation</strong></td>
</tr>
<tr>
<td><strong>25. Seasonal pressure to Migrate to EPO scenario</strong></td>
<td>= PULSE TRAIN(&quot;28. Migration to the Western Pacific Ocean WPO Season Starting Week&quot; + &quot;24. Weeks after Migration to add Pressure&quot;), &quot;30. Migration Back to Western Pacific Ocean Season Length&quot;</td>
<td>the pressure to return starts 12 weeks after the migration period starts</td>
<td><strong>Equation</strong></td>
</tr>
<tr>
<td><strong>27. Migration Back to Pacific Pattern</strong></td>
<td>=PULSE TRAIN(&quot;28. Migration to the Western Pacific Ocean WPO Season Starting Week&quot;, &quot;30. Migration Back to Western Pacific Ocean Season Length&quot;, 52, FINAL</td>
<td>Test the output of pulse ramp</td>
<td><strong>Equation</strong></td>
</tr>
<tr>
<td>Equation</td>
<td>Description</td>
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</tr>
<tr>
<td>30. Migration Back to Western Pacific Ocean Season Length</td>
<td>test number</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31. Fishing for Juvenile Tuna in Mexican Waters</td>
<td>As formulated initially this equation has too much effort based on remaining stock. Fishing normally continues throughout the period bluefin tuna are in Mexican waters. Fishing is presently banned from October, the end of the season, to January, before the beginning of the next season. This has no actual impact on bluefin tuna ranching as most BFT have already left Mexican waters.</td>
<td></td>
<td></td>
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<tr>
<td>32. Perceived Tuna in Mobile Cages</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>34. available tuna minus tuna in cages</td>
<td>This is the planned fishing effort per week. Dividing by FSL staggers the catching effort. Should test higher effort so that effort does not continue past fishing season length.</td>
<td></td>
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<tr>
<td>37. difference between market and breakeven price</td>
<td></td>
<td></td>
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<tr>
<td>38. price trend</td>
<td>This should be a smoothed average over some period of time</td>
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</tr>
<tr>
<td>42. Cage Capacity Utilization Factor</td>
<td>[ =1+(&quot;38. price trend&quot;**&quot;41. effect of price trend on capacity utilization&quot;) ]</td>
<td>This attempts to produce a long term effect of tuna prices on deployment of cages and could use more structure to test long term price increases or decreases. The base case sets the industry objective for fishing tuna somewhat higher than cage capacity, but the concept of pen capacity is not rigid, the weight placed on the price trend is set low.</td>
<td>Equation</td>
</tr>
<tr>
<td>46. Total Cage Capacity</td>
<td>[ =&quot;45. Capacity Per Cage&quot;**&quot;48. Total Cages&quot; ]</td>
<td>Equation</td>
<td></td>
</tr>
<tr>
<td>47. Tuna Ranches</td>
<td>[ =&quot;49. Tuna Ranch Construction&quot;(Time) ]</td>
<td>This is an incomplete approach to adding ranches since assumes the actual historical growth in Mexico, with no dynamics for keeping ranches idle, which is in fact what appears to have happened over time. In fact &quot;construction&quot; is misleading, as permanent infrastructure is limited. This compensated by deploying just enough pens to take care of the captured tuna</td>
<td>equation</td>
</tr>
<tr>
<td>48. Total Cages</td>
<td>[ =&quot;50. Cages Per Ranch&quot; * &quot;47. Tuna Ranches&quot; ]</td>
<td>Equation</td>
<td></td>
</tr>
<tr>
<td>56. tuna cages in operation</td>
<td>[ = \text{INTEGRAL} (&quot;57. putting cages into operation&quot; - &quot;58. removing cages from operation&quot;, 0) ]</td>
<td>This is removing the cages too quickly.</td>
<td>Equation</td>
</tr>
<tr>
<td>57. putting cages into operation</td>
<td>[ = (&quot;60. moving tuna to Fixed Cages&quot;*(1+&quot;55. perceived tuna in cages error&quot;))/(&quot;45. Capacity Per Cage&quot; * &quot;42. Cage Capacity Utilization Factor&quot;) ]</td>
<td>the number of pens put into operation, based on fish arriving to coast</td>
<td>Equation</td>
</tr>
<tr>
<td>58. removing cages from operation</td>
<td>[ = &quot;59. cages to remove from operation&quot; ]</td>
<td>(PULSE TRAIN(BlueFin Season Duration, Clear Duration, 52, FINAL TIME) * (tuna pens in operation/Clear Duration))</td>
<td>Equation</td>
</tr>
<tr>
<td>Equation</td>
<td>Description</td>
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</tr>
<tr>
<td>59. cages to remove from operation</td>
<td>MAX( &quot;56. tuna cages in operation&quot;-(&quot;64. Actual Processing Tuna&quot;/&quot;45. Capacity Per Cage&quot;), 0 ) this removes cages from operation. without having negative cages. a cage should be removed AFTER the tuna have been processed</td>
<td></td>
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<tr>
<td>60. moving tuna to Fixed Cages</td>
<td>&quot;32. Perceived Tuna in Mobile Cages&quot;/&quot;66. Delay in Transporting to Fixed Cages&quot;</td>
<td></td>
<td></td>
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<tr>
<td>61. Total Perceived Juvenile Tunas in Fixed Cages</td>
<td>= INTEG (&quot;60.moving tuna to Fixed Cages&quot;-&quot;62. Tuna Added to Fixed CagesTo Be Fattened&quot;,0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>62. Tuna Added to Fixed CagesTo Be Fattened</td>
<td>= &quot;61. Total Perceived Juvenile Tunas in Fixed Cages&quot;*(1-&quot;67. perceiving tuna to be fattened error&quot;) This allows for an estimated inaccuracy in the number of tuna in pens, leading to over or under feeding</td>
<td></td>
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<tr>
<td>64. Actual Processing Tuna</td>
<td>=(&quot;75. Total Perceived Biomass of Tuna in Fixed Cages&quot; / &quot;65. Expected Minimum Required Weeks in Cage&quot;) * &quot;89. pressure to process tuna from schedule&quot; * &quot;84. pressure to process tuna from price&quot; Preference is given to the Expected Weekly Processing quantity as long as there are enough tuna and they have been in a pen at least 3 months. This formulation is temporary placeholder pending better decision making structure. The Expected Minimum Required Weeks in Pen is the delay</td>
<td></td>
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</tr>
<tr>
<td>68. Cumulative tuna in mobile cages</td>
<td>= INTEG (&quot;69. accumulating tuna in mobile cages&quot;-&quot;70. clearing tuna in mobile cages&quot;,0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>72. Week to clear mobile cages</td>
<td>=IF THEN ELSE(&quot;32. Perceived Tuna in Mobile Cages&quot;&lt;1, Time , 0 ) This sets the week when mobile cage should be cleared. Sorry its IF THEN ELSE, but the decision is based on the time when the last mobile cage has transferred tuna to the permanent pens, and will vary based on the length of the fishing season, which is now subject both to the availability of BFT and Mexican government regulation</td>
<td></td>
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</tr>
<tr>
<td>74. Adding fished juvenile tuna to fixed pens</td>
<td>=&quot;62. Tuna Added to Fixed CagesTo Be Fattened&quot; This accumulates the newly fished bluefin tuna into fixed pens. The structure of the model should be streamlined, this is a clumsy construction</td>
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<tr>
<td>Equation</td>
<td>Description</td>
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</tbody>
</table>
| 75. Total Perceived Biomass of Tuna in Fixed Cages | \[ \text{INTEG (} + \text{"77. Adding Biomass to Tuna in Pens per week"} + \text{"74. Adding fished juvenile tuna to fixed pens"} \text{ - } \text{"64. Actual Processing Tuna"}, 0) \]  
The term "perceived" is used to accommodate the issue of overfeeding based on inaccurate information about the number and amount of tuna in pens. However, recent literature and practice seems aimed at improving feeding accuracy. |
| 77. Adding Biomass to Tuna in Pens per week | \[ \text{"75. Total Perceived Biomass of Tuna in Fixed Cages"} \times (\text{"76. Efficiency of Conversion of Sardines to Tuna Biomass"} \times \text{"80. Fraction Sardines Fed Per Tonne of Tuna in Fixed Pen per Week"}) \]  
feeding is based on pens in operation times the estimated amount of tuna in each pen. There is a concern that the amount of tuna is not accurately known so that overfeeding might occur. |
| 78. Sardines Fed to Tuna in Fixed Cages | \[ \text{"80. Fraction Sardines Fed Per Tonne of Tuna in Fixed Pen per Week"} \times \text{"75. Total Perceived Biomass of Tuna in Fixed Cages"} \]  
This is the total amount of sardines fed to tuna per week. It is subject to the constraint of availability of sardines. However in practice for BFT ranching in Mexico, this would be reflected in price, thus costs of feed, since it is assumed by experts that substitute sources and feeds are available. |
| 81. adding biomass | \[ \text{"77. Adding Biomass to Tuna in Pens per week"} \]  
This is a check on the efficiency of the ranching process. New scenarios promote using fewer juvenile tuna and carrying out the 'fattening process' longer to increase weight and get a more desirable proportion of fat in the fish. |
| 82. accumulated added biomass to tuna | \[ \text{INTEG (} \text{"81. adding biomass"} - \text{"83. clearing added biomass"}, 0) \]  
This is a check on the efficiency of the ranching process. New scenarios promote using fewer juvenile tuna and carrying out the 'fattening process' longer to increase weight and get a more desirable proportion of fat in the fish. |
| 83. clearing added biomass | \[ \text{(PULSE TRAIN( "71. BlueFin Season Duration", "73. Clear Duration", 52, FINAL TIME ) \times } \text{"82. accumulated added biomass to tuna"} \text{)} / \text{"73. Clear Duration"} \]  
This is a check on the efficiency of the ranching process. New scenarios promote using fewer juvenile tuna and carrying out the 'fattening process' longer to increase weight and get a more desirable proportion of fat in the fish. |
| 84. pressure to process tuna from price | \[ (1+\text{"86. market/desired price difference"}) \times \text{"85. weight of price difference on processing rate"} \]  
This is a check on the efficiency of the ranching process. New scenarios promote using fewer juvenile tuna and carrying out the 'fattening process' longer to increase weight and get a more desirable proportion of fat in the fish. |
<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
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<tbody>
<tr>
<td>86. market/desired price difference</td>
<td>[=\left(\frac{\text{Simulated weekly market price}}{\text{102. Desired wholesale price per kg of Mexican Bluefin Tuna}}\right) - \frac{\text{Breakeven price per kg of Mexican Bluefin Tuna}}{\text{102. Desired wholesale price per kg of Mexican Bluefin Tuna}}]</td>
</tr>
<tr>
<td>87. Simulated weekly market price</td>
<td>[=\frac{\text{102. Desired wholesale price per kg of Mexican Bluefin Tuna}}{\text{123. Price Pink Noise}}]</td>
</tr>
<tr>
<td>88. Normal Total Sardines for Tuna</td>
<td>[=\text{80. Fraction Sardines Fed Per Tonne of Tuna in Fixed Pen per Week}\times\text{65. Expected Minimum Required Weeks in Cage}]</td>
</tr>
<tr>
<td>89. pressure to process tuna from schedule</td>
<td>[=\frac{\text{108. Accumulated sardines per tonne of tuna}}{\text{88. Normal Total Sardines for Tuna}}\times\text{90. weight on schedule pressure to process}]</td>
</tr>
<tr>
<td>92. Cumulative Ranched Tuna per season</td>
<td>[=\text{INTEG}\left(\text{64. Actual Processing Tuna}\times\frac{\text{93. clearing ranched tuna}}{\text{92. Cumulative Ranched Tuna per season}}\right)]</td>
</tr>
<tr>
<td>93. clearing ranched tuna</td>
<td>[=(\text{PULSE TRAIN(\text{71. BlueFin Season Duration},\text{73. Clear Duration},52,FINAL TIME)\times\text{92. Cumulative Ranched Tuna per season})}/\text{73. Clear Duration}]</td>
</tr>
<tr>
<td>95. Cumulative Processed Gutted Tuna Per Season</td>
<td>[=\text{INTEG}\left(\text{96. accumulating processed gutted tuna}\times\frac{\text{97. clearing processed tuna}}{\text{95. Cumulative Processed Gutted Tuna Per Season}}\right)]</td>
</tr>
<tr>
<td>96. accumulating processed gutted tuna</td>
<td>[=\text{64. Actual Processing Tuna}\times\text{94. Net Yield Gutted Tuna}]</td>
</tr>
<tr>
<td>97. clearing processed tuna</td>
<td>[=(\text{PULSE TRAIN(\text{71. BlueFin Season Duration},\text{73. Clear Duration},52,FINAL TIME)\times\text{95. Cumulative Processed Gutted Tuna Per Season})}/\text{73. Clear Duration}]</td>
</tr>
<tr>
<td>98. clearing revenue</td>
<td>[=(\text{PULSE TRAIN(\text{71. BlueFin Season Duration},\text{73. Clear Duration},52,FINAL TIME)\times\text{99. Revenues per year})}/\text{73. Clear Duration}]</td>
</tr>
<tr>
<td>99. Revenues per year</td>
<td>[=\text{INTEG}\left(\text{96. accumulating processed gutted tuna}\times\text{87. Simulated weekly market price}\times10000\times\text{98. clearing revenue}\right)]</td>
</tr>
<tr>
<td>100. difference between market and breakeven price2</td>
<td>[=\text{87. Simulated weekly market price} - \text{101. Breakeven price per kg of Mexican bluefin tuna}]</td>
</tr>
<tr>
<td>Equation</td>
<td>Description</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>102. Desired wholesale price per kg of Mexican Bluefin Tuna</td>
<td>=&quot;101. Breakeven price per kg of Mexican bluefin tuna&quot;*(1+&quot;103. Standard Return on Investment&quot;) This should be labeled REQUIRED wholesale price. It has no profit, just the discount rate.</td>
</tr>
<tr>
<td>104. container shipments of fresh tuna crossing border from Mexico per week</td>
<td>=&quot;96. accumulating processed gutted tuna&quot;/&quot;91. fresh tuna per trailer container&quot;</td>
</tr>
<tr>
<td>105. Fresh Tuna departing LAX</td>
<td>=&quot;104. container shipments of fresh tuna crossing border from Mexico per week&quot;**&quot;91. fresh tuna per trailer container&quot;</td>
</tr>
<tr>
<td>106. Fresh tuna arriving in Tokyo Tsukiji fish market</td>
<td>=&quot;105. Fresh Tuna departing LAX&quot;</td>
</tr>
<tr>
<td>107. Sardines Required Per Week</td>
<td>=&quot;75. Total Perceived Biomass of Tuna in Fixed Cages&quot;**&quot;80. Fraction Sardines Fed Per Tonne of Tuna in Fixed Pen per Week&quot; This may have an error based on the fact the model might be starving tuna at the last part of the season. Tuna kept must be fed</td>
</tr>
<tr>
<td>108. Accumulated sardines per tonne of tuna</td>
<td>= INTEG (&quot;107. Sardines Required Per Week&quot; / (1+&quot;92. Cumulative Ranched Tuna per season&quot;))**&quot;109. clearing sardines&quot; (PULSE TRAIN( BlueFin Season Duration, Clear Duration, 52, FINAL TIME)**Cumulative Processed Gutted Tuna Per Season)/Clear Duration</td>
</tr>
<tr>
<td>109. clearing sardines</td>
<td>= (PULSE TRAIN(&quot;71. BlueFin Season Duration&quot;,&quot;73. Clear Duration&quot;, 52, FINAL TIME ) *&quot;108. Accumulated sardines per tonne of tuna&quot;)/&quot;73. Clear Duration&quot;</td>
</tr>
<tr>
<td>110. Baja California Sardines Stock</td>
<td>= INTEG (&quot;111. replacing BC sardines&quot; - &quot;113. fishing BC sardines&quot;, &quot;112. Initial BC Sardine Stock&quot;)</td>
</tr>
<tr>
<td>111. replacing BC sardines</td>
<td>= &quot;113. fishing BC sardines&quot;</td>
</tr>
<tr>
<td>113. fishing BC sardines</td>
<td>=&quot;107. Sardines Required Per Week&quot; This has no biological features, sardines remain in equilibrium. This could be changed to show either a constraint based on sardine scarcity, and a resulting increase in feed costs as substitutes are sought including imported feed, which would change the profitability</td>
</tr>
<tr>
<td>Equation</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>114. clearing accumulated sardines for season</td>
<td>=(PULSE TRAIN(&quot;71. BlueFin Season Duration&quot;, &quot;73. Clear Duration&quot;, 52, FINAL TIME) * &quot;115. Accumulated sardines fed to tuna per season&quot;)/&quot;73. Clear Duration&quot;</td>
</tr>
<tr>
<td>115. Accumulated sardines fed to tuna per season</td>
<td>= INTEG( +&quot;113. fishing BC sardines&quot; - &quot;114. clearing accumulated sardines for season&quot;,0)</td>
</tr>
<tr>
<td>116. Gulf of California Sardines Stock</td>
<td>= INTEG(&quot;117. replacing GoC sardines&quot;,&quot;118. fishing GoC sardines&quot;,&quot;120. Initial GoC Sardine Stock&quot;)</td>
</tr>
<tr>
<td>117. replacing GoC sardines</td>
<td>=&quot;118. fishing GoC sardines&quot;</td>
</tr>
<tr>
<td>118. fishing GoC sardines</td>
<td>= &quot;119. Fishing GoC Sardines per Week&quot;</td>
</tr>
<tr>
<td>121. White Noise</td>
<td>=&quot;51. Noise Standard Deviation&quot;<em>((24</em>&quot;53. Noise Correlation Time&quot;/TIME STEP)^0.5*RANDOM NORMAL (-1, 1, 0, 1, &quot;52. NOISE SEED TUNA&quot;) -0.5)</td>
</tr>
<tr>
<td>123. Price Pink Noise</td>
<td>=INTEG(&quot;122. Change in Pink Noise&quot;,0)</td>
</tr>
<tr>
<td>36. Fishing Tuna Effort Delay</td>
<td>=1</td>
</tr>
<tr>
<td>73. Clear Duration</td>
<td>=TIME STEP</td>
</tr>
<tr>
<td>91. fresh tuna per trailer container</td>
<td>=10</td>
</tr>
</tbody>
</table>

White noise input to the pink noise process.

Change in the pink noise value; Pink noise is a first order exponential smoothing delay of the white noise input.

Pink Noise is first-order autocorrelated noise. Pink noise provides a realistic noise input to models in which the next random shock depends in part on the previous shocks. The user can specify the correlation time. The mean is 0 and the standard deviation is specified by the user.

This introduces a smoothing and slight delay to the fishing effort.

a 20 foot container holds 10000 kg of fish.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>14. Migration to Mexico scenario</td>
<td>([0,0],(260,1),[520,0.1])</td>
<td>this allows for testing scenarios based on recent data on Northern Bluefin Tuna stock and fishing</td>
<td>Lookup</td>
</tr>
<tr>
<td>33. Effort Based on Remaining BFT Stock</td>
<td>= WITH LOOKUP (&quot;34. available tuna minus tuna in cages&quot;/(1+&quot;35. Planned Fishing Effort Per Week&quot;)) ([0,0],(0,0.1), (0.5,0.1), (0.8,0.4), (1.05), (1.5,0.7), (2,0.9), (5,1), (10,1))</td>
<td>This takes into account the remaining bluefin tuna stock in Mexico to slow then end tuna fishing and prevent &quot;negative&quot; tuna</td>
<td>Lookup</td>
</tr>
<tr>
<td>49. Tuna Ranch Construction</td>
<td>&quot;([0,0],(520,10)), (0,3), (1,3), (48,3), (52,5), (152,5), (156,7), (204,7), (208,9), (260,9), (520,9), (520,9))</td>
<td></td>
<td>Lookup</td>
</tr>
<tr>
<td>FINAL TIME</td>
<td>522</td>
<td>The final time for the simulation.</td>
<td>Model setting</td>
</tr>
<tr>
<td>INITIAL TIME</td>
<td>= 0</td>
<td>The initial time for the simulation</td>
<td>Model setting</td>
</tr>
<tr>
<td>SAVEPER</td>
<td>= 1 week</td>
<td>The frequency with which output is stored.</td>
<td>Model setting</td>
</tr>
<tr>
<td>TIME STEP</td>
<td>= 0.125</td>
<td>The time step for the simulation... Don't change to experiment with price noise, clearing tuna doesn't show up in the graphs</td>
<td>Model setting</td>
</tr>
<tr>
<td>5. fraction of juvenile bluefin fished locally in Western Pacific</td>
<td>=0.3</td>
<td>This is an arbitrary figure not based on actual practice. If this increases, the supply of tuna Mexico declines</td>
<td>Parameter</td>
</tr>
<tr>
<td>6. fraction juvenile bluefin fished on their way to WP</td>
<td>=0.1</td>
<td>This is an arbitrary value representing a known activity</td>
<td>Parameter</td>
</tr>
<tr>
<td>12. normal fraction of migrating juvenile bluefin</td>
<td>=0.33</td>
<td>This is an arbitrary specification. This can be reduced to represent a scenario of declining year class or increased fishing before the juveniles head to Mexico.</td>
<td>Parameter</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>-------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>16. Migration season start week</td>
<td>=1</td>
<td>This is when juvenile Pacific Bluefin Tuna start arriving in Mexican waters of the Eastern Pacific Ocean EPO</td>
<td></td>
</tr>
<tr>
<td>18. Migration to Mexico season Length</td>
<td>=8</td>
<td>Parameter</td>
<td></td>
</tr>
<tr>
<td>19. delay in returning to Mexico</td>
<td>=24</td>
<td>This represents how long some juveniles remain outside of Mexico but in the Eastern Pacific Ocean before rejoining the stock migrating from the Western Pacific Ocean WPO.</td>
<td></td>
</tr>
<tr>
<td>22. fraction of juveniles leaving Mexico to the EPO then WPO</td>
<td>=1</td>
<td>Nearly all juveniles leave Mexico at the end of season, but head north to US waters, where some are caught by sport fishers, who also fish near the tuna pens as well</td>
<td></td>
</tr>
<tr>
<td>23 A. Migration to EPO Pressure</td>
<td>=8</td>
<td>This value forces tuna to migrate from Mexican Waters to the EPO. A very small residual population remains, which could be eliminated by a higher pressure value, but is realistic. There must be a better way to do this using a lookup graph or something</td>
<td></td>
</tr>
<tr>
<td>26. fraction of juveniles returning to Mexico</td>
<td>=0</td>
<td>It is assumed that some fraction of juvenile tuna leave Mexico but return from waters in the Eastern Pacific Ocean, probably in cooler waters further north. This is an arbitrary fraction to test</td>
<td></td>
</tr>
<tr>
<td>28. Migration to the Western Pacific Ocean WPO Season Starting Week</td>
<td>=20</td>
<td>All bluefin tuna leave Mexican waters before the end of the season. This sets the time when migration begins. Fishing must end by week 29 according to Mexican Law. The model tries to clear bluefin tuna out of Mexican waters by week 44.</td>
<td></td>
</tr>
</tbody>
</table>
### Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>29. Migration to the Western Pacific Ocean WPO Season Ending Week</td>
<td>=44</td>
<td>All bluefin tuna are normally out of Mexican waters by this week. In the model calendar, fishing is banned after week 24. Migration is set to begin by week 28.</td>
</tr>
<tr>
<td>9. Equilibrium juvenile stock</td>
<td>=100000</td>
<td>This is an arbitrarily large quantity of bluefin tuna that creates no constraints on the Mexican Tuna Ranches. It is not based on biological reality.</td>
</tr>
<tr>
<td>24. Weeks after Migration to add Pressure</td>
<td>=9</td>
<td>This variable applies strong pressure for tuna to migrate the specified number of weeks after the Migration Back to Western Pacific Ocean WPO Season Starting Week.</td>
</tr>
<tr>
<td>70. clearing tuna in mobile cages</td>
<td>=(PULSE TRAIN( &quot;72. Week to clear mobile cages&quot;, &quot;73. Clear Duration&quot;), 52, FINAL TIME ) * &quot;68. Cumulative tuna in mobile cages&quot;) / &quot;73. Clear Duration&quot;</td>
<td>This clears the mobile cages based on the tuna towing season duration.</td>
</tr>
<tr>
<td>71. BlueFin Season Duration</td>
<td>=52</td>
<td></td>
</tr>
<tr>
<td>76. Efficiency of Conversion of Sardines to Tuna Biomass</td>
<td>=0.05</td>
<td>The range of biomass from a unit of sardines varies, and is different for wet weight (7 to 20 kg sardines per 1 kg tuna biomass) and dry weight of feeds (1.9 to 5.9 kg feed per 1 kg tuna biomass). 1 kg of sardines can yield 50 g to 142 g of biomass. source: P5 5:1587</td>
</tr>
<tr>
<td>85. weight of price difference on processing rate</td>
<td>=1</td>
<td></td>
</tr>
<tr>
<td>112. Initial BC Sardine Stock</td>
<td>=200000</td>
<td>this is an arbitrary figure. This is an equilibrium number not based on biology. Sardine availability could affect price of feed.</td>
</tr>
</tbody>
</table>
### Fishing GoC Sardines per Week

= 300000/52  
300000 is arbitrary figure, need a structure to match fishing with demand, however GoC stock is not used in tuna ranching. Sardines sold for many purposes, tuna ranches pay more to always have supply, or fish their own

<table>
<thead>
<tr>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>119. Fishing GoC Sardine Stock</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>120. Initial GoC Sardine Stock</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>51. Noise Standard Deviation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>52. NOISE SEED TUNA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>53. Noise Correlation Time</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>40. Fishing Season Start Time</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>41. effect of price trend on capacity utilization</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>43. Industry Objective for Fishing Tuna</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>46. Total Cage Capacity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>42. Cage Capacity Utilization Factor</td>
</tr>
</tbody>
</table>

The Tuna Farmer wants to have every pen filled. The contracts are open ended, each vessel is expected to fish as long as it can. Using conservative assumptions of 40 tonnes/pen x 10 ranches, industry capacity is 4000 tonnes of juveniles per season. The Government of Mexico has generalized current capacity at 5000 tonnes, Umami proposes that their
single facility can handle up to 4800 tonnes, Atkinson suggests that a lower capture of tuna of 2000 tonnes, if feed much longer, can produce 5000 tonnes.

<table>
<thead>
<tr>
<th>44. Fishing Season Length</th>
<th>=24</th>
<th>From P1 del Moral-Simanek 1:311 For 2012-2014, the Government of Mexico has banned (allowing some exception) tuna fishing from October to January, weeks 29 to 41 in the model year</th>
</tr>
</thead>
<tbody>
<tr>
<td>45. Capacity Per Cage</td>
<td>=40</td>
<td>Pen holds 40-80 tonnes or more of Tuna. The scenarios need to test different pen deployments, which in turn is based partly on tuna availability and market price effects on tuna operations. An overall low price will discourage less efficient producers.</td>
</tr>
<tr>
<td>50. Cages Per Ranch</td>
<td>=10</td>
<td></td>
</tr>
<tr>
<td>54. rate of loss during transit</td>
<td>=0.03</td>
<td>1-3% loss of tuna during transfer and transport process according to p5 Zertuche, 5% according to P10 Pedersen Bajamachi</td>
</tr>
<tr>
<td>65. Expected Minimum Required Weeks in Cage</td>
<td>=24</td>
<td>this sets the processing rate based on planned weeks. The pressure variables modify the plan somewhat.</td>
</tr>
<tr>
<td>66. Delay in Transporting to Fixed Cages</td>
<td>= 2</td>
<td>it takes 9+ days on average to move tuna to pens</td>
</tr>
<tr>
<td>67. perceiving tuna to be fattened error</td>
<td>=0</td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>Description</td>
<td>Value</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>79.</td>
<td>accuracy of feeding effort</td>
<td>=1</td>
</tr>
<tr>
<td>80.</td>
<td>Fraction Sardines Fed Per Tonne of Tuna in Fixed Pen per Week</td>
<td>0.56</td>
</tr>
<tr>
<td>90.</td>
<td>weight on schedule pressure to process</td>
<td>=0.75</td>
</tr>
<tr>
<td>101.</td>
<td>Breakeven price per kg of Mexican bluefin tuna</td>
<td>=15</td>
</tr>
<tr>
<td>103.</td>
<td>Standard Return on Investment</td>
<td>=0.1</td>
</tr>
</tbody>
</table>
"3. Bluefin Tuna Juveniles in Mexico" = INTEG ( "15. Bluefin Juveniles Migrating to Mexico" - "21. tuna migrating out of Mexico to the EPO then WPO" + "20. Juveniles Returning to Mexico from EPO" - "31. Fishing for Juvenile Tuna in Mexican Waters", 0 )

~ tonnes [0,?] 

Bluefin tuna juveniles are largely transient and are somewhat dispersed in the region.

~ Dmnl [0,60,0.1] 

This value forces tuna to migrate from Mexican Waters to the EPO. A very small residual population remains, which could be eliminated by a higher pressure value, but is realistic. There must be a better way to do this using a lookup graph or something

~ Dmnl

the pressure to return starts 12 weeks after the migration period starts

"21. tuna migrating out of Mexico to the EPO then WPO" = ("3. Bluefin Tuna Juveniles in Mexico" * "22. fraction of juveniles leaving Mexico to the EPO then WPO" ) * "23. Seasonal Pressure to Migrate to EPO" * "27. Migration Back to Pacific Pattern"

/ "30. Migration Back to Western Pacific Ocean Season Length"

~ tonnes/week
~ CURRENT ((Bluefin Tuna Juveniles in Mexico*fraction of juveniles leaving Mexico to the EPO then WPO)/Migration Back to Western Pacific Ocean Season Length) 

TRY (PULSE TRAIN( BlueFin Season Duration, Clear Duration, 52, FINAL \TIME )*Bluefin Tuna Juveniles in Mexico)/Clear Duration==Tuna head north as environmental conditions change. All tuna leave Mexican waters before the end of the season (Migration Pattern) and spend some time in USA, Canadian Waters, the EPO, before returning to the WPO ORIGINAL EQUATION ((Bluefin Tuna Juveniles in Mexico*fraction of juveniles leaving Mexico to the EPO then WPO)/Migration Back to Western Pacific Ocean Season Length)*(1+Time/Migration Back to Western Pacific Ocean Season Length)*Migration Back to Pacific Pattern

"4. Tuna Out of Mexican Waters to the Eastern Pacific Ocean EPO"= INTEG (+"21. tuna migrating out of Mexico to the EPO then WPO"-"11. Bluefin Juveniles Returning to Western Pacific"-"20. Juveniles Returning to Mexico from EPO",

0) 

~ tonnes 

~ This would represent the stock of bluefin tuna that has left Mexican waters at the end of the season but is still in the Eastern Pacific Ocean EPO. Some may remain over the winter and return, the rest returns to the Western Pacific Ocean WPO, where they may be fished by other countries.

"24. Weeks after Migration to add Pressure"=

9 

~ week [1,20,0.1]

~ This variable applies strong pressure for tuna to migrate the specified number of weeks after the Migration Back to Western Pacific Ocean WPO Season Starting Week.
"23. Seasonal Pressure to Migrate to EPO"=
   "23A. Migration to EPO Pressure"*"25. Seasonal pressure to Migrate to EPO scenario"
   ~ Dmnl
   ~ This equation needs to put pressure so that all bluefin tuna leave Mexican \ 
   Waters at the end of the season
 |

"58. removing cages from operation"=
   "59. cages to remove from operation"
   ~ pens/week
   ~ (PULSE TRAIN( BlueFin Season Duration, Clear Duration , 52 , FINAL TIME \ 
   )* (tuna pens in operation/Clear Duration))
 |

"108. Accumulated sardines per tonne of tuna"= INTEG ( 
   ("107. Sardines Required Per Week"/(1+"92. Cumulative Ranched Tuna per season"))-"109. clearing sardines"
   , 0)
   ~ tonnes*tonne
   ~ (PULSE TRAIN( BlueFin Season Duration, Clear Duration , 52 , FINAL TIME \ 
   )*Cumulative Processed Gutted Tuna Per Season)/Clear Duration
 |

"59. cages to remove from operation"= 
   MAX( "56. tuna cages in operation"-("64. Actual Processing Tuna"/"45. Capacity Per Cage"
   ), 0 )
   ~ pens/week
   ~ this removes cages from operation. without having negative cages. a cage \ 
   should be removed AFTER the tuna have been processed
 |

"31. Fishing for Juvenile Tuna in Mexican Waters"= 
   ("35. Planned Fishing Effort Per Week"*"33. Effort Based on Remaining BFT Stock")/"36. Fishing Tuna Effort Delay"
   ~ tonnes/week
   ~ As formulated initially this equation has too much effort based on \
remaining stock. Fishing normally continues throughout the period
bluefin tuna are in Mexican waters. Fishing is presently banned from October,
the end of the season, to January, before the beginning of the next season. This has no actual impact on bluefin tuna ranching as most BFT have already left Mexican waters!"

"99. Revenues per year" = INTEG ("96. accumulating processed gutted tuna" * "87. Simulated weekly market price" * 1000) - "98. clearing revenue", 0)
~ dollars
~ this is the total revenue from sales of tuna.

"14. Migration to Mexico scenario"( [(0,0)-(520,1)],(0,1),(260,1),(520,1))
~ Dimensionless
~ this allows for testing scenarios based on recent data on Northern Bluefin Tuna stock and fishing!"

"33. Effort Based on Remaining BFT Stock" = WITH LOOKUP ("34. available tuna minus tuna in cages"/(1 + "35. Planned Fishing Effort Per Week"))

~ ([(0,0)-
(10,10)],(0,0),(0.3,0),(0.5,0.1),(0.8,0.4),(1,0.5),(1.5,0.7),(2,0.9),(5,1),
(10,1))
~ Dimensionless
~ This takes into account the remaining bluefin tuna stock in Mexico to slow then end tuna fishing and prevent "negative" tuna."

"100. difference between market and breakeven price2" = "87. Simulated weekly market price" - "101. Breakeven price per kg of Mexican bluefin tuna"
~ dollars
~ This is just a simple tracking of gain or loss in price
"13. fraction of juvenile stock migrating"=
  "14. Migration to Mexico scenario"(Time)*"12. normal fraction of migrating juvenile bluefin"
  ~ Dmnl [0,1,0.001]
  ~ One third of the stock are juveniles that migrate. Note...amount \ migrating cannot be more than 1-assumed fraction of juvenile stock fished \ locally. This is not a biological formulation.

"98. clearing revenue"=
  (PULSE TRAIN( "71. BlueFin Season Duration", "73. Clear Duration" , 52 , FINAL TIME \ )"99. Revenues per year")/"73. Clear Duration"
  ~ dollars
  ~ Cumulative revenues per season

"107. Sardines Required Per Week"=
  "75. Total Perceived Biomass of Tuna in Fixed Cages"*"80. Fraction Sardines Fed Per Tonne of Tuna in Fixed Pen per Week"
  ~ tonnes/week
  ~ This may have an error based on the fact the model might be starving tuna \ at the last part of the season. Tuna kept must be fed

"92. Cumulative Ranched Tuna per season"= INTEG (
  "64. Actual Processing Tuna"-"93. clearing ranched tuna", 0)
  ~ tonnes
  ~

"74. Adding fished juvenile tuna to fixed pens"=
  "62. Tuna Added to Fixed CagesTo Be Fattened"
  ~ tonnes/week
  ~ This accumulates the newly fished bluefin tuna into fixed pens. The \ structure of the model should be streamlined, this is a clumsy construction

"72. Week to clear mobile cages"=
  IF THEN ELSE("32. Perceived Tuna in Mobile Cages"<1, Time , 0 )
week
This sets the week when mobile cage should be cleared. Sorry its IF THEN
ELSE, but the decision is based on the time when the last mobile cage has
transferred tuna to the permanent pens, and will vary based on the
length of the fishing season, which is now subject both to the availability of BFT and Mexican government regulation

"70. clearing tuna in mobile cages" =
(PULSE TRAIN( "72. Week to clear mobile cages", "73. Clear Duration", 52, FINAL TIME
)*"68. Cumulative tuna in mobile cages")/"73. Clear Duration"
~ tonnes/week
~ This clears the mobile cages based on the tuna towing season duration

"75. Total Perceived Biomass of Tuna in Fixed Cages" = INTEG ( 
+"77. Adding Biomass to Tuna in Pens per week"+"74. Adding fished juvenile tuna to fixed pens"
-"64. Actual Processing Tuna", 0)
~ tonnes
~ The term "perceived" is used to accomodate the issue of overfeeding based on inaccurate information about the number and amount of tuna in pens.

However, recent literature and practice seems aimed at improving feeding accuracy

"78. Sardines Fed to Tuna in Fixed Cages" =
"80. Fraction Sardines Fed Per Tonne of Tuna in Fixed Pen per Week"*"75. Total Perceived Biomass of Tuna in Fixed Cages"
~ tonnes
~ This is the total amount of sardines fed to tuna per week. It is subject to the constraint of availability of sardines. However in practice for BFT ranching in Mexico, this would be reflected in price, thus costs of feed, since it is assumed by experts that substitute sources and feeds are available
“77. Adding Biomass to Tuna in Pens per week” =
“75. Total Perceived Biomass of Tuna in Fixed Cages” * (“76. Efficiency of Conversion of Sardines to Tuna Biomass”)

* “80. Fraction Sardines Fed Per Tonne of Tuna in Fixed Pen per Week"

~ tonnes/week

~ feeding is based on pens in operation times the estimated amount of tuna

~ in each pen. There is a concern that the amount of tuna is not accurately known so that overfeeding might occur

“29. Migration to the Western Pacific Ocean WPO Season Ending Week” =
44
~ week [0,52,1]
~ All bluefin tuna are normally out of Mexican waters by this week. In the model calendar, fishing is banned after week 24. Migration is set to begin by week 28.

“93. clearing ranched tuna” =
(PULSE TRAIN( "71. BlueFin Season Duration", "73. Clear Duration", 52 , FINAL TIME 

*"92. Cumulative Ranched Tuna per season")/"73. Clear Duration"

~ tonnes/week

~

“22. fraction of juveniles leaving Mexico to the EPO then WPO” =
1
~ Dimensionless [0,1,0.01]
~ Nearly all juveniles leave Mexico at the end of season, but head north to the US waters, where some are caught by sport fishers, who also fish near the tuna pens as well.

“30. Migration Back to Western Pacific Ocean Season Length” =
“29. Migration to the Western Pacific Ocean WPO Season Ending Week” - “28. Migration to the Western Pacific Ocean WPO Season Starting Week"

~ week [0,52,0.1]
~ test number
"115. Accumulated sardines fed to tuna per season" = INTEG ( 
   +"113. fishing BC sardines"-"114. clearing accumulated sardines for season", 
   0) 
   ~ tonnes 
   ~ 

"114. clearing accumulated sardines for season" = 
   (PULSE TRAIN( "71. BlueFin Season Duration", "73. Clear Duration" , 52 , FINAL 
   TIME \ 
   ) "115. Accumulated sardines fed to tuna per season")/"73. Clear 
   Duration" 
   ~ tonnes/week 
   ~ 

"121. White Noise" = 
   STEP)^0.5*RANDOM NORMAL\ 
   (-1, 1, 0, 1,"52. NOISE SEED TUNA") -0.5 
   ) 
   ~ Dimensionless 
   ~ White noise input to the pink noise process. 
   ~ 

"67. perceiving tuna to be fattened error" = 
   0 
   ~ Dmnl 
   ~ 

"62. Tuna Added to Fixed Cages To Be Fattened" = 
   "61. Total Perceived Juvenile Tunas in Fixed Cages"*(1-"67. perceiving tuna to be 
   fattened error")\ 
   ) 
   ~ tonnes 
   ~ This allows for an estimated inaccuracy in the number of tuna in pens, 
   leading to over or under feeding. 
   ~ 

"52. NOISE SEED TUNA" = 
   0 
   ~ Dmnl [-10,10,0.01] 
   ~ This introduces price variation into the decisions to fish and process. 
   ~ There is a seasonal decision regarding harvest in time to get best price, 
   ~
as well as waiting long enough to increase the fat percentage, in view of accumulating costs. There is also a longer term investment decision if costs exceed return.

"85. weight of price difference on processing rate" =

1

\sim Dmnl [0,6,0.01] 

"43. Industry Objective for Fishing Tuna" =

"46. Total Cage Capacity" \times "42. Cage Capacity Utilization Factor"

\sim tonnes

\sim The Tuna Farmer wants to have every pen filled. The contracts are open ended, each vessel is expected to fish as long as it can. Using conservative assumptions of 40 tonnes/pen \times 10 ranches, industry capacity is 4000 tonnes of juveniles per season. The Government of Mexico has generalized current capacity at 5000 tonnes, Umami proposes that their single facility can handle up to 4800 tonnes, Atkinson suggests that a lower capture of tuna of 2000 tonnes, if feed much longer, can produce 5000 tonnes.

"38. price trend" = INTEG ( 
"37. difference between market and breakeven price"- ("38. price trend"/52),
"37. difference between market and breakeven price")

\sim dollars

\sim This should be a smoothed average over some period of time

"41. effect of price trend on capacity utilization" =

0.1

\sim Dmnl [-1,1,0.01] 

"42. Cage Capacity Utilization Factor" =

1+("38. price trend" \times "41. effect of price trend on capacity utilization")

\sim Dmnl [0,2,0.01]

\sim This attempts to produce a long term effect of tuna prices on deployment of cages and could use more structure to test long term price increases or decreases. The base case sets the industry objective for fishing tuna \backslash

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somewhat higher than cage capacity, but the concept of pen capacity is not rigid, the weight placed on the price trend is set low.

"123. Price Pink Noise" = INTEG("122. Change in Pink Noise",0) ~ Dimensionless ~ Pink Noise is first-order autocorrelated noise. Pink noise provides a realistic noise input to models in which the next random shock depends in part on the previous shocks. The user can specify the correlation time. The mean is 0 and the standard deviation is specified by the user.

"51. Noise Standard Deviation"=

0 ~ Dimensionless [-6,6,0.01] ~ The standard deviation of the pink noise process. This increases the difference between high and low noise values.

"88. Normal Total Sardines for Tuna"=

"80. Fraction Sardines Fed Per Tonne of Tuna in Fixed Pen per Week"*"65. Expected Minimum Required Weeks in Cage" ~ tonnes ~ This is the expected amount of sardines to be fed to a tonne of tuna according to schedule

"102. Desired wholesale price per kg of Mexican Bluefin Tuna"=

"101. Breakeven price per kg of Mexican bluefin tuna"*(1+"103. Standard Return on Investment") ~ dollars ~ This should be labeled REQUIRED wholesale price. It has no profit, just the discount rate.

"86. market/desired price difference"=
"87. Simulated weekly market price"="102. Desired wholesale price per kg of Mexican Bluefin Tuna"/
~ DMNL
~

"64. Actual Processing Tuna"=
("75. Total Perceived Biomass of Tuna in Fixed Cages"/"65. Expected Minimum Required Weeks in Cage"
   )*"89. pressure to process tuna from schedule"
*"84. pressure to process tuna from price"
~ tonnes/week
~ Preference is given to the Expected Weekly Processing quantity as long as there are enough tuna and they have been in a pen at least 3 months.
This formulation is temporary placeholder pending better decision making structure. The /Expected Minimum Required Weeks in Pen is the delay

"53. Noise Correlation Time"=
4
~ week [0,200,0.01]
~ The correlation time constant for Pink Noise.

"89. pressure to process tuna from schedule"=
("108. Accumulated sardines per tonne of tuna"/"88. Normal Total Sardines for Tuna")
   *"90. weight on schedule pressure to process"
~ DMNL
~ as the fraction increases, pressure to process increases so that all tuna are cleared from pens

"10. Increasing Juvenile Bluefin Tuna Stock"=
IF THEN ELSE(("2. Western Pacific Juvenile Bluefin Tuna Stock"<"9. Equilibrium juvenile stock"),"7. replacement rate of bluefin tuna",0)
~ tonnes/week
~

"87. Simulated weekly market price"=
"102. Desired wholesale price per kg of Mexican Bluefin Tuna" + "123. Price Pink Noise"
~ dollars
~ Why add Price Pink Noise to desired price?
|

"103. Standard Return on Investment" = 0.1
~ Dmnl
~ THIS SHOULD BE THE MINIMUM FOR LONG TERM INVESTMENT, no 'economic profit' \ 
is built in, however, short term price should influence the timing of \ selling tuna in the market
|

"84. pressure to process tuna from price" = (1 + "86. market/desired price difference") * "85. weight of price difference on processing rate"
~ Dmnl
~ |

"7. replacement rate of bluefin tuna" = "8. WP bluefin fished during return" + "1. fishing Western Pacific juvenile stock" + "15. Bluefin Juveniles Migrating to Mexico" 
~ "11. Bluefin Juveniles Returning to Western Pacific"
~ tonnes/week [0, 1, 0.001]
~ This is a completely arbitrary function that keeps the tuna stock in \ equilibrium. If spawning is reduced by overfishing or climatic \ conditions, then this rate could decline, and can be tested in scenarios
|

~ Dmnl
~ Change in the pink noise value; Pink noise is a first order exponential smoothing \ delay of the white noise input.
|

"37. difference between market and breakeven price" = INTEG ( 
(("87. Simulated weekly market price" - "101. Breakeven price per kg of Mexican bluefin tuna") / 52) - "37. difference between market and breakeven price"),
"90. weight on schedule pressure to process" =
0.75
~ Dmn [0.01,5,0.01]
~ This puts too much pressure on the schedule. The indicator of pressure to
process needs to be modified
|

"113. fishing BC sardines" =
"107. Sardines Required Per Week"
~ ~ tonnes/week
~ This has no biological features, sardines remain in equilibrium. This could be changed to show either a constraint based on sardine scarcity, and a resulting increase in feed costs as substitutes are sought including imported feed, which would change the profitability
|

"116. Gulf of California Sardines Stock" = INTEG ("117. replacing GoC sardines" - "118. fishing GoC sardines",
"120. Initial GoC Sardine Stock")
~ ~ tonnes
|

"112. Initial BC Sardine Stock" =
200000
~ ~ tonnes
~ this is an arbitrary figure. This is an equilibrium number not based on biology. Sardine availability could affect price of feed.
|

"120. Initial GoC Sardine Stock" =
1e+006
~ ~ tonnes
|

"111. replacing BC sardines" =
"113. fishing BC sardines"
~ ~ tonnes/week
~ |
"110. Baja California Sardines Stock" = INTEG ( 
   "111. replacing BC sardines" - "113. fishing BC sardines",
   "112. Initial BC Sardine Stock")
   ~ tonnes
   ~

"101. Breakeven price per kg of Mexican bluefin tuna" =
   15
   ~ dollars
   ~ THIS SHOULD BE A DYNAMIC NUMBER BASED ON ACTUAL FIXED AND
   VARIABLE COSTS
   ~

"117. replacing GoC sardines" =
   "118. fishing GoC sardines"
   ~ tonnes/week
   ~

"109. clearing sardines" =
   (PULSE TRAIN( "71. BlueFin Season Duration", "73. Clear Duration", 52, FINAL
   TIME \n   )*"108. Accumulated sardines per tonne of tuna")/"73. Clear Duration"
   ~ tonnes/week
   ~

"119. Fishing GoC Sardines per Week" =
   300000/52
   ~ tonnes/week
   ~ 300000 is arbitrary figure, need a structure to match fishing with
demand, \n   however GoC stock is not used in tuna ranching. Sardines sold for many \n   purposes, tuna ranches pay more to always have supply, or fish their own
   ~

"118. fishing GoC sardines" =
   "119. Fishing GoC Sardines per Week"
   ~ tonnes/week
   ~

"82. accumulated added biomass to tuna" = INTEG ( 
   "81. adding biomass" - "83. clearing added biomass",
   0)
   ~ tonnes
This is a check on the efficiency of the ranching process. New scenarios promote using fewer juvenile tuna and carrying out the 'fattening process' longer to increase weight and get a more desirable proportion of fat in the fish.

"96. accumulating processed gutted tuna" = "64. Actual Processing Tuna" * "94. Net Yield Gutted Tuna" 
\[ \text{tonnes/week} \]

"69. accumulating tuna in mobile cages" = "60. Moving Tuna to Fixed Cages" 
\[ \text{tonnes/week} \]

"79. accuracy of feeding effort" = 
\[ 1 \]
\[ \text{Dmnl} [0,1,0.01] \]
this accounts in part for the fact that according to some accounts, some ranchers do not know exactly how many tuna they have placed in pens...

"81. adding biomass" = 
"77. Adding Biomass to Tuna in Pens per week" 
\[ \text{tonnes/week} \]

"34. available tuna minus tuna in cages" = 
\[ \text{MAX( "3. Bluefin Tuna Juveniles in Mexico" - "68. Cumulative tuna in mobile cages", 0) \}
\[ \text{tonnes} \]

"71. BlueFin Season Duration" = 
\[ 52 \]
\[ \text{week} [0,12,0.1] \]

"65. Expected Minimum Required Weeks in Cage" = 
\[ 24 \]
\[ \text{week} [0,104,1] \]
"73. Clear Duration" = 
TIME STEP
~ week [0,12,0.1]
~

"83. clearing added biomass" = 
(PULSE TRAIN("71. BlueFin Season Duration", "73. Clear Duration", 52, FINAL TIME 
)"82. accumulated added biomass to tuna")/"73. Clear Duration"
~ tonnes/week
~

"97. clearing processed tuna" = 
(PULSE TRAIN("71. BlueFin Season Duration", "73. Clear Duration", 52, FINAL TIME 
)"95. Cumulative Processed Gutted Tuna Per Season")/"73. Clear Duration"
~ tonnes
~ (Pacific Bluefin Tuna Juveniles Mexico*Migration Back to Pacific Pattern)/Migration Back to Pacific Season Length
~

"104. container shipments of fresh tuna crossing border from Mexico per week" = 
"96. accumulating processed gutted tuna"/"91. fresh tuna per trailer container"
~ container/week
~

"95. Cumulative Processed Gutted Tuna Per Season" = INTEG ( 
"96. accumulating processed gutted tuna"-"97. clearing processed tuna", 0)
~ tonnes
~

"68. Cumulative tuna in mobile cages" = INTEG ( 
"69. accumulating tuna in mobile cages"-"70. clearing tuna in mobile cages", 0)
~ tonnes
~

"55. perceived tuna in cages error" =
"66. Delay in Transporting to Fixed Cages" =
2
~ ~ week
~ ~ it takes 9+ days on average to move tuna to pens

"76. Efficiency of Conversion of Sardines to Tuna Biomass" =
0.05
~ ~ Dmnl [0,1,0.001]
~ ~ The range of biomass from a unit of sardines varies, and is different for \wet weight (7 to 20 kg sardines per 1 kg tuna biomass) and dry weight of
\feeds ( 1.9 to 5.9 kg feed per 1 kg tuna biomass).  1 kg of sardines can \yield 50 g to 142 g of biomass.  source: P5 5:1587

"91. fresh tuna per trailer container" =
10
~ ~ tonnes/container
~ ~ a 20 foot container holds 10000 kg of fish

"106. Fresh tuna arriving in Tokyo Tsukiji fish market" =
"105. Fresh Tuna departing LAX"
~ ~ tonnes/week
~ ~

"80. Fraction Sardines Fed Per Tonne of Tuna in Fixed Pen per Week" =
0.56
~ ~ Dimensionless
~ ~ fraction of tuna biomass required as feed per day.  The range is 5% to 8%, or if 6 days feeding, 30 to 48% per week, or if 7 days feeding then 35-56% per week

"60. moving tuna to Fixed Cages" =
"32. Perceived Tuna in Mobile Cages" /"66. Delay in Transporting to Fixed Cages"
~ ~ tonnes/week
"61. Total Perceived Juvenile Tunas in Fixed Cages" = \text{INTEG} ( \\
\text{"60. moving tuna to Fixed Cages" - "62. Tuna Added to Fixed Cages To Be Fattened"}, \\
0) \\
\sim \text{tonnes} \\
\sim \text{tonnes} \\
\)

"94. Net Yield Gutted Tuna" = \\
\frac{1}{1.112} \\
\sim \text{Dmnl} \\
\sim \text{This is the ratio for converting processed to round tuna.} \\
\)

"56. tuna cages in operation" = \text{INTEG} ( \\
\text{"57. putting cages into operation" - "58. removing cages from operation"}, \\
0) \\
\sim \text{pens} \\
\sim \text{This is removing the cages too quickly.} \\
\)

"105. Fresh Tuna departing LAX" = \\
\text{"104. container shipments of fresh tuna crossing border from Mexico per week" * "91. fresh tuna per trailer container"} \\
\sim \text{tonnes/week} \\
\sim \text{tonnes/week} \\
\)

"57. putting cages into operation" = \\
\frac{\text{"60. moving tuna to Fixed Cages" * (1 + "55. perceived tuna in cages error")}}{\text{"45. Capacity Per Cage"}} \\
\sim \text{pens/week} \\
\sim \text{the number of pens put into operation, based on fish arriving to coast} \\
\)

"54. rate of loss during transit" = \\
0.03 \\
\sim \text{Dmnl} \\
\sim \text{1-3\% loss of tuna during transfer and transport process according to p5 \} Zertuche, 5\% according to P10 Pedersen Bajamachi} \\
\)

"20. Juveniles Returning to Mexico from EPO" = \\

("26. fraction of juveniles returning to Mexico"*"4. Tuna Out of Mexican Waters to the Eastern Pacific Ocean EPO"\)
/"19. delay in returning to Mexico"
~ tonnes/week
~ Some juveniles leave Mexican waters but remain in the Eastern Pacific \Ocean EPO and return the following year

"45. Capacity Per Cage"=
40
~ tonnes/pen
~ Pen holds 40-80 tonnes or more of Tuna. The scenarios need to test \different pen deployments, which in turn is based partly on tuna \availability and market price effects on tuna operations. An overall low \price will discourage less efficient producers.

"19. delay in returning to Mexico"=
24
~ week [1,1560,1]
~ This represents how long some juveniles remain outside of Mexico but in \the Eastern Pacific Ocean before rejoining the stock migrating from the \Western Pacific Ocean WPO.

"46. Total Cage Capacity"=
"45. Capacity Per Cage"*"48. Total Cages"
~ tonnes
~

"12. normal fraction of migrating juvenile bluefin"=
0.33
~ DmnI [0,1,0.1]
~ This is an arbitrary specification. This can be reduced to represent a \scenario of declining year class or increased fishing before the juveniles \head to Mexico.

"50. Cages Per Ranch"=
10
~ pens/ranch
"39. Fishing Season" =
    PULSE TRAIN("40. Fishing Season Start Time", "44. Fishing Season Length", 52, 
    FINAL TIME\)
    ~ Dmnl
    ~ May to August
|

"44. Fishing Season Length" =
    24
    ~ week
    ~ From P1 del Moral-Simanek 1:311 For 2012-2014, the Government of 
    Mexico has \
    banned (allowing some exception) tuna fishing from October to January, \
    \
    weeks 29 to 41 in the model year
|

"40. Fishing Season Start Time" =
    5
    ~ week
    ~ The consensus of researchers suggest Week 5 (First of May) as starting \
    time for fishing
|

"36. Fishing Tuna Effort Delay" =
    1
    ~ week [0,10,0.001]
    ~ This introduces a smoothing and slight delay to the fishing effort
|

"11. Bluefin Juveniles Returning to Western Pacific" =
    "4. Tuna Out of Mexican Waters to the Eastern Pacific Ocean EPO" * (1-"26. 
    fraction of juveniles returning to Mexico"
    )
    ~ tonnes/week
    ~ This is an arbitrary result not based in biological reality.
|

"48. Total Cages" =
    "50. Cages Per Ranch" * "47. Tuna Ranches"
    ~ pens
    ~

"49. Tuna Ranch Construction"("47. Tuna Ranches"

This is an incomplete approach to adding ranches since assumes the actual historical growth in Mexico, with no dynamics for keeping ranches idle, which is in fact what appears to have happened over time. In fact "construction" is misleading, as permanent infrastructure is limited. This compensated by deploying just enough pens to take care of the captured tuna.

"32. Perceived Tuna in Mobile Cages" = INTEG ("31. Fishing for Juvenile Tuna in Mexican Waters" - "60. moving tuna to Fixed Cages", 0) ~ tonnes

"35. Planned Fishing Effort Per Week" = ("39. Fishing Season" * "43. Industry Objective for Fishing Tuna")/"44. Fishing Season Length"

This is the planned fishing effort per week. Dividing by FSL staggers the catching effort. Should test higher effort so that effort does not continue past fishing season length.

This is an arbitrary quantity based on the functioning of the model, not biological reality.

8. WP bluefin fished during return =
   6. fraction juvenile bluefin fished on their way to WP * 11. Bluefin Juveniles Returning to Western Pacific
   ~ tonnes/week
   ~

9. Equilibrium juvenile stock =
   100000 tonne
   ~
   ~ This is an arbitrarily large quantity of bluefin tuna that creates no constraints on the Mexican Tuna Ranches. It is not based on biological reality.

15. Bluefin Juveniles Migrating to Mexico =
   (2. Western Pacific Juvenile Bluefin Tuna Stock * 13. fraction of juvenile stock migrating / 18. Migration to Mexico season Length) * 17. Migration to Mexico Pattern
   ~ tonnes/week
   ~ This function creates a movement of juvenile tuna stock to Mexico.

5. fraction of juvenile bluefin fished locally in Western Pacific =
   0.3 Dmnl [0,1,0.001]
   ~
   ~ This is an arbitrary figure not based on actual practice. If this increases, the supply of tuna Mexico declines.

1. fishing Western Pacific juvenile stock =
   5. fraction of juvenile bluefin fished locally in Western Pacific * 2. Western Pacific Juvenile Bluefin Tuna Stock
   ~ tonnes/week
   ~

6. fraction juvenile bluefin fished on their way to WP =
   0.1 Dmnl [0,1,0.001]
   ~ This is an arbitrary value representing a known activity.
"26. fraction of juveniles returning to Mexico"=
0
\~ Dmnl [0,1,0.001]
\~ It is assumed that some fraction of juvenile tuna leave Mexico but return
\ from waters in the Eastern Pacific Ocean, probably in cooler waters \ further north. This is an arbitrary fraction to test.

"27. Migration Back to Pacific Pattern"=
PULSE TRAIN("28. Migration to the Western Pacific Ocean WPO Season Starting
Week", "30. Migration Back to Western Pacific Ocean Season Length"
, 52, FINAL TIME )
\~ week [0,1,0.1]
\~ Test the output of pulse ramp\\

"16. Migration season start week"=
1
\~ week
\~ This is when juvenile Pacific Bluefin Tuna start arriving in Mexican \ waters of the Eastern Pacific Ocean EPO

"17. Migration to Mexico Pattern"=
PULSE TRAIN( "16. Migration season start week", "18. Migration to Mexico
season Length"
, 52 , FINAL TIME)
\~ Dmnl
\~ The model is not based on a calendar year biological reality, rather \ starts the season when the Tuna move. Months do not correspond to actual\ 
calendar based chronology of events.

"18. Migration to Mexico season Length"=
8
\~ week [0,52,1]
\~

"28. Migration to the Western Pacific Ocean WPO Season Starting Week"=
20
All bluefin tuna leave Mexican waters before the end of the season. This sets the time when migration begins. Fishing must end by week 29 according to Mexican Law. The model tries to clear bluefin tuna out of Mexican waters by week 44.

Simulation Control Parameters

FINAL TIME = 522
- week [0,4000,1]
- The final time for the simulation.

INITIAL TIME = 0
- week
- The initial time for the simulation.

SAVEPER = 1
- week [0,?]
- The frequency with which output is stored.

TIME STEP = 0.125
- week [0,1,0.001]
- The time step for the simulation... Don't change to experiment with price noise, clearing tuna doesn't show up in the graphs
### Appendix VIII. Simulation Version of Local Coastal Management Success Model

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Panel A  Local Coastal Management Success Model Overview

KEY LEVERAGE POINTS TO IMPROVE PERFORMANCE

4. effect of leadership on team engagement

5. effect of local research on team engagement

18. Minimum time required to complete plan

21a. average duration of action plans

"54. normal duration of awareness"

"13a. weight on national information"

"42. normal time to align behaviors"

"5. effect of local research on team engagement"

"4. effect of leadership on team engagement"

"18. Minimum time required to complete plan"

"21a. average duration of action plans"

18. Minimum time required to complete plan

54. normal duration of awareness

42. normal time to align behaviors

21a. average duration of action plans

4. effect of leadership on team engagement

65w. effectiveness using available resources to align behavior

"54. normal duration of awareness"

"13a. weight on national information"

"42. normal time to align behaviors"

"5. effect of local research on team engagement"

"4. effect of leadership on team engagement"

"18. Minimum time required to complete plan"

"21a. average duration of action plans"
Panel B  Compelling Local Problems, Local Leadership and Local Team Engagement Lead to Action Plans
Panel C Initiating Local Planning Projects

INITIATING AND ENDING LOCAL ACTION PLANS

23. Potential Places with Projects
24. Project Initiation Rate
25. Places with Projects
26. Places Ending Projects, Rate
27. Average Life of an Initiative
28. Initiation from Donor Support
29. Initiation from Donor Support
30. Initiation from Word of Mouth from Other Places
31. Initiation Fraction i
32. Contact Rate
33. Initial Contact Rate
34. Effect of Success on Contact Rate
35. Local Success Inspiring Potential Places

81. Allocation for Project Initiation
66. National Govt Fraction $ for Local
67. Donor Fraction for Local ICM
Panel D Completing Local Action Plans

21. Places with Completed action plans
   - 21a. average duration of action plans
   - 21b. expiring plans
   - 22a. Action plans waiting to be completed
   - 22b. identifying action plans to complete

18. Minimum time required to complete plan
   - 80b. average time required to complete plans

22. completing plans
   - 22a. Action plans waiting to be completed
   - 22b. identifying action plans to complete

24. Project Initiation Rate
   - 28. Initiation from Donor Support
   - 30. Initiation from Word of Mouth from other places

25. Places with projects
26. Places Ending Projects Rate
27. Average Life of an Initiative
28. Initiation from Donor Support
Panel E  Action Plans Lead to Success and Inspire New Projects

SUCCESS INSPIRES LOCALS TO START NEW PROJECTS
Panel F Local Support is Boosted by National Investments and Local Success, but Dampered by a Success Gap
Panel G NGOs Seek To Influence National Policy Because National Awareness is Crucial for Mobilizing Resources
Panel H  The Dynamics of Getting Increased Resources to Local Efforts
Panel I  Overview of local coastal management success model with scenarios
### Appendix IX Variables used for scenarios, outputs of scenario runs

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<th>base</th>
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<tbody>
<tr>
<td>1. degree of engagement by local teams %</td>
<td>0.51</td>
<td>0.57</td>
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<td>81. allocation for project initiation (initial donor contribution)</td>
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<td>0.25</td>
<td>0.25</td>
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### Appendix X  Summary of Simulation model variables, equations and comments

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<tr>
<th>MODEL VARIABLE</th>
<th>EQUATION</th>
<th>COMMENTS</th>
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<tbody>
<tr>
<td>1. degree of engagement by local teams</td>
<td>&quot;2. fraction compelling local problems identified&quot;&quot;4. effect of leadership on team engagement&quot;&quot;3. local leadership &amp; arrangements&quot;&quot;11. local research fraction of reliable knowledge&quot;&quot;5. effect of local research on team engagement&quot;</td>
<td>this generates a fraction based on the proportion of each available. this could be reformulated with weights</td>
</tr>
<tr>
<td>10. initial local fraction for ICM</td>
<td>0.2</td>
<td>the minimum amount of effort a local place is willing to invest in ICM</td>
</tr>
<tr>
<td>11. local research fraction of reliable knowledge</td>
<td>&quot;14. local research&quot;&quot;12. reliable knowledge&quot;</td>
<td>the share local research comprises of knowledge used in plans</td>
</tr>
<tr>
<td>12. reliable knowledge</td>
<td>&quot;14. local research&quot;&quot;13. national information&quot;&quot;15. traditional knowledge&quot;</td>
<td>all three components need to be present to have the highest score. these could be weighted, maximum should be 1</td>
</tr>
<tr>
<td>13. national information</td>
<td>&quot;66. national govt fraction $ for local ICM&quot;&quot;82. Goal for national information&quot;&quot;13a. weight on national information&quot;</td>
<td>usually, only national information is available. it depends on capacity. More commitment to local efforts, more information flow. this needs to be reformulated as it goes below zero</td>
</tr>
<tr>
<td>13a. weight on national information</td>
<td>1</td>
<td>this allows for testing and adjusting national information.</td>
</tr>
<tr>
<td>14. local research</td>
<td>(&quot;65. fraction of required resources available for local ICM&quot;&quot;14a weight on local research&quot;)&quot;83. Goal for local research&quot;</td>
<td>more local research improves reliable knowledge and motivates local teams</td>
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<tr>
<td>14a weight on local research</td>
<td>0.8</td>
<td>this is used to test the formulation of equation 14 and adjust its strength</td>
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<tr>
<td>15. traditional knowledge</td>
<td>&quot;15a. Initial traditional knowledge&quot;&quot;65. fraction of required resources available for local ICM&quot;</td>
<td>this splits remaining information among local and traditional...for now use scenarios to test the benefit of local research</td>
</tr>
<tr>
<td>MODEL VARIABLE</td>
<td>EQUATION</td>
<td>COMMENTS</td>
</tr>
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<tr>
<td>15a. Initial traditional knowledge</td>
<td>0.15</td>
<td>Initially a small fraction of traditional knowledge is applied to preparing action plans</td>
</tr>
<tr>
<td>16. quality of action plans</td>
<td>&quot;12. reliable knowledge&quot;*&quot;2. fraction compelling local problems identified&quot;</td>
<td>reliable knowledge and compelling issues improve plan quality</td>
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<td>17. Total Places N</td>
<td>100</td>
<td>The size of the total population. In this case the number of locations needing action plans and coastal management</td>
</tr>
<tr>
<td>18. Minimum time required to complete plan</td>
<td>2</td>
<td>It takes 2 years effort for a fully functioning team to complete a plan, and ideally one full year of team effort occurs per year for two years</td>
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<tr>
<td>2. fraction compelling local problems identified</td>
<td>&quot;6. table of effect of local process quality on identifying problems&quot;(&quot;7. average local process quality: capacity building, participation, support&quot;)</td>
<td>The higher the fraction of problems identified, the more likely compelling issues will be addressed</td>
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<tr>
<td>21. Places with Completed action plans</td>
<td>INTEG &quot;22. completing plans&quot;-&quot;21b. expiring plans&quot;,0)</td>
<td>This generates plans from projects initiated to create them.</td>
</tr>
<tr>
<td>21a. average duration of action plans</td>
<td>7</td>
<td>An action plan will have an impact on local implementation for about 7 years before it needs to be rewritten</td>
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<tr>
<td>21b. expiring plans</td>
<td>&quot;21. Places with Completed action plans&quot;/&quot;21a. average duration of action plans&quot;</td>
<td>This generates expired plans that have to be rewritten</td>
</tr>
<tr>
<td>22. completing plans</td>
<td>&quot;22a. Action plans waiting to be completed&quot;/(1/&quot;80b. average time required to complete plans&quot;)</td>
<td>This generates completed plans</td>
</tr>
<tr>
<td>22a. Action plans waiting to be completed</td>
<td>INTEG (&quot;22. completing plans&quot;+&quot;21b. expiring plans&quot;+&quot;22b. identifying action plans to complete&quot;,0)</td>
<td>This is the backlog of action plans needed to be completed by initiated projects</td>
</tr>
<tr>
<td>22b. identifying action plans to complete</td>
<td>&quot;24. Project Initiation Rate&quot;-&quot;26. Places Ending Projects, Rate&quot;</td>
<td>First a project has to be initiated, then the project site decides to go ahead with preparing an action plan</td>
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<tr>
<td>MODEL VARIABLE</td>
<td>EQUATION</td>
<td>COMMENTS</td>
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<td>----------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
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<tr>
<td>23. Potential Places with Projects</td>
<td>INTEG (&quot;24. Project Initiation Rate&quot; + &quot;26. Places Ending Projects, Rate&quot;, &quot;17. Total Places N&quot; - &quot;25. Places with projects&quot;)</td>
<td>The initial number of potential adopters is determined by the total population size and the current number of active adopters. It is reduced by adoption and increased when adopters discard their old unit and reenter the market.</td>
</tr>
<tr>
<td>24. Project Initiation Rate</td>
<td>(&quot;28. Initiation from Donor Support&quot; + &quot;30. Initiation from Word of Mouth from other places&quot;)</td>
<td>The rate at which a potential adopter becomes an active adopter. This is driven by advertising (or donor and national) efforts and the word of mouth effect.</td>
</tr>
<tr>
<td>25. Places with projects</td>
<td>&quot;24. Project Initiation Rate&quot; - &quot;26. Places Ending Projects, Rate&quot;, 0</td>
<td>The number of active adopters in the system. Increased by adoption and decreased when adopters discard their unit and reenter the market.</td>
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<tr>
<td>26. Places Ending Projects, Rate</td>
<td>&quot;25. Places with projects&quot; / &quot;27. Average Life of an Initiative&quot;</td>
<td>The discard rate is assumed to be first-order, with an average product life l.</td>
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<tr>
<td>27. Average Life of an Initiative</td>
<td>5</td>
<td>The average life of a donor funded project</td>
</tr>
<tr>
<td>28. Initiation from Donor Support</td>
<td>(&quot;66. national govt fraction $ for local ICM&quot; + &quot;67. donor fraction for local ICM&quot;) * &quot;81. allocation for project initiation&quot;) * &quot;23. Potential Places with Projects&quot; * &quot;29. Initiation effectiveness&quot;</td>
<td>Adoption can result from donor programs or national effort, according to the effectiveness of the effort with the pool of potential adopters.</td>
</tr>
<tr>
<td>29. Initiation effectiveness</td>
<td>0.5</td>
<td>50% of potential projects are assumed to not materialize initially</td>
</tr>
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<td>3. local leadership &amp; arrangements</td>
<td>&quot;8. table of effect of local process quality on leadership&quot; (&quot;7. average local process quality: capacity building, participation, support&quot;)</td>
<td>strong local process leads to leadership and effort to arrange for implementation</td>
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<td>30. Initiation from Word of Mouth from other places</td>
<td>&quot;32. Contact Rate&quot; * &quot;31. Initiation Fraction i&quot; * &quot;23. Potential Places with Projects&quot; * &quot;25. Places with projects&quot; / &quot;17. Total Places N&quot;</td>
<td>Adoption by word of mouth is driven by the contact rate between potential adopters and active adopters and the fraction of times these interactions will result in adoption. The word of mouth effect is small if the number of active adopters relative to the total population size is small.</td>
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<tr>
<td>MODEL VARIABLE</td>
<td>EQUATION</td>
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</tr>
<tr>
<td>31. Initiation Fraction i</td>
<td>0.1</td>
<td>The fraction of times a contact between an active adopter and a potential adopter results in adoption.</td>
</tr>
<tr>
<td>32. Contact Rate</td>
<td>&quot;33. initial contact rate&quot; + (&quot;35. local success inspiring potential places&quot; + &quot;34. effect of success on contact rate&quot;)</td>
<td>The rate at which active adopters come into contact with potential adopters, affected by success story messages</td>
</tr>
<tr>
<td>33. initial contact rate</td>
<td>5</td>
<td>the starting assumption about how frequently local success leads to a contact with a new location</td>
</tr>
<tr>
<td>34. effect of success on contact rate</td>
<td>3</td>
<td>it takes 3 places per year with success to add a 'contacted place'</td>
</tr>
<tr>
<td>35. local success inspiring potential places</td>
<td>&quot;36. Local success: Resource Use Behavior aligned with plan&quot; + &quot;38. behaviors required per action plan&quot;</td>
<td>an indication of how many successful places there are. some fraction of new behaviors per plan = success. this needs detail place by place</td>
</tr>
<tr>
<td>36. Local success: Resource Use Behavior aligned with plan</td>
<td>INTEG (&quot;37. aligning resource use behavior&quot;, 0)</td>
<td>this produces aligned behaviors. since plans are reworked every 7 years on average, that generates more than the theoretical number of behaviors, that is, in the best scenario total behaviors is higher than 46a total potential good behaviors</td>
</tr>
<tr>
<td>MODEL VARIABLE</td>
<td>EQUATION</td>
<td>COMMENTS</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>37. aligning resource use behavior</td>
<td>(((21. Places with Completed action plans)<strong>16. quality of action plans</strong>38. behaviors required per action plan)**41. effort to align behavior)**42. normal time to align behaviors)-(36. Local success: Resource Use Behavior aligned with plan)</td>
<td>This is the 'amount' of planned behavior which actually occurs, for example, hectares set aside and protected, rules to reduce impacts that are enforced, fishing practices. Lower quality means fewer behaviors can become aligned with plan.</td>
</tr>
<tr>
<td>38. behaviors required per action plan</td>
<td>100</td>
<td>Average number of policy elements per initiative</td>
</tr>
<tr>
<td>39. Total desired good behavior</td>
<td>&quot;38. behaviors required per action plan&quot;**&quot;17. Total Places N&quot;</td>
<td>this is the maximum needed behaviors</td>
</tr>
<tr>
<td>4. effect of leadership on team engagement</td>
<td>1.1</td>
<td>more leadership means better teams, could be accomplished through recruitment or training</td>
</tr>
<tr>
<td>40. local coastal resources quality &amp; abundance</td>
<td>(&quot;36. Local success: Resource Use Behavior aligned with plan&quot;,&quot;39. Total desired good behavior&quot;,&quot;44. wt on abundance)</td>
<td>1 = full aligned behavior this is the same as a proportional control, the idea is that locals are more skeptical and judge current abundance against ultimate desires</td>
</tr>
<tr>
<td>41. effort to align behavior</td>
<td>&quot;43. table for effect of leadership on effort(&quot;3. local leadership &amp; arrangements\,&quot;65. fraction of required resources available for local ICM&quot;65w. effectiveness using available resources to align behavior)</td>
<td>this increases or decreases the amount of work put into implementation, i.e. aligning behavior with the plan</td>
</tr>
<tr>
<td>42. normal time to align behaviors</td>
<td>2</td>
<td>it takes this many years to complete an action that generates a good behavior</td>
</tr>
<tr>
<td>44. wt on abundance</td>
<td>1</td>
<td>local prosperity makes it possible to handle more of the burden of coastal management</td>
</tr>
<tr>
<td>45. success gap: ideal - actual</td>
<td>&quot;39. Total desired good behavior&quot;-&quot;36. Local success: Resource Use Behavior aligned with plan&quot;</td>
<td>this is the same as desired production minus actual production</td>
</tr>
<tr>
<td>MODEL VARIABLE</td>
<td>EQUATION</td>
<td>COMMENTS</td>
</tr>
<tr>
<td>----------------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>46. Donor learning from success</td>
<td>&quot;36. Local success: Resource Use Behavior aligned with plan&quot;/&quot;46a. total potential good behaviors&quot;</td>
<td>learning occurs from success and failure, here the idea is that if local success occurs in initial sites, it justifies program expansion and longer term commitment. Success occurs as the fraction increases</td>
</tr>
<tr>
<td>46a. total potential good behaviors</td>
<td>(1+&quot;38. behaviors required per action plan&quot;**21. Places with Completed action plans&quot;)/1</td>
<td>this is the potential number of behaviors that should be changed</td>
</tr>
<tr>
<td>47. NGO Pressure to align national &amp; local policy</td>
<td>&quot;53. normal pressure to align policies&quot;+(&quot;51. table of effect of resource quality on pressure&quot;(&quot;40. local coastal resources quality &amp; abundance&quot;)*&quot;52. table of effect of learning on pressure&quot;(&quot;46. Donor learning from success&quot;))</td>
<td>this should be a pulse from agenda setting due to a gap between actual and desired resource quality, with donor learning adding additional pressure</td>
</tr>
<tr>
<td>48. building national awareness</td>
<td>(&quot;47. NGO Pressure to align national &amp; local policy&quot;*&quot;50. normal local participation in national policy&quot;)-(&quot;49. national awareness of local problems &amp; benefits of action&quot;/&quot;54. normal duration of awareness&quot;)</td>
<td>National awareness can range from 0 (completely unaware) to full awareness (1)</td>
</tr>
<tr>
<td>49. national awareness of local problems &amp; benefits of action</td>
<td>INTEG (&quot;48. building national awareness&quot;,&quot;55. initial national awareness&quot;)</td>
<td>this is a key contribution to generating information, economic support and financial resources for local coastal management</td>
</tr>
<tr>
<td>5. effect of local research on team engagement</td>
<td>1.1</td>
<td>Having local research information which they help gather boosts the engagement of local team</td>
</tr>
<tr>
<td>50. normal local participation in national policy</td>
<td>0.3</td>
<td>Extent to which national entities solicit policy guidance from local level</td>
</tr>
<tr>
<td>53. normal pressure to align policies</td>
<td>0.3</td>
<td>normal pressure to align national and local policies, as part of decentralization, democracy</td>
</tr>
<tr>
<td>54. normal duration of awareness</td>
<td>2</td>
<td>awareness lasts for two years on average (this should be reworked as a pulse)</td>
</tr>
<tr>
<td>55. initial national awareness</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>MODEL VARIABLE</td>
<td>EQUATION</td>
<td>COMMENTS</td>
</tr>
<tr>
<td>----------------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>56. recent success gap</td>
<td><code>SMOOTH(&quot;45. success gap: ideal - actual&quot;, &quot;58. time for recent success gap&quot;)</code></td>
<td>this smooths out the values generated in variable 45 which computes the success gap [note: in operation it appears not to have any effect]</td>
</tr>
<tr>
<td>57. success gap trend</td>
<td><code>(&quot;45. success gap: ideal - actual&quot;.&quot;56. recent success gap&quot;)/&quot;58. time for recent success gap&quot;</code></td>
<td>this is a crucial, sensitive variable that creates a smoothed interpretation of how well things are going at the local level.</td>
</tr>
<tr>
<td>58. time for recent success gap</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>59. wt on success gap trend</td>
<td>0.0001</td>
<td>this is a very sensitive parameter since the success gap trend is so dynamic. It should be changed very slightly in tests, and needs to be interpreted</td>
</tr>
<tr>
<td>60. local motivation to sustain effort based on trend</td>
<td><code>&quot;57. success gap trend&quot;**&quot;59. wt on success gap trend&quot;</code></td>
<td>local people can get discouraged after the initial excitement of a local coastal management project. Donor and national attention is needed to help overcome this. One key factor is national measures to boost local economic activity while the local people are writing and trying to implement the local plan</td>
</tr>
<tr>
<td>61. national economic development benefitting local places</td>
<td>&quot;79. fraction national policy alignment with local ICM&quot;**&quot;62a. wt on NEDBLP&quot;`</td>
<td>policy alignment for local ICM included economic development actions. Up to a point these have a beneficial effect on local commitment.</td>
</tr>
<tr>
<td>62. local commitment to sustain effort</td>
<td>&quot;40. local coastal resources quality &amp; abundance&quot;+&quot;60. local motivation to sustain effort based on trend&quot;+&quot;61. national economic development benefitting local places&quot;</td>
<td>local commitment is in-kind and perhaps less effective than $, this is the fraction of total required, and the hope is that it increases to cover all the costs over time</td>
</tr>
<tr>
<td>62a. wt on NEDBLP</td>
<td>0.3</td>
<td>This could be converted to a lookup graph showing diminishing benefits due to overdependence</td>
</tr>
<tr>
<td>64. local fraction $ for local ICM</td>
<td><code>INTEG(&quot;62. local commitment to sustain effort&quot;.&quot;64. local fraction $ for local ICM&quot;,&quot;10. initial local fraction for ICM&quot;)</code></td>
<td>there is some minimum local effort available for ICM but local commitment is generated through seeing results over time</td>
</tr>
<tr>
<td>MODEL VARIABLE</td>
<td>EQUATION</td>
<td>COMMENTS</td>
</tr>
<tr>
<td>----------------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>65. fraction of required resources available for local ICM</td>
<td>&quot;67. donor fraction for local ICM&quot;+&quot;64. local fraction $ for local ICM&quot;+&quot;66. national govt fraction $ for local ICM&quot;</td>
<td>this is the total fraction of resources available for local ICM</td>
</tr>
<tr>
<td>65w. effectiveness using available resources to align behavior</td>
<td>1</td>
<td>effectiveness, not just effort, is important in carrying out the work to implement a plan (i.e. align behaviors. This is an important George Richardson concept.</td>
</tr>
<tr>
<td>66. national govt fraction $ for local ICM</td>
<td>INTEG (&quot;79. fraction national policy alignment with local ICM&quot;<em>&quot;76. effect of national learning on $ for local&quot;</em>&quot;73. wt of learning on govt $ fraction&quot;)-&quot;66. national govt fraction $ for local ICM&quot;- (&quot;64. local fraction $ for local ICM&quot;<em>&quot;72. wt on local $ fraction&quot;)-&quot;67. donor fraction for local ICM&quot;</em>&quot;74. wt on donor $ fraction&quot;)-&quot;50. normal local participation in national policy&quot;)</td>
<td>the national government substitutes foreign or NGO assistance for its own budgeting</td>
</tr>
<tr>
<td>67. donor fraction for local ICM</td>
<td>(&quot;70. table of effect of local commitment on donor fraction&quot;<em>&quot;62. local commitment to sustain effort&quot;)</em>&quot;70. table of effect of local commitment on donor fraction&quot;(&quot;77. national leadership for local coastal problems&quot;)<em>&quot;68. potential gap in available resources&quot;</em>&quot;69. donor wt on resource gap&quot;)</td>
<td>This should be formulated as a proportion of total need. The donor fraction over time, is likely to be affected by donor fatigue and changing priorities</td>
</tr>
<tr>
<td>68. potential gap in available resources</td>
<td>(1-&quot;79. fraction national policy alignment with local ICM&quot;)/&quot;71. delay in perceiving resource gap&quot;</td>
<td></td>
</tr>
<tr>
<td>69. donor wt on resource gap</td>
<td>0.15</td>
<td>donors will consider filling a gap in resources... more feedback loops are needed to account for donor decision making, including fatigue</td>
</tr>
<tr>
<td>7. average local process quality: capacity building, participation, support</td>
<td>WITH LOOKUP (&quot;10. initial local fraction for ICM&quot;*&quot;9. table of effect of available resources on local process quality&quot;(&quot;65. fraction of required resources available for local ICM&quot;),</td>
<td>the bigger fraction of national resources going to local effort will improve leadership, as will the donor budget</td>
</tr>
<tr>
<td>MODEL VARIABLE</td>
<td>EQUATION</td>
<td>COMMENTS</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>71. delay in perceiving resource gap</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>72. wt on local $ fraction</td>
<td>0</td>
<td>this sets an effect of local decisions on how much effort to put into local projects on how the national level commits to supporting local action</td>
</tr>
<tr>
<td>73. wt of learning on govt $ fraction</td>
<td>2.5</td>
<td>[Note: this is an important variable that needs more testing and explanation]</td>
</tr>
<tr>
<td>74. wt on donor $ fraction</td>
<td>0</td>
<td>this sets an effect of donor activity on national decisions about funding local ICM</td>
</tr>
<tr>
<td>75. national learning from local places</td>
<td>&quot;77. national leadership for local coastal problems&quot;**25. Places with projects&quot;</td>
<td>more leadership insures maximum learning</td>
</tr>
<tr>
<td>76. effect of national learning on $ for local</td>
<td>&quot;75. national learning from local places&quot;/(1+&quot;25. Places with projects&quot;)</td>
<td>the more learning, the higher influence on national spending</td>
</tr>
<tr>
<td>77. national leadership for local coastal problems</td>
<td>&quot;78. table of effect of awareness on national leadership&quot;(&quot;49. national awareness of local problems &amp; benefits of action&quot;)</td>
<td>stronger leadership will increase policy alignment</td>
</tr>
<tr>
<td>79. fraction national policy alignment with local ICM</td>
<td>&quot;77. national leadership for local coastal problems&quot;+&quot;50. normal local participation in national policy&quot;</td>
<td>1 = perfect alignment and support for local plans</td>
</tr>
<tr>
<td>80b. average time required to complete plans</td>
<td>&quot;18. Minimum time required to complete plan&quot;*&quot;1. degree of engagement by local teams&quot;) WITH LOOKUP</td>
<td>Effectiveness of the team will reduce the time to complete the plan somewhat</td>
</tr>
<tr>
<td>81. allocation for project initiation</td>
<td>0.25</td>
<td>the share of national and donor resources going to initiate new projects</td>
</tr>
<tr>
<td>82. Goal for national information</td>
<td>(1-&quot;14. local research&quot;-&quot;15. traditional knowledge&quot;)/1</td>
<td>this sets a dynamic goal for emphasis on national level information</td>
</tr>
<tr>
<td>83. Goal for local research</td>
<td>1-&quot;15. traditional knowledge&quot;</td>
<td>this sets a target for increasing or decreasing effort on local research in support of action plans</td>
</tr>
</tbody>
</table>
normal local problem identification is 0.6, process improvements can increase this to 0.9

there is a minimum amount of local process, external resources can boost this considerably. In fact, projects get started where such enabling conditions are at least average. This is a precondition
normal local leadership is 0.4. Process quality can improve this to 0.8.
as resource quality improves, pressure to align policies drops

leadership is slow to respond to awareness and is distracted by many other issues
If local commitment is low at the outset, but greater than 0, donors will put money in for start up, and up to a point they will increase it, until they decide a place is "graduated." Then they withdraw funds.
"80b. average time required to complete plans" = WITH LOOKUP (  
"18. Minimum time required to complete plan"*"1. degree of engagement by local teams"  
),  
((0,0)-(3,3)),(0,1.25),(0.25,1.1),(0.35,1),(0.4,0.95),(0.5,0.9),(0.6,0.85),(0.7,0.8  
),(0.8,0.75),(1,0.7),(2,0.6),(3,0.6))  
~ Year  
~ Effectiveness of the team will reduce the time to complete the plan \  
somewhat. \|\|\|\|
|  

"22. completing plans"=
"22a. Action plans waiting to be completed"/(1/"80b. average time required to complete plans"
  )  
~ action plans  
~ this generates completed plans
|

"22b. identifying action plans to complete"=
"24. Project Initiation Rate"."26. Places Ending Projects, Rate"  
~ places/Year  
~ first a project has to be initiated, then the project site decides to go \  
ahead with preparing an action plan
|

"22a. Action plans waiting to be completed"= INTEG (  
"22. completing plans"+"21b. expiring plans"+"22b. identifying action plans to complete"
  ,  
0)  
~ action plans  
~ this is the backlog of action plans needed to be completed by initiated \  
projects
|

"21. Places with Completed action plans"= INTEG (  
"22. completing plans"."21b. expiring plans",  
0)  
~ action plans  
~ this generates plans from projects initiated to create them.
|

"21a. average duration of action plans"=
7  
~ Year [0,40,0.1]

369
an action plan will have an impact on local implementation for about 7 years before it needs to be rewritten.

"21b. expiring plans"=
"21. Places with Completed action plans"/"21a. average duration of action plans"
~ action plans/Year
~ this generates expired plans that have to be rewritten

"14. local research"=
("65. fraction of required resources available for local ICM"*"14a weight on local research"*"83. Goal for local research"
~ Dmnl [0,1,0.01]
~ more local research improves reliable knowledge and motivates local teams

"14a weight on local research"=
0.8
~ Dmnl [0,4,0.01]
~ this is used to test the formulation of equation 14 and adjust its strength

"13. national information"=
"66. national govt fraction $ for local ICM"*"82. Goal for national information"*"13a. weight on national information"
~ Dmnl [0,2,0.1]
~ usually, only national information is available. it depends on capacity.
~ More commitment to local efforts, more information flow. this needs to be reformulated as it goes below zero

"13a. weight on national information"=
1
~ Dmnl [0,8,0.1]
~ this allows for testing and adjusting national information.

"83. Goal for local research"=
1-"15. traditional knowledge"
~ Dmnl
~ this sets a target for increasing or decreasing effort on local research in support of action plans

"11. local research fraction of reliable knowledge"=
"14. local research"/"12. reliable knowledge"
~ Dmnl
the share local research comprises of knowledge used in plans

"15a. Initial traditional knowledge" = 0.15
~ Dmnl
~ Initially a small fraction of traditional knowledge is applied to preparing action plans

"15. traditional knowledge" = "15a. Initial traditional knowledge" * "65. fraction of required resources available for local ICM"
~ Dmnl
~ this splits remaining information among local and traditional...for now use scenarios to test the benefit of local research

"82. Goal for national information" = (1 - "14. local research" - "15. traditional knowledge") / 1
~ Dmnl [0, 2, 0.1]
~ this sets a dynamic goal for emphasis on national level information

"65w. effectiveness using available resources to align behavior" = 1
~ Dmnl [0, 2, 0.01]
~ effectiveness, not just effort, is important in carrying out the work to implement a plan (i.e. align behaviors. This is an important George Richardson concept.

"41. effort to align behavior" = "43. table for effect of leadership on effort" ("3. local leadership & arrangements") * "65. fraction of required resources available for local ICM" * "65w. effectiveness using available resources to align behavior"
~ Dmnl
~ this increases or decreases the amount of work put into implementation, i.e. aligning behavior with the plan

"81. allocation for project initiation" = 0.25
~ Dmnl
~ the share of national and donor resources going to initiate new projects

"29. Initiation effectiveness" = 0.5
50% of potential projects are assumed to not materialize initially

"48. building national awareness"=
(("47. NGO Pressure to align national & local policy"*"50. normal local participation in national policy")
 -("49. national awareness of local problems & benefits of action"
="/"54. normal duration of awareness"))

National awareness can range from 0 (completely unaware) to full awareness (1)

"64. local fraction $ for local ICM"= INTEG ("62. local commitment to sustain effort"-"64. local fraction $ for local ICM",
  "10. initial local fraction for ICM")

there is some minimum local effort available for ICM but local commitment is generated through seeing results over time

"61. national economic development benefitting local places"=
"79. fraction national policy alignment with local ICM"**"62a. wt on NEDBLP"

policy alignment for local ICM included economic development actions. Up to a point these have a beneficial effect on local commitment.

"7. average local process quality: capacity building, participation, support"= WITH LOOKUP ("10. initial local fraction for ICM"+"9. table of effect of available resources on local process quality"
("65. fraction of required resources available for local ICM"),
  [[(0,0)-{1,1}],(0,0.1),(0.370031,0.364035),(0.504587,0.504386),(0.752294,0.754386),(1,0.9)])

the bigger fraction of national resources going to local effort will improve leadership, as will the donor budget!

"67. donor fraction for local ICM"=
("70. table of effect of local commitment on donor fraction"("62. local commitment to sustain effort"
 )**"70. table of effect of local commitment on donor fraction"("77. national leadership for local coastal problems"
 ))+"68. potential gap in available resources"**"69. donor wt on resource gap"

372
This should be formulated as a proportion of total need. The donor fraction over time, is likely to be affected by donor fatigue and changing priorities.

"62a. wt on NEDBLP"=
0.3

This could be converted to a lookup graph showing diminishing benefits due to overdependence.

"74. wt on donor $ fraction"=
0

This sets an effect of donor activity on national decisions about funding local ICM.

"37. aligning resource use behavior"=
((("21. Places with Completed action plans"*"16. quality of action plans"*"38. behaviors required per action plan"*
"41. effort to align behavior")/"42. normal time to align behaviors")-"36. Local success: Resource Use Behavior aligned with plan")

This is the 'amount' of planned behavior which actually occurs, for example, hectares set aside and protected, rules to reduce impacts that are enforced, fishing practices. Lower quality means fewer behaviors can become aligned with plan.

"66. national govt fraction $ for local ICM"= INTEG (
"79. fraction national policy alignment with local ICM"*"76. effect of national learning on $ for local"
"73. wt of learning on govt $ fraction")-"66. national govt fraction $ for local ICM"-"64. local fraction $ for local ICM"*"72. wt on local $ fraction")-"67. donor fraction for local ICM"
"74. wt on donor $ fraction")-"50. normal local participation in national policy")

The national government substitutes foreign or NGO assistance for its own budgeting.

"69. donor wt on resource gap"=
0.15
4. effect of leadership on team engagement =
1.1

more leadership means better teams, could be accomplished through recruitment or training

47. NGO Pressure to align national & local policy =
53. normal pressure to align policies + (51. table of effect of resource quality on pressure) 
   (40. local coastal resources quality & abundance)
   ) * (52. table of effect of learning on pressure) (46. Donor learning from success) 

this should be a pulse from agenda setting due to a gap between actual and desired resource quality, with donor learning adding additional pressure

34. effect of success on contact rate =
3
places/Year

it takes 3 places per year with success to add a 'contacted place'

1. degree of engagement by local teams =
2. fraction compelling local problems identified * 4. effect of leadership on team engagement
   * 3. local leadership & arrangements
   ) * 11. local research fraction of reliable knowledge * 5. effect of local research on team engagement

this generates a fraction based on the proportion of each available. this could be reformulated with weights

71. delay in perceiving resource gap =
1
Year [0,4,0.01]

68. potential gap in available resources =
(1 - 79. fraction national policy alignment with local ICM) / 71. delay in perceiving resource gap

donors will consider filling a gap in resources... more feedback loops are needed to account for donor decision making, including fatigue
"5. effect of local research on team engagement" = 
1.1 
~ Dmn [0,4,0.01] 
~ Having local research information which they help gather boosts the \ 
engagement of local team

"42. normal time to align behaviors" = 
2 
~ Year [0,10,0.01] 
~ it takes this many years to complete an action that generates a good \ 
behavior

"72. wt on local $ fraction" = 
0 
~ Dmn [0,1,0.01] 
~ this sets an effect of local decisions on how much effort to put into \ 
local projects on how the national level commits to supporting local action

"33. initial contact rate" = 
5 
~ places/Year [0,60,0.01] 
~ the starting assumption about how frequently local success leads to a \ 
contact with a new location

"43. table for effect of leadership on effort"( 
[(0,0)-(1,1)],(0,0),(0.11315,0.29386),(0.275229,0.535088),(0.443425,0.714912),(0.675841,0.824561),(1,0.9)) 
~ Dmn 
~ declining return to effort on leadership

"59. wt on success gap trend" = 
0.0001 
~ Dmn [0,1,0.0001] 
~ this is a very sensitive parameter since the success gap trend is so \ 
dynamic. it should be changed very slightly in tests, and needs to be \ 
interpreted

"45. success gap: ideal - actual" = 
"39. Total desired good behavior" - "36. Local success: Resource Use Behavior aligned with plan" 
~ behaviors
"62. local commitment to sustain effort"
"40. local coastal resources quality & abundance" + "60. local motivation to sustain effort based on trend"
+ "61. national economic development benefitting local places"
~ Dmnl
~ local commitment is in-kind and perhaps less effective than $, this is the fraction of total required, and the hope is that it increases to cover all the costs over time
~

"58. time for recent success gap" =
1
~ Dmnl [0, 6, 0.01]
~

"60. local motivation to sustain effort based on trend"
"57. success gap trend" * "59. wt on success gap trend"
~ behaviors
~ local people can get discouraged after the initial excitement of a local coastal management project. Donor and national attention is needed to help overcome this. One key factor is national measures to boost local economic activity while the local people are writing and trying to implement the local plan
~

"56. recent success gap" =
SMOOTH("45. success gap: ideal - actual", "58. time for recent success gap")
~ behaviors
~ this smooths out the values generated in variable 45 which computes the success gap
~

"57. success gap trend" =
("45. success gap: ideal - actual" - "56. recent success gap") / "58. time for recent success gap"
~ Year
~ this is a crucial, sensitive variable that creates a smoothed interpretation of how well things are going at the local level.
~

"73. wt of learning on govt $ fraction" =
2.5
~ Dmnl [0, 4, 0.01]
~

"44. wt on abundance" =
local prosperity makes it possible to handle more of the burden of coastal management

"65. fraction of required resources available for local ICM"=
"67. donor fraction for local ICM"+"64. local fraction $ for local ICM"+"66. national govt fraction $ for local ICM"

this is the total fraction of resources available for local ICM

"39. Total desired good behavior"=
"38. behaviors required per action plan"*"17. Total Places N"

this is the maximum needed behaviors

"40. local coastal resources quality & abundance"=
("36. Local success: Resource Use Behavior aligned with plan"/"39. Total desired good behavior"

1 = full aligned behavior  this is the same as a proportional control, the idea is that locals are more skeptical and judge current abundance against ultimate desires

"2. fraction compelling local problems identified"=
"6. table of effect of local process quality on identifying problems"("7. average local process quality: capacity building, participation, support"

the higher the fraction of problems identified, the more likely compelling issues will be addressed

"46a. total potential good behaviors"=
(1+("38. behaviors required per action plan"*"21. Places with Completed action plans")]/1

this is the potential number of behaviors that should be changed

"6. table of effect of local process quality on identifying problems"(
[(0,0)-(1,1)],(0,0.1),(0.379205,0.381579),(0.70948,0.77193),(1,0.9))

normal local problem identification is 0.6, process improvements can
increase this to 0.9

"9. table of effect of available resources on local process quality"(  
[(0,0)-(1,1)],(0,0),(0.3,0.2),(0.5,0.4),(0.6,0.5),(0.8,0.7),(1,0.8)  
\~ Dmnl  
\~ there is a minimum amount of local process, external resources can boost \  
this considerable. In fact, projects get started where such enabling \  
conditions are at least average. This is a precondition \]  

"8. table of effect of local process quality on leadership"(  
[(0,0)-(2,2)],(0,0.25),(1,0.8),(2,1.2)  
\~ Dmnl  
\~ normal local leadership is 0.4....process quality can improve this to \  
0.8]  

"3. local leadership & arrangements"=  
"8. table of effect of local process quality on leadership"("7. average local process quality: capacity building, participation, support"\  
)  
\~ Dmnl  
\~ strong local process leads to leadership and effort to arrange for \  
implementation  

"77. national leadership for local coastal problems"=  
"78. table of effect of awareness on national leadership"("49. national awareness of local problems & benefits of action"  
)  
\~ Dmnl  
\~ stronger leadership will increase policy alignment  

"75. national learning from local places"=  
"77. national leadership for local coastal problems"**"25. Places with projects"  
\~ Dmnl  
\~ more leadership insures maximum learning  

"70. table of effect of local commitment on donor fraction"(  
[(0,0)-(1,1)],(0,0),(0.1,0.1),(0.2,0.35),(0.3,0.3),(0.350588,0.227758),(0.4,0.1),(0.5\  
,0),(1,0))  
\~ Dmnl  
\~ if local commitment is low at the outset, but greater than 0, donors will \  
put money in for start up, and up to a point they will increase it, until \  
they decide a place is "graduated " then they withdraw funds, often \
quickly. Donors may leave too soon, and fund too many start ups.

"76. effect of national learning on $ for local" =
"75. national learning from local places"/(1+"25. Places with projects")
~ Dmnl
~ the more learning, the higher influence on national spending

"78. table of effect of awareness on national leadership"(
[(0,0)-(1,1)],(0,0.1),(0.376147,0.280702),(0.46789,0.342105),(0.544343,0.469298),(0.626911,
,0.574561),(0.788991,0.657895),(1,0.7))
~ Dmnl
~ leadership is slow to respond to awareness and is distracted by many other issues

"10. initial local fraction for ICM" =
0.2
~ Dmnl [0,2,0.01]
~ the minimum amount of effort a local place is willing to invest in ICM

"54. normal duration of awareness" =
2
~ 1/Year [0,10,0.1]
~ awareness lasts for two years on average (this should be reworked as a pulse)

"53. normal pressure to align policies" =
0.3
~ Dmnl [0,2,0.01]
~ normal pressure to align national and local policies, as part of decentralization, democracy

"51. table of effect of resource quality on pressure"(
[(0,0)-(1,1)],(0,0.95),(0.1,0.9),(0.2,0.85),(0.5,0.6),(1,0.2))
~ Dmnl
~ as resource quality improves, pressure to align policies drops

"18. Minimum time required to complete plan" =
2
~ Year/Action Plan [0.1,10,0.1]
~ it takes 2 years effort for a fully functioning team to complete a plan, and ideally one full year of team effort occurs per year for two years
"46. Donor learning from success"=
"36. Local success: Resource Use Behavior aligned with plan"/"46a. total potential good behaviors"
~ behaviors
~ learning occurs from success and failure, here the idea is that if local success occurs in initial sites, it justifies program expansion and longer term commitment. Success occurs as the fraction increases.

"12. reliable knowledge"=
"14. local research"+"13. national information"+"15. traditional knowledge"
~ Dmn
~ all three components need to be present to have the highest score. these could be weighted, maximum should be 1.

"49. national awareness of local problems & benefits of action"= INTEG ( 
"48. building national awareness",
  "55. initial national awareness")
~ Dmn
~ this is a key contribution to generating information, economic support and financial resources for local coastal management.

"52. table of effect of learning on pressure"
((0,0)-(1,1)),(0,0.1),(0.2,0.2),(0.4,0.4),(0.5,0.6),(0.669725,0.864035),(0.847095,0.938596),(1,1))
~ Dmn
~ rate of learning peaks at about 75 per cent success.

"16. quality of action plans"=
"12. reliable knowledge"*"2. fraction compelling local problems identified"
~ Dmn
~ reliable knowledge and compelling issues improve plan quality.

"38. behaviors required per action plan"=
100
~ behaviors
~ Average number of policy elements per initiative.

"79. fraction national policy alignment with local ICM"=
"77. national leadership for local coastal problems"+"50. normal local participation in national policy"
"55. initial national awareness" = 0.2
"50. normal local participation in national policy" = 0.3
"35. local success inspiring potential places" =
"36. Local success: Resource Use Behavior aligned with plan" / "38. behaviors required per action plan"

~ action plans
~ an indication of how many successful places there are. some fraction of new behaviors per plan = success. this needs detail place by place

"36. Local success: Resource Use Behavior aligned with plan" = INTEG ("37. aligning resource use behavior", 0) behaviors
~ this produces aligned behaviors. since plans are reworked every 7 years on average, that generates more than the theoretical number of behaviors, that is, in the best scenario total behaviors is higher than 46a total potential good behaviors

********************************************************************************
.Bass
********************************************************************************

The Bass Innovation Diffusion Model with Discards
Copyright (c) 1999 John Sterman

This is the classic Bass innovation diffusion model, adapted to include discards of the product and repurchases. Adopters discard their units after an average lifetime and reenter the market as potential adopters.
Chapter 9.
"24. Project Initiation Rate" =
("28. Initiation from Donor Support" + "30. Initiation from Word of Mouth from other places"
)
~ Units/Year
~ The rate at which a potential adopter becomes an active adopter. This is driven by advertising (or donor and national) efforts and the word of mouth effect.

"28. Initiation from Donor Support" =
(("66. national govt fraction $ for local ICM" + "67. donor fraction for local ICM") * "81. allocation for project initiation"
)*

"23. Potential Places with Projects" * "29. Initiation effectiveness"
~ Units/Year
~ Adoption can result from donor programs or national effort, according to the effectiveness of the effort with the pool of potential adopters.

"26. Places Ending Projects, Rate" =
"25. Places with projects" / "27. Average Life of an Initiative"
~ Units/Year
~ The discard rate is assumed to be first-order, with an average product life l.

"32. Contact Rate" =
"33. initial contact rate" + ("35. local success inspiring potential places" / "34. effect of success on contact rate"
)
~ places/Year
~ The rate at which active adopters come into contact with potential adopters, affected by success story messages.

"25. Places with projects" = INTEG {
"24. Project Initiation Rate" - "26. Places Ending Projects, Rate", 0
}
~ Units
~ The number of active adopters in the system. Increased by adoption and decreased when adopters discard their unit and reenter the market.

"23. Potential Places with Projects" = INTEG {
-"24. Project Initiation Rate" + "26. Places Ending Projects, Rate",
"17. Total Places N" - "25. Places with projects"
}
~ Units
~ The initial number of potential adopters is determined by the total
population size and the current number of active adopters. It is reduced by adoption and increased when adopters discard their old unit and reenter the market.

| "17. Total Places N"= 100 Units |
| ~ The size of the total population. In this case the number of locations needing action plans and coastal management |

| "30. Initiation from Word of Mouth from other places"= "32. Contact Rate"*"31. Initiation Fraction i"*"23. Potential Places with Projects"* "25. Places with projects"/"17. Total Places N" Units/Year |
| ~ Adoption by word of mouth is driven by the contact rate between potential adopters and active adopters and the fraction of times these interactions will result in adoption. The word of mouth effect is small if the number of active adopters relative to the total population size is small. |

| "31. Initiation Fraction i"= 0.1 Dimensionless |
| ~ The fraction of times a contact between an active adopter and a potential adopter results in adoption. |

| "27. Average Life of an Initiative"= 5 Year [0,40,0.1] |
| ~ The average life of a donor funded project |

************************************************
Control
************************************************~ Simulation Control Parameters

| FINAL TIME  = 50 Year |
| ~ The final time for the simulation. |

| INITIAL TIME  = 0 Year |
The initial time for the simulation.

SAVEPER = 1
~ Year
~ The frequency with which output is stored.

TIME STEP = 0.0625
~ Year
~ The time step for the simulation.

\\---/// Sketch information - do not modify anything except names
V300 Do not put anything below this section - it will be ignored
## Appendix XII. Pwani Performance Management Report, 2011

<table>
<thead>
<tr>
<th>INDICATOR</th>
<th>Data Source</th>
<th>Baseline data, 2009</th>
<th>FY 10 Results</th>
<th>FY 11 Target</th>
<th>FY 11 Q4 results</th>
<th>% of FY 11 target reached in Q4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of hectares in areas of biological significance under improved management</td>
<td>project records, secondary records</td>
<td>180,117</td>
<td>56,414</td>
<td>104,000</td>
<td>102,046</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Number of hectares in areas of biological significance showing improved biophysical conditions for selected parameter(s)</td>
<td>project records, survey reports</td>
<td>26,734</td>
<td>-</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Number of policies, laws, agreements, or regulations promoting sustainable natural resource management and conservation implemented.</td>
<td>project records, secondary records</td>
<td>5</td>
<td>1</td>
<td>8</td>
<td>5</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Dollar value of funds leveraged</td>
<td>project records</td>
<td>0</td>
<td>189,471</td>
<td>No target</td>
<td>149,473</td>
<td>27,377</td>
<td>No Target</td>
</tr>
<tr>
<td>Number of stakeholders implementing risk reducing practices/actions to improve resilience to climate change as a result of USG assistance (NEW)</td>
<td>project records</td>
<td>0</td>
<td>-</td>
<td>400</td>
<td>563</td>
<td>74</td>
<td>19%</td>
</tr>
<tr>
<td>---</td>
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</tr>
<tr>
<td>Number of institutions with improved capacity to address climate change issues (adaptation) as a result of USG assistance (NEW)</td>
<td>training reports, vulnerability assessments, project records</td>
<td>0</td>
<td>6</td>
<td>10</td>
<td>0</td>
<td>0%</td>
<td>On target</td>
</tr>
<tr>
<td>Number of climate vulnerability assessments conducted as a result of USG assistance (NEW)</td>
<td>vulnerability assessments</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0%</td>
<td>On target</td>
</tr>
<tr>
<td>Number of individuals with increased economic benefits derived from sustainable NRM (SO 13, indicator 2)</td>
<td>lists of livelihood participants, surveys</td>
<td>0</td>
<td>301</td>
<td>260</td>
<td>334</td>
<td>51</td>
<td>19%</td>
</tr>
<tr>
<td>Number of households with improved access to finance, including those receiving community credit and start up grants</td>
<td>list of SACCO members</td>
<td>0</td>
<td>104</td>
<td>200</td>
<td>174</td>
<td>51</td>
<td>26%</td>
</tr>
<tr>
<td>Number of persons reached through community outreach that promotes HIV/AIDS prevention</td>
<td>Project records</td>
<td>44,385</td>
<td>66,244</td>
<td>30,000</td>
<td>29,968</td>
<td>4,901</td>
<td>16%</td>
</tr>
<tr>
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</tr>
<tr>
<td>Number of the targeted population reached with individual and/or small group level HIV prevention interventions that are based on evidence and/or meet the minimum standards required (PEPFAR P8.1.D)</td>
<td>Project records, meeting reports and participant lists</td>
<td>0</td>
<td>685</td>
<td>650</td>
<td>1,999</td>
<td>437</td>
<td>67%</td>
</tr>
<tr>
<td>Number of fishermen (mobile men with money) reached with individual and/or small group level preventive interventions that are based on evidence and/or meet the minimum standards required. (PEPFAR P8.3.D)</td>
<td>Project records, meeting reports and participant lists</td>
<td>0</td>
<td>203</td>
<td>450</td>
<td>753</td>
<td>154</td>
<td>34%</td>
</tr>
<tr>
<td>Number of targeted condom service outlets (PEPFAR P8.4.D)</td>
<td>Project records, condom outlet surveys</td>
<td>62</td>
<td>147</td>
<td>42</td>
<td>153</td>
<td>88</td>
<td>210%</td>
</tr>
<tr>
<td>Activity Description</td>
<td>Source of Data</td>
<td>Targets</td>
<td>Achievements</td>
<td>Percentage</td>
<td>Status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------------</td>
<td>-------------------------------</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Number of local organizations strengthened to manage endangered ecosystems, and to</td>
<td>project records,</td>
<td>0</td>
<td>18</td>
<td>14</td>
<td>14</td>
<td>0% On target</td>
<td></td>
</tr>
<tr>
<td>support sustainable livelihoods and cross-cutting issues such as HIV/AIDS and gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of individuals reached through community outreach and planning that promotes</td>
<td>project records, participant</td>
<td>2,506</td>
<td>1,719</td>
<td>2,240</td>
<td>1,412</td>
<td>490 22% Below target. The target was set too high</td>
<td></td>
</tr>
<tr>
<td>biodiversity conservation and improved gender equity</td>
<td>lists</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of individuals trained and/or certified in coastal governance, MPA management,</td>
<td>project records, trainNet</td>
<td>1,166</td>
<td>602</td>
<td>836</td>
<td>838</td>
<td>251 30% On target</td>
<td></td>
</tr>
<tr>
<td>HIV/AIDS action planning, and other cross-cutting issues (SO 13, indicator 4)</td>
<td>records</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>