International Coastal Management

Tools for Successful Regional
Regional Partnerships and Initiatives

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Coastal Governance as Sustained Learning and Adaptation

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Governance in the Anthropocene

Governance is the process by which human societies negotiate the purposes, the rules and the procedures by which they regulate their activities and distribute power, access to resources and wealth. All governance systems are driven by the values that reflect what a society believes to be important. Governance systems are also shaped by the ecosystems in which a society lives and by their relationships with other societies with which they interact. Together these combine to form perceptions of how the world works and how an individual or group fits within their ecosystem and society context. When we consider the issues posed by the governance of coastal ecosystems today we need to begin by considering our current understanding of ecosystem conditions and the processes of change that shape the context in which we are operating as coastal managers.

In this paper, I have used the term coastal management, or integrated coastal management (ICM) since these are the terms that are usually used when discussing attempts to steer the processes of change in coastal ecosystems. The better term, however, is "coastal governance." The differences between management and governance are significant. Management is the process by which human and material resources are harnessed to achieve a known goal within a known institutional structure. We therefore speak of business management, or town management, or even conflict management. Governance, on the other hand, sets the stage in which management occurs by defining–or redefining–the fundamental objectives, policies, laws and institutions by which societal issues are addressed. Governance is by no means only the purview of governments. In many settings the role of government in the governance of a coastal ecosystem is small. Since the behavioral changes required to make progress towards more sustainable forms of coastal development are so large and require re-thinking many fundamental assumptions, the term "coastal governance" or "coastal ecosystem governance" would more accurately convey what it is that we are attempting to do.

Welcome to the Anthropocene! When we consider the challenges and the emerging governance practices in coastal ecosystems we must first recognize that we are in a new, and strikingly different epoch in the evolution of human societies on this planet. The evidence is now incontrovertible that our species is changing the ecology of the planet as a whole. Our impacts are no longer merely local. We are changing the planet's climate. We are the cause of one of the largest and most rapid extinctions of our fellow species and we are altering the fundamental bio-geo-chemical cycles that govern the distribution of fresh water and the production of the nutrients that plants require (Box 1). Along coastlines we are destroying or degrading habitats critical to the functioning of these ecosystems such as wetlands, coral reefs and estuaries. These combinations of forces led Paul Crutzen and Eugene Stoermer (2000) to coin the term "Anthropocene" to describe the geological epoch in which the forces of human activity equal or surpass those of nature in modulating the behavior of the planet. These changes are occurring in periods measured in decades to a century or two centuries. In human terms this translates into the span of a few generations-from our grandparents to our grandchildren.

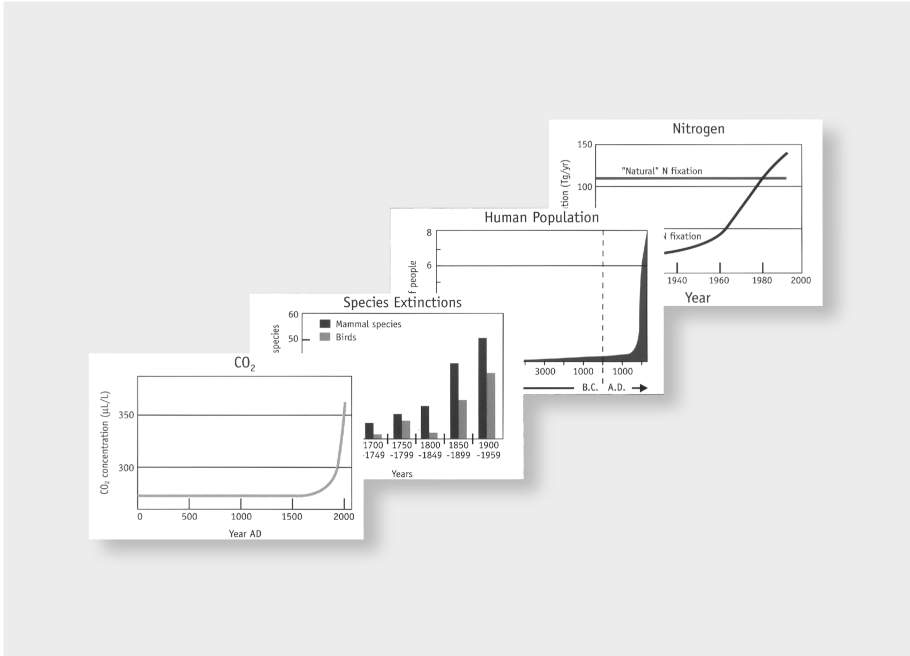


Illustration 1: The Nature of Global Change.

Global change is much more than climate change. These expressions of change are accelerating and interact with each other and with social and environmental conditions at local and regional scales (IGBP, 2001).

Until recently societal decisions were based on the assumption that nature is far bigger and more powerful than people. The realization that we are now shaping the ecology of the planet as a whole dates back only to the late 1950s when two oceanographers (Revelle and Suess, 1957) hypothesized that the emissions from burning fossil fuels might be changing the chemistry of the planet's atmosphere. They suggested monitoring carbon dioxide and other gasses at the Mona Loa observatory in the north-central Pacific, far from any immediate sources of these products of the industrial era. The measurements were subsequently made and they have shown that the annual carbon dioxide concentration in the high atmosphere is increasing steadily. This is now known to be caused primarily by the burning of fossil fuels. The Mona Loa signal triggered a burst of research on climate change and then, increasingly, investigations into other dimensions of the Anthropocene.

Beginning in 1991, the International Geosphere Biosphere Program (IGBP) has worked to synthesize the detailed quantitative science that multitudes of scientists have been producing. In a report on the "big picture findings" (IGBP, 2001) the program has concluded that biology plays a much stronger role that previously thought in keeping the planet's environment within habitable limits. Human activities are significantly influencing the functioning of the planet as a living ecosystem. Changes to the climate is only one of many expressions of our impact. These changes are clearly identifiable as beyond natural variability and are equal to some of the greatest forces of nature in their extent and their impact. Furthermore, cascading effects of human activities interact with each other and with local and regional conditions in multidimensional ways.

It is important to place current conditions and trends within the context of long term patterns of global change established long before the Anthropocene. This need to place current events into their larger context has produced major investments to improve our understanding of how the planet's climatic system functions and in documenting long-term cycles of change. The air bubbles captured in ice laid down long ago provide a fascinating record of cycles in the concentrations of carbon dioxide extending back over half a million years. The record traces four cycles of cooling and warming that have marked the advance and retreat of glaciers across the planet. Until the Anthropocene the pattern has remarkably consistent. Current conditions show that the concentrations are now far higher than they have been in any previous cycle. This places us in a "no anologue state" in which past patterns are of limited usefulness in suggesting what is likely to happen next.

The World's People are Divided into Two Groups

In the Anthropocene the planet's people are divided into two large groups. The tensions between the two are already great and are spawning conflict and mass migrations. One group, referred to as "the North," contains about a quarter of the planet's population. Members of this group live primarily in North America, Europe, Japan and such high-income countries in the Southern Hemisphere as Australia and New Zealand. By 1990, the North was consuming 70 percent of the world's energy, 75 percent of its metals, 85 percent of its wood and 60 percent of its food (UNDP, 1992). By the end of the 20^{th} century, the population growth in the North had stabilized. The economies of the North demand sustained growth and are based upon a culture of resource consumption. Its citizens, in fact, refer to themselves as "consumers."

"The South" contains three-quarters of the world's people, principally in the tropics and subtropics. They are younger, less educated and poor when compared to those inhabiting the North. While the North enjoys resource surpluses, the South suffers resource shortages. The North relies on technical knowledge and invests heavily in theory-driven research. In the South, traditional knowledge dominates.

Both groups are shaping the Anthropocene and both have major roles and major responsibilities in responding to the changes to the planet that are underway. The principle causes of global change lie in the North, while the impacts are most evident in the South. A recent paper published in Science (Kates et al., 2001) argues that overcoming the "digital divide" between the two groups is fully as important as successfully addressing the bio-physical expressions of planetary change. The scale of the differences between the two groups is great and poses enormous challenges to those working to develop the ethics and the global governance systems that the Anthropocene requires.

The Primary Human Habitat in the Anthropocene

An important feature of the Anthropocene is that the planet's people, their infrastructure and their activities are increasingly concentrated in a narrow band on the border of oceans, seas and great lakes. By 2000, nearly half the world's people lived within 150 km of a coastline (Cohen et al., 1997). If we eliminate Antarctica and the lands in the Arctic (but not sparsely populated deserts and high mountains elsewhere), this coastal fringe is approximately 15 percent of the inhabited land-space. By 2050, demographers predict that the proportion of the world's people living in this coastal fringe will have increased to 75 percent. By 2000, twelve of the world's largest fifteen cities were coastal. The increases in the density of coastal populations that will be the result of both migration from inland and, in the tropics, population growth in these coastal regions, will transform greater portions of coastlines into sprawling cities. Such urban growth will be greatest in the South.

Today coastal regions already support three-quarters of the infrastructure for transportation, energy production and manufacturing. They are therefore also the places where the consumption of natural resources is highest – and consequently the places where the most wastes are produced and released into the environment. Last but not least, tourism has become the world's largest industry, and by far the greatest numbers of tourism destinations are coastal.

Why have coastlines assumed such prominence? First, in a more interrelated global society far fewer people rely on resources in their immediate surroundings for their food and their livelihoods. This makes it possible for populations to concentrate. The great bulk of the world's goods and fossil fuels are transported over water by ships and the nodes in the distribution system are port cities. Industrial infrastructure and populations have clustered around these nodes. Since it is more efficient to utilize and transform such energy into goods and services close to their point of distribution, this too has spurred the growth of coastal cities.

The reasons for the importance of coastlines to people can also be attributed to the natural wealth they contain. According to Costanza et al. (1997), the annual value of the goods and services produced by coastal ecosystems are more than four times greater than the per unit area value of terrestrial systems and 16 times greater than those produced by the open ocean (Box 2). Water flows downhill, and runoff from the land, and the nutrients, sediments and other materials that it carries, are all released into estuaries and from there flow out along coastlines and across continental shelves. Waves, currents and tides produce vigorous mixing. The consequence is extraordinarily high biological productivity in estuaries and coastal waters, deltas of rich deep soils, abundant freshwater, a climate in which temperature highs and lows are modulated by the buffering effect of a large water body and, very often, seasonally generous rainfall. The result is that coastal waters produce 90 percent of the world's fish production and coastal lands contain a high proportion of the best farmland. Before modern medicine, many coastlines in the tropics were made inhospitable by such diseases as malaria, yellow fever and typhoid. These constraints have been much reduced since the 1950s and this has contributed to making the urbanization of tropical coasts feasible.

Biome	**Value in US$ per hectare per year**
Marine	577
Open Ocean	252
Coastal	4,052
Estuaries.	22,832
Seagrass/Algae Beds	19,004
Coral Reefs.	6,075
Shelf	1,610
Terrestrial	804
Forest.	969
Tropical	2,007
Temperate/Boreal	302
Grass/Rangelands	232
Wetlands	14,785
Tidal Marsh/Mangroves	9,990
Swamps/Floodplains	19,580
Lakes/Rivers	8,498
Desert	-
Tundra	-
Ice/Rock	-
Cropland	92
Urban	-

Table 2: Global Values of Annual Ecosystem Services Produced by Marine and Terrestrial Biomes (Costanza et al., 1997).
One of the most comprehensive studies estimated that the world's ecosystems provide goods and services worth at least $33 trillion a year, of which 63 percent is contributed by the world's oceans. Over half of the oceans' contribution to planetary wealth is accounted for by coastal ecosystems, such as mangrove swamps, coral reefs and sea-grass beds. While there is little agreement among the scientific community on the "value" of ecosystem services and natural capital, these estimates illustrate the relative importance of coastal resources.

Coastal Zone Management as a New Approach to Planning and Decision Making

During the 1960s, when concerns over the losses in environmental quality gained a place on the political agendas of many nations and within the international community as a whole, coastal regions emerged as a focal point. In the United States, the Stratton Commission (1969) argued for a “new approach” to planning and decision making in the “coastal zone.” The Commission found that that coastlines are the nation’s most valuable feature and argued that its development and the protection of its many qualities is in the national interest. The Commission found that local governments - that in the United States have authority over land use - and the states that regulate activities within three miles of the coast, are not capable of either planning for orderly development nor resolving the multiple conflicts that intensifying uses bring. The Commission recommended a new tiered governance system in which the federal government would provide major incentives to coastal states to develop “coastal zone management” plans and assemble the authorities and procedures by which to implement them. Such plans would have to meet detailed federal standards to win approval. Approved state plans would receive sustained financial and administrative support from the federal government. These recommendations gave rise, three years later, to the federal Coastal Zone Management (CZM) Act that in subsequent decades has catalyzed the formulation of state CZM programs. This legislation and the decentralized programs it has catalyzed is one in a series of federal initiatives that have addressed water pollution and fisheries management and funneled massive investments into the restoration of such severely degraded coastal ecosystems as the Chesapeake Bay and the Great Lakes.

The 1960s saw the beginnings of similar efforts to regulate human induced change to coastal ecosystems in other nations. For example, in Australia opposition to limestone extraction and oil drilling on the Great Barrier Reef led in 1975 to the declaration of the Great Barrier Reef Marine Park and eventually to stringent limitations to all forms of human use in an area of nearly 350,000 square kilometers. These efforts have indeed conserved the qualities of a very large coastal ecosystem despite greater use by the tourism and fishing industries and intensifying activity in the adjoining watersheds. In Europe, also in the 1960's, the continued diking and draining of wetlands surrounding the Wadden Sea that borders the Netherlands, Germany and Denmark led in 1982 to a binding tri-national agreement that has prevented further wetland losses and has halted the decline or restored other features of this 13,500 square kilometer estuary (Olsen and Nickerson, 2003).

By the time of the Rio Conference on the Environment and Development in 1992, an initial set of pilot projects sponsored by the United States Agency for International Development (USAID) was demonstrating that participatory, issue-driven approaches to coastal management could be successfully adapted to conditions in developing nations. These early experiences in developing nations, although largely undocumented in 1992, influenced the approach to coastal management adopted at Rio.

Integrated Coastal Management and Sustainable Development

At the Rio Conference on the Environment and Development, the concept of sustainable development was accepted as the ultimate goal of the conventions and non-binding agreements that were negotiated. The concept of sustainable development had emerged nine years before from the Bruntland Commission. It calls for engaging only in activities that do not compromise the ability of future generations to meet their needs. Chapter 17 of Agenda 21 puts forward ICM as the most promising means for achieving sustainable forms of development in coastal region. This call for a “new” approach echoes the one made by the Stratton Commission twenty-three years before. Chapter 17 stresses the importance of integration and precaution and calls for approaches that emphasize the participation of those affected and collaboration among the many agencies of government and groups with roles in how coasts are developed, used and conserved. However, the text on ICM in Chapter 17 is a tangle of principles, aspirations and means-to-ends that offer little practical guidance on what to do and how to do it.

During the 1990's, ICM was embraced by a host of global and regional environmental treaties. They include the Convention on Biological Diversity, the Convention on Climate Change, the Regional Seas Program, the Global Program of Action on Protection of the Marine Environment from Land-Based Activities, the International Coral Reef Initiative, the Cartagena Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region, and the Program of Action for the Sustainable Development of Small Island Developing States. These agreements all assign a central role to ICM in carrying out commitments to the conservation and sustainable development of coastal areas. The International Panel on Climate Change endorsed ICM as the best approach for meeting the challenges of rising sea level and shifts in long established weather patterns.

However, despite the appearance of several "guidelines" (references) practicing ICM as a means of advancing towards more sustainable forms of coastal development has proved to be very difficult if not downright confusing. What specifically must we do to chart an operationally feasible course towards a sustainable future in which there is equity among the planet's people, equity among generations, an acceptable quality of life and a healthy long-term relationship between people and the ecosystems of which they are a part? The clues emerged gradually during the 1990s. Herman Daly (1997) suggests that the defining characteristic of sustainability is the replacement of quantitative expansion (growth) with qualitative improvement (development). Lubchenco (1994), contrasted the traditional and dominant approach to managing both people and the environment in terms of a paradigm shift (Illustration 3). These ideas make the initial steps towards translating a concept into operational steps that can be acted upon. The term "adaptive management" has gained currency as an approach to the management of ecosystems that successfully makes the paradigm shift. Kai Lee (1993), in an analysis of adaptive management in the Columbia River basin, traced the interplay between new knowledge and the processes of debate and consensus building in a democratic society.

From	To
Individual species	Ecosystems
Small spatial scale	Multiple scale
Short-term perspective	Long-term perspective
Humans independent of ecosystems	Humans as integral parts of ecosystems
Management divorced from research	Adaptive management
Managing commodities	Sustained production potential for ecosystem goods and services

Illustration 3: Ecosystem Management as a Paradigm Shift (Lubchenco, 1994).

Early Experience in Applying the New Approach

The Coastal Resources Center (CRC) at the University of Rhode Island was founded in 1971 to assist a newly created state agency, the Rhode Island Coastal Resources Management Council, in assembling the knowledge, policies and procedures of a coastal zone management program at the scale of a single state. In the early 1970s, CRC also worked closely with the federal office of Coastal Zone Management as it worked to define the rules and procedures by which a state CZM program could win federal approval and gain the prize of a sustained infusion of federal funds to support its implementation. For the state of Rhode Island, the second reward of approval, the "consistency" clause in the federal legislation, at the time seemed less important. This requires that the agencies of the federal government conduct their planning and decision making within the boundaries of a state's coastal zone in a manner consistent with an approved state CZM program. In those early years of the federal program, the rules were drafted and re-drafted repeatedly. From the beginning, however, a defining feature of CZM was unprecedented requirements for involving the public in every step of the process and negotiating agreements with a host of state, regional and federal agencies. The plan and policies prepared by CRC that made Rhode Island one of the first states to win federal approval in 1976 proved to be unworkable as a basis for day to day permitting decisions. After this disappointing initial experience in implementation, CRC again worked with the state's Coastal Resources Management Council to rewrite and reapprove the program in 1983. This second version has been the basis for all decisionmaking since then.

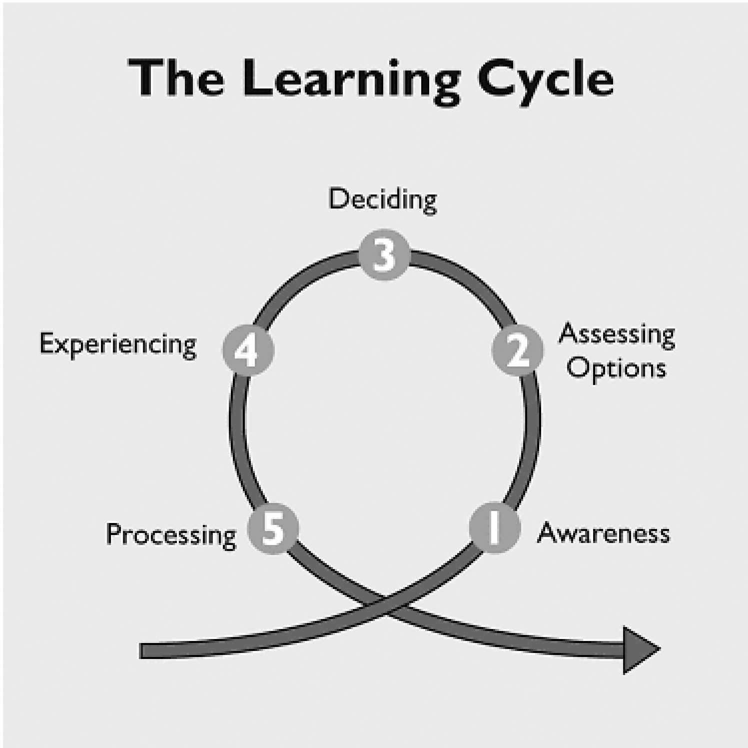
In 1985, the CRC was selected to lead an experimental program sponsored by USAID designed to assist selected developing nations in the management of their coastlines. The first phase of this program was extended to 1994. It enabled the CRC to work in long term partnership with governmental agencies in Ecuador, Sri Lanka and Thailand to apply a learning-by-doing approach to the formulation of coastal management programs at the national scale.

In practice the challenges of coastal management in the USAID supported pilots was simply to bring a measure of order and predictability to the processes of anthropogenically driven coastal change. The qualifier "a measure of" is important, since those involved in these pilot programs quickly learned that there is a great gulf between what *should* be done and what *can* be done in a given place at a given time. For example, in Ecuador extensive mangrove wetlands were being cut, burned and bulldozed to make way for shrimp ponds. Ecuador had become the world's largest producer of farmed shrimp and the boom had made many millionaires. But the industry was also displacing communities of subsistance fishers and was re-engineering estuaries, a process that in some cases reduced mangrove wetlands by 90 percent. In the 1980s, a fledgling coastal management program with no authority, scant support among government agencies and outright hostility within the shrimp growers associations had to concentrate its efforts in a few key areas. The program decided to demonstrate in four "special management zones" that a participatory and issue driven approach to planning and decision making would ultimately bring benefits to all (Robadue, 1995; Olsen et al., 2003). In Sri Lanka, a law passed in 1981 had given the Coastal Conservation Department authority to regulate development along a narrow strip of erosion prone coastline. Here the focus was to regulate the siting of new buildings along the shorefront and to control the sand and coral mining that were accelerating erosion in several areas (Lowry and Wickremaratne, 1989; Lowry, 2003). Both programs were important as incubators for new approaches to shaping the contemporary transformation of coastlines. They brought greater order to the process, but they were a long way from defining or achieving forms of development that could be considered as sustainable.

Organizing the Work as Cycles of Learning

In 1990, CRC began organizing itself to offer training programs for those engaged in ICM projects and programs. We needed to develop an organizing framework that could capture the essence of the practice and offer an operational framework for sequencing the many activities and thinking through a critical path that could lead to desired outcomes. Our experience in New England and a diversity of low-income countries in the tropics had made it clear that there was no formula. Programs have to be designed place by place and respond to the needs, the capabilities and the resources available at a given time. Yet the *process* that produced positive responses and progress was essentially the same. In looking for a readily recognizable image, we realized that the sequence of activities were essentially those by which we learn as individuals (Illustration 4).

The Cycle of Conscious Learning at the Individual Scale.



The learning process begins with awareness that some aspect of our behavior needs to change. For example, a person may realize that they are overweight. Their doctor has told them that they should do something about this and they have noticed that a walk up the hill requires more pauses than it used to. This is Step One. In Step Two, they consider their options. The person may read books by various experts and, very likely, get confused by the many, sometimes contradictory, strategies that they advocate for a diet. The most difficult step is to make the commitment to change behavior. In this case, the person may announce that they have selected one of the many diets, and have signed up for an exercise class at the local gym. This is Step Three and it may be greeted by some fanfare. Now comes the greatest challenge – to successfully implement the plan of action (Step Four). This step is often full of surprises. The requirements of the selected diet may have unexpected impacts on other members of the family and requires some adjustments to sustain harmony at the dinner table. For various reasons half the exercise classes are missed. Six months later, having lost only a fraction of the anticipated kilos the person reflects on their experience and considers what to do next. This is Step Five.

Illustration 4: The Coastal Management Cycle (adapted from GESAMP, 1996).

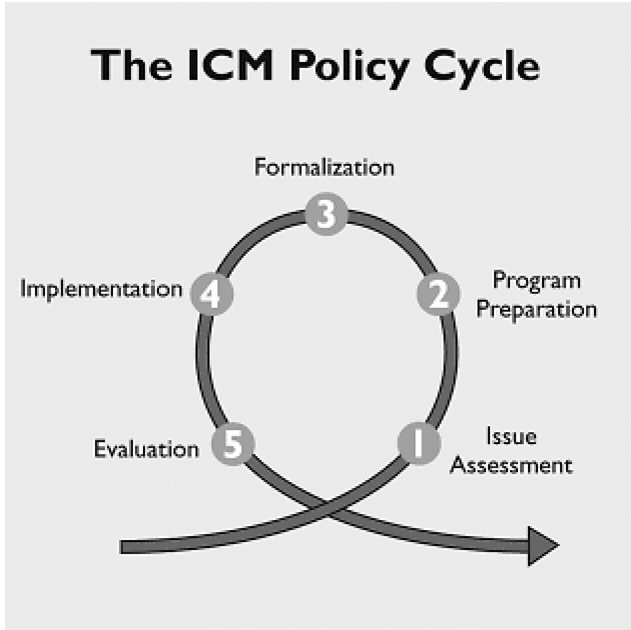


Illustration 5: The ICM Policy Cycle

When adapted to the process of launching and sustaining an ICM program (Illustrations 4 and 5), the learning cycle provides a framework for sequencing the many activities involved and understanding the interdependencies between the different steps. We identified the actions associated with each step that were proving to be most important (Illustration 6). For example, at the initiation of a program the focus must be upon the issues of concern to the groups and institutions with an interest in how the coast is changing and how its resources are being used and allocated. In Ecuador, international environmental groups saw the priority issue as the continuing destruction of mangroves. Within the farmed shrimp industry the primary concern was the increasingly high taxes on shrimp exports that was causing large scale smuggling of shrimp to exporting facilities in Peru. Coastal fishing com-munities were up in arms about their exclusion from traditional fishing grounds, and the collapse of previously abundant stocks of fish and shellfish. Their needs were for landing stations, ice and transport to markets. The scores of impoverished coastal communities saw potable water and basic sanitation as their priorities. An incipient coastal management program had to decide what issues it would address, at what geographic scale, and what alliances within a multitude of governmental agencies would be most critical to forward progress. These decisions are those associated with Step 1 and they must be made before detailed information gathering, planning and the constituency building process gets under way in Step 2. The policy cycle reminds a team that the culmination of all these early decisions and actions is the winning of a formal governmental mandate for a coastal management program and the authorities and funds that will be required to implement it. In Ecuador, this Step 3 threshold was initially achieved by winning an Executive Decree signed by the President in 1989 and the negotiation of a loan from the InterAmerican Bank (IDB) four years later that provided funding for an initial period of implementation.

Step	Indicators
Step 1: Issue Identification an Assessment	Principal environmental, social and institutional issues and their implications assessed Major stakeholders and their interests identified Issues upon which the ICM initiative will focus its efforts selected Goals of the ICM initiative defined Stakeholders actively involved in the assessment and goal-setting process
Step 2: Preparation of the Pla	Scientific research on selected management questions conducted Boundaries of the areas to be managed defined Baseline conditions documented Action plan and the institutional framework by which it will be implemented defined Institutional capacity for implementation being developed Second Order behavioral change strategies at pilot scales tested Stakeholders actively involved in planning and pilot project activities
Step 3: Formal Adoption and Funding	Policies/plan formally endorsed and authorities necessary for their implementation provided Funding required for program implementation obtained
Step 4: Implementation	Behaviors of strategic partners monitored, strategies adjusted Societal/ecosystem trends monitored and interpreted Investments in necessary physical infrastructure made Progress and attainment of Third Order outcomes documented Participation of major stakeholder groups sustained Constituencies, funding and authorities sustained Program learning and adaptations documented
Step 5: Self Assessment and External Evaluation	Program outcomes documented Management issues reassessed Priorities and policies adjusted to reflect experience and changing social/environmental conditions External evaluations conducted at junctures in the program's evolution New issues or areas for inclusion in the program identified

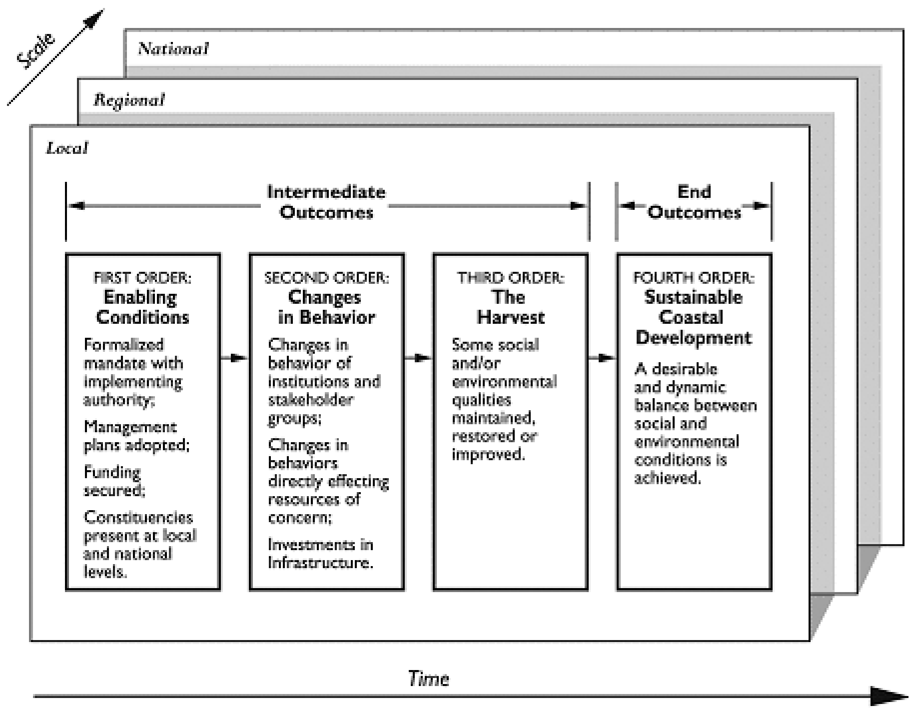
Illustraton 6: The ICM Learning Cycle and the Actions Associated with Each Step.

In Sri Lanka, experience in coastal regulation and planning had generated a body of experience and a foundation of institutional capacity within the Coastal Conservation Department (CCD) within the Ministry of Fisheries. Here the USAID funded pilot project was designed as a second generation effort in which the goal was to design and win formal approval of a management plan that would address critical habitats, public access and historic sites as well as the coastal erosion issue that had been the dominant concern of the program since its beginnings in the early 1970s.

The policy cycle framework has its roots in Lasswell's (1956) approach to making good governance operational by grouping the process by which public policy evolves into a sequence of functional steps. The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) (1996) offered a version of the policy cycle as a framework for grouping the activities associated with five steps within a "generation" of coastal management. There are many variations to how the policy cycle model can be adapted to coastal ecosystem management, but the central idea of a multiple step cycle that progresses from planning, to commitment to a course of action, to implementation and evaluation remains constant. Successive generations of a program typically address, as illustrated by Sri Lanka's program, an expanding agenda of issues and/or expansion of the program into a larger geographic area.

Measuring Progress through a Sequence of Outcomes

The learning cycle framework proved to be a useful tool for organizing the processes of coastal management during the initial phase of designing and launching an ICM program. Our experience in the pilot nations addressed through the USAID program were concerned primarily with the planning process with its attendant emphasis on building capacity within the partner institutions and constituencies within the affected society. While the learning cycle was a powerful tool for sequencing the many activities it shed little light on the outcomes that by which progress towards more sustainable forms of development could be mapped and assessed. Winning a formal mandate for a coastal program and the authorities and funds required for a sustained effort is clearly only the first threshold. These achievements, though typically consuming well over a decade to assemble at the scale of a nation, created the enabling conditions for a program that works to sustain or restore or sustainably develop the resources of a coastal region. We therefore turned our attention to formulating a second framework that charted the course from program creation forward to the ultimate goal of sustainable forms of coastal development (Olsen et al., 1995 and 1998). This framework is given in Illustration 7. It highlights the importance of changes in state (such as the abundance of fish or quality of human life), but recognizes that for each change in state, there are correlated changes in the behavior of the associated human society.



Source: Adapted from Oslen et al. 1998.
Illustration 7: The Four Orders of Coastal Governance Outcomes.

First Order outcomes constitute the full suite of conditions associated with Step 3 in the policy cycle. There is a major difference, however, between formalizing a plan of action (Step 3 in the policy cycle) and achieving *all* the conditions of the Fist Order threshold. These fall into four categories:

Unambiguous goals couched in terms of desired ecosystem (societal and environmental) qualities
Constituencies within the society that actively support the goals and advocate the changes in behavior required to achieve them
Commitment to the goals expressed as the authority and the financial resources required to implement a cross-sectoral plan of action
Adequate capacity in the institutions involved to implement the selected plan of action

In operational terms, the most difficult challenge is to balance the existing capacity of the implementing institutions and groups against the scope and the complexity of the issues to be addressed through a plan of action. Too often the needs for actions of many types and a failure to appreciate the difficulties involved produces plans of action and goals that outstrip the capacity of the institutions charged with carrying out the program. This breeds frustration and inefficiency.

The First Order Enabling Conditions are together the foundation for sustained behavioral change at the scale of a society. In many cases this threshold requires several generations of the policy cycle. For example, in Ecuador, the 1989 Presidential decree gave the program a mandate but it did not grant the program either the funds or the authority required to implement a program. The Inter-American Development Bank (IDB) loan provided funds for some activities but a four year delay in the release of those funds dismantled the program's staff and drastically reduced its capacity to implement its plan of action and sustain its constituencies along the coast. The loan increased the nation's debt by US$14 million, but the results were meager and the changes of behavior associated with its implementation were inconsequential. The loan execution, as is typically the case, was measured in terms of products (studies, reports) and infrastructure (latrines, water trucks). In this case the program's progress towards Fist Order Outcomes had probably been greater in 1993 than it was when the loan supported period ended in 2003 (Olsen et al., 2003).

In politically stable high income nations, the full suite of First Order Outcomes have been repeatedly assembled at a regional scale. The criteria set by the federal government for an approved state CZM program, for example, call for minimal standards of institutional capacity, public constituencies and commitment from the state's highest elected official (the governor). In Australia, the First Order threshold for the management of the Great Barrier Reef was achieved after fifteen years of intense effort. The designation of the entire region as a Marine Park and the creation of an Authority to plan and regulate the region came in 1975. An initial plan of action was not in place until 1979 (for the Capricornia section). Sustained funding and a power sharing agreement between the State of Queensland and the federal government was also negotiated in 1979 (Olsen and Nickerson, 2003). This illustrates the challenges of assembling all the conditions that fulfill the First Order.

Second Order outcomes are evidence of the successful implementation of a coastal management program. These include new forms of collaborative action among institutions, the successful actions of state-civil society partnerships, and the behavioral changes of resource users. Second Order changes in the behavior of organizations and user groups are the precursors to Third Order socioeconomic and environmental outcomes. These Third Order outcomes should mark physical evidence of progress towards sustainable forms of coastal development. Today the ultimate goal of sustainable forms of coastal development (Fourth Order outcomes) remains an undefined ideal.

Taken together, the policy cycle and ordered outcome frameworks allow us to analyze the evolution of a program in a manner that can set the stage for comparisons across initiatives undertaken in different locales.

ICM as an Adaptation of the Scientific Method

In essence, the steps of learning-based ICM are the steps of the scientific method. Much learning is unconscious and emerges by slow trial and error, often over long periods of time. Conscious learning is more efficient and it is a foundation of our contemporary civilization. Rather than applying a set of beliefs or a dogma to a problem, the scientific method calls for stating an idea for what the answer may be, designing a way to test this idea, carefully observing what happens, and then drawing conclusions. This objective and experimental way of learning was as radical a concept when it was developed by the ancient Greeks as it was when rediscovered during the European enlightenment that brought the societal transformations that have shaped today's world. It remains a radical idea when applied to how public policy is formulated and evaluated. Herein lie the many difficulties of making adaptive management an operational reality when developing systems of coastal ecosystem governance.

In its pure form, the scientific method requires a hypothesis that clearly states what an individual thinks is going to happen and it requires experiments designed to demonstrate whether the hypothesis is affirmed or rejected by reproducible events. Experiments must have controls. Without them, it is difficult to prove if the variables that are being probed are the cause of the outcomes being observed. Adaptive management can seldom attain this level of rigor, but the basics of experimentation remain the same. Applying adaptive management to how coastal management is practiced, therefore, requires:

- Stating clearly the assumptions that underlie a course of action and the expectations (or hopes) for what will happen as the result of those actions. This requires setting unambiguous goals.
- Deciding what should be monitored to demonstrate progress – or its absence – towards those goals.

Since rigorous controls are not feasible, critically observing and acknowledging how the context is changing during a generation of management and engaging those involved in assessing these events and adapting to them.

Drawing conclusions as they relate to the goals that were set and the adaptations to the plan of action that were made along the way. As much can be learned from failure as from success. Soliciting the views of informed outsiders is essential when drawing conclusions. The conclusions invariably fall short of a watertight "proof," but this does not negate their value.

By far, the most radical departure from the usual practices is (4) and (5). This is the heart of the scientific method, of science-based management, and of accountability and transparency in governing societies. But since so much public policy is shaped by beliefs and by values, this approach requires a degree of humility and flexibility that does not come easily to the bureaucracies that usually develop and implement public policy. As a result, the adaptive, learning-based approach is a difficult path to follow.

Emerging Good Practices

The challenges of governance in coastal ecosystems - our primary habitat - are becoming more critical with each passing decade. Adaptive, learning-based approaches hold the greatest promise of finding paths to viable futures, but they require significant reforms to how projects and programs are designed, administered and evaluated. In the interim, the following practices are proving effective as principles to guide those working to practice coastal governance at any scale.

Involve Those Affected in All the Steps of the Policy Cycle. In the United States, one of the unique features of the Coastal Zone Management Act was its stringent requirements for "public participation." This distinguished CZM from former efforts in regional planning. The requirements for public meetings, workshops and formal hearings on the topics to be addressed and the manner in which future decisions should be made forced a break from technocratic approaches. Formerly a plan and its policies were assembled inside a government agency with scant involvement of the public and the press before it was released, typically as a "done deal." If a CZM program is to engender real interest among the public it had to be organized around issues that people care about. If the options being considered are not readily understandable the responses and contributions of those that will ultimately be affected by the program will be at best lukewarm and at worst produce frustration and anger.

In the 1970s, when the CRC was shaping one of the first state CZM programs, we also learned that a well designed public participation program is a powerful antidote to the political cronyism and "backroom deals." As in other states, these had often been a dominant feature at earlier efforts to set policy on issues in which large amounts of money and political power were at stake. Most important of all, a vigorous and well-designed public participation program builds constituencies for the program. When those involved see that their concerns are being recognized and addressed, and the goals of the program appeal to their values they will become active supports of the program. Strong and well-informed constituencies become the backbone of successful implementation. When the public knows and believes in what the program is working to achieve, it will voluntarily comply with its policies and report infractions. Since successful implementation requires changed behavior among many groups and institutions a base of supportive constituencies is the key to a program's long-term success.

Construct Programs around Unambiguous Goals. A program that responds to the values and the needs of the people of the place must be clear about what it is working to achieve. The ultimate goal of sustainable development is so distant from current reality that we cannot imagine how we would recognize its achievement in anything other than abstract terms. First and Second Order outcomes are means to ends that are best defined as Third Order outcomes. It therefore is most effective to define a program's goals in terms of specific and achievable targets in the condition of the environment and societal qualities. For example, in Ecuador a goal of no further reduction of mangroves in a Special Area Management Zone and the provision of potable water to a specified percent of the population by a given date not only makes the purposes and values of the program tangible but hold those involved accountable to an unambiguous target. In Sri Lanka, similar goals could have called for the elimination of coral mining by a certain date. Such targets tend to be assiduously avoided by bureaucrats. Their value is more readily seen by politicians. Such goals were not set by most US CZM state programs and they were not a feature of the CRC pilots projects. In retrospect, they would have been very helpful. Not least they would have focused the program's energy and been a counterbalance to taking on too much too quickly. A review of coastal management programs that have operated successfully at regional scales for several decades (Olsen and Nickerson, 2003) demonstrates that setting unambiguous goals as desired environmental and societal outcomes is proving to be a central feature of their sustained success. In such programs, monitoring is directed at indicators that can document change as it relates to such goals. The setting of quantitative, time limited goals – how much by when - became the centerpiece of the Chesapeake Bay program in 1987. The Great Barrier Reef Park program recently adopted a similar goal-driven approach to address the impacts generated in the watersheds to the park.

Operate Simultaneously at Multiple Scales. Successful ecosystem management needs to link activities taken to conserve a neighborhood wetland, to city management, to watershed management and on up the scale to regional and global efforts. A golden role for a practitioner is to always assess forces and governance issues at least at the next scale bigger than the area of primary concern. Thus coastal management at the scale of a state should place an analysis of issues and a plan of action in the context of the nation, and a program for a nation should consider the forces at work in the region. In the USAID sponsored pilots, the CRC adopted a "two track strategy" that called for seeking the engagement and endorsement of the program's approach and activities at the very highest executive level. In Ecuador, this was the Office of the President and in Sri Lanka it was the Minister of Fisheries. Much of the effort was concentrated in Special Area Management Zones where progress could be made quickly and tangible results built constituencies for the program. At the local level issues become sharply focused and the practitioner soon learns the major impediments and opportunities to pursuing a policy that is being considered for adoption at a larger scale. "Demonstration projects" at the community level make it possible to complete all the steps in the policy cycle within months or a few years and to learn from the experience. Since the "experiment" is carried out at a small scale it need not threaten the prerogatives and the authorities of big governmental institutions – especially if the project has been sanctioned at the top levels in the governmental hierarchy.

Assess Program Success in Terms of Changes in Behavior. While the goals of a program should be set in terms of Third Order outcomes the business of assessing progress towards those goals must be directed towards predefined changes in behavior that signal the successful implementation of a program. An excellent manual for defining and monitoring progress as the changes in behavior of the key partners of a program has been prepared and applied by the International Development Research Center of Canada (Earle et al., 2001). Returning to the examples of mangrove cutting in Ecuador, progress by that program could best be assessed by monitoring change in the behavior of the enforcement officers in the three agencies responsible for permitting shrimp farms and conserving mangroves. These agencies had been willing partners in illegal construction during the shrimp farming boom and changes in their attitudes and behavior was central to success. Similarly, those seeing an infraction had to report it and the judge responsible for levying a fine on the culprits had to apply a meaningful penalty. Only when these changes in behavior worked in concert could progress towards a goal of no further cutting be realized.

It is essential to recognize, however, that in a complex system simple cause and effect relationships are elusive. The changes in behavior identified above may not be the major reason for a cessation in the expansion of shrimp ponds into the remaining mangroves. The spread of disease in the farmed shrimp industry idled many operations and this, rather than the changes in behavior promoted by the coastal management program, may be the major reason for achieving the goal. Nonetheless, the changes in behavior, if achieved, are honorable and important advances that should bring credit to the program and its partners.

Invest in Long Term Capacity Building. In the Anthropocene by far the biggest challenge is to change the attitudes and the behavior of human societies that are the barriers to progress towards a more sustainable form of development. A prevailing belief is that an as yet unknown "technical fix" will be discovered that will solve the problems outlined in the first section of this paper. While such a fix or fixes may indeed emerge it would be irresponsible not to energetically pursue the strategies that are available to us now. If we are to successfully confront the challenges of accelerating change in our primary habitat capacity building in the practice of adaptive ecosystem management must lie at the heart of all efforts.

The skills, attitudes and knowledge required of coastal managers have been the subject of other papers (Olsen, 1995 and Olsen, 2000). They span skills in strategic analysis and in navigating the many actions associated with the steps in the policy cycle. This requires the ability to synthesize, interpret and present complex sets of information. It also requires a high degree of leadership. A second critically important body of knowledge is an understanding of how ecosystems function and change. Last but not least is what can be termed "cultural literacy." This provides the practitioner with an appreciation for the importance of the culture of a place and an understanding for the traditions and the heritage of the people they are trying to serve. These three attributes are not usually the threads of a university curriculum designed for those who wish to pursue a career in ecosystem management. The challenges that are inherent in designing governance systems that promote stewardship for coastal ecosystems in the Anthropocene are very great. The outlines of successful practice can be seen but there is still much to learn about how to make the principles an operational reality at significant spatial scales.

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Mind the Gap: A Legal Perspective on Uncertainty and Fishery Management

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Introduction

One fundamental problem with our current legal approach to managing fisheries – the Magnuson-Stevens Fishery Conservation and Management Act – is that we have turned a blind eye to the uncertainty that pervades our understanding of fish populations. We haven't yet shaped the law to reflect the fact that many of the most important decisions in fishery management are made within the gaps of science.

These gaps reflect uncertainty and ambiguity of many different kinds and textures (Charest 2002). Despite their differences, gaps present similar dilemmas to the legislator seeking to place controls on agency decisionmaking, to the agency official attempting to make a decision, and to the judge deciding whether agencies are complying with legal mandates. How can policymakers ensure that gaps do not serve as grants of unlimited authority to agencies? How does an official make a decision when presented with inconclusive science? How will a court know if an agency decision complies with the law when agency scientists say that the decision may or may not achieve its intended result?

The Magnuson-Stevens Act's National Standard Two bears directly on the issue of science and decisionmaking (U.S. Congress 1976). This legal provision requires that agency decisions must be based on the "best scientific information available". As a "science-based mandate," similar to those found in other environmental laws, it is neither in theory nor in practice an effective means of regulating gap decisionmaking. In fact, National Standard Two has created additional problems by providing an incentive for the Regional Fishery Management Councils and the National Marine Fisheries Service (the government bodies responsible for most fishery decisionmaking in the United States) to minimize the significance of gap decisions in their communications with the outside world, and to overemphasize the extent to which decisions are science-based. This is because the admission that a decision is not firmly based on science would almost certainly result in the decision being thrown out by a federal court on National Standard Two grounds. In hiding gap decisions, agencies deny Congress and the public opportunities to observe and participate in important policymaking (Wagner 1995).

In addition to issues of excessive delegation, effective court review, and transparency, we should of course also be concerned about gap decisions for the non-legal reason that they have a major impact on whether or not fishery management succeeds. The greater the uncertainty, the more such decisions matter. For a variety of obvious reasons, including the fact that its subjects live in a deep, dark ocean, fishery science is characterized by more uncertainty than other environmental sciences (Mangel 2000). Thus, gap decisionmaking is even more important in the fishery management context than it is in other areas of environmental and natural resources law.

After briefly describing the mechanics of the Magnuson-Stevens Act, I give some examples of the kinds of gap decisions regularly made in the course of fishery management. Next, I analyze the strengths and weaknesses of some possible approaches to regulating these decisions. I put these approaches into four categories: *a priori* rules, disclosure rules, institutional emphasis, and *ex post* review. Finally, I discuss some strategies for mitigating decision risks and for reducing the importance of gap decisions to fishery management success.

Fishery management under the Magnuson-Stevens Act

Passed in 1976, the Magnuson-Stevens Act established a complete system for the management of fisheries in the Exclusive Economic Zone (EEZ) of the United States. The Magnuson-Stevens Act created eight Regional Fishery Management Councils (councils) and gave those councils primary responsibility for managing fisheries in their respective regions (Eagle and Thompson 2003).

Council membership consists of mandatory and appointed members. Mandatory members are representatives of state and federal fishery agencies. Appointed members, by law, are required to be individuals who, by reason of their occupational or other experience, scientific expertise, or training, are knowledgeable regarding the conservation and management, or the commercial or recreational harvest, of the fishery resources of the geographical area concerned (U.S. Congress 1976). In practice, the majority of appointed members are representatives of fishing industry sectors—commercial, recreational, or seafood processing.

Under the Magnuson-Stevens Act, the councils have a broad array of management tools at their disposal. The councils set out the management tools to be used in a specific fishery in that fishery's Fishery Management Plan (FMP). These plans provide background on the fishery, management goals, and the council's plan for achieving those objectives. The most commonly used management tool, in most regions, is the annual quota or total allowable catch (TAC). An annual quota sets a level of catch (by weight) that the fishery as a whole should not exceed.

Although the FMP may authorize the use of annual quotas, the FMP document itself generally does not specify the quotas for each year. Instead, the councils typically establish year-specific quotas through an annual process that allows for the input of current information on stock status. By law, the federal Department of Commerce, through the National Oceanic and Atmospheric Administration (NOAA) and NMFS, must approve the quotas set by the councils.

The science used by the councils in setting annual quotas originates in five regional Fisheries Science Centers. These science centers are not under the direction or supervision of the councils. Rather, they are directed by NOAA, which spends over $300 million annually on fishery science. Although scientists at the NOAA science centers conduct most fish stock assessments, the science centers occasionally will coordinate or review assessments performed by state government fishery scientists or by researchers hired by fishing industry associations.

Once a stock assessment has been performed, and before a council uses the assessment as the scientific basis for quota-setting, several advisory bodies to the council will first review the assessment. The names and composition of these advisory bodies vary by council, although by law councils are required to establish at least one reviewing body—a Scientific and Statistical Committee.

The council will set the annual quota for the following fishing year at one of its regular meetings. Ordinarily, the council will make this decision following a formal presentation of scientific advice by the stock assessment authors, comments by one or more of the advisory bodies, and testimony from the public, including fishers. A simple majority of voting council members can adopt a quota (Eagle and Thompson 2003).

Gap decisions

Individuals and groups make gap decisions from the beginning to the end of the quota-setting process. The timing and setting of a decision is important when thinking about regulation. The kind of uncertainty or ambiguity involved also impacts the choice of potential regulatory strategies. The following three abbreviated, semi-hypothetical case studies provide good examples of gap decisions in fishery management. Although they are all based on actual cases, I have taken liberties in summarizing and simplifying them for the purposes of this paper. I have also taken the even bolder liberty of attempting to explain difficult concepts in fishery science. Despite the certain mistakes and oversimplifications, the explanations should serve the purpose of illustrating the kinds of gap decisions made in fishery management processes.

The first case study centers on the choice of an important life-history parameter for the stock assessment model used in managing the imaginary Atlantic greenfish fishery. The second case study focuses on the decision between two competing stock assessment models for another imaginary, but commercially important fishery, the yelloweye tuna fishery off the Pacific coast. The third case study describes a decision faced by managers of the commercial and recreational red jamba fisheries off the coast of the Carolinas.

Setting the natural mortality rate of greenfish

In 1997, an analysis of greenfish catch data that had been collected over the previous ten years by the Management Body's scientists showed that significant changes in the age structure of the greenfish population were occurring. Most striking was the fact that the percentage of the catch made up by fully mature adult greenfish had declined from about 70 per cent in the late 1980s to about 10 per cent in 1996. The scientists were concerned that this trend indicated that they had historically overestimated the biological productivity of greenfish. Some of the scientists suggested that they reexamine their long-time assumption that the natural mortality rate of greenfish was equal to 40 per cent.

The natural mortality rate (usually denoted as M) is meant to be an estimate of the rate at which fish of a particular age die. For example, when fishery scientists state that M = 40% for adult greenfish, it means that 40 per cent of all adult greenfish die each year of natural causes. When fishery scientists use the term "natural causes," they do not mean to say that the fish die peacefully in their sleep. Instead, they mean that a certain percentage of fish die (probably violently) each year from causes other than fishing predation by humans. The M parameter is particularly important in stock assessment models because it has a strong bearing on the assessment's ultimate prediction of how many fish humans can catch. Fish populations with high natural mortality rates produce replacements at similarly high rates;

otherwise, populations would go extinct even in the absence of fishing. More productive stocks can sustain higher rates of fishing than less productive stocks.

The Management Body's scientists reviewed the published scientific literature and found that no one had ever measured the natural mortality of greenfish. In fact, no scientist had yet developed a reliable method for measuring natural mortality rates in wild fish. There were two methods for approximating these rates. First, scientists simply monitored a captive population (such as an aquarium population) over a number of years. Second, scientists used tag and recapture studies: after tagging a sample of wild fish, scientists then collect data from fishermen on the number of tagged fish caught. Some part of the difference between the two numbers represents fish that perished naturally. For obvious reasons, both of these methods were prone to substantial error.

The Management Body scientists found that the estimate of M=40% that had been used for more than 20 years in greenfish management was the same estimate that was frequently used by scientists around the world in assessing a variety of stocks. The estimate was based on three studies of captive fish populations, and one tag and recapture study, which variously estimated the range of M to be from 20 to 60 per cent. On average, these four studies estimated the natural mortality rate to be 40 per cent. The problem for the greenfish scientists was that none of these four studies were studies of greenfish. They were studies of four other species. While each of those species had some biological attributes in common with greenfish, the Management Body's scientists could not be sure which species provided the best M proxy for greenfish.

The scientists ran their assessment model three times, using three different estimates of M – 20, 40 and 60 per cent. If the 20 per cent estimate was used, then the model showed the greenfish population to be in dire straights. The model predicted that even reducing current catch levels by three-fourths would merely stabilize the stock's downward trajectory; only a cessation of fishing for 40 years would allow the stock to recover or "rebuild" to optimal levels. On the other hand, the 40 per cent M estimate resulted in a prediction that catches need only be reduced by about 10 per cent in order for the stock to rebuild within ten years. When scientists used the 60 per cent estimate in the model, it suggested that the stock would probably rebuild sometime in the next five to ten years without any catch reductions at all.

Choosing a stock assessment model

Commercial fisheries have targeted the valuable yelloweye tuna off the Pacific coast since the early 1960s. From the inception of the fishery until the mid-1970s, U.S. and foreign fleets caught significant numbers of fish of all ages. In the late 1970s, the Management Body began to develop its first fishery management plan for the yelloweye. In 1982, after determining that it was overfished, the Management Body implemented a recovery strategy for yelloweye based on annual quotas.

Scientists performing yelloweye tuna stock assessments used the same stock assessment model, known as the Traditional Model, from 1982 until 1998. During this time, the annual quota strategy did not appear to bear results. Scientists continued to consider the yelloweye overfished throughout this period, and their estimates of the adult population showed a slow but steady downward trend. In 1998, the Management Body invited a group of outside scientists to present its Committee on Research and Statistics with an alternative model, known as the Modern Model.

The two models contained very different assumptions about the relationship between the size of the adult population and the rate at which new adults ("recruits") entered the population each year. In the Traditional Model, scientists assumed that a larger adult population would produce more recruits. If there were twice as many adults, there would be almost twice as many recruits. In the Modern Model, the size of the adult population was not the primary determinant of recruitment. Rather, the number of annual recruits varied with changes in ocean conditions. So long as the adult population remained above some minimum threshold, it would remain capable of producing the same number of recruits as an adult population twice its size.

The Management Body asked its stock assessment scientists to assess the impact of three different annual quota options, each implemented for ten consecutive years. Under Option 1, the fleet could catch 3,000 tons each year; under Option 2, 1,500 tons; and, under Option 3, the Management Body would allow no catch at all for ten years.

The models generated vastly different predictions regarding the impact of catches on the stock's ability to rebuild under these scenarios. The Traditional Model predicted that Option 3 (no catch) would rebuild the stock in 25 years. The stock would not rebuild at all, but would remain in steady decline under Option 2. Under Option 1, the highest level of catch modeled, the yelloweye tuna population would go extinct within ten years. On the other hand, the Modern Model predicted that each of the options would rebuild the stock. Under the high-catch option, Option 3, the stock would be rebuilt within ten years; under Option 2, seven years; and, under Option 1, it would be rebuilt in five years.

Setting quotas for red jamba

March 4, 2005In the case of the red jamba, the target of valuable recreational and commercial fisheries, the Management Body's stated goal was to rebuild the overfished stock to a healthy level within ten years. Scientists had considered the red jamba to be overfished since 1985. In 1996, for the first time, scientific advisors presented their advice to the Management Body in the form of a probability table. In this very simple table, the advisors gave theirFig. 1: Probability table for red jamba quota-setting.
estimates of the probabilities that various annual quotas had of keeping the red jamba stocks on a ten-year recovery trajectory. (See Figure 1 for a replica of this chart.) The chart showed that while a quota of zero had a 100 per cent chance of keeping the stock on the right trajectory, extremely high quotas had nearly a zero per cent "chance of success." It showed that a 10,000-ton quota had a 25 per cent chance of success; a 5,000-ton quota, a 50 per cent chance, and, a 2,500-ton quota, a 75 per cent chance.

Quota (tons)	**Percent chance of remaining on rebuilding trajectory**
2,000	<1
15,000	10
10,000	25
5,000	50
2,500	75
0	100

Fig. 1: Probability table for red jamba quota-setting.

Regulating gap decisionmaking

There are three reasons why it is desirable from a legal perspective to regulate gap decisionmaking by agencies and agency officials, including scientists. First, in order to ensure that they act as agents of the legislature (or of treaty-writers, in the case of an international agreement), we need to constrain agencies (or commissions) to some extent. Put in practical terms, while it is useful, or usefully exigent, for legislators to delegate some policymaking power to groups such as the Regional Fishery Management Councils or our hypothetical Management Bodies, it is not desirable to give them the power to override the stated goals of legislation. Second, outsiders such as courts and the public need to have some way to measure whether or not agencies are actually implementing the laws they are charged with implementing. Citizen oversight through lawsuits and the threat of lawsuits is an important check on agency decisionmaking, and without some kind of measurable standard, courts are not easily able to review agency decisions (Thompson 2000). Finally, as a general matter of policy, we want agencies to be very open about the nature of the decisions they make. Transparency is an important democratic value. Furthermore, many gap decisions are policy decisions that would benefit from public input (Cuellar 2004). If the policy component of decisions is not clear, then the public cannot participate in a meaningful way (Wagner 1995).

There are four different approaches to regulating gap decisionmaking. Below I try to highlight the strengths and weaknesses of each, using examples from the three mini-case studies.

***A priori* rules**

One approach to regulating gap decisions is to have rules in place ahead of time, in the relevant statute or regulations, that tell decisionmakers how they should make decisions when faced with uncertainty or ambiguity. The current science-based mandate in the Magnuson-Stevens Act, National Standard Two, is one example of such as rule. This provision, however, merely instructs decisionmakers to use the "best scientific information available." What kind of practical guidance does it provide to the hypothetical Management Bodies? What is the best scientific information available on greenfish mortality rates or on the assumptions in the yelloweye models? In the case of greenfish, most scientists would probably feel uncomfortable arguing that any of the four prior studies is the "best" science, at least with respect to greenfish. There is no direct evidence in any of the studies bearing on the natural mortality rate of greenfish.

In the yelloweye case, the two models were both supported by different groups of scientists. Assuming that all of the scientists are all equally well-qualified, whose model is the "best" science? In the case of the red jamba probability distribution, what is the best science? All of the probabilities are supported by science; if the Management Body chooses a quota with a 5 per cent chance of success, are they following or disregarding the best available science?

Others have argued for a different interpretation of National Standard Two. Under this interpretation, the emphasis is on the word "available," not "best" (Rieser 2004). Thus, if very little information were available, as in the case of the greenfish, any choice of natural mortality rate parameter would be legally justifiable. Use of this interpretation has two benefits. First, it removes agencies' incentive to hide gap decisionmaking. Second, it allows agencies to take a precautionary approach to management. They are able to act with only very little scientific information, and the "quality" of that science – however measured – is not in issue. Even under this interpretation, though, National Standard Two does not give practical guidance to decisionmakers, nor does it limit agency discretion. If anything, it increases agency discretion and reduces opportunities for judicial review.

The precautionary principle itself is another example of an *a priori* rule. The most commonly cited version of this principle, found in Principle 15 of the Rio Declaration on Environment and Development of 1992, states that "lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (United Nations Conference on Environment and Development 1992). The principle could be viewed as requiring decisionmakers to take a conservative tack when operating within the gaps of uncertainty (Charest 2002). So, for example, in the case of the greenfish, the relevant decisionmaker perhaps ought to choose the lowest estimate of M, and in the case of yelloweye, it ought to pick the more conservative model. That seems clear enough, but what happens if, the following year, another group of equally qualified scientists introduces a third, even more conservative model? Are the decisionmakers obligated to use that model? Also, the precautionary principle provides no guidance to decisionmakers in the red jamba case. The only conclusion it would point to in that case would be a quota of zero; can this be the correct result?

The final example of an *a priori* rule is one that was created by a federal court in a recent case involving management of summer flounder on the Atlantic coast of the United States (*Natural Resources Defense Council v. Daley*, 209 F. 3d 747 (D.C. Cir. 2000)). In this case, a federal Court of Appeals overturned both the Mid-Atlantic Council's and the National Marine Fisheries Service's choices of quotas for the Atlantic summer flounder fishery. When presented with scientific advice that laid out various quota choices and the corresponding probabilities that those choices would result in successful management for the upcoming year, the Mid-Atlantic Council had chosen the quota with a 3 per cent chance of achieving the sought-after fishing mortality (another fishery science term meaning "number of dead fish"). The National Marine Fisheries Service, in one of the rare cases where it has overruled one of the regional councils, rejected the 3 per cent choice and substituted its own choice, a quota that had an 18 per cent chance of killing the "safe" amount of fish. While the first federal court to hear the case ruled in favor of the agency, the Court of Appeals overturned the lower court's decision and issued a ruling holding that a management measure must have at least a 51 per cent chance of success.

Does the "slightly more than Solomon" rule created by the Court of Appeals provide a viable option for regulating future decisionmaking? While it does provide clear guidance, it also raises some difficult questions. Is 51 per cent good enough? While it might be good enough in the context of fishery management, it probably is not in other contexts, such as endangered species protection or toxic waste management. It will set a floor for agency decisions, but will it also induce agencies to act less conservatively than they otherwise would have? What does it mean for cases like the yelloweye tuna, where the relative probabilities of the competing hypotheses are not known? Finally, like the precautionary approach, it is subject to manipulation by scientists: how would the subsequent introduction of a third yelloweye model change the result of the decision process?

Disclosure

A second approach to dealing with gap decisions is through stronger and more specific disclosure requirements (Wagner 1995). The idea is that while it might be impossible to directly regulate the way agency decisions are made, it is possible to mitigate some of the problems created by decisionmaking through greater transparency.

For example, the statute could require agency scientists and officials who are involved in assessment processes to keep careful logs of the decisions they made and the scientific information they reviewed before making those decisions. When an agency scientist chose to use 40 per cent as the natural mortality rate of greenfish, she would indicate what the other choices were and why she chose 40 and not 60 or 20. The law, and the instructions on the form used, would be clear that "professional judgment" is an acceptable explanation (Wagner 1995). The form would then be made available to the public when the notice of the proposed rule is published as required by law (Eagle and Thompson 2003).

The use of such Scientific Advice Documents, or SADs (an unfortunate acronym to be sure), would not only increase the openness of the decisionmaking process. As Wagner points out, it would allow for meaningful challenges to agency use of science. Instead of futilely litigating the question of whether or not a particular measure is based on science, interested parties would be able to challenge agency transparency. For example, failing to note that the figure it chose to use for the natural mortality rate of greenfish was based on four studies of other species and some professional judgment would require the agency to go back and redo its SAD. Agencies would be free to make decisions with minimal scientific support so long as they were honest about what they use. While the SAD approach would add some workload to individual scientists, it would also relieve those individuals (and their supervisors) from the burden of painting weak science as "sound science" in half-hearted attempts to meet the requirements of science-based mandates (Wagner 1995).

The disclosure approach, of course, only addresses one and a half of the three legal problems. It directly clears up the transparency problem. It solves half of the judicial review problem by creating something for courts to review. It would not, though, provide a means for courts (or citizen watchdogs) to put limits on agency discretion. In fact, it would perhaps increase agency discretion by acknowledging and legitimating it. However, it might well be that agencies and officials would be far more careful about how they made decisions if they had to reveal the extent to which they did *not* rely on science in making them.

Institutional emphasis
A third approach would be to focus not on the process of decisionmaking, but on the identity of the decisionmakers. In other words, if our policy objective is to have conservative decisionmaking, then we can choose decisionmakers who are likely to be conservative in their choices. Or, if our objective is to have balanced decisionmaking, we can create a representative and accountable decisionmaking body.

Separating conservation from allocation
One possibility would be to separate out the conservation decisions from the allocation decisions (Eagle, et al. 2003). Under this approach, one decisionmaker (or decisionmaking body) would be responsible for making decisions that have an impact on the health of the fish populations and the marine environment. Another would be given responsibility for allocating the catch between competing user groups.

The idea here is that conservation questions are fundamentally different than allocation questions, in large part because of their scientific context. While it is true that the two kinds of decisions are different, the case studies show that many conservation decisions made as part of the assessment and management process are not scientific questions. The clearest example is that of the red jamba, where the decision is more accurately described as one about risk than one about science. Even in the other cases, however, it is unclear who would be best qualified to make gap decisions.

On the one hand, we might think of a gap decision as similar to an art appraisal. While an experienced art appraiser may not have direct information about the market worth of a unique painting, she would be better suited to estimate its worth than would the average person. Similarly, though greenfish scientists may not have direct information on the fish's natural mortality rate, they might be best suited to estimate that parameter, based on their experience in the field. On the other hand, it is also possible to see the estimation of a natural mortality rate as a policy choice between a high-risk option for management, (60 per cent), a low risk option (20 per cent), and a mid-range option. If it is a policy choice, then wouldn't it perhaps be more desirable for the decision to be made by accountable public servants in a transparent forum?

There is no easy answer to this dilemma. As a practical matter, it may be difficult to bring a large number of questions, especially questions encased in technical terminology, into a public forum (Cuellar 2004). Even if we created the accountable body to make these decisions, it is unlikely that the public would hold anyone politically accountable for overestimating natural mortality rates. On the other hand, leaving responsibility with the scientists creates the possibility that policy will be made in a non-transparent way. In addition to depriving the public of an opportunity to participate, this approach would probably diminish the public's confidence in the decisions.

Council reform
An alternative to separating conservation from allocation would be to simply add diversity and accountability to the Regional Fishery Management Councils (Eagle, et al. 2003). Whether or not one supports the current system of council appointments, which has led to numerical domination of the councils by industry representatives, it is hard to argue that the system has created representative and accountable bodies. More than half of all voting council members, appointed and non-appointed, are representatives of groups with vested financial interests in the outcome of the gap decisions councils

must continuously make. In addition, the accountability of the council system is severely compromised by the fact that neither a federal agency nor Congress can remove council members from office (Eagle, et al. 2003).

The statute could be amended to rearrange or eliminate the councils. Congress could give responsibility for fishery decisonmaking directly to a federal agency, such as the National Marine Fisheries Service or the U.S. Fish and Wildlife Service. If it wanted to keep the councils, Congress could try to mandate diversity in membership, and it could increase members' accountability by giving itself the power to appoint and remove council members (Eagle, et al. 2003).

While institutional reform does not directly address the problems of transparency, delegation, or judicial review, such an approach may ironically be the most effective means of regulating gap decisionmaking. This is in large part due to the fact that regulating decisionmaking with *a priori* rules is so difficult. It is impossible to create rules that will cover every potential gap decision. In addition, an informational approach would only work to the extent that *someone* from the outside world paid attention to the decisionmaking process. By reshaping the decisionmaking institutions, we minimize the need for watchdogs by incorporating them into the process.

Review

The final approach to regulating gap decisionmaking is to mandate some form of post-decision review. This can be in the form of additional scientific or peer review, administrative review by agency officials, or judicial review by courts. While the "two heads are better than one" concept is appealing at first blush, it does not hold a great deal of promise in the context of gap decisions. First, it seems more efficient to create a system that gets it right the first time, rather than one that depends on regular intervention after the fact. Second, effective review of any kind requires measurable standards. As we have seen, these are difficult to develop. Finally, additional scientific or peer review of gap decisions does not make a great deal of sense because these decisions are not "based on science." In the best-case scenario, peer review of a gap decision would produce a second opinion; under a more probable scenario, it would simply lead to a delay of the management process.

Technology-based approaches as replacement or insurance

As Oliver Houck pointed out in a recent article, science-based environmental laws (such as the Magnuson-Stevens Act) have proven largely ineffective. This is because science cannot tell us what is safe: "while [it] is endlessly fascinating and constantly revelatory, [science] is rarely dispositive. And in the world of environmental policy, that which is not dispositive is dead on arrival" (Houck 2003). In other words, gap decisions are a major obstacle to the successful implementation of science-based environmental laws.

Houck provides evidence to support the claim that the alternative, a technology-based approach, has proven far more successful. This is because the implementation of technology-based laws is less dependent upon gap decisionmaking. Instead of focusing on how much of a particular activity is safe, agencies identify technologically and economically feasible ways to reduce the harm or potential harm caused by the activity. For example, instead of trying to decide how much pollution an automobile can safely emit, an agency requires that all automobiles use the best available mufflers. In addition to reducing gap decisionmaking, technology-based laws are easier to enforce – the car either has a conforming muffler or it does not.

If the poor track record of fishery management in the United States is an indicator of implementation difficulties, then marine fisheries are ripe for the application of a technology-based approach to management. Such an approach would include the mandatory use of certain technologies that are proven to increase ocean health such as the exceedingly low-tech "invention" of marine reserves, or no-fishing areas, that are akin to the ancient agricultural practice of fallowing fields.

At the same time, measures banning fishing gear that is particularly harmful to certain areas of the ocean, or to certain species in certain areas, would likely achieve far greater success than the current science-based approach. There are many examples around the world of cases where these kinds of technology-based approaches have succeeded. In Alaska, for example, salmon fisheries have done well (at least the stock-levels have remained high) because there are strict limits on the kinds of boats and gear that can be used for fishing. Similarly, one of the greatest achievements of marine conservation in the past twenty years has been the reduction of the number of dolphins killed by purse-seining gear in the Eastern Tropical Pacific (Hall 1996). Although there is still concern regarding the impact of the new fishing methods being employed there, it is clear that eliminating the former method has produced some significant improvements.

As Houck predicts, these measures are easier to implement because better technologies are simply identified, and then used. Enforcement is much simpler: A boat is either fishing over dolphins (and not backing off), or it is not; a boat is fishing in a closed area, or it is not.

Conclusion

No one of the above approaches to regulating gap decisionmaking is a panacea. The best strategy is a combination of an informational approach and institutional reform. While the informational approach relieves agencies of the burden of overstating the scientific case for their decisions by allowing them to bring embedded policy decisions into the light, institutional reform increases the likelihood that more balanced policy decisions will be made. At the same time, we ought to consider whether a "science-based" law, by itself, gives enough assurance of healthy oceans over the long-term.

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Climate Change and Pacific Island Developing Countries: Implications for Coastal Resources

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Introduction

As one commentator has observed, "one ironic and tragic aspect of this environmental crisis of greenhouse emissions is the fact that those parts of the world least responsible for creating the global warming problem will be the first to suffer its horrifying consequences."[1] Pacific Island Developing Countries (PIDCs) are responsible for only 0.03percent of the world's carbon dioxide emissions, and the average island resident produces only one quarter of the emissions of the average person worldwide.[2] However, it is anticipated that these nations will experience some of the earliest and most severe consequences of climate change over the next two centuries.[3] Some of the most serious ramifications for these nations may be for built and natural coastal resources. This chapter focuses on these potential impacts and possible adaptation responses. In this pursuit, I will, first, provide an overview of PIDCs, second, outline climate change science and projected trends globally and for PIDCs over the next century and beyond; third, outline the potential impacts of climate change on the coastal resources of PIDCs, and finally, set forth some potential mitigation and adaptation responses.

PACIFIC ISLAND DEVELOPING COUNTRIES AND COASTAL RESOURCES

Overview of PIDCs

There are nearly 30,000 islands in the Pacific Ocean, 1000 of which are populated.[4] Polynesian peoples populated Tonga, the Cook Islands and French Polynesia during the present interglacial period.[5] Melanesian peoples began to colonize the high islands of the western Pacific (Papua New Guinea, Solomon Islands, Vanuatu, and New Caledonia) as far back as 40,000 years ago,[6] millennia before settlement began in Europe,[7] and Micronesian peoples settled on many low islands, such as Micronesia and the Marshall Islands in the last 2000 years.[8]

PIDCs consist of 22 political entities, 15 of which are politically independent,[9] spread out over 11 million square miles of ocean[10] (see Table 1). Almost all PIDCs lie between 30º north and 30º south latitude, between the Tropic of Cancer and the Tropic of Capricorn in the southwestern portion of the Pacific.[11] With the exception of Papua New Guinea and Fiji, all PIDCs fall within the United Nations' definition of "small island states," which are islands with less than 10,000 square kilometers in land mass and with less than 500,000 inhabitants.[12] The majority of countries in the region fall well below these thresholds, with populations of less than 200,000 and land areas well below 1,000 square kilometers, and many fall into the category of "very small islands," with land areas less than 100 square kilometers or a maximum width of 3 kilometers.[13] The combined population of PIDCs in the region are slightly over six million, with the lion's share in Papua New Guinea.[14]

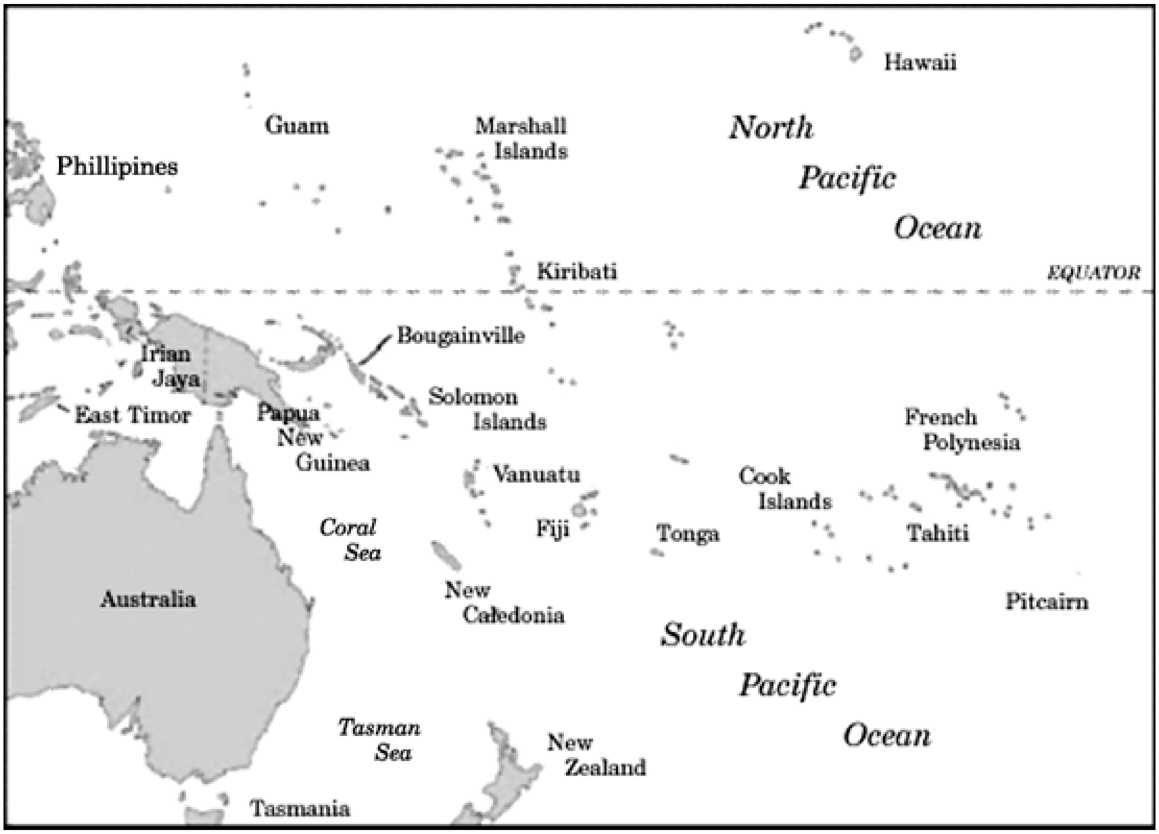

Figure 1: Pacific Island Developing Countries

Pacific islands are traditionally classified as "high" or "low," with a further subdivision into continental and volcanic islands in the former category and atolls and raised limestone islands on the other.[15] In most cases, PIDCs are a combination of these island types (see Table 2).[16] High islands primarily consist of rugged volcanic mountains surrounded by fringing or barrier reefs. They may also have a fringe of low-lying coastal plains surrounding the mountainous interior. Atolls consist of limestone reef deposits laid down on an underlying volcanic cone. In most cases, the portion of atolls above sea level is usually not more than a few square kilometers.[17] Raised atolls are uplifted coral atolls, some rising 60-70 meters above sea level, which consist almost entirely of limestone and dolomite.[18] Five countries in the Pacific are comprised entirely of low-lying atolls.[19]

COUNTRY	POLITICAL STATUS	POPULATION (2003 EST.)	LAND MASS (SQ. KM.)
America Samoa	Territory of the United States	70,264	199
Commonwealth of the Northern Marianas	Commonwealth in political union with the United States	80,006	477
Cook Islands	Self governing, in free association with New Zealand	21,008	240
Federated States of Micronesia	Independent Nation	108,143	702
Fiji	Independent Nation	868,531	18,270
French Polynesia	Overseas territory of France	262,125	4,167
Guam	Territory of the United States	163,941	541.3
Kiribati	Independent Nation	98,549	717
Nauru	Independent Nation	12,570	21
New Caledonia	Overseas territory of France	210,798	19,060
Niue	Self-governing, in free association with New Zealand	2,145	260
Palau	Independent Nation	19,717	458
Papua New Guinea	Independent Nation	5,295,816	462,840
Pitcairn Islands	Overseas territory of the United Kingdom	47	47
Republic of the Marshall Islands	Independent Nation	56,429	181.3
Samoa	Independent Nation	178,173	2,860
Solomon Islands	Independent Nation	509,190	28,450
Tokelau	Territory of New Zealand	1,418	10
Tonga	Independent Nation	108,141	748
Tuvalu	Independent Nation	11,305	26
Vanuatu	Independent Nation	199,414	14,760
Wallis and Futuna	Overseas Territory of France	15,734	274

Table 1: Profile of Pacific Island Developing Countries.[20]

COUNTRY	**TERRAIN**
America Samoa	5 Volcanic islands and 2 coral atolls
Commonwealth of the Northern Marianas	Limestone (southern islands); volcanic (northern islands)
Cook Islands	Coral atolls (north); volcanic (south)
Federated States of Micronesia	High volcanic islands; low coral atolls
Fiji	Primarily mountains of volcanic origins
French Polynesia	Rugged high islands and low atolls
Guam	Volcanic origin, limestone plateau
Kiribati	Primarily low-lying atolls
Nauru	Raised atolls
New Caledonia	Coastal plains with interior mountains
Niue	Raised atolls
Palau	High mountainous islands to low coral islands
Papua New Guinea	Primarily mountainous with coastal lowlands
Pitcairn Islands	Rugged volcanic formation
Republic of the Marshall Islands	Raised atolls
Samoa	Narrow coastal plain with volcanic, rocky, rugged mountains in interior
Solomon Islands	Primarily rugged mountains with low coral atolls
Tokelau	Low-lying coral atolls enclosing large lagoons
Tonga	Limestone bases with uplifted coral formation; limestone overlying volcanic bases
Tuvalu	Very low-lying and narrow coral atolls
Vanuatu	Primarily mountains of volcanic origin
Wallis and Futuna	Volcanic origin, low hills

Table 2: Terrain of Pacific Island Developing Countries[21]

CLIMATE CHANGE AND PIDCS

Climate Change Science: An Overview

The surface of the Earth is heated by solar radiation emanating from the sun at short wavelengths between 0.15 and 5 µm. Each square meter of the Earth receives an average of 342 watts of solar radiation throughout the year.[22] Approximately one-third of the incoming solar radiation is reflected back to space in the form of thermal infrared, or longer-wave radiation, at wavelengths of 3-50 µm.[23] Of the remainder, a portion is partly absorbed by the atmosphere, but most (168 watts per square meter) is absorbed by land, ocean and ice surfaces.[24]

Some of the outgoing infrared radiation is absorbed by naturally occurring atmospheric gases—principally water vapor (H_2O)—as well as carbon dioxide (CO_2), ozone (O_3), methane (CH_4), nitrous oxide (N_20) and clouds.[25] This absorption is termed the "natural greenhouse effect" because these gases, which are termed "greenhouse gases," operate much like a greenhouse: they are "transparent" to incoming short-wave radiation, but "opaque" to outgoing infrared radiation, trapping a substantial portion of such radiation and re-radiating much of this energy to the earth's surface.[26] This process is critical to the sustenance of life on earth, elevating surface temperatures by about thirty-three degrees Celsius.[27]

In the past, the net incoming solar radiation at the top of the atmosphere was balanced by net outgoing infrared radiation, contributing to climatic stability.[28] However, with the advent of fossil fuel burning plants to support industry, automobiles and the energy demands of modern consumers, "humans began to interfere seriously in the composition of the atmosphere."[29]

The burning of fossil fuels, mainly coal, oil and gas, has soared since the beginning of the Industrial Revolution, producing approximately 5.5 gigatons of carbon annually in recent years, nearly all of which enters the atmosphere as $C0_2$.[30] As a consequence, concentrations of carbon dioxide in the atmosphere have increased approximately twenty-five percent since 1850[31] from 270-280 parts per million (ppm) by volume in pre-industrial times to 379 ppm today,[32] with half of this increase occurring since 1965.[33] These concentrations have not been exceeded in the past 420,000 years,[34] with the increase over the last century "unprecedented" in the last 20,000 years.[35] Anthropogenic activities have also resulted in substantially increased atmospheric concentrations of other greenhouse gases, including methane and nitrous oxides,[36] as well as new sources, such as chlorofluorocarbons and halons.[37] Tropical land use changes from the clearing of natural vegetation and secondary forests adds approximately another 2.4 gigatons annually to the atmosphere, representing 29 percent of the combined total of anthropogenic emissions.[38]

Increases in the concentration of greenhouse gases reduce the efficiency with which the Earth's surface radiates to space. This results in an increased absorption of the outgoing infrared radiation by the atmosphere, with this radiation re-emitted both up to space and back down to Earth's surface.[39] As a consequence, the Earth's surface warms further and emits infrared radiation until the emitted radiation reaches a balance with the incident sunlight and other forms of energy.[40]

The latest assessment by the Intergovernmental Panel on Climate Change (IPCC)[41] concluded that rising concentrations of greenhouse gases are the primary cause[42] for the increase in average global temperatures of about 0.75° C in the past century.[43] In the Northern Hemisphere, "the increase in temperature in the 20th century is likely to have been the largest of any century during the past 1000 years."[44] Seventy percent of the increase of anthropogenic greenhouse gas emissions has occurred since 1950, as has the lion's share of warming since the late 19th Century.[45]

In the South Pacific, surface air temperatures have increased by 0.3-0.8° C during the 20th Century, with the greatest increase in the zone southwest of the Southern Pacific Convergence Zone.[46] Temperature increases in this region are well in excess of global rates over the past century.[47]

Unfortunately, as indicated in the next section, the unprecedented increases in temperatures over the last century are likely to be ratcheted up dramatically over this century, including in PIDCs.

CLIMATE CHANGE IN THE 21ST CENTURY: GLOBAL AND REGIONAL PROJECTIONS

Global Projections

Predicting future climate is an extremely imposing task because it requires an assessment of the future state of a wide array of complex climatic components, including the atmosphere, the ocean, the cryosphere, land surfaces, the stratosphere and the sun.[48] "Climate is commonly understood . . . as the product of the interaction of thermodynamics (the movement of heat) and dynamics (the atmospheric and oceanic circulation)."[49] The only practical method to make such projections is through the use of mathematical models, derived from weather forecasting, to represent the physical, chemical and biological processes that determine climate.[50]

The most sophisticated of these models, general circulation models (GCMs), use a three dimensional grid overlaying the surface of the earth with grid points 300-500 kilometers per side, within which cells are stacked about twenty layers deep.[51] Coupled atmosphere-ocean general circulation models seek to integrate atmosphere and ocean GCMs with sea ice models and those of land surface processes in an effort to obtain a realistic simulation of the Earth's climatic system, including feedbacks between these components.[52]

The vertical layers of a GCM represent levels in the atmosphere and depths in the ocean, dividing the surface of the planet into a series of horizontal boxes separated by lines similar to latitudes and longitudes.[53] Within each grid point, a series of equations are run on a super-computer, producing simulations of key climatic components, including wind, air-pressure, temperature, humidity, ice coverage and land surface processes.[54]

Climate models are usually run for several simulated decades, with the derived results compared to actual statistics on climatic indicia over this period, such as mean temperatures and precipitation. The models are then run with changes in external forcing, such as projected increases in atmospheric greenhouse gas concentrations, over a series of decades or centuries. "The differences between the two climates provide an estimate of the consequent climate change due to changes in that forcing factor."[55]

Greenhouse gas emissions are anticipated to rise by an additional 50 percent over the next few decades,[56] substantially accelerating the buildup of greenhouse gases in the atmosphere. The IPCC projects that by 2100 stratospheric carbon dioxide concentrations will have risen 90-250 percent above pre-industrial levels, to 540 to 970 parts per million.[57] This will result in an increase of globally averaged temperatures of 1.4 to 5.8° C by the end of this century, "very likely to be without precedent during at least the last 10,000 years."[58] In a subsequent study, Wigley and Raper sought to assess the IPCC's projected temperature range in probabilistic terms, concluding that the likeliest increase, with a 50 percent probability, will lie between 2.4-3.8° C, with further warming through the 22nd Century "virtually certain."[59]

The IPCC assessment also concluded that global mean sea level would rise by 9 to 88 centimeters by 2100 (with a mid-range estimate of approximate 50 centimeters) due to thermal expansion and the loss of mass from glaciers and ice caps.[60] This is equivalent to a 200-500 percent acceleration over sea-level rise in the 20th Century.[61] The United Kingdom's Hadley Centre's most recent climate change assessment concluded that sea levels will rise by 50 centimeters by 2100 if projected increases in greenhouse gas emissions are not reduced.[62] Moreover, the large thermal capacity of the oceans ensure that sea levels will continue to rise even after atmospheric concentrations of greenhouse gases are stabilized, rising by between 95 and 120 centimeters during the 22nd Century.[63]

More forebodingly, a recent study that focused on the potential impacts of warming on the Greenland ice-sheet concluded that if annual temperatures increase by more than 3° C in the region, which is highly likely by the end of this century, globally averaged sea-levels could increase by *7 meters* over a period of 1,000 years or more.[64] The study concluded that the projected sea-level rise could prove to be irreversible because the ice-sheet might not be regenerated.[65]

CLIMATE CHANGE IN PIDCS

Limitations of Regional Assessments of Climate Change

It must be emphasized at the outset of this section that general circulation models remain a crude instrument for assessing regional climate trends because their resolution is often too coarse at this level:

> [General circulation models] have difficulty in reproducing regional climate patterns, and large discrepancies are found among models. In many regions of the world, the distribution of significant surface variables, such as temperature and rainfall, are often influenced by the local effects of topography and other thermal contrasts, and the coarse spatial resolution of the GCMs can not resolve these effects.[66]

Resolution problems with GCMs are particularly acute for small landmasses in oceanic regions.[67] In the case of PIDCs, many of the circulation features that dominate the climate of the islands in the region are inadequately simulated by the current generation of GCMs.[68]

However, modeling of regional climate conditions has improved substantially in the past few years. In its most recent assessment of climate change impacts on small island states, the IPCC conducted a model validation exercise to assess the ability of leading GCMs to simulate present-day climate in the four major regions where the majority of small islands are located, including the Pacific. It concluded that several models "have reasonable capability in simulating the broad features of present-day climate and its variability over these regions."[69] Moreover, Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) has "nested" a higher resolution regional climate model within a GCM. The nested model is able to broadly simulate climatic conditions in the Pacific, although it diverges substantially from observed patterns of rainfall.[70]

With the caveat that regional climate assessments remain speculative, the following section summarizes current projections of climate change in PIDCs by the IPCC and CSIRO.

Climate Change and PIDCs in the 21st Century

The IPCC in its Third Assessment Report projects that temperatures in the Pacific will rise by approximately 2.0º C by 2050 and 3.0º C by 2080.[71] While it is anticipated that temperatures in the region will rise less than global mean averages over the next century,[72] it will constitute a dramatic increase over the substantial rise witnessed in the 20th century. CSIRO's projections are consistent with this assessment, though its analysis reveals differential temperature increases in the region, with the greatest increases in north Polynesia (0.7-0.9º C) and the least warming in south Polynesia (0.7º C).[73]

The IPCC Third Assessment projects that sea levels may rise in the region by as much as 5 millimeters per year over the next century,[74] and continue to rise in the 22nd Century due to lags in the climate effect.[75] Moreover, sea-level rise will raise the baseline for storm surges,[76] significantly increasing the vulnerability of coastal areas to inundation.[77]

Several GCMs also predict more frequent El Niño/Southern Oscillation (ENSO)-like patterns.[78] This could result in a 26-200 percent increase in rainfall over the central and east-central Pacific, with possible decreases in the Melanesian and Polynesian regions.[79] Additionally, warming could also lead to increased extreme rainfall intensity and frequency. One model projects a doubling of the frequency of 100 millimeter per day rainfall events and a 15-18 percent increase in rainfall intensity over large areas of the Pacific.[80]

Projected buildups in greenhouse gas emissions will likely raise ocean temperatures and ocean surface water temperatures to above 26º C in the next century.[81] This could result in a greater exchange of energy and add momentum to the vertical exchange processes critical to the development of tropical typhoons and cyclones. Therefore, some researchers estimate that the occurrence of tropical typhoons and cyclones could increase by as much as 50-60 percent under a scenario of the doubling of atmospheric carbon dioxide concentrations from pre-industrial levels,[82] and their intensity by 10-20 percent.[83] Even small increases in storm event severity can result in substantial increases in damage through the exceedance of critical thresholds,[84] with a 10-20 percent increase in intensity "creating potentially catastrophic impacts from waves, storm surges and wind."[85]

However, there is by no means universal agreement that climate change will visit an increase in violent weather events on PIDCs. Some researchers believe that the purported linkage between increased ocean temperatures and violent weather events is overly simplistic, citing other factors that influence storm development, including atmospheric buoyancy, instabilities in the wind flow, and vertical wind shear.[86] Moreover, some climate scientists argue that ocean circulation changes associated with climate change may counter the effects of added warmth.[87] In its most recent regional assessment report, the IPCC concluded that "[t]here is no consensus regarding the conclusions of studies related to the behavior of tropical cyclones in a warmer world … current information is insufficient to assess current trends, and confidence in understanding and models is inadequate to make firm projections."[88] However, the IPCC did conclude, with "moderate confidence," that the intensity of tropical cyclones is likely to increase by 10-20 percent in the Pacific region when atmospheric levels of carbon dioxide reach double pre-industrial levels.[89]

POTENTIAL IMPACTS OF CLIMATE CHANGE ON PIDC COASTAL RESOURCES

Inundation of Coastal Regions

As indicated above, it is anticipated that sea levels will rise substantially in the Pacific region over this century.[90] This has foreboding implications for both human built resources in coastal areas of PIDCs. Low-lying atoll states in the South Pacific are extremely vulnerable to even small rises in sea level. For example, a one-meter rise in sea level could result in the loss of 80 percent of the Majuro atoll in the Marshall Islands, home to half the nation's population, as well as 12.5 percent of the landmass in Kiribati,[91] and two-thirds of low-lying islands of Vanuatu.[92] Erosion associated with sea level rise and storm surges would further reduce land area, as well as increase the swampiness and salinity of land that remains above sea level.[93]

The ramifications of land loss for PIDCs are particularly serious. With the exception of some of the larger Melanesian islands, most urban and rural settlements, including capitals, are in coastal areas.[94] Moreover, most economic activities in PIDCs are carried out in coastal regions,[95] and many of the powerhouses in the region are located within 100 meters of the ocean.[96] Also, Pacific islanders are highly reliant on subsistence farming for food and cash crop production; unfortunately, virtually all crop production takes place at or near coastal regions threatened by inundation and increased storm activities associated with climate change.[97]

Threats to Species and Ecosystems

Coral reefs have been termed the "rainforests of the ocean," occupying less than 0.2 percent of the ocean's area, while serving as critical habitat for approximately one quarter of all marine species.[98] In the context of small island nations, coral reefs are "an extensive and vital" component of the ecosystem.[99] In the Pacific region, reefs provide habitat for fish and other marine species that meet 90 percent of the protein needs of PIDC inhabitants[100] "and represent almost the sole opportunity for substantial economic development for many of the small island nations."[101] Moreover, coral reefs serve as a buffer against coastline erosion and storms in the Pacific,[102] a function that will become even more important as climate change increases the threat of both these phenomena.[103] Coral reefs are also the primary source of carbonate sand that constitutes the majority of beach deposits on PIDCs.[104]

Coral reefs have extremely narrow temperature tolerances of between 25-29º, with some species in PIDCs currently living near their threshold of thermal tolerance.[105] Water temperature increases of 1-2 ºC over an extended period can result in coral "bleaching," whereby zooxanthallae, endosymbiotic algae species that live in coral fish, are expelled or reduced.[106] Projected sea temperature rises in the Pacific region over the next century are likely to result in a "catastrophic decline" in coral cover.[107] Beyond the ramifications this phenomenon would have for regional ecosystems, the loss of coral would have serious economic implications for PIDCs. For example, during the El Niño event of 1998-1999 sea surface temperatures in the Pacific rose to a level that may be common in the future under many climate change scenarios. This resulted in a massive coral bleaching event that wiped out one third of the Pacific island state of Palau's coral reefs, with coral reef species populations plummeting by as much as 99 percent.[108] The associated economic loss was estimated at approximately $91 million,[109] a devastating blow for a small island economy.[110] It has also been estimated that a single island in Fiji, Vitu levu, could face economic losses of $14 million or more by 2050 as a consequence of the loss of coral reefs associated with climate change.[111]

Increasing levels of carbon dioxide can also result in markedly reduced calcification rates for organisms such as corals, weakening reef infrastructures.[112] Projected increases in carbon dioxide levels during this century as a consequence of anthropogenic activities could result in a 40 percent decline in calcification rates,[113] significantly exacerbating the threat to reef integrity from rising temperatures and sea levels.[114]

Mangroves, also known as mangals, are a group of 34 tree species that grow in sheltered conditions in shallow tropical and subtropical waters.[115] There are over 343,000 hectares of mangroves in the Pacific, with the largest stands occurring in Papua New Guinea, the Solomon Islands, Fiji, and New Caledonia.[116] In addition to providing a range of products for humans, including construction material, firewood, tannin, and herbal medicines,[117] a critical ecosystem in many PIDCs. Mangroves serve as important nursery and feeding sites for nekton, including many fishery species, with surveys of fish and crustacean assemblages around mangroves recording high levels of diversity and abundance.[118] Also, mangrove trees serve as filters for sediment that threaten coral reefs,[119] and help to detoxify contaminants in PIDC waters.[120] Overall, economically, mangroves provide about $10,000 per hectare annually.[121]

Mangrove communities can often cope with sea-level rise where sedimentation rates are commensurate with or exceed local sea-level rise.[122] However, most small island states are characterized by microtidal, sediment poor
environments. Stratigraphy from low island mangrove systems in the Pacific, including Tongatapu, Tonga, the Marshall Island, Kiribati and Tuvalu, reveal sediment accumulation rates of only 12 centimeters per 100 years.[123] Thus, low-island mangroves are expected to suffer reductions in geographical distribution from projected sea-level rise over the next century.[124] Should the IPCC's middle-range estimates of sea-level rise come to fruition over the next century, high island mangroves with sediment accumulation rates of 45 centimeters percentury could also be threatened.[125] Increased salinity caused by sea-level rises may also result in decreased net productivity and stunted growth in certain species.[126]

On the other hand, climate change should also prove beneficial in some ways to PIDC mangrove ecosystems. Increased temperatures will increase the diversity of higher latitude marginal mangroves, facilitating expansion into mangrove margins only occupied currently by *Avicennia* species, as well as expansion of mangroves into salt marsh environments. Warming can also be expected to increase mangrove productivity, characterized by increased growth and litter production.[127]

Increased precipitation in some parts of the Pacific region could also benefit mangroves by reducing salinity and exposure to sulphate, while increasing delivery of terrigenous nutrients.[128] Conversely, decreased rainfall in some regions, with an attendant increase in evaporation, will likely reduce the extent of mangrove areas, particularly with the projected loss of the landward zone to unvegetated hypersaline flats.[129]

Climate change would also threaten an array of other species in the region. For example, projected temperature increases may denude the productivity of fisheries in some areas, such as shallow lagoons, by increasing hypersaline conditions.[130] It may also alter the migratory patterns of commercially important tuna species, reducing access fees that fishing companies pay to PIDCs for the privilege of fishing in their EEZs.[131]

Clams and sea turtles would be directly threatened by increased temperatures in the region also.[132] Finally, habitat destruction associated with storm surges and rising sea levels may affect several avian species, including the Brown Booby, the Masked Booby and the Red-Tailed tropicbird.[133]

Impact on Freshwater Resources

PIDCs are characterized by severely limited, even sometimes life threateningly low, supplies of unpolluted freshwater supplies.[134] Moreover, the vulnerability of many PIDCs, particularly low-lying atoll States, is exacerbated by their reliance on a single source of water.[135] Climate change may further imperil these resources in several ways. First, projected sea-level rise in the region could result in the intrusion of saltwater into freshwater lenses, basal aquifers that percolate through islands and float on denser salt or brackish water.[136] Groundwater is the primary source of water for some PIDCs,[137] such as Kiribati, and an important supplementary source to rainwater on many others.[138] Also, the intrusion of saltwater into freshwater lenses could result in severe reductions in several subsistence crops in PIDCs, including taro,[139] breadfruit, coconuts,[140] and sugarcane[141] as well as lowland forests.[142] If the width of small islands in the region is reduced by inundation or erosion, as we anticipate in many areas, it is anticipated that groundwater lenses will shrink beneath larger islands and "virtually disappear" under smaller islands.[143]

A second threat is posed by the projected changes in precipitation patterns throughout the region over the next century.[144] Increased rainfall in the central and eastern tropical Pacific will likely result in a substantial increase in flooding,[145] resulting in the intrusion of seawater through the aquifer recharge zones of islands, substantially reducing potable water supplies and threatening crops grown in coastal regions.[146] Many PIDCs suffered saltwater intrusion into freshwater lenses during recent ENSO events.[147] Heavy rains could also diminish water in freshwater lenses through losses by run-off into the sea.[148]

As discussed above, climate change could result in an increased incidence of ENSO events, which in the past have been associated with massive decreases in rainfall in the western portion of the Pacific.[149] This could substantially reduce freshwater supplies in nations such as Micronesia and the Marshall Islands, where rainwater is the primary source of supply.[150] Decreased rainfall could also diminish the volume of groundwater supplies. For example, a 25 percent reduction in rainfall in Kiribati could result in a 64 percent reduction of lens thickness on the island of Tarawa.[151] Declining rainfall could also contribute to drought conditions in PIDCs, which in the past have been associated with devastating reductions in production of major agriculture export commodities such as sugar cane in Fiji, squash in Tonga,[152] and copra and giant taro in Kiribati.[153] Additionally, serious outbreaks of cholera in PIDCs have been associated with inadequate water supplies during ENSO events.[154]

Freshwater resources may be further imperiled if the incidence and/or intensity of storms increase in the Pacific region as a consequence of climate change. Storms can generate waves that result in seawater inundation of groundwater resources, though they can also bring heavy rains that recharge these resources.[155]

Higher temperatures may result in an increase in potential evaporation (atmospheric water demand) rates in tropical regions.[156] This may accelerate the drying out of soil and vegetation, increasing water demand.[157] Additionally, streamflow on some PIDCs could be affected by the cumulative effects of increased evaporation from watersheds.[158]

Recommendations and Conclusions

In this final section, I will focus on a policy framework for responding to the threats posed by climate change in PIDCs. Such a framework must include both mitigation and adaptation components because, as outlined below, the former strategy may prove wholly inadequate, at least for the immediate future. For the purposes of this analysis, "mitigation" is defined as "policy, actions and other initiatives that reduce the net emissions of 'greenhouse gases,"[159] while "adaptation" is defined as "institutional, technological, or behavioral changes taken to reduce vulnerability to climate change or ameliorate its impacts . . ."[160] While climate change will result in both spontaneous adaptation as a reaction to climate stimuli, and planned adaptations by institutions,[161] I focus on recommendations for planned responses in this section.

Mitigation Initiatives

The primary international response to climate change is the United Nations Framework Convention on Climate Change (UNFCCC),[162] which entered into force in 1994 and currently has 189 parties.[163] The overarching objective of the treaty is "to achieve . . . stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[164] Unfortunately, in the face of resistance by several nations, most importantly the United States, the drafters of the UNFCCC were compelled to forgo binding greenhouse gas emissions reductions and timetables in favor of "constructive ambiguities."[165] Thus, the UNFCCC merely calls on the Parties in Annex I of the agreement (developed countries and economies in transition) to "aim" to return their emissions back to 1990 levels.[166]

Given the abject record of voluntary programs to reduce energy use and greenhouse gas emissions,[167] it is not surprising that the UNFCCC's history in mitigating greenhouse gas emissions has been discouraging. By 1995, the greenhouse gas emissions of most developed countries were already well above 1990 levels and a study by the Organization of Economic Cooperation and Development projected that emissions from industrialized countries would rise an additional 11-24 percent by 2010.[168]

Recognition of the need for stronger mitigation commitments led to the adoption of the Kyoto Protocol to the UNFCCC[169] at the Third Conference of the Parties in 1997. The Protocol calls for industrialized States and States with economies in transition to reduce their greenhouse gas emissions to at least 5 percent below 1990 levels in the commitment period 2008 to 2012.[170] With Russia's deposit of its instrument of ratification in November of 2004, the Protocol will come into force in February of 2005.[171]

Unfortunately, for several reasons the Protocol is not the panacea that the popular press sometimes portrays it to be. First, President Bush announced in 2001 that he would not submit the Kyoto Protocol to the U.S. Senate for ratification,[172] despite the fact that the United States, is responsible for 25 percent of the world's anthropogenic greenhouse gas emissions.[173] As an alternative, the President announced the Global Climate Change Initiative (GCCI) in 2002, which called for reducing the "greenhouse gas intensity" of the U.S. economy by 18 percent over the next ten years.[174] "Greenhouse gas intensity" is defined as the ratio of greenhouse gases to economic output.[175] While the Bush administration reaffirmed its commitment to the UNFCCC and its central goal of stabilizing greenhouse gas concentrations,[176] the GCCI is an extremely tepid response by the world's largest producer of greenhouse gases that runs counter to implementing the treaty. While ratification of the Kyoto Protocol would have committed the United States to reduce its greenhouse gas emissions by 7 percent below 1990 levels,[177] under the GCCI it is estimated that U.S. emissions will rise 32 percent above 1990 levels by the end of this decade.[178]

Second, even those nations that have committed themselves to the Kyoto Protocol may be hard pressed to meet their obligations given present trends. For example, Japan's emissions have increased 8 percent since 1990, and in Canada, emissions have risen a whopping 20 percent.[179] Moreover, the European Union has projected that under present circumstances its members, as a bloc, are slated to miss the Kyoto target by 7.5 percent.[180]

Finally, even if the Kyoto Protocol were faithfully implemented by all industrialized nations as originally drafted, it would constitute only an extremely modest down payment on what ultimately must be done to stabilize atmospheric concentrations of greenhouse emissions. Climate researchers have estimated that full implementation of Kyoto would reduce projected warming in 2050 by only about *one twentieth of one degree*, and projected sea level rise by a minimal amount.[181] By contrast, stabilization of atmospheric greenhouse gases will ultimately require us to reduce greenhouse gas emissions by 60-70 percent,[182] a truly daunting task given the substantial resistance to the far more modest Kyoto accord.

This goal is made all by the more imposing because neither the UNFCCC nor the Kyoto Protocol mandate greenhouse emissions reductions commitments by developing nations.[183] This bloc will account for the lion's share of emissions through the rest of this century,[184] making its participation in mitigation efforts critical in the long term.[185]

However, engendering the participation of major developing nations such as China, India and Brazil may prove to be daunting. Developing nations have consistently contended that developed nations must first demonstrate a tangible commitment to control their own emissions before poorer nations take on their own commitments.[186] Developing nations usually frame their arguments in equitable terms, contending that: (1) industrialized nations, comprising a mere 20 percent of the world's population, have been responsible for over 80 percent of the accumulated output of greenhouse gases since the beginning of industrialization;[187] (2) the per capita output of greenhouse gases of industrialized nations is more than seven times that of developing nations;[188] and (3) a distinction should be made between the "survival emissions" of developing States and the West's "luxury emissions."[189] Given the abject record of developed nations to date in reducing emissions, especially the United States, it is difficult to be sanguine about future negotiations in this context.

Moreover, developing nations will ultimately have to reduce their per capita emissions by 50 percent relative to today's levels if the world is stabilize atmospheric concentrations of greenhouse gases at levels that will avert many of the most serious ramifications of climate change.[190] Most climate scientists and a growing number of governments now believe that every effort should be made to not exceed atmospheric greenhouse gas concentrations of 450-550 parts per million (ppm).[191] This will necessitate "leapfrogging" over the fossil fuel-based economic development that has occurred in industrialized countries, mandating the deployment of advanced energy-saving and renewable energy technologies.[192] The tremendous cost of "de-carbonizing" the economies of rapidly growing developing nations necessarily will require substantial financial and technological assistance from developed nations.[193] However, while both the UNFCCC and the Kyoto Protocol mandate financial assistance and technological transfers by developed parties to facilitate mitigation efforts by developing nation parties,[194] the response of developed nations has been "insignificant" to date.[195]

While some commentators and policymakers seek to portray efforts to establish effective climate change mitigation strategies as a threat to the world's economy, in reality such an initiative could have *de minimis* economic impact. An analysis by Azar & Schneider concluded that even a highly stringent mandate that would stabilize atmospheric concentration of carbon dioxide at 350 ppm, below current levels, would "have a marginal impact on the overall pattern of global economic growth."[196] The researchers estimate that reducing emissions to this level would ultimately delay achievement of the projected ten-fold increase of global GDP during this century by a mere 1-2 years.[197] However, it is critical to immediately begin implementing long-term strategies to substantially reduce emissions lest the current trajectory of emissions quickly foreclose stabilization of atmospheric concentrations in a range of 450-550ppm.[198]

Adaptation Strategies
Given the intransigence of major greenhouse gas emitting States,[199] as well as the fact that historic levels of greenhouse emissions ensure some impacts of climate change will inevitably be visited upon PIDCs,[200] there is a compelling need for adaptive responses to climate change in the region.

One overarching concern is whether PIDCs have adequate financial resources and capacity to develop effective adaptive programs. Five of the PIDCs, the Solomon Islands, Kiribati, Tuvalu, Samoa and Vanuatu, were recently classified by Huq, et al. as among the 49 least developed countries in the world, based on GDP per capita income under $900, human resource weakness criterion and economic vulnerability criterion.[201] Moreover, islands nations typically suffer from limited adaptive capacity as a consequence of a variety of factors, including their physical size, extremely limited access to capital, and technological and human resource shortages.[202]

Thus, there is a compelling need for additional funding and capacity building programs to assist PIDCs in ameliorating the impacts of climate change. Unfortunately, while the UNFCCC calls for funding of programs to assist those nations most vulnerable to the impacts of climate change,[203] including small island states, the Parties have been slow to provide for adaptation assistance in developing nations. During the 1990s, the Parties largely limited themselves to funding the preparation of progress reports required under the treaty.[204] In more recent years, there has been some expansion of adaptation funding commitments. At the 6th Conference of the Parties, the Parties to the UNFCCC established an Adaptation Fund, the Special Climate Change Fund and a least developed countries fund in the Marrakech Accords.[205] However, as Najam, Huq and Sokona observed, it is difficult to be sanguine about the potential of these funds because "(a) they are voluntary, (b) they are to be managed via the still-controversial Global Environment Facility (GEF) which has inspired little confidence in the developing countries because its governance and agenda remains northern-dominated, and (c) they remain poorly funded."[206] The Assessments of Impacts and Adaptations to Climate Change project funded by the Global Environment Facility seeks to involve scientists from developing countries in research on climate change vulnerabilities and possible adaptation responses. However, the funding for this program is also very limited,[207] and the requirement that the funds can only be used for "incremental costs of global benefits" may substantially limit its utility since most benefits of adaptation will yield local, rather than global, benefits.[208]

There are also a number of regional and international organizations that provide funding for research and adaptation programs in the region, including the World Meteorological Organization, the United Nations Environment Program, the South Pacific Applied Geoscience Commission, the South Pacific Regional Environment Program (SPREP) and the Pacific Island Climate Change Assistance Program of the United Nations Development Program/SPREP. However, funding for these programs is extremely limited and in some cases is declining.[209] Given the fact that many adaptive strategies may require lead times of between 20-50 years,[210] it is critical that developed nations and intergovernmental institutions substantially increase their commitment to PIDCs to help them ameliorate the impacts of climate change in this century and beyond.

In the context of protecting coastal resources from the potential impacts of climate change, among the adaptive strategies that PIDCs should pursue are the following:

? Development of effective metrics for measuring the vulnerability[211] of small island States' human institutions and natural systems, and enhance the resilience of these sectors.[212] At this point, development of vulnerability indices by organizations such as the South Pacific Applied Geoscience Commission[213] in the South Pacific and the European Commission Humanitarian Office's Composite Vulnerability Index for the Caribbean[214] remains in the early stages. Even effort should be made to accelerate this process;[215]

? Acknowledgment that technologies are often assessed only for their effectiveness on a global level, with very little regard for their appropriateness for PIDCs.[216] A clear priority should be the establishment of an assessment system that takes into account the unique environmental and socio-economic circumstances of island states in the region must be developed;

? Development of programs to increase the resilience of critical coastal ecosystems, such as coral reefs, through approaches such as development of additional no-take areas and more emphasis on regional management approaches;[217]

? Exploration of means of enhancing the adaptability and resilience of agricultural sector in coastal regions, including the viability of crop diversification, the use of new farming techniques, such as advanced irrigation systems to facilitate taking advantage of changing climates, and the use of more natural fertilizers to reduce pollution of the surrounding environment, making it more resilient to climate change impacts;

? Promotion of programs to reduce loss of water through leakage. Aging and poorly installed infrastructure results in the loss of 50-70 percent of water supplies from the reticulation system of PIDCs.[218]

Of course, an emphasis on adaptation responses is not without its perils from a political perspective. As Pelling and Uitto observed, in recent years there has been a "dangerous shift in emphasis in discourse from limiting change through the control of greenhouse gas emissions to support for national programmes of adaptation and loss baring."[219] Adaptation must never be viewed as a primary response to climate change, because the nations of world, and most particularly, small island States, cannot "adapt" themselves to "business as usual" scenarios that could see greenhouse gas concentrations ultimately triple or quadruple above pre-industrial levels after 2100.[220] Adaptation must be consistently couched as a "bridge" strategy that buys us time while we structurally de-carbonize the world's economy. To ensure that adaptation strategies do not become an end in themselves, it is critical that the Parties to the UNFCCC quickly establish long-term mitigation objectives for the decades that follow after the first commitment period of the Kyoto Protocol is completed in 2012. This should also include clear incremental targets to ensure that mitigation efforts are being pursued in good faith.

Conclusion

In 1989, President Amata Kabua of the Marshall Islands expressed the collective fears of island States threatened by the specter of climate change, declaring:

> It is truly frightening to think that our ocean will turn against us. We have been sustained by the ocean for two millennia. It has been bountiful and continues to yield to us its bounty. We have learned that this harmony may be interrupted by the action of nations very distant from our shores. I hope that the appeal of the peoples of the Pacific can help convince the industrialized nations to discontinue their profligate contamination of the atmosphere.[221]

Indeed, while many developed nations invoke the perils of global terrorism, we must not forget that those very same nations are capable of inflicting upon the world a level of harm that may prove far more horrific. Small island nations can only hope that their voices are heard before it is too late.

Endnotes

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182. UK Meteorological Office, *The Greenhouse Effect and Climate Change,* A briefing from the Hadley Centre, Oct., 1999, at 5.

183. The UNFCCC does require all Parties to "formulate, implement, public and regularly update national and, where appropriate, regional programmes containing measures to mitigate climate change by addressing anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol . . .", UNFCCC, *supra* note 162, at art. 4(1)(b). However, the absence of any specific targets or timetables renders this mandate nugatory. By contrast, Article 4(2) outlines more specific, albeit still pliable, mandates for developed countries and economies in transition.

184. By 2015-2020, developing country emissions may exceed those of the developed world as a consequence of emissions growth rates that are approximately three times higher, U.S. EPA, Global Warming website, *Trends in Greenhouse Gas Emissions,* <http://Yosemite.epa.gov/oar/globalwarming.nsf>, site visited on June 22, 2004; Eileen Claussen & Lisa McNeilly, *The Complex Elements of Global Fairness* 16, Pew Center on Global Climate Change (1998). China, which relies on coal, the most carbon-intensive fuel, for 75 percent of its commercial energy consumption, World Resources Institute, *The Environment and China: Climate Change,*

<http://www.wri.org/china/climate.htm>, site visited on June 20, 2004, is already the second largest emitter of greenhouse gases in the world, and may surpass the United States by 2010, Michael Lisowski, *The Emperor's New Clothes: Redressing the Kyoto Protocol,* 2 CLIMATE POL'Y 161, 164 (2002). Measured from 2000, it is projected that OECD nations will be responsible for only 20-25 percent of cumulative emissions from 2025 onwards, Richard S.J. Tol & Roda Verheyen, *Liability and Compensation for Climate Change Damages – A Legal and Economic Assessment,* FNU-9 (2001), at 20, <http://www.uni-hamburg.de/Wiss/FB/15/sustainability/liability.pdf>, site visited on June 21, 2004.

185. Clare Breidenich, et al., *The Kyoto Protocol to the United Nations Framework Convention on Climate Change,* 92 AM. J. INT'L L. 315, 331 (1998).

186. Michael Grubb, *Cold Shower in a Hot Climate: Climate Change Responses on the Knife-Edge,* 29 ENERGY POL'Y 833, 835 (2001).

187. Globe International, *supra* note 173, at 4.

188. Daniel Sarewitz & Roger Pielke, *Breaking the Global-Warming Gridlock,* ATLANTIC MONTHLY, July, 2000, at 62; Panjabi, *supra* note 1, at 501.

189. Michael J. Kelly, *Overcoming Obstacles to the Effective Implementation of International Environmental Agreements,* 9 GEO. INT'L ENVTL. L. REV. 447, 456 (1997).

190. Stephen Bernow, et al., *America's Global Warming Solution,* A study for World Wildlife Fund & Energy Foundation, Aug. 1999, at 5. Bernow's study assumes an objective of stabilizing atmospheric carbon concentrations at 450 parts per million, *Id.* at 5.

191. *See* O'Neill & Oppenheimer, *supra* note 107, at 16415; Browne, *supra* note 183; King, *supra* note 34, at 176; Stephen H. Schneider & Christian Azar, *Are Uncertainties in Climate and Energy Systems a Justification for Stronger Near-Term Mitigation Policies?,* Pew Center on Global Climate Change, Oct., 2001, at 19; Hadley Centre, *Climate Change and Its Impacts,* Oct., 1999. Limiting carbon dioxide concentrations in the atmosphere to 450 parts per million would result in a 1.2-2.3°C temperature increase over the next 100 years, while limiting concentrations to 550 parts per million would result in temperature increases over this period of 1.5-2.9°C increase, Brian C. O'Neill & Michael Oppenheimer, *Dangerous Climate Impacts and the Kyoto Protocol,* 296 SCI. 1971, 1972 (2002). The broad range of temperature projections is a function of uncertainties in both the atmosphere's climate sensitivity (its response to increases in greenhouse gases) and future levels of other greenhouse gases. *Id. See also,* Nathan Rive, *A Long-Term Target for the Climate,* 2 CICERONE (2004), <http://www.cicero.uio.no/fulltext.asp?id-27388&lang=en>, site visited on June 22, 2004; Detlef van Vuuren, *Life After Kyoto?,* 55 CHANGE 7, 7 (2001). Of course, the threshold may be much lower for small island states given their higher than average vulnerability to climate change and limited capacity to respond. *Id.*

192. Bernow, *supra* note 190, at 5. Indeed, meeting this objective in developed nations will also require "an almost complete dismantling of existing energy systems and a tremendous growth of several new technological systems," Björn A. Sandén & Christian Azar, *Near-Term Technology Policies for Long-Term Climate Targets – Economy Wide Versus Technology Specific Approaches,* ENERGY POL'Y (in press, 2004), at 2. "In 2001, oil and gas collectively accounted for 79.5 percent of the global primary energy supply," New Economics Foundation, *The Price of Power: Poverty, Climate Change, the Coming Energy Crisis and the Renewable Revolution* 9 (2004), <http://www.neweconomics.org/gen/z_syspublicationdetail.aspx?pid=182>, site visited on June 23, 2004.

193. UNFCCC, 7th Conference of the Parties, *Implementation of Article 4, Paragraphs 8 and 9 of the Convention (Decision 3/CP.2 and Article 2, Paragraph 3, and Article 3, Paragraph 14, of the Kyoto Protocol),* Decision-/CP.7 (2001).

194. *See* UNFCCC, *supra* note 162, at arts. 4(1)(c); 4(3); 4(5); 4(9); 11(1); Kyoto Protocol, *supra* note 169, at arts. 10(c); 11(b).

195. Marte Nordseth, *CDM Challenges Discussed in Buenos Aires,* PointCarbon, Dec. 14, 2004, <http://www.pointcarbon.com/article.php?articleID=5713&categoryID=279>, site visited on Dec. 14, 2004; Suraje Dessai, *The Climate Regime from the Hague to Marrakech: Saving or Sinking the Kyoto Protocol?,* Tydall Centre Working Paper. No. 12, Dec. 2001, at 15.

196. Christian Azar & Stephen H. Schneider, *Are the Economic Costs of Stabilising the Atmosphere Prohibitive?,* 42(1-2) ECOLOGICAL ECON. 73, 77 (2002).

197. *Id. See also,* van Vuuren, *supra* note 193, at 7 (Stabilizing carbon dioxide emissions at 450 parts per million only reduces global GDP by 2percent in 2100).

198. Marcel M. Berk & Michel G.J. den Elzen, *Options for Differentiation of Future Commitments in Climate Policy: How to Realise Timely Participation to Meet Stringent Climate Goals?,* 1 CLIMATE POL'Y 465, 476 (2001); van Vuuren, *supra* note 193, at 7.

199. *See* sec. 5.1, *supra.*

200. John E. Hay, *Integrating Disaster Risk Management and Adaptation to Climate Variability and Change: Needs, Benefits and Approaches, from a South Pacific Perspective,* Proceedings of the United Nations Development Program's Expert Group Meeting – Integrating Disaster Reduction and Adaptation to Climate Change, June 2002, at 8.

201. Huq, et al., *supra* note 161, at 8. The small economic base of island states and their deep integration into world markets makes them especially vulnerable to the "vicissitudes of economic globalization . . . relative prosperity is often built on fragile economic foundations," Mark Pelling & Juha Uitto, *Small Island Developing States: Natural Disaster Vulnerability and Global Change,* 3 ENVTL. HAZARDS 49, 49 (2001).

202. IPCC, *supra* note 3, at 864; Hay, *supra* note 200, at 2.

203. UNFCCC, *supra* note 162, at art. 3(2); art. 4(3-5).

204. Ian Burton, *Adaptation to Climate Change: Advancing the Agenda for Collective Global Benefit,* 4(8) BRIDGES 9, 12 (2000).

205. UNFCCC, Meeting of the 6th Conference of the Parties, *The Marrakesh Accords,* Decision -/CP.7 (2001), at Secs. F & I. It is contemplated that all three of these funds, to be administered by the Global Environment Facility, will provide resources to developing countries, including small island States, for adaptation activities.

206. Adil Najam, Saleemul Huq & Youba Sokona, *Climate Negotiations Beyond Kyoto: Developing Countries Concerns and Interests,* 3 CLIMATE POL'Y 221, 225 (2003); *See also* CSE, *What's Up for Discussion at CoP-8?* (2002), at 3, <http://www.cseindia.org/html/eyou/climate/discussion.pdf>, site visited on Dec. 10, 2004. In the Marrakech Accords, several developed country Parties to the UNFCCC (the European Community and its member States, Canada, Iceland, New Zealand, Norway and Switzerland) pledged to contribute $410 million annually by 2005 to fund programs to

assist developing countries for, *inter alia,* adaptation to climate change impacts. *The Marrakech Accords, supra* note 205, at Sec. 4. While this sum is egregiously inadequate, a study released by Greenpeace and the New Economics Foundation at the Tenth Conference of the Parties to the UNFCCC revealed that these countries have actually only come up with about $20 million to date. Greenpeace & The New Economics Foundation, *Cast Adrift: How the Rich are Leaving the Poor to Sink in a Warming World* (2004), at 20, <http://www.neweconomics.org/gen/uploads/aml404yldaqrwc45wp53skbq10122004163124.pdf>, site visited on Dec. 12, 2004.

207. The GEF has allocated $50 million over three years for the program. Saleemul Huq, *International Policy in Supporting Adaptation,* idi21 insights.org (2004), <http://www.id21.org/insights/insights53/insights-iss53-art02.html> site visited on Dec. 12, 2004.

208. *Id.*

209. A. Falkland, *Tropical Island Hydrology and Water Resources. Current Knowledge and Future Needs,* Second Colloquium on Hydrology and Water Management in the Humid Tropics, 21-24 Mar. 1999, at 6.

210. Kaluwin & Smith, *supra* note 14, at 96.

211. "Vulnerability" in the context of climate change is defined as "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli." IPCC, *Summary for Policy Makers, Climate Change 2001: Impacts, Adaptation and Vulnerability,* IPCC Working Group II (2001), at 3. A distinction can be drawn between biophysical vulnerability, or the "potential for loss from natural hazards, environmental variability and change," and social vulnerability, "which refers to social and institutional capacities that determine both susceptibility to, and the ability to cope with hazards and environmental change," Canadian International Development Agency, *Environmental Change, Vulnerability and Security in the Pacific,* 1 AVISO, Jan., 1999, <http://www.gechs.org/aviso/January1999.html>, site visited on June 24, 2004. Indicia of vulnerability of PIDC coastal regions include the potential socio-economic losses of land, property and population in inundated areas, socio-economic risks of land, population and property in flooded areas, potential ecosystem losses, including assessment of potential total areas of inundated wetlands and key ecosystems; and potential loss of areas of cultural and historical significance, Kazuhito Yamada, et al., *Methodology for the Assessment of Vulnerability of South Pacific Island Countries to Sea-Level Rise and Climate Change,* 1 J. GLOBAL ENV'T ENGINEERING 101, 102 (1995).

212. "Resilience refers to the innate ability of biophysical and human systems to maintain their integrity when subjected to disturbance." IPCC, *supra* note 3, at 869. As such, resilience is the reciprocal concept to vulnerability, Pelling & Uitto, *supra* note 200, at 51.

213. *See* <www.sopac.org>, site visited on June 24, 2004.

214. *See* <http://www.disaster.info.desastres.net/dipecho>, site visited on June 24, 2004.

215. Pelling & Uitto, *supra* note 200, at 53.

216. SPREP, *supra* note 66, at 129.

217. Jordan M. West & Rodney V. Salm, *Resistance and Resilience to Coral Bleaching: Implications for Coral Reef Conservation and Management,* 17(4) BIO. CONSERVATION 956, 958-65 (2003).

218. WWF, *supra* note 97, at 9; South Pacific Applied Geoscience Commission, *Water Resources Assessment & Sanitation,* <http://www.sopac.org.fj/Secretariat/Units/Wru/wateract.html>, site visited on June 24, 2004.

219. Pelling & Uitto, *supra* note 200, at 57.

220. Azar & Schneider, *supra* note 196, at 73-4.

221. Nunn & Mimura, *supra* note 141, at 134.

Marine Protected Areas - the Australian Experience

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Abstract
Australia's record in establishing marine protected areas has been highly variable but has improved dramatically over the past six to seven years. Australia has an extended economic zone of 16 million km^2, one of the worlds largest. The development of a representative system of marine protected areas within a federal system of government has been a patchy and challenging exercise. The marine protected areas of Australia are a network of Commonwealth (generally beyond State waters) and State marine protected areas. Over 200 marine protected areas have now been established, ranging in size from less than 1 hectare to over 350,000 square kilometres and from the sub-Antarctic to the tropics. The impetus for recent improvements in the rate of establishment of marine protected areas in the last decade has been agreement on a framework for a comprehensive system of representative marine protected areas.

This paper provides an overview of the state of marine protection in Australia, and Australia's record in establishing a National Representative System of Marine Protected Areas. A brief history of the establishment of the Great Barrier Reef Marine Park is provided together with a summary of current initiatives for this innovative marine protected area. An emerging regime of additional protection of the EEZ through the development of regional marine plans under Australia's Oceans Policy is also discussed.

Marine Protected Areas in Australia - The Constitutional and Legal Context
The Commonwealth of Australia was created as a federation of existing sovereign states in 1901. The States and Territories which had been separate colonies under British rule formed the new nation of Australia, with a new Constitution and a national government. In the view of the States at the time, the new Commonwealth Government was regarded as a "child of the States" created with limited powers to act on behalf of the States. Under the Australian Constitution, Commonwealth powers include defence, external affairs, taxation and fisheries beyond State waters i.e. 3 nautical miles. The States retained powers relating to matters such as land management, fisheries and ports within 3 nautical miles of the coast, and the establishment of national parks including on islands within State waters. The federal government is now the first tier of government, an inevitable outcome of the need for national approaches to matters such as foreign affairs, economic management, taxation and defence.

However there is no specific head of power in the Australian Constitution that grants the federal government the right to legislate on environmental matters within the States, nor to exercise environmental protection powers within the 3 mile territorial sea. The United Nations Convention on Law of the Sea 1958-1982 (UNCLOS) provided the basis for Commonwealth sovereignty over the continental shelf to low water mark by creating national obligations to protect and manage the environment and resources of the continental shelf. The Commonwealth Parliament relied on the external affairs powers of the Constitution to give effect to obligations arising from this convention by enacting the *Seas and Submerged Lands Act 1973.* The constitutional validity of this legislation was challenged by the States in the High Court of Australia (the highest court within Australia for legal appeal), but upheld in 1975 (Lawrence et al 2001).

This decision confirmed that national sovereignty prevailed over offshore areas from low water mark on the coast, i.e. within the States former jurisdiction. As a result, the Commonwealth Government was able to give effect to legislation that was based on its newly declared extended jurisdiction. Among the first important pieces of conservation legislation was the *Great Barrier Reef Marine Park Act 1975*, which had been passed, but not enacted, prior to the High Court judgment. This ruling changed the face of environmental management in Australia and has provided the basis for Commonwealth regulation of many maritime activities such as historic shipwrecks, crimes at sea, whale protection, sea dumping and the installation of marine structures (Lawrence et al 2001). Subsequently the Commonwealth entered into an Offshore Constitutional Settlement with the States to allow them to continue to exercise certain rights within the 3 nautical mile territorial sea, rights that had been removed by the *Seas and Submerged Lands Act 1973.*

Establishment of Marine Protected Areas in Australia – a brief history and status report

Under the UNCLOS, Australia has rights and responsibilities for over 16 million square kilometres of ocean, an area almost twice the size of the Australian continent (Environment Australia 2003) (Figure 1). The declaration of marine protected areas is the responsibility of both the States (within State waters) and the Commonwealth (beyond State waters and within Australia's Exclusive Economic Zone). In many cases adjacent marine protected areas are declared under each jurisdiction to ensure that, where necessary, whole ecosystems are covered by the same protective measures e.g. Great Australian Bight Marine Parks (Commonwealth of Australia 2003b).

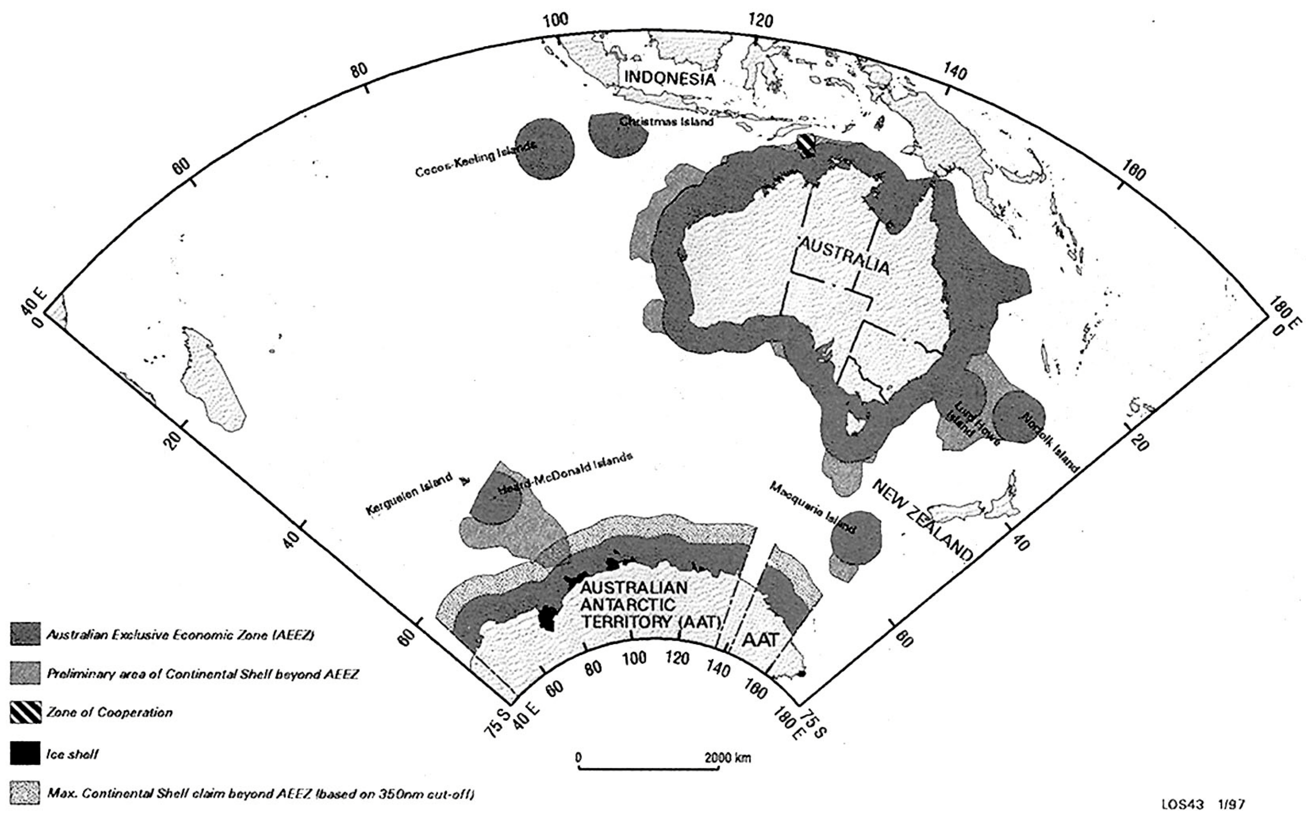

Figure 1. Map of Australia's Exclusive Economic Zone.

Prior to 1992 declaration of marine protected areas in Australia was largely uncoordinated and spasmodic, apart from the establishment of the Great Barrier Reef Marine Park and complementary Queensland Marine Parks. Some marine protected areas existed from the early part of the century but these were small and established mainly for recreation and seascape purposes rather than protection of a particular marine habitat (Lawrence et al 2001). Throughout the period of the mid 1970's to late 1980's the Great Barrier Reef Marine Park was progressively declared and established along with complementary marine parks within Queensland waters to ensure that virtually the entire marine area of the Great Barrier Reef from high water mark was protected, an area of over 350,000 km^2. This regime was atypical of the progress made in other Commonwealth, States and Territory waters prior to the 1990's. However since 1992, significant changes have occurred since the Commonwealth and the States reached agreement on a framework for establishing marine protected areas. Australia now has a growing National Representative System of Marine Protected Areas (NRSMPA).

The NRSMPA gives effect to Australia's obligations incurred when it signed the Convention on Biodiversity at the Earth Summit in Rio in 1992 and ratified the Convention in 1993. The Convention requires all nations to establish a system of protected areas and to develop guidelines for the selection, establishment and management of protected areas. The Convention introduced the principle of providing for adequate, comprehensive and representative reserves (Department of Environment and Heritage 2004) and built on the concept of marine bioregionalization that had been accepted in 1995. Other influences that flowed from national commitments to international conventions, that had a bearing on the establishment of marine protected areas, were the National Strategy for Ecologically Sustainable Development (1992) and the National Strategy for the Conservation of Australia's Biological Diversity (1996).

Through the Australia and New Zealand Environment and Conservation Council (ANZECC), Guidelines for the Establishment of Marine Protected Areas were agreed in 1998 (ANZECC 1998), followed by agreement on a strategic plan of action for such areas (ANZECC1999). The primary goal of the NRSMPA is to establish and manage a comprehensive, adequate and representative system of marine protected areas to contribute to the long-term ecological viability of marine and estuarine systems, to maintain ecological processes and systems, and to protect Australia's biological diversity at all levels. The following secondary goals were designed to be compatible with the primary goal:

1. to promote the development of marine protected areas within the framework of integrated ecosystem management;
2. to provide a formal management framework for a broad spectrum of human activities, including recreation, tourism, shipping and the use or extraction of resources, the impacts of which are compatible with the primary goal;
3. to provide scientific reference sites;
4. to provide for the special needs of rare, threatened or depleted species and threatened ecological communities;
5. to provide for the conservation of special groups of organisms, e.g. species with complex habitat requirements or mobile or migratory species, or species vulnerable to disturbance which may depend on reservation for their conservation;
6. to protect areas of high conservation value including those containing high species diversity, natural refugia for flora and fauna and centres of endemism;
7. to provide for the recreational, aesthetic and cultural needs of indigenous and non-indigenous people. (ANZECC, 1998).

ANZECC further defined the key characteristics that marine protected areas forming the NRSMPA should possess i.e. the marine protected area

1. has been established especially for the conservation of biodiversity (consistent with the primary goal);
2. is able to be classified into one or more of the six IUCN Protected Area Management Categories reflecting the values and objectives of the MPA;
3. must have secure status which can only be revoked by a Parliamentary process; and
4. contributes to the representativeness, comprehensiveness or adequacy of the national system.

The NSRMPA aims to achieve a comprehensive system of protected areas across all regions at the ecosystem level. In practice this involves determining which ecosystem types are not adequately represented and which are at risk as a result of immediate threatening processes. Protection of these ecosystems can be achieved through statutory declaration of protected areas, formal binding conservation agreements or through regional conservation agreements across a range of multiple use management categories (ANZECC, 1998).

Marine protected areas can range from highly protected areas to sustainable multiple use areas that provide for a wide range of human activities, within an ecologically sustainable framework. The territorial sea baseline is usually at low water mark on the coast but can be up to 60 nautical miles offshore in some areas. The Commonwealth generally is responsible for the area beyond three nautical miles and up to 200 nautical miles or the limit of the Australian Exclusive Economic Zone.

To assist in guiding the States and Commonwealth, an interim classification of Australia's coastal and marine environment (Interim Marine and Coastal Regionalisation for Australia) was completed in 1997 (IMCRA Technical Group 1997). IMCRA describes coastal and marine biogeographic regions at the meso (regional) and provincial (continental) scales for Australia's coastal and marine areas and provides a basis for determining national and regional priorities in the development of the NRSMPA (Cresswell and Thomas 1997). The IMCRA report describes the environmental characteristics for 60 meso-scale regions that encompass about 2.2 million km^2. Marine protected areas contained within that area total about 0.28 million km^2, or 12.5 percent of the total area (IMCRA Technical Group, 1997).

Since 1992 each State, Territory and the Commonwealth has pursued, with varying degrees of success, the establishment of marine protected areas within their own jurisdiction. By 2002, 192 marine protected areas under the NRSMPA program covered an area of 64.6 million hectares or 7 percent of Australia's marine jurisdiction (Department of Environment and Heritage 2004) (Table 1). This is an increase of 25 million hectares since 1997. This rate of declaration is expected to be maintained or increased as the States and Commonwealth implement their strategies for the establishment of marine protected areas – see for example the Victorian Government's strategy for 2003-2010 (Parks Victoria 2003).

Type	Number	Area (ha)	Jurisdiction
Antarctic Special Protection Area	1	2,088	Commonwealth
Aquatic Reserve	29	17,866	NSW, SA
Conservation Park	2	202	SA
Dugong Protection Area	16	637,298	Queensland
Fish Habitat Area	78	729,150	Queensland
Fisheries Reserve	5	3,357	Victoria
Historic Shipwreck	14	827	Commonwealth
Historic Shipwreck Protection Zone	1	78	South Australia
Marine & Coastal Park	3	62,143	Victoria
Marine National Nature Reserve	2	241,714	Commonwealth
Marine National Park	1	126,292	South Australia
Marine Nature Reserve	4	114,716	Tasmania, WA
Marine Park	25	59,731,953	Comm, NSW, NT, Qld, SA, Victoria, WA
Marine Reserve	5	6,532,748	Commonwealth, Victoria
National Nature Reserve	3	1,786,500	Commonwealth
National Park	2	3,307	Commonwealth
Nature Reserve	1	81,538	Tasmania
Total	192	64,615,554	

Table 1: Summary of Marine Protected Areas by Type as at 2002. Source: http://www.deh.gov.au/parks/nrs/capad/2002/national/nat-metype02.html .

However much remains to be done before Australia's NRSMPA is fully realised. The present distribution of marine protected areas across Australia's marine environment in highly variable. For example, 21 bioregions have no marine protected areas, 21 bioregions have protected areas that cover less than 1 percent and five bioregions have marine protected areas that cover between 1 and 10 percent of the bioregions. There are also 11 bioregions contained within very large marine protected areas, which make up over 92 percent of the total area of marine protected areas. These are found in a narrow band on the north-east tropical coast (the Great Barrier Reef Marine Park) the Great Australian Bight (State and Commonwealth components of the Great Australian Bight Marine Park), and the Western Australian coast (Shark Bay Marine Park and Ningaloo Marine Park). The Great Barrier Reef Marine Park is unique in that it encloses eight meso-scale bioregions plus additional areas. The Shark Bay and Ningaloo Marine Parks cover about 50 percent of their respective bioregions.

While many bioregions contain marine protected areas, most are very small and the few large areas contribute disproportionately to the total. The 60 IMCRA bioregions (2.2 million km^2) cover a small proportion of the 16 million km^2 area that comprises Australia's Exclusive Economic Zone (ANZECC, 1999). Ecosystems occurring seaward from the meso-scale IMCRA boundaries (i.e. the nominal edge of the continental shelf) to the limit of the EEZ (i.e. the 200 nautical mile boundary), an area of about 458,000,000 hectares, are either poorly represented or not represented at all in protected areas.

Great Barrier Reef Marine Park – lessons of experience

The Great Barrier Reef Marine Park is a unique and enduring example of a large multi-use marine park that was established in special circumstances arising out of the global and national concerns about environmental issues in the 1960's. At the same time international efforts to establish marine protected areas were gathering pace (Adams 1962). In 1975, IUCN convened the first conference on marine parks and protected areas. Technological advances of SCUBA diving, underwater films and television coincided with catastrophic marine disasters such as oil well blowouts at Santa Barbara in 1969 and the break-up of the oil tanker *Torrey Canyon* in the English Channel in 1967. On the Great Barrier Reef, the first recorded outbreak of crown-of-thorns starfish (a coral eating predator) was found at a popular tourist site in 1965, and was attributed by some to human impacts. (For a more detailed description of the events that lead to the establishment of the Great Barrier Reef Marine Park, see Lawrence et al 2001).

In 1972 a new federal Labor government with a social democratic reform agenda was elected. It immediately set about implementing one of its electoral promises to establish the Great Barrier Reef as a national park. The Great Barrier Reef Marine Park Act 1975 (GBRMP Act) was then passed in 1975 with bipartisan political support. It was strongly resisted by the State of Queensland which felt that the federal government was intruding on an area of "states rights."

The GBRMP Act was innovative and unprecedented in scope and direction. When enacted, the Act was one of the most powerful on the Australian Government's statute books. The GBRMP Act established a Federal statutory authority with sweeping powers to develop a marine park over the whole of the Great Barrier Reef Region, an area of approximately 350,000 km^2 (Figure 2). Commonwealth jurisdiction extended to low water mark on the coast and around the 962 islands most of which belonged to the State of Queensland. To attempt to manage the reefs and surrounding waters without due regard for the activities that occurred under State jurisdiction (e.g. fisheries and management of islands) would have been costly and inefficient. Co-operation with Queensland was essential and this was mandated in the legislation, through membership of the governing board and an advisory committee, as well as through agreements to provide funding to assist in the management of the whole area (Lawrence et al 2001).

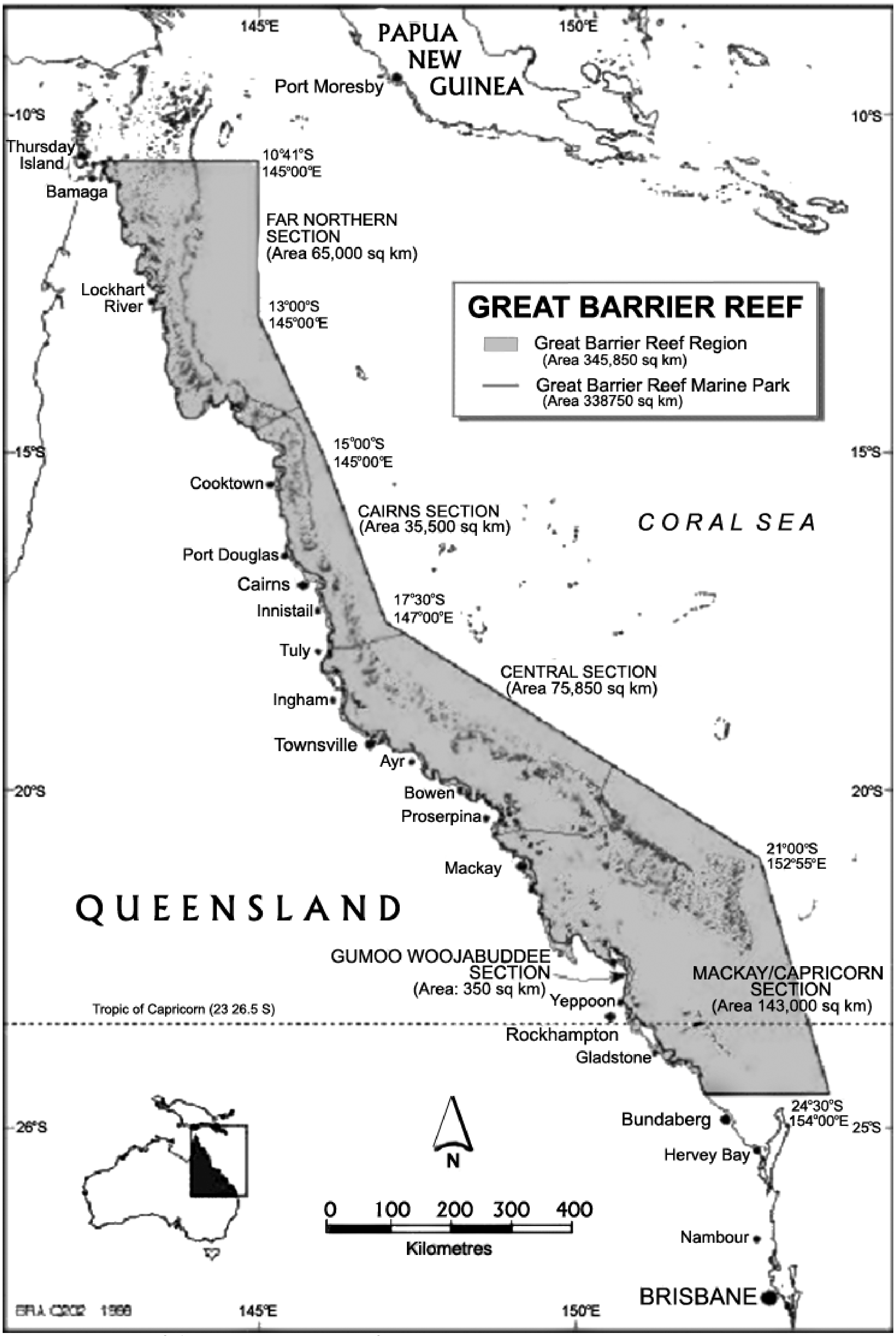

Figure 2. Map of the Great Barrier Reef.

The legislation also established the concept of a multi-use park within which "reasonable use" could co-exist with conservation. The guiding philosophy in the legislation was to establish a marine park while providing for "protection, wise use, understanding and enjoyment." Spatial zoning plans that provided for a gradation of uses from "general use" to "preservation" were mandated as the main management tool. Public consultation was required by law. Research, education and day-to-day field management in the form of surveillance, enforcement and education was also mandated.

One of the profound insights that came out of the process to establish the Great Barrier Reef Marine Park, is that the impetus came from emotions, perceptions and values rather than hard science or facts demonstrating risk to the environment. In 1975, knowledge of the effects of human activities on marine environments, and in particular the Great Barrier Reef, was patchy and scarce. Although scientists were influential in the establishment of the GBR Marine Park, it was the overwhelmingly public concern that carried the day.

Managing the Great Barrier Reef Marine Park is principally concerned with conserving biodiversity and providing for sustainable use through managing people's uses, expectations, perceptions and values. Intervention in natural processes is rare and most management uses a combination of persuasive or coercive tools to either encourage compliance or to deter non-compliance respectively. Achieving this over such a vast area and with limited resources requires substantial community education and support coupled with very targeted and risk-based enforcement (Skeat et al 2002). As with all environmental protection systems such as marine parks, they exist as a social contract between the community and the elected representatives of the community. The management agency must ensure that the Marine Park is managed in such a way that it enjoys substantial public support, as well as providing for the protection of the natural resources and for sustainable uses.

The organizations that are charged with the responsibility for managing marine protected areas, also need to be adaptable to changing conditions and demands of government and the community. Organizations need to renew themselves from time to time as well as renewing the planning and implementation programs to meet emerging challenges. In 1995 the Great Barrier Reef Marine Park Authority changed its management structure to meet new demands for improved governance and community and stakeholder expectations. A new focus was required on critical issues rather than on activities or functions such as planning, environmental impact management and research. The Authority is now structured to concentrate its planning, management and policy development on four critical issues (GBRMPA 2004):

1. sustainable tourism and recreation
2. sustainable fishing and fisheries
3. protection of conservation, biodiversity and world heritage values
4. management of the impacts of coastal development on Reef water quality

All operations are driven by and support the four critical issues, e.g. research, planning and field management. In adopting this critical issue approach and the cross-cutting issue of managing indigenous relations with the Authority, the Authority has had to review the outcomes of previous programs and develop new approaches to reflect contemporary needs.

Tourism and Recreation

In relation to tourism and recreation, management arrangements have moved from a mostly prescriptive regulatory approach to one that combines reduced regulation and co-operative self-management by the industry (GBRMPA 2004). Tourism is the main commercial use of the Great Barrier Reef Marine Park with an estimated economic value of A$4 billion p.a. (Productivity Commission 2003). A total of 730 permitted operations, utilising 1500 vessels, form the bulk of the reef-based tourism market, supported by island and coastal tourist resorts and activities. Management of tourism activities is a partnership between the management authorities and the industry. Since 1995 the approach has been to negotiate co-operative arrangements with industry and use a combination of regulatory tools with industry codes of conduct. The tourism industry is required to pay a fee (currently $4.00 per person per day) in return for the right to conduct approved tourism operations to a particular location or area. The funds raised are used for reef management and research. Operators who have investments in tourism are seeking longer tenure and exclusive use of reef sites and for this they are willing to pay user fees and to comply with high standards of environmental management and education for tourists.

Water Quality

Because of deteriorating water quality in the inshore reefs of the Great Barrier Reef a significant change in management practices was required (Brodie 2002, GBRMPA 2004). Most of the sources of marine pollution derive from land based activities that are outside the Authority's jurisdiction and within the responsibility of the State of Queensland. Zoning which is the main spatial planning tool within the marine park, is useless to deal with downstream effects of agriculture. A new co-operative approach was needed to deal with the 4-fold increase in pollutants that have been discharged into Reef waters since the beginning of agriculture in catchments draining into the Great Barrier reef Lagoon. Compliance by farmers with voluntary codes of practice to reduce fertiliser and sediment loss from farms has been poor. In 2003, the Commonwealth and Queensland Governments released a Reef Water Quality Protection Plan with the goal of "halting and reversing the decline in water quality entering the Reef within 10 years" (The State of Queensland and Commonwealth of Australia 2003). A combination of management initiatives will simultaneously address the goal, through:

1. discharge targets for pollutants from agriculture
2. sewage discharge standards
3. monitoring of pollutants and sediments and impacts on inshore reefs and animals
4. encouragement of best practice farming
5. engagement with catchment management groups through education and collaboration
6. onshore regulation of aquaculture operations

Fishing and fisheries

The management of fisheries in the Great Barrier Reef Marine Park is a co-operative system where the GBRMPA sets spatial limits on fishing activities and the Queensland State manages the fishery, through traditional fisheries tools such as licencing, gear restrictions, bag and size limits and seasonal closures (Cadwallader et al 2002). Recent research into the effects of bottom trawling for prawns and scallops has demonstrated unsustainable trawling practices and environmental degradation of bottom communities as well as effects on non-target species (GBRMPA 2004). In 2003, a significant reduction in trawling effort of 15 percent was negotiated and additional management controls introduced to eliminate illegal trawling. The most significant of these has been the introduction of a satellite-based vessel monitoring system; other changes have been the introduction of turtle excluder devices and research into bycatch reduction devices (GBRMPA 2004).

Significant declines in dugong numbers over the past 30 years, have been the trigger for changes in inshore netting of fin-fish, and the introduction under State legislation, of Dugong Protection Areas covering important dugong feeding and breeding areas.

Conservation, Biodiversity and World Heritage Values

The first zoning scheme for the park, did not reflect an adequate, comprehensive or representative approach to protection of all habitats (Day 2002, Day et al 2002). Only about 5 percent of the total area was protected through no-take zones and many of the no-reefal habitats were not contained within such zones. In 1975, the focus of public expectation and management was largely on reef-forming corals. The representative areas approach came 25 years later, following the 1993 ratification of the Convention on Biodiversity and the call for adequate, representative and comprehensive marine protected areas. The recent completed rezoning of the Marine Park meets this requirement by increasing the no-take protection across identified bioregions. This gives overdue recognition to all components of the marine ecosystems in the Great Barrier Reef, not just the coral reefs. Mangroves, seagrass beds (shallow and deepwater), algal and sponge 'gardens', deep ocean troughs, sandy and muddy bottom communities are all now represented to a similar degree in no-take zones.

Over the past 4 years, the Marine Park Authority has embarked on an enormous program to rezone the entire reef region with the target of having at least 20 percent of each of 70 bioregions in no-take zones. On average the percentage of bioregions now within no-take zones is over 30 percent. This program has been completed with substantial public involvement (over 30,000 public submissions) and will come into effect on 1 July 2004. (GBRMPA 2004). In one enormous program, the Authority has renewed the marine park to reflect contemporary needs and standards, and to provide the best possible opportunity to sustain the world heritage values of the area in perpetuity.

Emerging trends - Australia's Oceans Policy

In the Year of the Ocean 1998, the Australian Government launched Australia's Oceans Policy with the overall goal to "promote ecologically sustainable development of the resources of our oceans and the encouragement of internationally competitive marine industries, while ensuring the protection of marine biological diversity." This was an ambitious initiative to develop an integrated ecosystem-based approach to management of the whole of Australia's maritime area. Australia is the only country with full control of a continent and consequently is unique compared with other nations of similar size (Alder and Ward 2001).

The vision for Oceans Policy is "healthy oceans: cared for, understood and used wisely for the benefit of all, now, and in the future" (Commonwealth of Australia 1998a). The overall implementation of the policy is based on managing threats and conflicts through integrated and ecosystem based planning within Regional Marine Plans. (Alder and Ward 2001).

Specific goals are:

- to exercise and protect Australia's rights and jurisdiction over offshore areas, including offshore resources.
- to meet Australia's international obligations under the united nations convention on the law of the sea and other international treaties.
- to understand and protect Australia's marine biological diversity, the ocean environment and its resources, and ensure ocean uses are ecologically sustainable.
- to promote ecologically sustainable economic development and job creation.
- to establish integrated oceans planning and management arrangements.
- to accommodate community needs and aspirations.
- to improve our expertise and capabilities in ocean-related management, science, technology and engineering.
- to identify and protect our natural and cultural marine heritage.
- to promote public awareness and understanding.

The primary tool for developing an integrated and ecosystem-based management regime has been through Regional Marine Plans that seek to integrate existing and future sectoral activities within large marine ecosystems. The management model depends largely co-operation of the Commonwealth and State Governments, industry and stakeholder groups that use or value the offshore marine environment. The approach to date has been to seek to provide a coordinating mechanism within which sectoral activities of government and industry (e.g. shipping, fishing, mineral production) can develop in an ecologically sustainable way. The first Regional Marine Plan for the South-East Marine Region has been developed and work has commenced on the Northern Marine Regional Plan. This model depends very much on the co-operation of sectoral interests, both public and private. The National Oceans Office does not have the equivalent powerful legislative backing provided in the Great Barrier Reef Marine Park. Instead it relies on the existing Commonwealth and State legislation administered by other agencies of government to implement the goals of Oceans Policy. Therein lies the challenge of achieving success.

One of the key components of Oceans Policy is the establishment of representative marine protected areas within the Regional Marine Plans. Already significant areas of southern ocean have been declared as marine protected areas in the SE Marine Region. Macquarie Island Marine Park (16,200,000 ha), Tasmanian Sea Mounts Marine Reserve (38,900 ha)and the Heard Island and McDonald Islands Marine Reserve (6,460,000 ha) have been declared in the last five years. A process for identifying further candidate areas for possible declaration as marine protected area has been formulated (Commonwealth of Australia 2003a).

Conclusion

Management of marine parks is complex and conducted on different scales of time and space for social and natural systems. Planning is a relatively static process conducted in constantly changing social and political systems, and infinitely variable natural systems. Review and adaptation are essential to ensure that the gap between such systems and the plans does not ever become so wide that the plans become irrelevant to contemporary aspirations and uses. Values, expectations, uses and property rights (real or perceived) change over time. An adaptive management approach is needed. Such an approach takes marine park management as an experiment in which assumptions about outcomes need to be verified and in which uncertainty must be explicitly recognised. Adjustments to management approaches are always necessary, and should be informed by reviews of the results of the implementation of plans and the verification of assumptions built into those plans.

Australia's record in establishing marine protected areas has been highly variable but has improved dramatically over the past six to seven years. In 1975, in one unprecedented action, the Great Barrier Reef Marine Park was created after years of political and social concern. In size and complexity it stands as the benchmark for multi-use marine protected areas encompassing large marine ecosystems. Many years of slow progress in increasing Australia's marine protected area estate has been replaced with a recent period of significant additions. Marine protected areas by type and size have increased significantly over the period from 1997 to 2002. This has been largely the result of the development and implementation of the National Representative System of Marine Protected Areas. State governments are establishing marine protected area to meet the agreement to protect representative examples of bioregions in State waters. The Commonwealth government in some cases has established adjacent marine parks to complement the State parks. At a completely different scale the Commonwealth government has commenced a program to manage Australia's ocean realm through Oceans Policy. The identification and declaration of marine protected areas is one aspect of the large regional marine planning system being created. Such large scale marine planning is intended to ensure co-ordination and collaboration between users and governments towards ecologically sustainable management of the whole of Australia's marine environment.

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Marine Genetic Resources and the MesoAmerican Barrier Reef System Project: Incorporating an Ecosystem-Based Management Approach[1]

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Introduction

Marine Genetic Resources have generated significant scientific and commercial interest in recent years as sources of drugs and other biotechnological uses. However, one of the primary deterrents to future development is the absence of predictable and effective international and domestic legal rules governing ownership of these resources. Today's legal regime consists of an uncoordinated patchwork of national laws and policies founded upon outdated notions associated with the traditional rule of capture approach to resource ownership.[2] This study contends that the current regulatory regime governing access to shared marine genetic resources is inequitable, economically and biologically inefficient, and ripe for international discord.

It suggests that regional or ecosystem-based cooperative management approaches, similar to those that are currently used to manage so-called fugacious natural resources such as liquid oil and gas, international rivers, and migratory wildlife, are the best method of equitably and efficiently exploiting shared marine genetic resources. It further suggests that a cooperative project, known as the Mesoamerican Barrier Reef System Project (MBRSP), currently being undertaken by the nations of Belize, Guatemala, Honduras, and Mexico to conserve and manage the resources of their shared barrier reef, provides an outstanding opportunity to develop and test a regional or ecosystem-based approach to managing marine genetic resources.

The MBRSP could potentially play an instrumental role in shaping the future development of the global marine biotechnology industry in the following ways: by providing researchers carefully planned and controlled access to one of the most valuable natural laboratories in the world; by engaging in long-term environmental information collection and monitoring programs that provide the kind of reliable scientific baseline data that is essential to any successful effort to commercialize marine genetic resources; and by creating a regional or ecosystem-based method of managing marine genetic resources and sharing in their benefits that may serve as a model for other nations that share similar resources.

The Uses and Value of Marine Genetic Resources

Global biological diversity has provided natural product chemists an invaluable source of information in their quest to discover new drugs and other biotechnological uses. It has been estimated that fifty percent of all drugs marketed today are extracted directly from natural sources or synthesized from natural product material or templates.[3]

Although less well known than terrestrial species, marine organisms have been recognized as having an especially high probability of yielding useful natural products.[4] The ocean is far more biologically diverse than terrestrial environments. For example, it has been estimated that the marine environment contains more than 200,000 described species of algae and invertebrates alone.[5] This immense figure is thought to be only a small fraction of the species yet to be discovered. Diverse groups of archaea, fungi, algae, sponges and microorganisms have all exhibited unique potential for pharmaceuticals and other novel uses.[6]

While potentially valuable marine species live in all ocean environments, areas of high biodiversity and competition among organisms, such as coral reefs, are especially good sources of new drug and biotechnological products. Marine organisms exhibit unique adaptations to their environment. Many marine invertebrates live in densely populated habitats, are non-mobile, and possess relatively primitive immune systems. Consequently, they have evolved complex chemical compounds to help them survive in this intensely competitive environment.[7] Researchers have discovered that some of these unique chemical mechanisms interact with enzymes and receptors in the same manner as those involved in human disease processes and are especially well suited as pharmacological compounds.[8] One commentator claims that the probability of discovering a drug from marine sources is approximately a thousand times more likely than from terrestrial ones.[9] In fact, the unique structures and potent bioactivities found in marine-derived molecules have resulted in approximately three hundred patents being issued on marine natural products between 1969 and 1999.[10]

Marine Genetic Resource Development

Discovery of marine natural products involves a long and costly process of research and testing. Depending on the type of organism involved, a tissue sample of between twenty grams and one kilogram wet weight is collected, identified and documented for taxonomic purposes, and a portion is extracted into crude chemical constituents and genomic material.[11] If sufficient bioactivity is found in the extract, additional marine material is usually collected from the same species at multiple sites to see if they have higher or lower concentrations of a particular bioactive compound. It is commonplace in nature to have variations in bioactivity among members of the same species. Synthesis of bioactive compounds may be influenced by external environmental conditions such as presence of predators, infection with parasites, water temperature, depth, food sources, and nutrient levels or other internal factors.[12] Because chemical content often varies depending on where and when an organism is collected, precise taxonomic and environmental field data is essential in order to replicate hits and recollect bioactive populations.[13] If the compound shows sufficient promise a long series of scientific, clinical, and market-based tests are required prior to commercialization of the product.[14]

Because collecting marine organisms is an extractive process, it has potential to cause environmental impacts.[15] Strict collection protocols can minimize these impacts by limiting the size of samples, prohibiting collection of rare organisms, and preventing incidental damage to the surrounding habitat. Moreover, it can be persuasively argued that the environmental benefits provided by a well-planned field collection study more than compensates for the loss of a small number of marine organisms.[16] However, environmental problems may be considerably increased if large scale recollections are needed as part of the testing process or if large quantities of organisms are harvested to provide adequate supply of chemicals for the commercial production of a particular drug or other product.

While potentially problematic, the issue of over-collection may be overcome, to a great extent, by careful planning and oversight, as well as by developing synthetic analogues that mimic the chemical properties of the natural compound.[17] Promising results are also underway to artificially culture marine organisms of interest including gorgonians, sponges, bryozoans, ascidians, and microorganisms.[18]

Problems Associated With The Current Legal Regime Governing Marine Genetic Resources

One of the primary deterrents to future development of marine biotechnology is the lack of predictable, fair, and effective international and domestic legal rules governing ownership of marine genetic resources. Formal international recognition of source country sovereignty over genetic resources was achieved in 1993 with the entry into force of the Convention on Biological Diversity (CBD).[19] As a consequence of restrictions imposed by the CBD, foreign researchers are no longer able to commercialize a State Party's terrestrial or marine genetic resources without receiving its prior informed consent.[20]

The CBD encourages source States to facilitate foreign access to genetic resources.[21] In return, the Convention requires user States to enter into mutually agreed benefit sharing provisions[22] that include: (1) prior informed consent;[23] (2) participation in research;[24] (3) technology transfer;[25] and (4) up-front payments and/or a percentage share of proceeds resulting from commercialization.[26]

Today, in response to CBD requirements, an uncoordinated patchwork of national plans and laws have emerged that provide foreign access to marine genetic resources conditioned on the source nation sharing in some of the benefits.[27] Underlying this regulatory system is the traditional legal rule of capture, which awards ownership of natural resources coming from a common source of supply to the first party to reduce them to its dominion and control.[28] The obvious danger posed by the rule of capture is that it provides one nation with an incentive to quickly and wastefully exploit the resource before a competing nation can do so.[29] Consequently, it may often be in the self-interest of a coastal state to allow foreign access to its marine genetic resources under less than ideal terms so that it can capture any benefits prior to their being captured by neighboring states.

In addition, it is important to recognize that the asset of value as regards genetic resources is not the physical substance itself, but the genetic information contained in that substance. As a result of increasingly robust and binding global protections of intellectual property under the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) negotiated under the auspices of the World Trade Organization (WTO) treaty regime, substances derived from genetic materials may be patented and therefore protected from exploitation by others for a period of many years.[30]

Genetic resources, like other living natural resources, do not confine themselves within discrete political boundaries. Instead, they exist throughout biological ranges that sometimes overlap a number of terrestrial or marine political boundaries.[31] For all practical purposes, neighboring nations that share the same pool of genetic resources, but are not parties to a specific access agreement, will be deprived of receiving any future value should a commercial product be derived from that resource and subsequently protected by international patent.[32] Moreover, in most instances, the neighboring nations will also be prevented from sharing any of the up front benefits such as technology transfer, training, or fees.

In economic terms, genetic resources are becoming more rival.[33] More precisely, the exploitation of marine genetic resources is viewed as common pool, which are partly excludable and rival. In this regard they are akin to international freshwater resources. In contrast to open-access commons, such as high seas fisheries, non-source nations of marine genetic resources have no access to the resource and cannot benefit from them directly. Their benefits are also rival, because any genetic material that is commercialized and protected by intellectual property rights reduces the value available to other source nations.

The existing rule of capture approach also has a detrimental effect on environmental assessment activities. The rule of capture causes nations that share resources to compete rather than cooperate in obtaining useful scientific information relating to the resource. Given the possibility that one co-owning nation will receive all of the benefits from commercialization at the expense of the others, there are incentives to monopolize rather than share taxonomic and environmental information and infrastructure.

Finding Solutions To Current Legal Problems - Cooperative Management

Many of the problems associated with the current rule of capture approach to managing marine genetic materials may be overcome if the resources are governed similarly to the international rules applying to so-called fugitive resources such a liquid oil and gas, international watercourses, and migratory wildlife. It has long been recognized that unlike most natural resources, certain types of fugacious resources may exist in one nation one day, but migrate to another nation the next. For example, one nation may pump a transboundary pool of oil causing the oil to migrate across the boundary and thereby deprive the co-owning nation of its potential share of the resource. Similarly, one upstream nation may divert an international river so as to deny a downstream nation of any of the flow. The danger associated with exploiting fugacious resources rests in the power that one nation possesses to deprive another nation of all or essentially all of the commercial value of that common pool resource.

To resolve these problems, the international community has rejected traditional notions associated with the rule of capture.[34] Instead, it has developed more equitable legal rules such as the doctrines of correlative rights,[35] joint development,[36] and equitable utilization[37] that require nations to cooperatively manage and jointly exploit shared resources.

In similar fashion, when one nation shares genetic resources with other nations, yet unilaterally allows foreign access within its territory in return for benefits derived from the commercialization of genetic information, it does not cause the actual physical migration or loss of material, but it may cause the loss of all or essentially all of the commercial value associated with that resource. If one nation is perceived by its neighbors as arbitrarily and unfairly receiving all of the benefits from a shared genetic resource, it could lead to serious political and legal tensions and recriminations. To avoid these problems, a regional or ecosystem approach to management and exploitation should be adopted.

Applying a Regional or Ecosystem-Based Approach -- Managing Mesoamerican Barrier Reef Marine Genetic Resources

A. Physical Characteristics of the Mesoamerican Barrier Reef.

The 620-mile-long Mesoamerican Barrier Reef is second in size only to the Great Barrier Reef of

Australia. Located off of Mexico, Belize, Guatemala, and Honduras, the reef provides an outstanding example of a shared regional marine ecosystem of immense environmental, economic, and political importance[38] (see Figure 1).

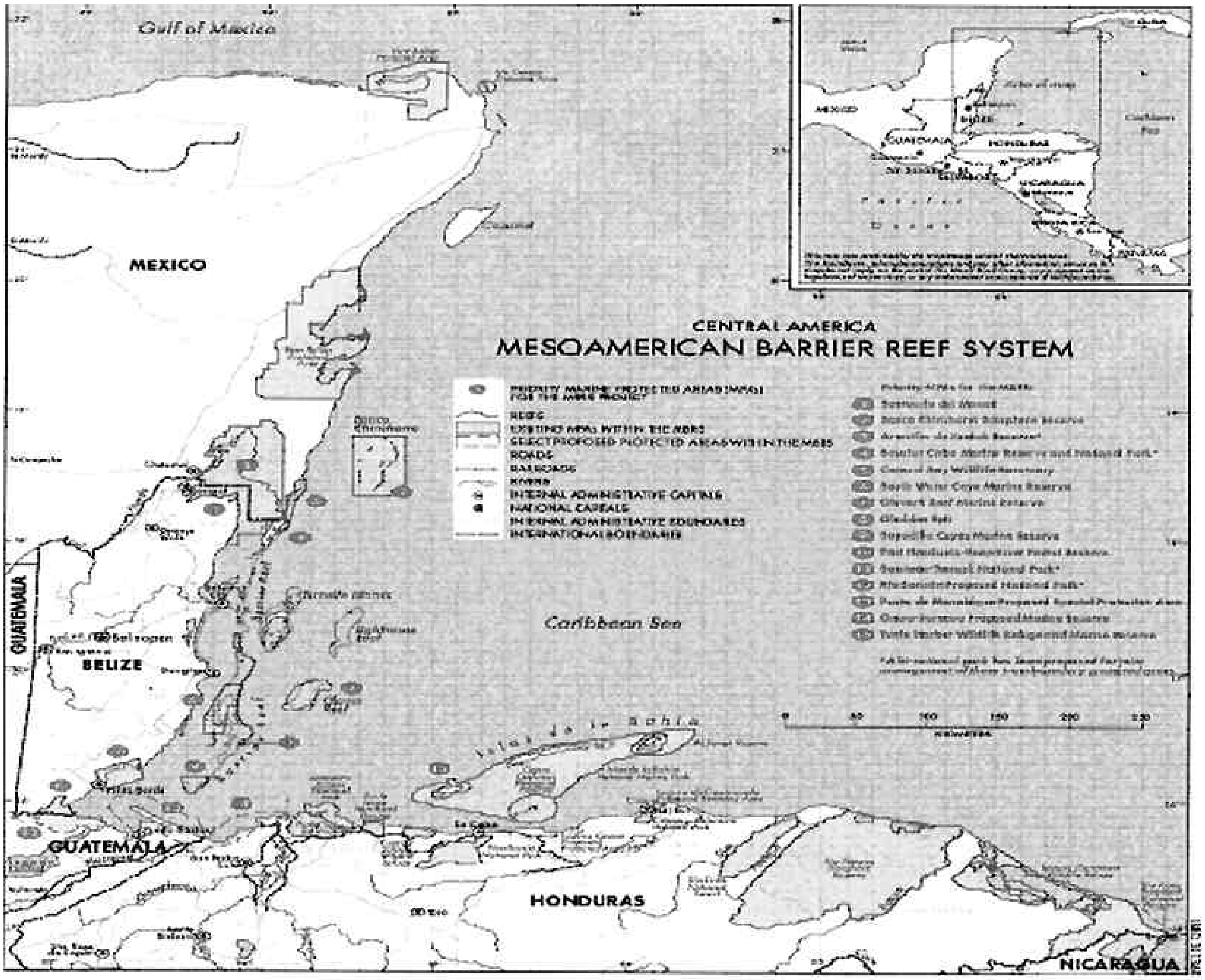

Figure 1

Because of its size, its array of reef types, and its exceptionally high biodiversity, the Mesoamerican Barrier Reef System is uniquely suited as a source of marine genetic materials. It contains all of the major reef types including: fringing reefs along the mainland coast; the barrier reef itself which grows along the edge of the continental shelf; and a number of offshore atolls.

Extraordinary biodiversity exists on the reef system. For example, Belize alone has sixty-five coral species and three hundred fish species, compared with just over seventy coral species and about 520 fish species in the entire Caribbean region.[39] The exceptionally high biodiversity and ecological significance of the reef system has resulted in seven sites being designated as World Heritage Sites under the UNESCO World Heritage Convention.[40]

B. The Mesoamerican Barrier Reef System Project

In 2001 Belize, Guatemala, Honduras, and Mexico, agreed to participate in the Mesoamerican Barrier Reef System Project (MBRSP). MBRSP was established with funding from the World Bank, Global Environmental Facility, and several other international and domestic funding sources to conserve and manage the shared barrier reef.[41] The four littoral states have drafted a fifteen-year conceptualized program to support the formulation of national and regional policies necessary for the conservation and sustainable development of the reef.[42]

Especially important among the program components is a Regional Environmental Monitoring and Information System (REIS). The purpose of the REIS is to make accessible to the project's clients, as well as the general public, information relevant to the management of the barrier reef system and the health of related ecosystems.[43] Included within the REIS will be information and data from the Synoptic Monitoring Program (SMP). As envisioned, the SMP will monitor up to twenty-three sites based on the presence of biodiversity-rich ecosystems; importance of the areas as sinks for recruitment of corals, fish, and other important community components; and existing or potential threats associated with pollution stemming from onshore activities.[44] Standardized monitoring methodology will allow comparisons between monitoring sites, countries, and regions.

Currently, foreign access to marine genetic resources has not been specifically identified as a project component.[45] However, MBRSP could readily serve in the future as an institutional vehicle to develop a harmonized set of guidelines and principles promoting an ecosystem- or region-based approach to managing these transboundary resources. The four national participants of MBRSP have a unique opportunity to avoid the potential problems associated with the rule of capture. Rather than competing with each other to negotiate individual agreements with foreign researchers and engaging in wasteful and redundant scientific and administrative efforts, MBRSP will allow scarce human and technical assets to be pooled and used more effectively. With a minimal amount of effort and expense, scientifically sound and cost effective specimen collection protocols, taxonomic data storage and retrieval systems, monitoring and enforcement mechanisms, and other capacity building activities may be piggybacked onto existing components of the MBRSP program. For example, the REIS and the SMP will provide biological, physical, and ecological baseline data this is of extraordinary value to researchers interested in accessing and commercializing marine genetic resources.

Additional efficiencies will be obtained by centralizing administrative efforts. By delegating regulatory authority to one administrative agency, model material transfer agreements can be developed, and streamlined permitting procedures can be employed. Improving the transparency and predictability of the regulatory system will encourage researchers to request access to the region's marine genetic resources.[46]

Moreover, efforts to improve regional cooperation and economic integration will undoubtedly be recognized by national, multinational, non-governmental, and private-sector funding entities. The positive attributes of collaborative scientific research on an ecosystem scale and efficient administrative control will make it more likely that these entities will contribute to MBRSP efforts than would be the case if the participating nations worked in isolation.

In summary, benefits provided by an ecosystem or region-based approach to managing marine genetic resources include:

1. improving the efficiency and cost effectiveness of scientific research;
2. providing uniformity and efficiency in specimen collection protocols, taxonomic data storage and retrieval systems;
3. offering broader opportunities for effective education and training programs;
4. enhancing monitoring and enforcement mechanisms;
5. reducing illicit cross-border movements of genetic resources;
6. encouraging funding opportunities from national, multinational, non-governmental, and private sector entities;
7. reducing inequities between sharing States and preventing potential disputes arising from unilateral exploitation of shared marine genetic resources; and
8. improving political relations between participating States.[47]

Incorporating a Marine Genetic Resources Component into the MBRSP

The organizational structure and substantive rights and obligations provided by an ecosystem-based marine genetic resources program will necessarily depend upon the individual circumstances and aspirations of the parties participating in the MBRSP. While the geographic boundaries of any proposed marine genetic resources program are already delineated under the International Agreement creating the MBRSP, there is no need to open the entire reef system to future bioprospecting activity. Predetermined areas of the reef should be established for marine genetic research based on their environmental, commercial, and political suitability. Moreover, it will be necessary for participating States to agree on some formula to allocate rights and responsibilities. This formula may be based on the size of the habitat located within each nation's boundaries; levels of financial or in-kind funding contributions of each nation; contributions per capita of population, or other suitable factors.[48]

Participating nations will have to determine whether domestic implementing legislation is required based on their individual needs and circumstances. If domestic implementing legislation is warranted, there are benefits to narrowly tailoring such legislation to limit its application only to the marine genetic resources located within MBRSP juridical boundaries rather than expanding it to include all genetic resources, including terrestrial. A number of features unique to the marine environment make it especially suitable for the cooperative model suggested in this paper and allow nations to avoid many of the political and legal pitfalls associated with commercializing terrestrial genetic resources. These features include the following:

1. organisms in marine areas are generally publicly rather than privately owned, and public ownership eliminates many of the domestic legal problems that likely occur when governmental action impinges on the rights of private property owners;
2. ocean space is used primarily as a source of marketable commodities rather than a permanent place for human habitation thereby reducing many of the legal, political, and ethical problems associated with long-standing occupancy rights;
3. unlike terrestrial areas, there is much less likelihood that indigenous peoples' traditional knowledge will be utilized thereby eliminating many of the thorny issues relating to intellectual

property right compensation;[49] and

4. the international community has historically relied more heavily on cooperative management techniques in the ocean than on land territory and they have traditionally served as models for later land-based collaborative efforts.[50]

In common with all internationally negotiated agreements, tensions will exist in attempting to balance functional benefits with the loss of sovereign prerogatives. While it is impossible to predict where this balance may fall, a few general observations may be useful.

First, the sovereign rights of member states should be respected and maintained if a marine genetic resource component within the MBRSP has any hope to succeed. As in the context of shared oil and gas and water resources, each nation in whose waters the genetic resource lies must retain sovereign rights over the resource subject only to the right of other sharing States to an agreed-upon portion of any benefits obtained from commercialization. In other words, each sharing State may have a right to an equitable share of the proceeds or benefits received from the commercialization of a particular marine genetic resource, but does not have a right to a share of the physical substance itself. This distinction is important because it will reassure each participating State that its sovereign right to regulate and control access to resources within its territory will be respected and that it will not be pressured to either provide or not provide access under conditions to which it has not agreed.

Second, the issue of recollection of samples as a source material for commercial products needs to be addressed in any regional agreement. Many of the arguments that justify treating marine genetic resources differently than other resources do not apply when they are being harvested not for their genetic information, but instead for their physical properties. Under such circumstances a nation may legitimately seek to treat the recollection effort as legally equivalent to the exploitation of fish or other commodified natural resources. However, if one of the parties unilaterally allows unregulated large-scale recollections of marine organisms to occur within their juridical waters, many of the benefits accorded to the parties under a cooperative regional approach could be severely undermined. Some accommodation, therefore, needs to be made in the agreement to provide a rational and predictable method of regulating future large-scale recollections in member States' waters.

Third, it is essential that all of the nations sharing the marine genetic resources be members of the regional entity and bound by its requirements. The goals and purposes of any regional effort could be easily nullified if one nation becomes a "free rider" and allows unregulated foreign access to its marine genetic resources. Every attempt should be made to persuade all eligible States of the practical benefits inuring to members of the regional entity.

Fourth, the regional agreement should contain some form of compulsory and binding dispute settlement mechanism. One of the most commonly cited weaknesses of existing regional fishery bodies is the failure of member states to fulfil their responsibilities.[51] A credible and effective dispute settlement mechanism will serve as a deterrent to potential violators and will allow for quick and cost-effective resolution of potential violations.

Finally, it is imperative that any regulatory system created under the auspices of the regional entity be transparent, and not too confusing or burdensome to those seeking access. Simplicity of regulatory process should be the guiding principle while still ensuring adequate benefit-sharing for each nation and the region.[52] Little point is served by creating a regulatory system that scares potential users into finding alternative sources outside of the region.

Conclusion

Unsettled legal issues concerning access to foreign marine genetic materials and ownership of the results of any discovery efforts have become primary obstacles to the commercialization of marine natural products. MBRSP has the unique opportunity to reverse this trend by taking on an effective coordinating and administrative function for the cooperative management of marine genetic resources. Incorporating a marine genetic resource component into MBRSP will provide tangible benefits to member States while conserving this globally important resource and harmonizing policies relating to the sustainable management of shared/transboundary marine genetic resources.

Just as Costa Rica and its partnership with the National Biodiversity Institute (INbio)[53] has served as a model to other nations which are interested in finding economically profitable yet environmentally benign uses for their terrestrial biological inventories, MBRSP can potentially serve the same function in the marine context. It is only a matter of time before the international community rejects the rule of capture as the fundamental method of managing transboundary marine genetic resources in favor of some form of cooperative regional or ecosystem-based approach. If properly planned and implemented, a cooperative marine genetic resource component within MBRSP will provide important guidance and impetus for this important global effort.

Endnotes:

1. The author would like to thank the Lamar Order at the University of Mississippi School of Law for its summer research support. Portions of this work are adapted from Richard J. McLaughlin, *Foreign Access to Shared Marine Genetic Materials: Management Options for a Quasi-Fugacious Resource*, 34 OCEAN DEVELOPMENT AND INTERNATIONAL LAW 297-348 (2003).

2. For a discussion of the rule of capture see discussion infra notes 28-29 and accompanying text.

3. NATIONAL ACADEMY OF SCIENCES, MONSOONS TO MICROBES: UNDERSTANDING THE OCEANIC ROLE IN HUMAN HEALTH 73 (1999). *See also* Grifo, F., et al., *The Origins of Prescription Drugs*, *in* BIODIVERSITY AND HUMAN HEALTH (F. Grifo and J. Rosenthal, eds., 1997) (estimating that eighty-five out of the top-selling 150 drugs in 1993 either contained one compound or were derived or patterned after compounds found in nature). Another study estimates that of all drugs known to mankind, roughly four-fifths are derived from natural sources. Edward O. Wilson, THE DIVERSITY OF LIFE 283 (1992).

4. Lyle Glowka, et al., *Best Practices for Access to Genetic Resources*, Information Paper commissioned by DG XI, European Commission and the German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety, section 2.1 (April 1998), available at http://www.biodev.de/English/content.html. See also, Gabriele M. Konig and Anthony D. Wright, *Marine Natural Products Research: Current Directions and Future Potential*, 62 PLANTA MEDICA 193, 193-211 (1996).

5. National Academy of Sciences, supra note 3, at 74.

6. Ibid.

7. Brad K. Carte and Randall K. Johnson, *Topotecan Development: An Example of the Evolution of Natural Product Drug Discovery Research, in* MEDICINAL RESOURCES OF THE TROPICAL FOREST 85 (M. Balick et al., eds., 1996).

8. For a useful discussion of current research explaining how many of these processes operate and their commercial drug potential, see DRUGS FROM THE SEA (N. Fusetani ed., 2000); Pushkar N. Kaul, *Drug Discovery: Past, Present and Future, in* 50 PROGRESS IN DRUG DISCOVERY 25-33 (J. Jucker ed., 1998); and Konig and Wright, supra note 4.

9. Kushal Qanungo, *Time for a New Deal on Marine Bioprospecting*, at http://www.scidev.net/index.asp (date posted January 17, 2002).

10. Fusetani, supra note 8, at 1. This figure significantly underestimates the number of patents that currently exist. The Division of Biomedical Marine Research at Harbor Branch Oceanographic Institution alone lists nearly one hundred patents that have been issued to its researchers. See, www.hboi.edu/dbmr/new_partners.html.

11. E.A. Evans-Illidge and P.T. Murphy, *A New Approach to Benefit Sharing in Bioprospecting*, at www.diodiv.org/programmes/socio-eco/benefit/case-studies.asp (Last updated Mar. 15, 2002) (Wendy Hollard ed., n.d.) (explaining the collection procedures used by the Australian Institute of Marine Science). *See also Marine Bioprospecting for the National Cancer Institute; From the Coral Reef Research Foundation of Palau: Dr. Patrick Colin Discusses the Realities of Marine Collecting,* www.reefnet.org/issue7/research7.html (describing how marine samples are collected for the National Cancer Institute).

12. Konig and Wright, supra note 4, at 196.

13. Researchers collect the same species from a variety of different sites to examine intraspecific levels of variability in chemical constituents. At each collection site, researchers perform biodiversity surveys, take GPS coordinates for future mapping and recollection purposes, and record general physical characteristics of the sites. These environmental data are used to evaluate the role of specific biological and physical characteristics of the environment on chemical variability. RESEARCH PARTNERSHIP FOR DRUG DISCOVERY: FINAL REPORT FOR THE PERIOD 1 AUGUST 2001 THROUGH 30 SEPTEMBER 2003, National Oceanic and

Atmospheric Administration Award Number NA16RU1496 (on file with the author).

14. For a useful discussion of steps in the drug development process, see James. D. McChesney, *Biological Diversity, Chemical Diversity, and the Search for New Pharmaceuticals,* in MEDICINAL RESOURCES OF THE TROPICAL FOREST 12-15 (M. Balick et al., eds., 1996).

15. David Farrier and Linda Tucker, *Access to Marine Bioresources: Hitching the Conservation Cart to the Bioprospecting Horse*, 32 OCEAN DEV. 7 INT'L L. 219 (2001) (providing past examples of large quantities of marine organisms being harvested to extract small amounts of bioactive compounds).

16. *Marine Prospecting for the National Cancer Institute*, supra note 11 (arguing that collection efforts in Palau are very selective and that volumes of scientific data on specific groups of invertebrates in the region have been published as a result of such research).

17. Fusetani, supra note 8, at 3 (some of the marine-derived drugs in clinical testing today have such analogues; but see, Paul R. Jensen and William Fenical, *Marine Microorganisms and Drug Discovery: Current Status and Future Potential*, in Fusetani, id, at 7 (noting that some marine-derived compounds have extremely complex structures that do not lend themselves to commercially viable syntheses).

18. Fusetani, id at 2; Jensen and Fenical, id.

19. Conventional on Biological Diversity, done on June 5, 1992, U.N. Doc. DPI/130/7 (1992), S. TREATY DOC. 20, 103d Cong. 1st Sess. (1993) reprinted in 31 I.L.M. 818 (1992) [hereinafter CBD] (entered into force Dec. 29, 1993; 182 nations are States Parties as of September 2001. The United States has signed but not ratified the Convention).

20. The overriding interest of developing nations during the negotiations of the CBD was to assert sovereignty over genetic resources and to prevent the Convention from being used to compel developing nations to conserve, at their own expense, biodiversity for international benefit. William Lesser, SUSTAINABLE USE OF GENETIC RESOURCES UNDER THE CONVENTION ON BIOLOGICAL DIVERSITY: EXPLORING ACCESS AND BENEFIT SHARING 4 (1998).

21. CBD, supra note 21, Article 15(2).

22. Ibid., Article 15(4)

23. Ibid., Article 15(5).

24. Ibid., Article 15(6).

25. Ibid., Article 16(3).

26. Ibid., Article 15(7).

27. Lyle Glowka, *Emerging Legislative Approaches to Implement Article 15 of the Convention on Biological Diversity*. 6 RECIEL 249 (1997); Richard J. McLaughlin, *Foreign Access to Shared Marine Genetic Materials: Management Options for a Quasi-Fugacious Resource*, 34 OCEAN DEVELOPMENT AND INTERNATIONAL LAW 297, 323-24 (2003).

28. For a useful discussion of the historical development of the Rule of Capture principle tracing it from the Roman era's Justinian's Institutes through English legal texts of the eleventh century and into early nineteenth century U.S. law, see the well known case of *Pierson v. Post*, 3 Cai. R. 175, 177-79 (N.Y. Sup. Ct. 1805).

29. In describing the problems associated with rule of capture in the context of oil production, one commentator stated, "the convenient rule of capture was allowed to gain full head. Gross waste and inequity were its monuments." R.O. Kellum, *A Century of Correlative Rights*, 12 BAYLOR L. REV. 1, 42 (1959). An especially graphic example of abusive behavior under the rule of capture is related in Carl Coke Rister, OIL! TITAN OF THE SOUTHWEST 92 (1949) describing an Oklahoma refinery which rapidly drained the oil beneath its own small lease of ten acres, as well as the oil under its neighbor's land.

30. General Agreement on Tariffs and Trade – Multilateral Trade Negotiations (The Uruguay Round): Agreement on Trade-Related Aspects of Intellectual Property Rights, Including Trade in Counterfeit Goods, Dec. 15 1993, 33 I.L.M. 81 (1994).

31. Elliot A. Norse, GLOBAL MARINE BIOLOGICAL DIVERSITY (1993) at 42 (because of buoyancy, viscosity, and other physical and chemical characteristics of seawater, marine organisms tend to have larger ranges than land organisms).

32. For a full discussion see Richard McLaughlin, supra note 27, at 303-06.

33. See Eyal Benvenisti, *Collective Action in the Utilization of Shared Freshwater: The Challenges of International Water Resources Law*, 90 AM. J. INT'L L 384, 388 (1996) (describing international water resources as common-pool resources, which are partially excludable and rival, and why they need to be managed collectively).

34. Supra notes 28-29 and accompanying text. A customary rule of law has emerged that rejects rule of capture in the exploitation of transboundary oil and gas pools. See, William T. Onorato, *Apportionment of an International Common Petroleum Deposit*, 17 INT'L AND COMP. L.Q. 85,101 (1968). ("At very least [an international tribunal] could quite justly provide that in no case could any party in interest proceed unilaterally with exploitation procedures based on unrestricted capture to the prejudice of all other interest-holders involved").

35. Correlative rights have been defined as: "[T]he opportunity afforded the owner of each property in a pool to produce, so far as it is reasonably practicable to do so without waste, his just and equitable share of the oil or gas, or both, in the pool." *Anshutz Corp. v. Wyo. Oil & Gas*

Conservation Commin, 923 P.2d 751, 757, n.1 (Wyo. 1996) (quoting WYO. STAT. ANN. Section 30-50101 (a)(ix) (Michie 1983).

36. Joint development of offshore petroleum deposits is "typically one where two or more countries enter into a formal agreement for the cooperative development of and the sharing of revenues derived from oil and gas activities within a given offshore area, by pooling their sovereign rights with respect to the area." Ian Townsend-Gault and William G. Stormont, *Offshore Petroleum Joint Development Arrangements: Functional Instrument? Compromise? Obligation?,* in THE PEACEFUL MANAGEMENT OF TRANSBOUNDARY RESOURCES (G. Blake et al., eds. 1995) at 51. By 1986, approximately forty coastal states that share transboundary oil and gas resources applied a conventional regime of cooperative management and exploitation. Alberto Szekely, *The International Law of Submarine Transboundary Hydrocarbon Resources: Legal Limits to Behavior and Experiences for the Gulf of Mexico,* 26 NAT. RESOURCES J. 733,766 (1986).

37. "Equitable utilization is now established as the principle governing the allocation of international surface water resources." Jonathan M. Wenig, *Water and Peace: The Past, The Present, and The Future of the Jordan River Watercourse: An International Law Analysis,* N.Y.U. J. Int'l L. & Pol'y 331, 346 (1995). In its most basic terms, equitable utilization allows a riparian state to utilize a shared water resource to the extent that its utilization does not interfere with the corresponding reasonable utilization of other sharing states. *See* Convention on the Law of Non-Navigable Uses of International Watercourses, G.A. Res. 51/229, U.N. GAOR, 51st Sess., U.N. Doc A/RES/51/229 (1997); reprinted in 36 I.L.M. 7000 (1997) at Article 5(1).

38. See, Document of The World Bank, PROJECT APPRAISAL DOCUMENT ON A PROPOSED PROJECT FOR U.S. $15.2 MILLION, INCLUDING A GRANT FROM THE GLOBAL ENVIRONMENT FACILITY TRUST FUND IN THE AMOUNT OF U.S. $11 MILLION EQUIVALENT TO THE CENTAL AMERICAN COMMISSION ON ENVIRONMENT AND DEVELOPMENT FOR A REGIONAL PROJECT FOR THE CONSERVATION AND SUSTAINABLE USE OF THE MESOAMERICAN BARRIER REEF SYSTEM (MBRS), April 5, 2001 (providing a detailed examination of the environmental and socio-economic importance of the reef to the region) (on file with author).

39. Sue Wells, *Case Study 3: Belize Barrier Reef*, http://www.ramsar.org/libbio7.htm.

40. Noel D. Jacobs, *Capacity for Protected Areas Management in the Mesoamerican Reef System*, PROCEEDINGS OF THE WORLD PARKS CONGRESS, Durban, South Africa, 2003 (on file with author).

41. Mesoamerican Barrier Reef System Project Annual Work Plan 2001-2002 (August 22, 2001) (on file with the author). Information about the MBRSP may also be found at its website, http://www.mbrs.org.bz/english/en_index.htm.

42. MBRSP currently contains five project components: Marine Protected Areas; Regional Environmental Information System; Sustainable Use of the Mesoamerican Barrier Reef System; Public Awareness and Environmental Education; and Project Management. Ibid., at 2.

43. Ibid., at 9.

44. Ibid., at 16.

45. See supra note 42 (describing the five current MBRSP components.)

46. Karen Young Kreeger, *In the Clinic/On the Shelf: Denizens of the Deep*, THE SCIENTIST, April 1, 1996, at 1, 8-9, (expressing the view that unsettled legal issues regarding foreign access to marine genetic resources and ownership of the results of drug discovery efforts have caused some U.S.-based pharmaceutical companies to refuse to screen samples collected outside of U.S. waters.)

47. For example, Belize and Guatemala have had a longstanding, and sometimes violent, legal and political dispute over their respective territorial boundaries including maritime boundaries. For a discussion of the history of the Belize/Guatemala territorial dispute and steps being taken to reduce tensions (albeit from Belize's point of view) see the Belize Government Website at http://www.belize-guatemala.gov.bz/belize_position.html.

48. Determining acceptable criteria and allocation formulas will surely be one of the most difficult aspects of negotiating a regional entity. While difficult, formulas to allocate member state rights and responsibilities have been successfully negotiated in a large number of existing bilateral and multilateral international agreements. For a discussion of many of these treaties in the marine context, see THE WORLD CONSERVATION UNION (IUCN), THE LAW OF THE SEA PRIORITIES AND RESPONSIBILITIES IN IMPLEMENTING THE CONVENTION (1995).

49. The legal rights of indigenous holders of knowledge is addressed in CBD, supra note 19, Article 8(j). In the context of the Mesoamerican Barrier Reef, it is unlikely that indigenous peoples in the region possess or utilize knowledge pertaining to medicinal uses of marine genetic resources. This assertion was confirmed by the author in numerous conversations with knowledgeable scientists and officials in the nation of Belize.

50. International law has always viewed governance of ocean areas differently than terrestrial ones. Recognition of exclusive coastal state jurisdiction over ocean areas has not come about simply to satisfy each nation's wish to exercise governmental power or sovereignty, but because coastal states have been judged the most effective custodians of the ocean and its resources. Ian Townsend-Gault and William G. Stormont, supra note 36, at 60.

51. Lawrence Juda, *Rio Plus Ten: The Evolution of International Fisheries Governance*, 33 OCEAN DEV. & INT'L L. 109, 125 (2002).

52. Glowka, supra note 27, at 261.

53. INbio is a private, nonprofit institution established in 1989 by the Costa Rican government. INbio's All-Taxa Biodiversity Inventory, undertaken in the Guanacaste National Park region, became the largest taxonomic undertaking of its kind in history. Its specific goals included producing field guides and creating a computer database of all of its taxonomic research. An important part of this project sought to identify natural products of potential commercial interest to private firms. By 1995, INbio's Biodiversity Information Management Systems placed nine thousand pages of taxonomic information on the internet, and scientists and environmentalists from around the world traveled to the INbio campus to seek guidance regarding similar initiatives in other nations. See generally, Paul F. Steinberg, ENVIRONMENTAL LEADERSHIP IN DEVELOPING COUNTRIES: TRANSNATIONAL RELATIONS AND BIODIVERSITY POLICY IN COSTA RICA AND BOLIVIA (2001) at 79-80; and William Allen, GREEN PHOENIX: RESTORING THE TROPICAL FORESTS OF GUANACASTE, COSTA RICA (2001) at 224-34.

Development of an Integrated Coastal Management Plan for the Gulf of San Miguel and Darien Province, Panama

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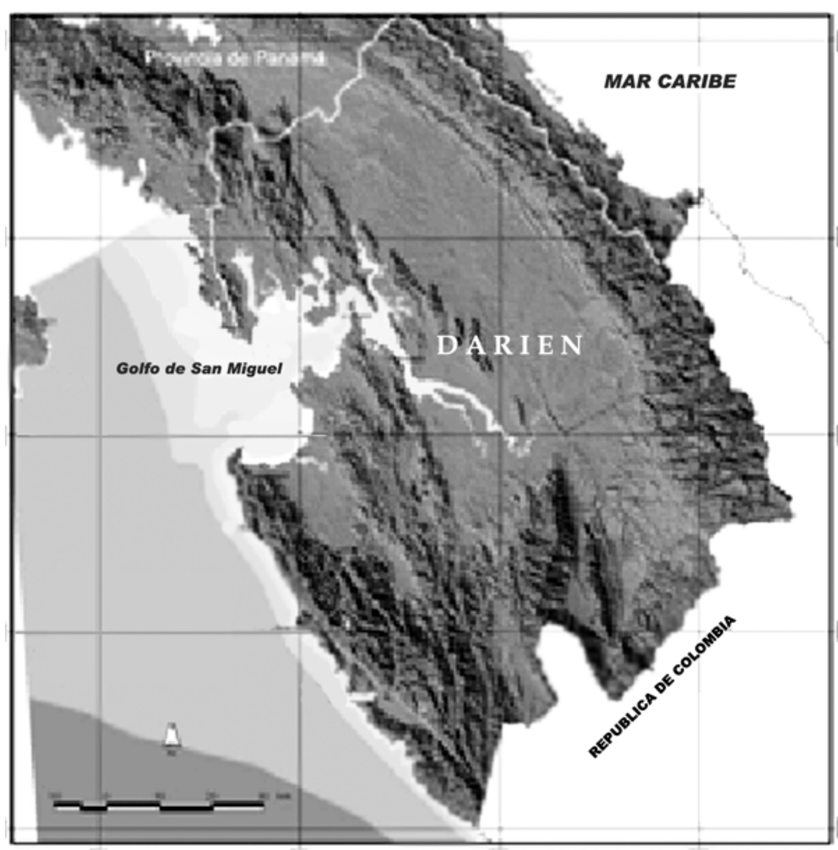
Keywords: Panama, Darien Province, coastal management, artisanal fisheries, industrial fisheries, mangroves, ecotourism, user conflicts, strategic planning

Introduction

At the end of 2002, the Government of Panama approved a coastal management project in the Darien Province with funding from the Inter-American Development Bank (IDB). The project is one of a package of over one hundred projects sponsored by the IDB through the Program for the Sustainable Development of Darien. The Panamanian institution with formal authority for coastal management is the Marine and Coastal Resources Directorate of the Panamanian Maritime Authority. The authorities selected a consortium formed of experts from the University of Miami, Arden & Price Consulting, and the University of Panama to carry out this project. The fifteen individuals participating in the project offer expertise in various disciplines including marine and terrestrial ecology, fisheries biology, geography and Geographic Information Systems (GIS), resource economics, sociology and anthropology, environmental law and planning, environmental education, and social work. The consultants and the government representatives are collaborating on this coastal management project for a period of approximately two years (2002-2004).



Map of Natural Features of Darien Province

Map of Coastal Communities in Darien Province

The Natural Environment
With an area of 16,803 square kilometers, Darien is Panama's largest province. It is located at the extreme eastern part of the country bordering Colombia to the east and the Pacific Ocean to the south. [See Map 1 of the Darien region.] Roads have penetrated into Darien only in the past twenty-five years, thus facilitating spectacular changes in land use as small farmers and cattle ranchers remove the tropical rainforest. Nevertheless, the mountainous eastern and southern parts of the province, as well as the coastal zones, remain relatively pristine today.

Marine Biogeography. Darien Province borders on the marine biogeographical zone known as the Panama Bight and, more specifically, on the Gulf of Panama. Nearshore upwelling caused by the Trade Winds, large freshwater input from numerous rivers, highly developed mangrove forests, high biological productivity, annual climatic shifts between dry and humid seasons as the Inter-Tropical Convergence Zone (ITCZ) passes over the isthmus, and dramatic oceanographic changes due to El Niño-Southern Oscillation (ENSO) phenomena all characterize the Panama Bight region.

Littoral Zone. The Darien coastline can be divided into two regions: the Pacific littoral zone and the Gulf of San Miguel. The Pacific Littoral Zone extends 130 kilometers from Punta Santa Bárbara to the Colombian border. This is an active coastline open to the full exposure of the Pacific Ocean. The narrow continental shelf extends only five to forty kilometers from the coastline in this zone. The Serranía del Sapo, reaching maximum height of 1,581 meters runs parallel to the coastline, and forested slopes plunge into the ocean.

Estuary. The second Darien coastal region is the Gulf of San Miguel, a large estuary with an area of approximately 1,760 square kilometers. The Gulf is relatively shallow (although the deep channel reaches forty meters in depth, in places). A complex system of rivers, deltas, mudflats, freshwater wetlands, and extensive mangroves forests comprise the Gulf of San Miguel.

This estuary is exceptionally dynamic. The daily tidal amplitude reaches four to five meters. The dry/humid seasonal cycle follows the movement of the ITCZ. While the first three months of the year are dry, the annual rainy season may bring over a meter of precipitation in Gulf of San Miguel coastal locations and up to five meters in the adjacent mountains. Additionally, the inter-annual variability caused by ENSO results in significant oceanographic and climatic shifts in the Gulf. Besides the temporal variability, the Gulf of San Miguel experiences great spatial variability resulting from the mixing of freshwater and saltwater.

The Gulf of San Miguel watershed (14,877 square kilometers) is the largest in area in the Gulf of Panama (33,828 square kilometers). Moreover, 45.2 percent of the precipitation in the Gulf of Panama watershed falls in the Gulf of San Miguel drainage area. The principal rivers of Darien - including Panama's largest river, the Tuira River, with an average annual discharge of 29.2 cubic kilometers - flow into the Gulf of San Miguel.

Vegetation. Tropical forests and mangroves are Darien's natural vegetation. The last large remaining stands of Tropical Dry Forest are found on Punta Garachiné, the peninsula to the south of the entrance of the Gulf of San Miguel. Tropical Humid Forests dominate the mountain slopes along the Pacific Littoral Zone. Approximately 465 square kilometers of highly complex mangrove forests border the Gulf of San Miguel and the lower courses of its rivers. These mangrove forests account for almost 3 percent of the surface area of the Darien and one third of the mangrove forest cover in Panama. Extensive stands of mangrove forests grow at the northern portions of the Gulf in the Congo, Cucunatí, and Sabanas River systems; along the internal Tuira and Balas River Systems; adjacent to the Ensenada de Garachiné on the southern portion of the Gulf of San Miguel; and along the Jaqué River on the open coastline. Four genera of mangroves are represented in Darien: red mangroves (*Rhizophora*), black mangroves (*Avicennia*), white mangroves (*Laguncularia*), and piñuelo mangroves (*Pelliciera*).

This project's structural analysis of the Darien mangrove forests indicates the high structural development of these forests. Some of the Darien mangrove stands are among the most structurally complex and highly developed in the Neotropics and are comparable in forest parameters (leaf area; diameter; height; species diversity, etc.) to mangrove forests in Ecuador, which have the highest structural indices in the Neotropics.

Protected Areas. The 579,000 hectare Darien National Park (UNESCO World Heritage Site and Biosphere Reserve) has formally protected the easternmost half of the province since its designation in 1980. An additional protected area, the Punta Patiño Natural Reserve, part of which was designated a Ramsar Site in 1993, includes 30,290 hectares of mangrove forests and tropical humid forests on the south central coast of the Gulf of San Miguel. Two forest reserves also exist in name but lack management or staff. Thus, the eastern half of the province maintains its natural tropical humid forest vegetation and is one of the centers of highest biodiversity in the tropical Americas. Colonists have deforested much of the western half of the province during the last twenty-five years, and today its vegetation cover is grassland and shrub forest used for extensive cattle grazing.

The Human Environment

Prior to the mid-1970s, Darien was effectively isolated from the rest of Panama. The only form of transportation to the province was by boat or small plane. In the 1970s, the Panamanian government began to extend the Pan-American Highway eastward into the Darien Province to open the region to colonization and (one day) to connect the road systems of Panama and neighboring Colombia (Girot

2002). By the end of the 1970s, the dirt (mud) road had reached Yaviza in the heart of the province. Twenty-five years has witnessed no change in the road, although secondary roads continue to extend from the Pan-American Highway. As a result of the road construction, small farmers from other regions of Panama (especially the Central Provinces of Los Santos and Herrera) have colonized significant areas of the western half of Darien along the road network.

The road and the colonization it stimulated are largely responsible for the province's population increases in recent decades, from 14,660 persons in 1950 to 48,530 in 2000 (Republic of Panama 1998, 2002). Mestizo colonists from central Panama account for much of Darien's population growth. This social and ethnic group tends to inhabit small towns and rural areas adjacent to the road system.

Ethnicity. Other social groups in Darien – besides the mestizo colonists - have closer links to the marine and riverine environments. Afro-colonial peoples tend to inhabit small towns adjacent to the Gulf and engage in small-scale fishing activities, as well as commerce, agriculture, and government employment. In recent years, Afro-Colombians have migrated to several towns located on the Gulf (La Palma, Punta Alegre, Garachiné) and the ocean coast (Jaqué) in search of economic opportunities, as well as to escape the violence in neighboring Colombia.
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Native peoples include two Chocó subgroups: the Emberá and Wounaan peoples. These groups traditionally lived in the forest along river banks in isolated family units. Government policy in the 1970s concentrated these peoples into nucleated communities to facilitate government provision of services. The Chocó peoples engage in agriculture and fishing (Torres 1980). In 1983, the Government of Panama declared two reservations (comarcas) to respect native land, but neither of these areas is immediately adjacent to the coast. Increasing numbers of Emberá and Wounaan people live outside their autonomous areas in neighborhoods that surround the largely afro-colonial coastal towns, as well as in several small villages with over 95 percent native population. The extra-comarca native population is becoming increasingly assertive in its demands for community-held land titles as mestizo colonists settle these same lands.

Population. Of the 48,530 persons living in Darien Province in 2000, 25,936 (53 percent) reside in the fifteen coastal municipalities. See Map 2 of coastal communities in Darien Province. Approximately 22 percent of the provincial population (10,518 persons) live in some fifteen small coastal towns and villages immediately adjacent to the ocean or the estuary. The most populated area is the upper Gulf of San Miguel, especially the municipalities of La Palma with the provincial capital of La Palma (1,741 inhabitants) and Santa Fé with its inland agricultural town of Santa Fé (1,140 inhabitants).

During the decade of the 1980s, immediately after the Pan-American Highway was completed to the town of Yaviza, population in Darien Province grew at rates (6.5 percent) more than twice the national average (2.9 percent) as colonists migrated from the central provinces in Panama. This growth was reflected in coastal municipalities but not in coastal towns.

In the 1990s, population growth in Darien Province slowed after the government removed agricultural price support programs and eliminated agricultural produce purchasing programs in most towns. While the average annual population growth rate from 1990-2000 for Panama was 2.19 percent, it was only 1.07 percent for Darien Province. Growth rates were somewhat higher for Darien coastal municipalities and towns (1.46 percent and 1.24 percent, respectively), perhaps fueled by immigration of residents of inland Darien villages in search of improved social services and employment opportunities (shrimp harvesting).

Recent Population Growth Indices in Darien and Panama

	Annual Population Growth 1980-1990	Annual Population Growth 1990-2000
Darien coastal towns	2.34%	1.24%
Darien coastal municipalities	5.07%	1.46%
Darien Province	6.5%	1.07%
Panama (national average)	2.9%	2.19%

Increasing populations in coastal towns translate into increased use and extraction of marine and coastal resources. Similarly, the population increases place demands on improved social services.

Social Conditions. All social indicators in Darien Province are lower than the national averages. The coastal municipalities and communities also reflect this tendency. A large percentage of the population fails to satisfy its basic human needs.

For example, 9.2 percent of houses in Panama lacked potable water in 2000 (República de Panamá 2001). However, 40.9 percent of homes in Darien Province lacked this service. However, almost all Darien coastal communities had aqueducts that supplied potable water – except for three towns (Punta Alegre, Taimatí, and Sambú).

Similarly, the percentages of homes in Darien Province lacking sanitary facilities (latrine or cesspit) is high (37.9 percent) in comparison to the national average (6.9 percent). In some coastal communities (Playa de Muerto, Río Congo, Punta Alegre), over two-thirds of homes lack sanitary facilities. Other social indicators, such as homes without electricity and infant mortality rates, are also elevated compared to national averages.

Panama is a highly literate nation with an illiteracy rate of about 7.6 percent. However, in Darin Province, the illiteracy rate jumps to 22.8 percent, while in some coastal communities (Mogue, Puerto Piña, Puerto Lara), more than one-third of the adult population is illiterate. These villages also have high percentages of indigenous population.

Marine & Coastal Resources

Fishery Resources. The Gulf of San Miguel contains ecosystems and coastal/marine resources that are important for Panama. The Gulf of San Miguel produces about 70 percent of the country's total catch of white shrimp (*Litopenaeus occidentalis*) that is largely exported and contributes U.S.$26 million to the national economy (Suman 2002). The shrimp harvest boomed in the 1990s with major growth of the artisanal fleet. Two distinct fishing fleets contribute to this catch in the Gulf: the industrial and artisanal fleets. Panama's industrial shrimp fleet is capped at 232 vessels, and a significant number use bottom trawls in the rich shrimp grounds of the Gulf. In addition, some one thousand artisanal fishers living in coastal towns surrounding the Gulf also catch large quantities of this high value resource. (The fish house owner/intermediary pays the fisher approximately U.S.$5 per pound of shrimp.) Curiously, both the artisanal and industrial marketing chains terminate in the same processing/exporting companies in Vacamonte or Coquira (Panama Province), and these are controlled by a handful of Greek-Panamanian entrepreneurs.

Artisanal fishers also supply finfish to the national and international markets, especially corvina/croakers, pargo/seabream, and robalo/snook. Hundreds of men, women, and children also collect shellfish near several Gulf of San Miguel coastal towns (Garachiné, Taimatí, Punta Alegre), supplying the national market with seven species of shellfish, including clams, mussels, and oysters. This harvest occurs during low tides in the extensive mudflats located in front of the mangrove forests, especially in the Ensenada de Garachiné.

Sportfishing based at the exclusive Tropic Star Lodge in Piñas Bay (Puerto Piña) on the ocean coast of Darién caters to gamefishing enthusiasts and is of international renown. Generally, sportfishing for billfish, such as black marlin, blue marlin, stripped marlin, and sailfish, occurs within six to twelve miles of Puerto Piña. This area holds more than 170 world records from the International Game Fish Association for billfish size. This activity is "high-end" tourism. For example, a week at the lodge can cost up to six thousand dollars. Guests arrive in Piñas in small charter plans directly from Panama City.

In 1994, the Panamanian government declared the marine area within a twenty-mile radius of Bahía Piña to be a sportfishing zone in which certain fishing arts (longlines, purse seines, trawl nets, and gillnets) were prohibited.

Mangroves. While fishing is the primary activity in the Gulf of San Miguel, other economic activities are also important. Little intervention has occurred in the extensive mangrove forests that surround the Gulf, and no mangrove wood products are exported from the province. Local villagers make only limited use of mangroves for fuelwood, gas being the preferred cooking fuel. In some areas of central Panama (Coclé, Herrera, and Panama Provinces), shrimp aquaculture ponds encroach on mangrove forests. However, to date, this activity does not occur in Darien.

Ecotourism. Ecotourism is a growing use of the natural resources of the area. Several ecotourism operators located in Panama City organize tours to the Punta Patiño Nature Reserve and nearby locations. Tours emphasize boat trips through the mangrove ecosystem, bird-watching, and visits to Emberá and Wounaan villages. In addition, several international cruise liners enter the Gulf to visit the Emberá village of La Chunga. Despite the enormous eco-tourism potential of Darien, only about a thousand tourists visit the province's coastal areas each year. While the Panamanian Tourism Institute has named many coastal areas of Darien a "tourism development zone," this designation is a mere formality, and no activity tourism support programs exist in the province.

Agriculture. Agriculture is a secondary activity in the Darien coastal zone. During the 1980s, the Panamanian government eliminated its program of subsidies and price controls for agricultural products and terminated its crop-purchasing programs. Agriculture collapsed in Darien, a region of Panama with high production costs and rudimentary transportation infrastructure to urban areas of the country. Moreover, at the same time, the fungus Black Sigatoka destroyed 75 percent of Darien's plantain production, once the primary agricultural product of the province. Thus, the shrimp boom of the 1990s provided welcome relief for people in coastal communities.

Deforestation and conversion to grasslands for cattle-grazing has occurred in the municipalities to the north and east of the Gulf of San Miguel in areas that have secondary road connection to the Pan-American Highway. Comparative satellite imagery indicates that the massive deforestation in these areas has occurred in the past two decades since the Pan-American Highway was opened to Yaviza, Darien, in the late 1970s. This deforestation has now reached the landward boundary of the extensive mangrove forests in the municipalities along the northern rim of the Gulf of San Miguel (Río Congo, Cucunatí, Santa Fé, Río Iglesias).

Transportation. The traditional means of transport in Darien was riverine-maritime. The construction of the pier in La Palma in 1978 facilitated transport of people and produce to and from Panama City via ocean-going wooden vessels. In 1993, a pier opened in Puerto Quimba across the Tuira River from La Palma and, for the first time, connected the Gulf of San Miguel by road with Panama City. During the past decade, the Puerto Quimba – Pan-American Highway alternative has steadily increased, eclipsing the La Palma-Panama City maritime route. Puerto Quimba appears to be situated for major growth as a trans-shipment point for the coastal communities of the Gulf of San Miguel. Improvements of the road and pier will accelerate the growth of this site.

Communication between the Gulf of San Miguel communities and up-river villages, however, is still the realm of small wooden vessels. The high price of gasoline (U.S.$3 per gallon) remains a limiting factor for communication.

Sand Mining. Several mining companies applied for sand mining concessions in the Gulf near Garachiné in 2001. Their requests fueled a vocal controversy between the mining companies, government agencies, and Darien residents. The strong opposition of residents and political leaders in the Gulf towns – especially Garachiné - blocked the grant of the mining concessions for the time being.

The Institutional Enviornment

While many institutions in Panama administer coastal resources, integrated coastal management (ICM) is only a recent phenomenon. Even with the acceptance of ICM terminology, development of institutional coordination has been difficult and slow to develop. For a detailed discussion of these institutional arrangements and problems, see Suman (2002).

The Marine and Coastal Resources Directorate (DGRMC) of the Panama Maritime Authority (AMP) is the lead agency for fisheries and coastal management. The 1998 Decree Law No. 7 mandated a major institutional reorganization and concentration of marine responsibilities in the newly formed AMP. This decree was the first legislation to make specific reference to ICM in Panama, and it specified that the DGRMC would have primary responsibility for coordination of coastal management and authority to manage coastal resources. Nevertheless, the decree failed to stipulate an inter-agency coordination mechanism, and most of DGRMC's energies continued to focus on its traditional expertise – fisheries management. The AMP's General Directorate of Ports administers the nation's smaller ports while the larger international ports have been granted to private concessionaires.

The National Environment Authority (ANAM) concentrates most environmental competencies in Panama and, through the mandates of the 1998 Environmental Law (Law No. 41), is a significant coastal area actor. ANAM coordinates the environmental assessment process, administers protected areas, manages endangered species, and possesses management authority over mangrove forests. Clearly, mangroves remain a point of institutional overlap and uncertain exercise of authority between ANAM and AMP/DGRMC; this ecosystem is a forest but also a coastal resource.

The Program for the Sustainable Development of Darien (PSDS), a unit within the Ministry of Economy and Finance (MEF), is a key institutional actor in the Darien and its coastal zone. The PSDS oversees numerous development projects in Darien funded by the Inter-American Development Bank's $70 million loan to the Panamanian Government. The PSDS exercises coordination responsibilities over all these projects even though they may fall within the substantive areas of competence of ten different governmental institutions.

Other national institutions also exercise (or could exercise) important roles in Darien's coastal zone. The Ministry of Health (MINSA) operates the health care system and carries out public health campaigns and services (latrines, potable water, malaria control). The mission of the Panamanian Tourism Institute (IPAT) is promotion of tourism, and IPAT has designated several coastal areas of Darien as a tourist development zone. The Ministry of Agricultural Development (MIDA) promotes crop and livestock development and grants land titles.

The fifteen municipal governments in Darien Province that border on the Gulf of San Miguel on the littoral zone are also institutional players. Generally, however, the local governments are relatively weak and do not have authority over management of natural resources. Nevertheless, they are important in community mobilization and organization.

Despite the many institutional actors in Darien's coastal areas, no institutional coordination mechanism exists at the national or regional level. Government authority is weak, and existing interventions and resources seldom consider the opportunities and benefits that could result from cooperation and integration.

Problems – Vulnerability and Conflict

Darien Province is a region of contrasts. Ecological devastation is evident in the western half of the province that is accessible by the Pan-American Highway. The eastern half of Darien and the province's coastal areas, however, preserve most of their natural vegetation cover. Problems of the coastal areas include overexploitation of marine resources (evident in the past ten years); competition between artisanal and industrial fishing fleets over the high value shrimp resource; extensive by-catch from the shrimp trawlers that is simply disposed into the Gulf waters; the arrival of the agricultural frontier to some areas immediately landward of the mangrove forests; deterioration of water quality around urban areas that lack sewage treatment facilities and organized trash collection; poverty of coastal residents and lack of community infrastructure (electricity, potable water, sanitary systems); and the relative lack of attention that government authorities dedicate to coastal Darien, its peoples, and management of coastal and natural resources. The Panamanian government initiated the Darien Coastal Management Program to address some of these issues and challenges.

Phases of the Project

The Inter-American Development Bank is funding a suite of projects in Darien Project, together grouped as the Program for the Sustainable Development of Darien (PDSD). The Development of an Integrated Coastal Management Plan for the Gulf of San Miguel and Darien Province is one of the approximately one hundred projects that comprise the PDSD.

The professional community (GESMAP 1996; Cicin-Sain and Knecht 1998) generally characterizes ICM as involving five phases, generally describes as follows:

- Phase 1 – Diagnosis of the coastal resources and the communities that use and depend on them; identification of priority problems.
- Phase 2 – Development of a coastal management plan that addresses the priority problems through government and community interventions.
- Phase 3 – Funding and formal approval of the coastal management plan.
- Phase 4 – Implementation of the actions and mobilization of resources to resolve problems.
- Phase 5 – Evaluation of the implementation plan using previously determined indicators. The evaluation phase should lead to adaptive management and revision of the management plan that takes into account lessons learned and emerging problems.

The responsibilities of this project team focused on the initial three phases with their unique objectives and activities. Products from these efforts will be useful to coastal resource managers and the resource users. Our task was to diagnose the state of Darien coastal resources and communities (ICM Phase 1); develop a coastal management plan with significant community involvement (ICM Phase 2); and propose detailed project work plans and recommend funding sources (ICM Phase 3). Responsibilities did not include lobbying for approval of the ICM plan nor its implementation.

Phase One. The first phase involved a diagnosis of the existing natural resources in Darien coastal areas and the people who utilize them. Much of the information presented in this manuscript is the result of the project's diagnostic phase. The initial task involved collection and evaluation of the existing knowledge about the region (both scientific and traditional) and identification of gaps and deficiencies in the knowledge base. The ecological subgroup characterized the most significant habitats; species and biological communities; living and non-living resources and their interactions. This group also analyzed tendencies in the state of the resources and identified sites, times, and/or species that are particularly vulnerable. The social subgroup initiated a characterization of the productive economic systems of Darien's coastal zone; social and community organization; the relationships between the residents and the marine and coastal resources; conflicts between social and economic groups related to access to or use of coastal resources; and the strengths and weaknesses of the responsible government institutions. The project was committed to involving the public in this phase of the project through interviews, surveys, focus groups, and the recognition of the importance of traditional knowledge.

The initial phase of the project produced several documents that constituted the basis for the development of an Integrated Coastal Management plan. These included: 1) an evaluation of the state, tendency, and vulnerability of the mangrove ecosystem, as well as other coastal wetland systems, 2) assessments of the state of the Gulf's shrimp and fishery resources and a determination whether overfishing of the resource occurs, 3) analyses of the social organization and community structures in coastal towns, 4) an atlas of marine and coastal resources in Darien coastal areas, and 5) a synthesizing document that analyzed the environmental and social conditions of the Darien's coastal zone and identified priority issues and sites that demand immediate attention.

The Darien Coastal Resources Atlas is a key product of Phase One of the project (Arden & Price Consulting/University of Miami 2003). No similar type of document has ever been developed in Panama. The atlas synthesizes oceanographic, meteorological, ecological, social data and indicators, and political information about Darien, particularly its coastal zone. The document emphasizes spatial use of coastal resources. The information appears in thirty-eight thematic maps. Surrounding each thematic map are descriptive paragraphs, tables, graphs, and photographs. GIS technologies were essential for development of the atlas.

Information sources for the thematic maps were multiple and included satellite imagery (sea surface temperature, chlorophyll-a in surface waters, transparency, wind patterns, vegetation coverage, and land use); census data (population and social indicators); observational analysis and participatory mapping (transportation systems, eco-tourism sites, artisanal and industrial fishing zones, marine resource marketing strategies, community services); as well as the research team's observations and critical analyses (conflict areas and vulnerable sites).

The Darien Coastal Resources Atlas should be of great utility for all institutions (governmental and non-governmental) that work in Darien. Its usefulness also extends to local authorities, user groups, coastal residents, researchers, and students. We hope that it will serve as a model for a national Panamanian coastal atlas in future years.

Phase Two. The second phase of the project is the preparation of an ICM plan for the Darien coastal zone that utilizes strategic environmental planning methodologies. This effort involved an evaluation and prioritization of the themes and issues that surfaced from the diagnostic phase through interactive workshops and focal groups with resource users and interested parties. The goal was to facilitate the communities of users and residents to reach a shared vision of the future of the coastal areas of Darien and the Gulf of San Miguel in particular. Based on the shared vision of the future, the project team and user groups together developed management strategies with associated specific actions to meet the objectives. The subsequent tasks involved consideration of alternative actions and their corresponding management requirements.

During the first four months of 2004, the project team developed a draft Darien Coastal Management Plan composed of five action plans focusing on critical issues for the province's coastal areas:

1. Fisheries
2. Conservation of coastal habitats and resources
3. Coastal water quality
4. Eco-tourism
5. Institution coordination

The five Action Plans identify priority problems and subsequently discuss specific strategies to resolve them. After a discussion of identified problems, each Action Plan presents a Vision that encapsulated that expressed by community representatives, government officials, and project team members during a series of workshops. The vision represents a projection of the desired scenario in twenty years. Each Action Plan then proposes a series of strategies to address each problem. Strategies are arranged in chronological order during a five-year period that is the proposed time frame for the management plan. The discussion suggests alternatives for the strategies offering greater or lesser resource protection or causing greater or lesser socio-economic impact. Additionally, the plan describes potential obstacles to implementation of the strategies and also identifies the lead agency for the strategy and institutions with secondary responsibilities.

The following tables highlight the identified problems and some of the key strategies that the project team proposed in the Management Plan.

FISHERIES ACTION PLAN

Priority Problem	Key Strategies
No institutional presence of the Directorate of Marine and Coastal Resources in Darien Province	A well-planned strategic increase in qualified staff, offices, and equipment in Darien Province
Lack of compliance with existing fishery regulations	Educational campaigns; increase in enforcement actions
Absence of regulations for species of highly significant economic importance (clams and corvine/croaker)	Population biology studies; monitoring and analysis; determination of fishing efforts; drafting of appropriate regulatory strategies
Lack of fishery statistics	Program to monitor fish landings and fishing effort
Potential over-capitalization of the industrial shrimp trawling fleet	Economic studies to clarify the economic state of that industry
Possible over-capitalization of the artisanal fleet	Economic studies of the artisanal fleet; estimation of optimal effort and size of fleet
Lack of organization of artisanal fishers	Sociological study of artisanal fishers to recommend the most appropriate organizational structure for this group; determination of the desired goals of the proposed artisanal fishers organization
Conflicts between the artisanal and industrial fleets for space and resources	Creation of an artisanal fishing zone in shallow nearshore areas of the Gulf of San Miguel
Conflict between sportfishing and industrial and artisanal fishing interests near Bahía Piña	Analysis of the goals and impacts of the current regulation that creates a sportfishing zone and limits gear that artisanal and industrial fleets may utilize
By-catch from industrial shrimp trawlers	Initial study of shrimp trawler by-catch to analyze its biodiversity and quantity; potential requirements for By-Catch Reduction Devices (BRDs)
Deficient marketing of finfish caught in Darien Province	Diagnostic study of the problem to determine its cause (deficiency in transport, lack of demand, lack of supply, absence of marketing structures, or high costs)
Under-utilization of the majority of species of finfish and shellfish	Diagnostic study of under-utilized species that might serve as alternatives to the current economic dependence on shrimp harvests

HABITAT AND RESOURCE CONSERVATION ACTION PLAN

Priority Problem	**Key Strategies**
Absence of conservation strategies for mangrove and wetland areas	Zoning strategy for mangrove areas
Insufficient institutional control for coastal resource and habitat protection	Improved planning and enforcement between the National Environment Authority and the Marine and Coastal Resources Directorate
Institutional overlap between the National Environment Authority and the Marine and Coastal Resources Directorate	Clear delineation of responsibilities and competences between the two institutions and adoption of a bilateral agreement
Lack of protection of sea turtle populations	Monitoring of sea turtle populations and signing of a memorandum of understanding between the National Environment Authority and the Marine and Coastal Resources Directorate
Loss of the last remaining Panamanian Tropical Dry Forest located in Punta Santa Bárbara due to deforestation	Inclusion of the peninsula in the Darien National Park

COASTAL WATER QUALITY ACTION PLAN

Priority Problem	**Key Strategies**
Poor management of trash and solid wastes ir coastal communities	Preliminary evaluation of the problem and identification of priority needs and sites; coastal clean-up campaigns; recommendation of alternative solid waste management solutions
Deficient management of human wastes	Preliminary evaluation of the problem and identification of alternative management strategies for the communities with urgent need
Absence of data on coastal water quality	Coastal water quality monitoring program

ECO-TOURISM ACTION PLAN

Priority Problem	Key Strategies
Lack of identification of potential eco-tourism sites	Evaluation of environmental, cultural, and scenic values of potential sites
Absence of trained human resources in the eco-tourism field	Evaluation of existing human resources; determination of needs; training programs in tourism by a local institution
Lack of tourism infrastructure	Evaluation of existing infrastructure and suggested projects (accommodations and restaurants; trails; transportation; sanitary facilities)
Lack of established limits and controls for eco-tourism activities	Preparation of Best Management Practices for tourism in Darien Province

INSTITUTIONAL COORDINATION ACTION PLAN

Priority Problem	Key Strategies
Absence of inter-agency coordination for resource management in Darien Province	Formulation of an Inter-agency Coordination Unit in Darien Province with representatives o key government agencies to coordinate planning, interventions, inspections, monitoring, community outreach, and conflict resolution
Lack of a forum for the involvement of the public in coastal management decision-making	Creation of a Gulf of San Miguel Management Committee involving national/provincial/municipal governments, non-governmental organizations, and representatives of organized resources users; responsibilities of the Management Committee would include monitoring the implementation of the Coastal Management Plan and conflict resolution

An additional product in Phase 2 is a Coastal Resource Monitoring Strategy that proposes collection of environmental and socio-economic data in Darien's coastal zone.

Phase Three. The third phase of the project involves a search for funding sources to implement the plan or its essential components. The activity involves developing a detailed description of the key interventions and project activities to be implemented in Year 1 of the management plan. Agency officials should be able to circulate the activity descriptions among funding sources and, hopefully, capture the financial resources needed to undertake the activity.

Problems and Lessons

As the project comes to a close, its experiences provide several lessons that may be of interest in Panama and other countries and regions. Confirmation of some of these lessons will come in several years when we view the implementation – or lack of implementation – of the coastal management plan and its successes and failures.

1. *Group responsible for the diagnosis of state of coastal resources and the development of the management plan.* Should the coastal resources agency (AMP/DGRMC) have performed the diagnosis of coastal resources and communities (Phase 1) and the development of the coastal management plan (Phase 2), or should an external group of expert consultants have undertaken these tasks? In Darien, the Inter-American Development Bank and the Panamanian government selected the second option. However, I question whether this was the wiser choice. If Panama is to embrace integrated coastal management, its institutions must develop staff expertise in these areas. Staff must develop close working relationships and trust with coastal users and communities. The development of the coastal management plan should involve the public in the statutorily-required mechanisms. This exercise must be a joint activity of government officials, resources users, and interested national groups. The only way to reach this shared vision of the future and develop consensus regarding coastal resource use is for the government to actively engage itself in the process. External consultants may develop a coastal management plan in a relatively short period of time. The work product may be technically satisfactory. However, if this plan does not involve "buy-in" of national institutions and communities, its actual implementation and usefulness may be limited. Perhaps a better use of external consultants would be to train national staff in the methodologies (GIS; social impact analysis, rapid ecological assessment; participatory mapping, and strategies environmental analysis, for example).

2. *Weak institutional presence in Darien.* Weak institutional presence presents great obstacles for this work in Darien. One of the major weaknesses of the institution responsible for fisheries and coastal management in Panama, AMP/DGRMC, has been its weak presence in Darien Province. At the beginning of the project, the DGRMC employed only a single staff member in Darien, and this person dedicated only a fraction of his efforts to his government responsibilities, which included enforcement of fishing regulations and collection of landing statistics. However, halfway through the project, the DGRMC eliminated this staff position, and it remains to be filled. The absence of permanent institutional presence in Darien Province created great difficulties for the project's diagnosis of the resource base and development of the management plan. Communication, support, logistics, and legitimacy all became significant issues. The lack of institutional presence in Darien also raised the question whether the government is seriously committed to fisheries and coastal management.

3. *Institutional coordination.* This coastal management project was one in a group of over one hundred projects in the Program for the Sustainable Development of the Darien, administered by a coordination unit within the Ministry of Economy and Finances. This unit has an active presence in Darien but lacks expertise in coastal resources. AMP/DGRMC was an additional institutional contact. This group lacks a strong presence in Darien, but has begun to develop skills in coastal management. The project team had to coordinate activities with both agencies and, similarly, undergo review and approval of work plans and products by both. The absence of a shared vision between the two agencies and their own coordination difficulties decreased the effectiveness of the project.

4. *Time frame for the project.* The donors established a short period for project completion. A time frame of less than one year for an environmental diagnosis in a region as large, remote, and

relatively unstudied as Darien was insufficient. As the manuscript already mentioned, this region experiences great environmental variability on daily, monthly, annual, and inter-annual scales. The short time period limited the meaningful observation of much of this environmental variability.

5. *Sustainability of the project.* Who will fund the ICM project and its implementation after the initial IDB funding ends? This project is one more example of major external funding for a coastal management project – in this case a loan from the Inter-American Development Bank to the Panamanian government. However, when the IDB funding ends in 2004 for the Darien coastal management project, it remains unclear whether Panama will continue to fund activities from its central budget. Alternatively, the IDB may opt for continued funding of specific activities, but this is unclear at the moment. Additional options could include financial support from non-governmental organizations, USAID, or other international donors. Nevertheless, without some financial commitment from the national government or some sustainable funding source, the initial investment may not generate great returns.

6. *Political realities.* The Darien Coastal Management Plan was submitted to the Panamanian Government immediately before the May 2004 presidential elections. In these elections, the Democratic Revolutionary Party ousted the Arnulfista Party, in power for five years. These two political parties have been the major political actors in Panama for the past thirty-five years and are archrivals. It is unclear whether the new government that takes power in September 2004 will embrace a coastal management plan that was developed during the previous government. Wise resource managers in the new administration should view the Coastal Management Plan as an excellent opportunity. The package was delivered to them as they enter power and includes easily implemented activities. The fact that the project was conceived and funded by the Inter-American Development Bank is a factor that should also encourage project continuance. However, political realities often overwhelm reality and the massive replacement of civil servants also creates challenges to institutional continuity.

Conclusions

This Darien ICM project is of significance because of the abundant marine and coastal resources of the region, their high biological diversity, and the important contribution that they make to the national and export markets. Despite the richness of Darien coastal resources and their isolation from areas of Panama with more developed infrastructure, Darien's coastal resources are already highly exploited. Development pressures and the expansion of the agricultural and colonization frontiers are reaching this province. This once inaccessible area is becoming more and more integrated into the national and international economies. The challenge for this ICM project is to recommend controls on the exploitation of coastal resources and the development of the coastal areas before overexploitation and uncontrolled development irreversibly damage the resources and coastal space. Moreover, this Darien project is Panama's first experience with ICM. As an ICM pilot project, the lessons it provides will serve as an example for similar projects in other areas of the country or for a national ICM program. Similarly, the obstacles and limitations of this project raise important questions for similar efforts throughout the world.

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