The primary role of the Integrated Coastal Zone Management model was to arbitrate conflicts between stakeholders in a living and natural resource environment characterized by a common property and open access doctrine. A chronology of events describes how the development and acceptance of an ecosystems approach policy began to converge and coincide with the spread and development of Integrated Coastal Zone Management. Those organizations that gave representation to the conservation ethic became internationally recognized as surrogate natural resource ‘users’, the interests of which possessed commonality with all stakeholder interests in general. The tenants of conservation policy were therefore largely employed to decide the merits of disputes over ocean and coastal resources.

In the 1990s, scientists created a forum to debate, better define, and institutionalize a sound basis for ecosystem management theory and practice. Protocols were developed that embedded science in living and natural resources planning and management. These protocols were shaped and adopted to serve an evermore contemporary Integrated Coastal Zone Management model. Improvements in methodology include the use of adaptive management, ecological modeling and monitoring, appropriate temporal and spatial scales, salient indicators, and stakeholder participation. This contemporary approach is dependent upon recognizing the benefits inherent in utilizing instruments capable of managing resources on a holistic level.

Bioregional planning and zoning accommodate the successful management of resources on this level. It is a direct outcome of the convergence of Integrated Coastal Zone Management and the ecosystems approach. Bioregional zoning schemes are capable of traversing the private property and common property doctrines that define the respective terrestrial and aquatic environments of the coastal zone.

A comparative case study of the Great Barrier Reef Marine Park and the Belize Marine Protected Area Program is included as an annex, the analysis of which is predicated upon the principles espoused in the literature.

1. Introduction

The science of conservation, which has its roots in the exploitation of renewable resources, is the latter day framework that unifies agents of Coastal Zone Management and natural resource management. Where claims to land use customarily include an exclusive right to the landscape, natural resources have traditionally been managed according to narrow assessments along government agency lines created to serve singular socioeconomic sectors focused on a particular facet of exploitation. In contrast, the coastal zone is usually distinguished by common property or open access rights, the establishment of which is remarkably similar around the world. Yet, an accounting of managed coastal resources reveals that they were formerly subjected to the same sectoral style management as terrestrial resources and that they were hardly managed for ecological impacts affecting conservation. In addition, although human populations began a significant migratory shift to the coast about the same time ecological science was being recognized, it was not respect for conservation, which would eventually precipitate the re-examination of institutions responsible for the management of coastal resources. It was conflict between users.

Integrated Coastal Zone Management (ICZM) is a management model that had its beginnings in the practice of conflict resolution, which was employed at regionally local levels in attempts to mediate disputes between coastal zone stakeholders. By the late 1960s and early 1970s, communities indiscriminately scattered
around the United States along coastal regions were experimenting with their own novel versions of ICZM. ICZM implements a system of central management across multiple sectors of resource users and it insists on vestment of the community interest at large in the process. ICZM finally delivered a platform that reflected the reality of open access and common property that exists in coastal areas. However, the tools with which ICZM could be exercised were still largely unchanged at this stage.

The geographic scale at which ICZM is applied is essentially set by the extent of the issues it is being used to confront [8]. The instruments used to achieve ICZM policies were regulatory measures at the disposal of local line agencies such as licensing fees and permit letting ([7,8]). As ICZM progressed to take on national and international proportions, similar types of ‘Command and Control’ measures were expanded upon and employed to effect changes in user behavior [7]. Government regulation and control of harvests and natural resource use became the norm as ICZM was implemented at increasingly higher levels of central authority [8]. The environmental impact statement, which was originally formulated to assess the effects of development, was adopted as one of the main tools used to execute an ICZM master plan [8]. By design, these tools eventually lead to permission for development or resource extraction [8].

Merely limiting the licensing of resource use allows exacerbation of the process by a few powerful stakeholders [23]. The results of the environmental impact statement, in particular, serve to satisfy government regulations usually at the expense of ignoring the interests of the community-at-large [33].

ICZM practitioners, faced with the immediacy of conflict, expedite the implementation of a strategy or a master plan with whichever tools jurisdictional authority has the will to fashion [7,8]. Yet, the tools at hand, when used alone, represent an oversimplified response to the complexity of natural cycles and, when unwittingly treated as benign, they can be manipulated to become instruments of mismanagement [23]. This can happen, for instance, when fisheries managers, who decide to concentrate on some measure of sustainable yield for a single commercial species, ignore the maintenance of ecosystem functions and processes, which support the overall health of the species [29].

2. History

Living resources are quicker to exhibit the consequences of inadequate or mislaid management. This observation was not lost on Lee Talbot and the leadership of the President’s Council on Environmental Quality who supported Thomas Lovejoy and the World Wildlife Fund (WWF), which sponsored a program of workshops to produce recommendations for improving the management of wild living resources as renewable resources in 1974 and 1975 [21]. Also participating in the program were The Ecological Society of America, the Smithsonian Institution and the International Union for the Conservation of Nature and Natural Resources (IUCN). On the agenda was a review of the scientific basis for supporting existing goals of conservation. The object was to create a statement of new principles that would illuminate the latest wisdom science had to offer on the topic, especially the science of ecology [21].

Key points of the statement included recognition of the failure of maximum sustainable yield (MSY) of a single stock or species as a method of resource management [21]. It was emphasized that there is a need to take into account the ecosystem as well as stocks to maintain a system that has the capacity to accommodate changing human valuations of what constitutes a possible resource while, at the same time, maintain an ecosystem that can persist through changing environmental conditions [21]. Another related proclamation was the prevention of irrevocable changes in the resource system as a consequence of human actions [21].

It was noted that commercial industries, managed on the MSY principle, build over capacity into their operations especially when stocks are stabilized above the MSY [21]. That industry practice is predicated upon the belief that this set of circumstances indicates an under utilization of a species or stock [21]. The end result is an over commitment of capital, labor, and fuel by private industry. It also encourages extraction methods that promote waste and misuse of other natural resources and the devastation of non-target species [21].

It was postulated that the amount of investment in monitoring and assessment should be related to the intensity of use, complexity of the problem, and vulnerability of the ecosystem to adverse impact. Information about the ecosystem is necessary to improve and correct management operations and to adjust them to any prevailing change in conditions [21].

Other important observations were made concerning the origins and use of indices for the health of a wild living resource such as determining where the threshold of reproductive success is sustained and what the limits of an ecosystem’s carrying capacity may be [21]. It was decided that, regarding the use of this sort of indicator, the goal should be to sustain the optimum carrying capacity of the habitat while maintaining its community structure [21]. The idea behind this decision is that a total yield can be arrived at as the sum of a balanced combination of species from a range of trophic levels in the ecosystem [21].

The statement on living resources produced by this program is recognized as the first formalized set of principles addressing ecosystem management [29]. However, the statement was also tailored to address problems particular to living marine resources [29]. The objective was to draft a set of principles for inclusion into the text instruments being prepared by the United Nations for its 1978 Conference on the Law of the Sea [21]. The Law of the Sea Convention is an international diplomatic settlement between multiple users, in this case represented by nations, of marine resources and it contains statutes and procedures used to settle disputes. The intention of the WWF program participants was to indoctrinate a conservation code as an interested user amongst other users like tourism, oil and gas, fisheries, or maritime transport.

As it turns out, The Law of the Sea Convention treaty was later used as the framework document for agreement on ocean issues during the 1992 United Nations Conference on Environment and Development [2]. Agenda 21 of that international conference was a blueprint for incorporating consideration of the environment and regional development in the formulation of government economic policy and decision-making [2]. The Law of the Sea Convention was chosen as the framework for Chapter 17 of Agenda 21 precisely because it obliges respect for the environment and inculcates protection of the coast and ocean from pollution within a legislative document agreed to by resource users and stakeholders [2].

Chapter 17 recognized the phenomena of cascading effects due to terrestrial pollution and called for a holistic approach for protecting the coast [2]. It introduced the concept of management predicated upon physical environmental factors and biological allotment in contrast to jurisdictional and political administrative units [2]. It paved the way for delineation of areas remarkable for their representation of critical habitat and necessitated special protection for them [2]. It went on to recommend a precautionary approach to resource extraction, which is a concept that originates from fisheries management. Nonetheless, it also highlighted the deep disparity between living natural resource biologists and commercial producers (Barcena 1992). In fact, the main theme: integrated management of marine living resources, stood out as the
most contentious issue confronted throughout Agenda 21 chapter negotiations [2].

Blame for the high level of controversy was laid upon the reality that there was no user rights system and that management of coastal and ocean resources was predicated upon obsolete circumstances [2]. The demands presented by a great leap in coastal settlement and industrial development had outstripped management capability and made it ineffective [2]. It was evident that overexploitation of common property was causing much conflict between users [2]. Conservation, having been empowered as a vested ‘user’ with an organized presence, was given a place at the negotiation table [2]. In the end, the conservation mission prevailed because the ethic underpinning it was the only viable way to mitigate the conflict at hand. Conservation organizations were heard because the environmental safeguards developed by ICZM were used as the model to execute the conference plans for marine resources management.

Chapter 17 demanded that policies stemming from the Law of the Sea Convention must be integrated across both private sectors and public agencies [2]. In addition, the only feasible way to implement Chapter 17 was to vertically integrate a centralized international and national effort on down through provincial and local levels [2].

This model of horizontal and vertical integration had already been tested in 1992 through a then recently completed program that was sponsored by the United States Agency for International Development (USAID) in order to help relieve marine resources depletion and coastal environmental degradation in South and Southeast Asia [7]. However, although the purpose of the program was to “manage environmental problems”, the ICZM model was used to as a de facto conduit for multisectoral development, albeit was to “manage environmental problems”, the ICZM model was used as a de facto conduit for multisectoral development, albeit that development was only permitted to go forward with the approved mix of user activities that produced the smallest amount of foreseeable harm to the environment [7].

The example of a land use conflict in Segara Anakan, Indonesia is instructive [7]. There a conflict grew out of the opportunity to exploit accreted land, which resulted from sedimentation due to the premature erosion of terrestrial soils [7]. Here it becomes obvious, once again, that the primary purpose of ICZM was to arbitrate conflict by simply relying upon the goals of conservation merely as a tool for mitigation between sectors. The holistic approach in this instance had already been lost.

On the other hand, ICZM tactical methods were pragmatic. The philosophy recognizes that compromise on implementation of the model is needed in order to create avenues for political and cultural acceptance [7]. So long as the ICZM process is empowered to wield the conservation ethic in the name of conflict resolution, it can mitigate even more serious levels of environmental degradation. However, not so long after the UN Conference on Environment and Development, proponents of the ICZM model could only offer naive expectations regarding the implementation of monitoring and assessment practices that, ostensibly, were to safeguard conservation goals. They were also in jeopardy of loosing ground in their cause of sustainable development, which was being precipitated by a collective process of attrition to ever increasing scales of socioeconomic development.

3. The mid 1990s: a feature role is given to science

By the mid 1990s, ecologists began to rally around the concept of ecosystem management in response to recent policy formulations at various policy levels of the U.S. government calling for an ecosystems approach to natural resource management [17,19]. Amongst key responses offered by institutions of ecological science were the formation of a ‘Special Committee’ chartered in 1993 by the Ecological Society of America to clarify the “Scientific Basis for Ecosystem Management” [19].

Consensus existed for a holistic management framework founded on ecosystem structures, processes, and functions [17]. The founding core principles were focused on the sustainability of this framework [19].

As promulgated by ecologists, the prospects for ecosystem sustainability must be intergenerational [29,9]. Any irreversible damage of human origin represents an unacceptable alternative [20]. The pattern of permanent reductions in ecosystem capacity, if left unbridled, was robbing and would continue to rob society of the ability to sustain a living for its members and their descendants. In order to understand the nature of sustainability, an understanding of how ecosystems are regulated in relation to how economies are regulated is necessary [29]. Ecosystems are regulated by natural limitations. There are many examples including: predator/prey relationships, soil nutrition/decay processes, and herbivory/plant toxin production [29]. On the other hand, economic systems are considered successful if they foster continual growth and expansion. They are generally regulated by supply and demand, and economies are relatively free of any constraints associated with carrying capacity or waste disposal [29]. Ecosystems, through their sensitivity to natural limitations, continually provide feedback and there was general agreement that they could be used as a barometer to guide economic systems [29].

To achieve that purpose, ecologists contended that natural resource policy should focus on ecosystem functions and processes that deliver goods and services as opposed to narrow definitions of deliverables [9]. Demands for goods and services should not originate with supply mandates or arbitrarily set harvests [29]. The facts are that ecosystem goods not only include the more obvious contributions of food or construction materials but, for example, they also include wild genes for domestic plants and animals [9]. Ecosystem services include not just the absorption and detoxification of contaminants but also the generation and maintenance of soils and the pollination of crops [9]. Further, ecosystem processes not only include biogeochemical cycling and storage but also the maintenance of biodiversity [9]. Mandates that could cripple the production of wild genes, the instruments of pollination, or the heterogeneous habitat that propagates biodiversity would only help to cripple the production capacity of ecosystems. Ecologists were arguing that, in terms of economics, such circumstances demonstrate a fatally flawed strategy.

They said that resilience is the property that maintains ecosystems and their capacity to produce [20]. Resilience was deemed the most appropriate measure of ecosystem stamina. It is a measure of “how quickly and completely an ecosystem returns to equilibrium after a disturbance” [6]. Its complimentary property is ecosystem ‘resistance’ to the forces of change. Ecosystems depend upon this stamina as a reserve with which to recover from natural and anthropogenic stresses. When the limits of resilience are surpassed, ecosystem processes become erratic and the structure and functioning of an ecosystem begin to breakdown making an ecosystem vulnerable to collapse (Holling 1996). Resilience was presented as the indicator by which natural resource policymakers and managers could measure the sustainability of various types of economic activity. It is a testable theory based on empirical scientific evidence [6]. The proclamation was that, once human induced fluctuations in an ecosystem become erratic, restoration of resilience should be the first order of management [20].

Ecosystem resilience is determined by evolutionary responses to a set of natural environmental disturbances or ‘disturbance regime’ [29]. It was determined that exploitation of natural resources should be structured to mimic this ecosystem disturbance regime and ecologists were declaring that scientists needed
to be indoctrinated into management roles as the only practical way to implement this and similar policy initiatives [30].

The following year, in March of 1994, a task force was formed, “to provide scientific advice concerning the prevention, reduction and control of the degradation of the marine environment” [15]. The task force was jointly sponsored by the United Nations and a number of its agencies (e.g., UNESCO Inter-governmental Oceanographic Commission) as well as the International Maritime Organization (IMO), the World Meteorological Organization (WMO), and the World Conservation Union (IUCN). The premise upon which the task force undertook its mission was that the proper management of complex ecosystems, being vulnerable to the considerable demands of humanity, could not be realized in the absence of science. Their findings demonstrated a level of “remarkable consistency” despite the fact that their studies drew upon an array of disparate social, economic, and ecological conditions from diverse regions located throughout the world. Their report chronicled the reasoning behind establishing scientific input at each stage of the Coastal Zone Management process.

A broad outline of integrated coastal management was used as a vehicle to highlight the role science had to play at each stage of implementation. The first stage is to define the context within which the program will unfold. Activity is largely centered on environmental assessments, which should be completed in a 6–18 months period so that institutional and stakeholder commitment can be adequately maintained [7,15]. These assessments, which employ methods that are tailored for conditions found in the coastal zone, have been modified from rapid rural assessment techniques [7]. Scientists mitigate this process by sifting through large quantities of data, assessing the quality and relevance of information at hand and prioritizing concerns [15]. Science may also catch deficiencies in essential information, be prepared to judge the severity of any information shortage, and be prepared to suggest methods to fill an information gap in reasonable time [15].

The second stage is planning [15]. During this phase, all of the options for action are considered [15]. A management plan should be formulated that articulates the character and quality of environmental standards that need to be reached and upheld, how resources should be apportioned amongst users, and suggest necessary modifications to the prevailing use of those resources [15]. The planning stage may involve pilot programs in order to test alternative options and to determine which option is most effective and has the broadest support [15]. Research should be initiated as soon as possible to define the structures and processes that regulate the coastal ecosystem(s) in question, which, in turn, should guide decision-making and compliance procedures [15].

Scientists should work closely with managers to provide a clear description of what is to be measured and for what purpose [15]. Together they should determine the parameters for scientific discourse so that the cost of research and monitoring is minimized without sacrificing optimum results and together they should pose the questions that will guide the scientific diligence to be done on behalf of management [15]. In support of constructing a plan, scientists need to estimate the magnitude of human disturbance in relation to natural disturbance, describe the trajectory of consequences for the continuation of existing trends in resource health and use, and devise ways to stabilize or restore ecosystem processes [15].

The third stage involves institutional acceptance and funding of the ICZM plan [15]. At this point, newly developed programs have customarily been dissected and challenged [15]. In many instances, programs have undergone revision before the approval process was finished [15]. Novel and unanticipated assertions may be manifested by interests in opposition to certain elements of the plan [15]. Further, just because a program has been approved does not always mean that it will be adequately funded [15]. Another review cycle may be mandated to search for ways to create improved efficiencies [15]. Scientific counsel is valuable and sometimes crucial to formulating competent responses to challenges posed during political negotiations [15].

During the fourth stage, the ICZM plan is actually employed in an operational sense [15]. Monitoring is the key here [15]. A steadfast supply of meaningful and accurate data is critical to the enforcement of the plan [15]. Studies, which focus on the protected resources, should be conducted [15]. These studies should rely upon comparisons of the baseline data compiled or generated in earlier phases of the program [15]. Scientists should be thoroughly involved in the design, execution, and supervision of these studies [15]. Managers should count on scientists to interpret the products of monitoring activities and to assess the virility of the new mode of operation in play [15]. The critical nature of these procedures is magnified when carried on within the scope of a pilot project [15].

The purpose of the fifth stage, evaluation, is to foster evermore-sustainable conventions of coastal development [15]. It generates the preconditions upon which the whole ICZM protocol is reincarnated [15]. The evaluation should model outcomes of the completed ICZM cycle in preparation for the next round. This evaluation should be predicated upon a set of inquiries [15]:

1) “What has the preceding generation of the programme accomplished and learned and how should this experience affect the design and focus of the next generation?”
2) “How has the context (priority issues, environmental governance) changed since the programme was initiated?”

Answers to these questions can only be found if goals have been stated in explicit terms from the outset of the program. Scientists should conduct a formal analysis of the research and monitoring results to determine whether they represent a germane and productive contribution in the pursuit of more highly sustainable renewable resources [15]. Scientists should also furnish an approximation of the scope of environmental and ecological change that has been derived from the ICZM program in contrast to other conceivable explanations [15].

4. Contemporary ecosystem approaches to management of the coastal zone

Between the mid 1990s and the present period, enthusiasm for the ecosystems approach has spawned a widespread effort to define and improve the operational framework instituted under the auspices of the EAM doctrine. These experiences inevitably have led to cross-disciplinary contributions, which in turn, fuels continuing discourse concerning formulation and refinement of universally acceptable EAM policy guidelines. Although there are many themes that vie for dominance, it is generally accepted that the overarching goal of all natural resource programs is to insure and maintain ecosystem integrity [3]. Further, no conspicuous trend has emerged, which unequivocally gives humanity an overriding privilege to supersede this imperative [3].

Traditional management efforts can unwittingly produce outcomes contrary to these policy objectives. Currently, a new paradigm is beginning to take shape, which is precipitating a shift away from strategies that are supporting failed objectives. It is retooling natural resource managers with a reengineered set of
management parameters and objectives that allow management strategies to be reset in tandem with the new priorities. The focus of management objectives is shifting from individual species to ecosystems and from exclusively small spatial scales to multiple spatial scales [3]. Management perspectives are shifting from short-term to long-term expectations and from a view of humanity that prospers independent of ecosystems to a view that humans are integral to ecosystems [3]. Management priorities are beginning to shift from managing commodities to sustaining the production potential for ecosystem goods and services [3]. There is also a notable shift away from a mode of management that is operationally detached from scientific research to modes, which recognize and adapt to scientific discovery [3].

Contemporary themes frequently emphasized in discussions of the ecosystems approach are: 1) adaptive management 2) ecological modeling and monitoring 3) the temporal scale of management 4) stakeholder participation 5) program indicators and 6) the spatial scale of management.

4.1. Adaptive management

Ecosystem cycles are tied to processes with long-term trajectories. It is, therefore, essential that management strategies are suited to ecosystem responses to development that likely will not be manifested within the timelines prescribed by shorter term natural resource management initiatives [1]. Adaptive management is a protocol that is central to an ecosystems approach because it encompasses reassessment of program assumptions and it facilitates the incorporation of new information that bears upon desired outcomes [1]. Additionally, it provides a mechanism for making the respective reciprocal changes in shorter term operational activities that may be necessary to meet management objectives [1] (See Box 1). The implementation of policies conducive to adaptive management is especially pertinent to coastal zone management where administrative or financial resources commonly lag behind those devoted to terrestrial ecosystems and where knowledge related to marine ecosystem responses to human activity are that much more uncertain [1,28].

Adaptive management compliments the widely advocated precautionary approach, which demands that apparent gaps in our knowledge of ecosystems be taken into account during the decision-making process [1,28]. The precautionary approach, as far as it recognizes the limitations of scientific understanding is not a valid excuse for delaying implementation of EAM initiatives, which are based on the ‘best available science’ [1,28]. That is because the best available science accommodates unforeseen circumstances by employing management tactics that favor ecological resilience [1,28]. Using these kinds of tactics, it becomes necessary to construct future scenarios and then select the best option for implementation [28]. During the final stages of a management program cycle, the most favorable options initially employed can be evaluated before adopting or modifying them for use once again in the next cycle [28].

4.2. Ecological modeling and monitoring

Maintaining evolutionary and ecological processes and maintaining the evolutionary potential of species and ecosystems are two cardinal directives of the ecosystems approach [17,3]. Related to these is a third, which is, maintaining viable populations of all native species [17,3]. Most phenomena associated with adaptation of species and evolutionary science are inextricably bound to long-term time horizons. Ecological models can play a crucial role by providing decision-making support in the planning stages of a Coastal Zone Management program. They can be used to forecast potential future scenarios based on the incorporation of management options into models before they are actually implemented [3]. The predictive power of ecological models is tied to the scope of the processes that they mimic and the level of precision in the estimated outcomes that they produce. With the development and introduction of new techniques, the latest generation of models has eliminated many of the inaccuracies of earlier prototypes [13]. Additionally, the scope of their forecasting is increasing in conjunction with the amount of available data [13]. The precision of forecasting is also increasing along with newfound insight into how the data are related [13].

Ecological modeling can now be conducted at all levels of biological organization. Models can reveal which sets of data are key to ecosystem functioning and, therefore, can identify key indices that are useful in reporting the status of broader ecosystem health [9].

Monitoring, or those activities associated with data gathering and analysis, has a dual purpose [9]. First, monitoring is undertaken for the sake of evaluating the effectiveness of management endeavors. Second, monitoring is conducted to determine whether ecosystems are behaving in a manner consistent with preferred future ecosystem states and trajectories as they have been described in ICZM goal statements [9,3]. When ecosystem stressors are being monitored, the data needs to be analyzed in terms of their combined and accumulative effects on the ecosystem [28].

Monitoring involves a host of activities [27,26] which include:

- On sight scientific sampling using specially outfitted ocean vessels
- Observations made by participating stakeholders who have intimate knowledge of local environments
- Environmental class satellite remote sensing platforms with instrumentation designed to track coastal and estuarine ecosystems
- Biosensors such as ecogenomic analyzers deployed on ocean buoys, which identify and quantify microbial organisms and functions using DNA and RNA sequencing.

4.3. The temporal scale of management

Coastal ecosystems need to be managed within the context of how human settlement has distorted their character through the ages relative to their original condition [28]. First, knowledge of past episodic ecosystem changes and the anthropogenic causes that precipitated it can provide enlightenment as to how ecosystems may react in the future [28]. Second, historical archives of pre-settlement ecosystem conditions can be useful as a surrogate for natural conditions in setting management program expectations [9].

Lack of a proper historical perspective can lead to confusion over baseline ecosystem states, which fosters an operational hazard known as “shifting baselines”, which can doom a management program to failure [28]. Shifting baselines are like operational decoys that are normally a result of misunderstanding the scale of transfiguration that has come to pass and the time frame over which ecosystem alterations have transpired [28]. In turn, plans are not properly calibrated for whatever extraordinary efforts may be necessary to restore, preserve, or improve ecosystem health. Such misinformed plans commonly advocate unrealistic performance indicators and are misaligned to stunted temporal scales [28].

A couple of good examples of ecosystem threats that are manifested over extended temporal scales include: genetic viability and recoverability of commercially exploited species and climate change, which causes elevation of sea levels, rises in sea temperature. Both threats cause large shifts in ecosystem character and
composition. The benefits of endeavors undertaken to mediate the impacts of this type of threat will only be observable and subject to reckoning upon the passing of each decade gone by. The amount of political will necessary for such long-term commitments will require a legal framework to assure success[28].

4.4. Stakeholder participation

Owing to its treatment as a common resource, coastal regions draw a wide spectrum of interested stakeholder sectors. Typically, these stakeholders can be relegated to three main sectors: 1) the local community, including civil, non-governmental, and labor organizations 2) the public sector, including central, provincial/state, and local government, public service agencies, and publicly chartered institutions and 3) the private sector, including fisheries, aquaculture, energy production and manufacturing industries, waste disposal, tourism, agriculture, and forestry[1,28]. The socioeconomic dynamics of the coastal commons are such that they generally produce benefits, which embellish a minority and which induce costs that are born by the majority[15].

It is under these circumstances that many environmental and natural resource management agencies have been relying upon a ‘decide, announce, and defend’ strategy of dealing with stakeholders[28]. This is a strategy that creates an arena for poor communication. At some point in the decision-making process, authorities simply broadcast what they have decided, which places them in a position where they are compelled to defend their recommendations and lobby or otherwise coax stakeholders to agree[28]. The environmental impact statement (EIS) often becomes an instrument of this sort of management style. The focus of the EIS is on government regulation and not on public expectations (Stanford and Poole 1996). Public focus begins to revolve around the resolution of conflict concerning compliance with line item EIS regulations instead of committing to an agenda to find solutions to overarching problems, i.e., an agenda that routinely leads to consensus[33].

Choices need to be presented to the public that are predicated upon scientific principles and they need to be presented in a fashion that allows the public to develop an understanding of the options available to them[1]. Communities, when actively engaged in decisions that cause them to evaluate their priorities, have a tendency to develop the knowledge and sophistication necessary to come to a consensus[33,28]. Early on in the decision-making process, stakeholders need to be involved in assigning rational targets while options are still open to them so that their recommendations have the occasion to make noticeable contributions (See Box 2). Early recognition and exercise of stakeholder potential foster support for project proposals and give stakeholders a sense of ownership.

Under certain co-management schemes, stakeholders may gain special insight into scientific research methods and timetables by actually participating in monitoring activities where they may have intimate knowledge or expertise of the indicators that have been chosen to measure project outcomes.
Box 2. Science and adaptive management at local ecosystem scales employing science as the basis by which the public formulates explicitly articulated goals in an iterative process of adaptive ecosystem management will foster stakeholder consensus and increase the probability of successful attainment of sustainable outcomes [33].

4.5. Indicators

Indicators serve three chief classes of users: 1) stakeholders and the community-at-large, 2) policymakers and natural resource managers, and 3) scientists and technicians [1]. In addition, indicators are chosen which affect the three primary fields of organization that contribute to the maintenance of sustainable ecosystems. They are the sociological, economic, and environmental indicators [28]. The purpose of indicators is to assess the performance of project measures to sustain or restore ecosystem processes and functions. They are used in field trials during the planning phase of a management program to assess their efficacy [15,1]; they can be structured to measure the responsiveness of planning phase of a management program to assess their efficacy [1,28]; or they can be derived from the management issues at hand [8]. When the issue is sustaining food webs in the face of resource extraction or other interactive stressors, which wreak havoc upon the ecological structure of ecosystems [29,3].

Long-term indicators, such as EcoQOs are needed to chronicle system-wide fluctuations in ecosystem states [28]. Key biophysical traits may be selected as indicators that will only percolate over extended intervals of time, consisting of many years due to ecosystem lag effects [28]. The ‘Marine Trophic Index’ is an instrument by which the rate of structural changes in marine ecosystem food webs may be measured and it is a prime example of monitoring for a long-term indicator [28]. The trophic level of a species is given an ordinal value of 1–5 with one representing primary producers and five representing top predators [28]. Microscopic plants, i.e., phytoplankton, have a value of 1; zooplankton that feed on them have a value of 2; small fish have a value of 3; larger fish that feed on them have a value of 4; and marine predators that feed on the largest fish and invertebrates have a value of 5 [28]. Using this index, scientists may monitor the loss of biodiversity, which can cause ‘cascade effects’ if there is a substantial loss in population of a key species. The loss of key species may precipitate the extinction of another species when its survival is intimately bound to the key species’ link in the food web.

Indicators should aid in the identification of stressors that can cause cascade effects and other interactive stressors, which wreak havoc upon the ecological structure of ecosystems [29,3].

4.6. The spatial scale of management

Area based management can be employed to meet the demands of maintaining food webs and other interspecific connections [18]. Coastal zone spatial planning increases the natural resource manager’s ability to avoid combined and cumulative ecosystem stresses and to manage multiple stresses in tandem [28,18].

Although there is no universal set of coastal zone boundaries, a set can be derived from the management issues at hand [8]. When the issue is sustaining food webs in the face of resource extraction or other application of the ecosystems approach, scientists will delineate the theater of management by formulating boundaries based on ecological process and structure [9]. It is reasonable to expect that the issues at hand should be managed according to the extent of the ecological processes and structures that they affect. Marine protected areas (MPAs) are custodial trusts increasingly favored by coastal zone managers as the standard vehicle by which they limit extractive or otherwise detrimental activities [18]. Marine reserves inside MPA’s are regions where all such activities are prohibited [18]. Regulatory ‘Zones of Influence’ are normally drawn immediately adjacent to MPA boundaries in order to address uses outside the MPA that could feasibly disturb the resource being protected within it [8]. Nevertheless, a master plan that includes
MPA zoning creates a system where biodiversity goals may be met without monopolizing every location [1]. MPA’s should be designed using a standard that demands full representation of each major habitat found in the ecosystem being managed [1,28] (See Box 3). Additionally, appreciable information on the benthic physical environment should be recognized as a suitable surrogate for biological information during the planning phase so long as a fundamental relationship has been established based on ground truth [28]. Lastly, the flexibility to include marginal habitat should be inherent in the bioregional zoning scheme in order to reconcile the consequences of global warming, including shifts in the boundaries of species range [28].

Some MPA’s include terrestrial areas beyond the intertidal zone [24]. Similarly, planners should always strive to achieve adjacency alongside protected areas that lie within the terrestrial coastal zone when planning an offshore MPA [24]. One of the chief concerns of coastal zone managers is the threat of upland development activity [8]. When the terrain of the coastal watershed is significantly altered, fresh water flow to the coast can be canalized, accelerated, detoured, overloaded with nutrients, or laden with sediment [8]. Managing the coastal zone at watershed scales will link marine and terrestrial conservation efforts [18]. Watershed scale coastal area management is also a proficient means of underscoring and isolating anthropogenic impacts because it focuses management and monitoring operations on a microcosmic portion of the coastal ecosystem, for example, a bay [18]. Bioregional planning provides an ideal framework for Coastal Zone Management because, among other advantages, it treats the land and sea as one integral system [24].

5. Discussion

Bioregional planning recognizes the necessity of operating across a range of spatial scales. It embraces the continuum of scales stretching from small ecological communities and habitats to coastal seas. Bioregional planning essentially is an upshot of the ICZM model that internalizes the ecosystems approach to management [24]. The coastal zone master plan of Australia, i.e., the Representative Areas Program, is predominately built upon the foundations of a bioregional zoning scheme, which is executed largely through a network of MPA’s (see Annex).

Examples of more widespread application of zoning schemes with a basis in bioregional planning can be formulated for coastal lands within the United States and, by extension, for upland ecosystems too. The major obstacle to an application of this type lies in the common property/open access rights of coastal waters versus the private property/ownership rights of most terrestrial environments. However, regarding the terrestrial environment, bioregional zoning can be enacted in ways that accommodate private ownership. That is, instead of prescribing bioregional zoning schemes to lands that encompasses private property, they could be used to guide the location of infrastructure such as transportation systems, communication networks, and electric utilities. This method would have the added benefit of being able to accommodate a seamless zoning scheme for infrastructure on both land and sea. Bioregional planning, utilized in this manner, is a mechanism that functionally integrates ecosystems management with natural resource management and land use planning.

Some U.S. state governments have already laid the groundwork for this type of bioregional zoning through their formulation of Wildlife Action Plans, which are predicated upon the fact that states exercise ownership over the wildlife found within their jurisdictional limits. The U.S. Congress authorized wildlife Action Plans in 2001 through the creation of the State Wildlife Grants Program, which provides for funding to state-level fish and wildlife agencies towards the formulation of plans to protect wildlife. For instance, the New Jersey Wildlife Action Plan [11] provides a host of wildlife conservation information. This information is deliberately linked to the State’s Landscape Project [31]. The Landscape Project ranks habitat patch types that increase in importance from: 1) generally suitable for wildlife to: 2) accommodation of regionally important population centers and key species to: 3) endangered/threatened species habitat. These habitat patches have been delineated within landscape zones that, then again, lie within landscape regions. In this particular example, the preliminary scientific and geographical framework for bioregional zoning already exists. Yet, what appears to be ignored in The Landscape Project revisions to date is the opportunity to characterize the marine habitat that lies within New Jersey’s three-mile seaward jurisdictional limit.

Nevertheless, in another instance, the state of California has a Wildlife Action Plan [5] that does include its three-mile seaward jurisdictional limit by encompassing the products of the California Marine Life Protection Act (MLPA), in force since 1999. The MLPA mandated a process now known as the MLPA Initiative that provides for the establishment of a network of MPA’s. This network is comprised of a system of state marine parks, conservation areas, and reserves that is still growing along with the Initiative. The Initiative recognizes the need to represent habitat within four biogeographically separate subregions or ‘marine regions’. The first phase of the Initiative, dubbed the Central Coast Project after the marine region it embraces, comprises 18 percent of state waters.

The challenge that presently unfolds is the question of how and in what manner can state-level plans be integrated so as to span political boundaries. In a report from the Research and Innovative Technology Administration of the U.S. Department of Transportation, Eco-Logical [4], the Steering Team outlines its vision for a ‘Regional Ecosystem Framework’ (REF) as the protocol to integrate management plans from various sectors including the States’ Wildlife Action Plans. Notably, they also advocate for State coastal

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Box 3. Summary of the benefits of marine protected areas [24].

- Conservation of biodiversity, especially critical habitats of threatened species;
- Protection of attractive habitats and species on which sustainable tourism can be based;
- Increased productivity of fisheries by: insurance against stock collapse; buffer against recruitment failure; increase in densities and average sizes of individuals; increase in reproductive output; provide centers for dispersal of propagules and adults (spillover); contain more natural species composition, age structure, spawning potential and genetic variability;
- Contribute to increased knowledge of marine science through information on functional linkages, implementation of the precautionary principle, provision of control sites for research and ecological benchmarks against which to measure human-induced change; potential as nodes in monitoring networks; more “natural” systems where natural mortality can be compared with fishing mortality;
- A refuge for intensely exploited species;
- Protection of genetic diversity of heavily exploited populations;
- Protection of cultural diversity, e.g. sacred places, wrecks and lighthouses.

Adapted from a list developed by Kathy Walls, Dept of Conservation, New Zealand.
management programs to be incorporated as components of REF's. The objective is to embed the ecosystems approach into the process of developing transportation infrastructure projects. In turn, REF's are foreseen as a means "to identify what work is desired and where it will be done." The REF is being born as a federal government integration mechanism and one that need not be relegated to transportation infrastructure alone. The manner in which that mechanism could be implemented is through bioregional zoning. If States legislate bioregional zoning with the intention of integrating the zonation scheme into an REF then the holistic protection of ecosystems can be made law at least to the extent that the underlying zoning schemes shield ecosystems from being overwhelmed by transportation and utilities infrastructure both on land and offshore. These protections would allow the benefits of established species level protections and conserved land and seascapes to meet their full potential in the form of increased levels of sustainability.

6. Conclusion

The demands of exponential human population increase have compelled natural and environmental resource managers to redefine their mission. Whereas that pressure is concurrently compounded by human migration to coastal regions, administration of the common property and open access doctrines that characterize those regions, has been undergoing reform. Science was the basis for the transformation during the threshold years of the 1990s. Science was the catalyst for the eminent growth of the ecosystems approach to management and it reinvigorated an underdeveloped ICZM model that was somewhat promising but then again had begun to collapse for lack of a comprehensive protocol that could consistently address the pressures at hand.

The methods that have evolved out of this hybridization of scientific policymaking and integrative management are inherently flexible enough to accommodate both natural and socioeconomic cycles as well as spatial and temporal scales. In addition, the science of modeling and monitoring is sufficiently robust to support the execution and maintenance of adaptive management protocols.

Bioregional planning and zoning consolidates the ecosystems approach and the ICZM model into an operational and contemporary convention capable of achieving sustainable development but only once it is universally implemented over the proper regional scales. It "provides recourse from the trap of trying to manage each piece until the whole is managed" [18]. One must not forget that it is ecosystem resilience that will ultimately determine the degree to which development is sustainable.

American institutions and its people are historical founders of both the ecosystem approach and ICZM [21,27]. As of today, the United States has still not met the goals that originated here. The ecosystems approach demands that goals be translated into operational objectives [9]. Additionally, "The ecosystem approach demands a vision of desired conditions for an ecosystem" [22]. However: "Most federal agencies, acting independently of all others, do not have the expertise for such analysis" [22]. Furthermore, in order for ICZM to be successfully implemented, there must emerge an independent central government body with the statutory power to coordinate interagency activity [7,28]. Yet, "Most existing federal statutes were not written with interagency coordination in mind. Instead, they focus on narrow jurisdiction..." [22].

The further research and development of operational conservation strategies such as bioregional zoning, has the potential to serve as the foundation for federal plans to incorporate the ecosystems approach into an integrated infrastructure protocol [4]. It could serve to support a nationwide system of marine and watershed protected areas designed at the state level. Moreover, the reinforcement of an integral central government framework to achieve and sustain these goals also needs to be further explored in order to coordinate a more effective national effort.

Annex

A comparative case study of the Great Barrier Reef Marine Park and the Belize Marine Protected Area Program

Synopsis of the Great Barrier Reef Marine Park

The worldwide acceptance of the 200 nautical mile Exclusive Economic Zone (EEZ) in the mid 1970s had momentous implications for the country of Australia. The Exclusive Economic Zone deeded to Australia a range of ocean waters, which are far greater in extent than the terrestrial range of the very country itself [25]. Lying within Australia’s EEZ boundary is the Great Barrier Reef, the world’s longest maze of coral reefs and cayes [25].

When The Great Barrier Reef Marine Park Act 1975 was enacted into law, it was destined to become a world-class example for legislating ecologically sustainable development inside an expansive natural area [25]. The legislation mandated that zoning plans be formulated for the Marine Park, which would delineate areas for the purpose fulfilling the provisions of the act [14]. These zoning plans establish a framework for the conservation and management of the park [14]. The legislation also created the Great Barrier Reef Marine Park Authority, which declared that its primary goal is "To provide for the protection, wise use, understanding and enjoyment of the Great Barrier Reef in perpetuity through the development and care of the Great Barrier Marine Park." Among a set of ten aims derived from this goal is a directive "To adapt actively the Marine Park and the operations of the Authority to changing circumstances." This clause allowed adaptive management protocol to become embedded in the management process and has since proven to be instrumental in successes achieved by the Authority.

Once the Great Barrier Reef was listed as a UNESCO World Heritage Area in 1981, policymakers were compelled to formally recognize the entire coastal ecosystem as one integral assemblage [14]. This included the catchments on the mainland that discharged water into the World Heritage Area (G. Kelleher In: GESAMP, Annex 2 1996). While coming to terms with that definition, there unfolded the realization that the zoning scheme should embody a set of objectives that would pertain to the whole ecosystem and not just to the Marine Park itself [G. Kelleher In: GESAMP, Annex 2 1996]. So it was that the first comprehensive zoning plan was unveiled in 1983 [32].

In parlimance with the rest of the world’s coastal ecosystems, over the years there developed increased use and activity even in areas considered remote to the GBR Marine Park [32]. Further, more scientific findings led to the knowledge that functionally important species and habitats were lacking adequate protection. Environments covering 94% of the GBR Marine Park that simply supported coral reefs around the margins, such as seagrass beds and sponge gardens, were afforded only 3% of the higher protection zone designations. In 2002, heeding the advice given by scientists that 20–50% of the coral reef ecosystems needed protection, The Marine Park Authority had the World Heritage Area scientifically classified into 30 reef bioregions and 40 non-reef bioregions (See Fig. 1) in preparation for a rezoning of the GBR Marine Park [32].

The GBR Marine Park would be completely rezoned through the Representative Areas Program (RAP), which was finally decided upon after 30,000 public submissions during two different phases of consultation.

RAP was implemented in 2003. The theme, which unifies RAP, is adequate cover for habitats that are representative of each
bioregion within zones that are reserved for a maximum of habitat protections [14]. RAP is also designed to enhance the resilience of protected areas that face external pressures and to afford singular protections to endangered species [32,14]. Further, it applies a coordinate based system to zone boundaries and removes historical inconsistencies through the uniform application of the zoning plan across geographic regions [32,14].

**Synopsis of the Belize Marine Protected Area**

In 1982, Half Moon Caye Natural Monument became the first MPA to be established in Belize (http://www.ambergriscaye.com/reefbriefs/). Others were to follow and in March 1990, the Coastal Zone Management Unit (CZMU) was inaugurated within the Department of Fisheries [16]. Later, in 1993, the United Nations Development Programme (UNDP) implemented the Coastal Zone
Management Project in support of CZMU with funding provided by the World Bank’s Global Environmental Facility (J. Gibson, et al. 1998). Preliminary agreements set an agenda designed to emulate Australia’s GBR Marine Park [16]. The assets at stake are similar because Belize controls the major share of holdings, which comprise the Mesoamerican Caribbean Reef. Along with holdings presided over by Mexico, Guatemala, and Honduras, the reef is the largest found in the Western Hemisphere. Recognizing that fact, UNESCO has also bestowed this reef ecosystem with the World Heritage Site designation [16].

Considerable emphasis has been placed on managing terrestrial environmental systems that affect the coast [16]. This objective has been administered through the Land Utilization Authority, which is responsible for strategic zoning through the imposition of Special Development Areas and the Central Housing and Planning Authority, which is responsible for clarification of land use plans and controls over construction [16].

Marine zoning in the EEZ waters of Belize has revolved around traditional regulation of the various commercial, industrial, and recreational boating and shipping thoroughfares: no-anchoring areas, shipping channels, and no-wake zones [16]. MPA zoning schemes revolve around small-scale traditional fishing and ‘no take’ zones [16].

MPA’s that are designated as a Marine Reserve is administered by the Fisheries Department [16]. MPAs that are designated as National Parks, Wildlife Sanctuaries, Natural Monuments, or Nature Reserves are administered by the Forest Department [16]. The CZM Program has envisioned a network of MPAs along the span of the Barrier Reef and on each of the atolls [16]. Bacalar Chico, one of the original protected areas has both a National Park and a Marine Reserve component [16].

Collaborative management of the individual MPAs’ spread amongst government agencies, non-governmental organizations, and local civic organizations. For instance, The Belize Audubon Society manages Half Moon Caye and Blue Hole National Monuments [16]. Each of these arrangements is charted by the central government [16].

Legislation would eventually establish the CZM Project Steering Committee as the Coastal Zone Management Authority through the Coastal Zone Management (CZM) Act of 1998 [16]. The Coastal Zone Management Authority’s mission is “to support the allocation, sustainable use and planned development of Belize’s coastal resources through increased knowledge and building of alliances, for the benefit of all Belizeans and the global community” [34]. The CZM Act of 1998 mandated that the Authority to produce a Coastal Zone Management Plan within three years [10]. In turn, the Authority embarked on the production of the CZM plan in two stages. The first stage entails the provision of “overarching national objectives (and) guidance on how these objectives can be met.” The second stage expands upon the original UNDP Coastal Zone Management Project’s preparation of the ‘Cayes Development Policy’ guidelines for nine coastal planning regions (See Fig. 2) [34]. These regions are founded on social, economic, geographic, and administrative bonds. In addition, they complement the Special Development Areas administered by the Land Utilization Authority [34].

The CZM Authority is not empowered to make decisions that will directly result in the performance of planning and development control recommendations [34]. That is because decision-making power over issues concerning development and natural resources management is vested throughout a collection of other government ministries [34,10]. Although necessarily chosen from a prescribed array of sectors by law, the Authority’s Board of Directors are appointed by the Minister of Fisheries and Agriculture.

Analysis

It is perhaps telling that the first purpose invoked within the GBRMP Authority’s goal statement supports ‘protection’ and the first purpose invoked in the Belizean CZM Authority’s goal statement supports ‘allocation’. The different aspects which separate the Coastal Zone Management plans of Australia and Belize are not only reflected in their goal statements but also in the purposes which govern the configuration of Australia’s bioregions and Belize’s planning regions. This circumstance can be traced to the involvement of the UNDP.

The UNDP, which implemented the Belizean Coastal Zone Management Project, has a mission that, by and large, recognizes sustainable development as an element that brings ‘added value’ to its formulation of what constitutes a socioeconomically developed nation. Sustainable development is treated as a means to meet the UNDP long-term goal of supporting the socioeconomic standing of lesser-developed countries. It is not surprising then that Belize created regions that primarily serve to support socioeconomic functioning while Australia created regions based upon representation of habitat. Notwithstanding, Belize has met with noteworthy success regarding the holistically inspired coordination between its coastal planning regions and its land based Special Development Areas.

In contrast, the Australian management of its natural resources is much more mature than the Belizean program and so it introduced bioregional zoning as the foundation of a second-generation program. By doing so, the Australian government has proven that adaptive management is not just management creed but, to its credit, is also an ecosystem management principle that it has the ability to exercise on a grand scale.

The opportunities for successful management of coastal resources are fundamentally less favorable for Belize than they are for Australia. The geopolitical stage that exists in Australia is united and rich with capital while the scenario in Belize is marked by the fact that the Mesoamerican Barrier Reef ecosystem spans the international borders and EEZ’s of less developed nations. Belize has been much more strident than its neighbors regarding domestic attempts to create an operational and sustainable management framework on the Reef even though it generally has no greater economic advantage than they. On the other hand, it is true that there exists a coordinated International effort in the form of the Project for the Conservation and Sustainable Use of the Mesoamerican Barrier Reef System, which was launched in 2001 at the behest of the host countries (Mexico, Belize, Guatemala, and Honduras) and financed by the Global Environmental Facility (http://www.mbrs.org.bz). Yet, despite its importance, this project has not diminished the influence of ministerial inertia over the forces of progress within Belize.

Although the original Belizean CZM Unit has been reincarnated a number of times over the years, its later day counterpart, the CZM Authority, remains within the Ministry of Fisheries and Agriculture as it is currently provided for under the CZM Act. This particular implementation of the ICZM model is reminiscent of the pilot projects spearheaded by Chua Thia-Eng’s team in Southeast Asia during an early stage in the model’s international application and development. One of the overriding objectives, at that time, was to intervene before insurmountable environmental damage became a forgone conclusion. The strategy was to employ whatever institutional platform happened to be the most politically expedient first and then to build out the ICZM institutional structure from that level [7,8]. As a consequence of failing to provide for the evolution of a separate central government agency, Belize has a robust ICZM plan but the CZM Authority remains only marginally effective. The problem is rooted in legislation that institutionalizes makeshift ICZM infrastructure, which subsequently diminishes the power
legally vested in the CZM Authority and undermines its mission to effectively coordinate interagency and stakeholder activity.

Belize necessarily relies on the benefits of co-management both as a historical construct [16] and for the sake of benefit/cost savings. However, exercising a widespread policy of co-management under these conditions can lead to the fragmentation of productive alliances and allow conflicts of interest to fester within government agencies responsible for oversight.

Australia has now encountered its own major setback regarding the ecosystems approach to management. The Australian government has recently shut down the operation of many Cooperative Research Centers (CRC) associated with environmental management. Simply put the mission of a CRC is to practice science in support of management priorities in an organization where scientists and managers work together. The vast majority of CRC’s that now remain support a wide range of commercial, industrial, and agribusiness interests but the following is a sampling of the CRC’s which is no longer in operation: CRC for Coastal Zone, Estuary and Waterway Management, CRC for Catchment Hydrology, CRC for Tropical Rainforest Ecology and Management, CRC for Greenhouse Accounting, and CRC for The Great Barrier Reef World Heritage Area.

References


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