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Article

Governing for Sustainable Coasts: Complexity, Climate Change, and Coastal Ecosystem Protection

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Abstract: The world's coastal ecosystems are among the most complex on Earth, and they are currently being governed unsustainably, by any definition. Climate change will only add to this complexity, underscoring the necessity of finding new ways to govern for these ecosystems' sustainable use. After reviewing the problems facing coastal ecosystems and innovations in their governance, this article argues that governance of coastal ecosystems must move to place-based adaptive management regimes that incorporate innovative and flexible regulatory mechanisms, such as market-based incentives.

Keywords: coastal ecosystems; sustainability; governance; adaptive management; place-based management; ecosystem-based management; market-based regulation; ecosystem services

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1. Introduction

Jane Lubchenco, Administrator of the National Oceanic and Atmospheric Administration (NOAA) recently noted that "all ocean ecosystems [are] rich in [] beauty, bounty, and history but fragile in [their] susceptibility to unsustainable practices on land and in the oceans" [1]. Estuaries and coasts are the most productive and important, but also the most complex, of ecosystems on the planet. Their unsustainable use arises from many sources, including fishing and coastal development, and additional threats to their integrity abound—from land-based pollution, from water-based pollution, and, most recently, from climate change. In the face of such complexity and the intensifying problem of climate change, designing sustainable governance institutions for estuaries and coasts is an ambitious, perhaps even audacious, undertaking.

Nevertheless, facing up to that challenge is necessary. Present use of coasts is unsustainable under any definition, and increased protection of ecosystems and ecosystem function—physically, chemically, and biologically—is critical to achieving sustainability. Given the inherent complexities of coastal ecosystems and the added complications of climate change, coastal managers need governance institutions that are simultaneously stronger and more flexible than many used to date. Unfortunately, sustainable governance institutions for coasts are still largely at the drawing board.

This article suggests that, in the face of multiple threats to these complex ecosystems, and particularly in an era of climate change, changing the law to allow for increased use of place-based regulation that incorporates adaptive management and increased use of innovative regulatory strategies, especially market-based mechanisms, presents the best next step forward toward sustainable governance of the coasts. Part I reviews the obstacles to achieving sustainability in coastal and estuarine ecosystems, including the goals for and problems plaguing these ecosystems identified in the Rio Conference in 1992, the World Summit on Sustainability in 2002, and the Millennium Ecosystem Assessment in 2005. Part II provides a survey of the general principles of sustainable governance, together with examples of how these principles have already been applied in coastal and estuarine governance. Part III then looks at place-based management tools and non-traditional means of regulation, such as market-based mechanisms, concluding that they could provide the comprehensiveness and flexibility that is currently lacking in coastal and estuarine regulation and hence increase the potential for sustainable governance of those ecosystems.

2. General Barriers to Achieving and Goals for Sustainability in Coastal Ecosystem

2.1. Barriers to Achieving Sustainability of Coastal and Estuarine Ecosystems

Both governance of marine ecosystems and the marine ecosystems themselves are generally considered more complex than their counterparts on land. In part, governance difficulties stem from pervasive lack of knowledge about marine ecosystems and hence uncertainty regarding what the goals for marine and estuarine governance should be [2,3]. As researchers have noted, “detailed knowledge of ecosystem structure, functioning, and dynamics is incomplete and uncertain in virtually all cases” [3]. Thus, when governance institutions pursue sustainability goals for these ecosystems based on scientific understanding, the lack of scientific knowledge can become a basis for inaction or, perhaps worse, governance systems that actually undermine the long-term sustainability of those ecosystems. The latter, for example, has been the all-too-frequent result in fishing regulation.

Moreover, from what *is* known about marine ecosystems, it is clear that those ecosystems are complex, complicating effective governance because governance measures must consider multiple factors simultaneously. Marine ecosystems are subject to “the cumulative and potentially synergistic impacts of multiple activities” [2] and processes occurring at multiple temporal and spatial scales and, spatially, in three full dimensions [4]. Driven by winds and ocean currents, nearly everything in the ocean is constantly in flux—temperature, salinity, location, nutrient concentrations, ambient light, plankton, fish, and other creatures [4]. Positive feedback loops and synergistic effects only add to the complexity [4].

Thus, effective governance of complex coastal and estuarine ecosystems requires consideration of multiple stressors. However, this reality generally fits uncomfortably into existing legal structures, because regulatory authority is generally fragmented among levels of government and medium- or subject-matter-based agencies [5]. In addition, technical challenges to jurisdiction and enforcement, such as determination of boundaries and tracking of violators [2,3], also undermine effective governance of the coastal and estuarine ecosystems.

Thus, even in coastal nations that possess sufficient institutional capacity to pursue sustainable governance, this complexity in both the ecosystems themselves and existing regulatory authority makes it unlikely that a unitary model of sustainable governance of coastal ecosystems will come to dominate. Moreover, a wide variety of political and social systems and economic and social needs exist in coastal nations. As a result, sustainable governance institutions are always likely to vary considerably among coastal ecosystems, depending on the particular political institutions and realities applicable to, local developmental needs and priorities for, and existing environmental conditions of any given estuary or coastal ecosystem [2]. The kelp forest ecosystem of Monterey Bay in northern California will be governed differently than a mangrove shrimp fishery in Indonesia—but it will also be governed differently than the Florida Keys coral reef ecosystem.

Of course, not all coastal nations possess sufficient institutional capacity to support sustainable governance of marine ecosystems. This lack of institutional capacity is itself a barrier to achieving sustainability, perhaps most dramatically demonstrated by the newsmaking rise of piracy off the coast of Somalia. Less dramatically, private property rights are often either non-existent in the ocean or far less well defined than they are on land [2]. As a result, property institutions, even if well-developed for terrestrial issues, often lack capacity to provide sustainable governance for marine ecosystems.

Similarly, lack of sufficient resources presents a barrier in many coastal nations to sustainable governance of coastal and estuarine ecosystems. At the governmental level, and especially given the technical difficulties that plague jurisdiction and enforcement [2,3], substantial resources (personnel, ships, surveillance, and so on) are often required to implement and enforce sustainable governance measures. The lack of property rights in marine resources generally means that these resources are a type of "commons" and that users lack property incentives to restrain or temper their exploitation. Finally, at the populace level, poverty and lack of alternative resources to provide for basic needs can pose both a practical and a political barrier to sustainable governance if such governance measures interfere with basic subsistence use of marine ecosystems [6].

Further complicating all efforts to achieve sustainable governance of the coasts is climate change. Climate change's impacts on coastal ecosystems are projected to be varied, synergistic, and significant. These impacts include increasing ocean temperatures, "sea level rise, changes in ocean chemistry and circulation, and shifts in the distribution and ecology of key species" [4]. Importantly, "the ecological and social effects of global climate change have already been detected and are predicted to be even more significant in coming decades" [4]. Because climate change impacts alter the structure and function of coastal ecosystems, and hence their ecosystem services, climate change also complicates the very process of defining "sustainability" both for sustainable governance generally and for a particular ecosystem. Climate change should thus be recognized as another obstacle to sustainable governance of these ecosystems.

2.2. General Goals for Sustainable Governance of Coastal Ecosystems

As Jane Lubchenco has noted, "Humans depend upon ocean ecosystems for a wealth of benefits—food, oxygen, protection of shores from storm damage, nutrient cycling, climate regulation, recreation, inspiration, cultural heritage, and religious value" [1]. Sustainable governance goals for coastal ecosystems must acknowledge this multitude of benefits, as well as the many threats to them. Internationally, Agenda 21, the World Summit Plan of Implementation, and the Millennium Ecosystem Assessment have articulated fairly comprehensively the procedural requirements necessary to achieve and the substantive goals that encapsulate what qualifies as sustainable governance of oceans, coasts, and estuaries.

These international evaluations of progress toward and goals for sustainability consistently identify five primary threats to sustainable use of marine ecosystems. These threats are: (1) overfishing; (2) land-based pollution; (3) marine-based pollution; (4) loss of habitat from coastal development; and (5) climate change.

Overfishing, for example, is a prominent concern in Agenda 21, the World Summit's Plan of Implementation, and the Millennium Ecosystem Assessment. When the United Nations Conference on Environment and Development (the Earth Summit) took place in June 1992 in Rio de Janeiro, it drafted Agenda 21, a sector-by-sector plan of action to achieve sustainable development [7]. Chapter 17 of Agenda 21 addresses ocean resources, and overfishing is one of its strong concerns ([7], Chapter 17.45). To protect living marine resources, nations "commit themselves to the conservation and sustainable use of marine living resources on the high seas" ([7], Chapter 17.4). Similarly, nations must address overfishing in national waters, because "[f]isheries in many areas under national jurisdiction face mounting problems, including local overfishing, unauthorized incursions by foreign fleets, ecosystem degradation, overcapitalization and excessive fleet sizes, underevaluation of catch, insufficiently selective gear, unreliable databases, and increasing competition between artisanal and large-scale fishing, and between fishing and other types of activities" ([7], Chapter 17.69, 17.71).

In Johannesburg in 2002, the World Summit on Sustainability issued a broader-based Plan of Implementation than Agenda 21 [8]. Notably, the Plan specifically encourages participants to apply the ecosystem approach to fisheries management and biodiversity protection by 2010 [8] and suggests specific actions to promote sustainable fisheries [8]. However, the Plan also seeks to restore and enhance marine biodiversity overall through a variety of governance techniques, such as integrated coastal management, ecosystem-based management, and marine protected areas, and fulfillment of the Convention on Biological Diversity [8].

The 2005 Millennium Ecosystem Assessment (MEA) underscores the importance of ecosystems in providing ecosystem services to humans. Emphasizing these connections will remain critical to sustainable governance institutions for estuaries and coastal ecosystems, which tend to have pervasive couplings with human societies [4]. Specifically, the MEA reports indicate that sustainable fisheries regulation will be a critical component of sustainable governance for these ecosystems. The MEA identifies capture fisheries as one of the two (of 24 studied) ecosystem services that is already being used at levels well beyond those that "can be sustained even at current demands, much less future ones. At least one quarter of important commercial fish stocks are overharvested (*high certainty*)" [6]. Such overuse comes with measurable social and economic costs [6].

The second threat, land-based marine pollution, is the focus of Agenda 21's program in Chapter 17 on marine environmental protection ([7], Chapter 17.19). For example, this program directs coastal nations to "take account of the Montreal Guidelines for the Protection of the Marine Environment From Land-Based Resources," which provide checklists of features for national legislation and international agreements ([7], Chapter 17.24); build and maintain adequate sewage treatment facilities; institute programs to control effluent discharge and monitor other sources of land-based marine pollution; require environmental impact assessments; eliminate discharges of pollutants that are toxic, persistent, and/or bioaccumulative; institute controls on nitrogen and phosphorus to control eutrophication, control runoff and other forms of nonpoint source pollution; and prevent coastal erosion and siltation ([7], Chapter 17.27–17.29). The World Summit's Plan of Implementation reinforces these recommendation for land-based pollution. For example, it lists measures to "[a]dvance implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities and the Montreal Declaration on the Protection of the Marine Environment from Land-based Activities, with particular emphasis during the period from 2002 to 2006 on municipal wastewater, the physical alteration and destruction of habitats, and nutrients" [8]. Finally, despite its emphasis on biodiversity, the MEA also recognizes that that sustainable governance must address numerous other threats. Of these, pollution is having a very high and rapidly increasing impact on coastal biodiversity [6].

With regard to pollution that derives from activities at sea, Chapter 17 of Agenda 21 encourages nations to implement fully the plethora of treaties addressing such pollution and to create additional measures to address pollution from cargo ships and nuclear fuel, air pollution from ships, hazardous substance transportation and disposal, pollution from oil and gas platforms, and pollutants found in anti-fouling paints ([7], Chapter 17.30–17.32). The World Summit's Plan of Implementation, in turn, recommends that nations increase and better enforce the International Maritime Organization standards for ships, prevent transportation of invasive species through ballast water [8], and protect the oceans during transportation of radioactive wastes [8].

Loss of coastal habitat reduces the size and function of coastal and estuarine ecosystems. In Agenda 21, Chapter 17 specifically notes that coastal habitats such as coral reefs, mangroves, and estuaries "are under stress or are threatened from a variety of sources, both human and natural" ([7], Chapter 17.72). Coastal states commit themselves to the "conservation and sustainable use of marine living resources under national jurisdiction" ([7], Chapter 17.74). In addition, the marine environmental protection program encourages nations to assess the impact of ships on sensitive areas, to act in coastal zones "to protect and preserve rare or fragile ecosystems, such as coral reefs and mangroves," to control the invasion of alien species via ballast water, and to ensure that their coasts and waters are well-charted ([7], Chapter 17.30). Thus, Chapter 17 not only explicitly addresses a broad array of coastal ecosystems—coral reefs, mangroves—but also incorporates a nascent recognition of coastal ecosystem services. The MEA's report is particularly grim with respect to coastal and estuarine ecosystems and notes the severe losses of coastal habitats such as wetlands, coral reefs, mangroves, tidal flats, and estuaries [6,9]. The MEA's statistics thus strongly suggest that habitat preservation needs to become a significant component of sustainable governance for coastal ecosystems and estuaries; however, it also notes that coastal development will also make the transition to sustainable governance challenging [6,9].

Finally, climate change threatens the very stability of marine ecosystems, calling into question the very definition of "sustainability" along the cost. Chapter 17 of Agenda 21 addresses climate change, noting that "[t]he marine environment is vulnerable and sensitive to climate and atmospheric changes. Rational use and development of coastal areas, all seas and marine resources, as well as conservation of the marine environment, requires the ability to determine the present state of these systems and to predict future conditions. The high degree of uncertainty in present information inhibits effective management and limits the ability to make predictions and assess environmental change" ([7], Chapter 17.96). According to the MEA, climate change's impacts on coastal ecosystem function and biodiversity are currently moderate, but very rapidly increasing [6], underscoring climate change's increasing importance for sustainable governance institutions. Thus, climate change and our lack of specific knowledge of how it will affect the marine environment are impediments to effective sustainable governance of estuary and coastal ecosystems.

The interactions of these five stressors will complicate sustainable governance of coastal and estuarine ecosystems. For example, the MEA notes that overfishing, invasive species, climate change, and nutrient loading are all potentially pushing coastal and estuarine ecosystems toward threshold shifts that may be irreversible [6]. As a result, these ecosystems are vulnerable to nonlinear and potential abrupt changes in the future [9], such as fisheries collapses and invasive species-induced changes [6].

3. Sustainable Governance, Its Guiding Principles, and Some Applications to Coastal Ecosystems to Date

Sustainable governance is governance that shifts societies to sustainable development and then maintains them in sustainability [10]. More expansively, Jill Jäger has emphasized that "[g]overnance *for* sustainable development ... implies the deliberate adjustment of practices of governance in order to ensure that human development proceeds along a more sustainable trajectory. Governance for sustainable development is the effort to link the systems of governance with the objective of sustainable development" [11].

Unfortunately, neither "governance" nor "sustainable development" (which this article uses interchangeably with "sustainability") is a precisely defined or uncontested term. "Governance" refers to the social activities that guide and manage societies, "denot[ing] the complex ways in which order and orientation are maintained in contemporary socio-political systems" [11]. It "describes the patterns that emerge from the governing activities of diverse actors that can be observed in what is deemed acceptable norms of behaviour, and divergent institutional forms" [10]. The constitutive processes of governance are deliberation, argumentation, and discussion, while the three main modes of governing are markets, networks, and hierarchies [10]. Sustainable development, in turn, seeks to promote human well-being, in the senses of both economic growth and social well-being, while simultaneously protecting and conserving the environment, in recognition that continued ecological health is a necessary condition of human well-being [10,12]. In 1987, in perhaps what is the most enduring definition of the concept, the Brundtland Commission formed by the United Nations General Assembly endorsed "sustainable development" as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [13].

Nevertheless, even in the best of circumstances, sustainable governance is not easy to put into practice. Achieving sustainability forces governance institutions to focus on the long term [7], which can be politically difficult. Moreover, in order to achieve sustainable development in particular places, governance institutions must identify with some precision *what* is to be sustained [10]. This point is important, because although sustainable development arose and gained political credence as a win-win model of development [10,12]—people could have it all—the evolving and more realistic view is that sustainable development requires trade-offs [1-3,14,15]. The sub-principles of sustainable development are often in conflict with each other, requiring governments and other governance institutions to balance, prioritize, and/or choose among them. Recognizing and addressing trade-offs and shifting priorities will become even more imperative as governance institutions respond to climate change impacts [16].

The sustainable development and governance literature establishes a number of basic principles for sustainable governance. The rest of this Part presents a brief survey of those principles, with examples of how they have already been applied to the governance of coastal and estuarine resources.

3.1. The Polluter Pays Principle

One of the bedrock principles of environmental policy is that the entity causing pollution or other harm should internalize the costs of that harm—the so-called "polluter pays" principle [17]. As elegant as the idea behind this principle might be, however, it has several theoretical and practical issues to overcome. First, it is not always clear who should bear the costs of abating an alleged harm, or even that it matters whether we assign blame in the first place. Second, the economic efficiency promised by the polluter pays principle—those who cause pollution will internalize the costs of paying for cleanups, preferably by preventing pollution in the first place—depends on polluters and enforcers knowing the full extent of the harms caused by the action. Third, even if we have accounted for all the harms, another problem the polluter pays principle faces is finding a mechanism to make the polluter pay the efficient amount to internalize them. Fourth, even when a method of making polluters pay is available, implementing the polluter pays principle can be more or less difficult depending on the source of the pollution and the difficulty of proving causation. It is not always easy, in other words, to find the polluter.

To be sure, where a particular polluter and the damages it causes are both readily identifiable, the polluter pays principle can be an effective mechanism for promoting sustainable governance. For example, 1989 *Exxon Valdez* oil spill in Alaska provides one case study of how the "polluter pays" principle can play out under the Clean Water Act's oil spill provisions (33 U.S.C. § 1321). The ship released 11 million gallons of crude oil, which eventually covered at least 10,000 square miles of coastal waters and oiled 1,000 miles of the Alaska coast [18]. Estimates of the damages included losses to commercial fishing, sportfishing, and tourism. However, they also included the estimated costs of replacing the animals killed, which ranged from $300,000 per killer whale to $22,000 per eagle to $390 per river otter [19]. Most controversially, economists estimated the passive use values lost as a result of the spill to be worth $2.8 billion [20]. Civil litigation over the *Exxon Valdez* spill settled, requiring Exxon to pay $900 million in damages, to be divided between the federal government and the State of Alaska [21].

In contrast, the polluter pays principle is seldom an efficient or politically viable tool for sustainable governance when the contributers to a particular problem are many and difficult to identify, their pollution difficult to track and measure, and individual contributions to resulting environmental harm difficult to prove. With respect to coastal and estuarine ecosystems, this problem arises most dramatically in the context of nonpoint source pollution (runoff) from land-based sources, particularly agriculture. For example, the eight countries surrounding the North Sea have negotiated several agreements to reduce pollution into that sea, one of the most important being in 1990. As is often the case, however, by the late 1990s:

> Reducing toxic pollution from point sources has proceeded, but coming to grips with nonpoint sources of pollution, particularly the hundreds of thousands of tons of nutrient pollution from agriculture, has proved impossible. The Netherlands has discovered, to its embarrassment, that it simply cannot regulate nitrogen inputs from diverse agricultural sources unless it revamps its entire agricultural base [22].

3.2. The Use of Best Available Science

Another standard of environmental law is that decisions should be made based on the “best available science” [23]. In the United States, the Endangered Species Act (ESA) represents the most aggressive adherence to this ideal, requiring that species be evaluated for listing as endangered or threatened “solely on the basis of the best scientific and commercial data available” (16 U.S.C. § 1533(a)) [24].

“Best available science” requirements act as a check on both the hasty application of regulatory power and the uninformed use of science. Accordingly, the courts have interpreted it to impose several practical guidelines on agencies, such as prohibiting agencies from manipulating their decisions, from disregarding scientifically superior evidence, and from insisting on conclusive data before making a decision [25]. The best available science standard thus has grown into a guide for *using* science in decision making, rather than dictating the way of *doing* science.

One example of this evolution in the United States has been the “best available science” requirement in the federal Magnuson-Stevens Fisheries Conservation and Management Act (16 U.S.C. §§ 1801 *et seq*.). The Act has long required the National Oceanic and Atmospheric Administration (NOAA), National Marines Fisheries Service (now NOAA Fisheries), and the regional Fisheries Management Councils (FMCs) to base the fisheries management plans “upon the best scientific information available” (16 U.S.C. § 1851(a)(2)). Application of this requirement, however, has traditionally been insufficient to either prevent or reverse overfishing [26]. Instead, integration of best available science requirements into the Act largely waited until the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 [27]. In this legislation, Congress amended the Act to require that each FMC appoint a Scientific and Statistical Committee to provide “ongoing scientific advice for fishery management decisions” ([27], § 103(b)). In addition, each FMC could establish a scientific peer review process ([27], § 103(b)), and FMCs were to work with the Committees to establish fisheries management research priorities ([27], § 103(d)). Importantly, catch limits set in fisheries management plans cannot exceed the Scientific and Statistical Committee's or peer reviewer's recommendations ([27], § 103(c)), removing much of the FMCs' previous discretion to factor in other considerations, such as economic impact on the relevant fishing communities, into their catch limits.

However, the Act still does not contain a definition of "best scientific information available." Moreover, as noted, scientific information regarding marine ecosystems and their components is often limited and poorly developed. As a result, a "best available science" requirement often may not sufficient constrain agency action toward sustainable governance, particularly in the absence of other guiding norms.

3.3. The Precautionary Principle

Environmental policy increasingly is converging around the so-called precautionary principle for guidance on setting the direction and level of burdens of proof, particularly in the face of scientific uncertainty [28-30]. Although many syntactic statements of the precautionary principle exist, the essence of all boils down to the following: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" [31].

Marine researchers have emphasized the importance of the precautionary approach to marine sustainable governance [3,14,32]. In the United States, for example, in 1994 the National Research Council noted that, in light of inevitable uncertainties regarding fish stocks, "[w]hen there is a significant risk of serious consequences that may be reversible only over the long term, and the best scientific evidence available is inadequate, precautionary measures such as moratoria, effort reductions, area closures, time limits, and gear restrictions may be needed" [26]. Partly in response to this report, Congress amended the Magnuson-Stevens Act in 1996 to incorporate a precautionary approach into fisheries management. These amendments specifically recognized that overfished fisheries exist, redefined "optimum yield" for such fisheries to require rebuilding, and required the FMCs to take account of the ecological effects of fishing ([33], § 102). Moreover, under the NOAA's regulations implementing the Act, the regional FMCs must "adhere to the precautionary approach ... when faced with uncertainty" (50 C.F.R. § 600.350(d)(ii)).

The precautionary approach has also been an important tool in managing marine pollution. The North Sea, for example, has been suffering from pollution since the 1960s. Beginning in the 1970s, the relevant nations have attempted to address these pollution problems through treaties [22]. However, the early treaties assumed that the North Sea had an assimilative capacity for pollution and presumed that pollutants are safe until proven otherwise [22]. As result, the North Sea continued to deteriorate. At the 1987 North Sea Conference in London, however, the eight participating nations decided to reverse the presumptions about pollution, consciously adopting a precautionary approach. Under this approach, all pollutants are deemed potentially harmful unless scientific evidence indicates otherwise [22].

Nevertheless, adopting the precautionary principle carries with it significant controversy [34,35]. For one thing, it is easy to substitute the economy or social equity for the environment in the statement of the precautionary principle, and in the context of sustainability there can be inherent trade-offs between environment, economy, and equity [36]. Thus, it is not always obvious toward which component of sustainability the precautionary principle should be exercised. The precautionary principle has also been criticized as imprecise and subject to manipulation to serve pre-determined policy interests [36]. Indeed, the statement of the principle lacks any process component for identifying how precaution is exercised or who makes and participates in the decision [37]. As robustly as it has been embraced in policy circles, the precautionary principle thus remains a work in progress. It has not been tested over the long run in the context of managing estuaries and coastal resources.

3.4. Intergenerational Sustainability

Sustainability is a multi-dimensional project that includes a temporal component [38], the classic statement being the Bruntland Commission's call for "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [13]. Particularly given the growing recognition that anthropogenic greenhouse gas emissions of the past two centuries will have profound impacts on resources and human populations, potentially for the next several centuries, cracking the code of intergenerational sustainability seems imminently important.

One approach is to change our thinking about economics. Neoclassical economics takes the position that functioning markets will produce continuous intergenerational equity because it would be inefficient for a present generation to waste resources or, for that matter, to sacrifice through underutilization [39]. In theory, in other words, rational economic behavior aggregated across multitudes of individuals and businesses will use resources at the efficient rate now and into the future, and if we start to run out of one thing—an ore, or a type of fish—scarcity will lead to efficient conservation, substitution, and technological fixes. However, this "open world" position assumes markets that function with perfect information about all relevant factors. It further assumes that technological innovation and other efficient behaviors can bounce us back from scarcity [39]. Neither assumption has worked very well over the long run in the real "closed world," where ecosystems run by their own rules [40,41]. Moreover, when people exercise individual choice in an environment of uncertainty—uncertainty about whether the market has all the information it needs and whether resources will remain sufficient in the long run—they tend to take a short-term approach to decision making: get it now while the market values it and it can be gotten [42]. The discipline of ecological economics has emerged over the past 20 years to inject the reality of how ecological resources operate into the theory of how markets operate [43,44].

Government, of course, has its own short-term monkey on its back—the political cycle. Public choice theory, which emerged in the 1960s, examines political behavior through the lens of economic theory, suggesting that, indeed, much of what happens in politics is symptomatic of the same incentives that lead to short-term planning in markets [45]. By requiring planning well beyond the current or the next political cycle, sustainability policy flies directly in the face of this system of political incentives, and thus faces an uphill battle against not only markets, but also the government institutions designed to counterbalance the effects of imperfectly operating markets.

Not surprisingly, there are very few robust examples of intergenerational sustainability having worked its way into concrete law and policy for coastal management. Notably however, this principle has provided a basis for arguments in support of creating marine reserves and marine protected areas [46,47], and it supports the contention that place-based management can foster sustainable governance of marine ecosystems. For example, the National Marine Sanctuaries Act in the United States explicitly provides that one purpose of the National Marine Sanctuaries Program is to "maintain for future generations the habitat, and ecological services, of the natural assemblage of living resources that inhabit these areas" (16 U.S.C. § 1431(a)(4)(C)).

Another example of nascent considerations of intergenerational equity is found in the European Union Marine Strategy Framework Directive. This Directive recognizes that "[t]he marine environment is a precious heritage that must be protected, preserved and, where practicable, restored with an ultimate aim of maintaining biodiversity and providing diverse and dynamic oceans and seas which are clean, healthy and productive" [48].

3.5. Transnational Sustainability

Sustainability policy also is focused on maintaining temporal sustainability of economic, environmental, and social equity goals across relevant spatial scales. In the coastal resource management context, this spatial dimension of sustainability is often a transnational problem. How one nation treats an inland watershed can affect estuarine resources in another nation and coastal resources in yet another. Straddling fisheries, marine pollution, and climate change necessarily transcend national boundaries.

Climate change has most clearly focused attention on the complex and delicate political realities of transnational sustainability, as developed nations emphasize the need for environmental sustainability while developing nations emphasize the need for economic sustainability. Complicating this dialogue in the marine context is the fact that such phenomena as ocean acidification, sea level rise, increasing ocean temperatures, and increasing numbers of increasingly severe marine storms—all of which threaten the sustainability of both coastal and estuarine ecosystems and the economies that depend upon them—are causally disconnected from the physical locations of the sources of greenhouse gas emissions.

At lesser spatial scales than climate change, however, international law routinely recognizes that attempts to protect estuarine and coastal resources from unsustainable development can raise transnational issues, and cooperative treaties are the frequent (if not always effective) result. For example, although unwieldy in title, the United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks provides a governance framework for sustainably managing fish that cross national boundaries, and 77 nations have become parties to it [49]. On a more regional scale, nations affected by each other's watersheds and marine pollution have entered into a number of focused treaties to address that pollution [50].

As these examples indicate, international agreements that acknowledge and resolve transnational environmental issues are one of the more routine mechanisms for spelling out sustainable development goals and for creating new governance structures to achieve those goals. Nevertheless, these agreements can also underscore the trade-offs inherent in the transnational pursuit of sustainable governance. The 1946 International Convention for the Regulation of Whaling, for example, is generally credited with preventing the extinction of most species of large whales and even allowing the recovery of a few, such as the generally coastal Pacific gray whale [51]. However, that level of ecological sustainability was actually achieved through a global moratorium on whaling, at the expense of economic development interests in nations such as Japan and Norway [52]. Moreover, issues of whether the moratorium embodied the proper balancing of goals have continued through the contemporary implementation of the Convention [53].

3.6. Accounting for Ecosystem Services

No one needs convincing that the ecosystem service values provided by coastal ecosystems are vast and immense [54,55], but ironically this is the root of a policy problem. That they are ubiquitous and seemingly ever-present has meant ecosystem service values from coasts have been largely taken for granted, treated by market and government institutions alike as essentially public goods provided for free and indefinitely [56]. In ecosystem services as in many other features, ocean resources such as coastal and estuarine resources suffer from a deeply engrained paradigm of inexhaustibility [57].

Public goods status applies to many flows of ecosystem services and the stocks of natural capital that supply them [58], but it is compounded in the marine context by the reality that the oceans, in all senses political and economic, truly are open access resources. Much of the discussion of ecosystem services policy focuses on adjusting property rights and economic incentives relevant to the owner of natural capital [59], but because no one owns the oceans there is little sense in discussing property rights or economic incentives [60]. Sustainability policy for oceans thus faces the daunting challenge of incorporating ecosystem service values in a political and economic context that has no developed institutional framework for thinking about property rights and economic incentives.

Of course, coasts and estuaries are subject to national sovereignty. To the extent that these sovereignty interests can be considered public "ownership" in a legally relevant sense, ecosystem services values can be incorporated both into governmental management decisions and into liability regimes to punish actions that illegally damage public resources. For example, in the United States, ecological values are one reason to establish National Marine Sanctuaries, with a goal of maintaining the "ecological services[] of the natural assemblage of living resources that inhabit these areas" (16 U.S.C. § 1431(a)(2), (4)(C)). Similarly, the European Union's Marine Strategy Framework Directive focuses on creating marine protected areas in recognition of the fact "that pressure on natural marine resources and the demand for marine ecological services are often too high" [48]. Thus, place-based management again appears to foster important aspects of sustainable governance.

In many nations, moreover, coasts are subject to private ownership or community management. There it does make sense to consider how to integrate ecosystem service values into economic and policy decision making, but then a different set of policy challenges arises. One of the leading policy tools for activating ecosystem service values as an economic incentive is to provide payments for ecosystem services (PES), particularly in developing nations where market institutions are not well established [61,62]. PES programs, as the name implies, pay owners of natural capital to alter resource management practices in ways designed to maintain sustainable flows of ecosystem services to beneficiary populations.

Where robust market institutions already are in place, PES programs face the different problem that the value of the PES payment may be insufficient to significantly alter resource management decisions, given the much higher value associated with alternative land use decisions [63]. Oftentimes, therefore, ecosystem service values have been introduced initially through regulatory policy that adjusts upward the baseline of expected resource management. Wetlands policy in the United States, for example, has recently mandated that government approval for the filling of wetlands and mitigation of such harms take into account the impact on the stock of natural capital and distribution of ecosystem services [58]. Such policy developments, however, are politically difficult to introduce, given the extent to which they may alter settled economic expectations, and they are bound to face continued controversy as they are implemented. Hence, as appealing as is the idea of incorporating ecosystem service values into sustainability policy—indeed, it is difficult to conceive how resource management could be sustainable without doing so—there are significant policy challenges to overcome, particularly in the context of managing privately owned resources for ecosystem services values.

3.7. Integrated Decisionmaking

Designing sustainability policy necessarily demands multidisciplinary expertise capable of modeling the impact of decisions at different temporal and spatial scales. Likewise, there is little reason to believe that *implementing* sustainability policy will not also require multi-institutional coordination across scales. Another foundational design question for sustainability policy, therefore, is how "integrated" *versus* "focused" to make the decision making process and apparatus.

Given the fragmented state of ocean governance, integration is generally likely to improve sustainable governance. Katrina Brown has argued that integration is most likely to be successful when six factors are met: (1) "[t]he full costs are taken into account"; (2) "[c]apacity exists in government and civil society institutions"; (3) "[a] feasible timescale to achieve objectives is possible"; (4) "[t]here is compatibility and no obvious conflict between objectives"; (5) "[t]he legal and institutional frameworks supporting the response are already in place"; and (6) "[r]elevant and timely information is at hand and extensive new data and research is not necessary" [64]. Thus, for example, the European Union's Marine Strategy Framework Directive advocates "a transparent and coherent legislative framework" that "contribute[s] to coherence between different policies and foster[s] the integration of environmental concerns into other policies" [48].

Nevertheless, there are contexts in which integrated decisionmaking is undesirable. In particular, because integrated decisionmaking—as in the European Union Directive—generally seeks to balance multiple goals and policy considerations, it may not be appropriate when there are real conflicts between policy objectives and prioritization of those goals is required. For example, the Endangered Species Act (ESA) flatly prohibits consideration of economic impact in the decision whether a species should be protected as endangered or threatened (16 U.S.C. § 1533(a)). Thus, in designing sustainability governance policies for marine ecosystems, coastal nations will inevitably have to choose from the spectrum of models between focused and fully integrated decision making, depending on the multiplicity of objectives they seek to pursue and the degree of conflict among those objectives.

3.8. Adaptive Management

As resource management has increasingly focused on ecosystem scales, new theories of decision making have emerged to account for the dynamic complexity of ecosystem processes and structures. One such emerging decision theory has dominated—adaptive management.

The discipline of adaptive management was forged in 1978 when C. S. "Buzz" Holling and his team of scientists published a book emphasizing that governance institutions must acknowledge the basic properties of ecological systems in order to manage resources effectively [65]. Whereas environmental protection and industry interests traditionally have battled to "lock in" positions through fixed rules and standards and preserve every inch of incremental ground gained, the adaptive management framework is more evolutionary, relying on iterative cycles of goal determination, model building, performance standard setting, outcome monitoring, and standard recalibration [66]. Management policy thus must put a premium on collecting information, establishing measurements of success, monitoring outcomes, using new information to adjust existing approaches, and a willingness to change. Indeed, some versions of adaptive management add an experimentalist element, in which there is deliberate probing for information to evaluate testable hypotheses about the effects of active intervention in ecological processes, such as the effects a chosen action might have on invasive species [67,68].

Since Holling's pathbreaking book, adaptive management has been joined at the hips with ecosystem management as the tool with which to implement the policy. Indeed, from the earliest emergence of ecosystem management policy there has been broad consensus among resource managers and academics that adaptive management is the only practical way to implement ecosystem management [69-72]. Recently, for example, the U.S. National Academy of Science's National Research Council convened a committee of scientists to explore how adaptive management might be used to improve resource agency decision making for ecosystem management in the Klamath River Basin, which straddles southern Oregon and northern California [73]. The committee outlined eight steps of adaptive management: (1) definition of the problem; (2) determination of goals and objectives for management of ecosystems; (3) determination of the ecosystem baseline; (4) development of conceptual models; (5) selection of future restoration actions; (6) implementation and management actions; (7) monitoring and ecosystem response; and (8) evaluation of restoration efforts and proposals for remedial actions [73]. The committee's description of the last stage provides some flavor of how adaptive management differs from conventional natural resources management:

> After implementation of specific restoration activities and procedures, the status of the ecosystem is regularly and systematically reassessed and described. Comparison of the new state with the baseline state is a measure of progress toward objectives. The evaluation process feeds directly into adaptive management by informing the implementation team and leading to testing of management hypotheses, new simulations, and proposals for

> adjustments in management experiments or development of wholly new experiments or management strategies [73].

Adaptive management has also emerged in marine resources policy as an important decision making theory [74]. For example, the European Union's Marine Strategy Framework Directive incorporates an adaptive management approach. To begin, the Directive recognizes both the need for flexibility among differing marine ecosystems and the need to develop the science of marine ecosystems to promote effective governance [48]. It also directly incorporates and promotes adaptive management as a sustainable governance mechanism in recognition of the complexity of marine ecosystems and their stressors, including the growing threat of climate change:

> In view of the dynamic nature of marine ecosystems and their natural variability, and given that the pressures and impacts on them may vary with the evolvement of different patterns of human activity and the impact of climate change, it is essential to recognize that the determination of good environmental status may have to be adapted over time. Accordingly, it is appropriate that programmes of measures for the protection and management of the marine environment be flexible and adaptive and take account of scientific and technological developments. Provision should therefore be made for the updating of marine strategies on a regular basis [48].

Nevertheless, as is true in other contexts, adaptive management in marine policy settings faces daunting questions of cost, authority, and public participation. Much of the decision apparatus of marine policy remains built around the resource management premises that Holling critiqued as static and unadaptive. Moreover, agencies have little incentive to risk political, judicial or public scrutiny by experimenting "outside the box" of decision making authority [66]. Although there is a growing number of examples of adaptive management being put into action in the marine resources context, it will take a sea change in legislative delegations of authority and agency internal practices to make adaptive management an integral component of sustainability policy decision making for estuary and coastal resource management.

4. Taking the Next Steps toward Sustainable Governance for Coastal Ecosystems

The discussion above indicates that sustainable governance for estuary and coastal ecosystems must address a multi-headed hydra [1] and hence that no easy panaceas to move these ecosystems to sustainability do—or can—exist. The importance of controlling land-based pollution indicates that coastal governance must look inland and suggests that watershed-based pollution control governance mechanisms must be part of the resulting governance institutions. Biodiversity-orientated governance mechanisms must simultaneously address mobile ships and fishers and provide place-based protections for critical coastal and estuarine habitats. All of this governance activity, moreover, must occur with recognition of influences outside of local and even national control, the results of all kinds of activities on the high seas and the increasing impacts of climate change which, for marine and coastal ecosystems, include rising water temperatures, rising sea levels, and ocean acidification. Finally, sustainable governance must occur even as "all ocean ecosystems are changing rapidly" [1] and in light of knowledge that historical baselines for most of these ecosystems have already shifted significantly [75,76].

To address this multiplicity of problems, institutions will need new tools to govern coastal ecosystems. This part looks at two sets of tools that could improve sustainable governance of coasts: placed-based management and regulatory innovations such as market-based regulation. Both allow sustainable governance policies to integrate many of the guiding principles just discussed.

4.1. Integrated, Place-Based Management Strategies

As has been noted, governance of ocean and coastal ecosystems suffers tremendously from regulatory fragmentation [4,77,78], prompting searches for "more holistic approaches to ocean management" [1]. Promising tools for more sustainable governance of these ecosystems include place-based management measures [2,3], especially when they are combined with resilience science [2,3,14] and adaptive management [14,79].

Coastal zones, including estuaries, are generally recognized as special regions worthy of particular legal protection [80]. However, "[t]he intrinsic complexity of coastal ecosystems and their association with human activities can explain the general failure of management strategies based on managing single aspects of coastal ecosystems independently of others" [79]. One of the earliest innovations to overcome challenges in managing coastal ecosystems, including estuaries, was integrated coastal zone management (ICZM).

ICZM defines the "coast" as a special region worthy of comprehensive management, that includes both terrestrial and marine components, and that includes both human settlements and important ecosystems. The exact definition of "coast" can vary from context to context (16 U.S.C. § 1453(1)) [4,22], but all acknowledge that the "coast" has both terrestrial and marine components, potentially eliminating the land-sea management barrier [22]. ICZM also seeks to govern all relevant stressors and activities in the coastal zone simultaneously and hence to integrate governance measures at all relevant scales [81]. The emphasis is on a comprehensive overview of what occurs in the coastal zone, in terms of both management goals and impacts and stresses [22], and hence on avoiding the regulatory and management fragmentation that deals with coastal resources and ecosystems on a piecemeal basis. At its best, ICZM integrates both natural and cultural science and incorporates a wide array of stakeholders [22].

Overall, ICZM encourages governance institutions to overcome regulatory fragmentation, to simultaneously address the multiple threats to coastal resources, to make explicit the trade-offs inherent in the various desirable uses of the coastal zone, and to prioritize those uses. All of these features of ICZM represent positive steps toward sustainable governance of coastal ecosystems and estuaries, especially over the short term. Thus, ICZM can still supply a helpful and productive first generation approach to sustainable governance of coastal ecosystems.

A second tool, estuary-based management, both acknowledges estuaries as particularly important coastal ecosystems and attempts to avoid one of the primary limitations of ICZM: the focus on the coastal zone. In particular, estuary-based management tends to arise in response to degradation of estuaries as a result of upstream pollution and hence inspires a watershed-based approach to estuary management and restoration.

The connection between degradation of estuaries and water pollution is made clear in the U.S.'s Clean Water Act, which created the National Estuary Program (NEP) (33 U.S.C. § 1330). NEP management demonstrates three aspects of governance relevant to achieving sustainability of coastal ecosystems, especially estuaries. First, protecting estuaries and coastal ecosystems from land-based impacts often requires expansion of the relevant governance institution beyond the locality that contains the estuary (33 U.S.C. § 1330(2)(A))—one of the potential limitations of traditional ICZM. In some cases, the relevant geographic regions can be quite extensive [82]. Second, the implementation of sustainable governance institutions can begin with a single, discrete problem, such as water pollution. Pragmatically if not theoretically, governance institutions generally cannot (and probably should not) attempt to achieve sustainability all at once by simultaneously and comprehensively addressing all stresses upon coastal ecosystems and estuaries [22]. Third, however, eventually—as the NEP conservation and management plans demand—sustainable governance requires consideration of all interrelated aspects of coasts and estuaries. Classically, estuarine concerns have included water quality, basic biodiversity (especially as is important to fishing and hunting), and human uses. Looking forward, however, relevant factors will have to include ecosystem function, ecosystem services, land use planning, and climate change.

Thus, an improvement on both ICZM and estuary-based management is true watershed-based management. Watershed management itself is not a new idea, but its practice has been slow to overcome inherent barriers [83]. It does not take long to see the problems that venturing down this path of reasoning is likely to produce. For example, comprehensive management of the Mississippi River watershed would incorporate about two-thirds of the land mass of the contiguous 48 states [84]. Nevertheless, watershed-based problems—including river fragmentation from the construction of dams, the loss of riverine wetlands, and the separation of river channels from floodplains through levees—demand watershed-based solutions. Accordingly, the need for watershed-based land use and resource management has gradually been integrated into concrete policy objectives [85].

From the marine side, place-based management focuses on marine protected areas (MPAs), which could contribute much to governance for coastal sustainability. MPAs are place-based marine management measures, roughly equivalent to state and national parks and preserves on land [48]. They have been used independently, to protect particular ecosystems such as kelp forests or coral reefs or particular resources such as species of fish, and also as part of more general marine protection policies, such as representative systems and ecosystem-based management [79,86]. Protected areas are well-recognized and often-recommended tools of sustainable governance [87], and MPAs can provide good first or partial attempts to protect estuaries and coastal ecosystems and to encourage marine tourism [48,57,74].

Nevertheless, MPAs are also subject to several limitations that affect their status as effective governance institutions. First, MPAs are generally subject to existing problems of jurisdictional fragmentation, both geographically and sectorally [3,86]. Moreover, the scales of marine ecological interactions often do not match the jurisdictional authorities of the relevant governments and other governance entities [5,79]. Second, as is true with many marine governance institutions, actual MPA placement and design can suffer from limitations in scientific knowledge about particular marine ecosystems [2,3]. This lack of knowledge regarding the ocean's heterogeneity and its multi-scalar interactions can impede implementation of sustainable governance [79]. Third, MPAs and marine reserves have not always been created with full regard for the relevant socio-ecological systems they affect. Instead, managers generally create MPAs based on scientific—classically, biological—criteria, but "[w]hile an MPA may be biologically successful, it can fail socially, which may lead to dwindling biological success in the long term" [4,74]. Finally, like all management measures undertaken in the face of lack of knowledge, MPAs can create unintended consequences. For example, if the MPA allows predator species to recover at faster rates than prey species (because predators were disproportionately the targets of intensive fishing), it may not be the best management choice for rebuilding stocks of species at lower trophic levels [86]. For all of these reasons, as the European Union's Marine Strategy Framework Directive has recognized, using adaptive management to pursue an MPA strategy will help to avert unintended consequences and to incorporate developing marine science [48].

As the European Union Directive also recognizes [48], MPAs can be one tool to promote a broader strategy for sustainable governance of the oceans: beyond simply setting aside areas of the ocean for protection, ecosystem-based management of marine resources is an idea that has gathered much support [26]. Edward Grumbine provided a comprehensive statement of the ten themes and five goals of ecosystem-based management [88], including the use of ecological rather than political boundaries, the promotion of ecological integrity, a commitment to adaptive management, and a recognition that humans are embedded in nature. Grumbine found that setting clear goals is crucial to the success of ecosystem management [88], and five specific goals were frequently endorsed: (1) Maintain viable populations of all native species *in situ*; (2) represent, within protected areas, all native ecosystem types across their natural range of variation; (3) maintain evolutionary and ecological processes (*i.e.*, disturbance regimes, hydrological processes, nutrient cycles, *etc.*); (4) manage over periods of time long enough to maintain the evolutionary potential of species and ecosystems; and (5) accommodate human use and occupancy within these constraints [88]. Nevertheless, true examples of this form of ecosystem-based management for coastal and estuarine resources have yet to be realized and will remain unrealized without political and public will to implement a new kind of management framework [89].

4.2. Market-Based Instruments and Other Regulatory Innovations

Dissatisfaction with so-called "command-and-control" forms of regulation has increased since the 1990s, the criticisms being that it is inefficient, ineffective, and far too rigid to handle the dynamic needs of environmental policy [90-93]. Regulatory innovation proposals have taken three broad forms: government-stakeholder network structures, indirect governance mechanisms, and economic incentive programs [94].

Government-stakeholder network structures emphasize collaboration, inclusiveness, and sufficient flexibility to tailor solutions to the circumstances of discrete situations. For example, in *negotiated rulemaking*, stakeholders in proposed regulatory initiatives negotiate terms of regulation in order to avoid post-promulgation litigation [94]. Similarly, *contract-based permitting* refers to procedures in which terms of regulatory permits, rather than relying on prescribed formulaic standards, are negotiated between the regulatory authority and permit applicant within a broader boundary of possible ingredients and outcomes [94]. Finally, *public-private "partnership" programs* allow regulators to team with private entities to engage cooperatively in developing solutions that optimize benefits to both interests, such as by providing public technical expertise for improved private land management [94].

The indirect governance mechanism approach, also known as "reflexive law," relies on information, consumer demands, and reputation values to induce desired behavior in the regulated community. For example, in *information reporting programs*, a requirement to report prescribed actions, such as discharges of pollutants, allows greater public dissemination of information that, given public reaction to the information, may induce the reporter to alter behavior in order to control the impact of the information effects [94]. *Certification programs*, in turn, encourage manufacturers meet certain standards, such as energy efficiency or forest stewardship, so as to obtain the right to "certify" their products and thereby, presumably, reap the benefits of consumer demand for more "environmentally friendly" products [94]. *Performance track programs* allow firms that perform at superior levels under prescribed standards to receive a reduced load of regulatory transactions, such as inspections and permit processing reviews, and an increased level of public recognition through awards and other official mention [94].

Finally, economic incentive programs tap into basic economic interests, using constructed market frameworks or direct incentives, to induce desired behavior or otherwise make it more likely to occur. For example, *cap-and-trade programs* impose industry-wide pollution ceilings and allocate pollution "credits" among firms in the industry based on some initial allocation formula, but then allow individual firms to trade their "credits" so as to take advantage of differential pollution control efficiencies [94]. In contrast, *banking programs*, allow some natural resource, such as wetlands or endangered species habitat, to be accumulated in a "bank" through restoration or enhancement, and then sold to third parties who require some level of mitigation as a condition to receiving a regulatory permit to engage in land development or other resource uses [94]. A third type of mechanism, *tax and subsidy programs*, more directly induces desired behavior by providing reward subsidies for delivery of environmental goods or by imposing punitive tax or fee consequences for engaging in environmentally undesirable behavior [94].

Marine governance institutions have begun to incorporate these tools. In the United States, for example, NOAA's National Estuarine Research Reserve (NERR) System, created through the Coastal Zone Management Act (16 U.S.C. § 1461) is a prominent example of a flexible system of public-private partnerships. Each NERR is designated originally through state and federal cooperation. Once a NERR is designated, however, government officials often partner with local universities, NGOs, and other local entities for management and stewardship projects, and the participation of these private partners is deemed critical to the success of sustainable estuary stewardship [95].

Fishery management has inspired a number of market-based management mechanisms to encourage sustainable fisheries. In 2005, for example, the Food and Agriculture Organization of the United Nations (FAO) published its *Guidelines for the Ecolabelling of Fish and Fisheries Products*, and a number of international organizations now provide for certification and labeling of sustainable fisheries products [96]. One of the most stringent of these programs is run by Friend of the Sea, which provides certification globally of sustainable seafood from both fisheries and aquaculture when those products adhere to the FAO guidelines. Certification entitles producers to market their products with Friend of the Sea's red circular seal [97]. More well known is the Marine Stewardship Council's fishery certification program. Fisheries that qualify as "sustainable" under this global certification program can market their fish with the Council's blue "ecolabel" [98].

A more direct market-based regulatory mechanism for fisheries is tradable fishing quotas [99], generally referred to either as Individual Fishing Quotas (IFQs) or Individual Tradeable Quotas (ITQs). For example, in 2006, when Congress amended the Magnuson-Stevens Act, it specifically sought to encourage market-based fisheries regulation and allowed for the creation of limited access fisheries and the creation of transferable fisheries privileges (16 U.S.C. § 1853a). IFQs guarantee each permit holder a share of the total allowable catch (a form of regulatory cap), eliminating the need for frantic fishing derbies, short fishing seasons, and fishing in unsafe conditions. IFQ systems generally also restrict new entrants into the fishery, reducing incentives to overcapitalize and the chances that too many fishermen will exceed the total allowable catch. Institution of IFQ system in the Alaska halibut fishery has been deemed a resounding success: "By restricting new entrants and establishing catch quotas, Alaska has broken the relentless cycle of overfishing and has invested fishers with a financial stake in the future health of the fishery" [100].

Clearly, IFQs have not been successful everywhere they have been implemented. Moreover, by focusing on only one component of an ecosystem—a particular fish species—an IFQ approach can actually undermine a more integrated ecosystem-based management approach, just as traditional species-focused fishing regulation can. Nevertheless, in marine ecosystems where overfishing of particular species is in fact the major stressor to the ecosystem and the major impediment to its sustainability, IFQs can be an appropriate approach.

Market-based mechanisms for land-based coastal issues have been more limited. Among the newest of these programs are payment for ecosystem services (PES) programs [101]. In addition, in the United States, the federal Environmental Protection Agency (EPA) is using its authorities under the Clean Water Act to experiment with pollutant trading in watersheds. Several watersheds have now implemented such water quality trading programs, including the Chesapeake Bay watershed [102].

Nevertheless, market-based mechanisms and other regulatory innovations could still be used more pervasively and creatively as part of new sustainable governance institutions. In particular, no holistic effort to incorporate innovative regulatory platforms has been proposed by relevant national or international bodies. Such innovations could allow for regular tinkering with incentives as a means of responding to increased understanding of marine ecosystems and/or changes in ecological systems as a result of climate change [16].

5. Conclusions

Governance of coastal ecosystems and estuaries has always been complex, even without sustainability goals, and climate change is only increasing that complexity. Given the number of different kinds of threats facing these ecosystems—land-based and ocean-based pollution, overfishing an other forms of over-exploitation, coastal development, and climates—and the fragmented status of existing governance institutions, both geographically and topically, an instantaneous, full-blown, comprehensive transition to sustainable governance of the coasts is unlikely in any country, even the richest and most powerful. Lack of full scientific understanding, entrenched institutional prerogatives and norms, and economically lucrative but ultimately unsustainable industries present significant political and practical barriers to any such attempt.

Luckily, governance can evolve toward sustainable governance. The governance principles and institutional arrangements discussed above are not mutually exclusive, and all allow initial governance measures to expand and become integrated into progressively more comprehensive sustainable governance institutions. Static ICZM plans can be amended to incorporate active adaptive management; local water pollution protections for estuaries can expand into comprehensive, watershed-wide management programs that incorporate market-based water pollution trading programs; and isolated MPAs can be incorporated into networks of MPAs pursuing larger biodiversity and ecosystem goals.

Many researchers place great hope in the more pervasive incorporation of ecosystem-based management into marine governance. As Anne D. Guerry has recently commented, “the move toward more holistic ecosystem-based management has immense potential—and is already making strides toward ensuring the sustainability of marine ecosystem and the billions of human lives that are so intricately tied to them” [78]. Others, like the MEA, stress the value of economics and innovative incentives for achieving sustainability [6]. Specifically, the MEA recommended “[e]limination of subsidies that promote excessive use of ecosystem services” and “[g]reater use of economic instruments and market-based approaches” [6].

Fortunately too, these new tools can be combined in a myriad of creative and flexible ways. Ecosystem-based management intrinsically takes account of ecosystem services, the benefits that marine ecosystems provide to humans [2], and hence the socio-ecological connections between humans and the marine environment [2], allowing for incorporation of market-based incentives and regulatory mechanisms. For example, ecosystem-based management could easily incorporate tradable IFQs for fisheries management and PES programs to compensate indigenous populations whose livelihoods may have depended on access to areas now protected from extractive uses. In addition, ecosystem-based management can be adapted to a range of spatial scales and support multiple objectives [2], providing flexibility in designing sustainable governance institutions for different coastal systems. “Finally, it is important to note that the concept of ecosystem-based management is grounded in the idea that ultimately we are managing people’s influences on ecosystems, not ecosystems themselves” [2]. Thus, ecosystem-based management allows for the incorporation of innovative regulatory tools while also (at least potentially) avoiding the trap, in a climate change era, of trying to preserve or restore coastal ecosystems in their current or historical states of function [16].

Ecosystem-based management and market-based incentives are not, of course, panaceas, and they do not automatically overcome the problems of regulatory fragmentation, incomplete scientific knowledge, and lack of financial resources to fund non-traditional regulatory programs and market-based incentives. Nor do they necessarily help to define what “sustainability” means in a climate change era.

Nevertheless, it is clear that new, more highly integrated, more cooperative, and more creative approaches to sustainable governance are needed. Ecosystem-based management that incorporates adaptive decision making mechanisms and the full panoply of regulatory tools, such as market-based regulation, appears to be one of the more promising approaches to achieve progress toward sustainable governance of coastal ecosystems.

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