Governing marine ecosystem restoration: the role of discourses and uncertainties

Abstract

Governing marine environments has evolved from dominant interests in exploitation, allocation, conservation, and protection to restoration. Compared to terrestrial and freshwater environments, restoration of and in marine ecosystems presents a new mode of intervention with both technical and governance challenges. This paper aims to enhance understanding of the important factors at play in governing marine ecosystem restoration. *Discourses* of marine ecosystem restoration are an important factor which shape how the restoration activity is governed, as discourses structure how actors and coalitions define problems and their approaches to solutions. The article produces a conceptual model of the discourses of marine ecosystem restoration, built on two dimensions: (1) the degree of human intervention and (2) motivations for restoration. Together, these dimensions create four broad restoration discourses: "Putting Nature First," "Bringing Nature Back," "Helping Nature support Humans," and "Building with Nature." Moreover, marine ecosystem restoration is confronted with different forms of *uncertainty*, such as incomplete knowledge, unpredictability, and ambiguity, which must be managed by actors participating in restoration initiatives. The article's overall contribution is the synthesis of these components, which illuminates the specific governance challenges under various circumstances.

1. Introduction

Restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed [1,2]. While the practice of ecosystem restoration in terrestrial and freshwater environments has been widely discussed in the literature [3,4,13,5–12] restoration of marine ecosystems is relatively new and presents different scientific, technical, and governance challenges [14–19]. Whereas the science of coastal and marine ecological restoration is rapidly advancing [20–22] numerous questions on the governance of marine ecosystem restoration remain [12,14,16,19].

Governance encompasses, "The rules of collective decision-making in settings where there is a plurality of actors or organizations and where no formal control system can dictate the terms of the relationship between these actors and organizations," [23]. The objective of this paper is to enhance understanding of two key factors in collective decision-making about marine ecosystem restoration: the ways actors define and operationalize restoration (the how and why of restoration), and the ways they perceive and address uncertainty. For this purpose, a conceptual framework is developed, consisting of two building blocks: a typology of discourses of marine ecosystem restoration and a typology of uncertainties relevant in marine governance.

Discourse entails the views and narratives of the actors involved: their norms, values, definitions of problems, and approaches to solutions [24]. Discourse coalitions draw on knowledge to make themselves legitimate and persuasive and deal with uncertainty in different ways, which ultimately affects decision-making [25–27]. Section 2 distinguishes different discourses of marine ecosystem restoration, constructed on two axes: (1) the degree of human intervention and (2) the motivations for restoration. Together, these axes generate four distinct discourses of restoration: "Putting Nature first," "Bringing Nature back," "Helping Nature support Humans," and "Building with Nature." In marine ecosystem restoration governance, different coalitions of actors (governmental and non-governmental) try to initiate, develop, and implement restoration activities centered in one of these dominant discourses. The dominant discourses and related coalitions determine the rules of the game and the availability of resources [28,29].

The second building block is uncertainty, elaborated in section 3. Uncertainty is crucial in policymaking and governance processes, particularly in regard to how society deliberates and decides among various alternatives [30]. Uncertainties stem from interlinked natural-technical-social systems [31]. Actors, who set priorities on why and how to restore and implement (marine) ecosystem restoration, grapple with distinct kinds of uncertainty [10,31–33]. Three types of uncertainty are distinguished in this paper—incomplete knowledge, unpredictability, and ambiguity. This section clarifies that uncertainty relates not only to scientific knowledge and the natural system being restored, but also to societal perspectives of those involved in or affected by restoration.

The way coalitions define marine restoration through restoration discourses and how they address the uncertainties related to these discourses affect the possibilities for governing marine ecosystem restoration. Section 4 elaborates on the four discourses of marine ecosystem restoration and, using examples of marine restoration from literature, relates the different types of uncertainties and their manifestations. For each discourse, governance challenges are identified. Finally, Section 5 presents conclusions.

2. Restoration: the interplay of human intervention and philosophical underpinnings

Numerous authors have debated definitions of ecological restoration e.g. [1,5,34]. The proliferation of terms tangential to restoration—recovery, reconstruction, regeneration, rehabilitation, rewilding, environmental repair—indicates the diversity of approaches in ecological restoration. Although detailed terms are favored by some arguing against conflation [3,35], others use the term restoration in a broad sense without being bothered about semantics [18]. Many authors acknowledge that terms are often used interchangeably because precisely distinguishing among terms is not easy and terms can be conflicting or overlapping [15,17,18]. Interpretation and fitness of certain terms can differ between marine and terrestrial applications; for example, Elliott et al. [17] disagree with Bradshaw [36] and propose restoration, rehabilitation, remediation and re-creation to be considered as synonyms for coastal and estuarine applications. Such ambiguity necessitates a systematic evaluation of terms and their definitions and the ontological roots of restoration along two key dimensions: (1) the degree of intervention by humans and (2) the motivations for marine restoration. Simply stated, there is a need to examine *how* recovery is to be achieved by delineating the various ways people intervene and practice marine ecosystem restoration. Additionally, questioning the *why* of ecosystem restoration probes the philosophical underpinnings of restoration motivations.

2.1 Restoration concepts and terminology: a spectrum of human intervention

Restoration is predominantly defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed [1,2]. This definition is carefully framed to draw attention to several aspects. First, recovery, across a range of degraded-to-destroyed ecosystems, is set at center stage. Second, it understands restoration as a process in which time is important at (a) the project level (e.g. the designing, planning, and monitoring of a restoration project [37–39], including the involvement of stakeholders to initiate a project [1,40]), and (b) the biological level (in terms of life cycles, return/rebuild of abiotic and biotic functions, replacement/introduction of structure (e.g. replanting key structural species or providing alternative structures), e.g., [41]). Third, “assisting” implies different strategies and degrees of human intervention, ranging from passive restoration—unassisted (spontaneous) recovery [16]—to active restoration, carried out via various human interventions to assist recovery (see Figure 1).

A number of fundamental conceptual restoration ecology models have been developed, e.g. [3,15,36,42]. Figure 1 illustrates a simple understanding for the application of the marine restoration process that differentiates types of restoration and some of the actions involved, ranging from hands-off, unassisted recovery to hands-on, assisted recovery involving direct ecosystem interventions. It is accepted that different types of restoration may end in variations of altered states [42], but that the aim should place an ecosystem on the trajectory to recovery relative to an appropriate reference ecosystem [5], re-establishing an interrupted ecological trajectory [43]. This is not aimed at a pre-disturbance ecosystem "turning back the clock" ignoring change [5], but at reinstating self-organization of the system along with structure, function, biodiversity and natural capital.

Unassisted restoration ("hands-off") includes two basic marine management approaches, i.e. regulate certain aspects to reduce pressures and lessen impacts and/or prohibit certain human activities as seen in many marine protection and conservation policies. For example, the designation of a no-take zone (NTZ) within a Marine Protected Area (MPA) intends to halt the loss and further anthropogenic decline of biodiversity through the no-take policy and secures the capacity of the marine ecosystem to recover or remain healthy by setting aside particular space in the ocean.

[Insert Figure 1 here]

Assisted recovery ("hands-on") can be achieved by various actions (see assisted recovery level in Figure 1). Restoration methods and actions include reducing causes of decline or removing problems. For example, removal of sea urchins, which cause barrens by overgrazing seagrass, occurs prior to the transplant of seagrass and bivalves [44]. More complex approaches include seeding, transplant of fragments and nursery grown corals, the introduction of artificial structures to support transplants of key ecosystem engineers (e.g. corals) and/or facilitating transplant success by other species (e.g. mussels with seagrass) [37,45,46]. A recent approach is directly linking the ecosystem services framework and the restoration of natural capital [47] to a family of restorative activities that can be carried out simultaneously or sequentially, at any site or ecosystem and regional levels to achieve long lasting positive impacts [3]. This family, shown in the approaches level of figure 1, includes environmental *remediation* (clean-up) of polluted areas, *reparation* and *recuperation* of degraded lands and water bodies to the more challenging tasks of *ecological rehabilitation* of natural or semi-natural ecosystems and *ecological restoration* of degraded ecosystems.

Recuperation is the partial recovery of ecosystem-based productivity and goods and services. Its goal is to bring a degraded site or ecosystem back to a state where sustainable use is once again possible [3]. The aim of *rehabilitation* is to reinstate a level of ecosystem functionality [5]. Rehabilitation, according to [17], is the activity of partially or fully replacing structural or functional characteristics of an ecosystem that have been lost, while *restoration* is the process of re-establishing a sustainable habitat or ecosystem with a healthy structure and functioning following degradation by human activities. Both recuperation and rehabilitation share a focus on historical or pre-existing ecosystems as references or models, but restoration incorporates the re-establishment of pre-existing biotic integrity in terms of species composition and community structure [1].

Encompassing different motivations and goals, habitat *re-creation* is about re-constructing a habitat that was present within historical records, while *creation* is an anthropogenic intervention that produces a habitat not previously on site. For example, artificial reefs placed on an otherwise sandy sea bottom should be regarded as creating a new habitat with the aim to increase the biodiversity, rather than replacing lost habitat [17]. *Creation*, in other words, is the intentional fabrication of an ecosystem (different from the one previously occurring on a site) for a useful purpose without a focus on achieving a reference ecosystem [5]. The reconstruction approach can be employed when damage is very high and where in addition to removing or reversing degradation by correcting all biotic and abiotic damage, to match the target local reference ecosystem, a major proportion of its biota need to be re-introduced. Desirable appropriate biota, usually structuring or keystone species, are reintroduced in areas where they previously disappeared to reestablish an ecosystem's important structural component [17,48]. In contrast, the intentional creation of biotic assemblages whose species have been selected to provide services without the aim of achieving a reference ecosystem, are called designer ecosystems [2]. Such marine examples are eco-engineered concrete microhabitats such as rock pools incorporated into marine infrastructure and coastal armoring [49]. These terms highlight the extent of human interventions from setting aside, hands-off to hands-on cultivating and transplanting to creating purpose-built ecosystems.

The focus here has been on how, or to what degree, humans intervene in order to restore degraded ecosystems. Some interventions are characterized as *passive* in the way that pressures are removed, but the intention is to have nature "fight back" against human induced degradation, where these forces find a new, steady state. *Active* restoration techniques adopt an ethos of "nature needs us" to jump-start and/or achieve full recovery. However, there is another distinguishing criterion in the modes of restoration: the motivation for restoration, or the *why*. To illustrate, imagine a situation of transplanting historically abundant species that are challenged to survive in changing environmental conditions, versus the introduction of new species that thrive in present environmental conditions and serve essential functions of historically prevalent species. The question of what is "natural" divides between maintenance of historical levels of biodiversity and the idea that nature has always been evolving and rather function becomes the primary concern [50]. Debates over the purpose of restoration primarily rests on one's view of the relationship of humans within or apart from nature and the determination of the intended recipients of restoration activities.

2.2 Motivations of marine restoration: why, and for whom?

Two measurement categories reflect underlying divisions in the motivation of restoration: adopt responsibility on behalf of the ecosystem and its constituent species or primarily serve the interests and needs of people. Much of the motivation of ecosystem restoration divides among distinct "ethical precepts": anthropocentrism, biocentrism, and eco-centrism [51]. Anthropocentrism takes the view that people and their needs hold the primary importance and captures an interpretation of the world exclusively through human values and experiences [52,53]. In contrast, biocentrism recognizes the survival rights of other organisms [51]. Eco-centrism evolves further from biocentrism and underscores that the conservation criteria of ecosystem stability and integrity, and that all biota are paramount [54]. Unlike anthropocentrism people are not recognized as omnipotent, "Humans count enough to have the right to flourish in ecosystems, but not so much that they have the right to degrade or shut down ecosystems," [54].

In this respect, ecosystem restoration and its permutations are grounded in the assumptions of the role or place of humans within or outside of nature. Dichotomies or spectrums capture on one end, a view of humans outside of nature and on the other side, some philosophies understand humans operating within ecosystems. Scholarship on conservation has given rise to compositionalism and functionalism, rooted in evolutionary and ecosystem ecology respectively [12,50]. In compositionalism, humans are viewed outside of the system and thus their influence is primarily viewed as pernicious [50]. This frame prioritizes biotic communities in ecosystems and seeks to have all the parts compiled or composed in the system, whereas functionalism emphasizes the maintenance of ecosystem functioning and sees people within these systems [12,50]. Functionalism reflects an anthropocentric orientation because the provision of goods or services represents the primary concern of ecosystem health with less concern for changes in biotic composition as long as ecosystems function in the same fashion. In contrast, compositionalism prioritizes biodiversity and sees the importance of ecosystems as independent of human needs.

Different restoration goals have been shown to affect restoration outcomes and divisions in motivation correlate with different stakeholder groups [55]. Hall [56] contrasts the differing views of degeneration and degradation of nature and their prescribed interventions as "gardener" or "naturalizer" depending on the perspective of human impact and role within the environment. Ecological engineering or novel ecosystems are rooted in anthropocentrism, whereas those holding an eco-centric view would be uninterested in restoration efforts that only meet function criteria and do not re-establish species and communities that were historically present.

Clewell and Aronson [57] recognize five general rationales or motivations for restoration including the biotic (e.g. for the benefit of threatened species), the idealistic (e.g. atonement for environmental damage or spiritual renewal) and the pragmatic rationale. Restoration of natural capital and ecosystem service provision represent important pragmatic motivations for restoration [55]. A focus on the return on investment or the question of costs and ecological payoffs [58] also underscore anthropocentric motivations. Studies on the success of ecosystem restoration often report transplant survival or biodiversity [37,59], ecosystem goods and services [60], or a combination of these [8,60,61]. Weinstein [12] suggests management schemes attending to differences in eco-centric and anthropocentric goals and anthropogenic use and impact on estuaries. These studies and articles demonstrate varied conceptions of restoration emphasized by different success measurements, which in turn are grounded in different values toward nature as elaborated above.

The primary question addressed here is why motivations matter in ecosystem restoration. Discourses and frames within environmental policy have political power [27,62,63]. For instance, evidence shows that scientific discourses on non-native species are taken up and amplified by the media, affecting public perceptions of the problem and thus constraining the policy and management prescriptions [26]. The motivations and frames for why to restore marine ecosystems, or more concretely how the problem of marine degradation is framed and thus interventions prescribed, ought to be considered when analyzing and evaluating marine ecosystem restoration governance.

2.3 Discourses of marine ecosystem restoration

Combining the dimensions of the degree of human intervention in restoration (section 2.1) and motivations for marine restoration (section 2.2) a conceptual model forms, showing different discourses of marine ecosystem restoration, each emphasizing distinct problems and solutions (Figure 2).

[Insert Figure 2 here]

The x-axis represents the degree of human intervention (low to high), or the *how* of marine ecosystem restoration. Along the y-axis, there are gradations of anthropocentric and eco-centric motivations, or essentially the *why* of restoration. Based on these dimensions the model distinguishes four ideal-typical discourses of marine ecosystem restoration: "Putting Nature First," "Bringing Nature Back," "Helping Nature support Humans," and "Building with Nature." These discourses are elaborated in Section 4. The following section will elaborate on the notion of uncertainty in the science and practice of ecological restoration.

3. Uncertainties and decision-making in (marine) ecological restoration

Nature often responds to human intervention in surprising ways [9,32]. Within natural resource management, the desire to eliminate or minimize uncertainty and surprise has gradually been replaced by acceptance of uncertainty as inherent to complex socio-ecological systems, and therefore unavoidable [30,64,65]. Decisions about and implementation of ecological restoration programs involve different forms of uncertainty which emerge from the plurality of values, assumptions, interpretations and behaviors of the various actors involved in governing restoration [9,30,31,66]. Therefore, analyses should explicitly incorporate uncertainties related to both scientific knowledge and plural actor perspectives in order to facilitate communication about uncertainties and devise strategies to deal with them in restoration governance settings.

3.1 Three kinds of uncertainty

Brugnach et al. [30] define uncertainty as "the situation in which there is not a unique and complete understanding of the system to be managed," and distinguish three kinds of uncertainty: *incomplete knowledge*, *unpredictability*, and *ambiguity* (Figure 3).

Uncertainty is characterized as *incomplete knowledge* when there is not enough data available, accessible, or of sufficient quality to provide reliable knowledge of the system to be managed. High research costs at sea mean that, for most marine ecosystems, large knowledge gaps exist about their structure, functions, biodiversity, and interactions. For example, restoration of deep-water ecosystems necessitates knowledge of the target species abundance, distribution, and life history, but the remoteness of the deep-sea, sampling/mapping challenges, and lack of taxonomic expertise severely hamper understanding of deep-sea benthic biodiversity [67,68]. Incomplete knowledge implies that collecting more or better data in principle could reduce uncertainty and in turn improve understanding of the system to be managed [69]. Nonetheless, attempts to complete knowledge do not always decrease uncertainty; new discoveries usually reveal new knowledge gaps, which lead to new uncertainties [9,32,64].

Unpredictability refers to the uncertainty that arises due to the complex, dynamic, and non-linear behavior of the system to be managed, be it a natural, technical, or social system. For instance, the impact of combined environmental stressors on coral reef ecosystems is unpredictable due to the interaction of multiple factors affecting various organisms in complex ways [70]. This complexity is compounded when humans are added to the equation, for example when fisheries and marine recreational activities, as well as restoration efforts take place within the same reef ecosystem. As Brugnach et al. [30] writes, "Unpredictability implies accepting that it is not possible to make deterministic predictions about a phenomenon and that doing more research will not change this situation in the near future." Unpredictability is approached differently in restoration, depending on how restoration is conceptualized (Section 2). While ecological engineering aims to remove this type of uncertainty by controlling natural processes for the provision of selected services, ecological restoration accepts unpredictability, as the biodiversity and final outcome of restored ecosystems is not entirely predictable over time [43]. Nonetheless, some ecosystem restoration scholars assert, "the discipline has matured from 'stamp collecting' to that of a *predictive* science," [71] (emphasis added). Bradshaw has argued for the ecological restoration as "an acid test for ecology," wherein the experimentation or tinkering with ecosystems' structures and functions and the potential failures advance the field of ecology [36].

Incomplete knowledge and unpredictability both reflect the underlying concern of "not knowing enough." However, uncertainty can also originate from knowing differently. In this case uncertainty arises from ambiguity [31,72]. *Ambiguity* is defined as "uncertainty due to the presence of multiple knowledge frames or different but (equally) sensible interpretations of the same phenomenon, problem or situation," [31]. Frames are sense-making devices that actors use to define issues, prioritize actions, and mobilize other actors and/or resources [33,73]. In multi-actor environmental governance settings, multiple knowledge frames shape interpretations of the problem at stake and its solution, which may lead to conflict and impede collective action [30]. In this way, frames are related to discourses. Rigs-to-reefs debates illustrate the different—and often conflicting—knowledge frames through which the problem of decommissioning obsolete oil and gas platforms is interpreted, as well as the solutions offered by different actors [27,74–76].

[Insert Figure 3 here]

3.2. Uncertainties and natural, technical, and social systems

The marine ecosystem to be restored is part of a complex natural-technical-social system. Although system components—natural, technical, and social—are closely interlinked, it is useful to make an analytical distinction of each component where the identified uncertainty originates [31]. The natural system comprises the ecosystem to be restored, including target species and habitats, abiotic factors such as water quality, and other natural phenomena that could either drive or affect restoration initiatives. For example, incomplete knowledge about native and non-native species interactions and ambiguity regarding the impact of non-native species fosters debates and influences views on necessary or appropriate intervention [26]. The technical system consists of infrastructures, technologies, and innovations through which people intervene in nature. Interventions such as genetic modification, translocation, and de-extinction made lead to controversies in restoration ecology [21,77]. High levels of all three forms of uncertainty surround such initiatives given their states of development (incomplete knowledge), unpredictability of ecological consequences, and likely resistance from society due to ethical concerns. The social system includes economic, legal, political, cultural, administrative and organizational aspects related to ecological degradation and restoration. Uncertainties pertaining to the social system are unpredictability of how social and political shifts may influence conservation and restoration policies, and ambiguity about what constitutes restoration "success" [78–80].

4. Synthesizing discourses and uncertainties to identify governance challenges

As demonstrated in Section 2, ecosystem restoration is a crowded space of interpretations and constructions. Although ecologists and restoration practitioners mention uncertainty as a challenge, seldom do they address the differences among the three types as elucidated in Section 3. The following section elaborates the four discourses and discusses uncertainties in connection to them. This exercise is not exhaustive, but rather illustrative through hypothetical scenarios grounded in real-world experiences in marine ecosystem restoration. How the uncertainties manifest in the four quadrants of the conceptual model will illuminate various governance considerations of marine ecosystem restoration.

4.1 Helping Nature support Humans (low intervention, anthropocentric)

In the lower, left quadrant of Figure 2, Helping Nature support Humans is characterized by a low degree of human intervention and an anthropocentric motivation. Spatial management measures such as NTZs established for fish stock recovery purposes exemplify management rooted in this discourse. NTZs are designated in the hopes that particular commercially or culturally significant species will regenerate in the absence of extraction. For example, the "fish refuges" in Quintana Roo in the Mexican Caribbean held the explicit goal of recovering commercially important lobster and finfish species [81,82]. In interventions categorized as Helping Nature support Humans, secondary goals may be articulated, e.g. increased biodiversity, but these initiatives are often dominated by a narrative that emphasizes direct benefits to people.

Within situations characterized by Helping Nature support Humans particular uncertainties arise. Incomplete knowledge and unpredictability are often invoked in the discussion of the effectiveness of NTZs, especially in light of confounding variables [83,84] and cumulative and interactive impacts in marine ecosystems [85]. Various forms of uncertainty were present in the NTZ designation in Quintana Roo, starting with the inherent unpredictability of NTZ's effectiveness [86,87], as well as knowledge gaps about the most suitable sites for closure [88]. Ambiguity regarding the value of closing areas for fishing and where those areas ought to be was also expressed by some in the local fisher cooperative. Some fishers claimed that their fishing practices were sustainable already, and thus they did not perceive NTZs as necessary [81]. Situations of incomplete knowledge of effectiveness, unpredictability of interactive and cumulative impacts, and ambiguity as to the necessity of interventions like NTZs highlight the importance of participatory processes for knowledge production and deliberative governance. In addition, spatial interventions at sea have a special challenge of monitoring and enforcement that should also be considered when establishing new governance arrangement around NTZ establishment.

4.2 Putting Nature First (low intervention, eco-centric)

Moving clockwise into the upper, left quadrant, Putting Nature First maintains a low degree of human intervention, but the motivations center on ecosystem-oriented outcomes in and of themselves. Once again, spatial tools are relevant, and in this case would likely be MPAs with broader ecosystem-level conservation goals. Additionally, prohibitions of certain human activities—spatially-bound or otherwise—would likely fall in this quadrant. Prohibitions, for example, which pay special attention to marine mammals or seabirds, or non-commercially relevant species highlight the eco-centric orientation of this discourse. The suggested prohibition of certain sunscreens due to their chemical effects on particular coral species [89] exemplifies the Putting Nature First discourse. Hawaii's ban of certain sunscreens also illustrates how incomplete knowledge and unpredictability intertwine when moving from laboratory experiments to predicting effects in the open ocean [90,91]. In addition, incomplete knowledge and unpredictability in species adaptations and survival can also challenge restoration initiatives when cumulative effects of climate change and commercial fishing pressure stress marine food webs—e.g. the Stellar sealion [92]. Participatory and deliberative governance processes will likely be key to meet such challenges. Governance regimes may also need to determine how to ease the social, economic, and cultural disruptions felt as a result of certain prohibitions, such as considering questions of compensation or dispensation.

4.3 Bringing Nature Back (high intervention, eco-centric)

Bringing Nature Back encapsulates the dominant discourse among (restoration) ecologists and restoration practitioners, moving closer to the gardener or cultivator paradigm, where people place installations or species in the sea. Such assisted restoration practices contrast the unassisted spatial designations of acceptable and unacceptable actions at sea or prohibitions of certain activities or products, as seen in previous sections. Thus, Bringing Nature Back remains under an eco-centric motivation, but marks a turn toward higher degrees of human intervention. Notable examples of this discourse are seagrass, mangrove, and coral transplantation. In the case of the Dutch Wadden Sea, the benefits to restoring seagrass are manifold, but the Bringing Nature Back discourse championed by environmentalists centers on the historical presence of seagrass beds and their dependent species assemblages [25].

Again, incomplete knowledge and unpredictability intertwine as to whether interventions will work. For instance, seagrass restoration in the Dutch Wadden Sea exemplifies incomplete knowledge and unpredictability as the natural system may have altered and surpassed certain thresholds. A key dimension of governance includes the ability to mobilize resources, e.g. scarce or sustained funding for restoration activities. Unpredictable outcomes—put bluntly, the inability to guarantee restoration success commensurate with allocated resources—will challenge marine ecosystem restoration. High cost of full-scale marine ecosystem restoration in coastal environments [93] and at deep sea [16] are notable barriers. Additionally, with eco-centric motivation the goals or intended benefits will likely be through positive externalities. Positive externalities are often provided through public goods or common-pool resources, which can face issues of payment for goods or services because exclusion is structurally difficult. Therefore, governance regimes will likely need to consider public or collective means to finance these measures and address free-rider problems.

Bringing Nature Back encapsulates the dominant discourse among (restoration) ecologists and restoration practitioners, as stated:

> We should not lose sight that what drives us is a sense of ethics and empathy for the diversity of organisms and ecosystem functions—perhaps ecosystems are valuable for their services but let us not narrow or impoverish our world view to only such concerns, [71].

These authors explicitly attend to eco-centric motivations. Nonetheless, there is also inherent ambiguity in Bringing Nature Back. The question remains: bringing nature back to *what*? Environmental historians aptly probe this question and cite a tendency to define restoration goals in pre-settlement terms [27,56,94]. Moreover, biodiversity often sits as the primary goal in such restoration initiatives, with an underlying assumption of the nobility of these practices as demonstrated by [71].

4.4 Building with Nature (high intervention, anthropocentric)

The fourth quadrant, Building with Nature exemplifies high degrees of human intervention, but motivated by anthropocentric needs. Ecological and geo- engineering fit squarely within this discursive frame. Building with Nature discourses often include efforts to "build resilience" in coastal areas through "living shorelines" or supplement natural geochemical or filtering processes to provide regulating or supporting ecosystem services [93,95]. In contrast to Bringing Nature Back, these initiatives often hinge upon the needs of society or maintenance of particular economic interests.

In the Netherlands the Ecoshape consortium developed and introduced a form of eco-dynamic design, which employs and enhances nature and simultaneously contributes to socioeconomic and environmental goals. In its Sand Engine Delfland project large amounts of the nourished sand will spread along 21.5 million m^3 of the Dutch coast through natural coastal and tidal dynamics [31,96]. The project contributes to flood protection by compensating for sand loses from erosion processes along the coastline, it creates temporary recreational and natural areas, and it contributes to natural dune formation [96].

In the Building with Nature arrangement, the dominant discourse or narrative is that human interventions and nature are no longer separate, but they are regarded as reinforcing, intertwined entities [97]. Other authors [31,98] conclude that ambiguity is the most significant kind of uncertainty in the Sand Engine project, but that the ambiguities identified (regarding recreational safety, drinking water quality, and financial commitment) are closely related to the other uncertainties (incomplete knowledge and unpredictability). Furthermore, according to [31,98] ambiguity can emerge when the significance or consequences of either unpredictability or incomplete knowledge are framed by project actors in different ways.

Unpredictability is often at play in Building with Nature as the unforeseen effects arise because people do not fully understand the intricate connections of complex ecosystems. Notably, Bradshaw [36] argued that re-constructing ecosystems and restoration experiments enlighten the field of ecology. Such unpredictability also connects to ambiguity in that there will be different determinations of appropriate interventions where some question how much to “meddle” in the environment for the sake of human needs or otherwise. The case of proposed iron fertilization to combat ocean acidification elucidates the challenges that arise when moving from theoretical models [99] to (unauthorized) experimentation—and resultant controversy—at sea (see [100] for summary).

Both examples also demonstrate the business opportunities emerging from such paradigm with geoengineering firms looking to capitalize, which may signal the coming wave of ecosystem restoration investors and private companies. Whereas Bringing Nature Back centers on the arising challenges of providing public goods or common-pool resources—both of which have the difficulty to exclude individuals—Building with Nature will often center on protecting the assets of private users (e.g. replenishing the coastline) which may hold primary benefits for coastal landholders, or in other cases equate to private damages or losses [93]. Once again, the discussion of allocating resources for interventions and the question of who benefits will be central to governance. With high degrees of human intervention will likely come higher costs, making the distinctions among who wins and who loses central in marine ecosystem restoration governance.

5. Conclusion

Governing marine ecosystem restoration activities and the effective implementation of restoration projects depends on where these activities are developed, who is involved, who is the responsible authority, the way marine ecosystem restoration is defined, and which uncertainties confront scientists, governments, and actors carrying out maritime activities and how they address these uncertainties. The conceptual model presented in this paper provides a means for clarifying the underlying means and motivations of marine restoration. When combined with the three types of uncertainties, particular governance challenges emerge. In cases of lower degrees of intervention, where spatial management and regulation of activity are prevalent, participatory and deliberative processes will be central in determining the extent of the intervention and bolster process and outcome legitimacy [101]. In instances of ambiguity, participation may not suffice and thus discussions of the relevance of dispensation or compensation may improve outcomes when monitoring and enforcement are difficult.

With higher degrees of human intervention will likely come higher costs. Depending on the structures of the goods and services provided—or the discursive frame of the proposed restoration outcome—public or private financing mechanisms will likely need to be determined. Differences in values, or ambiguity as to the benefits (and costs) of marine ecosystem restoration will need to be addressed in decision making, with communication holding great importance. To assume that eco-centric values are universal would be misguided; thus, restoration advocates/ecologists will need to be mindful of what a particular discourse assumes. As stated at the outset, governance encompasses the rules of collective decision-making in settings where there is a plurality of actors or organizations and where no formal control system can dictate the terms of the relationship between these actors and organizations [23]. Participatory and deliberative processes, communication, and debates on differentiated costs and benefits will be central in marine ecosystem restoration governance.

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6. References

[1] SER, SER International primer on ecological restoration, Tuscon, AZ, 2004.

[2] A.F. Clewell, J.C. Aronson, Ecological Restoration: Principles, Values, and Structure of an Emerging Profession, 2nd ed., Island Press, Washington, DC, 2013.

[3] J.C. Aronson, J.N. Blignaut, T.B. Aronsson, Conceptual Frameworks and References for Landscape-scale Restoration: Reflecting Back and Looking Forward, Ann. Missouri Bot. Gard. 102 (2017) 188–200.

[4] L.A. Brudvig, R.S. Barak, J.T. Bauer, T.T. Caughlin, D.C. Laughlin, L. Larios, J.W. Matthews, K.L. Stuble, N.E. Turley, C.R. Zirbel, Interpreting variation to advance predictive restoration science, J. Appl. Ecol. 54 (2017) 1018–1027. doi:10.1111/1365-2664.12938.

[5] T. McDonald, G.D. Gann, J. Jonson, K.W. Dixon, International Standards for the Practice of Ecological Restoration -- Including Principles and Key Concepts, Washington, DC, 2016. http://c.ymcdn.com/sites/www.ser.org/resource/resmgr/docs/SER_International_Standards.pdf (accessed June 13, 2017).

[6] T. McDonald, J. Jonson, K.W. Dixon, National standards for the practice of ecological restoration in Australia, Restor. Ecol. 24 (2016) S4–S32. doi:10.1111/(ISSN)1526-100X.

[7] R.H. Bark, L.J.M. Peeters, R.E. Lester, C.A. Pollino, N.D. Crossman, J.M. Kandulu, Understanding the sources of uncertainty to reduce the risks of undesirable outcomes in large-scale freshwater ecosystem restoration projects: An example from the Murray–Darling Basin, Australia, Environ. Sci. Policy. 33 (2013) 97–108. doi:10.1016/J.ENVSCI.2013.04.010.

[8] J.M.R. Benayas, A.C. Newton, A. Diaz, J.M. Bullock, Enhancement of Biodiversity and Ecosystem Services by Ecological Restoration: A Meta-Analysis, Science (80-.). 325 (2009) 1121–1124. doi:10.1126/science.1172460.

[9] J.M. Wheaton, S.E. Darby, D.A. Sear, The scope of uncertainties in river restoration, in: S.E. Darby, D.A. Sear (Eds.), River Restor. Manag. Uncertain. Restoring Phys. Habitat, John Wiley & Sons, Inc., 2008: pp. 21–42.

[10] S. Darby, D.A. Sear, River Restoration: Managing uncertainty in restoring physical habitat, John Wiley & Sons, Inc., 2008.

[11] A.P. Dobson, A.D. Bradshaw, A.J.M. Baker, Hopes for the Future: Restoration Ecology and Conservation Biology, Science (80-.). 277 (1997) 515–522. doi:10.1126/science.277.5325.515.

[12] M.P. Weinstein, Ecological restoration and estuarine management: placing people in the coastal landscape, J. Appl. Ecol. 45 (2008) 296–304. doi:10.1111/j.1365-2664.2007.01355.x.

[13] H.P. Jones, P.C. Jones, E.B. Barbier, R.C. Blackburn, J.M. Rey Benayas, K.D. Holl, M. McCrackin, P. Meli, D. Montoya, D.M. Mateos, Restoration and repair of Earth's damaged ecosystems., Proceedings. Biol. Sci. 285 (2018) 20172577. doi:10.1098/rspb.2017.2577.

[14] R.L. France, From land to sea: Governance-management lessons from terrestrial restoration research useful for developing and expanding social-ecological marine restoration, Ocean Coast. Manag. 133 (2016) 64–71. doi:10.1016/j.ocecoaman.2016.08.022.

[15] A. Abelson, B.S. Halpern, D.C. Reed, R.J. Orth, G.A. Kendrick, M.W. Beck, J. Belmaker, G. Krause, G.J. Edgar, L. Airoldi, E. Brokovich, R. France, N. Shashar, A. de Blaeij, N. Stambler, P. Salameh, M. Shechter, P.A. Nelson, Upgrading Marine

Ecosystem Restoration Using Ecological–Social Concepts, Bioscience. 66 (2016) 156–163. doi:10.1093/biosci/biv171.
[16] C.L. Van Dover, J. Aronson, L. Pendleton, S. Smith, S. Arnaud-Haond, D. Moreno-Mateos, E. Barbier, D. Billett, K. Bowers, R. Danovaro, A. Edwards, S. Kellert, T. Morato, E. Pollard, A. Rogers, R. Warner, Ecological restoration in the deep sea: Desiderata, Mar. Policy. 44 (2014) 98–106. doi:10.1016/j.marpol.2013.07.006.
[17] M. Elliott, D. Burdon, K.L. Hemingway, S.E. Apitz, Estuarine, coastal and marine ecosystem restoration: Confusing management and science? A revision of concepts, Estuar. Coast. Shelf Sci. 74 (2007) 349–366. doi:10.1016/j.ecss.2007.05.034.
[18] J. Geist, S.J. Hawkins, Habitat recovery and restoration in aquatic ecosystems: current progress and future challenges, Aquat. Conserv. Mar. Freshw. Ecosyst. 26 (2016) 942–962. doi:10.1002/aqc.2702.
[19] N. Ockendon, D.H.L. Thomas, J. Cortina, W.M. Adams, T. Aykroyd, B. Barov, L. Boitani, A. Bonn, C. Branquinho, M. Brombacher, C. Burrell, S. Carver, H.Q.P. Crick, B. Duguy, S. Everett, B. Fokkens, R.J. Fuller, D.W. Gibbons, R. Gokhelashvili, C. Griffin, D.J. Halley, P. Hotham, F.M.R. Hughes, A.A. Karamanlidis, C.J. McOwen, L. Miles, R. Mitchell, M.R.W. Rands, J. Roberts, C.J. Sandom, J.W. Spencer, E. ten Broeke, E.R. Tew, C.D. Thomas, A. Timoshyna, R.K.F. Unsworth, S. Warrington, W.J. Sutherland, One hundred priority questions for landscape restoration in Europe, Biol. Conserv. 221 (2018) 198–208. doi:10.1016/J.BIOCON.2018.03.002.
[20] P.S. Maxwell, J.S. Eklöf, M.M. van Katwijk, K.R. O'Brien, M. de la Torre-Castro, C. Boström, T.J. Bouma, D. Krause-Jensen, R.K.F. Unsworth, B.I. van Tussenbroek, T. van der Heide, The fundamental role of ecological feedback mechanisms for the adaptive management of seagrass ecosystems - a review, Biol. Rev. 92 (2017) 1521–1538. doi:10.1111/brv.12294.
[21] M.J.H. van Oppen, R.D. Gates, L.L. Blackall, N. Cantin, L.J. Chakravarti, W.Y. Chan, C. Cormick, A. Crean, K. Damjanovic, H. Epstein, P.L. Harrison, T.A. Jones, M. Miller, R.J. Pears, L.M. Peplow, D.A. Raftos, B. Schaffelke, K. Stewart, G. Torda, D. Wachenfeld, A.R. Weeks, H.M. Putnam, Shifting paradigms in restoration of the world's coral reefs, Glob. Chang. Biol. 23 (2017) 3437–3448. doi:10.1111/gcb.13647.
[22] I. Montero-Serra, J. Garrabou, D.F. Doak, L. Figuerola, B. Hereu, J.B. Ledoux, C. Linares, Accounting for Life-History Strategies and Timescales in Marine Restoration, Conserv. Lett. 11 (2018) 1–9. doi:10.1111/conl.12341.
[23] V. Chhotray, G. Stoker, Governance Theory and Practice. A cross disciplinary approach, Palgrave/Macmillan, New York, 2009.
[24] D. Liefferink, The Dynamics of Policy Arrangements: Turning around the Tetrahedron, in: B. Arts, P. Leroy (Eds.), Institutional Dyn. Environ. Gov., Springer, Dordrecht, 2006: pp. 45–68.
[25] J.R. Floor, C.S.A. (Kris) van Koppen, J.P.M. van Tatenhove, Science, uncertainty and changing storylines in nature restoration: The case of seagrass restoration in the Dutch Wadden Sea, Ocean Coast. Manag. 157 (2018) 227–236. doi:10.1016/J.OCECOAMAN.2018.02.016.
[26] E.C. Carballo-Cárdenas, Controversies and consensus on the lionfish invasion in the Western Atlantic Ocean Controversies and consensus on the lionfish invasion in the Western Atlantic, Ecol. Soc. 20 (2015) 24. doi:10.5751/ES-07726-200324.
[27] D. Jørgensen, An oasis in a watery desert? Discourses on an industrial ecosystem in the Gulf of Mexico Rigs-to-Reefs program, Hist. Technol. 25 (2009) 343–364. doi:10.1080/07341510903313030.
[28] R.B. Chaves, G. Durigan, P.H.S. Brancalion, J. Aronson, On the need of legal frameworks for assessing restoration projects success: New perspectives from São

Paulo state (Brazil), Restor. Ecol. 23 (2015) 754–759. doi:10.1111/rec.12267.
[29] B. Martín-López, C. Montes, L. Ramírez, J. Benayas, What drives policy decision-making related to species conservation?, Biol. Conserv. 142 (2009) 1370–1380. doi:10.1016/J.BIOCON.2009.01.030.
[30] M. Brugnach, A. Dewulf, C. Pahl-Wostl, T. Taillieu, Toward a relational concept of uncertainty: About knowing too little, knowing too differently, and accepting not to know, Ecol. Soc. 13 (2008). doi:10.5751/ES-02616-130230.
[31] R.E. van den Hoek, No Building on Uncertainty – How to Cope with Incomplete Knowledge, Unpredictability and Ambiguity in Ecological Engineering Projects, University or Twente, 2014. doi:10.3990/1.9789036535847.
[32] M. Gross, Ignorance and surprise: Science, society, and ecological design, MIT Press, Cambrige, MA, 2010.
[33] A.E. Buijs, Public support for river restoration. A mixed-method study into local residents' support for and framing of river management and ecological restoration in the Dutch floodplains, J. Environ. Manage. 90 (2009) 2680–2689. doi:10.1016/J.JENVMAN.2009.02.006.
[34] L.L. Jackson, N. Lopoukhine, D. Hillyard, Ecological Restoration: A Definition and Comments, Restor. Ecol. 3 (1995) 71–75. doi:10.1111/j.1526-100X.1995.tb00079.x.
[35] D. Jørgensen, Rethinking rewilding, Geoforum. 65 (2015) 482–488. doi:10.1016/J.GEOFORUM.2014.11.016.
[36] A.D. Bradshaw, Introduction and philosophy, in: M.R. Perrow, A.J. Davy (Eds.), Handb. Ecol. Restor. Princ. Restor., Cambridge University Press, Cambridge, UK, 2002: pp. 3–9.
[37] E. Bayraktarov, M.I. Saunders, S. Abdullah, M. Mills, J. Beher, H.P. Possingham, P.J. Mumby, C.E. Lovelock, The cost and feasibility of marine coastal restoration, Ecol. Appl. 26 (2016) 1055–1074. doi:10.1890/15-1077.
[38] E. Bayraktarov, M.I. Saunders, P.J. Mumby, H.P. Possingham, S. Abdullah, C.E. Lovelock, Response to "Rebutting the inclined analyses on the cost-effectiveness and feasibility of coral reef restoration," Ecol. Appl. 27 (2017) 1974–1980. doi:10.1002/eap.1583.
[39] K.D. Kirsch, K.A. Barry, M.S. Fonseca, P.E. Whitfield, S.R. Meehan, W.J. Kenworthy, B.E. Julius, The Mini-312 Program—An Expedited Damage Assessment and Restoration Process for Seagrasses in the Florida Keys National Marine Sanctuary, J. Coast. Res. (n.d.) 109–119. doi:10.2307/25736619.
[40] M. Gleason, S. McCreary, M. Miller-Henson, J. Ugoretz, E. Fox, M. Merrifield, W. McClintock, P. Serpa, K. Hoffman, Science-based and stakeholder-driven marine protected area network planning: A successful case study from north central California, Ocean Coast. Manag. 53 (2010) 52–68. doi:10.1016/J.OCECOAMAN.2009.12.001.
[41] F. Gianni, F. Bartolini, L. Airoldi, E. Ballesteros, P. Francour, P. Guidetti, A. Meinesz, T. Thibaut, L. Mangialajo, Conservation and restoration of marine forests in the Mediterranean Sea and the potential role of Marine Protected Areas, Adv. Oceanogr. Limnol. 4 (2013) 83. doi:10.4081/aiol.2013.5338.
[42] R.L. France, Restorative redevelopment of devastated ecocultural landscapes, CRC Press, Boca Raton, FL, 2011.
[43] J. Aronson, A. Clewell, D. Moreno-Mateos, Ecological restoration and ecological engineering: Complementary or indivisible?, Ecol. Eng. 91 (2016) 392–395. doi:10.1016/j.ecoleng.2016.02.043.
[44] T. Terawaki, K. Yoshikawa, G. Yoshida, M. Uchimura, K. Iseki, Ecology and restoration techniques for Sargassum beds in the Seto Inland Sea, Japan, Mar. Pollut.

Bull. 47 (2003) 198–201. doi:10.1016/S0025-326X(03)00054-7.
[45] M.M. van Katwijk, A.R. Bos, V.N. de Jonge, L.S.A.M. Hanssen, D.C.R. Hermus, D.J. de Jong, Guidelines for seagrass restoration: Importance of habitat selection and donor population, spreading of risks, and ecosystem engineering effects, Mar. Pollut. Bull. 58 (2009) 179–188. doi:10.1016/J.MARPOLBUL.2008.09.028.
[46] S.R. Bekkby T, Gerovasileiou V, Papadopoulou K-N, Sevastou K, Dailianis T, Fiorentino D, McOwen C, Smith CJ, Amaro T, Bakran-Petricioli T, Bilan M, Boström C, Carreiro-Silva M, Carugati L, Cebrian E, Cerrano C, Christie H, Danovaro R, Eronat EGT, Fraschetti S, State of the knowledge on European marine habitat mapping and degraded habitats. Deliverable 1.1., 2017.
[47] J. Blignaut, J. Aronson, R. de Groot, Restoration of natural capital: A key strategy on the path to sustainability, Ecol. Eng. 65 (2014) 54–61. doi:10.1016/j.ecoleng.2013.09.003.
[48] I. Montero-Serra, C. Linares, M. García, F. Pancaldi, M. Frleta-Valić, J.-B. Ledoux, F. Zuberer, D. Merad, P. Drap, J. Garrabou, Harvesting Effects, Recovery Mechanisms, and Management Strategies for a Long-Lived and Structural Precious Coral, PLoS One. 10 (2015) e0117250. doi:10.1371/journal.pone.0117250.
[49] L.B. Firth, K.A. Browne, A.M. Knights, S.J. Hawkins, R. Nash, Eco-engineered rock pools: a concrete solution to biodiversity loss and urban sprawl in the marine environment, Environ. Res. Lett. 11 (2016) 094015. doi:10.1088/1748-9326/11/9/094015.
[50] J.B. Callicott, L.B. Crowder, K. Mumford, Current normative concepts in conservation, Conserv. Biol. 13 (1999) 22–35. doi:10.1046/j.1523-1739.1999.97333.x.
[51] S.L. Yaffee, Three Faces of Ecosystem Management, Conserv. Biol. 13 (1999) 713–725.
[52] M. Boylan, ed., Anthropocentric versus Biocentric Justifications, in: Environ. Ethics, John Wiley & Sons, Inc., 2013: pp. 115–190.
[53] K. V. Kortenkamp, C.F. Moore, Ecocentrism and Anthropocentrism: Moral Reasoning about Ecological Commons Dilemmas, J. Environ. Psychol. 21 (2001) 261–272. Doi:10.1006/Jevp.2001.0205.
[54] H.I. Rolston, Environmental Ethics: Values in and Duties to the Natural World, in: M. Boylan (Ed.), Environ. Ethics, John Wiley & Sons, Inc., Somerset, 2013: pp. 135–151.
[55] V. Hagger, J. Dwyer, K. Wilson, What motivates ecological restoration?, Restor. Ecol. 25 (2017) 832–843. doi:10.1111/rec.12503.
[56] M. Hall, Earth Repair: A transatlantic history of environmental restoration, University of Virginia Press, Charlottesville, VA, 2005.
[57] A.F. Clewell, J. Aronson, Motivations for the restoration of ecosystems, Conserv. Biol. 20 (2006) 420–428. doi:10.1111/j.1523-1739.2006.00340.x.
[58] M.H.M. Menz, K.W. Dixon, R.J. Hobbs, Hurdles and Opportunities for Landscape-Scale Restoration, Science (80-.). 339 (2013). http://science.sciencemag.org/content/339/6119/526/tab-pdf (accessed July 4, 2017).
[59] T.F. Stevens, E.V. Sheehan, S.C. Gall, S.C. Fowell, M.J. Attrill, Monitoring benthic biodiversity restoration in Lyme Bay marine protected area: Design, sampling and analysis, Mar. Policy. 45 (2014) 310–317. doi:10.1016/j.marpol.2013.09.006.
[60] J.M. Bullock, J. Aronson, A.C. Newton, R.F. Pywell, J.M. Rey-Benayas, Restoration of ecosystem services and biodiversity: Conflicts and opportunities, Trends Ecol. Evol. 26 (2011) 541–549. doi:10.1016/j.tree.2011.06.011.
[61] B. Worm, E.B. Barbier, N. Beaumont, J.E. Duffy, C. Folke, B.S. Halpern, J.B.C. Jackson, H.K. Lotze, F. Micheli, S.R. Palumbi, E. Sala, K.A. Selkoe, J.J. Stachowicz, R. Watson, Impacts of Biodiversity Loss on Ocean Ecosystem Services, Science (80-.

). 314 (2006). http://science.sciencemag.org/content/314/5800/787/tab-pdf.
[62] J. Keulartz, C. van der Weele, Framing and Reframing in Invasion Biology, Configurations. 16 (2008) 93–115. http://search.proquest.com/docview/217781970/fulltext/B6905963EB31450EPQ/6?accountid=8144 (accessed June 29, 2017).
[63] J.S. Dryzek, The Politics of the Earth: Envioronmental Discourses, Oxford University Press, New York, 1997.
[64] F. Berkes, Understanding uncertainty and reducing vulnerability: lessons from resilience thinking, Nat. Hazards. 41 (2007) 283–295.
[65] C. Folke, Resilience: The emergence of a perspective for social–ecological systems analyses, Glob. Environ. Chang. 16 (2006) 253–267. doi:10.1016/J.GLOENVCHA.2006.04.002.
[66] L. Failing, R. Gregory, P. Higgins, Science, Uncertainty, and Values in Ecological Restoration: A Case Study in Structured Decision-Making and Adaptive Management, Restor. Ecol. 21 (2013) 422–430. doi:10.1111/j.1526-100X.2012.00919.x.
[67] F. Sinniger, J. Pawlowski, S. Harii, A.J. Gooday, H. Yamamoto, P. Chevaldonné, T. Cedhagen, G. Carvalho, S. Creer, Worldwide Analysis of Sedimentary DNA Reveals Major Gaps in Taxonomic Knowledge of Deep-Sea Benthos, Front. Mar. Sci. 3 (2016) 92. doi:10.3389/fmars.2016.00092.
[68] R. Danovaro, J.B. Company, C. Corinaldesi, G. D'Onghia, B. Galil, C. Gambi, A.J. Gooday, N. Lampadariou, G.M. Luna, C. Morigi, K. Olu, P. Polymenakou, E. Ramirez-Llodra, A. Sabbatini, F. Sardà, M. Sibuet, A. Tselepides, Deep-Sea Biodiversity in the Mediterranean Sea: The Known, the Unknown, and the Unknowable, PLoS One. 5 (2010) e11832. doi:10.1371/journal.pone.0011832.
[69] W.E. Walker, P. Harremoës, J. Rotmans, J.P. van der Sluijs, M.B.A. van Asselt, P. Janssen, M.P. Krayer von Krauss, Defining Uncertainty: A Conceptual Basis for Uncertainty Management in Model-Based Decision Support, Integr. Assess. 4 (2003) 5–17. doi:10.1076/iaij.4.1.5.16466.
[70] L.H. Pendleton, O. Hoegh-Guldberg, C. Langdon, A. Comte, Multiple Stressors and Ecological Complexity Require a New Approach to Coral Reef Research, Front. Mar. Sci. 3 (2016) 36. doi:10.3389/fmars.2016.00036.
[71] S.D. Murphy, S.K. Allison, Introduction: what next for restoration ecology?, in: S.K. Allison, S.D. Murphy (Eds.), Routledge Handb. Ecol. Environ. Restor., Routledge, London, 2017: pp. 1–4.
[72] J.R. Floor, C.S.A. (Kris) van Koppen, J.P.M. van Tatenhove, Uncertainties in the assessment of "" significant effect "" on the Dutch Natura 2000 Wadden Sea site – The mussel seed fishery and powerboat race controversies, Environ. Sci. Policy. 55 (2016) 380–392. doi:10.1016/j.envsci.2015.03.008.
[73] A. Dewulf, M. Craps, R. Bouwen, T. Taillieu, C. Pahl-Wostl, Integrated management of natural resources: dealing with ambiguous issues, multiple actors and diverging frames, Water Sci. Technol. 52 (2005).
[74] B.M. McCann, M. Henrion, B. Bernstein, R.I. Haddad, Integrating Decision Support Models with Market and Non-Market Value Attributes for Platform Decommissioning: An Effective Approach for Resolving the Challenges Inherent at the Nexus of Science and Policy, in: Offshore Technol. Conf., 2017.
[75] A.M. Fowler, P.I. Macreadie, D.J. Booth, Should we "reef" obsolete oil platforms?, Proc. Natl. Acad. Sci. U. S. A. 112 (2015) E102. doi:10.1073/pnas.1422274112.
[76] D. Jørgensen, Environmentalists on Both Sides: Enactments in the California Rigs-to-Reefs Debate, in: D. Jørgensen, F.A. Jørgensen, S.B. Pritchard (Eds.), New Natures Join. Environ. Hist. with Sci. Technol. Stud., University of Pittsburgh Press,

Pittsburgh, PA, 2013: pp. 51–68.
[77] M.P. Perring, R.J. Standish, J.N. Price, M.D. Craig, T.E. Erickson, K.X. Ruthrof, A.S. Whiteley, L.E. Valentine, R.J. Hobbs, Advances in restoration ecology: rising to the challenges of the coming decades, Ecosphere. 6 (2015) art131. doi:10.1890/ES15-00121.1.
[78] L. Wortley, J.-M. Hero, M. Howes, Evaluating Ecological Restoration Success: A Review of the Literature, Restor. Ecol. 21 (2013) 537–543. doi:10.1111/rec.12028.
[79] J.B. Zedler, Success: An Unclear, Subjective Descriptor of Restoration Outcomes, Ecol. Restor. 25 (2007) 162–168. doi:10.3368/er.25.3.162.
[80] B. Rinkevich, Rebuilding coral reefs: does active reef restoration lead to sustainable reefs?, Curr. Opin. Environ. Sustain. 7 (2014) 28–36. doi:10.1016/J.COSUST.2013.11.018.
[81] M. Velez, S. Adlerstein, J. Wondolleck, Fishers' perceptions, facilitating factors and challenges of community-based no-take zones in the Sian Ka'an Biosphere Reserve, Quintana Roo, Mexico, Mar. Policy. 45 (2014) 171–181. doi:10.1016/J.MARPOL.2013.12.003.
[82] V.M. Ucán Chan, Fisher's perspective on the network of fish refuges in Quintana Roo, Mexico, in: P. McConney, R. Medeiros, M. Pena (Eds.), Enhancing Steward. Small-Scale Fish. Pract. Perspect., Technical, 2014: pp. 145–146.
[83] S. Buglass, H. Reyes, J. Ramirez-González, T.D. Eddy, P. Salinas-de-León, J.M. Jarrin, Evaluating the effectiveness of coastal no-take zones of the Galapagos Marine Reserve for the red spiny lobster, Panulirus penicillatus, Mar. Policy. 88 (2018) 204–212. doi:10.1016/J.MARPOL.2017.11.028.
[84] M.J. Rees, N.A. Knott, J. Neilson, M. Linklater, I. Osterloh, A. Jordan, A.R. Davis, Accounting for habitat structural complexity improves the assessment of performance in no-take marine reserves, Biol. Conserv. 224 (2018) 100–110. doi:10.1016/J.BIOCON.2018.04.040.
[85] B.S. Halpern, K.L. McLeod, A.A. Rosenberg, L.B. Crowder, Managing for cumulative impacts in ecosystem-based management through ocean zoning, Ocean Coast. Manag. 51 (2008) 203–211. doi:10.1016/J.OCECOAMAN.2007.08.002.
[86] A. Moreno, L. Bourillón, E. Flores, S. Fulton, Fostering fisheries management efficiency through collaboration networks the case of the Kanan Kay Alliance in the Mexican Caribbean, Bull. Mar. Sci. 93 (2017) 233–247.
[87] K.I. Miller, G.R. Russ, Studies of no-take marine reserves: Methods for differentiating reserve and habitat effects, Ocean Coast. Manag. 96 (2014) 51–60. doi:10.1016/J.OCECOAMAN.2014.05.003.
[88] W.D. Heyman, M. Olivares, S. Fulton, L. Bourillón, J. Caamal, C. Ribot, S. Kobara, Prediction and verification of reef fish spawning aggregation sites in Quintana Roo Mexico, in: P. McConney, R. Medeiros, M. Pena (Eds.), Enhancing Steward. Small-Scale Fish. Pract. Perspect., Technical, CERMES-UWI, TBTI, 2014: pp. 73–81.
[89] C.A. Downs, E. Kramarsky-Winter, R. Segal, J. Fauth, S. Knutson, O. Bronstein, F.R. Ciner, R. Jeger, Y. Lichtenfeld, C.M. Woodley, P. Pennington, K. Cadenas, A. Kushmaro, Y. Loya, Toxicopathological Effects of the Sunscreen UV Filter, Oxybenzone (Benzophenone-3), on Coral Planulae and Cultured Primary Cells and Its Environmental Contamination in Hawaii and the U.S. Virgin Islands, Arch. Environ. Contam. Toxicol. 70 (2016) 265–288. doi:10.1007/s00244-015-0227-7.
[90] A. Fulton, Many Common Sunscreens May Harm Coral. Here's What to use Instead, Natl. Public Radio. (2018). https://www.npr.org/sections/health-shots/2018/07/02/624379378/many-common-sunscreens-may-harm-coral-heres-what-to-use-instead (accessed July 10, 2018).

[91] L. Bever, Hawaii just banned your favorite sunscreen to protect its coral reefs, Washington Post. (2018). https://www.washingtonpost.com/news/energy-environment/wp/2018/07/02/hawaii-is-about-to-ban-your-favorite-sunscreen-to-protect-its-coral-reefs/?utm_term=.4e4585f78a8d.
[92] B. Mansfield, J. Haas, Scale framing of scientific uncertainty in controversy over the Endangered Steller sea lion, Env. Polit. 15 (2006) 78–94. doi:10.1080/09644010500418795.
[93] D.M. Burdick, S.C. Adamowicz, Salt Marshes, in: S.K. Allison, S.D. Murphy (Eds.), Routledge Handb. Ecol. Environ. Restor., Routledge, London, 2017: pp. 261–273.
[94] W. Cronon, The Trouble with Wilderness or, Getting Back to the Wrong Nature, in: Uncommon Gr. Towar. Reinventing Nat., 1995: pp. 7–28.
[95] L.D. Coen, A.T. Humphries, Oyster-Generated Marine Habitats, in: S.K. Allison, S.D. Murphy (Eds.), Routledge Handb. Ecol. Environ. Restor., Routledge, London, 2017: pp. 274–293.
[96] S.K.H. Janssen, J.P.M. van Tatenhove, H.S. Otter, A.P.J. Mol, Greening Flood Protection—An Interactive Knowledge Arrangement Perspective, J. Environ. Policy Plan. 17 (2015) 309–331. doi:10.1080/1523908X.2014.947921.
[97] D. Korbee, Greening the Construction of Marine Infrastructure: a governance approach, Wageningen University, 2015.
[98] R.E. van den Hoek, M. Brugnach, A.Y. Hoekstra, Shifting to ecological engineering in flood management: Introducing new uncertainties in the development of a Building with Nature pilot project, Environ. Sci. Policy. 22 (2012) 85–99. doi:10.1016/J.ENVSCI.2012.05.003.
[99] L. Cao, K. Caldeira, Can ocean iron fertilization mitigate ocean acidification?, Clim. Change. 99 (2010) 303–311. doi:10.1007/s10584-010-9799-4.
[100] R. Waller, Iron Fertilization: Savior to Climate Change or Ocean Dumping? – National Geographic Blog, Chang. Planet Natl. Geogr. Blog. (2012). https://blog.nationalgeographic.org/2012/10/18/iron-fertilization-savior-to-climate-change-or-ocean-dumping/ (accessed July 9, 2018).
[101] S. Jentoft, Fisheries co-management: Delegating government responsibility to fishermen's organizations, Mar. Policy. 13 (1989) 137–154. doi:10.1016/0308-597X(89)90004-3.