

Article

A Global Synthesis Reveals Gaps in Coastal Habitat Restoration Research

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Abstract: Coastal ecosystems have drastically declined in coverage and condition across the globe. To combat these losses, marine conservation has recently employed habitat restoration as a strategy to enhance depleted coastal ecosystems. For restoration to be a successful enterprise, however, it is necessary to identify and address potential knowledge gaps and review whether the field has tracked scientific advances regarding best practices. This enables managers, researchers, and practitioners alike to more readily establish restoration priorities and goals. We synthesized the peer-reviewed, published literature on habitat restoration research in salt marshes, oyster reefs, and seagrasses to address three questions related to restoration efforts: (i) How frequent is cross-sector authorship in coastal restoration research? (ii) What is the geographic distribution of coastal restoration research? and (iii) Are abiotic and biotic factors equally emphasized in the literature, and how does this vary with time? Our vote-count survey indicated that one-third of the journal-published studies listed authors from at least two sectors, and 6% listed authors from all three sectors. Across all habitat types, there was a dearth of studies from Africa, Asia, and South America. Finally, despite many experimental studies demonstrating that species interactions can greatly affect the recovery and persistence of coastal foundation species, only one-fourth of the studies we examined discussed their effects on restoration. Combined, our results reveal gaps and discrepancies in restoration research that should be addressed in order to further propel coastal restoration science.

Keywords: collaboration; conservation; consumers; facilitation; habitat restoration; oyster reef; positive interactions; salt marsh; seagrass

1. Introduction

Coastal ecosystems and the valuable services they provide have been lost and degraded as a result of human-induced disturbances, land-use change, alteration of food webs, and climate-related stressors, among others [1,2]. Coastal habitat change and loss over the 20th century alone has been extensive, with hundreds of thousands of acres lost across the globe [1,3–5]. The magnitude of coastal and estuarine degradation has generated a pressing need for conservation strategies that actively combat decline. Early conservation efforts primarily focused on reducing human impacts and physical

stressors (as reviewed in [6,7]), but with increasing rates of habitat degradation, conservation alone may not be sufficient to protect and reestablish coastal ecosystems.

Habitat restoration has recently been promoted, along with other conservation strategies, such as spatial planning and reducing direct destruction of habitat, as a tool to combat habitat and biodiversity loss [6,8,9]. For restoration to be effective and employed as a primary method of coastal conservation, we must improve its efficiency [10]. One crucial step will be to identify when and where conservation paradigms have already been applied in habitat restoration and gauge their success. Knowledge and effort gaps need to be identified promptly to better align current ecological theory and research efforts with restoration priorities and best practices.

Relatively long-established coastal conservation strategies, such as protected areas and endangered species management, can be stymied by limited communication across institutions and interested parties (i.e., non-governmental organizations, governmental organizations, and academia [11]), mismatches between conservation priorities and regions where efforts and resources have been focused [12,13], lack of adaptive management, and incorporation of ecological advances [14]. In conservation science and practice, it is broadly recognized that collaboration across sectors can facilitate the transfer of both knowledge and resources in addition to promoting complex problem-solving in policy and management [15,16]. Research and information must be effectively communicated and congruent with the priorities of decision makers [17], and cross-sector collaboration can help to facilitate the assimilation of knowledge. Traditional conservation efforts have unfortunately been hindered by a general paucity of strategic and lasting cross-sector partnerships [18–22]. This lack of connection can impede the development and implementation of standardized methods for conducting and monitoring restoration making broad-scale comparison of restoration success difficult [23,24]. Moreover, slow-to-publish or pay-wall journals can inhibit small non-governmental organizations from accessing recently developed restoration research [25], and language barriers may further widen the research-implementation gap [26]. Emphasis has recently been placed on addressing these conservation challenges and enhancing dialogue between interested parties [27,28], but the extent to which cross-sector collaborations occur in peer-reviewed and published restoration research is unknown.

For effective conservation, it is also essential to identify and fill gaps in knowledge that are relevant to saving threatened species and habitats [26]. One simple approach to address this need is to map the distribution of conservation efforts and determine regions where additional action may be needed in response to biological threat or lack of research emphasis. For example, conservation societies have called on researchers to conduct studies where animals and habitats are most endangered [29,30]. Despite this recommendation, conservation science has historically done the opposite and focused efforts in areas that do not geographically align with areas that have the greatest number of threatened species [31]. Mismatches between the biological need for protection and conservation efforts have been well-documented in coral reefs [12,32], avian conservation [33], amphibians [31] and terrestrial protected lands in the United States [13], among others [31]. In addition, conservation is especially emphasized and practiced in the western hemisphere despite the global distribution of ecosystems in need of protection [31]. Determining if similar geographic gaps and/or habitat mismatches exist in coastal restoration will be crucial for informing and adapting future restoration priorities and efforts.

Another manner in which conservation science may move forward is by actively testing and incorporating new ecological theories and understanding. Coastal ecosystems were historically thought to be controlled primarily by abiotic and physical factors [34,35]). Thus, conservation approaches were similarly focused on the preservation and restoration of pristine physical conditions [36]. Empirical research in coastal ecosystems over recent decades, however, has shown that biotic interactions such as predation, competition, and, more recently, positive species interactions are also important controls, especially under high physical stress scenarios [37–40]. In particular, recent small-scale, experimental tests in marsh restoration have demonstrated that incorporating indirect positive interactions among transplants and between foundation species can increase

ecosystem recovery and resilience [41,42]. These results indicate that expanding restoration designs to also consider trophic controls and indirect species interactions in addition to the physical template may enhance restoration efficacy and yield [41,43]. Despite this, the extent to which direct and indirect interactions are put forth as considerations in the restoration literature has not been assessed.

We synthesized the peer-reviewed literature on seagrass, salt marsh, and oyster reef restoration in order to better identify knowledge gaps related to collaboration, distribution, and methodology. In particular, we examined author affiliations to better describe the amount of interaction that occurs between conservation research and practice. To determine if current restoration research occurred in at-risk areas, we examined the geographic distribution of study sites. Finally, to determine whether factors considered in restoration tracked with advances in ecological theory, we compared the incorporation of biotic and abiotic variables over time.

2. Materials and Methods

We conducted an extensive literature search and synthesis of the Web of Science™ (all databases and all years) using the query “Topic = (habitat restoration) AND Topic = (oyster* OR salt marsh*)”. This search resulted in 952 publications as of October 2016. We later expanded our study to include seagrass restoration studies and conducted a second literature search in March 2017 using the query “Topic = (habitat restoration) AND Topic = (seagrass*)”, which resulted in 251 publications, excluding papers that were discovered in the first search (24 studies). We focused our search on habitat restoration as opposed to ecosystem restoration because we were primarily interested in research that pertained to the restoration of habitat-forming foundation species [44]. Moreover, restoration of foundation species can be an avenue by which to restore ecosystems and ecosystem functions. This specific choice of search terms, however, may have led to the underrepresentation of multi-habitat and ecosystem enhancement restoration studies in our results.

Given the large number of studies on the topic, we randomly selected half of all articles to be scored [45]. Articles were randomly assigned to nine individuals for evaluation to minimize potential reader biases. To be included in our analysis the study (i) must have been published in a peer-reviewed, English-language journal; and (ii) must have pertained to restored salt marshes, oyster reefs, or seagrasses, or made explicit recommendations for the restoration of those habitats. Our analysis included only the published scientific literature because it is readily accessible and serves as a comprehensive documentation of substantiated restoration research, advancements, and priorities. From each study, we extracted author affiliations, funding sources and acknowledged organizations, journal of publication, article accessibility (open access or paywall), publication year, study location, habitat type, restoration/management phase represented (site selection, implementation, or monitoring), methodology (experimental, model, observational, or review), measured response variables (focal foundation species growth, abiotic factors, or biotic factors), and factors emphasized, tested, or employed. We utilized a vote-counting approach to provide an assessment of the state and development of the published restoration literature, the monitoring protocols and study methodologies employed, and the variables emphasized or considered in analyses.

2.1. Cross-Sector Collaborations

To determine the extent to which cross-sector collaborations occur in restoration research, we categorized author affiliations as one of three sectors: Academia, Non-Governmental Organizations (NGOs), and Governmental Organizations (GOs). Additionally, we extracted the affiliation category of any funders, organizations, and individuals mentioned in the acknowledgements section of each paper. Individuals whose affiliation was not stated in the acknowledgements were not included. Since we cannot accurately ascertain the extent of involvement for those listed in the acknowledgements, we focused primarily on authorship and funding as an indication of collaboration.

2.2. Restoration Geography

To determine the geographic distribution of published restoration studies, we extracted information regarding study locations by continent (or global study), country, and region if conducted in the United States. It is important to note that although our dataset includes some of the most recognized and prominent published papers in restoration research, it likely does not include all influential restoration literature due to the nature of randomly selecting half of the studies. Furthermore, because we also excluded non-English-language studies, studies conducted by and in non-English-speaking entities and countries are likely to be under-represented in our dataset. In addition, our vote-count examined only where published restoration research occurred, which may differ from where restoration efforts as a whole may be conducted.

2.3. Factors Considered in Restoration Methodologies

In order to address our third objective, we first defined 35 potential biotic and abiotic restoration factors *a priori* based upon preliminary literature reviews and recorded if a factor was stated as a consideration for restoration (Supplementary S1: Table S1). A factor was marked as an important consideration if the article stated the factor must be addressed for restoration of salt marshes, seagrasses, or oyster reefs to succeed, or that manipulating the factor could lead to positive or negative restoration outcomes. We further distinguished if a study explicitly tested a factor's effect on restoration and noted whether the factor was found to be significant or not.

3. Results

In total, 301 papers met the criteria for inclusion in the study—we assessed 177 salt marsh, 75 oyster reef, and 82 seagrass publications (Figure 1a, Supplementary S2). Of these, 8% of papers discussed two habitats, and 2% of papers discussed all three habitats. Additionally, the number of published papers on coastal restoration increased dramatically over the last 15 years (Figure 1b). The majority of restoration studies were observational in approach (55%, Figure 1c) and roughly 1/3 conducted experimental restoration. Across all studies, 57% made recommendations regarding restoration methodology and implementation, 46% for restoration monitoring, and 32% on site selection (Figure 1d).

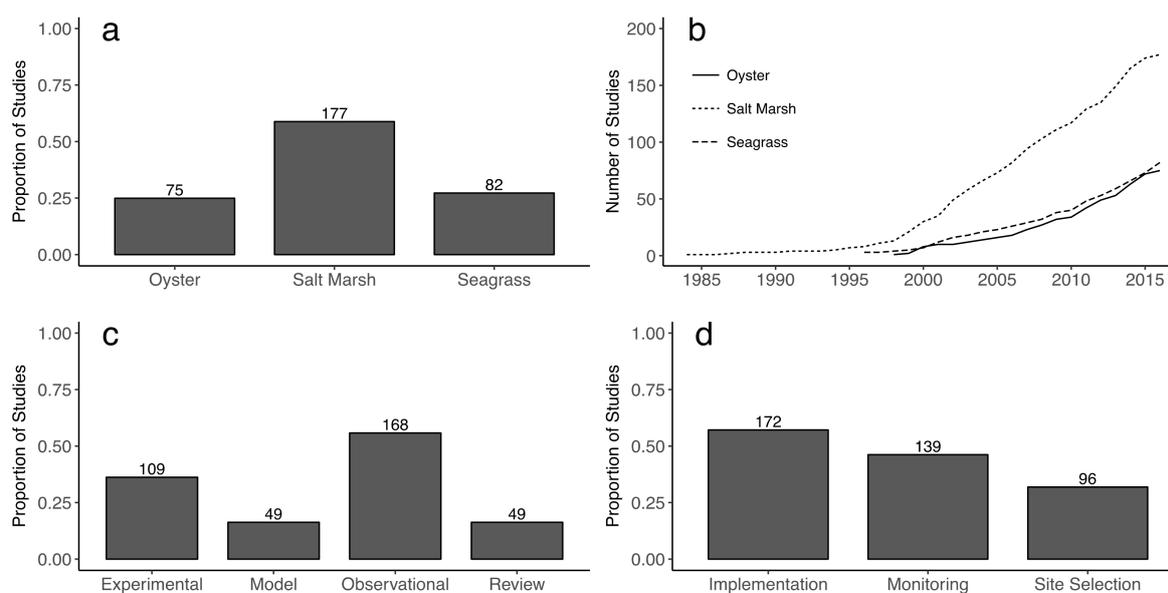


Figure 1. Journal article characteristics by (a) habitat; (b) publication date; (c) study methodology; and (d) restoration phase. Values above bars indicate the explicit quantity of studies. Note different y-axis on Figure 1b.

The vast majority of studies were authored by at least one researcher associated with a university (84%). Of our studies, 60% were published by authors representing only one sector; 34% were published by authors representing two sectors; and 6% had authors from academia, non-governmental organizations, and governmental organizations (Figure 2a). In contrast, government organizations alone accounted for nearly half (47%) of funding for restoration research, and 14% of studies did not state a funding source (Figure 2b). Approximately one-third of studies received funding from two or more sectors. When authors, funding sources, and acknowledgements were combined, cross-sector collaborations occurred in 89% of studies (Supplementary S1: Table S2). Of the 88 different journals in which studies were published, however, only nine were fully open-access (Supplementary S1: Table S3). Open-access articles, including those published as open-access in an otherwise subscription journal, accounted for less than 9% of all included studies.

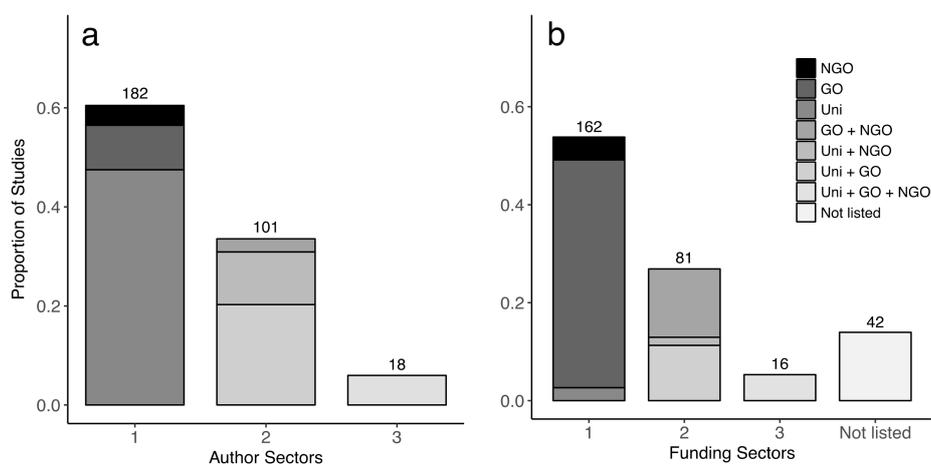


Figure 2. Collaborations in restoration research quantified by (a) listed authors and (b) acknowledged funding sources.

Globally, the vast majority of peer-reviewed restoration studies published in our database were conducted in North America followed by Europe and Asia (74%, 14% and 5% respectively; Figure 3a). An additional 4% of studies in our dataset were conducted across multiple continents. No studies that we reviewed occurred in either Africa or South America. In the United States, just over one third (36%) of all peer-reviewed restoration studies occurred in the northeastern United States followed by the Gulf and Pacific coasts (27% and 24%, respectively, Figure 3b). The majority of published salt marsh studies were conducted on the northeastern and Pacific coasts (both 33%), whereas seagrass studies were most often conducted on the northeastern and Gulf coasts (35% and 33%, respectively). Similarly, oyster restoration studies were predominantly conducted on the northeastern, Gulf, and southeastern coasts of the United States (39%, 27%, and 27%, respectively).

While the authors in our database were affiliated with organizations from 25 different countries (Supplementary S1: Tables S4 and S5, 70% of articles were published by authors solely affiliated with institutions in the United States; this bias likely affects our analysis of where restoration research has been conducted but likely has less influence on our study of what factors are emphasized or the extent of collaboration.

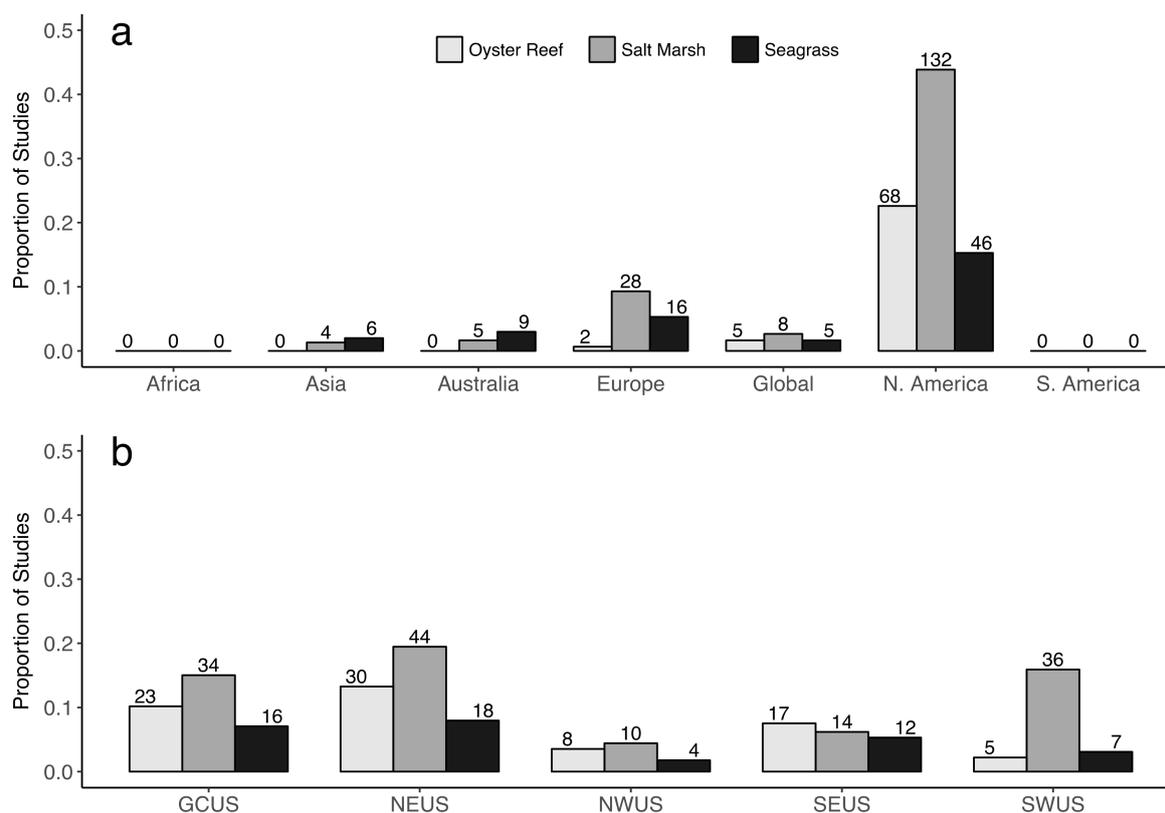


Figure 3. Oyster reef, salt marsh, and seagrass restoration study locations (a) by continent or globally and (b) by United States region. NEUS = Northeast United States, SEUS = Southeast United States, GCUS = Gulf Coast United States, PCUS = Pacific Coast United States. Values above bars indicate the explicit quantity of studies.

Nearly two-thirds of examined studies (64%, Figure 4a) discussed both biotic and abiotic factors as important considerations for restoration success. Studies that discussed only abiotic or physical factors as restoration considerations far outnumbered those that only discussed biotic considerations (Figure 4b). Across all habitats and factors, water depth/elevation, human interactions, tidal flow, temperature, and salinity were the most commonly recommended considerations for restoration (Figure 5, Table S2). The top three biotic factors considered for restoration success were human interactions, recruitment, and consumption (includes both predation and grazing). Salinity, water depth/elevation, and temperature were most often tested experimentally. Of the tested factors, salinity, water depth/elevation, and nutrients were most frequently found to have significant effects on restoration success across all habitats.

In contrast, the factor most frequently stated as critical for restoration success differed by habitat. Water depth/tidal elevation was most often stated as important for salt marsh restoration (50% of salt marsh papers). Human interactions and disturbances were the most considered factors for seagrasses (57% of seagrass studies), and recruitment was the most frequent consideration for oyster restoration (49% of oyster reef studies).

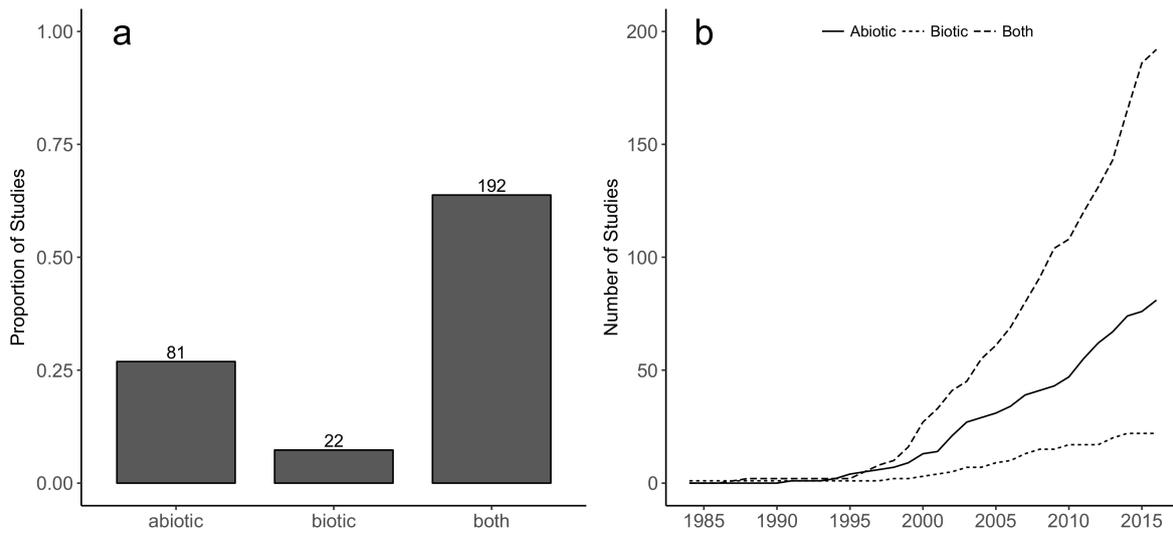


Figure 4. Quantification of physical or biological factors recommended in salt marsh, oyster reef, and seagrass restoration literature (a) total and (b) over time. Values above bars indicate the explicit quantity of studies.

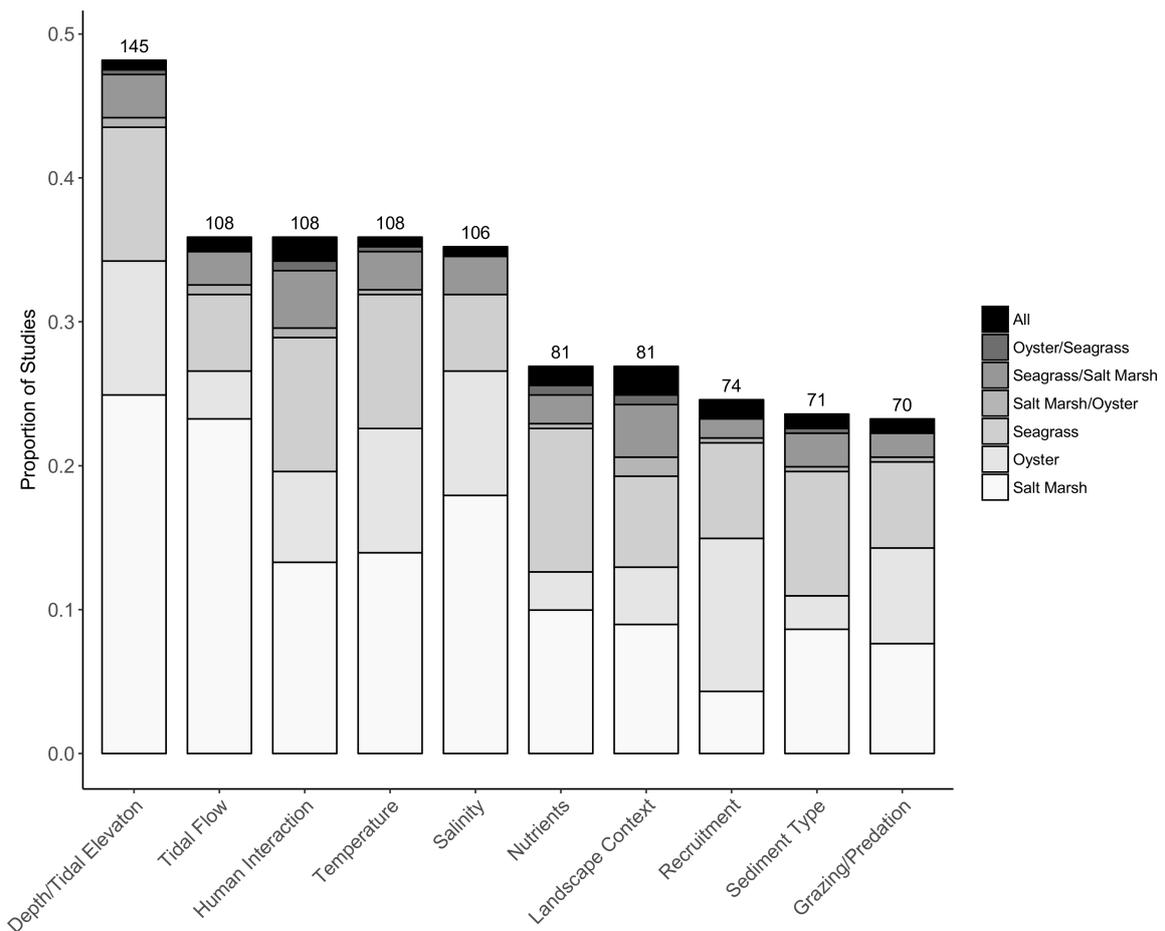


Figure 5. Top 10 factors considered for habitat restoration by ecosystem. Values above bars indicate the explicit quantity of studies.

There was little to no lag between when trophic interactions were first recommended as important considerations (1996) compared to non-trophic species interactions (Figure 6). However, less than one-fourth of studies mentioned either positive species interactions or top-down forcing in their studies. Only 3% of all studies in our dataset specifically tested for the impacts of incorporating positive species interactions into restoration designs, and 1% experimentally tested for the effects of top-down controls on restoration success.

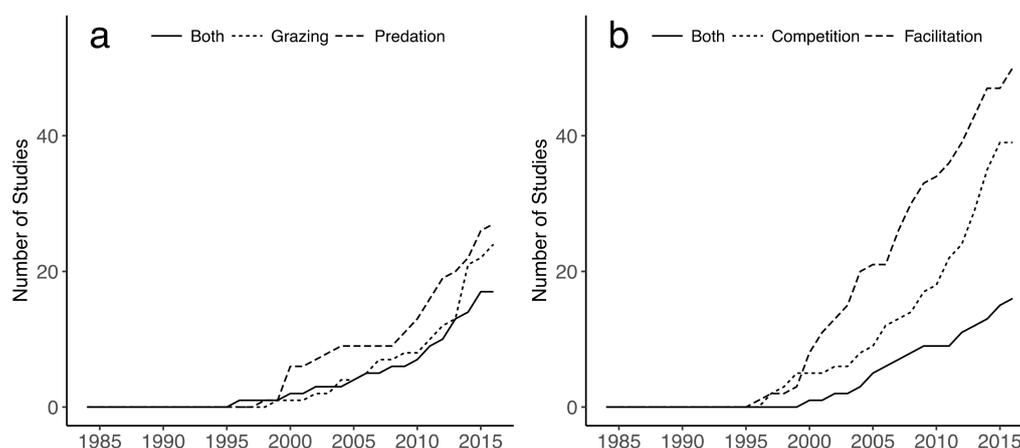


Figure 6. Cumulative number of studies over time that recommend considering (a) top-down trophic forScing and (b) non-trophic species interactions, specifically competition or facilitation.

4. Discussion

We conducted this synthesis of peer-reviewed journal publications to identify potential knowledge gaps and areas of improvement in coastal habitat restoration with respect to collaboration, location, and implementation methodology. Our vote-count revealed three major findings: (i) cross-sector collaboration as assessed by author affiliation occurred in about one-third of the studies examined and 89% of studies when authors, funders, and acknowledged organizations were considered; (ii) there is a dearth of peer-reviewed English-language studies from Africa, South America, Asia, and Australia; and (iii) abiotic factors were more frequently stated as important considerations for restoration success than biotic factors, but studies often addressed both. In particular, there was little difference in timing between when direct and indirect species interactions began to be recommended as important considerations in the restoration literature, however, very few of the studies specifically tested for their effects (<5%).

4.1. Cross-Sector Collaborations

Multiple studies have shown that the establishment of relationships between individuals, organizations, or sectors can facilitate the formation of common goals and lead to more effective and coordinated conservation efforts [46,47]. Our finding that roughly one-third of peer-reviewed restoration studies listed authors from at least two sectors, and 85% of papers represented a form of collaboration with respect to authorship, funding, and acknowledged work, suggests that previous restoration efforts have been collaborative. The sectors considered in this paper (i.e., NGO, GO, and academia) differentially specialize in implementation, policy, and innovation, and the nature of the collaboration ranges dramatically with respect to length, investment of resources, power, and involvement [48]. Given past findings from conservation studies, it is very likely that strategic approaches that form and support well-integrated and lasting relationships across individuals and organizations will increase the effectiveness of future restoration initiatives [48,49].

Cross-sector collaborations can offer a number of benefits in conservation efforts, including knowledge transfer, resource sharing, and cooperative problem-solving [10,15]. As researchers

decipher the complex interactions involved in restoring ecological communities, the information often does not get integrated into the practice of habitat restoration and vice-versa [50,51]. The research-implementation gap has been well-documented and criticized in conservation as a whole [20,26,52,53]. For example, many small NGOs may not have the financial resources to subscribe to scientific journals, and few studies are published open access. In contrast, many university researchers do not have the financial [54] or human-power to conduct broad-scale restoration, and both NGOs and academics often rely on government agencies to provide the financial means to restore habitats. Given these differential specialties and resources for all three sectors, bringing them together in lasting collaboration is likely to promote positive cooperative interactions and outcomes.

Although most listed authors were affiliated with academic institutions, our method of quantifying substantial collaboration does not take into account authors who may have multiple affiliations or collaborations that may occur between universities and other entities outside the domain of authorship. For example, we found that governmental agencies and NGOs were the predominant sources of funding for restoration research, but this contribution does not necessarily warrant authorship. However, because grantors ultimately determine what is funded, they likely play a disproportionately large role in determining restoration priorities and the scope of the projects to ensure they align with regulatory or management needs [54]. In addition, because we only included peer-reviewed articles, it is possible that studies by non-academics in general may be underrepresented in our dataset, as they publish more frequently in white or gray papers.

4.2. Restoration Geography

Our synthesis revealed that peer-reviewed restoration studies were strongly concentrated in the western hemisphere, and little to no research on coastal habitat restoration has occurred elsewhere. Most studies occurred in North America (74%), followed by Europe (14%), and few to no studies took place in Asia, Africa, or South America (3%, 0%, and 0%, respectively). The dearth of studies may be partially attributed to our selection of English-language journals, but may also be the result of fewer research universities as well as less funding opportunities in these areas. There may also be an emphasis on restoration and research of other coastal habitats, such as coral reefs or mangroves on some of these continents rather than on salt marsh, oyster reef, or seagrass meadows. Regardless, it is evident that the majority of restoration research published in peer-reviewed journals on temperate coastal habitats has occurred in North America and Europe. Restoration inherently occurs in high-stress or degraded areas [55,56], and, as a result, success can be highly variable [57,58]. For restoration research and experimentation to be broadly applicable, it should be conducted under similar environmental conditions and constraints, as larger restoration projects and aid in selecting areas with the highest likelihood of successfully restoring ecosystems and their services [59,60]. Where research has occurred, however, is likely influenced by multiple factors such as disaster response, local investment, and researcher concentration, among others.

Though we cannot directly ascertain whether restoration research has occurred in the appropriate locations, particularly with respect to areas with the greatest likelihood for success, our study sheds light on where there is an overall lack of restoration knowledge geographically. Few studies have provided estimates of coastal habitat extent and change in Africa, Asia, and South America [4,5,61]; thus, it is not surprising that we similarly found a lack of restoration studies. Studies that quantified global changes in seagrass, salt marsh, and oyster reefs estimate that declines range from 20–95% based upon region [4,5,61,62], suggesting that there is a pressing biological need for restoration research and transference of knowledge as a means of conservation. In response, the restoration community should redirect research and efforts to better address areas of threat where little is known regarding habitat loss and recovery.

4.3. Factors Considered in Restoration Methodologies

In our vote-count, we found that variables related to physical stress were by far the most considered factors in restoration studies. This is striking given that our knowledge of ecological systems suggests species interactions are fundamental in determining the structure and function of ecosystems [63–67]. Notably, marine restoration literature seems to recapitulate early ecological conventions and best practices from terrestrial restoration that prioritized abiotic over biotic forces for decades. When species interactions are included, there is often a focus on minimizing negative interactions, such as competition, rather than promoting positive interactions, such as facilitation. Furthermore, restoration practice has historically been influenced by forestry science, which emphasizes intra- and inter-specific competition as limiting forces for seedling recruitment success [43]. For decades, the paradigm of terrestrial restoration designs was to minimize competition between out-planted propagules by planting them at constant and dispersed distances [41]. In contrast, recent research demonstrated that salt-marsh restoration yield doubled simply by planting marsh grass plugs in aggregate (thus ameliorating abiotic stressors via increased intraspecific facilitation) [41]. This example underscores the idea that best practices learned from other terrestrial restoration projects may not necessarily be appropriate guidelines for marine restoration. Moreover, incorporating facilitation into restoration schemes has the potential to increase success with little additional expense.

Top-down control of transplants directly by grazers and predators has historically been recognized as another influential negative biological force. Consequently, we found many studies considered predation (15%) and grazing (14%) as important factors for restoration success. Grazers, for example, are known to exert strong control upon habitats. There are multiple examples where release of consumers from natural regulation by predators has led to complete habitat loss across a wide variety of grazer organisms (e.g., insects, echinoderms, small and big mammals, birds) and habitats (e.g., forests, savannas, kelp forests, mangroves, salt marshes, coral reefs; see [68] for a review). Thus, it is not surprising that consumers can strongly influence restoration success. In some cases, restitution of natural predators can be the only way to achieve habitat restoration by means of a trophic cascade, as in the case of the re-introduction of wolves in Yellowstone [69]. Although the ecological literature recognized the importance of top-down interactions, our study found that they were not commonly stated as considerations in coastal habitat restoration, potentially because top-down interactions are not always practical to manipulate, and their effects can be difficult to predict. However, when top-down interactions were directly employed and tested in restoration (4 studies, 1%), they were consistently found to have a significant effect on restoration success. Future studies in temperate marine systems should continue to investigate how accounting for and managing species interactions can affect restoration outcomes. In particular, testing and incorporating positive species interactions such as tri-trophic and facilitation cascades may greatly enhance restoration productivity and yield.

4.4. Recommendations for Coastal Habitat Restoration

Maximizing multi-functionality in habitat restoration, especially in coastal areas where there are a multitude of conflicting ecological, economic, and social priorities, is increasingly emphasized as a goal of conservation [70]. While restoration in and of itself should continue to be a priority, restoration schemes can be tailored to incorporate additional human priorities (e.g., shoreline erosion protection and aquaculture). For example, ecologists and restoration practitioners have recently begun to advocate for the use of shoreline stabilization strategies often referred to as “living shorelines” that prioritize coastal ecosystem restoration (e.g., salt marshes and oyster reefs), as well as coastal erosion protection. Living shorelines employ long-distance, intraspecific facilitation in the restoration scheme, whereby an offshore restored oyster reef attenuates wave energy and allows the persistence and potential expansion of a landward salt marsh where one might not be able to exist on its own. Living shorelines have been shown to enhance the services provided by coastal ecosystems [71,72]. Furthermore, the promotion of bivalve aquaculture in eutrophic areas has been proposed as a

mechanism for promoting the restoration of seagrass beds via the reduction of water column turbidity [73], while at the same time providing an economic and social benefit.

Proper site selection is also crucial for restoration success [74]; however, the means by which potential restoration sites are identified, prioritized, and selected are only beginning to be developed. Roughly one-fourth of the studies in our dataset researched factors that would inform the site-selection stage of restoration. Whether this represents a paucity of knowledge, or that there has been adequate research on this subject, cannot be discerned by our study, as we do not have information regarding long-term success of restoration studies, which is also a large gap in restoration knowledge. Restoration science and practice would benefit from more systematic, long-term monitoring that can be incorporated into predictive site-selection models [75,76]. Similarly, conducting basic research in regions where little is known regarding coastal habitat change will be crucial for identifying priority areas.

Ultimately, successful restoration will rely in part on minimizing per-unit restoration cost and enhancing our ability to restore at large scales [54,77,78]. This can potentially be achieved by promoting collaborative restoration efforts [79], incorporating planting strategies that can increase yield (i.e., utilizing aggregated over dispersed planting arrangements in wetland restoration) [41], and/or by designing restoration to simultaneously address multiple human priorities [80]. The fact that the most-frequently mentioned and tested factors in this study were abiotic in nature highlights the fact that re-creating the physical template remains the top priority for restoration. The inclusion of biotic factors, specifically species interactions, may greatly enhance restoration success when included in addition to the physical template [41,43,81,82]. Restoration efforts based solely on the re-creation of physical site characteristics may fail due to biotic issues like recruitment limitation [83] or underperform because of a failure to consider facilitation [41,43,84].

For restoration science and practice to advance as a method of conservation at large spatial scales, it is crucial to continually identify and address knowledge gaps, as well as develop and implement the most cost- and time-effective techniques. This includes actively developing and incorporating relevant ecological theories into designs and improving collaboration and communication across sectors. Thus, we suggest that the field of restoration science and practice could benefit from:

1. A broad discussion of the extent to which cross-sector collaborations with significant intellectual contributions from all participants occur as well as their effects on knowledge transference and adaptive management of restoration projects.
2. A greater emphasis on- and communication of restoration research that occurs outside of the western hemisphere.
3. The inclusion of biotic interactions, in addition to the physical template (specifically, top-down effects and facilitation) as a potential means to further enhance restoration yields.

Supplementary Materials: The following are available online at <http://www.mdpi.com/2071-1050/10/4/1040/s1>. Supplementary File S1: Table S1. Restoration factors quantified, Table S2. Author affiliation locations by continent, Table S3. Author affiliations by country excluding the United States, Table S4. Authors, funders, and acknowledged collaborations, Table S5. Article accessibility. Supplementary File S2: Peer-reviewed journal articles included in the present study.

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Eleanor Heywood, Carmen Hoyt, and Carter S. Smith collected the data; and Y. Stacy Zhang, William R. Cioffi, and Carmen Hoyt analyzed the data; all authors wrote the paper.

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