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# Shifting linguistic patterns in oyster restoration news articles surrounding the Deepwater Horizon disaster

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Populations of the eastern oyster *Crassostrea virginica* are declining globally. With the loss of oysters, sustainable provision of natural resources and ecosystem services are also threatened. In 2010, the Deepwater Horizon (DWH) oil spill became the largest marine oil spill in history, imperiling coastal and marine habitats in the Gulf of Mexico. Whereas ecological restoration serves as an important tool in natural resource management, its success depends on achieving ecological objectives and meeting public expectations. However, little is known about how the public perceives ecological restoration—even less in the context of disasters. It has long been understood that mass media messaging helps shape public understanding. Documenting patterned representation of oyster restoration in mass media texts can help set goals, improve stakeholder communication, and ensure required support for restoration activities. To address this goal, this study asks, does newspaper language on the topic of oyster reef restoration change in relation to an environmental disaster? If so, how? A 1.1 million-word Deepwater Horizon Oyster Restoration (DHORN) Corpus—a comprehensive body of newspaper articles about oyster restoration from 3 national and 18 gulf-state newspapers—was developed for the period April 2008–April 2014. The distribution and deployment of collocates of OYSTER\* across three DHORN subcorpora delimited by time (pre-, during, and post-Deepwater Horizon oil spill) were compared through iterative quantitative and qualitative analysis. Examination of salient collocates in use over time indicated an increase in the representation of oysters as quantifiable entities during/post-DWH; at the same time, there was a decrease in the representation of the roles of OYSTER\* in the Gulf ecosystem. Furthermore, multiple propositions associating oysters and oyster restoration activity with DWH and oil spills were introduced into language use by the disaster and persisted for years afterwards. This association was not present pre-DWH. Understanding shifts in linguistic patterns of oyster restoration in news articles before, during, and after Deepwater Horizon can be used to deliberately refine communication between the conservation community and both journalists and policymakers to promote conservation initiatives.

## KEYWORDS

corpus linguistics, *Crassostrea virginica*, disaster, discourse analysis, interdisciplinary, mass media, oil spill, public perception

## 1 Introduction

Eastern oysters, *Crassostrea virginica* are critical to the Gulf of Mexico's coupled social–ecological system. As filter feeders, they clean and clear bay waters (Dame et al., 1984; Nelson et al., 2004), and as reef builders, they create essential habitat (Stunz et al., 2010; Nevins et al., 2014) and protect shorelines (La Peyre et al., 2015). Despite being the largest producer of wild oysters in the US, Gulf of Mexico oyster populations are facing widespread environmental and economic losses due to human activities, extreme events, and climate stress (Kimbrow et al., 2017; Pace et al., 2020; Du et al., 2021).

Oyster reef restoration has become a best management practice to rehabilitate degraded oyster habitats (Kennedy et al., 2011; Blomberg et al., 2018) and is often accomplished by deploying settlement substrates to support larval oyster recruitment and population expansion (La Peyre et al., 2014; Bersosa Hernández et al., 2018). Although resource managers and scientists recognize the importance of restoration to ameliorate the effects of habitat loss, such efforts are contingent upon threshold levels of political, and thus public, support (Bliss and Fischer, 2011; Greening et al., 2014). When ecosystem degradation is well documented and shared with the public, the demand for action can compel political intervention toward the development of policy frameworks and funding structures to support restoration efforts (Hobbs and Harris, 2001; Federal Register, 2009; DeAngelis et al., 2020).

Mass media influences public perceptions about a range of issues (Dunaway and Graber, 2022) including environmental conservation (Hmielowski et al., 2014; Junsheng et al., 2019; Miller et al., 2018). As a primary form of mass media, newspaper texts play a role in shaping public opinion through sheer reach (Santa Ana, 2002) and agenda setting, priming, and framing mechanisms (Miller and Riechert, 2013; Govaerts, 2021). For example, Junsheng et al. (2019) employed structural equation modeling of participant media consumption, demographic, climate change attitudes, and climate change knowledge data. Among their randomly sampled participants, newspapers were the leading source of information about climate change. The authors found a “significant relationship among the roles of the mass media in creating awareness, attitude, and knowledge about climate change that positively affect environmentally friendly behavior” (p. 8). Because of this relationship, within conservation science, newspaper coverage of issues such as aquaculture (Rickard and Feldpausch-Parker, 2016; Olsen and Osmundsen, 2017), wildlife–human interactions (Miller et al., 2018), climate change (e.g., Junsheng et al., 2019), shellfish contamination (Suldovsky et al., 2018), and endangered species management (e.g., Schiffman et al., 2021) have been the subject of study. News coverage during disasters presents a special case since the public's demand for coverage and impressionability to coverage both increase (Ewart and McLean, 2019). Suldovsky et al. (2018) argue that studies of media content on a particular environmental issue can be used “to inform media communication strategies” (p. 6). However, little is known about newspaper coverage of oyster reef restoration, generally, or in the context of a disaster, specifically.

In 2010, the Deepwater Horizon (DWH) oil spill released nearly 5 million barrels of crude oil into the Gulf of Mexico, making it the largest marine oil spill in history (BPOSC, 2011; Kujawinski et al., 2020). Injuries

to numerous coastal resources, including oysters, resulted from direct oiling and response activities, including large freshwater releases from the Mississippi River to prevent ingress of oil (Baker et al., 2017; Powers et al., 2017). To begin to understand how news media present oyster restoration to the public, Brown et al. (2020) conducted a deductive (top–down) analysis of regional and national newspaper texts published before, during, and after the Deepwater Horizon oil spill. In their analysis, the authors coded local and national newspaper articles by frame (e.g., economic, environmental, and community) and role of the first quoted stakeholder (e.g., scientist, resource manager, and fishers). They examined the first two paragraphs of each article in the data set and identified differences in these variables between national and regional sources and over time. Among their results, Brown et al. (2020) found that coverage of oyster restoration in newspaper media increased during and after the DWH spill, and while environmental frames were predominant across time, both economic and community frames increased notably during and after the DWH spill. The current study builds on Brown et al. (2020) by approximately replicating their data set and applying a corpus linguistic analysis.

Corpus linguistics is an empirical methodological approach for discourse analysis within applied linguistics that uses quantitative and qualitative techniques to examine large data sets of naturally occurring language through software interfaces (Biber and Reppen, 1998). The approach allows for inductive and data-driven analyses of large data sets of language data. Like all applied linguistic analysis, corpus linguistics understands language data as observations of a complex language system and its many interrelating subsystems (e.g., syntactic, semantic, phonemic, and pragmatic systems) (The Ohio State University, 2011). Corpus linguistics studies often explore newspaper texts to identify linguistic patterns that function to shape representations of salient social constructs. The field of ecolinguistics, which focuses on how language mediates interactions among living things and their environments, has used corpus linguistics methods to explore climate discourse, representations of nonhuman animals, and eco-relevant terms such as sustainability (Poole, 2022).

A frequent unit of analysis in corpus linguistics is the collocate. Collocates are words that frequently and meaningfully co-occur with another word of interest (i.e., a node word) in a text or a corpus of texts (Xiao, 2015). For example, some of the most common collocates for EARTH in the Corpus of Contemporary American English (Davies, 2008) are ON, PLANET, MOTHER, and HEAVEN. Collocates are identified through a set of quantitative parameters that are manipulated by the researcher (Brezina et al., 2015).

Collocates are theorized as important variables in discourse analysis for multiple reasons. In his seminal theory of lexical priming, Hoey (2005) proposes that lexical collocation driven by a user's personal database of associations from previous language exposure is at the heart of language production. From an analytical perspective, collocations reveal syntactic, semantic, and discursive patterns in linguistic data (Crossley and Lowerse, 2007). Furthermore, taken individually or as a group (e.g., cluster), collocates reveal essential information about how the node word is defined and situated among other ideas repeatedly across texts (Stubbs, 1996; Baker, 2006). For example, Poole's (2002) analysis of collocates of WILDERNESS over time found a decrease in

representation of wilderness as “*savage, barren, and desolate*” (p. 80) in the Google Books corpus. One mechanism through which collocation reveals meaning is semantic prosody: “the collocational meaning arising from the interaction between a given node word and its collocates ... operates beyond the meanings of individual words” (McEnery et al., 2006, p. 83). That is, semantic prosody is a meaning generated by the deployment of the collocation itself within and across texts. Thus, collocates were identified as the linguistic variable through which to explore changing representations of oysters over time in this study.

The corpus linguistic analysis conducted in this study compliments Brown et al. (2020) by using the entirety of each text for inductive (bottom-up) analysis to identify patterns revealed by collocates in the corpus. That is, the design of this study allows for the identification of unexpected patterns in the data and makes use of all of the language data in the newspaper articles for analysis. The research questions (RQ) were the following: (RQ1) is the representation of oysters in newspaper articles about oyster restoration *substantially different* during and following a disaster in comparison to pre-disaster? (RQ2) In what ways is the representation of oysters in newspaper articles about oyster restoration different during and following a disaster in comparison to pre-disaster?

## 2 Methods

### 2.1 Deepwater Horizon and Oyster Restoration News corpus

The diachronic Deepwater Horizon and Oyster Restoration News (DHORN) corpus (1,118,983 words) was developed to replicate the data set presented in Brown et al. (2020), which captured newspaper texts from 3 national and 18 Gulf state newspapers, “with the keywords ‘oyster restoration’ and ‘Gulf’” between 10 April 2008 and 11 April 2014. To replicate their corpus, the authors of the current study contacted Brown et al. and received a spreadsheet documenting each regional article (i.e., from Gulf state newspapers) meeting their initial search criteria ( $n = 949$ ). Using Access World News, we obtained each of the articles in the spreadsheet that was not a duplicate of another article already captured and one/month of any articles that announced local events (e.g., Community Calendar). This resulted in  $n = 761$  regional articles.<sup>1</sup> For national articles, Brown et al. (2020) did not provide their initial search spreadsheet, and their three national newspapers (*Wall Street Journal*, *New York Times*, *USA Today*) were not indexed in Access World News at the time of corpus development for this study. Therefore, search criteria reported in Brown et al. (2020)<sup>2</sup> were approximated in the ProQuest News

1 In contrast, Brown et al. (2020) reported excluding all articles from the spreadsheet if “a) the article had no clear article frame, and/or b) the article did not contain sources” (p. 5) which resulted in  $n = 695$  regional articles.

2 That is, date range = 20 April 2008–20 April 2014; newspaper title = publication title, “oyster,” and “restoration” and “Gulf” anywhere in the text.

Databases to initially identify  $n = 62$  national articles. After excluding any duplicate texts (as was done with the regional texts), there were  $n = 44$  national texts included in the corpus<sup>3</sup>.

Although this study focused on the same 6-year time span used in Brown et al. (2020) (2008–2014), the pre-/during/post-Deepwater Horizon periods were delimited differently. For the during Deepwater Horizon time span, we were interested in only the time that the well was leaking. Thus, in this study, the pre-DWH period covers 20 April 2008–19 April 2010, the during-DWH period spans 20 April 2010–20 September 2010 (well officially sealed; Westerholm et al., 2016), and the post-DWH period includes 21 September 2010–20 April 2014 (Table 1). In sum, the DHORN corpus is a diachronic corpus of major national and Gulf state newspaper articles referencing oyster restoration for the 6 years buffering including the Deepwater Horizon oil spill and closely approximates the data set studied in Brown et al. (2020).

### 2.2 Analysis

To address RQ1, the authors determined a result based on the preponderance of evidence across several metrics. For each time span (i.e., pre-DWH, during-DWH, post-DWH), words/month and articles/month were calculated. In addition, collocates of the node word OYSTER\*<sup>4</sup> for each time span were calculated using #LancsBox6.0 (Brezina et al., 2021) and compared using WordSmith (Scott, 2016). In this study, the parameters used were a parameter of association, MI3(9)<sup>5</sup>; a parameter of location, L5-R5<sup>6</sup>; and a parameter of frequency ( $x$ ), where  $x$  maintains the same ratio of minimum collocate frequency/subcorpus word count across all three subcorpora (i.e.,  $x = 23$  pre,  $x = 15$  during,  $x = 112$  post). The MI3 scores are a measure of the strength of association between a node and a given collocate in a corpus. Once calculated, words identified as collocates across time spans were interpreted as markers of continuity over time, and collocates that were unique to each time span were interpreted as markers of change over time. Collocates of OYSTER\* identified in this study using the parameters described above and found to be unique to a given time span are referred to as *salient collocates* in that they are thought to be salient

3 In contrast, there were  $n = 68$  national texts in the Brown et al. (2020) final sample.

4 The \* indicates a wildcard search, which will identify all tokens that include “OYSTER” at the beginning of the string.

5 MI3(9) denotes that the statistic used was the MI3 score set at a threshold of 9.0. Relative to other association values used to identify collocational relationships among words, MI3 scores indicate collocates that occur both frequently and exclusively in each other’s company (Brezina, 2015). A threshold of 9.0 is a high threshold for indicating a strong relationship between words (Baker, 2016).

6 L5-R5 indicates that the word span investigated was five words to the left through five words to the right of the node.

TABLE 1 DHORN text and word count by time span and level (calculated using #LancsBox 6.0).

	Pre-Deepwater Horizon (20 April 2008–19 April 2010)	During-Deepwater Horizon (20 April 2010–20 September 2010)	Post-Deepwater Horizon (21 September 2010–20 April 2014)
National Newspapers	1 article 741 words	20 articles 25,116 words	23 articles 42,287
Regional Newspapers	139 articles 165,274 words	66 articles 84,690 words	556 articles 775,357 words
Total	140 articles 166,015 words	86 articles 109,806 words	579 articles 817,644 words

to and at least partially representative of how oysters are presented within a particular time span of this study.

To address RQ2, four sets of salient collocates were examined. Those sets were (1) collocates unique to the pre-DWH period, (2) collocates unique to the during-DWH period, (3) collocates unique to the post-DWH period, and (4) collocates shared by the during- and post-DWH periods (but not the pre-DWH period). For each set of salient collocates, patterns associated with the use of each collocation unit in the corpus were examined in WordSmith (Scott, 2016) for thematic, semantic, and grammatical patterns across occurrences of the collocation within the time span. Both concordance lines (Figure 1) and full co-text of the collocations in question were evaluated. A collocation unit was operationalized as a L5-R5 span of any frequency including the salient collocate of interest and OYSTER\* (Figure 1). Once patterns were identified by collocation, the first author, as the methodological expert, synthesized the patterns by time span, looking for patterns indexed by multiple salient collocates within a time span. As part of this synthesis, four principal propositions in linking oysters to the DWH spill were identified. This synthesis was then presented to the second author for validation as the subject area expert.

### 3 Results

Results of the analysis for each research question are presented below. For RQ1, the result of each measure is presented individually followed by a composite result. For RQ2, results are presented by

time span. For each time span, each of the major patterns identified in the synthesis is presented along with exemplar data in which the salient collocates for that time span demonstrate the pattern being presented. Discourse has a nested structure; therefore, for each time span, patterns with a smaller scope (microstructures) are presented before patterns that build upon them (macrostructures). Interpretation of the results will follow in Discussion.

#### 3.1 RQ1: Is the representation of oysters in newspaper articles about oyster restoration substantially different during and following a disaster in comparison to pre-disaster?

One set of metrics identified to address this research question involved the amount of text in the DHORN corpus by time span. Because the time spans were not of equal length, counts of both words and articles for each time span were normalized by month. Both measures increased by roughly threefold from pre- to during-DWH and then decreased slightly in the post-Deepwater Horizon time span (Table 2), indicating a change over time in the volume of newspaper texts and language including the topic of oyster restoration during- and post-Deepwater Horizon.

A second set of metrics identified to address this research question was the distribution of collocates unique to time spans (i.e., salient collocates) in comparison to collocates shared across

N	Concordance
1	already be preparing to deflect criticism over the oyster deaths. In its article, The Wall Street Journal
2	legitimate claims* but declined to say whether the oyster deaths are among them. Mr. Melancon is
3	is valued at \$330 million. On Thursday, Banks said oyster deaths also were found west of the
4	legitimate claims* but declined to say whether the oyster deaths are among them. In an underlying
5	spill. The Associated Press broke the story of the oyster deaths last week, and local news outlets
6	releases are responsible for killing oysters. The oyster deaths in Louisiana -- which produces more

FIGURE 1 Concordance lines for the collocation of the node OYSTER\* and the collocate DEATHS from the during-DWH time span subcorpus.

TABLE 2 Articles per month and words per month in DHORN corpus for each time span.

	Pre-Deepwater Horizon	During-Deepwater Horizon	Post-Deepwater Horizon
Articles/month	5.8	17.2	13.5
Words/month	6,917	21,961	19,015

time spans (Table 3). Because the number of collocates of OYSTER\* for each time span was different, this distribution is calculated as a percentage of the total number of collocates for each time span. This shows that, while many collocates of OYSTER\* are shared across all three time spans—indicating consistency in linguistic representation over time—the percentage of shared collocates of oyster\* decreases over time from 76% pre-DWH to 56% post-DWH. In addition, the percentage of salient collocates of OYSTER\* increases over time from 15% pre-DWH to 33% post-DWH.

Taken together, these metrics show that the representation of OYSTER\* in newspaper articles about oyster restoration is substantially different during and following DWH in comparison to pre-DWH. RQ2 investigated the quality of that difference.

### 3.2 RQ2: In what ways is the representation of oysters in newspaper articles about oyster restoration different during and following a disaster in comparison to pre-disaster?

#### 3.2.1 Pre-Deepwater Horizon

The collocations of OYSTER\* with the salient collocates pre-DWH were examined to establish ways that OYSTER\* was presented in texts about oyster restoration pre-DWH that were not salient once the disaster occurred. Table 4 presents the salient collocates for each time span along with the MI3 scores that show the strength of association between the node and the collocate during the time span. The salient collocates for this time span were SHELL, HABITAT, PROVIDE, BAY, and ABOUT. After working together to examine the collocations of OYSTER\* with each of the focal collocates, two main patterns were identified.

First, the collocations (OYSTER\*, SHELL), (OYSTER\*, BAY), and (OYSTER\*, HABITAT) often occurred in descriptions of specific oyster restoration projects. Exemplars (1–3) below show how these collocates are used in reference to specific projects.

- (1) *The initial deployment of oyster shell is planned for early March.* (#06)
- (2) *“I knew that (City of Naples) Natural Resources Manager Mike Bauer had done a previous project building an oyster reef in the bay,” Bradley said, “so I decided to add to it.”* (#923)

- (3) *Habitat Protection Advisory Panel Topics include ... an update on oyster restoration in Galveston Bay*(#437)

Throughout the corpus pre-DWH, SHELL refers to materials used in the project (1), BAY is used to locate a specific project (2), and HABITAT situates a specific project within a broader ecological context.

There was also a clear theme of oysters as ecologically beneficial entities that was indexed through the use of the collocations (OYSTER\*, HABITAT) and (OYSTER\*, PROVIDE).

- (4) *The students in Russell McFee’s Advanced Placement Environmental Science class had a unique opportunity to learn first-hand how oyster habitat benefits estuary environments.* (#737)
- (5) *Oyster habitat is vital to the health of an estuary, filtering nutrients, fine sediments, and toxins from the water column.* (#672)
- (6) *“Beyond just culinary delight, oysters provide a number of services,” she said, such as filtering out sediments in the water and providing habitat for juvenile fish.* (#92)

Exemplars (4–6) illustrate a pattern in which oysters are represented as a habitat, which provides ecological benefits to other wildlife directly (6) or indirectly through ecosystem services (5, 6).

These same collocations (OYSTER\*, HABITAT) and (OYSTER\*, PROVIDE) were also used to indicate that oysters, themselves, have dependencies. That is, in exemplars (7–8), PROVIDE and HABITAT work together to point to environmental requirements of oysters and how those requirements are being met through restoration efforts.

- (7) *The cultch, which is comprised of fossilized shell, is being used to construct a shoreline oyster reef that will provide habitat for oyster colonization.* (#737)
- (8) *If it is important enough for the Congress to provide funding to restore oyster beds, then it seems to me that due diligence would demand that the resource managers make the reef environment as receptive as possible for oyster culture.* (#533)

In exemplar (8), oysters need both ecological (i.e., “reef environment”) and fiscal (i.e., “funding”) provisions.

In fact, the analysis revealed several cases in which these two patterns (i.e., oysters provide and oysters are provided for) were

TABLE 3 Percentage of collocates shared across time spans or unique to a time span, by time span.

Collocates...	Pre-Deepwater Horizon	During-Deepwater Horizon	Post-Deepwater Horizon
Shared across all three time spans	25/33 = 76%	25/41 = 61%	25/45 = 56%
Shared pre/during	2/33 = 6%	2/41 = 5%	N/A/45
Shared pre/post	1/33 = 3%	N/A/41	1/45 = 2%
Shared during/post	N/A/33	4/41 = 10%	4/45 = 9%
Unique to time span	5/33 = 15%	10/41 = 24%	15/45 = 33%

N/A, Not Applicable.

TABLE 4 Salient collocates for each time span with MI3 scores.

Pre-DWH Collocates	MI3 score	During-DWH Collocates	MI3 score	Post-DWH Collocates	MI3 score
Shell	16.41062	Deaths	16.52459	Ground	24.51684
Habitat	16.00299	Areas	15.8383	Reservation	23.04681
Provide	15.33582	Shrimp	14.45888	Impacts	22.80014
Bay	14.74626	Acres	13.91652	Commission	22.38834
About	13.65119	Been	13.44048	Grounds	22.1532
		Louisiana	13.42598	Surveys	22.01006
		Water	12.66468	Productive	21.9941
		State	12.37852	Public	21.921
		More	11.96831	Compensation	21.89489
		New	11.82905	Potential	21.49429
				Wetland	20.79379
				Area	20.52145
				Within	19.58127
				May	19.26923
				Located	18.77467

used together. Exemplars (9–10) both indicate a series of cause-and-effect relationships starting with oyster restoration efforts providing for oysters, which in turn provide for other ecological entities.

(9) *The recycled oyster shells will provide suitable site for young oysters to settle and create an oyster reef. The oyster reef will attract fish and create habitat for small marine plants and animals.* (#06)

(10) *State officials dropped river rock and crushed concrete into East Bay to provide a place for oyster larvae to settle and grow into adult oysters. ...Oyster reefs also provide habitats for bottom-dwelling fish and invertebrates, which are then eaten by larger game fish.* (#430)

Oysters as ecologically beneficial was the dominant theme among the salient collocations pre-DWH. None of the collocations pointed towards oil spills or relationships among oysters and the oil and gas industry. In fact, the word SPILL occurred only once in any of the pre-DWH texts: “When you look at the probability of having a spill, modern drilling techniques are 13 times safer than transporting oil by tanker. Alabama, Louisiana, Mississippi, and Texas all have oil and gas rigs off our coast. Yet even during Hurricane Katrina, there were no spills in the Gulf.” (#584).

### 3.2.2 During Deepwater Horizon

There were 10 collocates of OYSTER\* uniquely salient to the time span in which the Deepwater Horizon spill was active (April–September 2010). They were DEATHS, AREAS, SHRIMP, ACRES, BEEN, LOUISIANA, WATER, STATE, MORE, and NEW. The qualitative analysis of the deployment of those collocations revealed three patterns.

The first notable pattern is that Louisiana was highly focal in the texts published during the Deepwater Horizon spill. The collocations (OYSTER\*, DEATHS), (OYSTER\*, AREAS), (OYSTER\*, LOUISIANA), and (OYSTER\*, STATE) all repeatedly pointed to the state. The collocation (OYSTER\*, DEATHS) was exclusively used in reference to deaths of oysters that occurred as a result of freshwater diversions from the Mississippi River in Louisiana that were released as a response to the DWH spill, as exemplified in (11).

(11) *Attributing specific numbers of oyster deaths to the freshwater diversions would be difficult, the spokesman said.* (#992)

(OYSTER\*, AREAS) was used to refer to oyster harvesting or seed bed locations governed by the state of Louisiana (12, 13).

(12) *Two oyster areas reopened, one closed. The Louisiana Department of Health and Hospitals on Monday reopened oyster harvesting areas 19 and 21, which are both west of the Mississippi River, to give harvesters more time to get their oysters before any potential impact from the oil spill.* (#195)

(13) *The Department of Wildlife and Fisheries has designated certain areas in the coastal waters of the State of Louisiana as Oyster Seed Bed Areas.* (#322)

STATE was either used in the cluster “State of Louisiana” (13) or as a general noun (i.e., “the state”) (14) to refer to the state of Louisiana as a manager of natural resources.

(14) *a Houma oyster processor, said the state needs to convey the message that “the world’s not over and we’ve got to move through this.” But, he said: “Let’s be honest, we’ve got a big challenge.”* (#242)

Two texts accounted for most of the occurrences of (OYSTER\*, LOUISIANA). These two texts were public notices of mineral leases published in the regional Louisiana newspaper, the *Franklin Banner-Tribune*, which noted the existence of oyster seed bed areas protected by the Louisiana state Department of Wildlife and Fisheries within lease boundaries (13).

Second, there were patterns of contrasting prosodies of loss and abundance. Across the collocations (OYSTER\*, DEATHS), (OYSTER\*, ACRES), and (OYSTER\*, BEEN), a semantic prosody of loss was presented. Of the collocations (OYSTER\*, DEATHS), 93% occurred with deaths in the R1 position (i.e., one word to the right of the node), and 100% of the collocations were in reference to oyster death in relation to the freshwater diversions spurred by DWH. Use of DEATHS connoted a sense of loss of not only oyster life but also economic value (15).

(15) *Public reefs account for up to half of Louisiana's oyster harvest, an industry that employs about 6,000 people and is valued at \$330 million ... chairman of the Louisiana Oyster Task Force, a state committee overseeing the industry, said the reports of oyster deaths on private leases are worrisome.* (#547)

The collocation (OYSTER\*, ACRES) was used to provide evidence of loss in relation to oyster deaths (16).

(16) *Now, some oyster fishermen along the coast are reporting mortality rates as high as 80 percent along thousands of acres of oyster beds.* (#992)

The collocation (OYSTER\*, BEEN) was used in past participle constructions with OYSTER in the subject (i.e., oyster has/have/had been PAST PARTICIPLE). The verb in these constructions signaled loss in 79% of these cases. Past participles in this slot included LOST (17), DESTROYED, HARVESTED, MINED, and REDUCED.

(17) *Worldwide, 85 percent of oyster reefs have been lost.* (#972)

(18) *the oyster shuckers who have been out of work since the BP oil spill.* (#291)

As with (OYSTER\*, DEATHS), exemplar (18) shows that (OYSTER\*, BEEN) conveys the prosody of loss of not only oysters themselves but also employment opportunities for individuals in the oyster industry. That is, while the prosody of loss was most focused on biological losses, it was also extended to ecological and social loss as well.

Yet, the semantic prosody of abundance was also apparent in the during-DWH data indexed by use of the collocations (OYSTER\*, ACRES), (OYSTER\*, MORE), and (OYSTER\*, NEW). In the same way that (OYSTER\*, ACRES) was used as a metric of loss, it was used (though in a more limited way) to convey growth and abundance (19).

(19) *We can give them that place to start life over right away—by building 100 miles of new, clean oyster reef and 1,000 acres of new, clean marsh and seagrass habitat in Mobile Bay.* (#481)

The collocation (OYSTER\*, MORE) was used to convey abundance of oysters (20), economic value of oysters, and benefits of oysters (20), even within articles with a central focus on the loss of oyster reefs.

(20) *The animal most responsible for maintaining the integrity of these estuaries is the oyster, which provides much more than New Orleans's most delectable appetizer. Oysters occur in great abundance in the gulf's shallow coastal waters.* (#972)

Exemplars (19, 21) show how (OYSTER\*, NEW) conveyed a prosody of abundance in which oyster and oyster reef numbers are increasing, thus supporting increased quantities of other desirable entities (“protection,” “habitat,” and “species”).

(21) *the new reefs should be well-populated with new oysters within five years, providing both an added layer of erosion protection to the island and new habitat for as many as 170 marine species native to the Gulf of Mexico, including fish, shrimp and crabs* (#182)

Overall, these contrasting prosodies indicate a discursive focus on quantity in association with oysters and oyster habitat.

The third pattern is the broadest in scope and concerns the positioning of oysters/oyster reefs/oyster restoration almost exclusively in relation to the Deepwater Horizon oil spill through four principal propositions. The propositions are a macro-discourse structure that incorporate more microstructures described above (Figure 2).

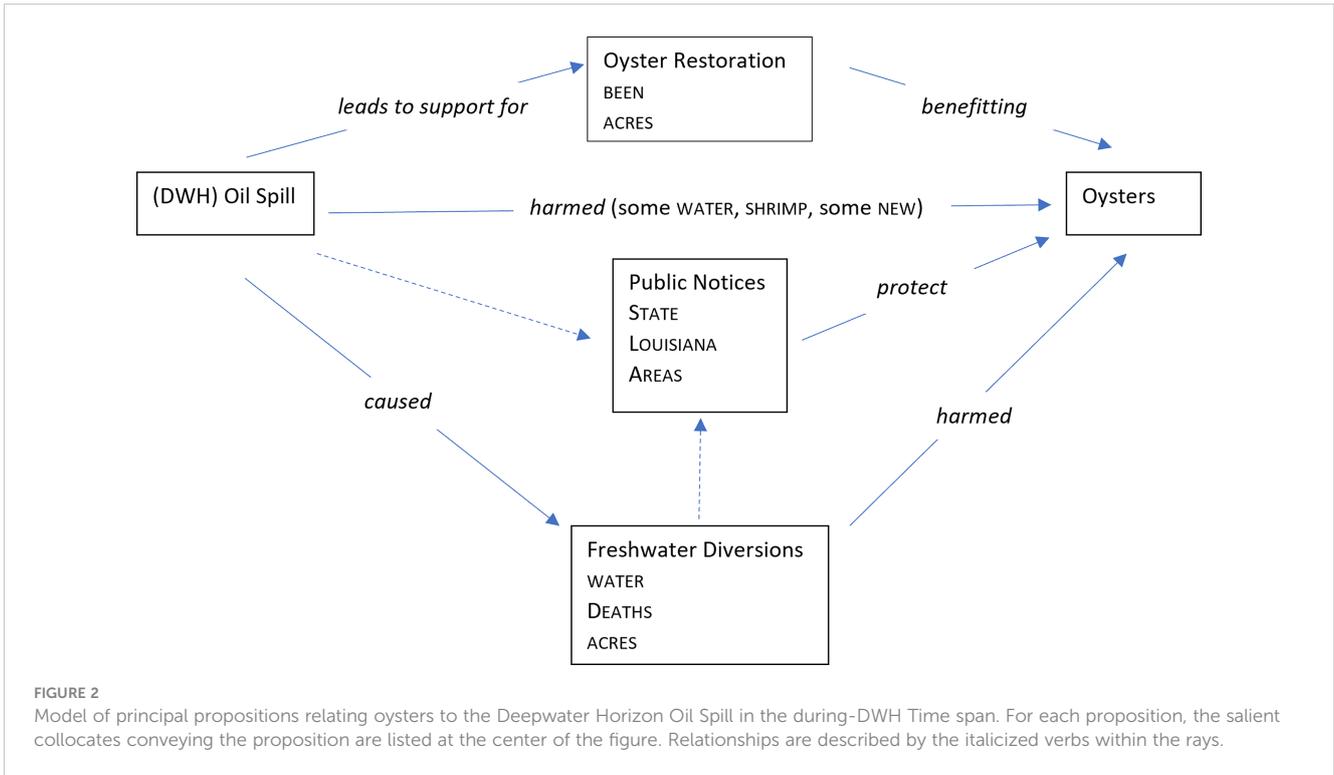
The first proposition, *the DWH oil spill harmed oysters*, directly relates the Deepwater Horizon oil spill to oysters. The collocations (OYSTER\*, SHRIMP), (OYSTER\*, WATER), and (OYSTER\*, NEW) all contributed to the expression of this proposition. The deployment of (OYSTER\*, SHRIMP) most consistently explicitly presented this relationship. In these collocations, oyster and shrimp were included in lists of species of wildlife described as directly threatened by the DWH oil spill (22).

(22) *The growing oil spill in waters near Louisiana is a threat to an astonishing range of life, from endangered sperm whales and sea turtles to migratory birds and prized shrimp and oysters.* (#402)

In the collocations of (OYSTER\*, WATER) that evoked this first proposition, the quality of the water in which oysters live was positioned as directly negatively affected by oil (23).

(23) *Depending on the concentrations of oil in the water, much of the state's oyster production could be rendered useless for months, he said.* (#239)

Finally, some occurrences of (OYSTER\*, NEW) presented scenarios in which recently established reefs/oysters were damaged by the spill (#24).



(24) *If the oil comes to Palm Beach County shores, tar balls could reach the **new oyster** beds from the Atlantic Ocean tides coming and going through the Jupiter Inlet, Arrington said. (#824)*

This straightforward proposition was common in deployment of these collocates—especially in texts immediately following the disaster.

The second proposition relating the disaster to oysters was *the DWH oil spill caused the freshwater diversions that harmed oysters*. The association between the DWH spill and oysters created by this proposition was negative but indirect—mediated by the freshwater diversions from the Mississippi discussed above. Occurrences of the collocations (OYSTER\*, DEATHS), (OYSTER\*, WATER), and (OYSTER\*, ACRES) worked to convey this frame. As described above, (OYSTER\*, DEATHS) was used exclusively in reference to the freshwater diversions (11) (15)(25). The occurrences of (OYSTER\*, WATER) conveying this proposition referenced the fresh WATER from the diversions, which were connected to oyster deaths in the prose (25).

(25) *Oysters are dying in their beds in the brackish marshes of southern Louisiana, but the culprit isn't oil spilling from the Gulf. It is, in part, fresh water....Linking a specific number of **oyster deaths** to the fresh-water releases will be difficult, he said. (#957)*

(26) *Now, some **oyster** fishermen along the coast are reporting mortality rates as high as 80 percent along thousands of acres of **oyster** beds. In Barataria Bay, one of Louisiana's most productive oyster fisheries, some beds are 60 percent dead, largely because of the freshwater influx (#992)*

Finally, the occurrences of (OYSTER\*, ACRES) that supported this proposition were a subset of those described above conveying the semantic prosody of loss. In these cases, the loss of acres of oyster reef or beds were linked to the diversions as in (26).

The third proposition relating DWH to oysters, *the DWH oil spill leads to support for oyster restoration, benefitting oysters*, was indirect as well. It was indexed by the collocations (OYSTER\*, BEEN) and (OYSTER\*, ACRES). This frame incorporates the semantic prosody of abundance described above in which (OYSTER\*, ACRES) was used to convey a metric of oyster growth. While ACRES in (27) is linked to “marsh wetlands,” it occurs as a parallel object with “miles of oyster reefs,” and both are being used with the controlling verb “establish” to present an increase in oysters associated with a restoration project. In this proposition, (OYSTER\*, BEEN) is used to claim that oyster restoration projects have BEEN occurring more frequently as a result of the Deepwater Horizon spill (27).

(27) *An ambitious habitat-restoration plan for Mobile Bay and Mississippi Sound announced Tuesday would establish 100 miles of **oyster** reefs and 1,000 **acres** of marsh wetlands and grass beds over the next five years ... Small-scale **oyster**-reef rebuilding projects have **been** under way for the past couple of years, but the Gulf of Mexico oil spill became a rallying point for a much larger effort. (#658)*

While the first two propositions relating DWH to oysters suggest a negative relationship between the oil spill and oyster health, the outcome for oysters from this frame is more optimistic.

Finally, (OYSTER\*, STATE), (OYSTER\*, LOUISIANA), and (OYSTER\*, AREAS) were all used in three public notice documents introduced above (13), which informed readers of mineral leases and expressed

a proposition, *oysters are protected by the state*. There is no language in these texts linking these leases or this proposition to the Deepwater Horizon oil spill explicitly. However, findings from the post-DWH data presented later help place this proposition implicitly in relation to the DWH disaster.

### 3.2.3 Post-Deepwater Horizon

There were 15 collocates of OYSTER\* uniquely salient to the time span after the Deepwater Horizon oil spill in the data. Those collocates were GROUND, RESERVATION, IMPACTS, COMMISSION, GROUNDS, SURVEYS, PRODUCTIVE, PUBLIC, COMPENSATION, POTENTIAL, WETLAND, AREA, WITHIN, MAY, and LOCATED. In addition, four collocates were salient during- and post-DWH: SEED, FISHERIES, OR, and AT. The use of these four collocates post-DWH will be included in the analysis presented in this section. The major patterns apparent during this time span across multiple collocations were (1) a theme of the local, (2) a theme of uncertainty, (3) a persistence of the model of propositions first salient during-DWH, and (4) increased prevalence of public notices referring to oysters.

Two salient collocates in the post-DWH texts were often used in conjunction with OYSTER\* to reference the local. The collocation (OYSTER\*, AREA) was deployed in two ways. OYSTER referred to a restoration project directly (28) or indirectly by referencing a part of a restoration project such as shells (29). AREA was either used directly as an adjective to describe the restoration (28) or more indirectly as an adjective to describe an entity associated with a restoration project (29).

(28) *Volunteers flocked to Harbour Pointe Park on Monday morning to help bag oyster shells donated from area restaurants. The St. Lucie County Erosion District and Florida Oceanographic Society are working together in an oyster restoration project for the Indian River Lagoon, using the shells for area oyster restoration.* (#708)

(29) *The center hopes to restore Eastern Oyster habitats by recycling oyster shells collected from area businesses.* (#860)

The collocation (OYSTER\*, AT) worked similarly with OYSTER referencing a component of a restoration project and AT functioning as the head of an adverbial prepositional phrase locating the project.

(30) *pass bags of oyster shells to put in the water at Goose Island State Park* (#355)

(31) *assembling bags of oyster shell at the Florida Oceanographic Coastal Center* (#715)

(32) *create oyster reefs at 11 sites in the lagoon near Fort Pierce.* (#696)

In all of these cases, the collocations were used to situate an oyster restoration project within a localized community.

Another theme present in the post-DWH data (and introduced in the during-DWH data) was one of uncertainty. The collocation (OYSTER\*, MAY) was most often deployed with OYSTER as the adjective describing the subject (oyster beds, oyster farmers, and oyster production) and MAY conditioned the possibility of the subject's verb as tentative (32).

(33) *His report adds, however, that some oyster beds may not recover for 6 to 10 years, and that there will be fewer fish, shrimp and crabs in the nets in some areas.* (#301)

In occurrences of (OYSTER\*, OR), OR joined a noun phrase including oyster with another noun phrase (33, 34).

(34) *He said besides marketing to help economic recovery, remaining money might be used for things such as rebuilding oyster reefs or other restoration projects.* (#79)

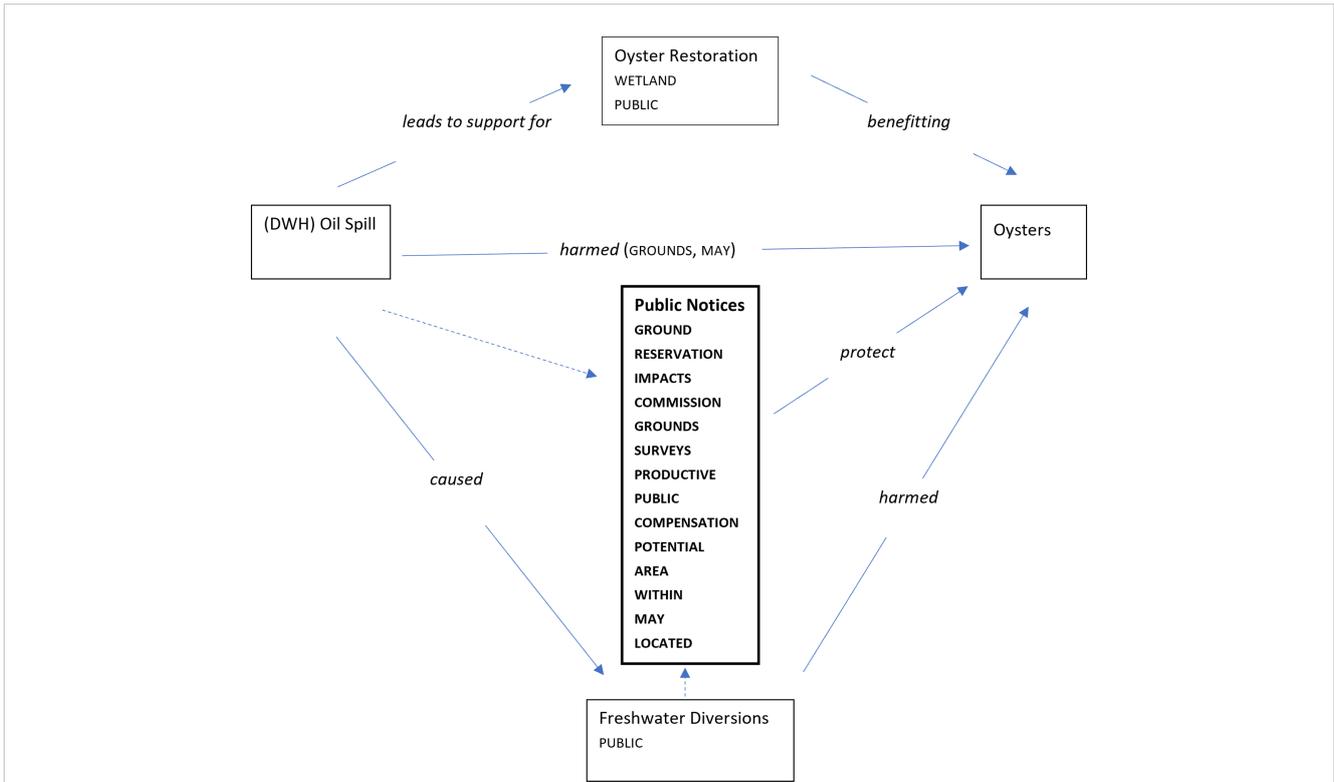
(35) *the reef program involves distributing limestone, oyster shell or crushed concrete to provide habit for oysters* (#90)

This construction served to present multiple options either for restoration projects themselves or for elements of oyster restoration projects. Together, these collocations connote the uncertain and dynamic environments in which oysters and their conservators operate.

The post-DWH data showed evidence for the persistence of the model of principal propositions relating oysters to the Deepwater Horizon Oil Spill that was first apparent in the during-DWH data (Figure 3). Exemplar data for each set of salient collocations indexing the principal propositions in this time span were provided (Table 5). Of note, while there was evidence of the proposition, *the DWH oil spill caused the freshwater diversions which harmed oysters*, provided by use of one of the salient collocates, it was only found in two texts (#166, #176) associated with the collocation (OYSTER\*, PUBLIC). This suggests that this proposition may have lost prominence during the post-DWH time span, with the more nuanced, indirect relationship between the oil spill and oysters reduced to the more direct relationship presented in the first proposition, *the DWH oil spill harmed oysters*.

Finally, the most dominant pattern in the analysis of the post-DWH salient collocations was the presence of 27 public notices all published in the *Franklin Banner-Tribune*, which included formulaic passages using all of the salient collocates in close proximity to one another.

(36) *NOTE: This tract is located in an area designated by the Louisiana Legislature or the Wildlife and Fisheries Commission as a Public Oyster Seed Ground, Reservation, or area of Calcasieu or Sabine Lake. Proposed projects occurring in these areas will be evaluated on a case by case basis by Louisiana Department of Wildlife and Fisheries. Modifications to proposed project features including, but not limited to, access routes, well sites, flowlines, and appurtenant structures maybe required by the Louisiana Department of Wildlife and Fisheries. In addition, compensatory mitigation will be required to offset*



**FIGURE 3** Model of principal propositions relating oysters to the Deepwater Horizon Oil Spill in the post-DWH time span. For each proposition, the salient collocates conveying the proposition are listed at the center of the figure. Relationships are described by the italicized verbs within the rays.

*unavoidable habitat impacts... Compensation and/or oyster seed ground surveys may be required by the Department for potential impacts to productive oyster seed grounds located within the management area.*

identified in the during-DWH data, they conveyed a proposition that *oysters are protected by the state*. What is noteworthy in this time span is the increase in these notices that occurred at a rate of 0.08 notices/month pre-DWH (and were not tied to salient collocates), 0.5 notices/month during-DWH, and 0.675 notice/month post-DWH. Recall that the presence of such notices and/or the proposition, *oysters are protected by the state* could not be

With the exception of one public notice, these texts were all notifications of mineral leases. And like the three notices

**TABLE 5** Collocations and text exemplars for principal propositions relating DWH to oysters in post-DWH time span.

Principal Proposition	Collocations indexing proposition	Exemplars
<i>The DWH oil spill harmed oysters.</i>	(OYSTER*, GROUNDS)	<i>The state had hoped BP would pay to restore <b>oyster grounds</b> and wetlands damaged by the spill and build a fish hatchery to help replenish fish stocks.</i> (490)
	(OYSTER*, MAY)	<i>it <b>may</b> take years before Louisiana’s <b>oyster</b> production will return to what it was before the BP disaster.</i> (171)
<i>The DWH oil spill caused the freshwater diversions which harmed oysters.</i>	(OYSTER*, PUBLIC)	<i>State officials’ decision to turn on a number of freshwater diversions full blast to block oil from entering coastal wetlands on both sides of the Mississippi River—a strategy that decimated private and <b>public oyster</b> beds</i> (176)
<i>The DWH oil spill leads to support for oyster restoration, benefitting oysters.</i>	(OYSTER*, WETLAND)	<i>The scope of the restoration work that can be undertaken will depend entirely on the size of the fine paid by BP, he said, but there are obvious priorities, no matter how much money is available. “<b>Oyster</b> reef restoration and <b>wetland</b> restoration are very important.”</i> (477)
	(OYSTER*, PUBLIC)	<i>The list of initial projects covered by \$1 billion pledged by BP to begin to repair the damage done by the 2010 oil spill includes creating 104 acres of marsh, placing <b>oyster</b> cultch on six <b>public</b> seed beds and upgrading a Grand Isle oyster hatchery.</i> (260)

connected directly to the Deepwater Horizon oil spill through text in the during-DWH time span. However, that is not the case with the post-DWH data.

In addition to the increase in number of texts expressing this proposition in the post-DWH time span, one text in particular shed light on the connection between the public notices and the DWH disaster. Excerpt 37 is from an article published 02/03/2011 in the *Times Picayune* (Schleifstein, 2011):

(37) *Louisiana will spend \$12 million to restore wetlands and rebuild oyster beds damaged directly or indirectly by the BP oil spill and will bill the company for repayment, Gov. Bobby Jindal announced Tuesday. Some of the money also will be used to build artificial oyster reefs to protect segments of the coastline stressed by oil from the spill, he said....That money will come from the wildlife agency's Oyster Seed Ground Development Account, which is funded with compensation payments by oil exploration and production companies and others that disturb existing oyster beds....*

This article explains that the Oyster Seed Ground Development Account referenced indirectly in the public notices and flagged by the salient collocates is the primary financial account that the state of Louisiana planned to draw on for their oyster restoration work mitigating DWH damage.

## 4 Discussion

Newspapers are an important source of information for local and national audience, even in the era of social media (Suldovsky et al., 2018; Banham and Mykkänen, 2022). Media communication can influence public agendas and policies related to environmental issues (King et al., 2017) and facilitate timely disaster response and recovery actions (Barnes et al., 2008). Understanding shifts in linguistic patterns of oyster restoration in news articles before, during, and after Deepwater Horizon can be used to deliberately refine communication between the conservation community, journalists, and policymakers to increase understanding, prioritize actions, and accelerate recovery throughout all phases of an environmental disaster.

In this analysis, while stability over time was identified, notable change was observed in how oysters were represented in Gulf/national newspapers during- and post-DWH in comparison to pre-DWH. Like Brown et al. (2020), this analysis confirmed an increase in coverage of oyster restoration during- and post-DWH as compared to pre-DWH using both words/month and articles/month as metrics. This is unsurprising, since approximately the same data set was used in both studies. However, by identifying the salient collocates of OYSTER\* over time and examining patterns associated with their use in this inductive analysis, this study also provided quantitative and qualitative analyses of change in the language of the coverage—further developing the findings from Brown et al. (2020).

The salient collocates identified and examined in this study pointed to the most noteworthy linguistic changes in the

representation of oysters over time in relation to the DWH disaster. One change identified in this study is that, in the context of the DWH disaster (during and after the spill), the focus on the ecological benefits of oysters and their concomitant ecological and fiscal dependencies was not salient. Conversely, this was the most prevalent pattern indexed by collocations of OYSTER\* in the 2 years of coverage pre-DWH. In addition, during the DWH spill, the representation of OYSTER\* became more quantitative in nature. This was primarily expressed through the semantic prosodies of loss and abundance (i.e., a focus on either the increasing or decreasing trajectories of oyster populations). During and after the spill, Louisiana dominated as a context associated with OYSTER\*, despite the fact that the data set included newspapers from all five Gulf states, each with strong local ties to oyster restoration, industry, and management.

Taken together, these patterns indicate that simplification of messaging and narrowing of geographic scope in the coverage of oyster restoration occurred concurrently with increases in the number of outlets and volume of coverage. This finding supports previously reported research. In their quantity of coverage theory, Mazur and Lee (1993) propose that increased media coverage of environmental problems is often presented along with simple visual images and that the combination of increased coverage and simplified messaging (via images) shapes public uptake of the coverage. In their study of Italian media coverage of natural disasters, Pasquare and Pozzetti (2007) found minimal “in depth scientific coverage” (p. 168) in their data set. Finally, in their study of newspaper coverage of the Convention in International Trade in Endangered Species (CITES), Schiffman et al. (2021) found simplification of messaging by focusing on particular species types and omitting others (e.g., terrestrial vs. marine), repeatedly grouping multiple species into one linguistic chunk (e.g., “sharks and rays”) (p. 8), and over-presenting some CITES procedures while not presenting others. Additional research is warranted to evaluate how narrowing of scope in media coverage may influence public understanding.

Finally, in our corpus of oyster restoration texts, oysters became associated with DWH both during and after the disaster. Prior to the spill, there was no evidence of an association between oysters and oil spills. OYSTER\* was associated with DWH through four principal propositions, whose dispersion in coverage changed over time. These propositions were (1) *the Deepwater Horizon spill harmed oysters*, (2) *the Deepwater Horizon spill caused freshwater diversions which harmed oysters*, (3) *the Deepwater Horizon spill leads to support for oyster restoration which benefits oysters*, and (4) *oysters are protected by the state*. While there are ways in which this is an intuitive change, it is important to note that the representation of oil spills was not only not salient in oyster restoration newspaper coverage prior to DWH but also essentially not present in news coverage in the 2 years prior to DWH (save for one occurrence). Thus, the strong association of oyster restoration during- and post-DWH to the oil spill itself represents an important shift in how oyster restoration was presented to the public through mass media. Whether that association persists and the effects of such association on public agenda setting might be the focus of future studies.

## 5 Conclusion

The interrelationship of human and wildlife systems informed this study. The identification of statistically and socially meaningful patterns about wildlife was distributed across a large data set of the uniquely human system—language. Furthermore, media coverage influences public understanding of environmental issues. In addition, newspapers are an important repository of social information. Newspaper language about oysters and oyster restoration changed in the context of the human-caused DWH oil spill. While the number of articles about oyster restoration increased threefold, the salient messages about oysters became more simple, consistent with previous scholarship. It may be advantageous, then, for scientists and natural resources managers to prepare messages for dissemination during a disaster that are simple but still convey qualitative information about the multiple economic and ecological benefits of oyster reefs. It may also be advantageous to proactively develop communication channels between environmental managers, scientists, and news media. Improved understanding of the role of habitat restoration in accelerating recovery after disasters will help build public support for human investments in wildlife conservation and management actions.

## Data availability statement

The original contributions presented in the study are included in the article. Further inquiries can be directed to the corresponding author.

## Author contributions

SF-D and JBP conceived the study. SF-D designed the corpus, led the analysis of the data, and wrote the first draft of the manuscript. JBP and SF-D contributed to editing and revising subsequent versions of the manuscript. SF-D and JBP obtained the funding. All authors contributed to the article and approved the submitted version.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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