frontiers | Frontiers in Environmental Science

TYPE Editorial
PUBLISHED 04 May 2023
DOI 10.3389/fenvs.2023.1203443

OPEN ACCESS

EDITED AND REVIEWED BY
Jaan H. Pu,
University of Bradford, United Kingdom

*CORRESPONDENCE
Charles W. Martin,
martin.charles.w@gmail.com

RECEIVED 10 April 2023
ACCEPTED 27 April 2023
PUBLISHED 04 May 2023

CITATION
Martin CW, López-Duarte PC, Olin JA and Roberts BJ (2023), Editorial: Gulf of Mexico estuaries: ecology of the nearshore and coastal ecosystems impacted by the Deepwater Horizon oil spill.
Front. Environ. Sci. 11:1203443.
doi: 10.3389/fenvs.2023.1203443

Editorial: Gulf of Mexico estuaries: ecology of the nearshore and coastal ecosystems impacted by the Deepwater Horizon oil spill

Charles W. Martin [1]*, Paola C. López-Duarte [2], Jill A. Olin [3] and Brian J. Roberts [4]

[1]Stokes School of Marine and Environmental Sciences, University of South Alabama, Dauphin Island Sea Lab, Dauphin Island, AL, United States, [2]Department of Biological Sciences, University of North Carolina at Charlotte, Charlotte, NC, United States, [3]Department of Biological Sciences, Great Lakes Research Center, Michigan Technological University, Houghton, MI, United States, [4]Louisiana Universities Marine Consortium, Chauvin, LA, United States

KEYWORDS

Macondo, pollution, anthropogenic threats, stressors, natural resources

Editorial on the Research Topic
Gulf of Mexico estuaries: ecology of the nearshore and coastal ecosystems impacted by the Deepwater Horizon oil spill

The Gulf of Mexico: productive despite a legacy of stressors

Estuaries of the northern Gulf of Mexico (GoM), from the freshwater, tidally-influenced wetlands to the nearshore coastal waters, are among the most productive on the planet (Chesney et al., 2000). As a result, these areas provide some of the most ecologically, economically, and culturally significant natural resources in the United States. These areas have also been subjected to a long history of numerous anthropogenic and natural disturbances. GoM estuaries have been influenced by extensive changes to the upstream watersheds resulting in altered water quantity and quality; routinely impacted by increasingly larger hurricanes; extensively modified for commercial shipping, recreational/tourism opportunities, and urbanization; remain vulnerable to climate change via sea level rise, warming, species distribution changes, and other climate effects; and heavily exploited for natural resources ranging from the historically productive fisheries to economically important minerals and their processing and refinement (Chesney et al., 2000; Lellis-Dibble et al., 2008).

Among the largest recent disturbance in the area is the highly publicized *Deepwater Horizon* (DwH) oil spill, which released an unprecedented amount of crude oil and gaseous hydrocarbons that heavily impacted GoM ecosystems (Nixon et al., 2016). The influx of funding generated by penalties associated with DwH sparked renewed interest in chemical, physical, and biological processes and functions of these GoM ecosystems and allowed for detailed research that greatly increased our understanding (Lubchenco et al., 2012). Impact assessments frequently highlighted surprising resilience of faunal communities (Able et al.,

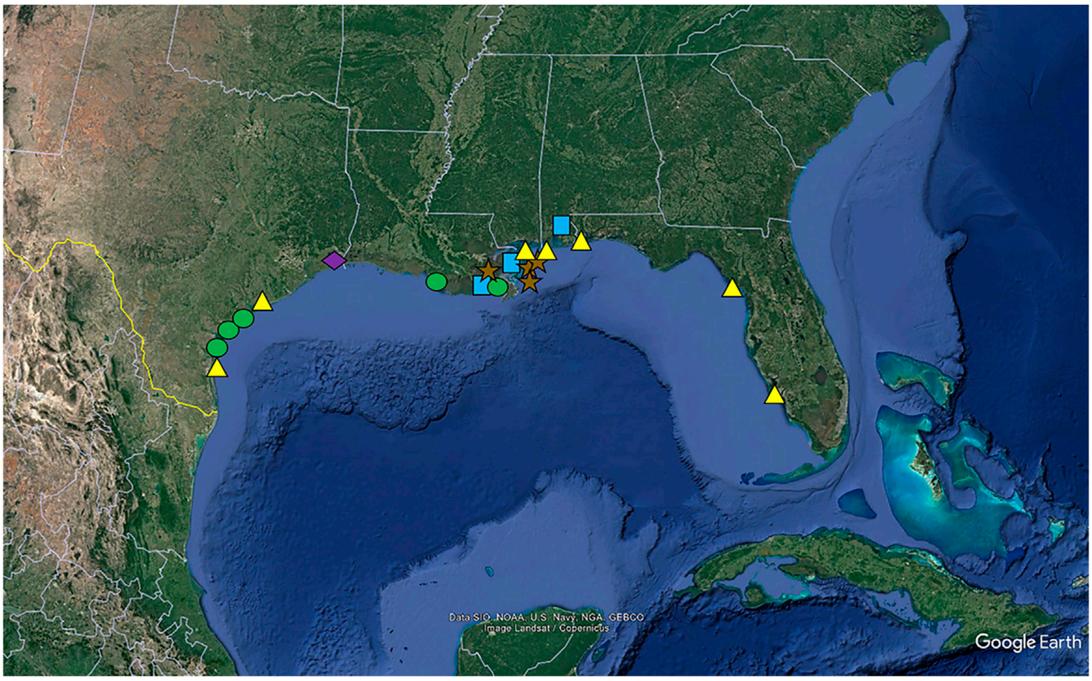

FIGURE 1
Approximate geographic locations of studies in the northern Gulf of Mexico included in this Research Topic using categories described in "Contributions of this Research Topic" section: 1) baseline studies (yellow triangles; Correia et al.; Rakocinski et al.), 2) non-oil stressors (blue squares; Lamb et al.), 3) spatial gradients (green circles; Husseneder et al.; Hu et al.), 4) oil effects (brown stars; Tatariw et al.; Berke et al.; Kiskaddon et al.; Snider et al.), and 5) restoration (purple diamond; Armitage et al.). Not depicted are Martin et al.; Carmichael et al. as they either represent a synthesis or Gulf-wide assessment.

2015; Olin et al., 2017) and food webs (McCann et al., 2017; Lewis et al., 2022), however to properly address oil impacts, previously unknown natural history knowledge was necessary. This included factors such as marsh fish physiology, demographics, site fidelity, and movement patterns (Vastano et al., 2017; Jensen et al., 2019), trophic interactions and energy flow pathways (Martin and Swenson, 2018; Keppeler et al., 2021; McDonald et al., 2022), and influences of other factors such as the multitude of confounding variables (Fodrie et al., 2014) and restoration efforts (Keppeler et al., 2023), all of which was attainable with DwH-facilitated funding.

Contributions of this Research Topic

Few article collections capture the complexities and multiple stressors GoM estuaries face. The aim of this Research Topic is to address this gap by illustrating the advances in ecological understanding and providing scientists and management practitioners with a roadmap for future studies that will contribute to the conservation of these coastal ecosystems for decades to come. In sum, the thirteen articles in this Research Topic detail our improved understanding of GoM ecosystem dynamics through documenting new insights into ecological processes and species distribution patterns, estuarine responses and resilience to various forms of disturbance and gradients, and finally providing critical baseline information that will improve future disturbance and restoration assessments (Figure 1).

GoM estuaries contain a mosaic of habitats, including sandy beaches, saltmarshes, mangroves, seagrass beds, and oyster reefs, to name a few. The productivity, complexity, and sensitivity of these different habitats to disturbance can be variable, further complicating efforts to produce overarching impact assessments. Despite this, important lessons have still emerged in the post-DwH research arena that merits attention and are highlighted in this Research Topic:

1) *Baseline information is critical to informing future disturbances.* A synthesis of post-DwH studies discusses an alarming lack of historical data which led to only ~3% of field-based studies employing preferred before-after-control-impact analytical approaches (Martin et al.). In light of this, numerous articles in this Research Topic present baseline data, including pertinent information on beach macrofauna (Rakocinski et al.) and economically important nekton assemblages (Correia et al.; Byrnes et al.) that can provide comparative information for future disturbances. These studies highlight an important lesson learned during this spill, that adequate preparation (e.g. , well-designed monitoring programs) is a key factor for future successful damage assessments.
2) *A legacy of disturbances affects GoM estuaries.* Centuries of exploitation and insults to ecosystems may produce synergistic effects. In this Research Topic, pollutants such as mercury are explored in this context, as mercury may become more bioavailable in the presence of stressors such as oil (Lamp et al.). Multiple stressors are known to unpredictably affect

10.3389/fenvs.2023.1203443

ecosystems, and other pollutants (e.g., PFAS, microplastics, DDT, etc.) and their emergent effects when combined with other stressors require future consideration.

3) *Natural gradients exist, which can be leveraged for improved understanding.* Taking advantage of gradients can provide empirical evidence of the role of different environmental influences on the ecosystem. Here, several papers explore the influence of these gradients. For example, salinity effects on metazoan biodiversity is explored across Louisiana salinity zones, with detailed reports on species occurrences and distributions (Husseneder et al.). In addition, estuarine water aragonite saturation state is examined along a Texas climate gradient, with reported impacts attributable to freshwater discharge (Hu et al.). Given that future ecosystems will be inherently different, these studies also serve as important baseline information for future assessments.
4) *Oil impacts were context dependent.* Differential sensitivities may lead to changes in assemblages, altered energy flows, and modified rates of ecosystem functions. In this Research Topic, the role of mangrove expansion effects on biogeochemistry in oiled wetlands is reported (Tatariw et al.). Important changes to infauna community composition were found at a range of oil impacted sites in the Chandeleur Islands, Louisiana (Berke et al.), and this oil exposure impacted infaunal family richness but not phylogenetic diversity (Kiskaddon et al.). Dietary composition of seaside sparrows at oiled and unoiled sites were found to be strongly influenced following a major hurricane (Sinder et al.). Finally, analysis of a dolphin stranding database highlights the role of human activities, including oil exposure, in stranding occurrences (Carmichael et al.). These studies are not the first to illustrate variability in oil spill impacts (e.g., Fodrie et al., 2014; Martin et al., 2020), and this Research Topic highlights the complexity of such holistic oil spill damage assessments.
5) *Restoration remains a viable option for mitigating historic and ongoing damages.* Restored habitats may encourage rehabilitation of natural flora and fauna and thereby promote rejuvenated ecosystem properties. In this Research Topic, a case study is presented on coastal wetland restoration, finding that trophic relationships and food webs still varied between reference and restored areas, with key advice to practitioners to incorporate geomorphological heterogeneity and plant diversity in restoration practices (Armitage et al.). Moving forward, restoration activities such as those described in this study will be important for maintaining productive ecosystem services.

Historical and emerging threats to Gulf of Mexico estuaries

We conclude by outlining the known and potential emerging threats to GoM estuaries. Petroleum exploitation was a known liability based on previous spills elsewhere, however few could have predicted the magnitude and economic harm the DwH event caused. The next major disaster may or may not be a known threat and we posit here potential future disturbances:

1) Alterations to hydrology can have far-reaching impacts. Water-related Research Topic persist, including Mississippi River protection levees and diversions, hydrologic alterations implicated in the decline oyster fisheries in Florida and Mississippi, impediments (e.g., dams and other structures) that stifle connectivity among upstream and downstream ecosystem components, and canalization rerouting water flow (e.g., Florida Everglades).
2) Habitat loss through urbanization, development, and industry has already extensively occurred. This includes canal dredging, spoil bank creation, and modifications for navigation. Notably, a booming tourism industry also threatens many GoM estuaries and plans for increased human access continue.
3) Climate change alters GoM estuaries at large spatial scales. Examples abound of increased temperatures, rising sea levels, salinity changes from altered weather patterns, and species distribution changes, and climate changes interacts with other disturbances, often producing synergistic and/or unpredictable consequences.
4) The productivity of these ecosystems has long driven local economies, and culturally-important fisheries may be at risk of overexploitation. Working waterfronts have been priced out due to prime real estate, but fishing activities are now more advanced than ever. Activities such as trawling can have unintended impacts (e.g., bycatch, benthic damage).
5) The GoM contains many valuable mineral resources. Oil and gas exploration and production continues despite known risks, and other resources (phosphate, etc.) may pose additional risks.
6) Point- and nonpoint-source pollution continues to threaten water quality. Eutrophication from fertilizers originating from inland agriculture triggers plankton blooms leading to the hypoxic “dead zone”, and smaller localized sources (e.g., lawn, golf courses) may also have negative impacts. Harmful algal blooms occur almost annually in some areas and are linked to eutrophication.
7) Novel species have established, however inshore areas have yet to see a major reorganization of landscape-level communities or food webs as a result. To date, these are predominately species with low salinity tolerance or offshore, reef-associated fishes. Other novel species include climate-expanding species, however the next invader or climate vagrant may be the exception.

Predicting the next major disturbance is impossible; however, the knowledge attained in the wake of the DwH spill and summarized in this Research Topic will undoubtedly serve as critical baseline information to inform future disturbances. We encourage researchers to continue predictive, scenario-based research on the above factors, especially in the context of multiple, interacting stressors, as estuaries will undoubtedly continue to be subjected to contemporary and emerging, simultaneous challenges. It is our hope that information contained herein finds utility throughout future years and drives continued conservation of GoM’s vital, productive, valuable, and culturally-important estuaries.

Author contributions

All authors contributed to the conception, implementation, and execution of this Research Topic. CM wrote the first draft of this editorial, and JO, PL-D, and BR contributed to the manuscript revision and approved the submitted version. All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication. All authors contributed to the article and approved the submitted version.

Acknowledgments

We thank the leadership of the Gulf of Mexico Research Initiative (GoMRI), attendees of GoMRI and GOMOSES conferences, and all our colleagues that worked on DwH-funded research for productive discussions that advanced our understanding of GoM ecosystems.

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.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Able, K. W., López-Duarte, P. C., Fodrie, F. J., Jensen, O. P., Martin, C. W., Roberts, B. J., et al. (2015). Fish assemblages in Louisiana salt marshes: Effects of the Macondo oil spill. *Estuaries Coasts* 38, 1385–1398. doi:10.1007/s12237-014-9890-6

Chesney, E. J., Baltz, D. M., and Thomas, R. G. (2000). Louisiana estuarine and coastal fisheries and habitats: Perspectives from a fish's eye view. *Ecol. Appl.* 10 (2), 350–366. doi:10.1890/1051-0761(2000)010[0350:leacfa]2.0.co;2

Fodrie, F. J., Able, K. W., Galvez, F., Heck, K. L., Jr, Jensen, O. P., López-Duarte, P. C., et al. (2014). Integrating organismal and population responses of estuarine fishes in Macondo spill research. *BioScience* 64 (9), 778–788. doi:10.1093/biosci/biu123

Jensen, O. P., Martin, C. W., Oken, K. L., Fodrie, F. J., López-Duarte, P. C., Able, K. W., et al. (2019). Simultaneous estimation of dispersal and survival of the gulf killifish *Fundulus grandis* from a batch-tagging experiment. *Mar. Ecol. Prog. Ser.* 624, 183–194. doi:10.3354/meps13040

Keppeler, F. W., Junker, J. R., Shaw, M. J., Alford, S. B., Engel, A. S., Hooper-Bùi, L. M., et al. (2023). Can biodiversity of preexisting and created salt marshes match across scales? An assessment from microbes to predators. *Ecosphere* 14 (3), e4461. doi:10.1002/ecs2.4461

Keppeler, F. W., Olin, J. A., López-Duarte, P. C., Polito, M. J., Hooper-Bùi, L. M., Taylor, S. S., et al. (2021). Body size, trophic position, and the coupling of different energy pathways across a saltmarsh landscape. *Limnol. Oceanogr. Lett.* 6 (6), 360–368. doi:10.1002/lol2.10212

Lellis-Dibble, K. A., McGlynn, K. E., and Bigford, T. (2008). Estuarine fish and shellfish species in U.S. commercial and recreational fisheries: Economic value as an incentive to protect and restore estuarine habitat. *National Marine Fisheries Service*. Office of Habitat Protection, NOAA tech. memo. NMFS-F/SPO; 90.

Lewis, K. A., Christian, R. R., Martin, C. W., Allen, K. L., McDonald, A. M., Roberts, V. M., et al. (2022). Complexities of disturbance response in a marine food web. *Limnol. Oceanogr.* 67, S352–S364. doi:10.1002/lno.11790

Lubchenco, J., McNutt, M. K., Dreyfus, G., Murawski, S. A., Kennedy, D. M., Anastas, P., et al. (2012). Science in support of the Deepwater Horizon response. *Proc. Natl. Acad. Sci.* 109(50), 20212–20221.

Martin, C. W., Lewis, K. A., McDonald, A. M., Spearman, T. P., Alford, S. B., Christian, R. C., et al. (2020). Disturbance-driven changes to northern Gulf of Mexico nekton communities following the Deepwater Horizon oil spill. *Mar. Pollut. Bull.* 155, 111098. doi:10.1016/j.marpolbul.2020.111098

Martin, C. W., and Swenson, E. M. (2018). Herbivory of oil-exposed submerged aquatic vegetation *Ruppia maritima*. *PLoS ONE* 13 (12), e0208463. doi:10.1371/journal.pone.0208463

McCann, M. J., Able, K. W., Christian, R. R., Fodrie, F. J., Jensen, O. P., Johnson, J. J., et al. (2017). Key taxa in food web responses to stressors: The deepwater Horizon oil spill. *Front. Ecol. Environ.* 15 (3), 142–149. doi:10.1002/fee.1474

McDonald, A. M., Martin, C. W., Rieucau, G., and Roberts, B. J. (2022). Prior exposure to weathered oil influences foraging of an ecologically important saltmarsh resident fish. *PeerJ* 10, e12593. doi:10.7717/peerj.12593

Nixon, Z., Zengel, S., Baker, M., Steinhoff, M., Fricano, G., Rouhani, S., et al. (2016). Shoreline oiling from the Deepwater Horizon oil spill. *Mar. Pollut. Bull.* 107 (1), 170–178. doi:10.1016/j.marpolbul.2016.04.003

Olin, J. A., Bergeon Burns, C. M., Woltmann, S., Taylor, S. S., Stouffer, P. C., Bam, W., et al. (2017). Seaside Sparrows reveal contrasting food web responses to large-scale stressors in coastal Louisiana saltmarshes. *Ecosphere* 8(7), e01878.

Vastano, A. R., Able, K. W., Jensen, O. P., López-Duarte, P. C., Martin, C. W., and Roberts, B. J. (2017). Age validation and seasonal growth patterns of a subtropical marsh fish: The Gulf Killifish, *Fundulus grandis*. *Environ. Biol. Fishes* 100, 1315–1327. doi:10.1007/s10641-017-0645-7