Spring 5-24-2023

Interannual Variation of Ichthyofaunal Utilization of a Man-Made Salt Marsh Creek in Mission Bay, California

Maria Angst
University of San Diego

Honors Thesis Approval Page

Student Name: Maria Angst

Title of Thesis: Interannual Variation of Ichthyofaunal Utilization of a Man-Made Salt Marsh Creek in Mission Bay, California

Accepted by the Honors Program and faculty of the Department of Environmental and Ocean Science, University of San Diego, in partial fulfillment of the requirements for the Degree of Bachelor of Science.

FACULTY APPROVAL

Dr. Drew Talley		
Faculty Project Advisor (Print)	Signature	Date
Dr. Susannah Stern		
Honors Program Director	Signature	Date

Interannual Variation in Ichthyofaunal Utilization of a Man-Made Salt Marsh Creek in Mission Bay, California

A Thesis

Presented to

The Faculty and the Honors Program

of the University of San Diego

By

Maria Angst

Environmental and Ocean Sciences

2023

Abstract

Marsh restoration and creation are increasingly being used to mitigate Southern California's drastic decline in wetlands due to human activities. This study used minnow traps to resample the ichthyofauna of a created marsh (Crown Point Mitigation Site; CPMS) and an adjacent natural marsh (Kendall Frost) in Mission Bay, California, 26 years following the marsh creation. Data from this study were compared to data collected immediately after marsh creation from 1995-1998, and from 2021. Fishes captured included *Fundulus parvipinnis, Gillichthys mirabilis, Acanthagobius flavimanus, Ctenogobius sagittula*, and *Mugil cephalus*. Species richness and dominance measures were higher in the natural relative to the created marsh. The size-structure of *F. parvipinnis* populations in the natural marsh were skewed towards larger sizes relative to those in the created marsh. These size differences were similar to 2021 but opposite of those noted in the years immediately following marsh creation, suggesting long-term changes rather than inter-annual variability. The changes in size-structure appear to arise from differences in creek morphology between the created and natural systems, with the created marsh creek having become shallower through time. To determine nutrient (nitrate and phosphate) concentrations, surface water samples were collected, filtered, and analyzed with a SEAL Analytical AQ400. No significant difference for nutrients were detected between the marshes. The differences in ichthyofaunal communities between the created and natural systems suggest that marsh/creek geomorphology may be affecting the suitability of habitat for resident fishes and should be more carefully considered when designing marsh restoration projects.

Acknowledgements

I would like to thank my thesis advisor, Dr. Drew Talley, for his willingness to take an advisory role for this research and his patience with me as well as helpful suggestions, intellectual support, and advice in the process of conducting my research. I would also like to express my gratitude to Dr. Bethany O'Shea, my advisor and second thesis advisor, for always being able to meet with me when I visited her office hours and for instructing me on the technical aspects of this project; especially for nutrient methodology for this research. I am grateful to McNair Scholars at the University of San Diego (USD) and the USD Environmental and Ocean Science department for supporting this project. This paper was improved thanks to the comments and guidance of Dr. Drew Talley who was invaluable in conducting this study. Lastly, I would like to thank my family who have continually supported me through this journey and that of everyday life.

.

Table of Contents

List of Figures

Introduction

Background

Coastal marshes and wetlands are complex and diverse ecosystems that are found in the transition zone between land and sea. They are characterized by the presence of emergent vegetation, which is adapted to survive in saline and brackish water conditions. Coastal wetlands provide several ecosystem services that are essential to the overall health of the planet (Shepard et al., 2011). Wetlands and marshes are important regulators for the global climate and hydrological cycle that provide human welfare through shoreline erosion control, flood protection, natural filtration, and other opportunities for recreation while also protecting biodiversity, accounting for about 47% of the global ecosystem values (Xu et al., 2019). These ecosystems play a crucial role in carbon sequestration due to their ability to store large amounts of carbon in their soils, which helps to mitigate climate change. Coastal marshes are estimated to sequester approximately 30% of the global carbon stored in soils, despite covering only 0.5% of the earth's surface (McLeod et al., 2011). In addition, they serve as breeding and feeding grounds for several fish and shellfish species that provide significant economic benefits to humans and provide essential habitat for endangered and threatened species.

California is climatically, topographically, and geologically diverse, which contributes to the great habitat richness their wetlands but they are among the most threatened habitats on earth, having lost 90% of their historical acreage to human activities (Schoenherr, 1992). Coastal development, agricultural runoff, and pollution are some of the major threats to these ecosystems, however, in recent years the leading cause of widespread coastal wetland loss is the inability to build vertically at rates comparable to relative sea-level rise (SLR) (Liu et al., 2021). The degradation of coastal marshes can lead to a loss of ecosystem services, including carbon sequestration, nutrient cycling, flood protection, erosion control, and habitat provision, which can have significant economic and ecological consequences from the loss of these services. Mission Bay, in San Diego, CA, was largely an intertidal marsh and mudflat habitat as recently as 1940, but now consists of only three small, isolated remnant marshes (Marcus, 1989). With wetland loss continuing, marsh restoration and creation are increasingly being used to mitigate Southern California's wetland decline, and recent studies have been focusing on the effectiveness of marsh creation (e.g., (Gu et al., 2018; Liu et al., 2021; Race and Christie, 1982).

Research Significance and Objectives

This study aims to answer the following questions: (1) Has the resident fish community composition and abundance in a marsh creek changed over the last 21 years, and does it resemble that in an adjacent natural marsh creek? (2) What are the patterns of inter-annual variability in ichthyofaunal assemblages in the created and natural marsh creeks? (3) How has the size-structure of the dominant marsh-resident fish taxa in the created creek changed in relation to that of the natural creek? (4) Does nutrient concentration in water differ between the created and natural marsh creeks?

Effective conservation and restoration efforts rely on accurate understanding of the factors that control community structure and function. Our understanding is largely through small scale research since wetland systems are frequently protected, and thus large-scale manipulations within these systems are rarely possible (Levin and Talley, 2002). This study is important in evaluating the progression of the ecological systems since the construction of the created marsh in San Diego, providing additional evidence of how effective the conservation and/or restoration efforts have been with respect to the ichthyofaunal assemblage.

Methods

Study Site

Fishes were sampled in the creeks of a natural (Northern Wildlife Preserve) (NWP) and adjacent created (Crown Point Mitigation Site) (CPMS) marsh in the northern part of Mission Bay, San Diego, California (32◦ 47" N, 117◦ 14'W) (Figure 1A). The NWP is a natural marsh of approximately 12 hectares that was established in 1974 by the University of California, San Diego (UCSD) and is managed by both the City of San and UCSD. The NWP has three discrete creek systems; the system closest to the mitigation marsh was used for this study (Figure 1B). The CPMS is a created salt marsh system with approximately 2.8 hectares of intertidal and subtidal habitat and approximately 0.8 hectares of upland habitat. The created marsh was constructed from dredge spoils on what was formerly an unsuccessful Least Tern nesting site, and historically was a tidal wetland home to over 200 bird species, including several endangered and threatened species such as the light-footed clapper rail and the California least tern (Marcus, 1989). The CPMS was first opened to tidal flushing on December 14, 1995, and marsh plant revegetation took place from March 22–26, 1996.

Ichthyofauna Collection

Sampling for fishes followed the protocols of Talley (2000), using similar locations, soak time, and assessment methods. The ichthyofauna were sampled with Gee® minnow traps, 22-cm diameter from the center, tapering to 19 cm at each end, made of 0.6 cm wire mesh with 2 cm openings. Traps, baited with canned cat food, were attached to stakes with 2–3 m of rope and placed at four locations in the creek at CPMS and four locations in the NWP (Figure 1). This study refrained from utilizing one former trap location in the CPMS from the Talley 2000 studies due to its frequent desiccation and lack of support for aquatic organisms (Figure 1C). From the months of June to August of 2021 and 2022, minnow traps were placed weekly during daytime low-tide and were recovered approximately 24 hours later. During trap recovery, all fish were counted, identified to species, measured (total length) to the nearest mm, and released.

Nutrient Collection

To determine nutrient (nitrate and phosphate) concentrations, surface water samples were collected in February 2023 from both marshes directly into separate 250 mL dark Nalgene bottles, placed on ice, and transported to the laboratory for processing. Once in the lab, the surface water samples were filtered through a vacuum filtration using a glass fiber filter (pore size 1µm, diameter 47 mm) and total nutrients on the filtered water samples were then analyzed using a SEAL Analytical AQ400.

Statistical Analysis

Excel was used to calculate averages ± one standard error. Species richness and a Shannon index were calculated to evaluate ichthyofaunal diversity.

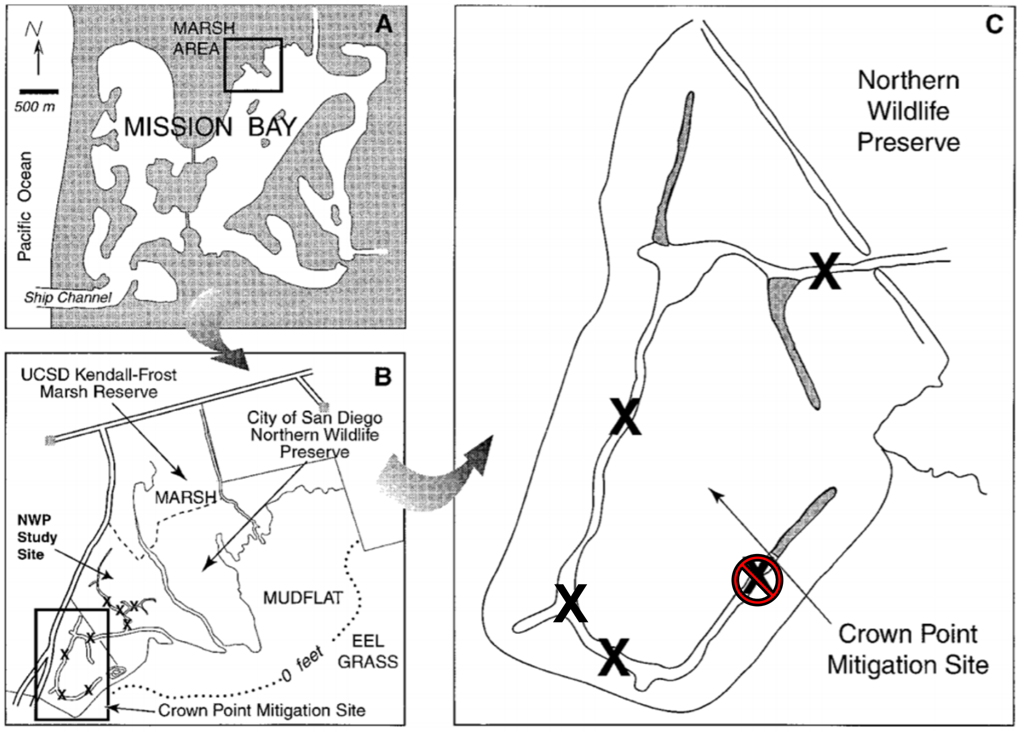

Figure 1. Map of study site, showing (A) Mission Bay, San Diego, CA and (B) the Crown Point Mitigation Site (CPMS) and Northern Wildlife Preserve (NWP) site. Shaded area in (C) indicates shallow subtidal habitat. Xs mark the locations of minnow traps. The prohibition sign marks a former minnow trap.

Results

Population Differences Among Marshes

Over the entire course of the sampling, a total of four species were recorded including *F. parvipinnis, Gillichthys mirabilis, Ctenogobius sagittula* (long-tailed goby), and *Mugil cephalus* (mullet). All four species were captured in the NWP, however, only *F. parvipinnis* and *G. mirabilis* were captured in the CPMS. The *F. parvipinnis* population size-structure showed differences between the created and natural creeks. *F. parvipinnis* populations in the NWP were skewed towards larger individuals relative to the CPMS at all sampling times (paired t-test, $p < 0.05$; Figure 2). Between 2021 and 2022, average *F. parvipinnis* total lengths from the NWP increased while those from CPMS decreased (t-test, $p<0.05$; Figure 3). Contrary to the previous study, diversity patterns are now trending towards higher diversity in the natural marsh, with the Shannon index trending higher in the NWP natural marsh than the CPMS created marsh as well (Figure 4).

Depth and Water Quality Differences Among Marshes

The depth of the current average CPMS is shallower compared to both the Talley 2000 study and the NWP at present, indicating a significant difference, while the NWP has maintained a consistent depth throughout the same period (t-test, $p <0.05$; Figure 5). Nutrient analysis showed no differences between the CPMS and NWP in terms of nitrate levels, however, there was a significant difference of phosphate levels between the two marshes (t-test, $p <0.05$; Figure 7).

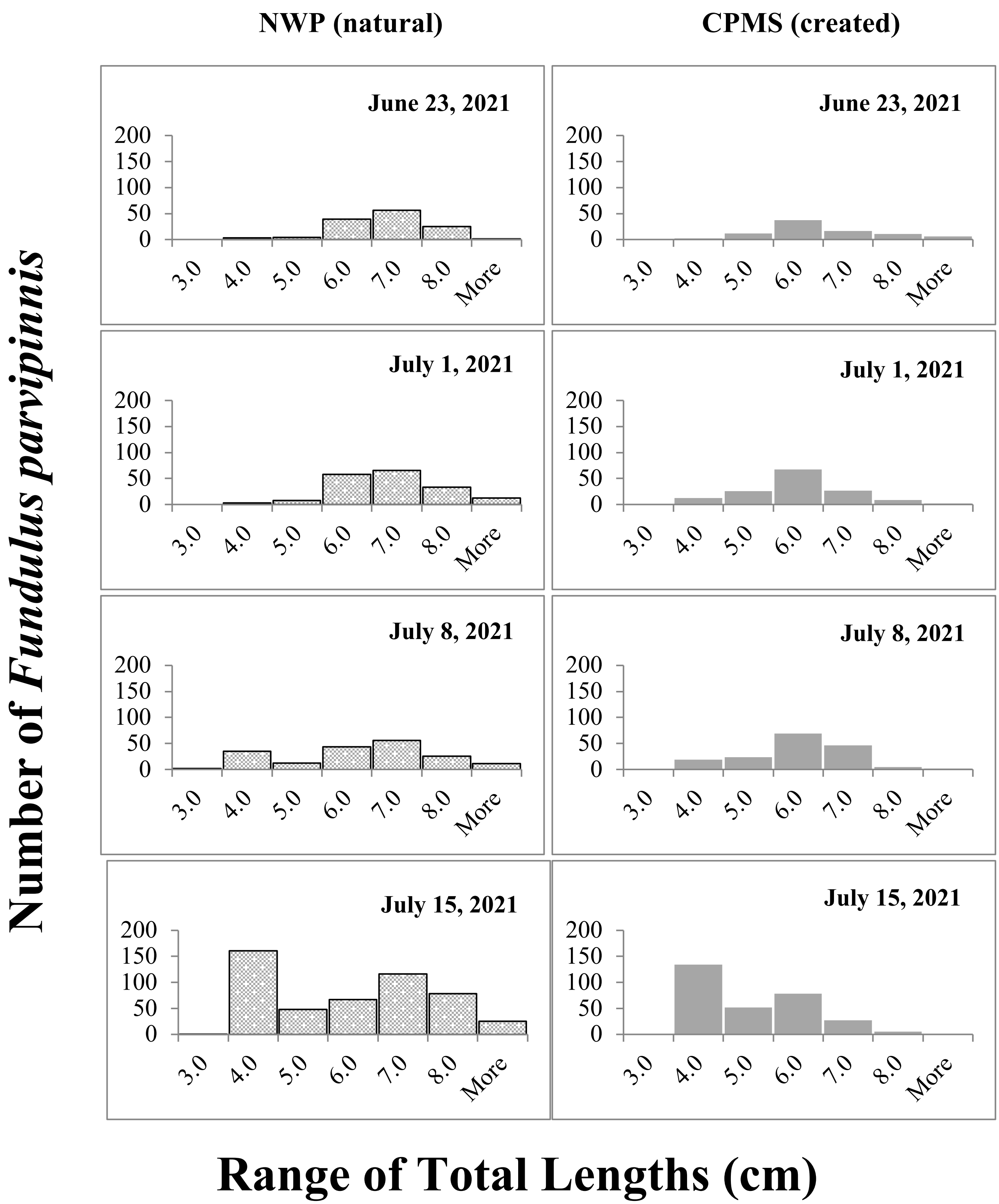

Figure 2. Length-frequency histograms for *Fundulus parvipinnis* from the Crown Point Mitigation Site (CPMS) and the Northern Wildlife Preserve (NWP) creeks.

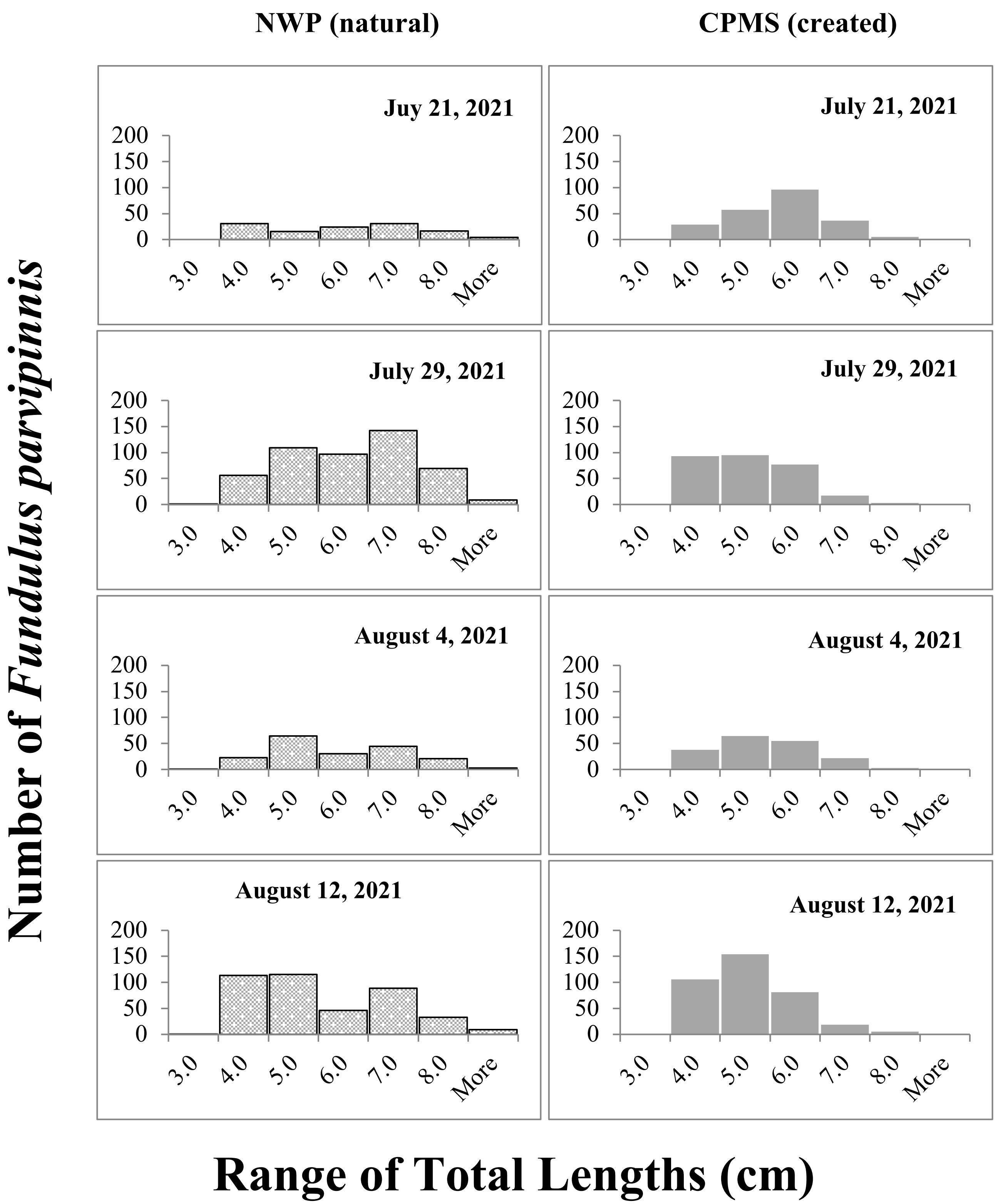

Figure 2. Continued.

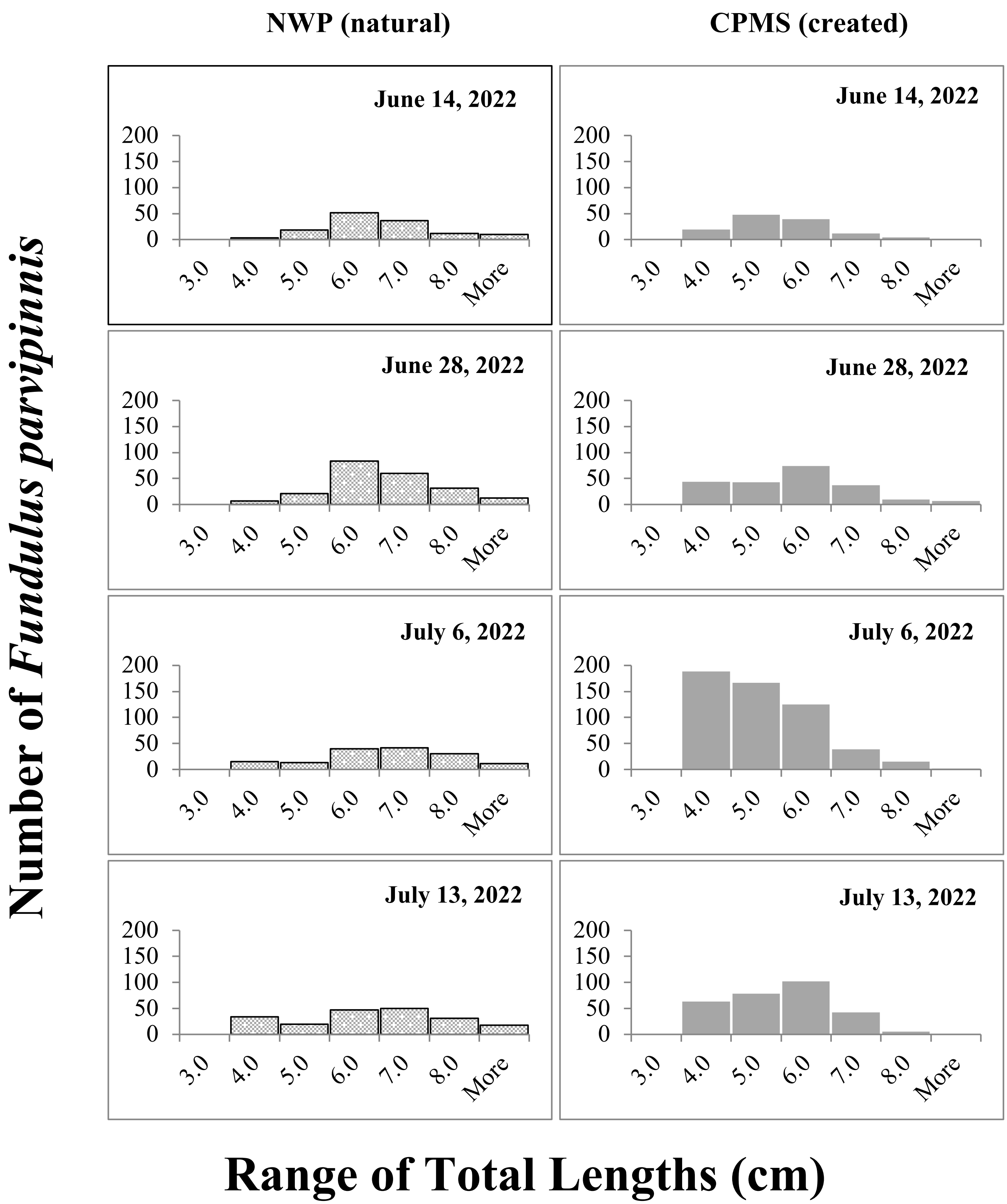

Figure 2. Continued.

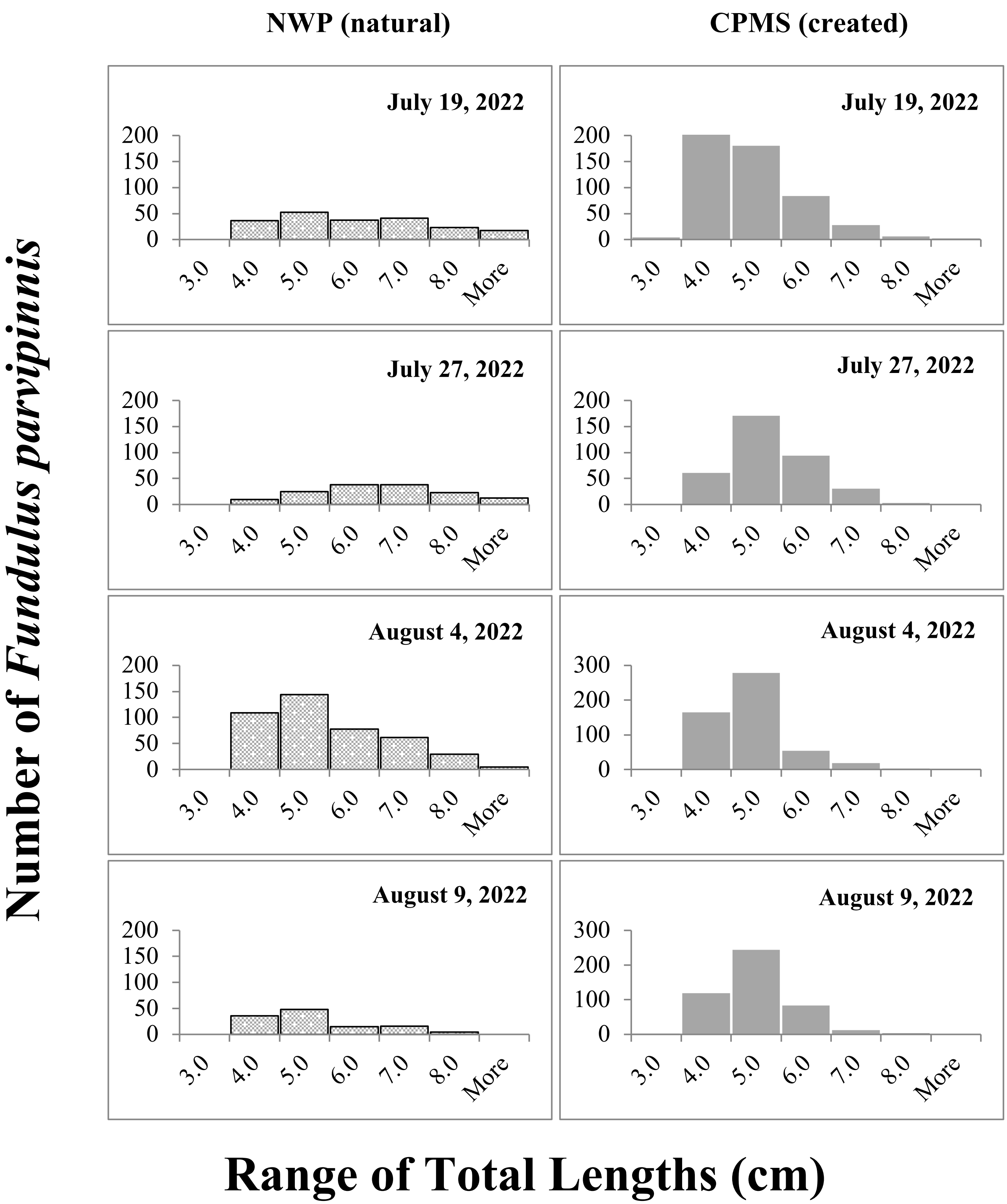

Figure 2. Continued.

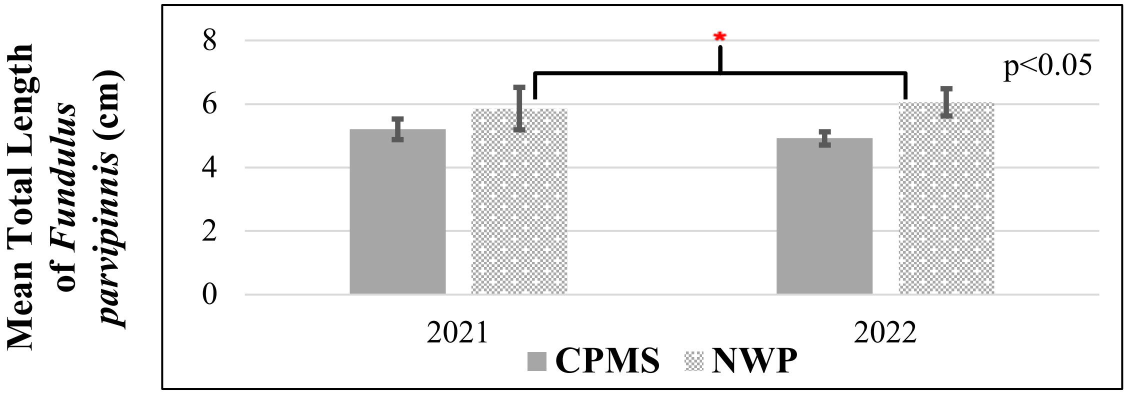

Figure 3. Calculated mean total length for *F. parvipinnis* from the Crown Point Mitigation Site (CPMS) and the Northern Wildlife Preserve (NWP) marsh in 2021 and 2022. Error bars represent ± 1 standard error. Observation year with an asterisk show a significant difference in average total lengths between the two marshes (t-test, p<0.05).

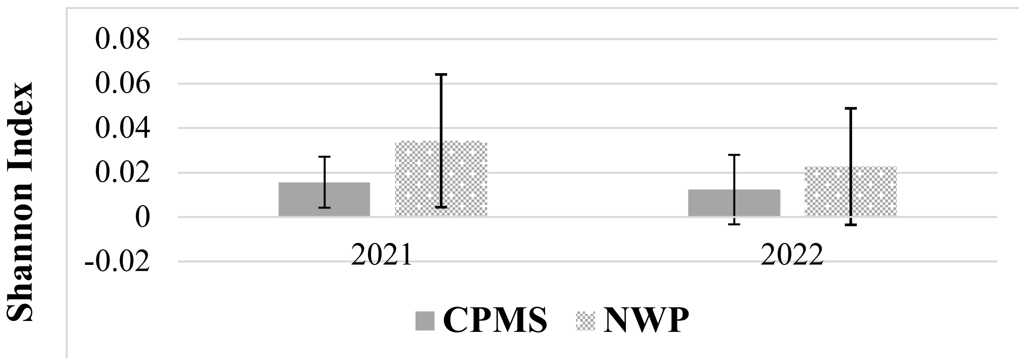

Figure 4. Calculated species richness from the Crown Point Mitigation Site (CPMS) and the Northern Wildlife Preserve (NWP) marsh in 2021 and 2022.

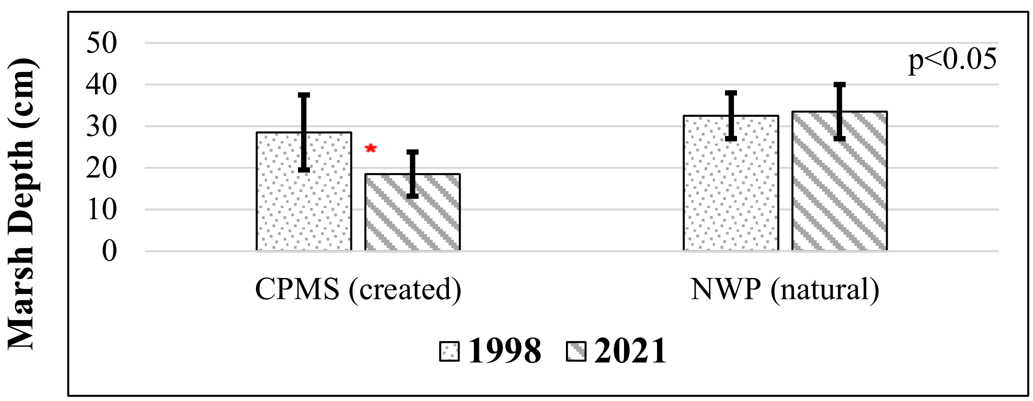

Figure 5. Depth of Crown Point Mitigation Site (CPMS) and the Northern Wildlife Preserve (NWP) marsh in 1998 and 2021. Error bars represent ± 1 standard error. Observation with an asterisk show a significant difference in marsh depth between the two marshes (t-test, p<0.05).

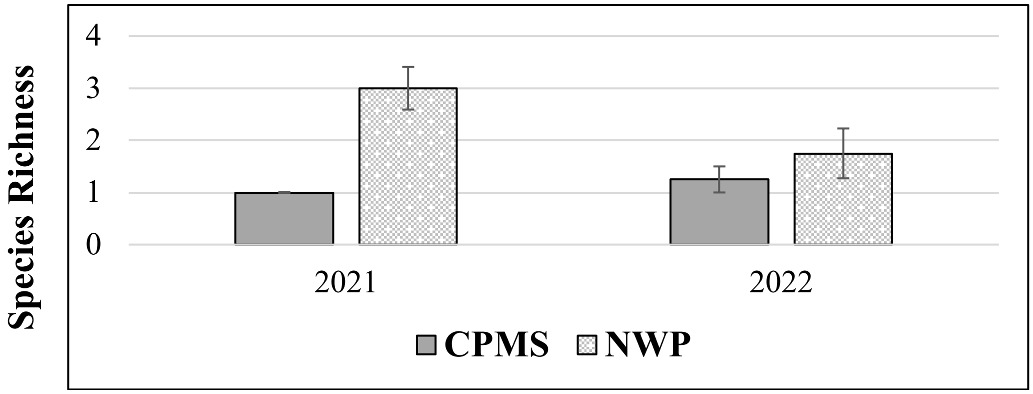

Figure 6. Species Richness at Crown Point Mitigation Site (CPMS) and the Northern Wildlife Preserve (NWP) marsh in 2021 and 2022. Error bars represent ± 1 standard error.

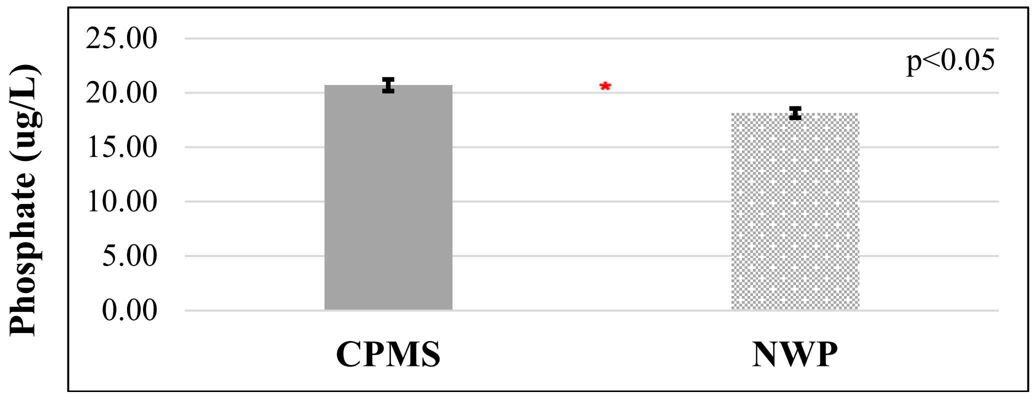

Figure 7. Phosphate levels of Crown Point Mitigation Site (CPMS) and the Northern Wildlife Preserve (NWP) marsh in 2022. Error bars represent ± 1 standard error. Observation with an asterisk show a significant phosphate difference between the two marshes (t-test, $p<0.05$).

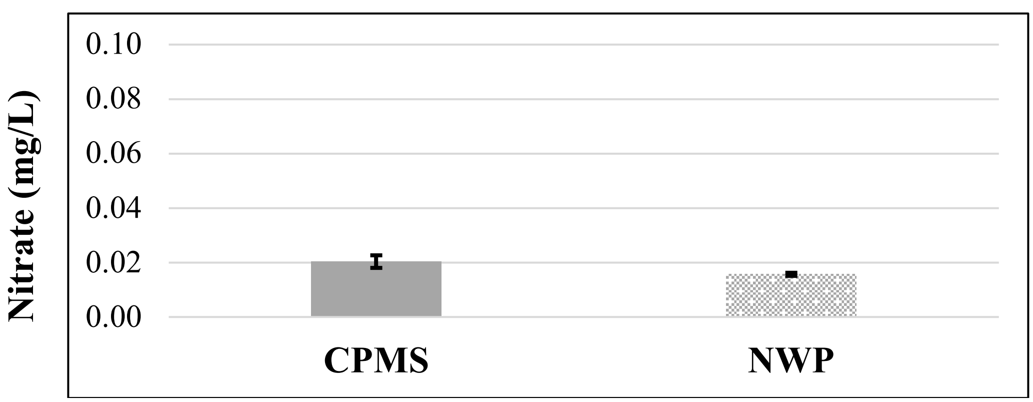

Figure 8. Nitrate levels of Crown Point Mitigation Site (CPMS) and the Northern Wildlife Preserve (NWP) marsh in 2022. Error bars represent ± 1 standard error.

Discussion

Ichthyofaunal Changes

Results from this study support the emerging view that functional equivalence of a created marsh requires more than simply abundance or diversity similarities (Castellon and Smith, 2002). Size-structure of the numerically dominant fish, *F. parvipinnis*, was skewed towards larger size classes in the natural marsh, contrary to previous results (Talley, 2000). This difference most likely resulted from an increase in shallow-water habitat now present in the created marsh (Figure 5). When the created marsh was constructed in 1998, the natural and created marsh creeks themselves were not significantly different in depth, although the created marsh had less overall shallow water habitat than did the natural marsh (Talley, 2000); however, the CPMS is now shallower than it was during the previous study and even shallower than the NWP in 2021 (t-test, $p<0.05$; Figure 5). It appears the CPMS channel has filled with sediment, creating far more shallow-water habitat and less deep-creek habitat than it had in 1998 (Figure 5). This difference in depth between the marshes likely accounts for the smaller fishes in CPMS relative to NWP, since juveniles prefer shallow water that provides protection from potential predators (Kneib, 1987). The differences in size-structure and species richness between the created and natural systems suggest that marsh and creek geomorphology may affect the suitability of habitat for resident fishes.

Possible Effects of Landscape Characteristics on Fish Communities

The landscape characteristics of marshes have significant effects on fish communities such as marsh depth and shape. Marsh depth has been shown to affect fish species richness and abundance, with many studies demonstrating that an increase in diversity is associated with increasing marsh depth (e.g., Able and Hagan, 2003; Colombano et al., 2021). This supports the contention that the natural NWP marsh had higher abundances and more species during this study due to creek morphology (Figure 5). The shape of the marsh is another important landscape characteristic that can affect fish communities in marshes. Marshes with more complex shapes, such as irregular shorelines and multiple channels, tend to have higher fish diversity and abundance compared to marshes with simple shapes since complex shapes provide more diverse habitats for different fish's characteristics, thus supporting a wider variety of species (Deegan et al., 2012). A comparison between the natural NWP marsh and the created CPMS reveals the NWP having a higher number of channels while the CPMS has only one primary channel and lacks many secondary channels (Figure 1B).

Water Conditions

The similarity in water quality, specifically with sulfate concentrations, indicates that there is a level of hydrological connectivity between the natural and created marshes. This suggests that there is a substantial flow of water between the marshes, facilitated by channels, tidal creeks, or underground water systems (Mortimer, 1941). As a result, dissolved substances, including nitrate and phosphates, can easily move back and forth, leading to similar concentrations in both marshes, especially if the marshes share the same water source, such as a common river or estuary (Johnston, 1991). The phosphate levels on the other hand, show that there is a significant difference between the marshes, however, those differences are unlikely to be of ecological significance. The levels of phosphate are extremely high when compared to Mission Bay, the main estuary in which the two marshes flow outwards to, where values in there were 1-2 orders of magnitude lower than what was found in this study (Bradshaw, 1972). The high level of phosphate in the created can be plausibly linked to the shallow sediments that are becoming anoxic despite overlying aerated water, which are contributing to internal phosphorus loading (Tammeorg et al., 2020). Moreover, as the marsh is situated near a manhole and an urbanized region, it naturally becomes a repository for heavy metals. However, the presence of these human-induced elements contributes to a significant nutrient load, leading to an unnatural elevation of phosphate levels (Papaslioti et al., 2020).

Limitations

This study had the primary limitation of time constraint. Since it was conducted solely during the summer season and did not span the entire year, the results may not account for any seasonal variations that may have occurred outside of summer.

Conclusion

This study has shown that the CMPS is still not functionally equivalent to the adjacent natural marsh, but rather is inhabited by a lower diversity and smaller size classes of fishes. Thus, after 25 years, the created CPMS marsh still doesn't have the equivalent functions from the perspective of the ichthyofaunal species examined as the natural NWP marsh. The differences in ichthyofaunal communities between the created and natural systems suggest that marsh and creek geomorphology may be affecting the suitability of habitat for resident fishes (Burdick and Roman, 2012), and implies the need for long-term monitoring of these dynamic systems and a reassessment of design in marsh restoration projects to understand more of the geomorphology and salt marsh functions under a wide range of natural variation in environmental settings.

References

Able, K., Hagan, S., 2003. Impact of common reed,Phragmites australis, on essential fish habitat: Influence on reproduction, embryological development, and larval abundance of mummichog (*Fundulus heteroclitus*). Estuaries 26, 40-50.

Bradshaw, S.J.M., J. Peta, 1972. Some Aspects of Pollution in San Diego County Lagoons Calif. Mar. Res. Comm., 84-94.

Burdick, D.M., Roman, C.T., 2012. Salt Marsh Responses to Tidal Restriction and Restoration, in: Roman, C.T., Burdick, D.M. (Eds.), Tidal Marsh Restoration: A Synthesis of Science and Management. Island Press/Center for Resource Economics, Washington, DC, pp. 373-382.

Castellon, T., Smith, E., 2002. Recommended Design for More Accurate Duplication of Natural Conditions in Salt Marsh Creation. Environmental management 29, 813-823.

Colombano, D.D., Handley, T.B., O'Rear, T.A., Durand, J.R., Moyle, P.B., 2021. Complex Tidal Marsh Dynamics Structure Fish Foraging Patterns in the San Francisco Estuary. Estuaries and Coasts 44, 1604-1618.

Deegan, L., Johnson, D., Warren, R., Peterson, B., Fleeger, J., Fagherazzi, S., Wollheim, W., 2012. Coastal eutrophication as a driver of salt marsh loss. Nature 490, 388-392.

Gu, J., Luo, M., Zhang, X., Christakos, G., Agusti, S., Duarte, C.M., Wu, J., 2018. Losses of salt marsh in China: Trends, threats and management. Estuarine, Coastal and Shelf Science 214, 98-109.

Johnston, C.A., 1991. Sediment and nutrient retention by freshwater wetlands: Effects on surface water quality. Critical Reviews in Environmental Control 21, 491-565.

Kneib, R.T., 1987. Predation Risk and Use of Intertidal Habitats by Young Fishes and Shrimp. Ecology 68, 379-386.

Levin, L.A., Talley, T.S., 2002. Natural and Manipulated Sources of Heterogeneity Controlling Early Faunal Development of a Salt Marsh. Ecological Applications 12, 1785-1802.

Liu, Z., Fagherazzi, S., Cui, B., 2021. Success of coastal wetlands restoration is driven by sediment availability. Communications Earth & Environment 2, 44.

Marcus, L., 1989. The Coastal Wetlands of San Diego County. California State Coastal Conservancy, Sacramento.

McLeod, E., Chmura, G., Bouillon, S., Salm, R., Björk, M., Duarte, C., Lovelock, C., Schlesinger, W., Silliman, B., 2011. A blueprint for blue carbon: Toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2. Frontiers in Ecology and the Environment 9.

Mortimer, C.H., 1941. The Exchange of Dissolved Substances Between Mud and Water in Lakes. Journal of Ecology 29, 280-329.

Papaslioti, E.-M., Pérez-López, R., Parviainen, A., Phan, V.T.H., Marchesi, C., Fernandez-Martinez, A., Garrido, C.J., Nieto, J.M., Charlet, L., 2020. Effects of redox oscillations on the phosphogypsum waste in an estuarine salt-marsh system. Chemosphere 242, 125174.

Race, M.S., Christie, D.R., 1982. Coastal zone development: Mitigation, marsh creation, and decision-making. Environmental Management 6, 317-328.

Schoenherr, A.A., 1992. A natural history of California / Allan A. Schoenherr. University of California Press, Berkeley.

Shepard, C.C., Crain, C.M., Beck, M.W., 2011. The Protective Role of Coastal Marshes: A Systematic Review and Meta-analysis. PLOS ONE 6, e27374.

Talley, D., 2000. Ichthyofaunal utilization of newly-created versus natural salt marsh creeks in Mission Bay, CA. Wetlands Ecology and Management 8, 117-132.

Tammeorg, O., Nürnberg, G., Niemistö, J., Haldna, M., Horppila, J., 2020. Internal phosphorus loading due to sediment anoxia in shallow areas: implications for lake aeration treatments. Aquatic Sciences 82, 54.

Xu, T., Weng, B., Yan, D., Wang, K., Li, X., Bi, W., Li, M., Cheng, X., Liu, Y., 2019. Wetlands of International Importance: Status, Threats, and Future Protection. Int J Environ Res Public Health 16.