Shared Beaches, Contrasting Spatial Dynamics: Interannual Nesting Distribution of Shorebirds and Seabirds on an Urban Barrier Peninsula

Rolando Gutierrez[a]; Mariola Camacho-Lie[b]

[a]NGO-Conservation of Endangered Species; [b]Universidad de Guadalajara

Corresponding author: rolando@conservationes.org

This document is presented for the 50th Annual Meeting of the Waterbird Society in Cape May, New Jersey, USA, 2-5 November 2026

Abstract

Barrier beaches provide shared nesting landscapes for shorebirds and seabirds, but these groups may differ in the spatial breadth and interannual consistency of their nesting distributions. We compared 260 nests recorded during the 2025 and 2026 breeding seasons across four sectors of the Rockaway Peninsula, New York City. We quantified proportional nest allocation among sectors, spatial breadth as the number of occupied sectors, and total variation distance between years. Shorebird nests occurred in all four sectors in both years, whereas seabird nests occurred only in the managed urban beach and ocean-facing sectors. Shorebird allocation shifted toward the ocean-facing sector (32.9% to 40.9%) and away from the managed urban sector (35.5% to 25.8%; group D = 0.127). Piping Plover showed the greatest species-level redistribution (D = 0.324), whereas American Oystercatcher remained more spatially consistent (D = 0.108). Seabird nests increased from 45 to 73 but remained strongly concentrated in the managed urban sector (84.4% to 93.2%; group D = 0.087). Least Tern increased from 35 to 65 nests while its proportional distribution remained nearly unchanged (D = 0.009). Common Tern was recorded only in 2025, whereas Black Skimmer was recorded only in 2026. Seabird abundance and composition therefore changed within a persistently concentrated distribution, whereas shorebirds retained broader spatial coverage but showed species-specific redistribution. These exploratory results establish an explicit shorebird-seabird comparison without attributing the observed patterns to unmeasured causal factors.

Keywords: Piping Plover; Least Tern; interannual redistribution; spatial breadth; barrier-beach nesting.

Introduction

Sandy beaches and barrier islands provide essential nesting habitat for shorebirds and seabirds, but they are also dynamic coastal environments subject to recurrent natural and anthropogenic change. Storms, erosion, sediment redistribution, vegetation succession, shoreline stabilization, coastal development, and recreational activity can alter the amount, configuration, and accessibility of nesting habitat over relatively short periods. Along the Atlantic coast of North America, these processes influence species of conservation concern that depend on sparsely vegetated beaches and early-successional coastal habitats. Previous studies have shown that storms and subsequent landscape change can modify the extent and location of Piping Plover habitat, while human activity and protective management may also influence the availability and use of nesting areas (Maslo et al. 2018, Zeigler et al. 2019, Kwon et al. 2021).

Beach-nesting assemblages include species with contrasting forms of spatial organization. American Oystercatcher (*Haematopus palliatus*) and Piping Plover (*Charadrius melodus*) generally establish individual nesting territories across suitable coastal habitat, whereas Common Tern (*Sterna hirundo*), Least Tern (*Sternula antillarum*), and Black Skimmer (*Rynchops niger*) frequently nest in colonies (Palestis 2014, Elliott-Smith and Haig 2020, Gochfeld et al. 2020, Working Group et al. 2020). Tern colony formation and persistence can be influenced by social attraction, group adherence, breeding dispersal, site fidelity, and the availability of suitable colony sites (Palestis

2014). These behavioral differences may produce contrasting spatial patterns even when species occupy the same coastal system. Moreover, species exposed to shared environmental and anthropogenic pressures do not necessarily exhibit parallel responses. For example, long-term monitoring of sympatric Piping Plovers and American Oystercatchers on Atlantic barrier islands revealed contrasting population trajectories under broadly shared conditions (Kwon et al. 2021). Consequently, ecological-group comparisons can reveal broad differences between colonial seabirds and territorial shorebirds, but species-level analyses remain necessary to identify the dynamics underlying those patterns.

Spatial heterogeneity may be important in urban coastal landscapes, where natural beach processes interact with infrastructure, recreation, habitat management, and variation in coastal morphology. Studies of public and urbanized beaches have documented substantial spatial and temporal variation in bird abundance, richness, and species composition among nearby coastal areas (Lafferty et al. 2013, Graells et al. 2022). These findings indicate that apparently continuous shorelines may contain sectors with different habitat conditions and bird assemblages. On the Rockaway Peninsula, previous spatial assessments have also demonstrated variation in the predicted availability of Piping Plover nesting habitat, providing direct evidence that this urban barrier system is not environmentally uniform (Zeigler et al. 2017). However, less is known about whether shorebirds and seabirds exhibit similar spatial breadth and interannual consistency when nesting within the same urban barrier landscape.

Changes in the number of recorded nests do not necessarily correspond to changes in spatial distribution. Nesting activity may increase or decrease while remaining concentrated in the same sectors, whereas similar annual totals may conceal redistribution among sectors or changes in species composition. Distinguishing these dimensions is relevant to monitoring and conservation because spatial concentration and broad spatial use imply different monitoring coverage and management requirements.

We therefore compared the nesting distributions of American Oystercatcher, Piping Plover, Common Tern, Least Tern, and Black Skimmer across four sectors of the Rockaway Peninsula during the 2025 and 2026 breeding seasons. We quantified recorded nest numbers, community composition, proportional allocation among sectors, spatial breadth as the number of occupied sectors, and interannual redistribution using total variation distance. We asked whether shorebirds and seabirds differed in the spatial breadth and interannual consistency of their nesting distributions. The analysis was explicitly exploratory and descriptive: its purpose was to determine what changed in nesting activity, composition, and spatial allocation, without attributing the observed patterns to unmeasured environmental or biological mechanisms.

Study Area

The Rockaway Peninsula, located in Queens, New York City, forms a barrier beach system along the Atlantic coast and constitutes the southern boundary of Jamaica Bay. The peninsula is part of the broader chain of barrier islands extending along the southern shore of Long Island and the eastern seaboard of North America. Its geomorphology reflects long-term coastal processes driven by wave action, littoral drift, and sediment redistribution, which have promoted westward barrier growth and the formation of sandy beaches, dunes, and tidal habitats (Sanderson 2016, Greenlees 2020). These processes continue to shape shoreline morphology and sediment availability, producing substantial spatial variability in beach width and coastal structure over relatively short distances (Wei and Miselis 2022, Janda et al. 2025).

Barrier island systems such as the Rockaway Peninsula are inherently dynamic and shaped by interactions among geological framework, hydrodynamic forcing, and sediment supply. Variability in shoreface morphology and sediment thickness contributes to differences in beach stability and shoreline change rates, influencing how coastal segments respond to storms and sea-level rise (Wei et al. 2021, Wei and Miselis 2022). Along the south shore of Long Island, longshore sediment transport generally moves from east to west, promoting sediment accumulation

near the western end of the peninsula while other segments experience more moderate shoreline change (Janda et al. 2025). These processes are further modified by coastal engineering structures, nourishment projects, and other human interventions that alter sediment fluxes and shoreline morphology.

Beyond natural coastal dynamics, the peninsula lies within one of the most densely populated metropolitan regions in the world. Urban development, coastal infrastructure, and recreational use have substantially modified portions of the coastline while leaving other segments relatively undeveloped. Human alterations to Jamaica Bay, including dredging, inlet stabilization, and land reclamation, have modified hydrodynamics and storm tide propagation, increasing sensitivity to storm surge and coastal flooding (Orton et al. 2020). Consequently, coastal ecosystems in the peninsula reflect a complex interaction between geomorphic processes and anthropogenic pressures.

The system is also highly vulnerable to coastal hazards. Barrier beaches within the Gateway National Recreation Area exhibit varying susceptibility to shoreline change, overwash, and sea-level rise depending on local geomorphology, coastal slope, wave exposure, and historical shoreline change rates (Pendleton et al. 2005). Extreme events such as hurricanes and nor'easters can produce substantial coastal erosion, storm-surge flooding, and rapid morphological change, processes often amplified in densely developed coastal regions of the northeastern United States (Coch 2015).

Within this heterogeneous coastal landscape, four nesting sites were selected to represent contrasting environmental conditions and levels of human influence along the peninsula. In combination, these sites capture a gradient of geomorphological exposure, habitat configuration, and anthropogenic disturbance that enables examination of spatial variation in nesting ecology within a single urban barrier island system:

a) **Beach 37th St.-56th St.** represents a managed urban beach sector characterized by wide sandy beaches, low dune systems, and high recreational use. Although intensively maintained for public access, the site retains open sandy substrates suitable for beach-nesting shorebirds. Nesting habitat is strongly influenced by proximity to infrastructure, boardwalks, and pedestrian access, making this the most urbanized portion of the study system. Previous monitoring indicates that nesting often occurs within relatively small sections of shoreline where management actions such as fencing and symbolic barriers are implemented to reduce disturbance (Arndtsen 2022).

b) **Fort Tilden**, located within the Gateway National Recreation Area, comprises a semi-natural coastal landscape including oceanfront beach, dune systems, maritime vegetation, and adjacent wetlands. Compared with the urban sector, infrastructure density and human disturbance are lower, and dune systems are more structurally developed. Coastal protection structures have been implemented in parts of this site to mitigate storm impacts and protect natural and cultural resources (Bearmore et al. 2016).

c) **Breezy Point Ocean Side** represents a largely undeveloped and highly exposed ocean-facing environment at the western tip of the peninsula. The site contains extensive dune systems and wide beaches shaped primarily by Atlantic wave action and storm-driven processes. Sediment accumulation is influenced by longshore transport and coastal structures such as the Breezy Point jetty, which historically altered patterns of westward barrier growth (Pendleton et al. 2005, Greenlees 2020).

d) **Breezy Point Bay Side** contrasts strongly with the ocean-facing zones, bordering the sheltered waters of Jamaica Bay. This environment is characterized by tidal flats, salt marshes, and narrower sandy margins reflecting estuarine geomorphology rather than open-ocean exposure. Nesting habitat is more spatially constrained than on ocean-facing beaches, and the bay system has experienced substantial geomorphic change and wetland loss over the past century due to both natural processes and human modification (Sanderson 2016, Orton et al. 2020).

Together, these four study sites form a gradient of geomorphological exposure, sediment dynamics, habitat configuration, and anthropogenic pressure. This gradient provides an opportunity to examine how environmental conditions and landscape structure influence the spatial ecology and reproductive investment of beach-nesting shorebirds within a single metropolitan coastal system.

Methodology

Nest records and ecological grouping

This section outlines the methodological framework used to quantify spatial variables associated with shorebird and seabird nesting along the Rockaway Peninsula during the 2025-2026 breeding season. Measurements were designed to ensure high spatial accuracy while minimizing disturbance to nesting birds and preserving the integrity of sensitive reproductive processes. American Oystercatcher and Piping Plover were classified as shorebirds. Common Tern, Least Tern, and Black Skimmer were classified as seabirds.

Nesting monitoring was conducted weekly over a 15-week period from late April to early August 2025 and 15-week period from early May to early August 2026. Surveys covered four focal stretches: Beach 37th St.- 56th St., Fort Tilden, Breezy Point Ocean Side, and Breezy Point Bay Side, totaling approximately 30 observation hours per site across the breeding season. The objective was to precisely identify and geolocate shorebird nests while minimizing human disturbance.

Upon first detection of a new nest, a rangefinder was used to determine distance relative to pre-established seasonal beach nest markers (installed prior to the nesting season at each site), and a GPS unit recorded the nest marker for identifying the precise nesting coordinates once the nesting season was over. To prevent data duplication and reduce disturbance, only the GPS location with the highest egg count was recorded per nest. No repeated nest-level measurements were conducted in subsequent visits, and hatching success was not assessed, as reproductive outcomes were beyond the scope of this study. Importantly, all final nesting GPS coordinates used for analysis were collected after the conclusion of the nesting season to ensure zero disturbance to active nests.

Exploratory spatial analysis

For each species, ecological group, year, and sector, we calculated nest counts and the percentage of annual nests assigned to each sector. Spatial breadth was summarized as the number of sectors with at least one recorded nest. Interannual redistribution was measured using total variation distance (Guerrero et al. 2025):

$$D = \frac{1}{2}\sum_{i}\left|p_{i,2025} - p_{i,2026}\right|$$

where $p_{i,2025}$ and $p_{i,2026}$ are the proportions of nests in sector i during each year. The factor 1/2 prevents the same redistribution from being counted once as a loss and again as a gain. Thus, D ranges from 0, indicating identical proportional distributions, to 1, indicating complete redistribution. D was calculated only for species recorded in both years. All analyses are exploratory and descriptive. We evaluate what changed in abundance, composition, spatial breadth, and allocation; we do not infer why the observed differences occurred.

Results

Spatial distribution within sectors

Nest-location maps complement the sector-level summaries by displaying the recorded configuration within each study unit. They are used here as descriptive evidence only; no within-sector point-pattern statistic or causal environmental model is included in this conference manuscript.

- **Beach 37th-56th St** (Figure 1)**.** This map shows the most visibly aggregated nesting pattern. In both years, Least Tern nests formed compact groups, particularly within the central portion of the beach. American Oystercatcher nests were more widely dispersed and extended across nearly the entire sector. Piping Plover occurred at a smaller number of scattered locations. Common Tern was concentrated mainly toward the eastern portion in 2025, while Black Skimmer appeared in localized central and eastern areas in 2026.

- **Fort Tilden** (Figure 2)**.** Fort Tilden contained only American Oystercatcher and Piping Plover nests. American Oystercatcher was broadly dispersed along the narrow coastal strip in both years, with noticeable gaps between some locations. Piping Plover occurred at fewer points interspersed within the oystercatcher distribution. Its mapped locations also appeared farther east along the sector in 2026 than in 2025.

- **Breezy Point Ocean Side** (Figure 3)**.** Nest locations at Ocean Side followed a more dispersed and linear pattern along the shoreline. American Oystercatcher was distributed across much of the sector in both years. Piping Plover occurred at relatively few locations in 2025 but appeared across a larger portion of the sector in 2026. Common Tern and Least Tern were represented by isolated points or small groups rather than by a dense aggregation.

- **Breezy Point Bay Side** (Figure 4)**.** Bay Side displayed the sparsest and most discontinuous distribution. Nest locations occurred mainly near the northern and southern portions of the sector, while much of the central section contained no recorded nests. American Oystercatcher occurred at widely separated locations. Piping Plover was restricted primarily to the southern portion and was less represented on the 2026 map.

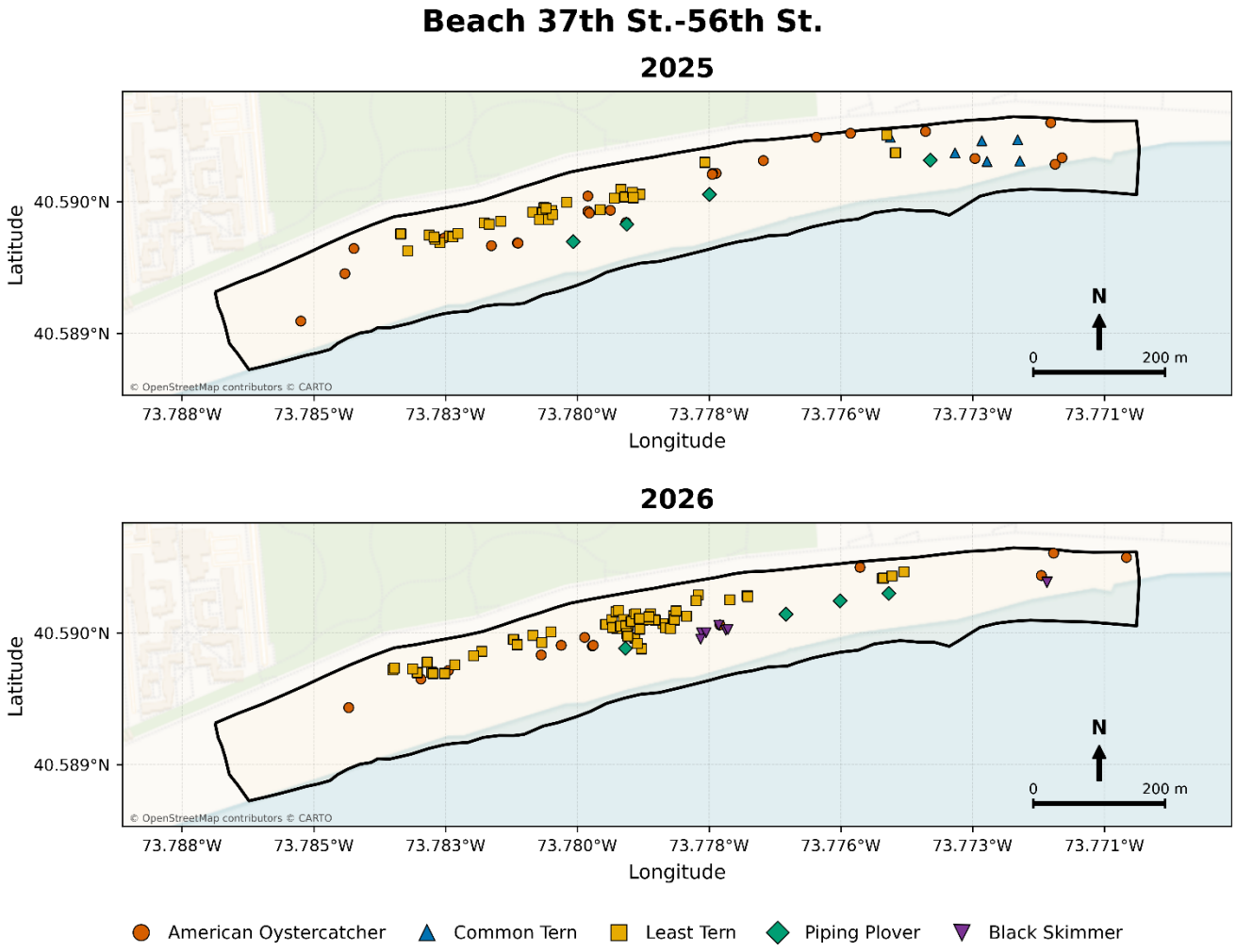

Figure 1. Recorded nest locations at Beach 37th St.-56th St. during 2025 and 2026.

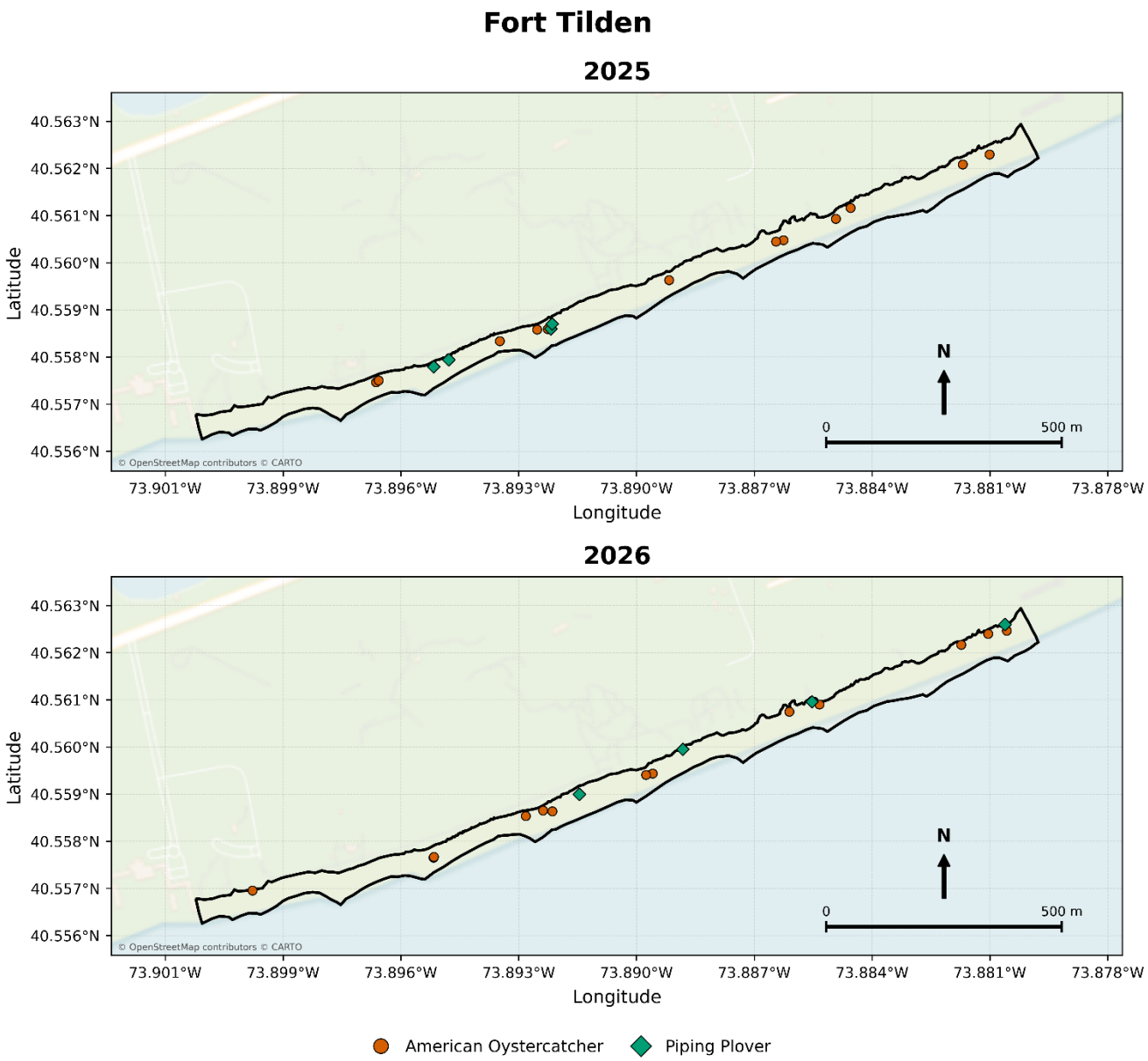

Figure 2. Recorded nest locations at Fort Tilden during 2025 and 2026.

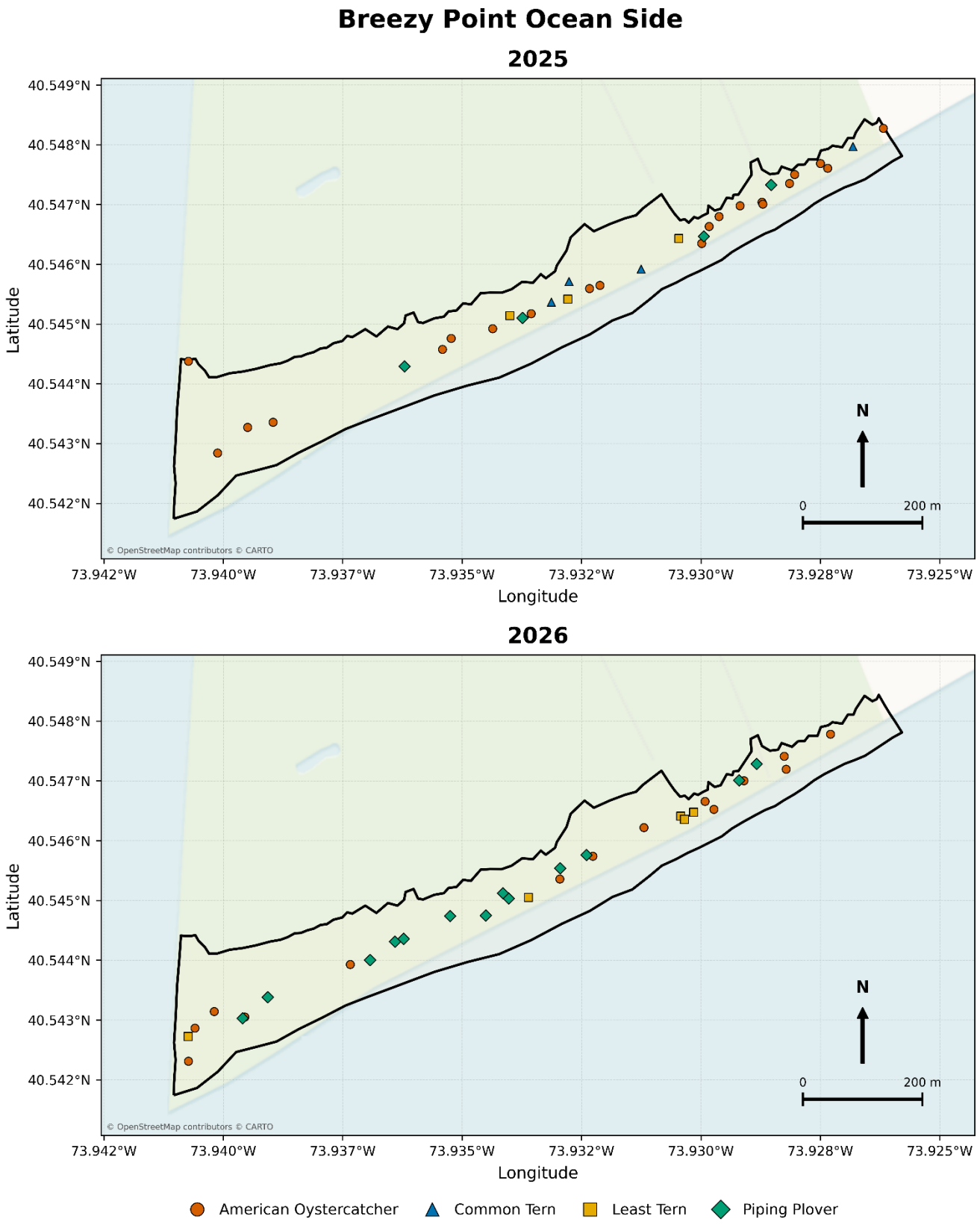

Figure 3. Recorded nest locations Breezy Point Ocean Side during 2025 and 2026.

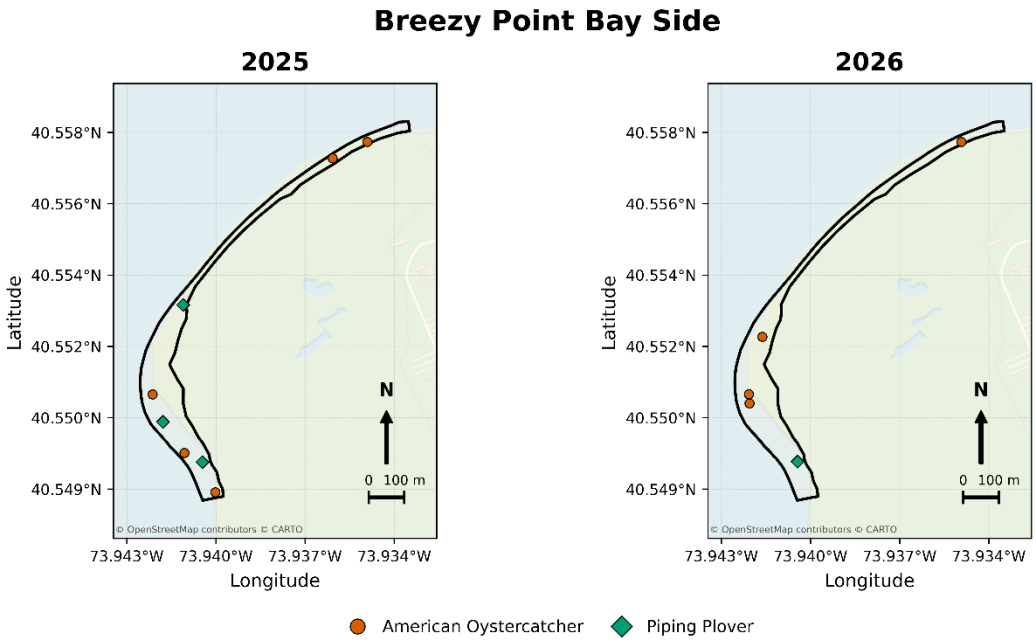

Figure 4. Recorded nest locations at Breezy Point Bay Side during 2025 and 2026.

Interannual Changes in Nesting Activity, Community Composition, and Spatial Allocation Selection

Across the Rockaway Peninsula, total recorded nesting activity increased by 14.9%, from 121 nests in 2025 to 139 in 2026. This increase was accompanied by a change in community composition rather than a uniform increase across ecological groups. Shorebird nests decreased from 76 to 66 (-13.2%), reducing their contribution from 62.8% to 47.5% of all recorded nests between years. Conversely, seabird nests increased from 45 to 73 (+62.2%), and their contribution increased from 37.2% to 52.5% (Table 1).

Table 1. Recorded nest counts and interannual spatial redistribution by ecological group and species. D is total variation distance; NC indicates not calculated because the species was not recorded in both years.

	2025	2026	Nest change	D
Shorebirds	**76**	**66**	**-10 (-13.2%)**	**0.127**
American Oystercatcher	61	44	-17 (-27.9%)	0.108
Piping Plover	15	22	+7 (+46.7%)	0.324
Seabirds	**45**	**73**	**+28 (+62.2%)**	**0.087**
Common Tern	10	0	-10 (-100.0%)	NC
Least Tern	35	65	+30 (+85.7%)	0.009
Black Skimmer	0	8	+8	NC
All nests	121	139	+18 (+14.9%)	-

Despite these contrasting changes in recorded nest numbers, the proportional spatial distributions of both groups retained considerable overlap between years. Shorebirds occupied all four sectors in both years and had a total variation distance of ($D = 0.127$). Their proportional allocation decreased in Beach 37th-56th St. from 35.5% to 25.8%, while increasing in Ocean Side from 32.9% to 40.9% and in Fort Tilden from 21.1% to 25.8%. Seabirds remained restricted to Beach 37th-56th St. and Ocean Side and showed an even smaller group-level redistribution ($D = 0.087$). Their allocation became more concentrated in Beach 37th-56th St., which supported 84.4% of seabird nests in 2025 and 93.2% in 2026 (Figure 5). Thus, the principal group-level contrast was not the magnitude of redistribution, but the broader spatial coverage of shorebirds compared with the restricted concentration of seabirds.

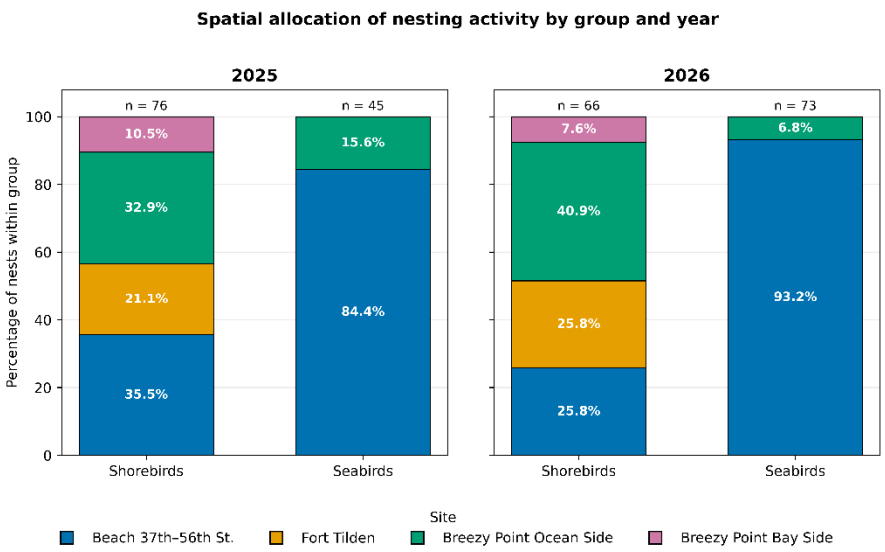

Figure 5. Proportional allocation of shorebird and seabird nests among four Rockaway Peninsula sectors in 2025 and 2026. Each bar totals 100%; n indicates the number of recorded nests.

Species-level results showed that these aggregated group patterns concealed different interannual dynamics. American Oystercatcher occupied all four sectors in both years and maintained a relatively similar proportional distribution ($D = 0.108$), despite declining from 61 to 44 nests. Piping Plover also occupied all four sectors but exhibited the greatest redistribution among species recorded in both years ($D = 0.324$). Its allocation to Ocean Side increased from 26.7% to 59.1%, while its contributions to the other three sectors declined. In contrast, Least Tern increased from 35 to 65 nests but retained an almost identical proportional distribution ($D = 0.009$); more than 91% of its nests occurred in Beach 37th-56th St. in both years. Common Tern was recorded in two sectors only in 2025, whereas Black Skimmer was recorded exclusively in Beach 37th-56th St. in 2026. Consequently, seabird species composition changed between years while the group remained spatially concentrated in the same portion of the peninsula (Figure 2).

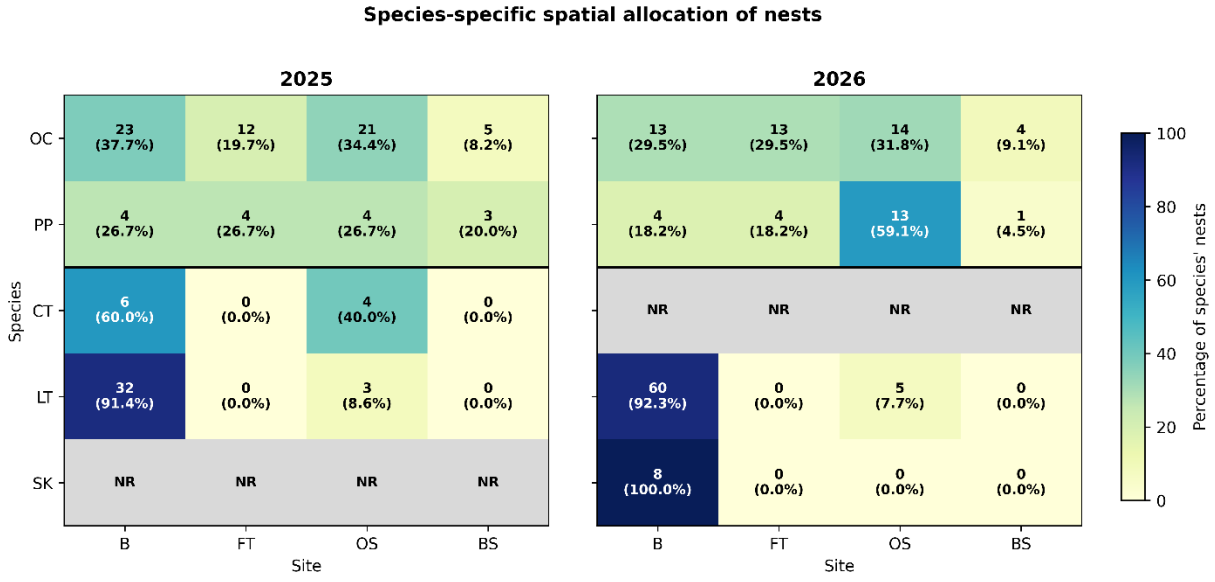

Figure 6. Species-specific allocation of recorded nests among four Rockaway Peninsula sectors in 2025 and 2026. Cells show the nest count and percentage of each species' annual total. Shorebirds, shown above the horizontal line, include American Oystercatcher (OC) and Piping Plover (PP); seabirds include Common Tern (CT), Least Tern (LT), and Black Skimmer (SK). B = Beach 37th-56th St.; FT = Fort Tilden; OS = Breezy Point Ocean Side; BS = Breezy Point Bay Side; NR = Not Recorded.

Discussion

Contrasting Spatial Organization within a Shared Barrier-Beach Landscape

The mapped nest locations indicate that nesting activity was spatially structured within the Rockaway Peninsula rather than uniformly distributed across apparently continuous beach habitat. The most conspicuous contrast occurred between the compact Least Tern aggregations at Beach 37th-56th St. and the broader, more dispersed distribution of American Oystercatcher across several sectors. This pattern is consistent with fundamental differences between colonial and territorial nesting strategies. Tern colonies are influenced by social attraction, group adherence, site fidelity, and the availability of suitable colony sites, which can produce strongly localized nesting aggregations (Palestis 2014). In contrast, American Oystercatcher nests were distributed as separated locations along extensive sections of shoreline. Piping Plover exhibited an intermediate and more variable configuration, occurring at scattered locations in multiple sectors and appearing more broadly distributed at Ocean Side in 2026. Previous research has similarly shown that sympatric Piping Plovers and American Oystercatchers can exhibit contrasting responses within shared barrier-island environments (Kwon et al. 2021).

Differences among the four maps further suggest that the study sectors were not interchangeable components of the nesting landscape. Beach 37th-56th St. contained the clearest colonial aggregation and the greatest mixture of species, Ocean Side supported a more diffuse multispecies distribution, and Fort Tilden and Bay Side were used exclusively by shorebirds. This interpretation is consistent with studies showing that environmental heterogeneity and human modification can produce distinct bird assemblages within urban coastal systems (Lafferty et al. 2013, Graells et al. 2022). Research on Atlantic barrier islands, including the Rockaway Peninsula, also demonstrates that potential Piping Plover nesting habitat is spatially heterogeneous and can change across the landscape (Zeigler et al. 2017). Therefore, the maps support viewing Rockaway as a spatial mosaic in which different sectors contribute differently to colonial concentration, dispersed nesting, and overall species coverage. However, the mapped distributions do not identify the mechanisms producing these patterns. Habitat availability, vegetation, substrate, disturbance, flooding, predation, and interactions among species would need to be evaluated before attributing the observed configurations to habitat selection or ecological processes.

Decoupling of Nest Numbers, Composition, and Spatial Redistribution

The principal finding was that changes in recorded nest numbers, community composition, and spatial allocation did not occur in parallel. Least Tern provided the clearest example: its recorded nesting activity increased substantially, but less than 1% of its proportional sector allocation changed between years ($D = 0.009$). At the seabird group level, the disappearance of Common Tern records and appearance of Black Skimmer records produced compositional turnover without altering the location of the principal nesting concentration. Conversely, Piping Plover showed only a moderate increase in nest numbers but the greatest spatial redistribution ($D = 0.324$), meaning that approximately 32.4% of its proportional allocation would need to be reassigned among sectors for the two annual distributions to coincide. These results demonstrate why nest totals alone cannot distinguish population-level change from redistribution and why comparisons of proportional distributions provide complementary information about temporal turnover (Yuan et al. 2016).

The restricted seabird distribution, particularly the consistent concentration of Least Tern in Beach 37th-56th St., is compatible with the colonial nesting behavior of terns. Colony-site selection, social attraction, group adherence, and site fidelity can maintain concentrated distributions even when colony size changes between years (Palestis 2014). However, the current results do not establish which of these mechanisms produced the Rockaway pattern. In contrast, shorebirds maintained broader sector coverage, but their species-level responses were not uniform. The relative consistency of American Oystercatcher and stronger redistribution of Piping Plover agree with

evidence that sympatric beach-nesting shorebirds can follow contrasting trajectories under shared environmental and anthropogenic pressures (Kwon et al. 2021). Therefore, ecological groups provided a useful broad comparison, but species-level analyses were necessary to reveal the dynamics underlying each group.

The contrasting contributions of the four sectors further indicate that the Rockaway Peninsula should not be interpreted as homogeneous or spatially interchangeable nesting habitat. Studies of urban coastal environments have similarly documented differences in bird composition and habitat use among nearby areas with different environmental characteristics and levels of human modification (Lafferty et al. 2013, Graells et al. 2022). Moreover, standardized habitat assessments have demonstrated spatial variation in potential Piping Plover nesting habitat across Atlantic barrier islands and specifically within the Rockaway Peninsula (Zeigler et al. 2017). Our findings extend this perspective by showing that the same sectors contributed differently to seabird concentration, shorebird spatial breadth, and species-specific redistribution across two breeding seasons.

These contrasting patterns have direct implications for monitoring and conservation. The continued concentration of seabirds in a limited portion of the peninsula supports sustained protection of core nesting areas because localized disturbance or habitat loss could affect a large proportion of recorded seabird nesting activity. Shorebird management, however, should retain surveillance and response capacity across all four sectors because the location of nesting activity, particularly for Piping Plover, can change between seasons. This combination of stable core protection and flexible peninsula-wide monitoring is consistent with evidence that managing human activities can expand suitable nesting opportunities for Least Tern and Piping Plover and improve habitat conditions for American Oystercatcher and Black Skimmer (Maslo et al. 2018). Nevertheless, the present analysis does not identify the causes of redistribution or demonstrate differences in habitat quality or reproductive success. Habitat availability, disturbance, vegetation, substrate, flooding, predation, survey effort, and nest fate should therefore be evaluated before attributing the observed patterns to specific ecological mechanisms.

Conservation and Management Implications

The contrasting distributions support a spatially differentiated approach to conservation. Beach 37th-56th St. should be recognized as a core seabird nesting sector because it supported 84.4-93.2% of recorded seabird nests and more than 90% of Least Tern nests in both years. Maintaining consistent seasonal protection of this concentration area should therefore remain a priority. Where locally documented threats warrant intervention, protection may include clearly marked nesting areas and management of recreational access and other sources of disturbance. Ocean Side should also remain within seabird monitoring because it was the only additional sector used by this group. Maintaining more than one protected nesting opportunity is consistent with the connected-colony perspective recommended for tern conservation (Palestis 2014) and with evidence that management of human activities can increase available nesting habitat for Least Tern and other beach-nesting species (Maslo et al. 2018).

Shorebird conservation requires a broader and more flexible spatial approach. American Oystercatcher and Piping Plover occupied all four sectors, and Piping Plover exhibited substantial redistribution between years. Protection should therefore not be based exclusively on the sectors or nest locations used during the preceding season. Peninsula-wide pre-breeding surveys and adjustment of protective areas as territories, nests, and broods are detected would better accommodate interannual changes in distribution. Management should also consider connections among nesting, brood-rearing, roosting, and foraging habitats because shorebirds may use important areas beyond protected nest sites, and habitat requirements can vary among behavioral and reproductive stages (Monk et al. 2020, Robinson et al. 2021).

Future monitoring should maintain comparable survey effort among sectors and years while recording nest numbers, occupied sectors, nest fate, hatching and fledging success, habitat conditions, flooding, predators, and

indicators of human disturbance. Annual proportional allocation can identify spatial redistribution, whereas demographic measurements are needed to determine whether occupied sectors provide productive habitat. Because the present baseline comprises only two breeding seasons, a fixed management threshold would be premature. Continued standardized monitoring would establish the expected range of interannual variability and allow unusual redistribution or loss of use from a core sector to trigger targeted field assessment and management review (Brush et al. 2019, Walters et al. 2020).

Conclusions

Across two breeding seasons, shorebirds and seabirds exhibited contrasting spatial dynamics within the same urban barrier-beach system. Seabird nesting activity increased, and species composition changed, yet proportional allocation remained strongly concentrated in Beach 37th-56th St. Least Tern provided the clearest evidence that nest numbers and spatial distribution can change independently: recorded nests increased substantially while sector allocation remained nearly unchanged. Shorebirds retained broader coverage across all four sectors, but their interannual dynamics differed by species. American Oystercatcher remained comparatively consistent, whereas Piping Plover showed the greatest redistribution, principally toward Ocean Side.

These findings demonstrate that nest numbers, community composition, spatial breadth, and proportional redistribution represent complementary dimensions of change. They also indicate that the four sectors are not interchangeable: some maintain concentrated seabird nesting, while others contribute to the broader and more variable distribution of shorebirds. The results support sustained protection of the seabird concentration area together with flexible, peninsula-wide monitoring for shorebirds. Because the study included only two seasons and did not evaluate habitat availability, detection probability, disturbance, or reproductive success, the observed differences should be interpreted as an exploratory baseline rather than as long-term trends or evidence of causal mechanisms distribution or loss of use from a core sector to trigger targeted field assessment and management review (Brush et al. 2019, Walters et al. 2020).

Acknowledgments

The NGO Conservation of Endangered Species led this research, contributing to the United Nations Sustainable Development Goals, particularly SDG 14 (Life Below Water) and SDG 15 (Life on Land), through applied research supporting shorebird and seabird conservation. We thank the U.S. National Park Service and New York City Parks and Recreation for their commitment to protect coastal ecosystems.

References

Arndtsen, C. (2022). The Role of Nest Location on the Reproductive Success of Piping Plovers Breeding at Rockaway Beach, New York. [Online.] Available at https://academicworks.cuny.edu/hc_sas_etds/927.

Bearmore, B., B. Ozolin, and P. Sacks (2016). Fort Tilden Historical Bulkhead Assessment. *American Society of Civil Engineers*:744–751.

Brush, J. M., R. A. Pruner, and M. J. L. Driscoll (2019). GoMAMM Strategic Bird Monitoring Guidelines: Shorebirds. In *Strategic Bird Monitoring Guidelines for the Northern Gulf of Mexico* (R. R. Wilson, A. M. V. Fournier, J. S. Gleason, J. E. Lyons and M. S. Woodrey, Editors). 1st edition. Mississippi Agricultural and Forestry Experiment Station Research Bulletin 1228, pp. 171–202.

Coch, N. K. (2015). Unique Vulnerability of the New York–New Jersey Metropolitan Area to Hurricane Destruction. *Journal of Coastal Research* 31:196–212.

Elliott-Smith, E., and S. M. Haig (2020). Piping Plover (Charadrius melodus), version 1.0. *Birds of the World*. https://doi.org/10.2173/bow.pipplo.01

Gochfeld, M., J. Burger, and K. L. Lefevre (2020). Black Skimmer (Rynchops niger), version 1.0. *Birds of the World*. https://doi.org/10.2173/bow.blkski.01

Graells, G., J. L. Celis-Diez, D. Corcoran, and S. Gelcich (2022). Bird Communities in Coastal Areas. Effects of Anthropogenic Influences and Distance From the Coast. *Frontiers in Ecology and Evolution* 10:1–10.

Greenlees, K. (2020). Panarchy on the Peninsula: Rockaways' Risk, Response and Resilience Following Superstorm Sandy. [Online.] Available at https://www.researchgate.net/publication/346574156.

Guerrero, M. J., C. Sánchez-Giraldo, C. A. Uribe, V. M. Martínez-Arias, and C. Isaza (2025). Graphical representation of landscape heterogeneity identification through unsupervised acoustic analysis. *Methods in Ecology and Evolution* 16:1255–1272.

Janda, C. N., J. A. Warrick, D. Buscombe, and S. Batiste (2025). Shoreline Change of Western Long Island, New York, from Satellite-Derived Shorelines. *Coasts* 5:1–29.

Kwon, E., S. Robinson, C. E. Weithman, D. H. Catlin, S. M. Karpanty, J. Altman, T. R. Simons, and J. D. Fraser (2021). Contrasting long-term population trends of beach-nesting shorebirds under shared environmental pressures. *Biological Conservation* 260:109178.

Lafferty, K. D., D. A. Rodriguez, and A. Chapman (2013). Temporal and spatial variation in bird and human use of beaches in southern California. *SpringerPlus* 2:38.

Maslo, B., K. Leu, T. Pover, M. A. Weston, and T. A. Schlacher (2018). Managing birds of conservation concern on sandy shores: How much room for future conservation actions is there? *Ecology and Evolution* 8:10976–10988.

Monk, J. D., E. Kwon, A. Derose-Wilson, S. G. Robinson, H. A. Bellman, S. M. Karpanty, D. H. Catlin, and J. D. Fraser (2020). Extensive Use of Intertidal Habitat by Shorebirds Outside Protected Nesting Areas. *The Journal of Wildlife Management* 84:1338–1347.

Orton, P. M., E. W. Sanderson, S. A. Talke, M. Giampieri, and K. MacManus (2020). Storm tide amplification and habitat changes due to urbanization of a lagoonal estuary. *Natural Hazards and Earth System Sciences* 20:2415–2432.

Palestis, B. G. (2014). The role of behavior in tern conservation. *Current Zoology* 60:500–514.

Pendleton, E. A., E. R. Thieler, and S. J. Williams (2005). Coastal vulnerability assessment of Gateway National Recreation Area (GATE) to sea-level rise. U.S. Geological Survey 2004–1257.

Robinson, S., H. Bellman, K. Walker, D. Catlin, S. Karpanty, S. Ritter, and J. Fraser (2021). Adult piping plover habitat selection varies by behavior. *Ecosphere* 12:e03870.

Sanderson, E. W. (2016). Cartographic Evidence for Historical Geomorphological Change and Wetland Formation in Jamaica Bay, New York. *Northeastern Naturalist* 23:277–304.

Walters, J. R., A. A. Dayer, S. J. Dinsmore, M. H. Godfrey, C. L. Gratto-Trevor, E. Nol, and S. R. Riggs (2020). Evaluating Past and Present Management of Beach-Nesting Wildlife Species at the Cape Hatteras National Seashore. [Online.] Available at https://americanornithology.org/wp-content/uploads/2020/08/CAHA-report_final-AOS.pdf.

Wei, E. A., J. L. Miselis, and A. S. Forde (2021). Shoreface and Holocene sediment thickness offshore of Rockaway Peninsula, New York. U.S. Geological Survey 2021–1100.

Wei, E., and J. Miselis (2022). Geologic Framework, Anthropogenic Impacts, and Hydrodynamics Contribute to Variable Sediment Availability and Shoreface Morphology at the Rockaway Peninsula, NY. *Journal of Marine Science and Engineering* 10:1–26.

Working Group, A. O., E. Nol, and R. C. Humphrey (2020). American Oystercatcher (Haematopus palliatus), version 1.0. *Birds of the World*. https://doi.org/10.2173/bow.ameoys.01

Yuan, Y., S. T. Buckland, P. J. Harrison, S. Foss, and A. Johnston (2016). Using Species Proportions to Quantify Turnover in Biodiversity. *Journal of Agricultural, Biological, and Environmental Statistics* 21:363–381.

Zeigler, S. L., B. T. Gutierrez, E. J. Sturdivant, D. H. Catlin, J. D. Fraser, A. Hecht, S. M. Karpanty, N. G. Plant, and E. R. Thieler (2019). Using a Bayesian network to understand the importance of coastal storms and undeveloped landscapes for the creation and maintenance of early successional habitat. *PLOS ONE* 14:e0209986.

Zeigler, S. L., E. R. Thieler, B. T. Gutierrez, N. G. Plant, M. Hines, J. D. Fraser, D. H. Catlin, and S. M. Karpanty (2017). Smartphone technologies and Bayesian networks to assess shorebird habitat selection. *Wildlife Society Bulletin* 41:666–677.