Topography and Shoreline Position Are Associated with Hurricane Flood Exposure of Beach-Nesting Birds on an Urban Barrier Island

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Introduction

Measurements of distance to high tide, nest elevation, and spatial location allow us to assess nest vulnerability under hurricane-storm scenarios. These data help compare managed urban and natural beaches, evaluate coastal habitat resilience to extreme events, and improve predictions of climate-change impacts on the Rockaway Peninsula.

Study Area

- **Beach 37th–56th St.**: Managed urban beach with wide sand, low dunes, high recreation, and nearby infrastructure.
- **Breezy Point Ocean Side**: Exposed, largely undeveloped oceanfront with wide beaches, extensive dunes, and strong Atlantic influence.

Methodology

- **Nest Monitoring:** Weekly surveys for 15 weeks recorded species, egg counts, and new nests while minimizing disturbance.
- **Spatial Location:** GPS and rangefinder measurements documented precise nest locations and distances.
- **Tidal & Storm Exposure:** GPS mapping recorded maximum high-tide lines and Hurricane Erin flooding extent (August 21, 2025).
- **Beach Slope:** Rangefinder measurements were used to calculate slope at each nest location and assess potential flooding exposure:

$$\theta = \tan^{-1}\frac{h}{R}$$

where h represents the elevation differential and R the horizontal distance measured by the rangefinder.



Statistical Analysis

- **Descriptive Analysis:** Compared nest elevation and distance to high tide between the urban and natural beaches.
- **Correlation & Regression:** Evaluated relationships between local beach slope and distance to the high-tide line.
- **Spatial Structure:** Moran's I with permutation tests was used to evaluate spatial autocorrelation in shoreline distance and local beach slope across neighborhood distances of 50–200 m.
- **Storm-Flood Exposure:** Nest locations were classified as exposed or unexposed using the observed Hurricane Erin flood extent. Within Beach 37th–56th St., exposed and unexposed locations were compared using Mann–Whitney U tests and rank-biserial effect sizes.

Main Results

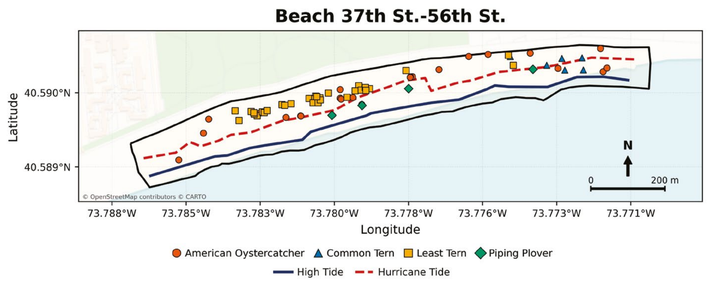

Figure 1. **Nest locations and coastal flood lines at Beach 37th–56th St.:** Nest locations were distributed across a wider range of shoreline positions, with only part of the nesting area intersecting the Hurricane Erin flood extent.

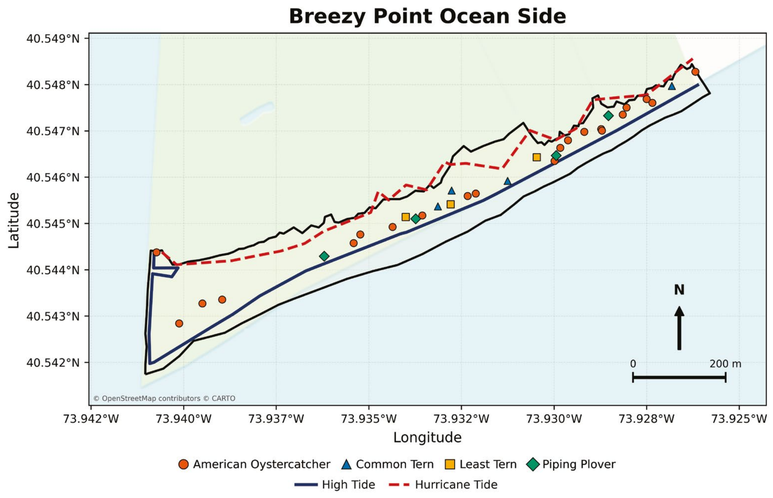

Figure 2. **Nest locations and coastal flood lines at Breezy Point Ocean Side:** Nest locations occurred closer to the shoreline, and the Hurricane Erin flood extent encompassed the sampled nesting area.



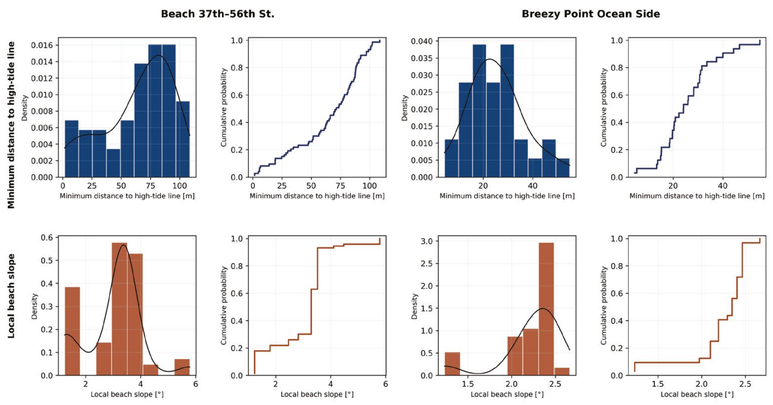

Figure 3. **Topographic Differences:** Beach 37th–56th St. showed wider variation in high-tide distance and local beach slope, while Ocean Side was more clustered, with nest locations generally closer to the high-tide line and local slopes concentrated around 2.0–2.6°.

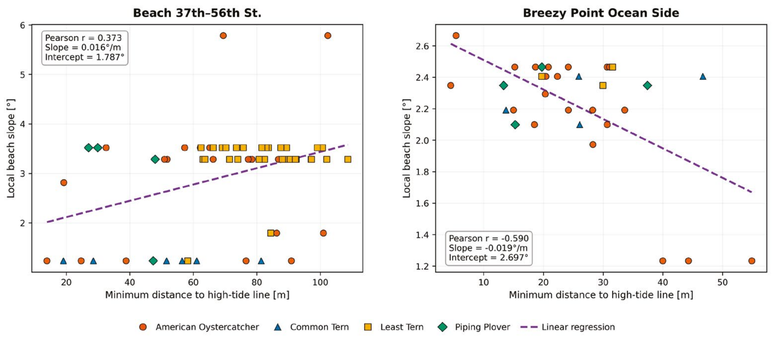

Figure 4. **Local Slope–Distance Relationship:** Beach 37th–56th St. showed a moderate positive relationship, with nest locations farther from the high-tide line generally occurring on steeper local slopes. In contrast, Breezy Point Ocean Side showed a moderate negative relationship, indicating a different spatial organization of shoreline distance and local beach slope.



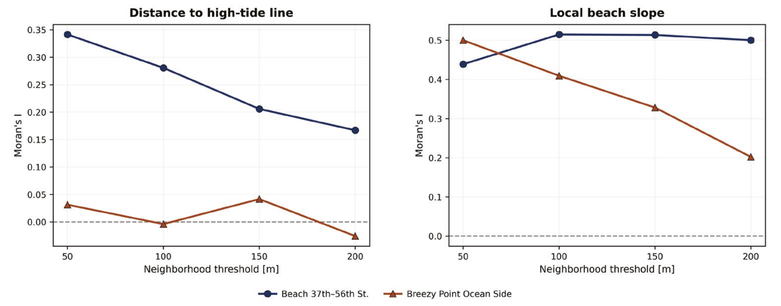

Figure 5. **Spatial autocorrelation of nest-site conditions across neighborhood thresholds:** Moran's I was evaluated using cumulative neighborhood thresholds of 50–200 m with permutation tests. Shoreline distance showed consistent positive spatial autocorrelation at Beach 37th Street to 57th Street, but no significant spatial autocorrelation was detected at Breeze Point Ocean Side. Local beach slope was positively spatially autocorrelated at both sites across all evaluated thresholds.

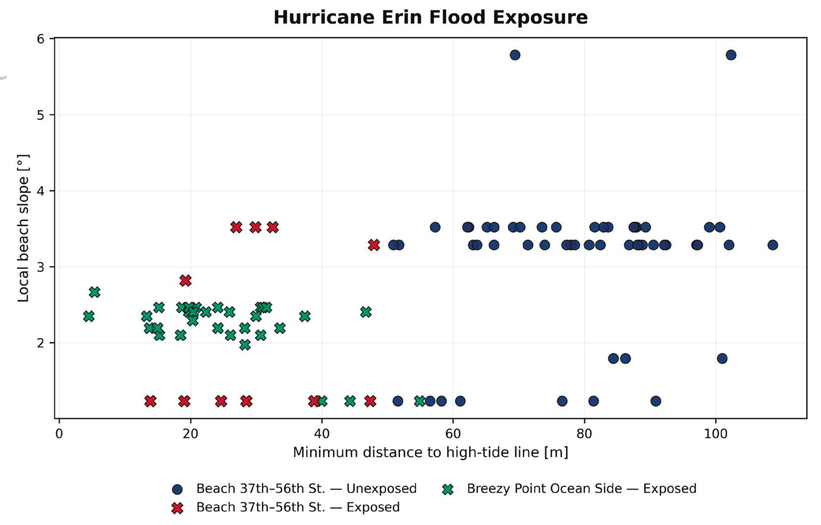

Figure 6. **Hurricane Erin flood exposure in relation to nest-site conditions:** Nest locations are shown according to shoreline distance and local beach slope. Hurricane Erin flood exposure encompassed 11 of 65 nest locations (16.9%) at Beach 37th–56th St. and all 32 nest locations (100%) at Breezy Point Ocean Side. At Beach 37th Street to 57th Street, exposed locations occurred closer to the high-tide line than unexposed locations, whereas local beach slope showed greater overlap between exposure groups.

Variable	Exposed	Unexposed	p-value	$\lvert r_{rb} \rvert$
Shoreline distance	28.5 m	81.5 m	<0.001	1.000
Local beach slope	1.23°	3.29°	0.032	0.394

Table 1. **Nest-site conditions by Hurricane Erin flood exposure at Beach 37th–56th St.:** Values are medians. Exposed and unexposed nest locations were compared using two-sided Mann–Whitney U tests; $\lvert r_{rb} \rvert$ represents the absolute rank-biserial effect size. Breezy Point Ocean Side was not tested because all nest locations were exposed.



Geomorphology and Nest Vulnerability a *Spatial Structure and Flood Exposure*

Nest-site conditions showed distinct spatial structure between beaches. Local beach slope was spatially structured at both sites, while shoreline distance showed consistent structure only at Beach 37th–56th St. Flood exposure differed between sites and, within Beach 37th–56th St., was most clearly associated with shoreline position, while local slope showed a weaker pattern.

Fine-scale physical heterogeneity can create areas of contrasting flood exposure within coastal nesting habitat. Recognizing this variation may help identify less-exposed nesting areas and support spatially targeted monitoring and management.

Acknowledgments

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