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Outdoor Recreation Study: Counter Calibration and Visitor Assessment Report

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Corresponding Author

Aleia Clark Fobia, NOAA NCCOS
aleia.fobia@noaa.gov

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Outdoor Recreation Study:
Counter Calibration and Visitor Assessment Report

Authors

Ramesh Paudyal,[1] Sarah Ball Gonyo,[2] and Aleia Clark Fobia[2]

[1] *CSS, Inc., under contract to NOAA, National Ocean Service, National Centers for Coastal Ocean Science*
[2] *NOAA, National Ocean Service, National Centers for Coastal Ocean Science*

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Background

Understanding the timing and location of visits to coastal and marine recreational areas is crucial for effective natural resource management and improving visitor experiences. To this end, the National Oceanic and Atmospheric Administration (NOAA) National Centers for Coastal Ocean Science (NCCOS) deployed vehicle and pedestrian counters in specific parks and natural areas. These installations were strategically located around the York River in Virginia (Figure 1) and within the Grand Bay National Estuarine Research Reserve (NERR) in Mississippi (Figure 2), enabling the collection of comprehensive visitation data.

The York River, extending approximately 34 mi from its headwaters to the Chesapeake Bay, encompasses numerous parks and natural areas, providing a diverse range of recreational opportunities. Similarly, the Grand Bay NERR in southeastern Mississippi is a picturesque coastal region renowned for its rich biodiversity and various outdoor recreation opportunities. Jointly managed by the Mississippi Department of Marine Resources and NOAA, the Grand Bay NERR offers educational programs and trails that emphasize the ecological significance of estuaries, fostering public engagement and nature-based tourism along the Gulf Coast.

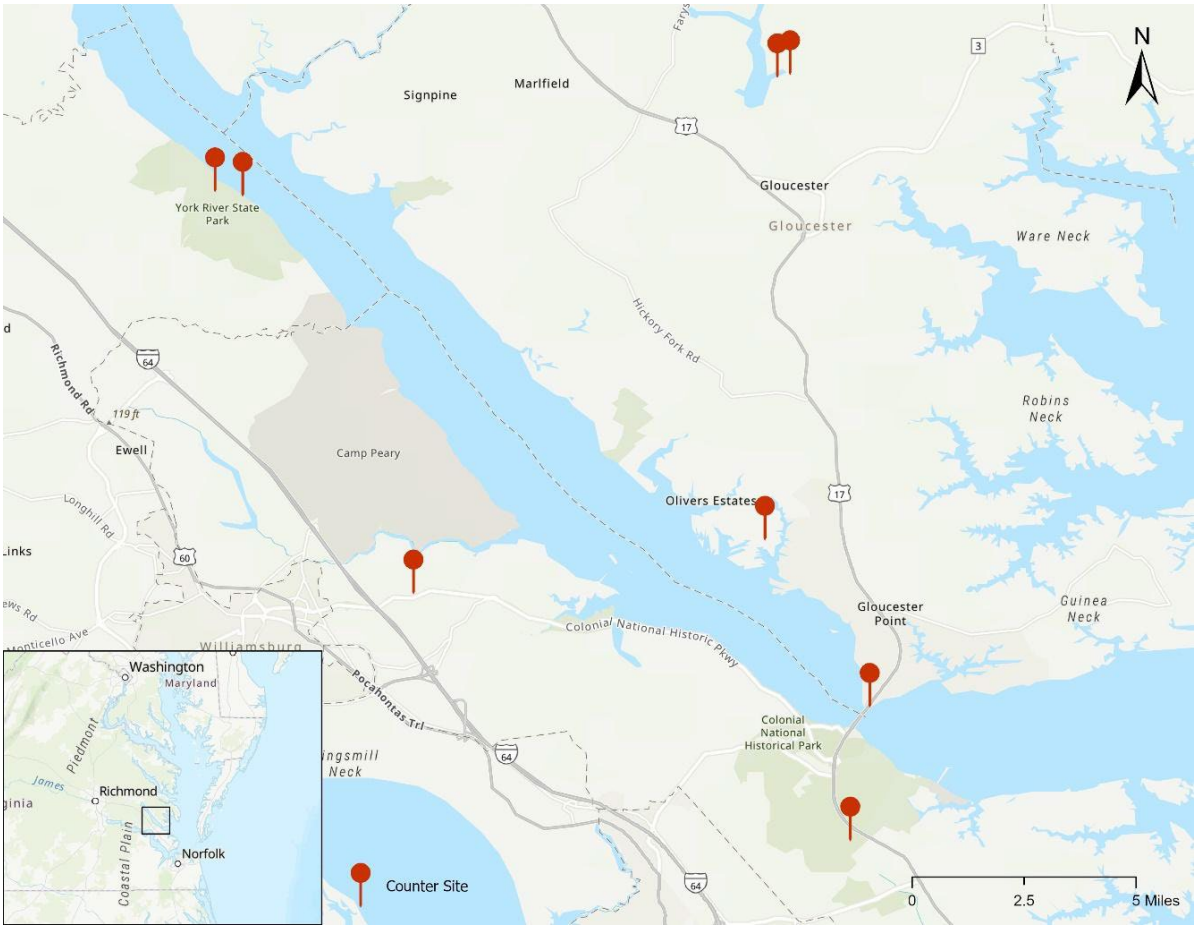

Figure 1. Vehicle and pedestrian counter locations in coastal Virginia.

Figure 2. Pedestrian counter locations in Grand Bay NERR.

In Virginia, counters were installed across two state parks, three county parks, and one national park (Table 1). In Grand Bay, one counter was placed at the Savanna Trail Boardwalk near the visitor center, with a second counter placed along the Savanna Trail Loop. Three distinct types of counters were utilized: TRAFx vehicle counters, TRAFx pedestrian counters, and Eco-Counter PYRO-Box Evo pedestrian counters. TRAFx vehicle counters operate using electromagnetic sensors, detecting vehicles when they pass within a predetermined distance (e.g., 10 ft). In contrast, pedestrian counters, including both TRAFx and Eco-Counter models, detect movement via infrared sensors. Data collection for this initiative took place from February 2024 to March 2025 in Virginia, and from March 2024 to April 2025 in Grand Bay.

Table 1. Park sites and types of counters installed in coastal Virginia.

Park	Site	Counter coordinates	Counter type	Count mode
York River State Park	Taskinas Creek Trail	37.41207, −76.71504	TRAFx pedestrian	Two-way
	Fossil Beach Trail	37.41064, −76.70612	TRAFx pedestrian	Two-way
Machicomoco State Park	Interpretive Area	37.29967, −76.53751	TRAFx vehicle	Two-way
Colonial National Historical Park	Yorktown – Historical Tour Road	37.20262, −76.50994	TRAFx vehicle	One-way
Gloucester Point Beach Park	Parking lot entrance	37.24576, −76.50366	TRAFx vehicle	One-way
New Quarter Park	Lakeshead Drive (park entrance)	37.28234, −76.65098	TRAFx vehicle	Two-way
Beaverdam Park	Main Entrance Trailhead (joint trailhead for Nature Trail and Hiking Trail)	37.44890, −76.53348	Eco-Counter pedestrian	Two-way
	Hiking and Nature Trail	37.44986, −76.52938	Eco-Counter pedestrian	Two-way
Grand Bay NERR	Savanna Trail Boardwalk	30.42937, −88.42854	Eco-Counter pedestrian	Two-way
	Savanna Trail Loop	30.43191, −88.42766	Eco-Counter pedestrian	Two-way

Methods

Counter Installation and Setup

Counters were installed in Virginia from February 26–28, 2024, and in Grand Bay on March 13, 2024. TRAFx vehicle counters were installed along roadsides either underground—enclosed in utility valve boxes—or above ground, fastened to trees or wooden posts (Figure 3). In both installation types, the counters were protected from moisture using waterproof polyvinyl chloride (PVC) enclosures and desiccants. The placement and configuration of these counters were customized based on the width of the road, proximity to stop signs or parking lots, and the expected speed of passing vehicles. Vehicle counters were programmed to collect hourly data and were set to either one-way or two-way mode, depending on the anticipated flow of traffic. In two-way mode, the counters recorded vehicles traveling in both directions; in one-way mode, they captured traffic in a single direction only.

Figure 3. TRAFx vehicle counter installation in Machicomoco State Park Interpretive Area (left; credit: Ramesh Pauydal, CSS/NOAA NCCOS) and in New Quarter Park along Lakeshead Drive (right; credit: Ramesh Pauydal, CSS/NOAA NCCOS).

TRAFx pedestrian counters, enclosed in metal switch boxes, were mounted to trees or wooden posts. These were installed within the manufacturer's recommended maximum distance of 10 ft from the far edge of the trail. Eco-Counters, housed in recycled posts, were placed in ground within 15 ft of the trail's far edge. Both Eco-Counter and TRAFx pedestrian counters' sensors were positioned at the recommended waist height of 3.3 ft above ground. Given that the boardwalk at Grand Bay was elevated approximately 1.5 ft above ground, a 4 in. × 4 in. wooden post was first installed to raise the recycled counter post to the correct height (Figure 4). All pedestrian counters were configured to operate in two-way mode, capturing hourly counts of total incoming and outgoing foot traffic.

Following installation at all sites, all counters underwent field testing following procedures described in Ross (2005). Pedestrian counters were walk-tested by passing in front of them on foot at least 10 times, ensuring the devices accurately detected people at varying speeds, directions (entry versus exit), and distances from the sensor. Similarly, vehicle counters were drive-tested by passing vehicles at least 10 times under varied conditions. These tests ensured the counters were properly detecting and recording traffic before the start of formal data collection.

Figure 4. Eco-Counter pedestrian counter installation at Grand Bay Boardwalk Trail (left; credit: Ramesh Pauydal, CSS/NOAA NCCOS) and TRAFx pedestrian counter installation at York River State Park Taskinas Creek Trail (right; credit: Ramesh Pauydal, CSS/NOAA NCCOS).

Data Collection

Coordination occurred with staff from each park where counters were installed to download data, ensure counter safety, and conduct regular observations of people or vehicles for calibration purposes. Data from TRAFx counters were manually downloaded each month using the TRAFx data logger. Data from the Eco-Counters in Grand Bay were downloaded using Eco-Link Evo, the Eco-Counter's cell phone app via a Bluetooth connection, whereas data from the Eco-Counters in Virginia were downloaded remotely through Eco-Visio, Eco-Counter's web platform. Each month, data from all counters were

reviewed for anomalies, such as unusual counts or missing data, and any issues were resolved promptly. NCCOS staff visited the sites occasionally to monitor counter status, replace batteries, and observe vehicles or people for data calibration.

With the exception of York River State Park Fossil Beach Trail, data collections in all counter sites in Virginia were concluded, and counters were removed on March 11–13, 2025. The Fossil Beach Trail had been closed to visitors from mid-February to mid-April 2024 for trail restoration, so data collection at this site was extended through May 13, 2025, to allow for a complete year of observations. In Grand Bay, the data collection was concluded on April 14, 2025.

For each site, hourly counter and observational data were compiled and formatted for analysis. For the purpose of this analysis, data from Fossil Beach Trail were filtered from May 1, 2024, to April 30, 2025, whereas data from all other sites in Virginia were filtered from March 1, 2024, to February 28, 2025, to cover a full 12-month period of data collection. Similarly, data from Grand Bay counters were filtered from April 1, 2024, to March 31, 2025. These datasets were used to estimate calibrated daily, monthly, and annual visitation totals.

The TRAFx counters were not equipped with the ability to detect travel direction. Thus, the hourly counter data downloaded from the two-way–mode TRAFx counters included incoming and outgoing total visitors. However, the Eco-Counter model used in this study was equipped with the ability to detect travel direction and reported incoming (IN) and outgoing (OUT) counts separately. Thus, total hourly counts of each Eco-Counter were calculated as below:

$$Total\ hourly\ counts\ =\ IN\ +\ OUT$$

Calibration and Visitor Estimation

Pedestrian counters are known to produce inaccurate counts when multiple visitors walk side by side (Yang et al., 2010), while vehicle counters can undercount or overcount when two vehicles pass too closely or when a vehicle moves too slowly. Therefore, calibration of each counter is crucial for accurate visitor estimates. Data from each counter were calibrated using corresponding observation counts. Observation of vehicles also included noting the number of passengers in the observed vehicles. Observation hours varied depending on park staff availability, ranging from 10 hours in Grand Bay Savanna Trail Loop to 47 hours in Machicomoco State Park's Interpretive Area (Table 2). Although sample sizes of our observation hours across the sites were low, these numbers are comparable to observation hours reported in other studies for similar counters (Greene-Roesel et al., 2008; Ozbay et al., 2010; Pettebone et al., 2010; Yang et al., 2010). Data analysis was conducted in R (R Core Team, 2024).

In Grand Bay, most observation counts were gathered by NERR staff watching security camera footage, rather than direct observation, except for a few hours during setup. The counter locations near the visitor center were visible from existing security cameras. Due to low visitor use on this trail, NCCOS staff

strategically selected the hours for observation, focusing on instances where the counter recorded unusually high visitor numbers or significant discrepancies between incoming and outgoing visitors. NERR staff then reviewed the camera footage for the selected dates and times to verify the counts. NCCOS staff did not have access to the footage, and the data collection did not include any personally identifiable information. Using video cameras instead of direct observation is a common practice in counter data validation and calibration (Arnberger et al., 2005; Greene-Roesel et al., 2008). In total, the Savanna Trail Boardwalk counter was observed for 22 hours, and the Savanna Trail Loop counter for 10 hours (Table 2).

Table 2. Calculated metrics of errors in vehicle and pedestrian counters. MAPE = mean absolute percentage error.

Counter site	Counter	Observation hours	Pearson correlation	Range of relative errors (%)	MAPE (%)	Overall error (%)
York River State Park – Taskinas Creek Trail	TRAFx pedestrian	14	0.95	−50, 50	15	0
York River State Park – Fossil Beach Trail	TRAFx pedestrian	14	0.99	−50, 50	16	−13
Machicomoco State Park – Interpretive Area	TRAFx vehicle	47	0.76	−58, 250	61	43
Colonial National Historical Park	TRAFx vehicle	17	0.99	−25, 15	4	−1
Gloucester Point Beach Park	TRAFx vehicle	22	0.98	−50, 29	12	4
New Quarter Park	TRAFx vehicle	14	0.97	−33, 30	11	−3
Beaverdam Park – Main Entrance Trailhead	Eco-Counter pedestrian	14	0.98	−17, 150	25	−3
Beaverdam Park – Hiking and Nature Trail	Eco-Counter pedestrian	13	0.97	−25, 50	14	−3
Grand Bay Savanna Trail Boardwalk	Eco-Counter pedestrian	22	0.87	−29, 317	25	2
Grand Bay Savanna Trail Loop	Eco-Counter pedestrian	10	0.98	−67, 40	25	−6

The linear relationship between observed counts and counter counts was evaluated using a Pearson correlation test. The correlation values ranged from 0.76 for Machicomoco State Park to 0.99 for Colonial National Historical Park (Table 2). Counter accuracy was examined using three error metrics: relative error, mean absolute percent error (MAPE), and overall error. Relative error indicates accuracy per observation period, with positive values indicating overcounts and negative values indicating undercounts. Since averaging the relative errors could cancel out the positive and negative values and mask inaccuracies (Yang et al., 2010), MAPE was used as the primary measure of average error. Overall error assesses counter performance across the entire test duration.

Assuming Xt is the counter count at period t and Yt is the observation count at period t:

$$Relative\ error\ per\ period\ (\%) = \frac{X_t - Y_t}{Y_t}$$

$$Mean\ absolute\ percent\ error\ (\%) = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{X_t - Y_t}{Y_t}\right|$$

$$Overall\ error\ (\%) = \frac{\sum_{t=1}^{n} X_t - \sum_{t=1}^{n} Y_t}{\sum_{t=1}^{n} Y_t}$$

The error rates differed by counter type and site (Table 2). The TRAFx vehicle counter's overall error ranged from −1% in Colonial National Historical Park (one-way counts) to 43% in Machicomoco State Park (two-way counts). TRAFx pedestrian counters' overall error rates were 0% at York River State Park's Taskinas Creek Trail and −13% in York River State Park's Fossil Beach Trail. Eco-Counter pedestrian counters' overall error rates were −6% in Grand Bay Savanna Trail Loop, 2% in Grand Bay Savanna Trail Boardwalk, and −3% each in Main Entrance Trailhead and Hiking-Nature Trail of Beaverdam Park. The counters' overall error rates found in this study were in line with the error rates of TRAFx counters and Eco-Counters found in other studies (Greene-Roesel et al., 2008; Turner et al., 2007; Yang et al., 2010). In terms of overall error, the highest accuracy was observed with Eco-Counter pedestrian counters, followed by TRAFx pedestrian counters, while TRAFx vehicle counters were, on average, the least accurate. However, when comparing all error types across sites, results are mixed. For instance, the TRAFx vehicle counter at Colonial National Historical Park performed more accurately than counters in other sites. This implies that the performance of automated counters may rely not only on the type and brand of the counters but also on the site conditions and use patterns.

Calibration coefficients for each counter were calculated and compared using two methods: the ratio method and the linear regression method. In the ratio method, the sum of observation counts was divided by the sum of counter counts (Laws, 2013; TRAFx Research Ltd., 2022) as shown in the equation below.

$$Calibration\ coefficient = \frac{\sum observation\ counts}{\sum counter\ counts}$$

In the regression method, a linear model was fitted using the observed counts as the dependent variable and the counter counts as the independent variable. Following Pettebone et al. (2010), the model was specified without a constant term to force the regression line through the origin. This approach is represented by the equation:

$$y = \beta_1 x$$

where y represents the observed counts, x represents the counter counts, and the resulting slope, β_1, is the regression coefficient.

This coefficient was then used as the correction factor to estimate the calibrated data. Forcing the regression line through the origin is a logical necessity for this type of calibration, as it ensures that a counter reading of zero events will correctly predict an observed count of zero, which is expected during times with no visitors, such as overnight hours. Margins of error for regression coefficients were then calculated as:

$$Margin\ of\ error = t\ critical * std.errors$$

When the counter recorded both incoming and outgoing visitors or vehicles (two-way mode), the total counts were divided by two. For vehicle counters, the average number of people per vehicle (APV) was used to estimate the number of visitors.

To summarize, calibrated visitors from pedestrian and vehicle counters were estimated as below:

Two-way pedestrian counters

$$Calibrated\ hourly\ visitors = \frac{Calibration\ coefficient * hourly\ counter\ counts}{2}$$

One-way vehicle counters

$$Calibrated\ hourly\ vehicles = Calibration\ coefficient * hourly\ counter\ counts$$

$$Calibrated\ hourly\ visitors = Calibrated\ hourly\ vehicles * Average\ person\ in\ the\ vehicle\ (APV)$$

Two-way vehicle counters

$$Calibrated\ hourly\ vehicles = \frac{Calibration\ coefficient * hourly\ counter\ counts}{2}$$

$$Calibrated\ hourly\ visitors = Calibrated\ hourly\ vehicles * Average\ person\ in\ the\ vehicle\ (APV)$$

Although the two calibration methods produced slightly different coefficients, the values from the ratio method fell within the margin of error of the regression method for all sites (Table 3). Therefore, the final visitor estimates for each site were calculated using the regression method's coefficients.

Table 3. Metrics of calibration of hourly counter data. APV = average person in vehicle.

Counter site	Ratio method	Regression method				APV
	Calibration coefficient	Calibration coefficient	p value	Margin of error	R^2	
York River State Park – Taskinas Creek Trail	1.000	0.917	<0.01	± 0.121	0.95	NA
York River State Park – Fossil Beach Trail	1.147	1.079	<0.01	± 0.082	0.98	NA
Machicomoco State Park – Interpretive Area	0.699	0.652	<0.01	± 0.082	0.85	1.659
Colonial National Historical Park	1.012	0.982	<0.01	± 0.051	0.99	1.964
Gloucester Point Beach Park	0.962	0.961	<0.01	± 0.039	0.99	1.377
New Quarter Park	1.026	1.016	<0.01	± 0.056	0.99	1.336
Beaverdam Park – Main Entrance Trailhead	1.032	1.091	<0.01	± 0.108	0.97	NA
Beaverdam Park – Hiking and Nature Trail	1.027	1.048	<0.01	± 0.101	0.98	NA
Grand Bay Savanna Trail Boardwalk	0.978	0.950	<0.01	± 0.127	0.92	NA
Grand Bay Savanna Trail Loop	1.066	1.191	<0.01	± 0.176	0.96	NA

Note: Margin of error values are at a 95% confidence level.

In Grand Bay, the Savanna Trail Loop extends the original Savanna Trail Boardwalk. Depending on pedestrian use of these two trails and the two installed Eco-Counters (see Figure 2), there were four scenarios where a person visiting this trail system could be counted from the visitor center:

1. Enters the trail system via the Savanna Trail Boardwalk and returns back: the Savanna Trail Boardwalk counter counts twice, IN and OUT.
2. Enters the trail system via the Savannah Trail Boardwalk and exits from the Savanna Trail Loop: the Savanna Trail Boardwalk counter counts once (IN) and the Savanna Trail Loop counter counts once (OUT).

3. Enters the trail system via the Savanna Trail Loop and returns back: the Savanna Trail Loop counter counts twice, IN and OUT.
4. Enters the trail system via the Savanna Trail Loop and exits from the Savanna Trail Boardwalk: the Savanna Trail Loop counter counts once (IN) and the Savanna Trail Boardwalk counter counts once (OUT).

It should be noted that the placement of the Savanna Trail Loop counter introduces a potential limitation. The device was positioned approximately 200 ft from the parking lot to mitigate false counts from environmental factors such as ground vegetation, vehicles, and direct sunlight or tree shadows on the counter sensor. A consequence of this distant placement is that visitors who did not proceed 200 ft down the trail would not have been recorded. Observational evidence confirmed this was the case for some groups, including school groups of small children on educational visits. Therefore, the data presented may not capture the total visitation for this trail system.
Despite this site-specific limitation, all collected data underwent a uniform analysis. After the data from each counter were calibrated separately, the total hourly visitation for the entire Savanna Trail system was calculated by combining the counts from the two devices along the Savanna Trail Boardwalk and Savanna Trail Loop using the following formula:

$$Calibrated\ total\ hourly\ visitors = \frac{Boardwalk\ Trail\ calibrated\ hourly\ total\ counts\ +\ Loop\ Trail\ calibrated\ hourly\ total\ counts}{2}$$

Once calibrated hourly visitors were calculated, data were further analyzed to estimate daily, monthly, and yearly total visitors across all study sites. Statistical differences within the months and days of the week were calculated using the 95% confidence intervals of final estimates. For instance, when the range between lower and upper bounds of the estimates for a month did not overlap with those of another month, estimated visitors for those two months were statistically different.

Among the vehicle counters, the APV ranged from 1.33 in New Quarter Park to 1.96 in Colonial National Historical Park (Table 3). Additionally, 77% of observed vehicles in New Quarter and 63% at Gloucester Point Beach Park carried only a single visitor compared to 45% in Machicomoco State Park and 34% in Colonial National Historical Park. These patterns suggest that Gloucester Point Beach Park and New Quarter Park attract more solo visitors than Colonial National Historical Park and Machicomoco State Park. Although the range of observation hours in this study were within the range in existing literature (Greene-Roesel et al., 2008; Ozbay et al., 2010; Pettebone et al., 2010; Yang et al., 2010), it should be noted that the APV estimates are based on the small sample sizes of observation. Also, given the small sample size, this analysis does not account for seasonal variations (if any) in APV calculations.

Results

York River State Park – Taskinas Creek Trail

The pedestrian counter at York River State Park's Taskinas Creek Trail was observed for 14 hours. Observations spanned all 9 a.m. through 5 p.m. hourly bins, four days of the week (Tuesday, Wednesday, Friday, Saturday), and four months of the year (February, March, July, December). A strong correlation was found between observation counts and counter counts (Table 2). Counter errors during observation hours ranged from −50% to +50%. The overall error of the counter was 0% and the MAPE was 15% (Table 2).

From March 2024 to February 2025, total visitation to the trail was 4,457 ± 580 visitors. Visitation peaked in March (584 ± 78 visitors) and April (533 ± 69 visitors), declined through July (252 ± 33 visitors), then increased again until November, before dipping with some fluctuation between December and February (Figure 5a). Sundays (24 ± 4 visitors) and Saturdays (21 ± 3 visitors) saw a high average visitation, while weekdays received low visitation (7 ± 1 to 9 ± 2 visitors) (Figure 5b). Daily visitor counts ranged from zero to a peak of 111 ± 14 on January 1, 2025 (New Year's Day), and 100 ± 13 on June 2, 2024 (Taskinas Creek Half Marathon). The site averaged 12 ± 2 visitors per day, with hourly visitation peaking between 10:00 a.m. and 2:59 p.m. at 1.5 ± 0.2 visitors per hour (Figure 5c).

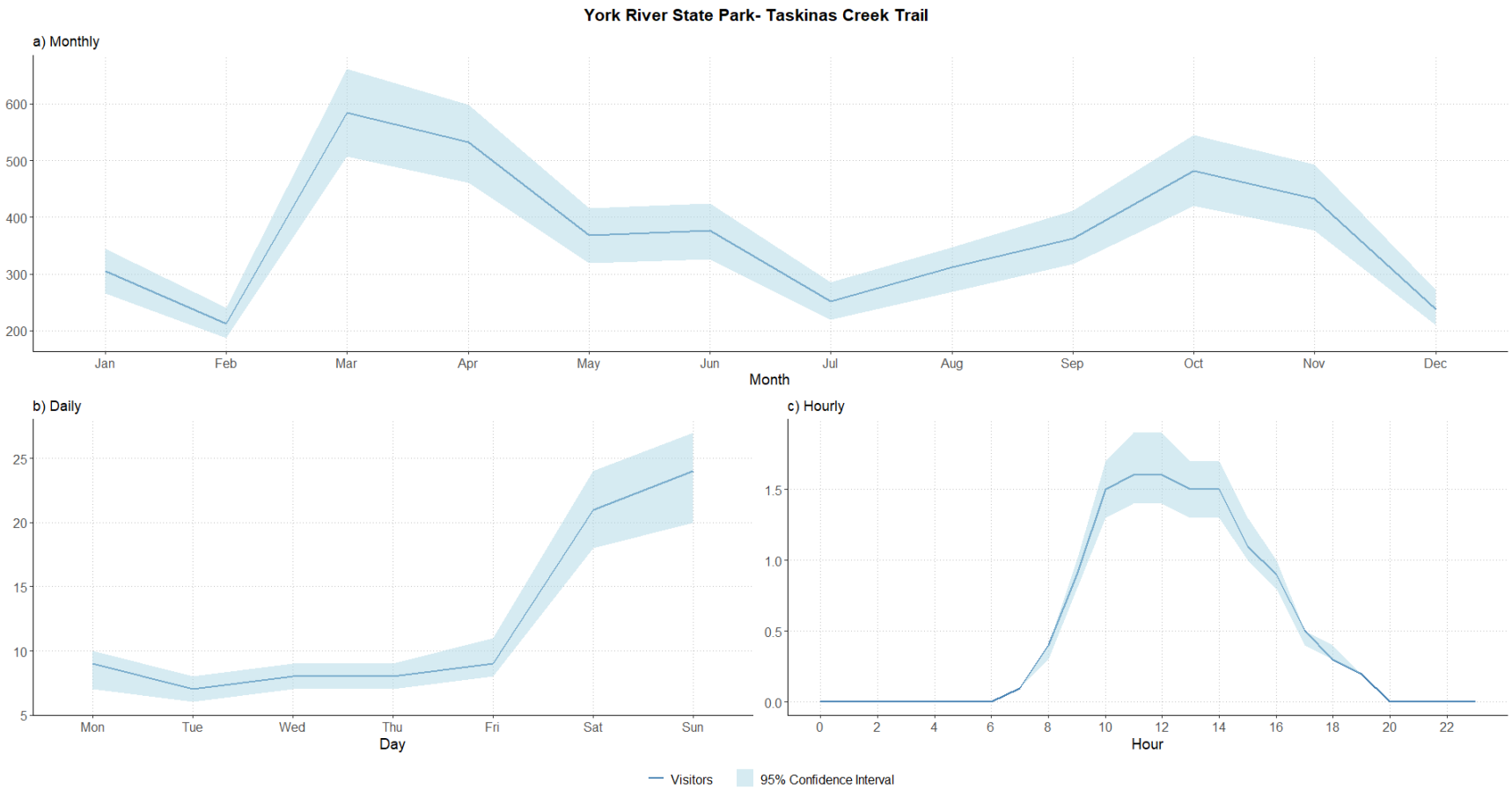

Figure 5. Estimated visitors by a) month of the year, b) day of the week, and c) hour of the day in York River State Park Taskinas Creek Trail. Note: Hour labels (e.g., “9 a.m.”) represent full one-hour intervals of the day (9:00–9:59).

York River State Park – Fossil Beach Trail

The pedestrian counter at York River State Park's Fossil Beach Trail was observed for 14 hours. Observations spanned all 9 a.m. through 5 p.m. hourly bins, three days of the week (Tuesday, Wednesday, Saturday), and four months of the year (February, March, July, December). A strong correlation was found between observation counts and counter counts (Table 2). Counter errors during observation hours ranged from −50% to +50%. The counter's MAPE was 16%, and the overall error was −13% (Table 2).

From May 2024 to April 2025, total visitation to the trail was 18,822 ± 1,444 visitors. Monthly visitation peaked in March (2,242 ± 172) and April (2,186 ± 166), declined through July (1,506 ± 116), then gradually increased with some fluctuations until October (1,815 ± 138). Visitation then declined to the lowest (891 ± 71 to 1058 ± 82 visitors) during the winter months of December, January, and February (Figure 6a). Saturdays (96 ± 7 visitors) and Sundays (81 ± 6 visitors) had higher average visitation, while weekdays had lower visitation (33 ± 2 to 37 ± 3 visitors) (Figure 6b). Daily counts ranged from zero to 398 ± 30 on January 1, 2025 (New Year's Day) and 324 ± 24 on May 12, 2024 (Mother's Day), with a daily average of 52 ± 4 visitors. Hourly visitation peaked from 11:00 a.m. to 2:59 p.m., averaging 7.3 ± 0.5 visitors per hour (Figure 6c).

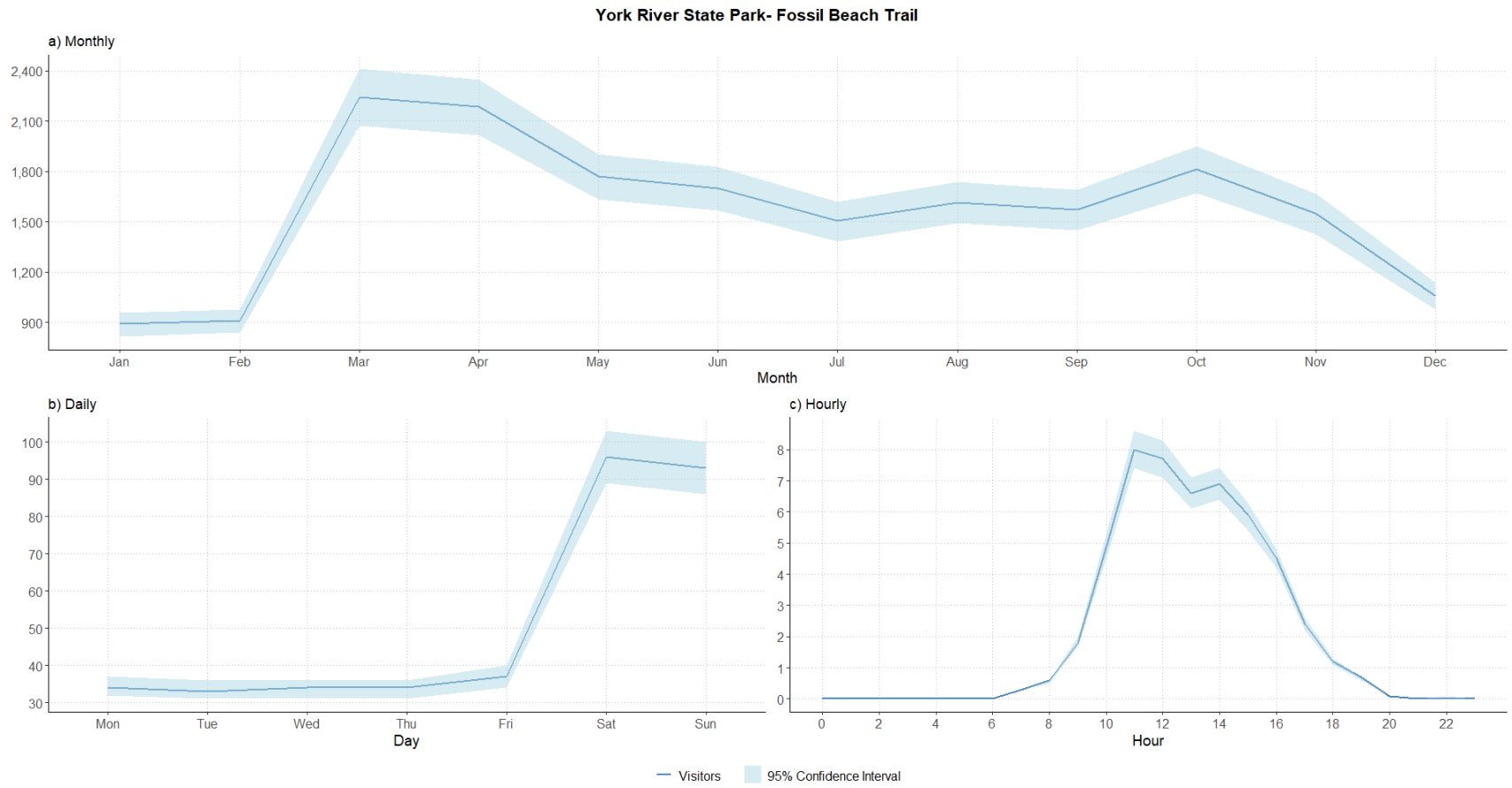

Figure 6. Estimated visitors by a) month of the year, b) day of the week, and c) hour of the day in York River State Park Fossil Beach Trail. Note: Hour labels (e.g., “9 a.m.”) represent full one-hour intervals of the day (9:00–9:59).

Machicomoco State Park

The vehicle counter at Machicomoco State Park's Interpretive Area was observed for 47 hours. Observations spanned all 9 a.m. through 5 p.m. hourly bins, all days of the week, and all months of the year except January, March, and November. A strong correlation was found between observation counts and counter counts, although this correlation value was not as high as in other sites (Table 2). Counter errors during observation hours ranged from −58% to +250%. The counter's MAPE was 61%, and the overall error was 43% (Table 2).

From March 2024 to February 2025, total visitation was 15,040 ± 1,888 vehicles and an estimated 24,946 ± 3,142 visitors. Visitation rose from a low in March (1,033 ± 130 vehicles; 1,710 ± 216 visitors) to a high in May (1,546 ± 194 vehicles; 2,565 ± 324 visitors), then declined to July, increased again to a peak in October (1,661 ± 209 vehicles; 2,753 ± 343 visitors), and dropped to a low in February (802 ± 102 vehicles; 1,137 ± 168 visitors) (Figure 7a). Saturdays (61 ± 8 vehicles; 101 ± 13 visitors) and Sundays (54 ± 6 vehicles; 90 ± 12 visitors) had higher average visitation, while weekdays had lower visitation (33 ± 4 vehicles, 54 ± 7 visitors to 38 ± 4 vehicles, 62 ± 8 visitors) (Figure 7b). Daily visitation ranged from 5 ± 0 vehicles (9 ± 1 visitors) on February 12, 2025, to 206 ± 26 vehicles (342 ± 43 visitors) on January 1, 2025. The average was 41 ± 5 vehicles (68 ± 9 visitors) per day. Hourly visitation peaked between 12:00 p.m. and 4:59 p.m., with 4.1 ± 0.5 vehicles (6.8 ± 0.8 visitors) per hour (Figure 7c).

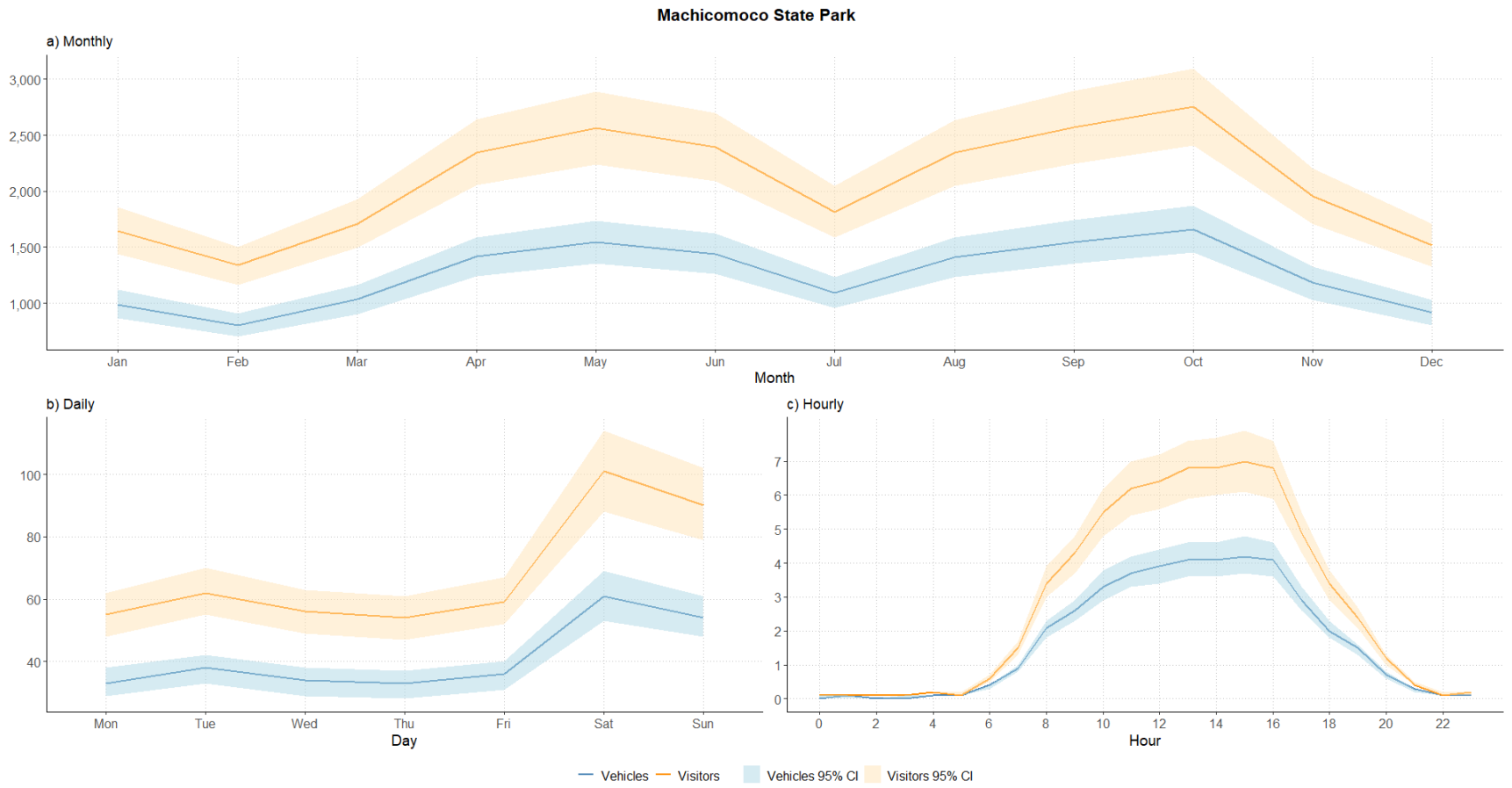

Figure 7. Estimated vehicles and visitors by a) month of the year, b) day of the week, and c) hour of the day in Machicomoco State Park Interpretive Area. Note: Hour labels (e.g., “9 a.m.”) represent full one-hour intervals of the day (9:00–9:59).

Colonial National Historical Park

The vehicle counter at Colonial National Historical Park Tour Road was observed for 17 hours. Observations spanned all 9 a.m. through 3 p.m. hourly bins, four days of the week (Monday, Tuesday, Wednesday, Thursday), and all months of the year. A strong correlation was found between observation counts and counter counts (Table 2). Counter errors during observation hours ranged from −25% to +15%. The counter's MAPE was 4%, and the overall error was −1% (Table 2).

From March 2024 to February 2025, total visitation was 22,740 ± 1,186 vehicles and an estimated 44,644 ± 2,321 visitors. Visitation rose steadily from March to July (2,572 ± 136 vehicles; 5,044 ± 261 visitors), dipped in August and September, spiked again in October, then declined to the lowest in January (750 ± 40 vehicles; 1,473 ± 77 visitors) and February (763 ± 40 vehicles, 1501 ± 78 visitors) (Figure 8a). Sundays (79 ± 4 vehicles; 155 ± 8 visitors) and Saturdays (75 ± 4 vehicles; 148 ± 8 visitors) had higher average visitation, while weekdays had lower visitation (55 ± 3 vehicles; 108 ± 6 visitors to 58 ± 3 vehicles, 113 ± 6 visitors) (Figure 8b). Daily visitation ranged from zero to peaks of 150 ± 8 vehicles (295 ± 15 visitors) and 140 ± 8 vehicles (276 ± 14 visitors) on July 6 and 5, 2024 (Independence Day Weekend). The site averaged 62 ± 3 vehicles (122 ± 6 visitors) per day. Hourly visitation peaked from 12:00 p.m. to 4:59 p.m., with 7.9 ± 0.4 vehicles (15.5 ± 0.8 visitors) per hour (Figure 8c).

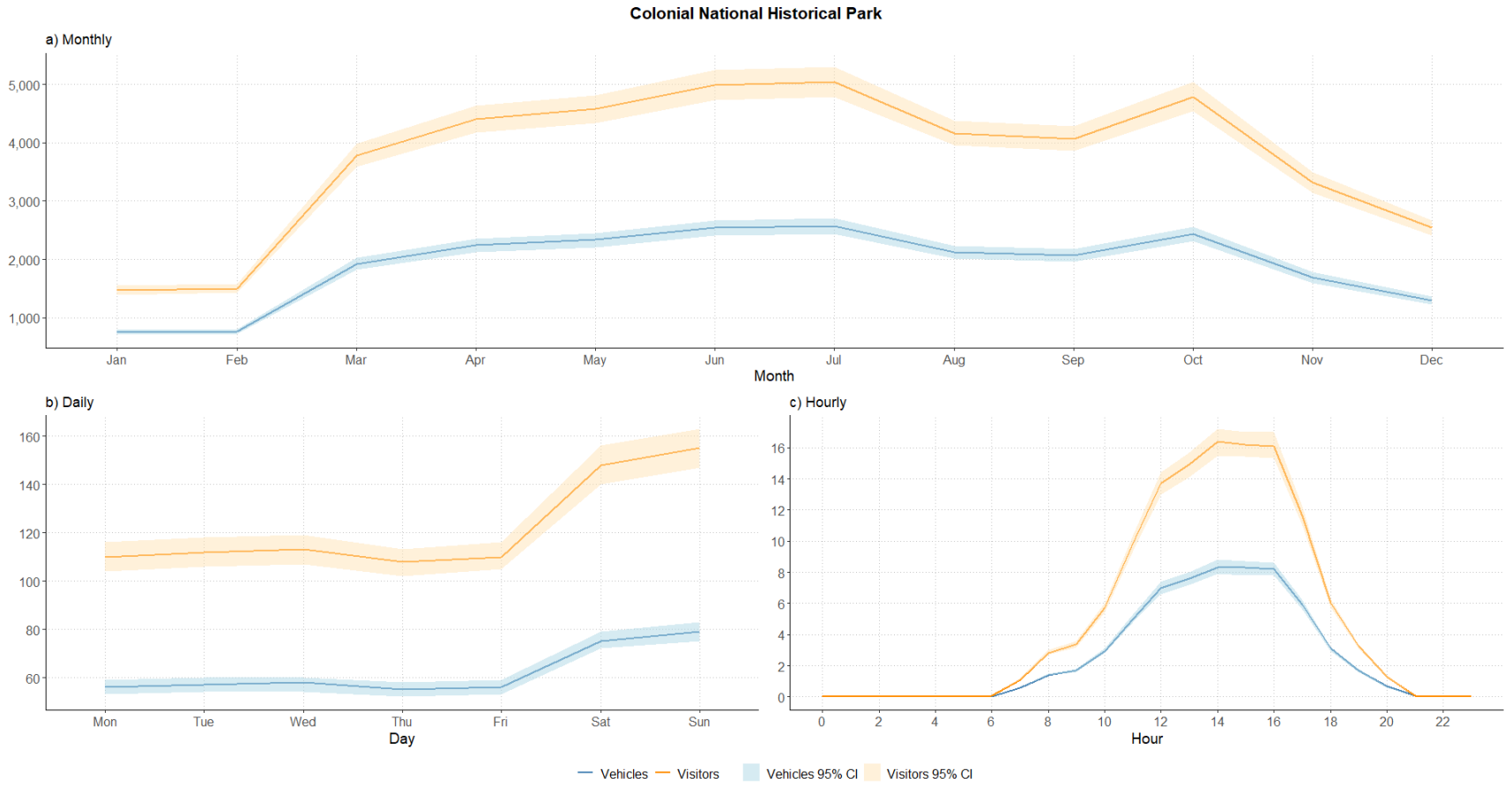

Figure 8. Estimated vehicles and visitors by a) month of the year, b) day of the week, and c) hour of the day in Colonial National Historical Park (Yorktown) Historical Tour Road. Note: Hour labels (e.g., “9 a.m.”) represent full one-hour intervals of the day (9:00–9:59).

Gloucester Point Beach Park

The vehicle counter at Gloucester Point Beach Park was observed for 22 hours. Observations spanned all 8 a.m. through 6 p.m. hourly bins, all days of the week, and all months of the year except January, June, and July. A strong correlation was found between observation counts and counter counts (Table 2). Counter errors during observation hours ranged from −50% to +29%. The counter's MAPE was 12%, and the overall error was 4% (Table 2).

From March 2024 to February 2025, total visitation reached 68,201 ± 2,784 vehicles and an estimated 93,944 ± 3,856 visitors. Visitation increased from March to June (11,811 ± 481 vehicles; 16,268 ± 666 visitors), then declined steadily to a low in January (1,955 ± 80 vehicles, 2,687 ± 108 visitors) and February (1,949 ± 79 vehicles; 2,688 ± 109 visitors) (Figure 9a). Saturdays (254 ± 10 vehicles; 349 ± 14 visitors) and Sundays (233 ± 10 vehicles; 321 ± 14 visitors) had higher average visitation, while weekdays had lower visitation (154 ± 6 vehicles; 212 ± 8 visitors to 174 ± 7 vehicles, 240 ± 10 visitors) (Figure 9b). Daily visitation ranged from 34 ± 2 vehicles (46 ± 2 visitors) on January 6, 2025, to 1,240 ± 51 vehicles (1,708 ± 70 visitors) on July 4, 2024 (Independence Day). On average, the site received 187 ± 8 vehicles (257 ± 11 visitors) per day. Hourly visitation peaked from 12:00 p.m. to 2:59 p.m., with 14.9 ± 0.6 vehicles (20.5 ± 0.8 visitors) per hour (Figure 9c).

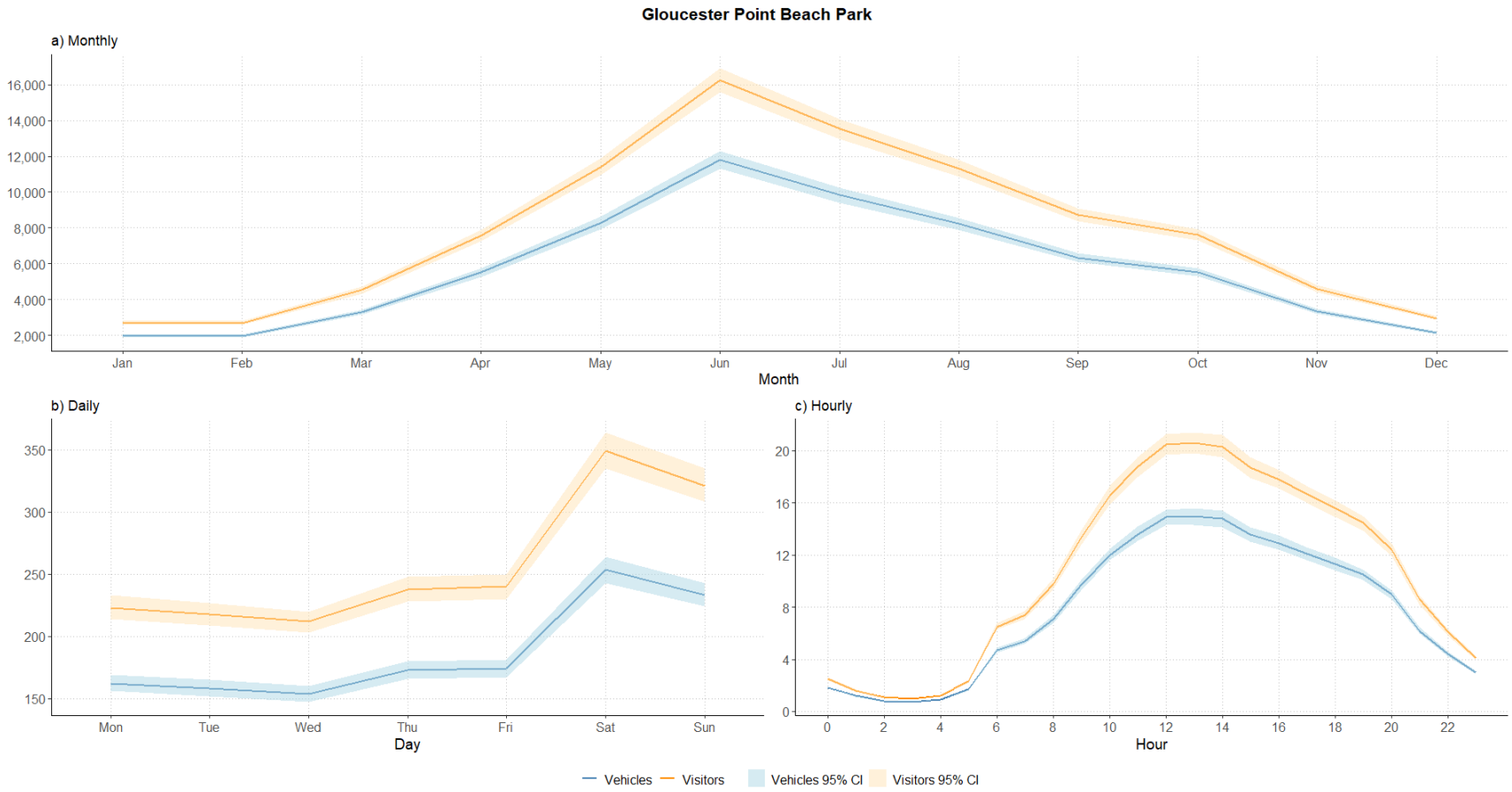

Figure 9. Estimated vehicles and visitors by a) month of the year, b) day of the week, and c) hour of the day in Gloucester Point Beach Park. Note: Hour labels (e.g., “9 a.m.”) represent full one-hour intervals of the day (9:00–9:59).

New Quarter Park

The vehicle counter at the entrance to New Quarter Park was observed for 14 hours. Observations spanned all 8 a.m. through 7 p.m. hourly bins, except the 4 p.m. hour, and occurred three days of the week (Sunday, Tuesday, Wednesday) and four months of the year (February, March, July, December). A strong correlation was found between observation counts and counter counts (Table 2). Counter errors during observation hours ranged from −33% to +30%. The counter's MAPE was 11%, and the overall error was −3% (Table 2).

From March 2024 to February 2025, total visitation to the park was 39,929 ± 2,222 vehicles and an estimated 53,330 ± 2,964 visitors. Visitation rose from March to June (3,953 ± 220 vehicles; 5,283 ± 296 visitors), dipped slightly in July, increased again through October, then declined to the lowest in winter months of December, January, and February (2,251 ± 126 vehicles; 3,001 ± 164 visitors to 2,549 ± 142 vehicles, 3,403 ± 190 visitors) (Figure 10a). Saturdays (139 ± 8 vehicles; 186 ± 10 visitors) and Sundays (138 ± 8 vehicles; 185 ± 10 visitors) had higher average visitation compared to weekdays (92 ± 5 vehicles; 123 ± 7 visitors to 104 ± 6 vehicles, 139 ± 8 visitors) (Figure 10b). Daily counts ranged from 31 ± 2 vehicles (42 ± 2 visitors) on March 6, 2024, to 298 ± 16 vehicles (398 ± 22 visitors) on March 30, 2024 (Queens Lake 5K and Easter Weekend). The Park averaged 109 ± 6 vehicles (146 ± 8 visitors) per day. Hourly visitation peaked between 10:00 a.m. and 4:59 p.m., with 9.8 ± 0.5 vehicles (13.0 ± 0.7 visitors) per hour (Figure 10c).

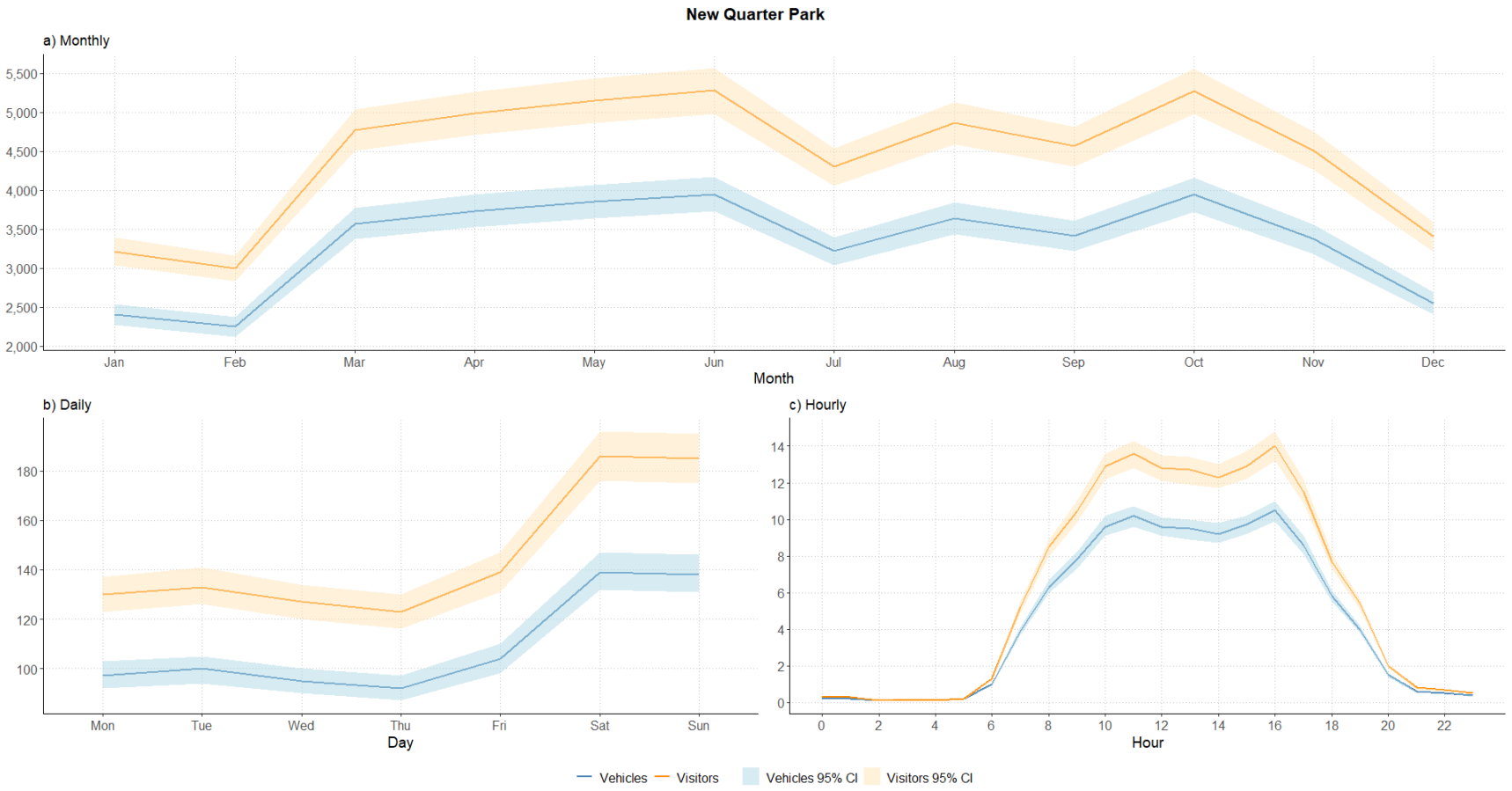

Figure 10. Estimated vehicles and visitors by a) month of the year, b) day of the week, and c) hour of the day in New Quarter Park. Note: Hour labels (e.g., “9 a.m.”) represent full one-hour intervals of the day (9:00–9:59).

Beaverdam Park – Main Entrance Trailhead

The pedestrian Eco-Counter at Beaverdam Park Main Entrance Trailhead was observed for 14 hours. Observations spanned all 9 a.m. through 4 p.m. hourly bins, four days of the week (Sunday, Tuesday, Wednesday, Thursday), and four months of the year (February, March, July, December). A strong correlation was found between observation counts and counter counts (Table 2). Counter errors during observation hours ranged from −17% to +150%. The counter's MAPE was 25%, and the overall error was −3% (Table 2).

From March 2024 to February 2025, total visitation to this trail was 24,461 ± 2,432 visitors. Visitation remained high from March to June, dipped in July, then rose to a peak in October (2,767 ± 275 visitors) before declining to the lowest in winter months of December, January, and February (1,053 ± 106 to 1485 ± 146 visitors) (Figure 11a). Sundays (102 ± 10 visitors) and Saturdays (89 ± 8 visitors) had higher average visitation compared to weekdays (45 ± 4 to 65 ± 6 visitors) (Figure 11b). Daily visitor counts ranged from zero to 243 ± 24 on March 3, 2024, and 241 ± 24 on March 16, 2024 (hiking event and St. Patrick's Day weekend). The daily average was 67 ± 7 visitors, and hourly visitation peaked between 12:00 p.m. and 3:59 p.m. at 7.0 ± 0.7 visitors per hour (Figure 11c).

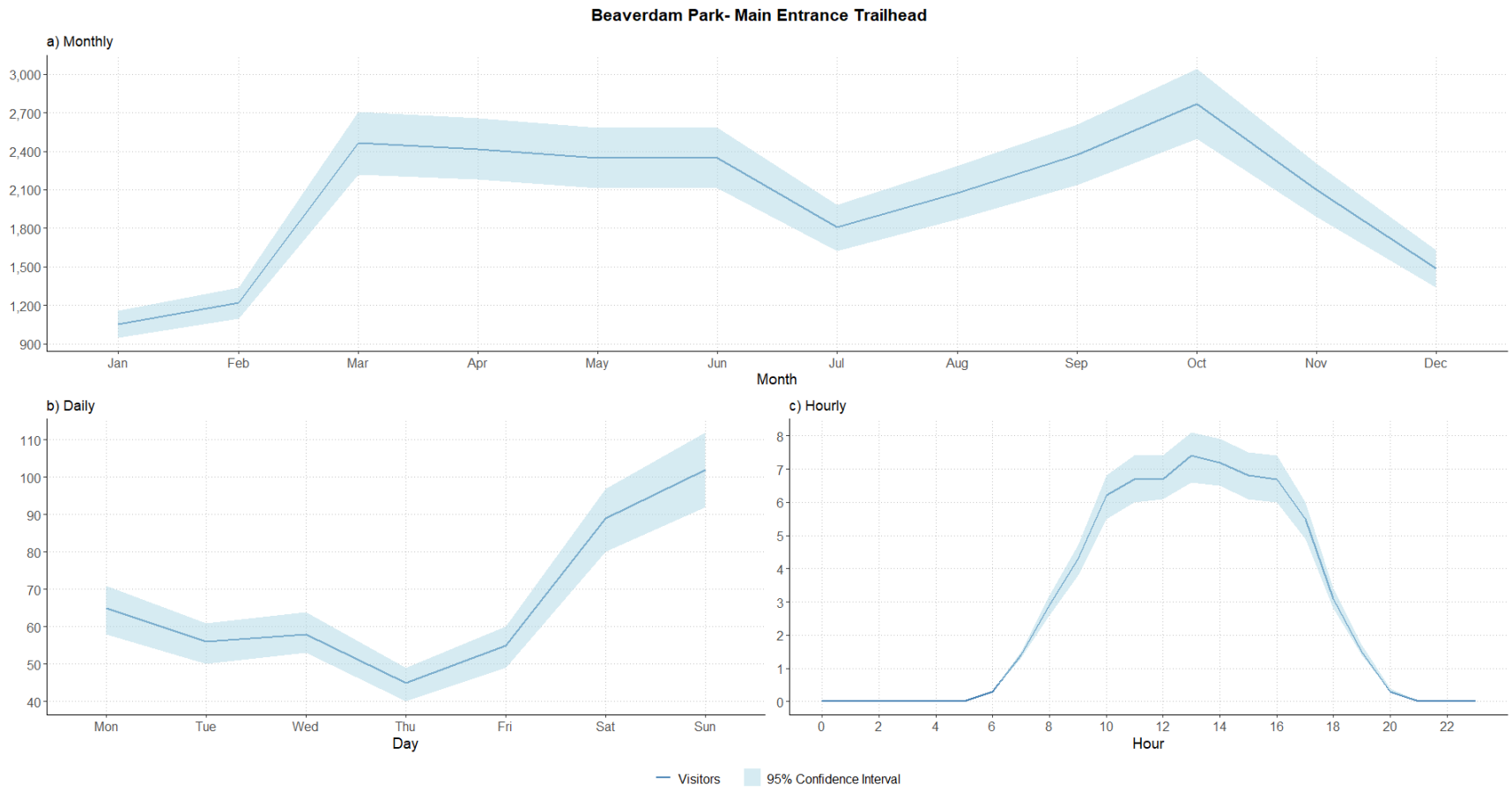

Figure 11. Estimated visitors by a) month of the year, b) day of the week, and c) hour of the day in Beaverdam Park Main Entrance Trailhead. Note: Hour labels (e.g., “9 a.m.”) represent full one-hour intervals of the day (9:00–9:59).

Beaverdam Park – Hiking and Nature Trail

The pedestrian Eco-Counter at Beaverdam Park Hiking and Nature Trail was observed for 13 hours. Observations spanned all 9 a.m. through 5 p.m. hourly bins, except the 11 a.m. hour; all days of the week, except Friday, Saturday, and Sunday; and four months of the year (February, March, July, December). A strong correlation was found between observation counts and counter counts (Table 2). Counter errors during observation hours ranged from −25% to +50%. The counter's MAPE was 14%, and the overall error was −3% (Table 2).

During the period March 2024 to February 2025, total visitation to this trail was 12,560 ± 1,209 visitors. Visitation declined steadily from March (1,215 ± 115 visitors) to July (819 ± 80), then rose sharply to a peak in October (1,594 ± 152) before falling to the lowest in January (543 ± 54) (Figure 12a). Sundays (54 ± 6 visitors) followed by Saturdays (43 ± 4 visitors) had higher average visitation compared to weekdays (23 ± 2 to 36 ± 4 visitors) (Figure 12b). Daily visitation ranged from zero to 156 ± 15 on October 9, 2024 (cross-country meet), with an average of 34 ± 3 visitors per day. Hourly visitation peaked between 11:00 a.m. and 4:59 p.m., averaging 3.6 ± 0.4 visitors per hour (Figure 12c).

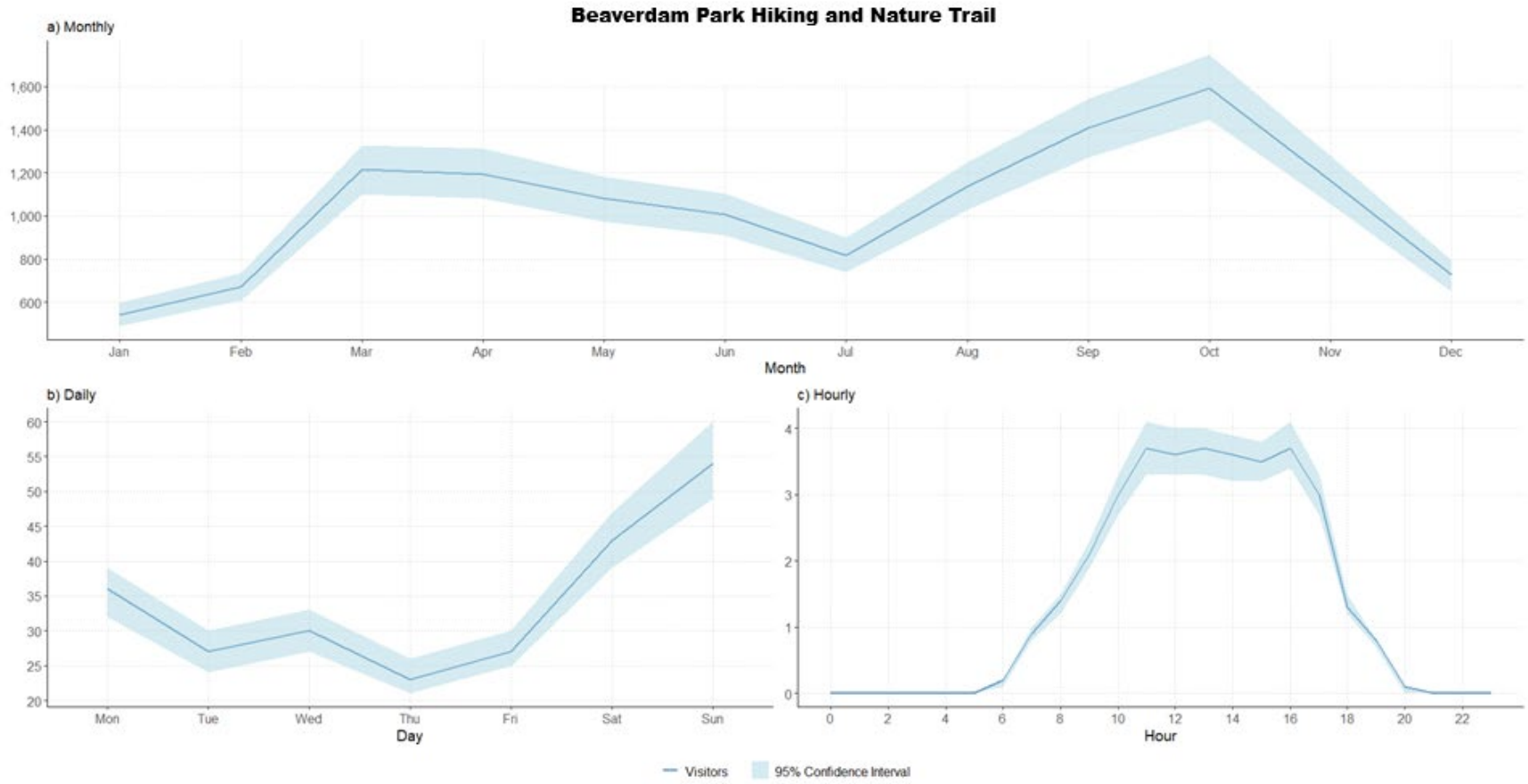

Figure 12. Estimated visitors by a) month of the year, b) day of the week, and c) hour of the day in Beaverdam Park Hiking and Nature Trail. Note: Hour labels (e.g., “9 a.m.”) represent full one-hour intervals of the day (9:00–9:59).

Grand Bay NERR – Savanna Trail Boardwalk and Savanna Trail Loop

The pedestrian Eco-Counter at the Savanna Trail Boardwalk was observed for 22 hours. Observations spanned all 10 a.m. through 5 p.m. hourly bins, except the 4 p.m. hour; all days of the week, except Saturday; and five months of the year (March, April, May, July, September). Similarly, the pedestrian Eco-Counter at the Savanna Trail Loop was observed for 10 hours. The observation spanned all hours between 10 a.m. and 6 p.m., except 11 a.m., 2 p.m., and 4 p.m., all days of the week, except Sunday, and four months of the year (April, May, August, September). Most observations at the two Grand Bay counter sites were conducted using security camera footage rather than direct observation. Relative errors for the Savannah Trail Boardwalk counter ranged from −29% (undercounts) to +317% (overcounts). For the Savanna Trail Loop counter, relative error ranged from −67% to +40%. While the overall error rate was +2% for the Savanna Trail Boardwalk counter and −6% for the Savanna Trail Loop counter, MAPE was equal (25%) on both counters (Table 2).

Once data from each counter were calibrated separately, total calibrated hourly visitors to the entire Savanna Trail system were calculated by combining the calibrated counts from two counters. From April 2024 to March 2025, total visitation to the trail system was 2,571 ± 450 visitors. Visitation reached a high in April (326 ± 54 visitors) and then declined, with some fluctuations, to the lowest in August (91 ± 13 visitors), then increased again to a peak in October (412 ± 70 visitors), before declining to another low in February (113 ± 23 visitors) (Figure 13a). Thursdays (10 ± 2 visitors) saw a high average visitation followed by Tuesday (9 ± 2 visitors), while Sunday received the lowest visitation (2 ± 0 visitors) (Figure 13b). Daily visitor counts ranged from zero to a peak of 93 ± 12 on December 14, 2024 (star party) and 82 ± 24 on November 15, 2024 (homeschool field trip). The trail system averaged 7 ± 1.2 visitors per day, with hourly visitation peaking between 10:00 a.m. and 2:59 p.m. at 1.0 ± 0.2 visitors per hour (Figure 13c).

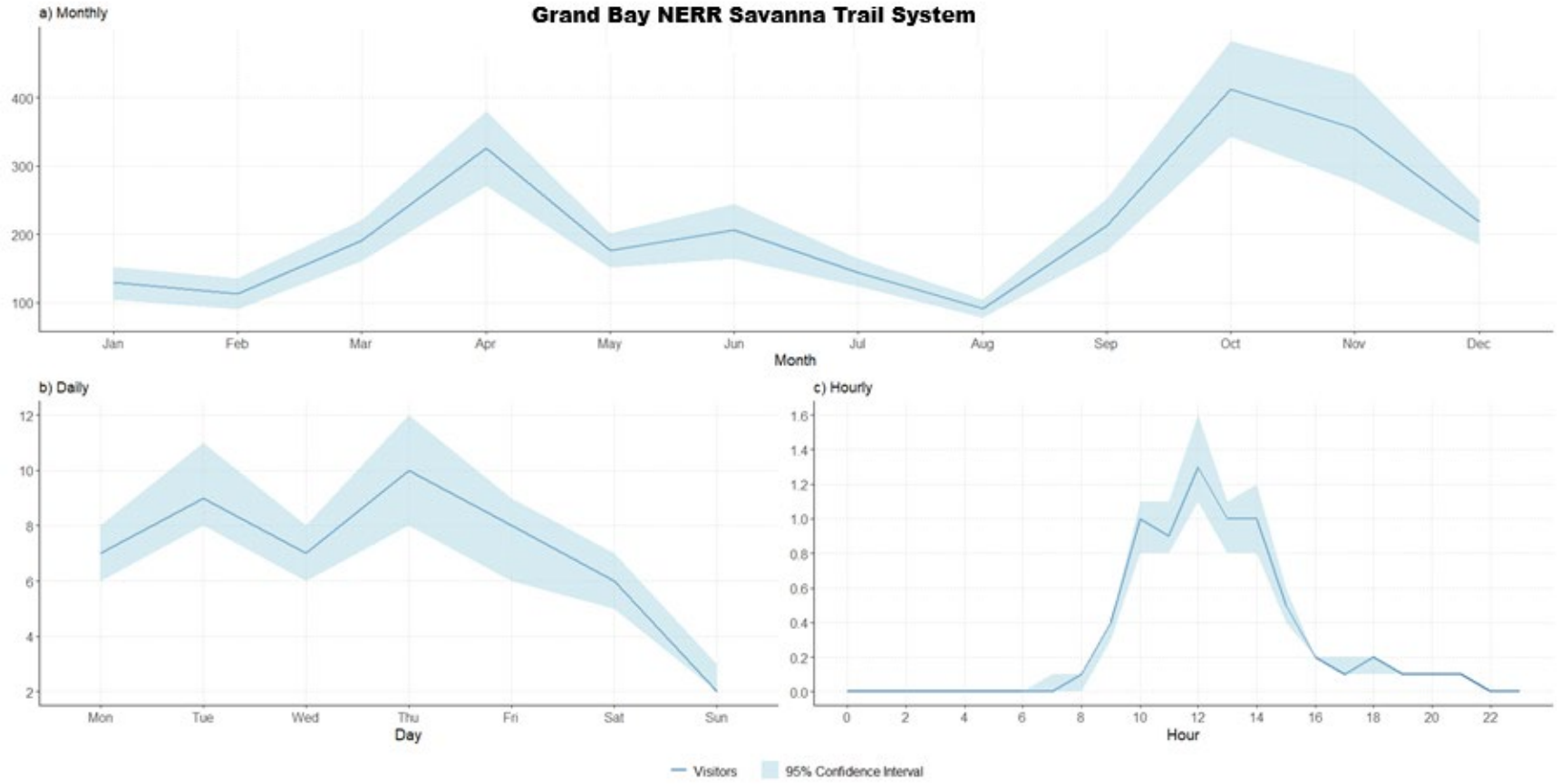

Figure 13. Estimated visitors by a) month of the year, b) day of the week, and c) hour of the day in Grand Bay NERR Savanna Trail system. Note: Hour labels (e.g., “9 a.m.”) represent full one-hour intervals of the day (9:00–9:59).

Conclusion

Visitation patterns across park sites followed clear and consistent trends, with peak activity during the spring and fall, on weekends, and around midday. Major spikes were also observed on holidays (e.g., New Year's Day, Independence Day weekend, Mother's Day) and during special events (e.g., running races) (Table 4). Gloucester Point Beach Park and New Quarter Park recorded the highest total visitation over the 12-month study period, while Taskinas Creek Trail at York River State Park, the Hiking-Nature Trail at Beaverdam Park, and Grand Bay NERR saw lower totals (Figure 14). However, these differences may reflect counter placement as much as actual popularity—counters at Gloucester Point and New Quarter were positioned to measure overall park use, whereas others captured trail- or section-specific activity.

These findings offer a valuable foundation for operational planning. Concentrating staffing, maintenance, and programming during high-use periods and at high-traffic sites can enhance accessibility, safety, and the overall visitor experience. At the same time, off-peak patterns present opportunities to diversify engagement strategies and promote broader park use. Future work could explore how specific park features, outreach efforts, and external factors—such as weather patterns or school calendars—influence visitation, supporting more responsive and data-informed site management.

Table 4. A comparison of annual visitor counts, peak seasonality, and notable events across all counter sites.

Park	Counter Site	Annual Visitation		Peak Visitation Month	Notable Events
		Visitors	Vehicles		
York River State Park	Taskinas Creek Trail	4,457 ± 580	N/A	March: 584 ± 78 visitors	• January 1, 2025 (New Year's Day): 111 ± 14 visitors • June 2, 2024 (Taskinas Creek Half Marathon): 100 ± 13 visitors
	Fossil Beach Trail	15,541 ± 1,198	N/A	October: 1,815 ± 138 visitors	• January 1, 2025 (New Year's Day): 398 ± 30 visitors • May 12, 2024 (Mother's Day): 324 ± 24 visitors
Machicomoco State Park	Interpretive Area	24,946 ± 3,142	15,040 ± 1,888	October: 1,661 ± 209 vehicles, 2,753 ± 343 visitors	• January 1, 2025 (New Year's Day): 206 ± 26 vehicles, 342 ± 43 visitors
Colonial National Historical Park	Historical Tour Road	44,644 ± 2,321	22,740 ± 1,186	July: 2,572 ± 136 vehicles, 5,044 ± 261 visitors	• July 5, 2024 (Independence Day Weekend): 140 ± 8 vehicles, 276 ± 14 visitors • July 6, 2024 (Independence Day Weekend): 150 ± 8 vehicles, 295 ± 15 visitors
Gloucester Point Beach Park	Parking Lot	93,944 ± 3,856	68,201 ± 2,784	June: 11,811 ± 481 vehicles, 16,268 ± 666 visitors	• July 4, 2024 (Independence Day): 1,240 ± 51 vehicles, 1,708 ± 70 visitors
New Quarter Park	Park entrance (Lakeshead Drive)	53,330 ± 2,964	39,929 ± 2,222	June: 3,953 ± 220 vehicles, 5,283 ± 296 visitors	• March 30, 2024 (Queens Lake 5K & Easter weekend): 298 ± 16 vehicles, 398 ± 22 visitors
Beaverdam Park	Main Entrance Trailhead	24,461 ± 2,432	N/A	October: 2,767 + 275 visitors	• March 16, 2024 (hike event & St. Patrick's Day Weekend): 241 ± 24 visitors
	Hiking and Nature Trail	12,560 ± 1,209	N/A	October: 1,594 ± 152 visitors	• October 9, 2024 (cross country meet): 156 ± 15 visitors
Grand Bay NERR	Savanna Trail system	2,571 ± 450	N/A	October: 412 ± 70 visitors	• December 14, 2024 (star party): 93 ± 12 visitors

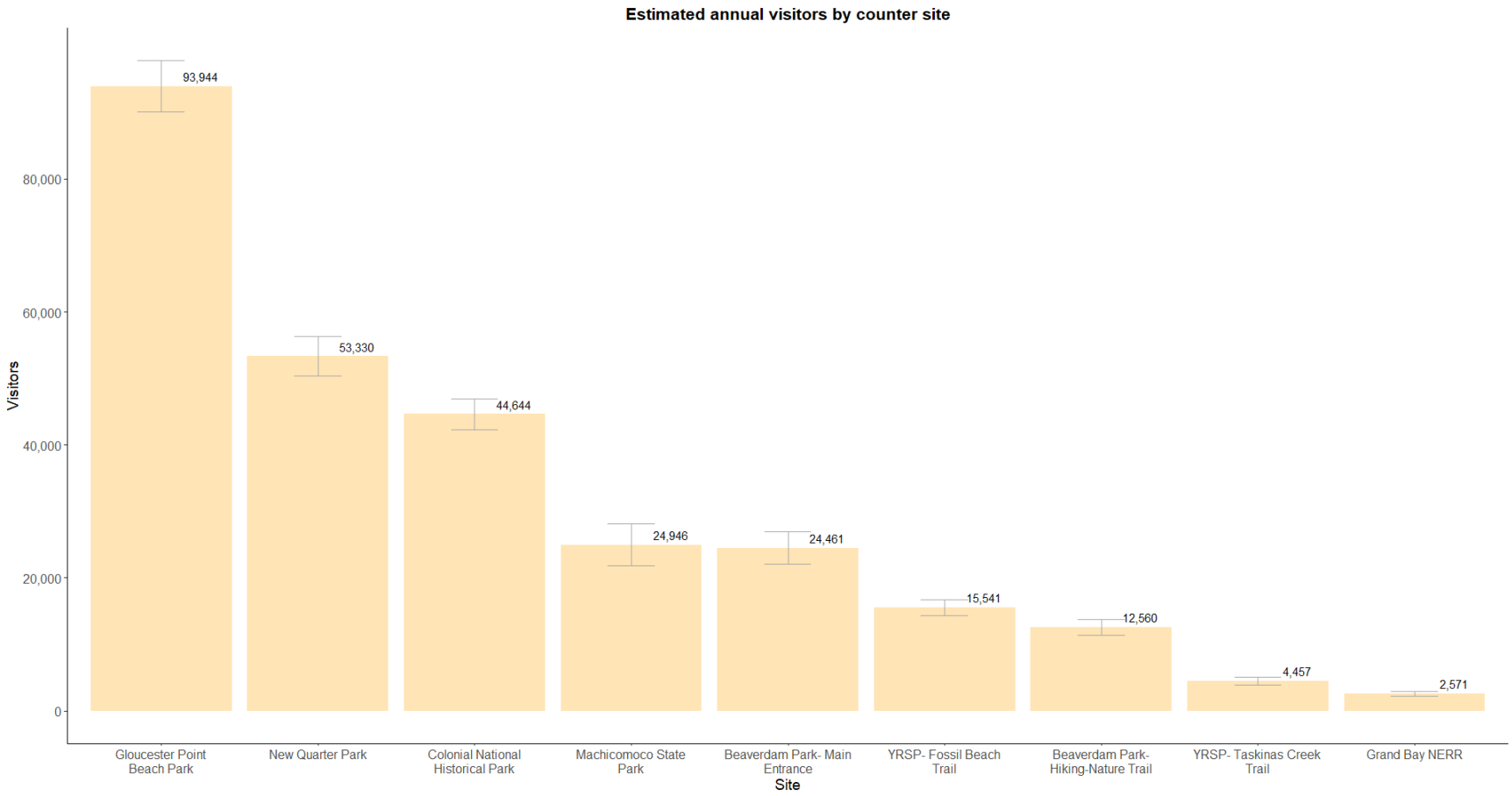

Figure 14. Comparison of estimated annual visitors by counter site. YRSP = York River State Park; NERR = National Estuarine Research Reserve.

References

Arnberger, A., Haider, W., and Brandenburg, C. (2005). Evaluating visitor-monitoring techniques: A comparison of counting and video observation data. *Environmental management*, *36*(2), 317–327. https://doi.org/10.1007/s00267-004-8201-6

Greene-Roesel, R., Diogenes, M. C., Ragland, D. R., and Lindau, L. A. (2008). Effectiveness of a commercially available automated pedestrian counting device in urban environments: Comparison with manual counts. University of California Transportation Center. https://escholarship.org/uc/item/2n83w1q8

Laws, T. R. (2013). Trail counter calibration: The search for influences in Sequoia and Kings Canyon National Parks [Unpublished doctoral dissertation]. Western Washington University.

Ozbay, K., Bartin, B., Yang, H., Walla, R., and Williams, R. (2010). Automated pedestrian counter: Final report, February 2010. Rutgers University. FHWA-NJ-2010-001. https://rosap.ntl.bts.gov/view/dot/17680

Pettebone, D., Newman, P., and Lawson, S. R. (2010). Estimating visitor use at attraction sites and trailheads in Yosemite National Park using automated visitor counters. *Landscape and Urban Planning*, *97*(4), 229–238. https://doi.org/10.1016/j.landurbplan.2010.06.006

R Core Team. (2024). R: A language and environment for statistical computing (Version 4.4.1) [Computer software]. R Foundation for Statistical Computing. https://www.R-project.org/

Ross, J. (2005). *Visitor counters in parks: Management practice for counter calibration*. New Zealand Department of Conservation Technical Series 33. https://www.doc.govt.nz/documents/science-and-technical/docts33.pdf

TRAFx Research Ltd. (2022). *How to calibrate a counter*. V220122. https://www.trafx.net/downloads/How_to_calibrate_a_counter.pdf?v=220121

Turner, S., Middleton, D. R., Longmire, R., Brewer, M., and Eurek, R. (2007). *Testing and evaluation of pedestrian sensors*. Texas Transportation Institute, Texas A&M University System. Report number SWUTC/07/167762-1. https://rosap.ntl.bts.gov/view/dot/16328

Yang, H., Ozbay, K., and Bartin, B. (2010). Investigating the performance of automatic counting sensors for pedestrian traffic data collection. *Proceedings of the 12th World Conference on Transport Research*. Lisbon, Portugal, July 11–15, 2010.

U.S. Department of Commerce
Howard Lutnick, Secretary

National Oceanic and Atmospheric Administration
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