



Coastal Topography Change at Padre Island National Seashore, Texas

2017–2021 Data Summary

Natural Resource Data Series NPS/GULN/NRDS—2022/1347



ON THE COVER

Photo taken in August 2020 near mile marker 40, after Hurricane Hanna. It shows sloped beach and eroded foreshore dune margin. NPS photo / GULN staff.

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Summary and Key Findings

In May and June 2017, April 2019, and May 2021, the Gulf Coast Network (GULN) collected coastal topography data at Padre Island National Seashore (PAIS) as a part of the NPS Vital Signs Monitoring Program. Monitoring was conducted following methods detailed in *Monitoring Coastal Topography at Gulf Coast Network Parks: Protocol Implementation Plan* (PIP; Bracewell 2017).

Key findings from this effort are as follows:

- A fixed set of 23 topographic transects distributed along the Gulf shore were surveyed.
- The most accelerated change in profile area occurred in the transect groups located near Mile Markers 15 and 37. This is likely due to the impacts from Hurricane Hanna.

- The transects on the south end of Padre Island National Seashore near Mansfield Channel showed short-term losses in profile area (2019 to 2021) that are less than the longer-term losses (2017 to 2021). The transect nearest the channel showed substantial recovery, which is related to the deposition of dredged material.

This project is in the early phases of implementation and will benefit from future surveys to better understand the influence of slight changes in survey timing and other environmental variations.

Introduction

As stated by Psuty et al. (2010)

Changes in coastal topography, whether caused by erosion or accretion, vary both spatially and temporally. Understanding these variations is key to early recognition of potential problems affecting natural resources and cultural resources in coastal parks. For managers, an understanding of the spatial and temporal patterns of geomorphologic change is basic to optimal management of any coastal park because the interface of marine and land systems: (1) is highly dynamic and driven by multiple forcing mechanisms; (2) results in alterations to resource patterns and dynamics at habitat and ecosystem levels; and (3) can eventually result in the loss of static resources. The establishment of local, long-term monitoring programs provides metrics . . . to help understand the processes that are driving coastal change of beaches, dunes, and bluffs within the parks.

Methods for monitoring coastal topographic change were developed by the Northeast Coastal and Barrier Network in Psuty et al. (2010) and adapted for use by the Gulf Coast Network (GULN) in Bracewell (2017). Following this guidance, the Gulf Coast Network has created a network of permanently established reference points that allow for the collection of highly accurate elevation data along beach and dune transects at Gulf Islands National Seashore (GUIS) and Padre Island National Seashore (PAIS). Profiles created from these elevation data are tracked through space and time to better understand geomorphic processes and spatial patterns as they relate to park resources.

This report provides a summary of coastal topography data collected to address this objective at Padre Island National Seashore from May 2017 through April 2021.

Study Area

Padre Island National Seashore was established in 1962, and consists of approximately 130,000 acres (52,609 hectares [ha]) of land and water. At 113 kilometers (70 miles [mi]), it is the longest stretch of undeveloped barrier island in the world, and ranges in width from 0.8 to 4.8 kilometers (0.5 to 3 mi; Cooper et al. 2005). The authorized boundary of the seashore includes not only the barrier island itself, but also portions of the Gulf of Mexico and the Laguna Madre.

There are a number of aquatic and terrestrial ecosystems in Padre Island National Seashore. Beginning on the Gulf-side and going west to the Gulf Intracoastal Waterway, the park includes the nearshore waters, the foreshore (swash zone) and backshore (from high-tide line to dunes) on the beach, foredunes, vegetated flats behind the dunes with

shallow fresh- or brackish-water ponds and marshes, back-island dunes in some areas, wind-tidal flats, and shallow, hypersaline seagrass beds in the lagoon. The interplay of climate, physiography, and geomorphology results in a landscape that is largely shaped by wind (Withers et al. 2004).

The purpose of this document is to report the most recently collected data from within the park as part of an ongoing long-term topographic-change monitoring program. Figure 1 shows the Gulf Coast Network coastal topography monitoring transects. Other data collected during this survey are available at the [Gulf Coast Network Coastal Topography Monitoring Project](#).

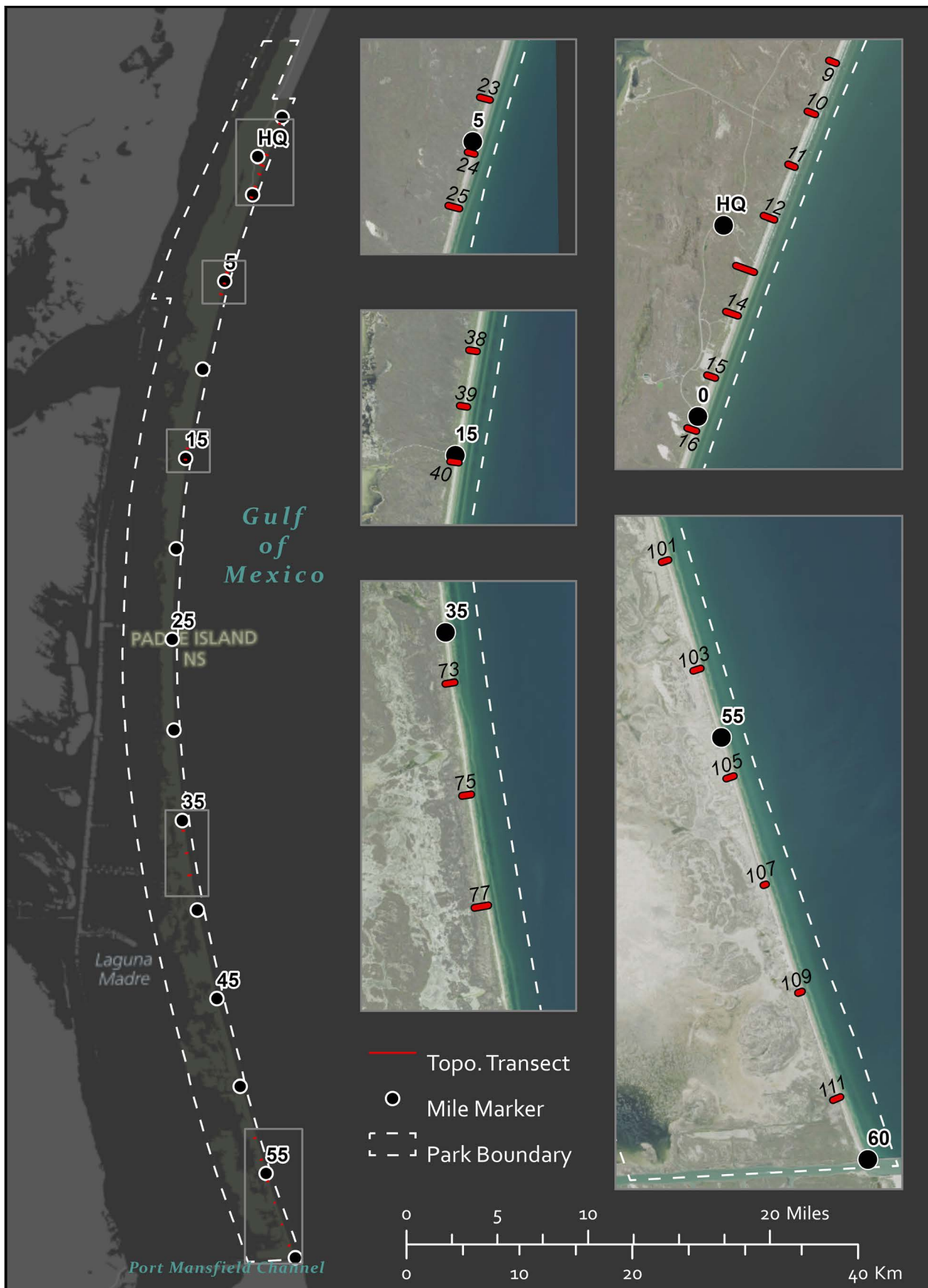


Figure 1. The 23 Gulf Coast Network coastal topography survey transects at Padre Island National Seashore.

Methods

The Gulf Coast Network has established a framework of equally spaced cross-shore transects in a Geographic Information System (GIS) along the entire shoreline of Padre Island National Seashore. From this framework, a set of monitoring sites was selected to support high-priority

park resource management decisions and other GULN vital signs monitoring projects (Figure 1). To collect monitoring data, a crew member records elevation using precision GPS equipment at the topographic inflections in the beach and primary dune complex along the transect (Figure 2).



Figure 2. Field crew measuring the topo point at transect 105 in Padre Island National Seashore. NPS photo / GULN staff.

Standard Operating Procedures

Table 1 presents the standard operating procedures (SOPs) that are critical to maintaining continuity between data sets across many surveys so results are comparable. No significant changes were made to SOPs between 2019 and 2021, and version numbers in the table apply to both efforts.

Timing of the Topographic Survey

Topographic surveys are timed to be concurrent with GULN shoreline position surveys, which are conducted during neap

tides in April and May of every other year. Neap tides are the two periods per month when high and low tides are the least different. For a given survey season, these neap tide periods are determined based on predicted water levels using the closest NOAA monitoring station at Bob Hall Pier (NOAA 2019). The dates and transects surveyed for 2017, 2019 and 2021 are listed in Table 2. Although lower water levels make surveying lower beach elevations easier and safer, the topographic survey is not dependent on neap tides to complete the work and to produce comparable results.

Table 1. Standard operating procedures used for topographic data collection, processing and reporting.

SOP number	SOP title	SOP version
CT03	Survey Timing and Mission Planning	1.0
CT04	Settings for Collection of Topography	1.0
CT05	Conducting the Survey	1.0
CT06	Initial Post Survey Processing	1.0
CT07	Data Analysis and Reporting	1.0

Table 2. List of survey collection days and transects surveyed.

Season	Survey Collection Date	Surveyed Transects
Spring 2017	5/30/2017	9, 10, 11, 12, 13, 15, 16
Spring 2017	5/31/2017	101, 103, 105, 107, 109, 111
Spring 2017	6/1/2017	23, 24, 25, 38, 39, 40, 73, 75, 77
Spring 2017	6/2/2017	14
Spring 2019	4/17/2019	13, 14, 15
Spring 2019	4/18/2019	101, 103, 105, 107, 109, 111
Spring 2019	4/19/2019	9, 10, 11, 12, 16, 38, 39, 40, 73, 75, 77
Spring 2019	4/20/2019	9
Spring 2021	5/6/2021	11, 12
Spring 2021	5/7/2021	111
Spring 2021	5/8/2021	10, 11, 13, 14, 15, 16, 23, 24, 25
Spring 2021	5/9/2021	38, 39, 40, 73, 75, 77
Spring 2021	5/10/2021	101, 103, 105, 107, 109
Spring 2021	5/11/2021	23, 24, 25

Natural and Anthropogenic Events affecting Coastal Geomorphology

Position

Five named storms between 2017 and 2021 caused water levels to rise to or above 1.2 meters (3.94 feet [ft]; NAVD 88) at Bob Hall Pier, including Hurricane Harvey in 2017 and Hurricanes Hanna, Laura, Beta and Delta in 2020 (Figure 3). These water levels are among the highest recorded at Bob Hall Pier during the past five years. A list of high-water level events exceeding 0.9 meters (2.95 ft; NAVD88) at Padre

Island National Seashore between January 2017 and the survey date of May 7, 2021 is included in Appendix A. Tidal conditions approaching +1m NAVD 88 will extend water levels to the shoreward margin of the primary dune complex. Wind and wave action can exaggerate impacts from high water levels and further degrade the beach and foredune. High water marks surveyed at the PAIS Visitor Center and Malaquite Campground boardwalks following Hurricane Hanna were from 2.8 meters (9.18 ft; NAVD 88) to just over 3 meters (9.84 ft; NAVD 88; Bracewell 2020).

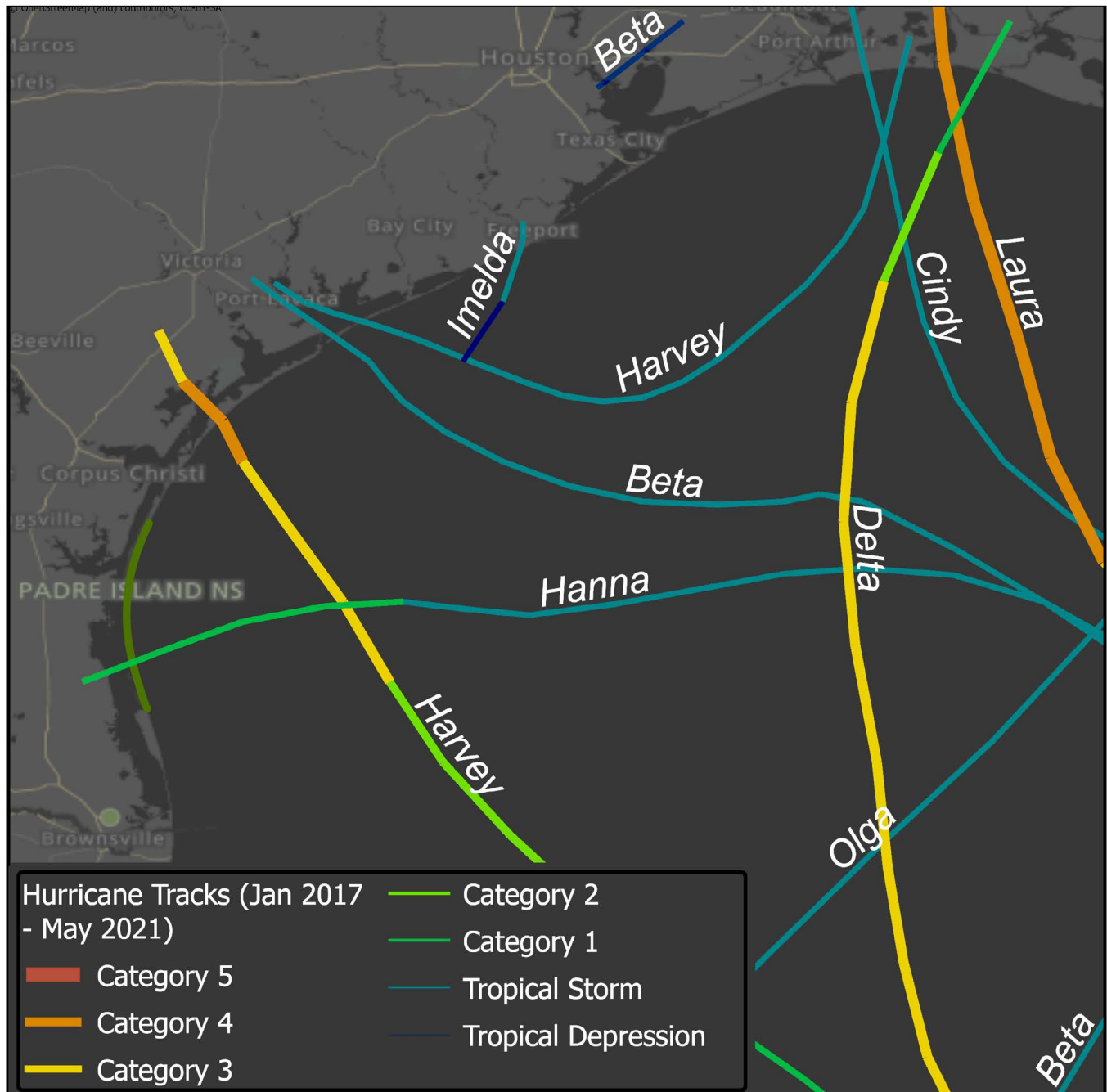


Figure 3. Named storms that made landfall on the Texas and western Louisiana coasts between January 2017 and May 2021.

Recent dredging at the Mansfield Channel, the southern boundary of the park, nourished a 1-kilometer (0.62-mile) stretch of beach at Mile Marker 60. In late 2019, a hopper dredge transported material from Mansfield Channel to a nearshore disposal site north of the north jetty. A larger

project, started in October 2020 and completed in early 2021, placed 970,000 cubic yards (741,618 cubic meters) of material dredged from the channel on the adjacent northern beach (Figure 4). No maintenance dredging had occurred on the channel since 2011 (USACE 2014).



Figure 4. Photo taken May 7, 2021 near Port Mansfield Channel, facing south. This section of the park experienced the highest shoreline advance following the recent placement of dredged material.

Results

Topographic Positional Data Quality

Topographic elevations were recorded in May through June 2017, April 2019, and May 2021. In each of the three years, all 23 monitoring transects were surveyed. Pre- and post-survey check-ins on geodetic benchmarks were all within the 0.05-meter (0.16-ft) horizontal and vertical tolerance as outlined in the protocol implementation plan (Bracewell 2017). The average horizontal and vertical positional precisions remained at or below 0.024 meters (0.08 ft; Table 3).

Topographic Measurements

Figure 5 presents the key dimensions for an example profile. Each profile distance measurement originates at a physical or virtual benchmark at zero meters. Measurements are taken in the active part of the beach/dune system and may not extend to the origin. All elevation measurements are referenced to NAVD 88, Geoid 12B. Throughout this document, 'dune crest' refers to the foredune crest. Table 4 provides the key dimensions that describe the topographic profiles for each surveyed transect. See Appendix B for graphical depictions of each profile in each year.

Table 3. Table listing the average horizontal and vertical Global Navigation Satellite System (GNSS) positional precision of the topographic features collected during 2017 and 2019.

Survey Date	Average of Horizontal Precision (meters)	Average of Vertical Precision (meters)
May/June 2017	0.016	0.024
April 2019	0.009	0.004
May 2021	0.012	0.003

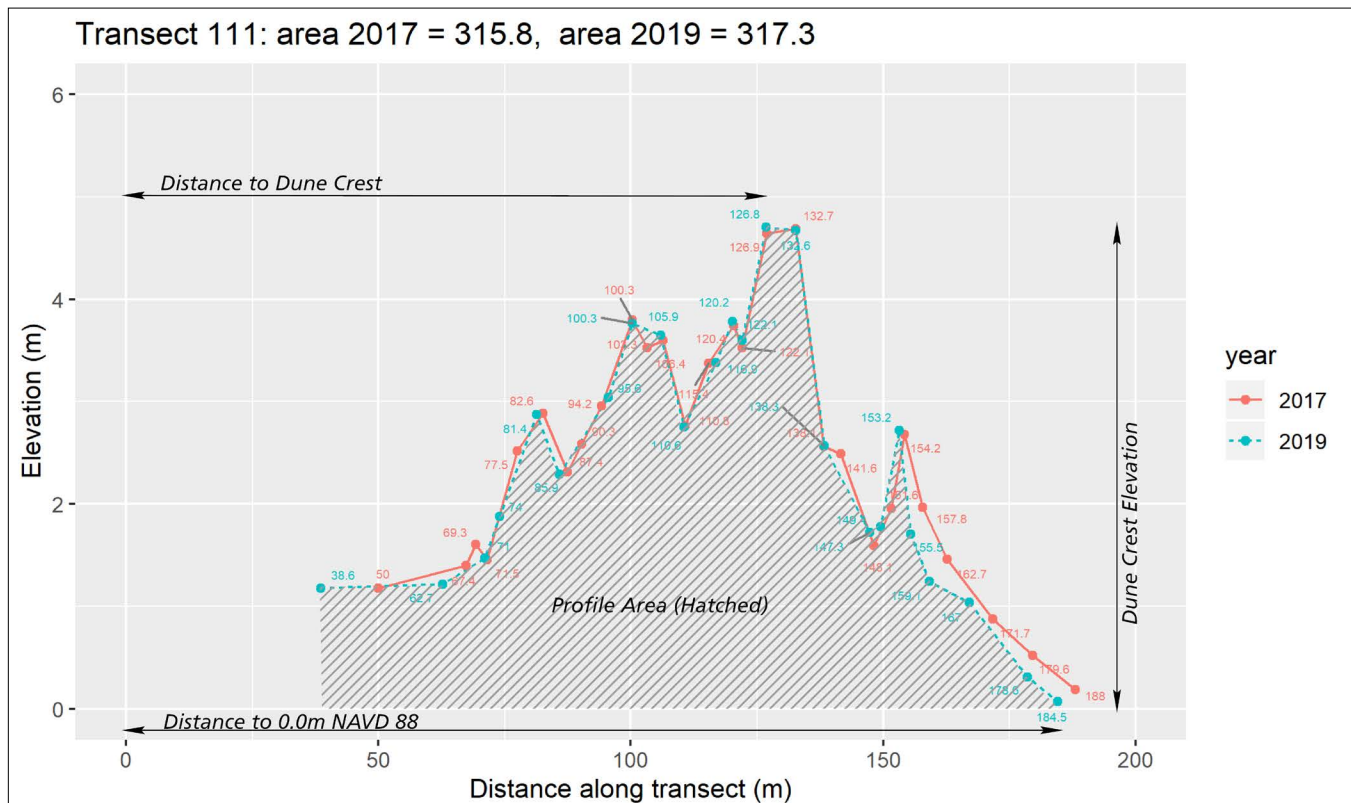


Figure 5. Example graph showing key profile dimensions. Arrows indicate: Distance to dune crest, Dune crest elevation, and Distance to 0.0 meters NAVD 88. The hatched portion under the 2019 profile represents the area calculated for profile area dimension. Each topographic measurement point is labeled with 'distance from benchmark' for each year.

Table 4. Topographic profile dimensions for 2017, 2019, and 2021 surveys at Padre Island National Seashore. All distance and elevation measurements are in meters. Elevation values are referenced to NAVD 88 and the profile area is reported in square meters.

Transect	2017	2017	2017	2017	2019	2019	2019	2019	2021	2021	2021	2021
	Dune Crest Distance from Benchmark	Dune Crest Elevation	0.0 Elevation Distance from Benchmark	Profile Area above NAVD88	Dune Crest Distance from Benchmark	Dune Crest Elevation	0.0 Elevation Distance from Benchmark	Profile Area above NAVD88	Dune Crest Distance from Benchmark	Dune Crest Elevation	0.0 Elevation Distance from Benchmark	Profile Area above NAVD88
9	182.06	5.88	296.47	181.32	5.82	300.26	183.05	5.80	294.82	5.80	294.82	321.70
10	263.75	4.42	340.39	263.68	4.38	340.26	263.76	4.49	334.22	4.49	334.22	377.80
11	180.60	4.11	249.56	180.28	4.02	252.73	180.56	4.07	241.23	4.07	241.23	269.50
12	206.46	5.06	286.39	206.44	4.94	281.92	205.52	5.08	281.10	5.08	281.10	353.10
13	315.71	4.09	379.87	315.21	4.03	380.25	315.29	4.14	385.71	4.14	385.71	378.10
14	215.16	3.81	294.74	214.75	3.83	284.72	214.85	3.92	282.75	3.92	282.75	608.80
15	76.77	7.74	215.93	77.22	7.76	206.81	77.11	7.75	210.45	7.75	210.45	490.20
16	150.87	5.39	227.67	151.91	5.42	221.96	152.06	5.35	222.09	5.35	222.09	594.50
23	187.56	5.40	252.19	187.28	5.53	249.91	185.81	4.64	247.81	4.64	247.81	459.50
24	132.56	4.58	197.37	132.82	4.61	202.52	130.09	5.04	200.81	5.04	200.81	231.70
25	167.57	4.17	245.31	165.47	4.43	256.38	165.82	4.59	249.37	4.59	249.37	267.00
38	136.30	5.81	203.35	137.83	5.87	209.39	134.56	5.79	202.95	5.79	202.95	244.30
39	100.88	4.58	182.81	101.00	4.65	186.43	101.08	4.68	184.72	4.68	184.72	301.40
40	117.96	5.27	204.49	117.69	5.28	209.81	117.67	5.46	214.00	5.46	214.00	290.60
73	127.37	7.68	199.27	127.53	7.70	212.47	127.43	7.78	220.42	7.78	220.42	416.30
75	144.85	10.68	278.02	145.31	10.76	267.25	146.16	10.73	271.64	6.60	271.64	583.90
77	227.60	7.45	341.94	227.79	7.44	322.94	227.48	7.43	332.27	5.39	332.27	440.50
101	109.56	7.31	173.38	110.50	6.72	178.13	109.88	6.98	169.34	6.98	169.34	225.20
103	145.62	5.37	176.52	143.51	5.46	189.87	143.62	5.61	199.96	5.61	199.96	250.00
105	153.24	6.31	215.93	153.45	6.23	205.16	153.35	6.44	193.75	6.44	193.75	330.80
107	93.40	4.29	132.14	87.72	2.82	110.72	57.80	2.08	109.30	2.08	109.30	71.30
109	93.24	5.65	118.37	87.99	3.40	121.78	64.07	2.15	121.22	2.15	121.22	90.70
111	132.66	4.69	188.02	126.78	4.71	184.51	132.64	4.73	217.39	4.73	217.39	225.10

Topographic Change

Table 5 provides key dimensional metrics of change between 2019 and 2021 surveys. An average of all transects shows only slight changes in dune crest distance, crest elevation, and distance to NAVD 0.0 elevation, -2.34 meters (-7.68 ft), -0.05 meters (-0.16 ft), and 0.48 meters (1.57 ft) respectively. Transects 107 and 109 stand out as having particularly large losses in dune crest distance and elevation, and this

is because they are located at the margins of a washover channel and are highly dynamic (Figure 6). When the influence of these transects is removed, the dimensional changes shrink to 0.0 meters, 0.04 meters (0.13 ft) for dune crest distance and elevation, while distance to NAVD 88 0.0 elevation advances to 0.62 meters (2.03 ft). Topographic change is averaged for transect groups based on proximity or park-defined areas of interest in Table 6.

Table 5. Summary of topographic profile dimensional change between 2019 and 2021. Negative numbers represent landward retreat or lower elevations. Summary statistics for all transects are included in the last two rows [min=minimum; max=maximum].

Transect	Dune Crest Distance from Benchmark (meters)	Dune Crest Elevation (meters)	0.0 Elevation Distance from Benchmark (NAVD 88, meters)
9	1.73	-0.02	-5.44
10	0.08	0.11	-6.04
11	0.29	0.05	(min) -11.50
12	-0.92	0.14	-0.82
13	0.08	0.12	5.46
14	0.10	0.10	-1.97
15	-0.11	-0.02	3.64
16	0.15	-0.07	0.12
23	-1.47	-0.89	-2.11
24	-2.73	(max) 0.42	-1.70
25	0.35	0.16	-7.01
38	-3.27	-0.08	-6.44
39	0.08	0.02	-1.71
40	-0.02	0.18	4.19
73	-0.10	0.07	7.95
75	0.85	-0.03	4.39
77	-0.31	-0.01	9.33
101	-0.62	0.27	-8.79
103	0.12	0.16	10.09
105	-0.10	0.21	-11.41
107	(min) -29.92	-0.74	-1.42
109	-23.92	(min) -1.25	-0.56
111	(max) 5.86	0.03	(max) 32.88
Mean	-2.34	-0.05	0.48
Standard Deviation	7.98	0.39	9.34

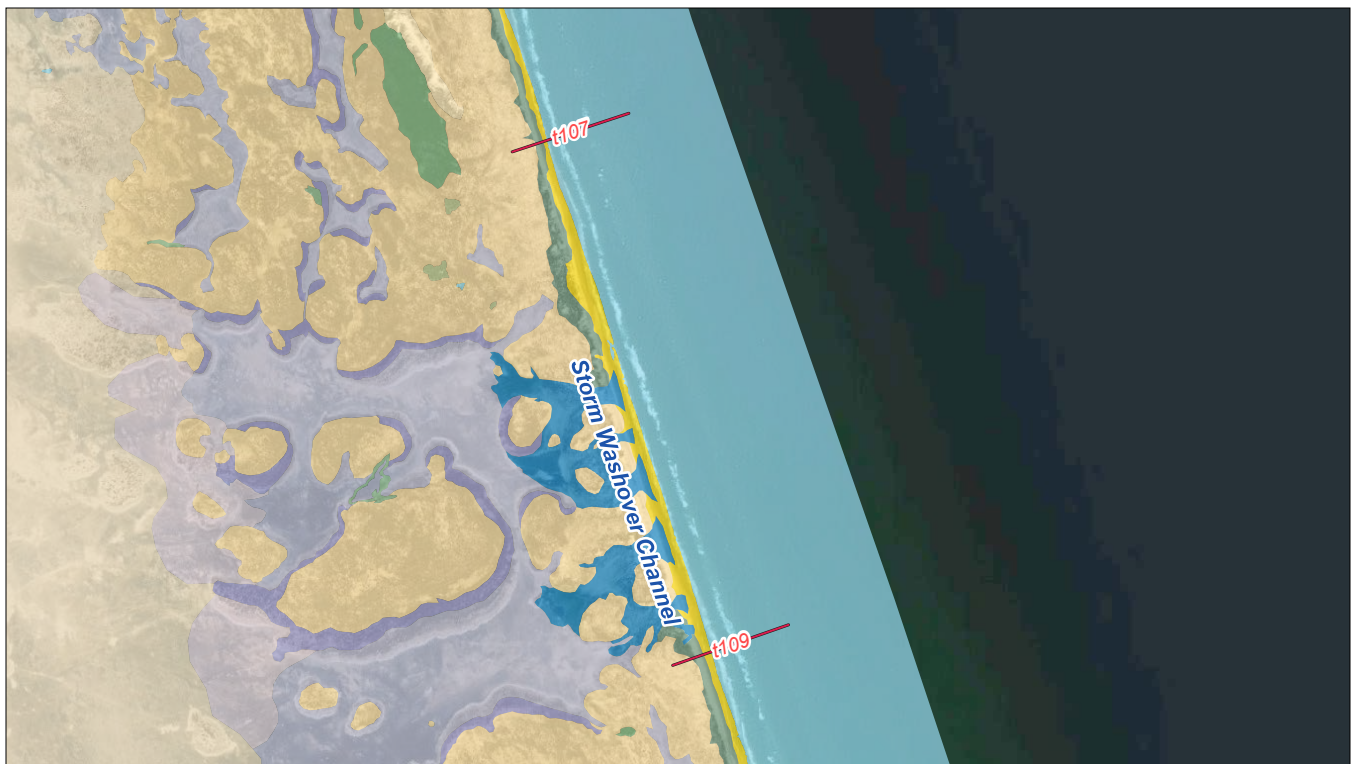


Figure 6. Storm washover channel between transects 107 and 109 as indicated in the National Park Service Surficial Geology Map for Padre Island National Seashore (NPS 2012).

Table 6. Group means for topographic profile dimensional change between 2019 and 2021 [min=minimum; max=maximum].

Transect	Dune Crest Distance from Benchmark (meters)	Dune Crest Elevation (meters)	0.0 Elevation Distance from Benchmark (NAVD 88, meters)
Average of Transects 9–15 (Closed Beach)	(max) 0.25	(max) 0.08	(min) -3.67
Average of Transects 14–16 (MM 0, GULN Vegetation Panel 8)	0.04	0.00	0.60
Average of Transects 23–25 (MM 5, GULN Vegetation Panel 18)	-1.29	-0.10	-3.61
Average of Transects 38–40 (MM 15, GULN Vegetation Panel 28)	-1.07	0.04	-1.32
Average of Transects 73–77 (MM 37, GULN Vegetation Panel 38)	0.15	0.01	(max) 7.22
Average of Transects 101–111 (Mansfield)	(min) -8.10	(min) -0.22	3.46

Profile Profile area metrics produce what may be the most comprehensive assessment of change in this report. With three surveys completed, it is possible to consider change at two temporal scales: recent change (2019–2021) versus longer term change (2017–2021). Change can also be measured as raw differences and percent change $[(\text{final value} - \text{initial value}) / \text{initial value}]$, which are the results presented in Tables 7 and 8 and Figure 7.

An average of all transects shows a greater change in profile area for the longer time period (-9.37% from 2017 to 2021), when compared with the shorter time period (-5.91% from 2019 to 2021; Table 7). However, two of the six transect groups were contrary to this general pattern, and showed a greater loss in percent of existing area in the shorter time period (Table 8). These transect groups were at mile markers

15 and 37, and their accelerated recent changes are likely due to impacts from Hurricane Hanna, which made landfall near PAIS mile marker 40.

Another notable transect group, in terms of change in area, was the southernmost Mansfield group. For raw differences, the Mansfield group lost far less than other groups between 2019 and 2021, and 111, the southernmost transect, continued to accrue area (Tables 7 and 8). For percent change, however, the Mansfield group had the greatest loss among groups for 2017 to 2021 and the second greatest among groups for 2019 to 2021 (Table 8). Like with previously presented distance and height measurements, averaged percent change in profile area for the Mansfield group was heavily influenced by losses at two of the six transects in that group, 107 and 109.

Table 7. Profile area by transect. Percent change addresses change from 2017 to 2021, and 2019 to 2021. Percent change is calculated as $(\text{final value} - \text{initial value}) / \text{initial value}$. Min notes biggest loss in profile area and Max notes biggest gain.

Transect	2017	2019	2021	Area Change 2017–2021	Area Change 2019–2021	Percent Change 2017–2021	Percent Change 2019–2021
9	335.2	327.2	318.0	-17.2	-9.2	-5.13%	-2.81%
10	396.4	393.4	382.2	-14.2	-11.2	-3.58%	-2.85%
11	254.9	255.3	232.2	-22.7	-23.1	-8.91%	-9.05%
12	374.8	363.6	353.1	-21.7	-10.5	-5.79%	-2.89%
13	399.1	386.1	378.1	-21.0	-8.0	-5.26%	-2.07%
14	635.5	621.8	608.8	-26.7	-13.0	-4.20%	-2.09%
15	507.5	507.1	490.2	-17.3	-16.9	-3.41%	-3.33%
16	610.1	598.1	572.4	-37.7	-25.7	-6.18%	-4.30%
23	490.0	492.7	459.5	-30.5	-33.2	-6.22%	-6.74%
24	257.9	254.3	231.7	-26.2	-22.6	-10.16%	-8.89%
25	278.9	279.8	267.0	-11.9	-12.8	-4.27%	-4.57%
38	291.0	293.3	244.3	-46.7	(Min) -49.0	-16.05%	-16.71%
39	320.3	327.5	296.2	-24.1	-31.3	-7.52%	-9.56%
40	310.4	310.6	311.4	1.0	0.8	0.32%	0.26%
73	403.0	436.5	432.2	29.2	-4.3	7.25%	-0.99%
75	635.9	623.6	583.9	-52.0	-39.7	-8.18%	-6.37%
77	488.8	466.8	440.5	-48.3	-26.3	-9.88%	-5.63%
101	271.1	251.5	225.2	-45.9	-26.3	-16.93%	-10.46%
103	261.5	250.5	250.0	-11.5	-0.5	-4.40%	-0.20%
105	398.3	364.3	330.8	-67.5	-33.5	-16.95%	-9.20%
107	120.7	73.0	52.5	(Min) -68.2	-20.5	(Min) -56.50%	(Min) -28.08%
109	128.4	98.7	85.0	-43.4	-13.7	-33.80%	-13.88%
111	294.9	283.9	325.1	30.2	(Max) 41.2	(Max) 10.24%	(Max) 14.51%
Average All	–	359.1	342.2	(Max) 25.8	-16.9	-9.37%	-5.91%
Standard Deviation	–	146.3	143.8	24.9	17.8	13.40%	7.74%

Table 8. Group means for transect profile area percent change. *Indicates short-term losses that exceed the longer-term losses.

Transect Group	Change in Area 2017 to 2021	Change in Area 2019 to 2021	Change in Percentage Area 2017 to 2021	Change in Percentage Area 2019 to 2021
Closed Beach	-19.36	-12.40	-5.73%	-3.93%
Mile Marker 0	-27.23	-18.53	-4.60%	-3.24%
Mile Marker 5	-22.87	-22.87	-6.88%	-6.73%
Mile Marker 15	-23.27	-26.50	-7.75%	* -8.67%
Mile Marker 37	-23.70	-23.43	-3.60%	* -4.33%
Mansfield	-34.38	-8.88	-19.72%	-7.88%

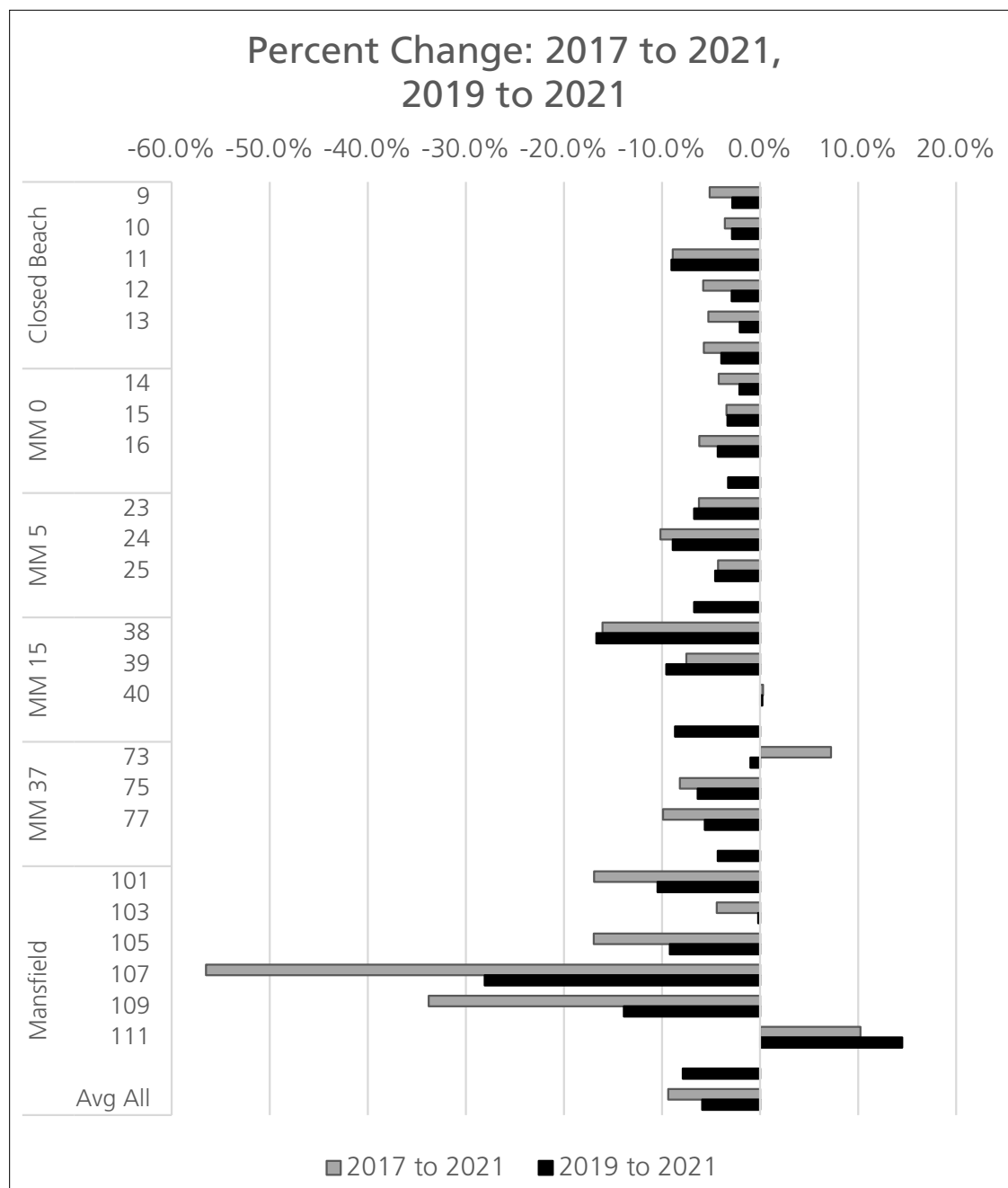


Figure 7. Profile area percent change from 2017 to 2021 and 2019 to 2021.

Areas of Special Interest

During scoping meetings for this topographic monitoring project, PAIS Resource Management staff expressed special interest in Closed Beach (north of Mile Marker 0) and the area north of Mansfield Channel (Mile Markers 55 to 60). Closed Beach showed stability in dune crest measurements and slight retreat and reduction in distance to 0.0 NAVD 88 and profile area (Tables 6 and 8). The relative stability in this group is also indicated by the slight reduction in loss of profile area in the shorter-term evaluation (Table 8).

The Mansfield Channel group exhibited dimensional change measurements that were mixed compared with park-wide means. While the dune crest distance retreated some, the dune crest elevation remained stable and the distance to 0.0 NAVD 88 advanced slightly (Table 6). The Mansfield Channel group has the smallest mean profile area, 199 square meters (2,142 square feet [ft²]) compared with a mean of 340 square meters (3,660 ft²) for all transects (calculated

on 2021 metrics). Alongside the presence of washover channels, the relatively small geomorphic stature of this region likely plays an important role regarding variability in topographic change. Recent beach nourishment should help fortify the beach/dune interface in at least parts of this region. More information about dredging at the Mansfield Channel is available in Bracewell (2021).

Problems and Concerns

There were high tide events at beginning of May that peaked at 0.817 meters (2.68 ft) above NAVD 88 on May 1 (Figure 8). Figure 9 presents a five-year record of water levels recorded at Bob Hall Pier and the reports the frequency of levels exceeding the mean of 0.31 meters (1.02 ft). Tide levels exceeding 0.8 meters (2.62 ft) are relatively uncommon, having occurred only about 50 times in this five-year period. Despite the infrequency of the pre-survey high tide condition, there was no evidence of recent scarping or other noteworthy geomorphic changes.

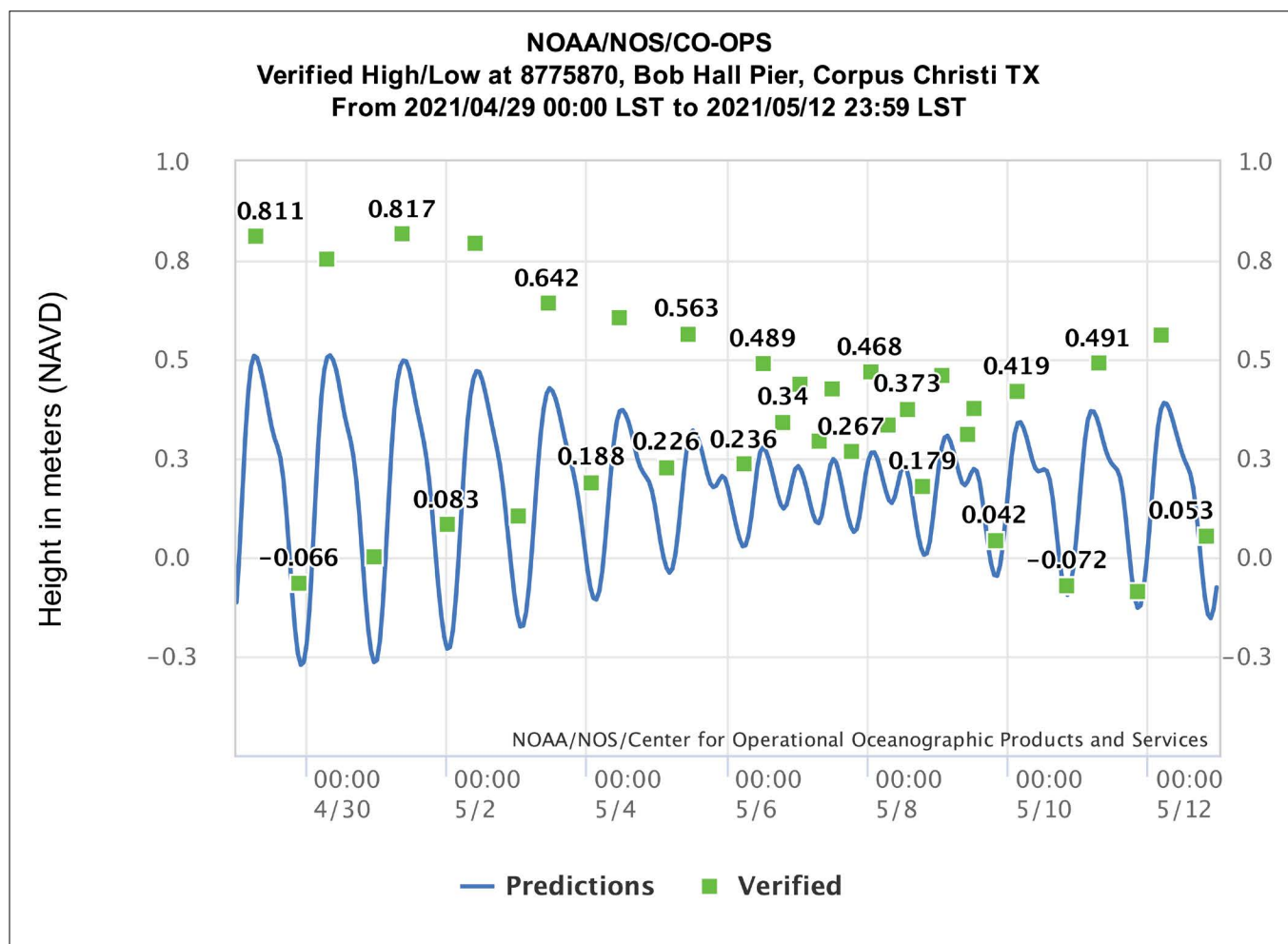


Figure 8. Water levels recorded at Bob Hall Pier in advance and during the GULN spring 2021 topography survey.

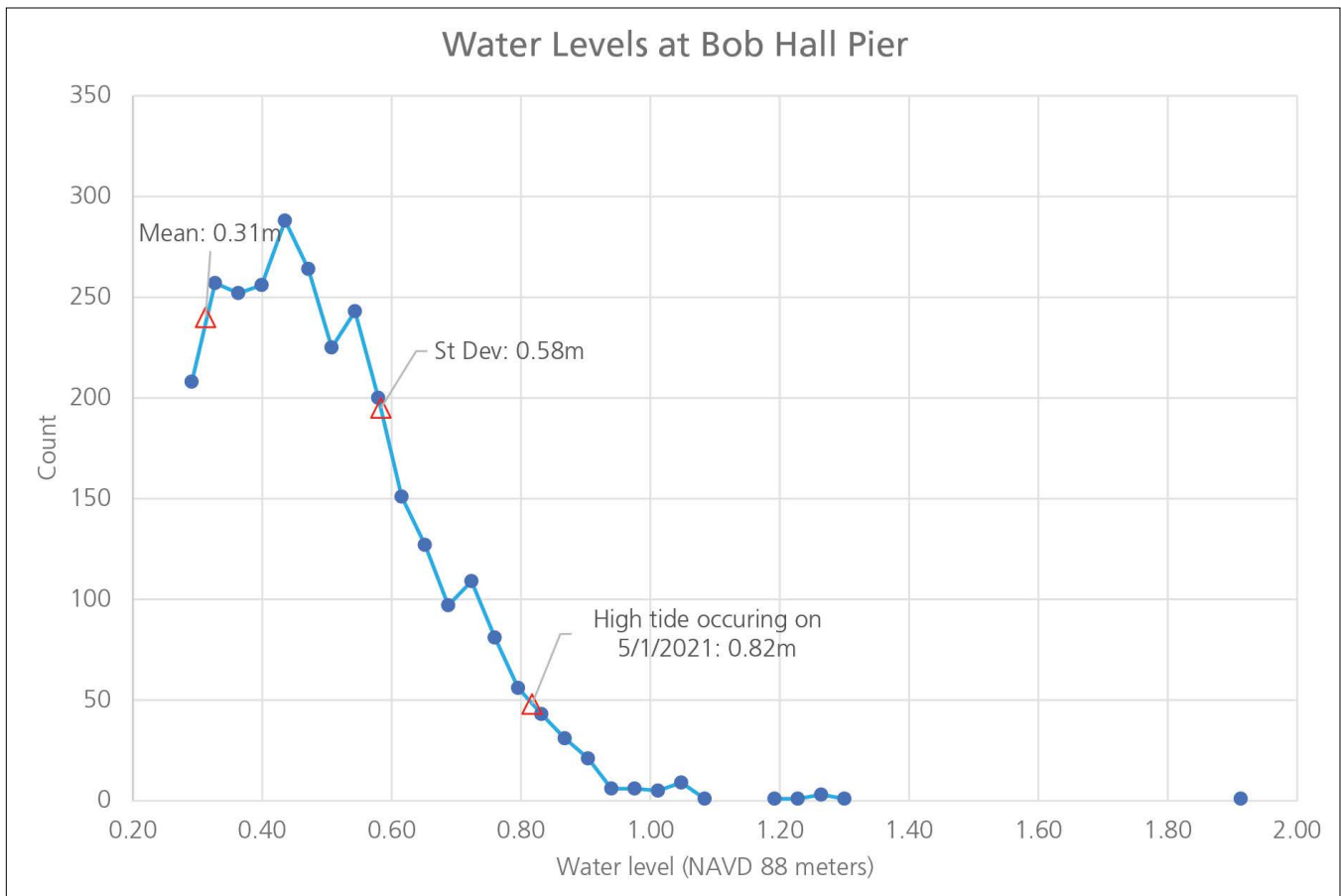


Figure 9. Frequency distribution of water levels above the five-year mean (2017 to 2021) of 0.31 meters (1.02 ft) at Bob Hall Pier.

This is the first in a continuous series of every-other-year reports related to monitoring topographic change at Padre Island National Seashore. It is expected that future reports will benefit from the accumulation of data sets, allowing for better interpretation of the measurement variation attributed to geomorphic differences (e.g., slope), as well as weather, seasonal and tidal differences.

Protocol Changes

No major changes occurred to the GULN protocol implementation plan (Bracewell 2017) between its initial publication in 2017 and composition of this report (August, 2019).

Additional Information

Analyses confirmed statistically significant differences in

profile area between some transect groups and between survey years. Between group differences are expected due to the varying lengths of survey transects, and varying heights and widths of the beach/dune systems along the PAIS Gulf shore. Significant differences were found from 2017 to 2021, and 2019 to 2021 surveys, but not 2017 to 2019. Again, this is likely the outcome of Hurricane Hanna impacts in 2020. Between group, year, and year-group statistical tests are outlined in Appendix C.

For data and information related to this report please visit the [Gulf Coast Network Coastal Topography Monitoring Project](#). For information about the GULN's complementary coastal dynamics project mapping changes in shoreline position, see the [Gulf Coast Network Shoreline Monitoring Project](#).

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- Psuty, N. P., T. M. Silveira, M. Duffy, J. P. Pace, and D. E. Skidds. 2010. Northeast Coastal and Barrier Network geomorphological monitoring protocol: Part I—ocean shoreline position. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/664308> (last accessed November 2021).
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Appendix A. High Tide Events at Bob Hall Pier

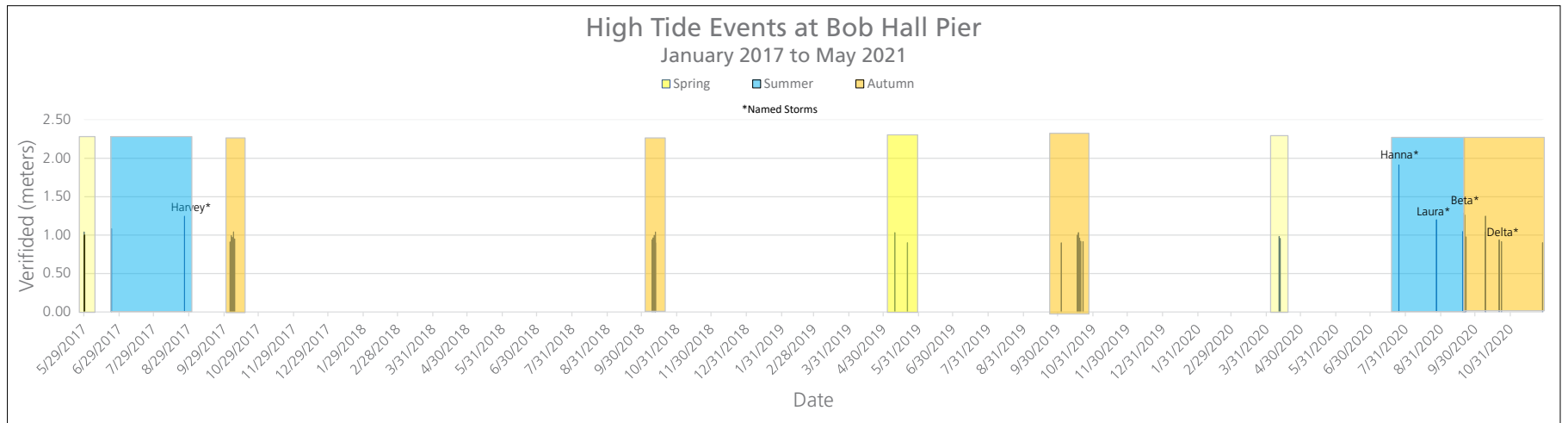


Figure A-1. High tide events measured at Bob Hall Pier from Jan 2017 to May 7, 2021. The average water level, calculated on daily high/low tides, for this entire three-year period is 0.31 meters (1.02 ft; NAVD88). Graph extends to the last occurrence of an extreme tidal event before the 2021 survey.

Appendix B. Graphs Comparing Transect Profiles

Graphical depiction of topographic profiles with dimensional measurements for the years surveyed. Information regarding the measuring transects can be found in the 'Transect Measurements' section of the main document.

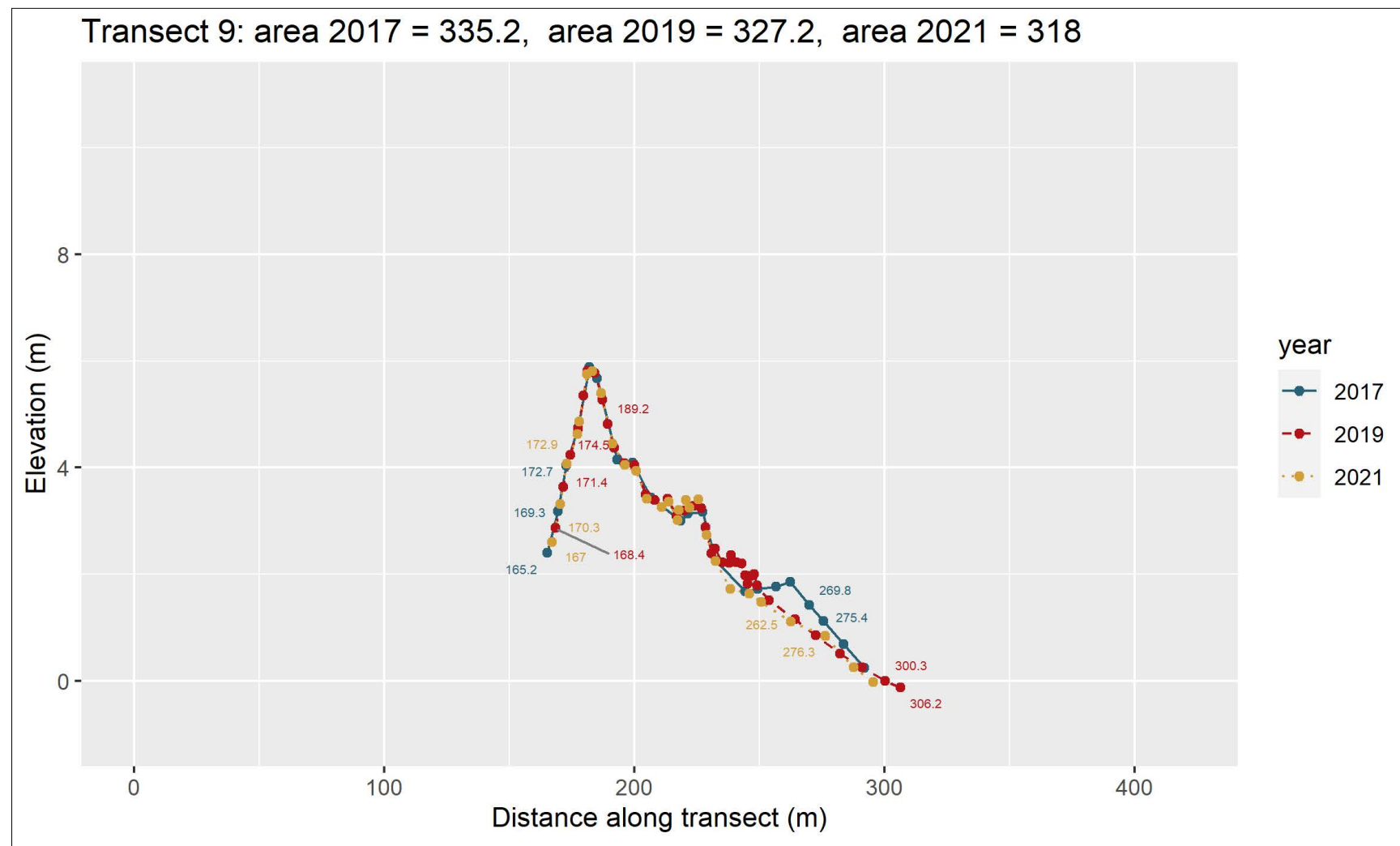


Figure B-1. Transect 9 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

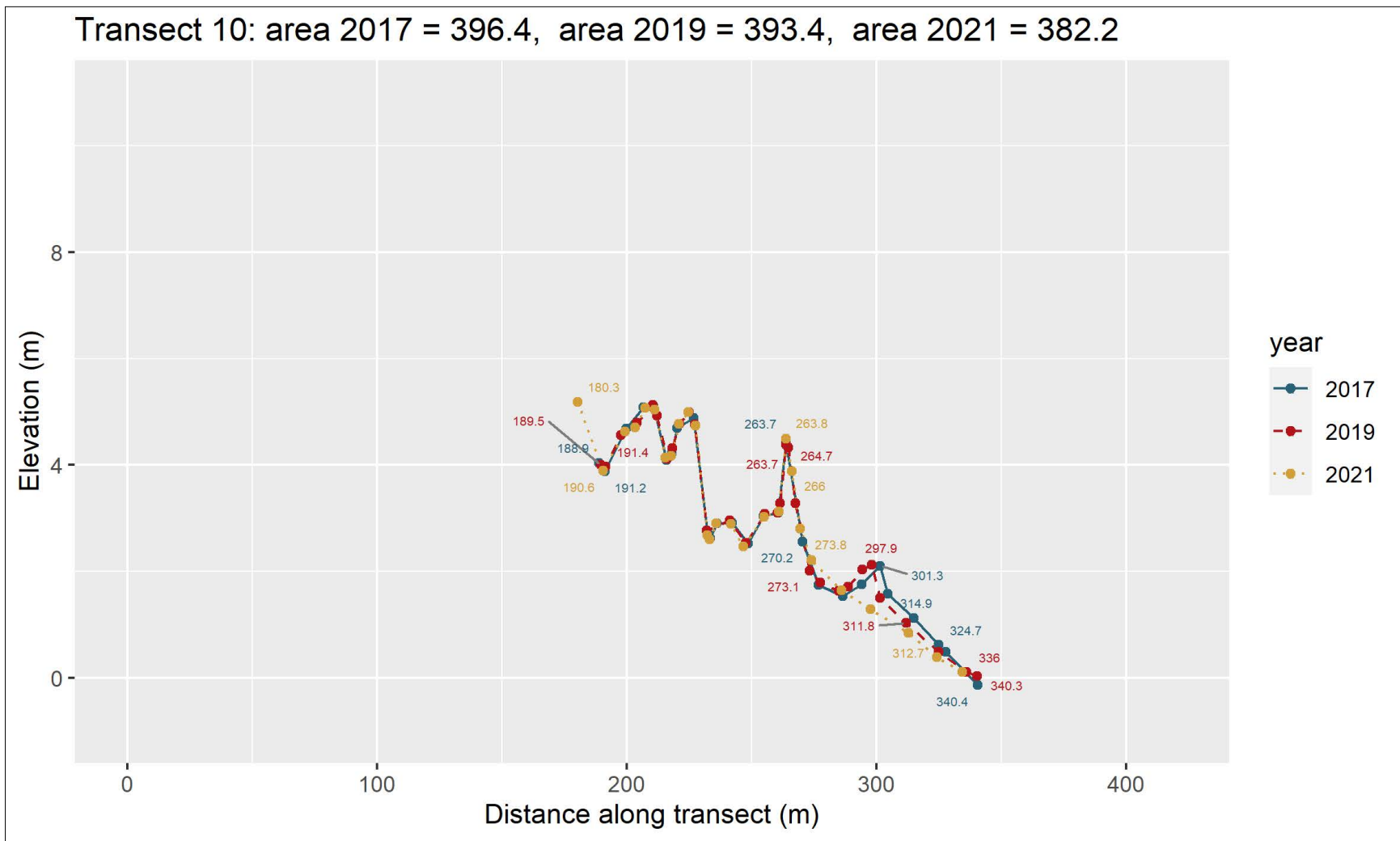


Figure B-2. Transect 10 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

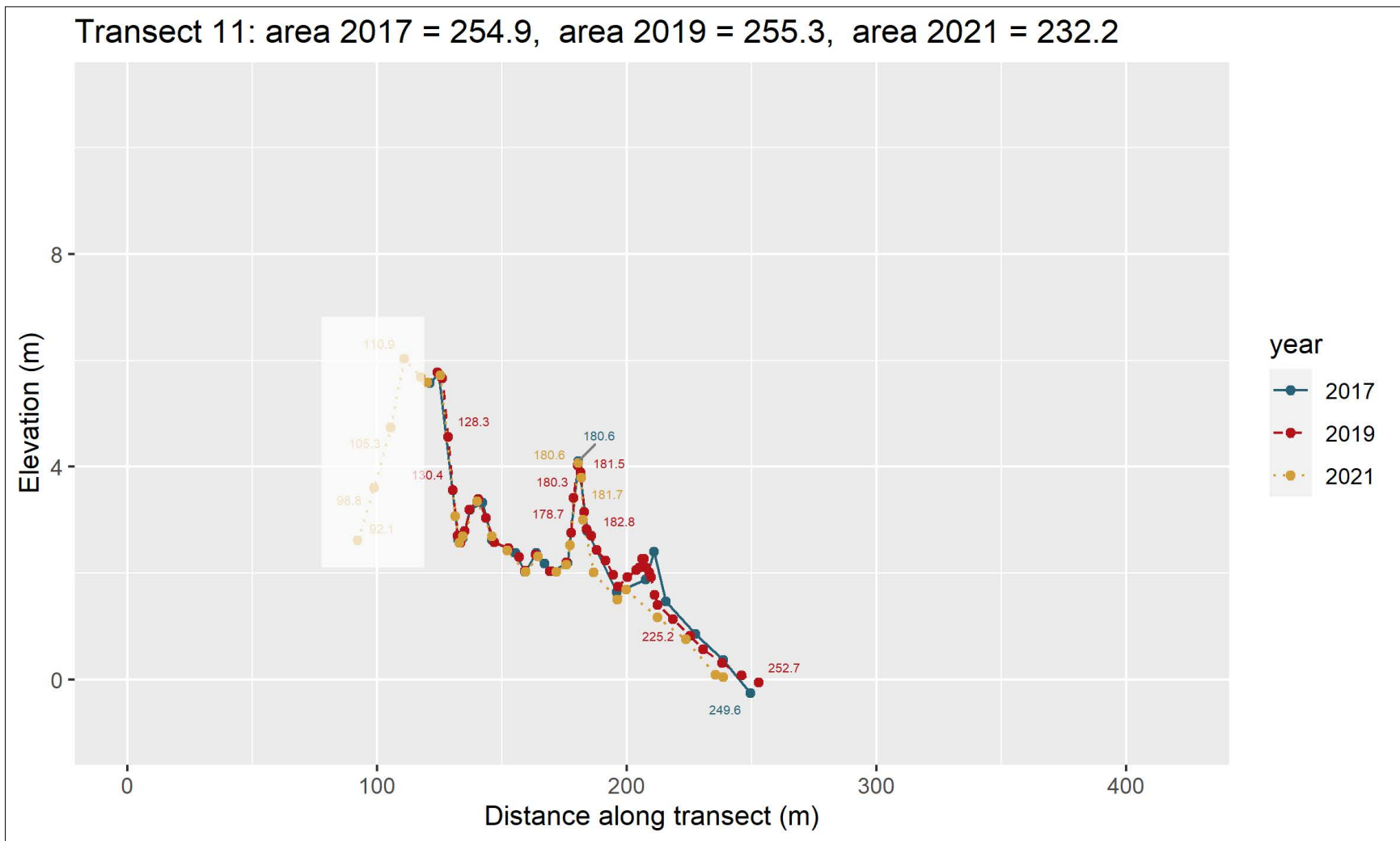


Figure B-3. Transect 11 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

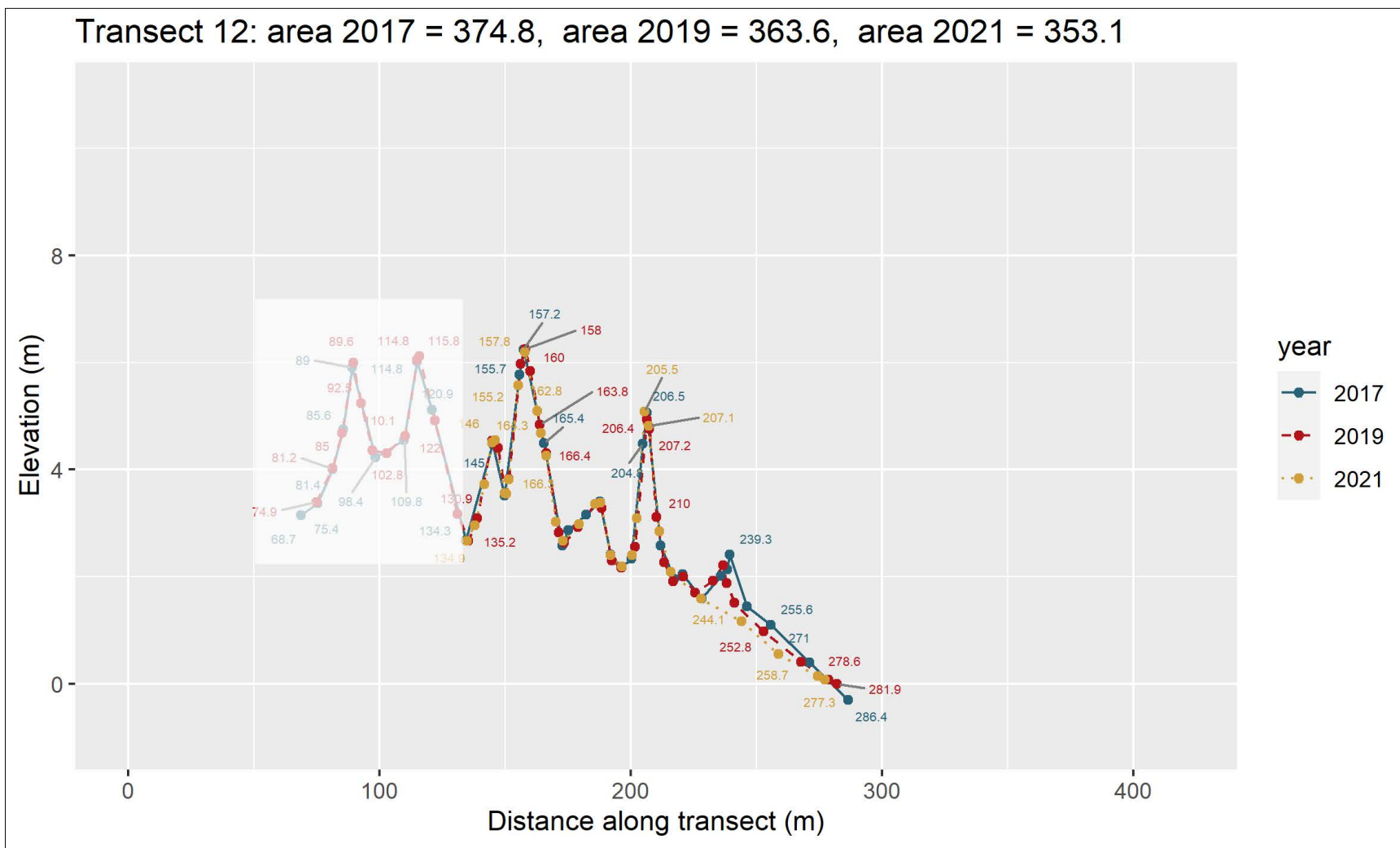


Figure B-4. Transect 12 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

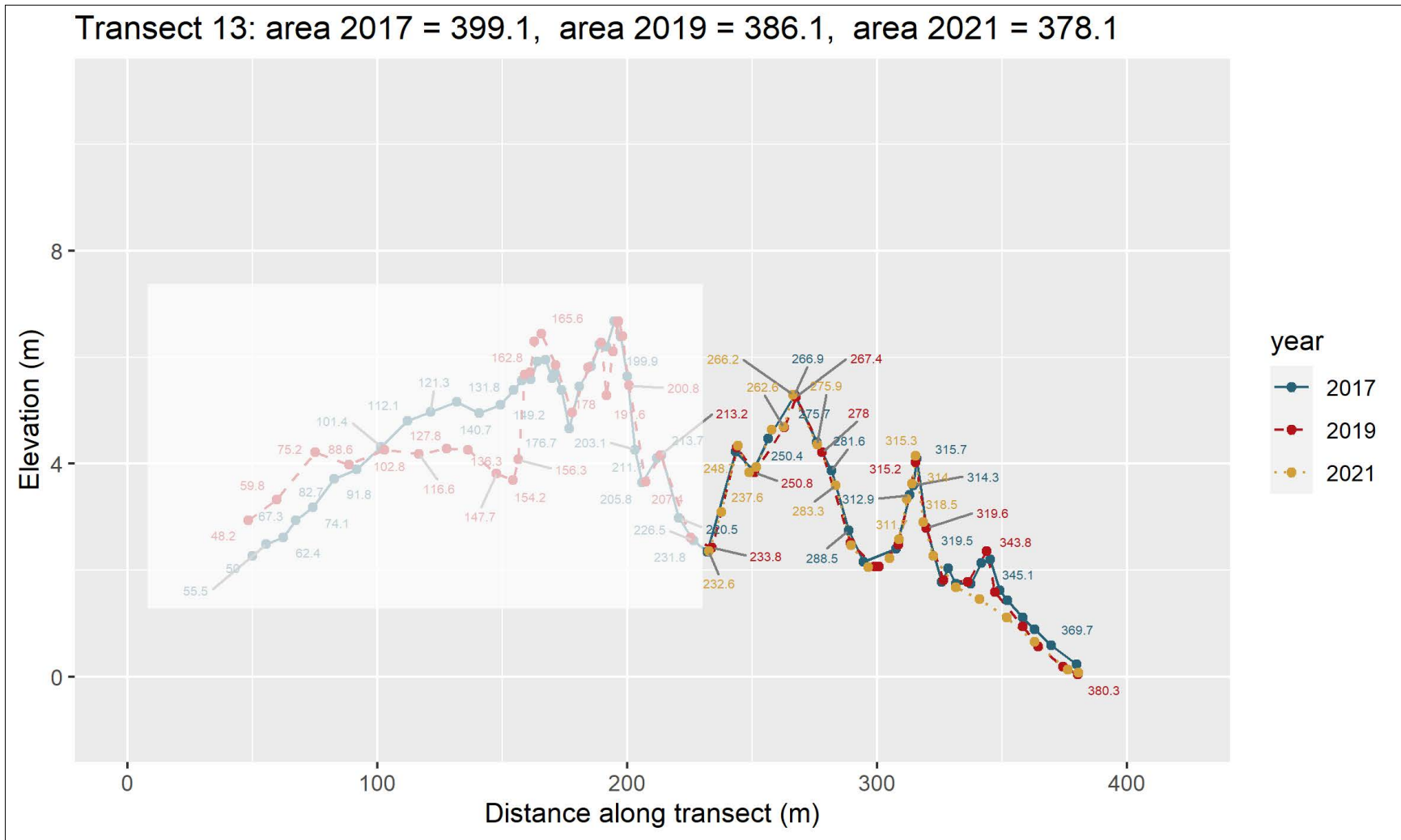


Figure B-5. Transect 13 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

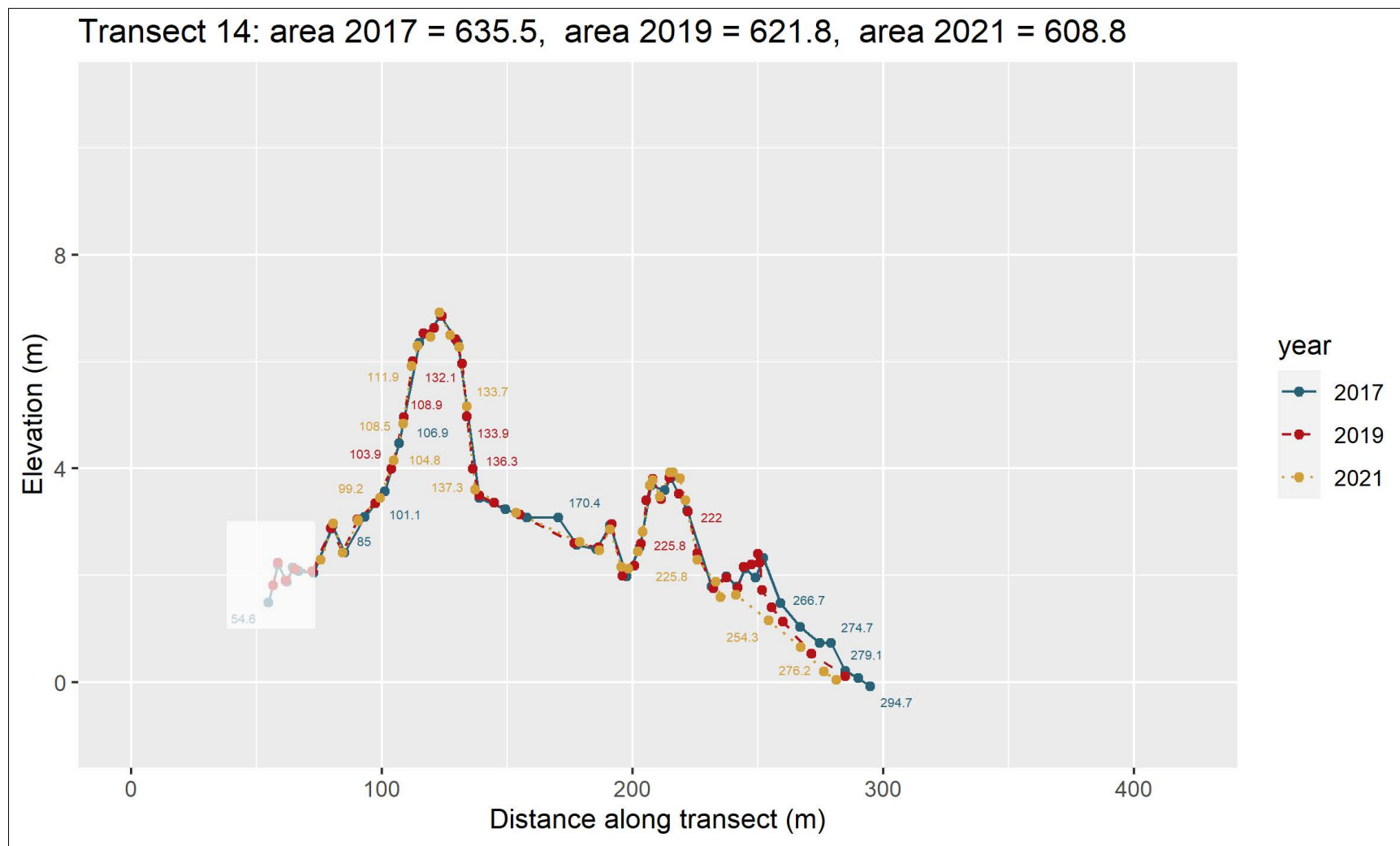


Figure B-6. Transect 14 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

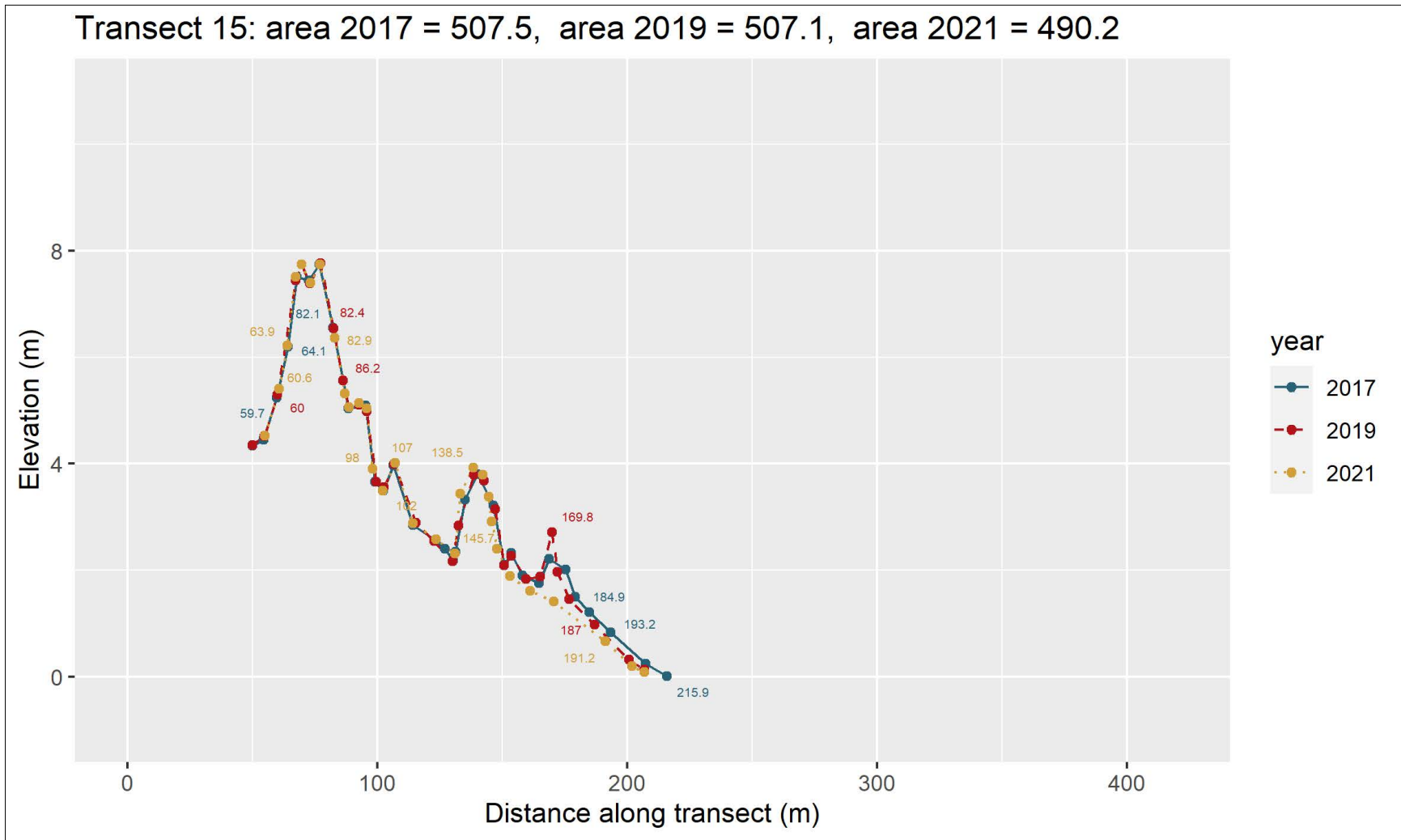


Figure B-7. Transect 15 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

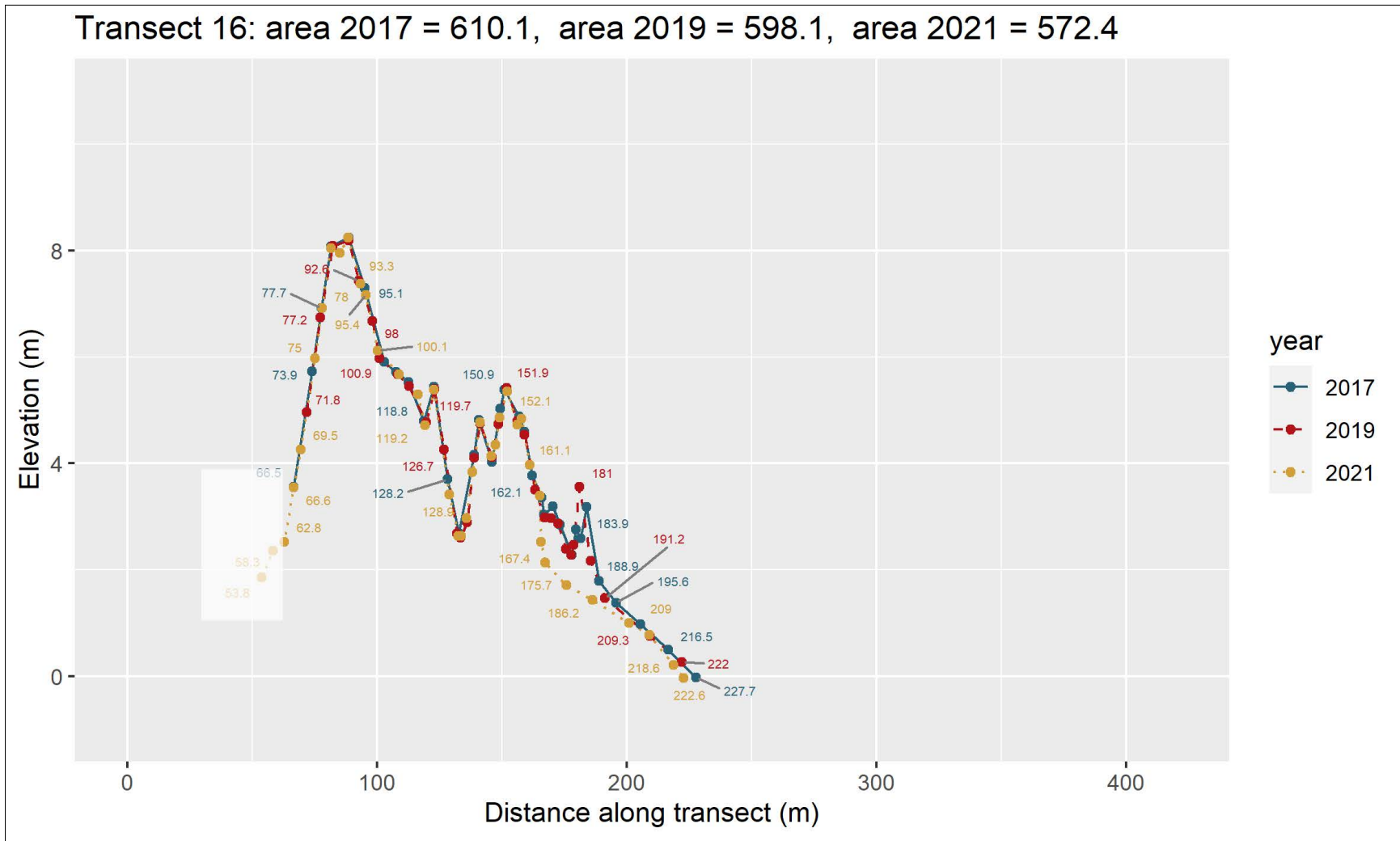


Figure B-8. Transect 16 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

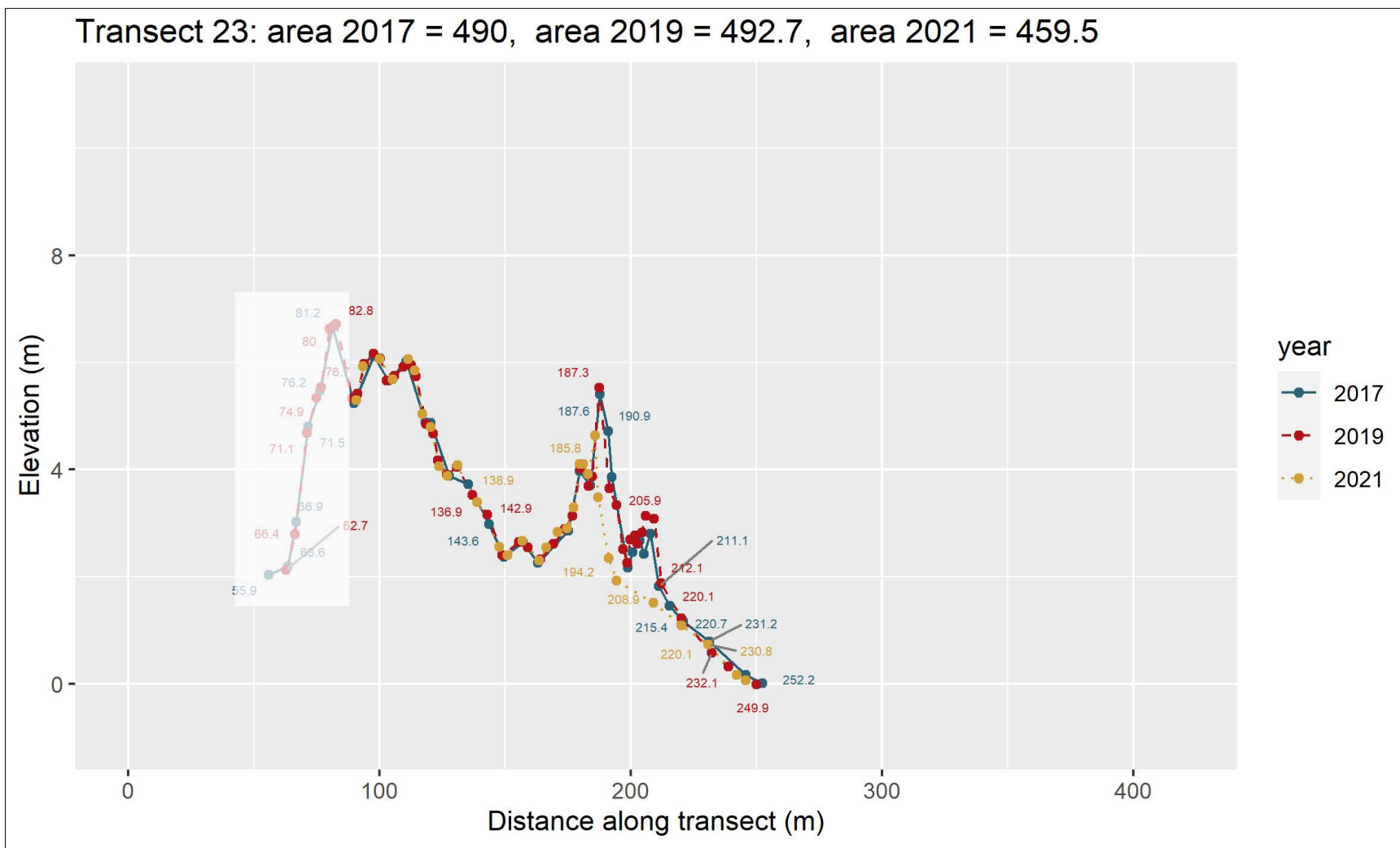


Figure B-9. Transect 23 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

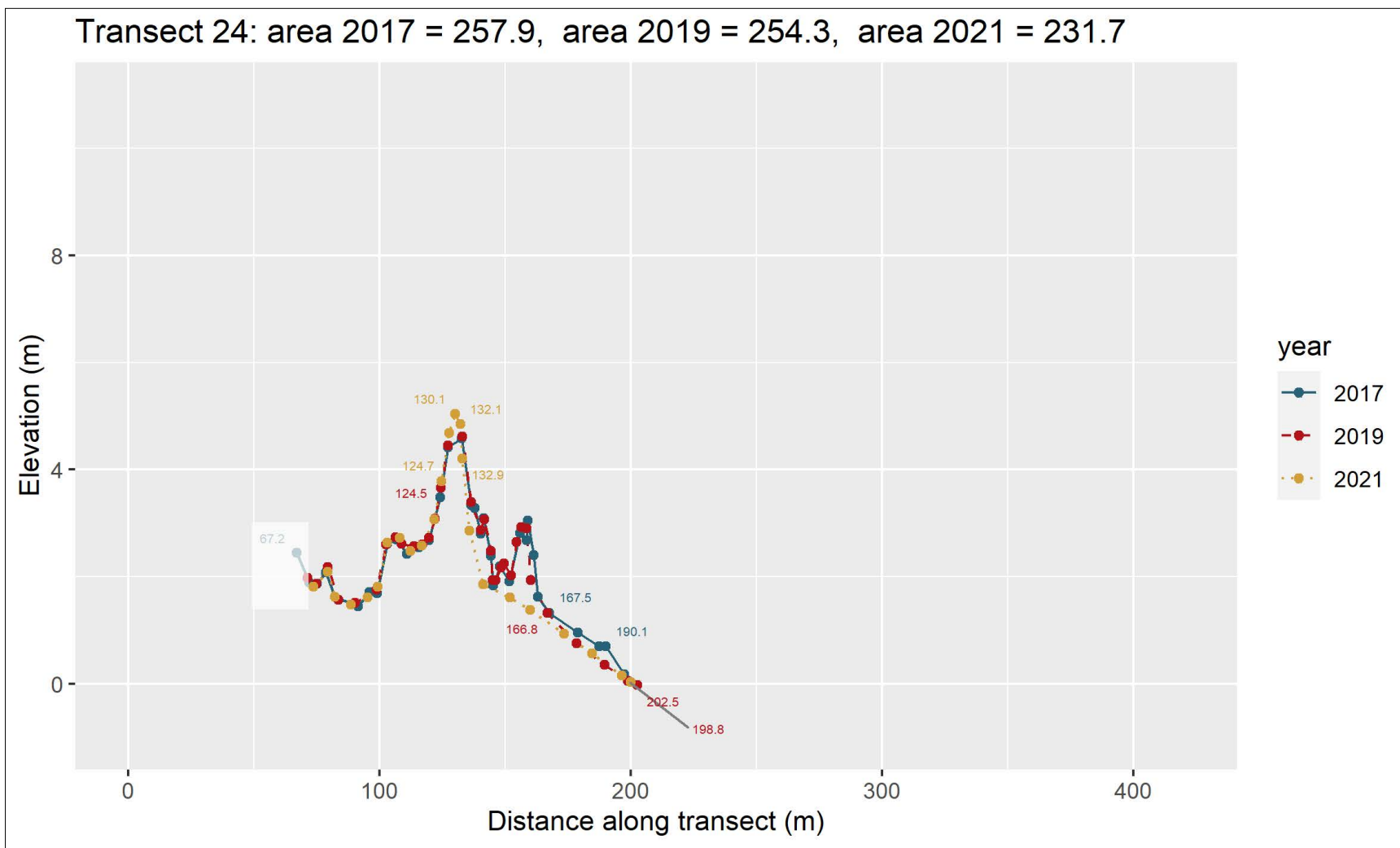


Figure B-10. Transect 24 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

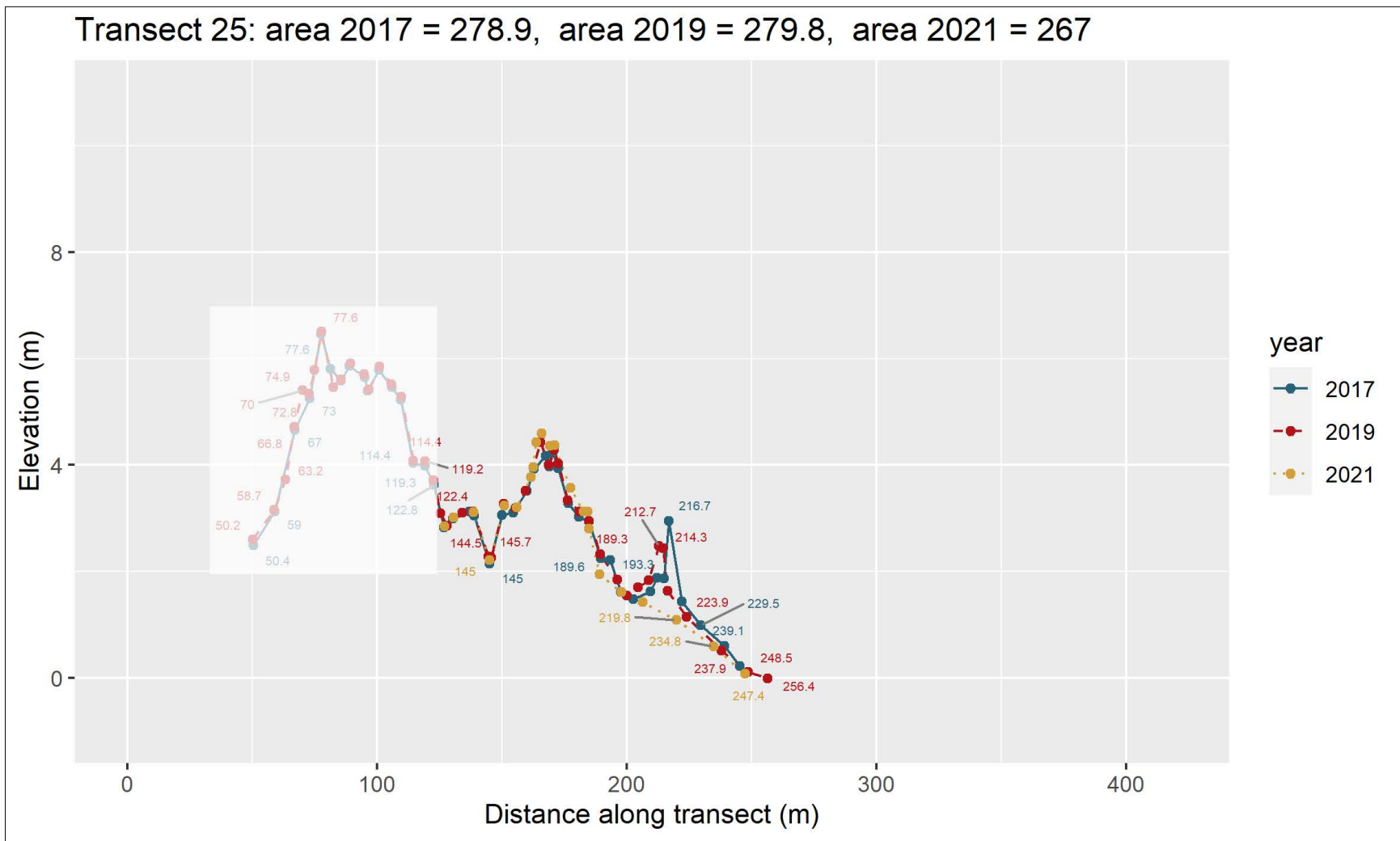


Figure B-11. Transect 25 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

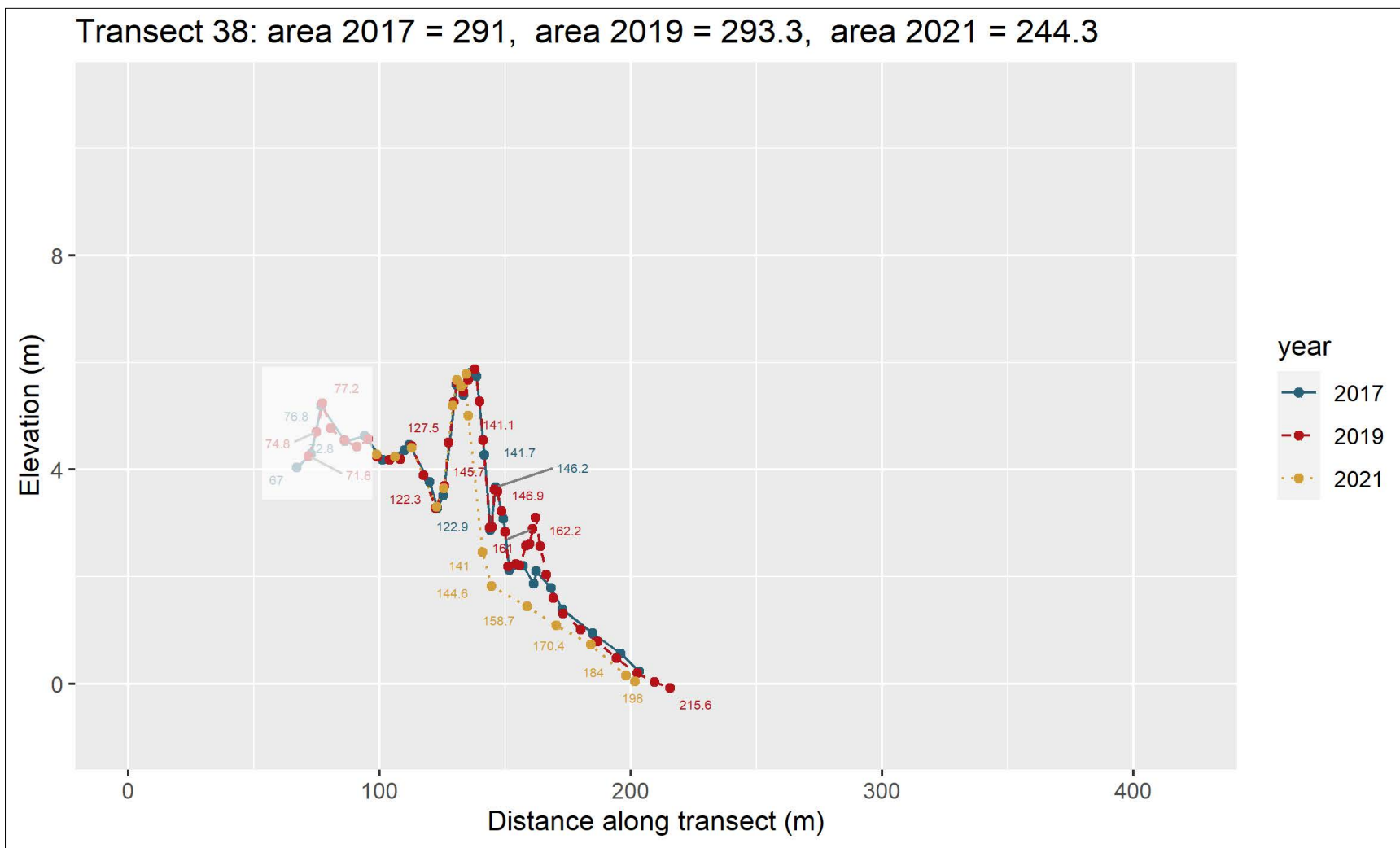


Figure B-12. Transect 38 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

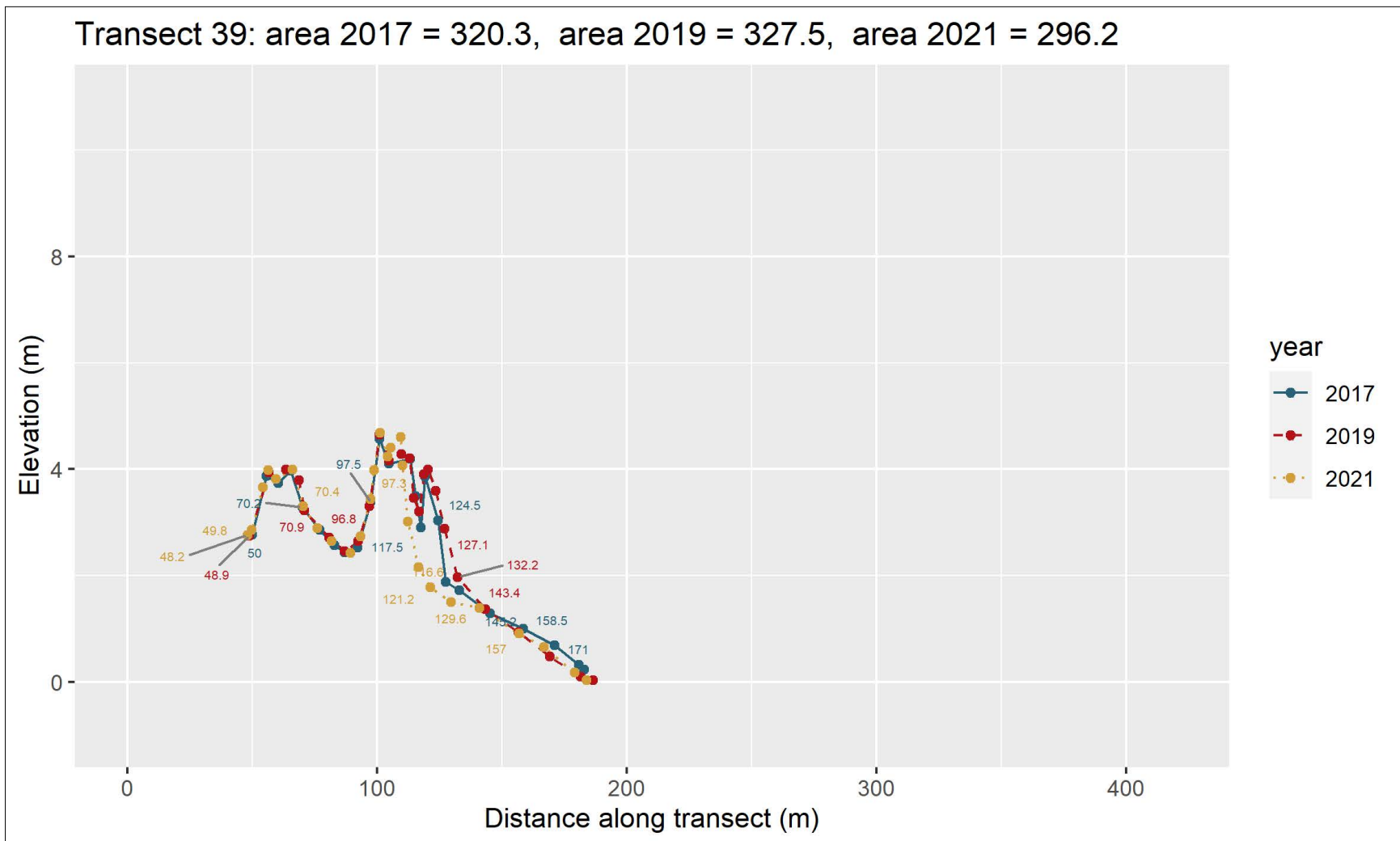


Figure B-13. Transect 39 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

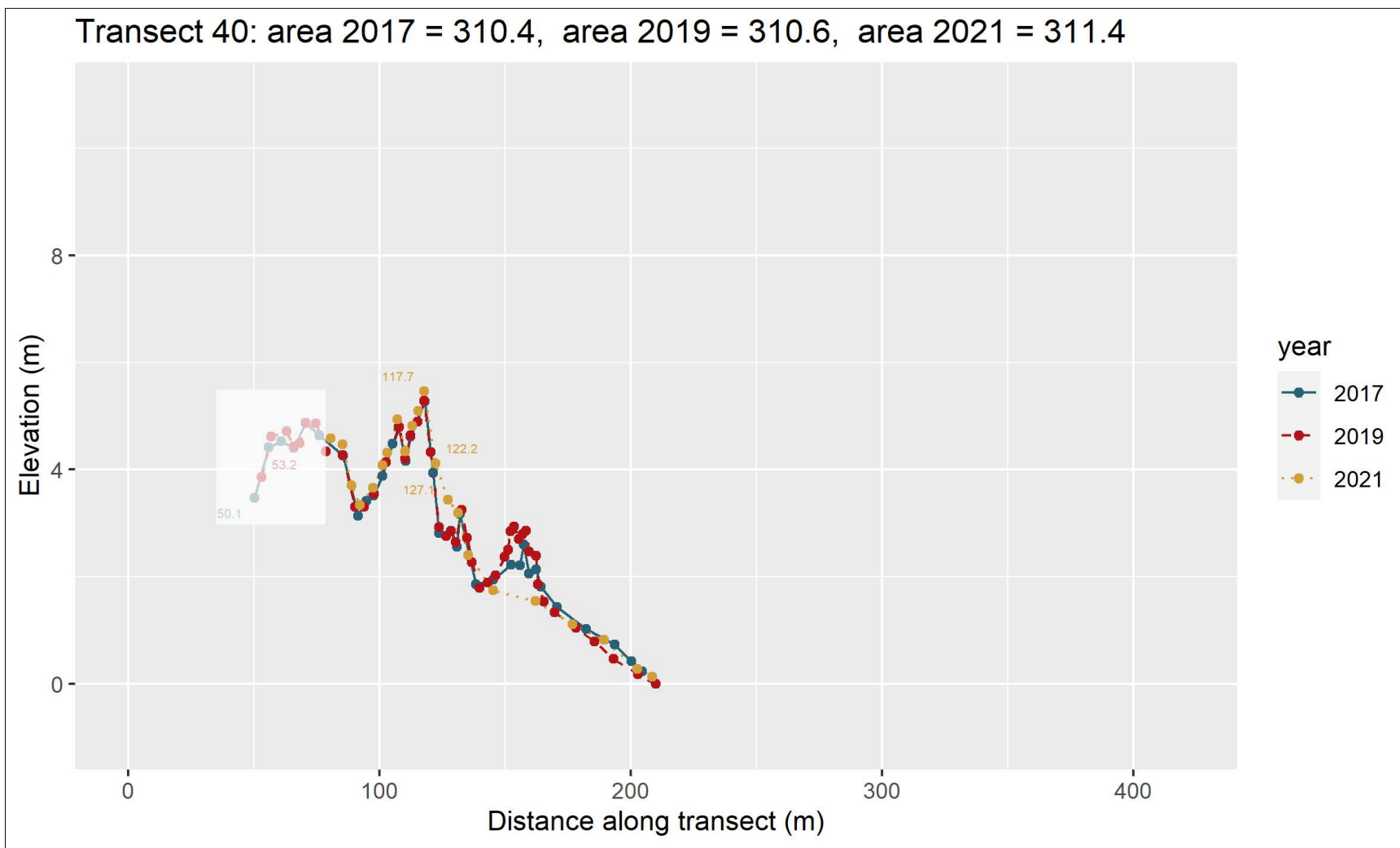


Figure B-14. Transect 40 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

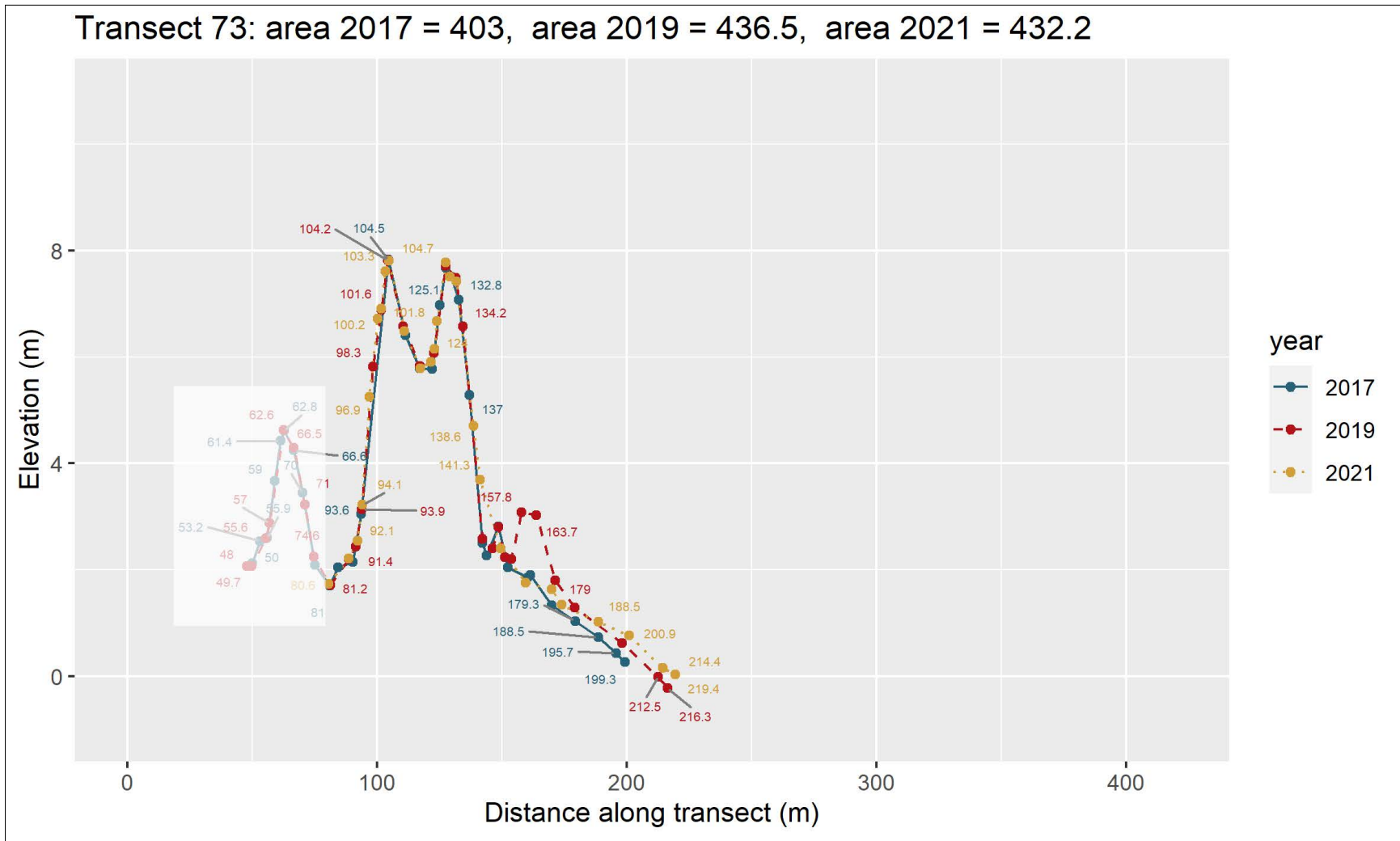


Figure B-15. Transect 73 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

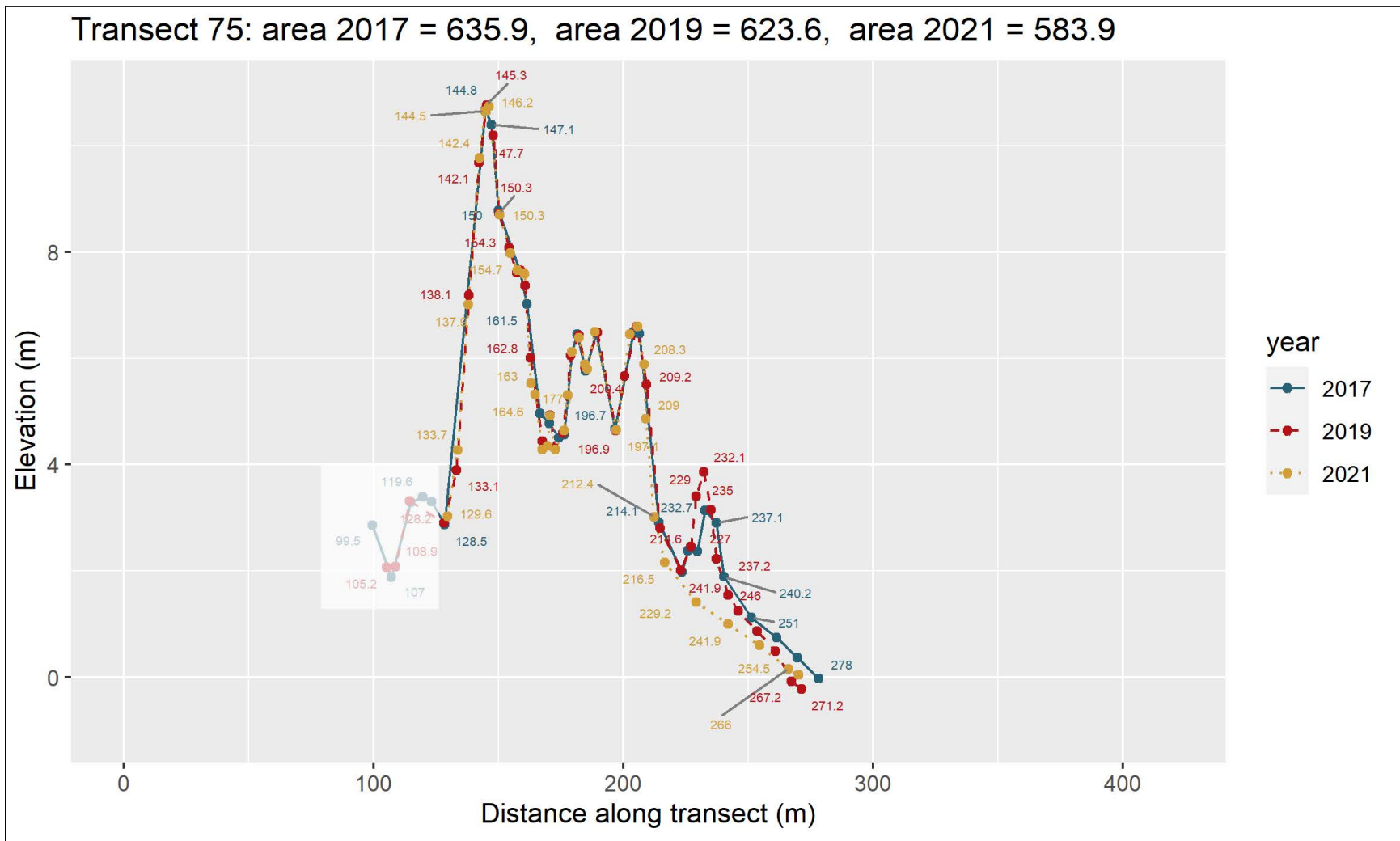


Figure B-16. Transect 75 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

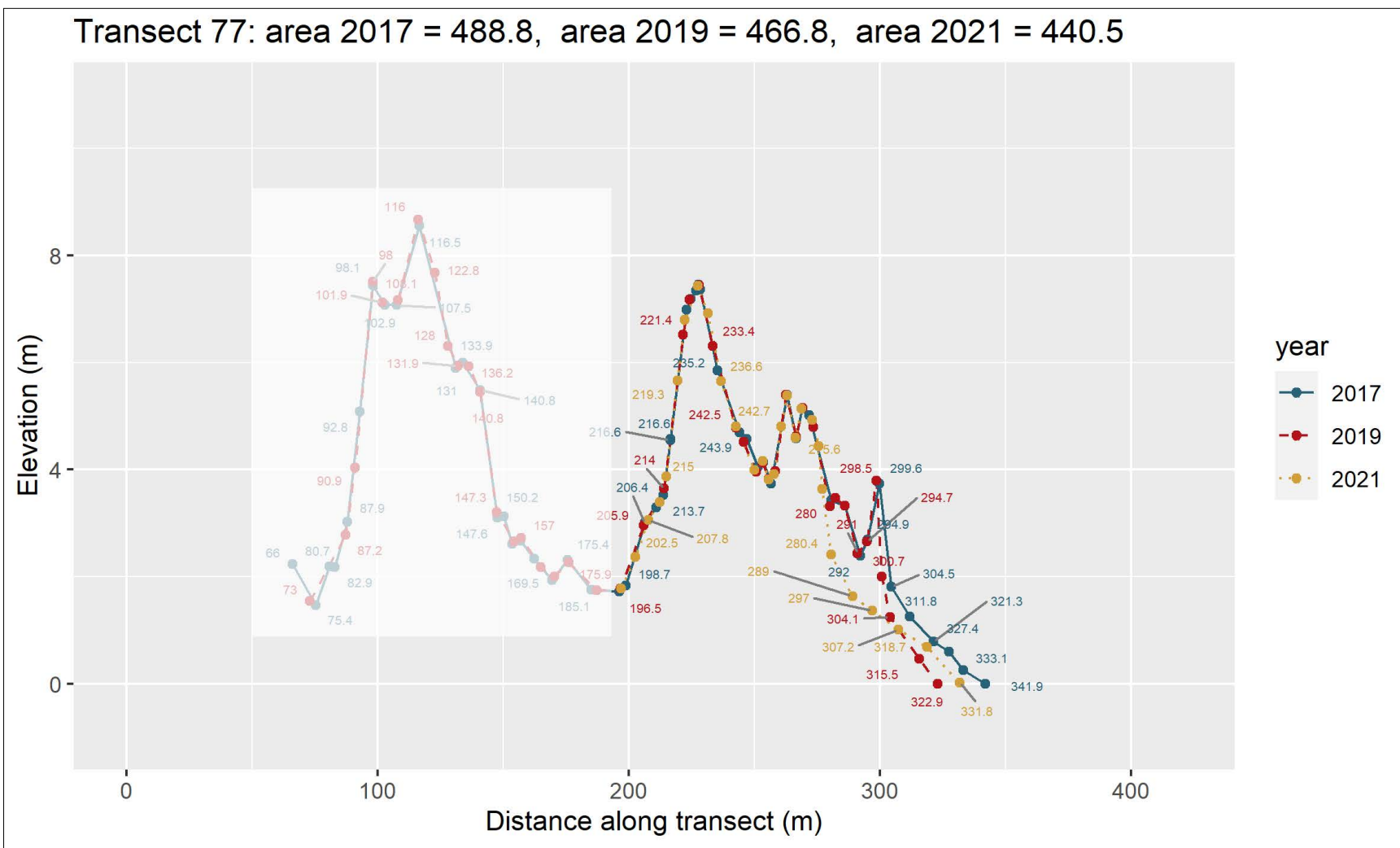


Figure B-17. Transect 77 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

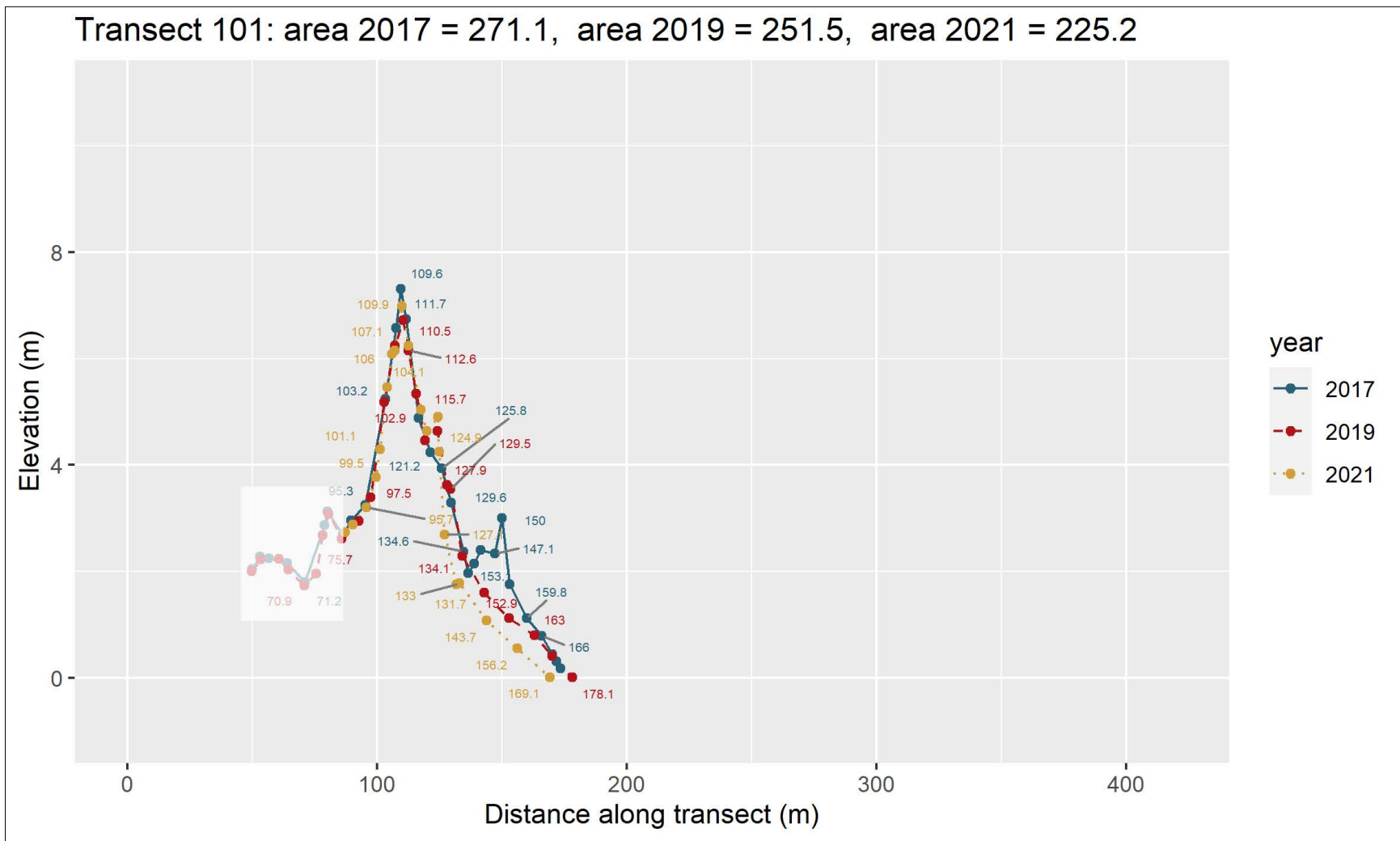


Figure B-18. Transect 101 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

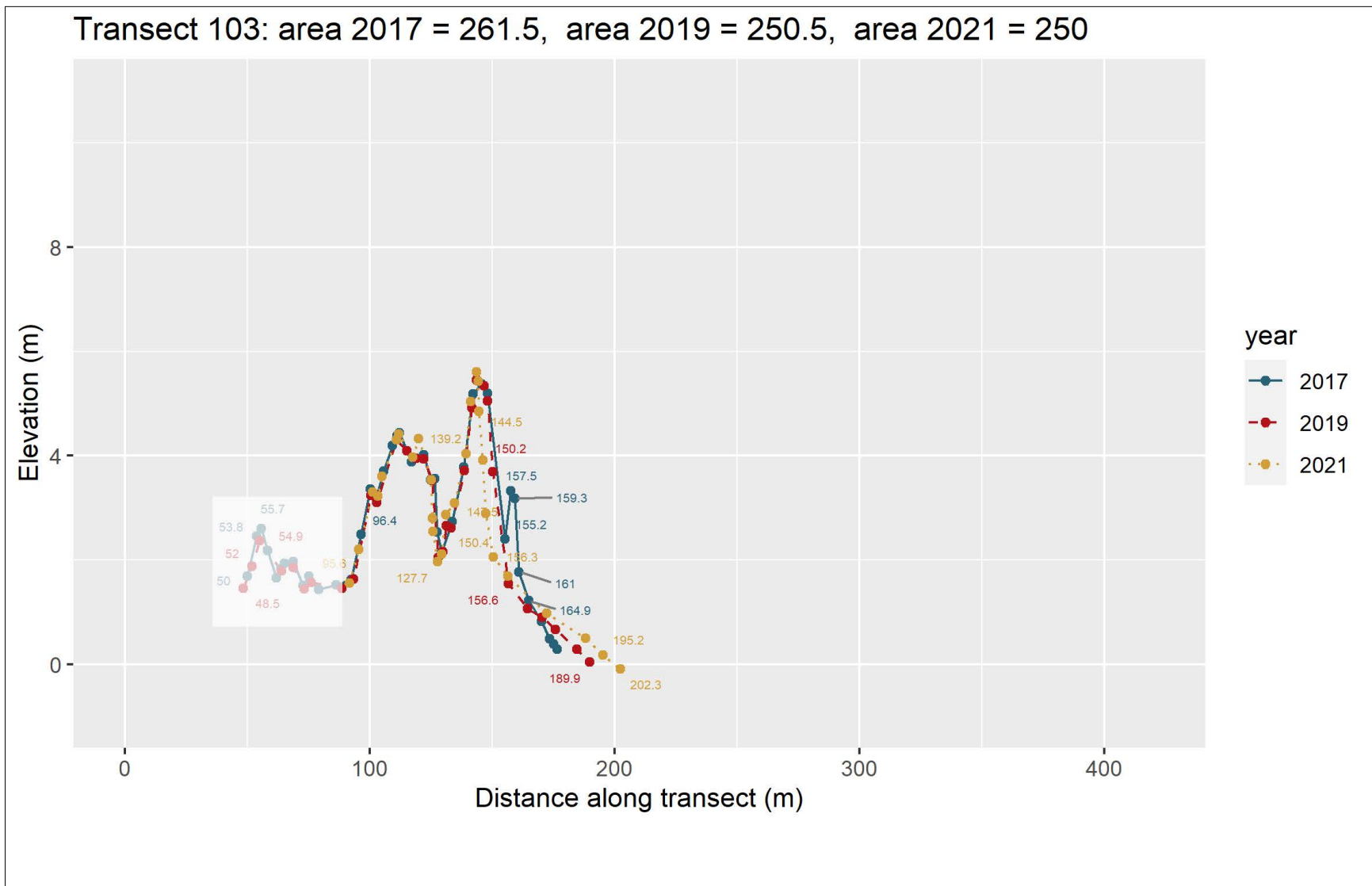


Figure B-19. Transect 103 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

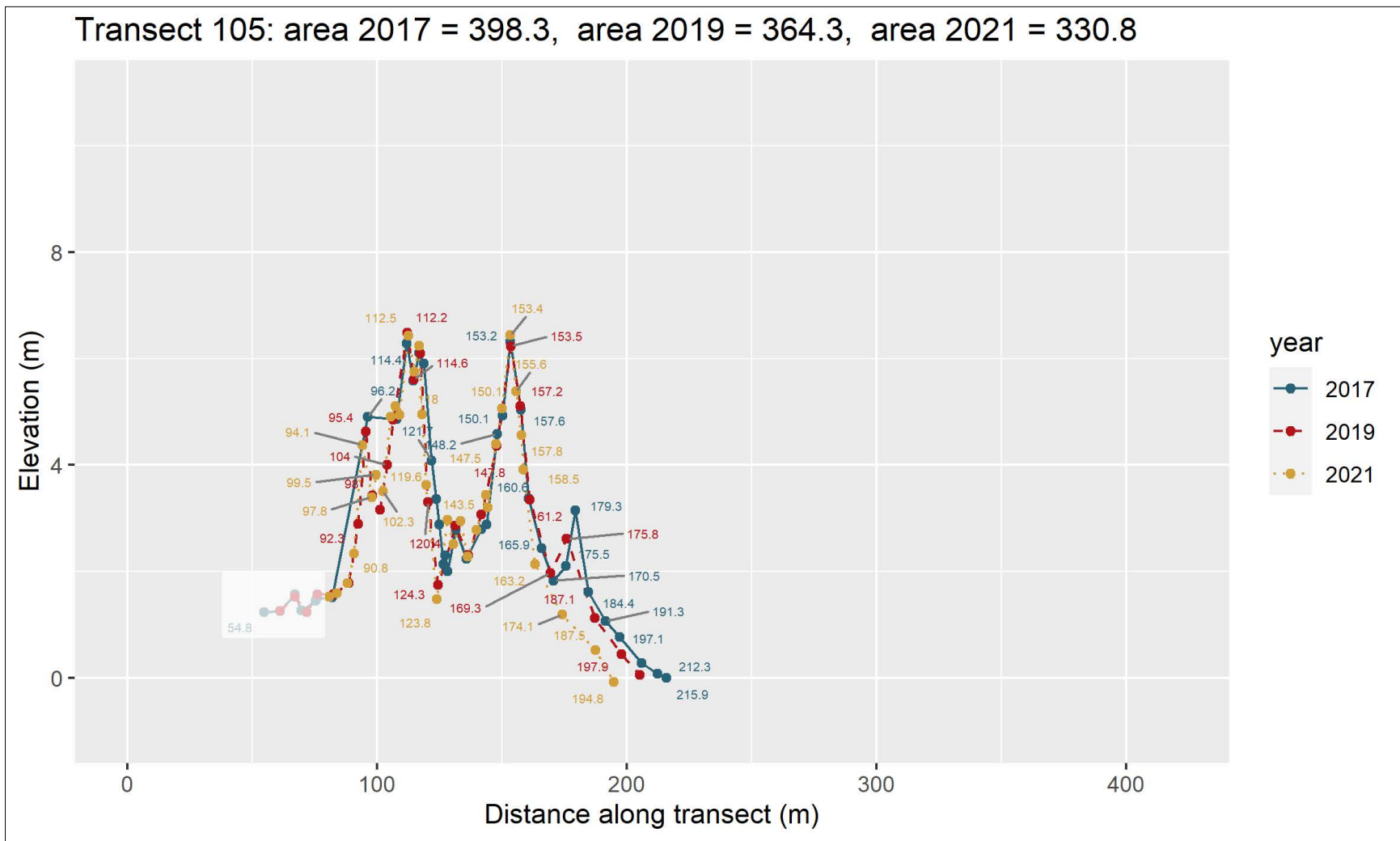


Figure B-20. Transect 105 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

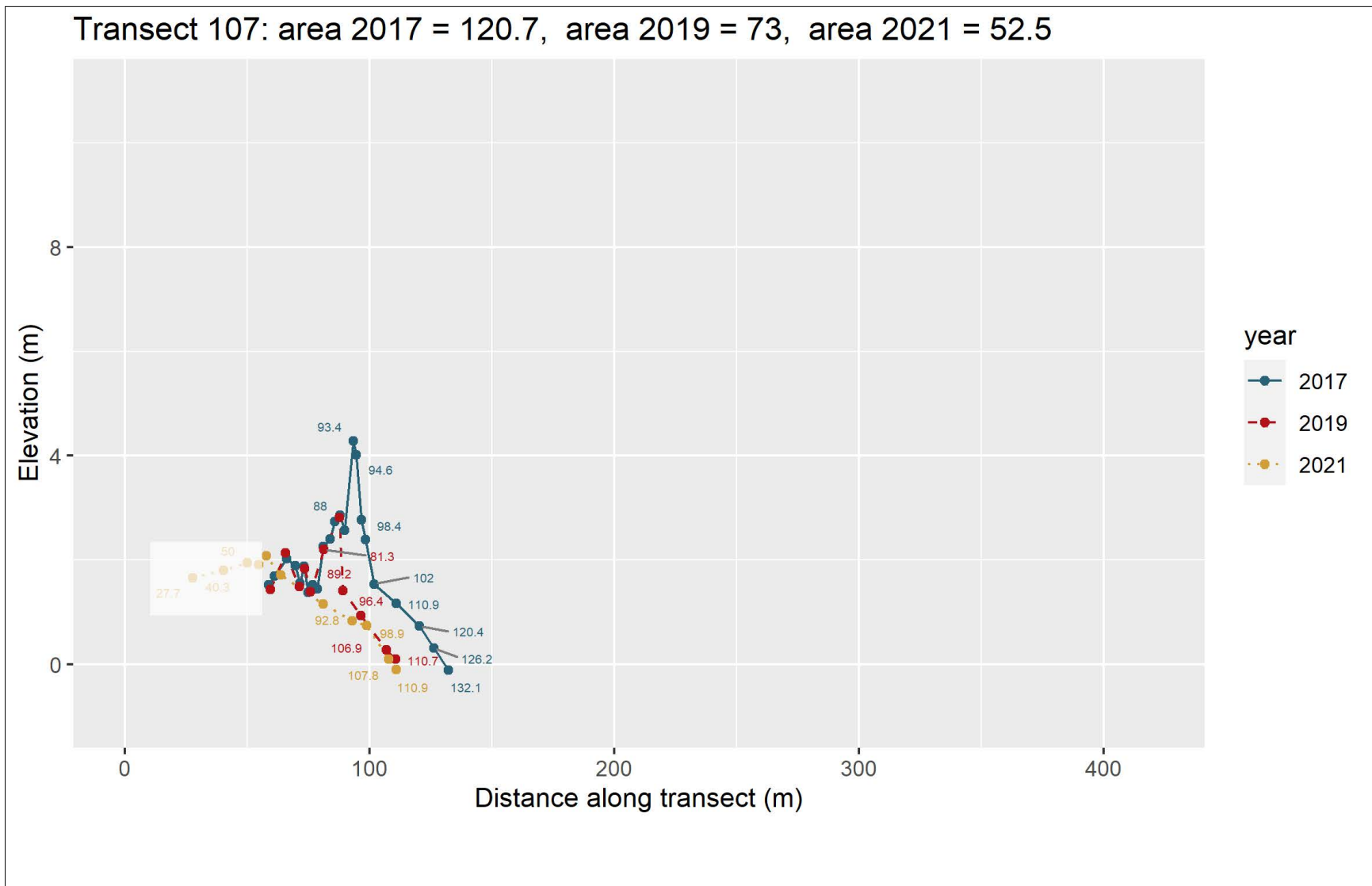


Figure B-21. Transect 107 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

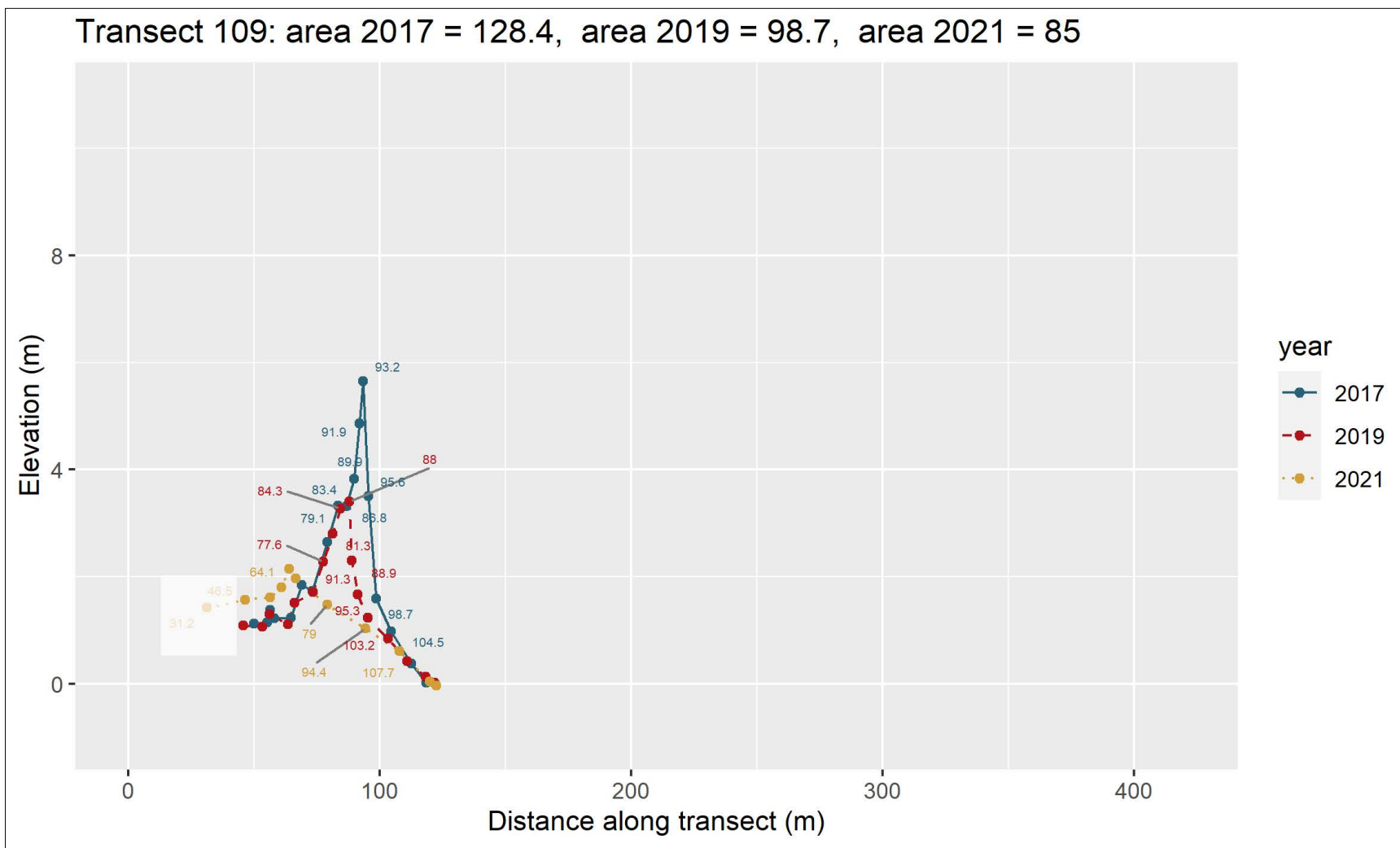


Figure B-22. Transect 109 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

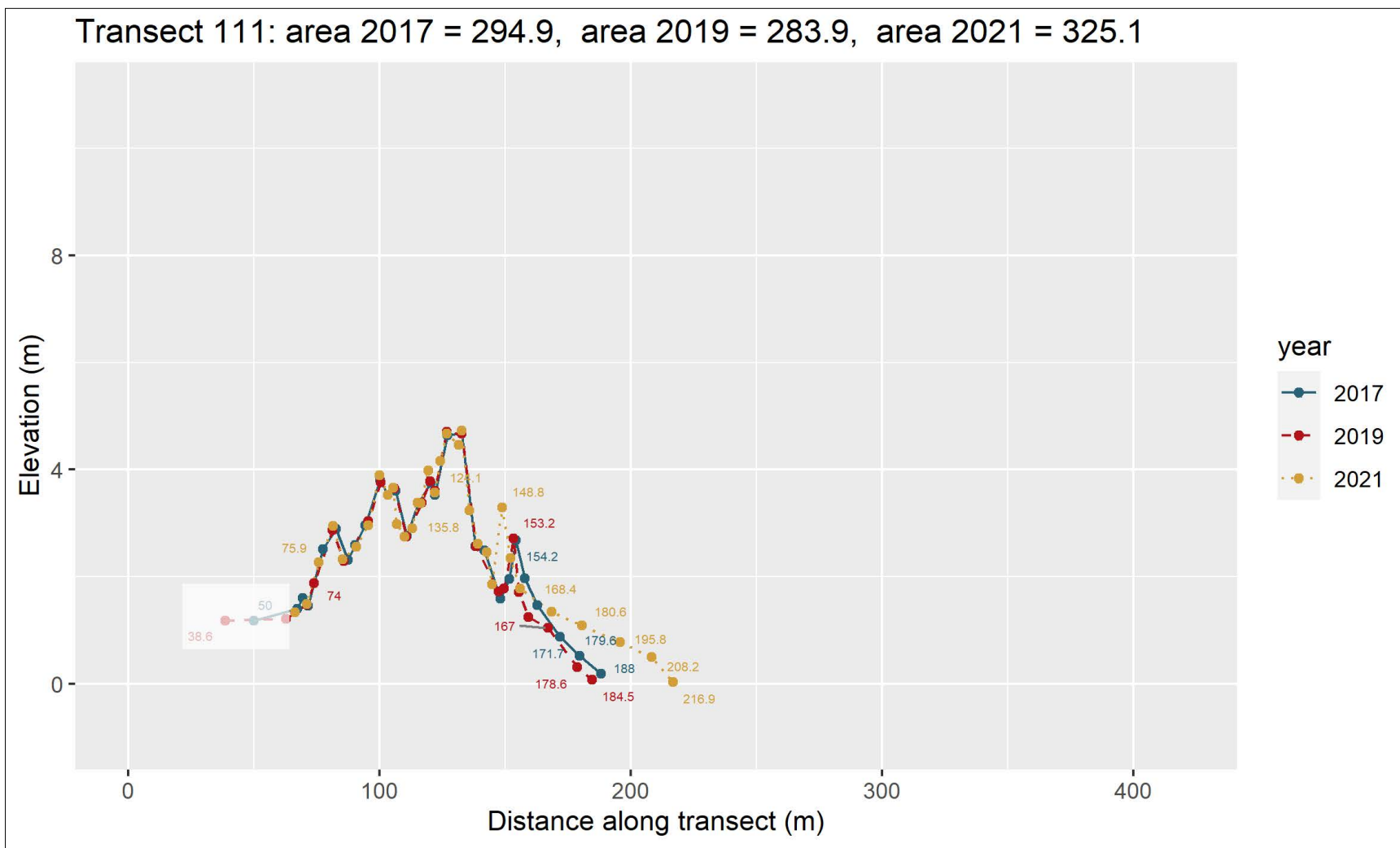


Figure B-23. Transect 111 profiles for 2017, 2019 and 2021 at Padre Island National Seashore. Opaque area is not included in profile area calculation.

Appendix C. Statistical Analysis of Profile Area Change

Statistical analyses are included to objectively assess the significance of change between survey groups and years. Tests were only performed on profile area metrics, but later analyses may include other dimensional variables. Table C-1 shows that there are statistical differences in the amount of change among both years and groups. The lack of a significant interaction term in “year by group” ($p > 0.05$) indicates no spatiotemporal relationship in profile area change, an outcome of within-group variation.

Year Contrast: Tables C-1 and C-2 show which years and which groups are significantly different. Figure C-1 shows the differences between years and a general loss in profile area over time. Table C-2 indicates that change between 2017 to 2021 and 2019 to 2021 is significant, but not 2017 to 2019. This contrast likely illustrates impacts from Hurricane Hanna in 2020.

Group Contrast: Profile area for several group contrasts show significant differences in profile area ($p < 0.05$), as indicated in Table C-3. Groups two and five have the largest profile area on average and group six, near the Mansfield Channel has the smallest (Figure C-2). It is expected that there would be differences in profile area between groups as geomorphic expressions vary across space at Padre Island National Seashore. That is to say that there are little dunes, big dunes; the presence or absence of incipient dunes, varying beach widths and other nuanced geomorphic arrangements that may cause profile area to be different from one place to another. It is conjectured that the ranks of these groups will not change over short time intervals but may change over a decadal scale.

Table C-1. Analysis of Variance (ANOVA) Table of type III with Kenward-Roger approximation for degrees of freedom. Mixed model with repeated measures on transects. R package ‘lme4’.

Year/Group	SUM SQ	MEAN SQ	NUMDF	DENDF	F.VALUE	P.VALUE
Year	7232.3	3616.2	2	34	16.7546	< 0.0001
Group	8474.4	1694.9	5	17	7.8529	< 0.001
Year by Group	1431.7	143.2	10	34	0.6634	0.75

Table C-2. Results of a test of differences among years, with year coded as categorical.

Contrast	ESTIMATE	SE	DF	T.RATIO	P.VALUE
2017–2019	6.37	4.51	34	1.410	0.3472
2017–2021	25.14	4.51	34	5.567	< 0.0001
2019–2021	18.77	4.51	34	4.157	0.0006

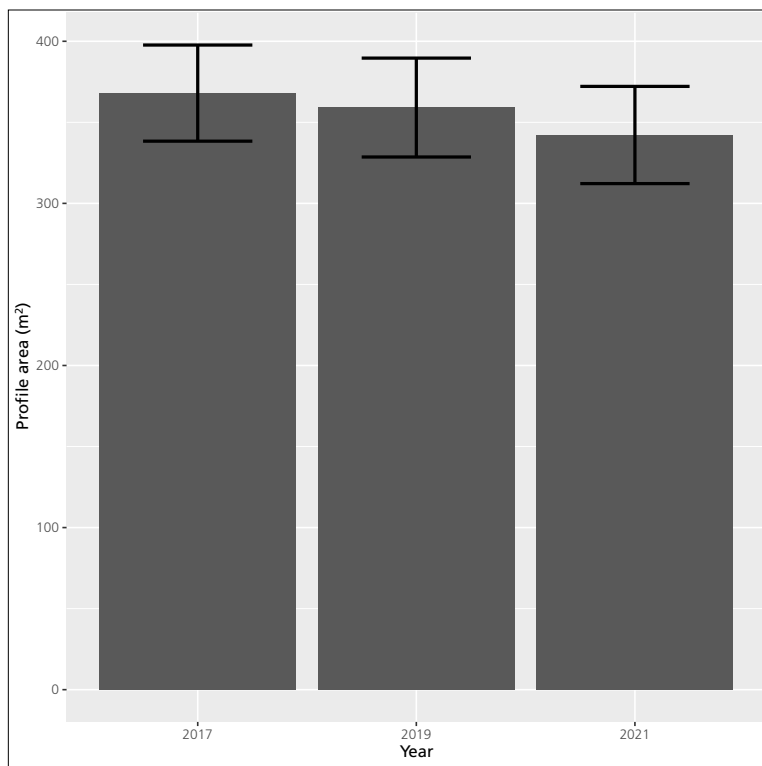


Figure C-1. Plot of mean profile area by year with error bars indicating ± 1 SE.

Table C-3. Pairwise contrast of transect groups show differences between these group pairs: 1,2; 2,3; 2,4; 2,6; 5,6. The group labels are ordered from north to south and are coded as follows: 1=Closed Beach; 2=Mile Marker 0; 3=Mile Marker 5; 4=Mile Marker 15; 5=Mile Marker 37; 6=Mansfield Channel.

CONTRAST	ESTIMATE	SE	DF	T.RATIO	P.VALUE
1-2	-229.08	65.6	17	-3.492	0.028
1-3	8.66	65.6	17	0.132	1
1-4	42.75	65.6	17	0.652	0.985
1-5	-157.94	65.6	17	-2.408	0.2079
1-6	117.45	54.4	17	2.159	0.3052
2-3	237.74	73.3	17	3.242	0.046
2-4	271.83	73.3	17	3.707	0.0182
2-5	71.14	73.3	17	0.97	0.9213
2-6	346.53	63.5	17	5.456	0.0005
3-4	34.09	73.3	17	0.465	0.9968
3-5	-166.6	73.3	17	-2.272	0.2578
3-6	108.79	63.5	17	1.713	0.542
4-5	-200.69	73.3	17	-2.736	0.1186
4-6	74.7	63.5	17	1.176	0.842
5-6	275.39	63.5	17	4.336	0.005

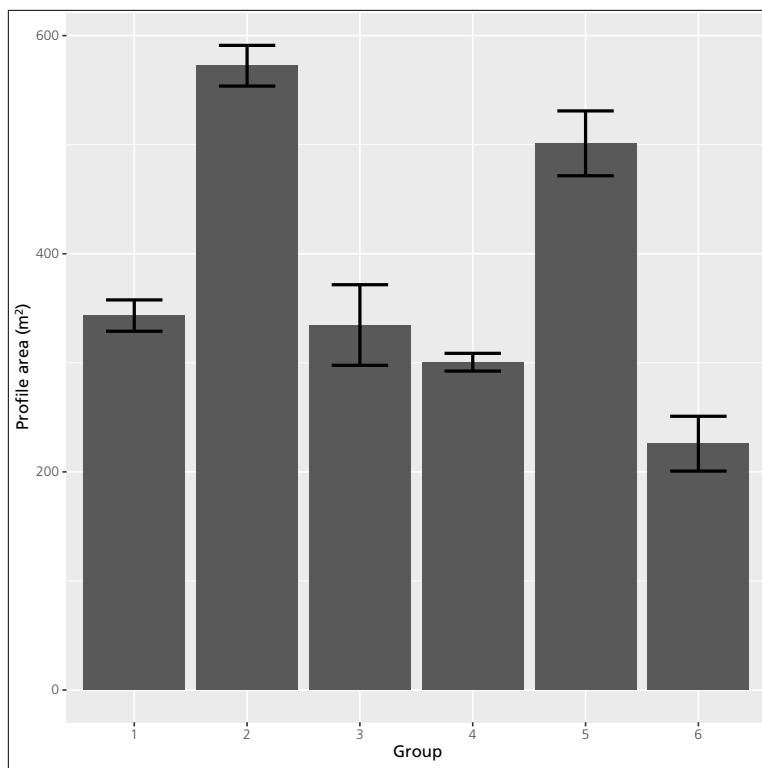


Figure C-2. Mean profile area by group with error bars indicating ± 1 SE.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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Natural Resource Stewardship and Science

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