

Post Hurricane Hanna Assessment of Beach/Dune Morphology at Padre Island National Seashore.

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Contents

Contents	1
Introduction.....	1
Methods.....	4
Survey Accuracy	7
Results.....	9
Topographic Profiles.....	9
Shoreline Position.....	10
High Water Marks.....	11
Literature Cited	13
Appendix A. Graphs Comparing Transect Profiles	14
Appendix B. Shoreline Displacement Maps.....	37

Introduction

Following the passage of Hurricane Hanna at Padre Island National Seashore (PAIS), the park Science and Resource Management Division requested assistance from the Gulf Coast Inventory and Monitoring Network (GULN) to measure geomorphic impacts from the storm. The GULN conducted shoreline position and dune topography surveys, August 7 thru 12, 2020, using an established monitoring framework and methods outlined in Bracewell (2017a) and Bracewell (2017b) to measure storm impacts through short-term comparisons with a previous survey, conducted in April 2019. Also surveyed were a small set of High-Water Marks (HWM) located on piers supporting the Visitor Center and Malaquite Campground beach access boardwalks.

Hurricane Hanna made landfall near PAIS mile marker 40 on July 25, 2020 with maximum sustained winds of 90mph (Figure 1). At Bob Hall Pier, water levels ran almost 2m above predicted estimates

(Figure 2). By the time this survey work commenced in early August, actual tide levels had resumed a close relationship to predicted levels (Figure 3).

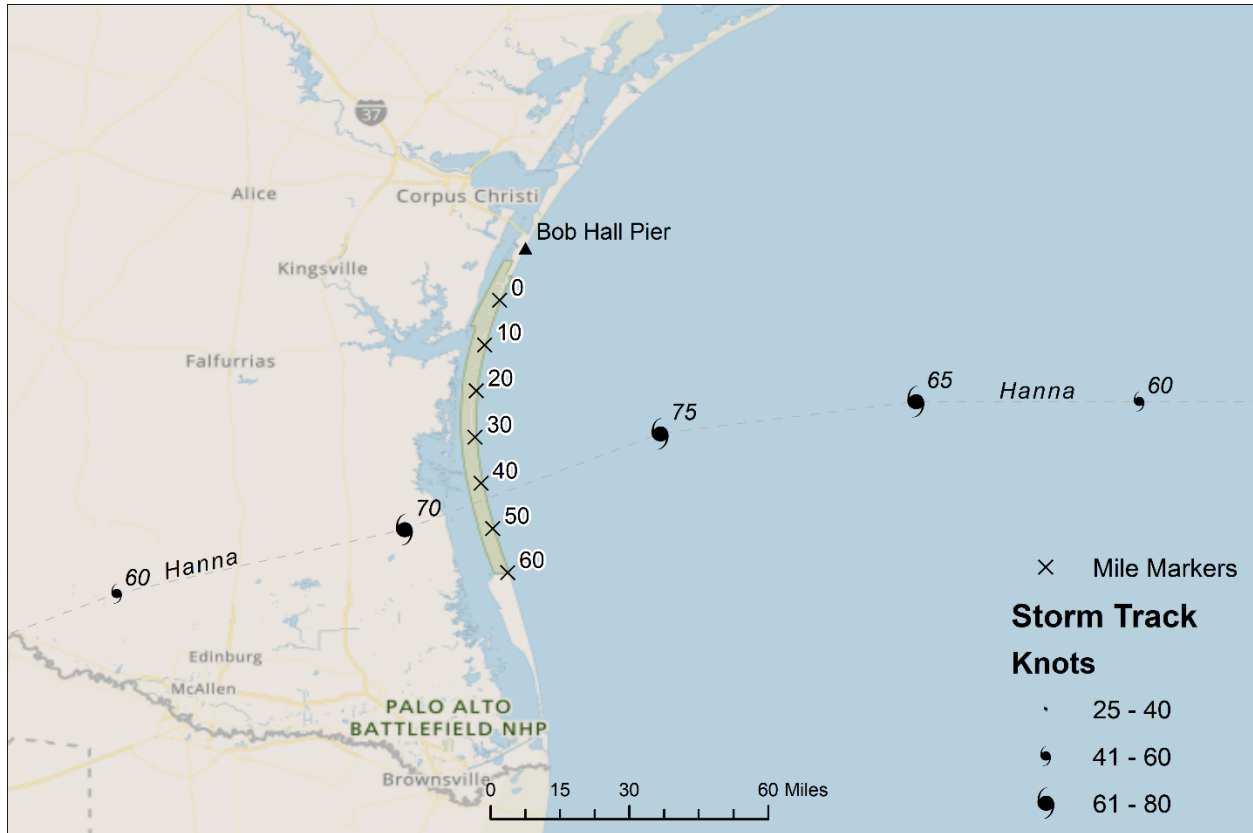


Figure 1. Storm track for Hurricane Hanna showing general location of landfall. The location of Bob Hall Pier, where the nearby near-shore NOAA tide station is co-located is also shown.

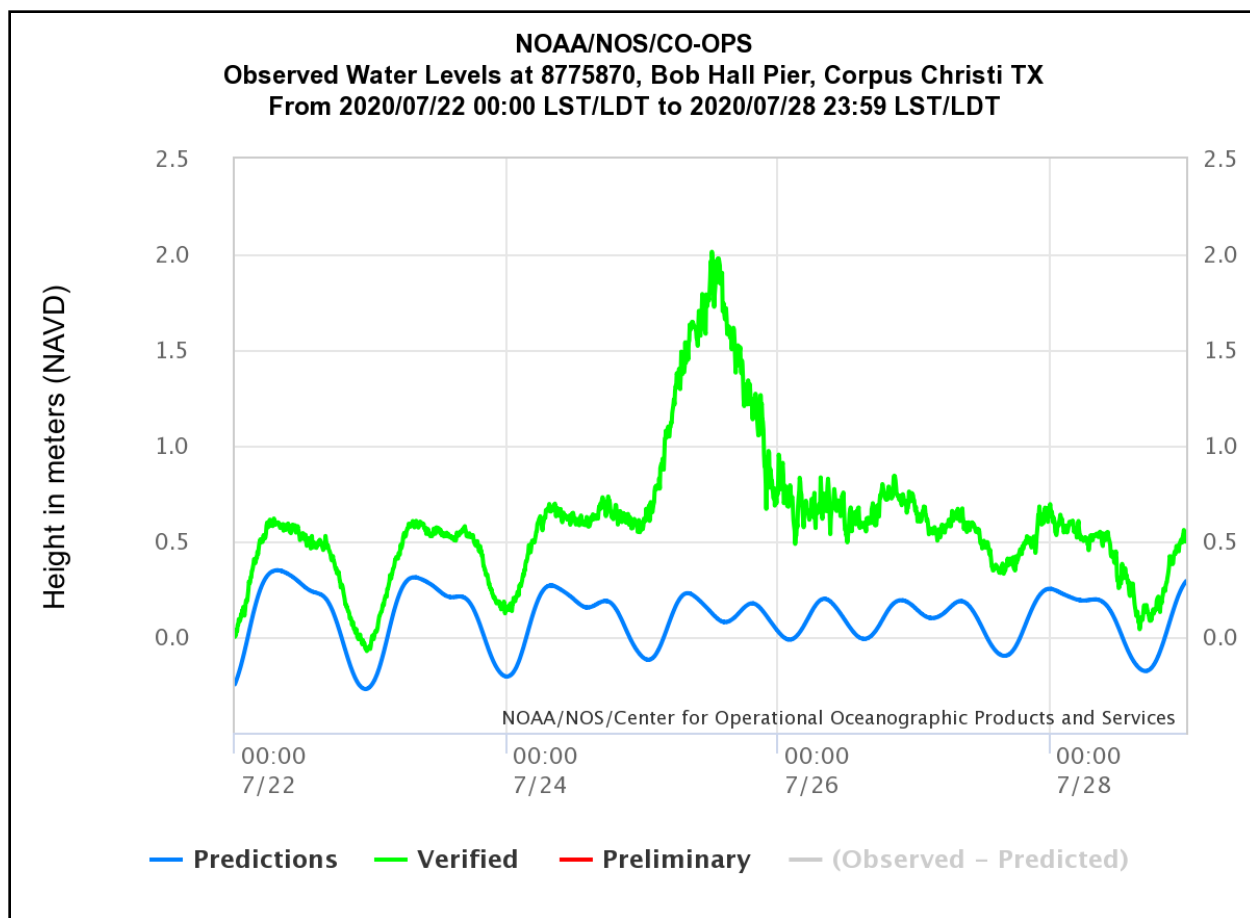


Figure 2. Tidal conditions reported at Bob Hall Pier in advance and after Hurricane Hanna made landfall at PAIS.

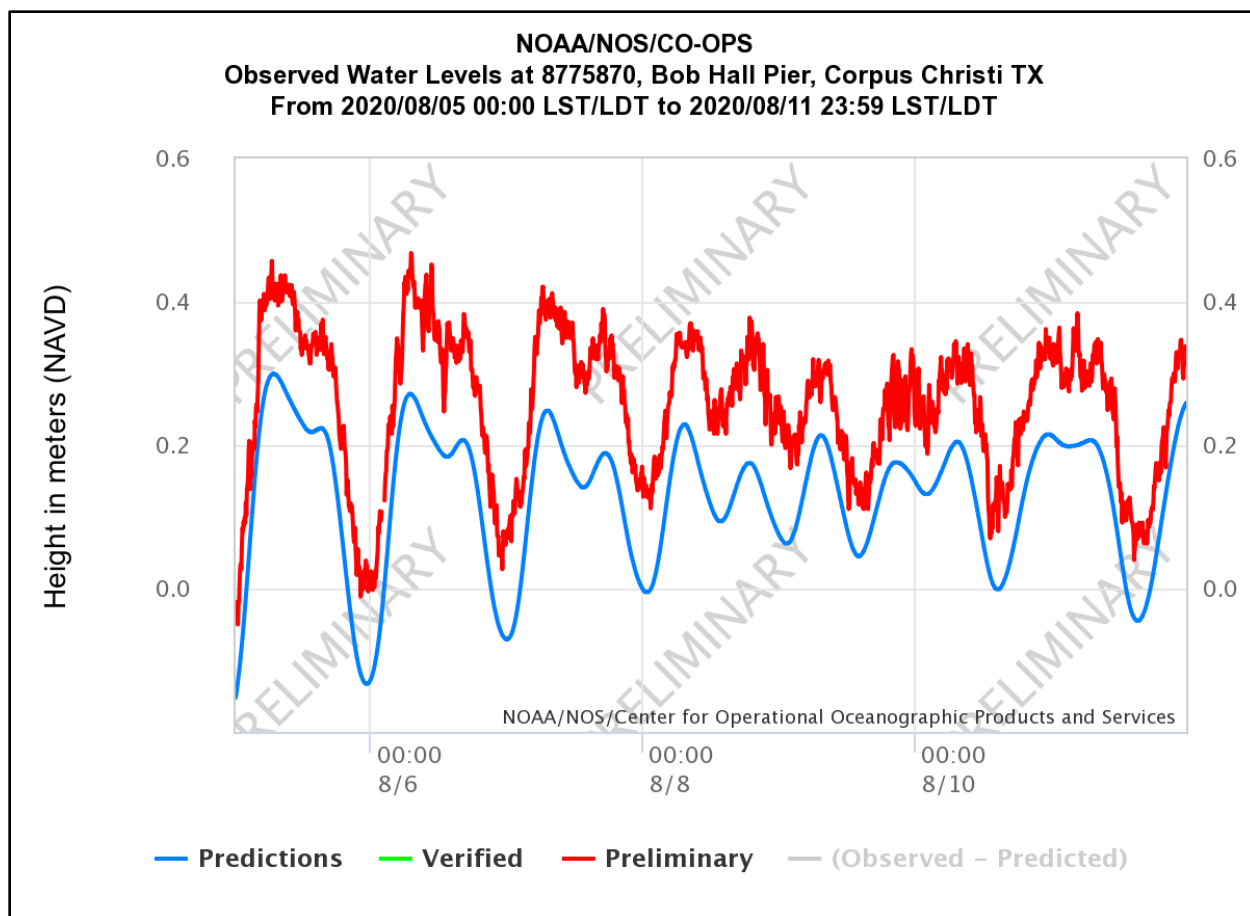


Figure 3. Tidal conditions reported at Bob Hall Pier in advance and during topographic and shoreline position surveys. Note that water levels are preliminary.

Methods

Topography: The Gulf Coast Network surveyed an established framework of 23 equally spaced cross-shore transects using precision Real Time Kinematic (RTK) GPS equipment to record elevation at topographic inflection points in the beach and primary dune complex along each transect (Figure 4).

Shoreline Position: The high tide swash line was mapped using a Global Positioning Unit (GPS) unit, then differentially corrected results were exported into a standard GIS format. Digital Shoreline Analysis System (DSAS; Theiler et al. 2008) was used to analyze the shoreline change along spatially fixed cross-shore transects distributed every 50 meters (164 ft). Shoreline change rates were calculated, measuring total displacement between the two survey events. This report addressed shoreline change between April 14, 2019 and August 8, 2020.

High Water Marks: The remnant silt line located on piers was semi-permanently marked by installing a wood screw. A level line was stretched from the screw to an area out from under the boardwalk with open sky view so that an RTK-derived elevation could be recorded.

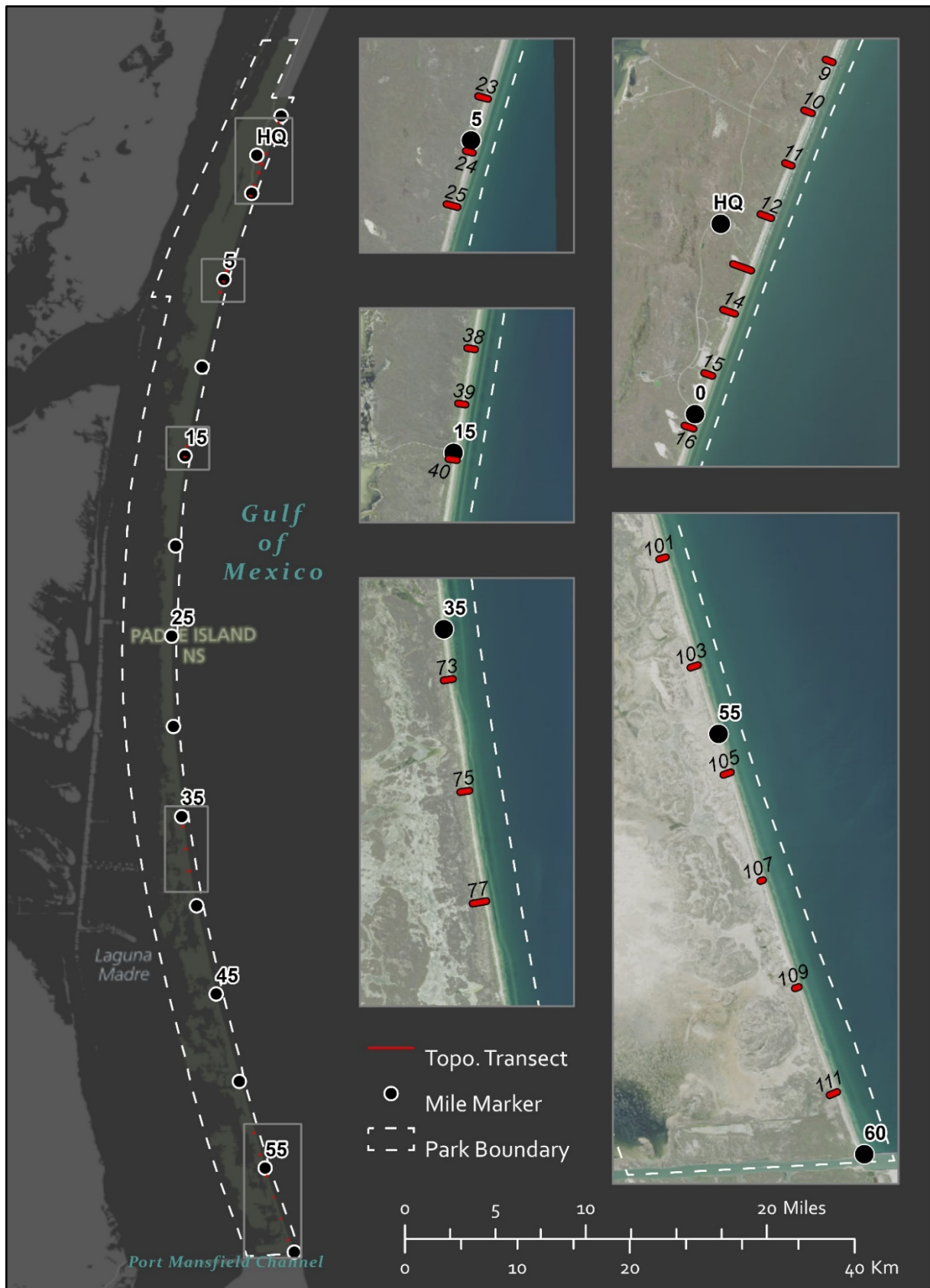


Figure 4. GULN's set of twenty-three coastal topography survey transects at PAIS.

Survey Accuracy

Topography: All surveyed points were within 0.5m horizontal of the virtual transect, fitting within accuracy tolerances outlined in the GULN's Coastal Topography protocol. Overall vertical accuracies were good but drifted outside of the survey protocol's specified 0.05m tolerance on three out of twenty-five accuracy checks (Table 1). One of these check-ins was on a storm-tilted benchmark and should be disregarded. It is currently unknown as to why the accuracy at the remaining two locations strayed, but, given the reasonably good vertical alignment in graphed products, and the overall scale of change between survey periods, this discrepancy of 1-3cm outside of tolerance bears little weight on interpretation of the results presented here.

Table 1. Elevation difference between established benchmark elevations and the elevations recorded during the August 2020 topographic survey. Elevation reported in meters above NAVD88. Survey Accuracy for High Water Marks can be referenced to the first group, Base = 'HQ'.

Transect BENCHMARK	BASE	ESTABLISHED ELEVATION	SURVEYED ELEVATION	DIFFERENCE	DIFFERENCE (ABSOLUTE)
t009	HQ	3.33	3.34	0.01	0.01
t010	HQ	2.5	2.53	0.03	0.03
t011	HQ	2.12	2.15	0.03	0.03
t012	HQ	2.23	2.26	0.03	0.03
t013	HQ	2.11	2.13	0.02	0.02
t014	HQ	4.49	4.49	0.00	0.00
t015	HQ	2.57	2.58	0.01	0.01
t016	HQ	5.69	5.68	-0.01	0.01
Prouty	HQ	3.86	3.86	0.00	0.00
Hq2	HQ	2.94	2.96	0.02	0.02
<i>average difference</i>				0.01	0.02
t023	SixPigs	2.56	2.59	0.03	0.03
t024	SixPigs	1.67	1.7	0.03	0.03
t025	SixPigs	3.08	3.11	0.03	0.03
<i>average difference</i>				0.03	0.03
t038	Goody	4.26	4.3	0.04	0.04
t039	Goody	2.68	2.7	0.02	0.02
t040	Goody	3.42	3.45	0.03	0.03
<i>average difference</i>				0.03	0.03
t073	Sassine	1.91	1.94	0.03	0.03
t075	Sassine	3.52	3.6	0.08	0.08
t077	Sassine	1.8	1.86	0.06	0.06
<i>average difference</i>				0.06	0.06
t101	Clapp	2.83	2.82	-0.01	0.01
t103	Clapp	1.57	1.6	0.03	0.03
t105	Clapp	1.32	1.36	0.04	0.04
<i>average difference</i>				0.02	0.03
t107 (damaged)	Walker	1.55	1.48	-0.07	0.07
t109	Walker	1.17	1.2	0.03	0.03
t111	Walker	1.24	1.29	0.05	0.05
<i>average difference</i>				0.00	0.05

Shoreline Position: The survey accuracy report generated during post-processing shows that horizontal positions were generally within 0 to 0.30m, well within the GULN's Shoreline Position Monitoring Protocol tolerance of 1m (Table 2).

Table 2. Estimated horizontal accuracies for 11037 corrected shoreline positions are as follows:

Range	Percentage
0-5cm	27.82%
5-15cm	39.70%
15-30cm	30.69%
30-50cm	1.66%
0.5-1m	0.12%
1-2m	0.01%

Results

Topographic Profiles: Coppice dunes and shore-facing margins of the foredune were substantially impacted by Hanna. Except for the southern-most group (t101 to t111), transect profiles had previously exhibited well-developed coppice dunes and foredune marginal ridges, commonly one to two meters in stature (Appendix A). Following the storm, these features were flattened to conform with the overall beach slope, and generally resulted in the seaward advance of the shoreline. In cases where the foredune bases retreated, they did so on average of about 8 meters, but up to approximately 18 meters (Table 3).

Table 3. Table summarizing changes in beach/foredune morphology. Foredune position estimates were interpreted from profile graphs presented in Appendix A.

Tran ID	Comment	Foredune Base Position			Profile Area		% of 2019
		2020	2019	Displacement	2020	2019	
t009	coppice dunes eroded	minimal change			184	198.8	0.93
t010	coppice dunes eroded	minimal change			149.7	174.8	0.86
t011	coppice dunes eroded	205	212	-7	96	123	0.78
t012	coppice dunes eroded	minimal change			122.4	135.3	0.90
t013	coppice dunes eroded	minimal change			463.7	468.4	0.99
t014	coppice dunes eroded	minimal change			562.8	559.5	1.01
t015	coppice dunes eroded	minimal change			142.1	159.2	0.89
t016	coppice dunes eroded	166	178	-12	207	233.4	0.89
					average difference		0.91
t023	coppice dunes eroded	190	199	-9	153.4	182.7	0.84
t024	coppice dunes eroded	135	144	-9	211.7	235	0.90
t025	coppice dunes eroded	minimal change			229.5	245.8	0.93
					average difference		0.89
t038	coppice dunes eroded	137	144	-7	195.4	253.9	0.77
t039	coppice dunes eroded	112	130	-18	172.2	204.5	0.84
t040	coppice dunes eroded	minimal change			234	271.1	0.86
					average difference		0.82
t073	coppice dunes eroded	213	220	-7	309.8	347.4	0.89
t075	coppice dunes eroded	278	291	-13	266.9	308.4	0.87
t077	coppice dunes eroded	130	134	-4	239.8	297	0.81
					average difference		0.85
t101		130	134	-4	210.3	236.3	0.89
t103		152	157	-5	169.7	193.1	0.88
t105		163	169	-6	230.5	290	0.79
t107		minimal change			58.5	73	0.80
t109		88	91	-3	82.7	82.9	1.00
t111		minimal change			265.8	254.9	1.04
					average difference		0.90

Shoreline Position: Contrary to what many might expect, the shoreline generally advanced seaward. As alluded to in the previous section, this outcome is a result of the collapse of backshore and foredune features, and the subsequent seaward movement of sediment. Summarizing shoreline change in 5-mile groups, advance was greatest on the northern extent of the seashore, the greatest of which occurred between mile markers 0 and 10 (Table 4). The least amount of net advance occurred between mile markers 45 and 50. Only about 6 percent of individual shoreline position transects exhibited retreat, and less than 1 percent of transects retreated more than 5 meters.

The reader should note that some seasonal variation is conflated into both shoreline position and topographic survey results. Routine monitoring by the GULN occurs exclusively within a two-month window (April/May) to limit this influence. That said, given the overall impact of Hurricane Hanna on Seashore beach/foredune morphology, it is assumed that the seasonal portion of the total variation presented here is minimal.

Table 4. Summary table of changes in shoreline position.

Section	Count of Transects	Min of Disp(lacement)	Max of Disp	5% of Disp	95% of Disp	Average of Disp
North Beach	36	8.6	19.4	8.8	18.4	12.6
Closed Beach	146	6.3	22.2	8.3	17.3	11.9
MM 0 - 5	160	8.1	18.6	10.0	17.6	14.4
MM 5 - 10	160	8.4	21.0	10.1	19.0	14.2
MM 10 - 15	161	4.0	18.5	5.2	17.5	11.6
MM 15 - 20	160	4.7	23.6	7.1	20.2	12.7
MM 20 - 25	161	6.8	22.3	8.3	17.4	12.3
MM 25 - 30	161	4.9	20.9	6.3	15.2	10.7
MM 30 - 35	160	-1.1	14.4	2.2	12.2	7.7
MM 35 - 40	161	-7.5	13.8	-2.8	11.6	5.6
MM 40 - 45	161	-6.8	22.3	-4.5	17.1	5.5
MM 45 - 50	160	-9.9	26.9	-5.2	15.0	3.3
MM 50 - 55	161	-6.2	25.5	-1.8	17.9	5.3
MM 55 - 60	158	-6.8	28.5	-2.3	18.2	8.0

High Water Marks: High water mark elevations were consistent between and within survey areas and reasonably well interrelated with maximum water levels recorded at Bob Hall Pier. Seaward elevations of HWMs were around 10cm lower than those of their landward counterparts (Figures 5 and 6). This is possibly the impact from wave run-up forcing water across the topographic incline and/or increasing downslope hydrologic force as water levels recede. Landward elevation marks are likely more accurate in representing maximum storm inundation in these areas.



Figure 5. High water mark elevations at Malaquite Campground.



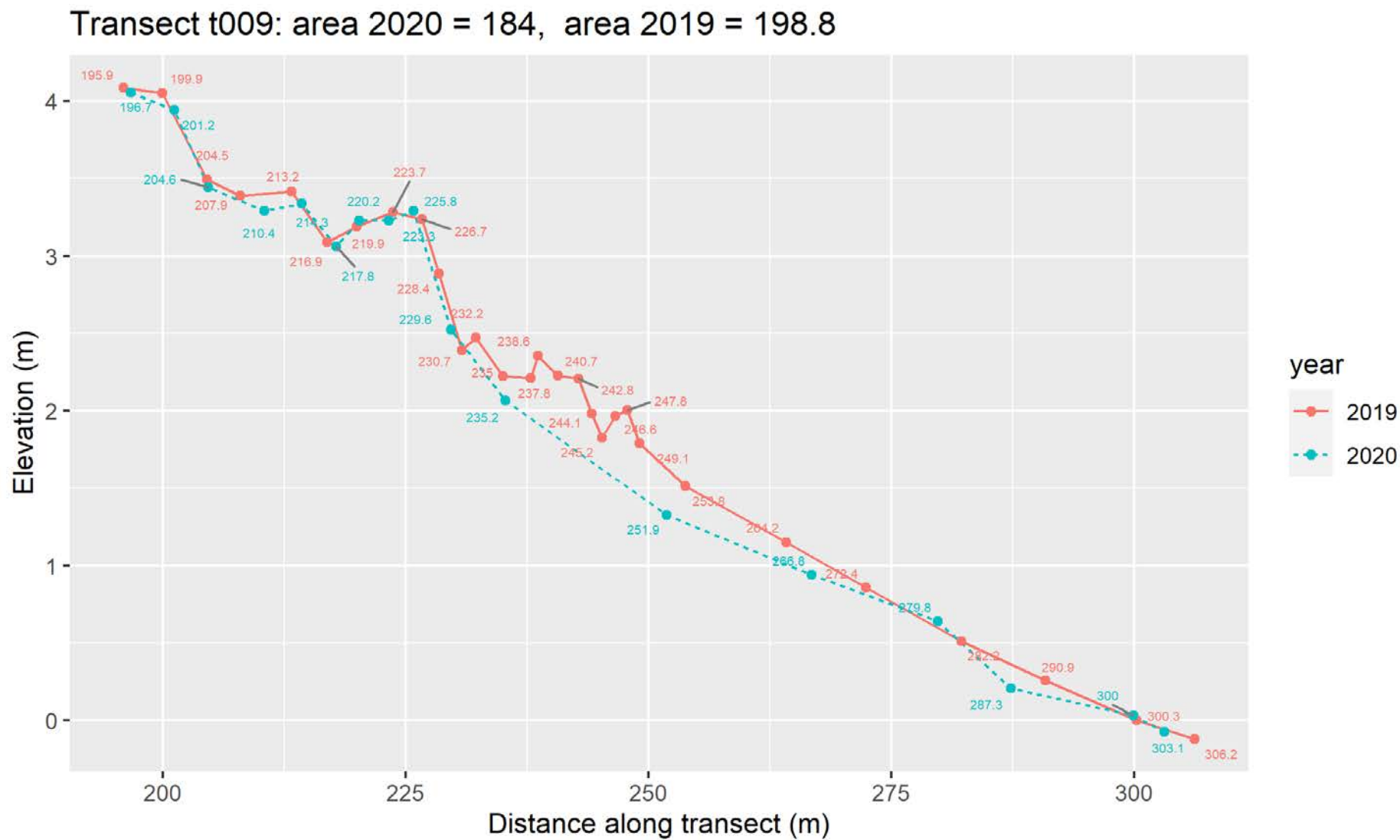
Figure 6. High water mark elevations at PAIS Visitor Center.

Literature Cited

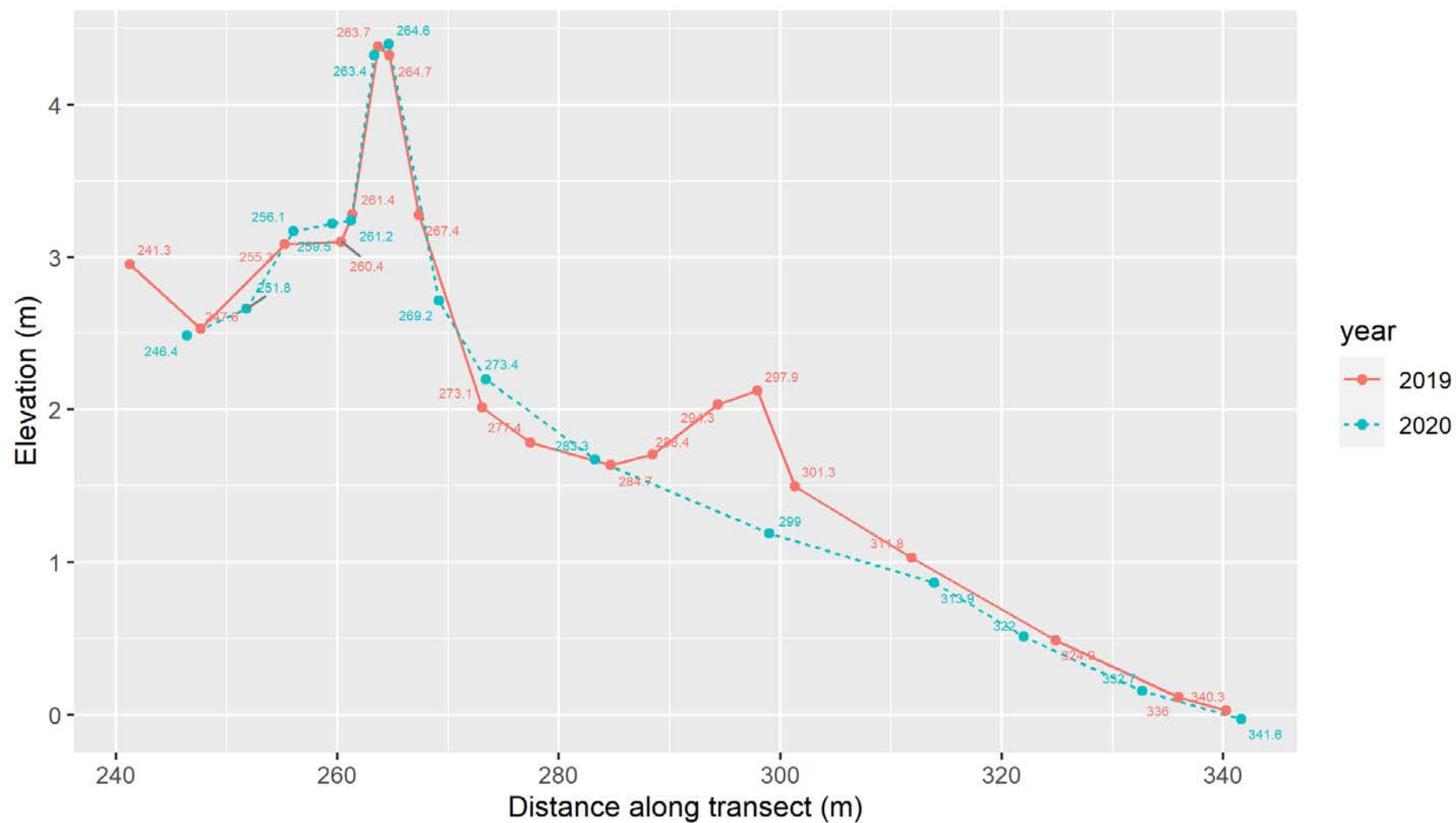
- Bracewell, J. 2017a. Monitoring shoreline position at Gulf Coast Network parks: Protocol implementation plan. Natural Resource Report NPS/GULN/NRR—2017/1501. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2243708> (last accessed September 2019).
- Bracewell, J. 2017b. Monitoring coastal topography at Gulf Coast Network parks: Protocol implementation plan. Natural Resource Report NPS/GULN/NRR—2017/1522. National Park Service, Fort Collins, Colorado.
- Thieler, E. R., E. A. Himmelstoss, J. L. Zichichi, and A. Ergul. 2008. The digital shoreline analysis system (DSAS) version 4.0—an ArcGIS extension for calculating shoreline change. Open-File Report 2008-1278. U.S. Geological Survey. Available at: <https://cmgds.marine.usgs.gov/publications/DSAS/of2008-1278/> (last accessed August 2019).

Appendix A. Graphs Comparing Transect Profiles

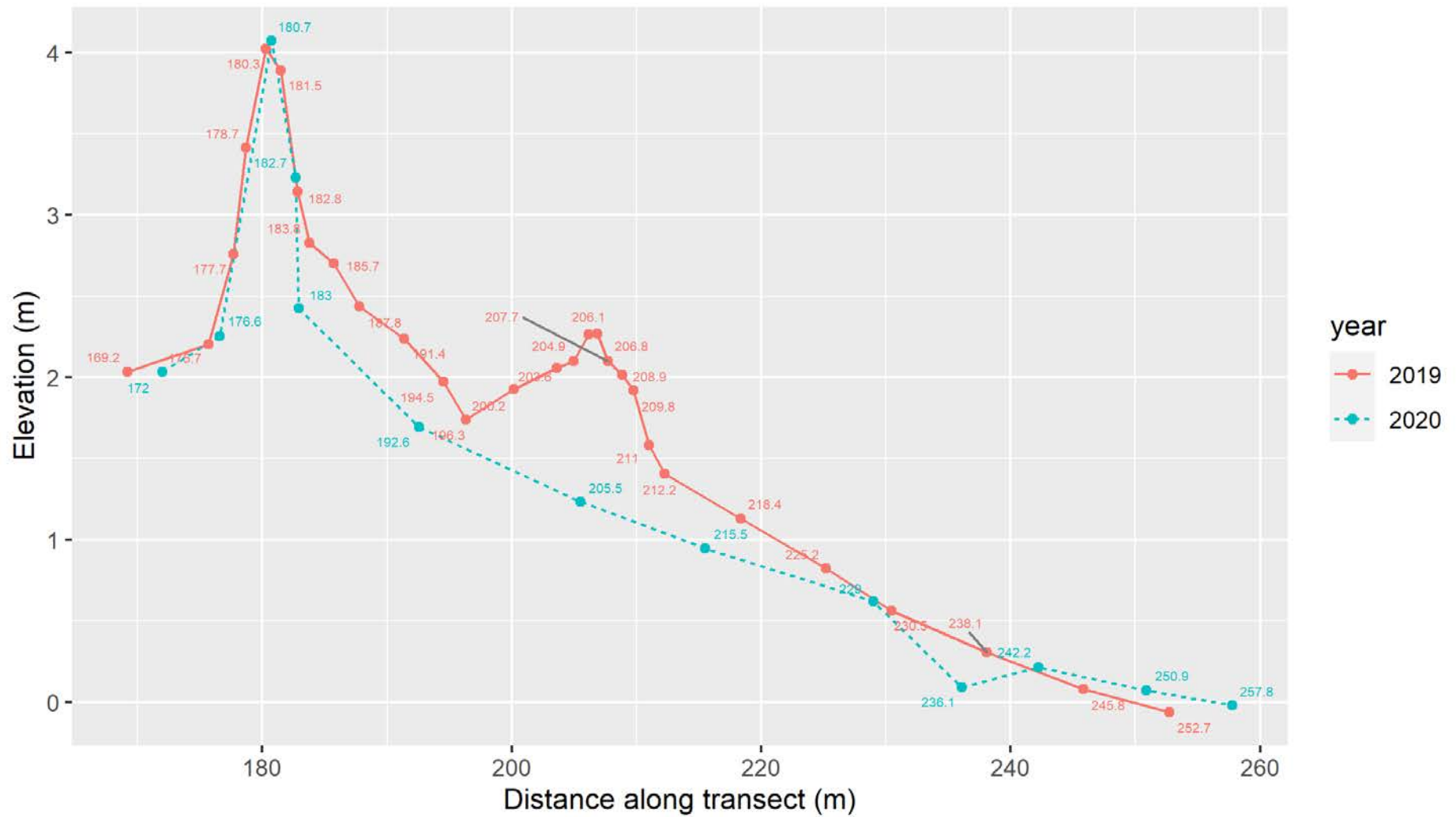
Graphical depiction of topographic profiles with dimensional measurements for the years surveyed. Each profile distance measurement originates at a physical or virtual benchmark and extends seaward to approximately 0.0 meters NAVD 88. Measurements are taken in the active part of the beach/dune system and may not extend to the origin. All elevation measurements are referenced to NAVD 88, Geoid 12B



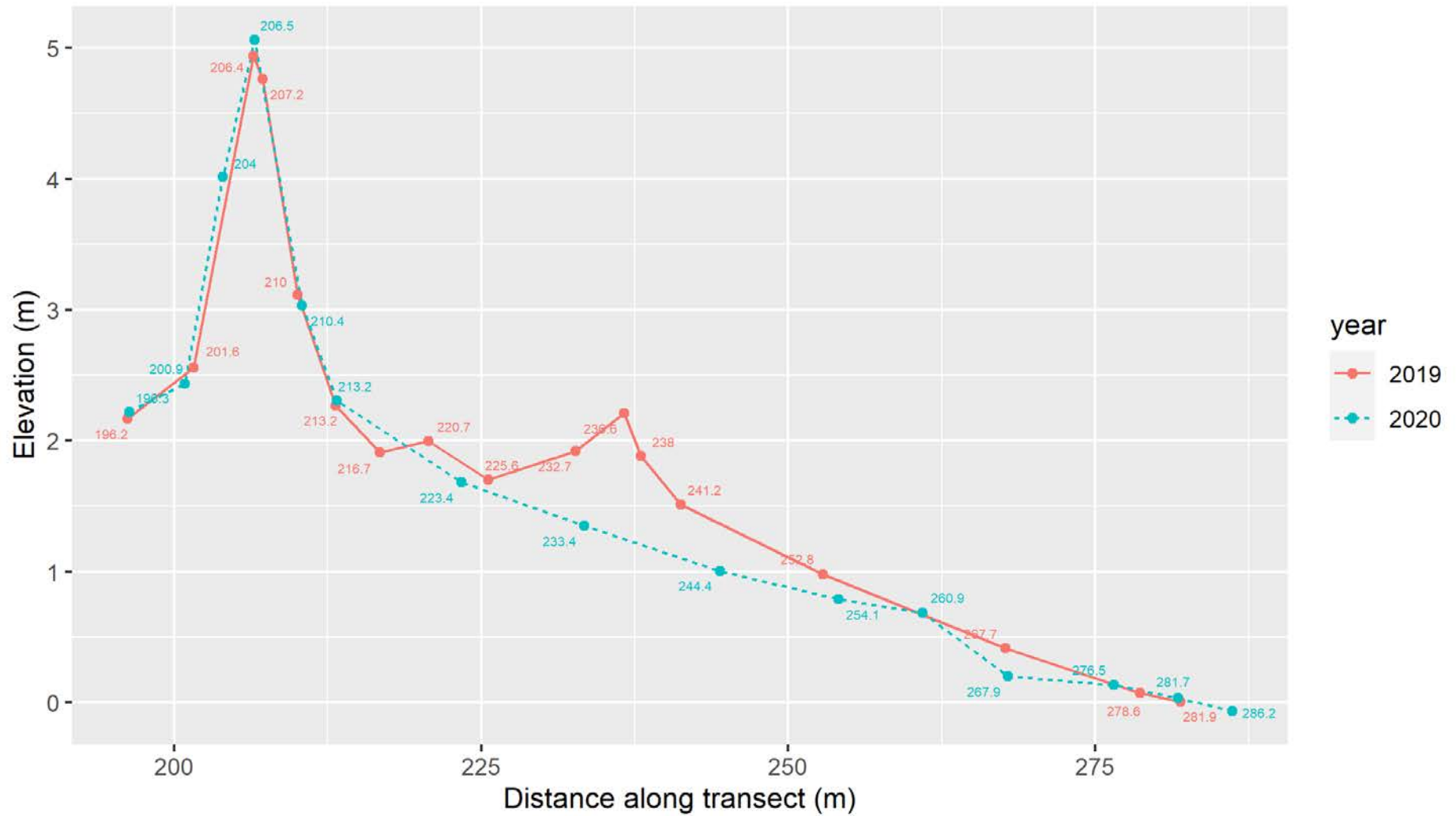
Transect t010: area 2020 = 149.7, area 2019 = 174.8



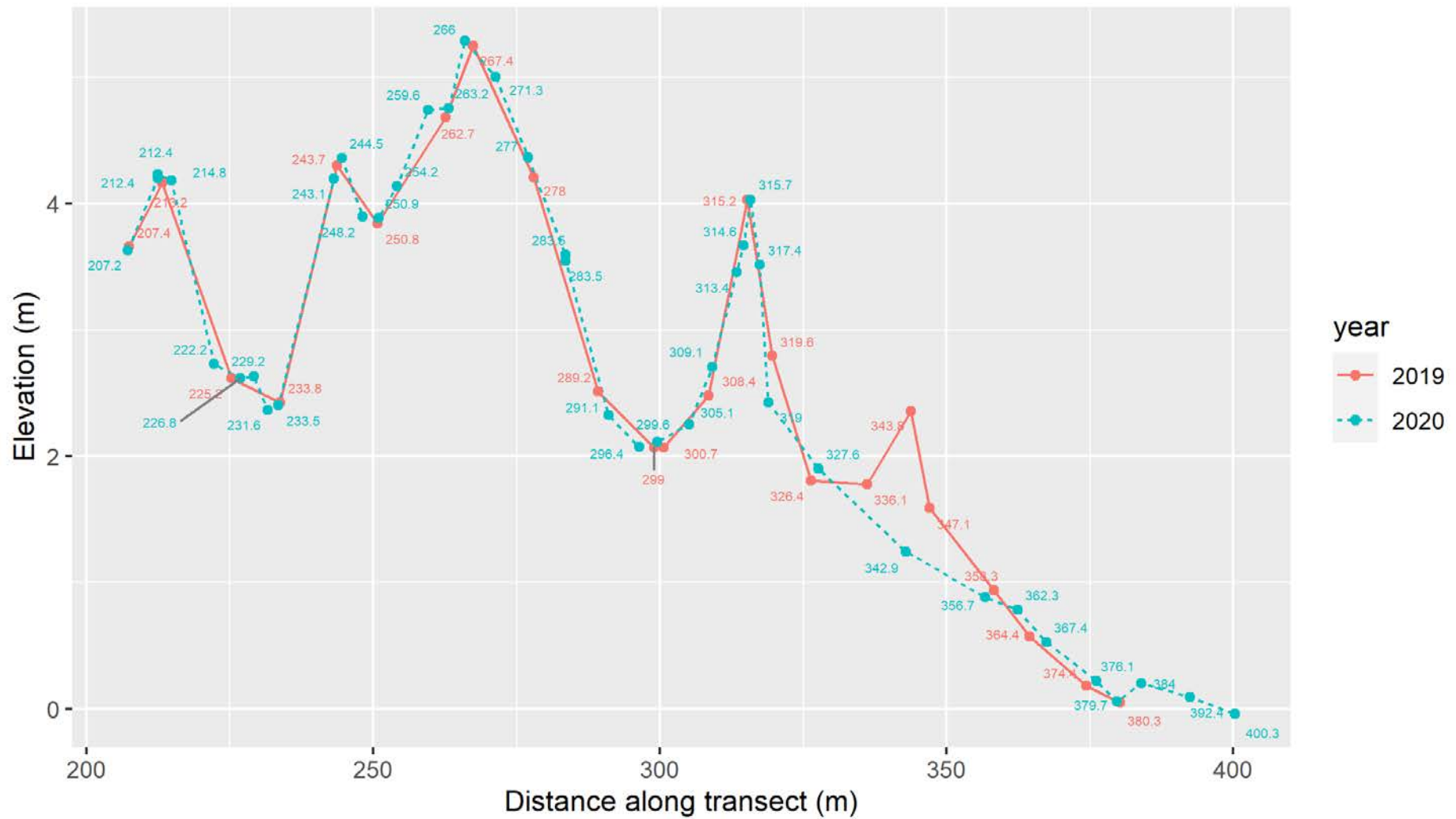
Transect t011: area 2020 = 96, area 2019 = 123



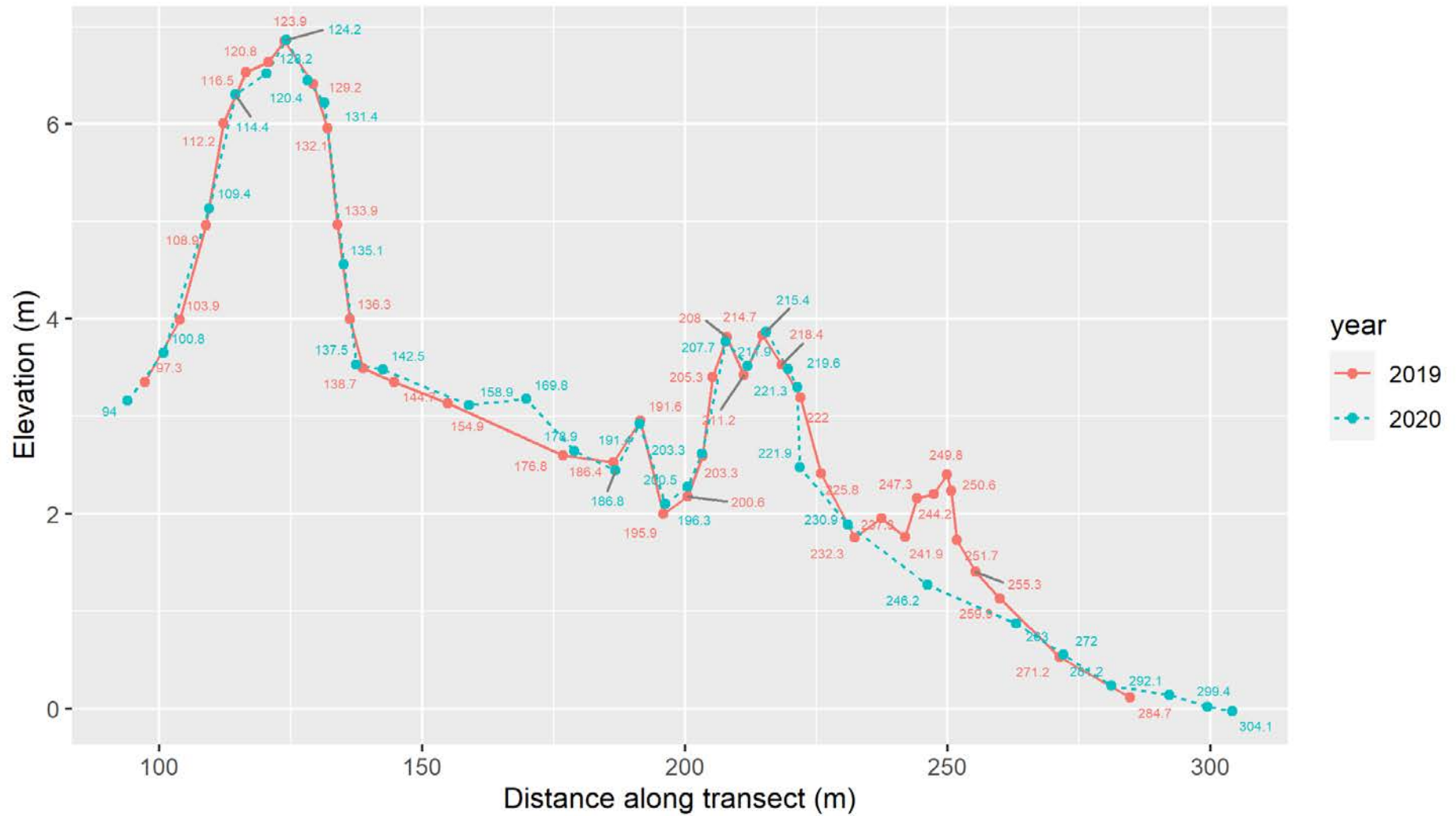
Transect t012: area 2020 = 122.4, area 2019 = 135.3



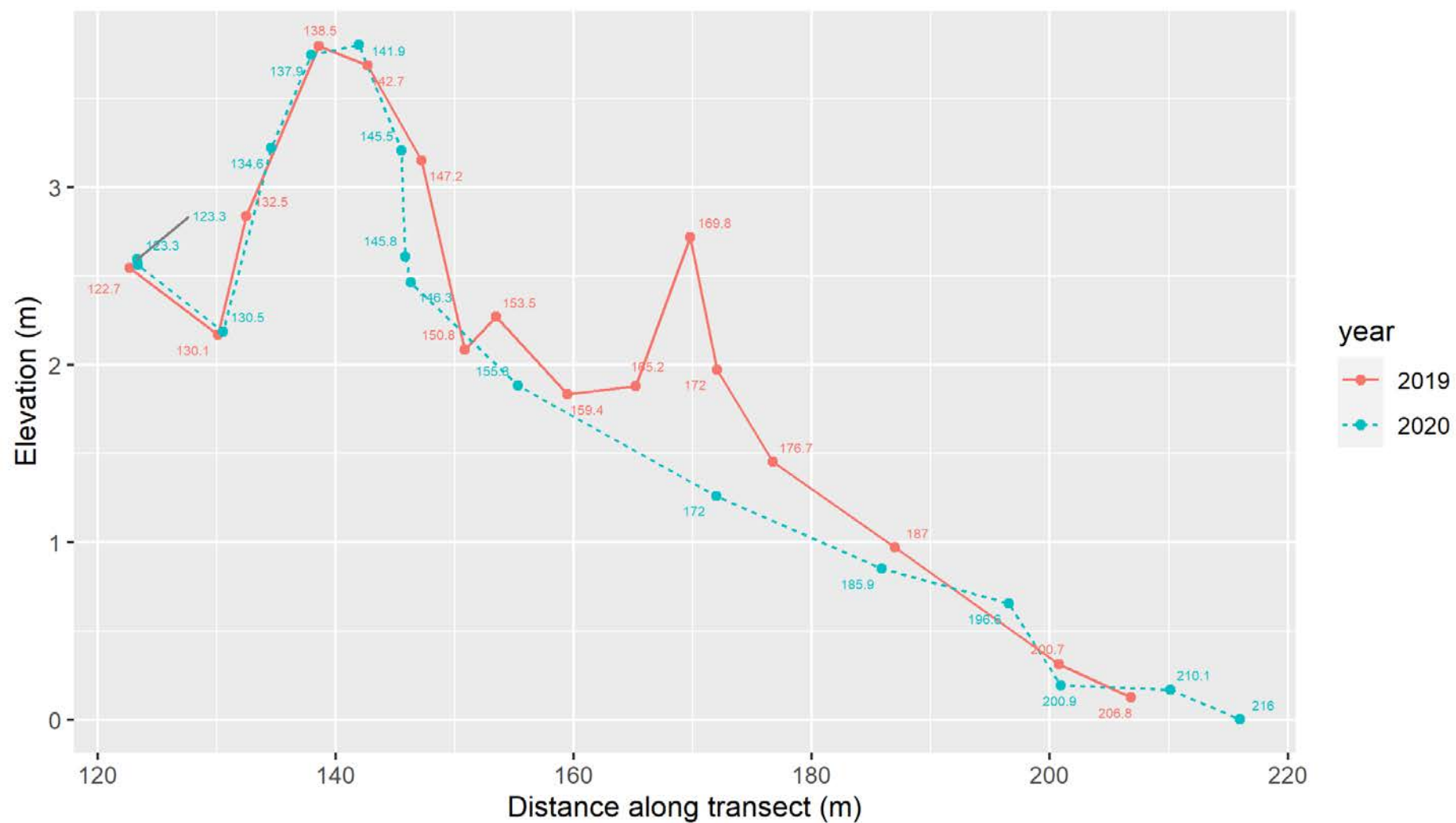
Transect t013: area 2020 = 463.7, area 2019 = 468.4



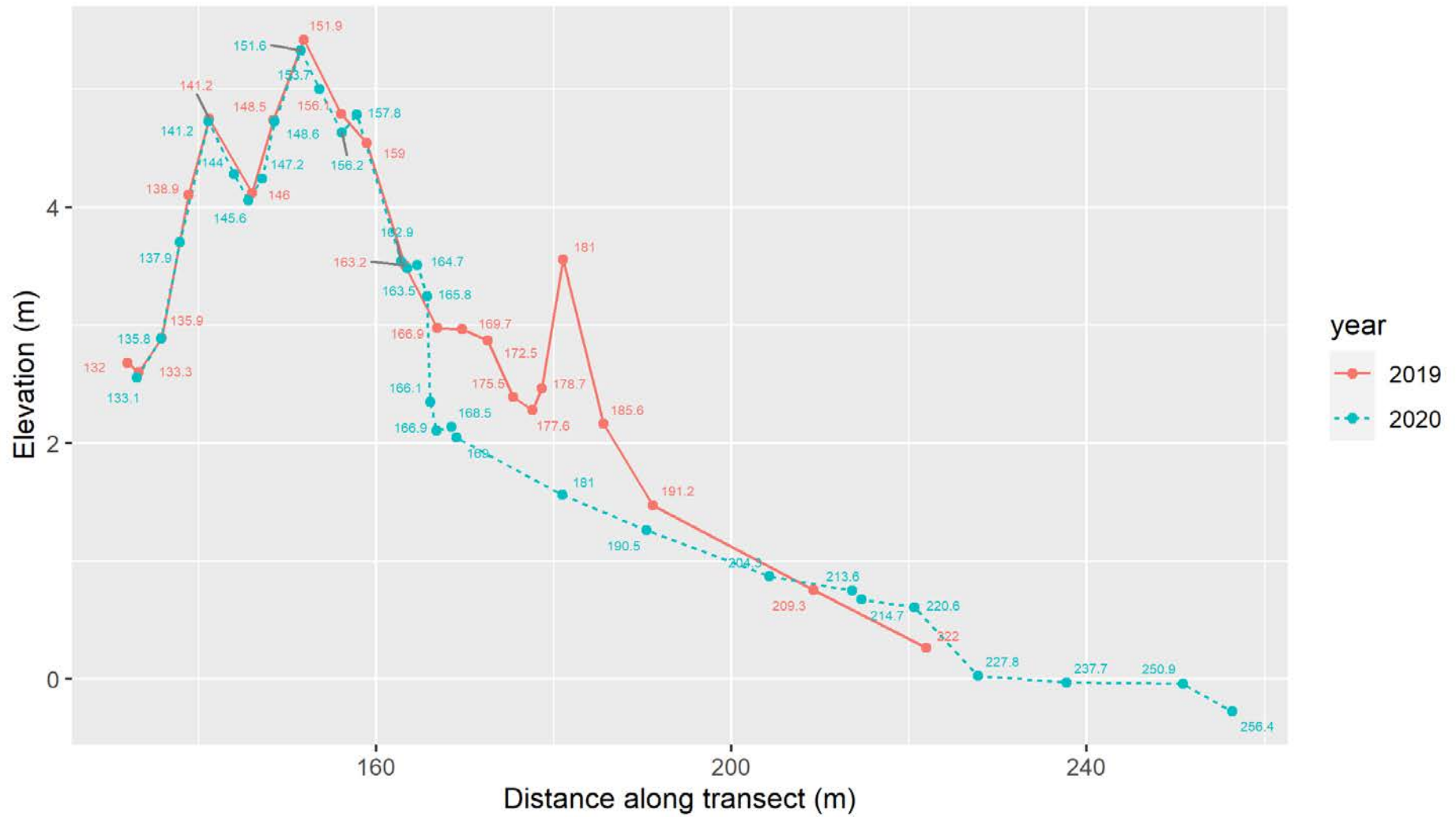
Transect t014: area 2020 = 562.8, area 2019 = 559.5



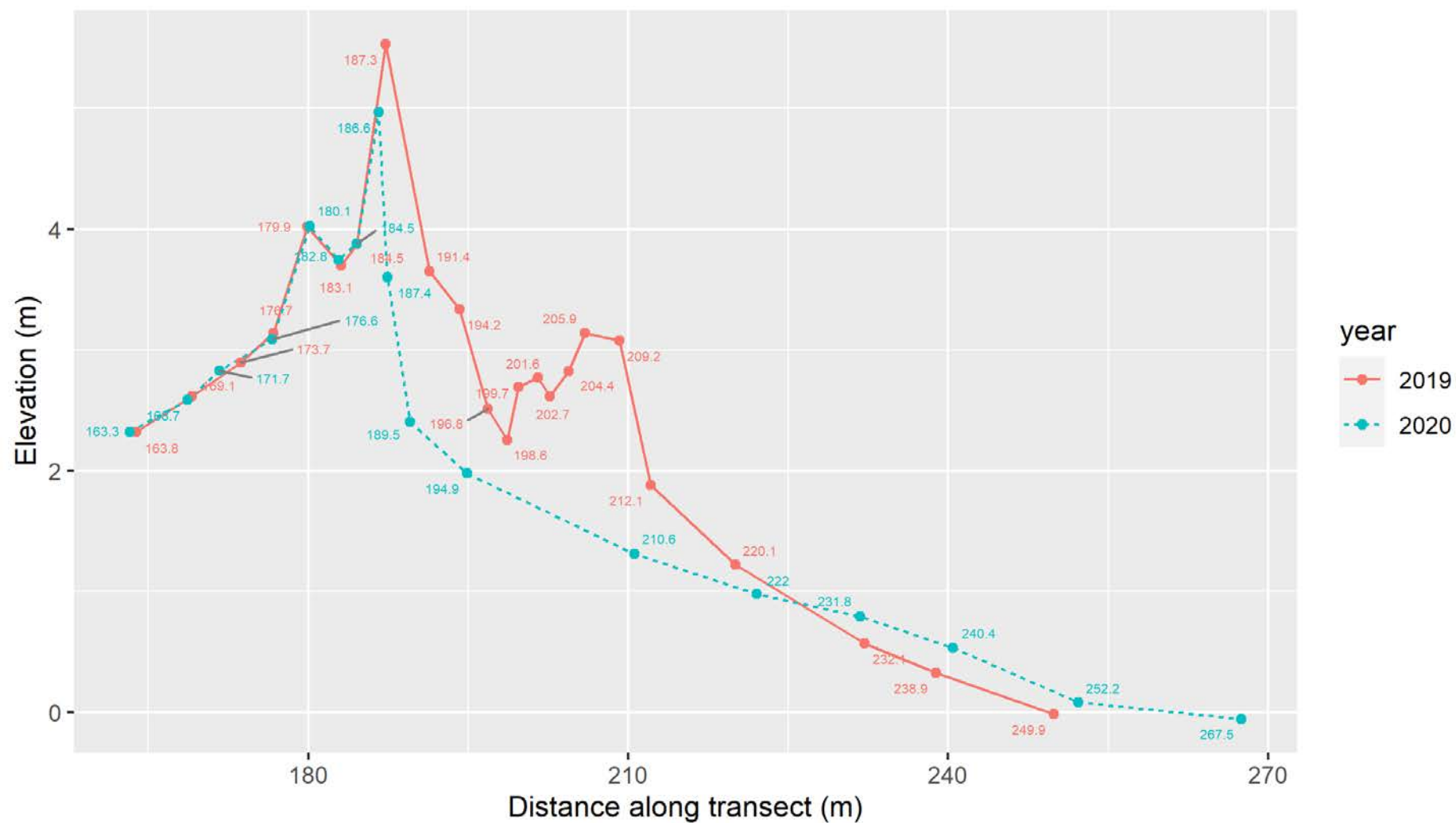
Transect t015: area 2020 = 142.1, area 2019 = 159.2



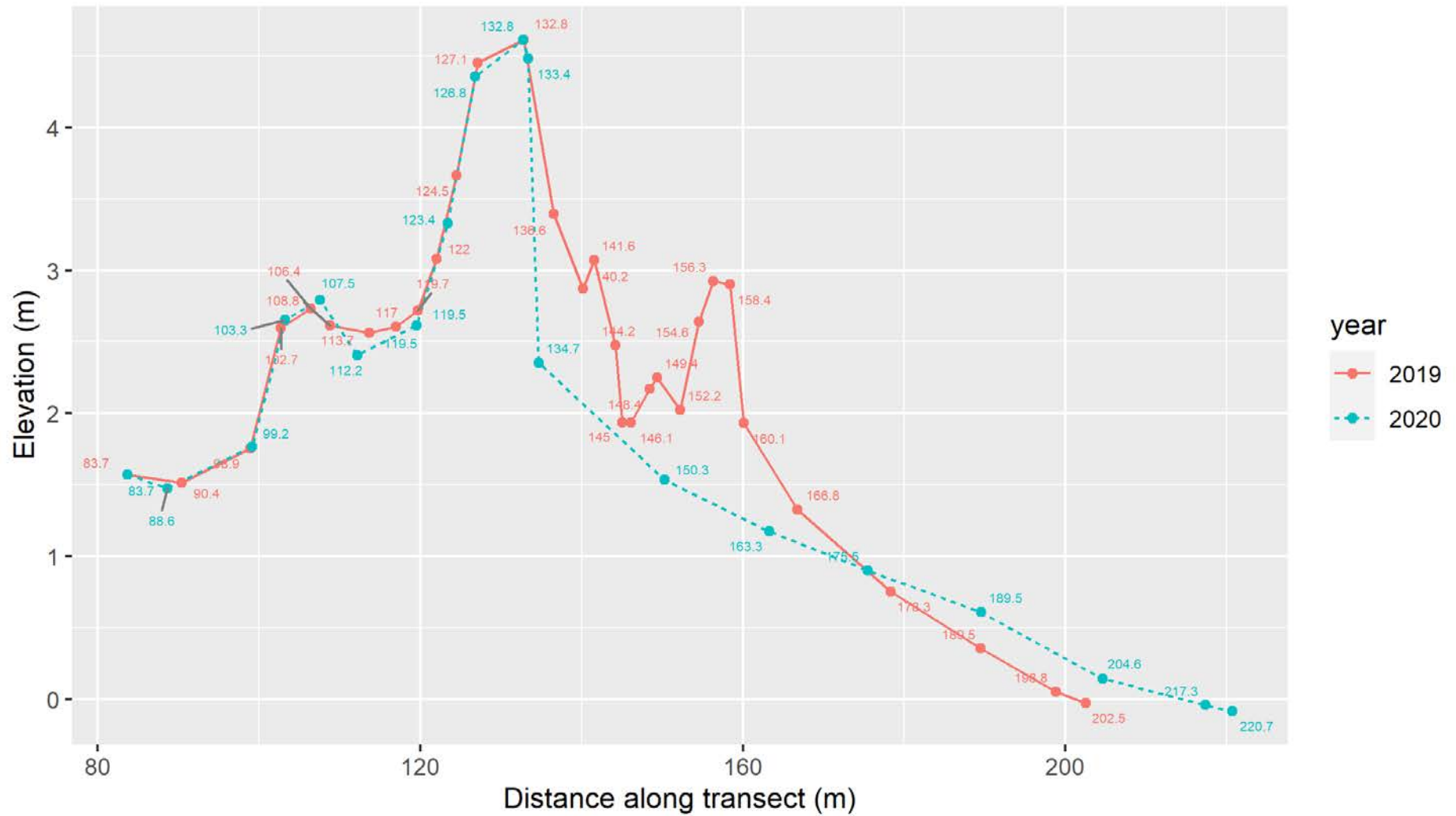
Transect t016: area 2020 = 207, area 2019 = 233.4



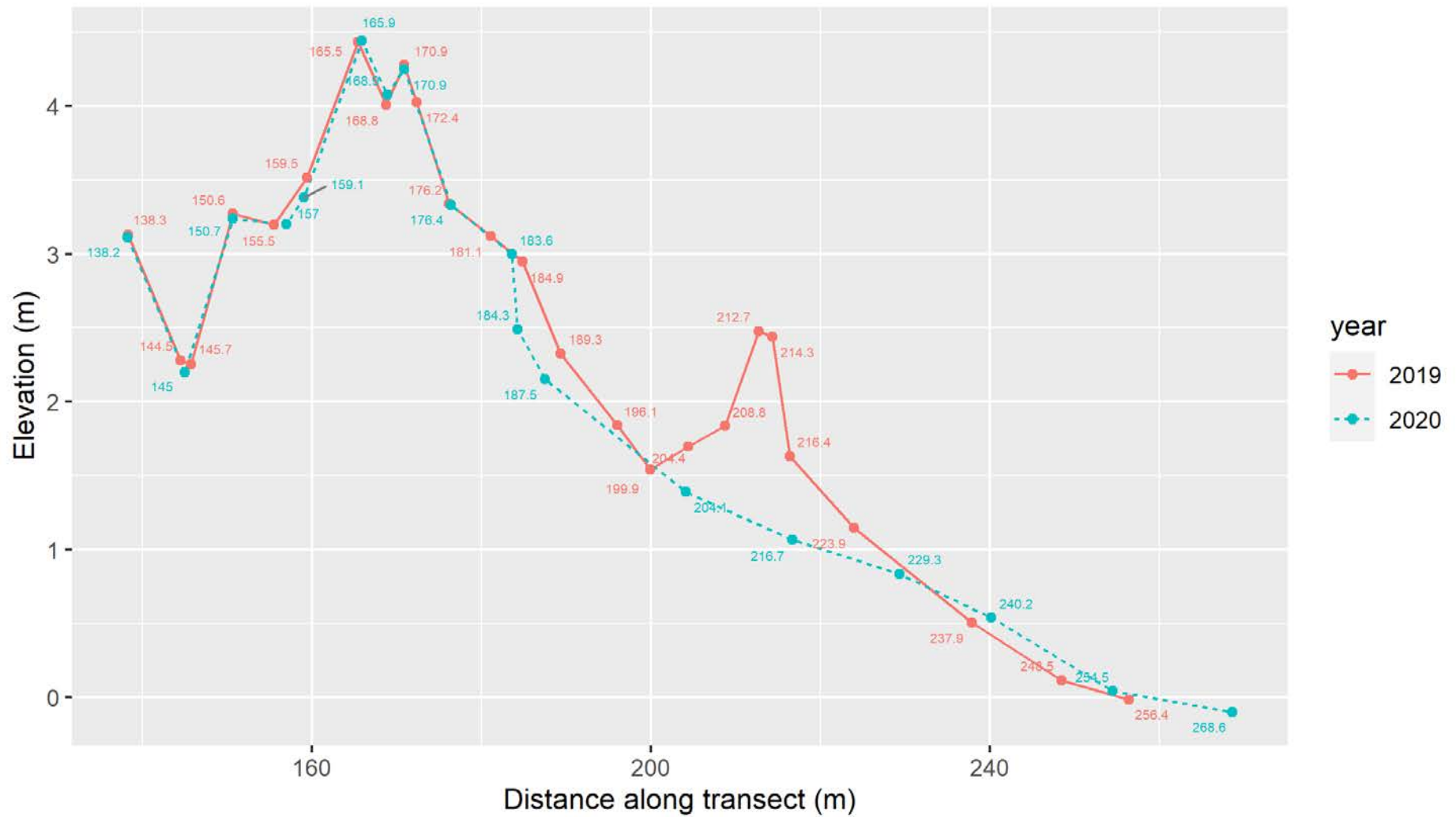
Transect t023: area 2020 = 153.4, area 2019 = 182.7



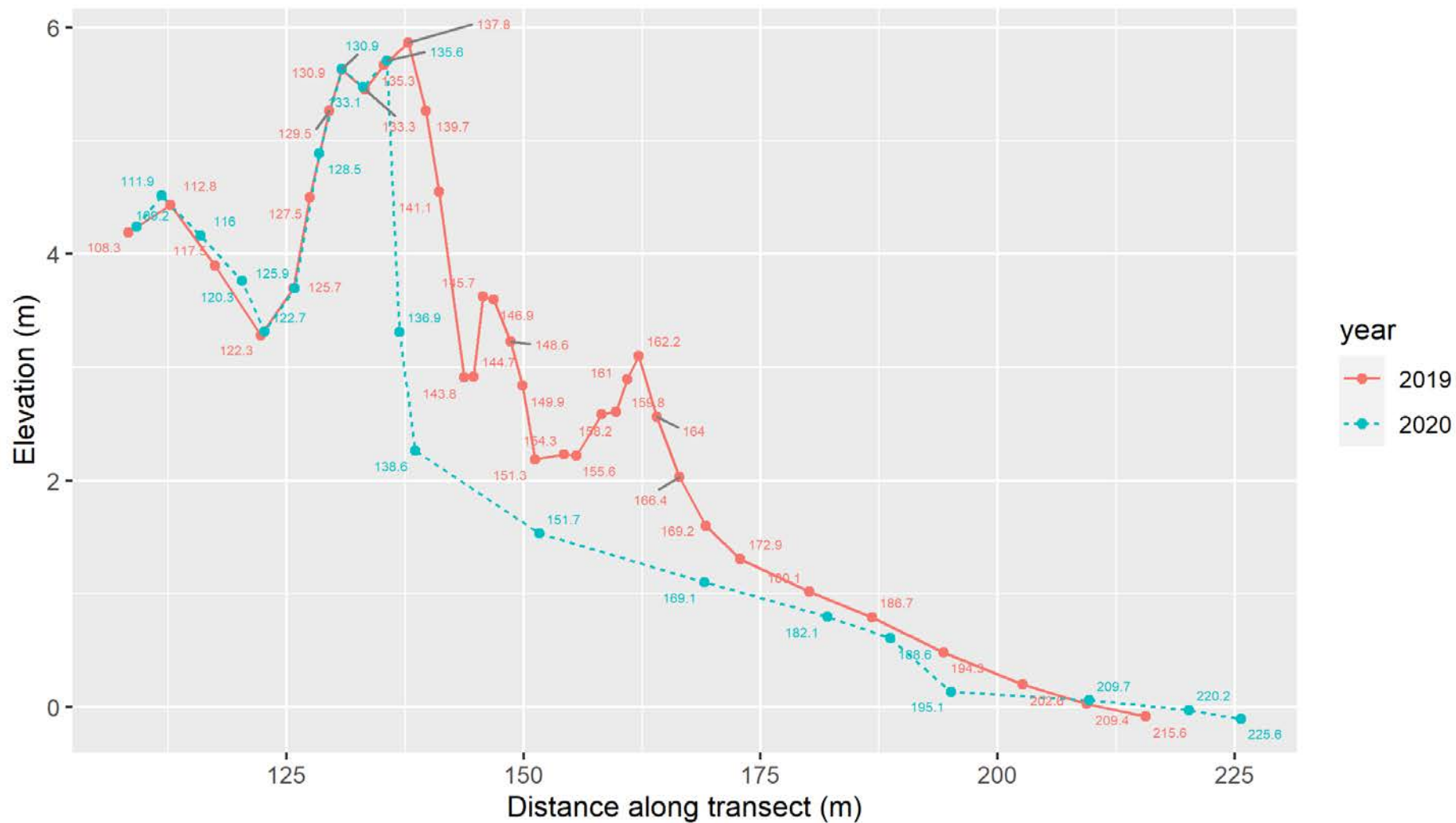
Transect t024: area 2020 = 211.7, area 2019 = 235



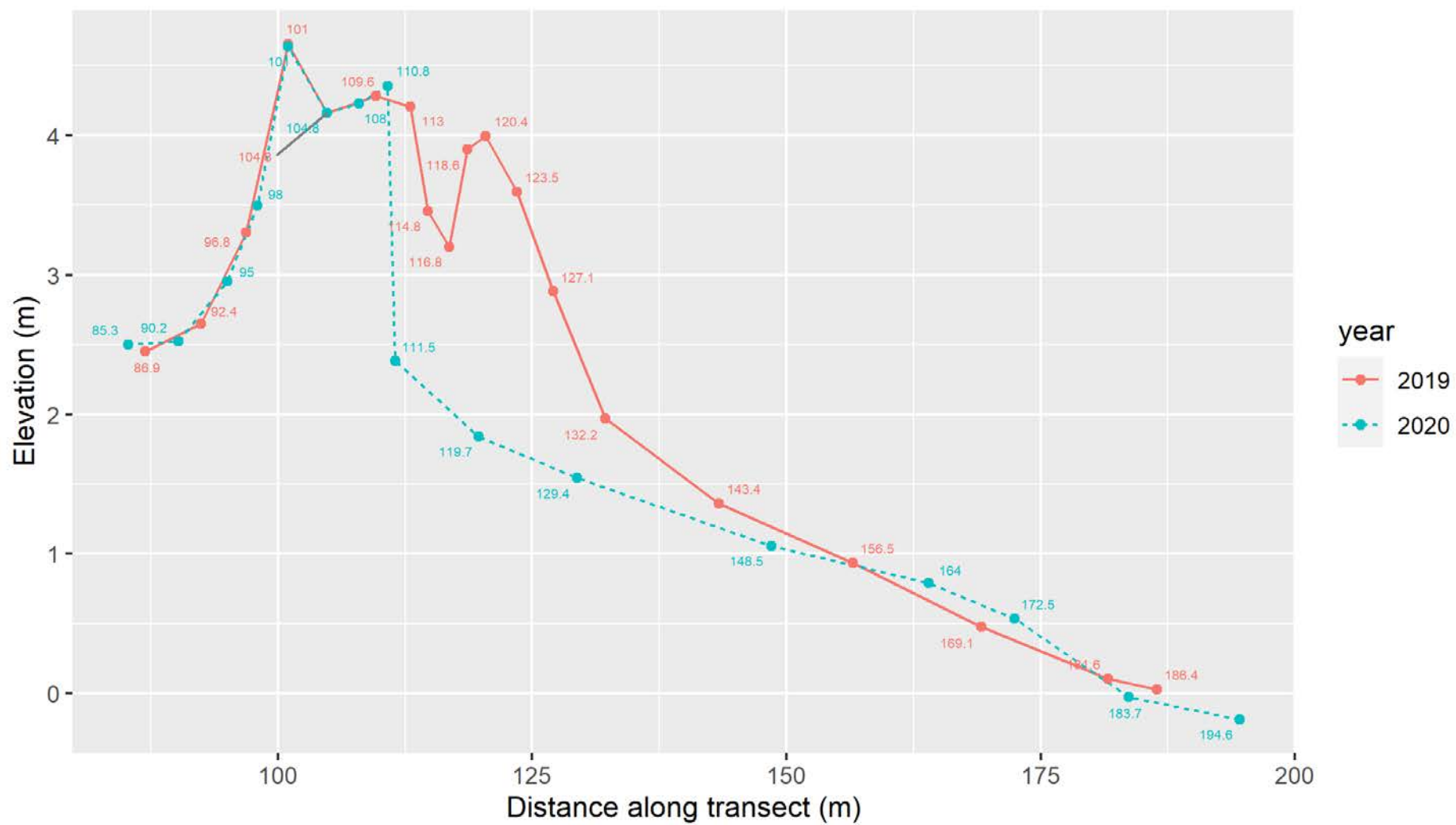
Transect t025: area 2020 = 229.5, area 2019 = 245.8



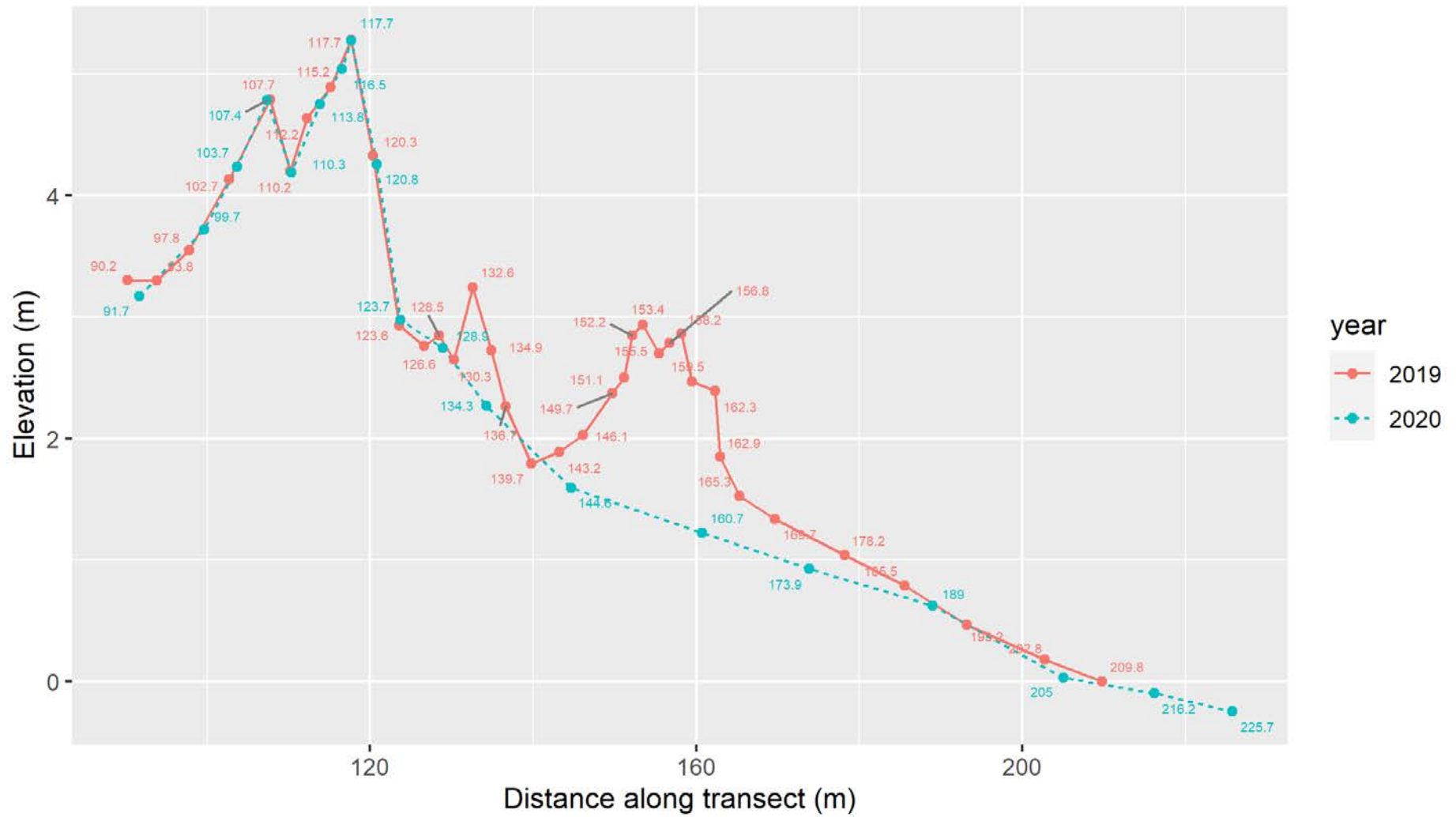
Transect t038: area 2020 = 195.4, area 2019 = 252.9



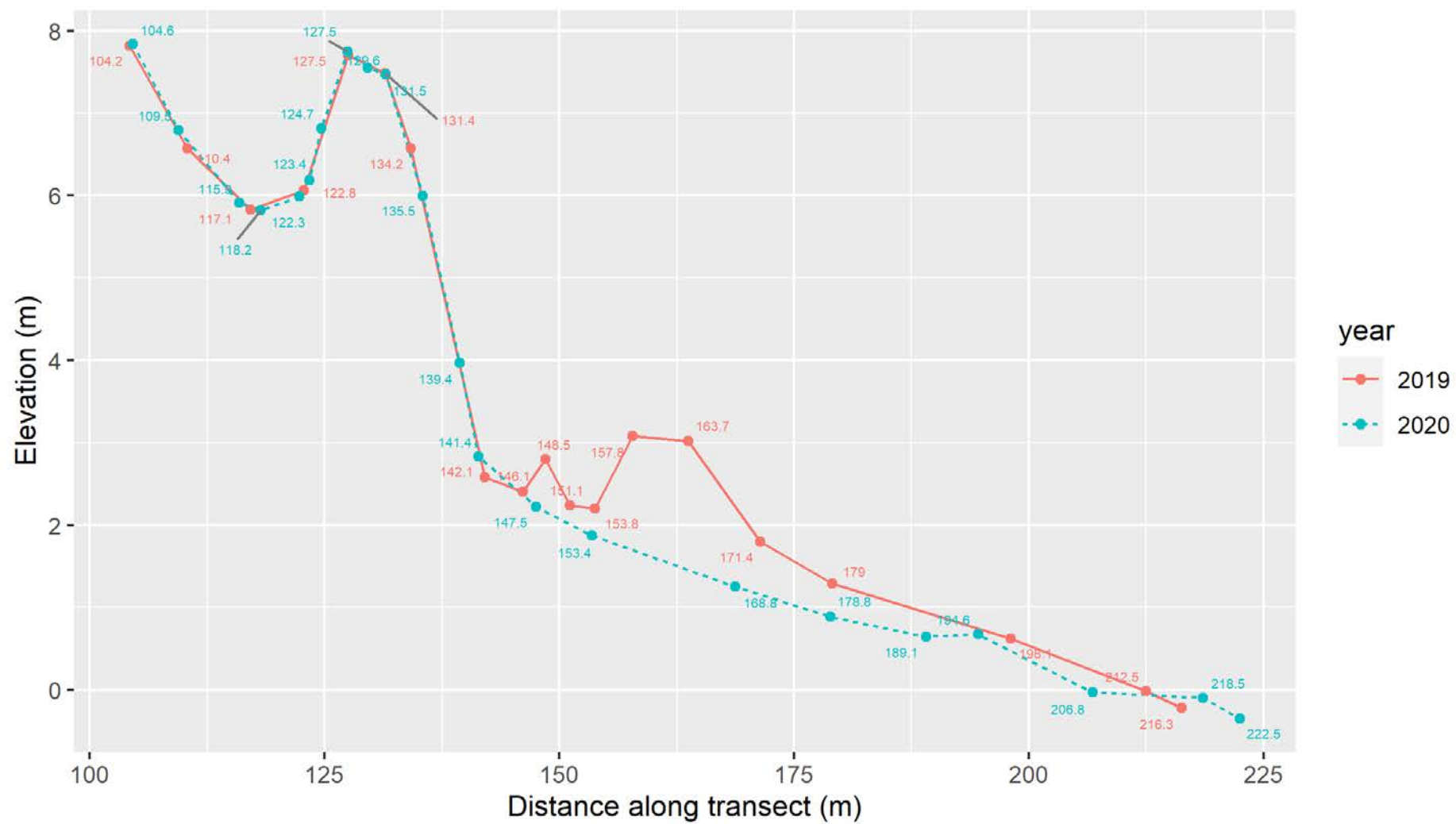
Transect t039: area 2020 = 172.2, area 2019 = 204.5



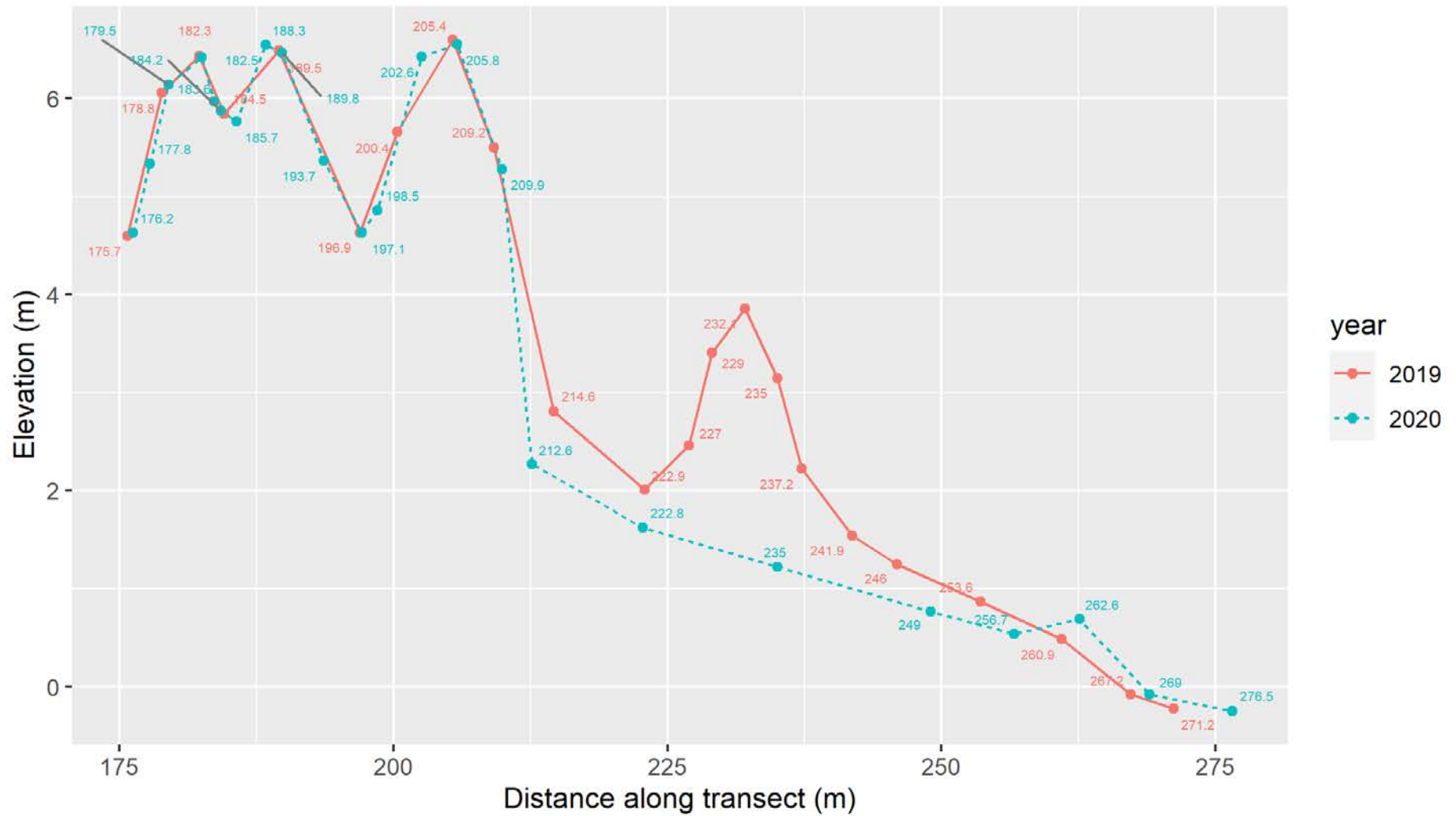
Transect t040: area 2020 = 234, area 2019 = 271.7



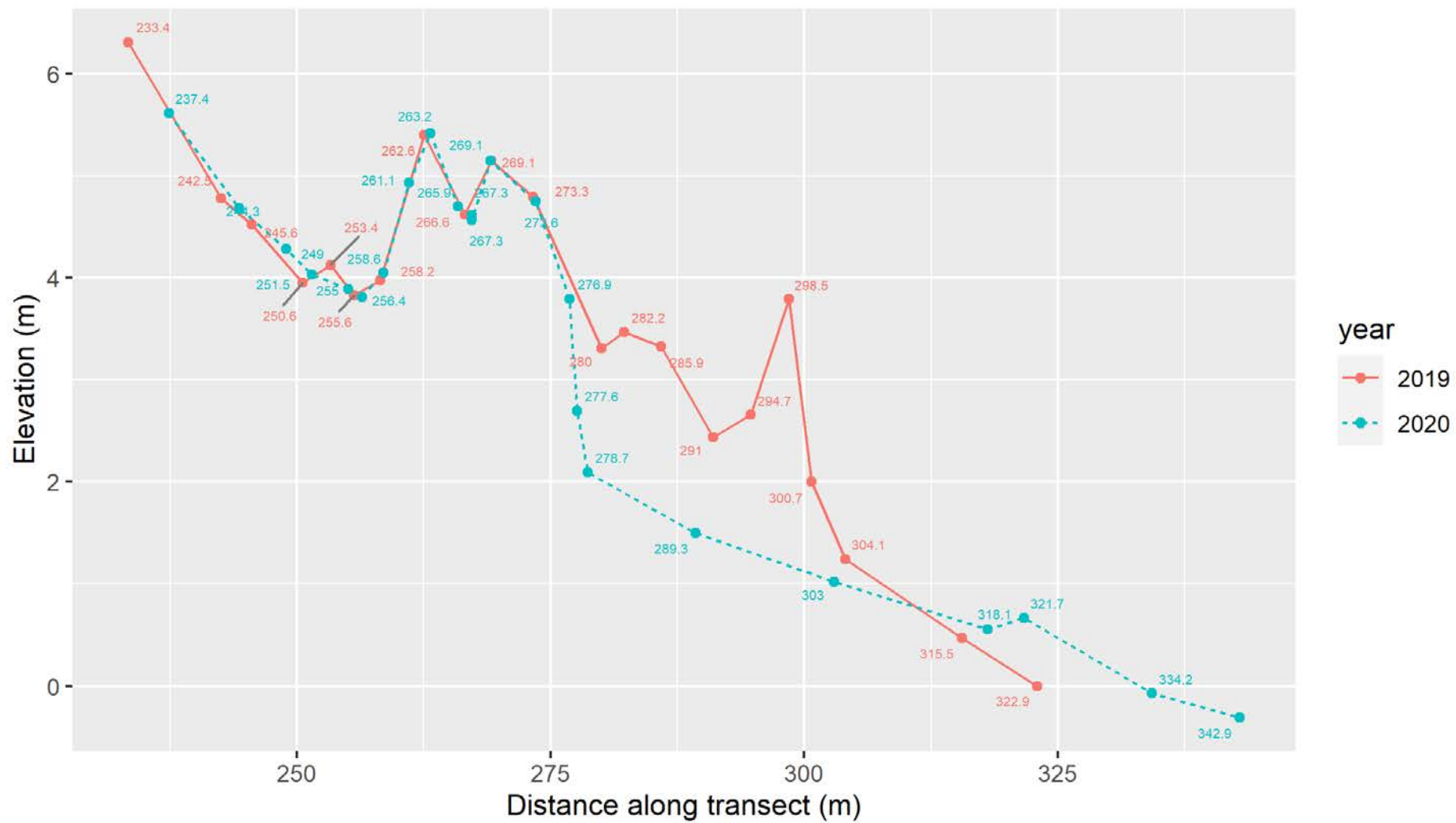
Transect t073: area 2020 = 309.8, area 2019 = 347.4



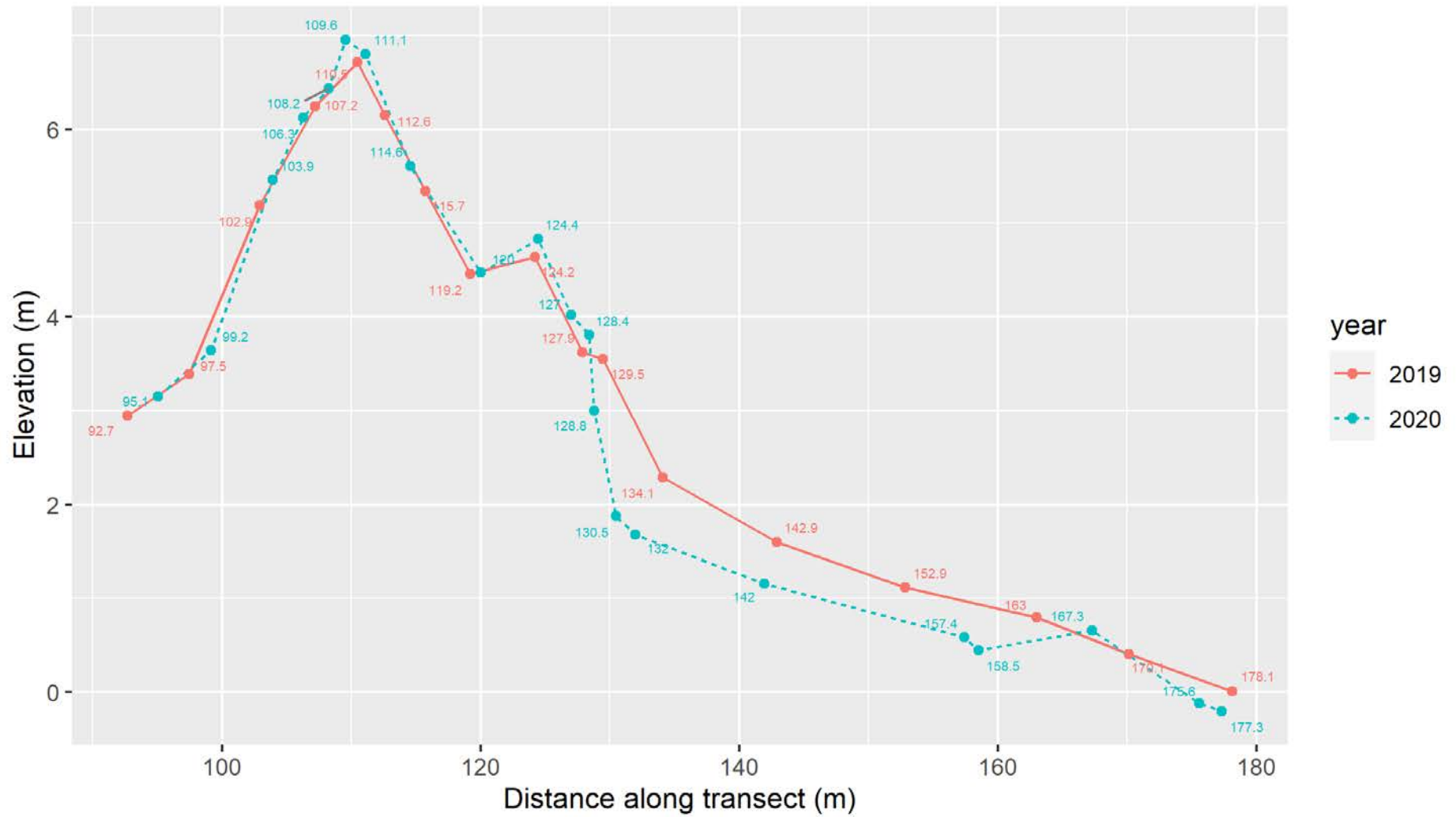
Transect t075: area 2020 = 266.9, area 2019 = 308.4



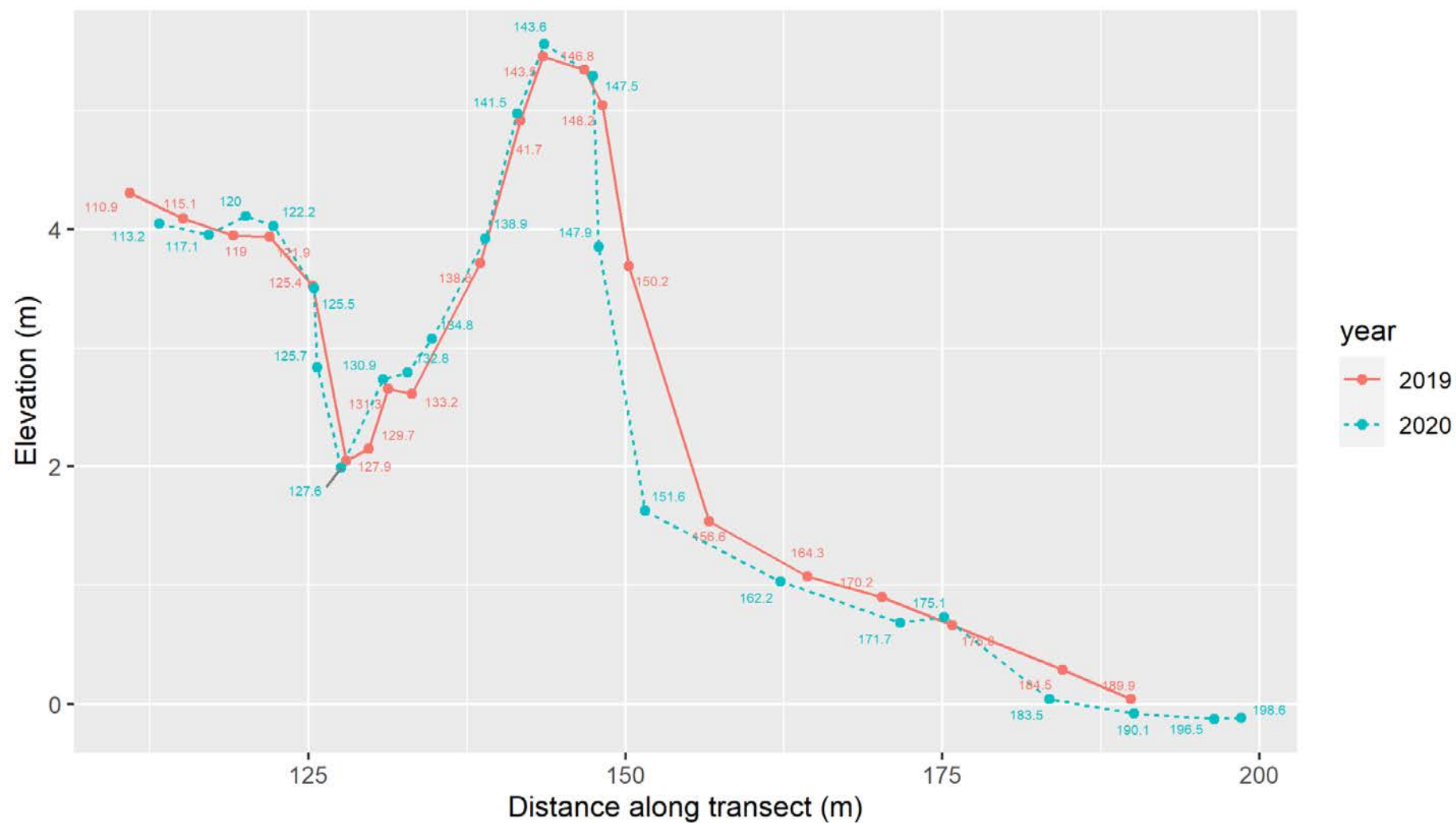
Transect t077: area 2020 = 239.8, area 2019 = 297



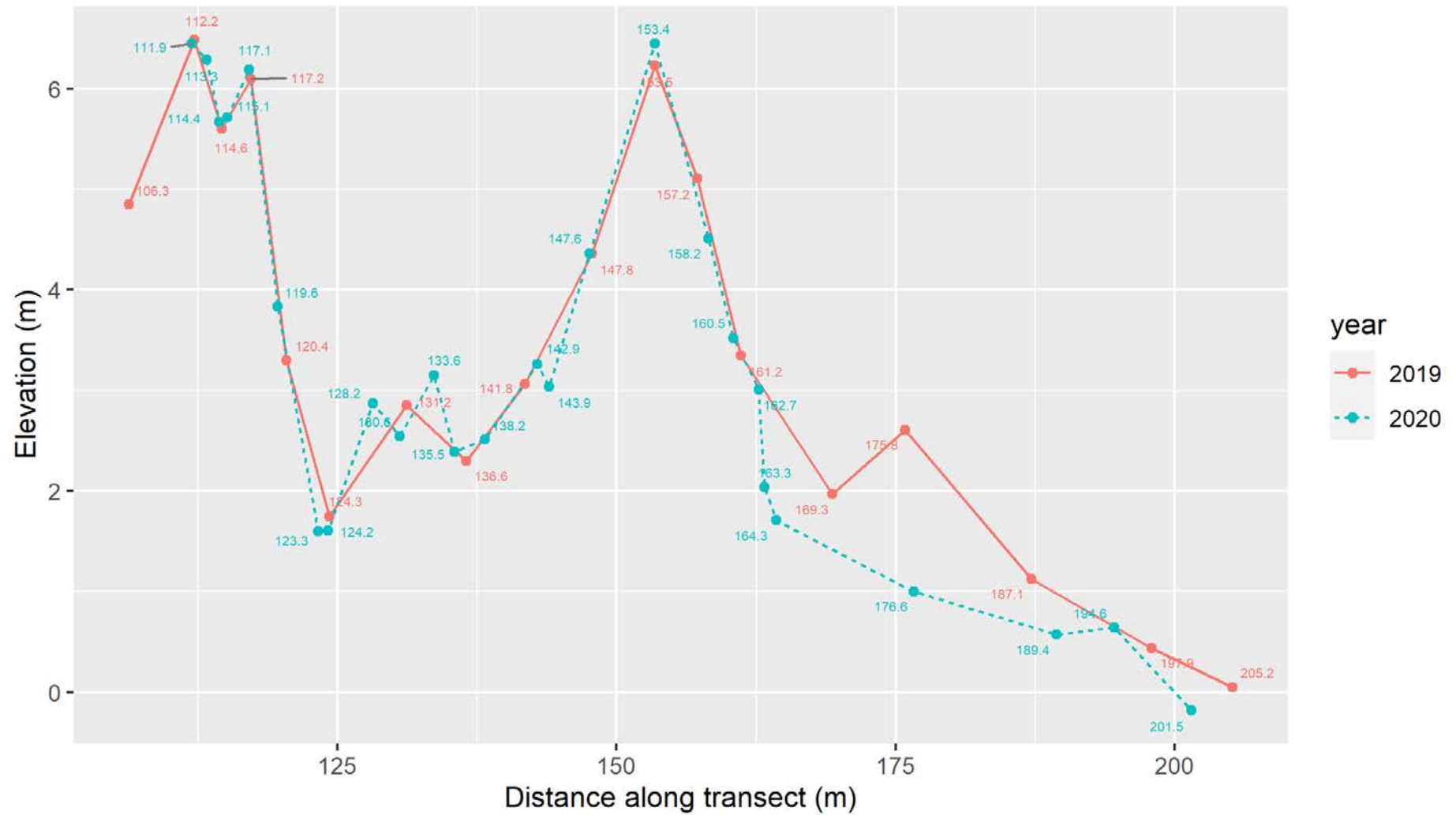
Transect t101: area 2020 = 210.3, area 2019 = 236.3



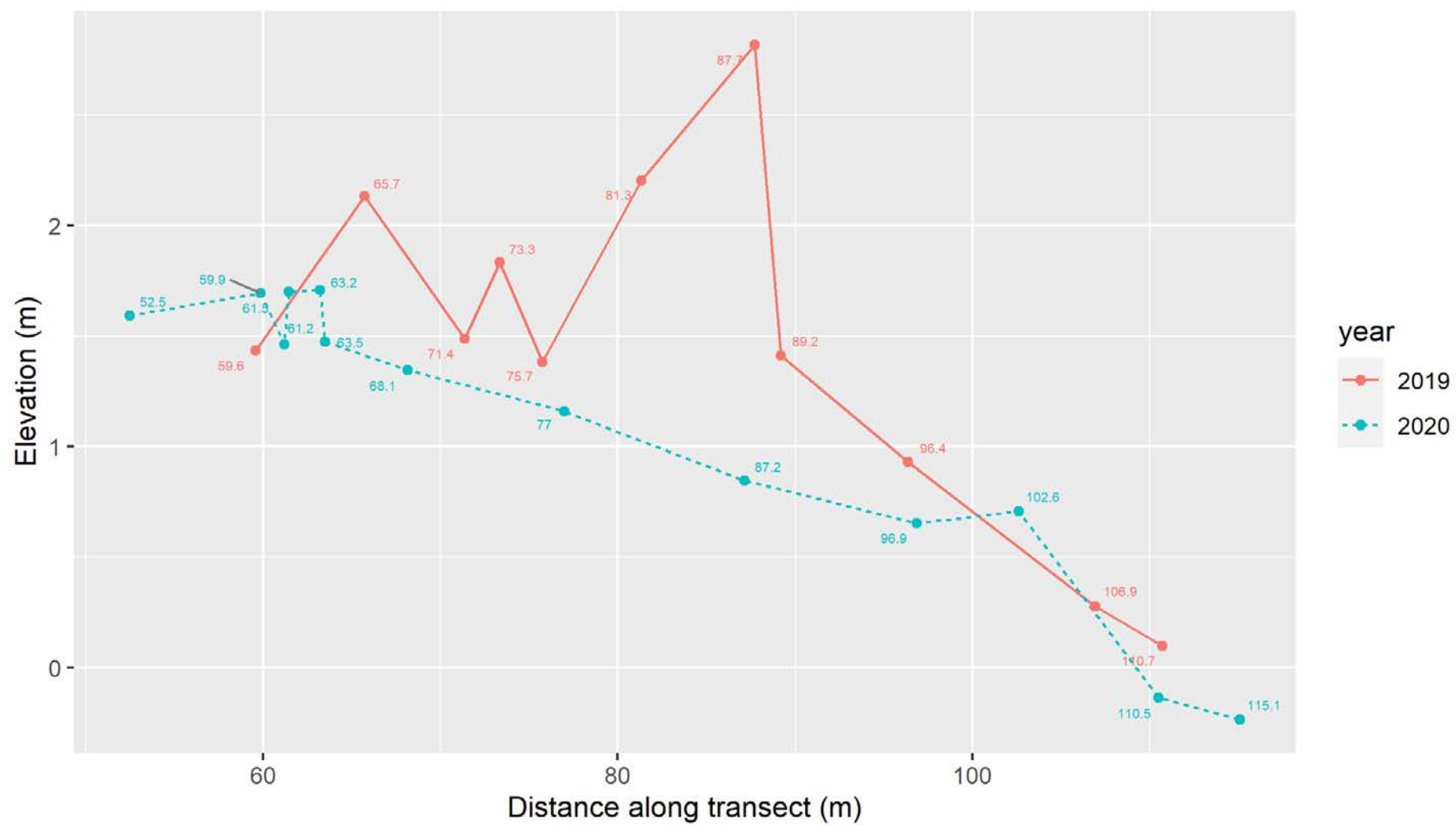
Transect t103: area 2020 = 169.7, area 2019 = 193.1



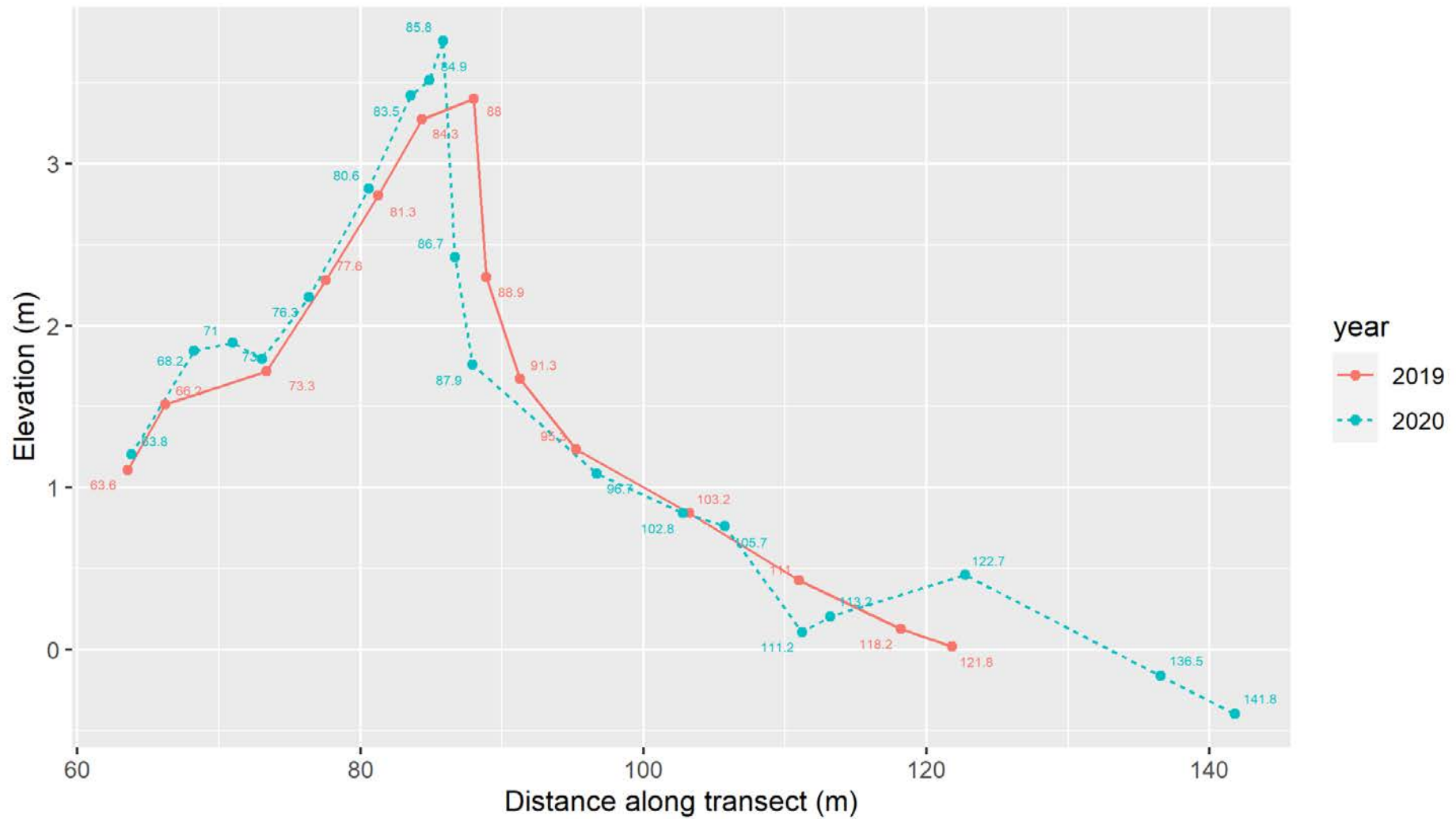
Transect t105: area 2020 = 230.5, area 2019 = 290



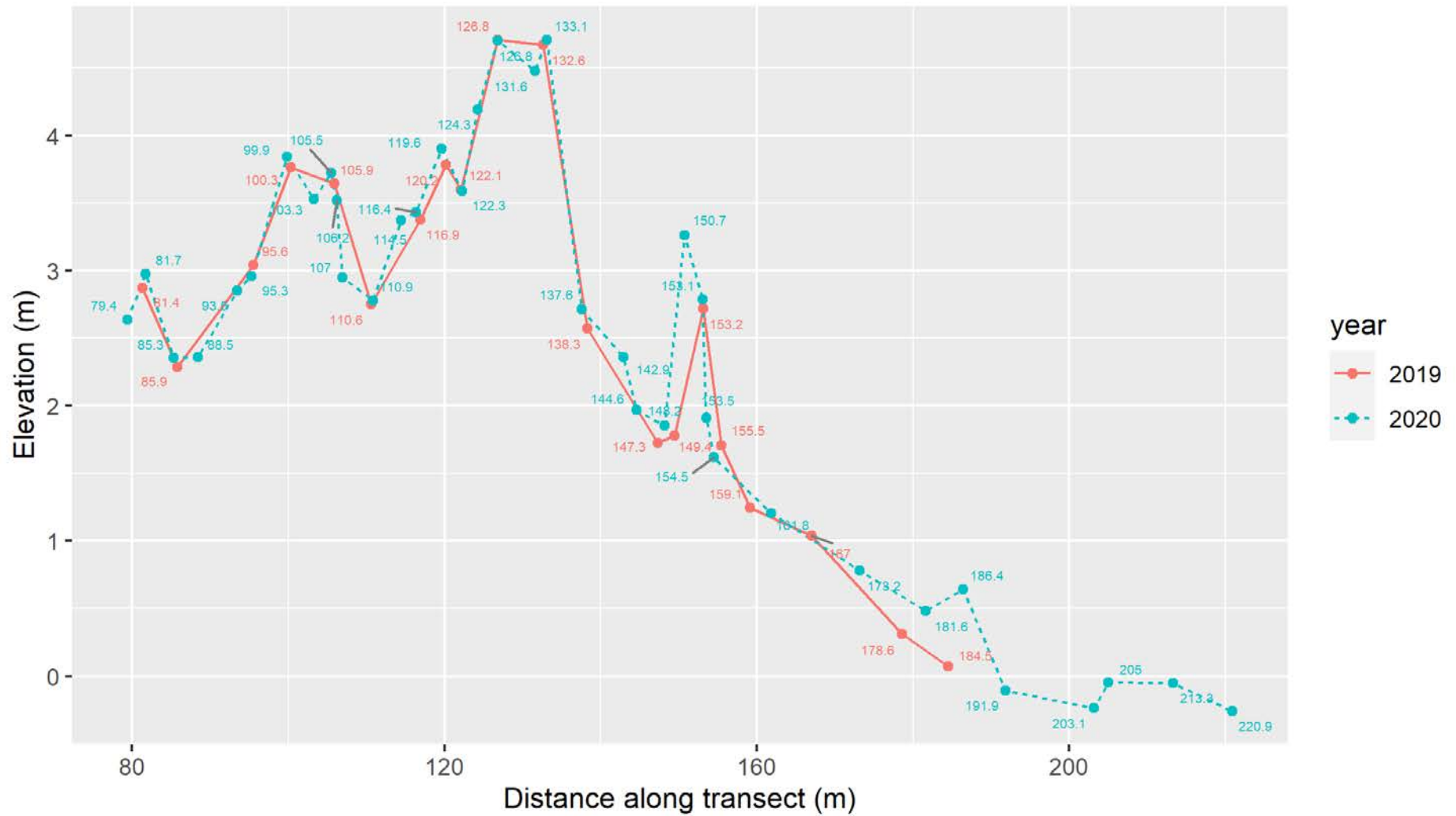
Transect t107: area 2020 = 58.5, area 2019 = 73



Transect t109: area 2020 = 82.7, area 2019 = 82.9



Transect t111: area 2020 = 265.8, area 2019 = 254.9



Appendix B. Shoreline Displacement Maps

Maps represent the change in shoreline position between April 2019 and August 2020, following Hurricane Hanna. Displacement is measured in meters and transect colors are scaled from red to blue indicating degree of shoreline retreat or advance.

