

Survey of *Limulus polyphemus* Spawning at Cove Point, Community and Flag Ponds Beaches in 2015

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Introduction and Methods

In 2015, Cove Point, Community and Flag Ponds beaches were surveyed for horseshoe crab spawning activity. As in previous years, a survey consisted of a single pass along a beach, within one hour of high or low tide. Workers recorded 1) the GPS location of all females, males and spawning groups and 2) the number of males associated with each spawning females. Cove Point and Community beaches were surveyed on four nights around four tide cycles in May, June and July. Flag Ponds beach was surveyed once each tide cycle. In October 2015, we conducted a beach profile for Cove Point beach, using the Emery rod system that we employed in previous profiles.

Summary of Results

1. We observed 252 spawning females at Cove Point and 279 at the Community beach to the south. Fewer females spawned at the Community beach in 2014. The majority of Community beach females occurred along a narrow spit of sand extending from the lighthouse. This area is new and was not present last year. As in previous years, spawning at Flag Ponds was considerably higher than observed at either Cove Point or the Community beach. Spawning was greatest during the May tide cycle. Spawning in 2015 was lower than in 2014 but still elevated compared with earlier years. This supports the hypothesis that spawning activity has increased at Cove Point beach.
2. As in previous years, most females spawned along the southern section of Cove Point beach. However, long-term records show a significant trend towards increased spawning on the northern beach, although spawning totals are still low. There was a significant decrease in spawning in the middle section of Cove Point beach.
3. Although no tagging occurred in 2015, 16 tagged animals were re-sighted. They included animals tagged in both 2013 and 2014. Overall re-sighting results suggest that animals usually return to the beach where they were tagged. Females may return within a tide cycle. Males may return within a tide cycle, on subsequent tide cycles and in subsequent years.
4. Beach profiles were conducted in October 2015 and compared with profiles from 2011 and 2013. Elevations are generally higher in 2015 compared with previous years. Southern profiles generally showed lower slopes than in previous years, while northern sections showed greater slope. There appears to have been some erosion and loss of beach in the southern section. There was continued erosion in the middle section but sand accretion and a wider beach just inside the breakwaters in the northern section.

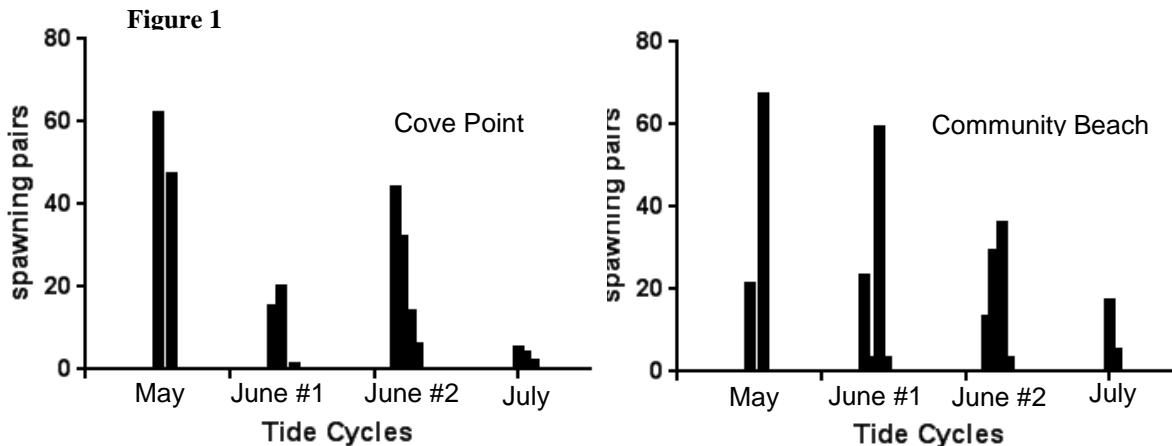
Detailed Results

Total Spawning Groups for all Beaches - The total observed females and males from all beaches are shown in Table 1.

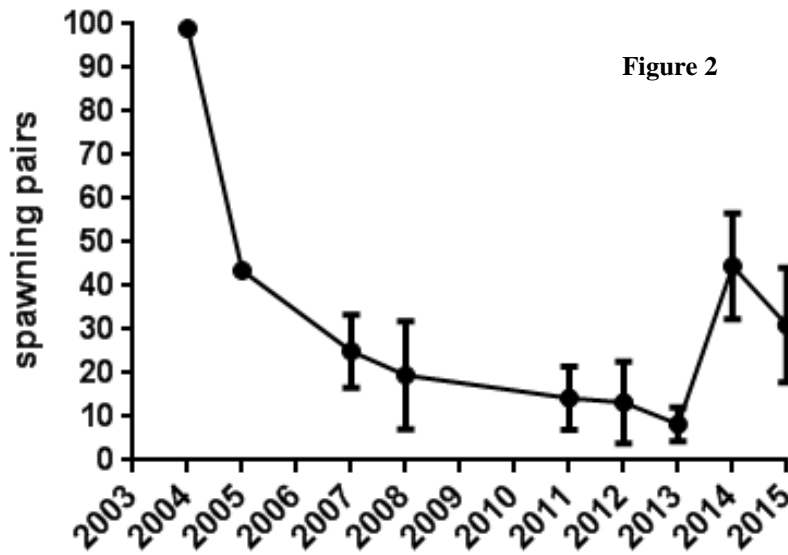
Table 1

Date	Cove Point		Community		Flag Ponds	
	M	F	M	F	M	
5/17/2015	85	62	26	21		
5/18/2015	88	47	93	67	426	194
6/1/2015	17	15	59	23		
6/2/2015	38	20	4	3	375	98
6/3/2015	0	0	132	59		
6/4/2015	1	1	3	3		
6/15/2015	130	44	41	13	312	66
6/16/2015	78	32	107	29		
6/17/2015	25	14	133	36		
6/18/2015	6	6	3	3		
7/2/2015	7	5	32	17	32	14
7/3/2015	4	4	9	5		
7/4/2015	2	2	0	0		
Totals	481	252	642	279	1145	372

Spawning Females at each Tide Cycle – Figure 1 shows the number of spawning females using Cove Point and the Community beach at each tide cycle. For both beaches, spawning was greatest during the May tide cycle. On many nights, the Community beach was utilized as much or more than Cove Point. This is reflected in the total counts, shown in Table 1 (Cove Point: 252 females vs. Community beach: 279 females). This pattern is different from the 2014 cycle, where there were many more spawning females at Cove Point.



Long-Term Spawning Numbers at Cove Point – In 2014, we reported an increase in spawning activity at Cove Point. This followed a long-term decline in spawning females over the last decade. Figure 2 shows this long-term trend with 2015 counts included. Each yearly point represents mean spawning females (\pm SEM) based upon a survey from the peak night of each tide cycle. The 2015 mean was less than 2014 but within a statistical margin of error. Both years were higher than previous years and support the hypothesis that horseshoe crabs have increased spawning activity at Cove Point.



Spawning Maps - The mapped locations of all spawning groups are shown in figures 3-28. The Google Earth photos used were taken in October 2013.

Cove Point

Figure 3: May 17, 2015

This tide cycle was associated with a new moon. The beach was surveyed from 1:40 am to 2:20 am. Workers counted 62 females and 85 males in a single pass from the lighthouse to the northern breakwater.



Figure 4: May 18, 2015

This was a new moon night. 47 females and 88 males were counted between 2:00 am and 2:41 am.

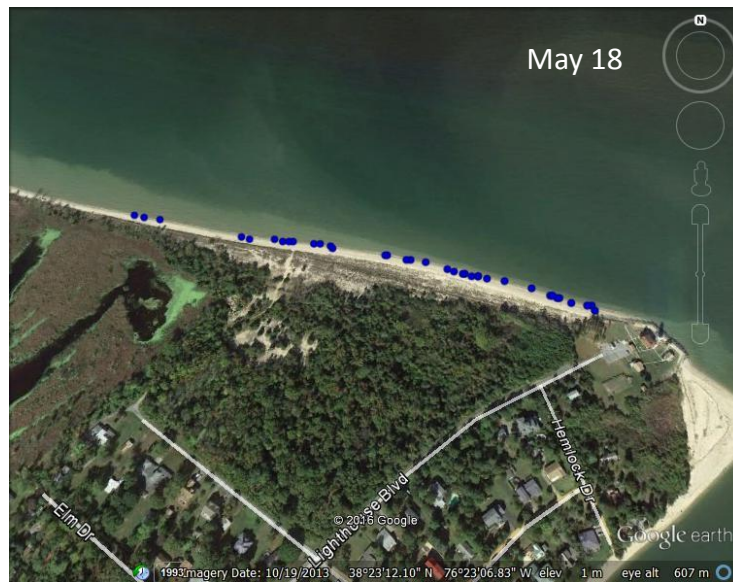


Figure 5: June 1, 2015.

This was the first survey tide for a full moon cycle. 15 females and 17 males were counted from 1:10 am and 2:00 am.



Figure 6: June 2, 2015.

This was a full moon night. From 1:50 am to 2:10 am, workers counted 20 female and 38 males in a single survey.



June 3, 2015

Workers observed high winds and strong surf this night. Waves were breaking very high up the beach, with no useable beach area. In a survey from 3:00 am to 3:40 am, no crabs were observed.

Figure 7: June 4, 2015

High winds and strong surf were reported again on this night. In a survey from 3:43 to 4:14 am, workers found a single spawning pair.

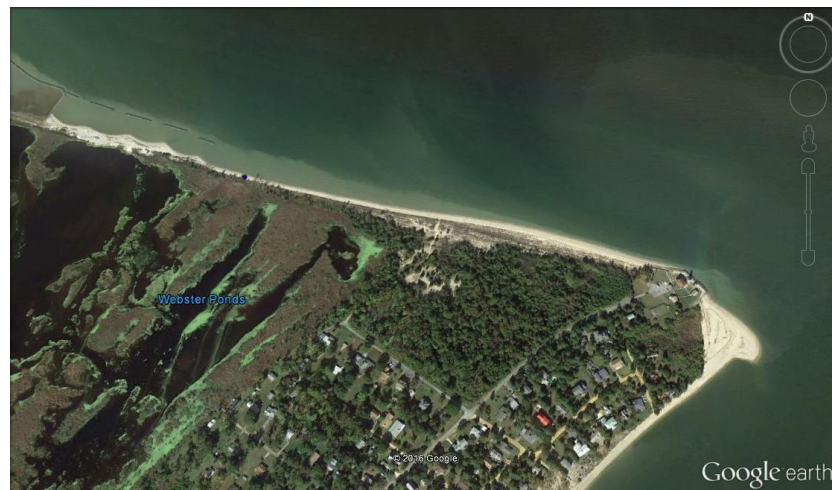


Figure 8: June 15, 2015.

This was the first night of a tide cycle associated with a new moon. In a survey from 1:37 am to 2:32 am, workers counted 44 females and 130 males.

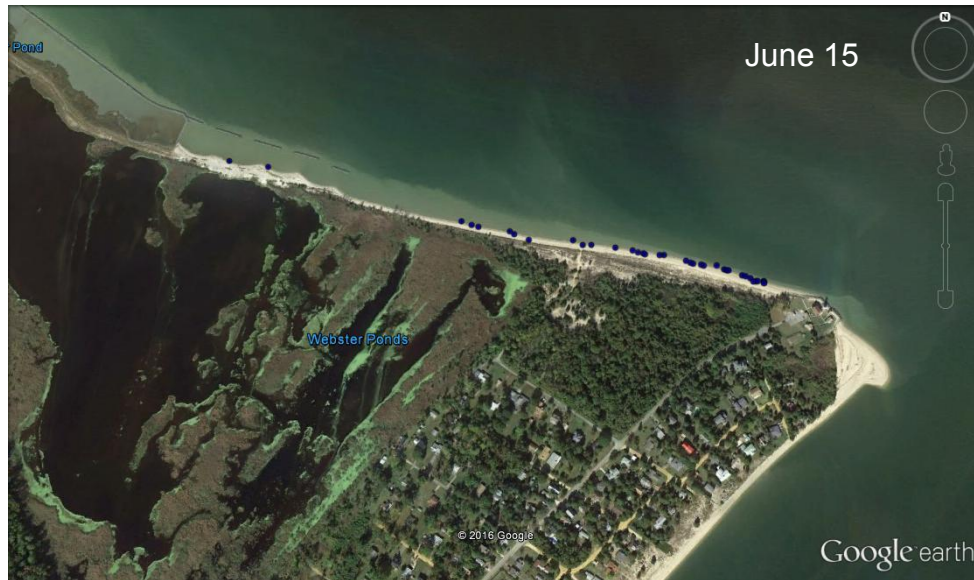


Figure 9: June 16, 2015.

This was the new moon night for this cycle. In a survey from 2:14 am to 3:02 am, workers counted 32 females and 78 males on the beach.



Figure 10: June 17, 2015

Workers surveyed from 2:51 am to 3:45 am and counted 14 female and 25 males on the beach.



Figure 11: June 18, 2015

Workers counted 7 females and 7 males from 3:51 am to 4:30 am.

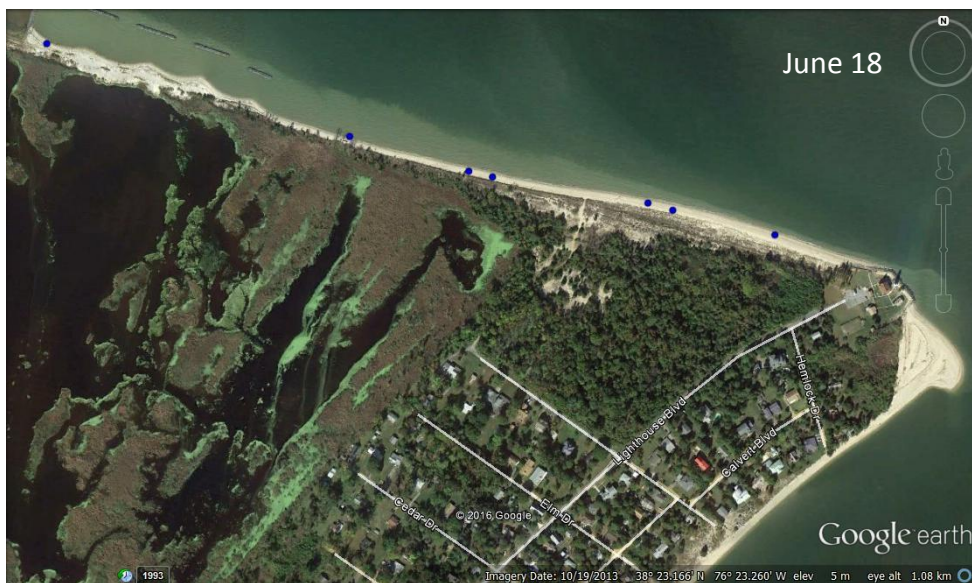


Figure 12: July 2, 2015

This tide cycle was associated with a full moon. July 2 was the full moon night. Workers counted 5 females and 7 males during a survey from 2:30 to 3:10 am.



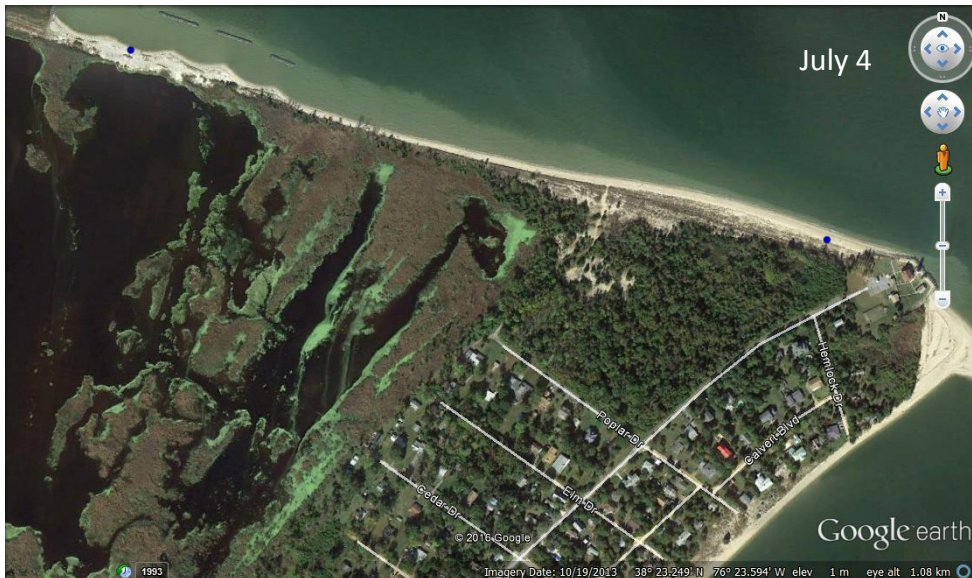
Figure 13: July 3, 2015

On this night, a survey from 4:00 am to 4:34 am found 4 females and 4 males.



Figure 14: July 4, 2015

This was the last survey night of the season. A survey from 4:30 to 4:55 am found 2 females and 2 males.



Community Beach

Figure 15: May 17, 2015

Times and tides follow those described for Cove Point beach. Workers counted 21 females and 26 males. The shape described by the GPS coordinates reflects the changed shape of the beach in 2015. The beach was narrower just south of the lighthouse, and a long spit of sand, not present in this 2013 photo, extended much further out than in previous years.

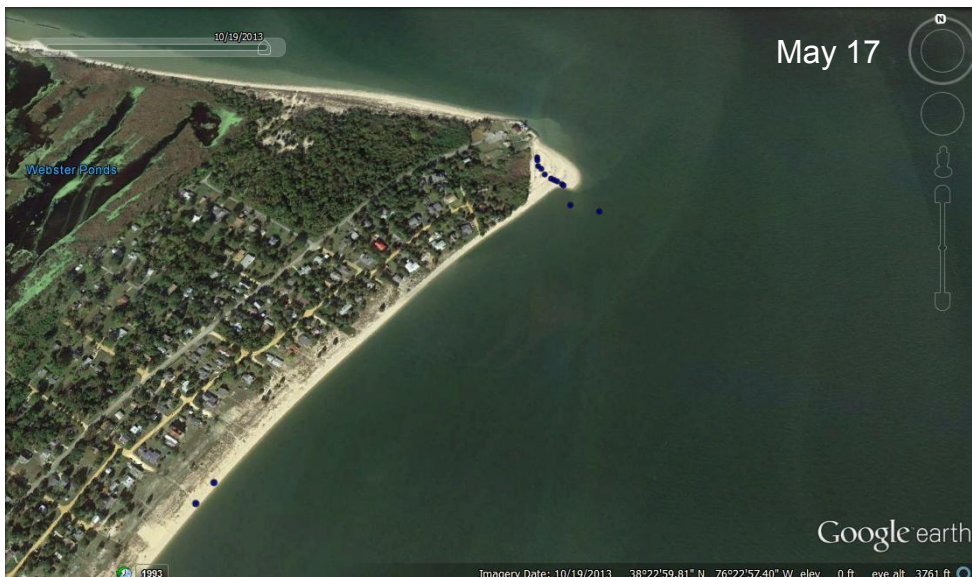


Figure 16: May 18, 2015

Workers counted 67 females and 93 males.

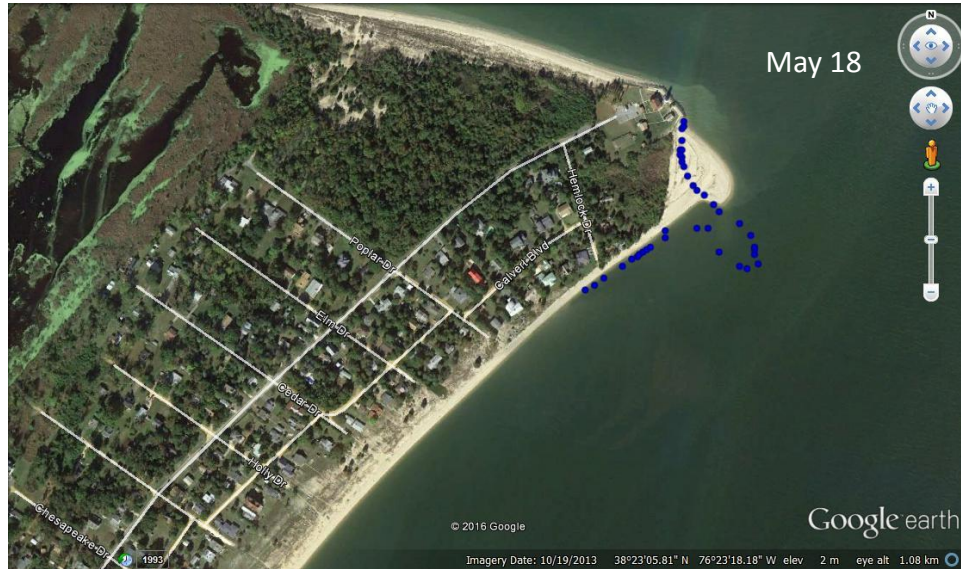


Figure 17: June 1, 2015

Workers counted 23 females and 59 males. Five large clusters of spawning groups, all along the sand spit south of the lighthouse.

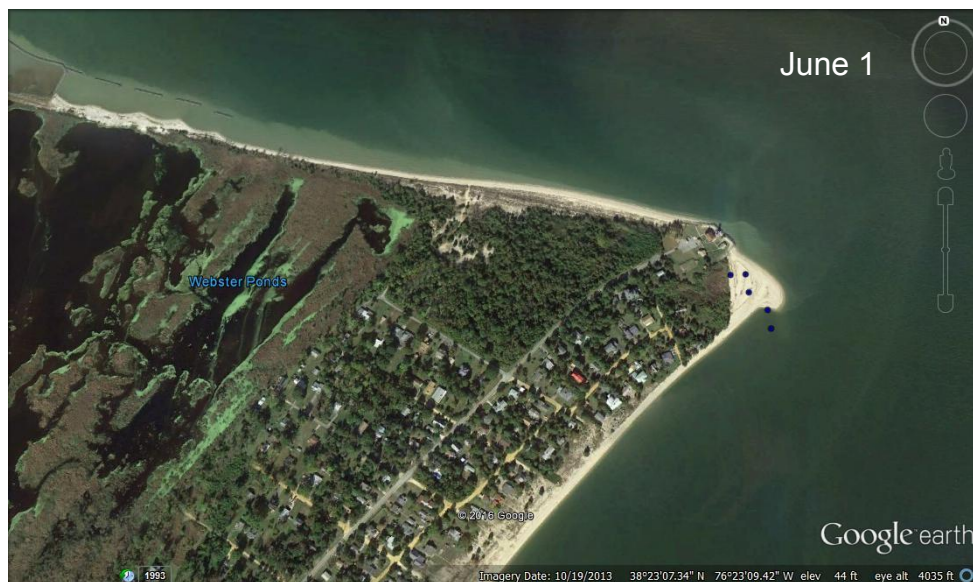


Figure 18: June 2, 2015

Workers counted three females and four males.

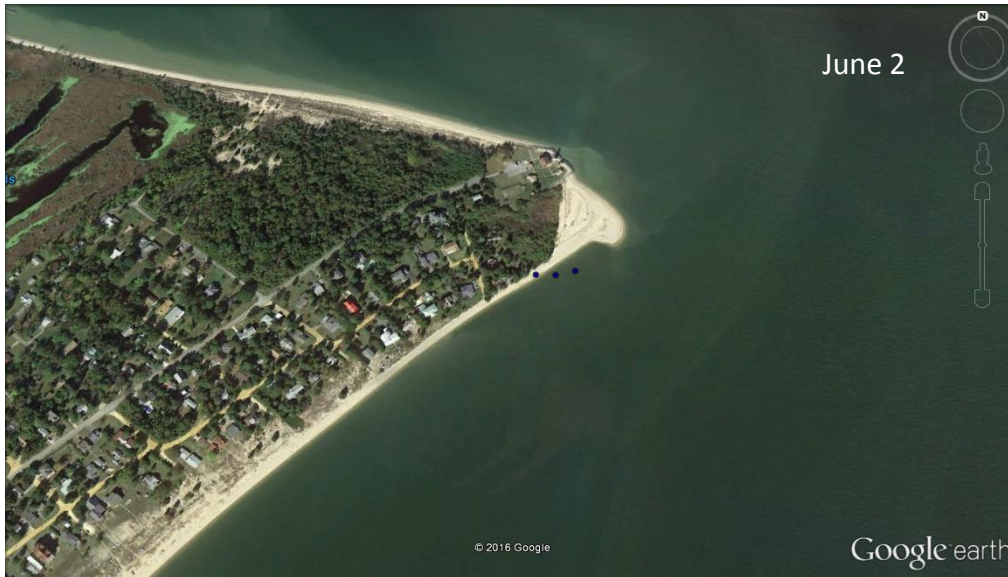


Figure 19: June 3, 2015

Workers counted 59 females and 132 males.

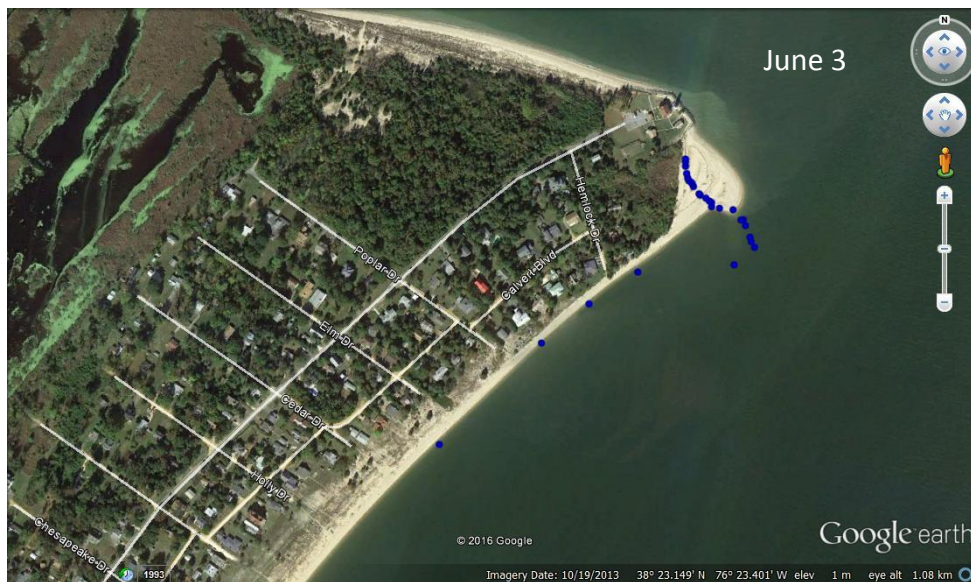


Figure 20: June 4, 2015

Workers counted 3 females and 3 males.

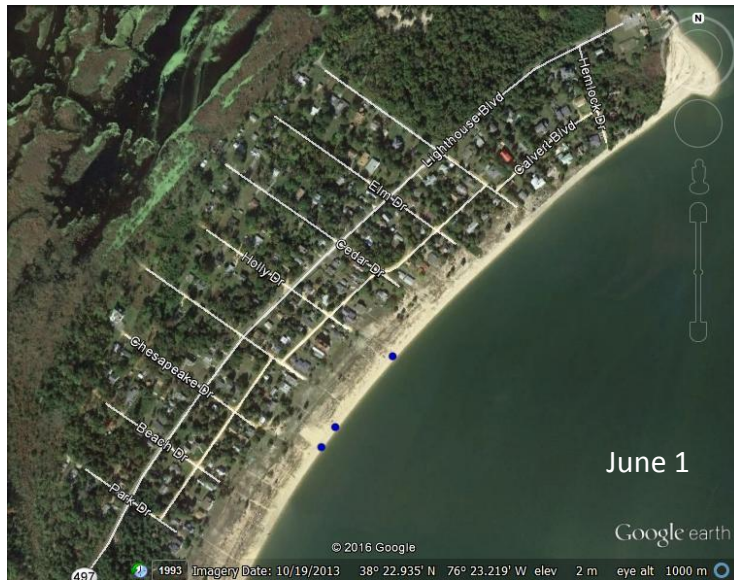


Figure 21: June 15, 2015

Workers counted 13 females and 41 males.

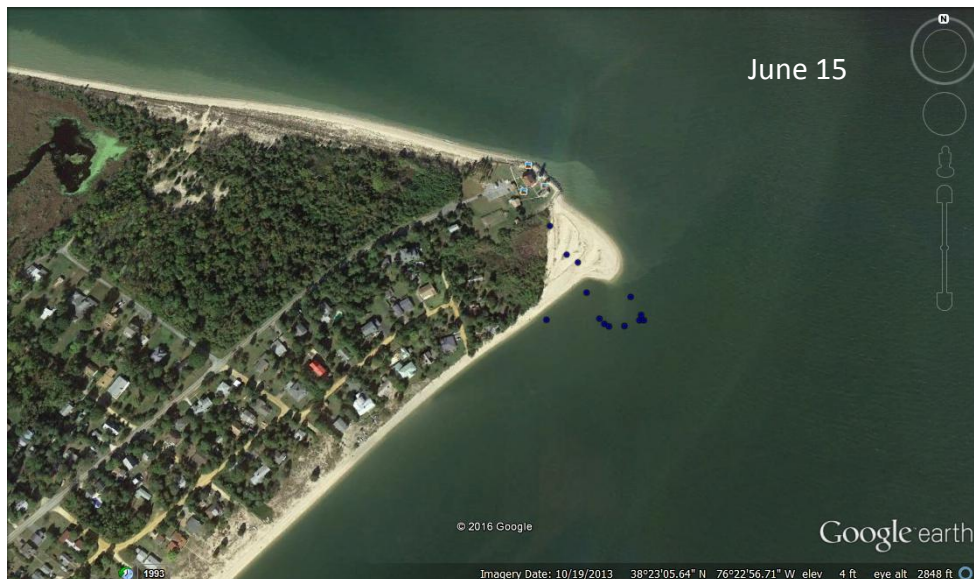


Figure 22: June 16, 2015

Workers counted 29 females and 107 males.

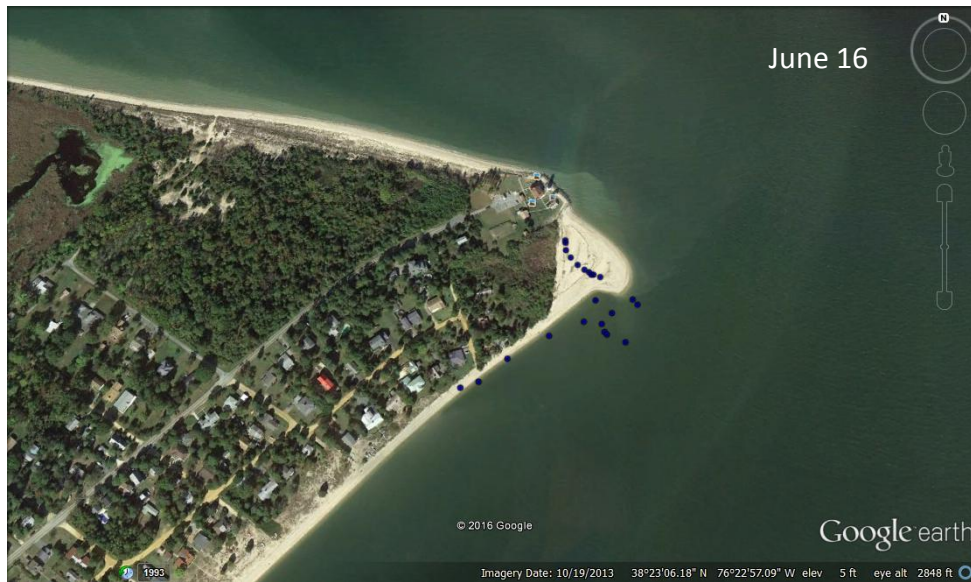


Figure 23: June 17, 2015

Workers counted 26 females and 133 males.

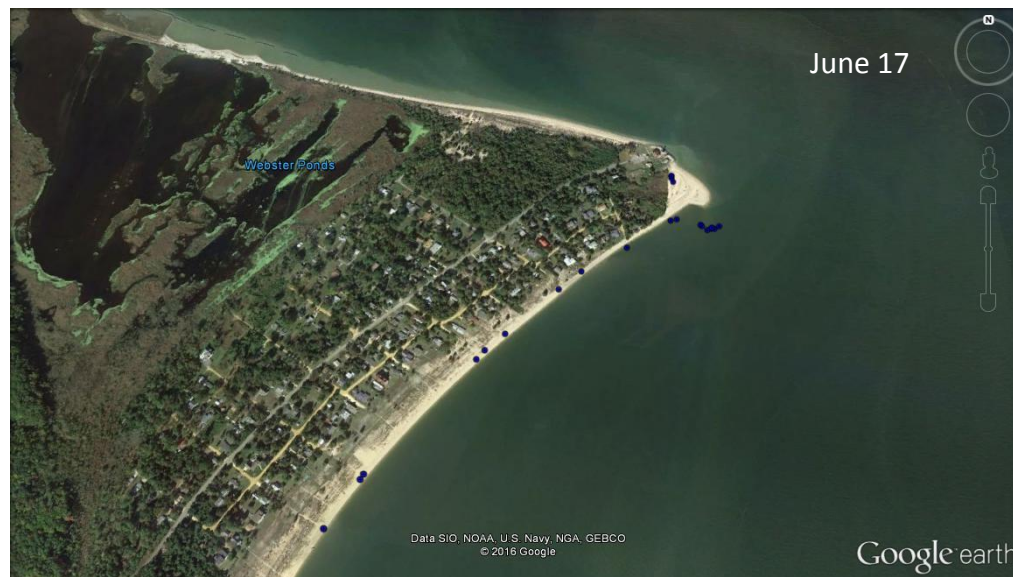


Figure 24: June 18, 2015

Workers counted three females and three males.

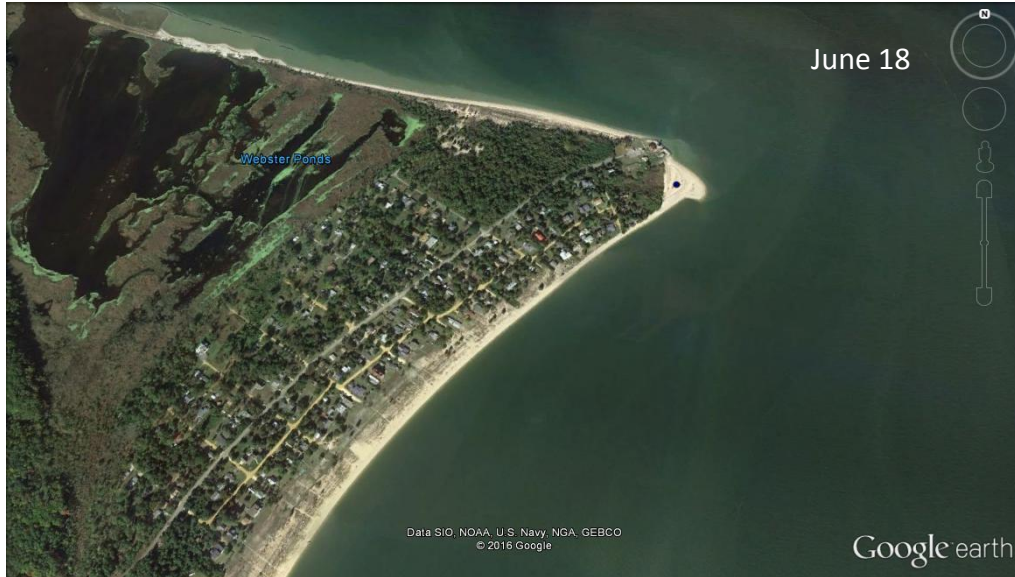


Figure 25: July 2, 2015

Workers counted 17 females and 32 males.

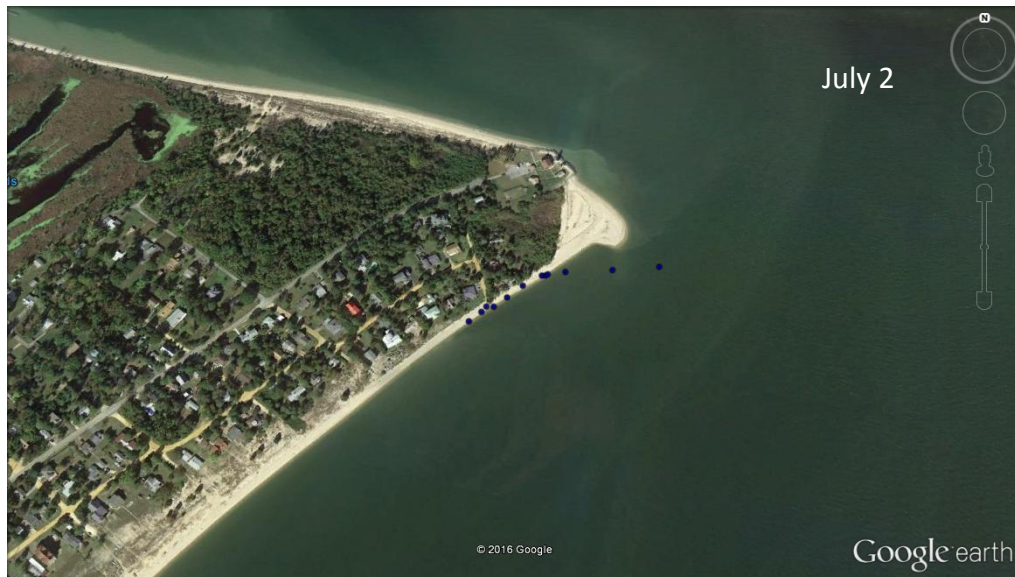
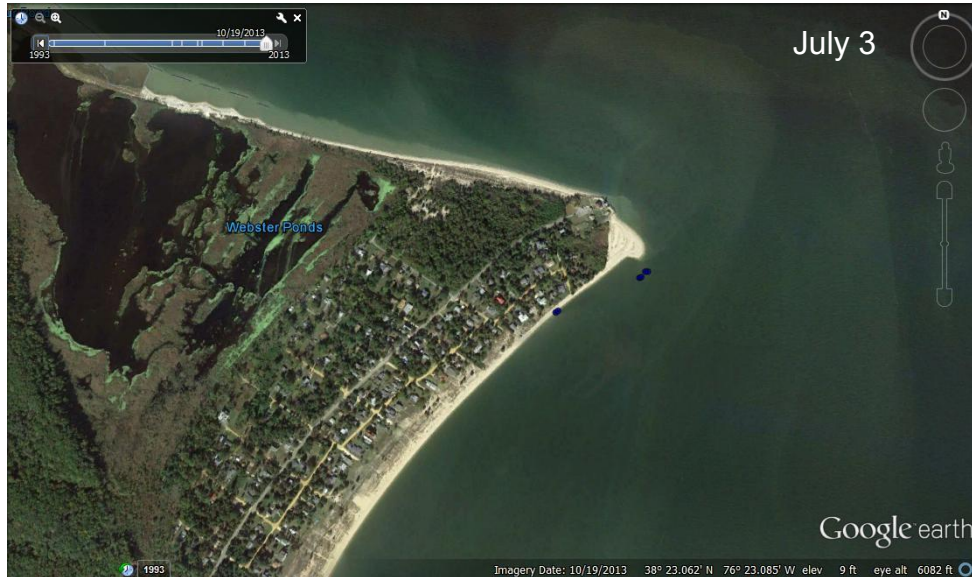


Figure 26: July 3, 2015

Workers counted five females and nine males.



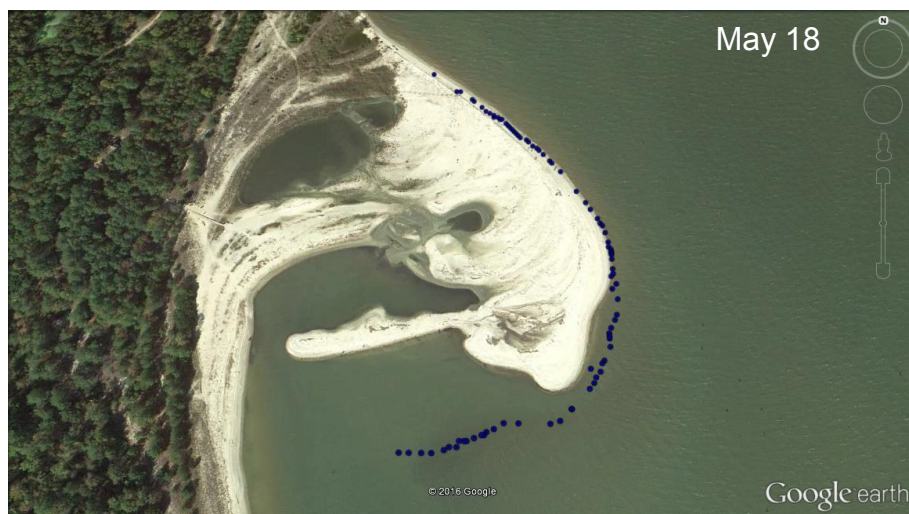
July 4, 2015

No crabs were observed on the Community beach during this survey.

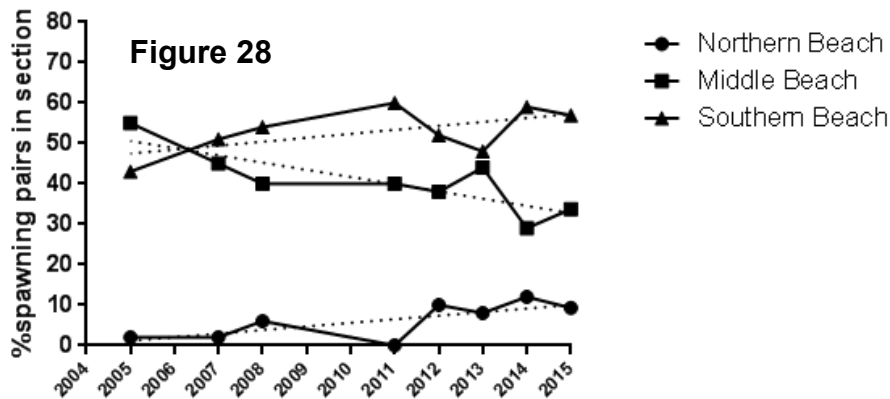
Flag Ponds

Figure 27: May 18, 2015

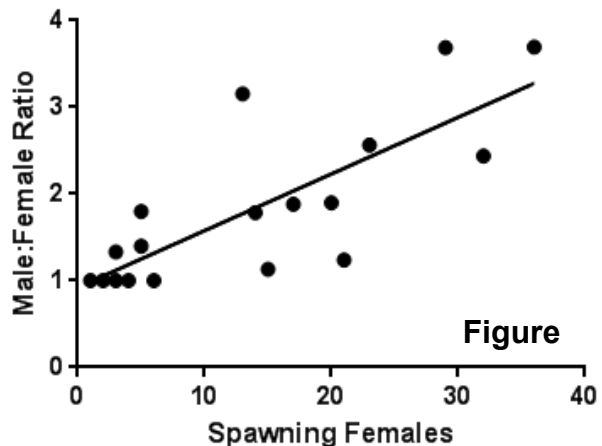
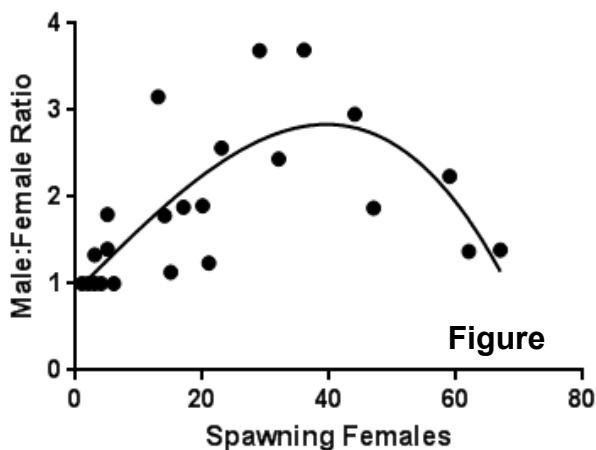
Workers counted 194 females and 426 males. There is a spit of land extending westward from the southern tip of the beach that is not shown in this 2013 photo. The line of spawning crabs extending into the water reflects this sand spit. The other three Flag Ponds surveys were similar, and are not shown.



Utilization of Cove Point Beach – The 2015 survey is consistent with our suggestion in 2014 that spawning at the northern beach, inside the breakwaters, is increasing (Fig. 28). Northern beach spawning, while still much less than other beach sections, has significantly increased since 2005 (linear regression: $F = 6.60$, $p = 0.04$). Middle beach spawning has significantly decreased (linear regression: $F = 12.08$, $p = 0.01$). The southern beach, the site of the majority of spawning females, has shown no significant change in spawning numbers.



Increased Male Recruitment with Female Spawning Numbers – Increased numbers of females on Cove Point beach resulted in proportionally more associated males. When the number of spawning females is low, the male:female ratio approaches 1. With more spawning females, the male:female ratio increases. With very high female numbers, however, the ratio again declines. This trend is shown in Figure 29. There is strong evidence that spawning females release a chemical signal that attracts males (Saunders et. al. *Current Zoology* 56 (5): 485–498, 2010). It is likely that higher numbers of spawning females release more signal, and thus recruit increasing numbers of males to the spawning beach. It is also likely that there is a finite number of available males on any given night. Therefore, at higher female densities the male:female ratio declines, as there are fewer additional males to recruit. Our data set suggests that for Cove Point this decline begins at approximately 40 females, which corresponds with approximately 90 males. When only female numbers below 40 are examined, there is a significant linear relationship between female spawning number and male:female ratio (Fig. 30; linear regression $F = 28.66$, $p < 0.0001$).



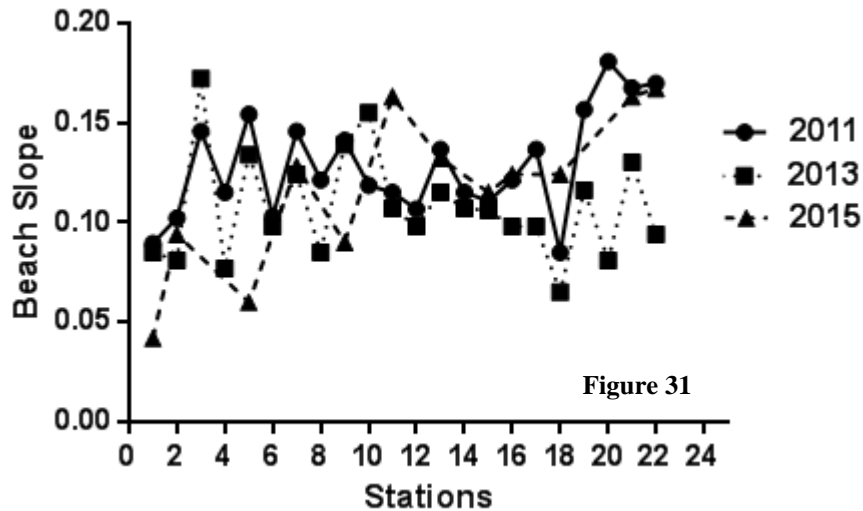
Tag Re-sighting – In 2013 and 2014, a total of 615 crabs were tagged at Cove Point and Flag Ponds beaches. No crabs were tagged in 2015, but re-sightings were noted. A total of 16 re-sighted animals were observed at Cove Point, Community or Flag Ponds beaches.

Observations in 2015 were generally consistent with previous years. Animals re-sighted in 2015 were tagged in 2013 or 2014. Some females were re-sighted more than once over a tide cycle, suggesting that they were spawning on multiple nights. Some males were re-sighted on multiple nights within a tide cycle, and on multiple tide cycles. With a few exceptions, most animals returned to the beach where they were tagged, both within and between seasons. Only one animal was re-sighted at a beach (Cove Point) that was different from where he was tagged (Flag Ponds). This male, 282684, was re-sighted multiple times. He was observed on Cove Point beach on June 15, June 16, and June 17. Table 2 shows a summary of re-sightings for 2015.

Table 2

Tag #	Sex	Beach Re-sighted	Date	Beach Tagged	Date Tagged
282964	F	Cove Point	5/17/2015	Cove Point	5/30/2014
282779	M	Flag Ponds	6/2/2015	Flag Ponds	6/23/2013
282903	M	Flag Ponds	6/2/2015	Flag Ponds	6/23/2013
282693	M	Flag Ponds	6/2/2015	Flag Ponds	6/23/2013
282775	M	Flag Ponds	6/2/2015	Flag Ponds	6/23/2013
282875	M	Flag Ponds	6/2/2015	Flag Ponds	6/9/2013
282857	M	Flag Ponds	6/15/2015	Flag Ponds	6/9/2013
282596	F	Cove Point	6/15/2015	Cove Point	6/29/2014
282684	M	Cove Point	6/15/2015	Flag Ponds	6/23/2013
282438	M	Cove Point	6/15/2015	Cove Point	5/15/2014
282755	M	Flag Ponds	6/15/2015	Flag Ponds	6/23/2013
307240	M	Flag Ponds	6/15/2015	Flag Ponds	6/15/2014
282779	M	Flag Ponds	6/15/2015	Flag Ponds	6/23/2013
282684	M	Cove Point	6/16/2015	Flag Ponds	6/23/2013
282522	M	Cove Point	6/16/2015	Cove Point	5/14/2014
282684	M	Cove Point	6/17/2015	Flag Ponds	6/23/2013

Beach Profiles – In October 2015, we conducted a series of beach profiles. As in previous profiles, we used Emery rods (Emery, K.O., *Limnology and Oceanography* v. 6, p. 90-93, 1961) to carry out the profiles at 22 stations ranging from the southern lighthouse to the riprap at the northern end of the beach. Each 2015 profile was compared with the profile from 2013 and the 2011 profile if a profile was done at that station. Each profile was plotted 5 meters landward from the shoreline, and to an elevation of 60 cm. This area was considered to be the most relevant for impacts on horseshoe crab spawning. Total elevation and beach slope (within 2 meters of the waterline) were calculated at each station. Beach slope influences the impact of breaking waves and therefore could influence spawning behavior in females. Changes in elevation could indicate beach sand accretion or erosion.



There does not appear to be any consistent change in beach slope from 2011 to 2015 (Fig. 31). Slope was generally lower along the southern beach in 2015, compared with previous profiles. Along the northern beach, slope was lower in 2013. The 2015 profiles showed steeper slopes which were more similar to those from 2011.

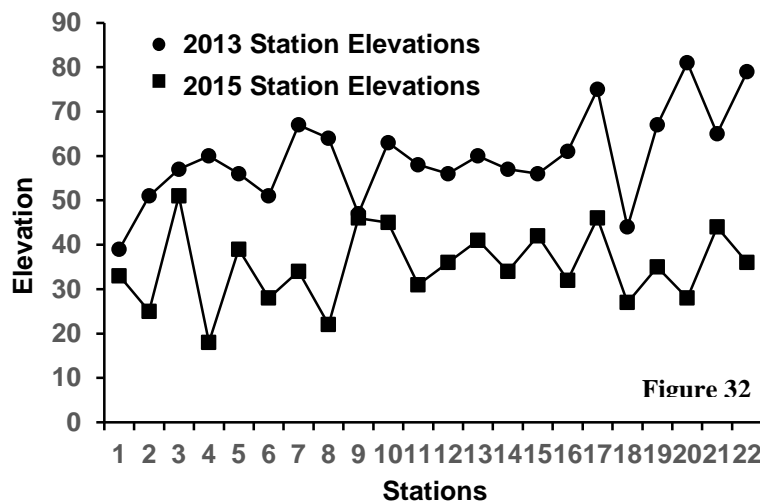
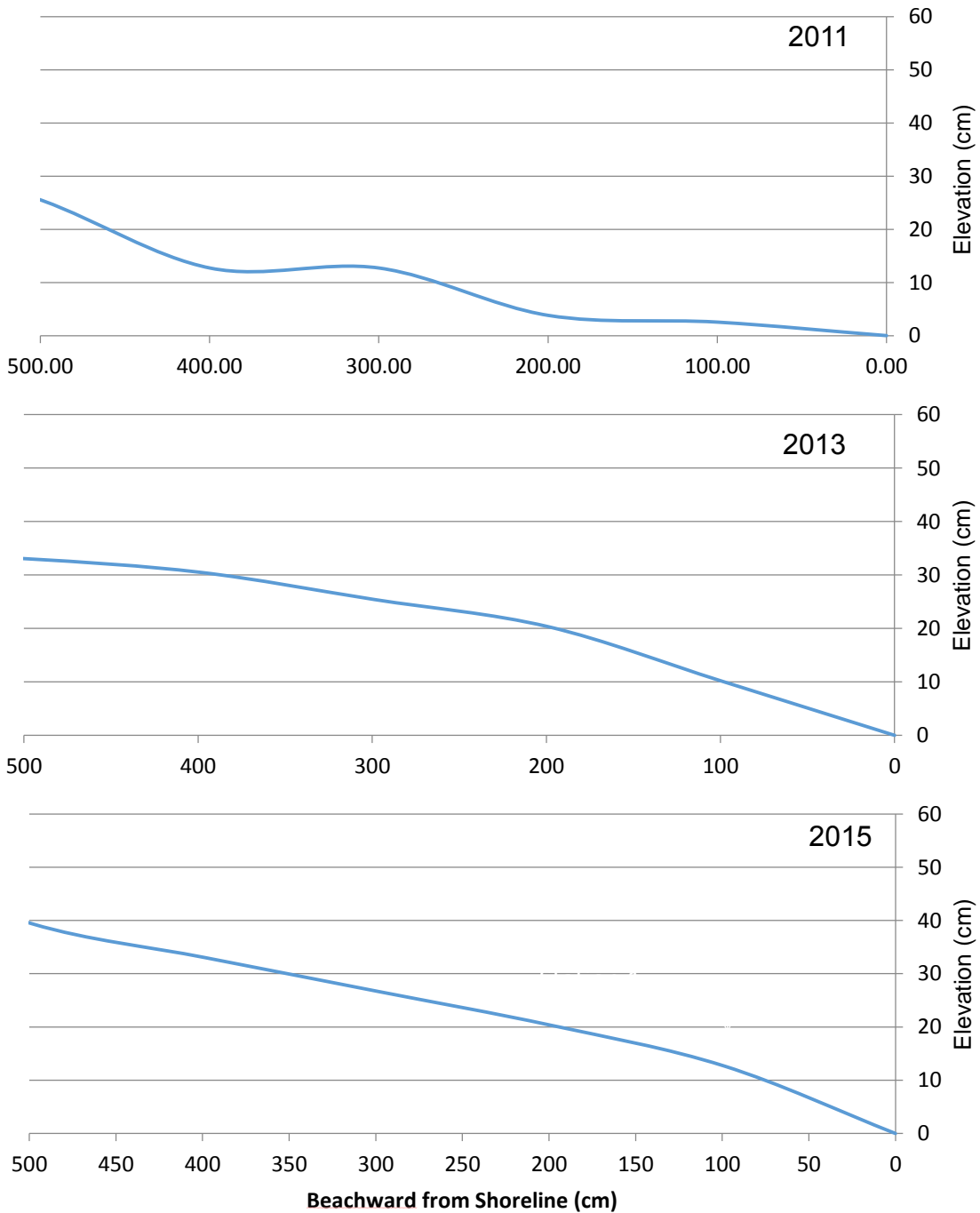


Figure 32 shows elevation from the shoreline to 5 meters landward for each station in 2013 and 2015. Elevations were consistently higher in 2015 compared with 2013. It is possible for both sand accretion and erosion to produce higher elevations. For the southern beach, erosion is the more likely explanation for these differences. The southern section appeared to be narrower in 2015. As sand was lost, the shoreline moved landward, cutting into higher landforms. Further north, at stations 14-16, the beach was both wider and more elevated in 2015, suggesting sand accretion. Cove Point beach experienced sand loss to the south and sand accretion in the northern sections.

Profile details are presented below for all 22 stations, and compared with profiles from 2013 and 2011.

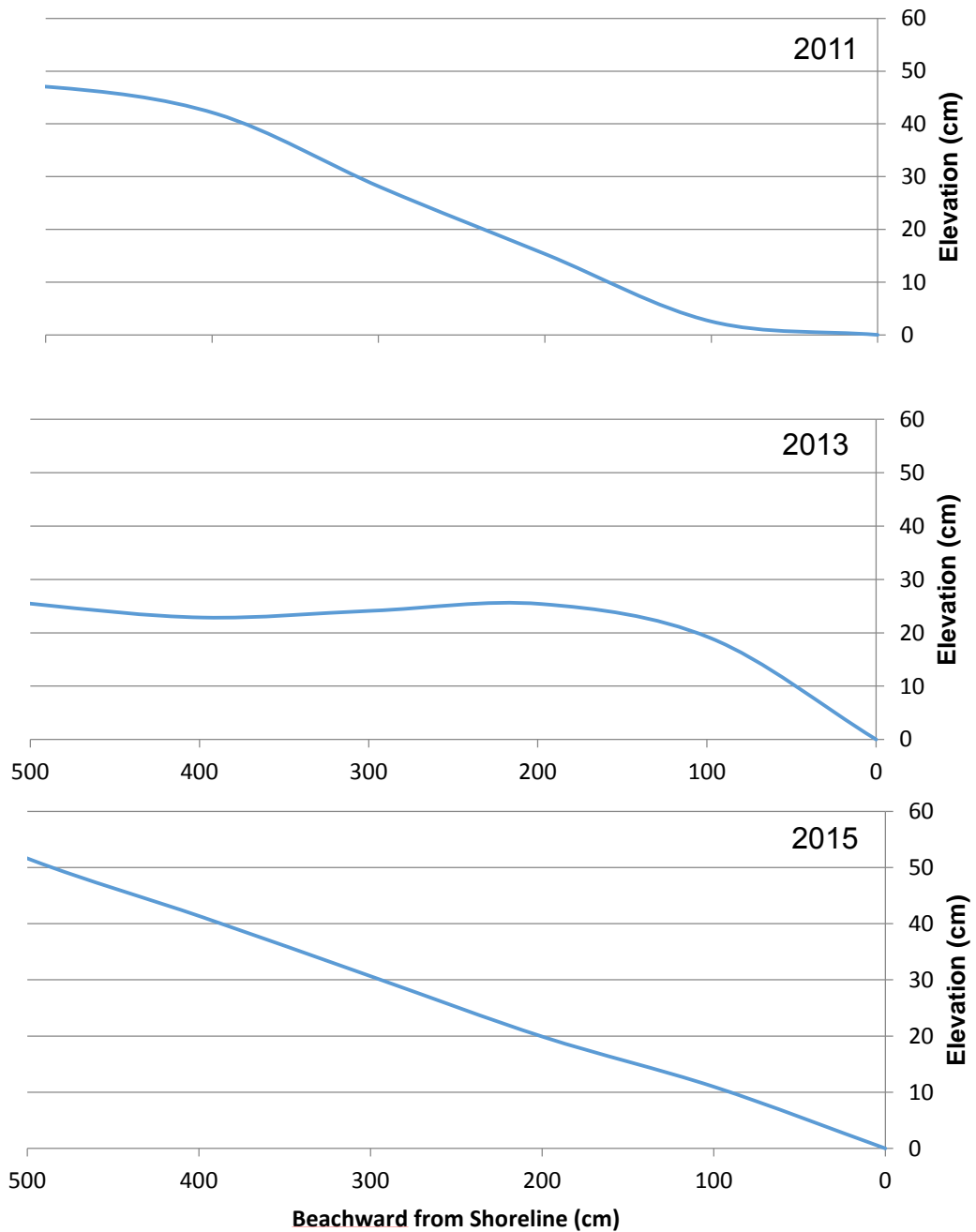
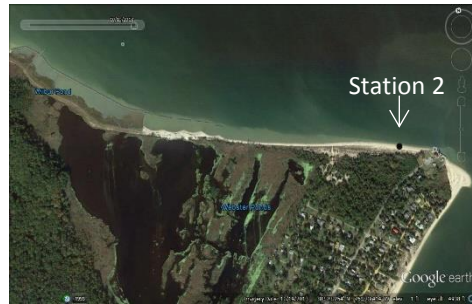
Station One

The 2013 and 2015 profiles are similar in slope and elevation. The beach appears higher and steeper than 2011.



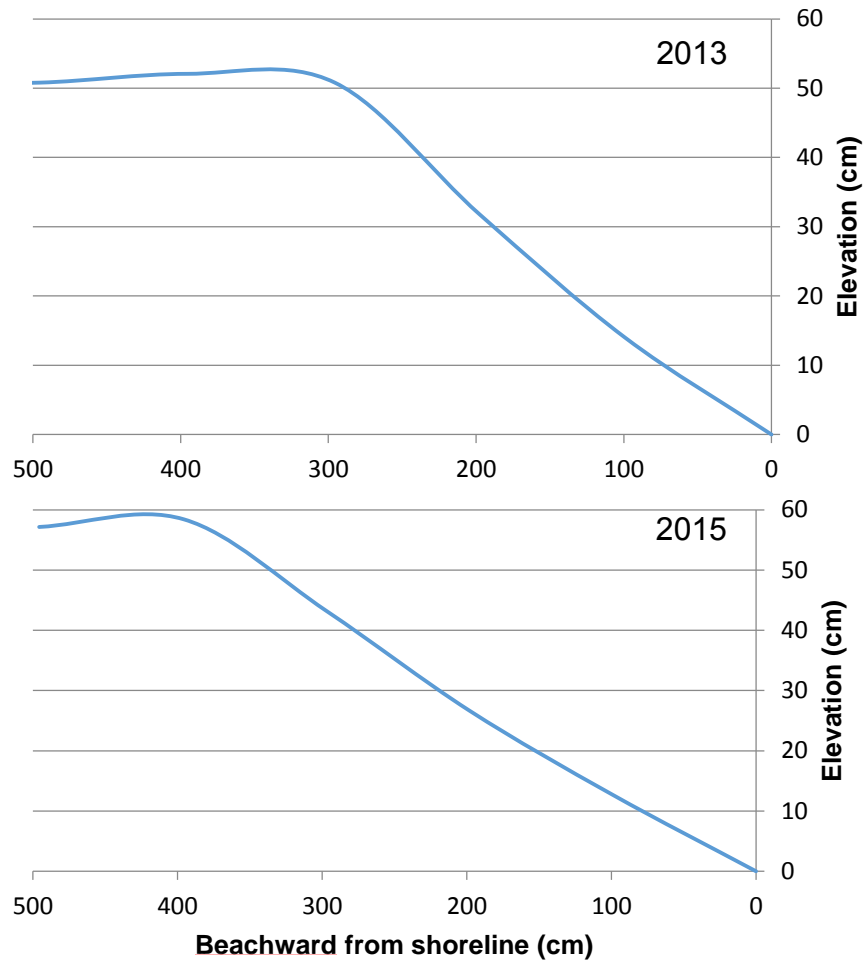
Station Two

The 2015 profile shows greater elevation and a steeper slope compared with 2013.



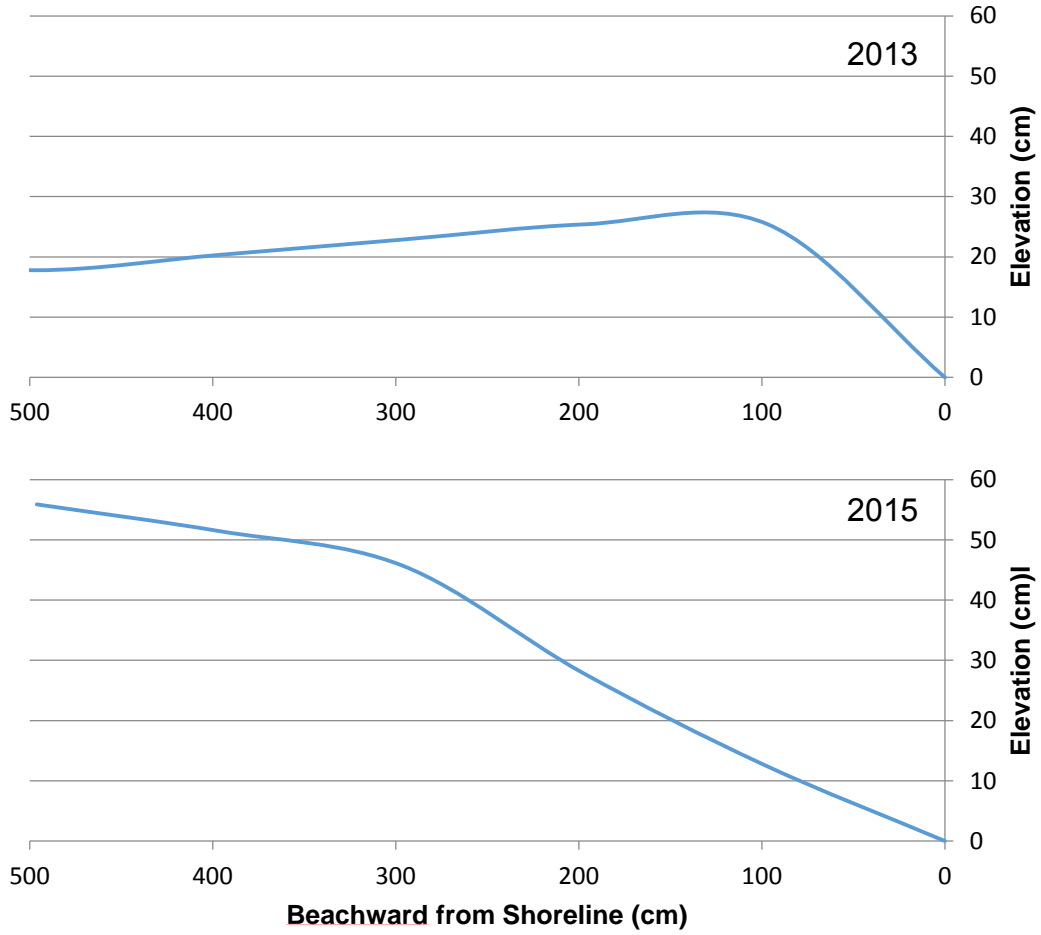
Station Three

The 2015 and 2013 profiles show a similar elevation and slope. A 2011 profile was not performed at this station.



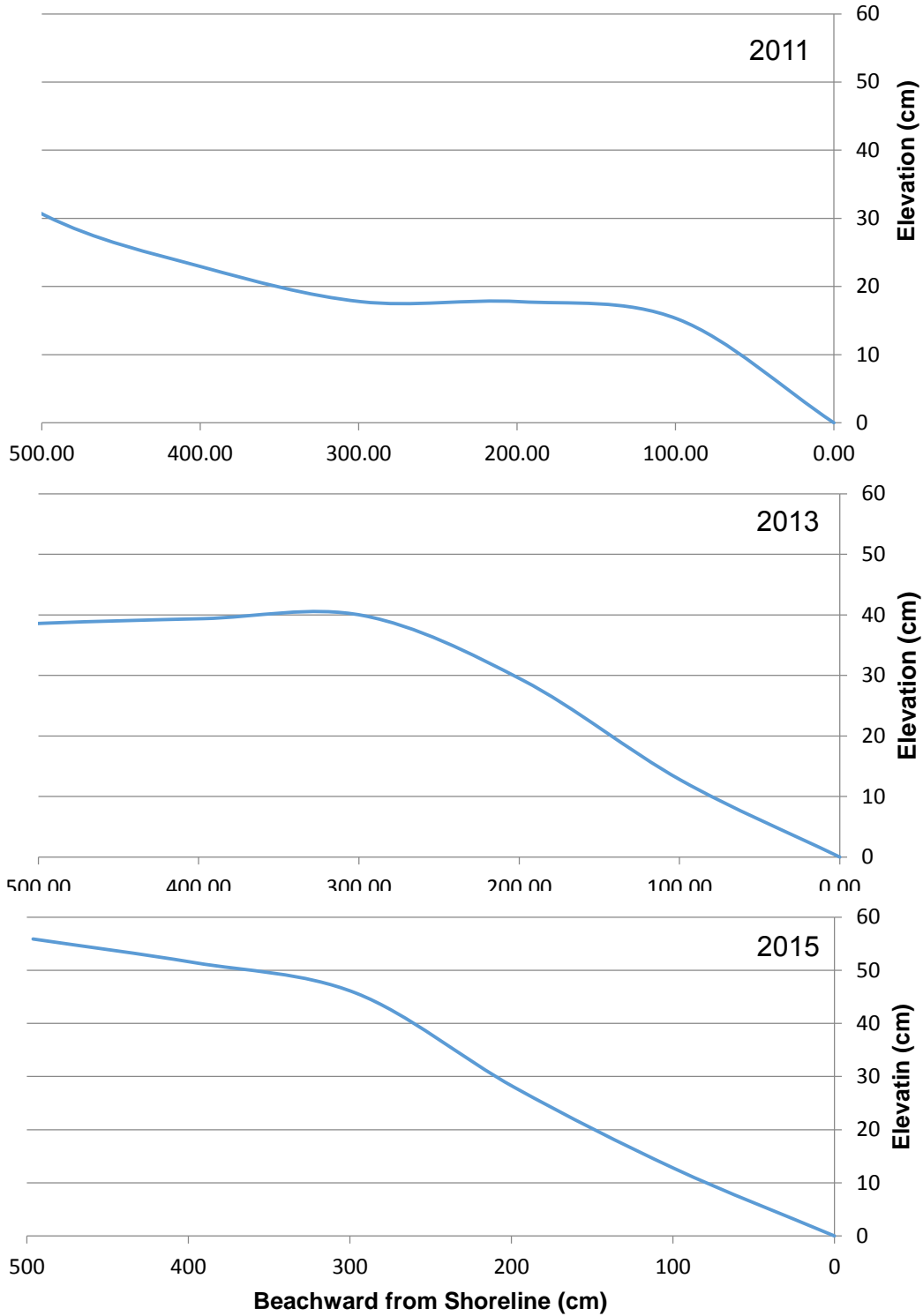
Station Four

The 2015 profile shows a greater beach elevation but less slope compared with 2013. A 2011 profile was not performed at this station.



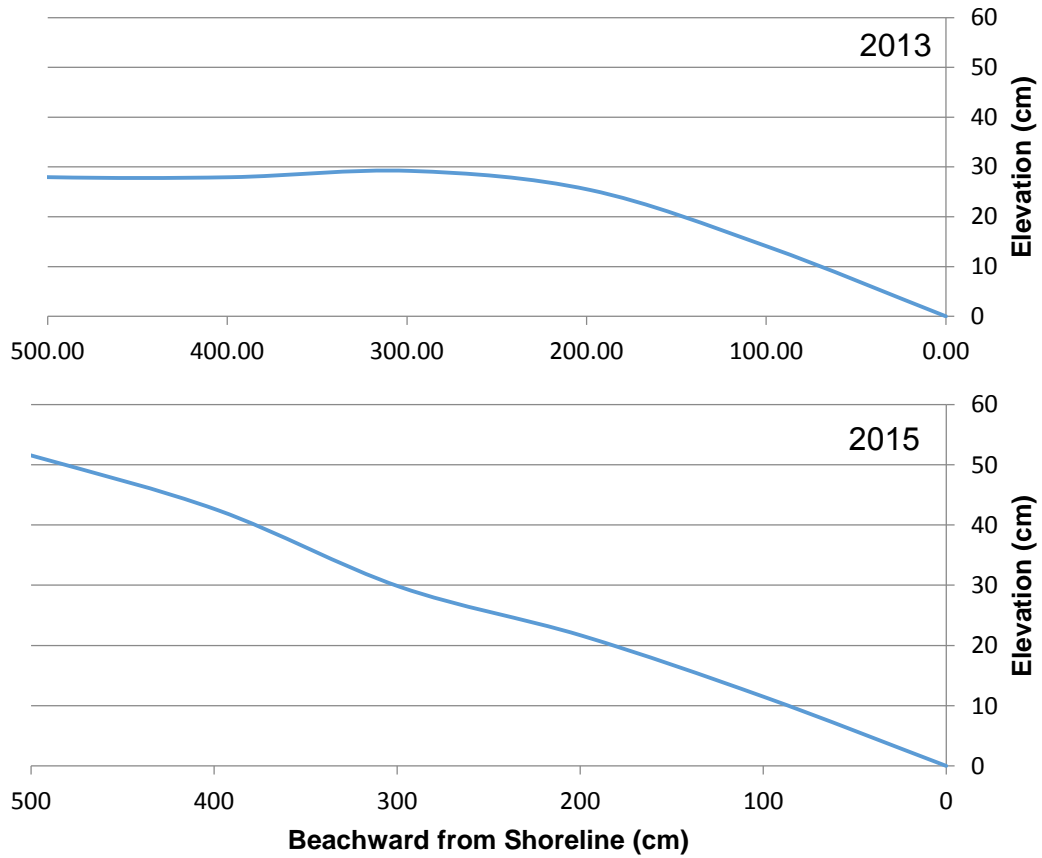
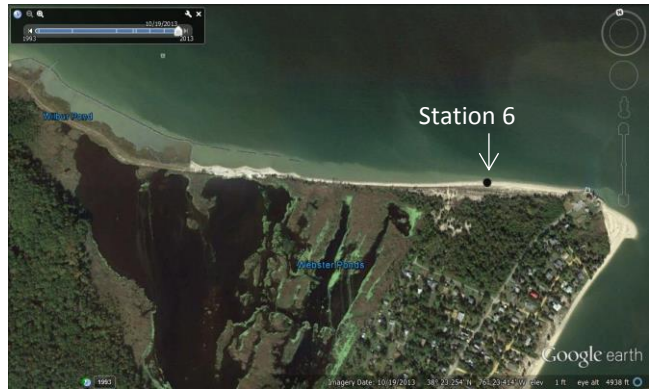
Station Five

The 2015 profile shows a slope similar to 2013 and an elevation greater than 2013 or 2011.



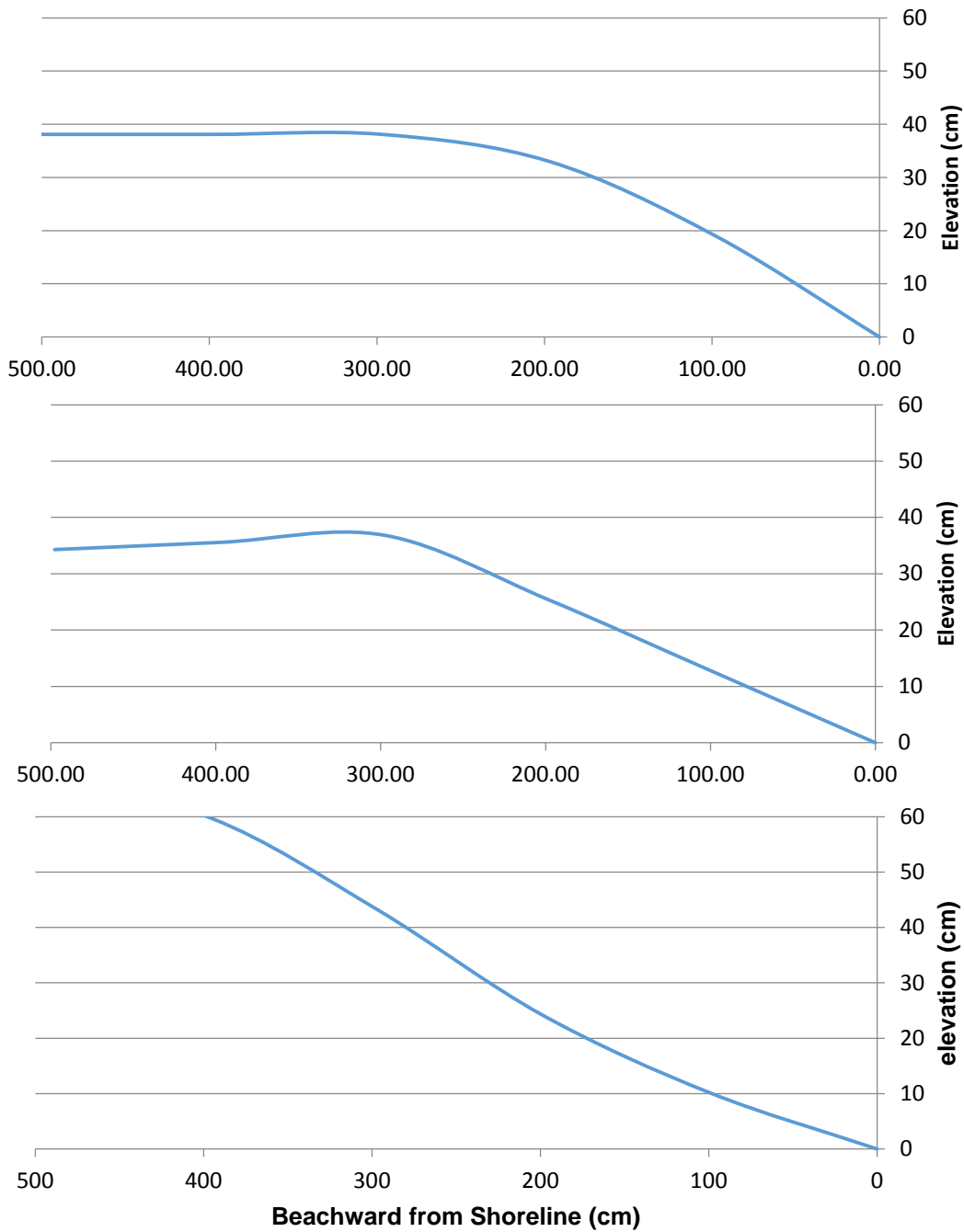
Station Six

The 2015 profile shows a slope similar to 2013 but greater elevation. There was no 2011 profile for this station.



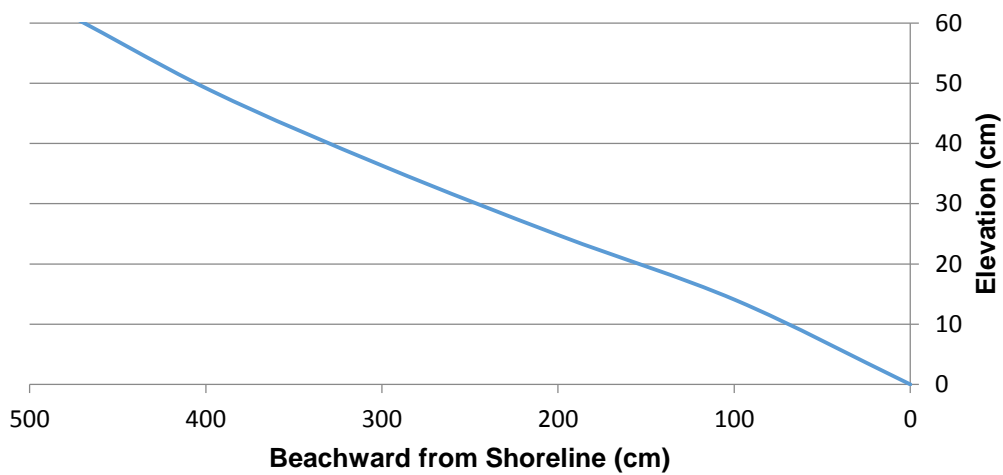
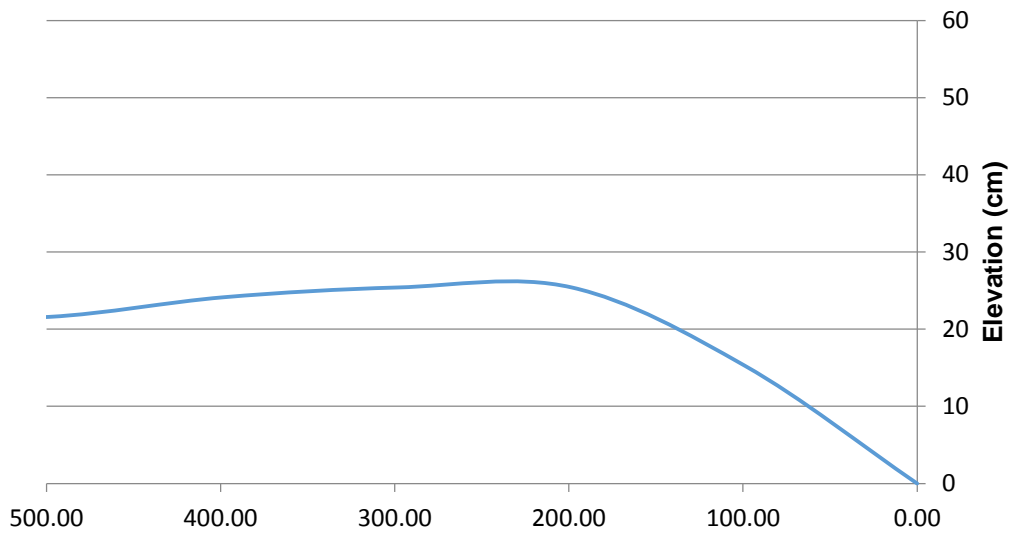
Station Seven

Compared with both 2013 and 2011, the 2015 profile shows a shallower, concave slope and greater elevation.



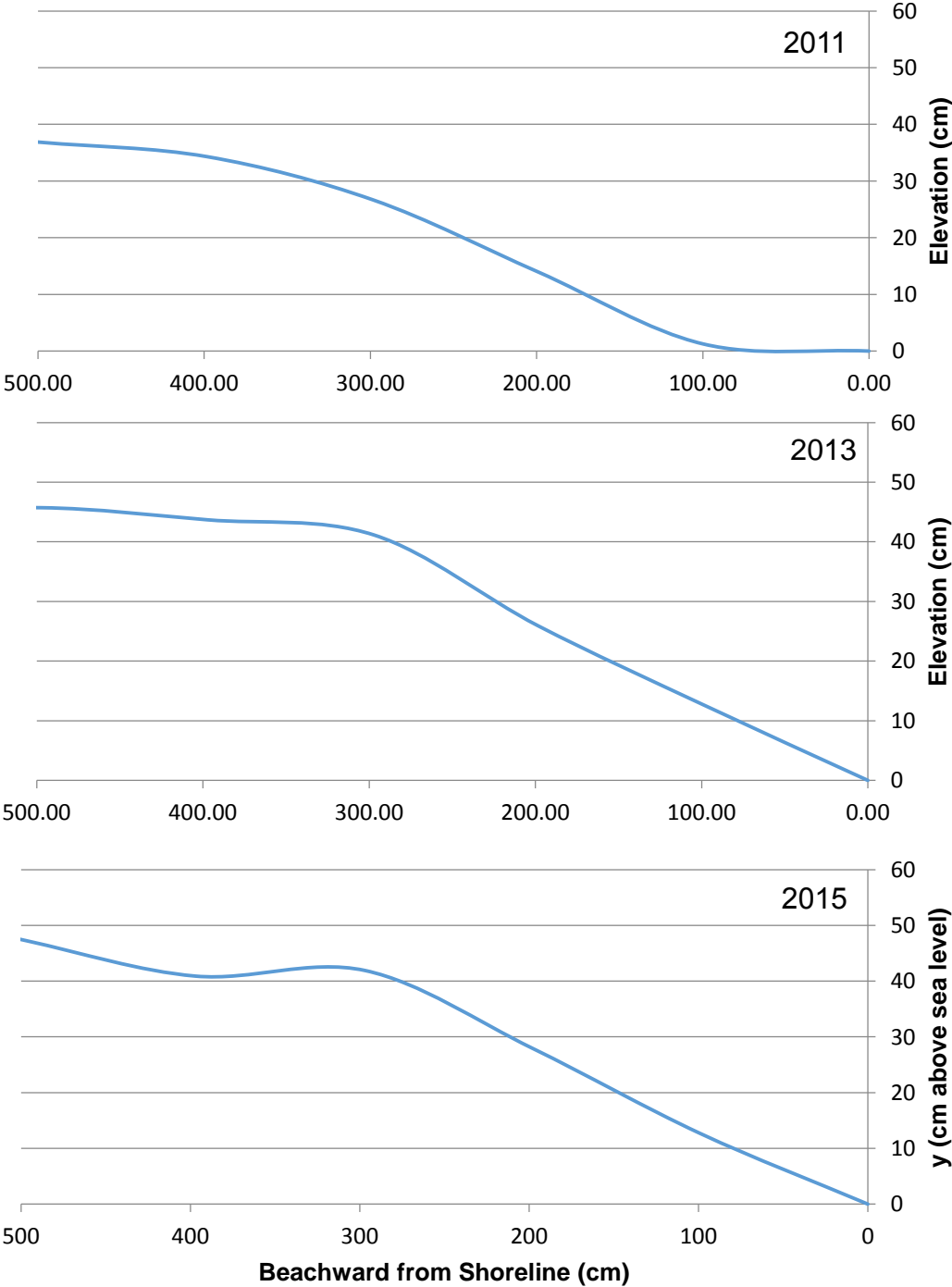
Station Eight

The 2015 profile shows a shallower, concave slope and greater elevation compared to 2013. There was no 2011 profile at this station.



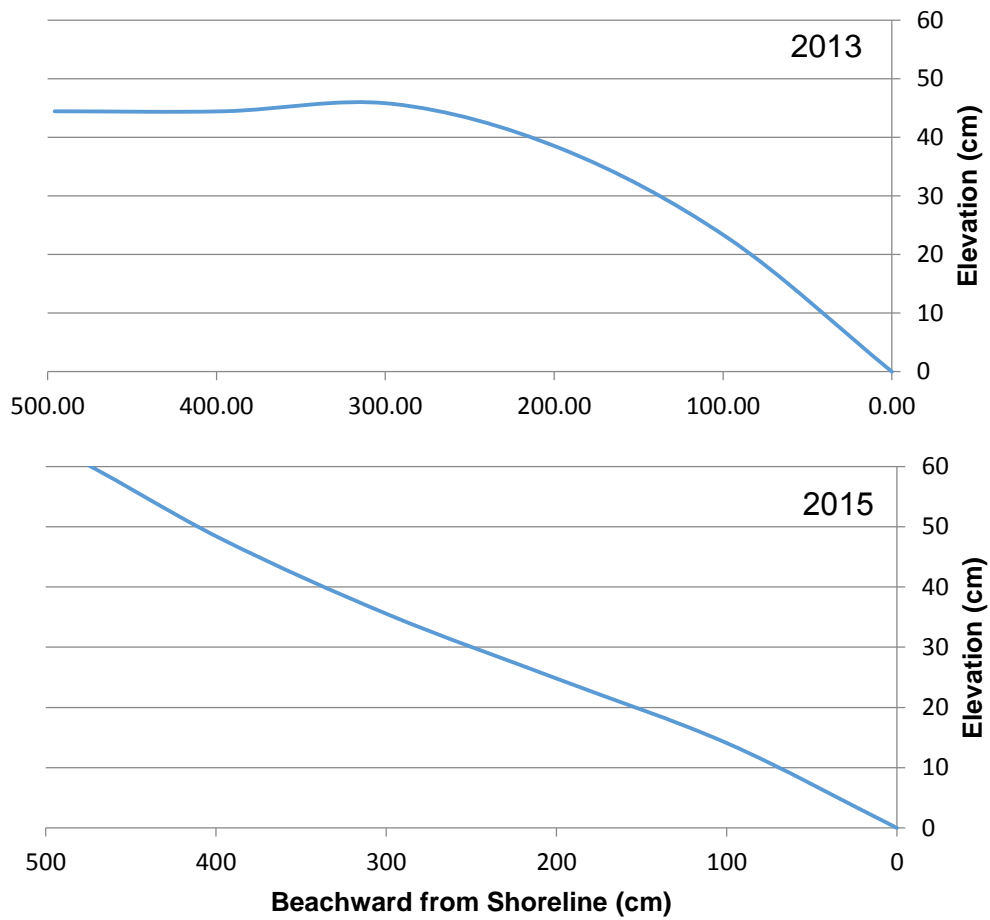
Station Nine

The 2015 profile shows a steeper slope and greater elevation compared with profile in previous years.



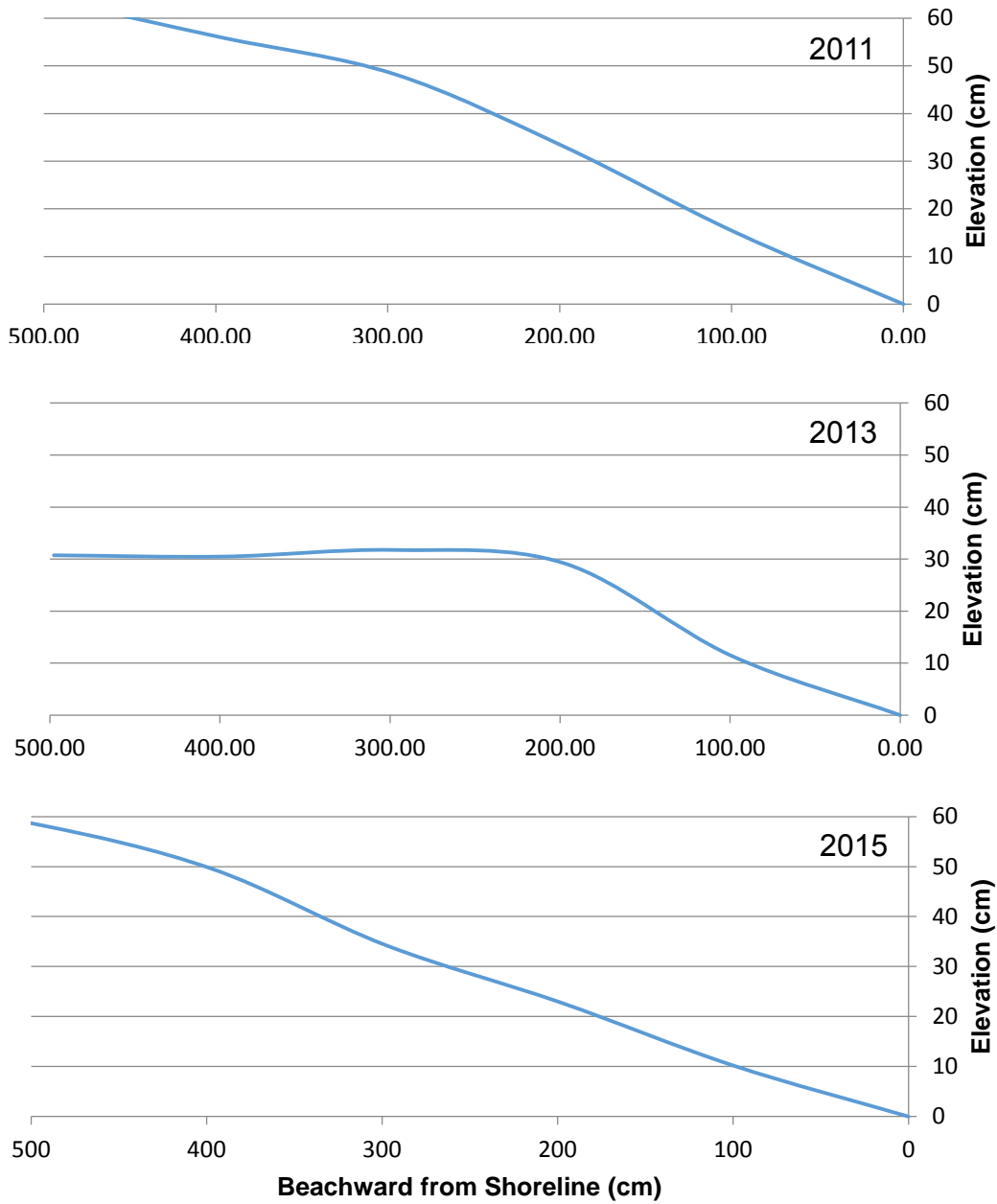
Station Ten

The 2015 profile shows a shallower slope and greater elevation compared with 2013. There was no 2011 profile at this station.

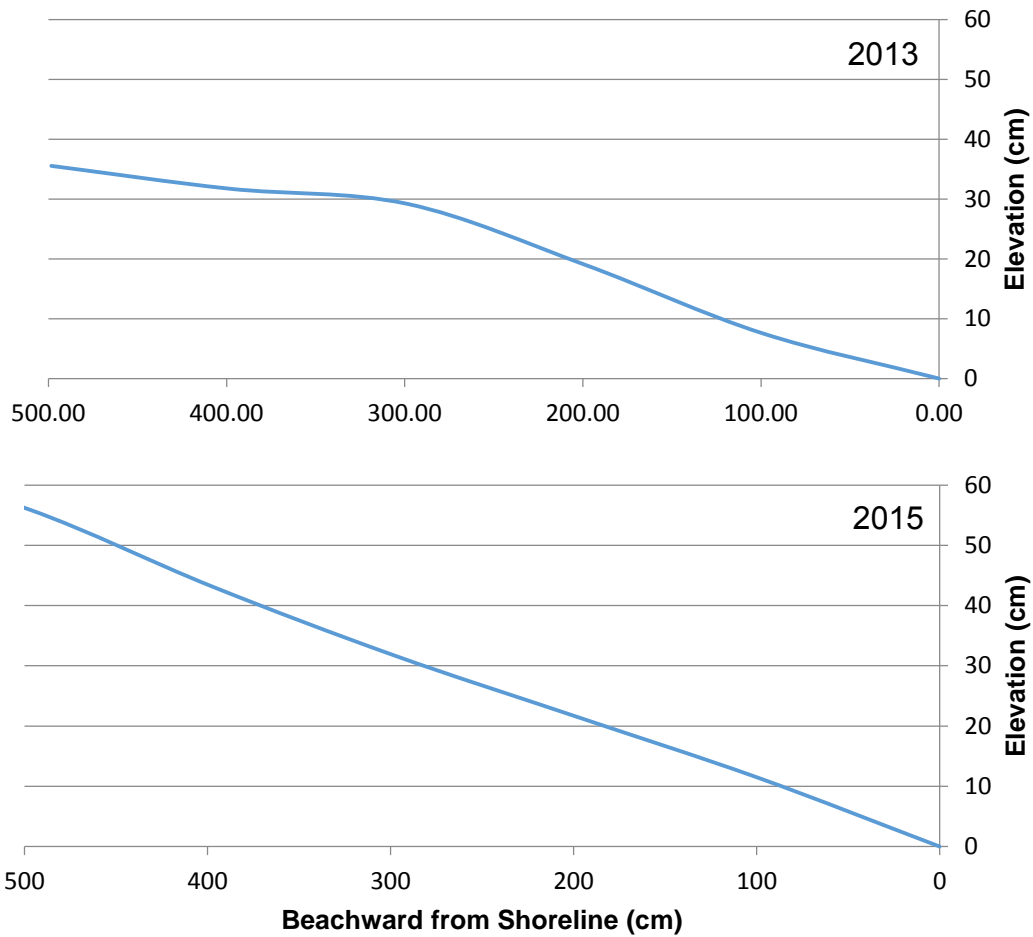


Station Eleven

The 2015 profile shows a shallower slope compared with 2013 and 2011. Elevation was higher than 2013 and similar to 2011.

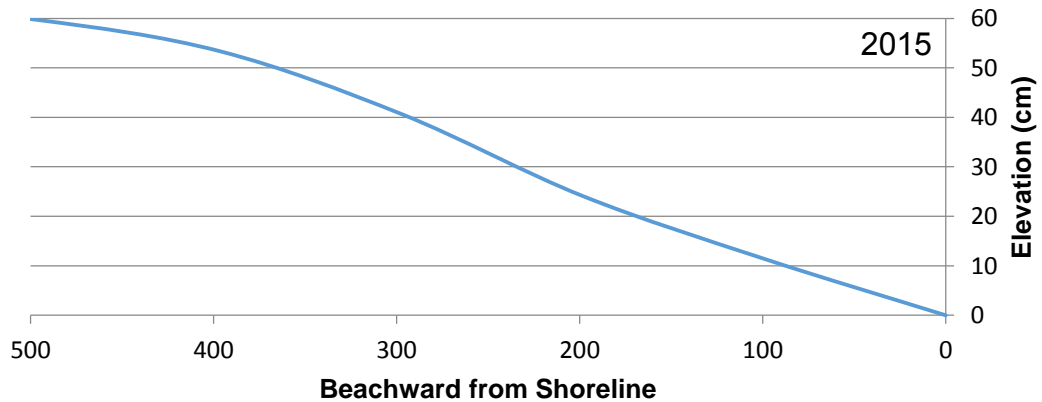
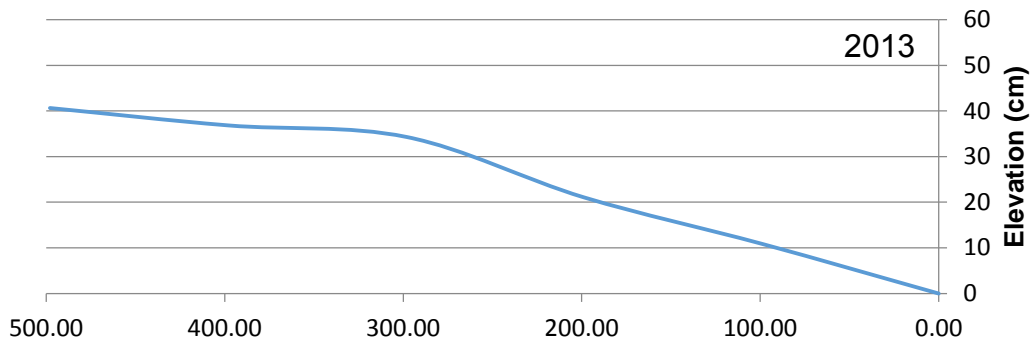
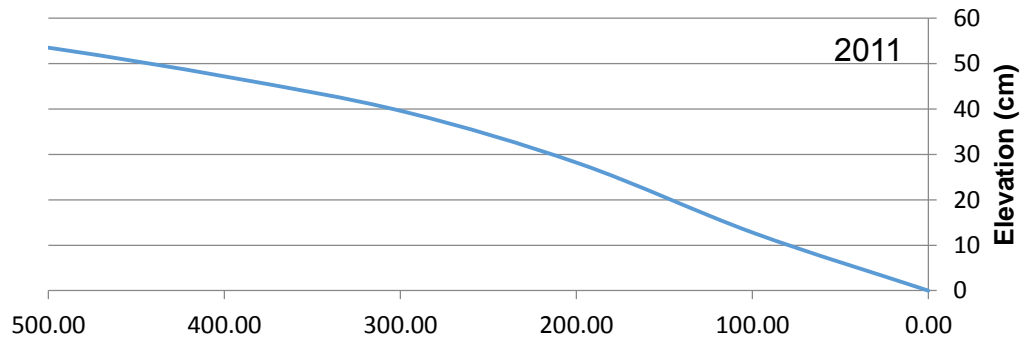


Station Twelve
 The 2015 profile shows a shallower slope and greater elevation compared with 2013. There was no 2011 profile at this station.



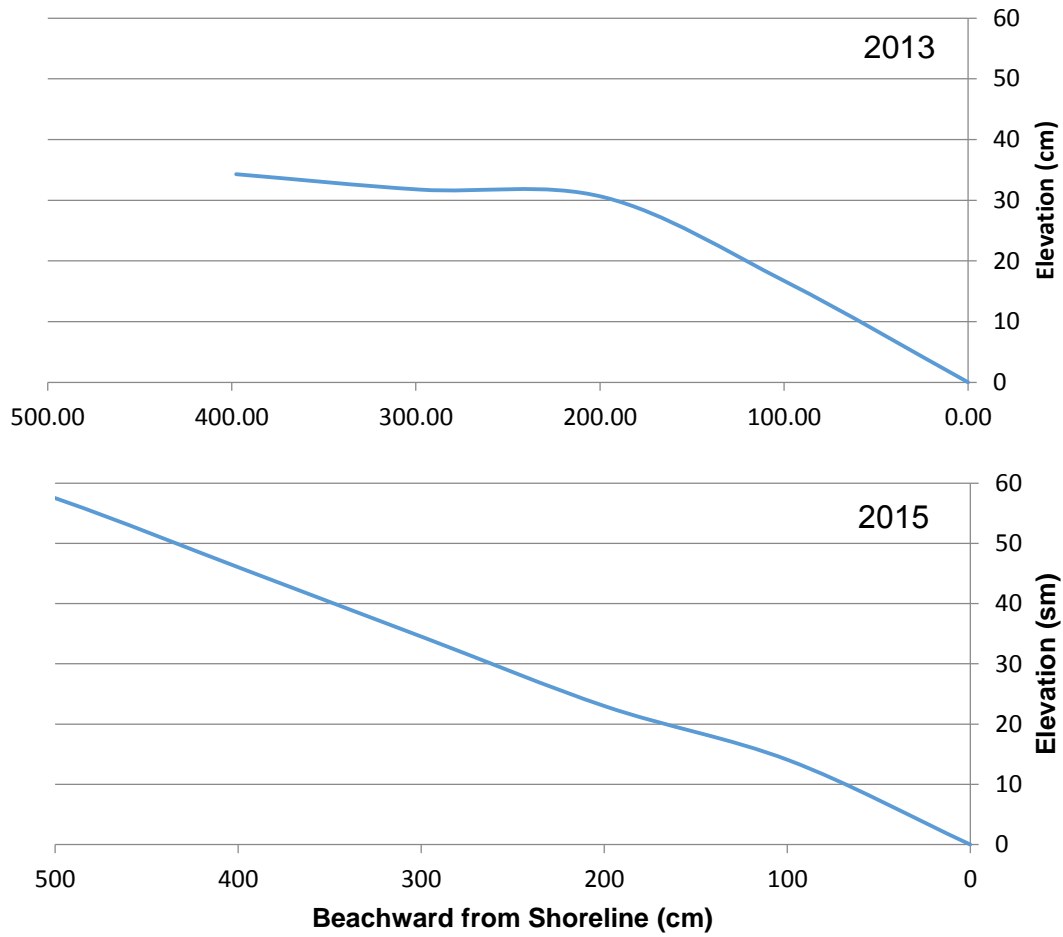
Station Thirteen

The 2015 profile shows a shallower slope and greater elevation compared with both 2011 and 2013.



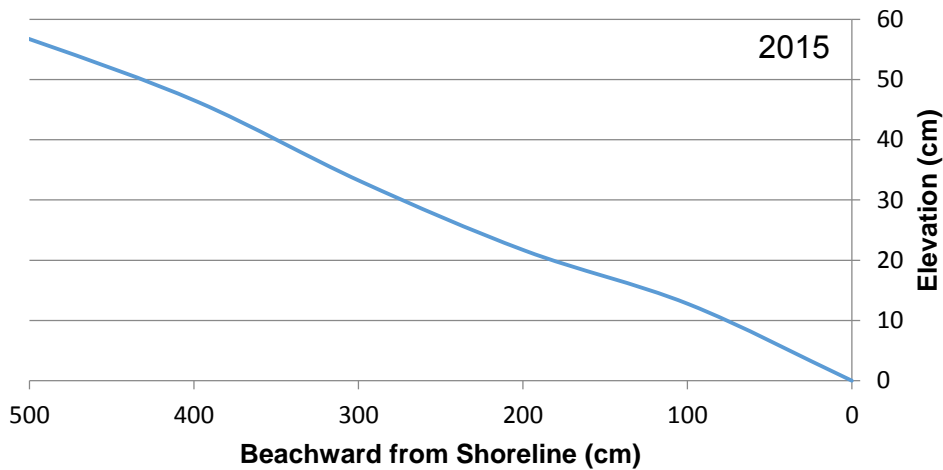
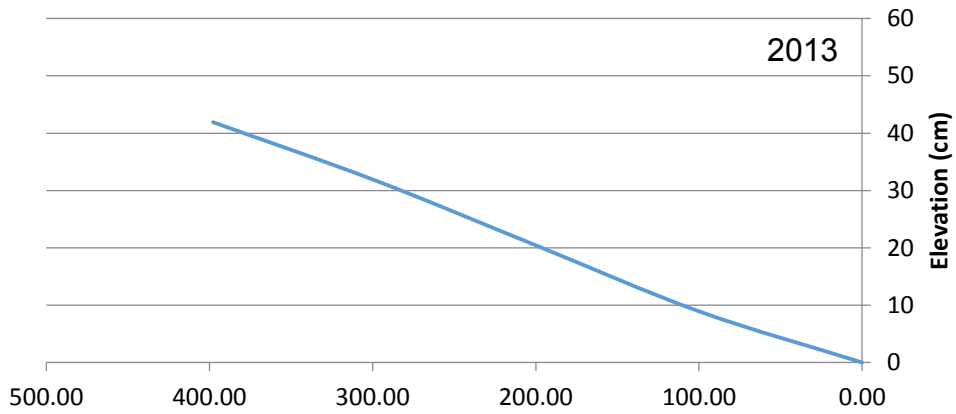
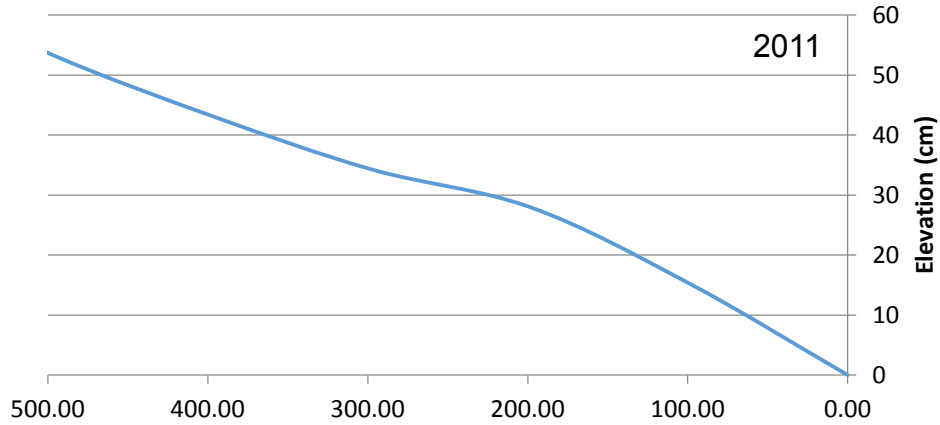
Station Fourteen

The 2015 profile shows a steeper slope, greater elevation and a longer beach compared with 2013. There was not a 2011 profile at this station.



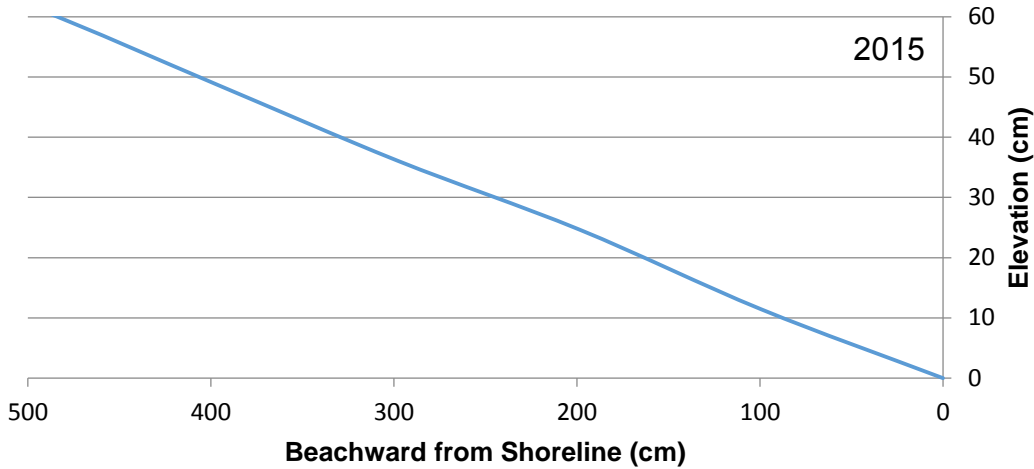
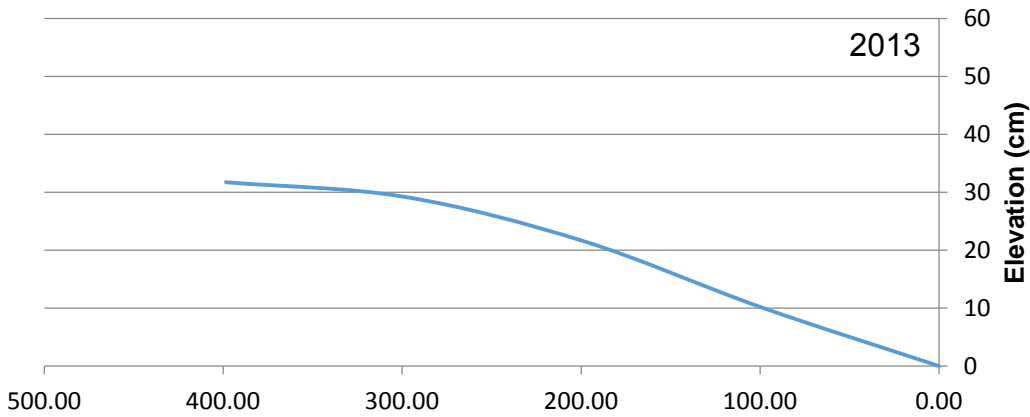
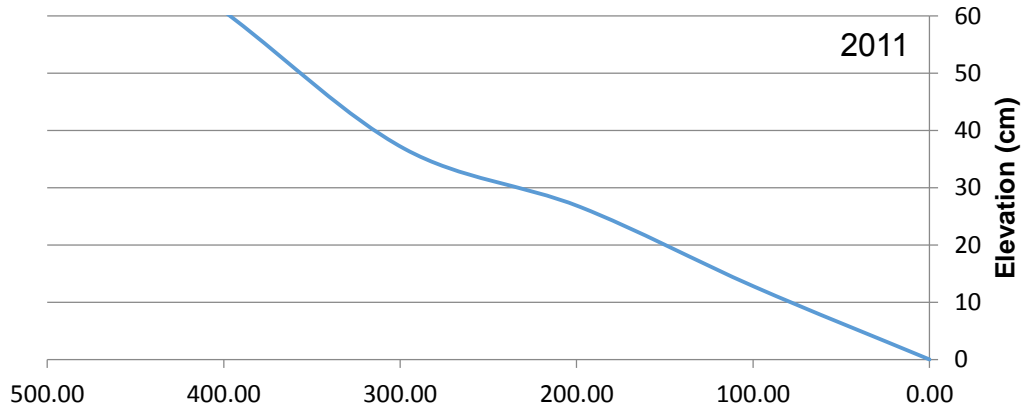
Station Fifteen

The 2015 profile is similar to 2011. It shows less slope and greater elevation than the 2013 profile. The shorter profile in 2013 suggests a shorter beach compared to both 2011 and 2015.



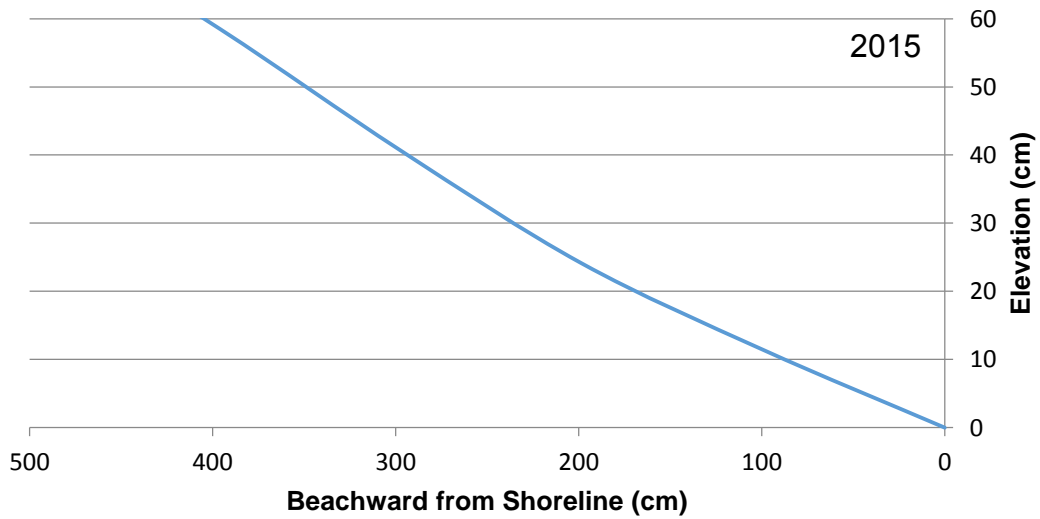
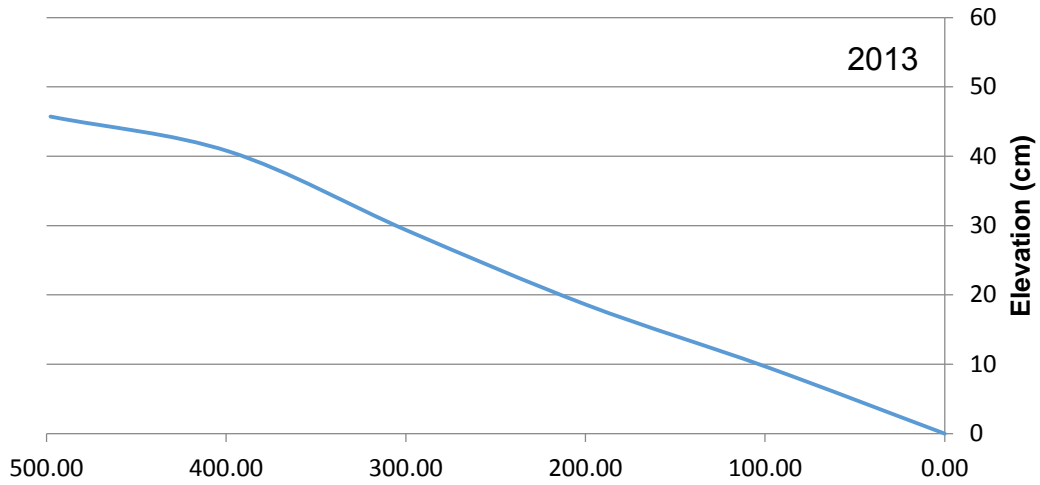
Station Sixteen

The 2015 profile is steeper and has greater elevation than in 2013. It is less steep and has less elevation than the 2011 profile. The beach was short in 2013, ending less than 5 meters from the waterline.



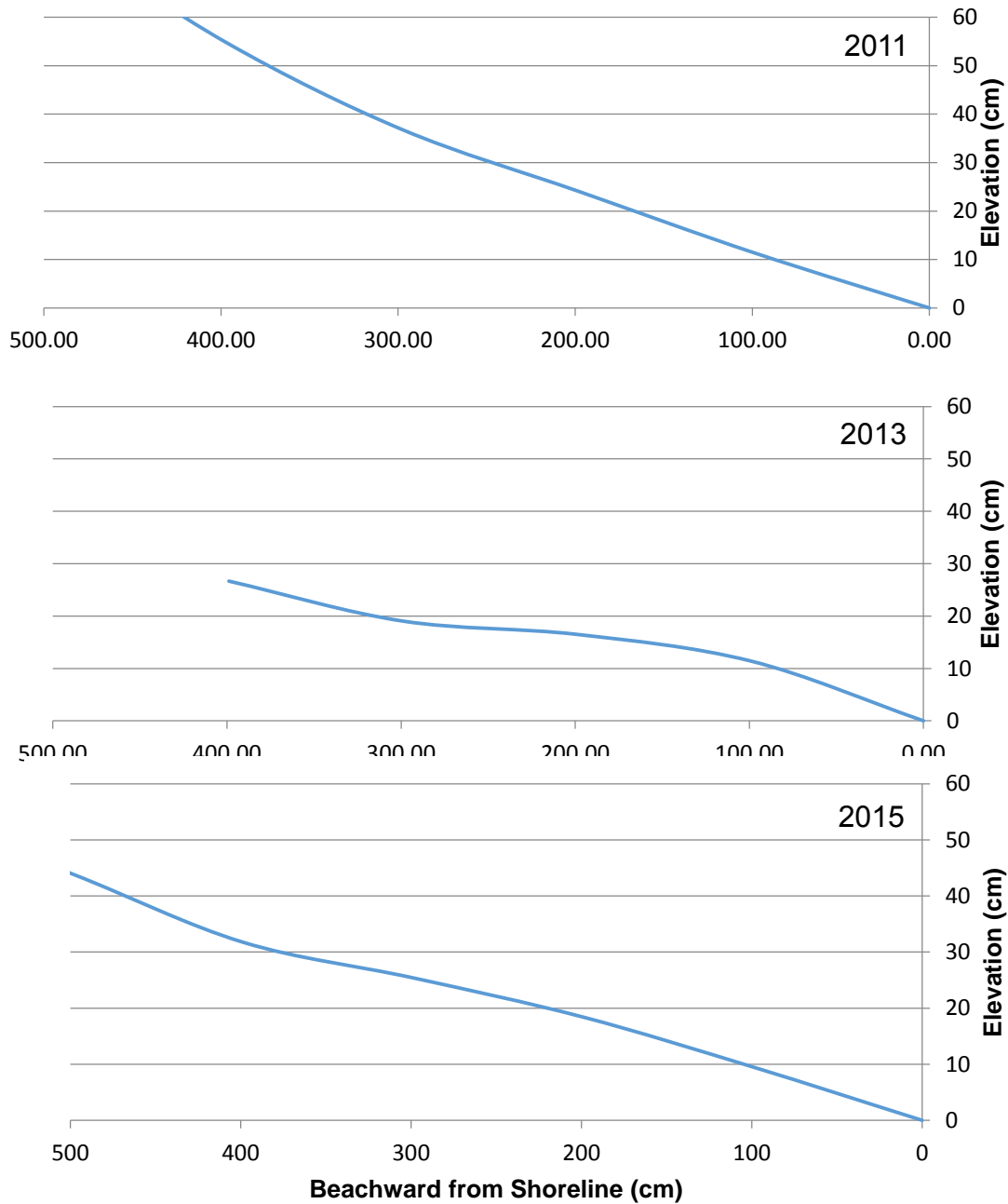
Station Seventeen

The 2015 profile is steeper and has greater elevation than in 2013. There was no 2011 profile at this station.



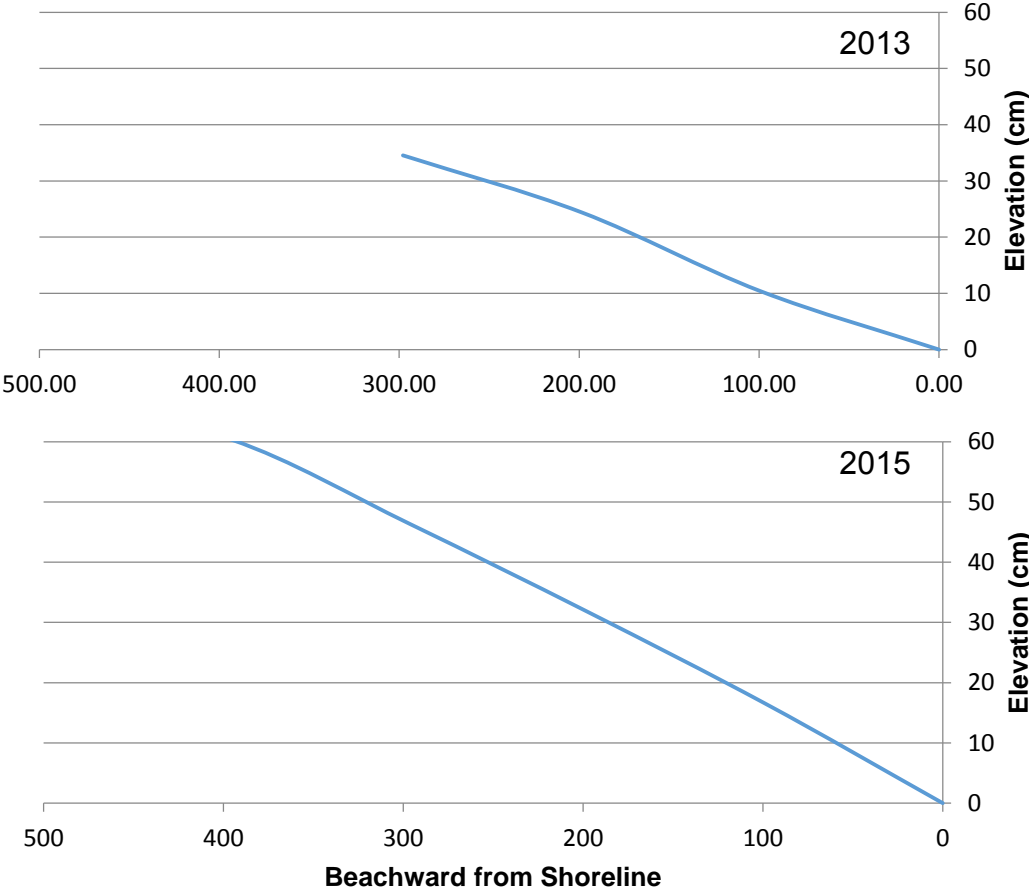
Station Eighteen

The 2015 profile is steeper and has greater elevation than in 2013, although shallower and with less elevation than the 2011 profile. The 2013 profile shows a shorter beach than 2011 or 2015.



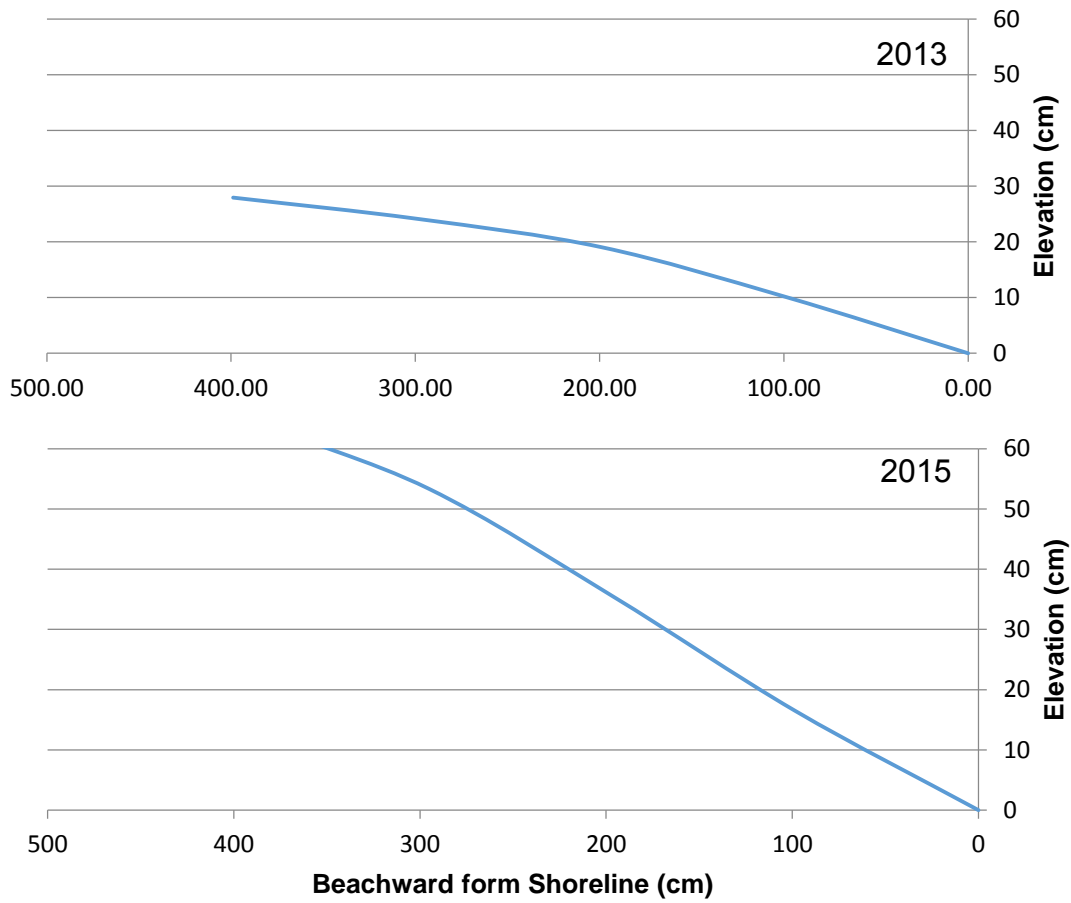
Station Nineteen

The 2015 profile is steeper and has greater elevation than in 2013. The 2013 profile shows a shorter beach. There was no 2011 profile at this station.



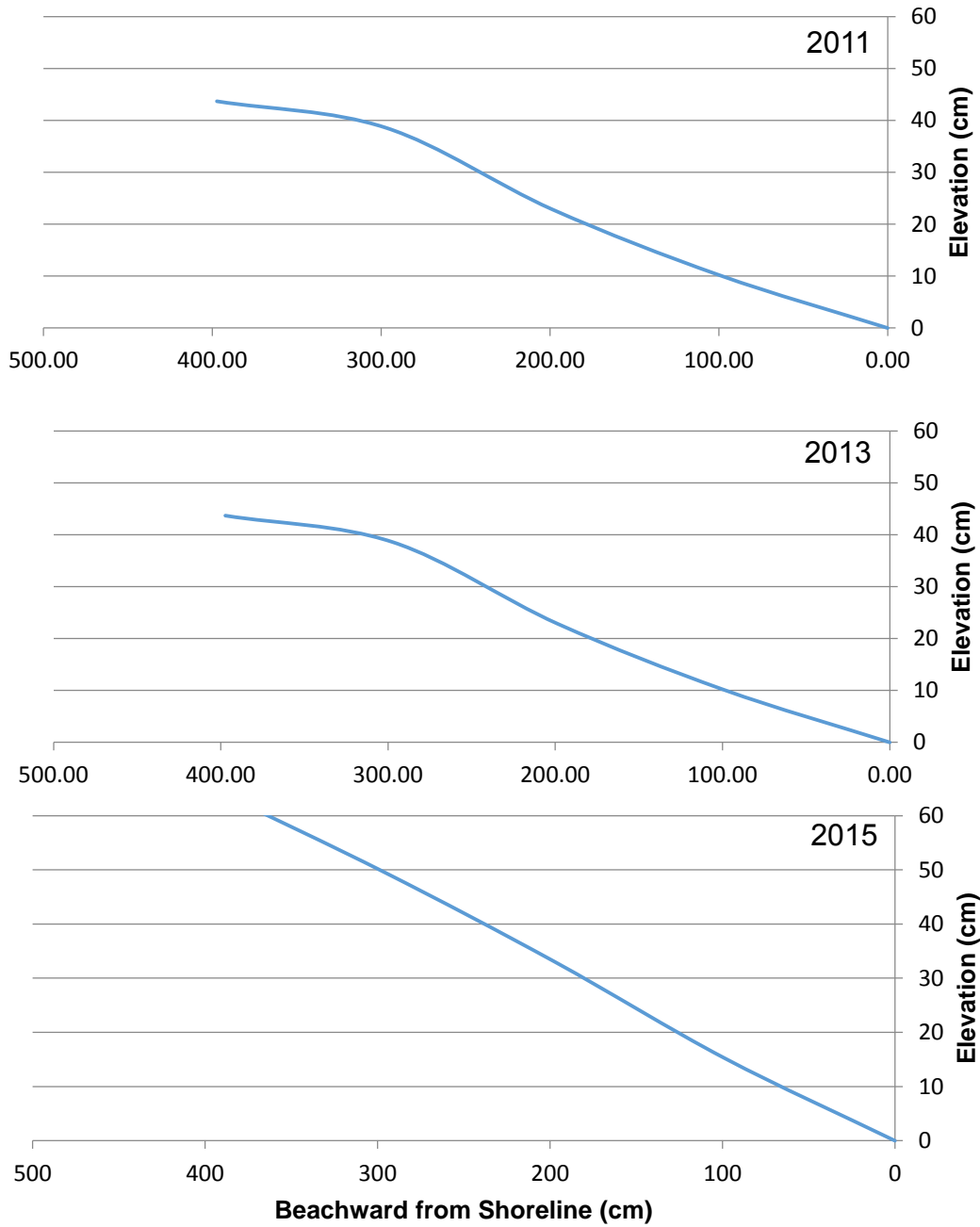
Station Twenty

The 2015 profile is steeper and has greater elevation than in 2013. The 2013 profile shows a shorter beach. There was no 2011 profile at this station.



Station Twenty-one

The 2015 profile is steeper and has greater elevation than both 2011 and 2013 profiles. The beach was shorter in 2011 and 2013 compared with a2015.



Station Twenty-two

The 2015 profile is steeper and has greater elevation than in 2013. It is similar to the 2011 profile

