

Humboldt Coastal Resilience Project

Phase 3 Beach-Dune Transect Profiles

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The following is a compilation of graphs depicting shoreline change over three years in 73 transects located along 32 km of shoreline between Little River and Centerville Beach. This report follows the Phase 1 and 2 progress reports, and incorporates new data from 2019. These data will ultimately be used to quantify volumetric changes along the shoreline and to parameterize a model for sea-level rise/climate change response. They are presented here as a preliminary product to provide information to landowners and managers.

Although there is much variation, certain trends can be discerned along the littoral cell. Graphs are grouped according to ownership, and we provide a succinct description of trends within each ownership over 3 years. Maps showing location of transects and property boundaries are provided in Appendix A.

The Little River transects were relatively stable, although exhibiting seasonal variation. Clam Beach transects were similarly stable, with the exception of the southernmost transect that occurs near the Mad River mouth, which migrated north in the past year and wiped out much of the transect. Mad River spit showed accretion at the crest of the spit. The Mad River, Long, and Woll area had very high steep transects that retreated by scarping. The Bair transects, which take in the Lanphere Adaptation Site, were scarped but then recovered via scarp-fill ramping. Much of the Lanphere area saw the loss of the incipient foredune, with some deposition on the stoss face of the established foredune. Ma-le'l North showed a similar trend of incipient foredune loss. BLM's Ma-le'l South showed both losses and gain of the incipient foredune. Friends of the Dunes and Manila Community Services District experienced scarping or loss of the incipient foredune. Samoa Pacific, Cal Redwoods, and Fairhaven Power experienced scarping and/or retreat of the established foredune. City of Eureka also showed scarping and retreat of the established foredune. The Samoa transects were variable but showed no trend. South Spit was variable and did not exhibit a trend overall. Table Bluff exhibited retreat of the berm. Eel River Wildlife Area experienced scarping followed by the formation of a wood-based incipient foredune. Eel River Estuary Preserve showed scarping of the established foredune, and an area of new foredune breaching, and in previously breached area translation of the berm inland. The Russ parcel, which had been previously breached, also showed inland translation.

Overall, the behavior of the foredune during the past 3 years varies from north to south. Northernmost transects at Little River and Clam beach (excepting the transect affected by the river) were stable. At the upper end of the North Spit barrier, the high foredunes experienced retreat; ramps were not able to build sufficiently high to allow for recovery. The Lanphere adaptation site exhibited scarping followed by ramping, a resilient response. The Lanphere and Ma-le'l dunes saw the erosion of the incipient foredune that had built in the preceding 5 years, these are generally ephemeral features. The South Spit was mostly stable, but Table Bluff retreated. The Eel River Wildlife Area had a lot of scarping initially but large wood was deposited and formed the nucleus of a new incipient foredune. Eel River Estuary Preserve exhibited the highest erosion, with a new foredune breach, and erosion of existing foredunes. Both EREP and Russ overwash areas translated inland.

Glossary

- Backdune: the landscape located behind foredunes, which may include different dune morphologies (e.g., relict foredunes, parabolic dunes, blowouts) and other landforms (e.g., swales, ponds, overwash fans, etc.)
- Backshore (upper beach): The part of the beach seaward of the foredune and above average high tides, usually reached only by storm waves. Sparse vegetation and incipient dunes may be present.
- Bar: a ridge of sediment in the intertidal or sub-tidal zone formed by wave action. Bars often migrate on- or offshore with storm events and changes in the wave climate and they can be oriented parallel or oblique to a shoreline, depending on wave climate. Bars may also attach or 'weld' to the foreshore and upper beach.
- Beach cusp: crescentic, often raised features on a beach formed by wave and/or rip currents. Cusps typically form parallel to the shoreline and result in variations in beach width alongshore.
- Berm: a low ridge or terrace feature formed on the upper beach above high tide by deposition of sediment by wave action.
- Deflation basin: an area of windblown (aeolian) erosion of sediment from a typically flat surface between or within dunes. Deflation basins are often the source of sediment for dune deposits immediately downwind (e.g., depositional lobes of parabolic dunes).
- Established Foredune: The first prominent dune ridge backing and oriented parallel to the beach, formed by windblown (aeolian) sand transport from the beach and deposition in vegetation or other rough surfaces (e.g., large wood deposits).
- Foredune breach: An area where wave action has removed the foredune.
- Foredune lee slope: typically, the rear, inland-facing or downwind slope of the foredune.
- Foredune stoss face: typically, the front, seaward-facing or windward slope of the foredune.
- Foredune swale: A low-lying area between the foredune and adjoining dune ridges behind it.
- Foreshore (lower beach): The intertidal portion of the beach between the average high and low tide elevations.
- Incipient foredune: a smaller, often ephemeral, foredune that forms seaward of the established foredune in the backshore. These may be removed during storm events, or can develop into established foredunes depending on beach sediment budgets and/or regional sea level trends.
- Nebkha: a type of dune that forms around or in the lee of shrub vegetation (often referred to colloquially as a hummock).
- Relict foredune: A stabilized foredune that has become stranded from the input of beach-derived sediment due to the formation of one or more foredunes seaward by new accretion events and/or the colonization of stabilizing vegetation.
- Scarp: a steep cliff or escarpment formed by wave erosion of foredune, incipient foredune, or beach deposits.
- Slipface: the steep leeward face of a dune where sediment deposited at the crest often avalanches down and forms a characteristic angle of approximately 30-34degrees. Slip faces often have limited vegetation cover.

- Transverse dune: a typically unvegetated dune ridge oriented with its crestline perpendicular to the dominant transporting wind direction.
- Washover: An area at or behind a foredune breach where storm wave overwash reaches and can erode or deposit sediment.
- Washover lobe or fan: A deposit of sediment behind the foredune breach, left by storm wave overwash.
- Wood Deposits: Large deposits of drift logs left during storms. In areas within or near large river estuaries, these deposits may also be associated with riverine flood events.

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Little River Transect 1

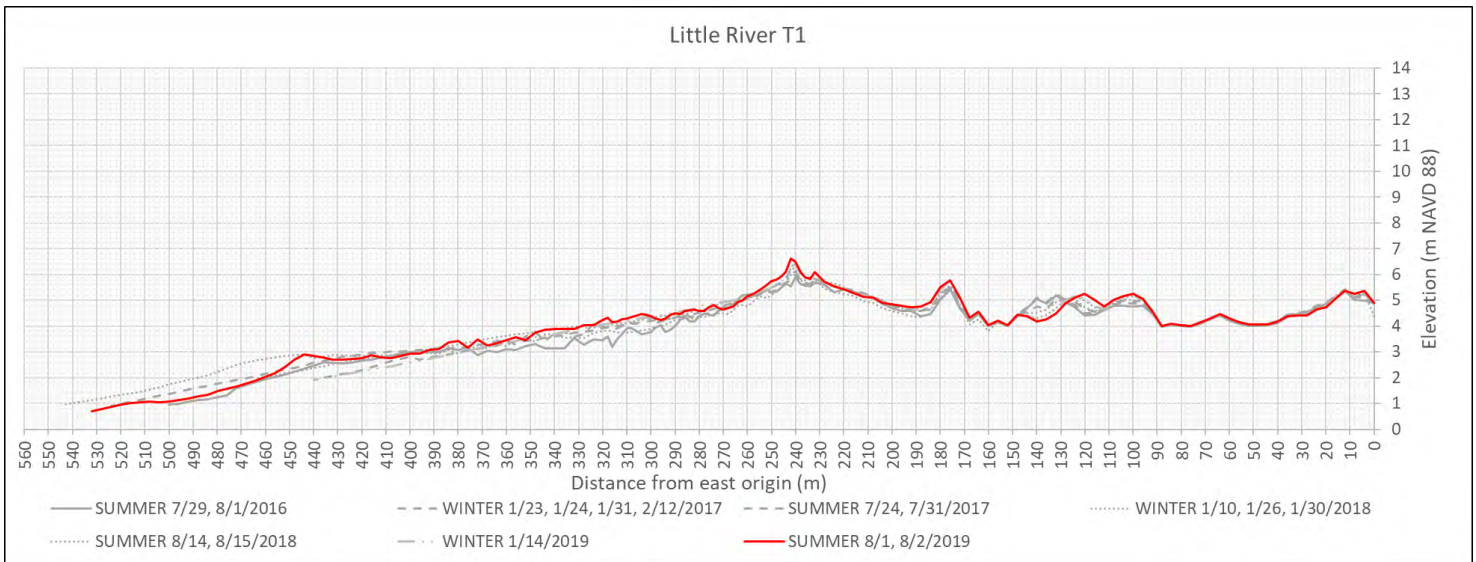


View north at 242 m (foredune crest)

Notes: The transect is located in an area of Little River State Beach restored through the removal of European beachgrass (*Ammophila arenaria*) by heavy equipment beginning with a pilot project in 2004 and completed in 2008. Data are not available for winter 2016 but profiles otherwise show a winter storm flattening of the backshore by wave runup, erosion, and deposition, followed by development of transverse dunes in summer. The backshore gradually rises in elevation landward and transitions to a low foredune zone composed of a plateau-like nekha field, reaching a maximum elevation of 6.2 m NAVD 88. The transect bisects the concave portion of a beach cusp and the foredune zone is lower and narrower than in Transect 2 to the south, although in summer 2017 a transverse dune slipface at the boundary between the backshore and foredune zone reached elevation 6.2 NAVD 88 (240 m). In summer 2017 the westernmost vegetation occurred at 318 m. Between 90 m and 190 m upland areas in-



tersperse with deflation basins. Between winter 2018 and summer 2018 there was a loss of up to 0.4 m seaward as well as inland of the foredune, as well as a lowering of the foredune crest by 0.2 m. Between 2018 and 2019 the foreshore gained in elevation, and the transverse dunes in the backdune area migrated east.



Little River Transect 2

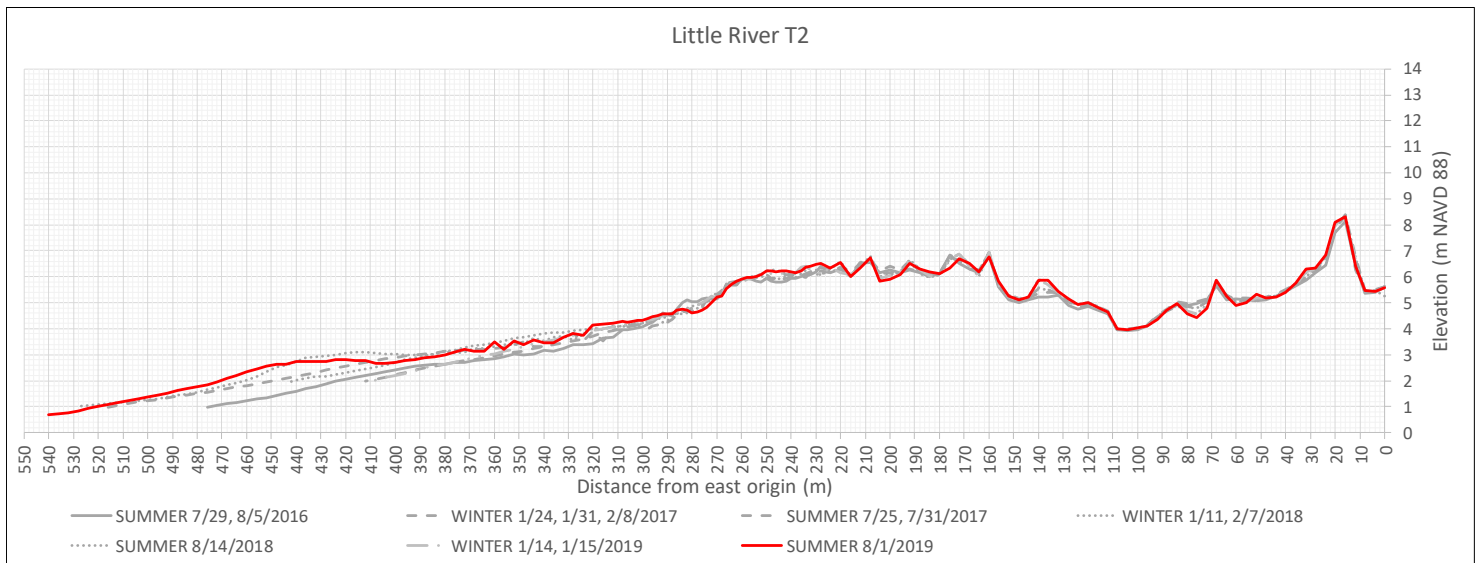


View north at 208 m (foredune crest)

Notes: Similar to Transect 1, and located in an area of Little River State Beach restored through the removal of *Ammophila* by heavy equipment. Data are not available for winter 2016. Profiles show a winter flattening of the backshore by storm wave runup, erosion, and deposition, followed by development of transverse dunes in summer, with net accretion of up to 2 m on the lower beach between summer 2016 and summer 2019. The backshore gradually rises in elevation and transitions to a foredune zone consisting of a plateau-like nebkha field. The foredune zone is wider and higher than Transect 1, and is located at a convex portion of the beach cusp (as present in 2016). Nebkha show translation inland between summer 2017 and summer 2019. Maximum elevation of the foredune zone along the transect is 7.0 m NAVD 88 on the crest of the slipface just above and west of the deflation plain (160 m). The transect then extends through the deflation plain where there was both erosion and accretion in summer 2018. There is an abrupt peak at a relict,



unrestored foredune (16 m) where *Ammophila* is continuing to trap sediments from the deflation plain.



Little River Transect 3

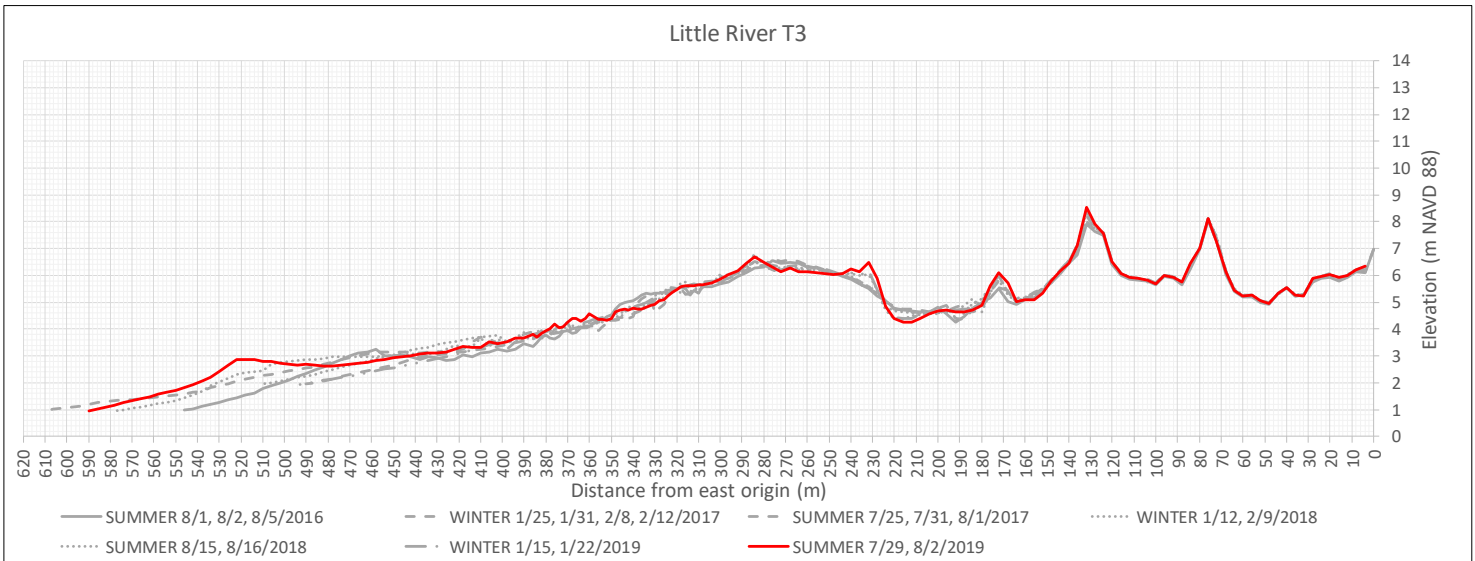


View north at 284 m (foredune crest)

Notes: Similar to Transects 1-2, located in the southern portion of the restored area at Little River State Beach but extending into the unrestored backdune. Data are not available for winter 2016. Profiles show annual winter flattening of the backshore by storm wave runup, erosion and deposition, followed by summer formation of transverse dunes. The backshore gradually rises in elevation and transitions to a low rounded foredune zone. There is less vegetation and more even topography in the foredune zone of this transect compared with 1 and 2. Deposition at 284 m in summer 2018 raised the maximum elevation of the foredune zone by 0.4 m to 6.8 m. The eastern edge of the foredune zone steepened in 2018 indicating slipface development.



Beyond the foredune zone the transect passes through a deflation basin that underwent erosion in summer 2018, with resulting deposition downwind. The two relict *Ammophila* foredunes (132 m and 76 m) remained stable in 2018. East of these relict ridges is a second deflation plain in the more stable, backdune (unrestored) area

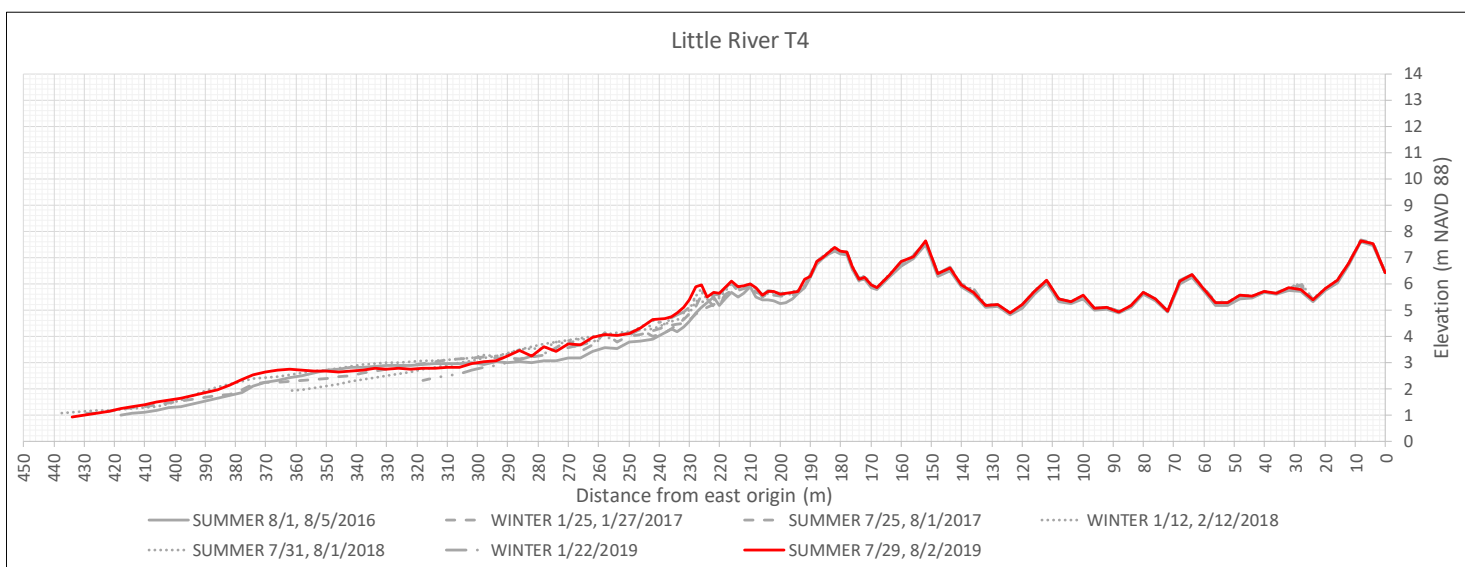


Little River Transect 4



View south at 230 m (foredune base)

Notes: The transect, located south of the restored area at Little River State Beach, is characterized by a broad, sparsely vegetated (*Ammophila*) backshore /incipient foredune that forms transverse dunes during summers and is flattened by wave runup in winters. From summer 2017 to summer 2019 the backshore/incipient foredune experienced net deposition. There is a stable established foredune separated from a relict foredune by a foredune swale. A backdune region has some deflation basins among *Ammophila* nebkha. The east end of the transect is an older, landward, relict foredune. The photographs above are taken looking south from the base of the foredune.

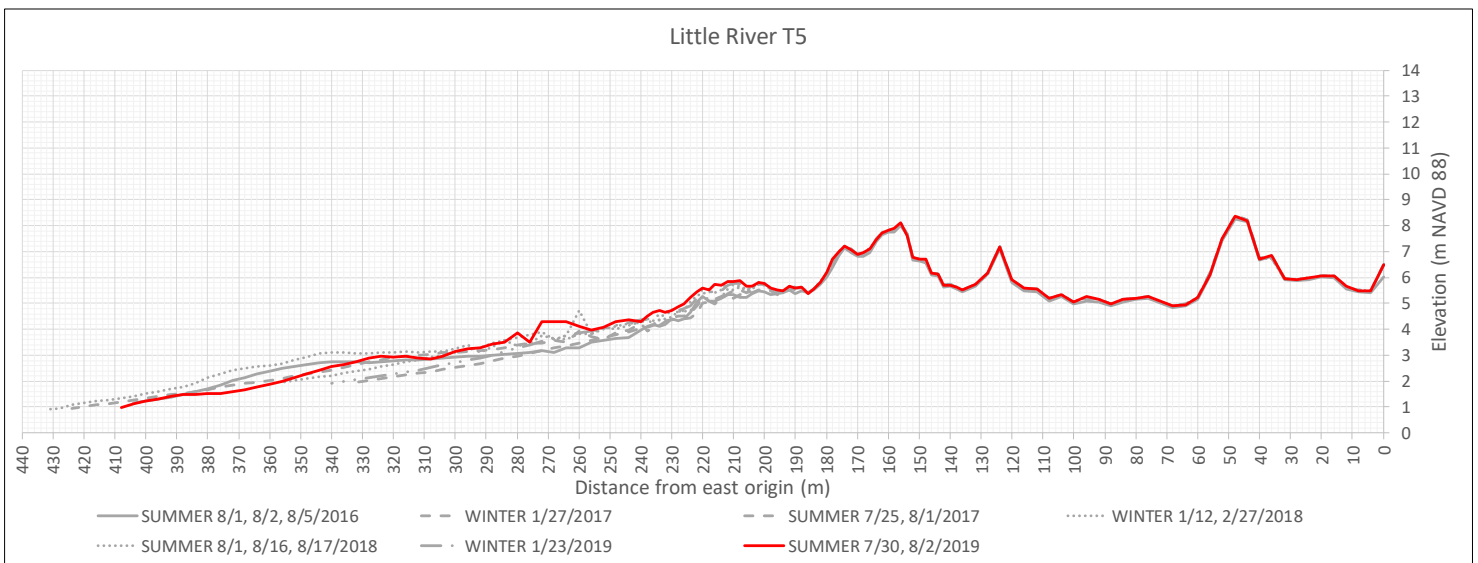


Little River Transect 5



View north at 160 m (foredune crest)

Notes: Similar to Transect 4, Transect 5 (located in the unrestored portion of Little River State Beach) is characterized by a broad *Ammophila* backshore/incipient foredune that forms transverse dunes during summers. The incipient foredune experienced up to 1 m of deposition between summer 2016 and summer 2019. There is an established, two-peaked *Ammophila* foredune separated from a landward relict foredune by a foredune swale, and a deflation plain separates these from an older, landward, relict foredune at approximately 60 m.

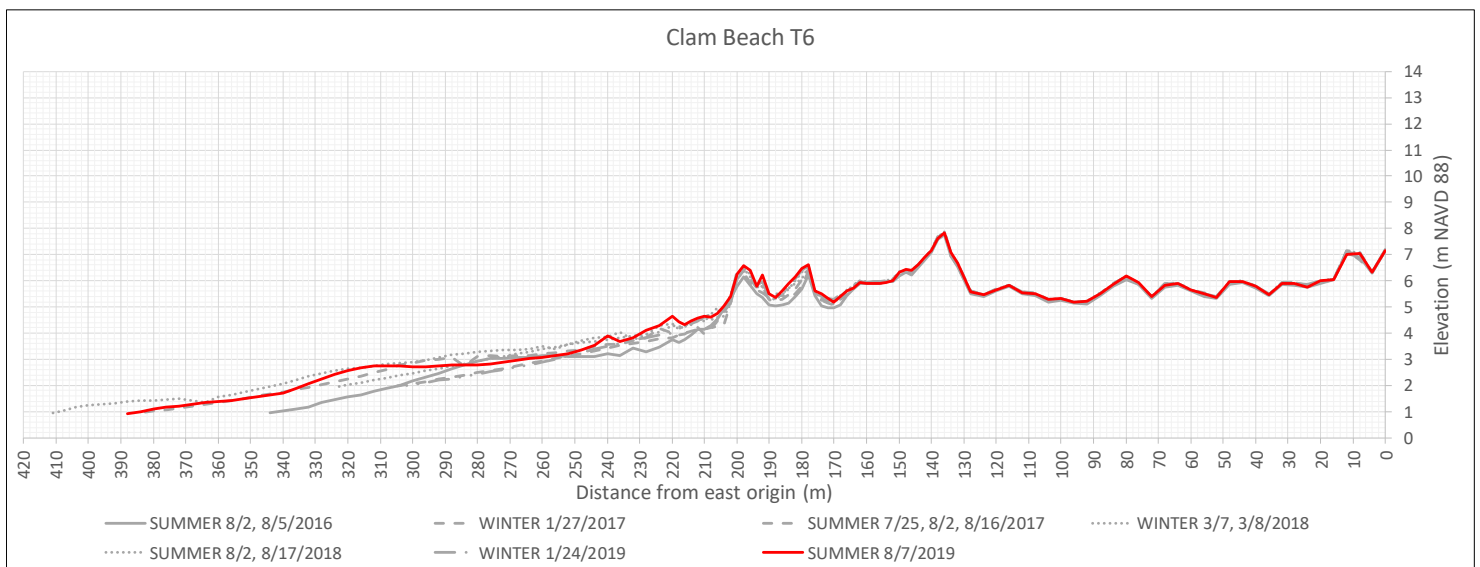


Clam Beach Transect 6



View southeast at 252 m (upper beach looking towards incipient foredune)

Notes: Data from winter 2016 are not available. The profile displays two relatively low and sparsely vegetated incipient foredune ridges. The outer incipient foredune was scarped in winter 2017, but ramping had smoothed the scarp by summer 2017. Deposition occurred on the backshore as well as the crest, lee and swale of the two incipient foredunes between summer 2016 and summer 2019. From summer 2017 to summer 2019 additional deposition occurred on the backshore and the stoss face of the inland incipient foredune. The higher, established foredune at 140 m remained stable, as did the backdune in general.

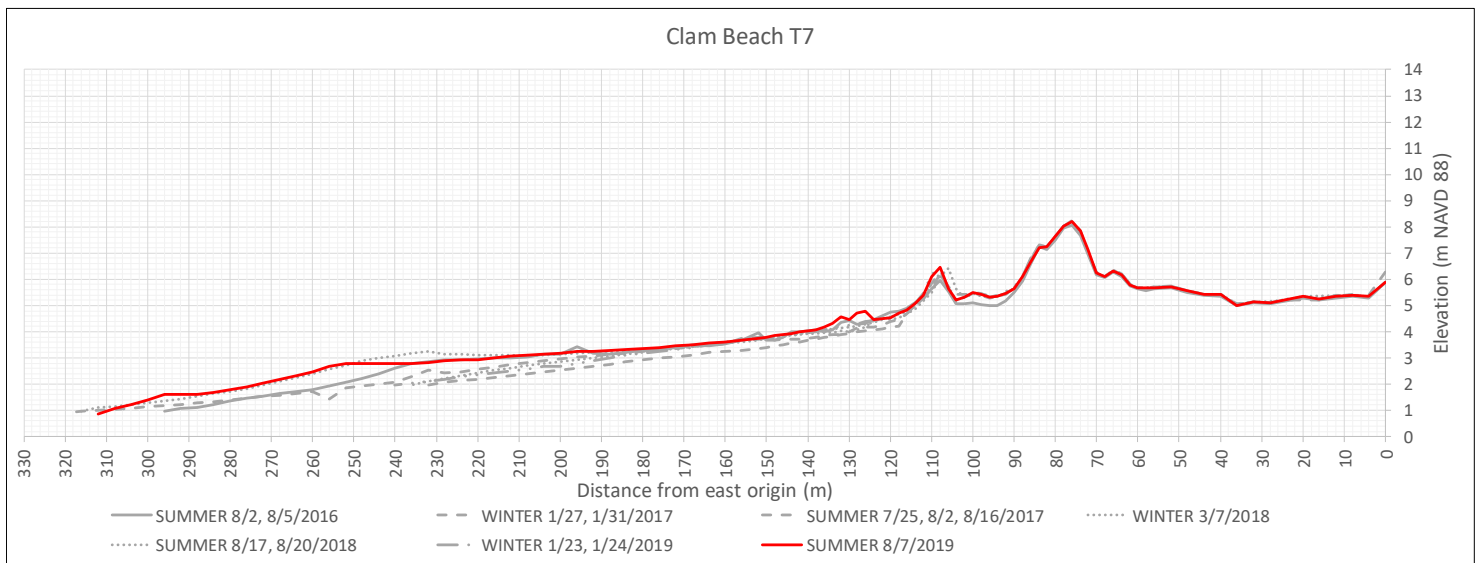


Clam Beach Transect 7



View north at 108 m (foredune crest)

Notes: Data for winter 2016 are not available. The base of the incipient foredune was scarped in winter 2017, with sediment deposited at the crest and in the swale between the incipient and established foredunes. Between winter 2018 and summer 2018 the incipient foredune translated inland. The backshore gained up to 1 m in elevation (240 m) between summer 2017 and summer 2018. Deposition on the backshore in summer 2019 brought it back to 2016 levels. The established foredune has been stable.



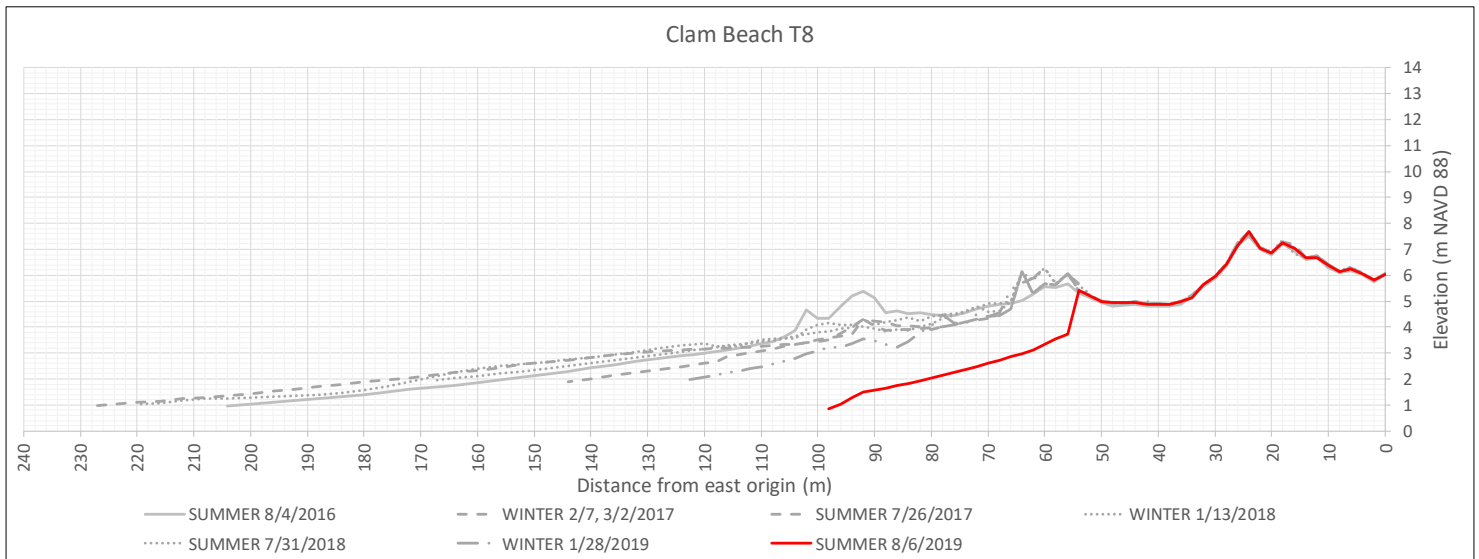
Clam Beach Transect 8



Clam Beach T8 View northwest at 58 m (Incipient Foredune)

Notes: Topographic data for winter 2016 are not available, but air photos show a large wood deposit on the upper beach following high water events. This transect is located north of the mouth of the Mad River and represents a dynamic area. The foreshore underwent seasonal deposition and erosion, with net deposition of up to 0.4 m between summer 2016 and summer 2017. The rounded topographic feature present between 88 m and 105 m in summer 2016 was unvegetated but may represent the initiation of an outer, seaward incipient foredune that was removed during high water events in winter 2017. Following the winter survey, wood was deposited on the more landward incipient foredune (causing the high peaks at 64 m and 56 m in the summer 2017 profile).

The established *Ammophila* foredune (2-30 m) had minor deposition on the crest and lee slopes of the two peaks in winter 2017, but lowered to 2016 levels in summer 2017. Between winter and summer 2019 surveys the entire seaward incipient foredune was removed when the river migrated northward.

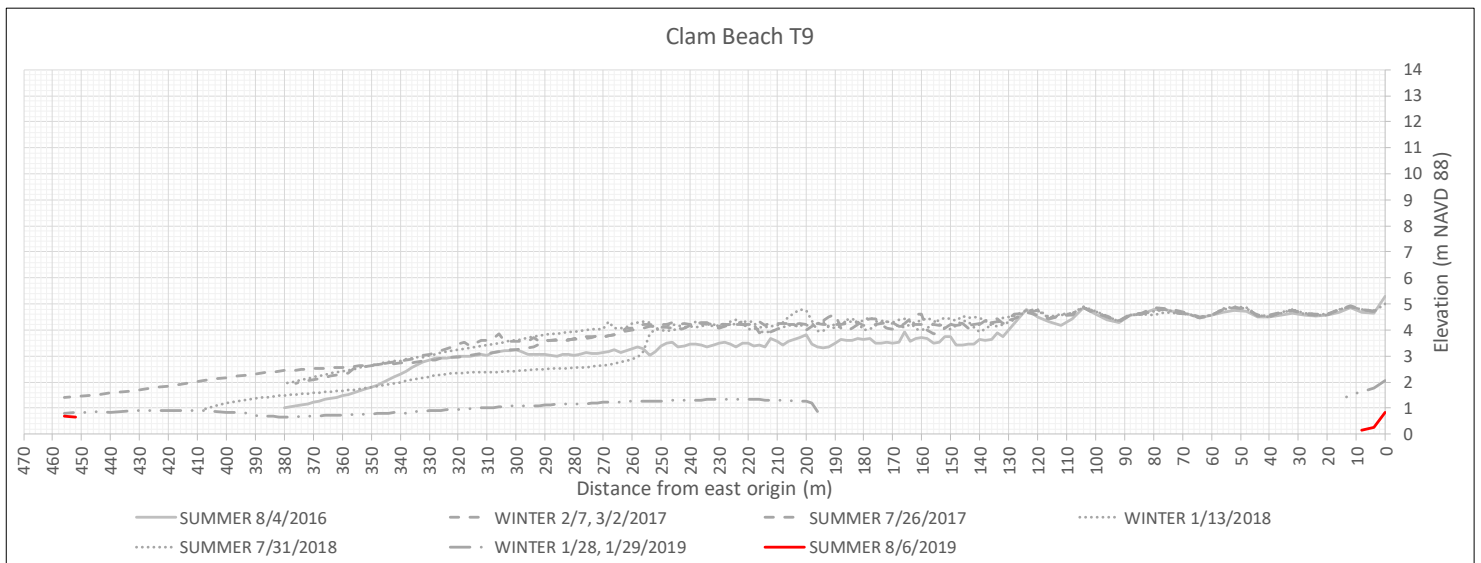


Clam Beach Transect 9



View north at 104 m (foredune crest)

Notes: The transect is located just north of the mouth of the Mad River in a dynamic area. Ongoing *Ammophila* removal occurred to the north. Winter 2016 data are not available, however a scarp line is visible on the winter 2016 air photo. The profiles show prevailing overwash influence with deposition of up to 1 m, from summer 2016 to summer 2018. The upper beach flattens in winter, followed by aeolian formation of transverse dunes in summer, with scattered *Elymus mollis* and *Cakile* spp. colonizing as far west as 274 m. In 2019 the mouth of the Mad River migrated north obliterating most of the transect and only a few points could be taken at the east end.

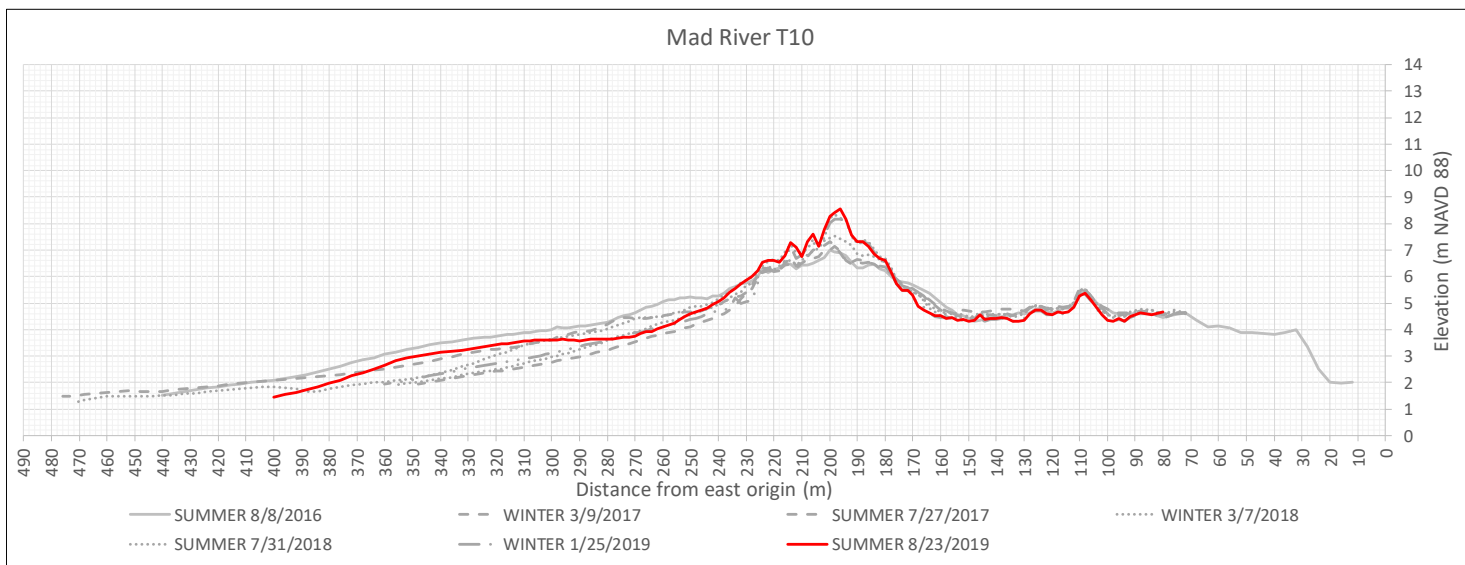


Mad River Transect 10



View southeast at 194 m (foredune crest)

Notes: This profile comprises a cross section of the Mad River Spit near its southern end. Data are not available for winter 2016. In summer 2017 the transect began farther to the east. Erosion along the east edge of the spit during the winter of 2017 resulted in adjustment of the east end of the transect further west. The spit is not well vegetated and the profile exhibits dynamic changes. The crest of the spit (characterized here as the foredune crest) has steadily gained in elevation. In summer 2018 over 1 m of deposition occurred in the region around 194 m. This can be seen in the photographs above in which the advancing lobe of sand has covered the wood visible the previous winter. The crest saw only minor deposition in summer 2019, however the upper beach was eroded, losing 1 m of elevation.

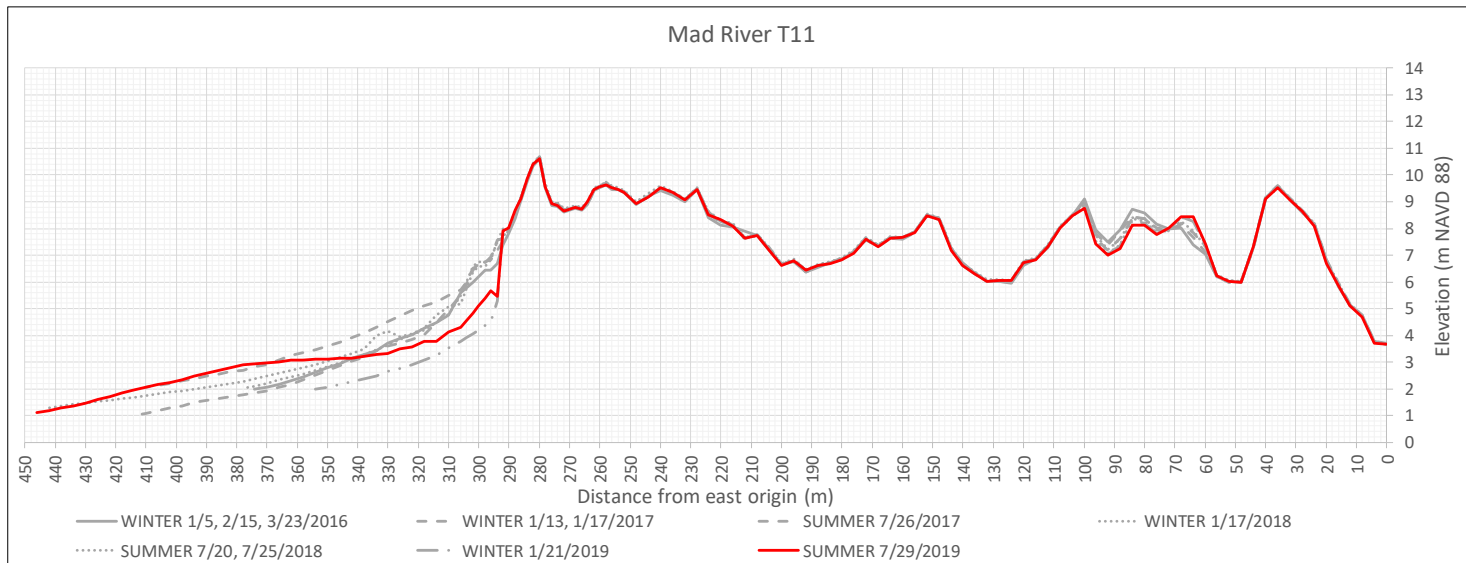


Mad River Transect 11



View north at 282 m (foredune crest)

Notes: This transect located in Mad River County Park is the first transect located south of the Mad River mouth, and the first going south along the littoral zone to exhibit a foredune over 10 m in elevation (10.7 m NAVD 88). In winter 2016 the upper beach was relatively steep, and by winter 2017 the beach had accreted almost a meter in elevation. However, a high water event and foredune scarping occurred soon after the survey was completed, and by summer 2017 the elevation was again lost, leaving a steep beach with some deposition at the toe of the foredune. The upper beach has shown mostly minor recovery in elevation since then. Between winter and summer 2019 the foredune rescarped, and additional elevation was lost from the beach. There are areas of open sand in the eastern portion of the transect, and the profile shows continued translation of one slipface to the east.

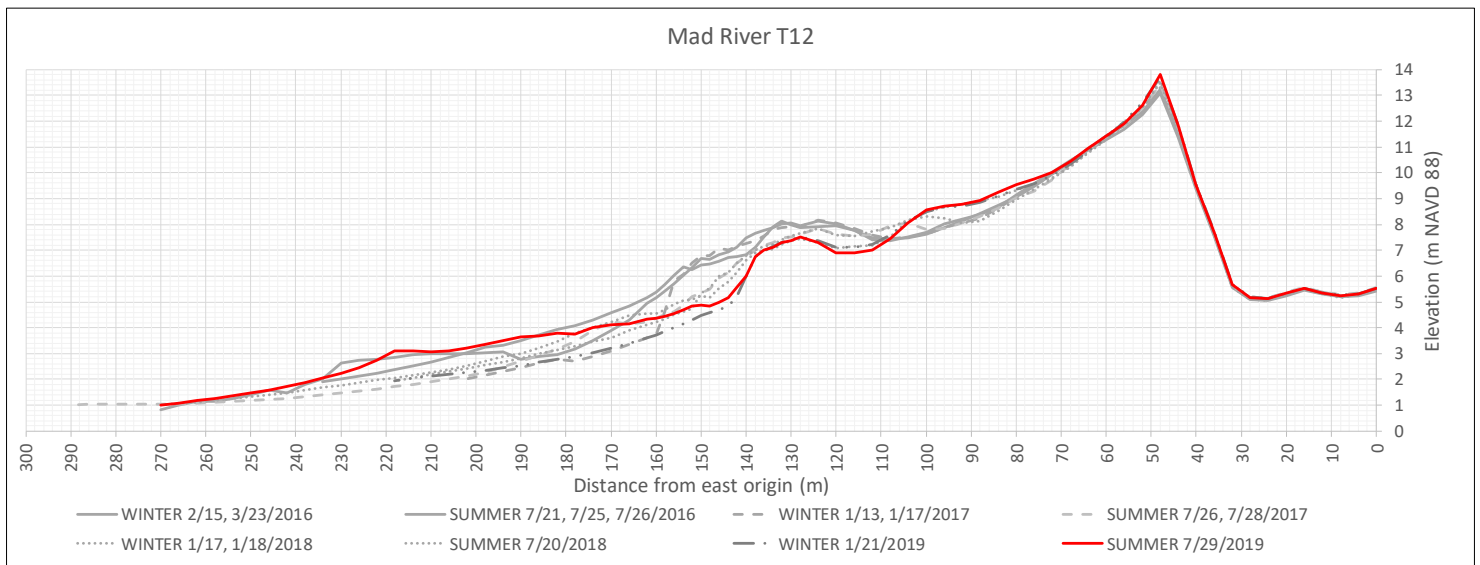


Mad River Transect 12



View southeast at 160 m winter 2017 and at 152 m on 7/20/2018 (incipient foredune/scarp)

Notes: The transect runs along the axis of the southern-most of a series of foredune blowouts, yielding a distinctive profile ending in the steep slipface of its depositional lobe. An incipient foredune seaward of the mouth of the blow-out was scarped after the survey in winter 2016. Erosion of the backshore persisted into summer 2016 although the incipient foredune had ramped and gained elevation. In winter 2017 high water events scarped the incipient foredune, removing 2.0 m vertically (see photo above left). Ramping and erosion of the scarp during summer 2017 reactivated the blowout, shifting the foredune crest west, and a new depositional lobe formed and has continued to migrate inland. In 2019 the incipient foredune lost elevation, but sand was deposited to the east. The eastern slipface of the larger depositional lobe has been stable over the three-year period.

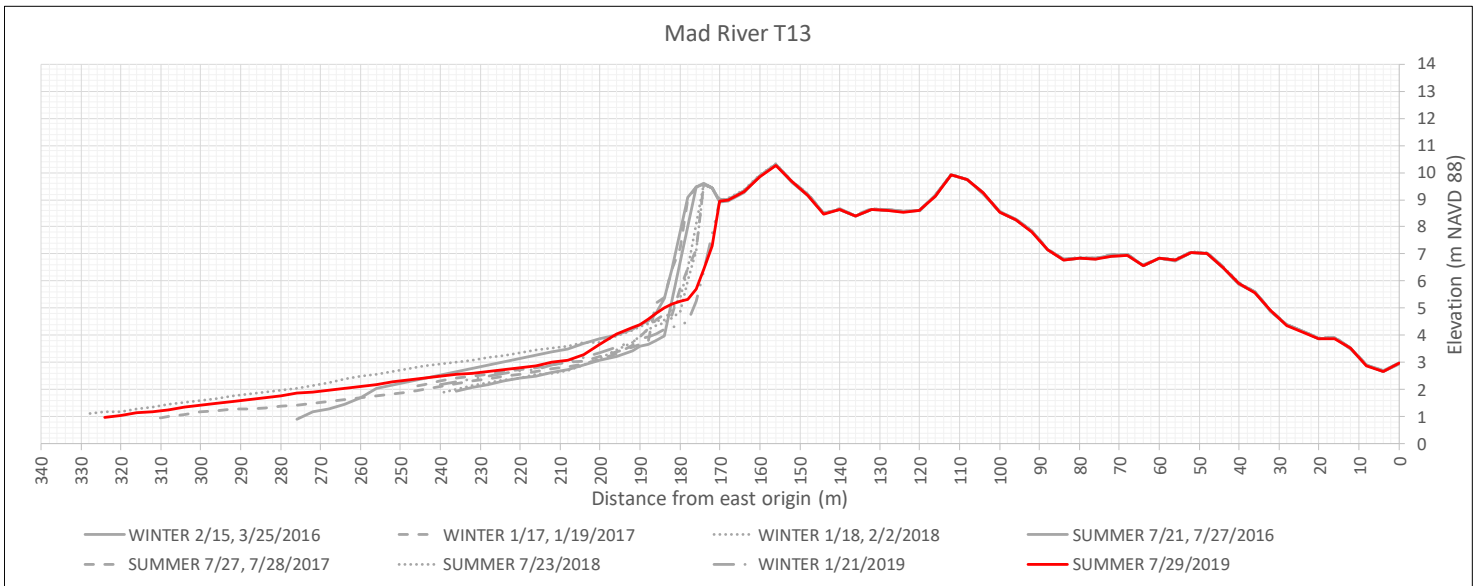


Mad River Transect 13



View north at 184 m (scarp)

Notes: The *Ammophila* foredune was significantly eroded during a high water event just before the winter 2016 survey, leaving a high, vertical scarp at the time of the survey. The scarp has since undergone slumping and additional scarping (following the winter 2017 survey). Since winter 2016 the upper beach has recovered approximately 0.8 m of elevation. Ramping had begun to occur in summer 2019.

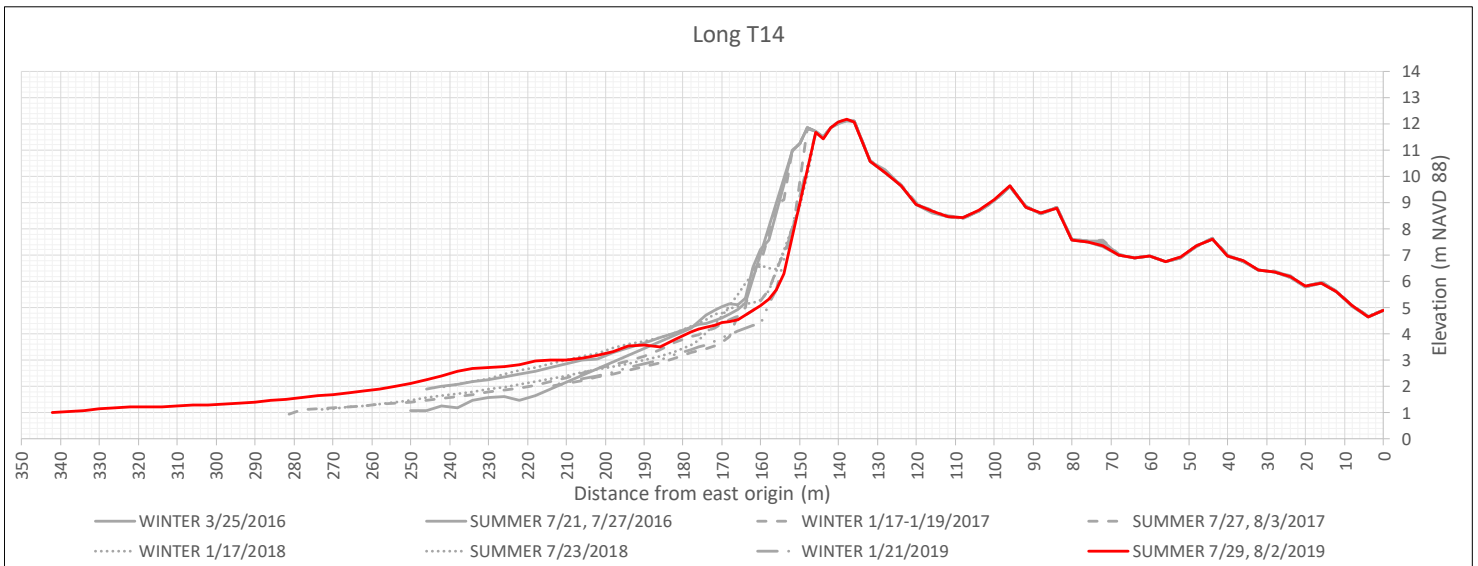


Long Transect 14



View north at 162m (scarp)

Notes: Moving from north to south, the elevation of the foredune crest has increased, reaching a maximum on this transect of 12.0 m NAVD 88. The *Ammophila* foredune was significantly eroded during a high water event just before the winter 2016 survey, leaving a high, vertical scarp at the time of the survey. The scarp remained virtually unchanged through summer 2016, while the foreshore steepened and there was minor deposition on the backshore at the base of the foredune. Prior to the winter 2017 survey the backshore eroded, losing up to 1 m elevation near the base of the foredune, and block slumping had occurred on the scarp. A high water event after the survey rescarped the entire foredune causing up to 8 m horizontal retreat, which shows up in the summer 2017 profile. By summer 2018 the profile was little changed except for the formation of a low scarp fill ramp, which reformed in summer 2019.

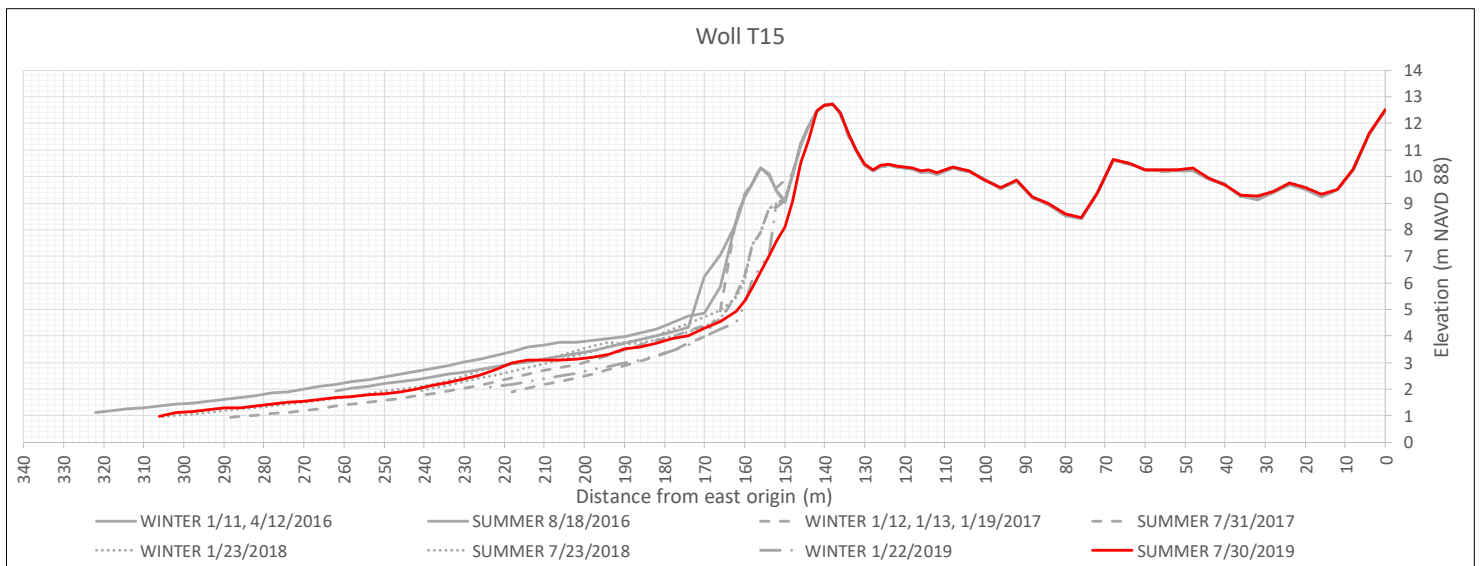


Woll Transect 15



View north at 166 m (scarp)

Notes: This high *Ammophila* foredune has a crest elevation of 12.6 m NAVD 88. The base of the incipient foredune had been scarped in winter 2016 prior to the survey, and between the winter and summer 2016 surveys it retreated an additional 5 m horizontally, although the beach gained in elevation by the summer survey. In winter 2017 the beach was lowered by 1.0 m vertically by the time of the winter survey. Soon after the survey a high water event removed the incipient foredune. By summer 2017 slumping had occurred, the backshore had received deposition of 0.5 m, and a ramp was forming. In 2018 the stoss face of the foredune changed little, but the upper beach elevation received deposition of 0.4-0.6 m. In 2019 the scarp receded further.

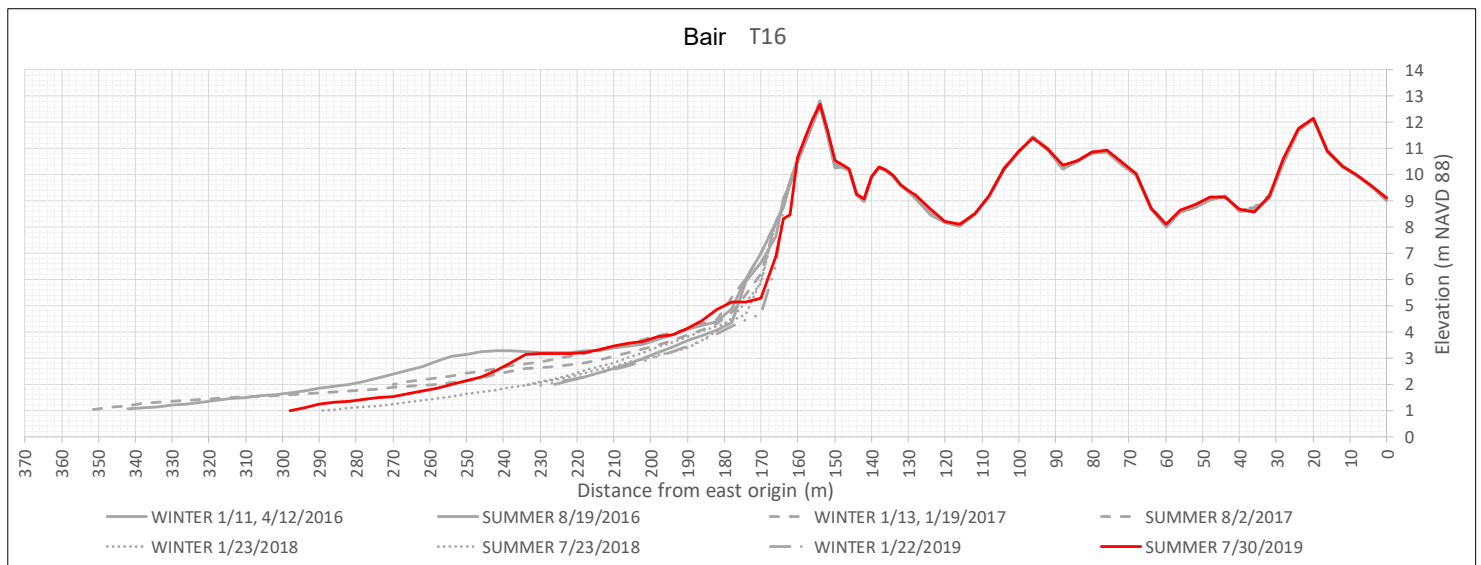


Bair Transect 16



View north at 154 m (foredune crest)

Notes: The foredune crest elevation of this steep, peaked *Amophila* foredune is 12.7 m NAVD 88. Low scarping occurred at the base of the foredune in winter 2016 prior to the survey, and from then until winter 2017 the backshore built up slightly and a scarp-fill ramp formed. Soon after the winter 2017 survey a high water event scarped the base of the foredune, causing retreat of up to 6 m horizontally and lowering the backshore 0.5 m vertically. By summer 2017 the base of the scarp had slumped and the backshore had increased in elevation, contributing to the formation of a scarp-fill ramp. By summer 2018 the ramp was still present but erosion had lowered the elevation of both the ramp and the upper beach, ending with an elevation similar to winter 2016. The foredune saw additional scarping in winter 2019. In summer 2019 a burn treatment occurred on the foredune, as is visible in the 2019 photograph.



Bair Transect 17

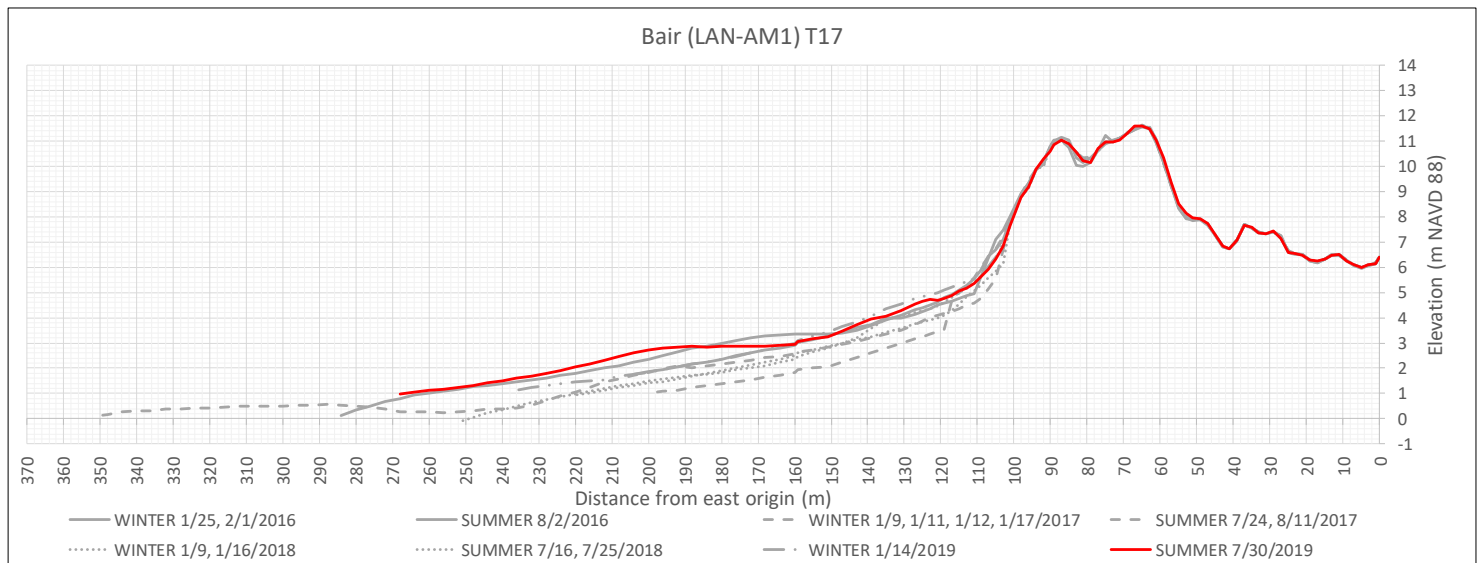


View north at 119 m (left, showing scarp) and 105 m (right, and below showing ramp)

Notes: Significant scarping of the established foredune and lowering of the beach occurred prior to the winter 2016 survey (no incipient foredune was present). By summer 2016 a combination of slumping and ramping had smoothed the foredune slope. By the time of the winter 2017 survey the upper beach had scarped and lowered 1.0 m, and shortly after a large highwater event scarped the foredune back 10 m horizontally. By summer 2017 the beach had accreted 0.5 m vertically, but the ramp was only just reaching the base of the scarp. Therefore, sand transport from the beach to the foredune was limited during this season. Between summer 2017 and summer 2018 the foredune toe had regained elevation and the ramp was fully formed, allowing sand transport from the beach to the foredune. This transect is located in the Lanphere Adaptation Site, where *Ammophila* was removed from the foredune in winter 2016, and native species planted in winter 2017. Post vegetation removal, the first foredune crest deflated approximately .2 m, with sand deposited in the swale between the two foredune crests. As vegetation became



established there was little change in this area from summer 2017 to summer 2018. The foredune base and ramp changed little between 2018 and 2019.



Bair Transect 18

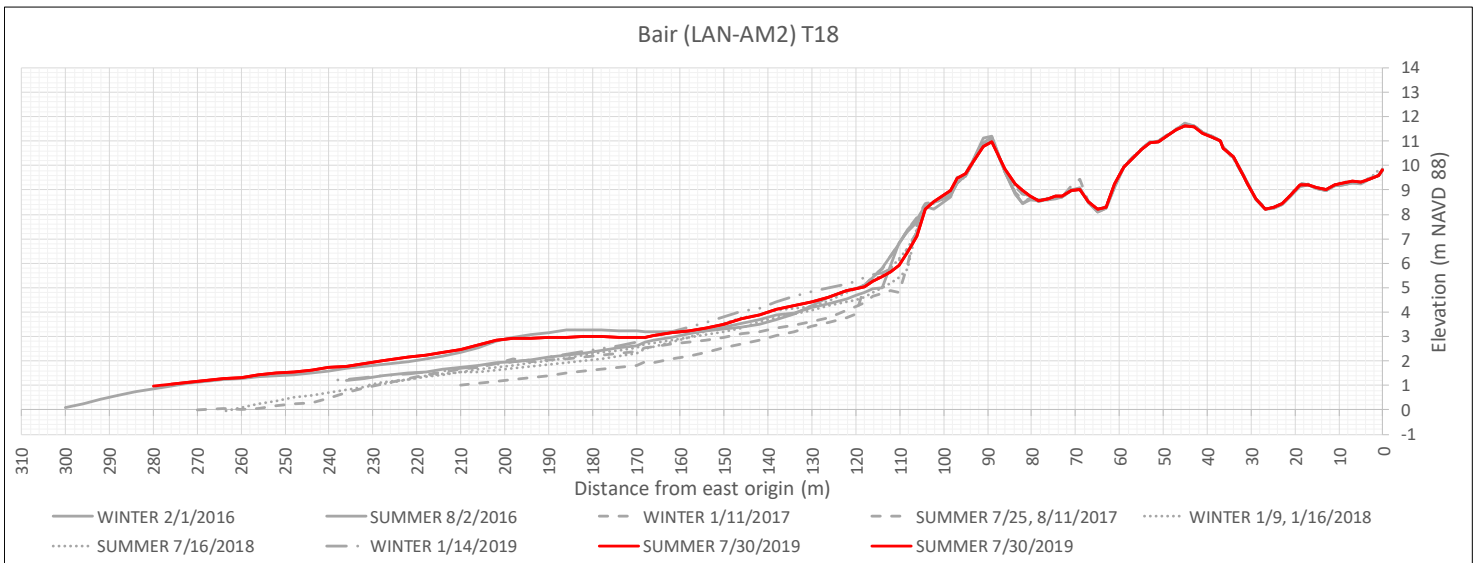


View north at 120 m (left, showing scarp) and 110 m (right, showing ramp)

Notes: Scarping of the established foredune occurred prior to the winter 2016 survey resulting in 1.0 m loss of beach elevation and 10 m horizontal erosion of the lower stoss face of the foredune. By summer 2016 a combination of slumping and ramping had filled the scarp but only slightly raised the upper beach. Prior to the winter 2017 survey the upper beach scarped, losing 1.0 m of elevation. Soon after the winter survey a highwater event caused further erosion, with horizontal loss of 10.0 m and vertical loss of 1.4 m at the base of the foredune. By summer 2017 the beach had accreted 0.6 m vertically, but the ramp was only just reaching the base of the slumping scarp. Therefore, sand transport from the beach to the foredune was limited during this season. Between summer 2017 and summer 2018 the foredune toe had regained elevation and the ramp was fully formed, allowing sand transport from the beach to the foredune. This transect is located in the Lanphere Adaptation Site, where *Ammophila* was removed from the foredune in win-



ter 2016. In summer 2019 the lower stoss face steepened, eroding approximately 1 m in width.

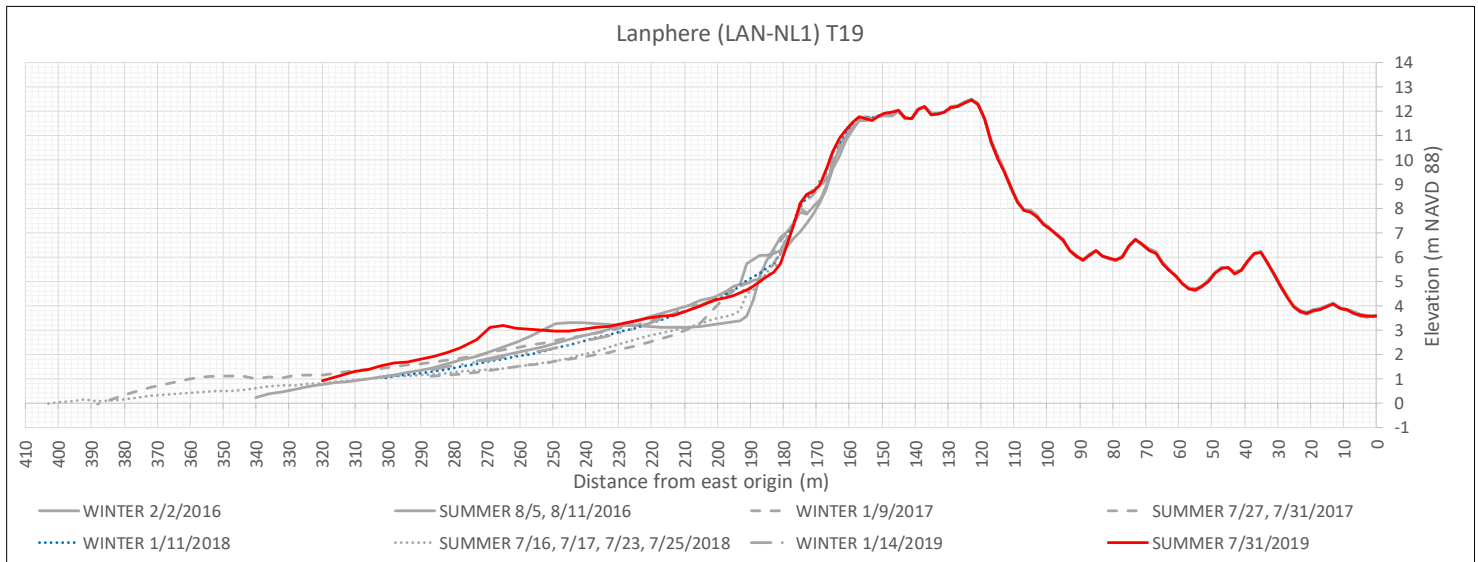


Lanphere Dunes Transect 19



View north at 147 m (foredune crest)

Notes: The profile describes a high, broad foredune vegetated by native species. Significant scarping after the winter 2016 survey shows up in the summer 2016 profile, having removed 2.6 m vertically including the small incipient foredune. By winter 2017 a scarp-fill ramp was forming and the backshore had regained 2.0 m of elevation, although the foreshore had not recovered. However by summer 2017 the ramp was continuous and becoming vegetated and the beach has recovered to winter 2016 elevations. From 2017 to 2018 erosion of the backshore and foredune toe returned this portion of the profile to conditions similar to summer 2016. The crest of the foredune has undergone 0.2 m of deposition during the two year period, visible in the photographs above. However, there was little change to the profile between 2018 and 2019, with its relatively mild winter, although the position of the offshore bar shifted.

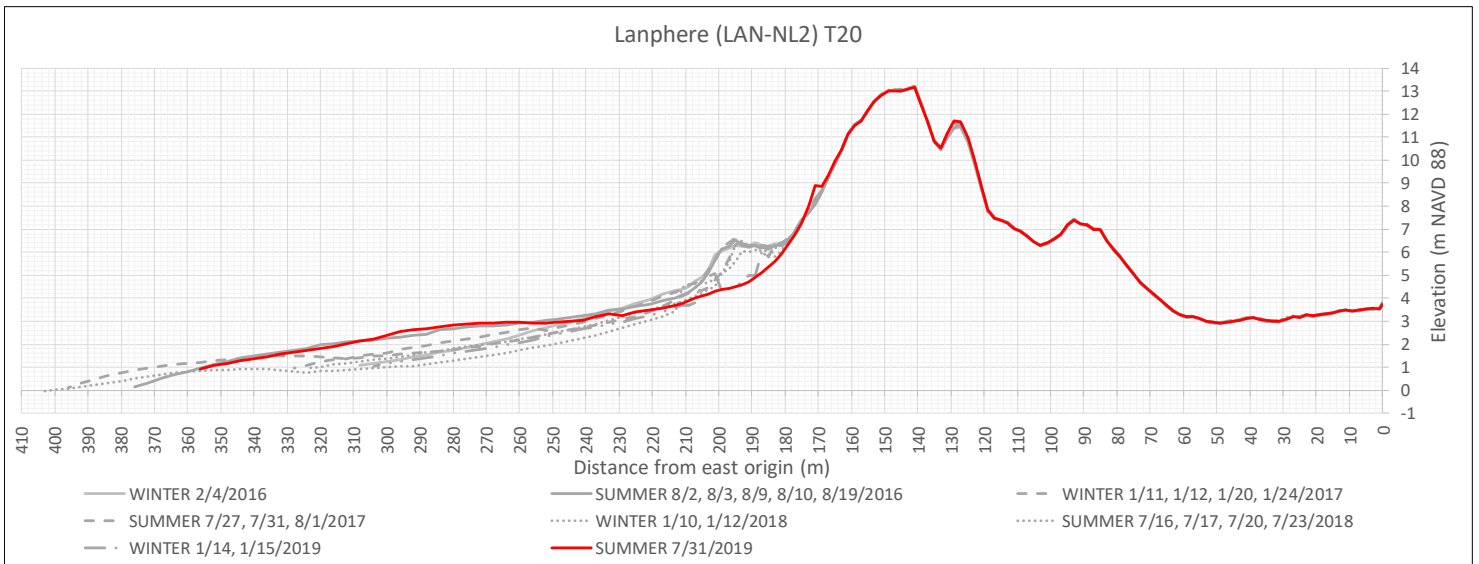


Lanphere Dunes Transect 20



View North at 197 m (foredune crest)

Notes: The established, native, two-peaked foredune was relatively stable over much of the two year period, with minor deposition on the landward peak where the transect crosses the depositional lobe of an old stabilizing blowout. The incipient foredune was scarpd between the winter 2017 and summer 2017 surveys, and continued eroding, with upper beach lowering, through summer 2018. Between winter 2019 and summer 2019 the incipient foredune eroded away completely. At elevation 13.1 NAVD 88, this transect represented one of the highest foredune crests surveyed in the study area.

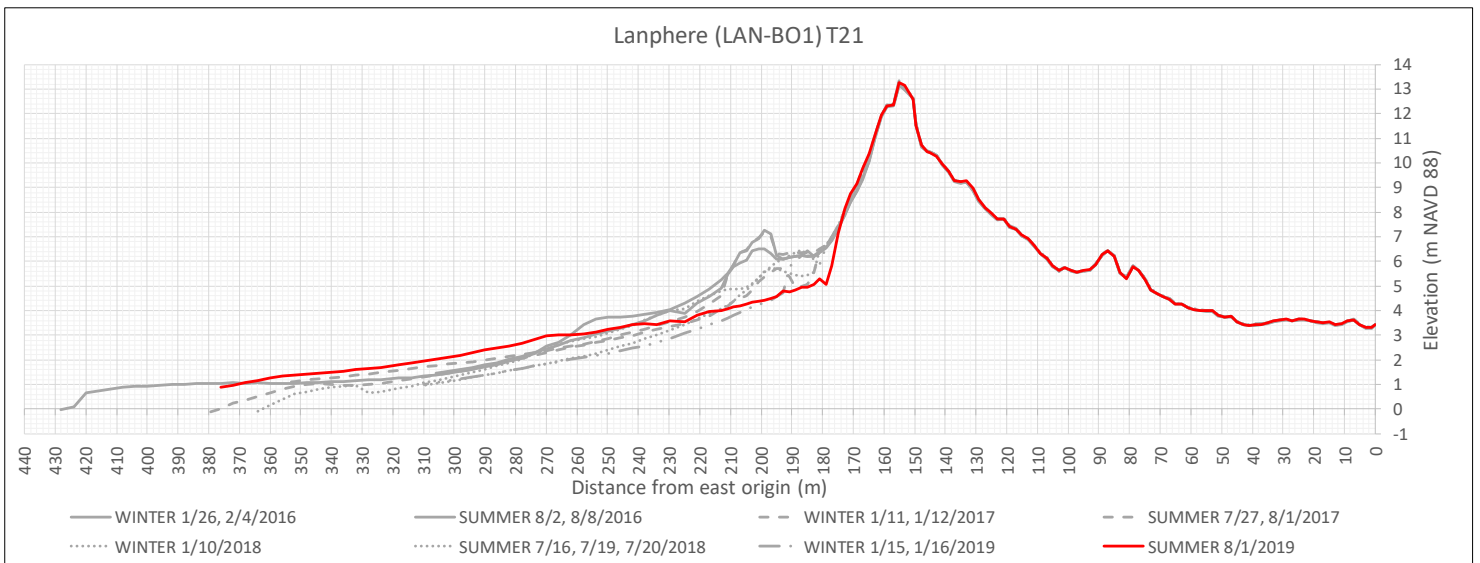


Lanphere Dunes Transect 21



View southeast at 199 m (incipient foredune)

Notes: The transect extends up an old, now-stabilized blowout, causing a peaked foredune topography vegetated with native species. The incipient foredune increased in elevation up to 1.0 m from winter 2016 to summer 2016. Following the winter 2017 survey it was severely scarping, losing up to 2.0 m vertically and 20 m horizontally, as seen in the summer 2017 profile. Post-scarping, by the summer 2017 survey a scarp-fill ramp had formed and by summer 2018 the incipient foredune increased in elevation by 0.8 m (see photos above taken SE along the transect). In winter 2019 the incipient foredune scarping, and between winter and summer 2019 further scarping occurred, removing the incipient foredune completely. The crest of the foredune, at 13.2 m NAVD 88, was the highest crest elevation measured along any of the transects in the study area.

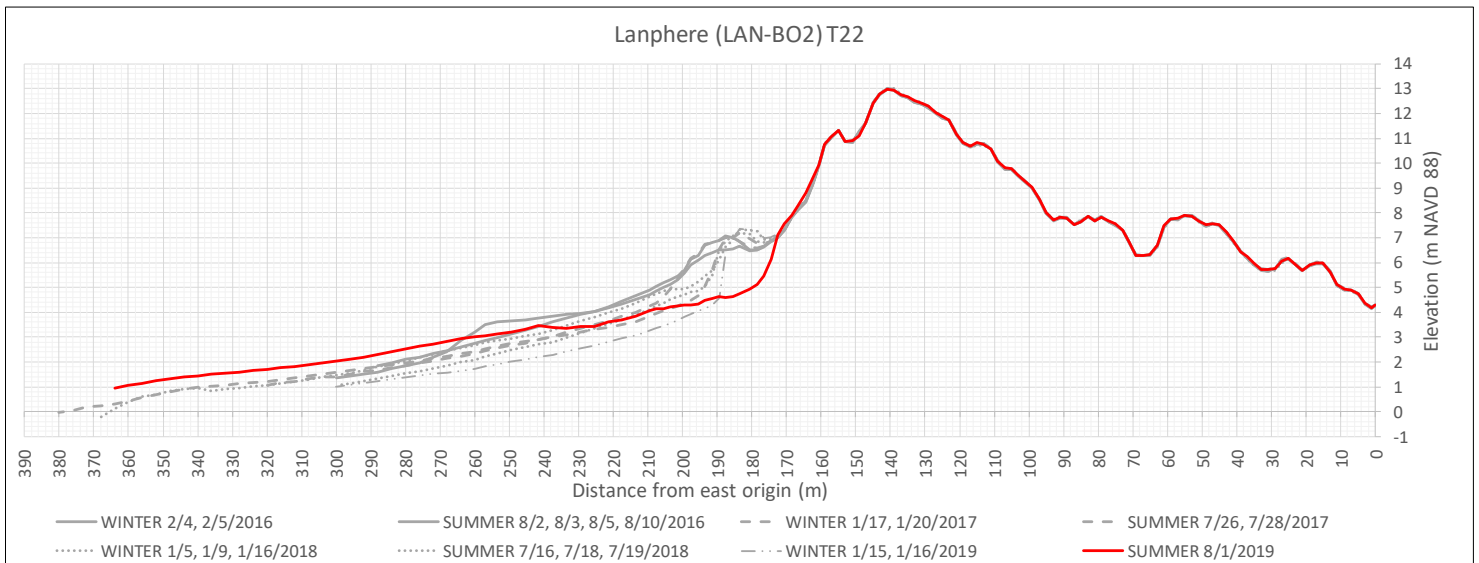


Lanphere Dunes Transect 22



View south at 187 m (incipient foredune)

Notes: The profiles show a high, stable, established foredune with a more dynamic incipient foredune. Vegetation is native. The incipient foredune increased in elevation 0.5 m between winter 2016 and summer 2017, remaining stable until the winter 2017 survey. However, scarping in winter 2017 (after the survey) resulted in narrowing and translation of the incipient foredune inland by summer 2017. By summer 2018 the incipient foredune has begun to weld onto the established foredune (see above photograph taken at base of established foredune). The foredune crest elevation is high, at 13.0 NAVD 88. Between winter 2018 and summer 2019 the incipient foredune scarped and was completely removed.

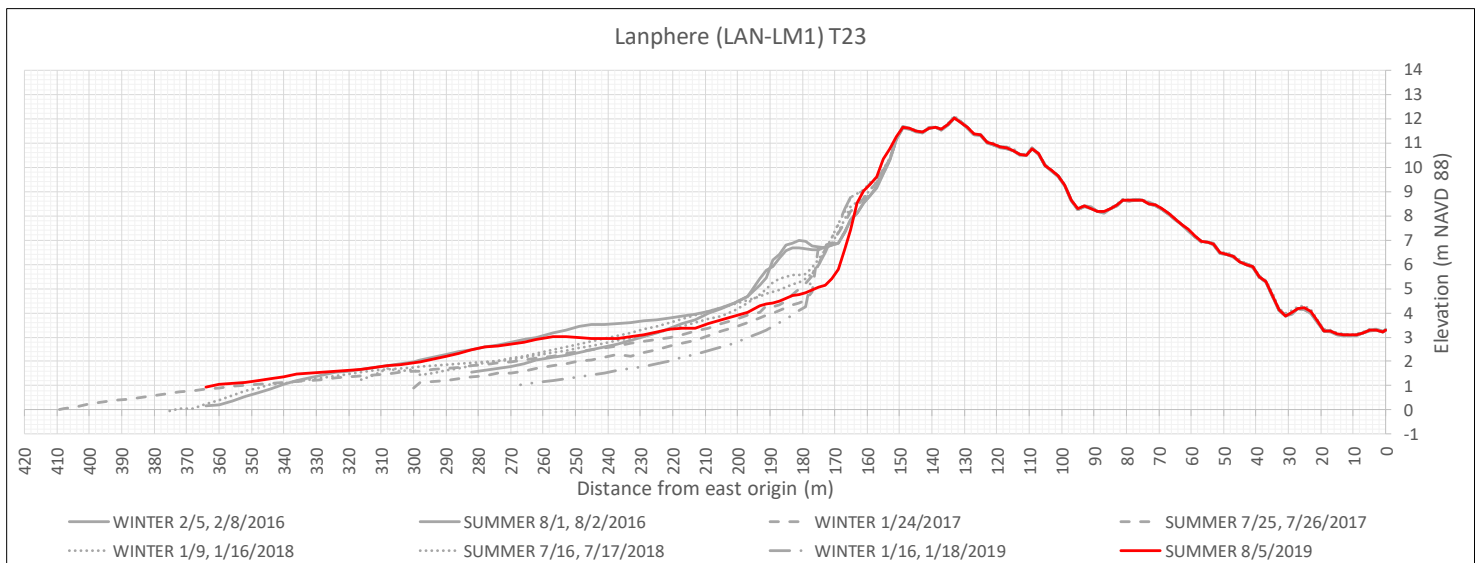


Lanphere Dunes Transect 23



View north at 165 m (foredune base)

Notes: This high (12.0 m NAVD 88), native, established foredune has been stable over the three year monitoring period, with a more dynamic incipient foredune. The incipient foredune was stable for the first year while the beach underwent seasonal changes. In winter 2017, prior to the survey, the incipient foredune was entirely removed through a dramatic 2.0 m vertical scarping event resulted in 20 m of retreat. By summer 2018, the beach had recovered some of its elevation especially on the backshore. Between winter and summer 2019 the established foredune scarped, retreating 8 m at its base.

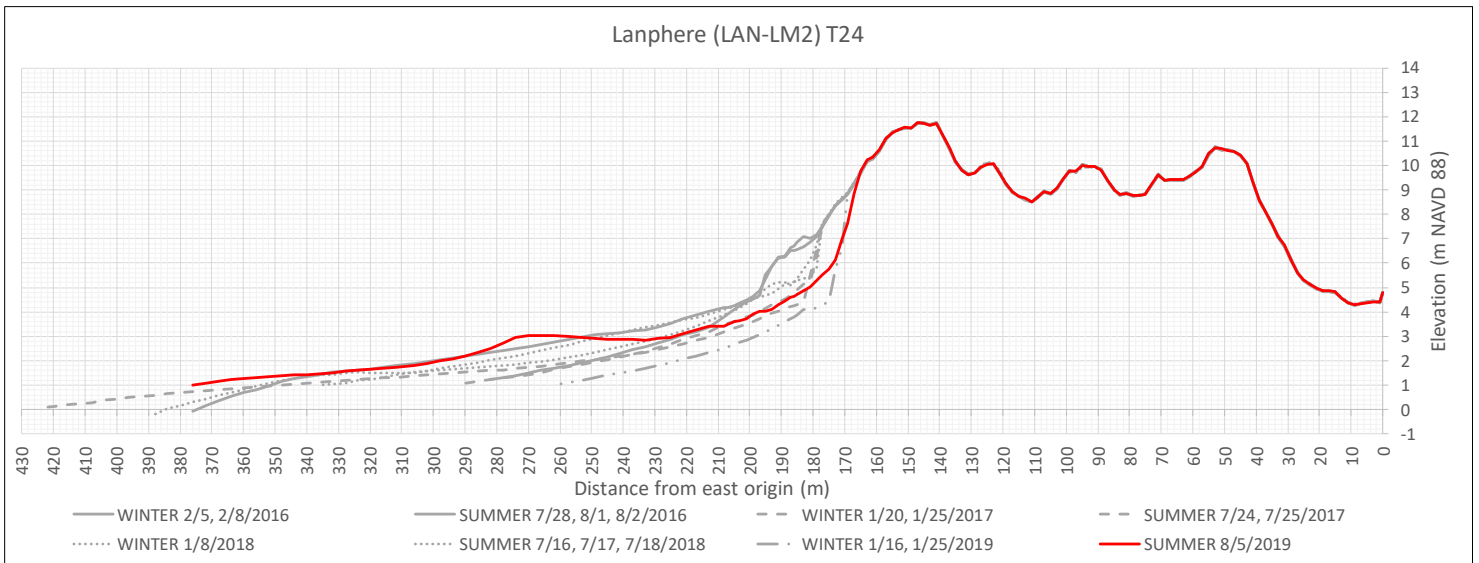


Lanphere Dunes Transect 24



View north at 181 m (foredune base)

Notes: Similar to T23, the broad, native, established foredune has been stable, while the incipient foredune was entirely removed in winter 2017 prior to the survey. High water events led to a 2.0 m vertical elevation loss, and 17 m of retreat. By 2018 ramping had occurred at the base of the foredune (see photo above). In winter 2019 the established foredune scarped back 10 m, although by summer 2019 deposition of +1 m had occurred on the upper beach.

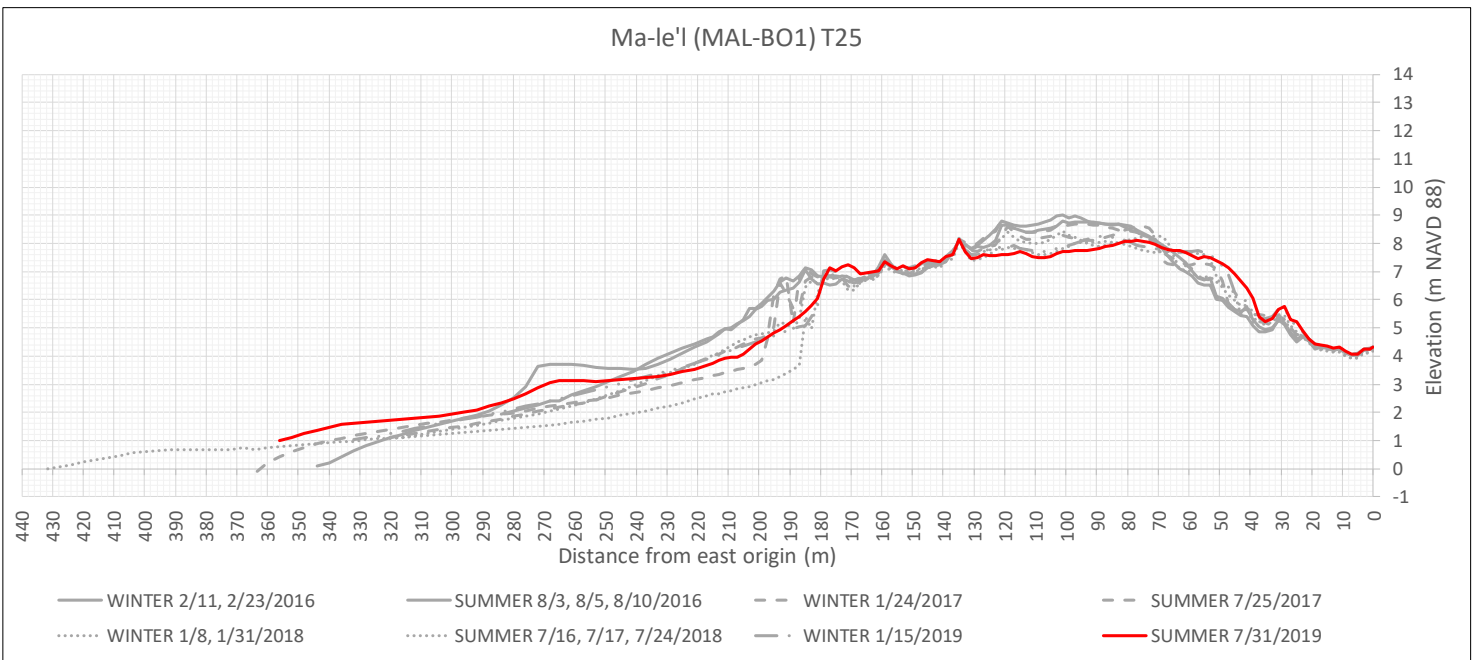


Ma-le'ī North Transect 25



View southeast at 207 m (upper beach)

Notes: The profile describes a sparsely vegetated parabolic dune that recently differentiated from a transgressive dunefield. It is fronted by a developing, native foredune. In winter 2017 the foredune was severely scarp'd with a loss of 1.6 m vertically. Additional scarping and beach lowering occurred by summer 2017 due to the narrow width of beach resulting from a persistent rip current. Some slumping but no ramping of the scarp had occurred by summer. Between the winter 2018 and summer 2018 surveys a high water event eroded the incipient foredune back another 12 m horizontally, removing the cusped edge. The beach was lowered by 0.5 m. Note the low beach and unusually high water line in the summer photo. By summer 2019 deposition on the upper beach and formation of a ramp allowed for some recovery of the developing foredune.

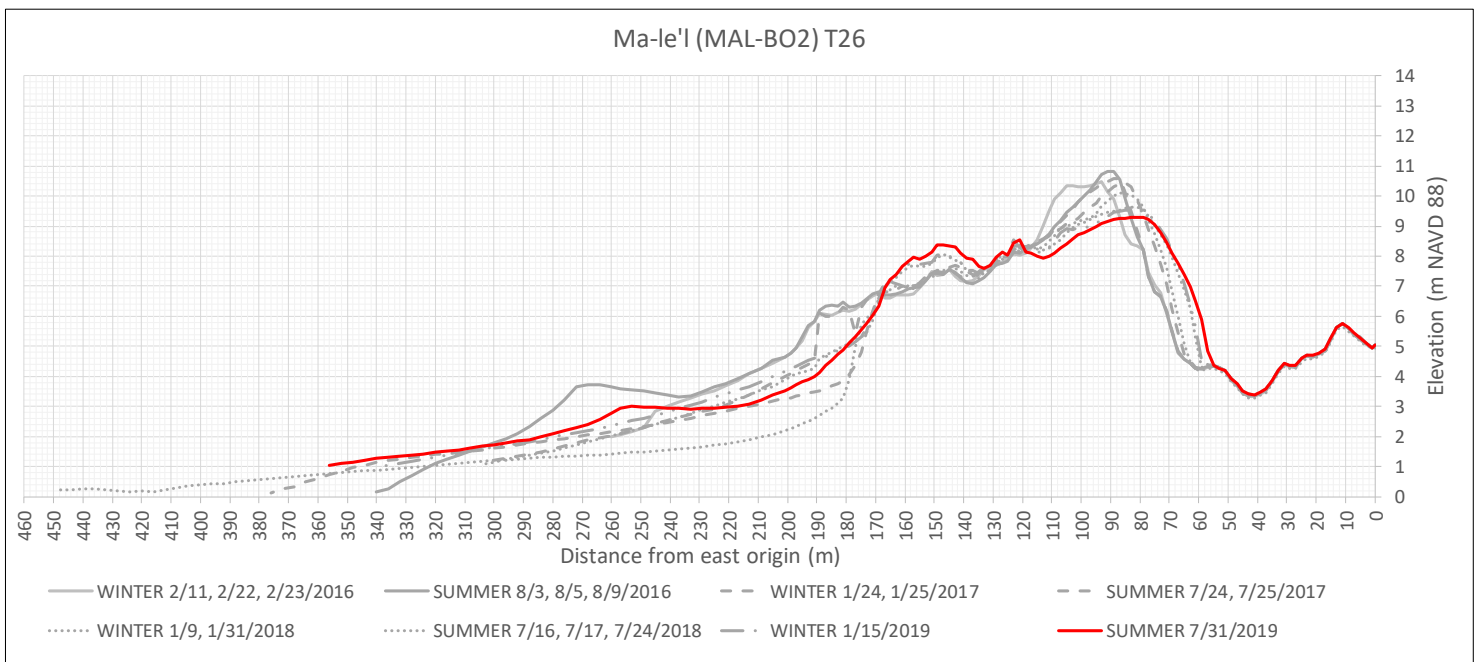


Ma-le'i North Transect 26



View southeast at 191 m (upper beach)

Notes: Adjacent to and similar to Transect 25 although this parabolic dune is shorter and its terminal slipface higher and steeper. In winter 2017 the developing fore-dune was scarped, losing 1.5 m of elevation, and the back-shore was lowered by 0.8 m. By summer 2017 an additional 20 m of retreat had occurred from renewed scarping due to the narrow width of beach resulting from a persistent rip current. Slumping had occurred along with some ramping. Between the winter and summer 2018 surveys the upper beach eroded up to 1.4 m, removing the ramp. In 2019 deposition on the upper beach rebuilt the ramp. At its eastern edge the parabolic dune has translated, with the slipface steepening through winter 2018 as a result of the relatively static position of its base, which was anchored by *Salix* growing in a deflation basin. Between winter 2018 and summer 2019 the base migrated inland 10 m horizontally.

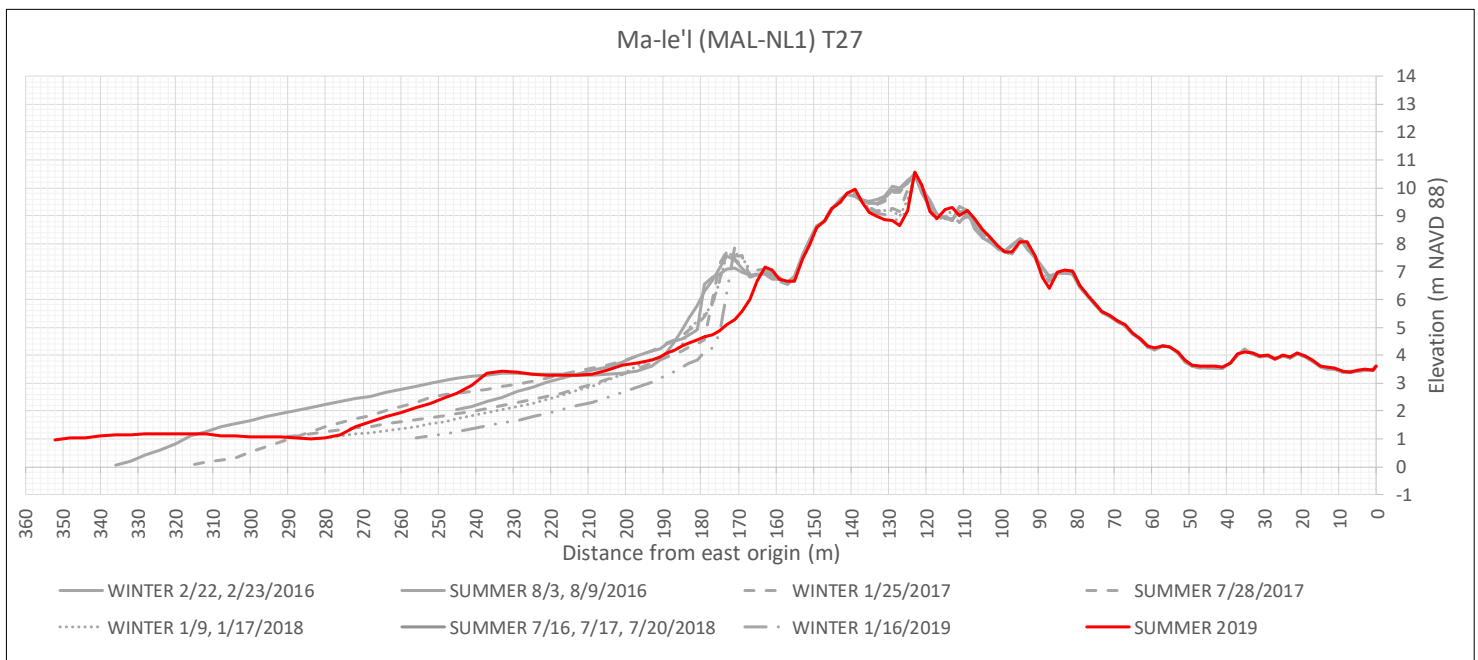


Ma-le'I North Transect 27



View north at 171 m (incipient foredune)

Notes: Scarping of the incipient *Elymus* foredune occurred in winter 2016, followed by scarp-fill ramping in summer 2016. The incipient foredune was then rescarped in winter 2017 during the high water event that emplaced the wood pictured in the photo above. Although little ramping occurred in summer 2017, the upper beach gained in elevation. Scarping resulted in mobilization of sand on the crest of the incipient foredune, similar to the slipfaces that can be seen to the north in the photograph. In 2019 additional scarping of the IFD occurred, leaving only a small IFD.

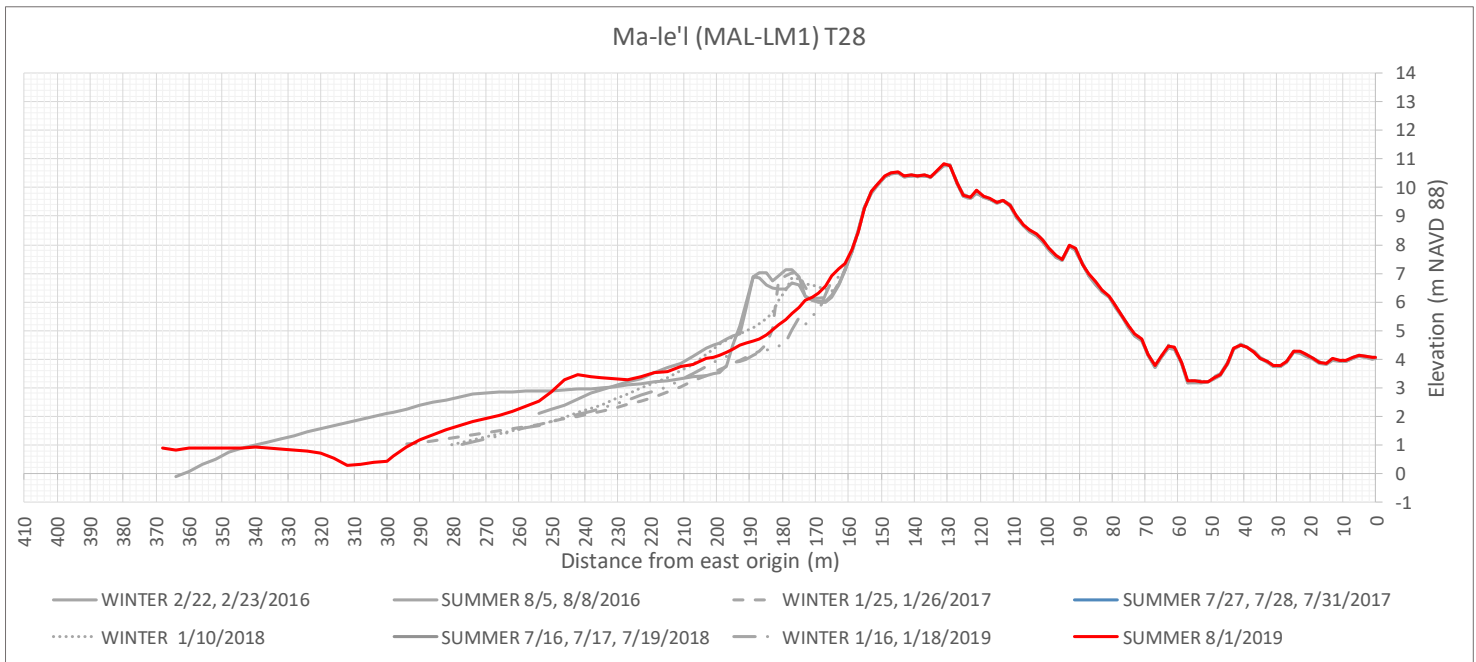


Ma-le'i North Transect 28



View north at 177 m (incipient foredune)

Notes: A 2.0 m vertical scarp occurred in the incipient *Elymus* foredune in winter 2016. By summer 2016 the scarp had increased in height from further erosion and sand at the top of the scarp mobilized, forming a slipface. In winter 2017 the incipient foredune re-scarped, retreating an additional 10 m, and up to 10 m of sediment eroded from the backshore. By summer 2017 the crest of the incipient foredune had migrated inland, de-emphasizing the incipient foredune swale. The beach regained elevation to near the level of summer 2016. Between summer 2017 and summer 2018 the incipient foredune remained relatively unchanged (see photos above). However, in 2019 the incipient foredune was entirely removed.

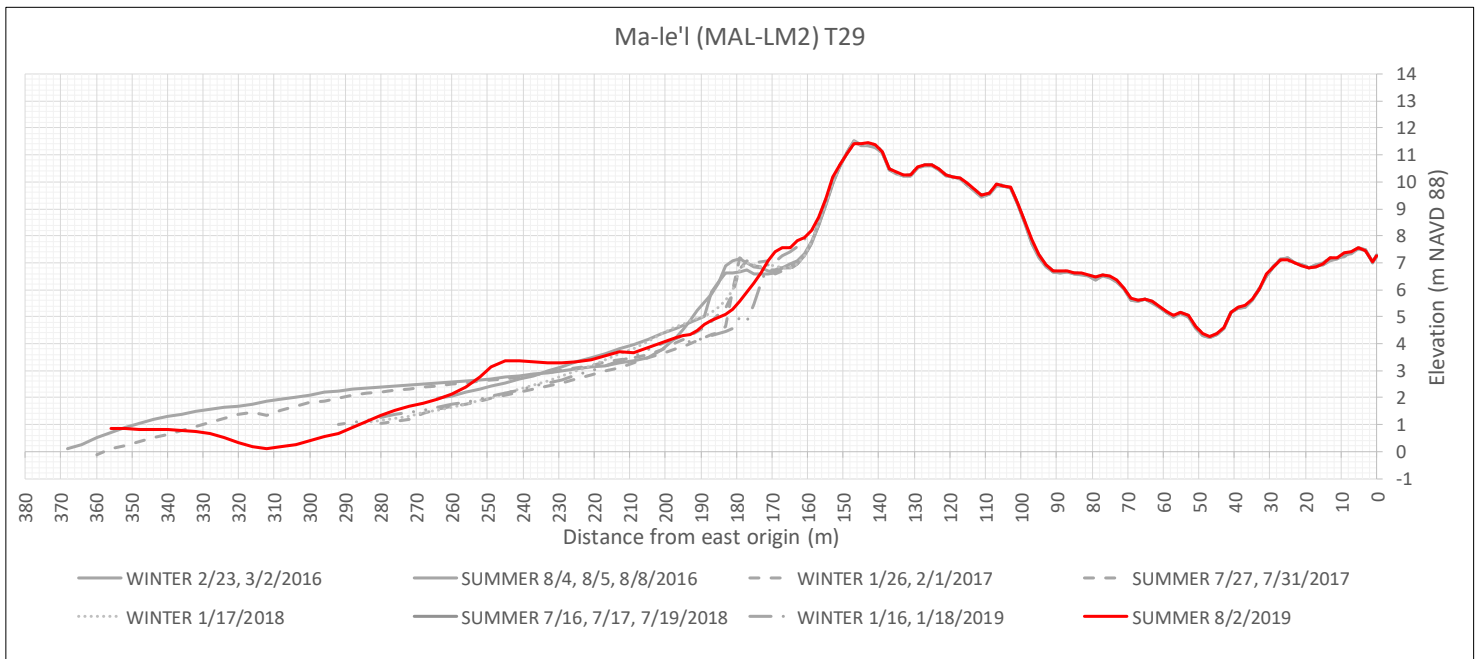


Ma-le'I North Transect 29



View south at 175 m (incipient foredune swale)

Notes: Similar to the previous transect, this profile depicts a stable, native, established foredune and a dynamic incipient foredune. Scarping of the incipient *Elymus* foredune occurred in winter 2016 with additional erosion of the upper beach occurring before the summer 2016 survey, which shows scarp-fill ramp formation. In high water events of winter 2017 the incipient foredune retreated an additional 10 m, leaving a 2.5 m scarp. In summer 2017 the mobilized sand on the incipient foredune crest formed a slipface, and by summer 2018 additional deposition had filled the swale (see photos above). In 2019 the incipient foredune had translated and become incorporated in the established foredune.

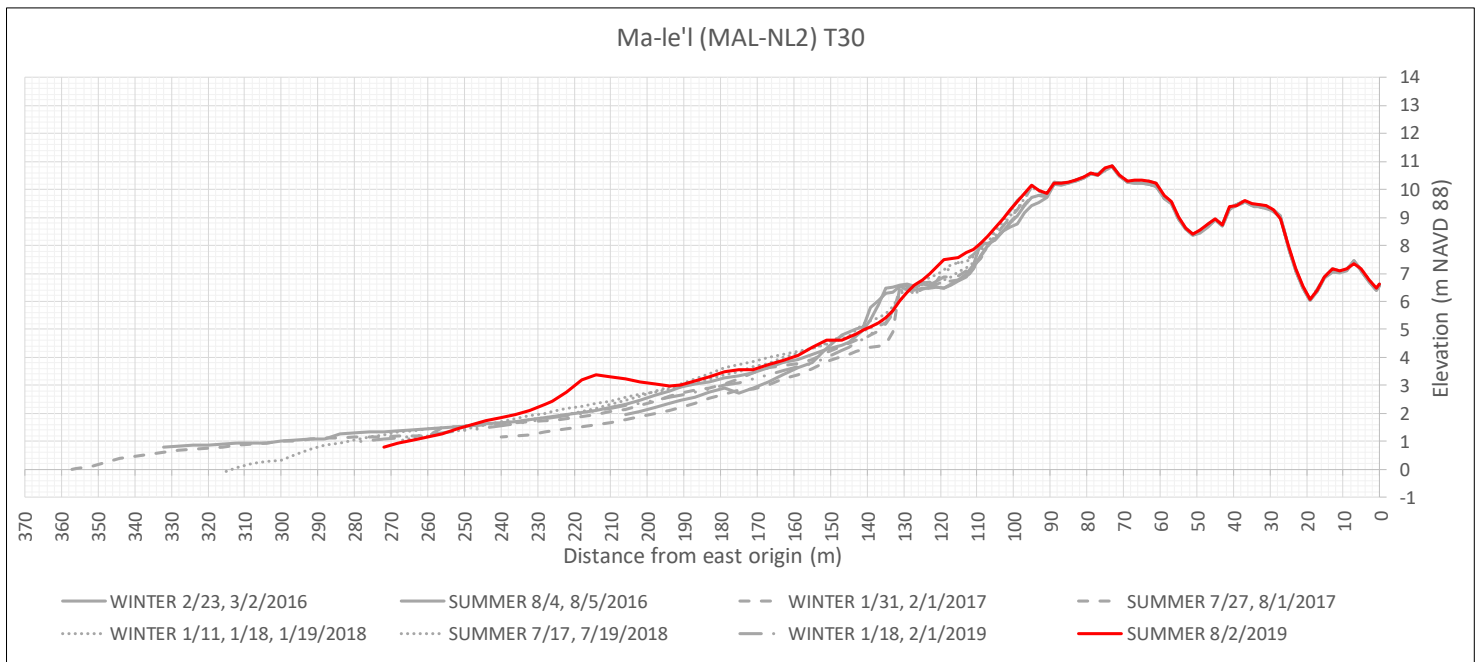


Ma-le'i North Transect 30



View southeast along transect at 147 m showing scarp (left) and ramped foredune (right)

Notes: The incipient *Elymus* foredune scarped dramatically in winter 2017, losing 2.0 m vertically and lowering the fore-shore and backshore. By summer 2017 the beach had regained the lost elevation and the incipient foredune slope was smoothed by erosion and ramping. The small peak at 109 m midway up the stoss face of the established foredune in winter 2016 is the relict of a knoll that eroded during the previous 3 years. The sand from the knoll moved up the face of the established foredune. By summer 2018 the incipient foredune was no longer a distinct feature, having welded on to the stoss face of the established foredune.. By 2019 this feature had migrated up the foredune.

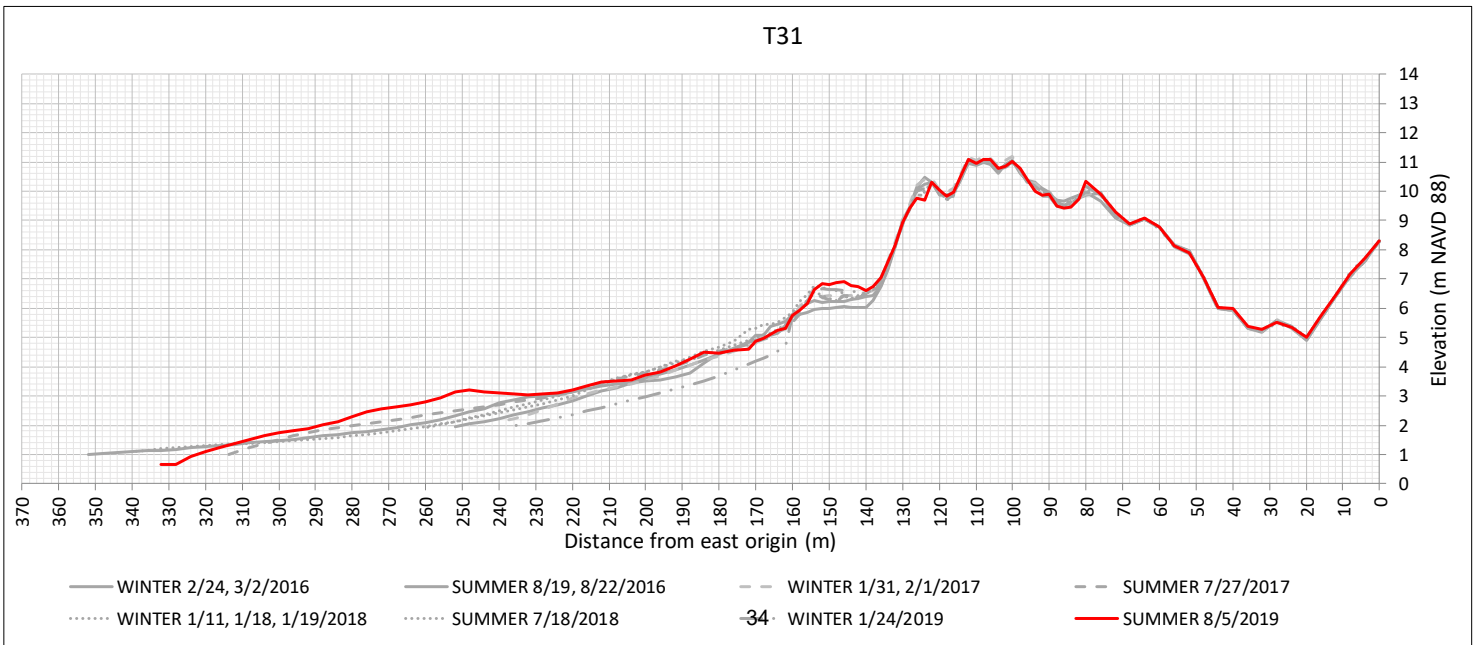


Ma-le'I South Transect 31



View north at 156 m (incipient foredune)

Notes: This stretch of restored shoreline at Ma-le'I South is described by a bench-like incipient *Elymus* foredune below a broad, native established foredune. Between winter 2016 and summer 2016 there was seasonal deposition on the upper beach and incipient foredune and minor erosion at the established foredune crest. In winter 2017 the incipient foredune was slightly scarped, leading to deposition and slipface formation on the crest. The profile changed little by the following summer other than 0.2 m deposition on the beach. By summer 2018 deposition had raised the incipient foredune crest, forming more of a swale between the incipient foredune and established foredune. In summer 2019 the incipient foredune continued to build. Relative to transects to the north, the beach and incipient foredune volumes have not varied widely over the three years of surveys.

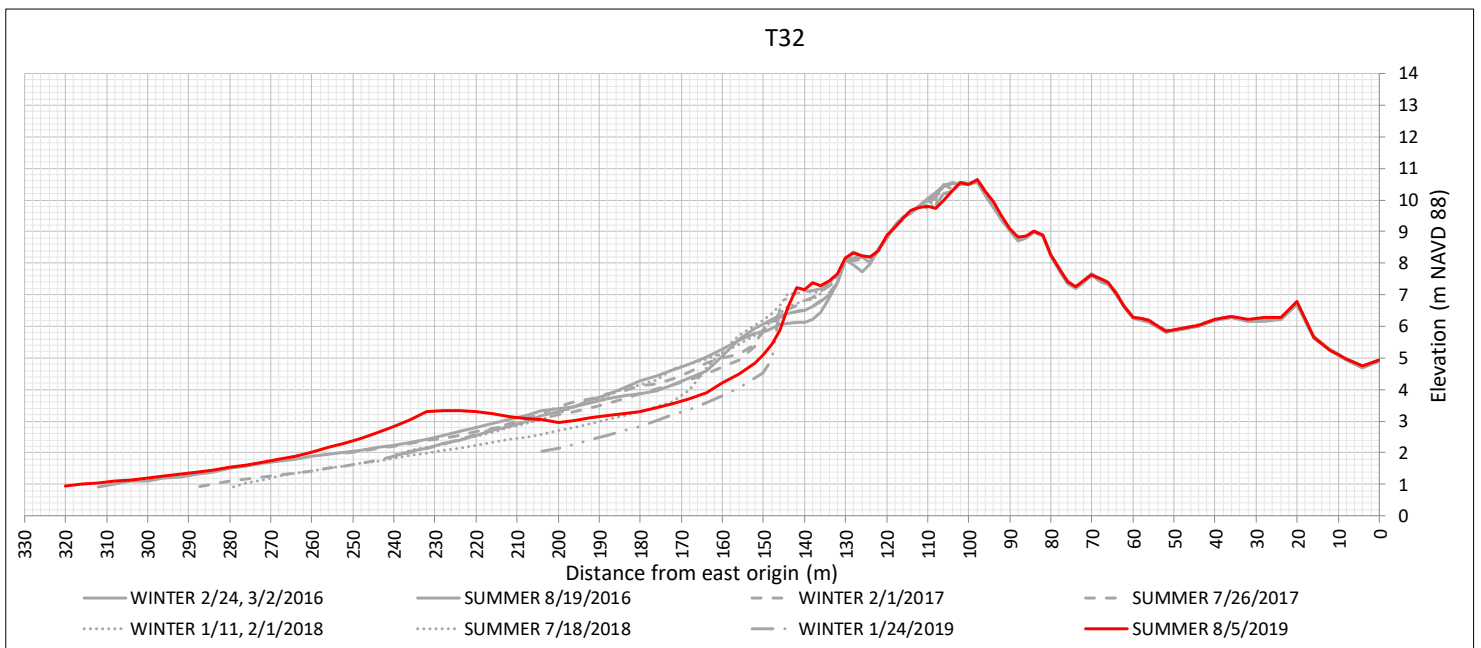


Ma-le'i South Transect 32



View north at 144 m (incipient foredune)

Notes: The broad, bench-like incipient foredune (similar to the previous transect) was scarped in winter 2016 and a steep beach slope resulted. In summer 2016 mobilized sand at the crest of the incipient foredune migrated into the incipient foredune swale and there was 0.5 m of deposition as the result of scarp-fill ramping. In winter 2017 the upper beach scarped and eroded. By summer 2017 sand had filled the scarp and deposition occurred on the incipient foredune. Additional deposition on the incipient foredune occurred by summer 2018, although erosion occurred on the upper beach. In 2019 the incipient foredune and upper beach were substantially scarped, as is visible in the photo at right



Ma-le'i South Transect 33

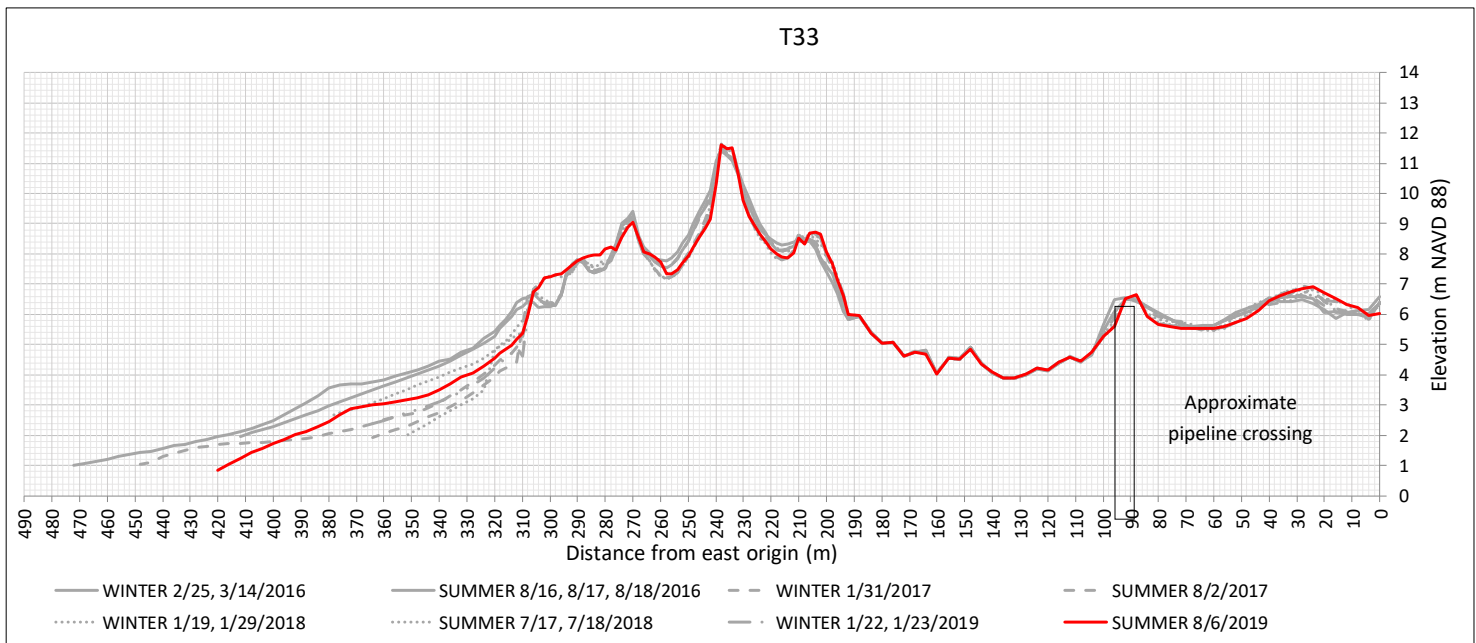


View north at 306 m (incipient foredune)

Notes: A 2.0 m vertical scarp formed in the incipient *Elymus* foredune during high water events in winter 2017. By summer 2017 0.4 m deposition occurred on the upper beach, but the vertical scarp remained, although sediment was mobilized on its crest. By summer 2018 a scarp-fill ramp had formed and sediment had translated inland and filled the incipient foredune swale (see photos above). The established native foredune is eroded into hummocks and erosion occurred in the blowout between the peaks at 230 and 270 m. In 2019 the upperbeach was eroded and the troughs were filled. This profile extends further inland than most in order to capture the Humboldt Bay Municipal Water District pipelines in an area that has been vulnerable to erosion and exposure in the past. This area is actively managed, with sand deposited over an exposed portion of the pipeline in 2015. Eastward translation of the sand



placed over the pipeline suggests future vulnerability. Note that the profile to the immediate west of the pipeline is stable, and the migration of the dunes at and east of the pipeline is unconnected to processes at the beach and foredune.

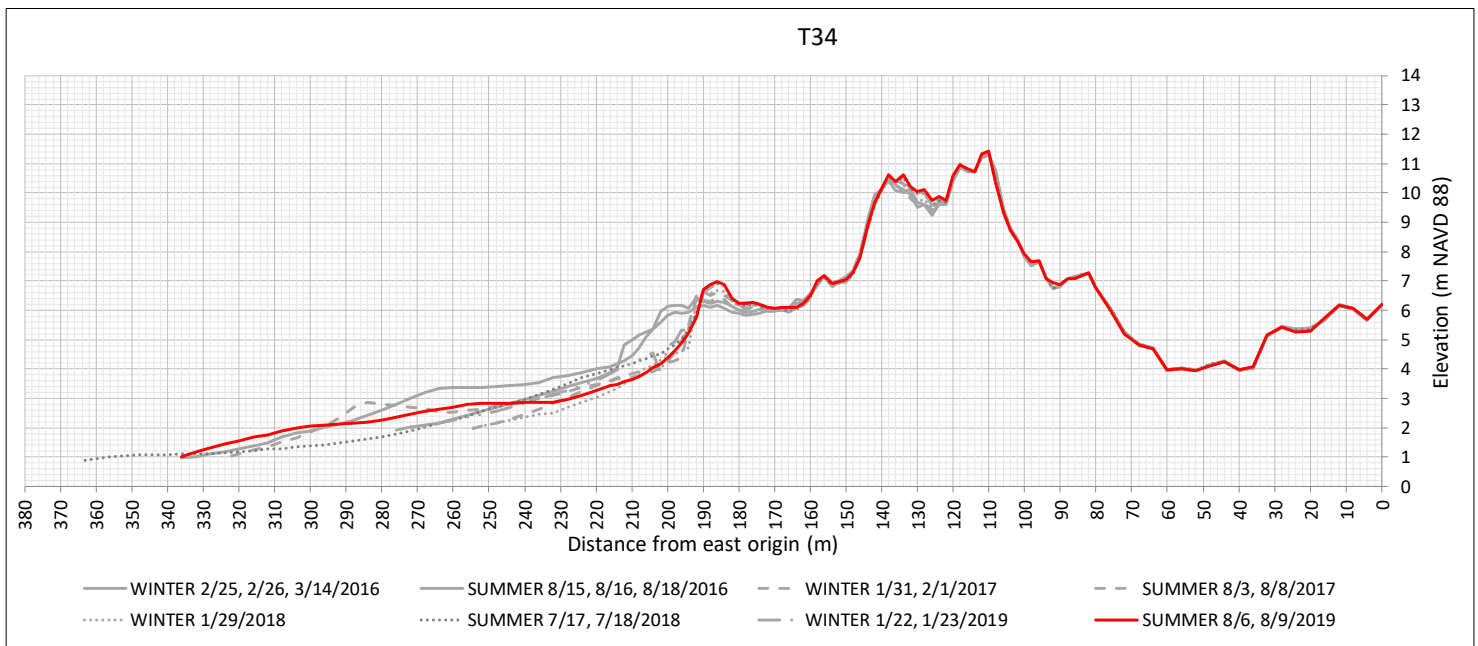


Ma-le'i South Transect 34



View north at 184 m (incipient foredune)

Notes: The original profile describes a broad, flat incipient foredune fronting a two-peaked established foredune. The incipient foredune was scarped prior to the winter 2017 survey and by summer deposition had occurred on the backshore, a scarp-fill ramp had formed, and the crest of the incipient foredune had eroded, creating a gradual slope from the upper beach. High water events in winter 2017 created a 1.8 m scarp in the incipient foredune, which retreated horizontally 12.0 m. The beach was lowered from 1.0-1.5 m. By summer 2018 a scarp-fill ramp had formed and the incipient foredune crest had increased in elevation. There was very little change in 2019.

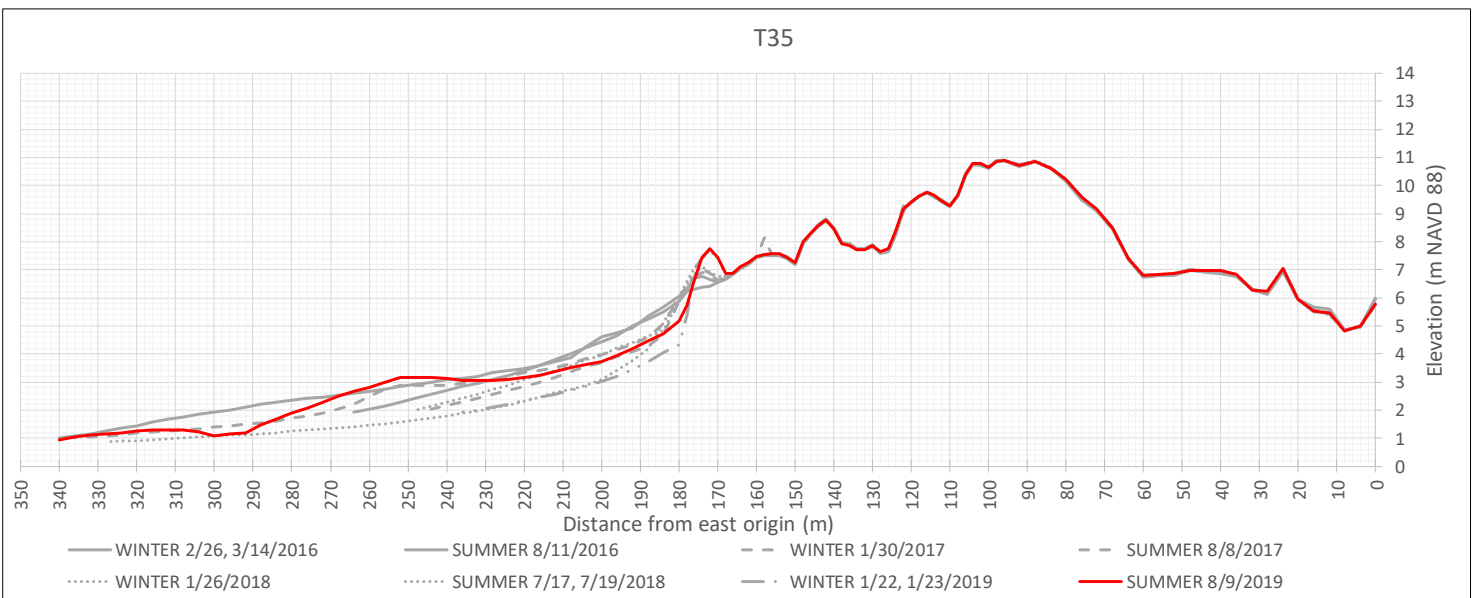


Ma-le'i South Transect 35



View southeast along transect from upper beach at 196 m

Notes: Through summer 2016 a wide, hummocky incipient foredune sloped gradually from the upper beach to the established foredune. In winter 2017 high water events carved a 1.2 m scarp, creating a more defined incipient foredune. The beach was lowered by 1.0 m and the incipient foredune retreated 15 m. Sand was mobilized on the crest of the incipient foredune, forming a slipface that partially buried *Elymus*. During winter 2018 the incipient foredune rescarped, and between the winter and summer 2018 surveys, additional beach erosion lowered the upper beach by 1.0 m, however a scarp fill ramp had formed (see photos above) and 0.5 m deposition occurred on the crest of the incipient foredune by summer 2018. By summer 2019 the incipient foredune had translated inland and increased in elevation.

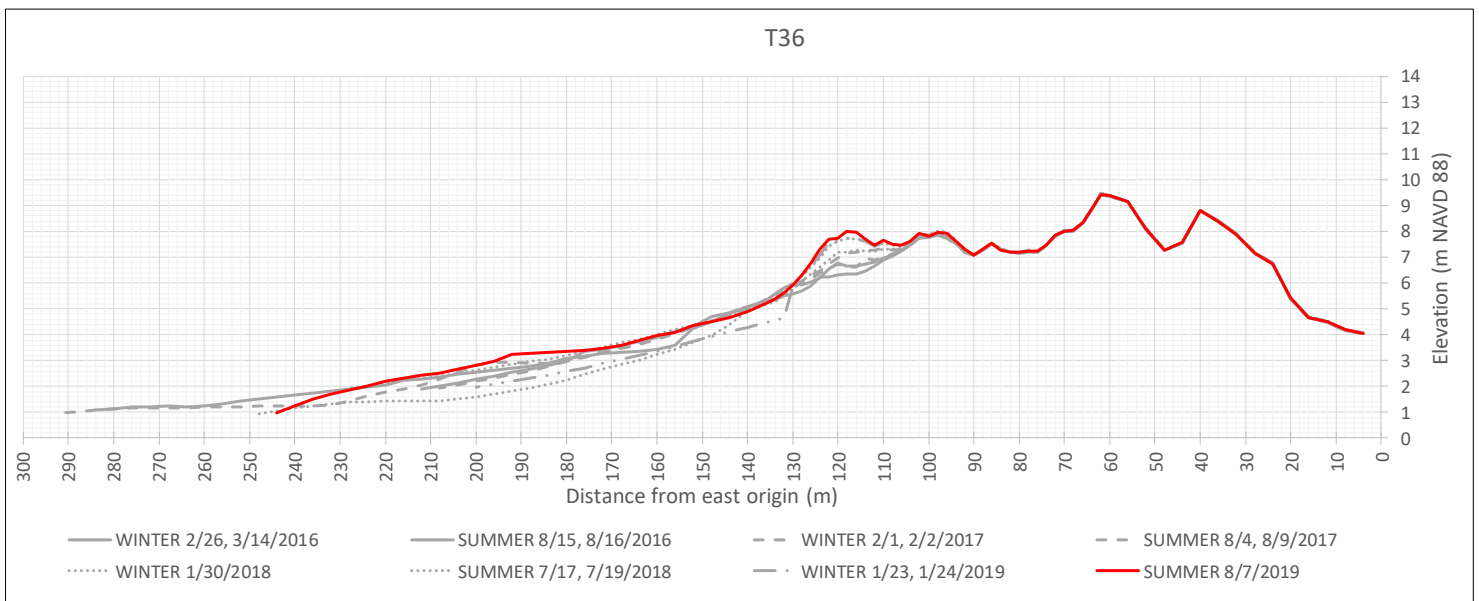


Ma-le'i South Transect 36



View northwest at 104 m (incipient foredune)

Notes: A wide, hummocky incipient foredune sloped gradually from the upper beach to the established foredune from winter 2016 through summer 2016. The beach remained relatively stable. In summer 2017 the incipient foredune built seaward, with 0.2 m of deposition at its western edge, which is visible in the rear of the left photograph taken from the crest of the incipient foredune looking northwest along the transect. There was little change during winter 2018, and in summer 2018 the incipient foredune had an additional .5 m of deposition (see photo on right), while the upper beach was eroded an equivalent amount. There was little change in 2019.

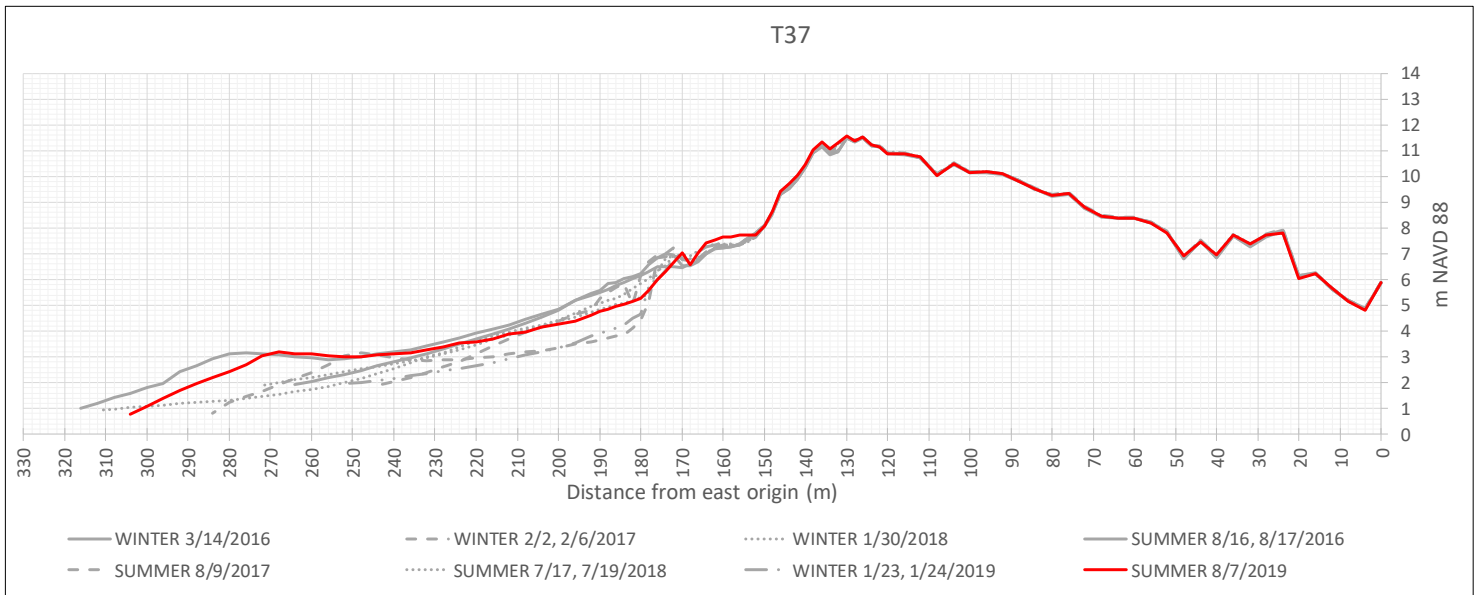


Ma-le'i South Transect 37



View southeast along transect from upper beach at 208 m

Notes: The broad, native established foredune at this site sloped gradually to the backshore in winter 2016, and in summer 2016 an incipient foredune formed with the deposition of 0.5 m on the backshore. The incipient foredune was then eroded during winter 2017 leaving a 1.0 m scarp and the loss of 0.5 m of upper beach. The deep incision in the profile is caused by the oblique transect crossing two sides of an eroded cusp in the incipient foredune. Additional scarping and beach lowering occurred after the survey during winter 2017. This shows up in the summer 2017 profile as a 3.0 m scarp and 12.0 m of horizontal retreat. The beach remained low during the summer, with high tides in August reaching the bottom of the scarp. However, by summer 2018 a scarp fill ramp had formed and over 1 m of deposition occurred on the upper beach, returning the profile to a condition similar to 2016. In 2019 the incipient foredune increased 0.3 m in elevation, translating inland.

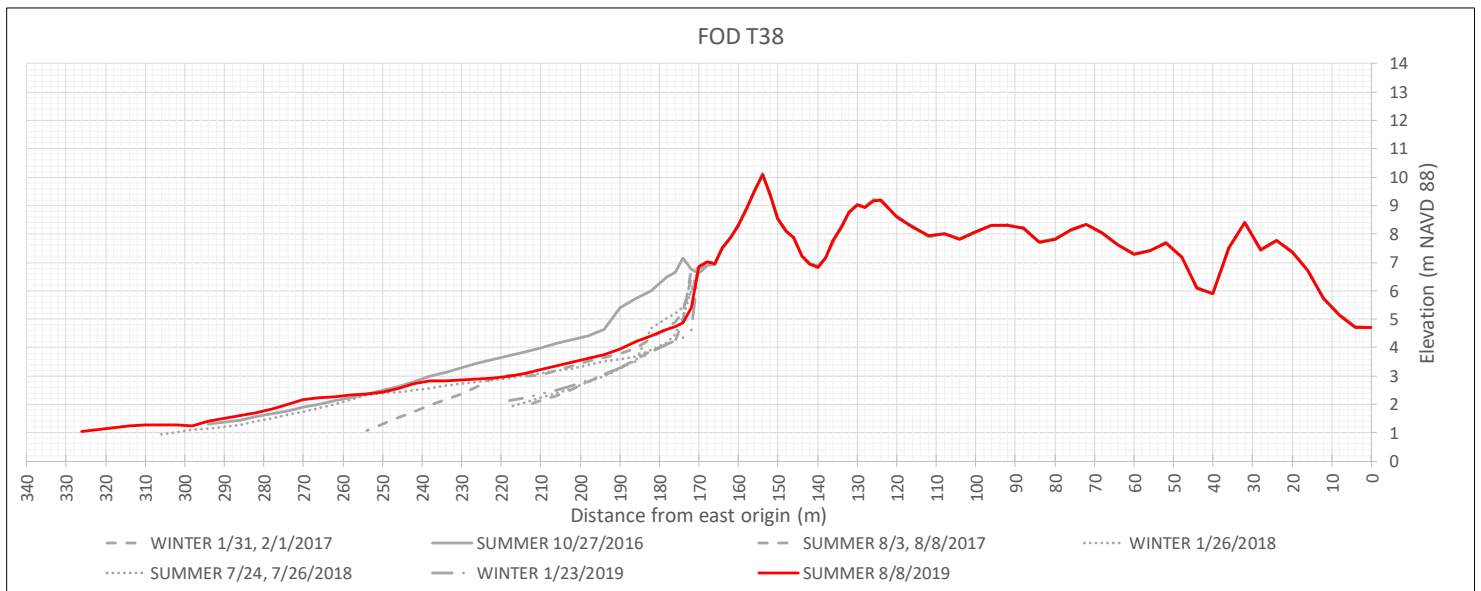


Friends of the Dunes Transect 38



View southeast along transect at 180 m from upper beach showing incipient foredune

Notes: The profile describes a stable, peaked *Ammophila* foredune seaward of an older, formerly native foredune, with a dynamic incipient foredune. Data are not available for winter 2016 but summer 2016 shows a well developed incipient *Ammophila* foredune that was significantly scarped (2.0 m elevation loss and 20 m horizontal retreat) in winter 2017, effectively removing the incipient foredune. Beach deposition occurred in summer 2017 but no scarp-fill ramping occurred, just minor slumping. By summer 2018 a loss of 0.5 m vertically had occurred on the upper beach at the toe of the incipient foredune (see photos above). Additional erosion of the upper beach occurred in 2019.

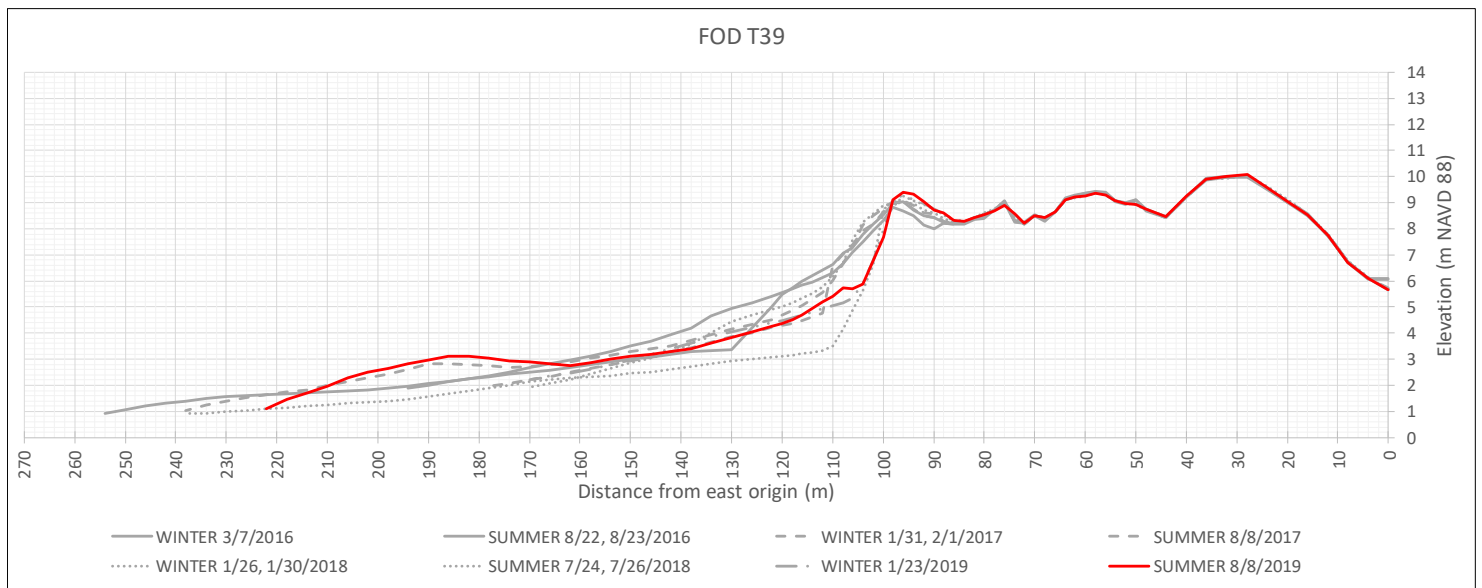


Friends of the Dunes Transect 39



View southeast along transect at 114 m (upper beach) with view of scarped established foredune

Notes: The profile extends through a manual restoration area, although *Ammophila* was not removed on the outer incipient foredune until October 2017. Scarping of the upper beach occurred at some point between the winter 2016 and summer 2016 surveys, allowing the mobilization of sand in the summer such that deposition of 0.1-0.3 m occurred on the incipient foredune stoss, crest and lee faces. In winter 2017 the upper beach again underwent significant lowering and scarping (1.6 m elevation loss, 30 m horizontal retreat along the transect). Deposition on the beach, slumping of the scarp, and scarp-fill ramping occurred in summer 2017, creating a smoothly sloping upper beach (see photograph for view looking inland along transect from upper beach). Between the winter and summer 2018 surveys, the established foredune was scarped, with the stoss face retreating up to 10 m midway up the stoss face (see photos above). A scarp fill ramp was partially built during winter and summer 2019.

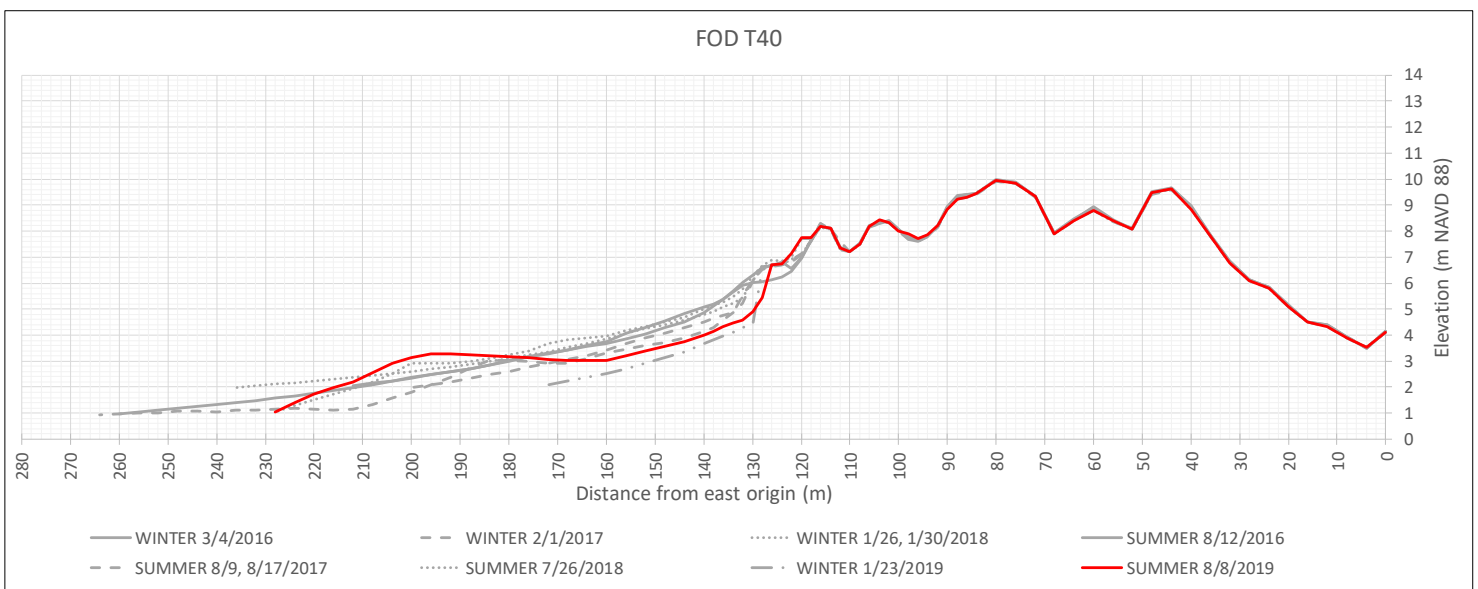


Friends of the Dunes Transect 40



View southeast at 134 m showing incipient foredune

Notes: The profile depicts multiple incipient and established foredunes built by *Ammophila*, although the area behind the first persistent incipient foredune (crest at 115 m) has undergone *Ammophila* removal. Between winter 2016 and summer 2016 deposition of 0.5 m occurred on the upper beach, creating a new sparsely vegetated *Ammophila* incipient foredune (crest at 125 m). This incipient foredune was then scarp-ed in winter 2017 and the beach eroded, emphasizing the incipient foredune topography although its crest elevation was unchanged. Some slumping had occurred by summer 2017 (see left photograph above looking inland along transect from base of scarp) but the incipient foredune profile did not change. By summer 2018 a scarp-fill ramp had formed (right photo above). The feature was again scarp-ed in winter 2019, with some recovery in summer 2019.

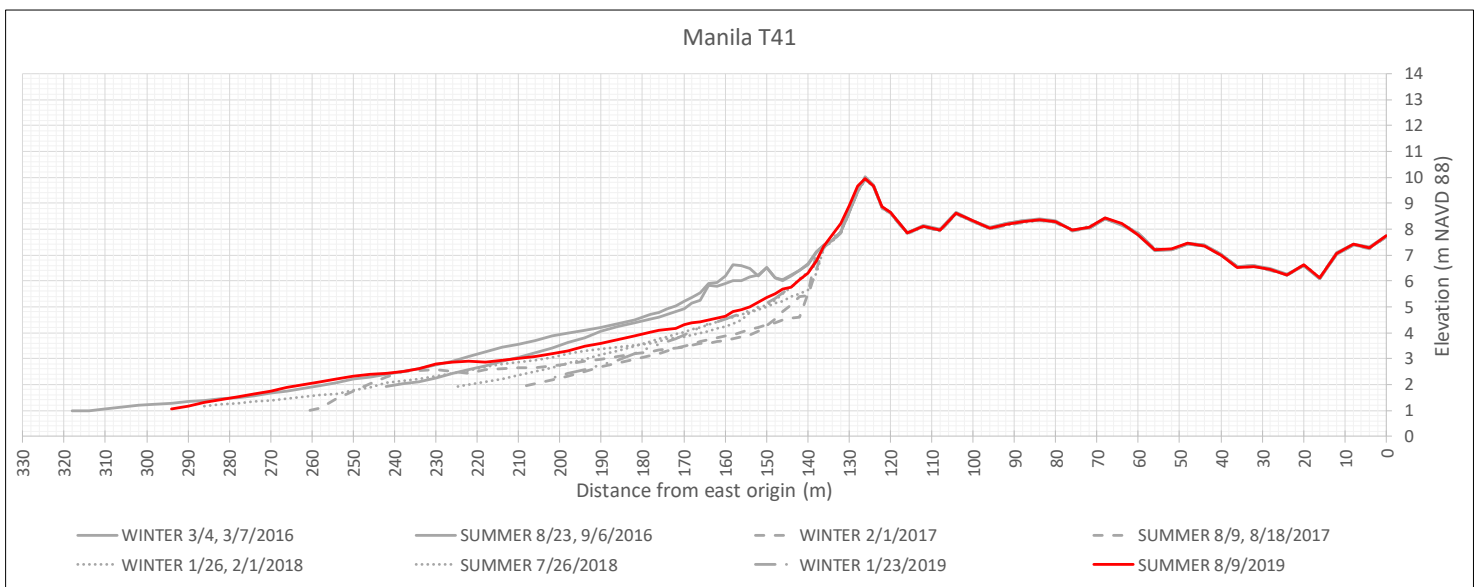


MCSD Transect 41



View southeast along transect at 152 m, showing incipient foredune from upper beach.

Notes: The transect is located in an unrestored portion of property owned by the Manila Community Services District. The profile depicts a dynamic incipient foredune and a stable peaked *Ammophila* foredune fronting a backdune area stabilized by *Ammophila* and *Carpobrotus*. The incipient *Ammophila* foredune saw deposition of up to 0.6 m between winter and summer 2016. It was then almost entirely scarped in winter 2017 (loss of 2.4 m vertically and 24 m horizontally). By summer 2017 there was minimal recovery, although some upper beach deposition occurred, as can be seen in the photograph at left above, taken at the upper-beach looking southeast. Between winter 2018 and summer 2018 a scarp fill ramp formed, with deposition of up to 0.7 m on the upper beach. By summer 2019 vegetation was colonizing the upper beach (photo right).

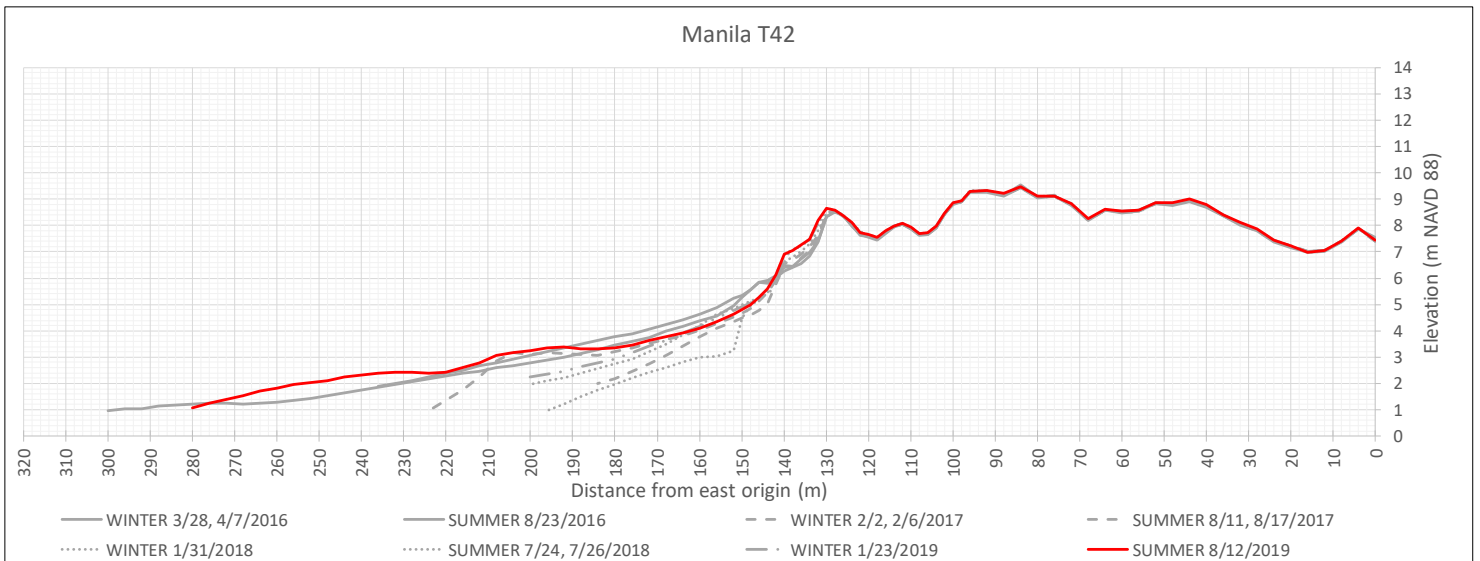


MCS D Transect 42



View southeast along transect at 156 m (upper beach) showing beach

Notes: The transect is located in the Manila Dunes Recreation Area. The area was restored in the 1990s-2000s, but was not maintained, and *Ammophila* has reinvaded the foredune zone. An incipient foredune was forming in summer 2016, but was scarped in the high water events of winter 2017, losing 1 m vertically and retreating 10 m horizontally along the oblique transect. While scarp-fill ramping smoothed the upper beach profile by summer 2017, elevation of the upper beach was still 0.8 m below the previous year's elevation and the incipient foredune had not rebuilt. Between winter and summer 2018 surveys the lower beach scarped dramatically, resulting in the loss of up to 1.0 m elevation (see photos above). By summer 2019 a new scarp fill ramp had established (see photo at right).

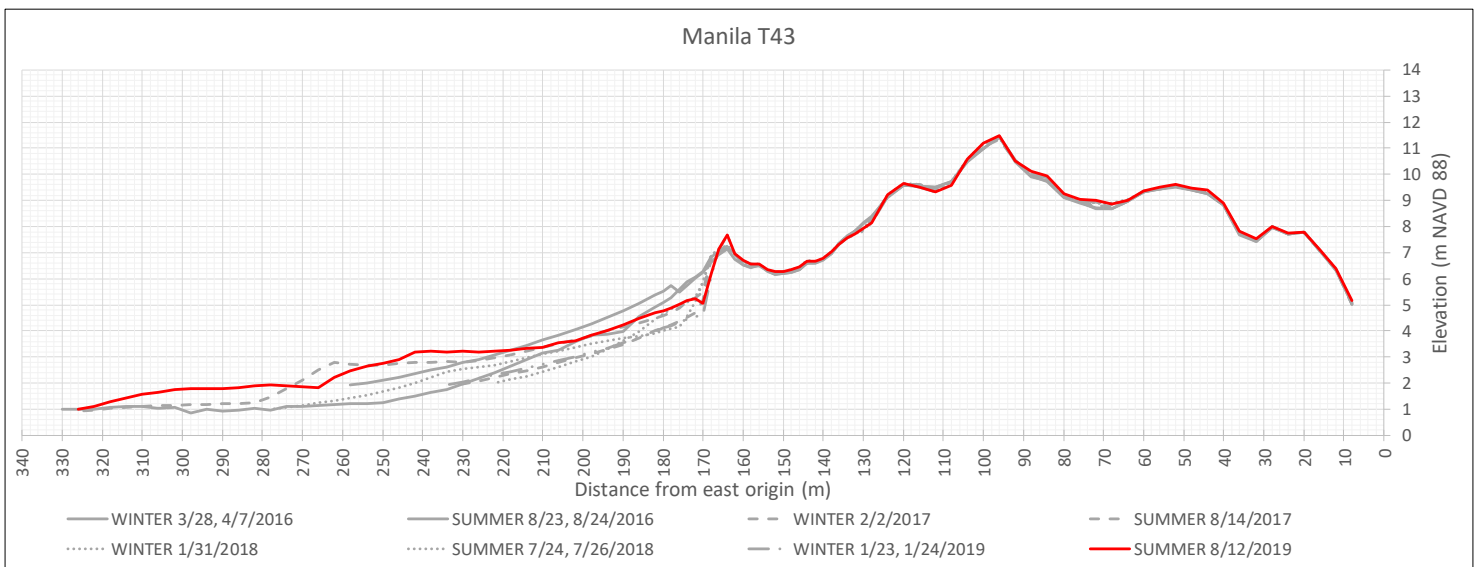


MCS D Transect 43



View north at 172m of foredune base

Notes: The transect is located in the Manila Dunes Recreation Area. The area was restored in the 1990s-2000s, but was not maintained, and *Ammophila* has reinvaded the foredune zone. The profile describes a dynamic incipient *Ammophila* foredune, behind which a formerly erosional area slopes up to a now stable (per the three year monitoring period), native, established foredune. The incipient *Ammophila* foredune was scarped 1.4 m vertically in winter 2017, retreating 16 m along the transect. By the summer 2017 survey, a scarp-fill ramp had formed and partially filled the scarp (photo upper left). Between the winter 2018 and summer 2018 surveys the ramp was eroded and the beach lowered, By summer 2019 a scarp fill ramp had reformed (photo right).

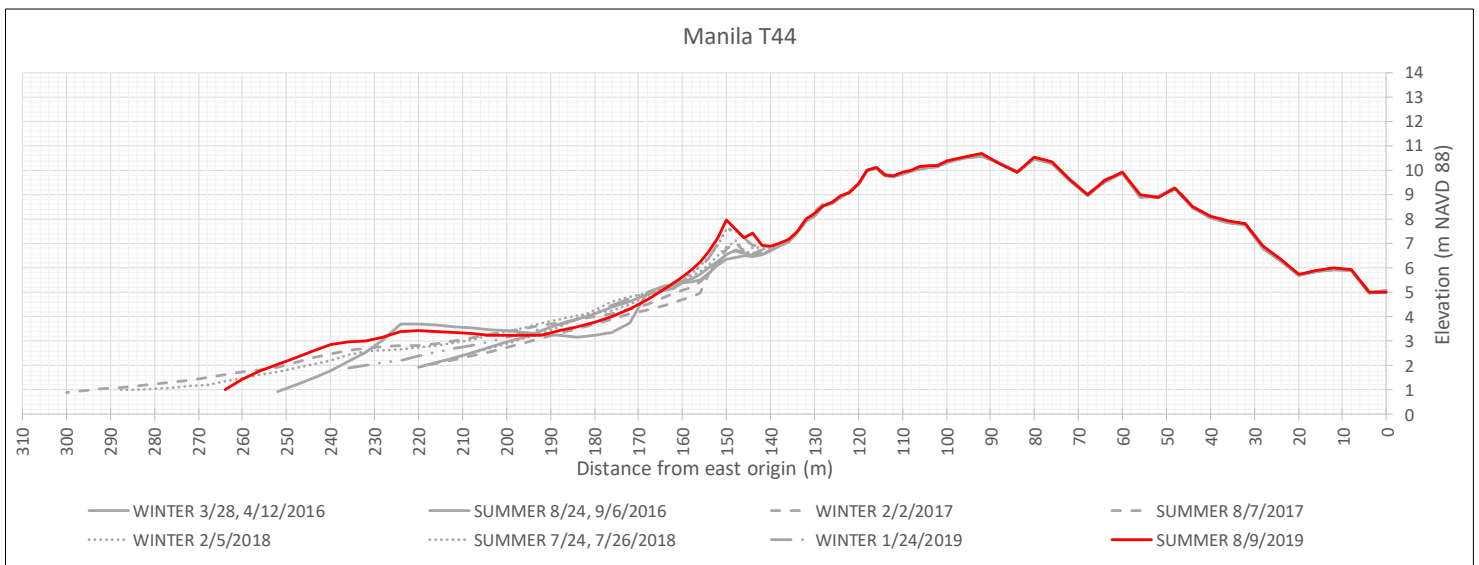


MCS D Transect 44



View northwest along transect taken at foredune base (140 m) showing incipient foredune

Notes: The transect is located in the Manila Dunes Recreation Area. The area was restored in the 1990s-2000s, but was not maintained, and *Ammophila* has reinvaded the foredune zone. The profile describes a dynamic incipient *Ammophila* foredune in front of a broad, restored (but reinvading) stable, established foredune that slopes down to the deflation plain. The back-shore and incipient *Ammophila* foredune was scarped (approximately 0.8 m vertical loss and 15 m horizontal loss along the transect) during high water events in winter 2017. By the summer 2017 survey, a scarp-fill ramp had formed, raising the backshore elevation and partially filling the scarp. In addition, new deposition (0.5 m) occurred at the crest of the incipient foredune following scarping. Between summer 2017 and summer 2018 the incipient foredune grew in elevation by an additional 0.5 m (see photos above, note burial of wood by sand deposition on left photo). In summer 2019 the incipient foredune increased in height by 0.5 m.

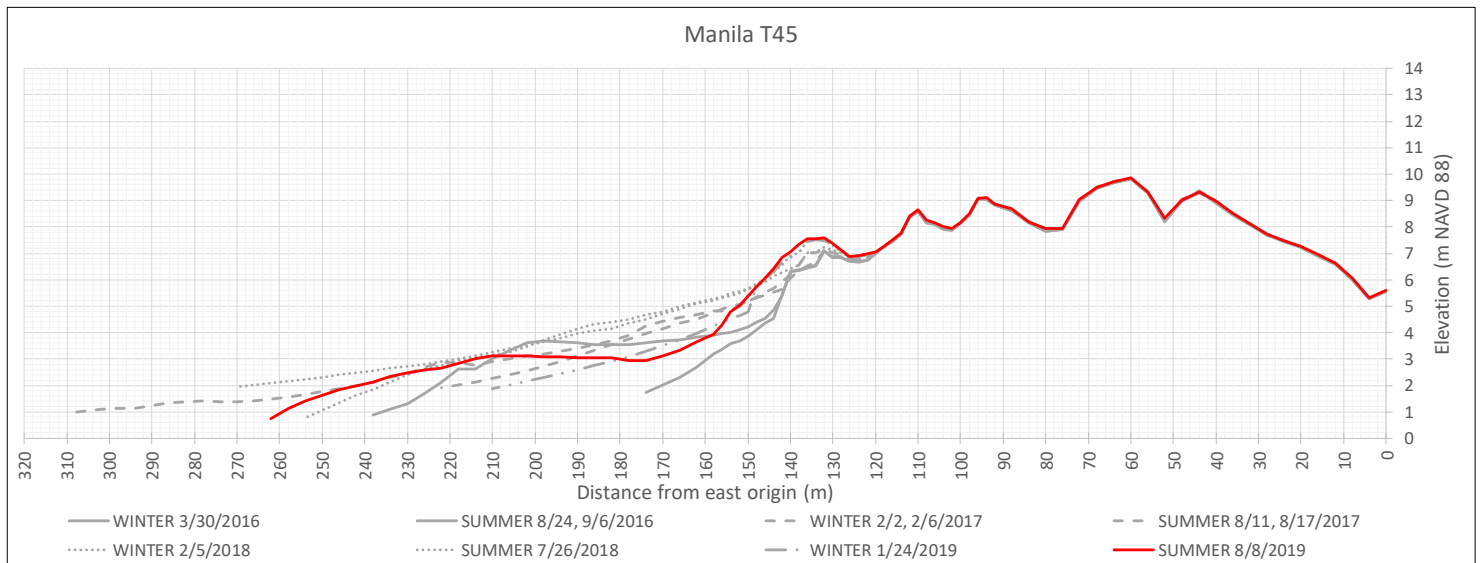


MCS D Transect 45



View north west at 144 m (incipient foredune)

Notes: The transect is located in the Manila Dunes Recreation Area. The area was restored in the 1990s-2000s, but was not maintained, and *Ammophila* has reinvaded the foredune zone. The profile describes a dynamic incipient *Ammophila* foredune (crest 130 m) in front of an older, now established *Ammophila* foredune (crest 110m). Behind that are relict native foredune peaks at 94 and 60 m. The incipient foredune scarped in winter 2016 prior to the survey, creating a more defined incipient foredune topography in summer 2016. By the following winter a scarp-fill ramp had filled the scarp, creating a gently sloping backshore. From winter 2017 to summer 2017, sand mobilized by the scarp deposited 0.5 m on the incipient foredune crest. Between summer 2017 and summer 2018 the incipient foredune increased in elevation by an additional 0.5 m. Deposition occurred on the upper beach in winter 2019, This profile began with scarping followed by steadily increasing volumes in the backshore and incipient foredune over the three year monitoring period.

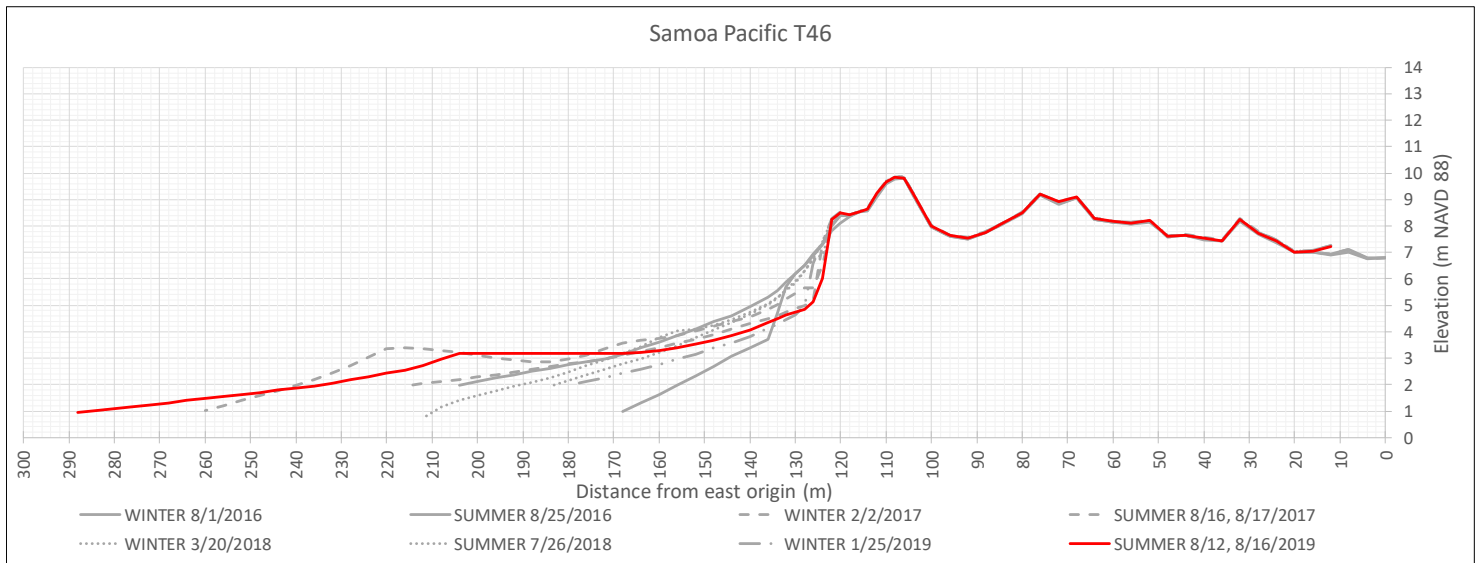


Samoa Pacific Transect 46



View north at 126 m (foredune base)

Notes: The transect describes a steep *Ammophila* foredune (crest 106 m) with a relict native (now invaded) foredune at 76 m. The base of the foredune was scarped between the winter and summer 2016 surveys, resulting in beach lowering of 1.5 - 2.0 m. In winter 2017 the foredune was further scarped, re-treating 10 m horizontally and removing 2.2 m vertically. From winter to summer 2017 there was upper beach deposition, with a scarp-fill ramp beginning to form, and minor deposition at the crest of the scarp. By summer 2018 the stoss face was completely ramped and had recovered the foredune morphology present in 2016. In 2019 additional scarping occurred, resulting in a steep foredune stoss face.

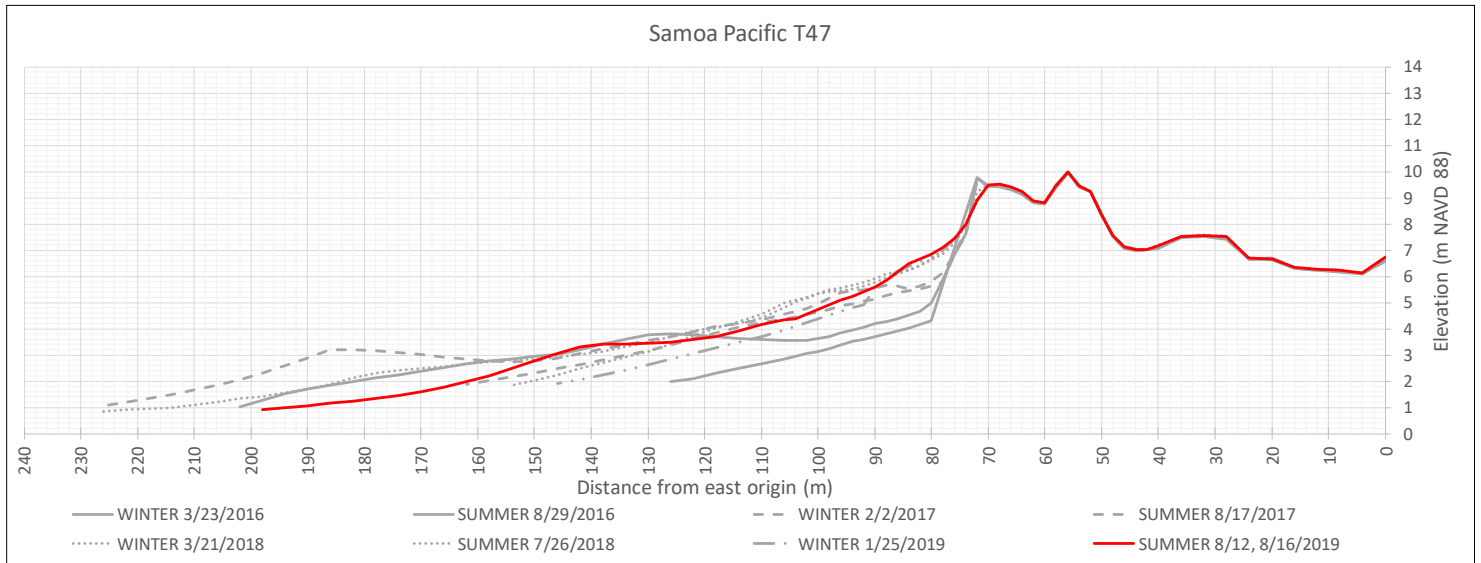


Samoa-Pacific Transect 47



View north showing scarp at 78 m (left) and scarp-fill ramp at 72 m (right and below)

Notes: The transect is composed entirely of dunes that formed since 1939 and under the influence of *Ammophila* rather than native vegetation. The established *Ammophila* foredune was severely scarpd prior to the winter 2016 survey, leaving a 5 m vertical scarp and presumably lowering the beach. Since that time the beach has gradually recovered 2+ m of elevation. By summer 2018 a scarp-fill ramp had formed, and was present in similar proportions in summer 2019.

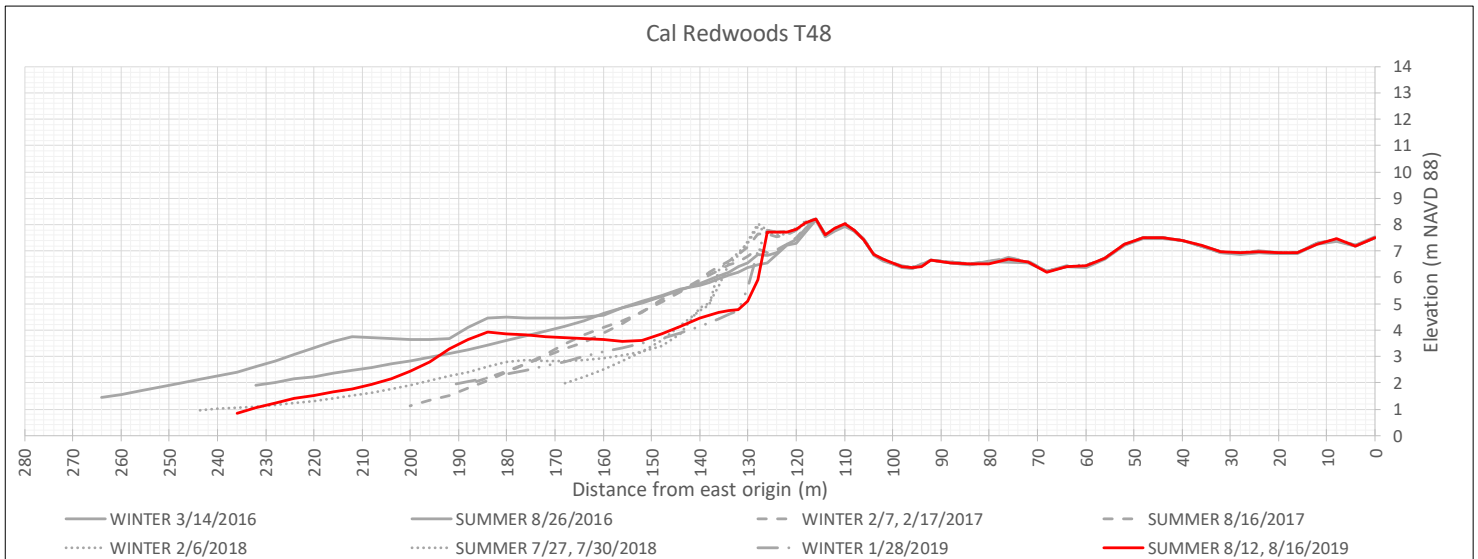


Cal Redwoods Transect 48



View southeast along transect at 148 m (backshore) looking towards foredune.

Notes: The profile describes a low *Ammophila* foredune in front of a lower backdune area. Deposition of 0.4 m occurred on the backshore in summer 2016 suggesting the start of an incipient foredune, along with up to 1.0 m seasonal deposition on the beach at 184 m. Erosion in winter 2017 removed substantial sediment from the beach (2.2 m at 184 m), creating a steeply sloping beach. However, some deposition occurred on the incipient foredune. In summer 2017 the beach did not increase in elevation, but there was 0.8 m deposition on the crest of the incipient foredune, essentially merging it with the established foredune. In winter 2017 scarping removed 2.0 m of vertical sediment from the backshore (see photo above above right) and very little change occurred between winter and summer 2018 other than deposition in the foreshore. In winter 2019 additional scarping occurred, the scarp being preserved through summer 2019.

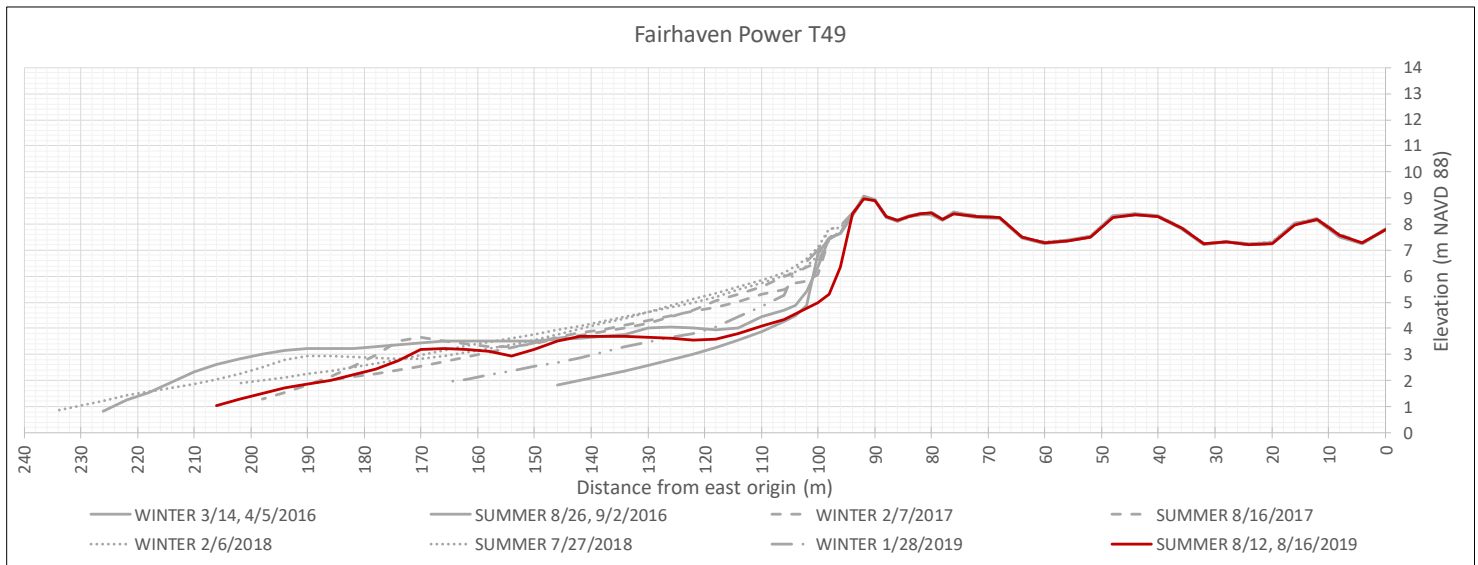


Fairhaven Power Transect 49



View south at 100 m (foredune base)

Notes: The established *Ammophila* foredune was severely eroded in winter 2016 prior to the survey, resulting in a 2.0 m vertical scarp. The beach steadily regained elevation in the following two years, and by summer 2017 a scarp-fill ramp had almost completely welded to the former crest of the foredune as can be seen to the south in the photograph. By summer 2018 deposition was occurring on the stoss face of the foredune (photo above right). However, between winter and summer 2019 major scarping occurred, eroding the foredune 5 m horizontally.

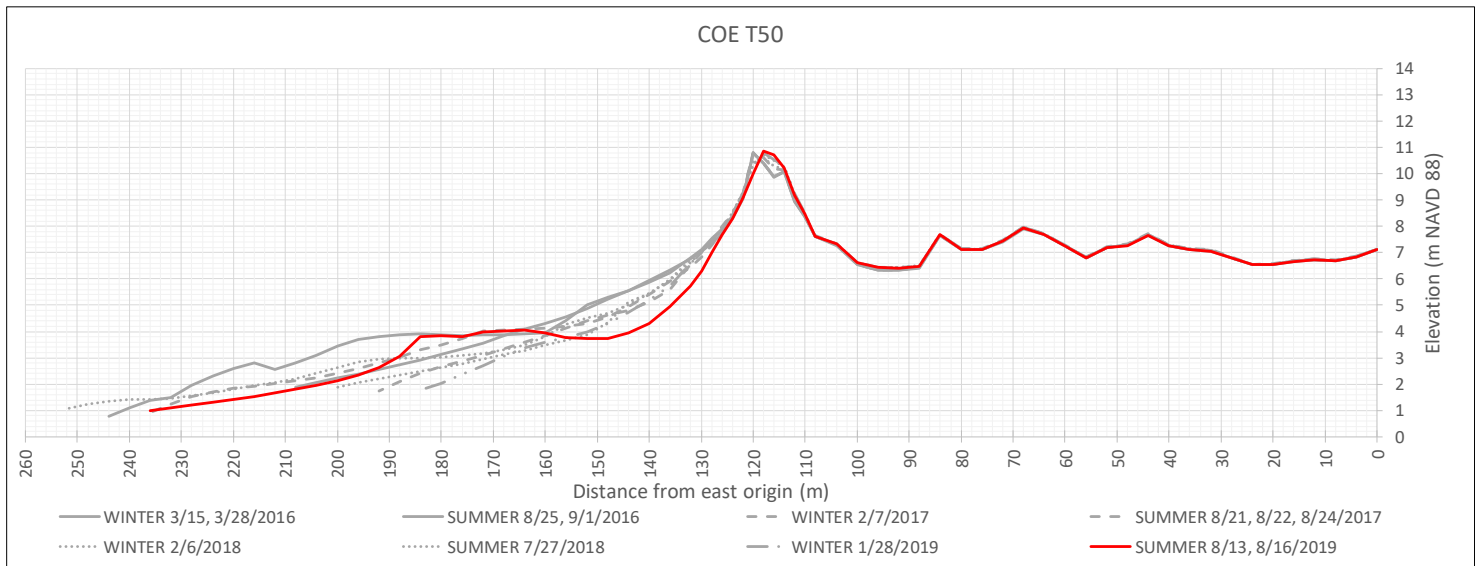


City of Eureka Transect 50



View north at 120 m (foredune crest)

Notes: The transect is located near the City of Eureka’s Samoa airstrip, and depicts a peaked *Ammophila* foredune backed by a low *Ammophila*-stabilized backdune area. The backshore was relatively stable during 2016, with the foreshore exhibiting typical seasonal changes. In winter 2017 the backshore was scarped and lowered by 1.0 m vertically. By summer 2017 the backshore was still low, and the steep beach is visible in the photo taken at the crest of the foredune looking north. Between summer 2017 and summer 2018 deposition occurred in the foreshore and additional deposition occurred behind the foredune crest (see photos above). Between 2018 and 2019 the backshore lost up to 1.0 m in elevation.

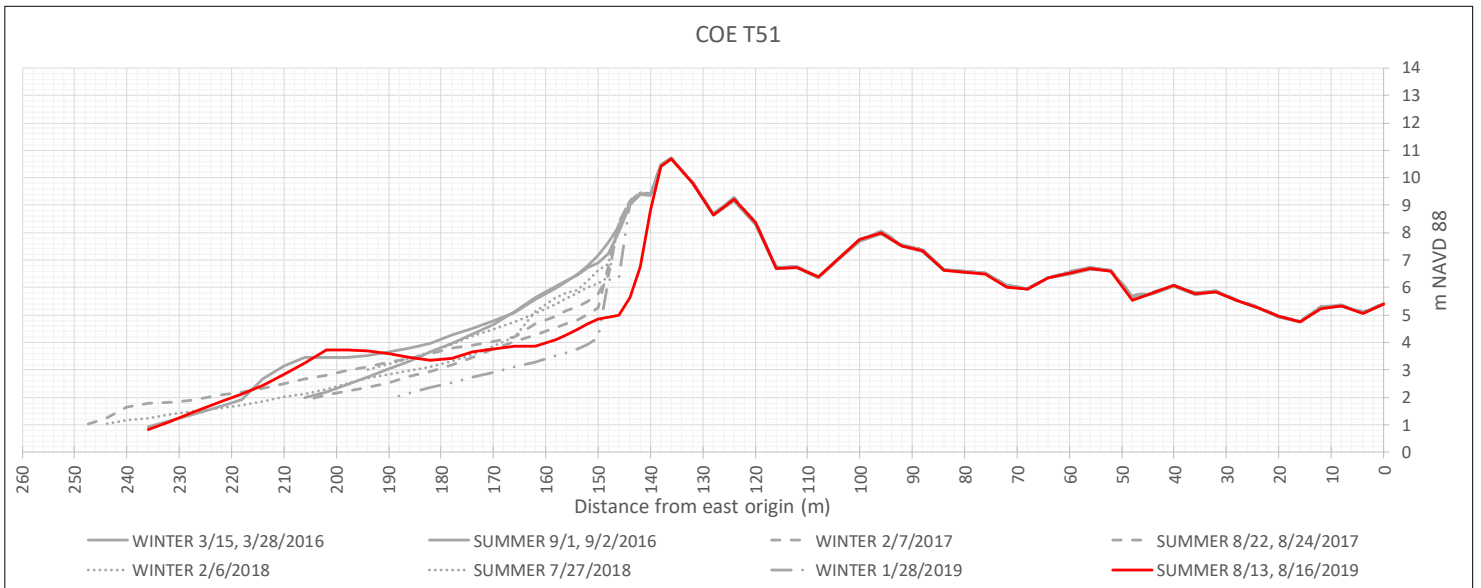


City of Eureka Transect 51



View southeast along transect at 154 m (upper beach) looking towards foredune

Notes: The transect extends through an *Ammophila* dominated area that includes ATV trails in the extended area of the Samoa Dunes Recreation Area. The foredune was severely scarped in the winter of 2017, with approximately 2.0 m of vertical loss of foredune. By summer 2017, slumping had occurred but the upper beach had regained only 0.5 m of elevation. During 2018 deposition on the upper beach resulted in scarp fill ramping (see photos above). However, in 2019 the foredune rescarped, losing up to 5 m horizontally.

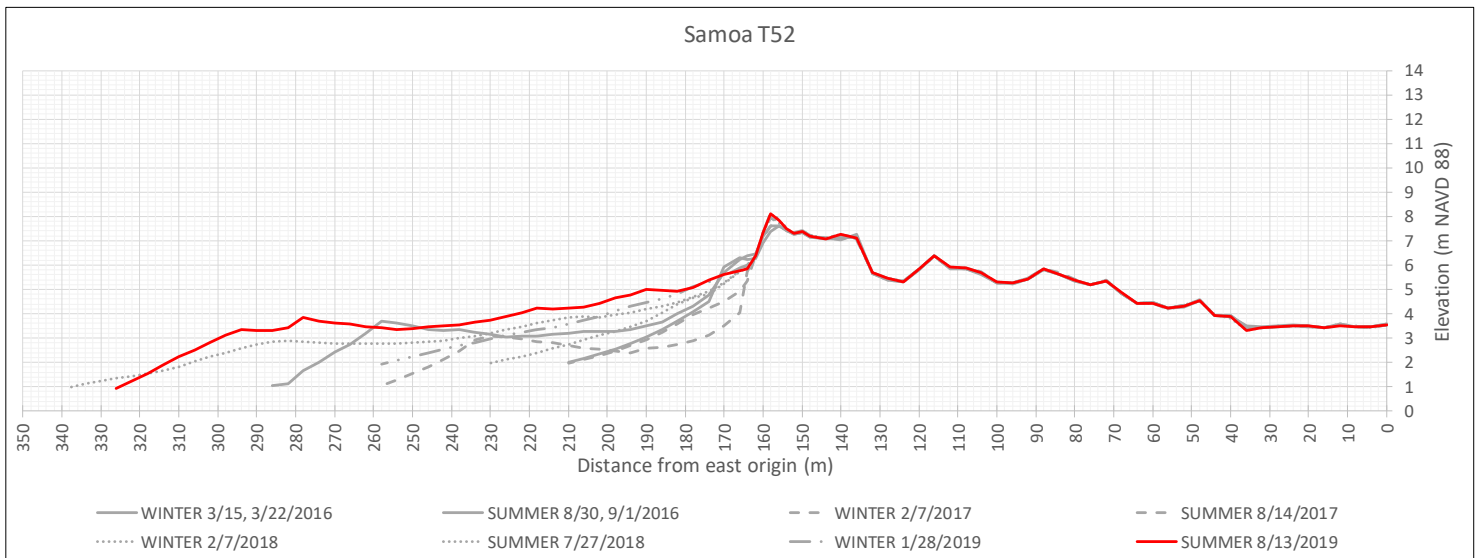


Samoa Transect 52



View north at 162 m (foredune base)

Notes: The transect is within the Samoa Dunes Recreation area and crosses several ATV trails that bisect an area stabilized by *Ammophila*. This is also an area of continuing high erosion since at least the 1930s, influenced by its proximity to the north jetty. In winter 2016 the backshore was characterized by a bench-like feature that may have been caused by beach scarping prior to the survey. In summer 2016 1 m of sediment was deposited below the bench. In winter 2017 the backshore was scarped and the bench removed, losing 1 m vertically and retreating 10 m horizontally. Additional erosion occurred after the survey, lowering the beach by another meter at the base of the foredune in the summer 2017 profile. By summer 2018 1.5 m of deposition had occurred on the backshore, returning the profile to near 2016 levels. In summer 2019 deposition of up to 1 m occurred on the backshore, bringing it to its highest elevation since monitoring began.

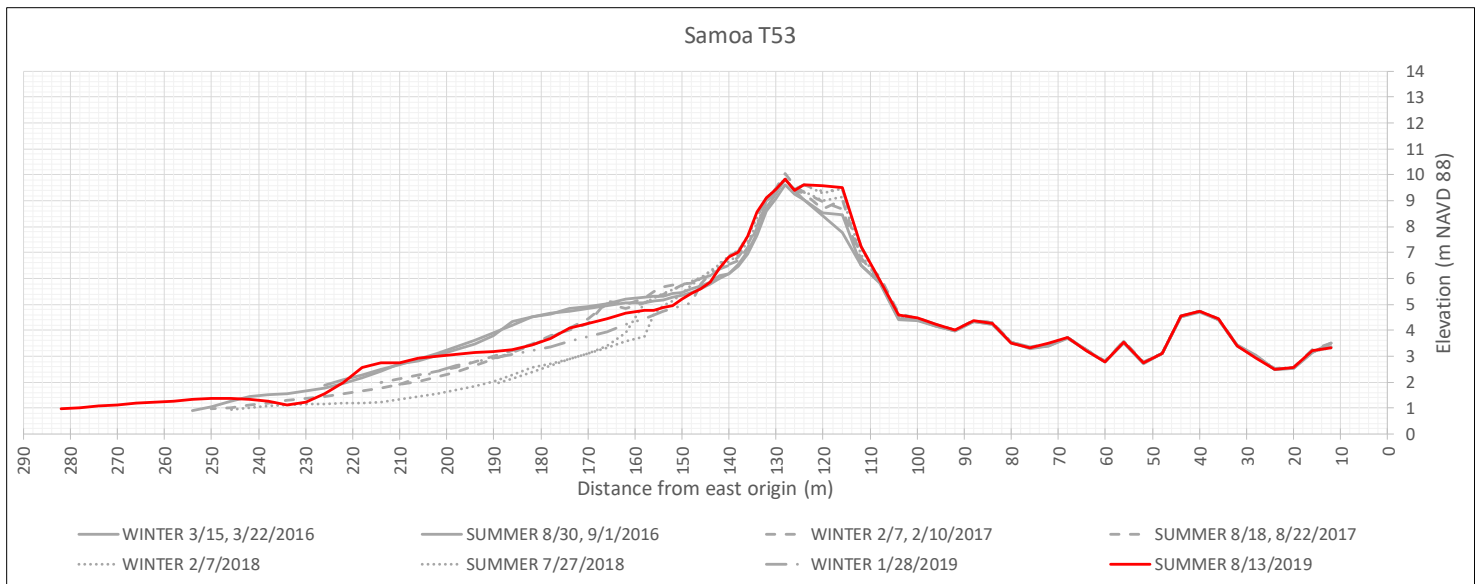


Samoa Transect 53



View southeast at 144 m (upper beach) looking towards foredune

Notes: The transect is within the Samoa Dunes Recreation area and crosses several ATV trails that bisect an area stabilized by *Ammophila*. This is also an area of continuing high erosion since at least the 1930s, influenced by its proximity to the north jetty. The foreshore lost 1 m of elevation between 2016 and 2017, but the backshore gained 0.4 m and there was deposition on the foredune, especially on the lee slope where an ATV trail crosses the transect at 116 m. Between summer 2017 and summer 2018 up to 1.2 m eroded vertically from the upper beach, and there was additional deposition on the lee slope. In winter 2019 10+ m was eroded vertically from the backshore, which stayed at that elevation through summer 2019.

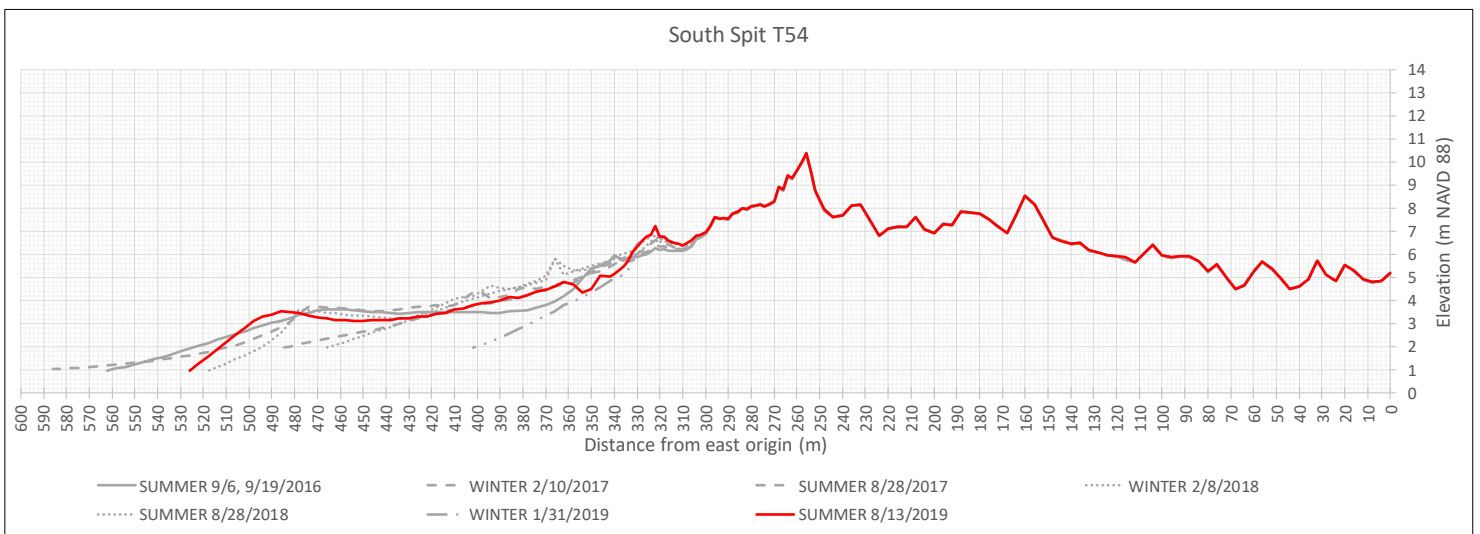


South Spit Transect 54



View northwest along transect at 322 m (incipient foredune)

Notes: This transect intersects the South Spit at its widest point, in an area that vegetation is not managed. The profile demonstrates multiple, relict *Ammophila* foredune ridges from shoreline accretion. Data are not available for winter 2016. From summer 2016 through summer 2017 the backshore increased in elevation up to 1 m, becoming colonized by *Cakile* spp.. In summer 2017 transverse dunes were migrating inland on the beach below the vegetation line, visible as ridges in the profile. The incipient foredune crest also gained in elevation up to 0.5 m between summer 2016 and summer 2017. Between summer 2017 and summer 2019 the upper beach assumed incipient foredune morphology.

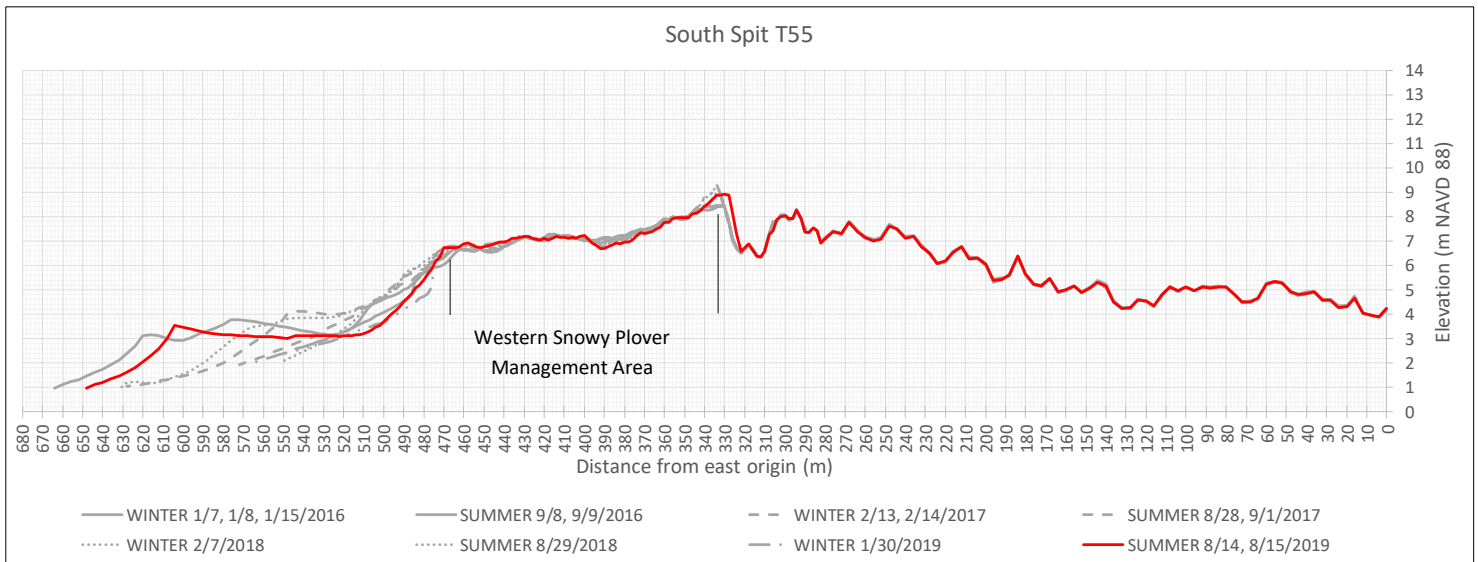


South Spit Transect 55



View north at 480 m (foredune base)

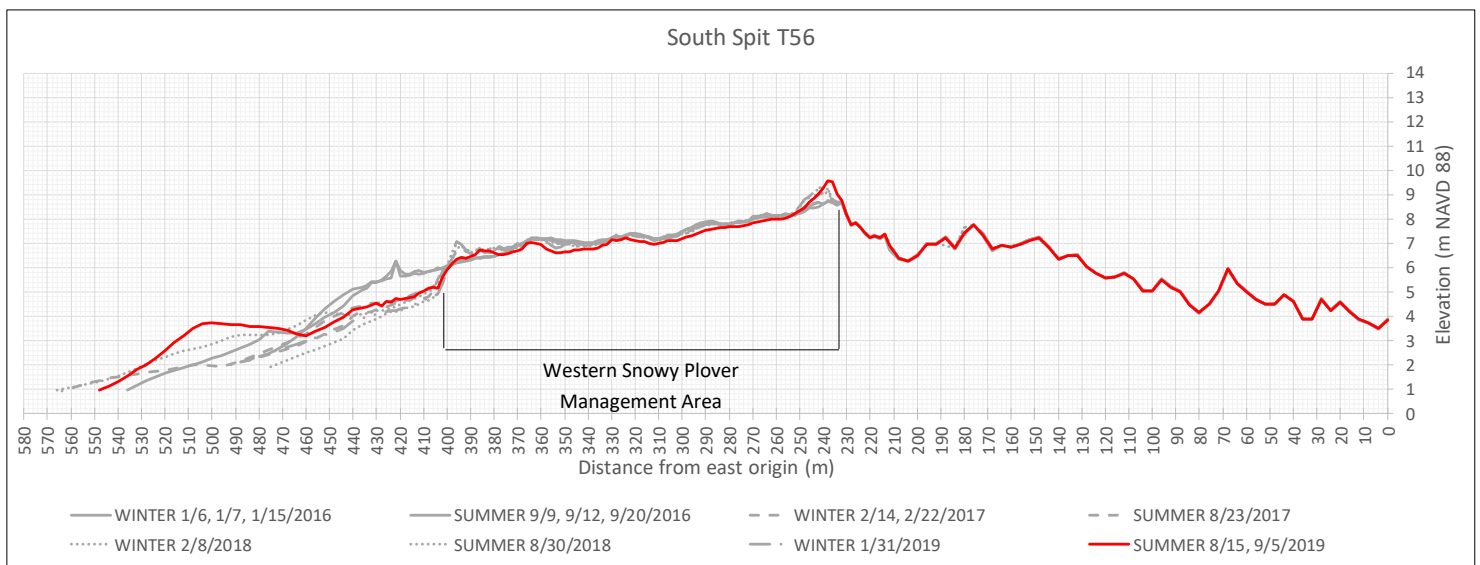
Notes: This transect intersects the BLM's Western Snowy Plover Management Area, which was bulldozed to decrease vegetation cover and is maintained through dozing and/or disking annually. As a result, there is no distinct foredune feature, and the profile in the managed area shows shifting sand, as can be seen in the photographs taken near the vegetation line looking north. In winter 2016 the backshore was steep, but the summer 2016 profile shows backshore deposition of 0.4 m landward of offshore bars. In summer 2017 the backshore gained an additional 0.5 m of elevation. By summer 2018 there was additional minor deposition on parts of the backshore. In winter 2019 the upper beach scarped. The topographic rise at approximately 330 m is the east edge of the restoration area. Bulldozed sand was pushed up at this location. In summer 2017 localized deposition occurred here, where dense vegetation slows winds.



South Spit Transect 56



View northwest along transect at 406 m (foredune)



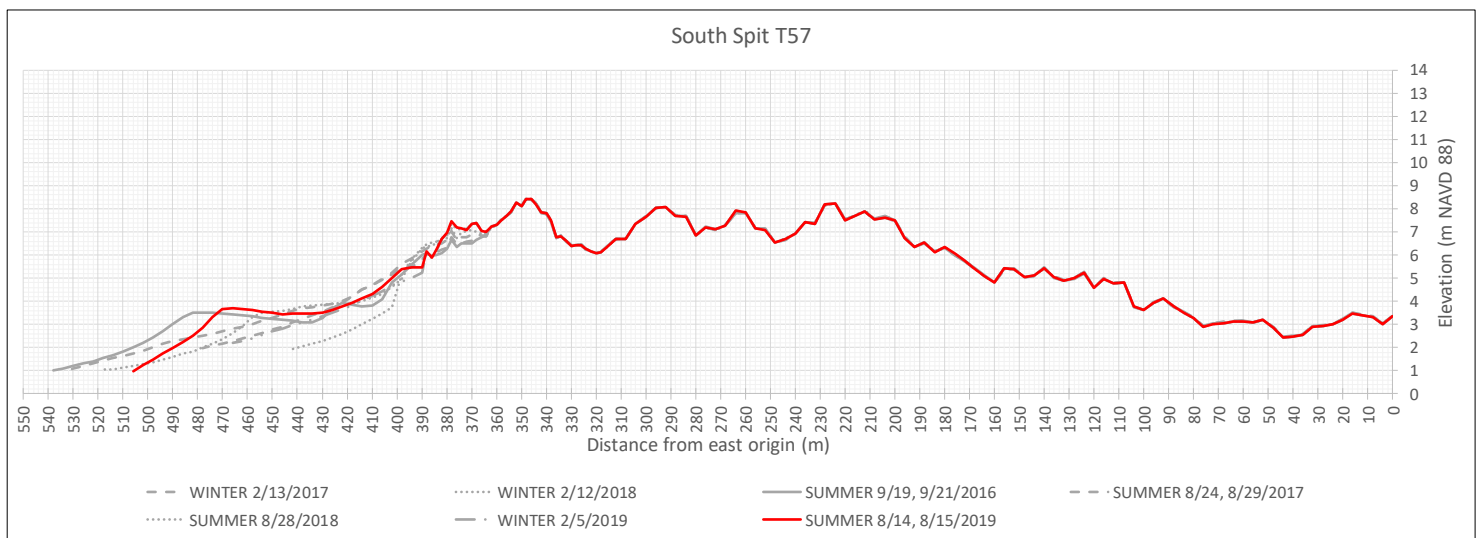
Notes: Similar to Transect 55, Transect 56 intersects the BLM's Western Snowy Plover management area. There is more of a foredune-like feature in this profile (with a similar feature visible to the north in the photograph which is taken northwest along the transect from the base of the ridge). This feature originated as a wave cut escarpment in winter 2017, and managers did not grade it in 2017. Aeolian deposition occurred on its crest in summer 2017. There was only minor filling of the scarp in summer 2017 and by summer 2018 those sediments had eroded. Similar to T55, there was deposition in summers 2017-2019 at the east end of the management area where dense, unmanaged *Ammophila* begins. In winter 2018 there was erosion on the upper beach and in summer 2019 there was erosion throughout the managed area, which might have been the result of grading.

South Spit Transect 57



View northwest along transect at 352 m (foredune crest)

Notes: There are no data available from winter 2016, but the upper beach was relatively steep in summer 2017, and underwent significant deposition by winter 2017. By summer 2017 deposition had also occurred on the incipient foredune, visible in the upper left of the 2017 photograph (taken from the foredune crest northwest along the transect) and in summer 2018 up to 0.4 m was added to the incipient foredune. In summer 2019 the incipient foredune was built up even further. The profile is located in an unmanaged portion of the spit, and two relict *Ammophila* foredunes can be seen east of the present day foredune in the profile. The third ridge to the east is a relict native foredune. This transect spans the entire width of the spit and depicts a stable profile east of the incipient foredune over the three-year period.

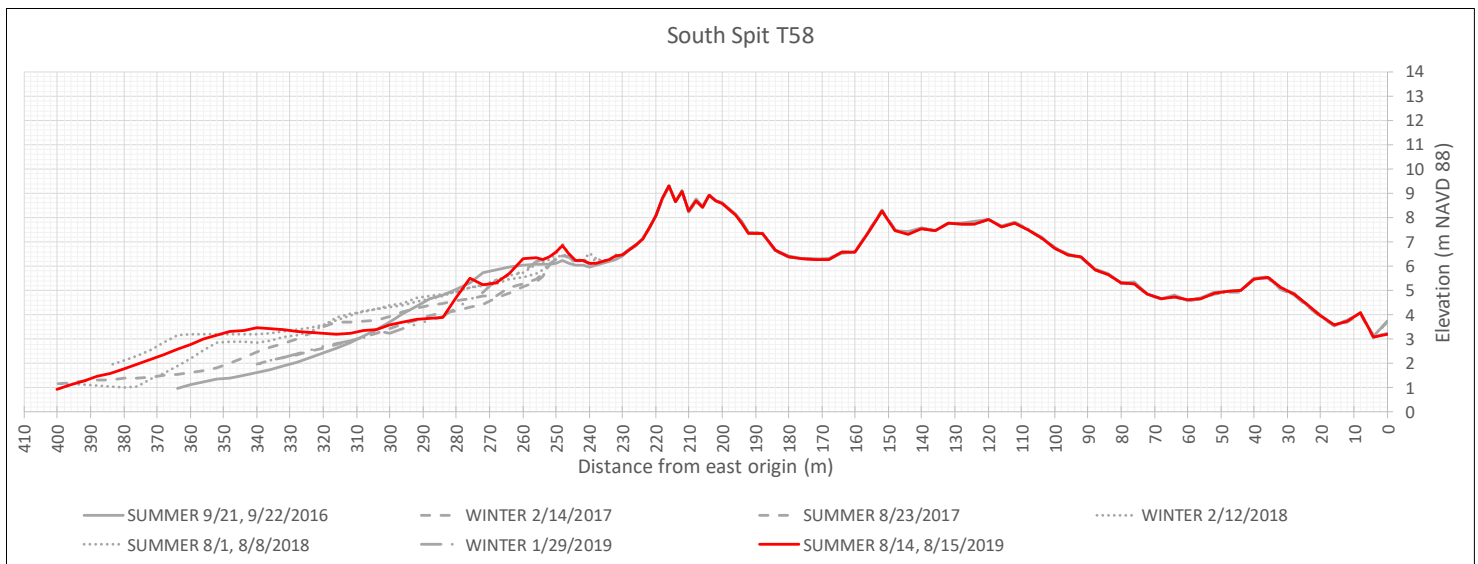


South Spit Transect 58



View northwest along transect at 216 m (foredune crest)

Notes: There are no data available from winter 2016. The transect is located in a portion of the South Spit in which vegetation is not managed and *Ammophila* is dominant. An incipient foredune topography was forming and was scarped during high water events in winter 2017. The scarp emphasized the incipient foredune morphology, and a driftwood deposit was placed in the swale of the incipient foredune, remaining through summer 2019 and visible in the photographs taken from the crest of the foredune and looking northwest along the transect. In summer 2017 the upper beach and incipient foredune did not change significantly but by summer 2018 additional deposition had occurred on the incipient foredune, with the morphology shifting in summer 2019 into transverse dunes climbing up the incipient foredune.

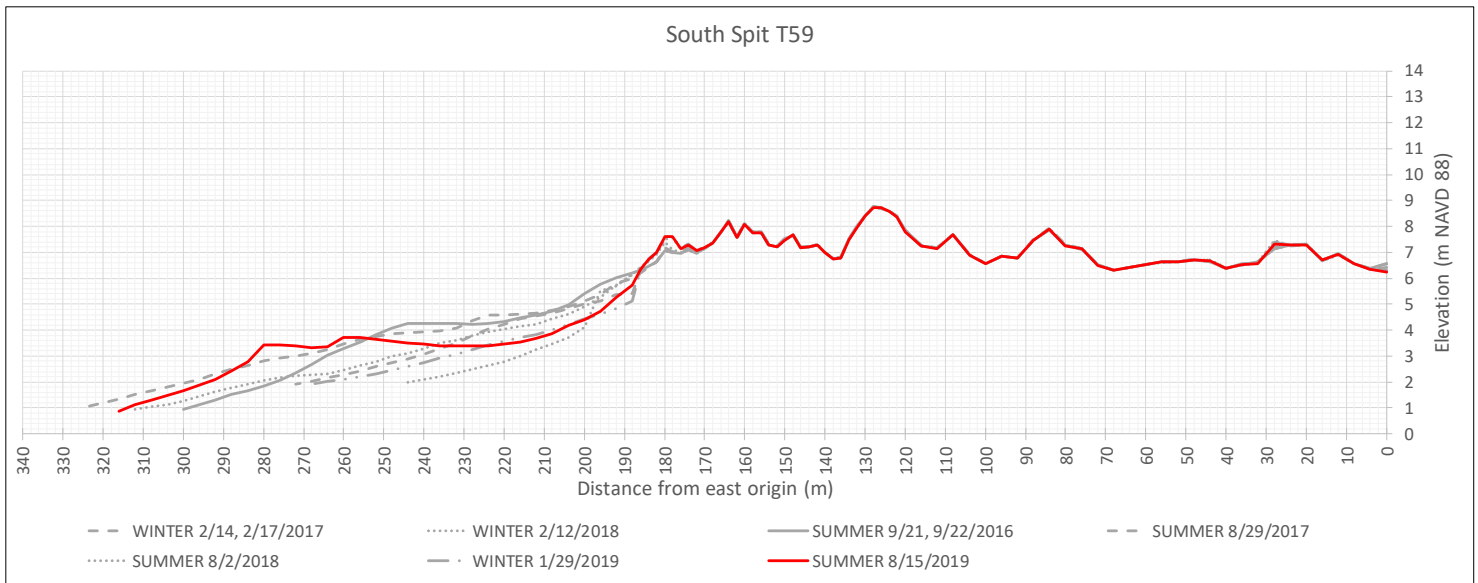


South Spit Transect 59



View northwest along transect at 170 m taken at foredune base

Notes: There are no data available from winter 2016. The profile is located on a portion of the South Spit that does not receive vegetation management. Multiple relict *Ammophila* foredunes are present reflecting accretion events. Between summer 2016 and winter 2017 the western edge of the incipient foredune scarped, but by summer 2017 a scarp-fill ramp had formed as can be seen in the photograph looking northwest along the transect from the incipient foredune towards the backshore. The beach regained elevation levels present in summer 2016. By summer 2019 the incipient foredune had gained in elevation and breadth (deposition can be seen in right rear of summer 2019 photograph).



South Spit Transect 60



View northwest along transect at 138 m (foredune crest)

Notes: This portion of the South Spit has been restored by the manual removal of *Ammophila* and vegetation is native. The profile exhibited normal seasonal changes from winter 2016 through summer 2017 with a relatively stable vegetated backshore and established foredune. The peak at 180 m was a large stump. In winter 2017 the backshore was eroded up to the base of the established foredune resulting in a vertical loss of up to 1.2 m. By summer 2018 there was only minimal rebuilding. Further scarping occurred in winter 2019. Over the three year period, there was some sediment movement on the established foredune, with 0.4 m of deposition at 126 m.

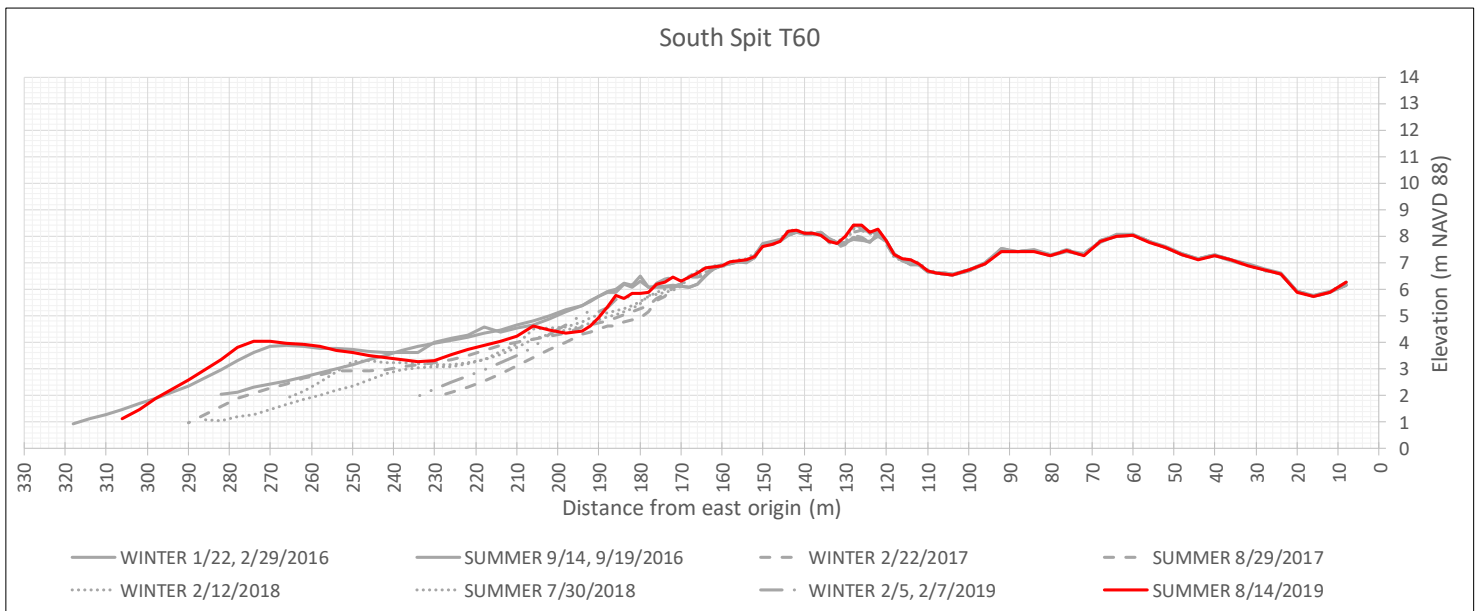


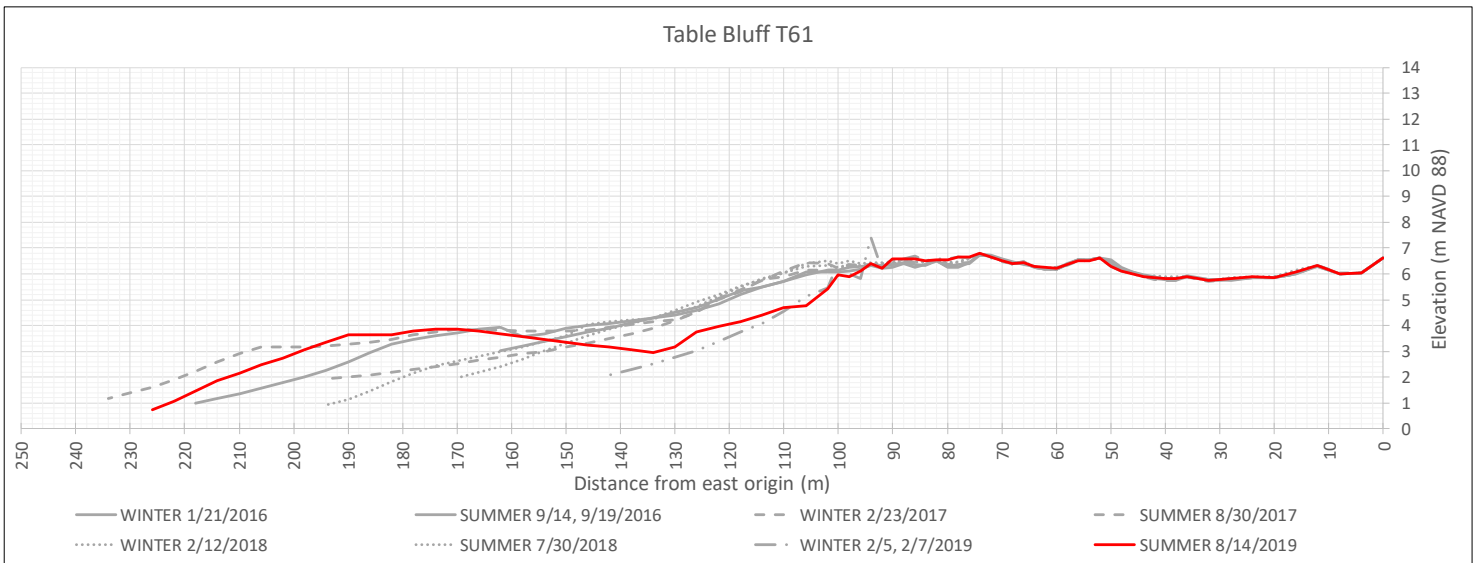
Table Bluff Transect 61



View northwest at 100 m (foredune base)

Notes: This transect is located where the dune system narrows at the base of Table Bluff and restoration to native dune mat has occurred.

In winter 2019 this feature was scarped, losing 1 m vertically. The vegetated backshore west of 76 m has experienced deposition over the three year period. The greatest deposition (0.5 m) occurred west of the vegetation line. Large wood was deposited in this area in winter 2017. The newly deposited sand from summer 2019 is visible in the photographs taken from near the vegetation line looking northwest along the transect.

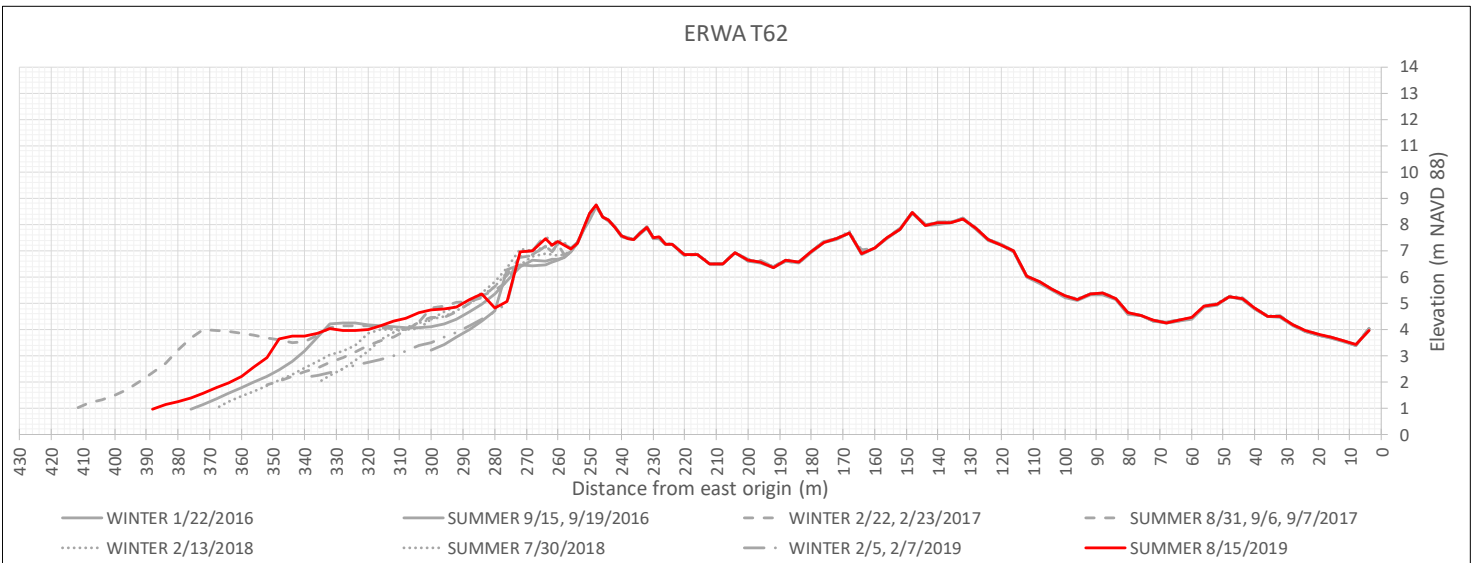


Eel River Wildlife Area Transect 62



View northwest at 246 m (foredune base) looking towards incipient foredune

Notes: The transect is located on the north barrier of the Eel River in an unrestored system stabilized by *Ammophila*. The backshore had been scarped at 276 m prior to the winter 2016 survey. By the summer 2016 survey, scarp-fill ramping had occurred. In winter 2017 high water events deposited a large amount of wood on the backshore. All points from 258-268 m were taken on wood and create the peaks in the graph. In Summer 2017 sand had been deposited among the wood and *Ammophila* was increasing, creating something of a wood incipient foredune. By summer 2018 most of the wood had been buried by sand, although the elevation had increased by only approximately 0.2 m. In winter 2019 additional wood was deposited and by summer deposition had occurred. The photograph is taken from the base of the established foredune looking northwest along the transect, showing the new incipient foredune.

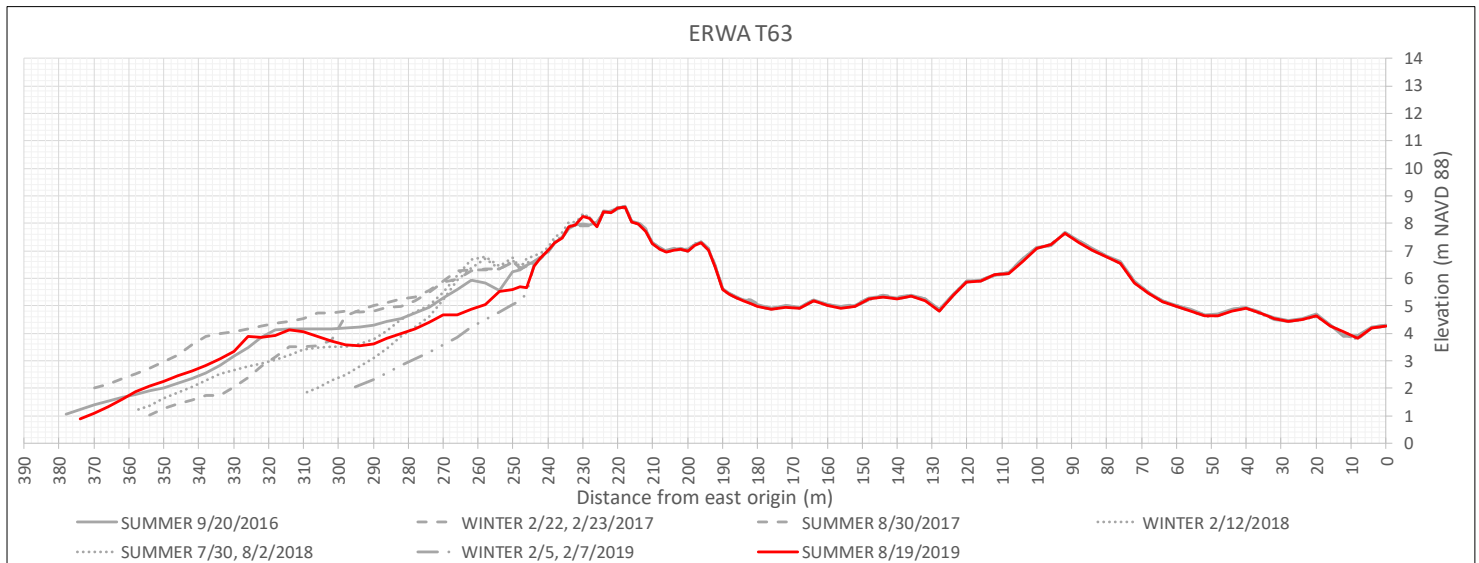


Eel River Wildlife Area Transect 63



View northwest at 242 m (foredune base) looking towards incipient foredune

Notes: The transect is located on the north barrier of the Eel River in an unrestored system stabilized by *Ammophila*. Data from winter 2016 are not available. In winter 2017 a large amount of wood was deposited on the upper beach, and all points from 248-270 m were taken on top of wood. In summer 2017 the backshore was virtually unchanged, and the wood deposit can be seen in the left photograph taken from the base of the foredune looking northwest along the transect. By summer 2018 sand had been deposited on the incipient foredune, burying a portion of the wood deposit (see photos above). In winter 2019 a significant scarping event occurred on the upper beach, with some recovery through deposition in summer 2019. The profile is distinctive in having broad foredune swale between the relict and present day foredunes.



Eel River Wildlife Area Transect 64

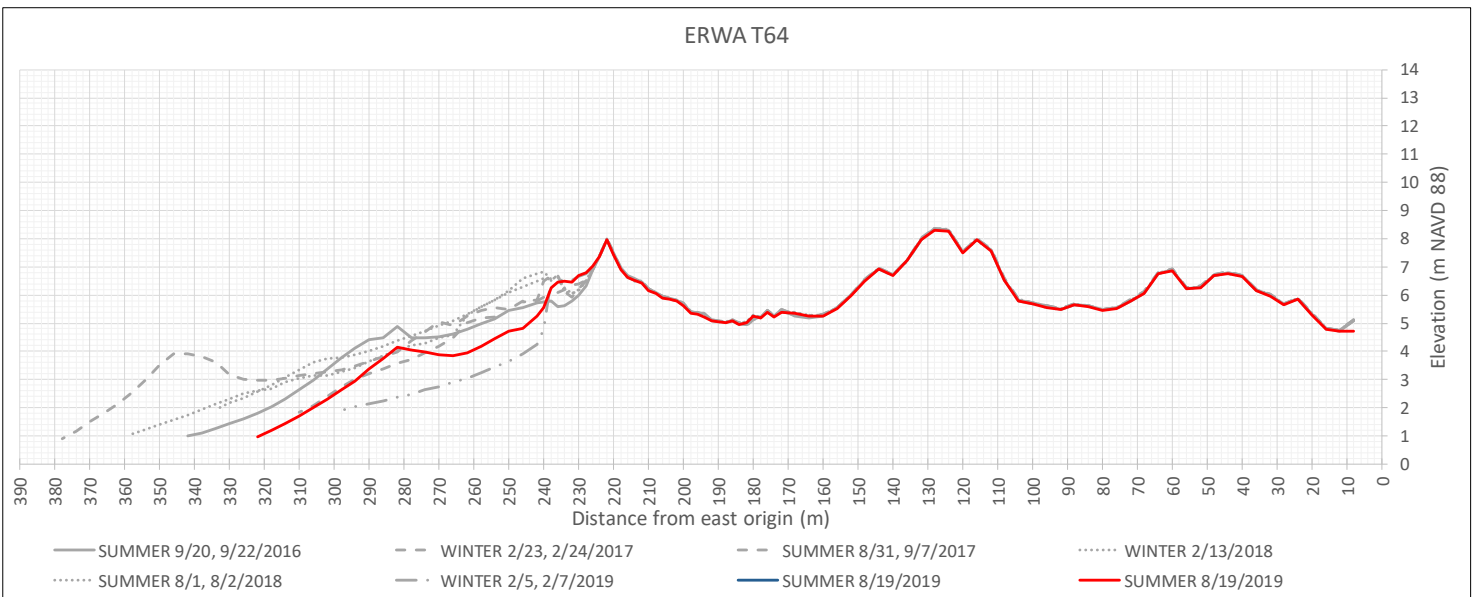


View northwest at 230 m (foredune base) looking towards incipient foredune

Notes: The transect is located on the north barrier of the Eel River in an unrestored system stabilized by *Ammophila*. Data from winter 2016 are not available. In summer 2016 a wood deposit was present in the vicinity of 282 m. In winter 2017 during high water events the beach eroded and a 1+ m vertical loss occurred in that vicinity. At that time a large amount of wood was deposited higher up on the beach up against the base of the foredune. By summer 2017 the wood deposit had moved lower on the beach and was higher in elevation. Points at 236 to 240 m were taken on wood. Sand deposition had occurred within the wood, forming a distinctive incipient foredune-like feature, visible in the photograph taken from the base of the foredune and looking northwest along the profile. In winter 2019 there was significant erosion of the upper beach, causing 2 m of vertical loss. In summer 2019 approximately half of the elevation was regained and the incipient foredune received depo-



sition that covered much of the wood. Similar to the previous transect, the profile is distinctive in having a broad foredune swale between the relict and present-day foredunes.



Eel River Wildlife Area Transect 65

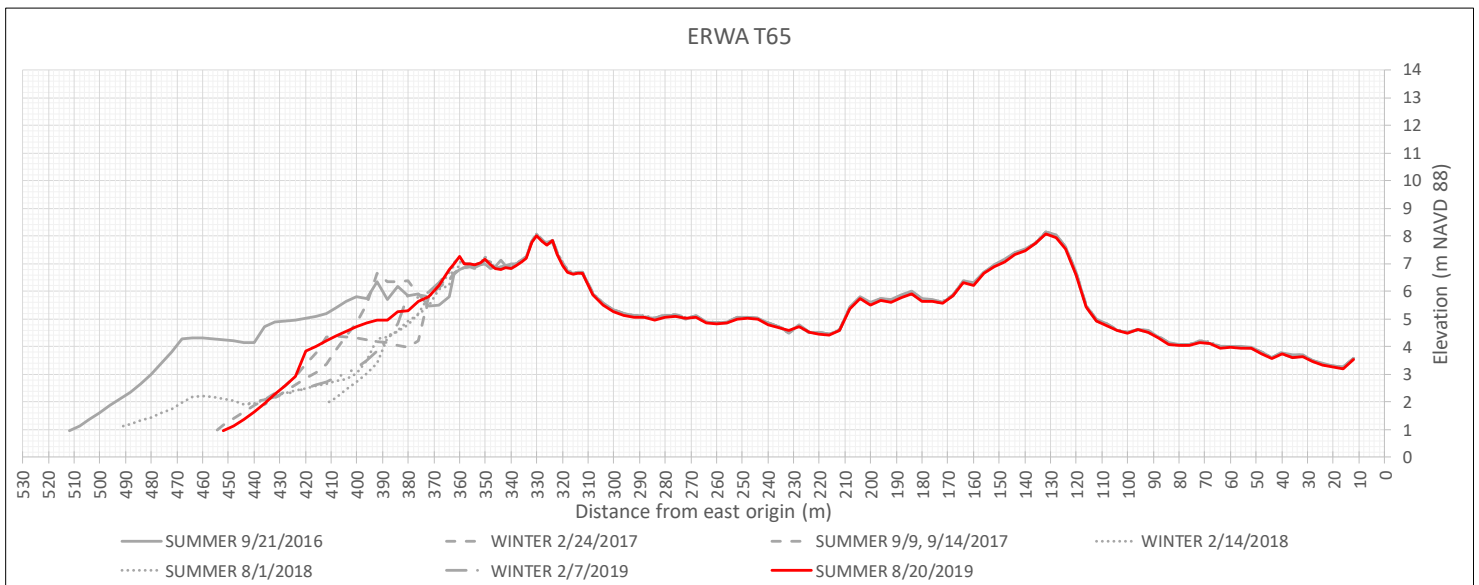


View southeast at 384 m (upper beach) looking towards incipient foredune

Notes: This transect is located near the dynamic spit at the mouth of the Eel River and exhibits high variability on its seaward side. Topographic data from winter 2016 are not available. The transect passes through a relict foredune scarp associated with mouth migration at 132 m. In summer 2016 the beach was wide and the backshore extended west to approximately 468 m. A wood deposit was present from 372-396 m. In winter 2017 during high water events the foreshore was eroded up to 3 m vertically, and the backshore retreated landward to 396 m leaving a very steep beach. The wood deposit remained, and sand infilling occurred, forming an incipient foredune-like morphology, with a net rise in elevation of up to 0.5 m. By summer 2017 further erosion had scarped and removed the western portion of the wood deposit/incipient foredune, as seen in the photo taken from the backshore and looking southeast back along the transect towards the scarp. Between summer 2017 and summer 2018 there



was almost 1 m of deposition that filled the scarp (see photo on right). In winter 2019 there was scarping of the upper beach, with infilling the following summer.

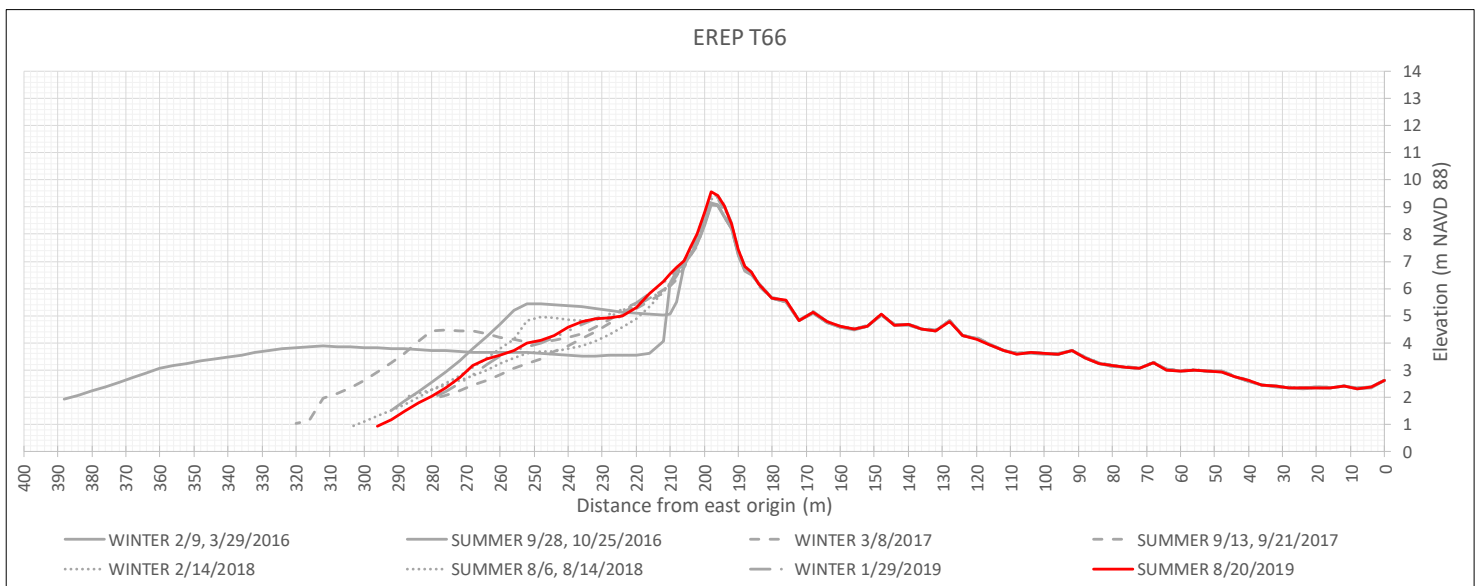


Eel River Estuary Preserve Transect 66



View north at 210 m (foredune base)

Notes: This transect is located on the Eel River southern barrier, south of the true spit, and consists of a dynamic beach and a narrow peaked *Ammophila* foredune in front of a low backdune area that slopes down to the estuary. The foredune was scarped in winter 2016 prior to the survey, creating a 2.0-2.5 m drop in elevation. By summer 2016 the foredune had eroded back an additional 0.4 m horizontally, while the backshore regained approximately half of the elevation lost, forming a berm. By the following winter the berm had eroded, but a ramp had formed, creating the smoothly sloping rather steep backshore visible in the photo (taken from the base of the foredune looking north). By summer 2018 the berm had partially rebuilt on the upper beach. By summer 2019 the berm was no longer present and there was a continuous slope from the upper beach to the foredune. The profiles suggests a dynamic beach with high rates of annual volumetric change.



Eel River Estuary Preserve Transect 67

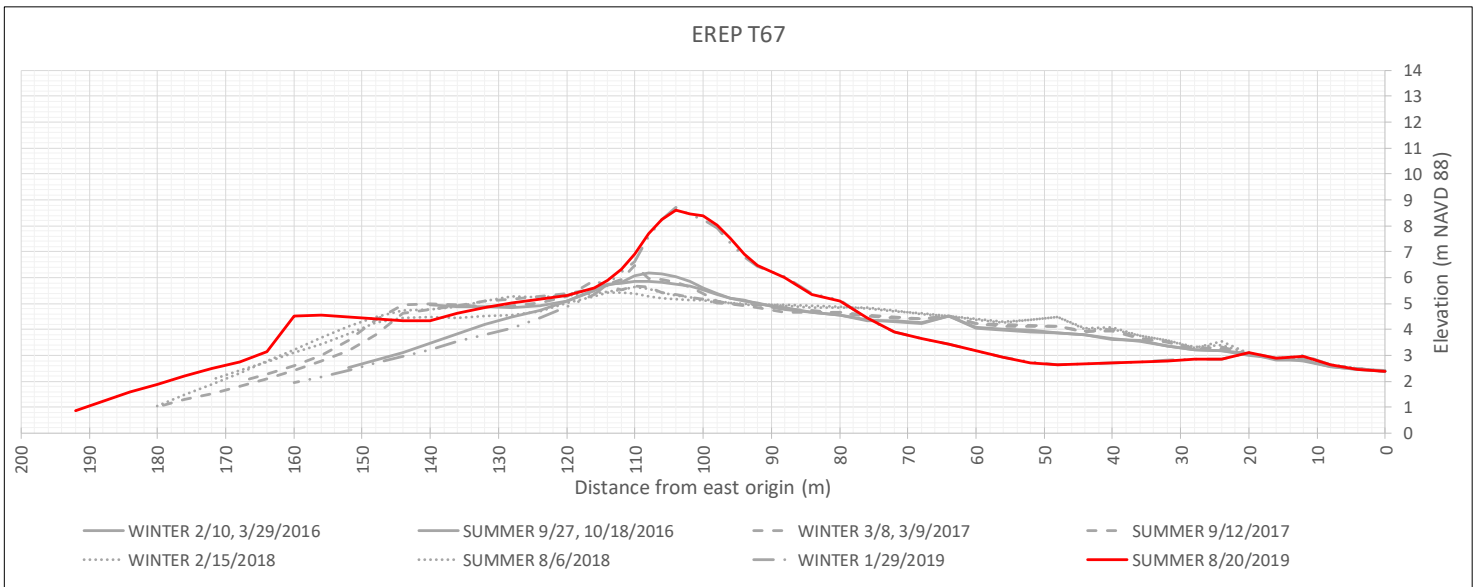


View south at 102 m (foredune crest)

Notes: This transect was placed within a foredune breach that was overwashed during high water events. The transect was placed perpendicular to the shoreline (rather than parallel with predominant wind) in order to include the overwash lobe. The lack of foredune is apparent from the initial low profile. Overwash occurred in winter 2016, but was followed by a large depositional event on the beach which led to aeolian deposition at the position of the foredune in summer 2016. High water events in winter 2017 again eroded 0.6 m of the aeolian deposits through overwashing, but built a 2 m beach berm present at the time of the winter survey. Subsequent aeolian deposition recurred in the region of the foredune, but to a lower elevation than the previous year. The abrupt peaks in the profiles at 110 and 116 m represent a large piece of driftwood that moved during winter storms. The winter 2017 beach berm persisted into summer and can be seen on the photograph taken on the foredune crest looking south. There was only minor deposition by the



summer 2018 survey. In summer 2019 the foredune was rebuilt by recontouring sand in the overwash fan and creating a new foredune. There was no erosion of the foredune in winter 2019.

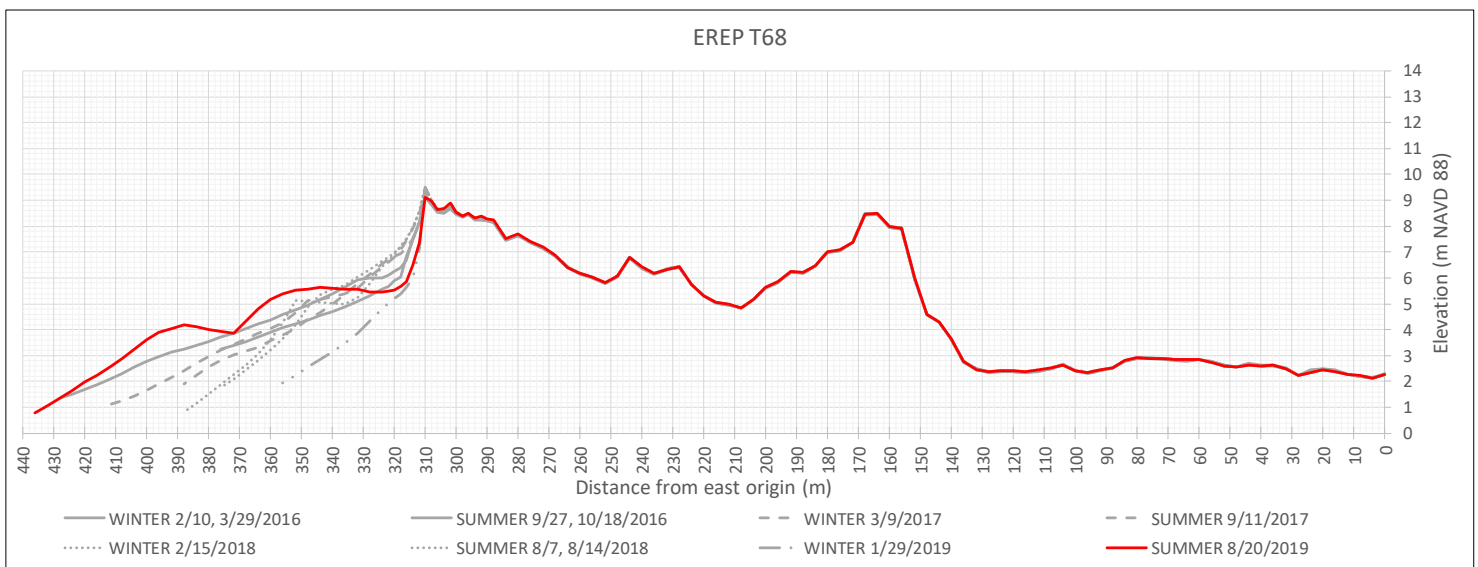


Eel River Estuary Preserve Transect 68



View south at 316 m (foredune base)

Notes: The transect intersects the dune system at one of its widest points, and the profile depicts multiple relict *Ammophila* foredunes. The present-day foredune had been recently scarped, with up to 3.0 m of elevation loss, at the time of the 2016 survey. Between winter 2016 and summer 2017 a scarp-fill ramp gradually reconnected the backshore to the foredune crest, resulting in deposition on the stoss and lee face of the foredune by summer 2017. The foreshore lost 1 m of elevation in winter 2017 and regained only part of it in summer 2017, with additional loss of up to 2 m by summer 2018. Deposition occurred at the base of the foredune prior to the winter 2018 survey, but had been removed by summer 2018. Scarping of the foredune in winter 2019 resulted in a steep stoss face that persisted into summer 2019.

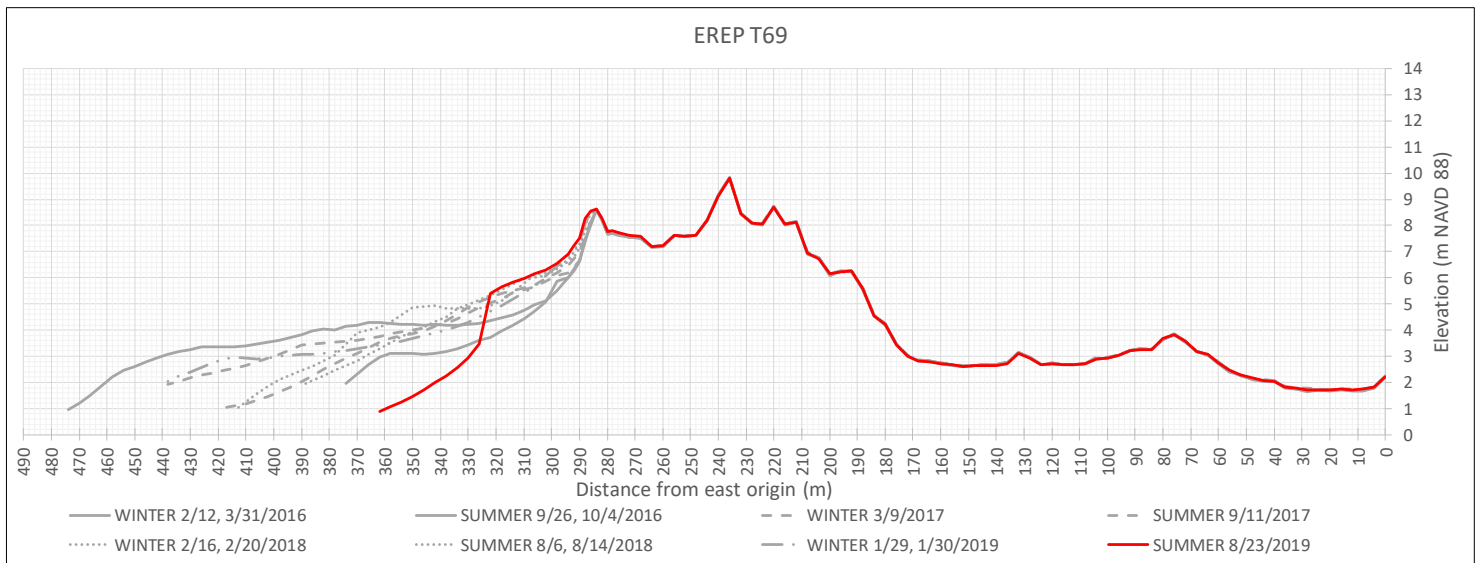


Eel River Estuary Preserve Transect 69



View north at 294 m (foredune base)

Notes: The profiles describe a peaked *Ammophila* foredune and foredune swale backed by a relict foredune, and a stable back-dune area sloping down to the estuary. The foredune was scarped during winter 2016 prior to the survey. Between winter 2016 and summer 2016 significant deposition occurred in the mid to lower beach (up to 1+ m) while the beach at the base of the scarp changed little. By winter 2017 the backshore had experienced deposition, which continued through summer 2017, resulting in a net gain of 1+ m. The resulting gently sloping backshore can be seen in the photograph taken from the transect and looking north (above left). However, the foreshore stayed up to 2.4 m below summer 2016 levels. In summer 2018 the backshore received up to 1 m of deposition. Between winter and summer 2019 the upper beach eroded, losing up to 2.5 m vertically.

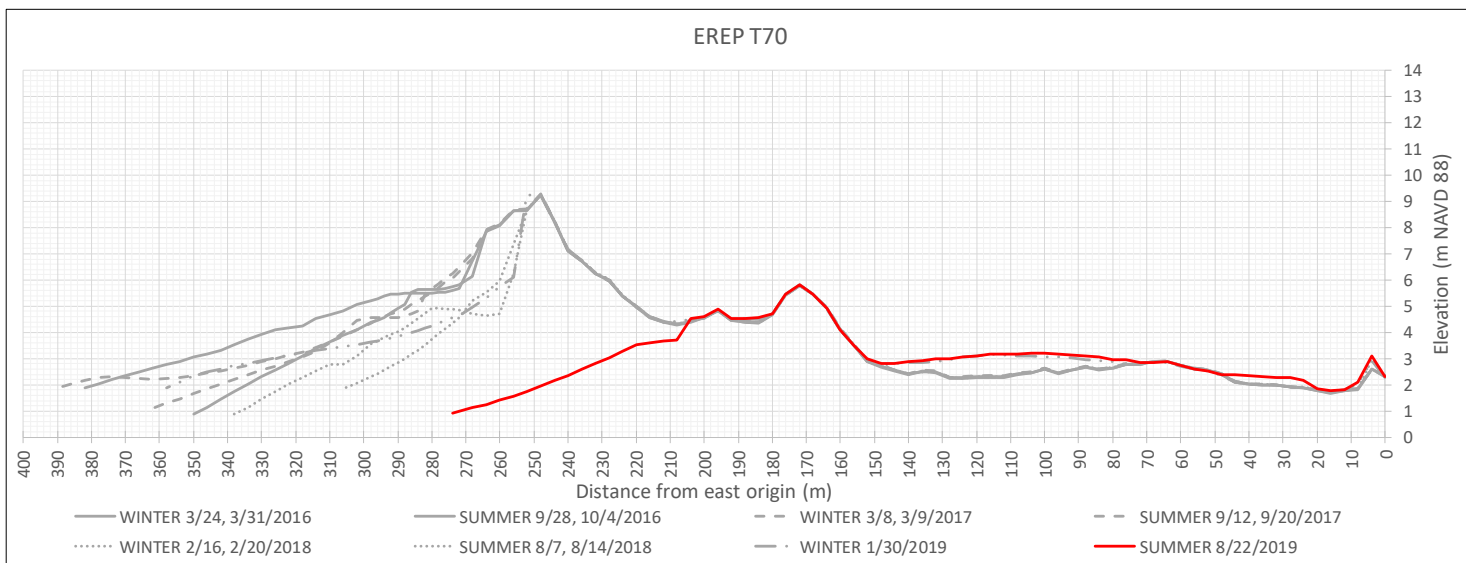


Eel River Estuary Preserve Transect 70



View north at 256 m (foredune crest, left and scarp, right) and below at 252 m

Notes: The transect is located near the south end of the barrier where the dune system narrows just north of a fore-dune breach area. The *Ammophila* foredune was scarped during winter 2016 prior to the survey. By summer 2016 additional scarping had occurred and the foreshore lost 1.5 m of elevation. A Scarp-fill ramp was created during winter and summer 2017. Between the summer 2017 and winter 2018 survey a major scarping event eroded the foredune 10 m horizontally (see photos above). By the summer 2018 survey the scarp had further eroded at the base but up to 1 m of sediment was deposited on the upper beach, forming a bench. Between winter and summer 2019 the foredune was breached and eroded entirely (see photo to right).

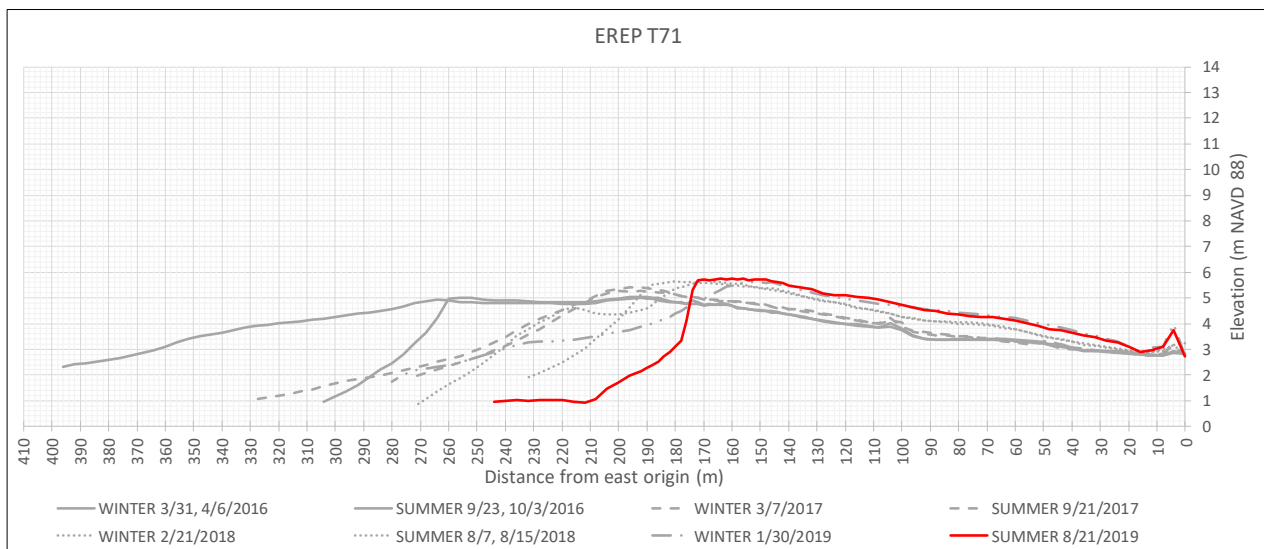


Eel River Estuary Preserve Transect 71



View north at 166 m (overwash area)

Notes: The transect passes through a large foredune breach area that is subject to washover during high water events. The profile describes a berm that is primarily influenced by waves in the winter months and modified by aeolian action in the summer, and is translating inland. Extensive beach erosion occurred in winter 2016 after the survey, creating a steep berm in summer 2016. Additional erosion occurred on the seaward side of the berm in winter 2017, but deposition of 0.3 m occurred on the crest of the berm. Minor deposition by aeolian processes occurred in summer 2017 at the crest. The berm eroded back 30 m between summer 2017 and winter 2018, but deposition by summer 2018 replaced some of it, leaving a swale in the area of the former crest of the berm. Between winter and summer 2019 there was major erosion of the berm, which retreated horizontally and lost up to 2 m vertically.



Eel River Estuary Preserve Transect 72

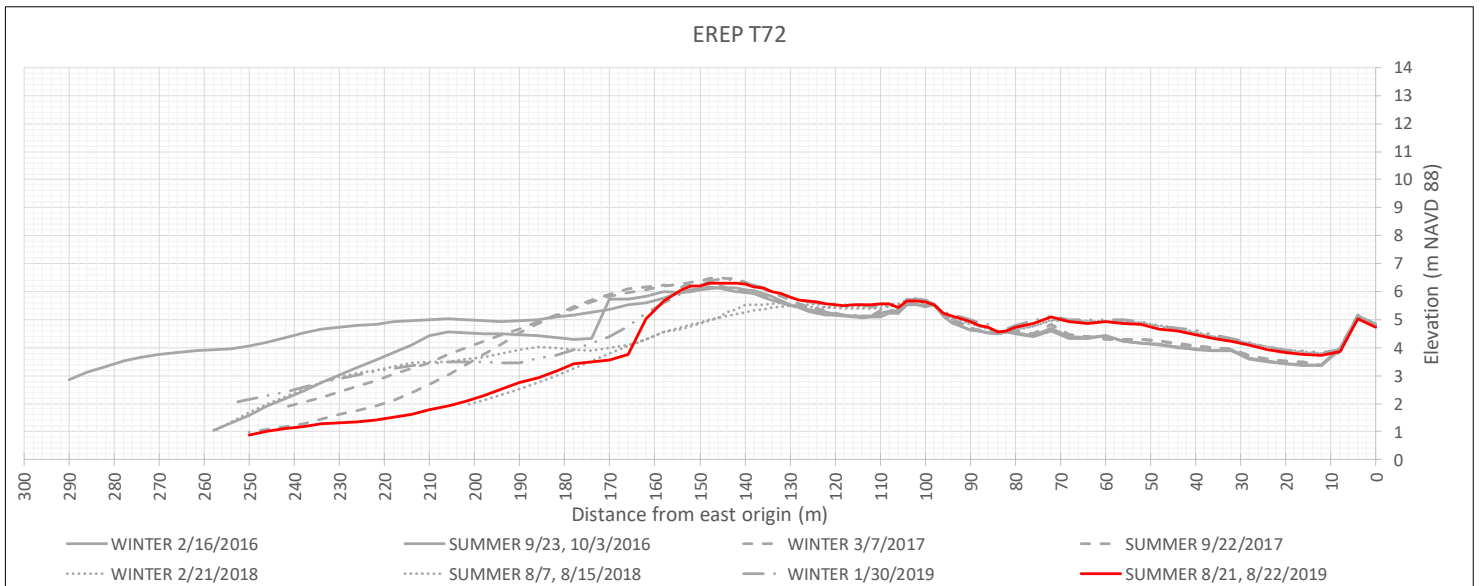


View southeast at 190 m (upper beach) looking southeast towards breach

Notes: The transect passes through remnant vegetated areas between narrow breach areas that are subject to washover during high water events. The former foredune area is within the washover and is now a berm that is primarily influenced by waves in the winter months and modified by aeolian action in the summer. The transect skirts the edge of the remnant foredune to the north as can be seen in the photograph above taken southeast along the transects from the upper beach. As in Transect 71 to the north, there was significant beach scarping between winter and summer 2016 forming a berm. The area was overwashed in winter 2017, and the berm was reshaped to a gradually sloping beach. Some aeolian deposition occurred during summer 2017, moving the crest of the berm landward. Between summer 2017 and winter 2018, the crest of the berm eroded 40 m horizontally and lost 1.0 m of elevation. Up to 0.5 m was deposited in the overwash lobe. Additional erosion of the berm occurred between winter and summer



mer 2019. The berm has translated significantly inland since monitoring began in 2016.



Russ Property Transect 73

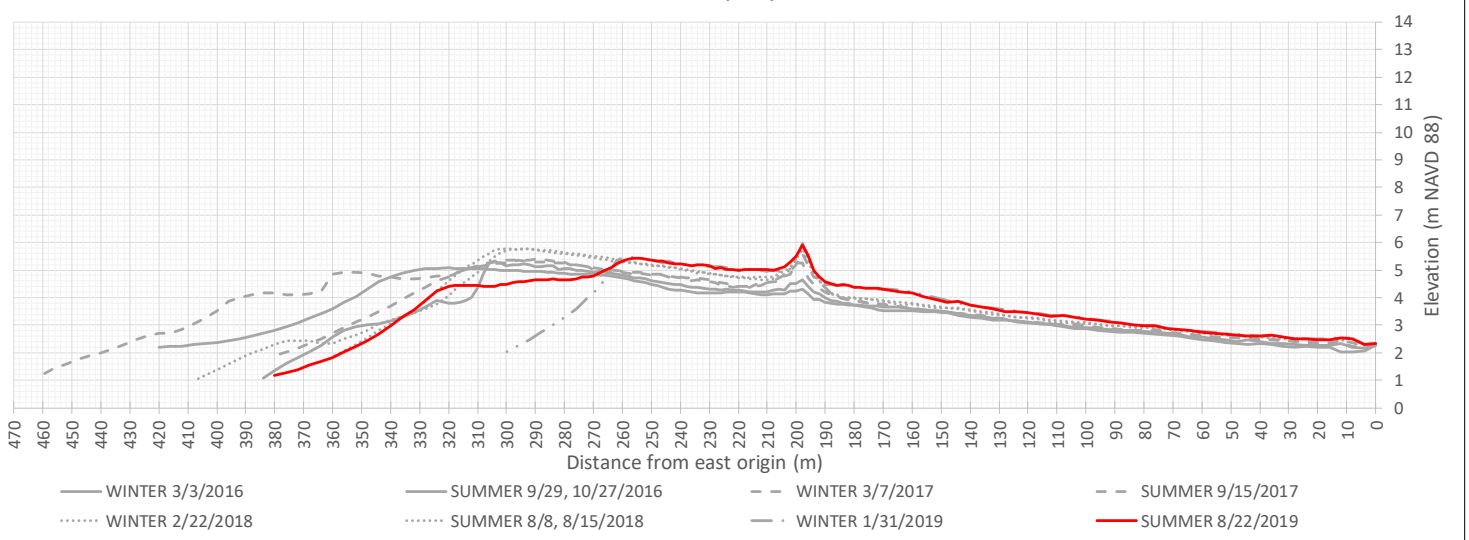


View south at 296 (upper beach)

Notes: The transect is located within the long, continuous overwash area north of Centerville Beach. Similar to washovers to the north, the profile describes a berm that is primarily influenced by waves in the winter months and modified by aeolian action in the summer. Extensive beach erosion and overwash occurred in winter 2016 after the survey, creating a steep beach scarp in summer 2016 that was 30 m landward of the former berm crest, but adding 0.2 m of elevation to the overwash fan. The area was again overwashed in winter 2017, which filled in the scarp and added an additional 0.2 m to the overwash fan. In summer 2017 there was a large pulse of sediment from intertidal bars welding to the beach, and additional aeolian deposition occurred on the berm crest. During 2018 the bar was removed and the profile returned to conditions similar to winter 2017. In winter and summer 2019 erosion occurred on the berm, causing further retreat. The peak in the graph at 198 m is an *Ammophila nebkha* that has continued to trap sediment.

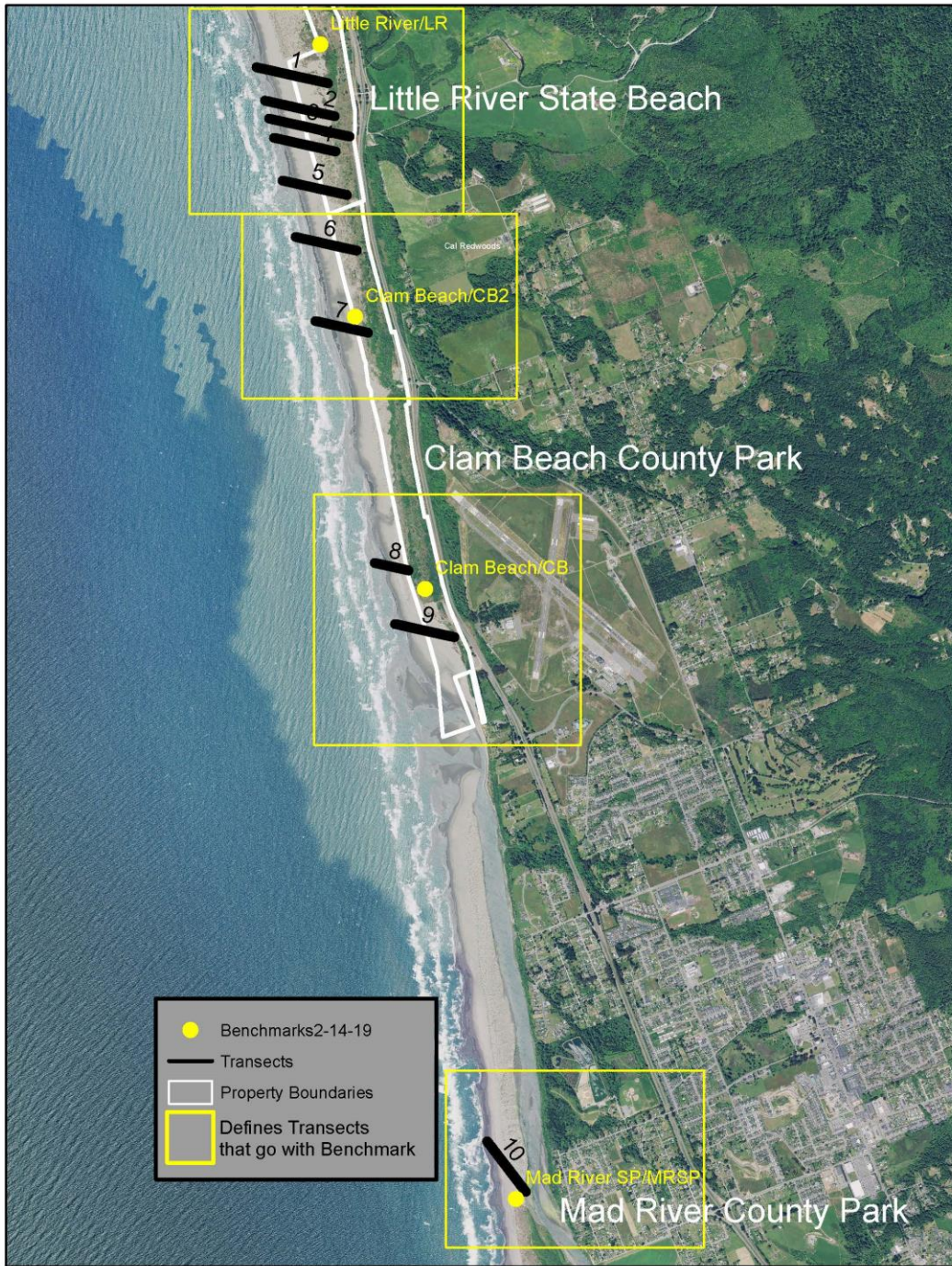


Russ Property T73

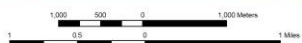
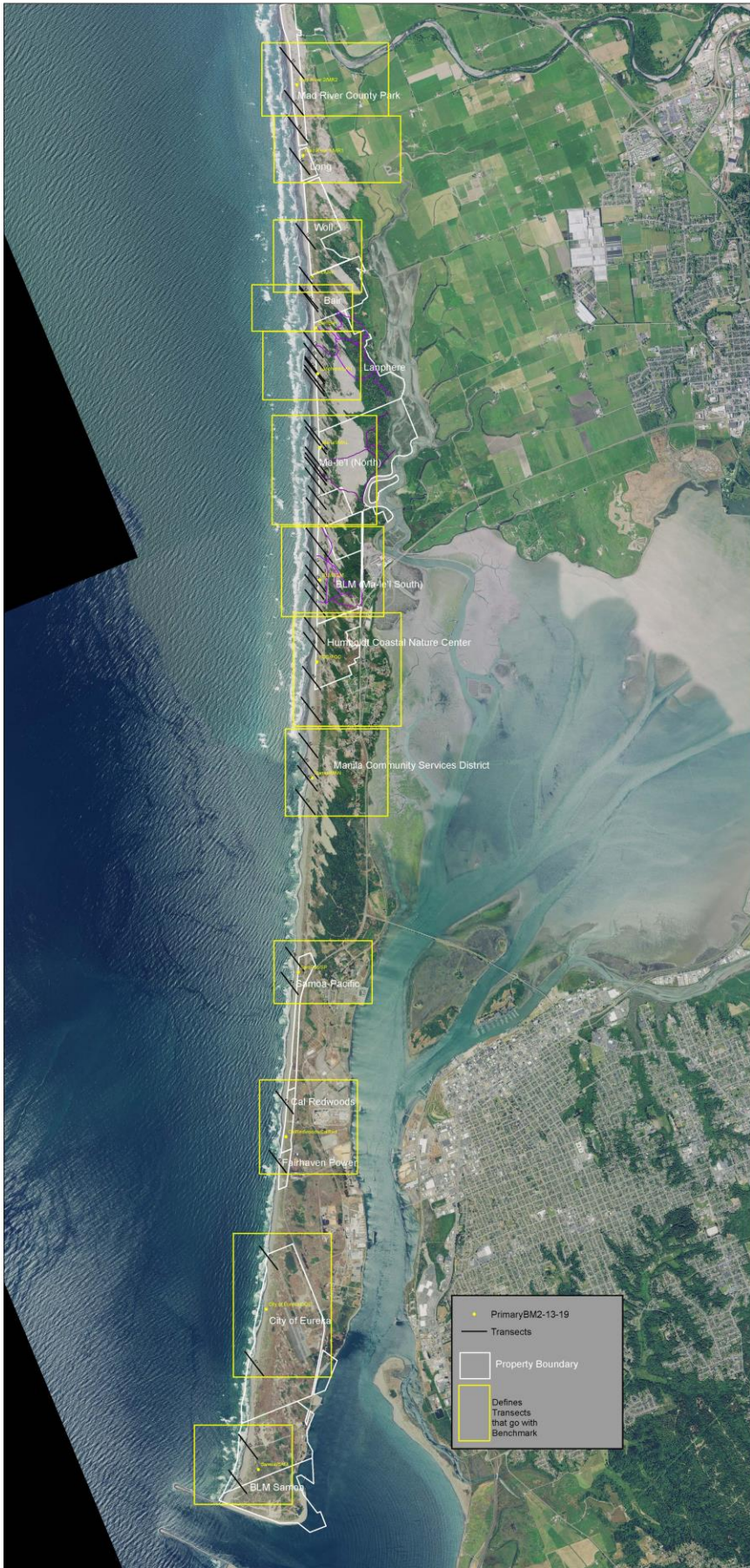


APPENDIX A: MAPS

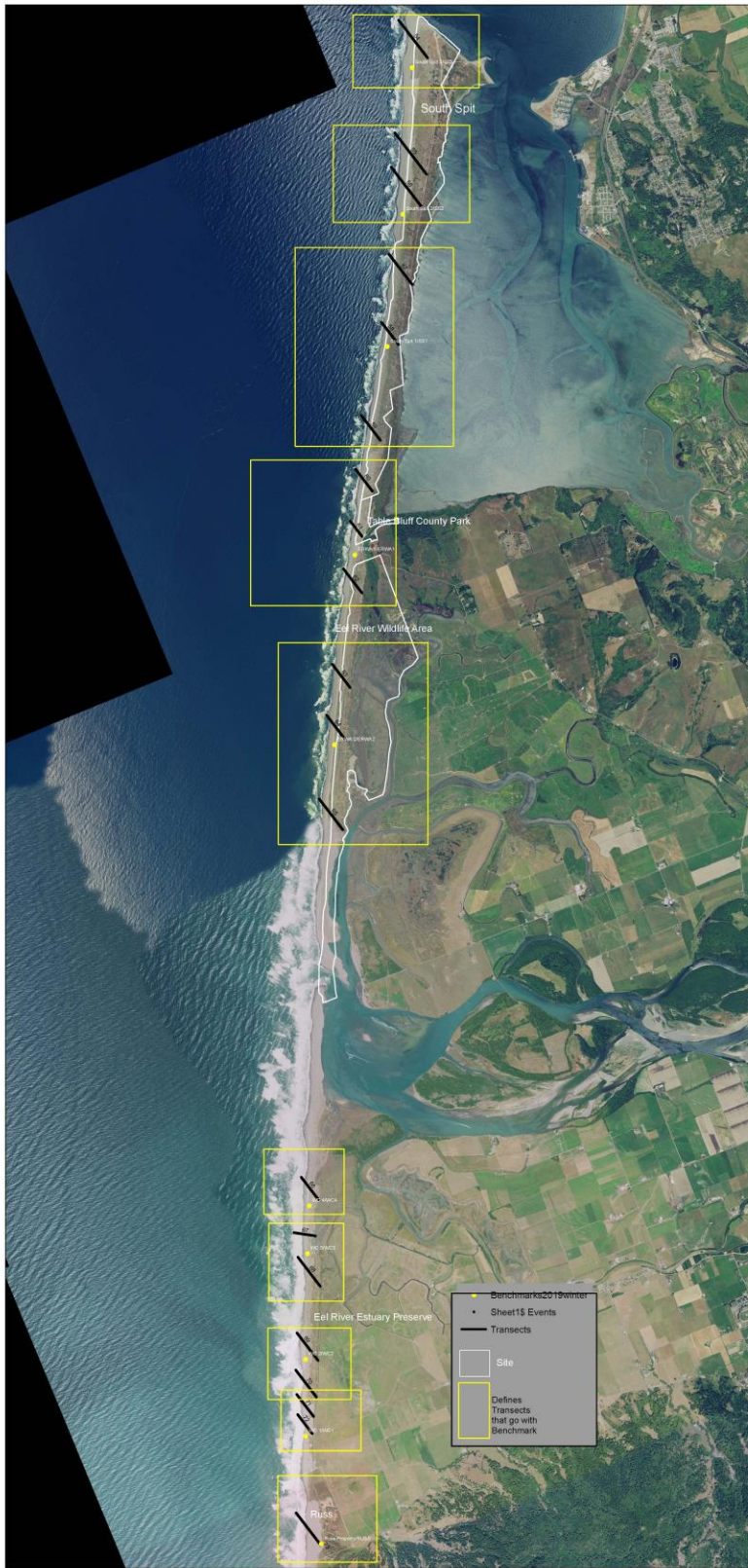
Little River/Clam Beach Transects, Benchmarks, and Property Owners Dunes Climate Ready Project



Northern Transects and Benchmarks



Southern Transects and Benchmarks



12-17-2018