HUMBOLDT COASTAL RESILIENCY PROJECT

AND

CLIMATE READY PROJECT

SUMMARY DATA FOR CROSS-SHORE TRANSECTS

WINTER 2016-SUMMER 2020

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July 2021

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Introduction

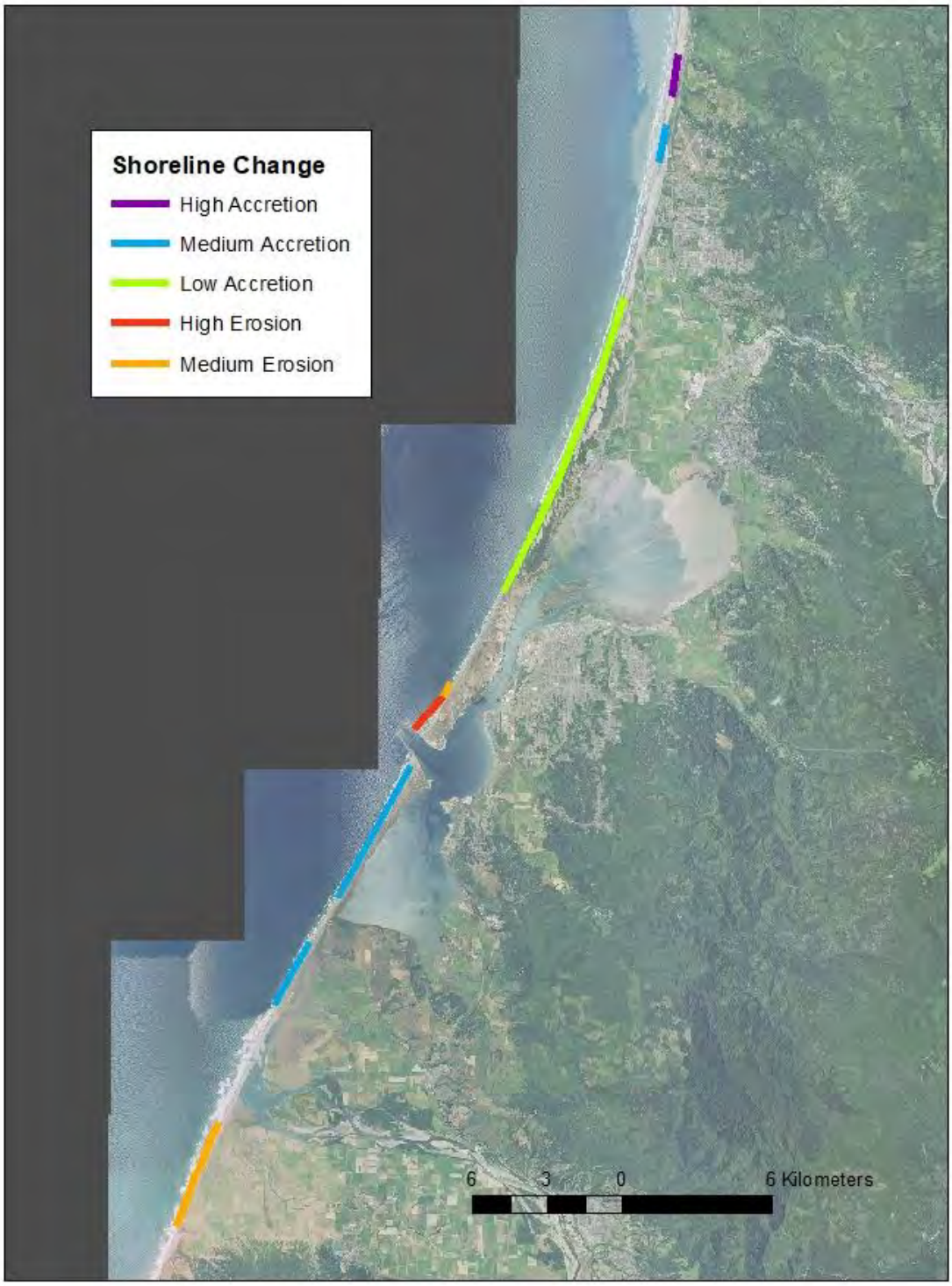
Sea level rise and/or extreme events are capable of causing excessive erosion on the beaches and foredunes that line the outer edges of the barriers enclosing Humboldt Bay and the Eel River delta within the Eureka littoral cell. Erosion of these protective barriers threatens the natural and cultural resources and infrastructure behind them in two significant estuaries. A major goal of the Climate Ready Project and the Humboldt Coastal Resilience Project was to quantify present day beach-dune morphodynamics, which could then be used to model the impacts of sea level rise and extreme events. For this purpose, a total of 73 cross-shore transects were established along the littoral cell. Elevation and vegetation data collected on transects will be used in a quantitative model to predict beach, dune and barrier responses to sea level rise and extreme events. The purpose of this report is to present raw data in the form of graphs of elevation change along transects as the basis of qualitative observations of response during the period of data collection, 2016-2020. The primary audience is property owners within the study site. Conclusions of this report are based on qualitative analysis and may change when modeling is completed.

Methods

Transects were located along the extent of the Eureka littoral cell, from Little River to Centerville. Transect sites were chosen to encompass variation in beach/dune morphology and dominant vegetation. Data collected along transects included elevation, dominant vegetation, and mean vegetation height. Benchmarks were established along the littoral cell, and transects were assigned a parent-child relationship with benchmarks, allowing missing benchmarks or transects to be relocated if needed. A base station was set up for each set of associated transects, and an RTK GPS was used to measure elevations at 2-4 m intervals. A vegetation sampler followed behind the GPS rover and took a vegetation sample surrounding the elevation point. Vegetation results are not covered in this report. Photopoints were taken at geomorphic landmarks including upper beach, foredune base, foredune crest, and scarps when they appeared. Transects were measured twice per year, in winter and summer, from winter 2016 through summer 2020. The Lanphere-Ma-le'l transects had begun earlier in 2012 and the start date transect is included in this report as it informs longer term trends.

Results by Site

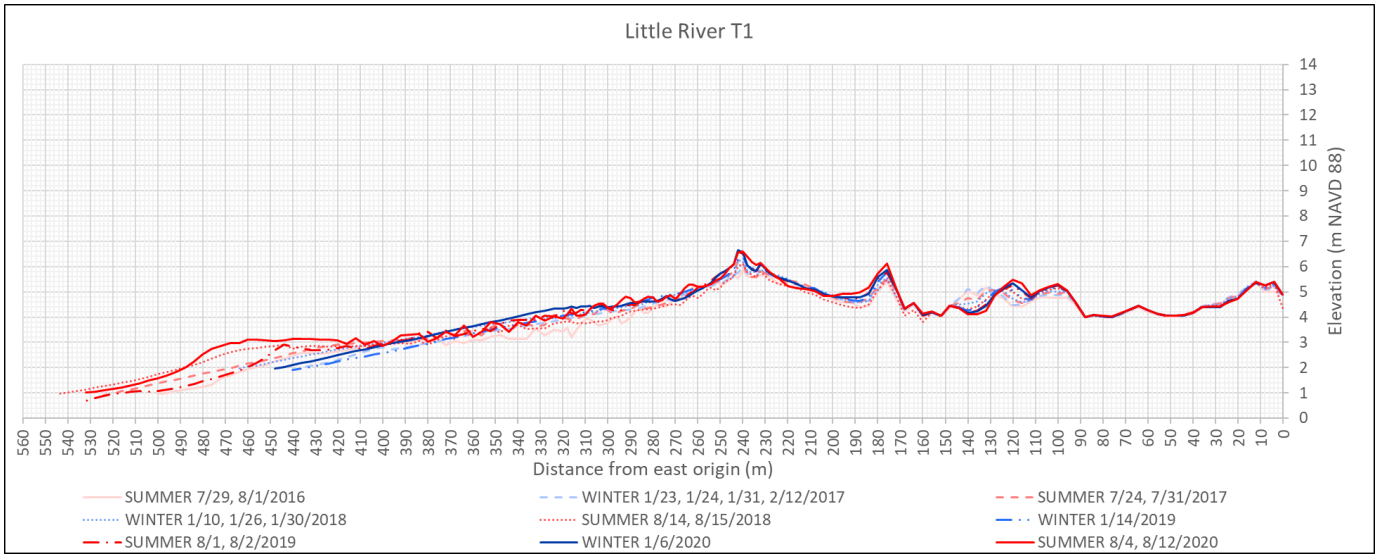
This section contains graphs of all transects, organized by property ownership, which generally reflects consistent management. A map of transects is provided using NAIP 2016 imagery as a base map. Two graphs are shown for each site. The first (top) graph includes all dates of the surveys. The second (bottom) set shows only Summer 2016 and Summer 2020 as an indication of net changes in volume of sediment along the transect. All graphs have the same x axis range (0-14 m NAVD 88), but horizontal axes and therefore vertical exaggeration differs. Transects are presented from north to south. A summary of results is provided at the end of each site section. A map of long-term shoreline change for the littoral cell is presented below.

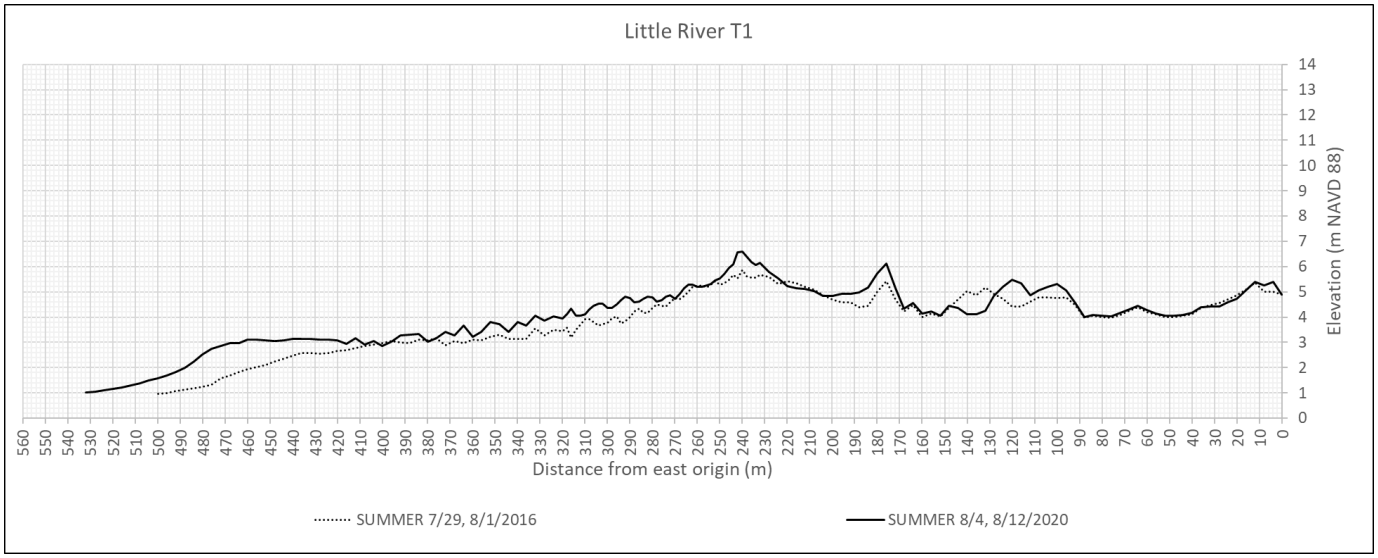


HISTORIC SHORELINE CHANGE MAP. This map illustrates historic change in shoreline position from 1939/1948 through 2016 based on McDonald (2017) and GHD (2017).

Little River State Beach

Little River Transect 1





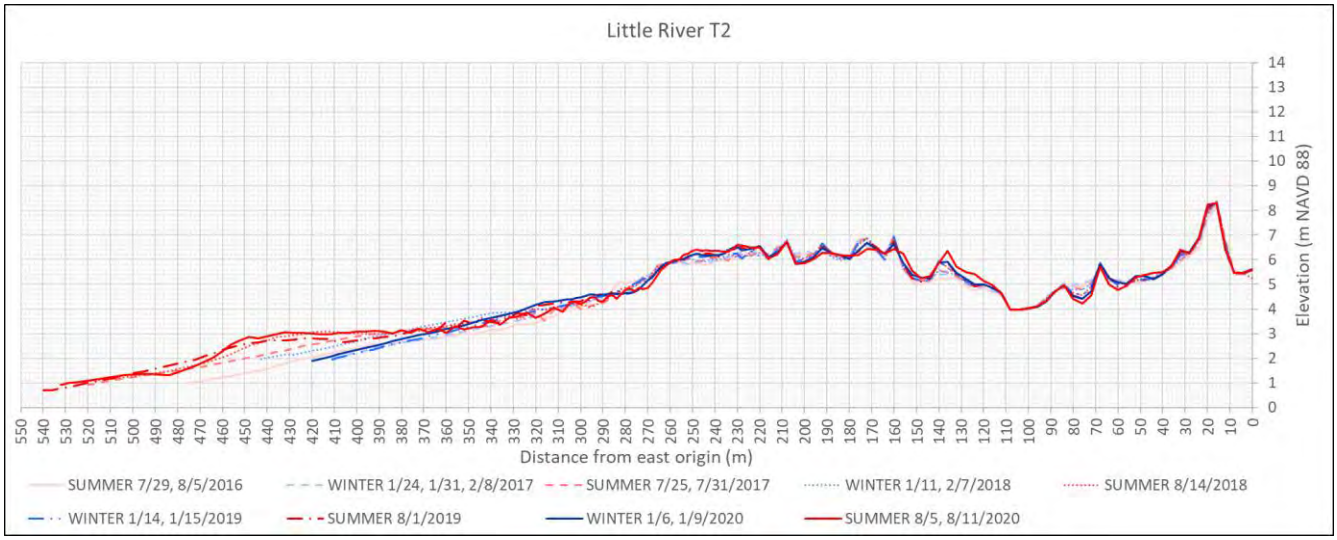
Notes: The transect is located in an area of Little River State Beach, restored through the removal of European beachgrass (*Ammophila arenaria*) by heavy equipment beginning with a pilot project in 2004 and completed in 2008. Data are not available for winter 2016 but profiles otherwise show a winter 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 plateau-like nebkha field, reaching a maximum elevation of 6.6 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. Between 90 m and 190 m upland areas intersperse with deflation basins. Between 2018 and 2020 the foreshore gained in elevation, and the transverse dunes in the backdune area migrated east. Over the entire period 2016-2020 there was net deposition on the upper beach and foredune. Little River dunes have been shown to be an area of net accretion in other studies.

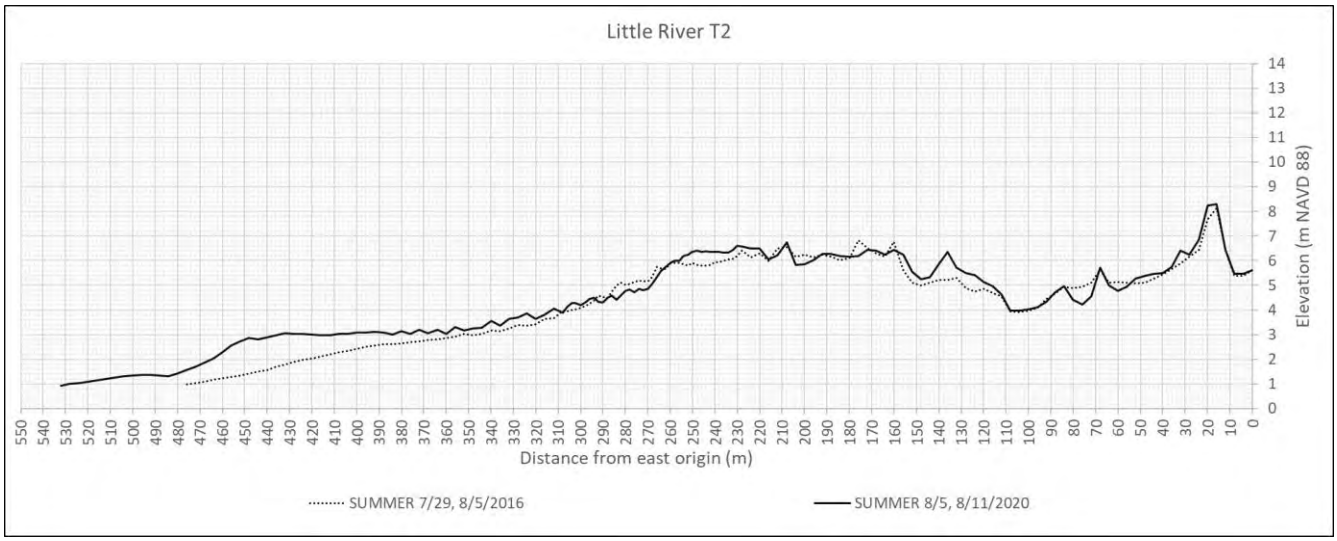
Little River Transect 1

Upper beach.

View northwest, at 328 m, illustrating transverse dunes on the upper beach forming annually in summer.

Little River Transect 2



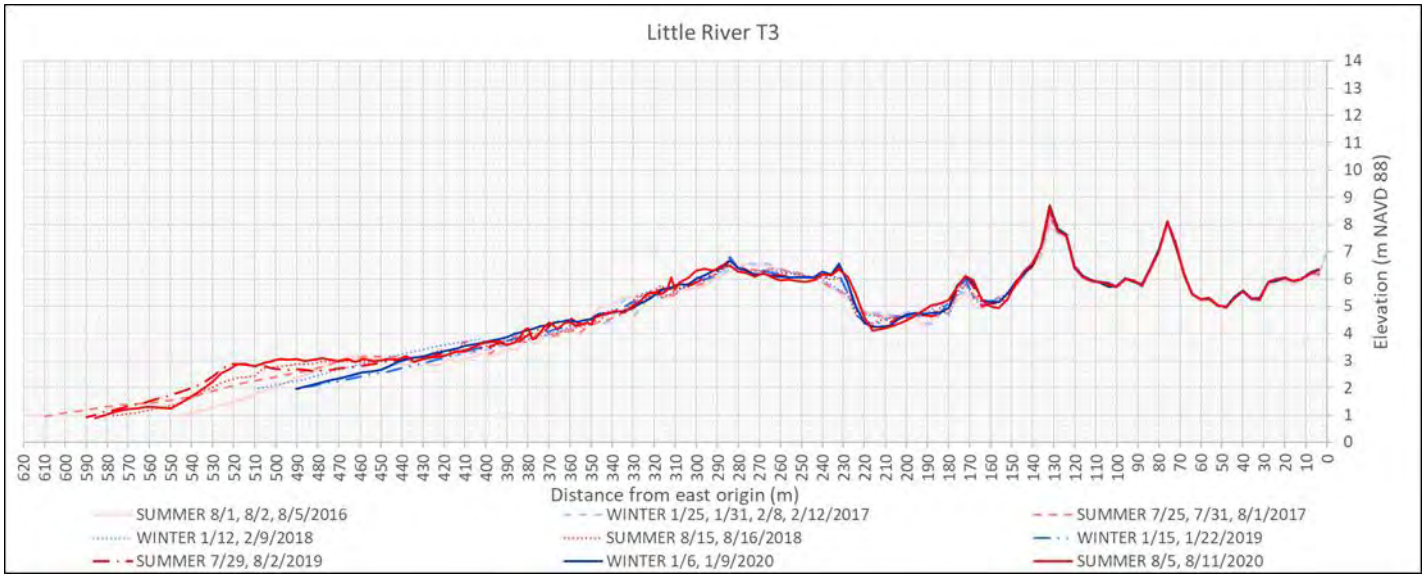


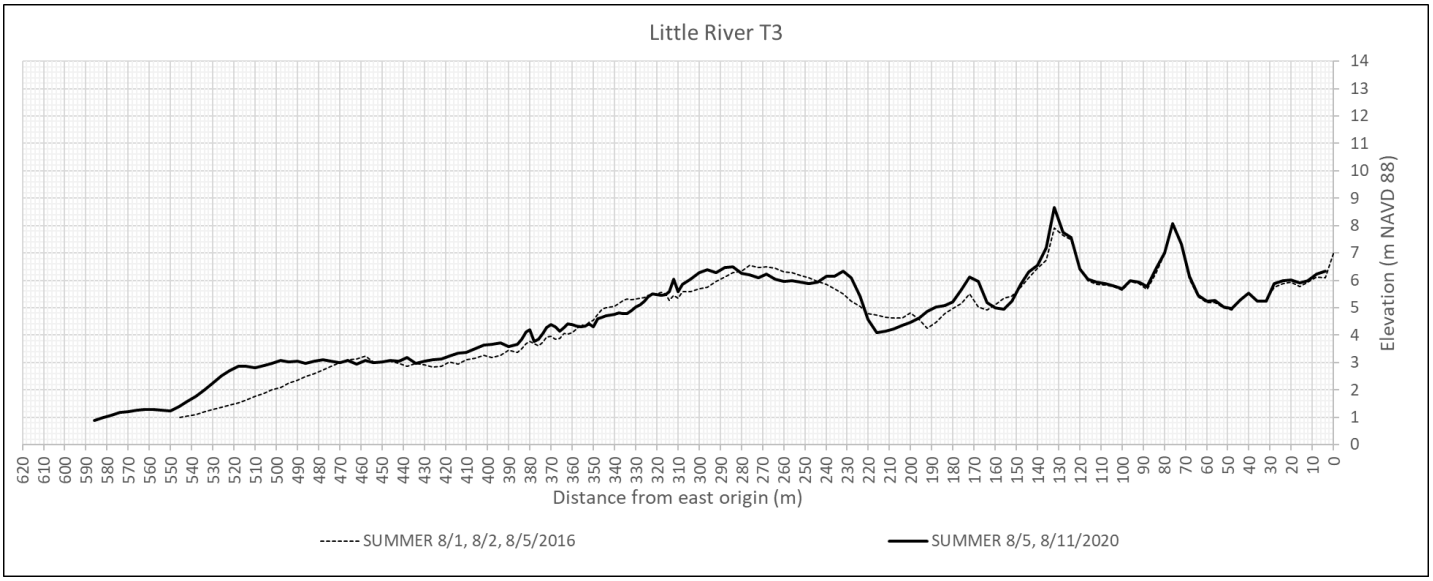
Notes: Similar to Transect 1 and located in an area of Little River State Beach restored through the removal of *Ammophila* by heavy equipment. Transects show a winter flattening of the backshore by storm wave runup, erosion, and deposition, followed by development of transverse dunes in summer, with net accretion of up to 1.2 m on the lower beach between summer 2016 and summer 2020. The backshore gradually rises in elevation and transitions to a broad plateau-like nebkha field. Nebkha show both flattening (see photo below) and in some areas development of new slipfaces between summer 2016 and summer 2020. Maximum elevation of the nebkha zone along the transect is 6.7 m NAVD 88 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. Over the course of the study there was net deposition both on the beach and in the nebkha field.

Little River Transect 2

Foredune crest
View north at 208 m (foredune crest) showing deflation of nebkha

Little River Transect 3



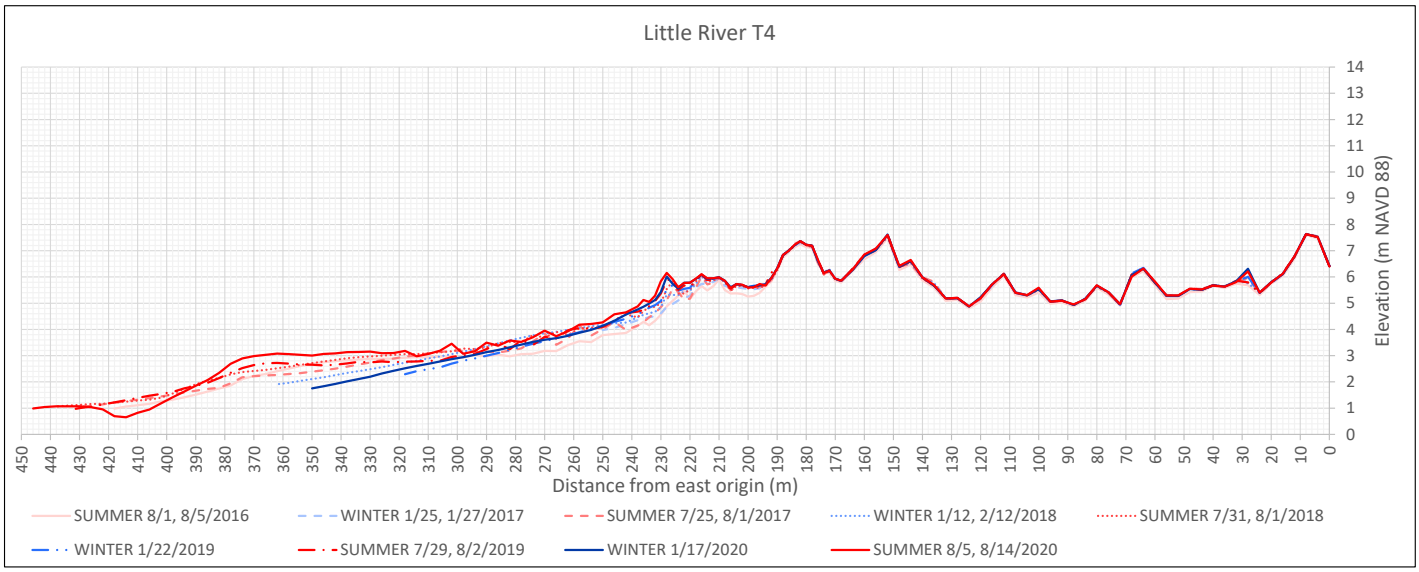


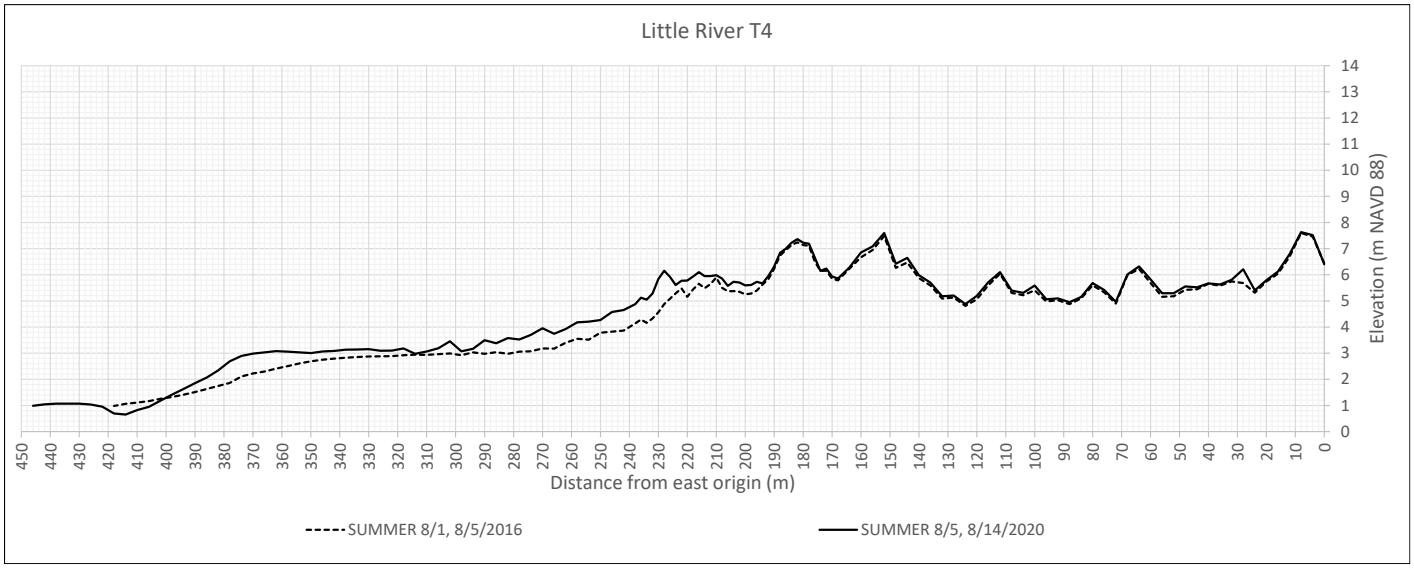
Notes: Similar to Transects 1-2, located in the northern portion of the restored area at Little River State Beach but extending into the unrestored backdune. Data are not available for winter 2016. The transect shows annual winter flattening of the backshore by storm wave runup, erosion and deposition, followed by summer formation of transverse dunes. The backshore gradually rises in elevation and transitions to a nebkha field. There is less vegetation and more even topography in the this transect compared with 1 and 2. Deposition at 284 m in summer 2018 raised the maximum elevation of the nebkha zone by 0.4 m to 6.8 m Over the course of the study there was net deposition in the backshore and to a lesser extent, the nebkha field.

Little River Transect 3

View north at 322 (foredune base) showing excavation/reburial of wood and spread of *Ammophila*.

Little River Transect 4



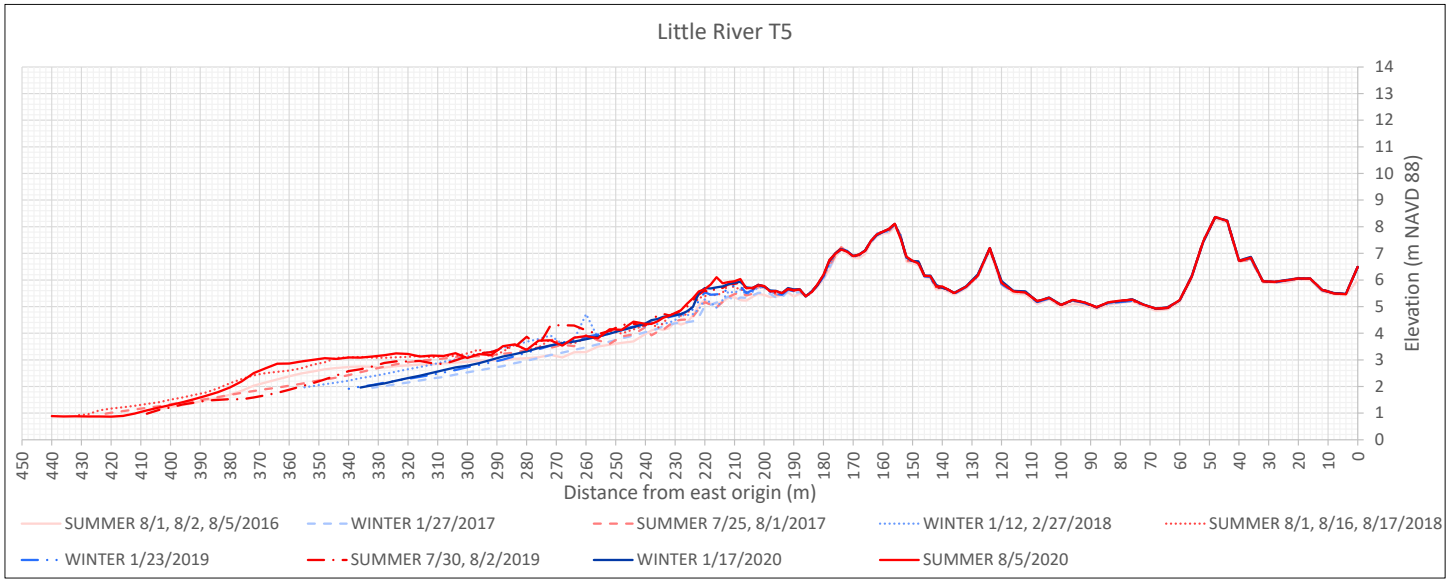


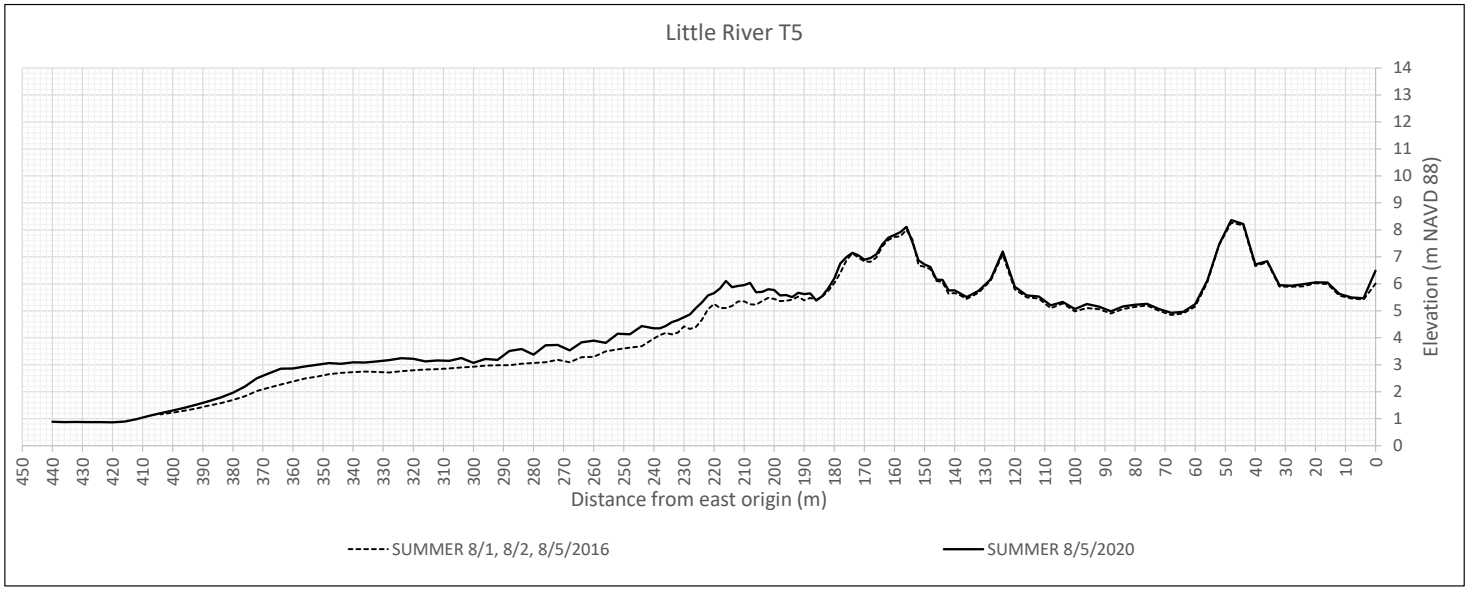
Notes: The transect, located south of the restored area at Little River State Beach, is characterized by a broad, sparsely vegetated (*Ammophila)* backshore that forms transverse dunes during summers and is flattened by wave runup in winters. From summer 2017 to summer 2020 the backshore experienced net deposition. Deposition at the west end of the backshore is visible in the photos between summer 2019 and 2020. 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. There was very little change in the stabilized backdune over the course of the study, whereas the incipient foredune prograded 10.0 m.

Little River Transect 4

View south at 230 m (foredune base)

Little River Transect 5





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 2020 (see photos below). 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. Overall, there was net deposition on the backshore and incipient foredune over the course of the study, while the backdune remained stable.

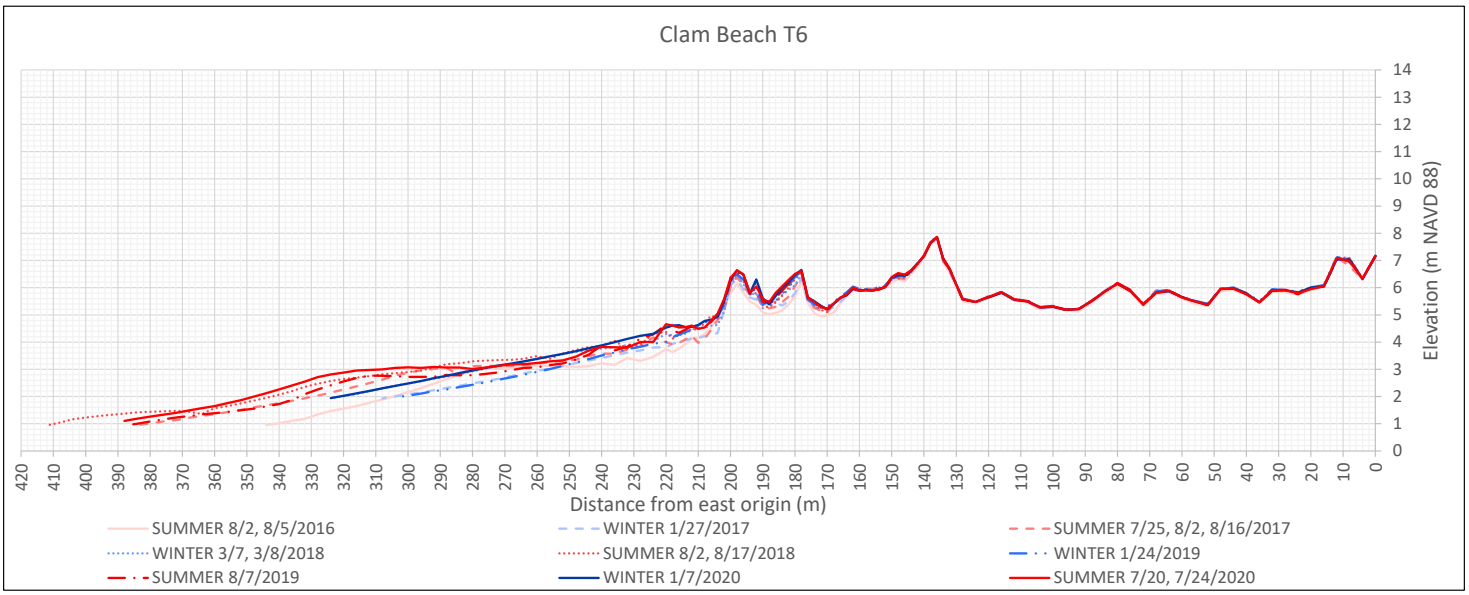
Little River Transect 5

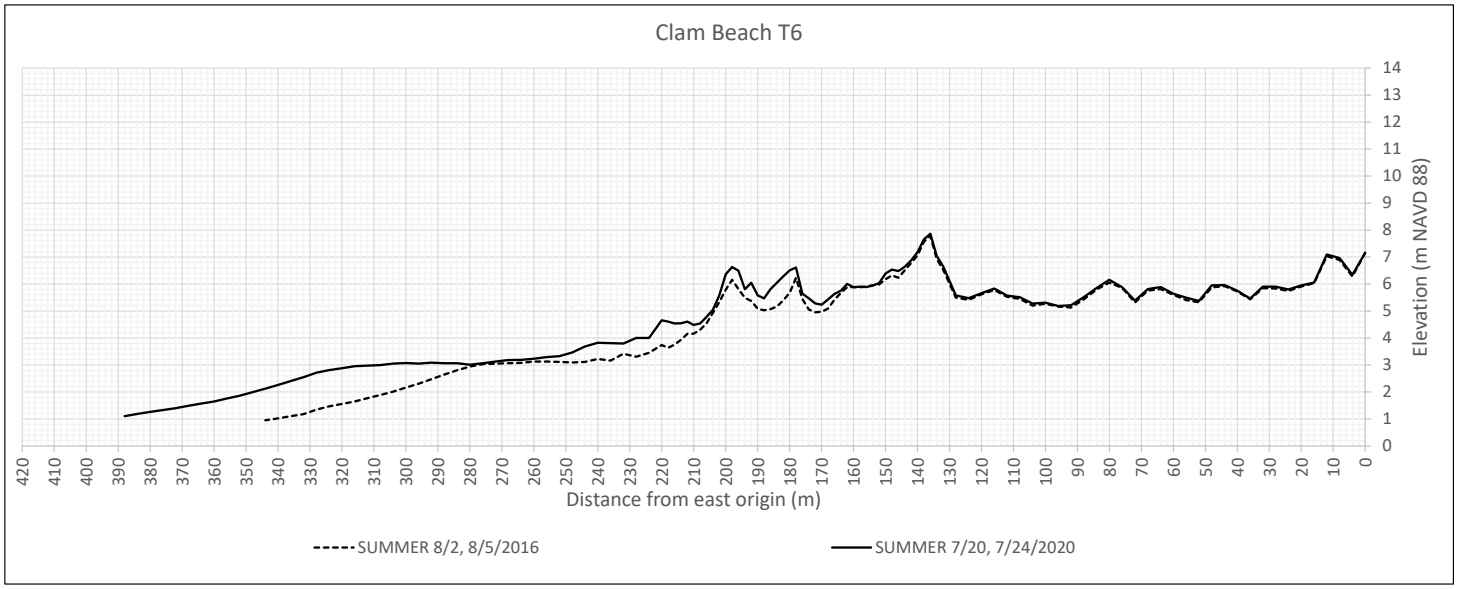
Photos taken at 224 m from the crest of the incipient foredune show deposition and expansion of vegetation.

LITTLE RIVER SUMMARY. This stretch of shoreline has historically been accretional (see map below), which is consistent with the trend of net deposition/progradation during this study. Both restored and unrestored areas showed deposition on the beach and foredune, but only restored areas showed net deposition in the backdune. There was deposition or progradation in all five transects. This area exhibits resilience based on sediment budgets observed in this study.

Clam Beach

Clam Beach Transect 6





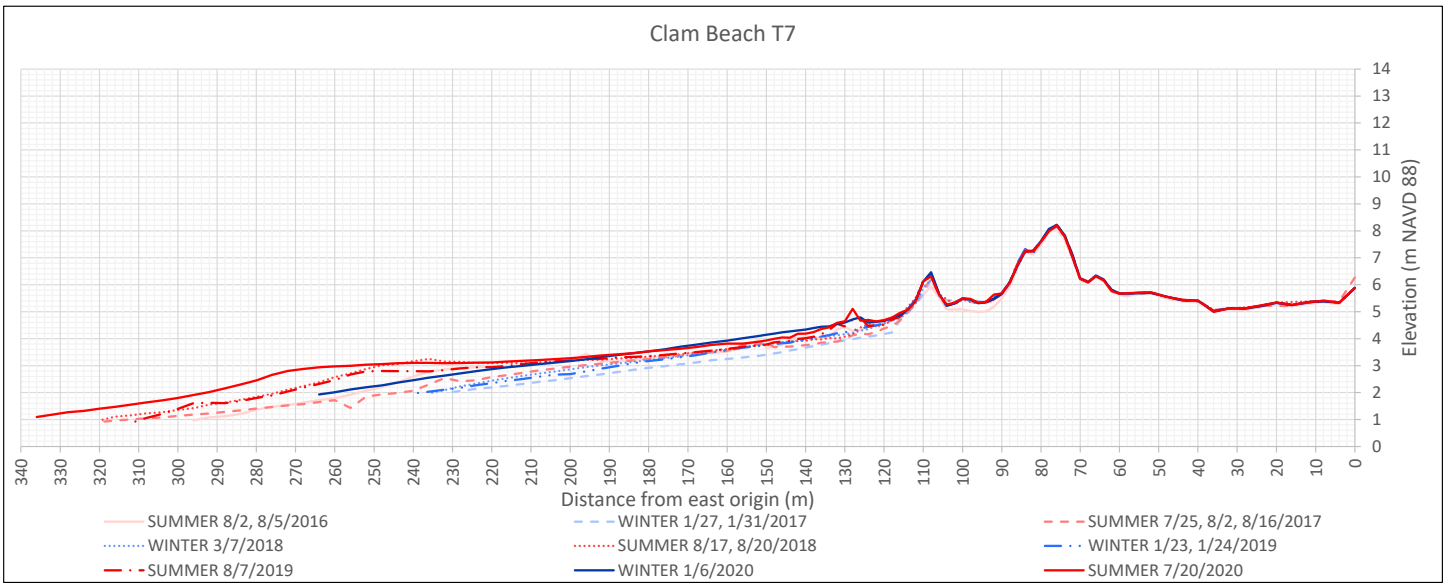
Notes: Data from winter 2016 are not available. The profile displays two relatively low and sparsely vegetated incipient foredune ridges. The outer incipient foredune was scarped in winter 2017, but ramping had smoothed the scarp by summer 2017. Deposition occurred on the upper beach as well as the crest, lee and swale of the two incipient foredunes between summer 2016 and summer 2020. Over the course of the study, there has been net deposition on the beach and incipient foredune.. The higher, established foredune at 140 m remained stable, as did the backdune in general.

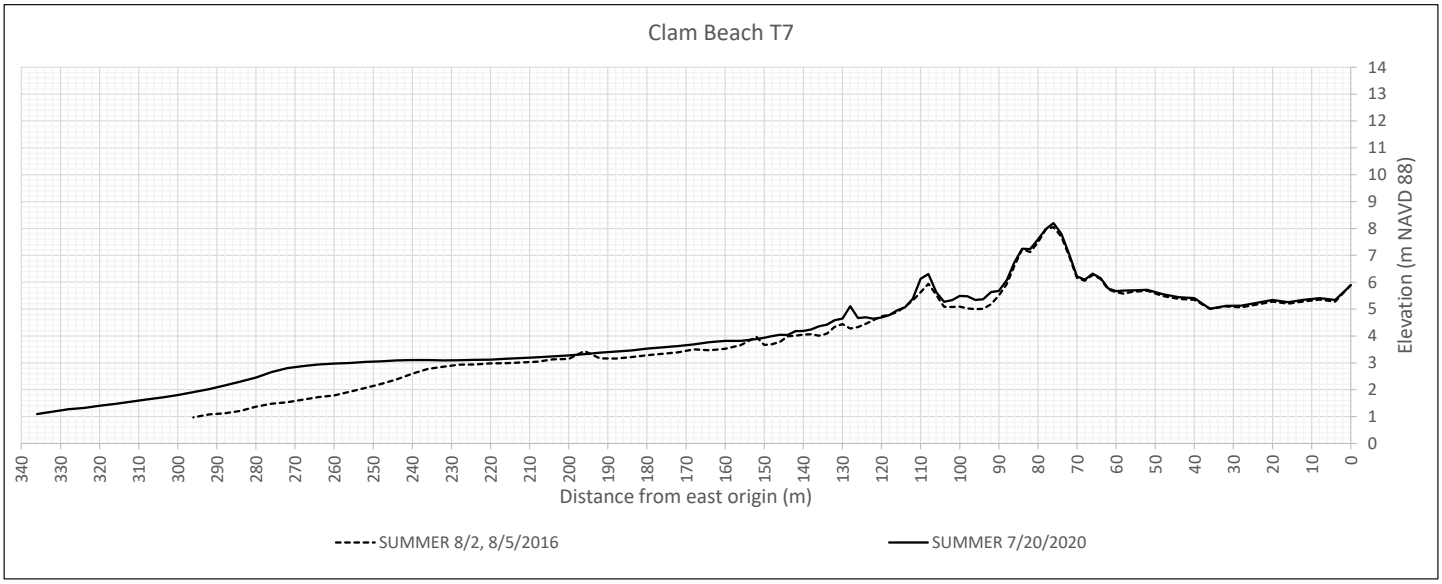
Clam Beach Transect 6

View north from foredune base at 204 m,

showing accretion of incipient foredune

Clam Beach Transect 7



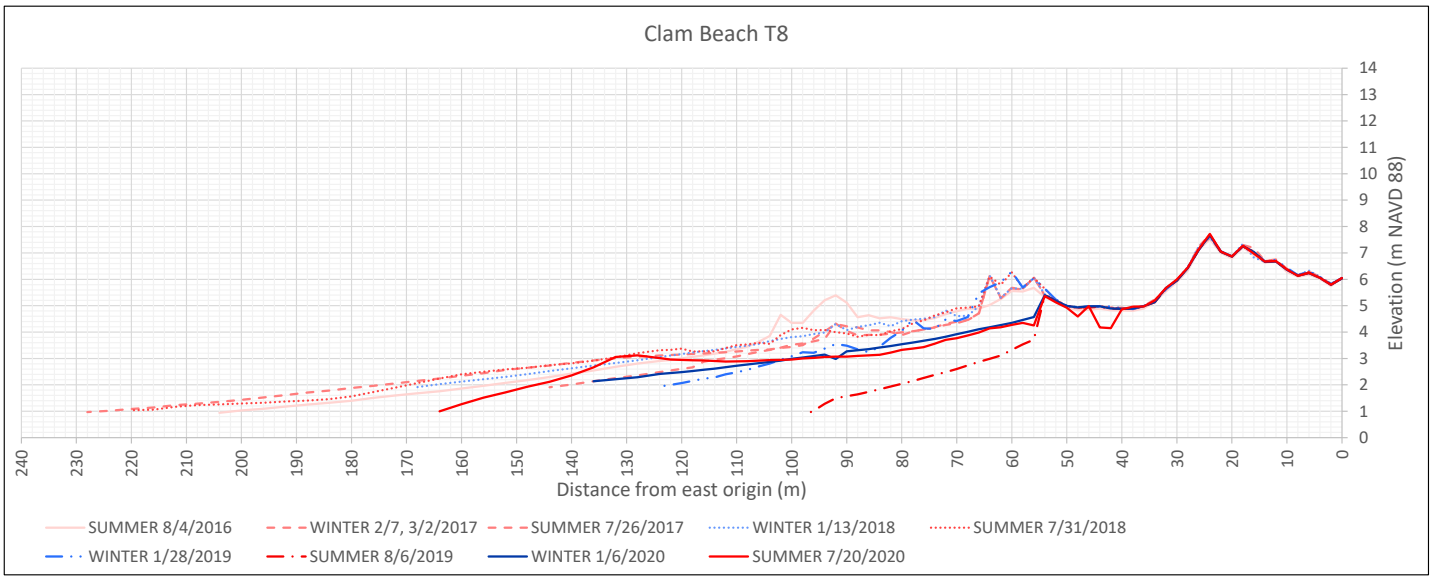


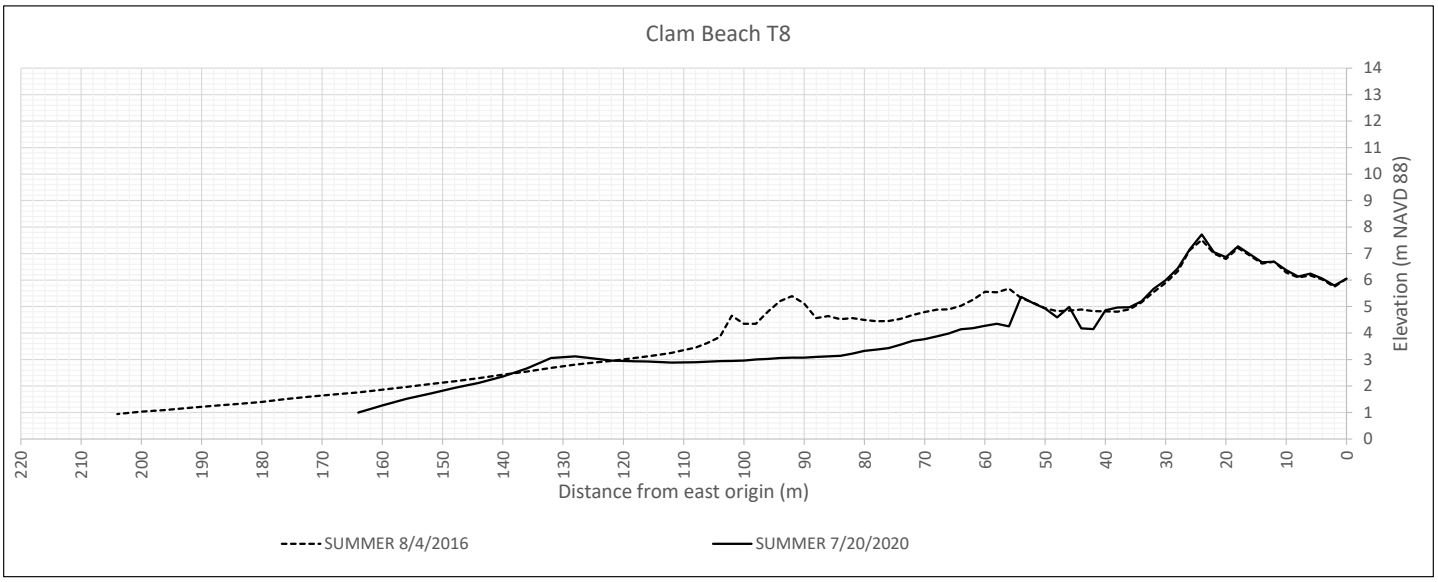
Notes: Data for winter 2016 are not available. The base of the incipient foredune was scarped in winter 2017, with sediment deposited at the crest and in the swale between the incipient and established foredunes. Between Summer 2016 and summer 2020 there was deposition on the incipient foredune as well as the swale behind it. The backshore gained up to 1 m in elevation (240 m) between summer 2017 and summer 2020. Deposition on the upper beach in summer 2019 brought it back to 2016 levels. The established foredune, vegetated by dense *Ammophila,* has been stable. Over the course of the study the profile has been relatively stable.

Clam Beach Transect 7

View north at 108 m (foredune crest)

Clam Beach Transect 8



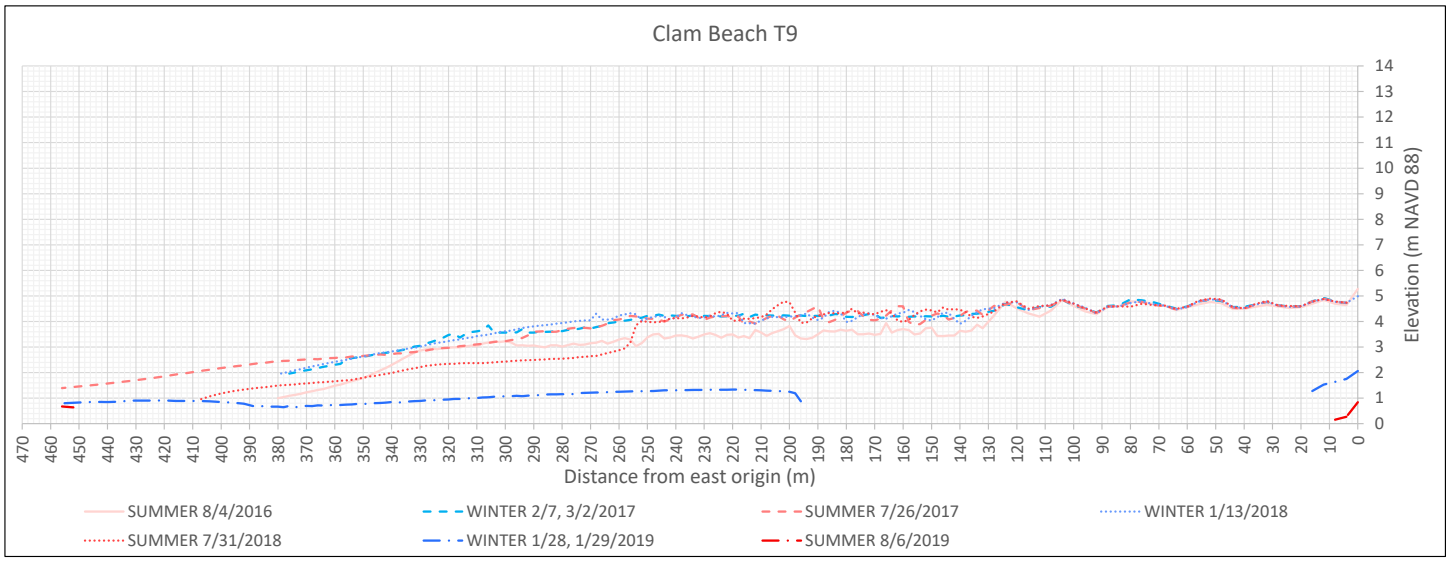


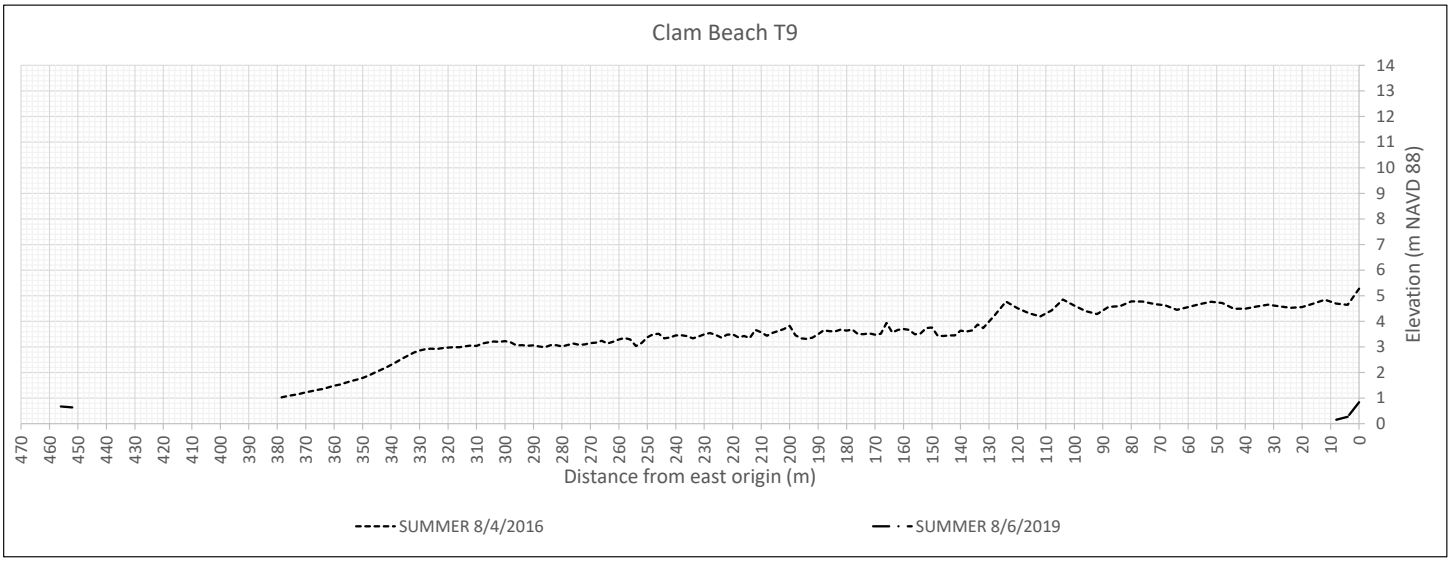
Notes: This transect is located north of the mouth of the Mad River and represents a dynamic area. The incipient foredune present at the start of the surveys was completely eroded when the river migrated northward, with a smaller incipient foredune forming behind it at 42 m. Over the course of the study the incipent foredune was removed and a new one began to form 40 m eastward.

Clam Beach Transect 8

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

Clam Beach Transect 9





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 in 2020.

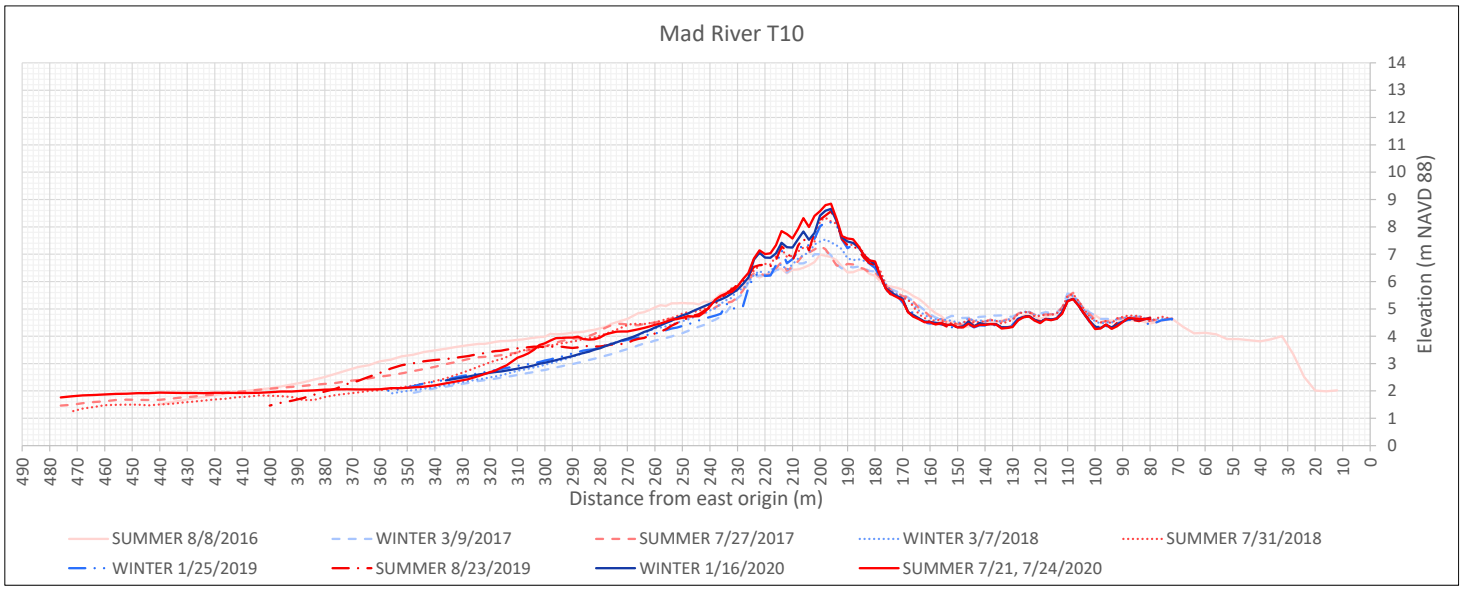
Clam Beach Transect 9

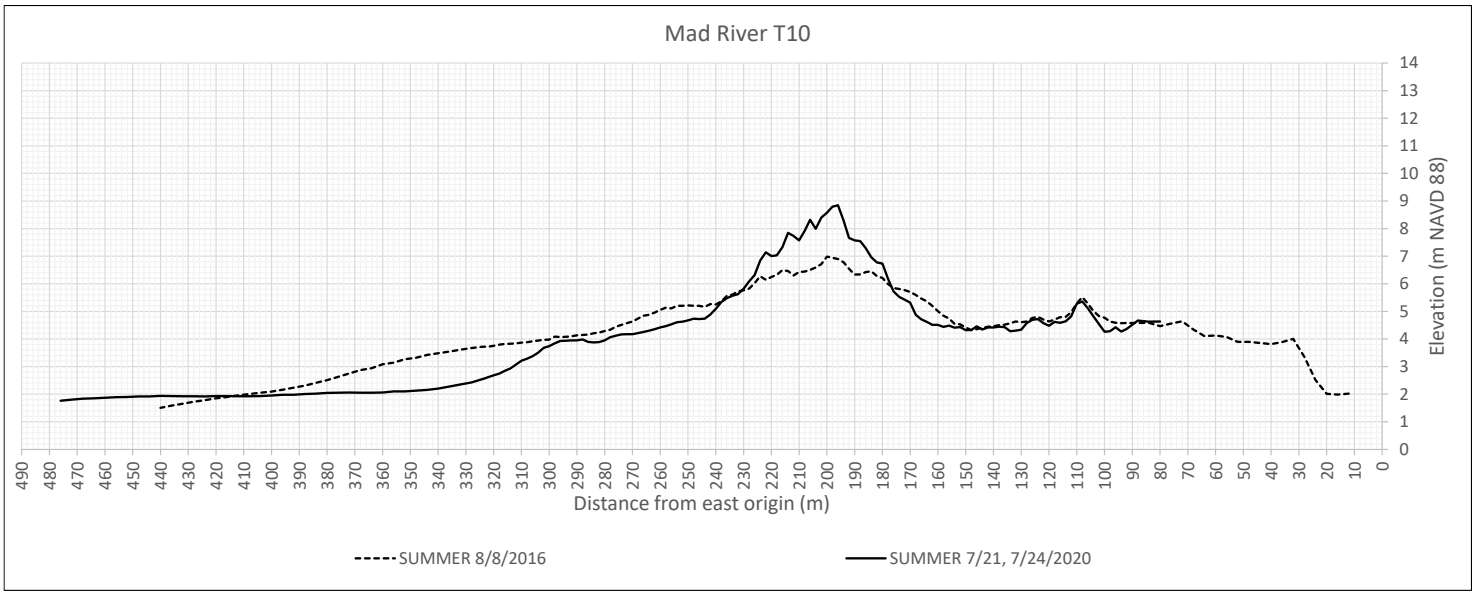
View north from east end of transect

CLAM BEACH SUMMARY. This area is contiguous with Little River and shows similar foredune depositional trends in the north, consistent with historic accretion (see Map). There are no restored areas and net deposition is confined to the beach and incipient foredune, with no change in the backdune. The transects to the south are influenced by the mouth of the Mad River, which migrated during the course of the study such that Transect 8 had its incipient foredune eroded and most of Transect 9 was completely eroded and under water. The northern portion of this regions indicates a resilient shoreline, but the southern portion is subject to movement of the Mad River mouth.

Mad River

Mad River Transect 10



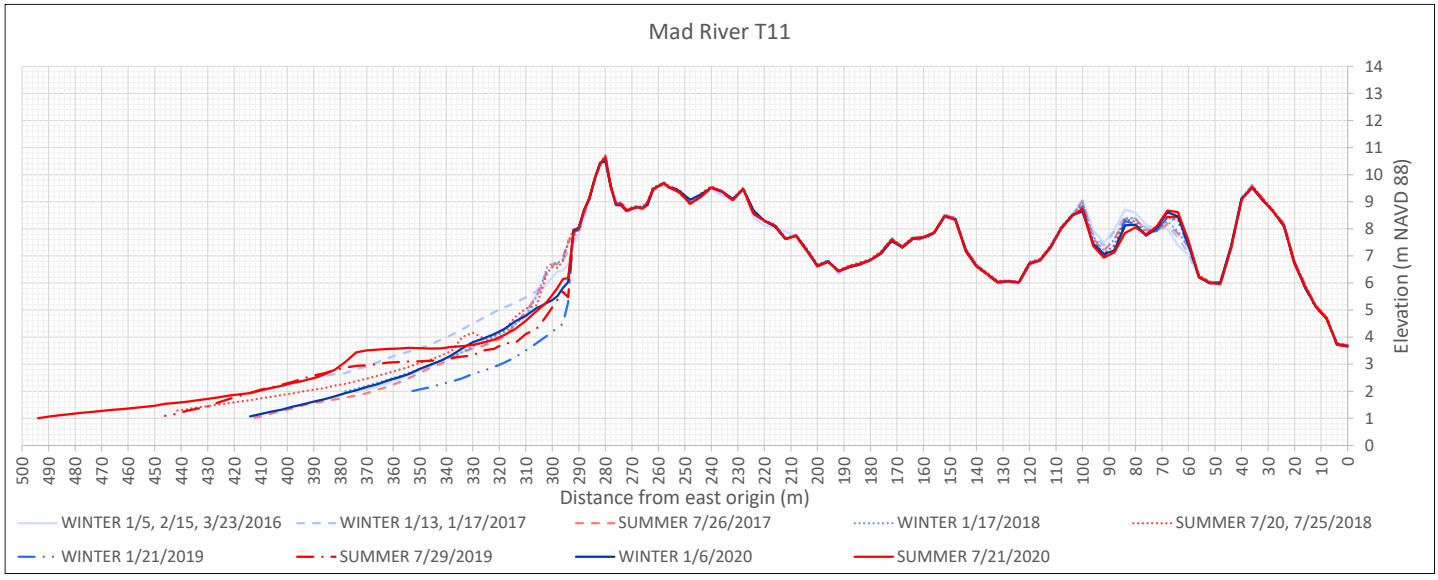


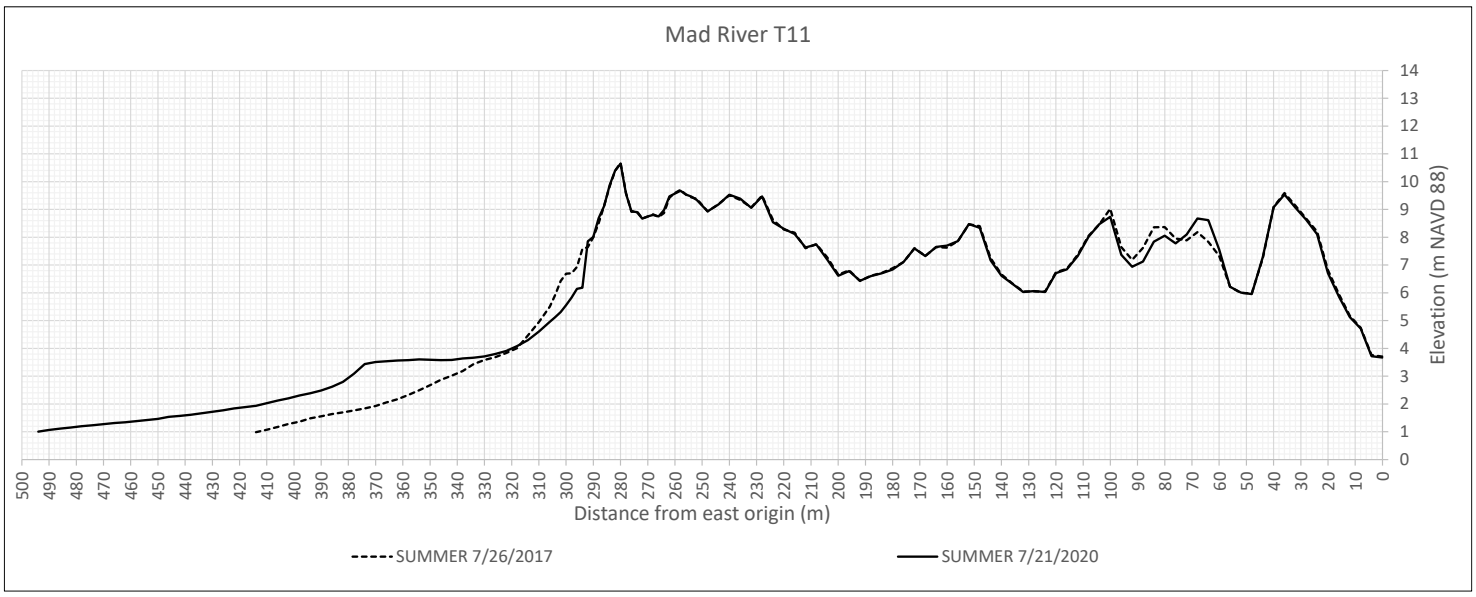
Notes: This profile comprises a cross section of the Mad River Spit near its southern end. Data are not available for winter 2016. In summer 2017 the transect began farther to the east. Erosion along the east edge of the spit during the winter of 2017 resulted in adjustment of the east end of the transect further west. The spit platform is generally sparsely vegetated and the profile exhibits dynamic changes. The central portion of the spit hosts a foredune that has steadily increased in elevation. By summer 2020, approximately 2.0 m of deposition occurred near the crest at 194 m. This is shown in the photographs by an advancing lobe of sand that has covered wood debris visible the previous winter. However the upper beach was eroded, losing up to 1.5 m of elevation. Over the course of the study the foredune increased in elevation by 1.5 m and the spit narrowed, eroding on its east edge.

Mad River Transect 10

View southeast at 194 m (foredune crest)

Mad River Transect 11



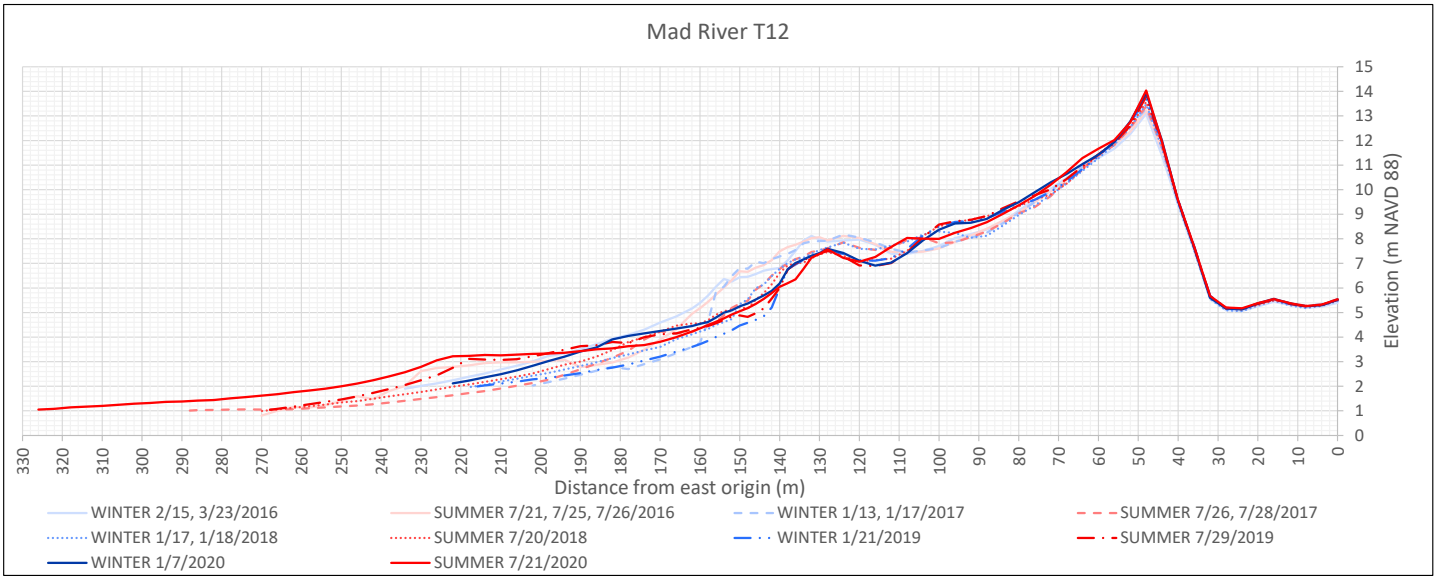


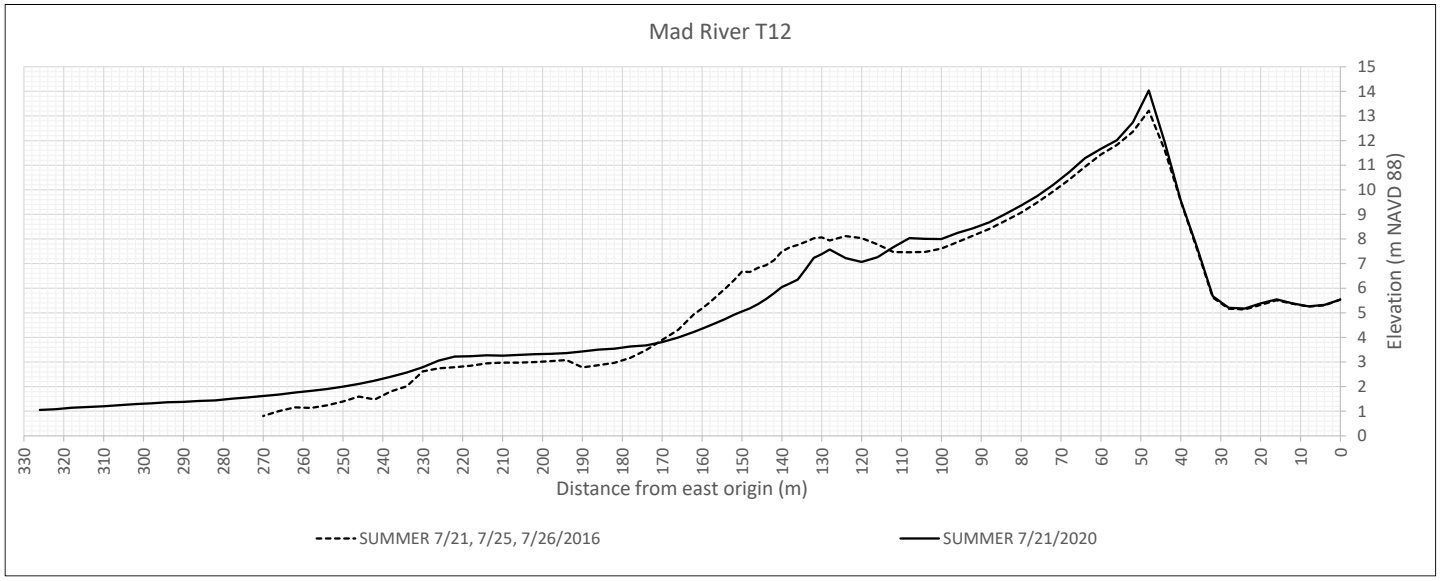
Notes: This transect located in Mad River County Park is the first transect located south of the Mad River mouth, and the first going south along the littoral zone to exhibit a foredune over 10 m in elevation (10.7 m NAVD 88). In winter 2016 the upper beach was relatively steep, and by winter 2017 the 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. Over the course of the study, this transect exhibited scarping and steepening of the foredune, the base of which retreated up to 10.0 m, while the foredune crest remained stable.

Mad River Transect 11

View north at 282 m (foredune crest)

Mad River Transect 12



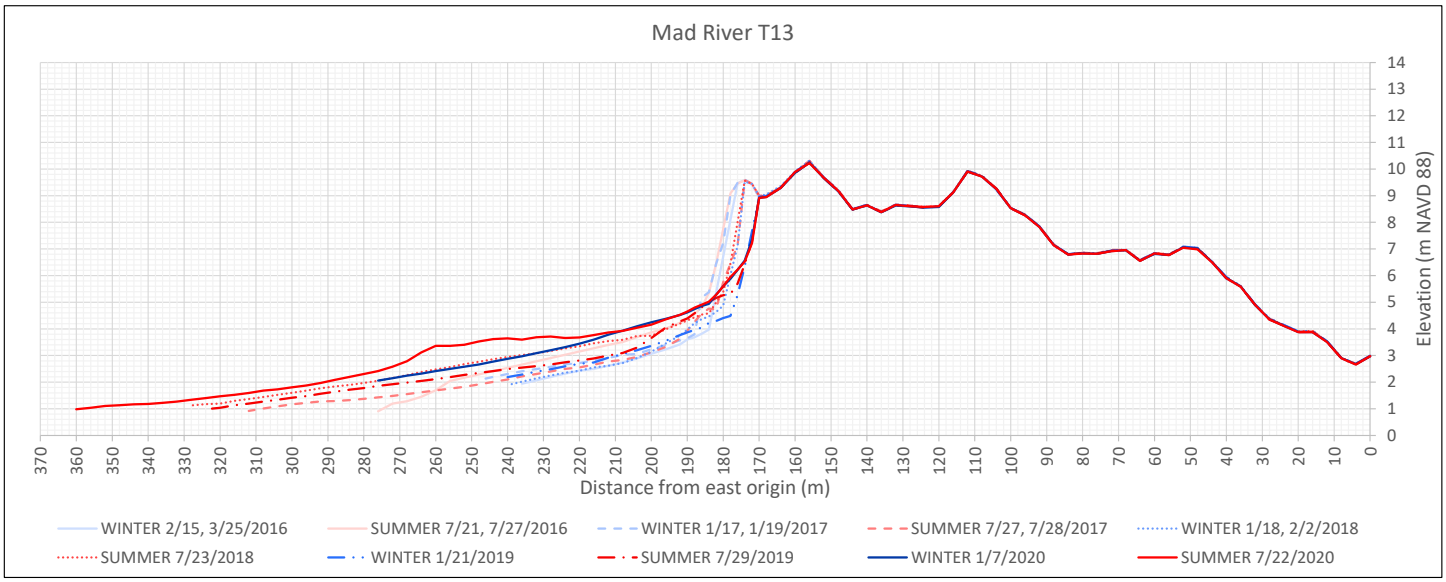


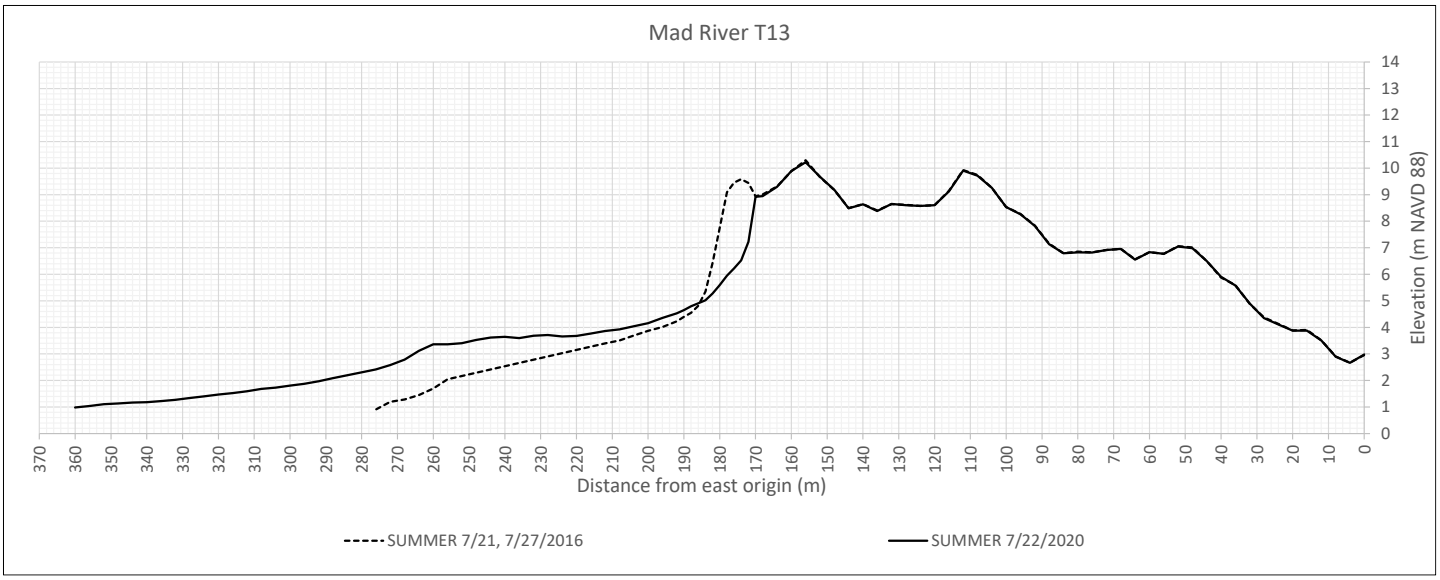
Notes: The transect runs along the axis of the southernmost of a series of foredune blowouts, yielding a distinctive profile ending in the steep slipface of its depositional lobe. An incipient foredune seaward of the mouth of the blowout was scarped after the survey in winter 2016. Erosion of the upper beach 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 below). Ramping and erosion of the scarp during summer 2017 reactivated the blowout, depositing sand on the windward side of the depositional lobe. By 2019 rebuilding of the scarp by windblown sand had begun to form a low sand ramp at the base of the blowout, which continued through 2020. To date, however, the foredune crest remains largely disconnected from aeolian sand delivery from the beach. Over the course of the study the the incipient foredune retreated 10.0 m, and the dune face became more homogeneous, gaining in elevation at the slipface crest.

Mad River Transect 12

View southeast at 160 m winter 2017 and at 152 m summer 2018-2020 (incipient foredune/scarp)

Mad River Transect 13





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. By 2019 ramping had begun at the base of the foredune and continued through 2020, Over the course of the study the foredune remained steep retreating 10.0 m, with sand unable to reach the crest.

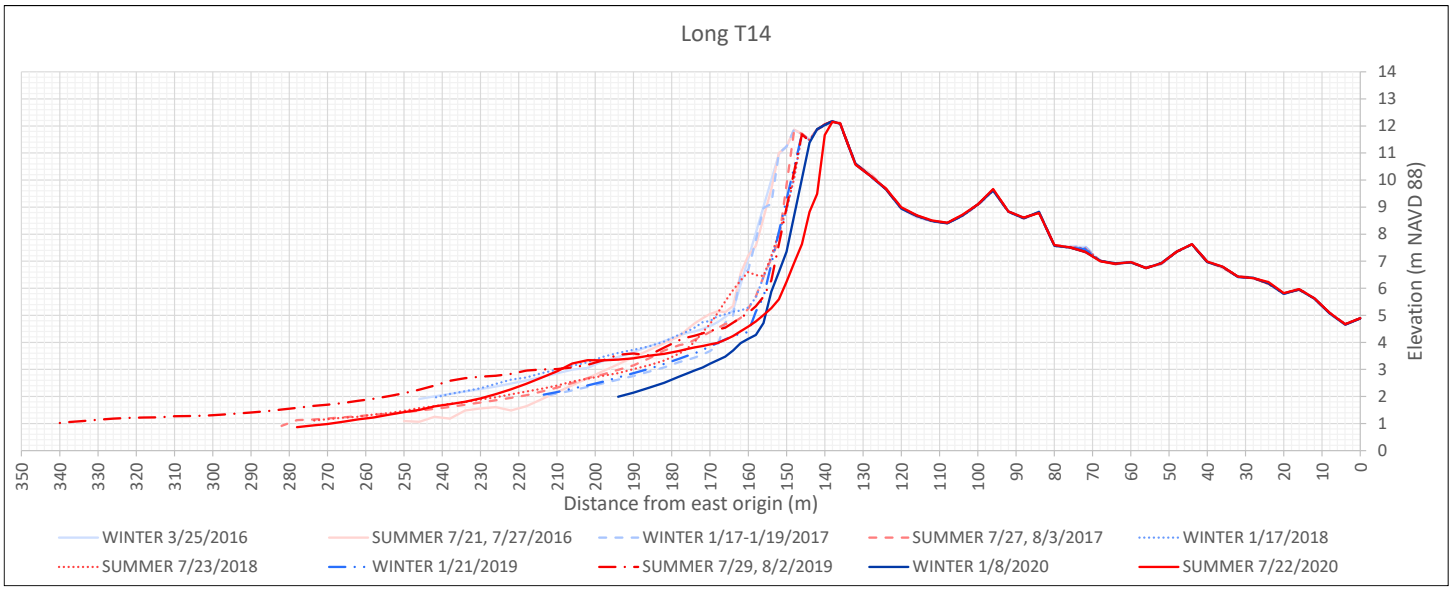
Mad River Transect 13

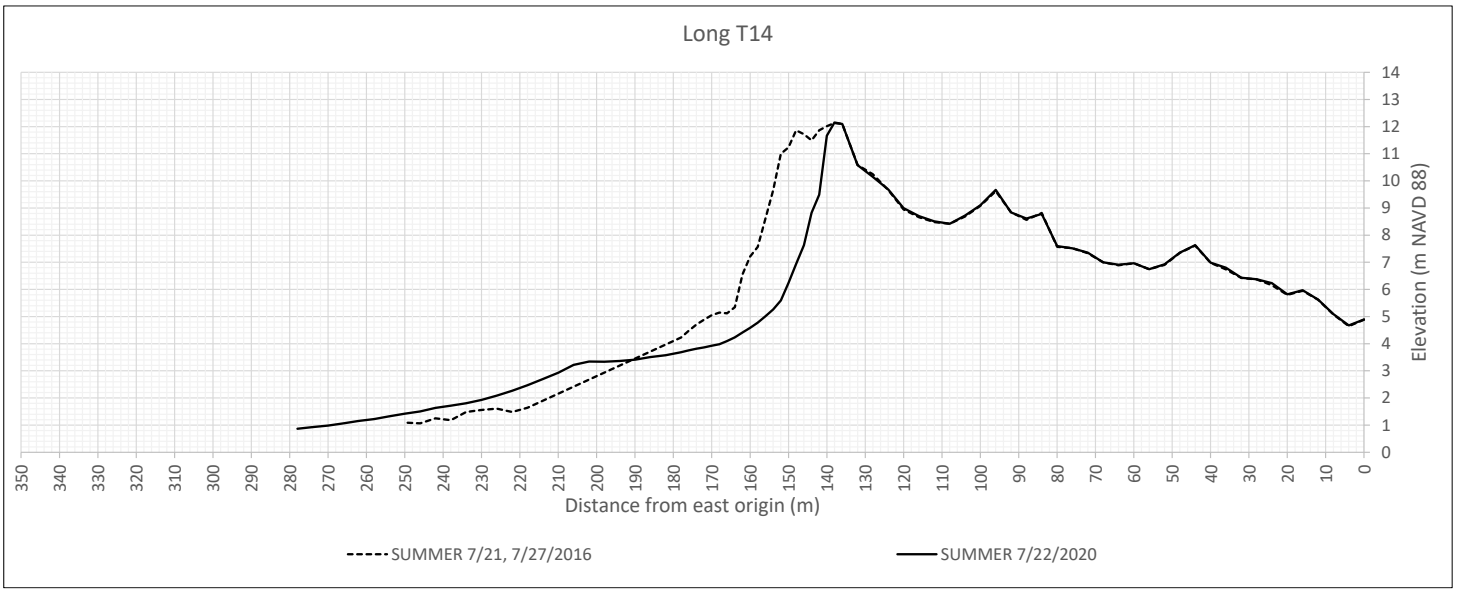
View north at 184 m (scarp)

MAD RIVER SUMMARY. Transect 10 is located on the Mad River spit. It exhibited net deposition at the crest of the spit, and erosion on the east end by the river. The remainder of the transects in this area, located to the south, are characterized by high, steep foredunes (in one case a blowout depositional lobe/slipface) and all exhibited erosion of the foredune over the course of the study. Although this stretch of shoreline has been historically characterized by low accretion, the height and steepness of the foredunes suggests recovery through scarp-fill ramping would be difficult. These conditions do not confer resiliency.

Long Parcel (HBNWR)

Long Transect 14





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 lower beach steepened and the upper beach underwent minor deposition at the base of the foredune. Prior to the winter 2017 survey the upper beach eroded, losing up to 1 m elevation near the base of the foredune, and block slumping occurred on the scarp. A high water event after the survey rescarped the entire foredune resulting in the inability of sand to reach the crest of the foredune. Over the course of the study the stoss face of the foredune retreated 10.0 m.

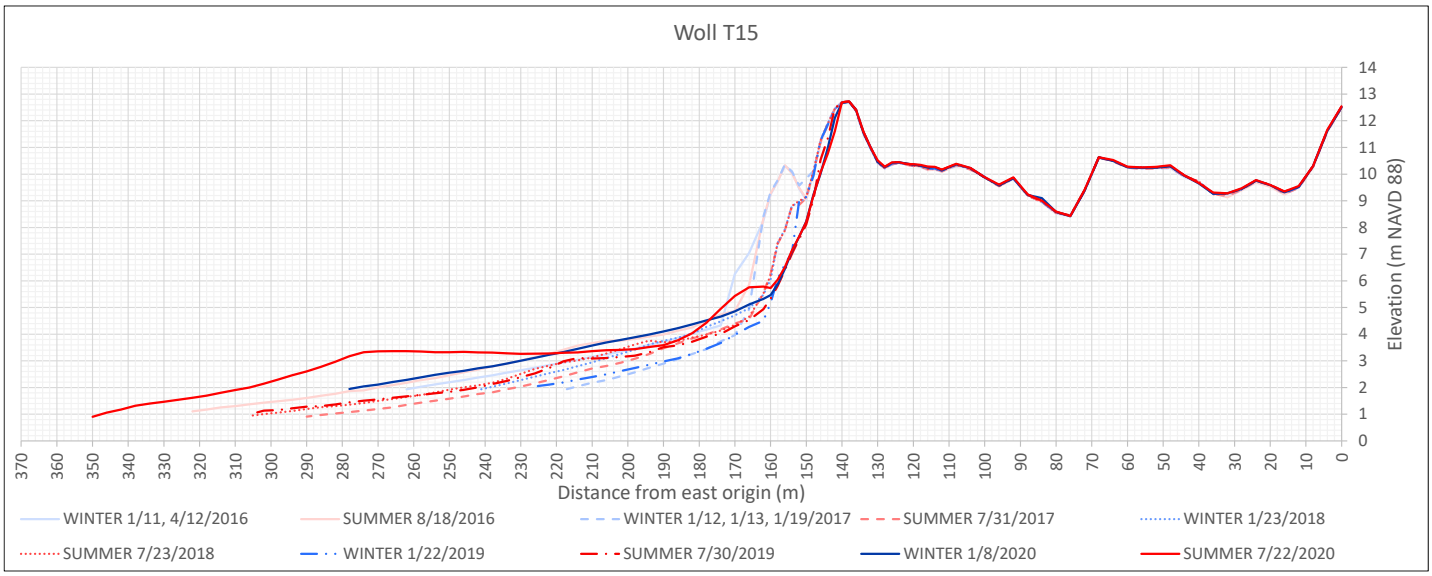
Long Transect 14

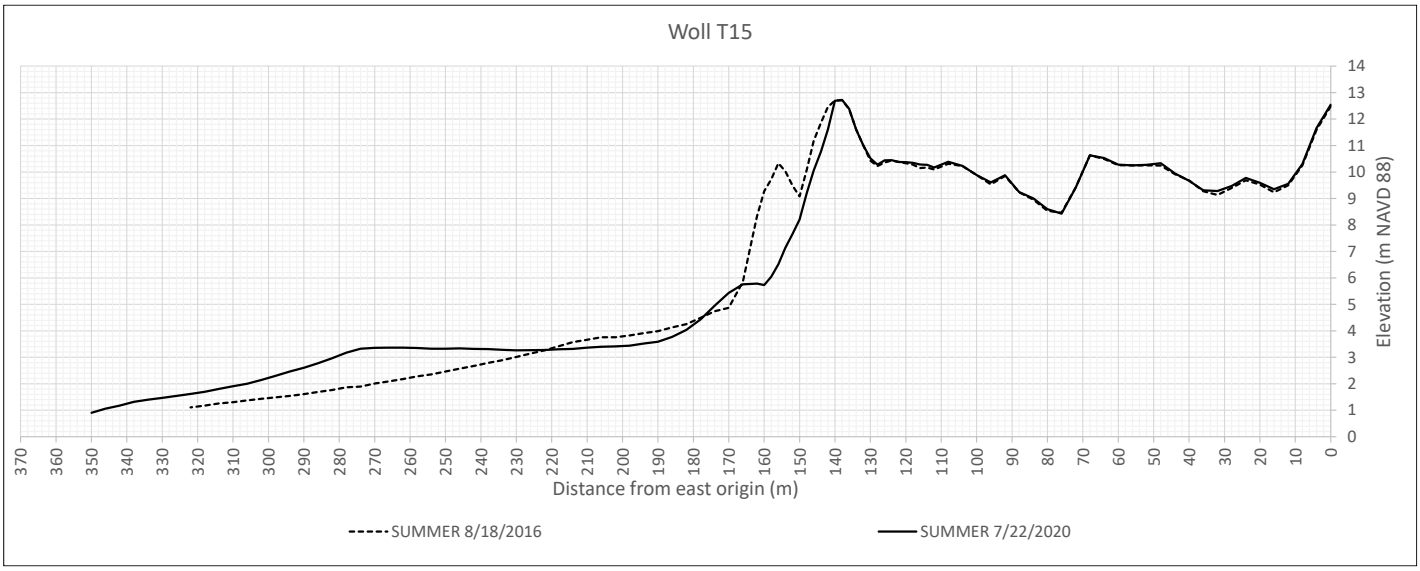
View north at 162m (scarp)

LONG SUMMARY. See Woll Summary.

Woll Parcel (HBNWR)

Woll Transect 15





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 upper beach 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. By summer 2019 the foredune had retreated a total of 12.0 m since surveys began, losing both the incipient foredune and part of the established foredune. The foredune remained steep with little opportunity for sand to reach the crest. A ramp was present at the toe of the foredune in summer 2020. Over the course of the study the incipient foredune eroded and the foredune retreated 12.0 m.

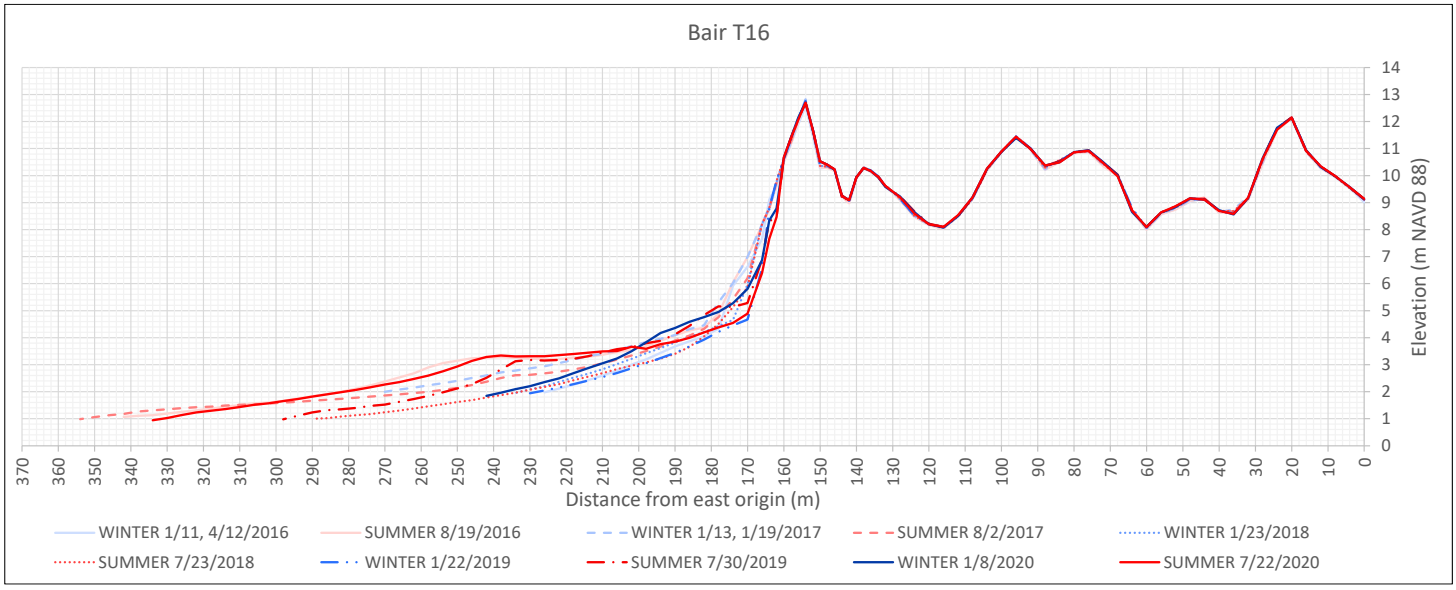
Woll Transect 15

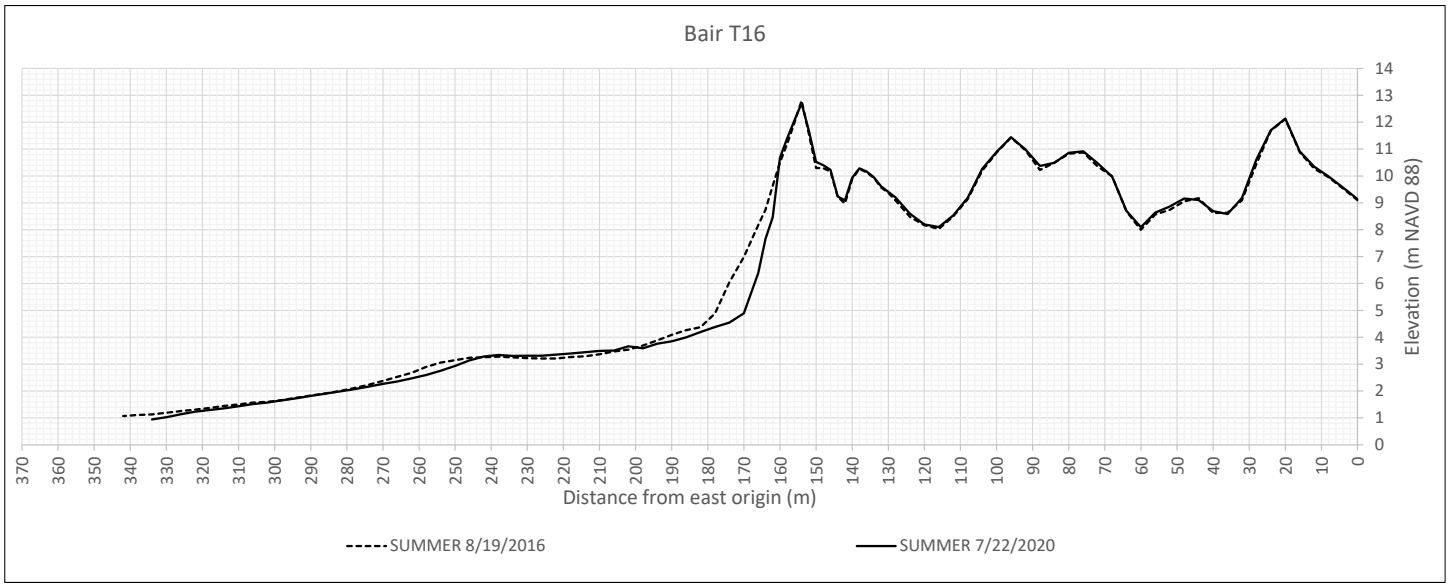
View north at 166 m (scarp)

LONG/WOLL SUMMARY. The Long and Woll parcels are adjacent to the Mad River section, and shows a similar pattern of high steep foredunes, repeated erosion and low resiliency,despite historic conditions of low accretion.

Bair Parcel (HBNWR)

Bair Transect 16



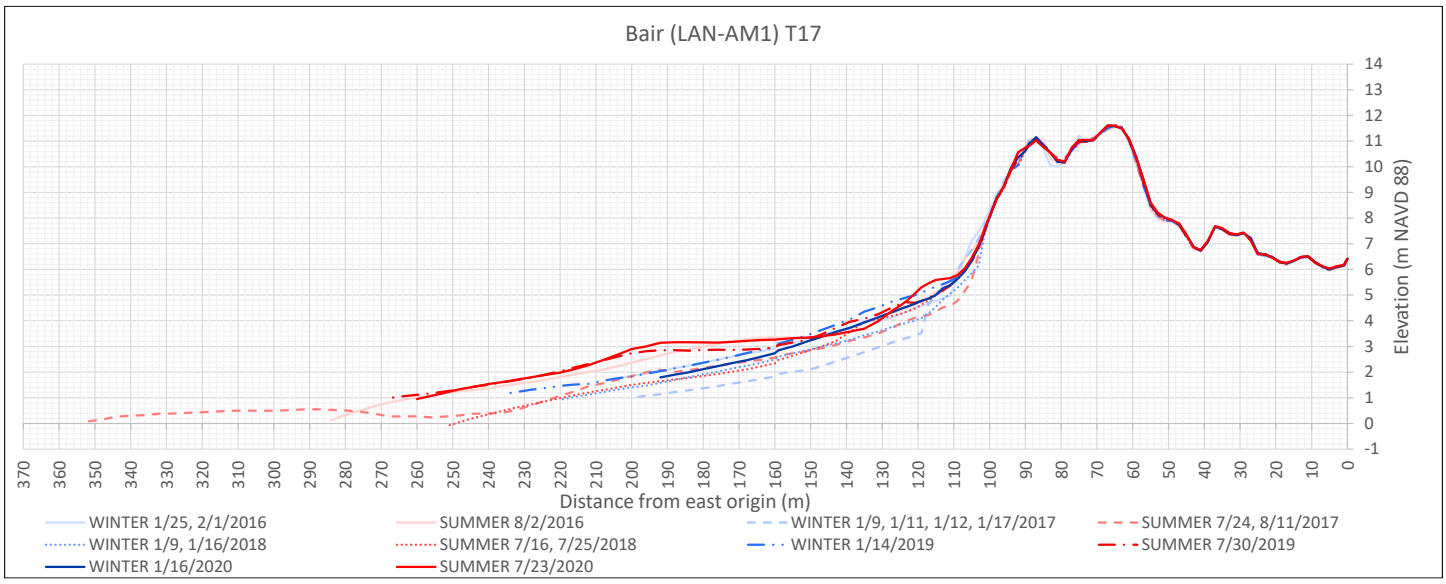


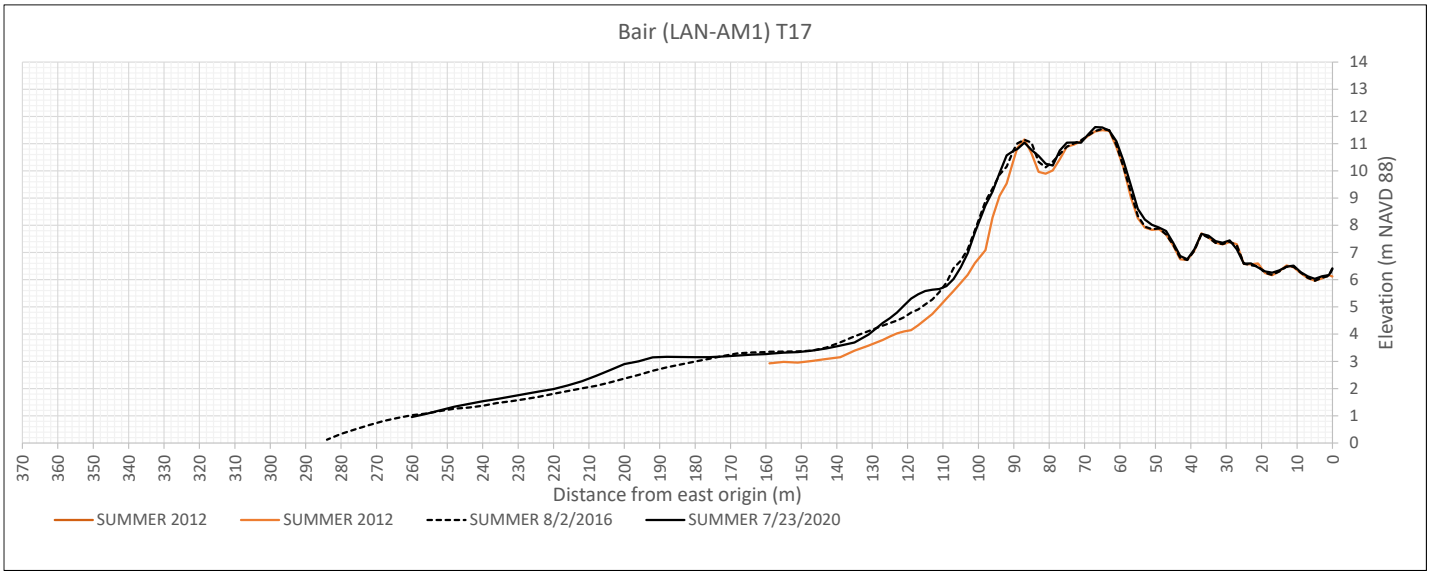
Notes: The foredune crest elevation of this steep, peaked *Ammophila* foredune is 12.7 m NAVD 88. Low scarping occurred at the base of the foredune in winter 2016 prior to the survey, and from then until winter 2017 the upper beach built up slightly and a scarp-fill ramp formed. Soon after the winter 2017 survey a high water event scarped the base of the foredune, causing retreat of up to 6 m horizontally and lowering the beach 0.5 m vertically. By summer 2017 the base of the scarp had slumped and the beach 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 and 2020 photos. Over the course of the study, the foredune stoss slope steepened from scarping, the seaward toe retreated by approximately 10 m, and the crest remained stable .

Bair Transect 16

View north at 154 m (foredune crest)

Bair Transect 17



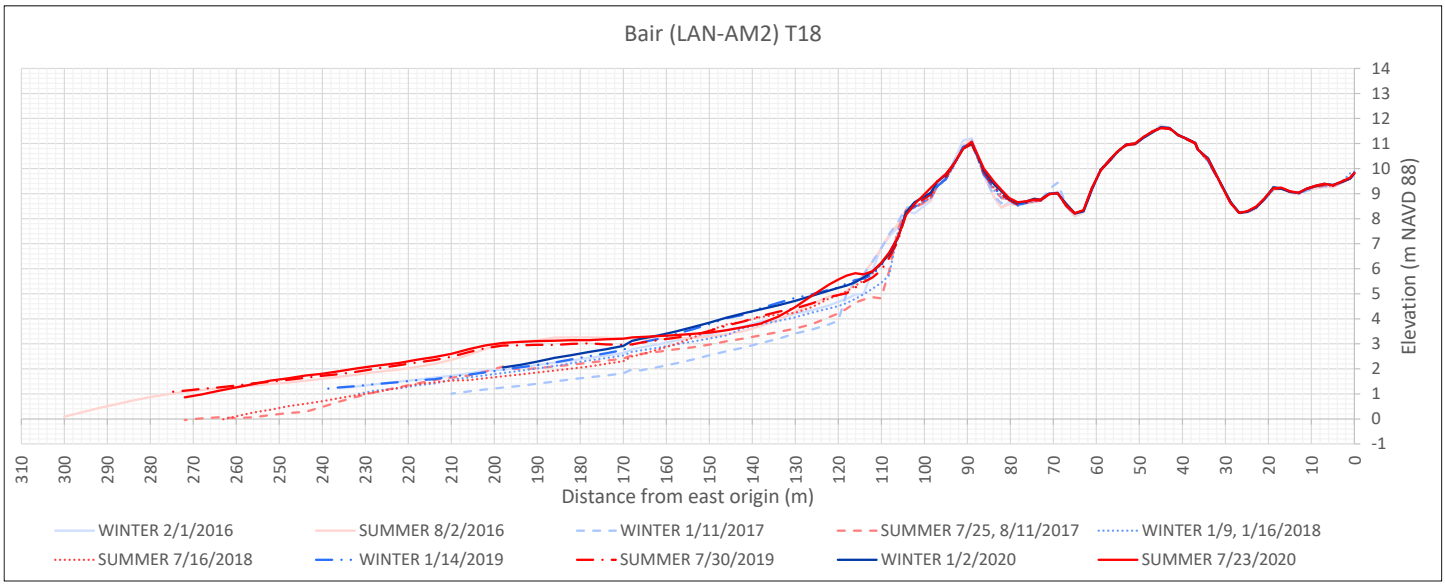


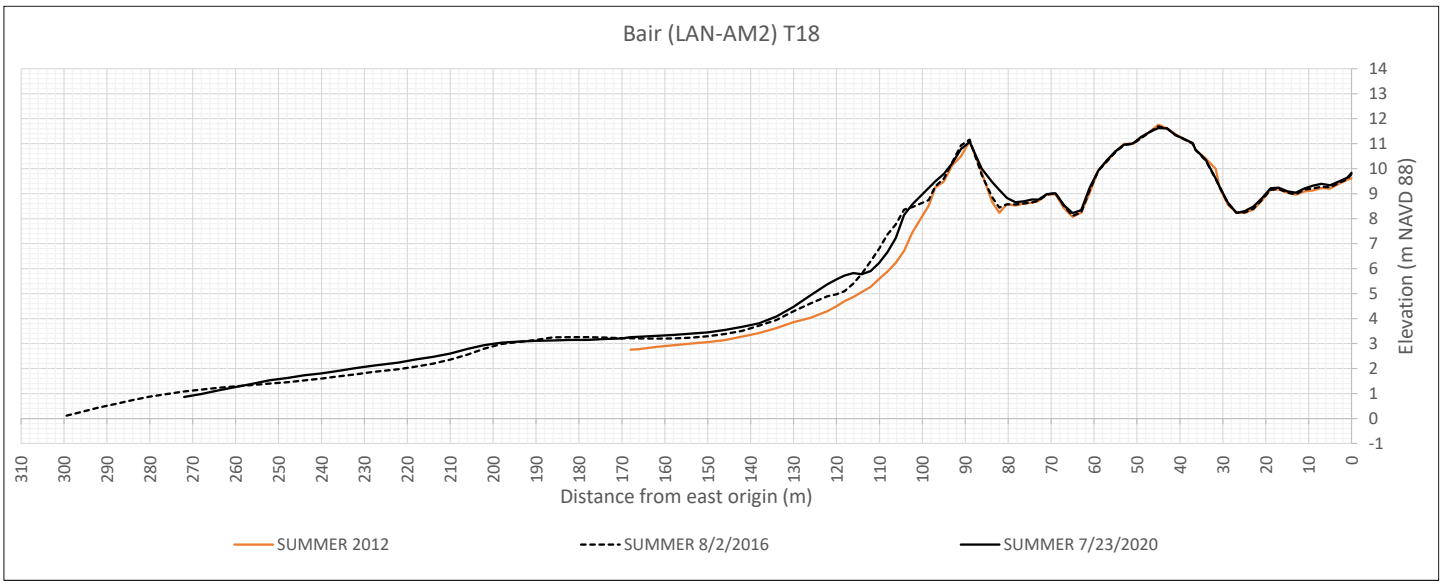
Notes: Between 2012 and 2016 there was deposition of 0.5 m on the stoss slope of the foredune. Significant scarping of the established foredune and lowering of the beach occurred in 2016 prior to the winter 2016 survey (no incipient foredune was present). By summer 2016 a combination of slumping and 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 10.0 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 0.2 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. Over the course of the study, and in response to restoration treatments, the foredune broadened with net deposition on both the upper stoss and lee slopes and steepening of the lower stoss face, but with limited change in position and elevation of the crest.

Bair Transect 17

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

Bair Transect 18





Notes: Between 2012 and 2016 there was accretion of 0.5 m on the stoss face of the foredune. Removal of *Ammophila* arenaria occurred in 2016. Scarping of the established foredune occurred in winter 2016 prior to the survey, resulting in 1.0 m loss of beach elevation and 10.0 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 high water 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 winter 2016. Over the course of the study, and in response to restoration treatments, the foredune broadened with net deposition on both the upper stoss and lee slopes and steepening of the lower stoss face, but with limited change in position and elevation of the crest .

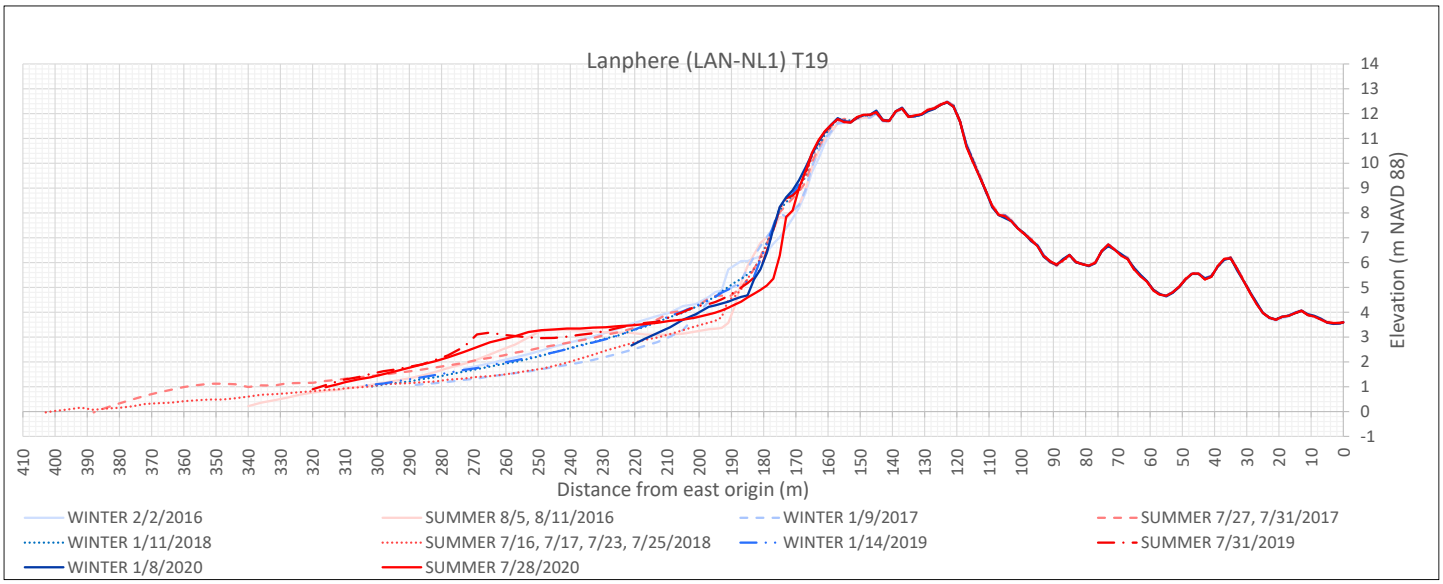
Bair Transect 18

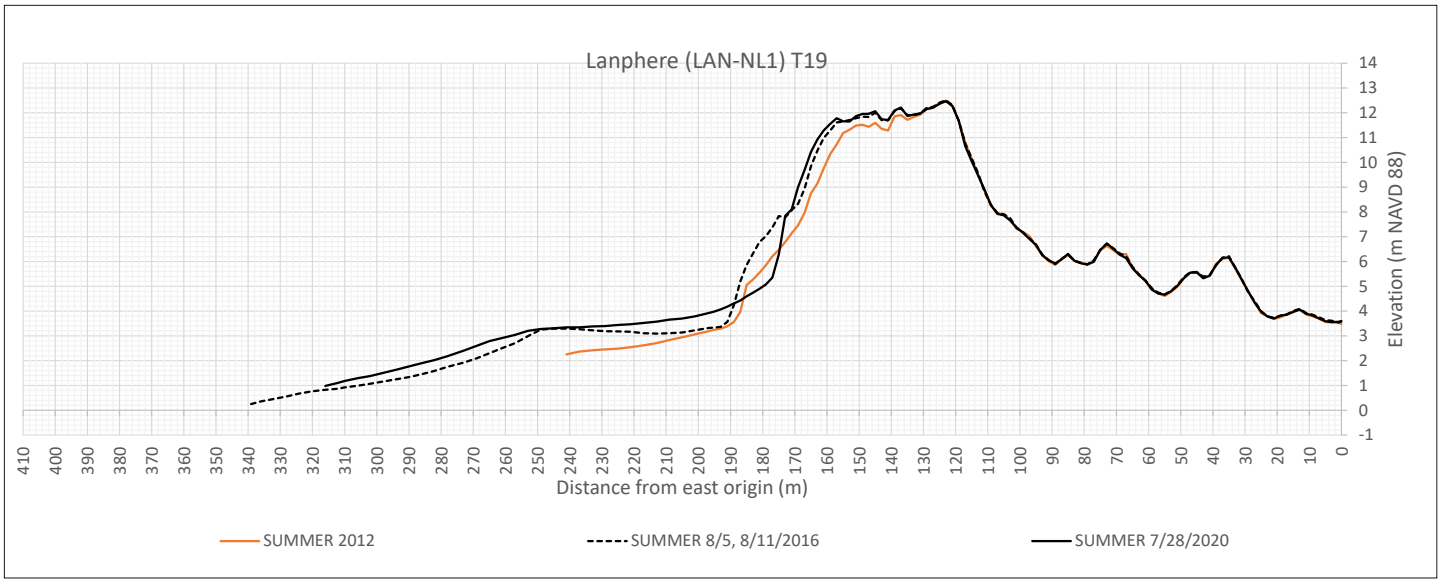
View north at 120 m (left, showing scarp) and 110 m (right, showing ramp)

BAIR SUMMARY. Transects 17 and 18 are located in the Lanphere adaptation site and monitoring began in 2012, with removal of Ammophila in 2016. All three transects featured a high steep Ammophila foredune. Between 2012 and 2016 Transects 17 and 18 accreted 0.5 m on the stoss face of the foredune. Over the course of the study these two transects accreted on the stoss face and on the crest, showing broadening of the foredune. They both developed scarp-fill ramps following high water events, indicating a resilient response. Transect 16, which did not have Ammophila removed, underwent erosion and steepening of the foredune. These transects fell within the low accretional class for historic shoreline change.

Lanphere (HBNWR)

Lanphere Dunes Transect 19



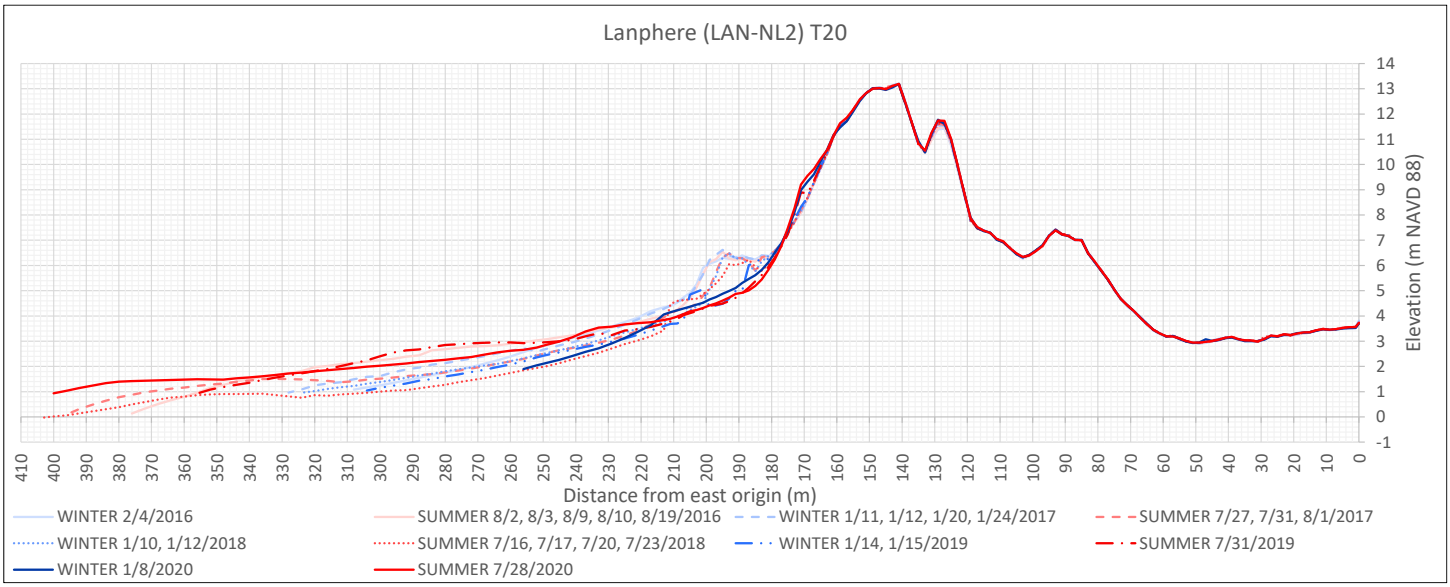


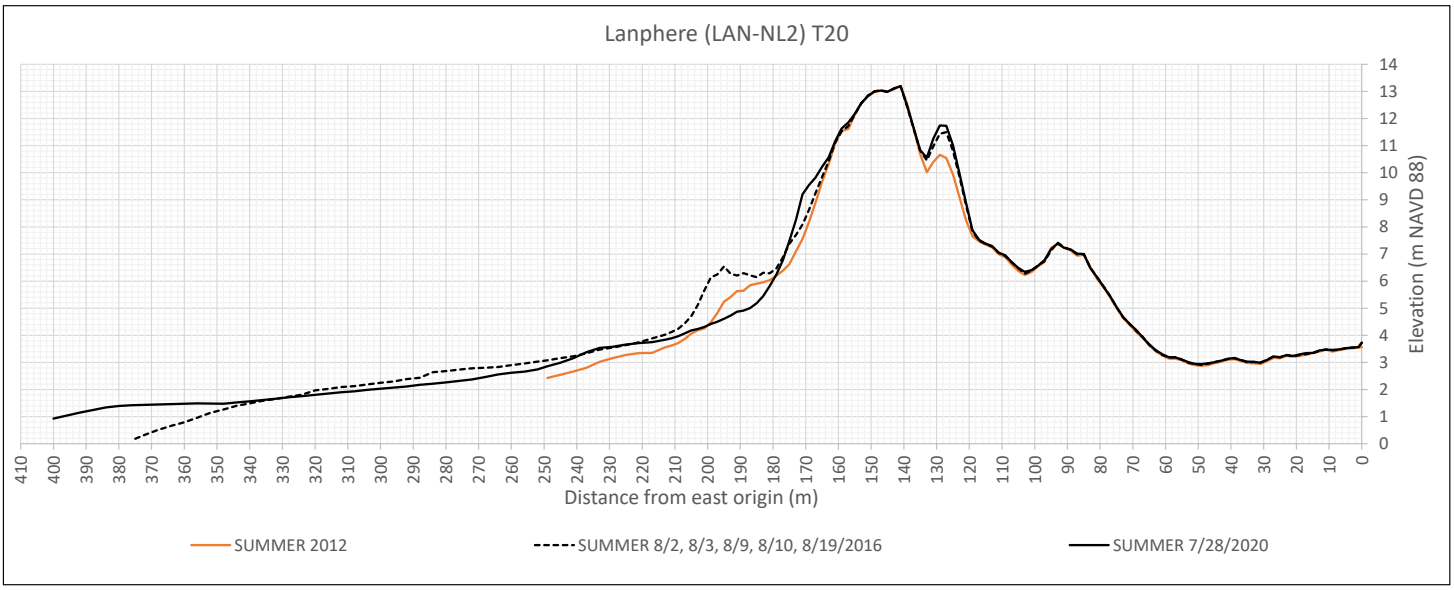
Notes: The transect describes a high, broad foredune vegetated by native species. Between 2012 and 2016 up to 1.0 m of accretion occurred on the stoss face and crest of the foredune. Significant scarping after the winter 2016 survey shows up in the summer 2016 profile, having removed 2.6 m vertically including the small narrow incipient foredune. By winter 2017 a scarp-fill ramp was forming and the upper beach had regained 2.0 m of elevation, although the lower beach had not recovered. However by summer 2017 the ramp was continuous and becoming vegetated and the beach had recovered to winter 2016 elevations. From 2017 to 2018 erosion of the upper beach and foredune toe returned this portion of the transect to conditions similar to summer 2016. There was little change to the profile between 2018 and 2019, with its relatively mild winter, although the position of the offshore bar shifted. Between winter and summer 2020 the lower stoss face of the foredune was scarped back 5.0 m. Over the course of the study the profile lost its incipient foredune, with the base of the foredune retreating 10.0 m. Since 2012 there has been deposition of 0.5 m on the crest of the foredune.

Lanphere Dunes Transect 19

View south at 179 m (foredune crest)

Lanphere Dunes Transect 20



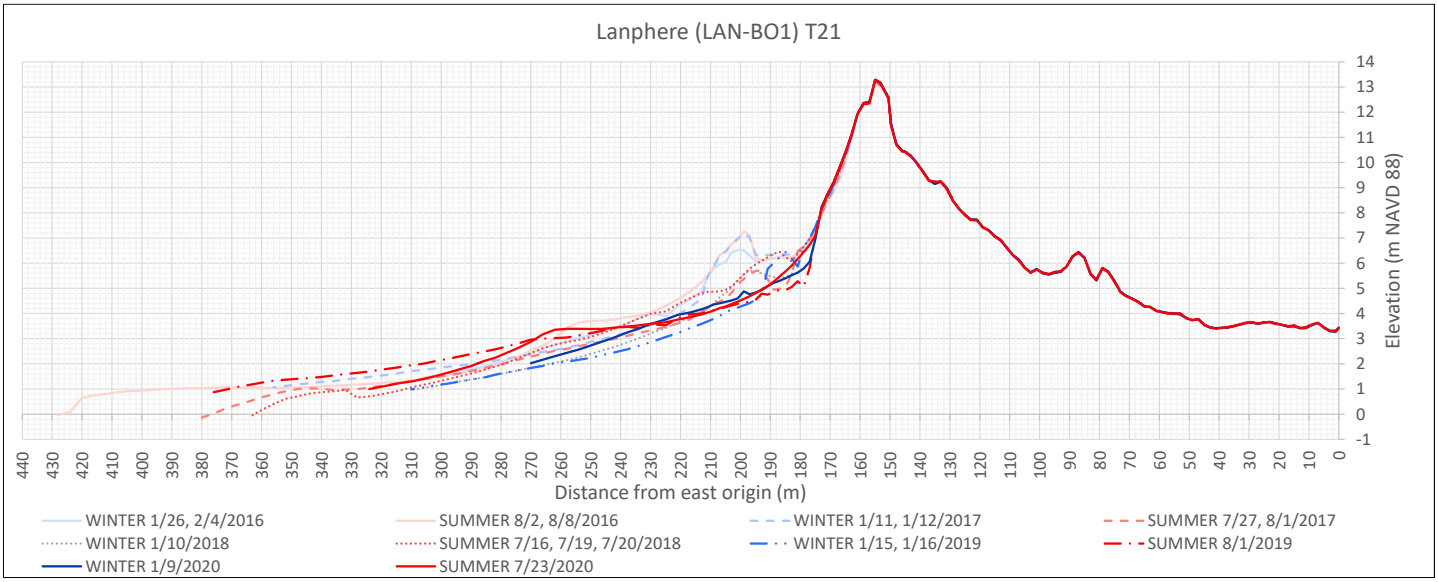


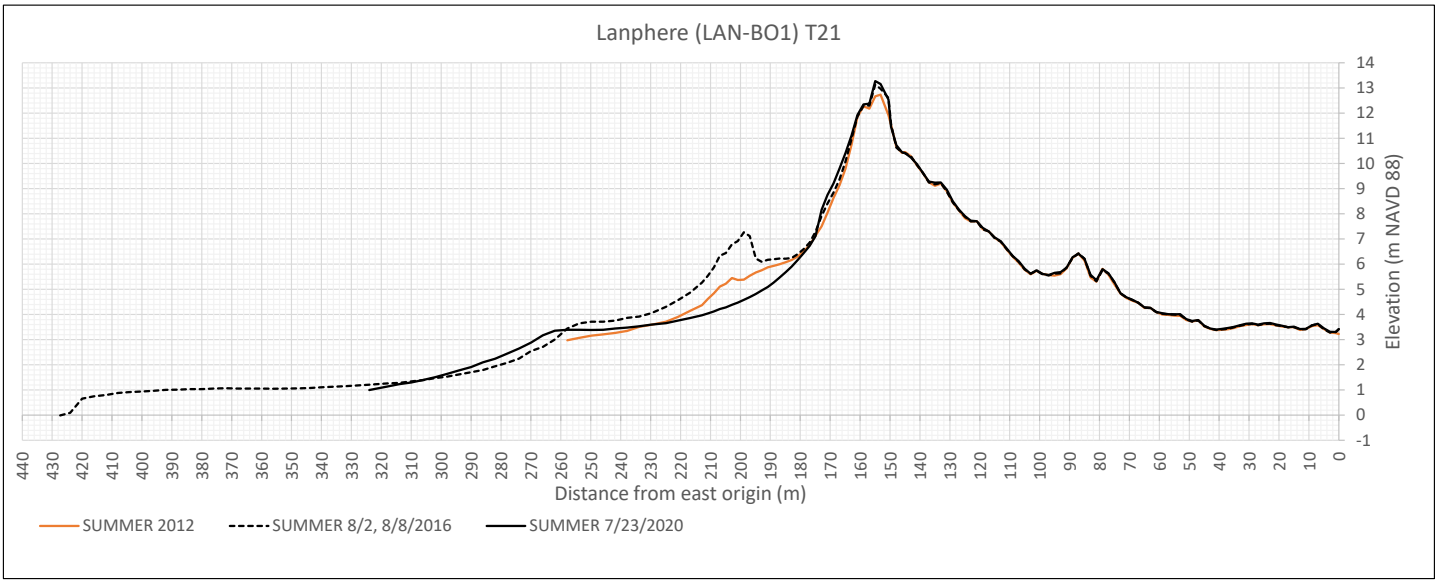
Notes: Between 2012 and 2016 an incipient foredune formed and the depositional lobe of a blowout behind the foredune increased in height by 1.0 m. The established, native foredune was relatively stable between 2016 and 2020, with minor deposition on the landward peak where the transect crosses the depositional lobe of an old stabilizing blowout. The incipient foredune was scarped between the win-ter 2017 and summer 2017 surveys, and continued eroding, with upper beach lowering, through sum-mer 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. Over the course of both studies an incipient foredune formed and then eroded over 20 m horizontally, and the depositional lobe on the lee side of the foredune increased in height.

Lanphere Dunes Transect 20

View NW from incipient foredune crest at 193 m

Lanphere Dunes Transect 21



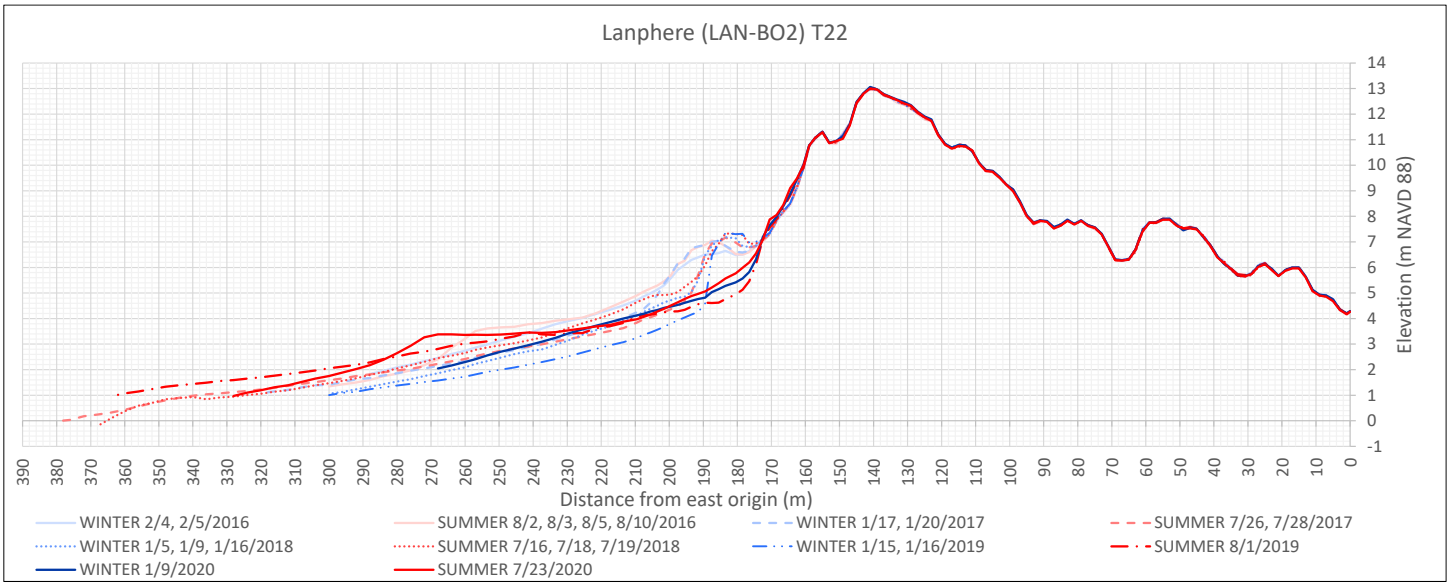


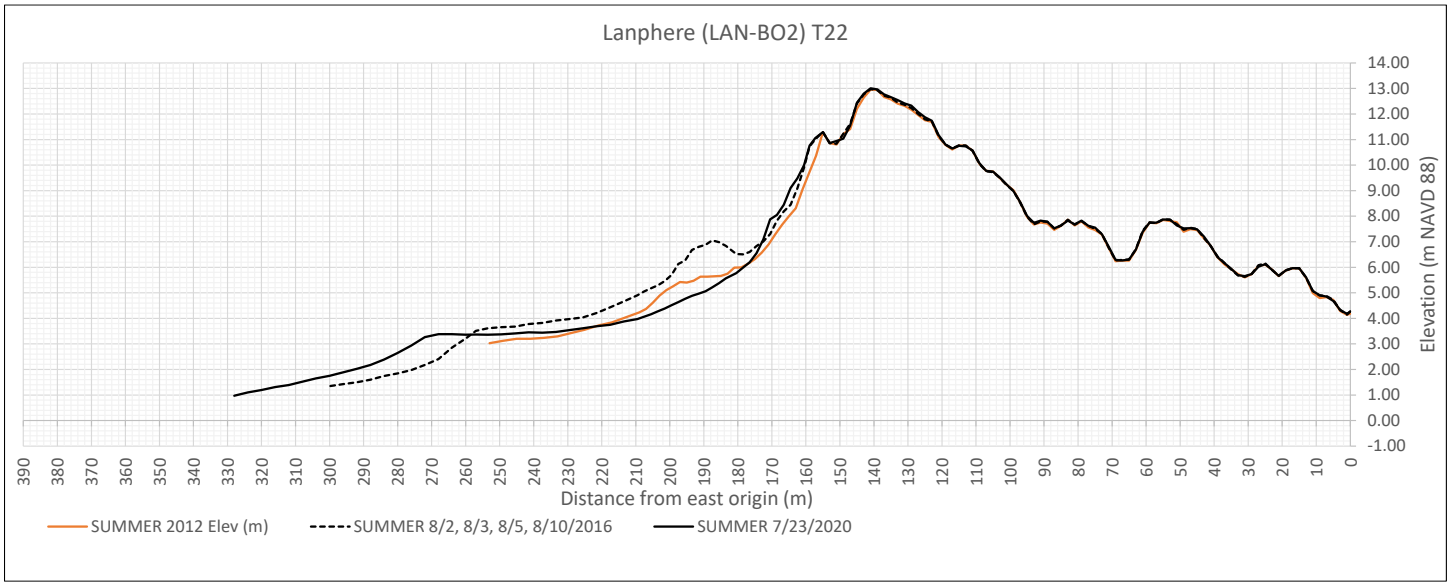
Notes: The transect extends up an old, now-stabilized blowout, causing a peaked foredune topography vegetated with native species Between 2012 and 2016 an incipient foredune formed. Following the winter 2017 survey the incipient foredune was severely scarped, losing up to 2.0 m vertically and 20 m horizontally, as seen in the summer 2017 profile. 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 below taken SE along the transect). In winter 2019 the incipient foredune scarped, and between winter and summer 2019 further scarping occurred, removing the incipient foredune completely. By summer 2020 a ramp was forming (see photo). 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. Over the course of both studies the foredune remained quite stable with some deposition on the stoss face and crest, however the incipient foredune formed and then eroded over 30 m horizontally.

Lanphere Dunes Transect 21

View southeast at 199 m (incipient foredune)

Lanphere Dunes Transect 22



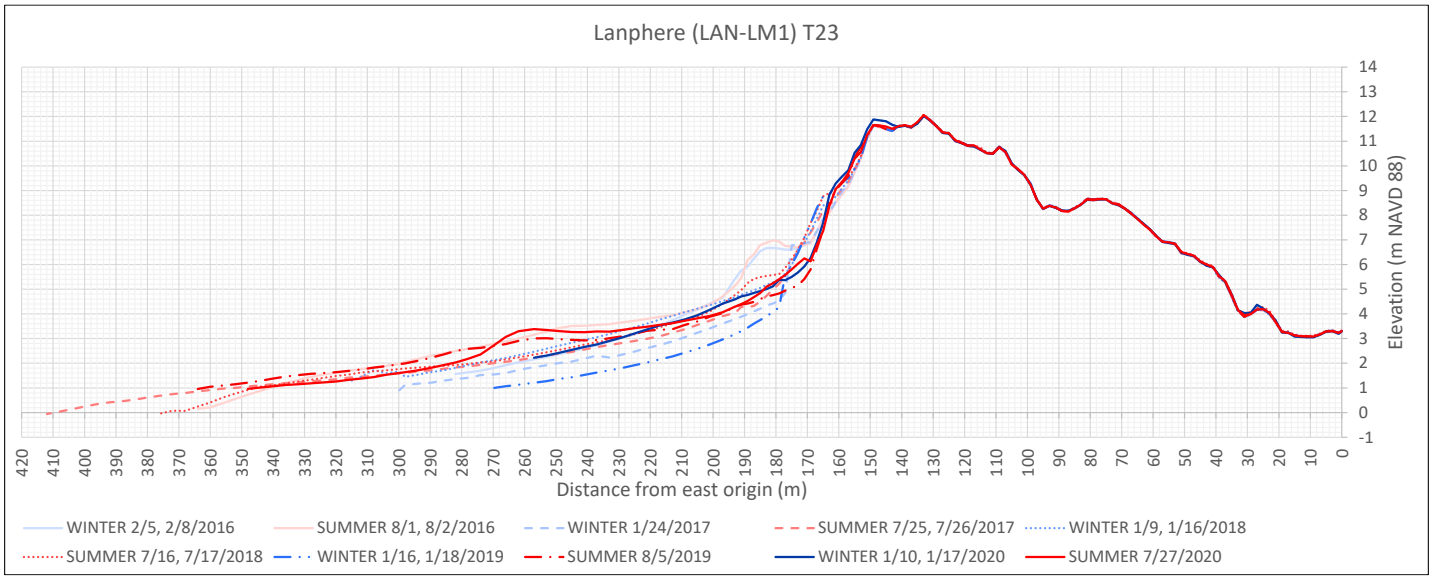


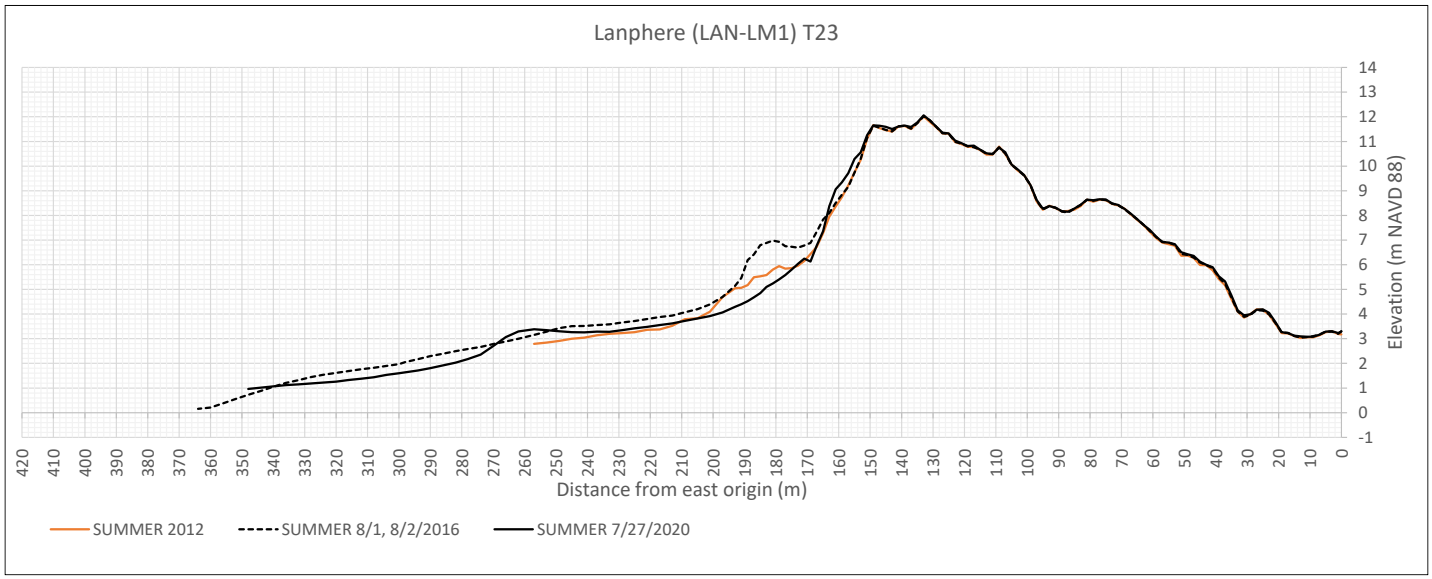
Notes: The transect depicts ahigh, stable, established foredune with a more dynamic incipient foredune. Vegetation is native. Between 2012 and 2016 an incipient foredune formed and there was deposition on the stoss face of the foredune. The incipient foredune increased in elevation 0.5 m between winter 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 had begun to weld onto the established foredune (see 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. Over the course of both studies there was deposition on the stoss face of the foredune and formation of followed by complete removal of the incipient foredune, which eroded 30.0 m horizontally.

Lanphere Dunes Transect 22

View south at 187 m (incipient foredune)

Lanphere Dunes Transect 23



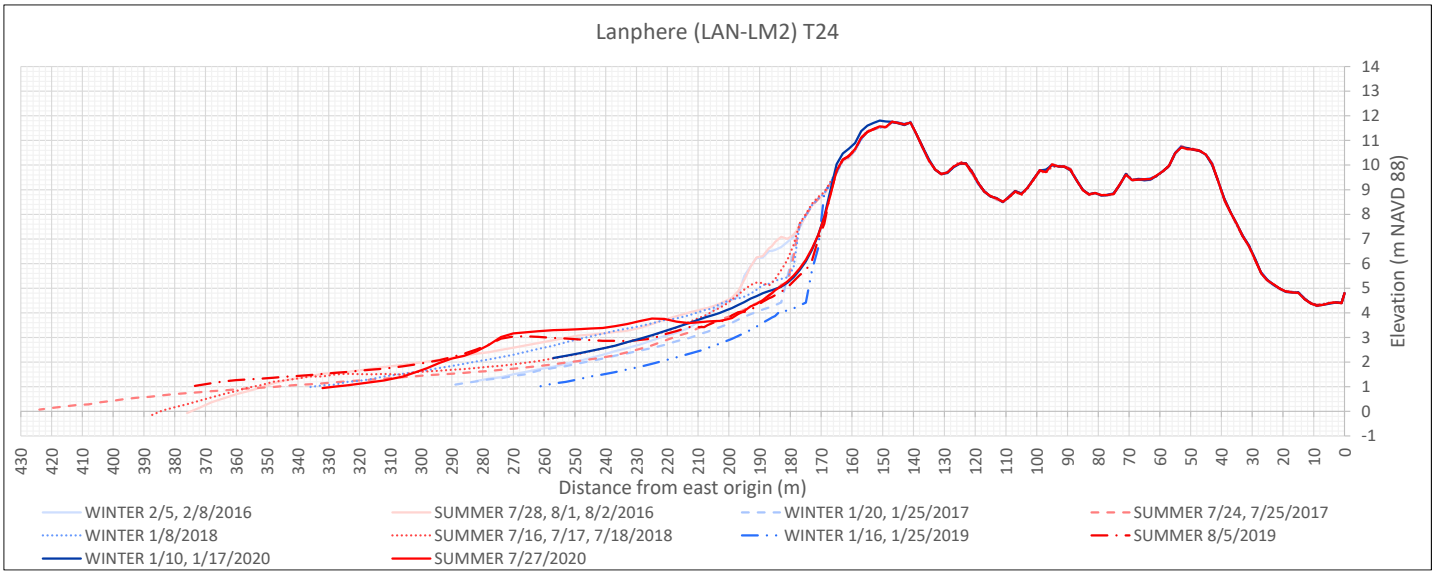


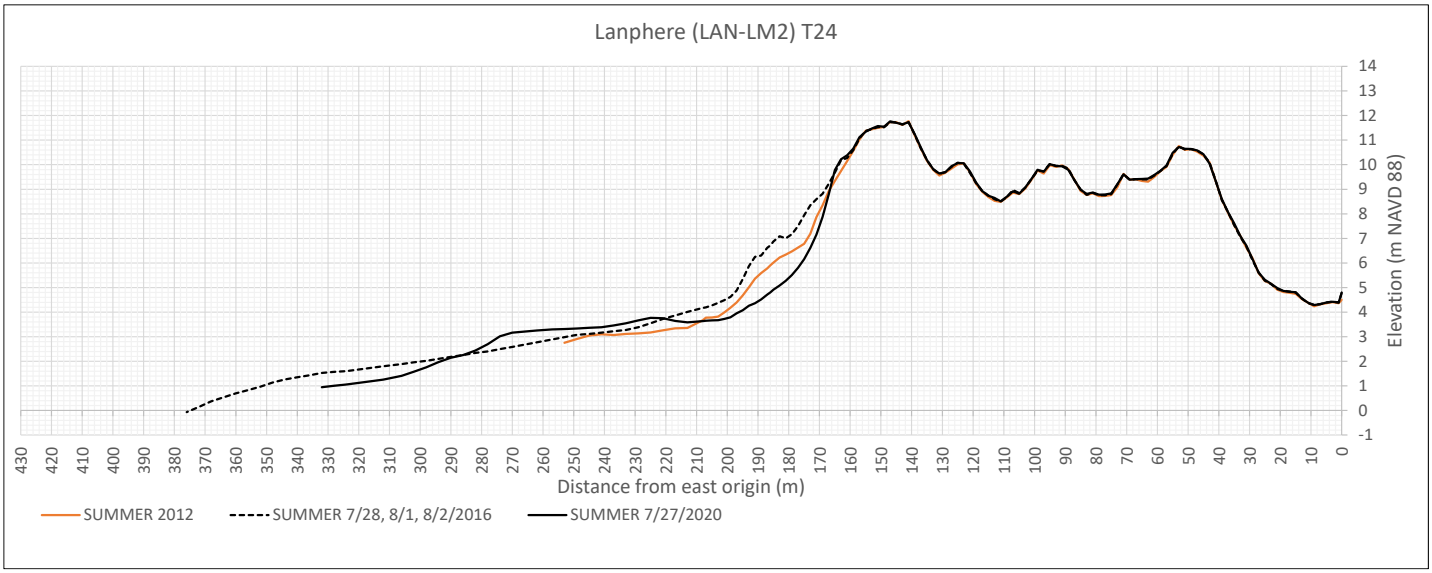
Notes: This is a high (12.0 m NAVD 88), native, established foredune with a dynamic incipient foredune. The incipient foredune formed between 2012 and 2016, and was stable for the first year while the beach underwent seasonal changes. In winter 2017, prior to the survey, the incipient foredune was entirely removed through a dramatic 2.0 m vertical scarping event that 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. By 2020 a ramp was forming, and there was deposition on the stoss face of the foredune. Over the course of both studies the incipient foredune was formed and then eroded, retreating over 30.0 m, and the upper stoss face accreted.

Lanphere Dunes Transect 23

View north at 165 m (foredune base)

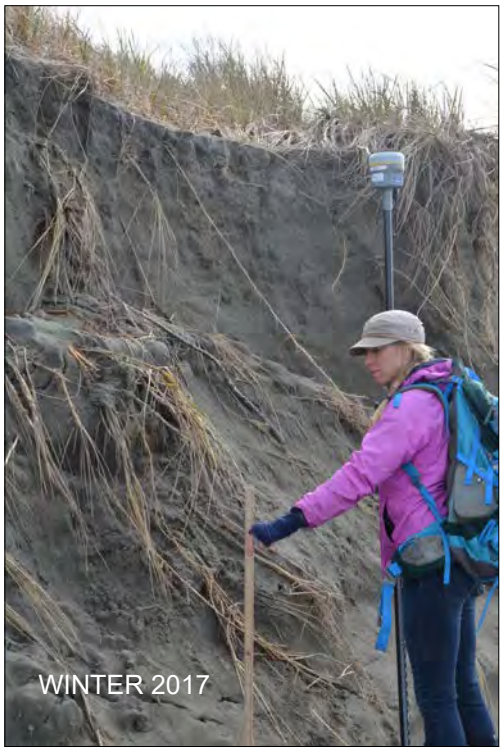
Lanphere Dunes Transect 24





Notes: The incipient foredune was formed between 2012 and 2016, and 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 . In winter 2019 the established foredune scarped back 10 m, although by summer 2019 deposition of +1 m had occurred on the upper beach. By 2020 a ramp was forming on the scarp (see photo). Over the course of both studies the incipient foredune was formed and then removed, retreating over 20.0 m, and the established foredune eroded on its stoss face, but was showing signs of recovery through scarp-fill ramping.

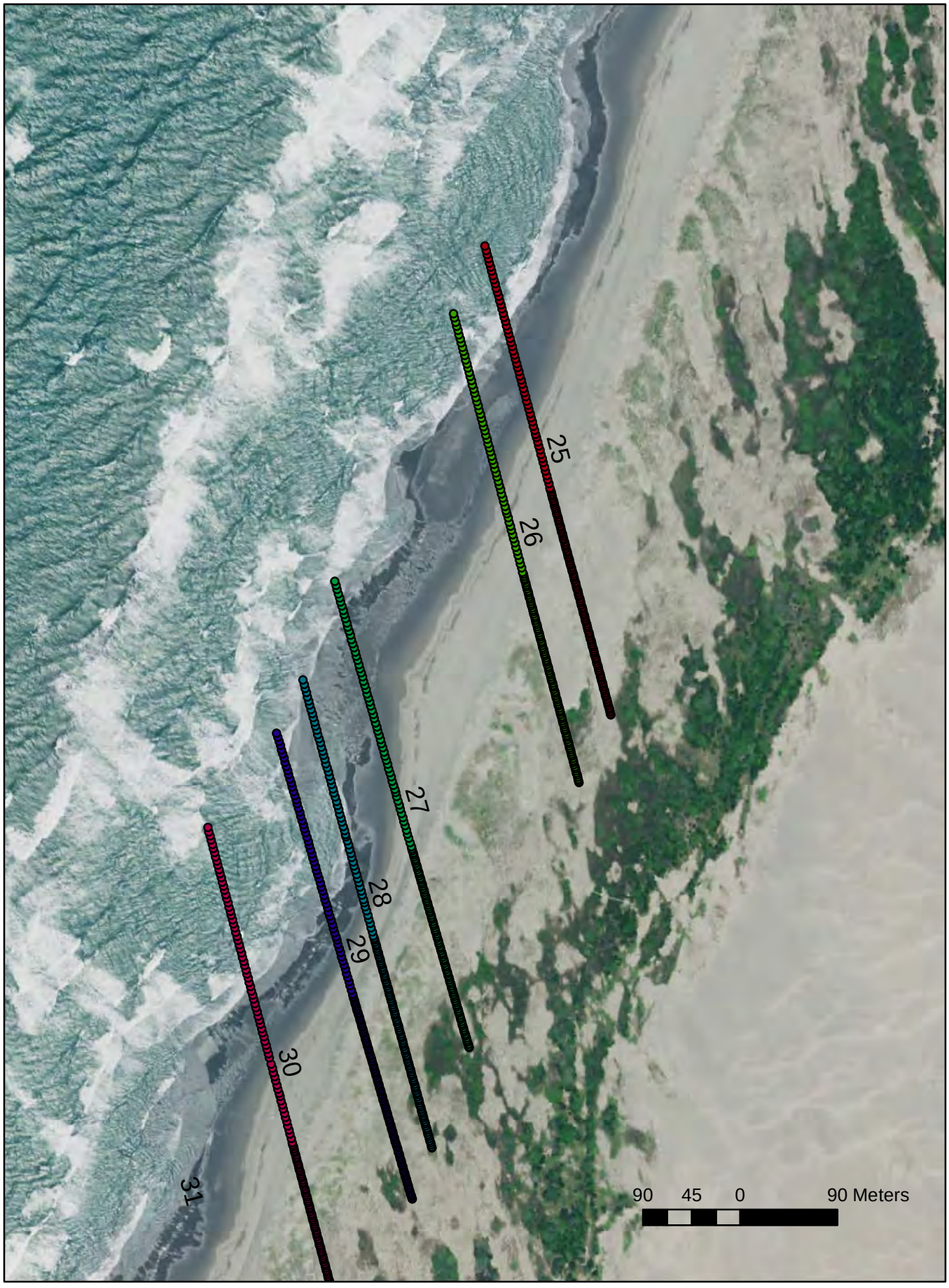
Lanphere Dunes Transect 24



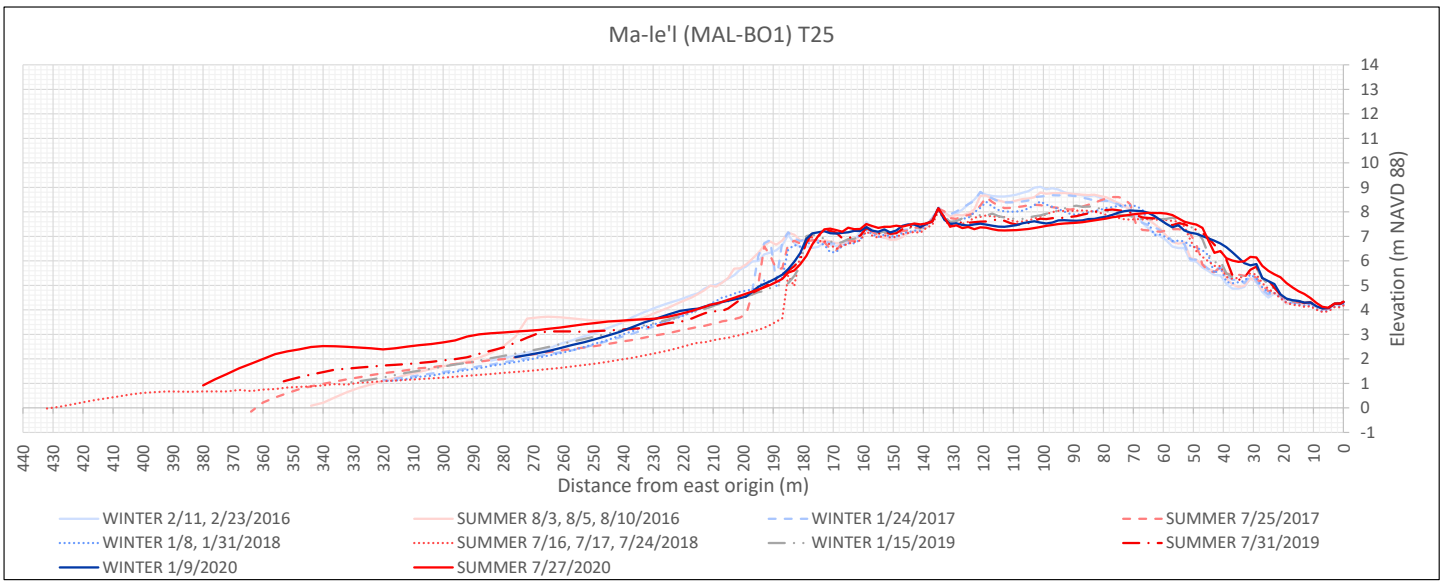
View souteast of scarp at 183 m.

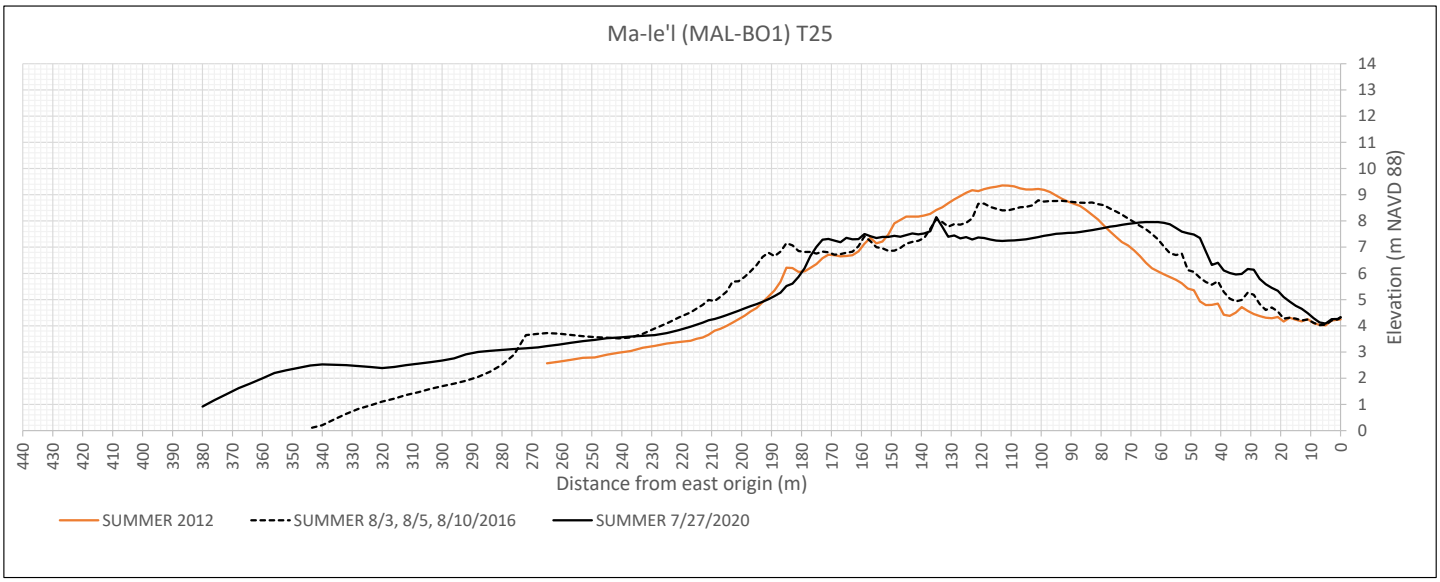
LANPHERE SUMMARY. Transects 19-24 cross restored foredunes vegetated with native species. Most of the transects developed an incipient foredune between 2012 and 2016. The incipient foredunes were then eroded during the El Niño and La Niña winters that occurred between 2016 and 2020. The established foredunes saw little change, although there was some minor accretion or erosion. Incipient foredunes have been ephemeral in this dune system in the past. They constitute a resilient condition in that they reduce erosion to the established foredune. All transects fell within the low accretional class of historic shoreline change. Erosion of the incipients foredunes alternate with accretion, and in the past the established foredune has also accreted at times.

Ma-le'l North (HBNWR)



Ma-le’l North Transect 25



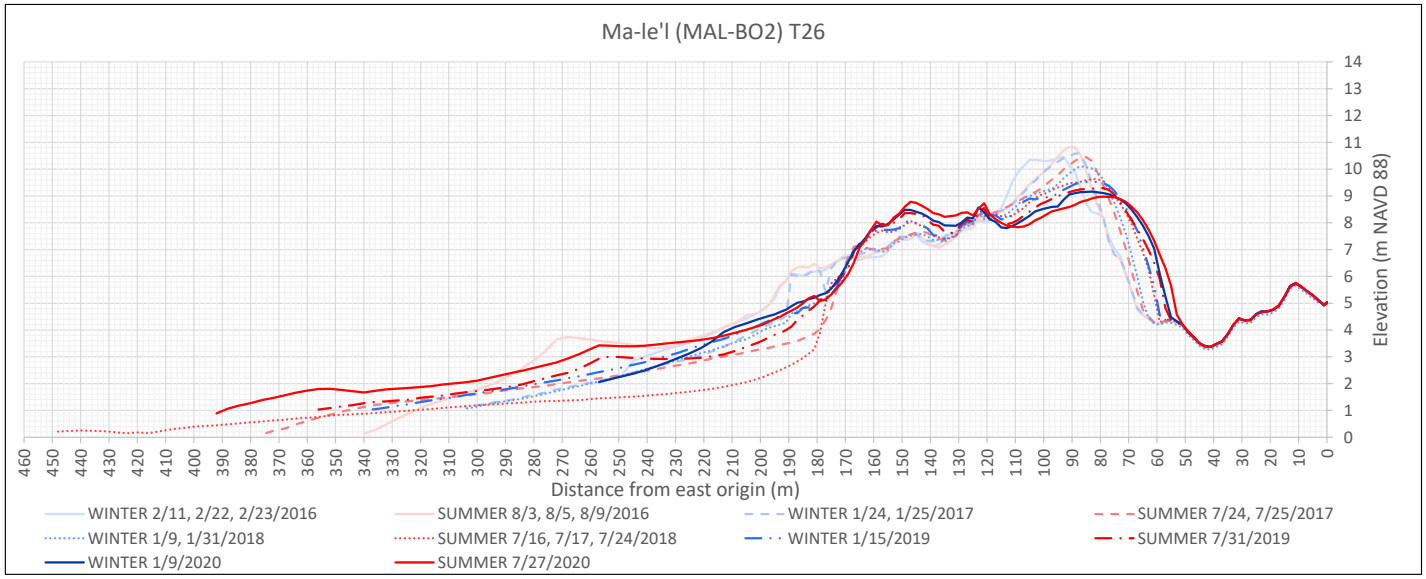


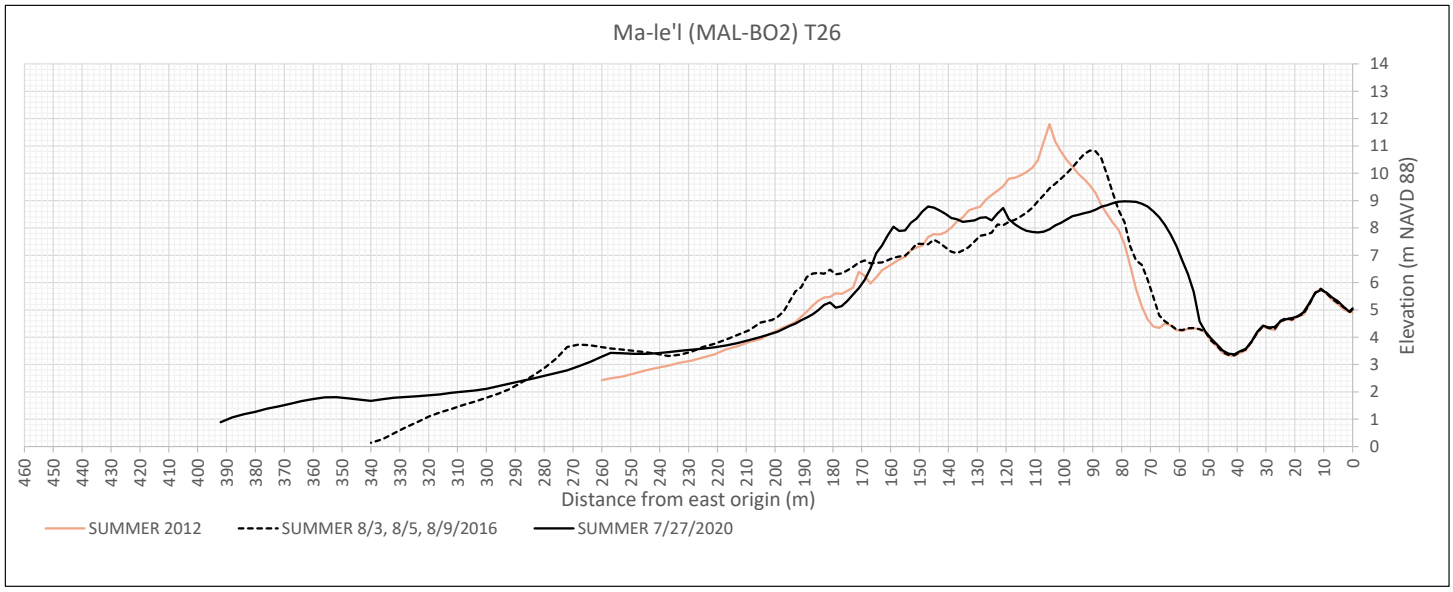
Notes: The profile describes a sparsely vegetated to unvegetated parabolic dune. From 2012 through 2016 a foredune began forming. In winter 2017 the foredune was severely scarped with a loss of 1.6 m vertically. Additional scarping and beach lowering occurred by summer 2017 due to the narrow width of 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 fore-dune back another 12.0 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 2018 photo. By summer 2020 deposition on the upper beach and formation of a ramp allowed for some recovery of the developing foredune, the crest of which was now 20.0 m to the east. Over the course of the two studies the slipface of the dune migrated inland 10.0 m, with the foredune crest broadening and increasing in elevation, and the back of the blowout lowering in elevation 10 m.

Ma-le’l North Transect 25

View southeast at 207 m (upper beach)

Ma-le'l North Transect 26



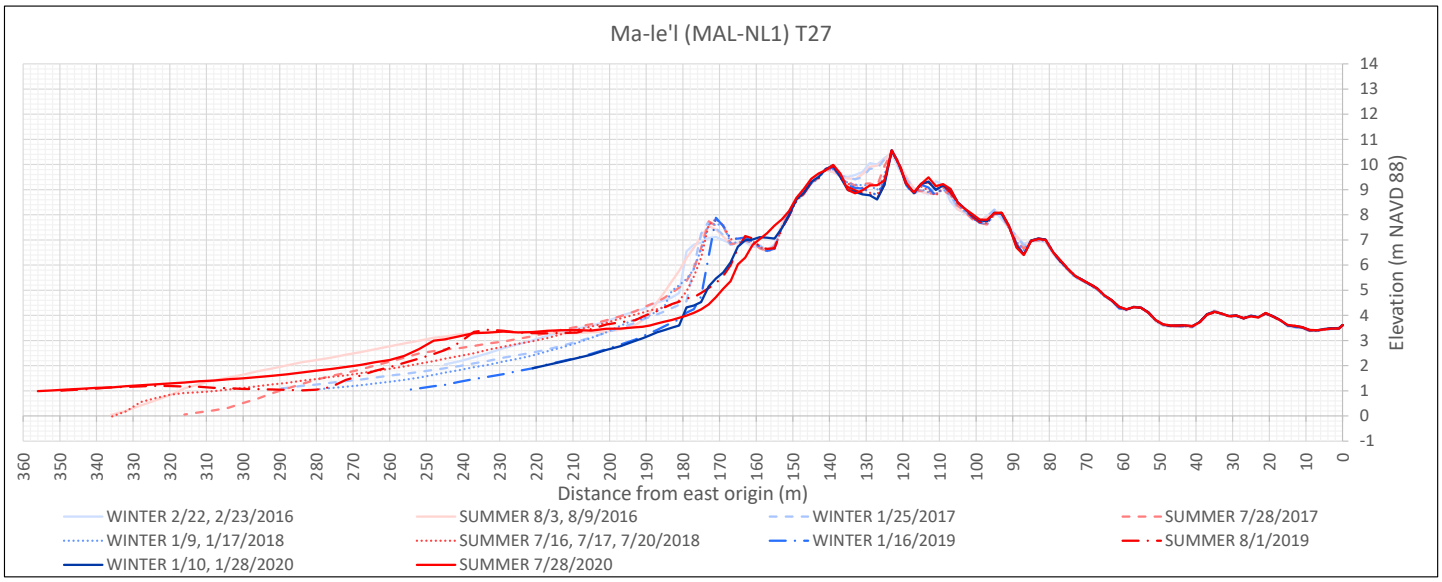


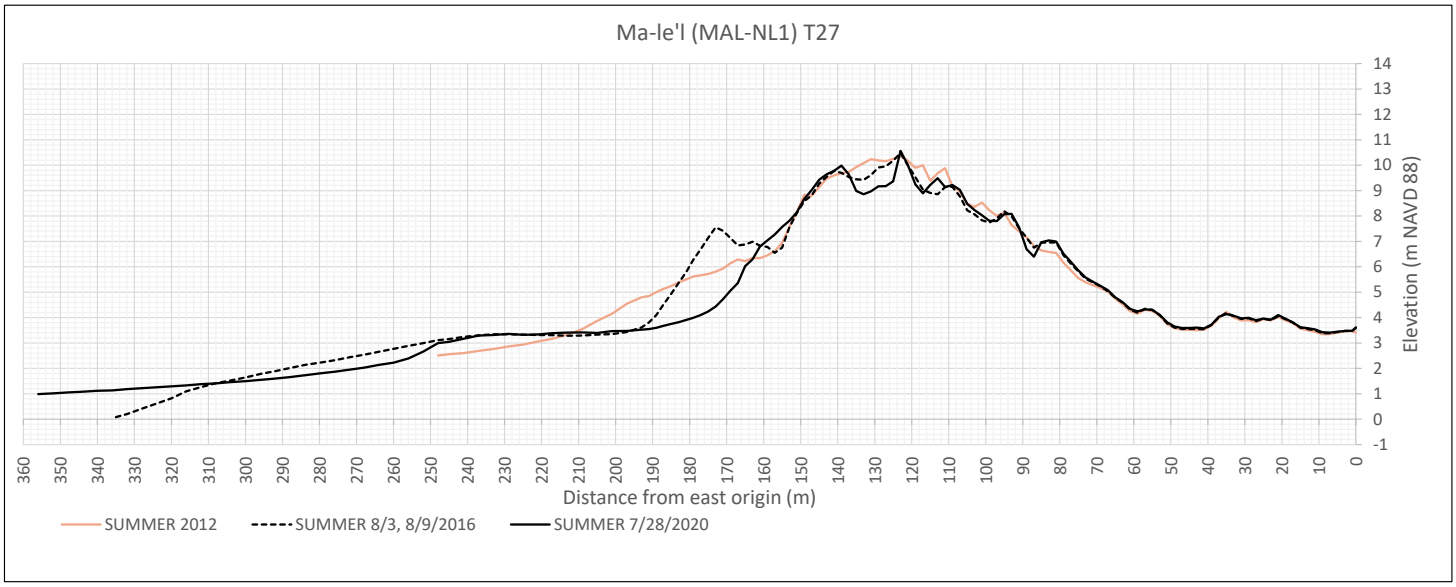
Notes: Adjacent to and similar to Transect 25 although this parabolic dune is shorter and its terminal slipface higher and steeper. Between 2012 and 2016 a foredune began to develop, and the slipface of the dune migrated 0.5 m eastward and lost elevation of up to 1.5 m. In winter 2017 the developing foredune was scarped, losing 1.5 m of elevation, and the backshore was lowered by 0.8 m. By summer 2017 an additional 20.0 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 migrated, 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. Over the course of the two studies *t*he foredune translated eastward but gained over 1.0 m in elevation.

Ma-le’l North Transect 26

View southeast at 191 m (upper beach)

Ma-le'l North Transect 27



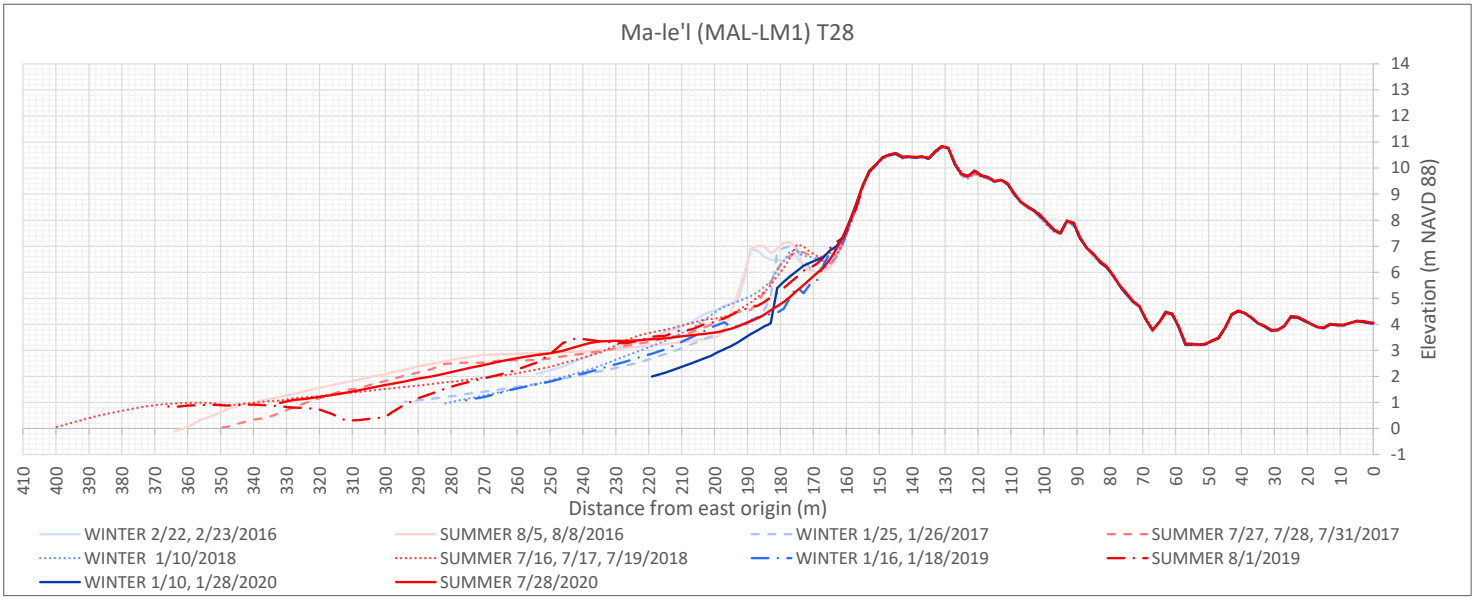


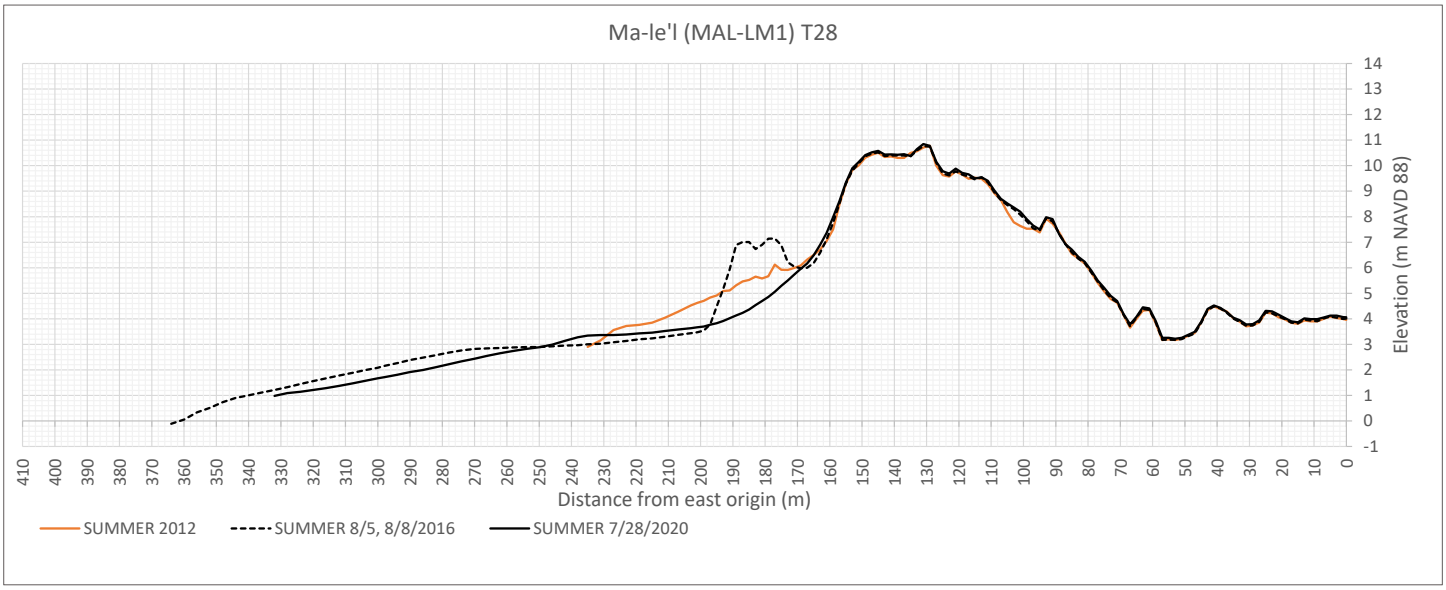
Notes: Between 2012 and 2016 (prior to the current study), an incipient foredune developed. Scarping of the incipient foredune occurred in winter 2016, followed by scarp-fill ramping in summer 2016. The incipient foredune was then rescarped in winter 2017 during the high water event that emplaced the wood pictured in the photo below. 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 incipient foredune occurred, leaving only a small remnant. By summer 2019 there was no incipient foredune. Over the course of both studies the incipient foredune formed and then eroded.

Ma-le’l North Transect 27

View north at 171 m (incipient foredune)

Ma-le’l North Transect 28



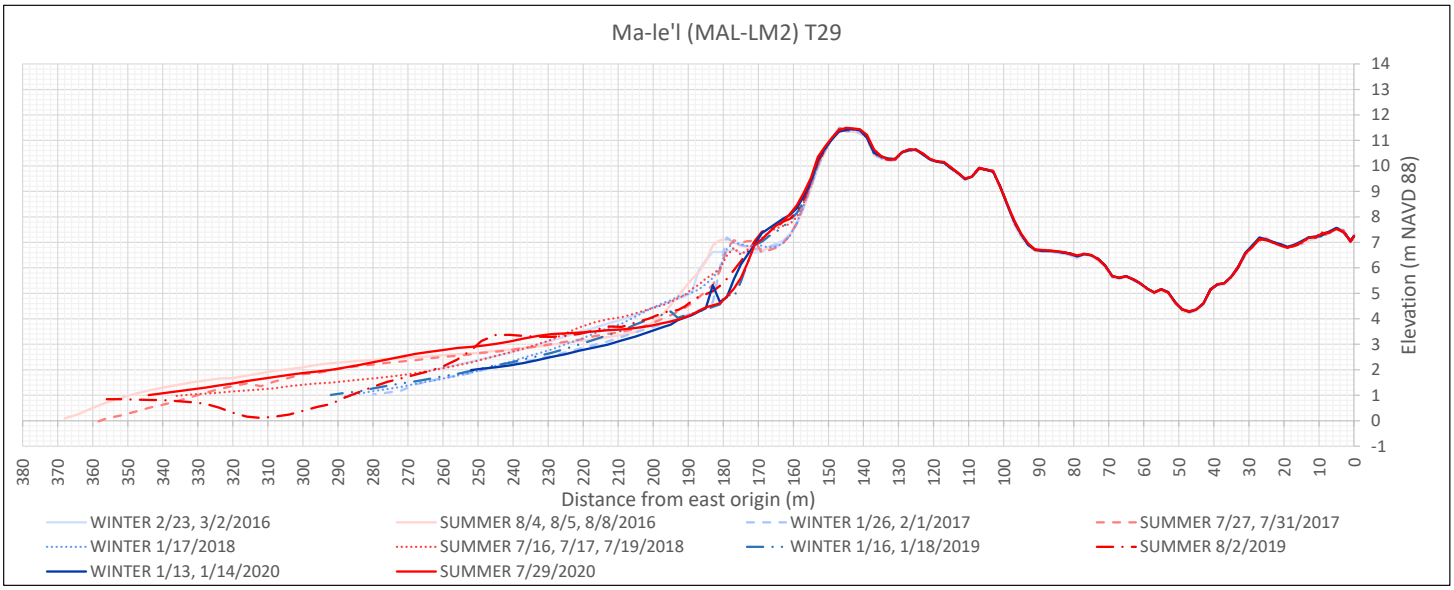


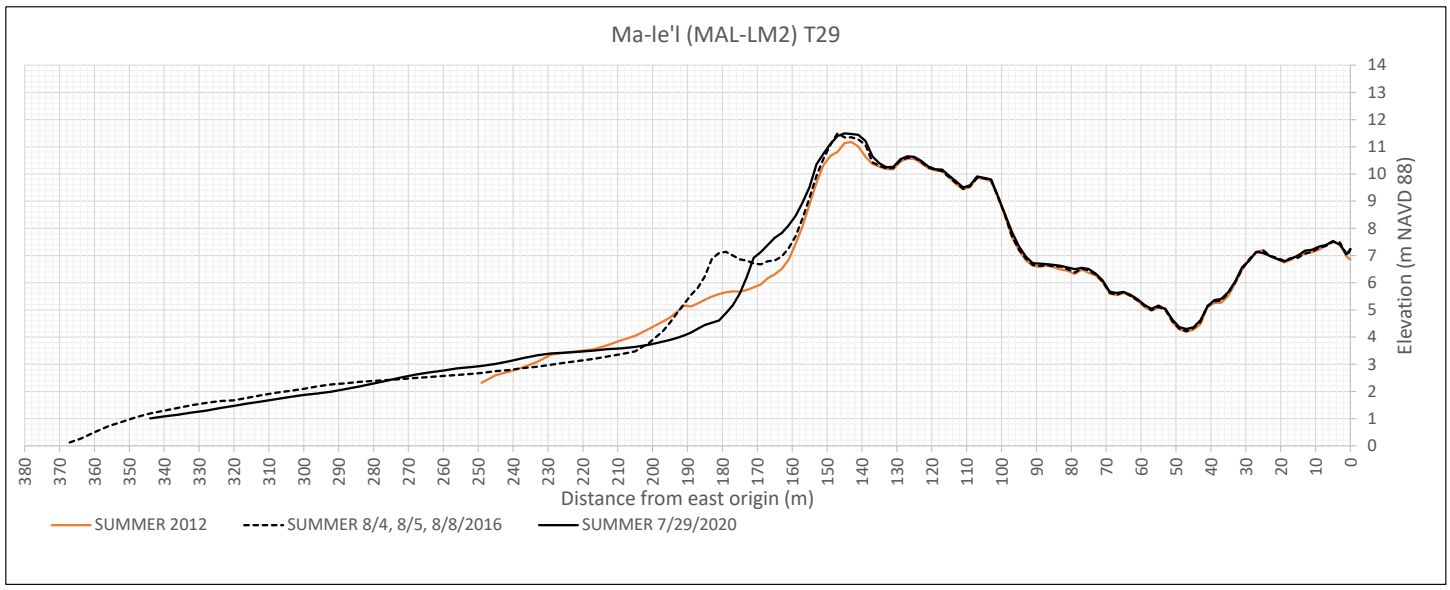
Notes: Between 2012 and 2016 (prior to this study), an incipient foredune formed. A 2.0 m vertical scarp occurred in the incipient *Elymus* foredune in winter 2016. By summer 2016 the scarp had increased in height from further erosion and sand at the top of the scarp mobilized, forming a slipface. In winter 2017 the incipient foredune re-scarped, retreating an additional 10.0 m, and up to 10.0 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). However, in 2019 the incipient foredune was entirely removed. Over the course of both studies the established foredune was stable, but the incipient foredune was first formed and then completely eroded.

Ma-le’l North Transect 28

View north at 177 m (incipient foredune)

Ma-le’l North Transect 29



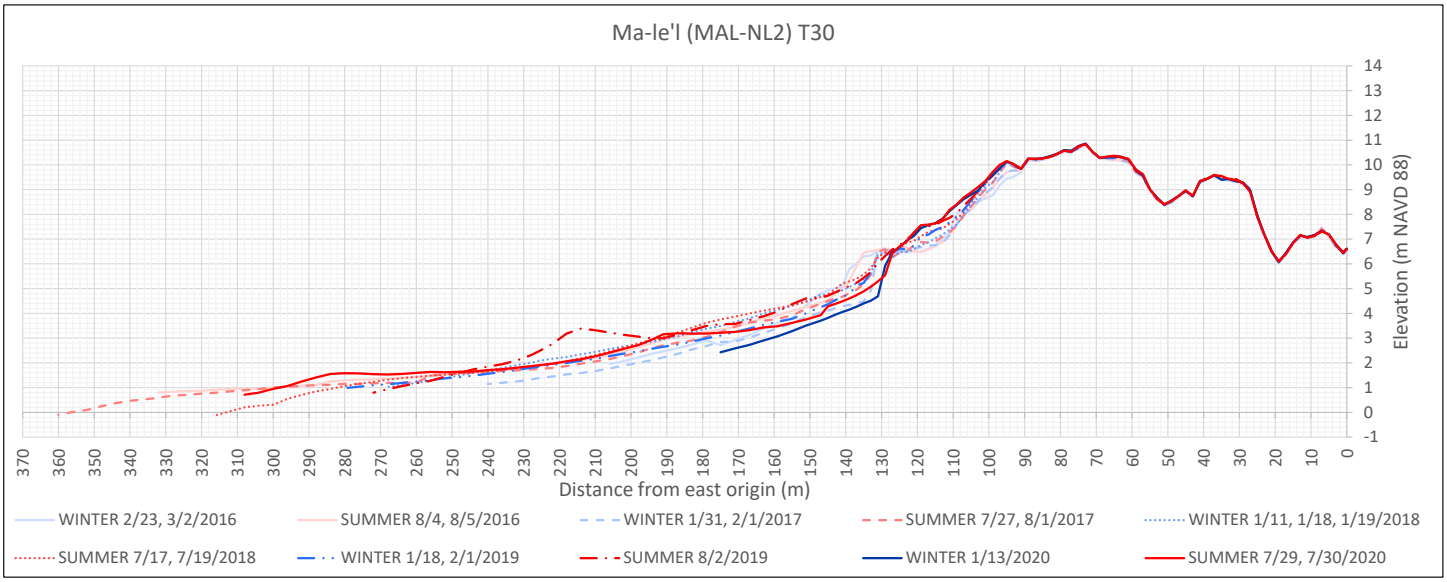


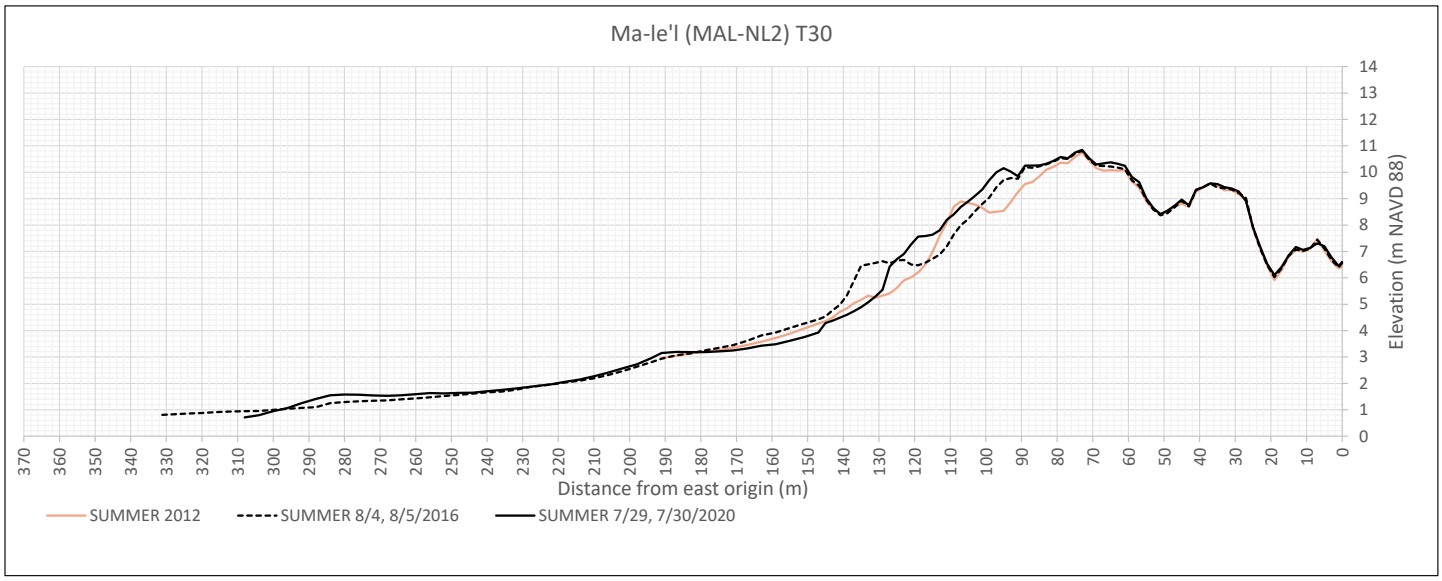
Notes: Between 2012 and 2016 an incipient foredune formed. Scarping of the incipient *Elymus* foredune occurred in winter 2016 with additional erosion of the upper beach occurring before the summer 2016 survey, which shows scarp-fill ramp formation. In the high water events of winter 2017 the incipient fore-dune retreated an additional 10.0 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 incipient foredune swale (see photos below). In 2019 –2020 the incipient foredune had translated and become incorporated in the established foredune. Over the course of the two studies the incipient foredune first formed, and then was removed. The established foredune underwent deposition on the stoss face and foredune crest.

Ma-le’l North Transect 29

View northwest along transect at 147 m (foredune crest)

Ma-le’l North Transect 30





Notes: Between 2012 and 2016 an incipient foredune formed. The incipient *Elymus* foredune scarped dramatically in winter 2017, losing 2.0 m vertically and lowering the beach. 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. Over the course of both studies the incipient foredune formed and then eroded/translated causing deposition of up to 1 m on the stoss slope of the foredune.

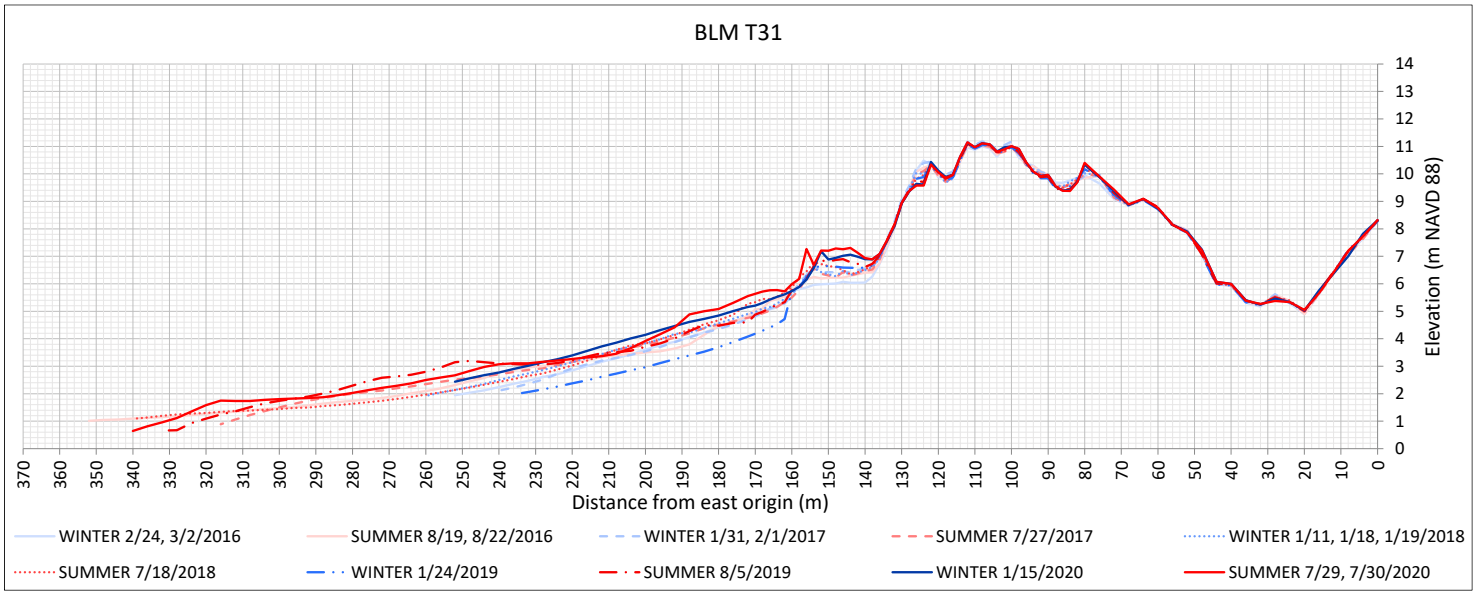
Ma-le’l North Transect 30

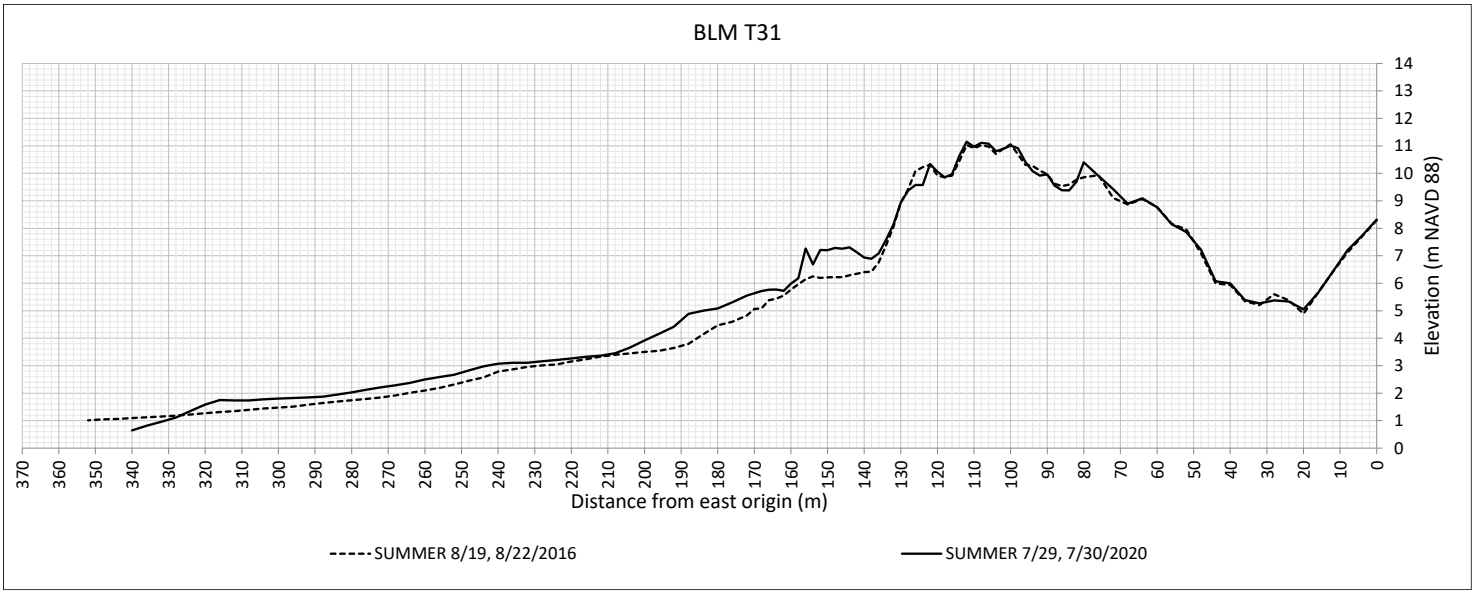
View southeast along transect at 117 m foredune base showing deposition on stoss face

MA-LE’L NORTH SUMMARY (FWS). This stretch of coastline consists of restored, native, vegetated dunes. Transects 25 and 26 are located in an area of past foredune failure following a high water event (ca 2000), which resulted in the formation of a transverse dune field that has now differentiated into two parabolic dunes. Although a foredune has developed it is lower than areas to the north and south. The foredune on both transects translated to the east between 2012 and 2020 due in part to scarping that resulted from a persistent rip current and narrow beach. The crest and slipface of the parabolic dunes migrated east and lowered. This section of coastline does not show signs of resiliency. Although it is characterized by low historic accretion, fine scale studies showed that there has been little accretion here since 1939 (Pickart and Hesp 2019). The remaining transects in Ma-le’l North showed similar patterns to the Lanphere transects. Incipient foredunes formed between 2012 and 2016 and were eroded between 2016 and 2020 during stormy winters. Two transects exhibited deposition on the stoss face and crest of the foredune. As discussed under Lanphere, ephemeral incipient foredunes form under more quiescent periods and then erode during periods of stormy weather. This confers resiliency as the incipient foredunes protect the established foredunes during stormy intervals.

Ma-le'l South (BLM)

Ma-le'l South Transect 31



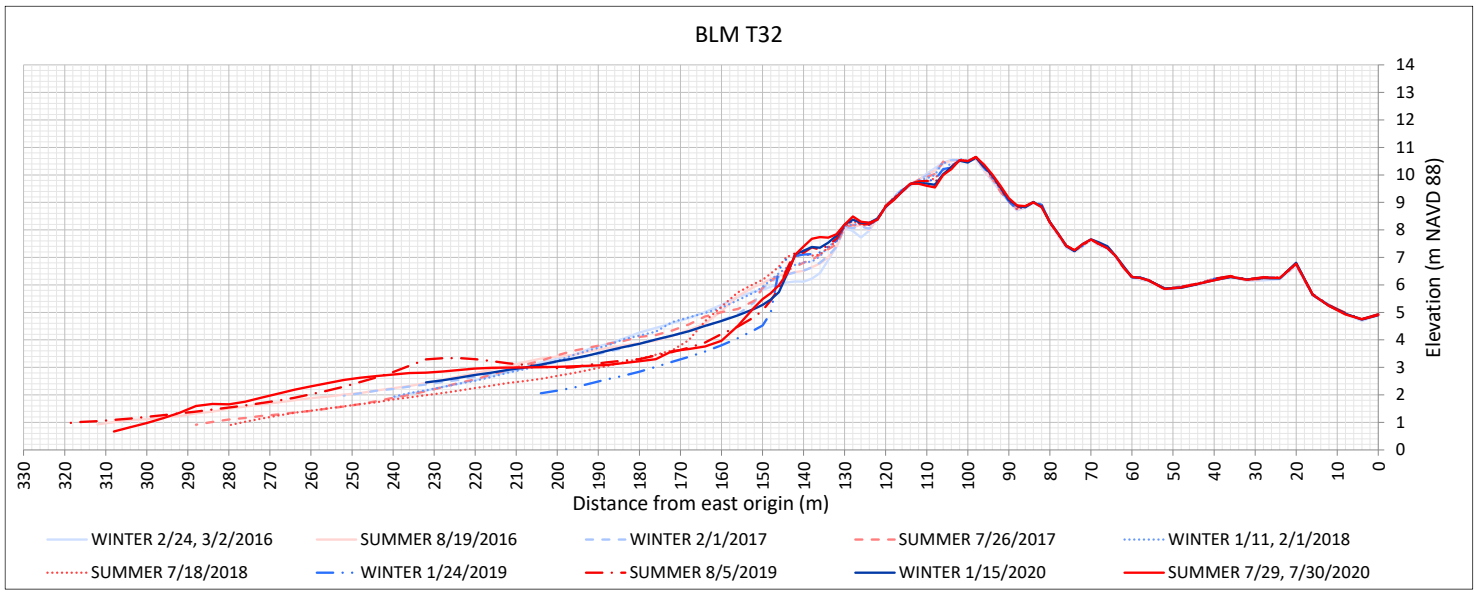


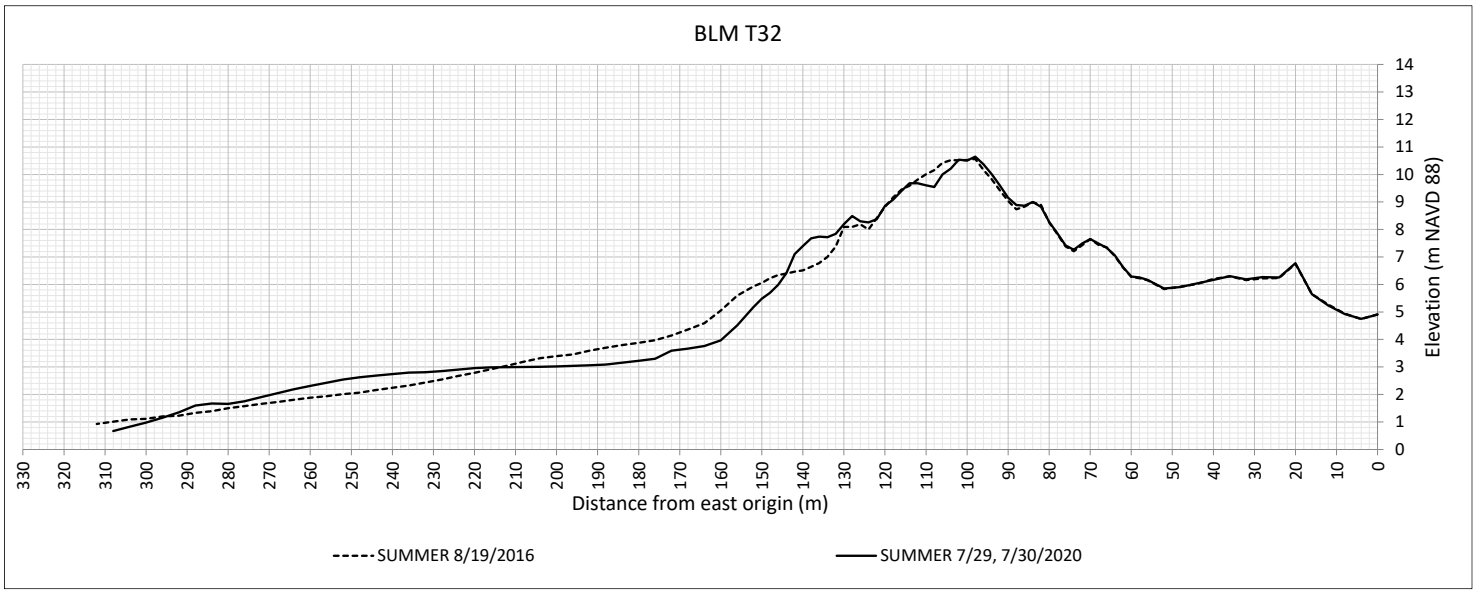
Notes: This stretch of restored shoreline at Ma-le'l South began with a bench-like incipient *Elymus* foredune below a broad, native established foredune. Between winter 2016 and summer 2016 there was seasonal deposition on the upper beach and incipient foredune, and minor erosion at the established foredune crest. In winter 2017 the incipient foredune was eroded, leading to deposition and slipface formation on the crest of the incipient foredune. 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 and summer 2020 the incipient foredune continued to build. Over the course of the study the incipient foredune increased in elevation and prograded 30.0 m.

Ma-le'l South Transect 31

View north at 156 m (incipient foredune)

Ma-le'l South Transect 32



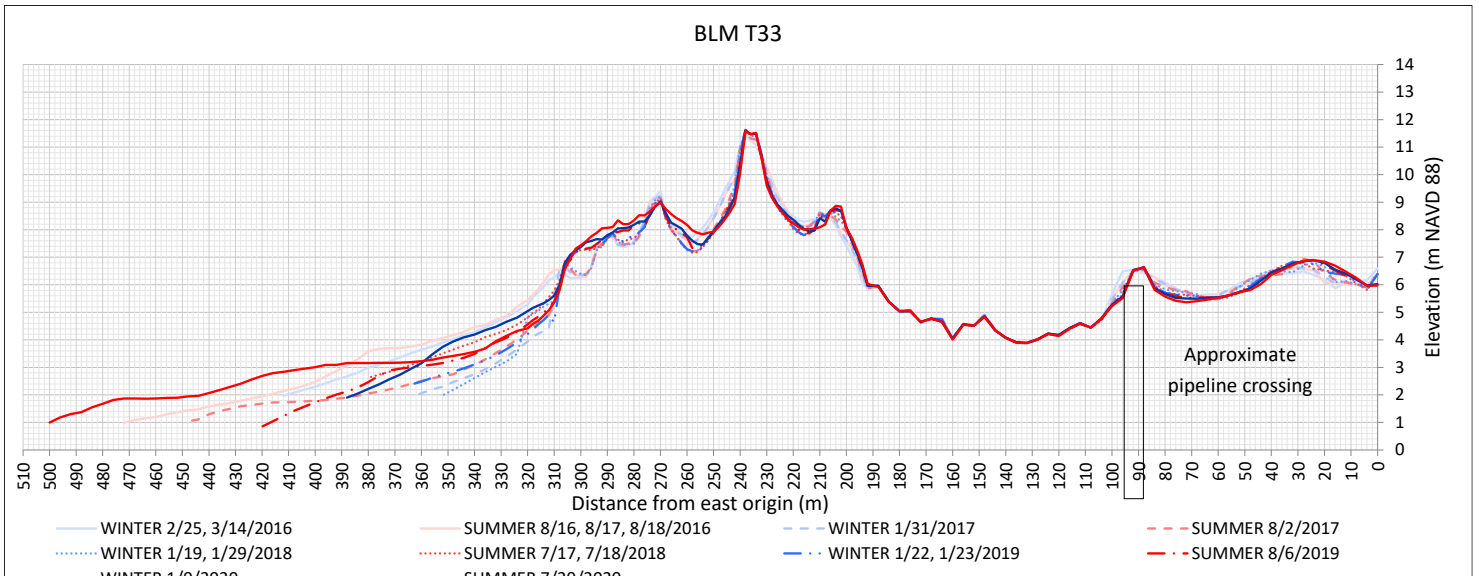


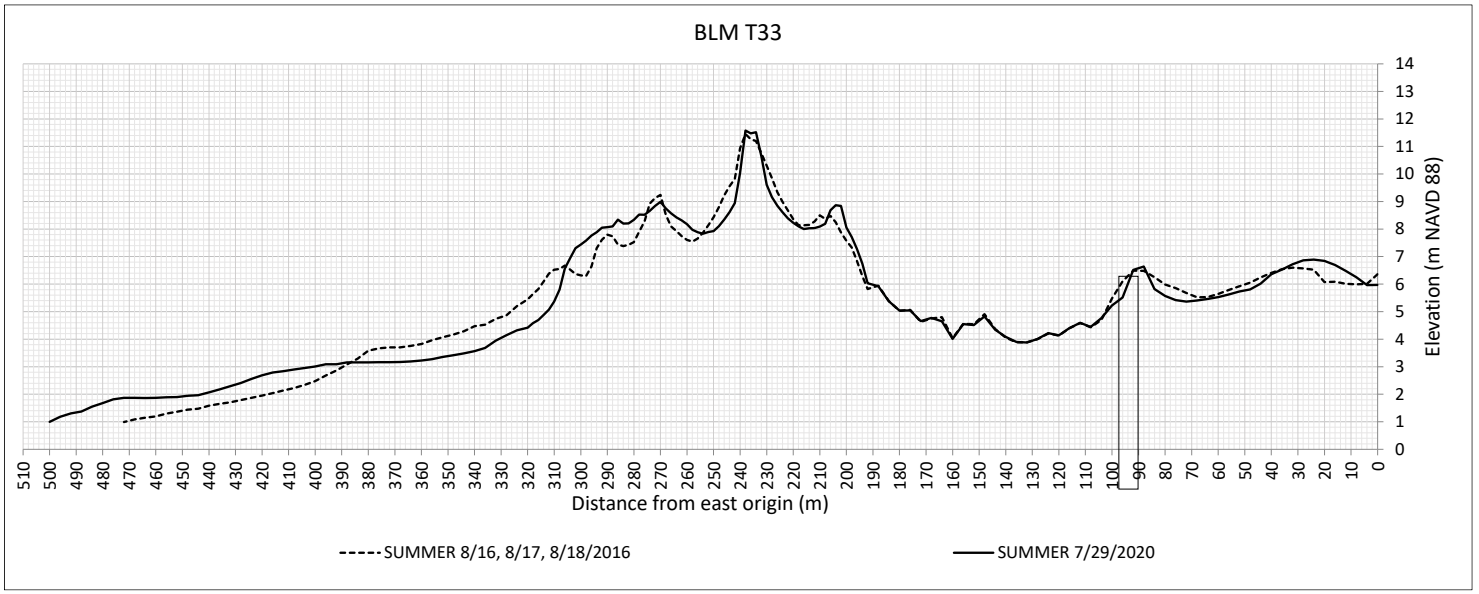
Notes: The broad, bench-like incipient foredune (similar to the previous transect) was scarped in winter 2016 and a steep beach slope resulted. In summer 2016 mobilized sand at the crest of the incipient foredune migrated into the incipient foredune swale and there was 0.5 m of deposition as the result 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 below. By Summer 2020 a ramp had formed filling the scarp. Over the course of the study the incipient foredune was removed, retreating 20.0 m, but deposition occurred on the upper stoss face of the established foredune. There was also erosion at the crest.

Ma-le'l South Transect 32

View north at 144 m (incipient foredune)

Ma-le'l South Transect 33



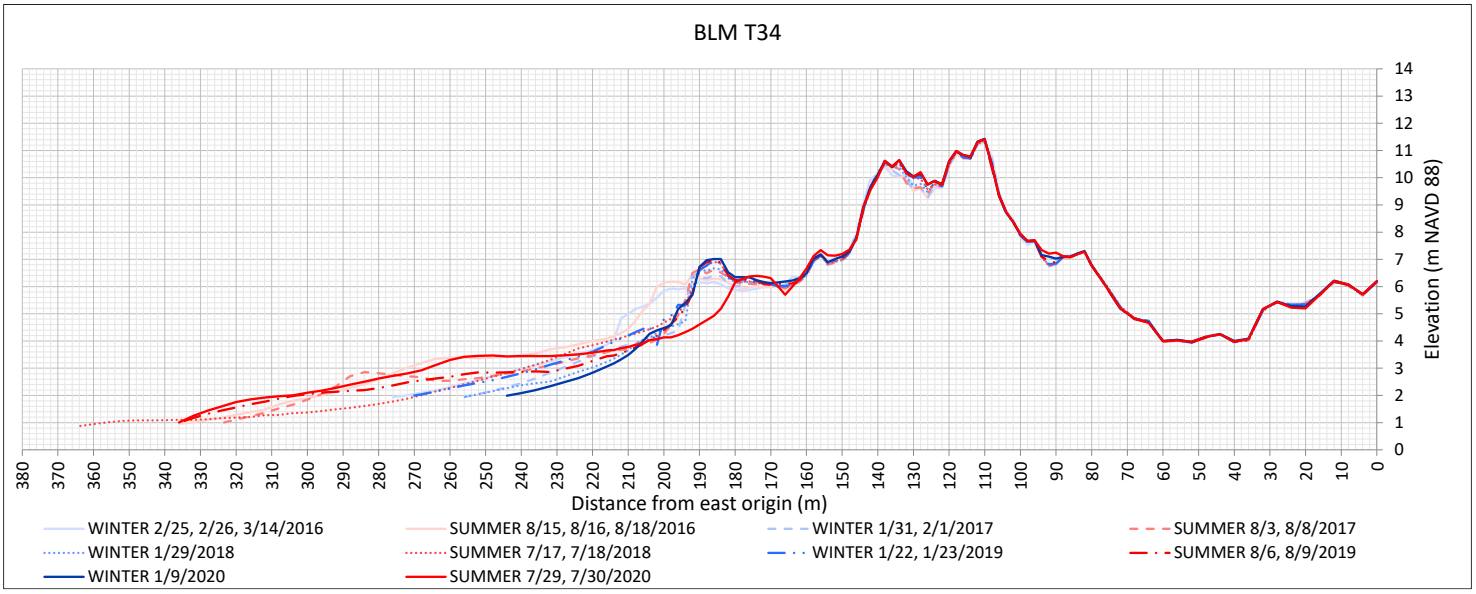


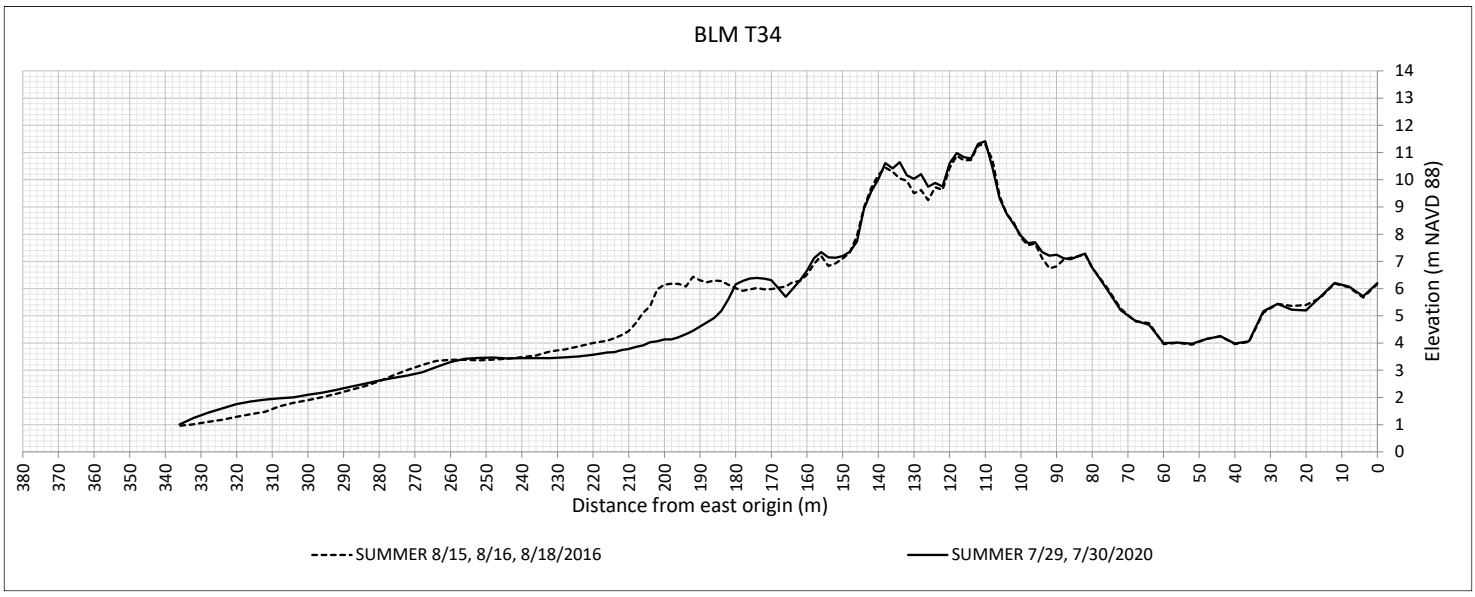
Notes: A 2.0 m vertical scarp formed in the incipient *Elymus* foredune during high water events in winter 2017. By summer 2017 0.4 m deposition occurred on the upper beach, but the vertical scarp remained, although sediment was mobilized on its crest. By summer 2018 a scarp-fill ramp had formed and sediment had translated inland and filled the incipient foredune swale (see photos below). 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 fore-dune troughs were filled. By summer 2020 the peaks had coalesced into a more typical foredune. This profile extends further inland than most in order to capture the Humboldt Bay Municipal Wa-ter District pipelines in an area that has been vulnerable to erosion and exposure in the past. This area is actively managed, with sand placed over an exposed portion of the pipeline in 2015. Erosion is occurring on both sides of the knoll that sits on top of the pipeline. 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. Over the course of the study the foredune retreated 10.0 m.

Ma-le’l South Transect 33

View southeast at 298 m (foredune base)

Ma-le'l South Transect 34



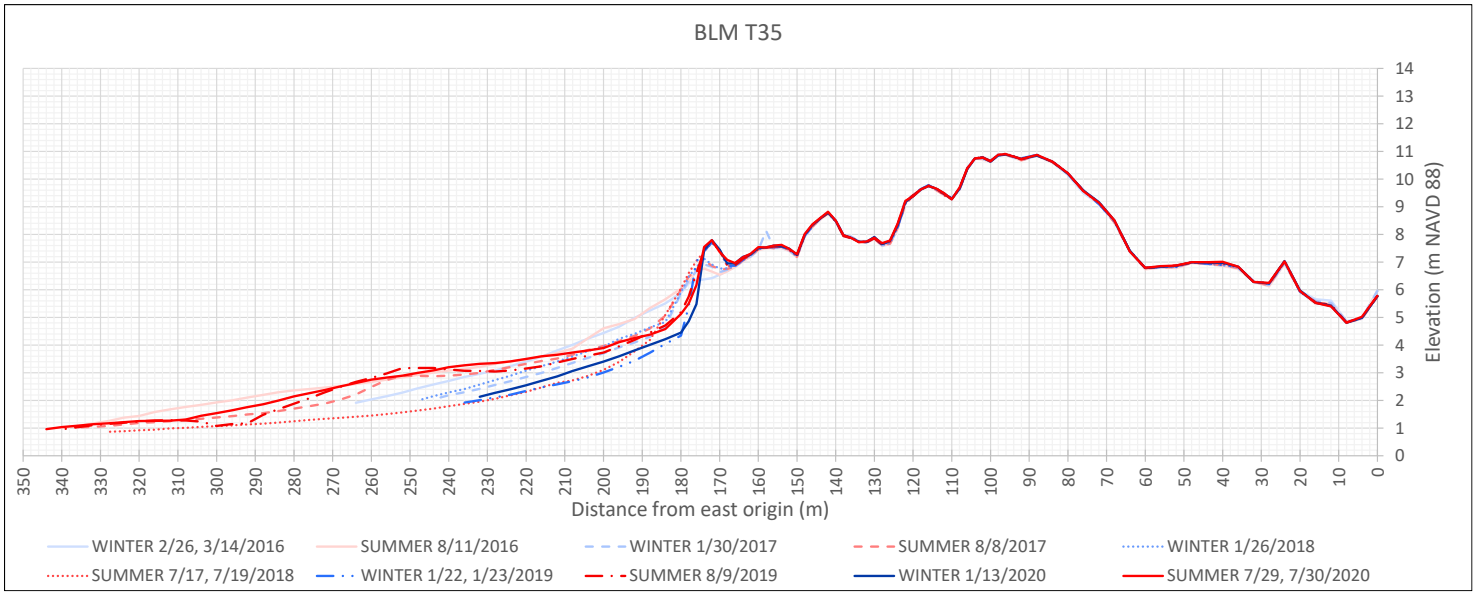


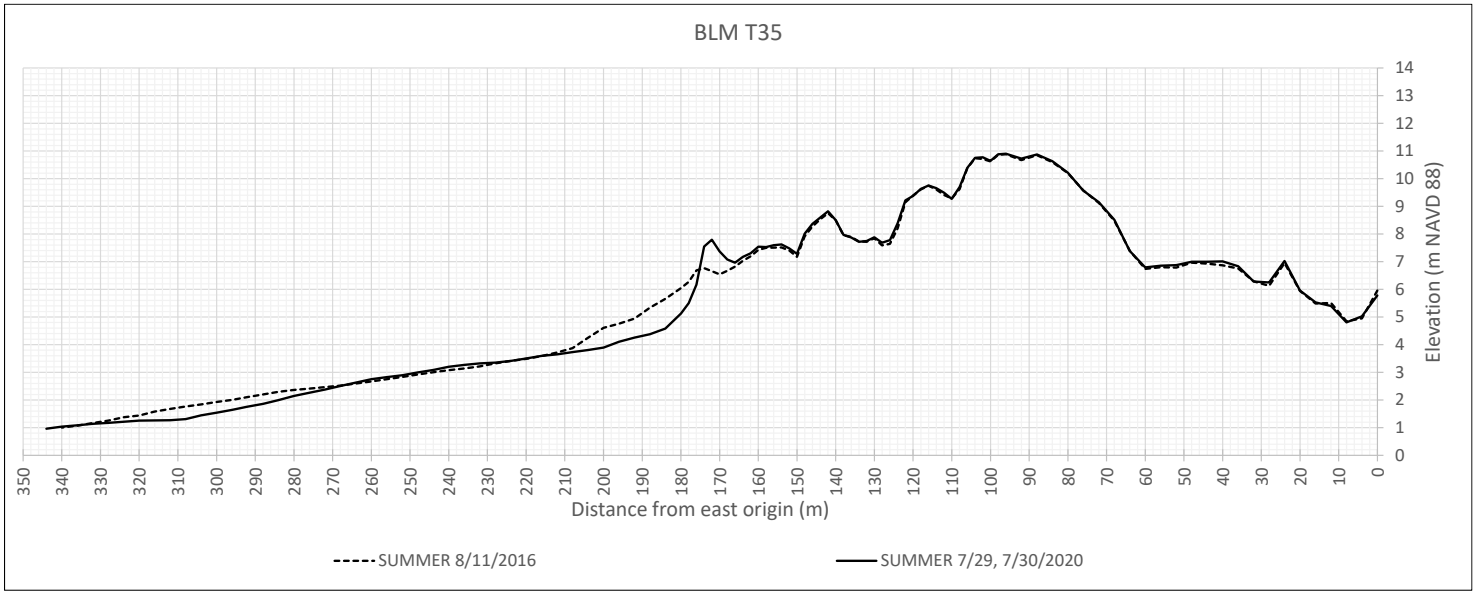
Notes: The original profile describes a broad, flat incipient foredune fronting a two-peaked established foredune. The incipient foredune was scarped prior to the winter 2017 survey and by summer deposition had occurred on the backshore, a scarp-fill ramp had formed, and the crest of the incipient foredune 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 a new incipient foredune east of the old one. This feature remained constant through summer 2020. The established foredune is two--peaked, and deposition occurred on the lee side of the western peak. Over the course of the study the foredune retreated 20.0 m.

Ma-le'l South Transect 34

View north at 184 m (incipient foredune)

Ma-le'l South Transect 35



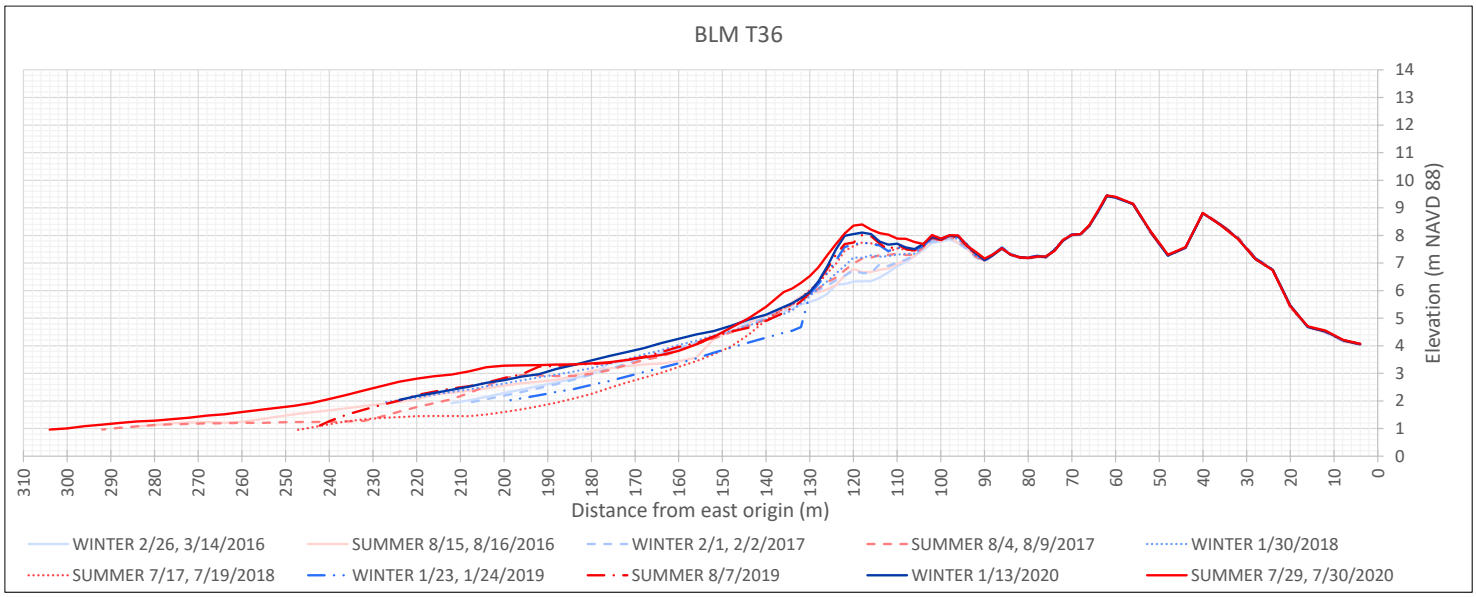


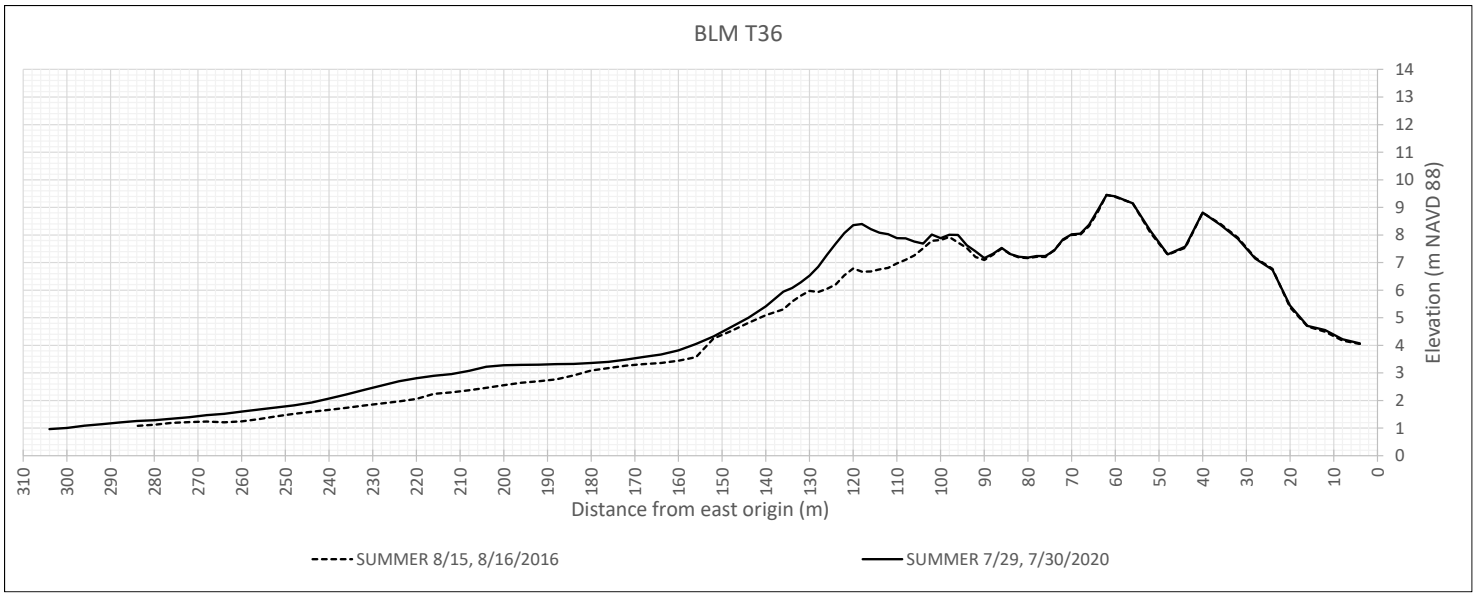
Notes: Through summer 2016 a wide, hummocky incipient foredune sloped gradually from the upper beach to the established foredune. In winter 2017 high water events carved a 1.2 m scarp, creating a more defined incipient foredune. The beach was lowered by 1.0 m and the incipient foredune retreated 15.0 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) and 0.5 m of deposition occurred on the crest of the incipient foredune by summer 2018. In summer 2019 the incipient foredune had translated inland and increased in elevation. This morphology remained through summer 2020. Over the course of the study the foredune retreated 15.0 m.

Ma-le'l South Transect 35

View southeast along transect from upper beach at 196 m

Ma-le'l South Transect 36



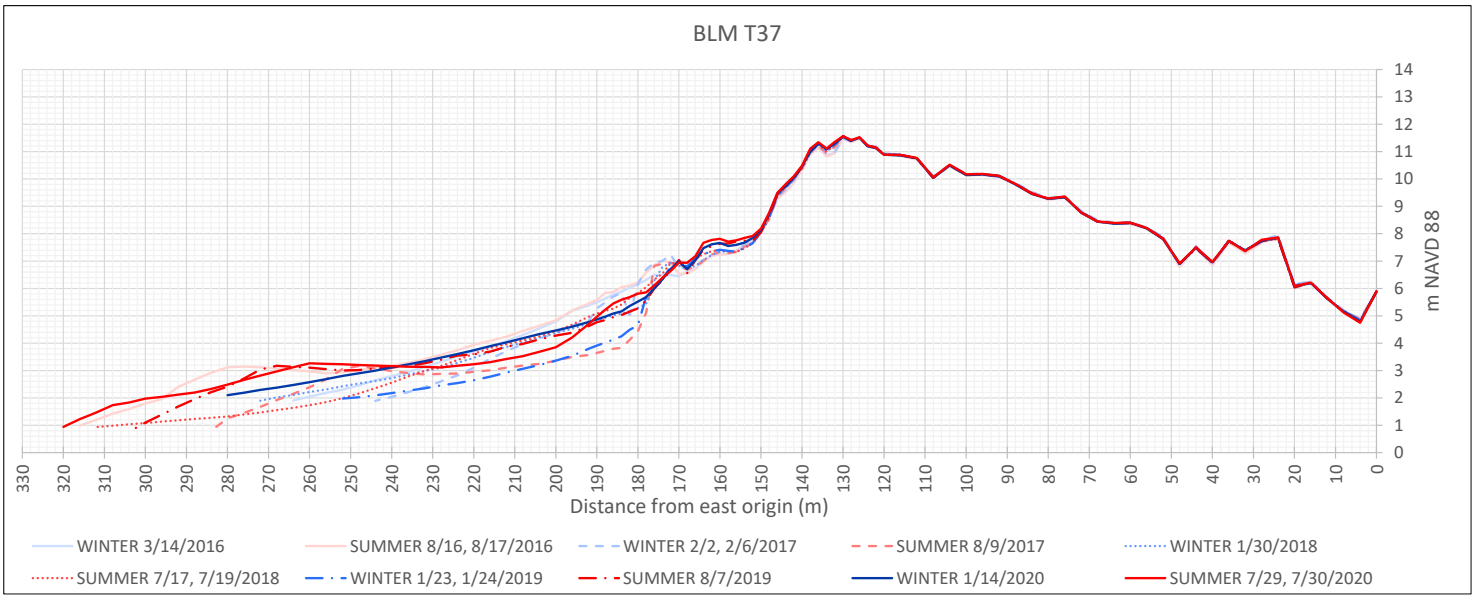


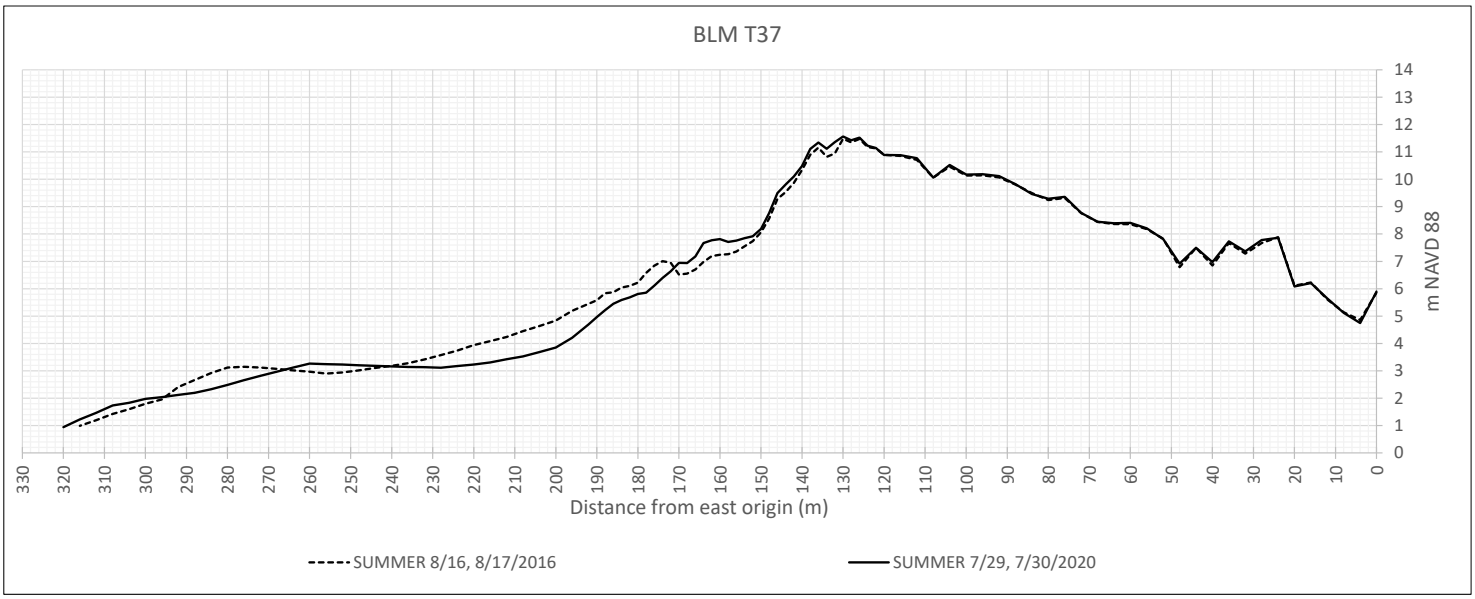
Notes: A wide, hummocky incipient foredune sloped gradually from the upper beach to the established foredune from winter 2016 through summer 2016. The beach remained relatively stable. In summer 2017 the incipient foredune built seaward, with 0.2 m of deposition at its western edge, which is visible 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), while the upper beach was eroded an equivalent amount. There was little change in 2019. By summer 2020 there was additional deposition on the incipient foredune. Over the course of the study the incipient foredune gained up to 1.5 m in elevation and welded to the foredune.

Ma-le’l South Transect 36

View northwest at 104 m (incipient foredune)

Ma-le'l South Transect 37





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 1.0 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, and the scarp healed. In summer 2020 there was additional deposition. Over the course of the study the incipient foredune translated up and east, retreating 10.0 m, and deposition occurred on the stoss face of the established foredune.

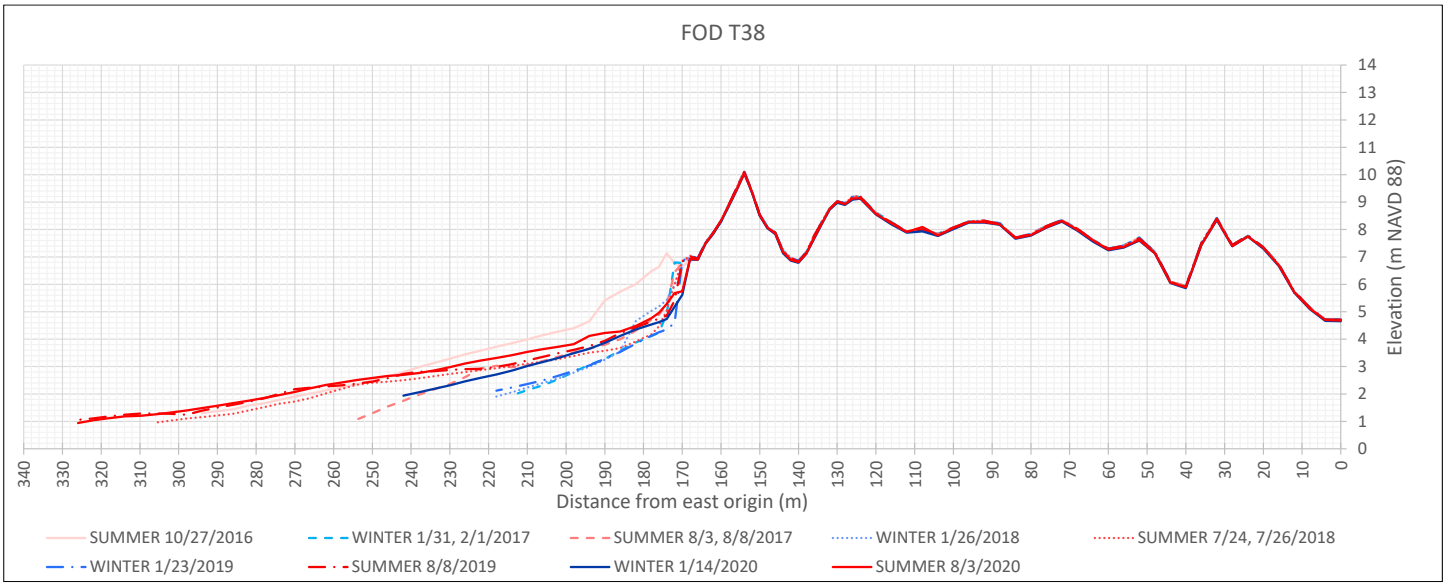
Ma-le’l South Transect 37

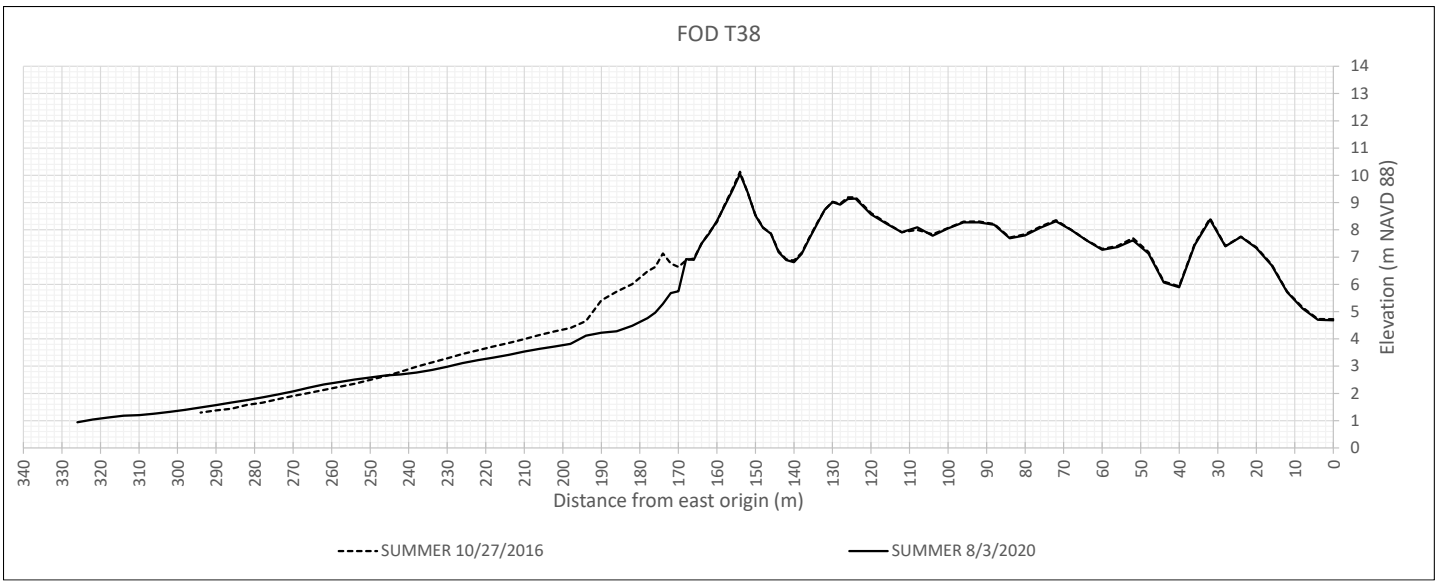
View southeast along transect from foredune crest at 136 m

MA-LE’L SOUTH SUMMARY (BLM). Ma-le’l South, a restored area, did not show a consistent trend across transects. Transect 31 showed deposition on the incipient foredune and some movement of sand in the backdune (both deposition and erosion). Transect 32 showed changes (both deposition and erosion) over the entire established foredune. Transect 33 exhibited deposition in the incipient foredune and erosion in the established foredune. Transect 34 showed retreat of the incipient foredune and some deposition in the established foredune. Transect 35 exhibited an increase in the incipient foredune and a stable established foredune. Transect 36 formed a new incipient foredune. Transect 37 exhibited erosion of the incipient foredune but deposition on the stoss face of the foredune. Several of the Ma-le’l South transects were located in areas where the foredune had deteriorated to a series of nebkha. Overall, this area exhibited a mixture of lower and higher resiliency, in a stretch of shoreline historically characterized by low accretion.

Friends of the Dunes

FOD Transect 38



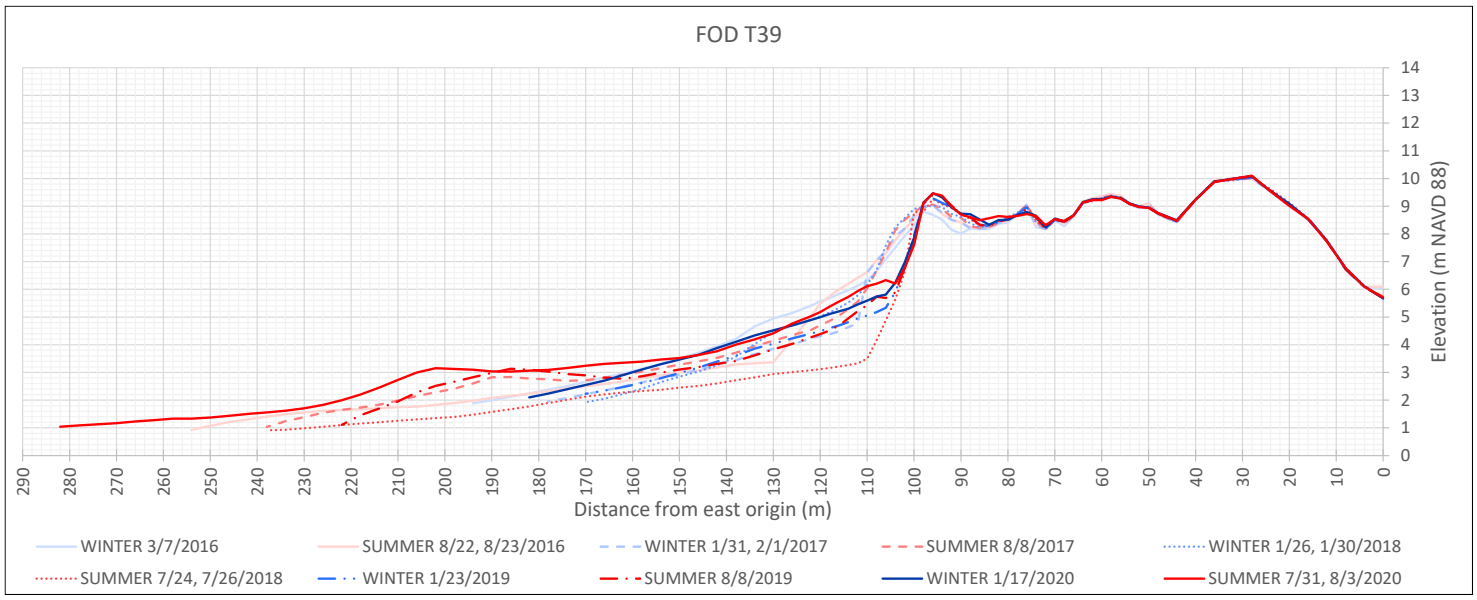


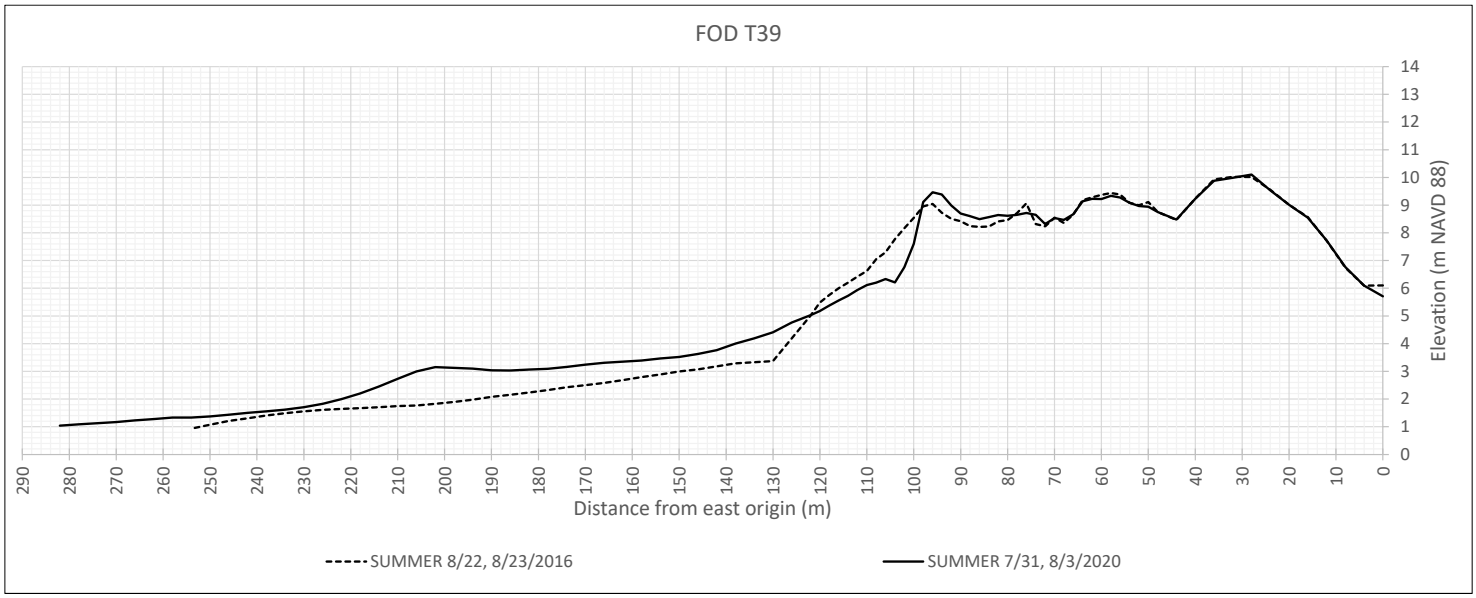
Notes: The profile describes a stable, peaked *Ammophila* foredune seaward of an older, formerly native foredune, with a dynamic incipient foredune. Data are not available for winter 2016 but summer 2016 shows a well developed incipient *Ammophila* foredune that was significantly scarped (2.0 m elevation 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. Over the course of the study the incipient foredune completely eroded, retreating 15.0 m, while the established foredune was stable.

FOD Transect 38

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

FOD Transect 39



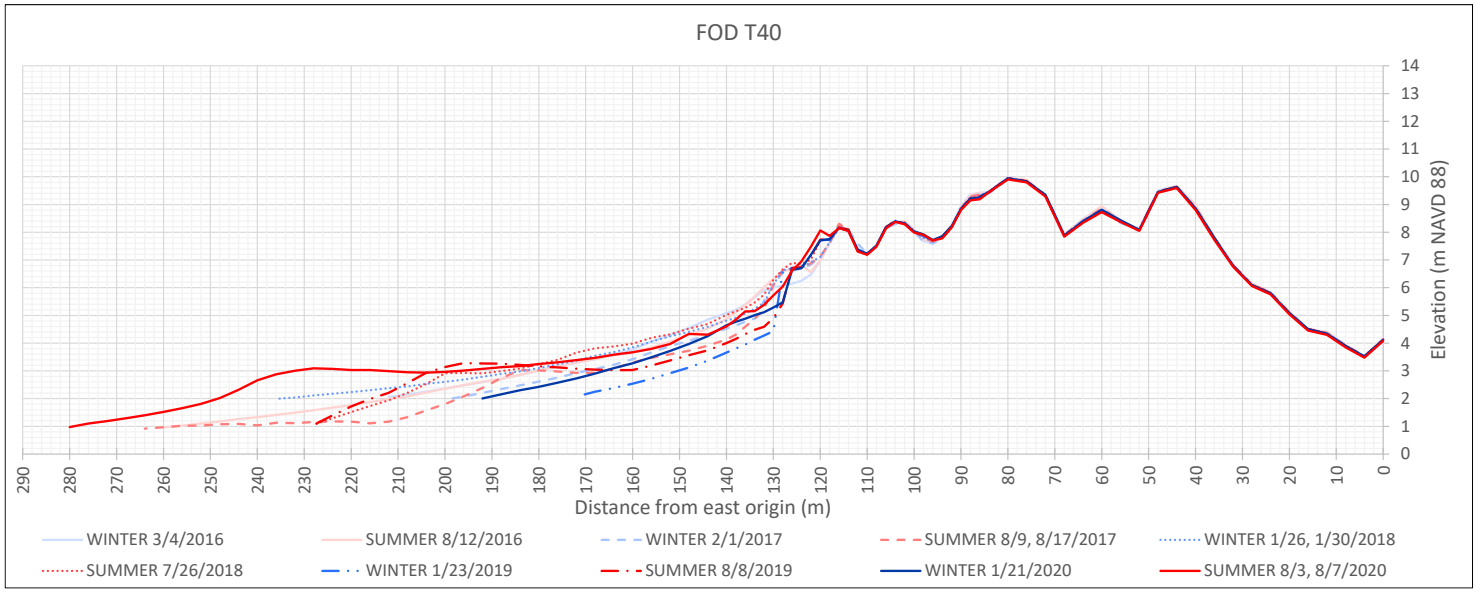


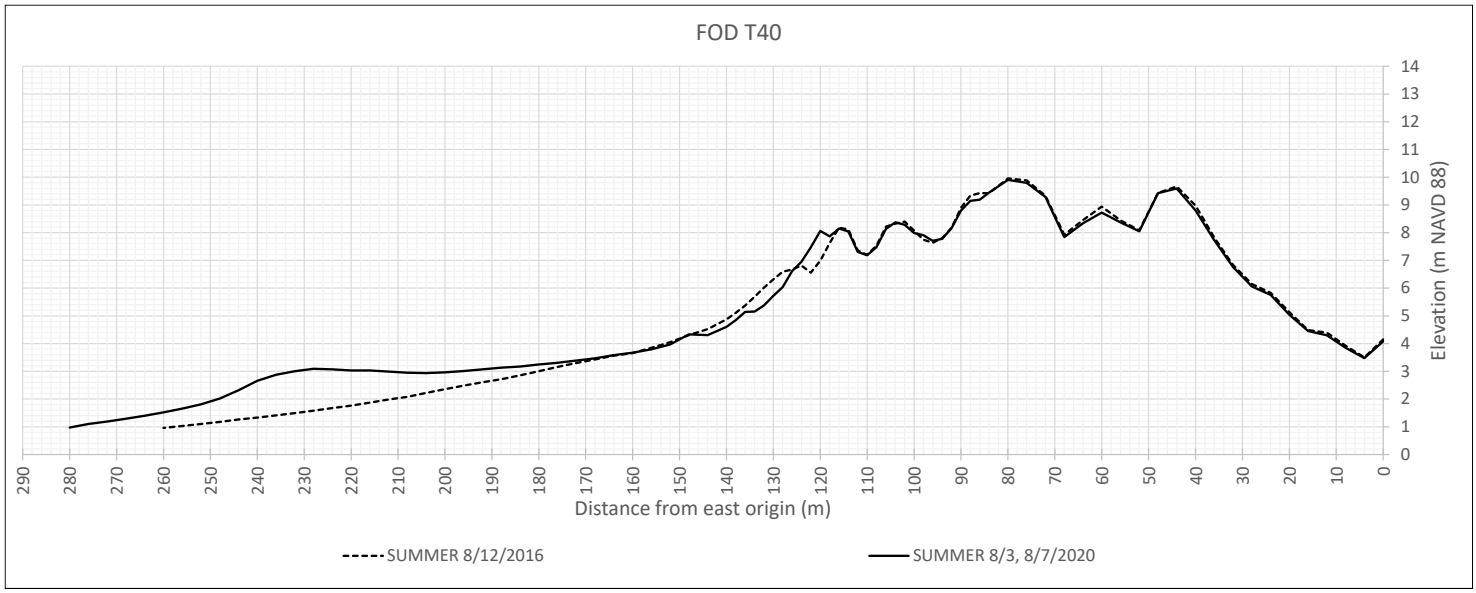
Notes: The profile extends through a restoration area, although *Ammophila* was not removed on the outer incipient foredune until October 2017. Scarping of the upper beach occurred at some point between the winter 2016 and summer 2016 surveys, allowing the mobilization of sand in the summer such that 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). A scarp fill ramp was partially built during winter and summer 2019. By summer 2020 some of the scarp remained. Over the course of the study the foredune increased in height and steepness, retreating at the midpoint of the stoss face 10.0 m.

FOD Transect 39

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

FOD Transect 40





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 scarped 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 looking inland along transect from upper beach) but the incipient foredune profile did not change. By summer 2018 a scarp-fill ramp had formed (top right photo). The feature was again scarped in winter 2019, with some recovery in summer 2019. By summer 2020 a scarp fill ramp had formed. Over the course of the study the outer incipient foredune was eroded, retreating 2.0m, and the more inland incipient foredune increased in breadth (prograding 2.5 m) due to ramp formation.

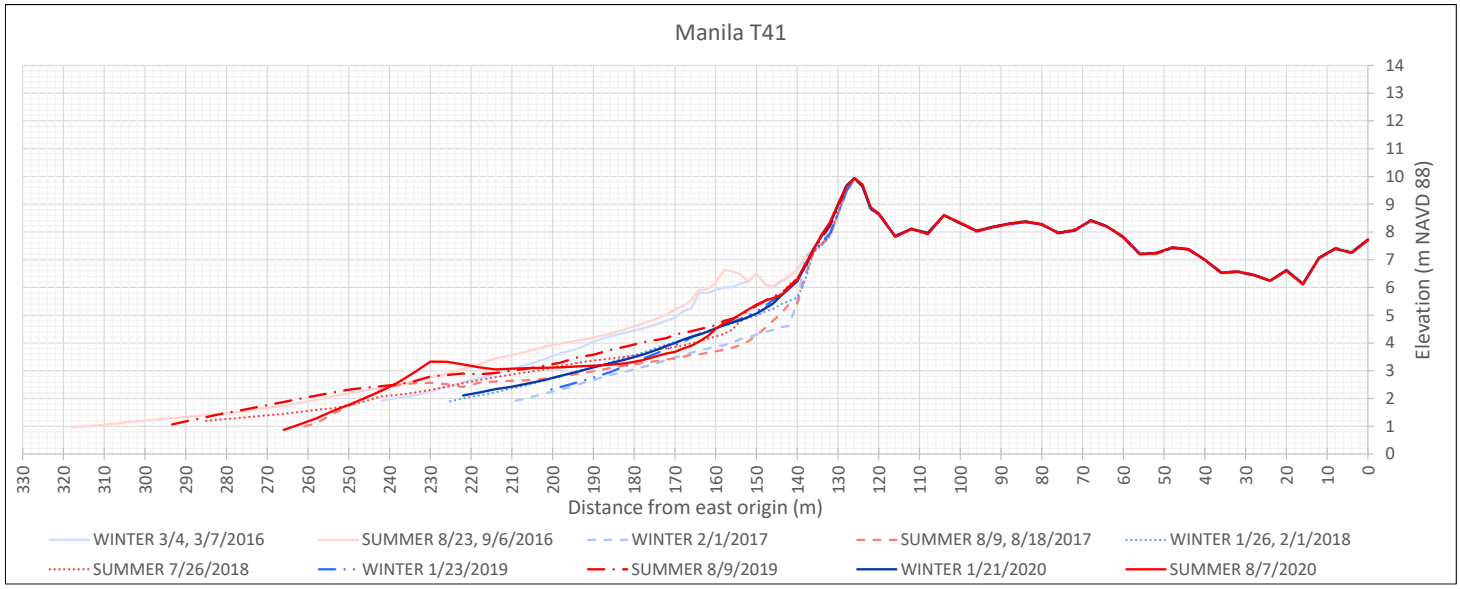
FOD Transect 40

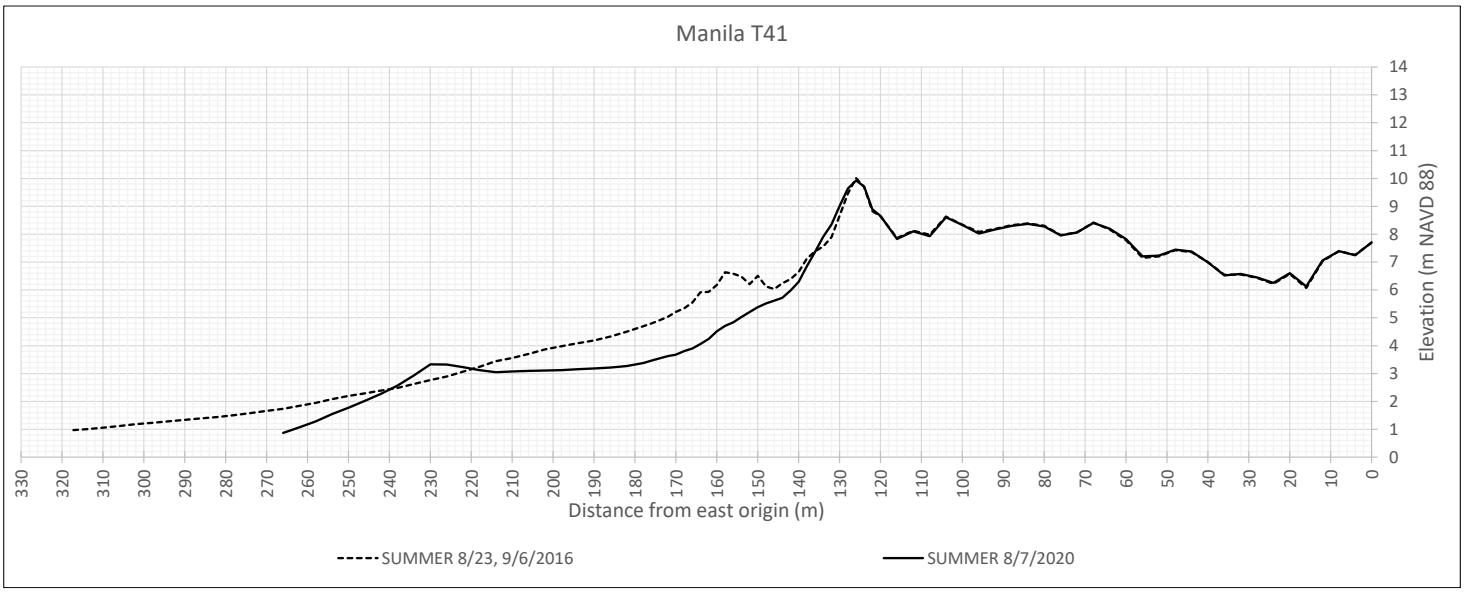
View southeast from upper beach showing incipient foredune

FRIENDS OF THE DUNES SUMMARY. These 3 transects received different management. The northernmost transect received no restoration and consisted of a typically peaked *Ammophila* foredune. The incipient foredune was eroded over the course of the study but the established foredune remained static. On the middle transect, *Ammophila* was removed behind the foredune. Deposition occurred behind the foredune over the four- year period. Along the third transect restoration also occurred inland of the foredune. The outer incipient foredune eroded but a new *Ammophila* incipient foredune formed due to scarp-fill ramping. Overall the northern transect exhibited low resiliency but the southern two transects were more resilient. This stretch of shoreline is characterized as historically low accretion.

Manila Community Services District

MCSD Transect 41



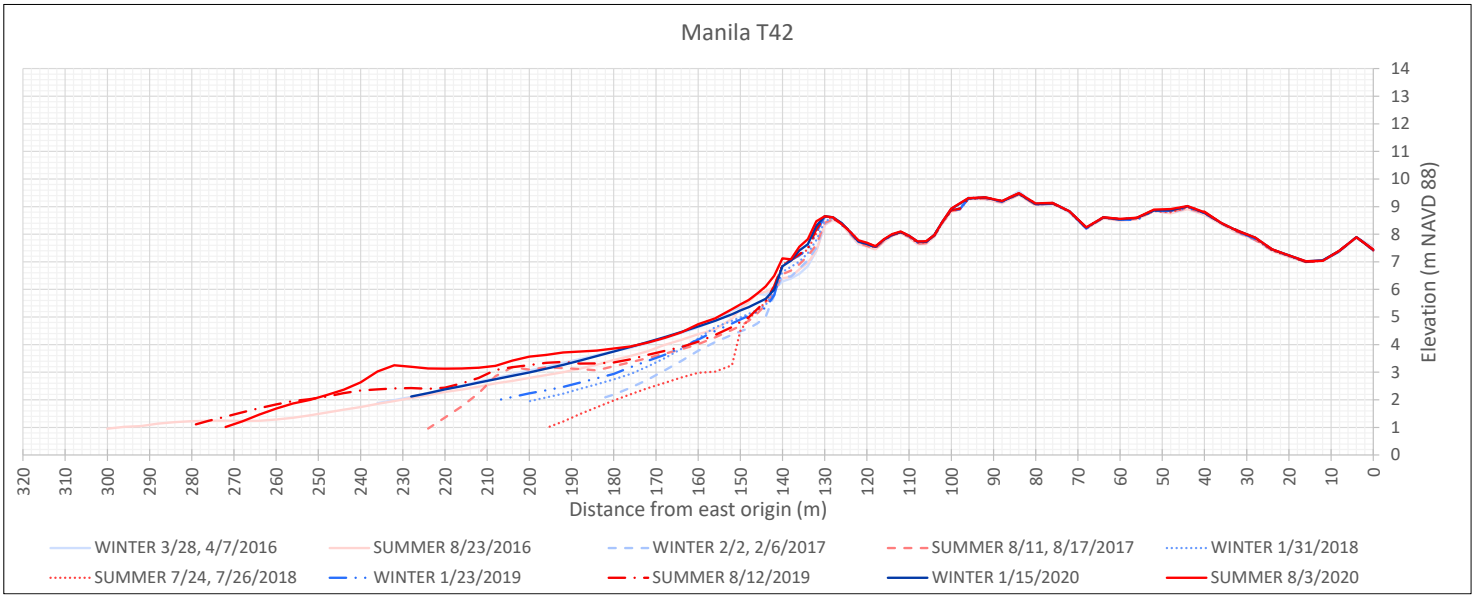


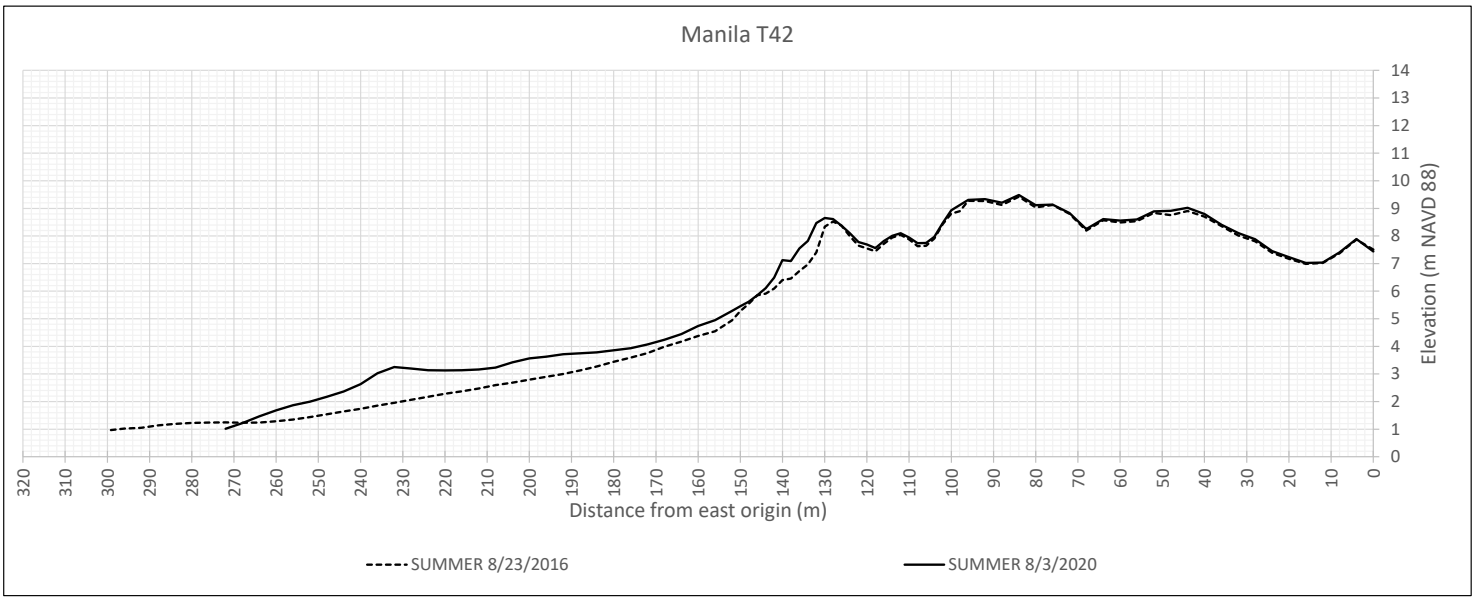
Notes: The transect is located in an unrestored portion of property owned by the Manila Community Services District. The profile depicts a dynamic incipient foredune and a stable peaked *Ammophila* foredune fronting a backdune area stabilized by *Ammophila* and *Carpobrotus.* The incipient *Ammophila* 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 24.0 m horizontally). By summer 2017 there was minimal recovery, although some upper beach deposition occurred, as can be seen in the photograph taken at the upperbeach 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. Over the course of the study, the incipient foredune was completely removed, retreating 20.0 m, and there was deposition of the stoss face of the foredune.

MCSD Transect 41

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

MCSD Transect 42



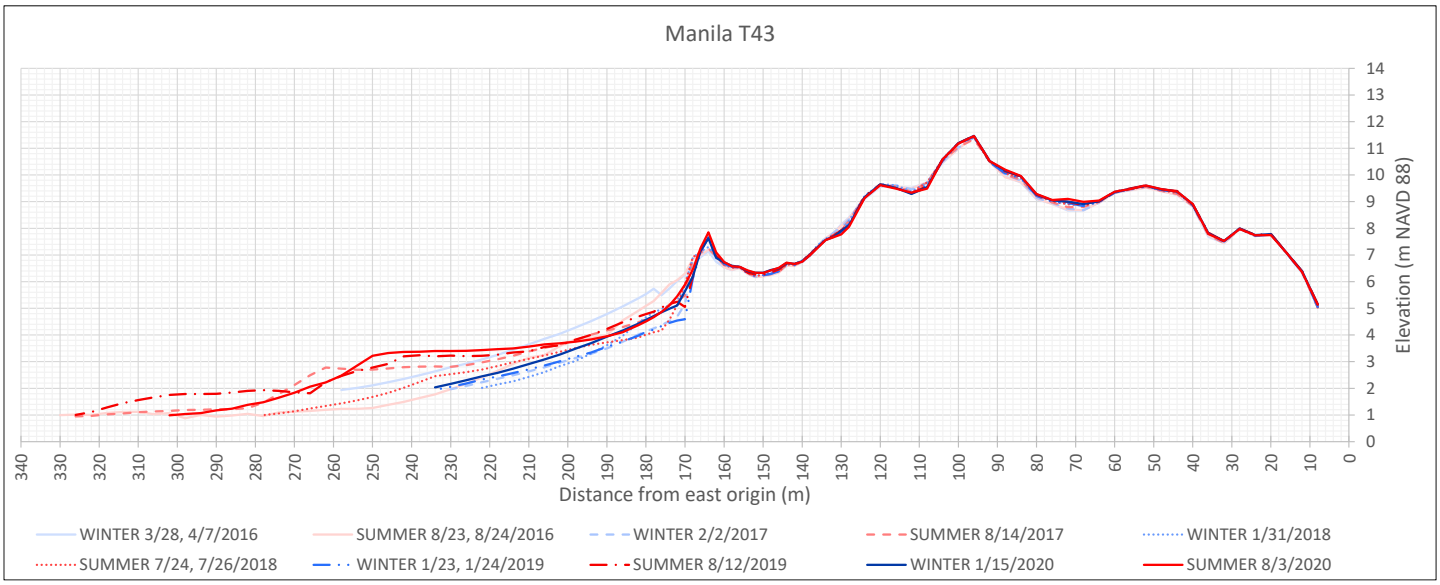


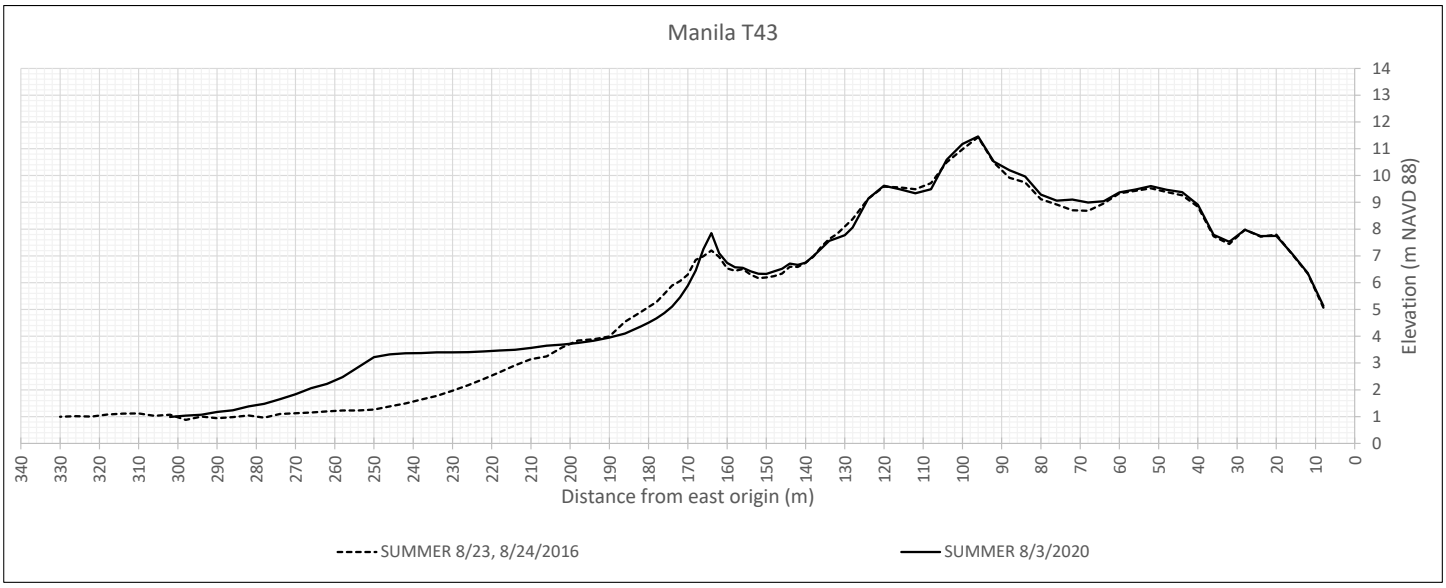
Notes: The transect is located in the Manila Dunes Recreation Area. The area was re-stored in the 1990s-2000s, but was not maintained, and *Ammophila* has reinvaded the foredune zone. An incipient foredune was forming in summer 2016, but was scarped in the high water events of winter 2017, losing 1.0 m vertically and retreating 10.0 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 below). By summer 2019 a new scarp fill ramp had established (see photo below) and by summer 2020 there was deposition of up to 0.5 m on the stoss face of the established foredune. Over the course of the study the incipient foredune eroded, retreating 10.0 m, and the foredune saw accretion of 0.5 m on the stoss face.

MCSD Transect 42

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

MCSD Transect 43



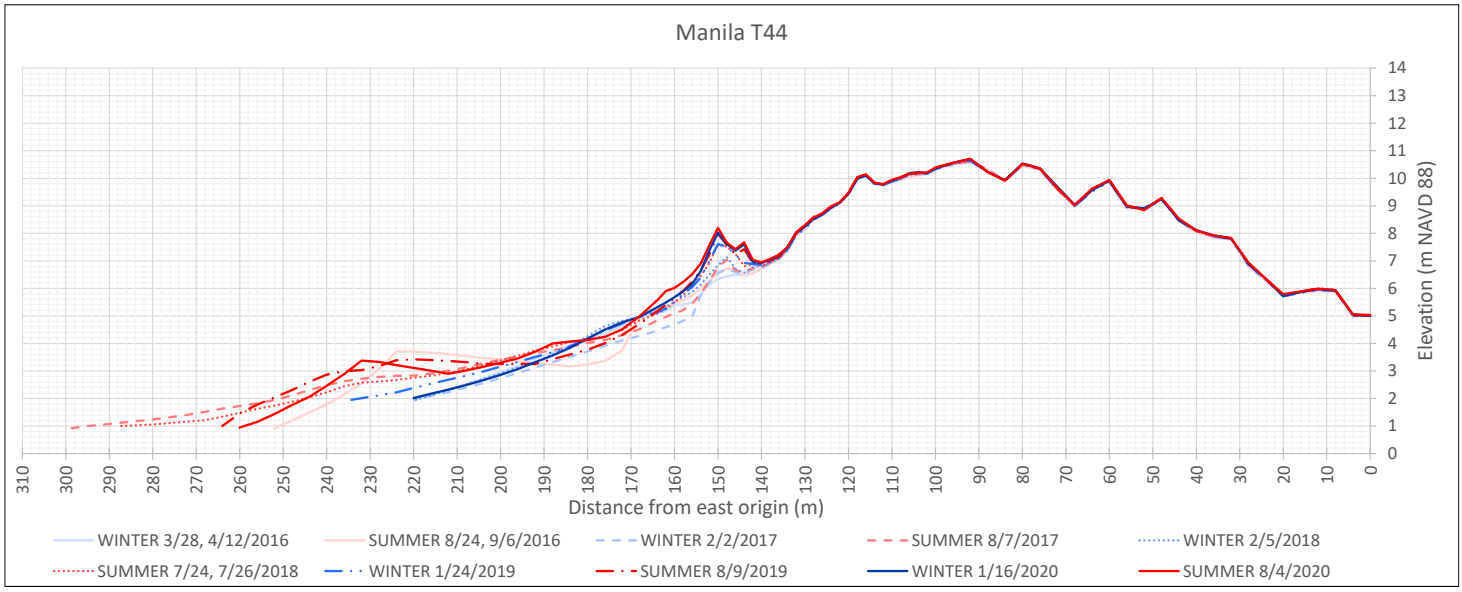


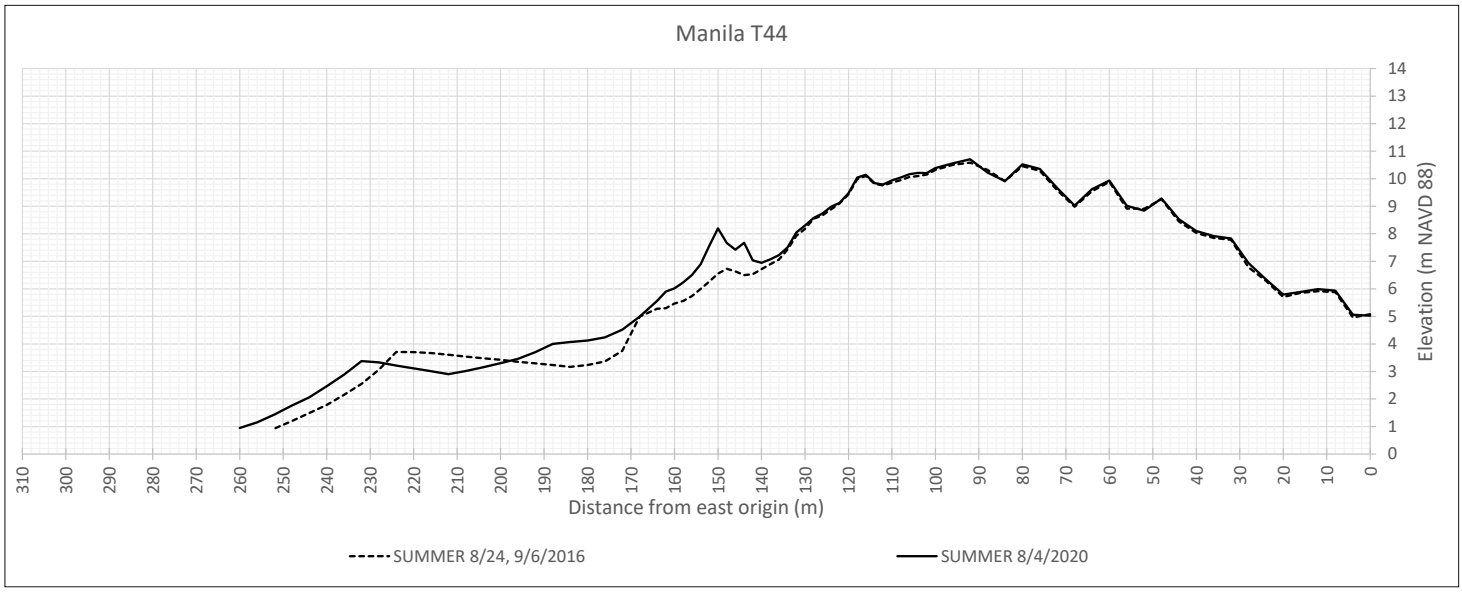
Notes: The transect is located in the Manila Dunes Recreation Area. The area was restored in the 1990s-2000s, but was not maintained, and *Ammophila* has reinvaded the foredune zone. The profile describes an incipient *Ammophila* foredune fronting a higher native foredune. The incipient *Ammophila* foredune 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. 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. The ramp attached to the incipient foredune by summer 2020. Over the course of the study the incipient foredune evolved from a lower more gently sloping feature to a more peaked feature due to repeated scarping. The incipient foredune retreated 6.0 m horizontally.

MCSD Transect 43

View north at 172m at foredune base

MCSD Transect 44



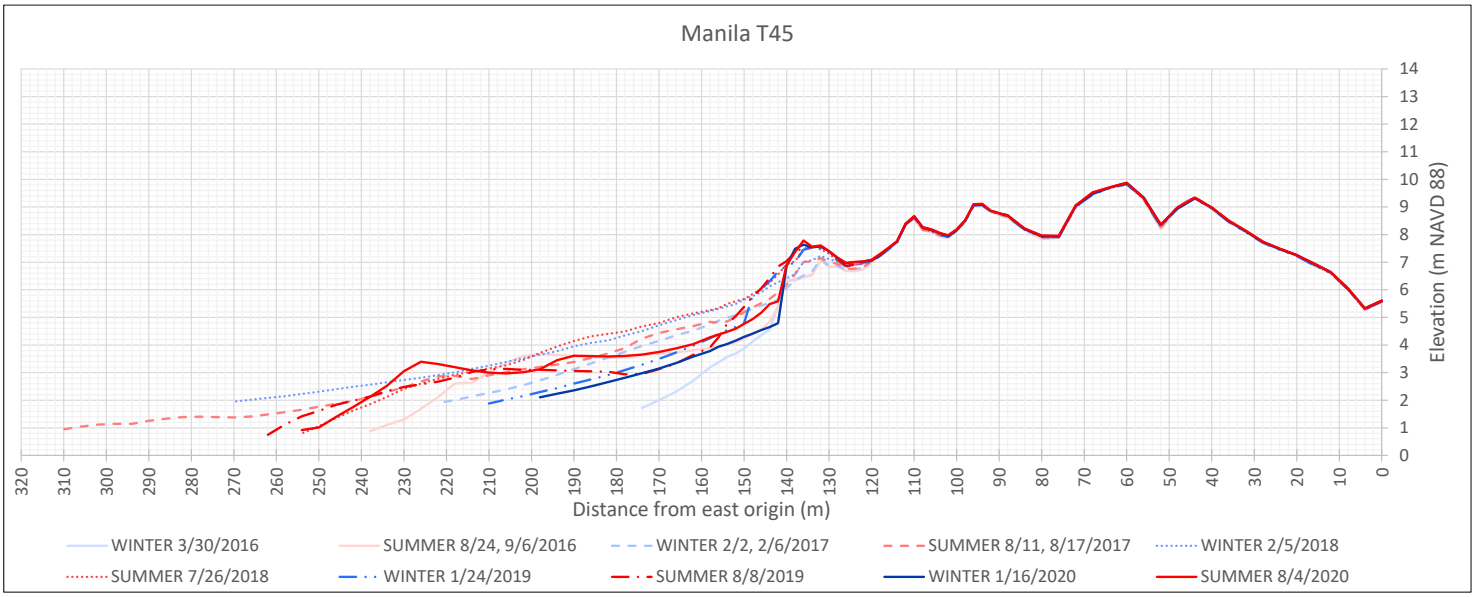


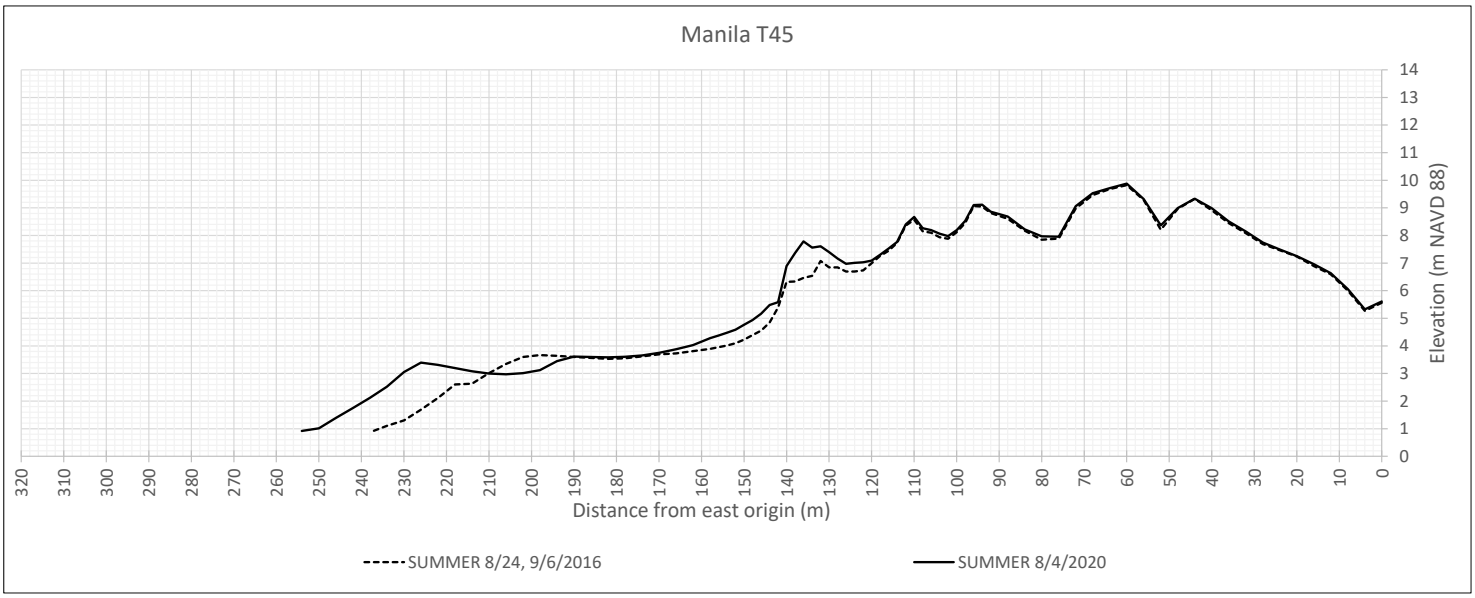
Notes: The transect is located in the Manila Dunes Recreation Area. The area was restored in the 1990s-2000s, but was not maintained, and *Ammophila* has reinvaded the foredune zone. The profile describes a dynamic incipient *Ammophila* foredune in front of a broad, restored (but reinvading) stable, established foredune that slopes down to the deflation plain. The backshore 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 below, note burial of wood by sand deposition on left photo). In summer 2019 the incipient foredune increased in height by 0.5 m. There was additional minor deposition in summer 2020. Over the course of the study, the incipient foredune first eroded and then eventually built in elevation by 1.5 m.

MCSD Transect 44

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

MCSD Transect 45





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 110 m). 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 four year monitoring period. *Ammophila* is now establishing on the backshore below the incipient foredune, as can be seen in the photograph taken on the incipient foredune looking north-west along the transect.

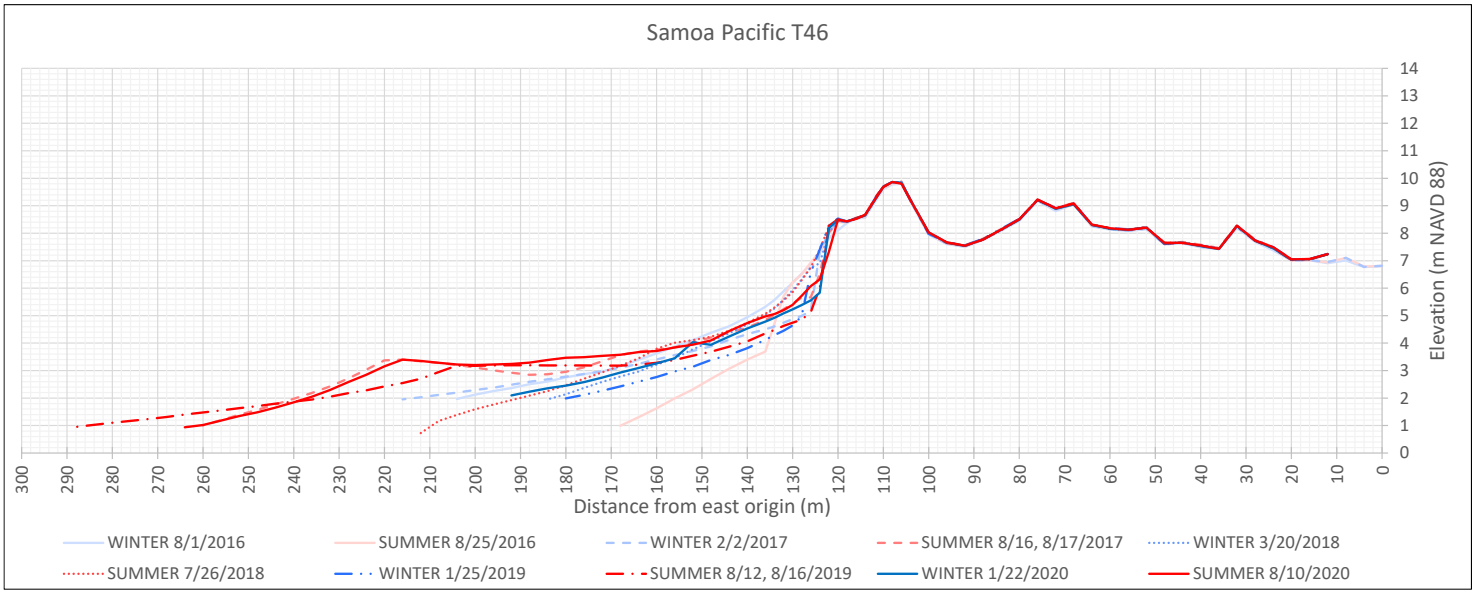
MCSD Transect 45

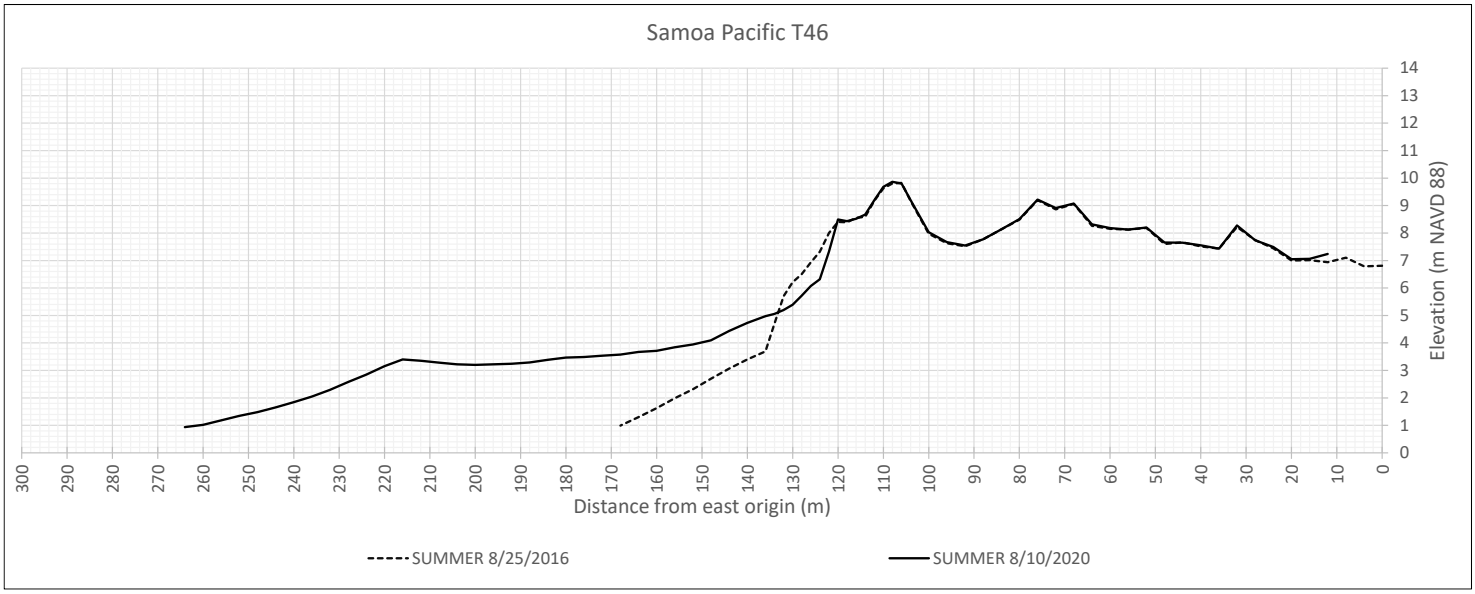
View north west at 144 m (incipient foredune)

MANILA COMMUNITY SERVICES DISTRICT SUMMARY. The northernmost transect saw the erosion of the incipient foredune, however the southern transects underwent net deposition of the incipient foredune. The established foredune was static. This site primarily exhibited resiliency and lies along a low accretion stretch of shoreline.

Samoa Pacific

Samoa Pacific Transect 46



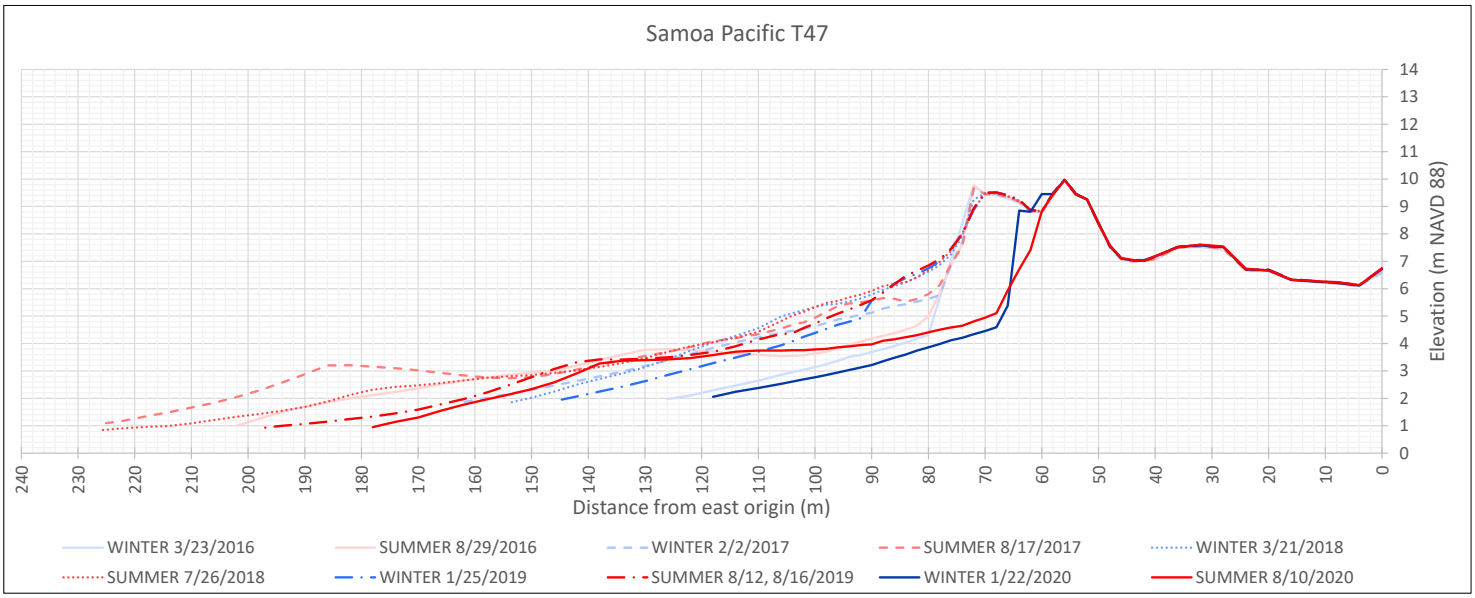


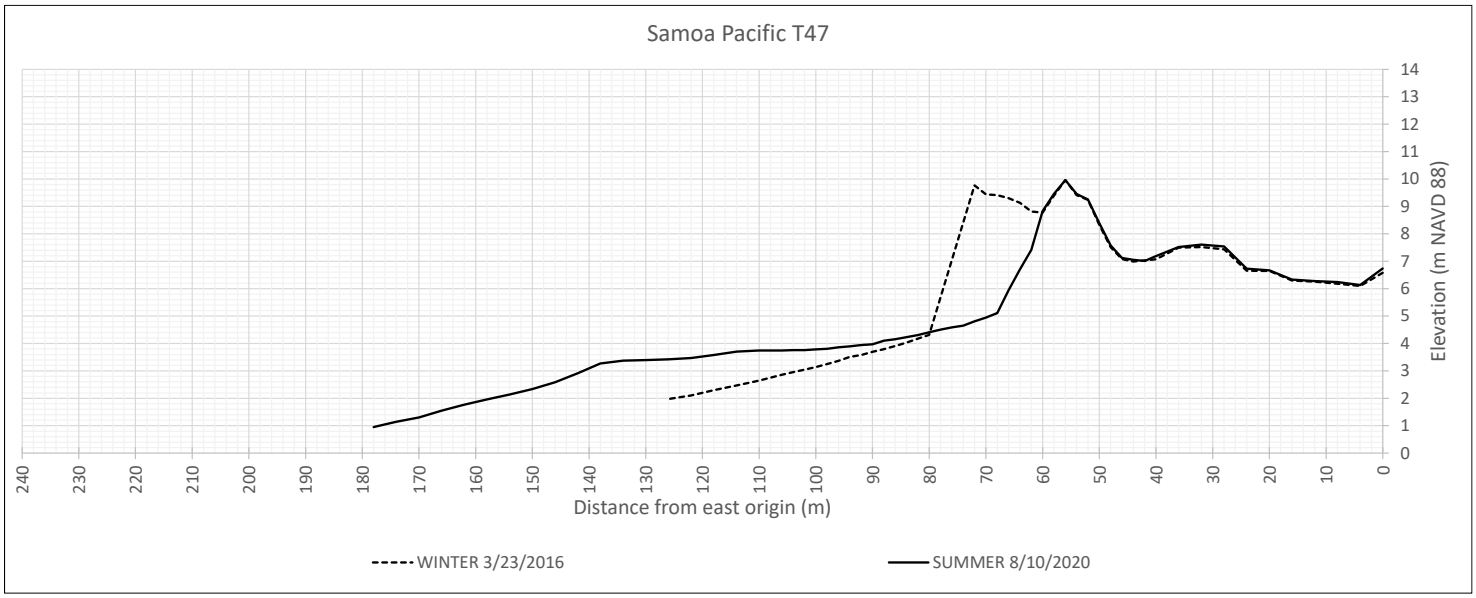
Notes: The transect describes a steep *Ammophila* foredune (crest 106 m) with a relict native (now invaded) foredune at 76 m. The base of the foredune was scarped between the winter and summer 2016 surveys, resulting in beach lowering of 1.5 - 2.0 m. In winter 2017 the foredune was further scarped, retreating 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 and 2020 additional scarping occurred in winters, resulting in a steep foredune stoss face. Over the course of the study the foredune stoss face retreated 5.0 m but the beach gained in elevation. There is a pattern of winter scarping and summer beach deposition and ramp formation.

Samoa Pacific Transect 46

View north at 126 m (foredune base)

Samoa Pacific Transect 47





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 scarped prior to the winter 2016 survey, leaving a 5.0-m vertical scarp and presumably lowering the beach. The beach gradually recovered 2+ m of elevation. By summer 2018 a scarp -fill ramp had formed , and was present in similar proportions in summer 2019. In winter 2019 the foredune was scarped again and retreated 15 m., lowering the beach. In summer 2020 the beach gained some in elevation. Over the course of the study the foredune retreated 15 m.

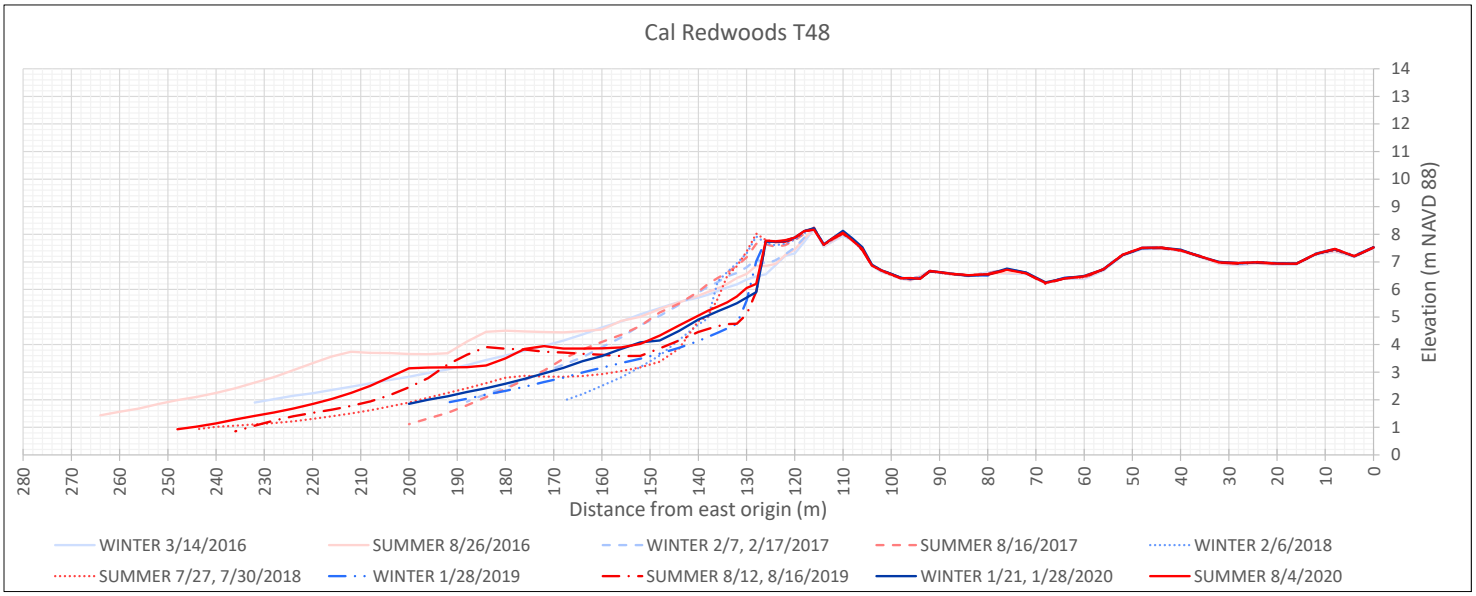
Samoa-Pacific Transect 47

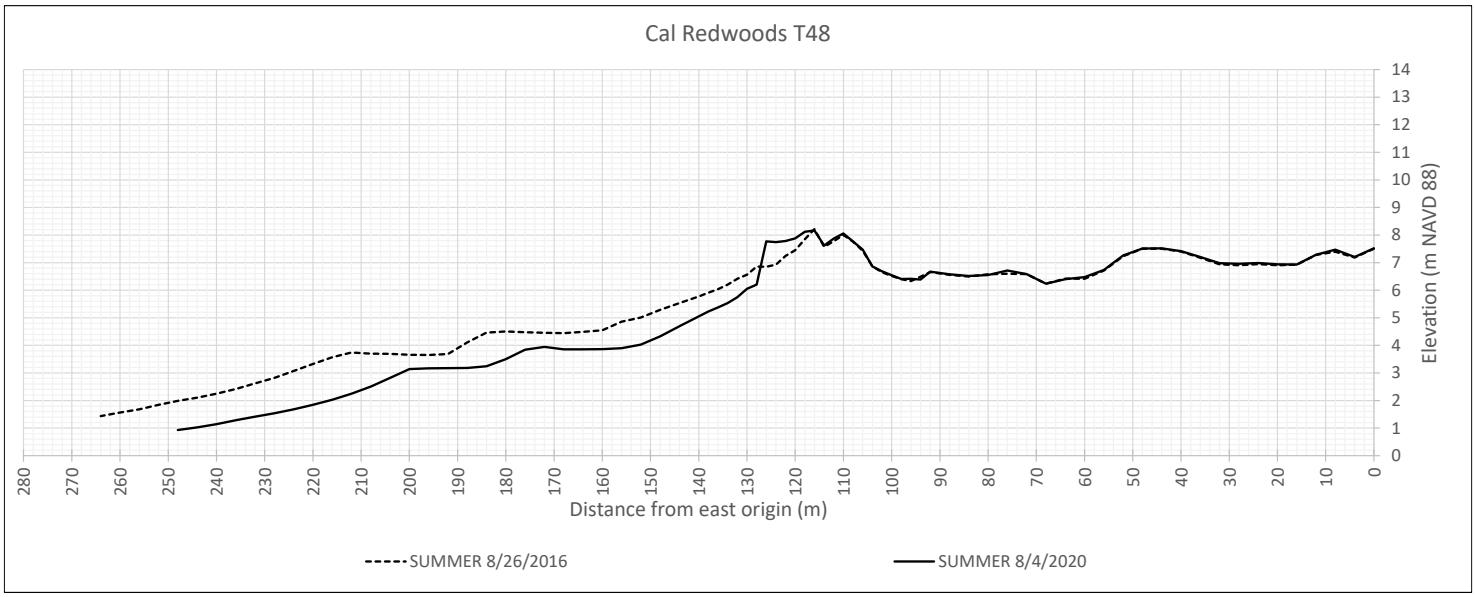
View north showing scarp at 78 m (left) and scarp-fill ramp at 72 m (right and below)

SAMOA-PACIFIC SUMMARY. This site had two transects, both of which were erosional over the course of the study, exhibiting retreat of the shoreline. The site had a steep foredune at the start of the study. The northern transect was able to recover after the first erosional incident but ultimately saw net erosion. The southern transect saw the loss of half of the width of the established foredune. In this transect a scarp-fill ramp was not able to form between erosional events, indicating a lack of resiliency, despite the fact that this site has historically been characterized by low accretion.

Cal Redwoods

Cal Redwoods Transect 48





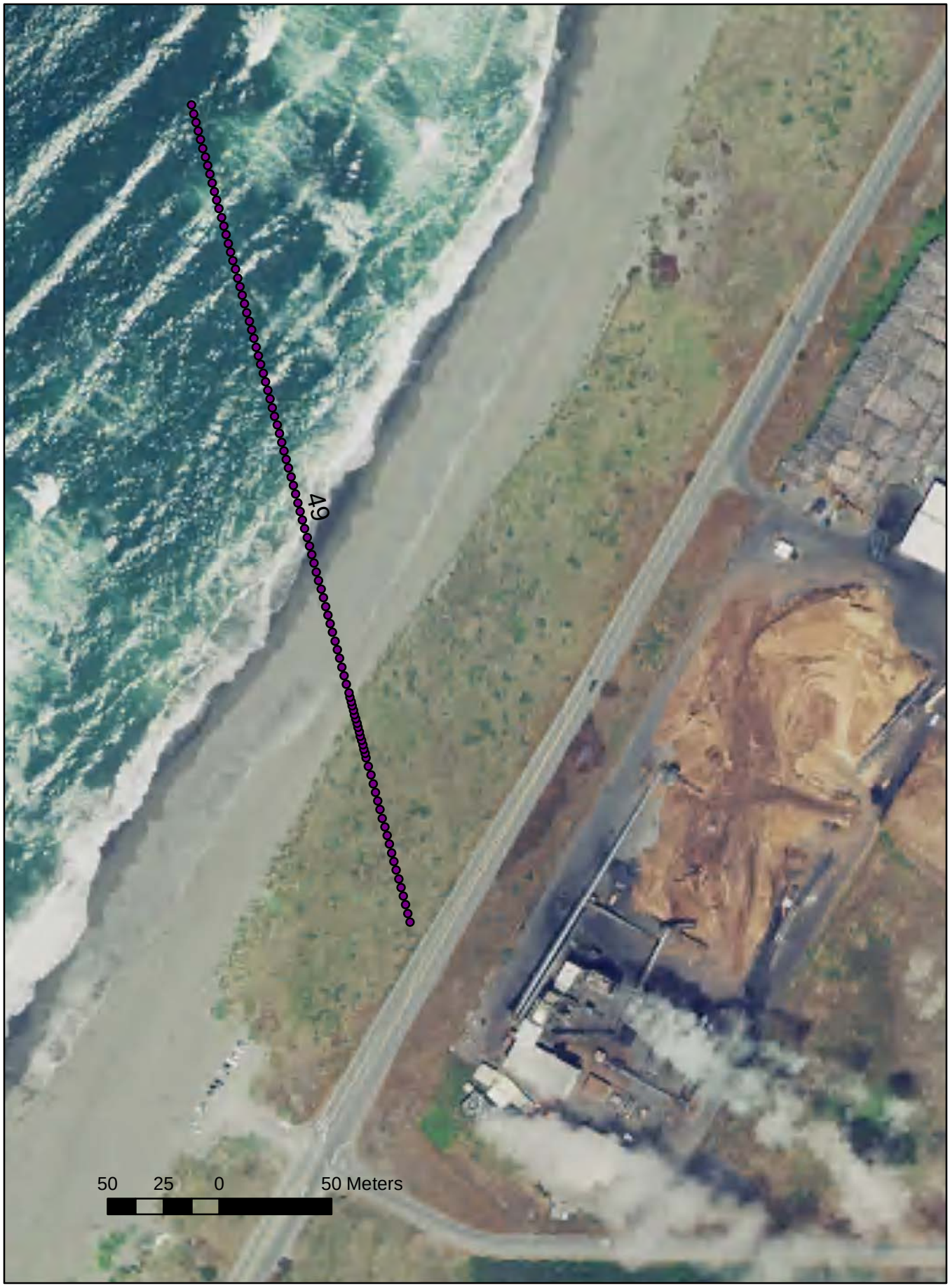
Notes: The profile describes a low *Ammophila* foredune in front of a lower backdune area. Deposition of 0.4 m occurred on the backshore in summer 2016 suggesting the start of an incipient foredune, along with up to 1.0 m seasonal deposition on the beach at 184 m. Erosion in winter 2017 removed substantial sediment from the beach (2.2 m at 184 m), creating a steeply sloping beach. However, some deposition occurred on the incipient foredune zone. 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 below right) and very little change occurred between winter and summer 2018 other than deposition in the foreshore. In winter 2019 additional scarping occurred. By summer 2020 ramping/slumping had occurred but the top portion of the foredune was still scarped. Over the course of the study the foredune broadened , with 0.7 m of deposition on the crest, but assumed a scarped morphology.

Cal Redwoods Transect 48

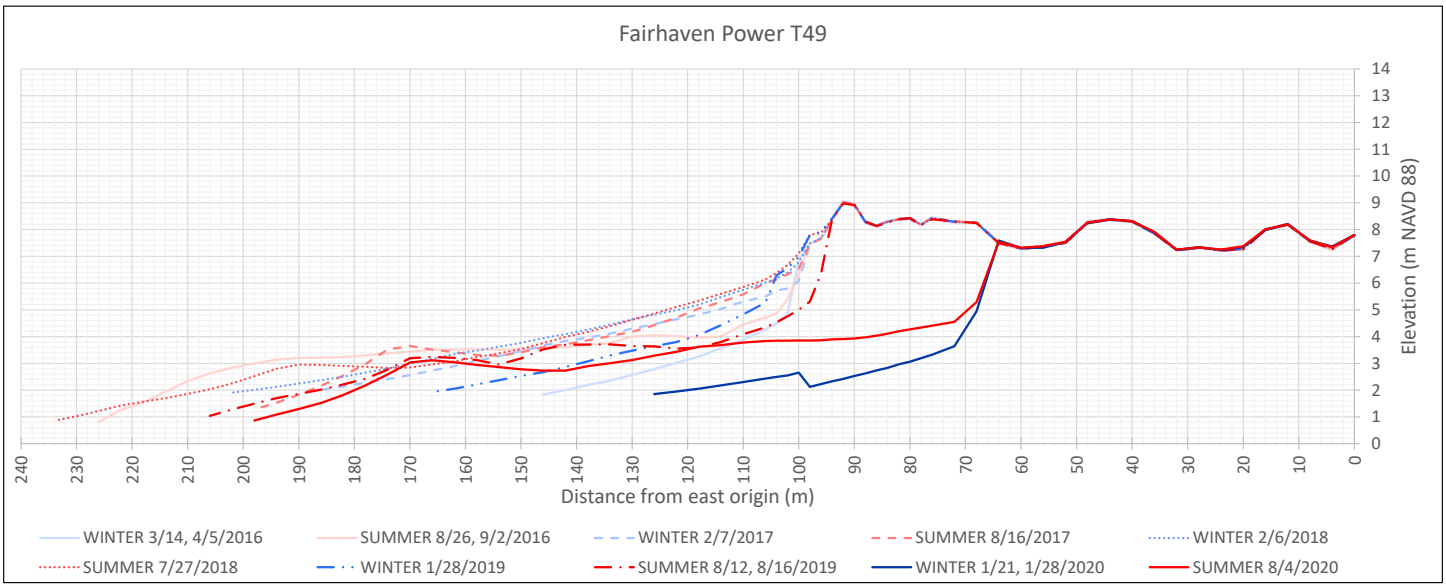
View southeast along transect at 148 m (backshore) looking towards foredune.

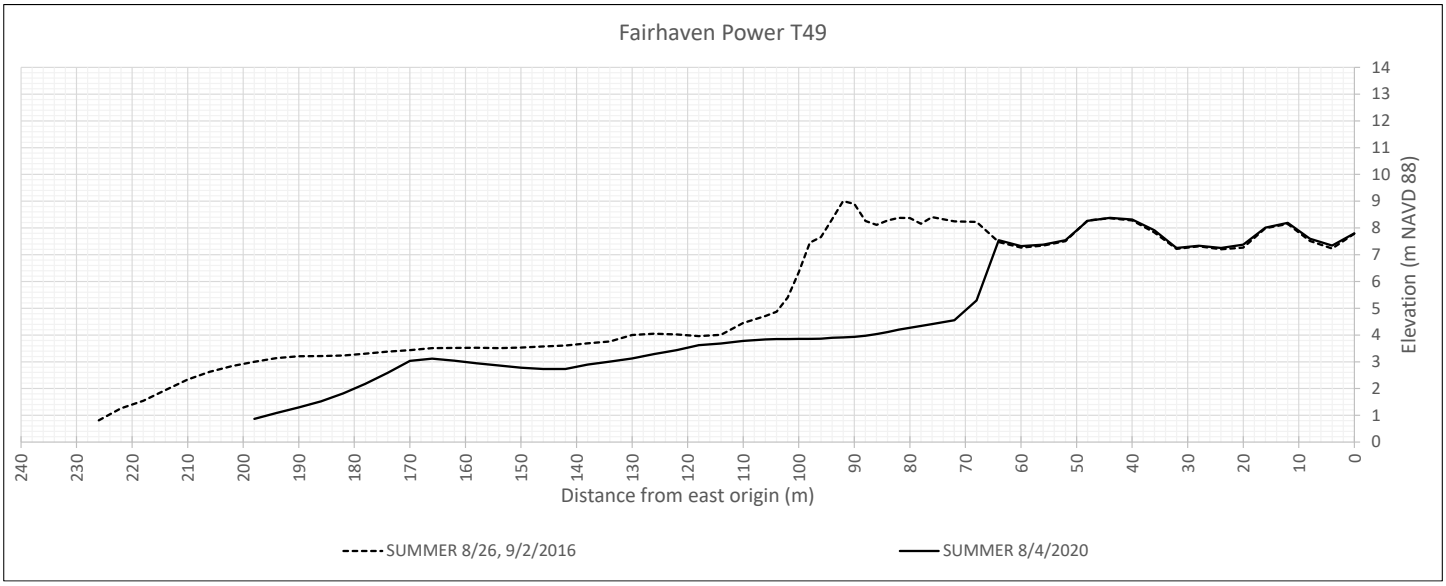
CAL REDWOODS SUMMARY. There was only one transect on this property. Although proximal to the Samoa Pacific site, this transect showed far less erosion. The foredune gained in breadth, but underwent subsequent scarping leaving a steep stoss face with low resilience. This stretch of shoreline did not exhibit statistically significant accretion or retreat historically.

Fairhaven Power



Fairhaven Power Transect 49





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 below. By summer 2018 deposition was occurring on the stoss face of the foredune (photo below). However, between winter and summer 2019 major scarping occurred, eroding the foredune 5.0 m horizontally. In winter a major erosional event eroded the foredune completely, causing a retreat of 35.0 m. In summer 2020 deposition on the foreshore reduced the height of the scarp. Over the course of the study, this site was severely erosional, with complete loss of the foredune and retreat of 30.0 m.

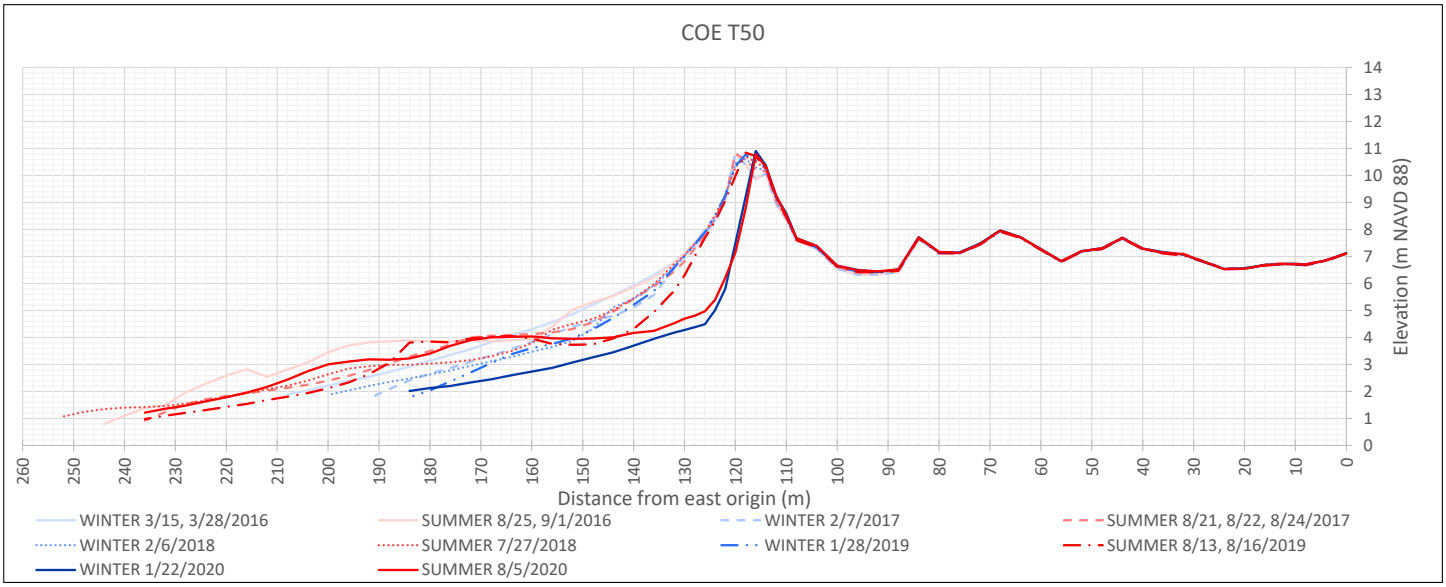
Fairhaven Power Transect 49

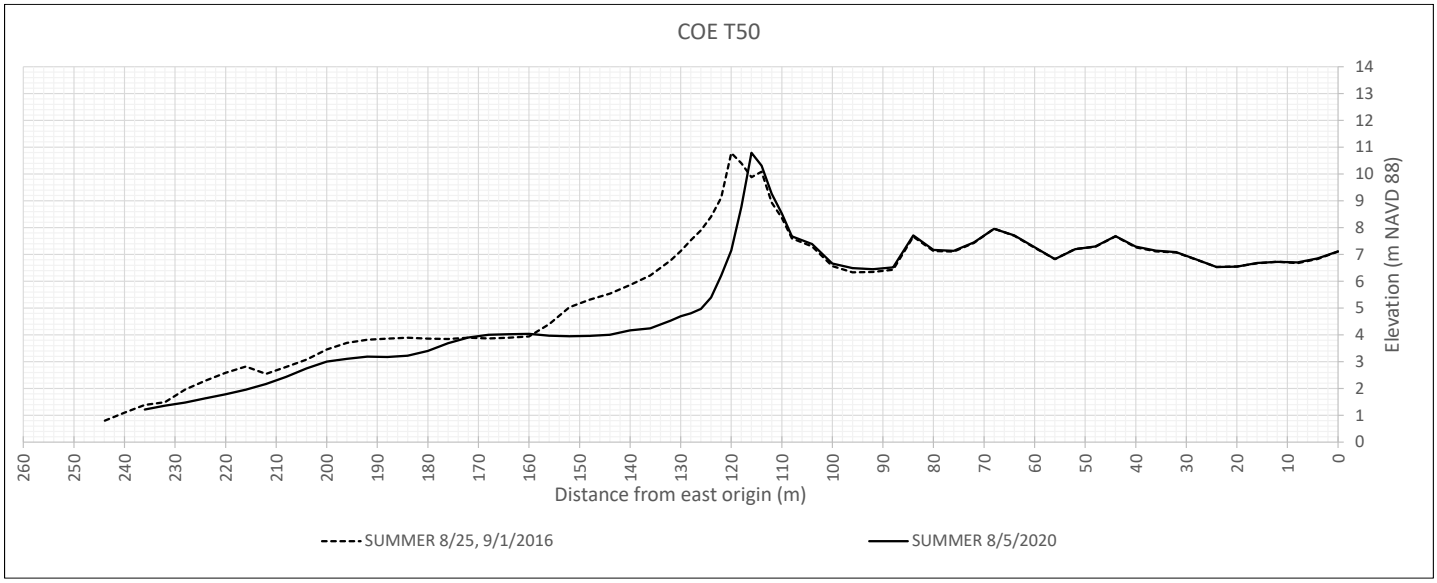
View south at 100 m (foredune base and scarp)

FAIRHAVEN POWER SUMMARY. The single transect showed the most erosion of any other transect on the North Spit. The foredune completely eroded, retreating a total of 35.0 m and indicating low resiliency. The section of shoreline did not exhibit statistically significant change historically.

City of Eureka

City of Eureka Transect 50





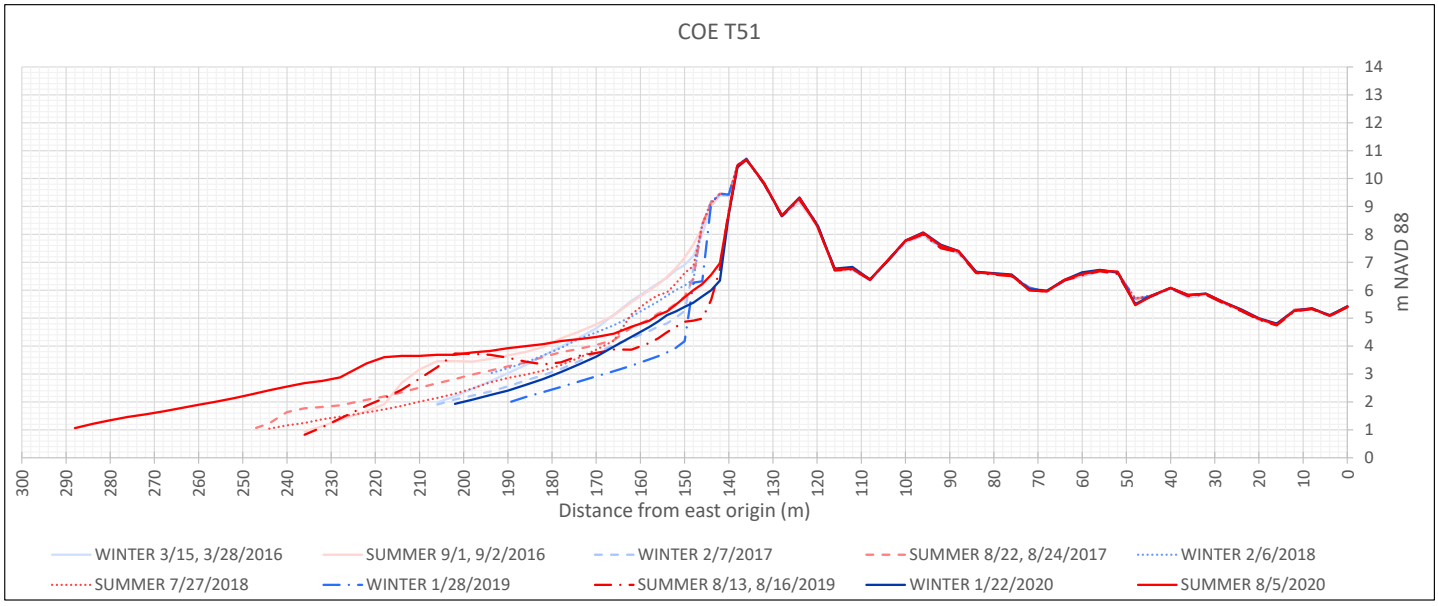
Notes: The transect is located near the City of Eureka's Samoa airstrip, and depicts a peaked *Ammophila* foredune backed by a low *Ammophila*-stabilized backdune area. The backshore was relatively stable during 2016, with the foreshore exhibiting typical seasonal changes. In winter 2017 the backshore 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 deposi-tion occurred behind the foredune crest (see photos below). Between 2018 and 2019 the backshore lost up to 1.0 m in elevation and the foredune base was eroded. In winter 2020 the foredune scarped, retreating up to 10m. Over the course of the study the foredune lost almost half its breadth (10.0 m).

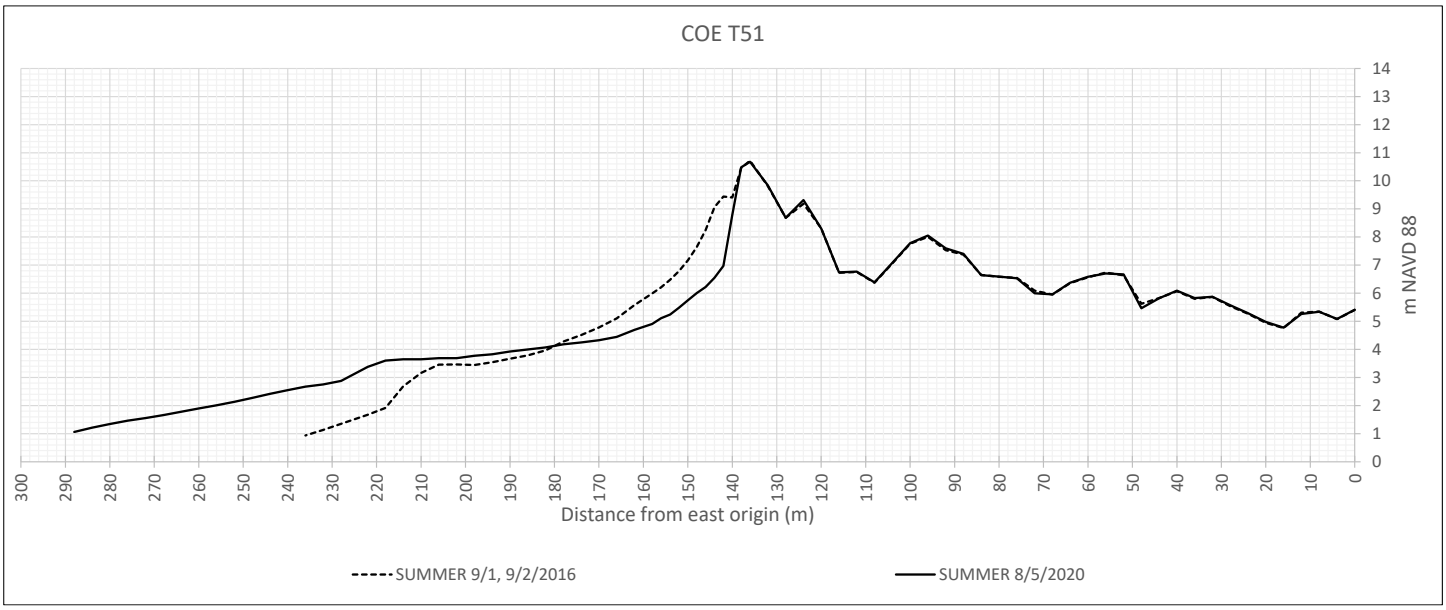
City of Eureka Transect 50

View north at 120 m (foredune crest)

Note, the summer 2020 photo could not be taken because the photopoint had eroded away.

City of Eureka Transect 51





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). However, in 2019 the foredune re-scarped, losing up to 5.0 m horizontally. In summer 2020 ramping had occurred, but the upper portion of the scarp remained. The beach was high enough to support *Cakile.* Over the course of the study the foredune retreated 10.0 m.

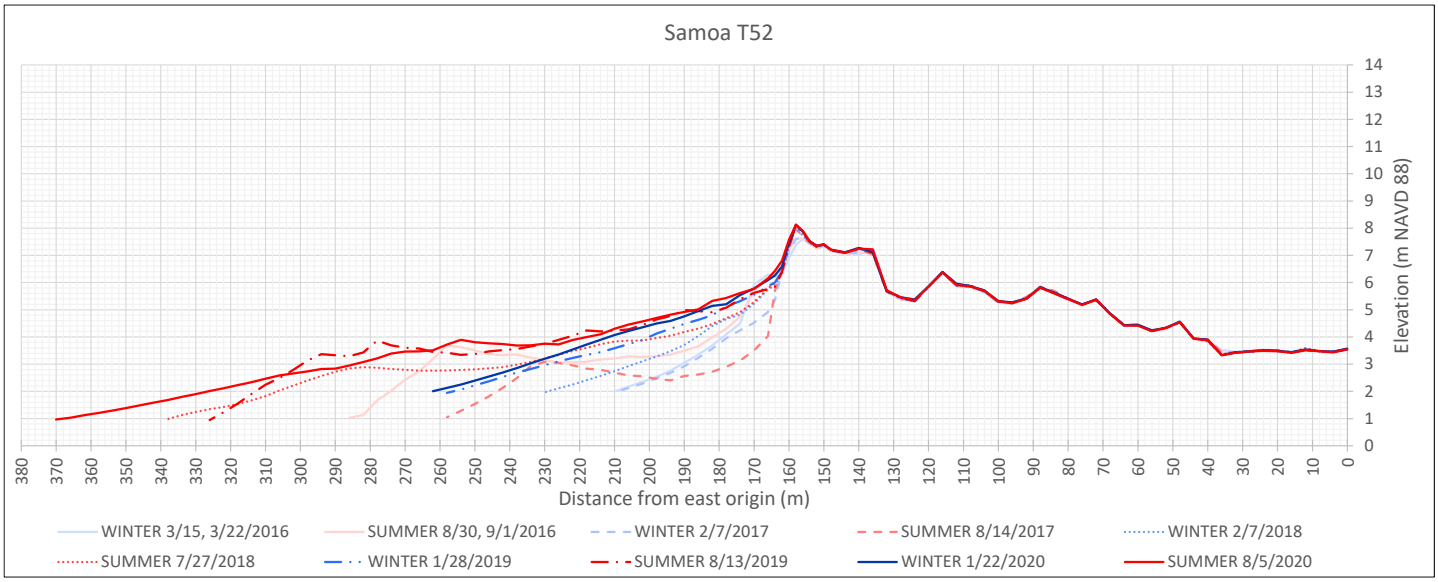
City of Eureka Transect 51

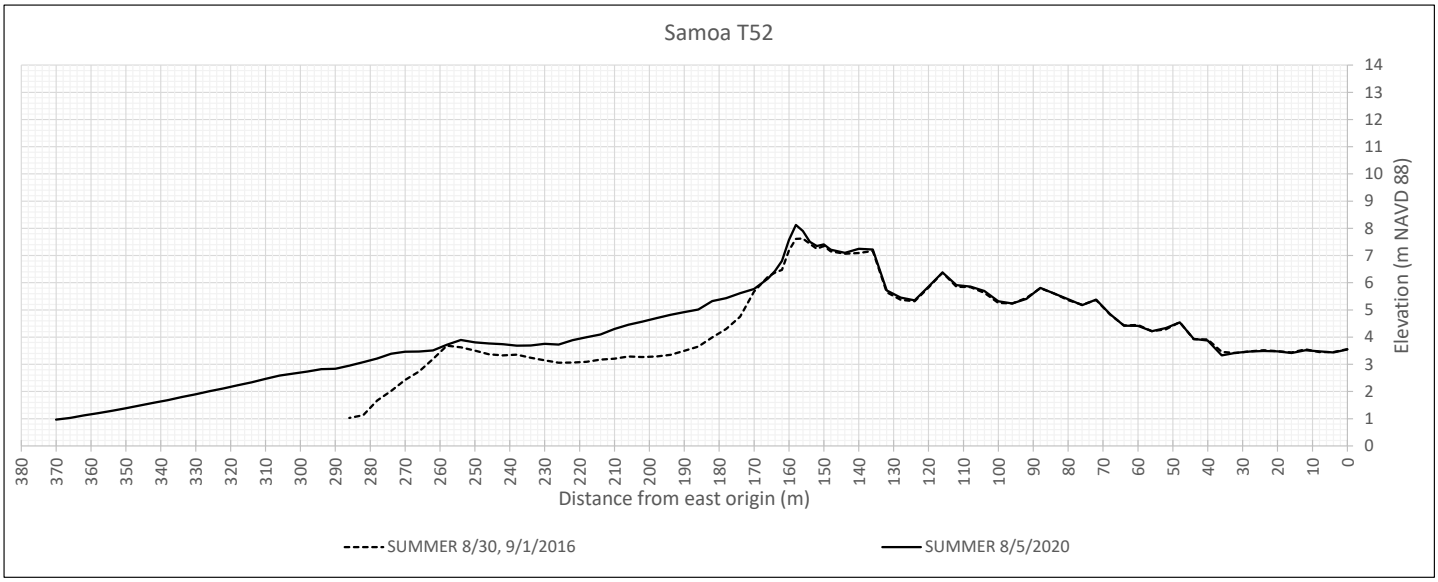
View southeast along transect at 154 m (upper beach) looking towards foredune

CITY OF EUREKA SUMMARY. Both transects in the City of Eureka property exhibited significant loss of the established foredune, without seasonal recovery, indicating a lack of resilience. One of the transects is located in an area of historic shoreline retreat, while the other did not show statistically significant change.

Samoa

Samoa Transect 52



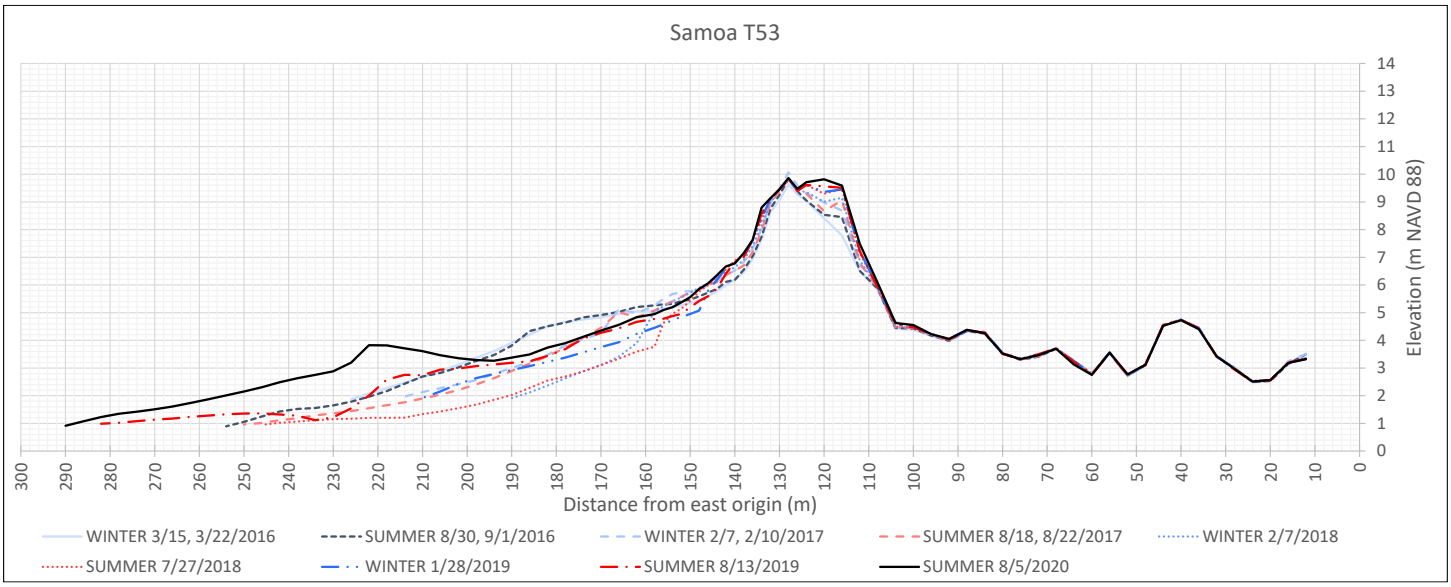


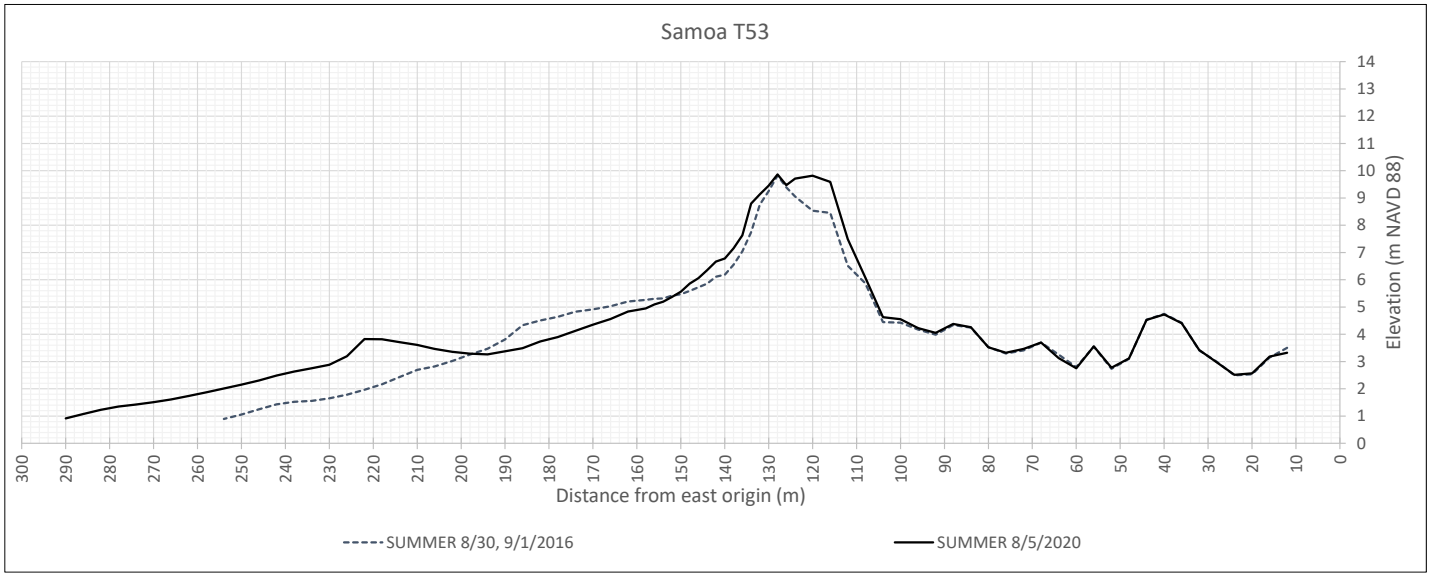
Notes: The transect is within the Samoa Dunes Recreation area and crosses several ATV trails that bisect an area stabilized by *Ammophila*. This is also an area of continuing high erosion since at least the 1930s, influenced by its proximity to the north jetty. In winter 2016 the backshore was characterized by a bench-like feature that may have been caused by beach scarping prior to the survey. In summer 2016 1.0 m of sediment was deposited below the bench. In winter 2017 the backshore was scarped and the bench removed, losing 1.0 m vertically and retreating 10.0 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 1.0 m occurred on the backshore, bringing it to its highest elevation since monitoring began. In summer 2020 the profile remained at approximately 2019 levels. Over the course of the study, there was net deposition on the foreshore and backshore. The foredune remained static except for deposition on the crest in 2020.

Samoa Transect 52

View north at 162 m (foredune base)

Samoa_Transect 53





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 1.0 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. Over the course of the study the backshore gained in elevation while the foreshore decreased in elevation. The foredune saw deposition both on the stoss and lee, the result of a vehicle trail that formed a slipface on the lee side.

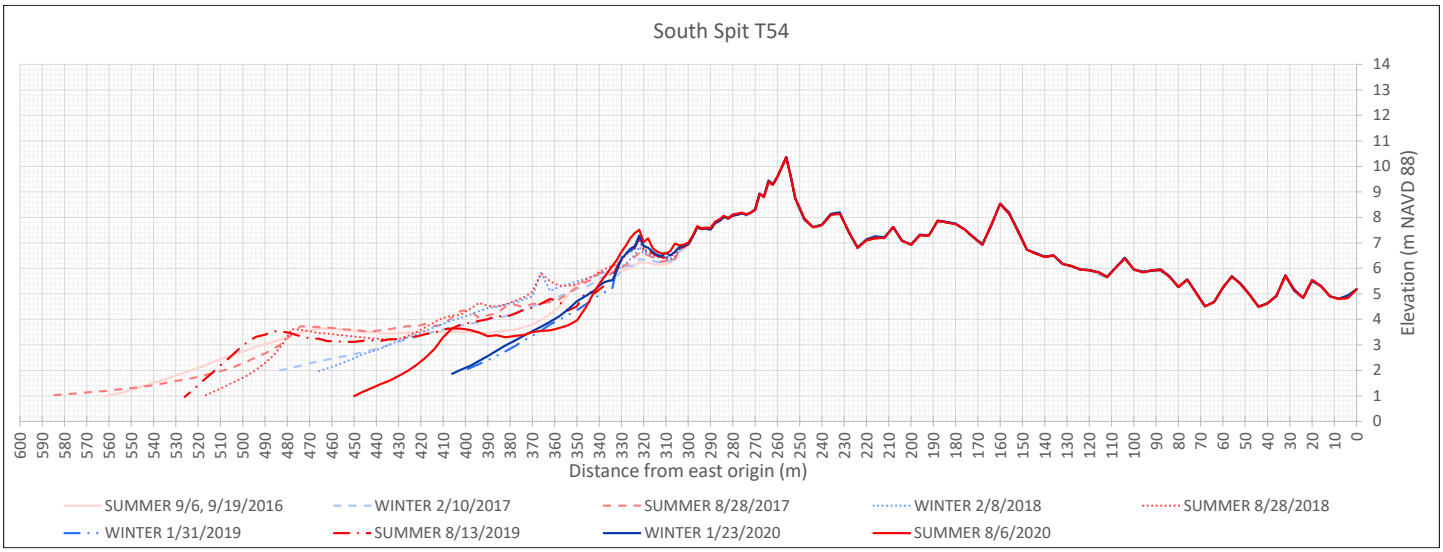
Samoa_Transect 53

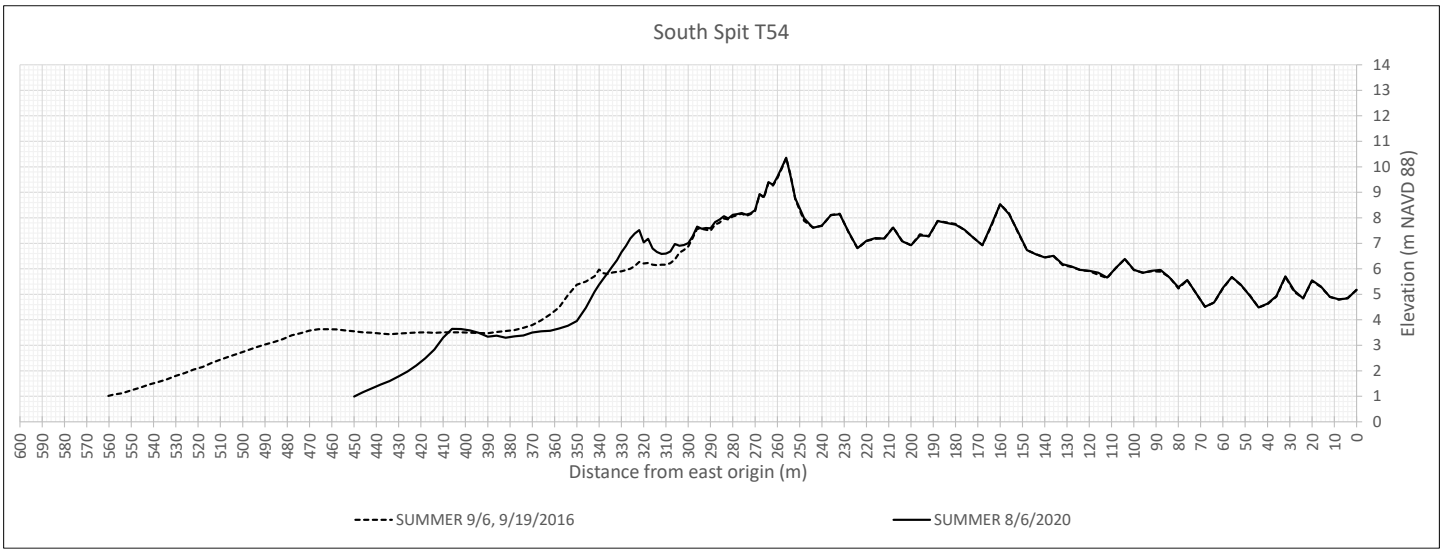
View southeast at 144 m (upper beach) looking towards foredune

SAMOA SUMMARY. These two transects underwent significant changes in the upper beach, with erosional winters and depositional summers. The established foredune showed little change, suggesting resiliency. This is contradictory with the historic trend of high erosion.

South Spit

South Spit Transect 54



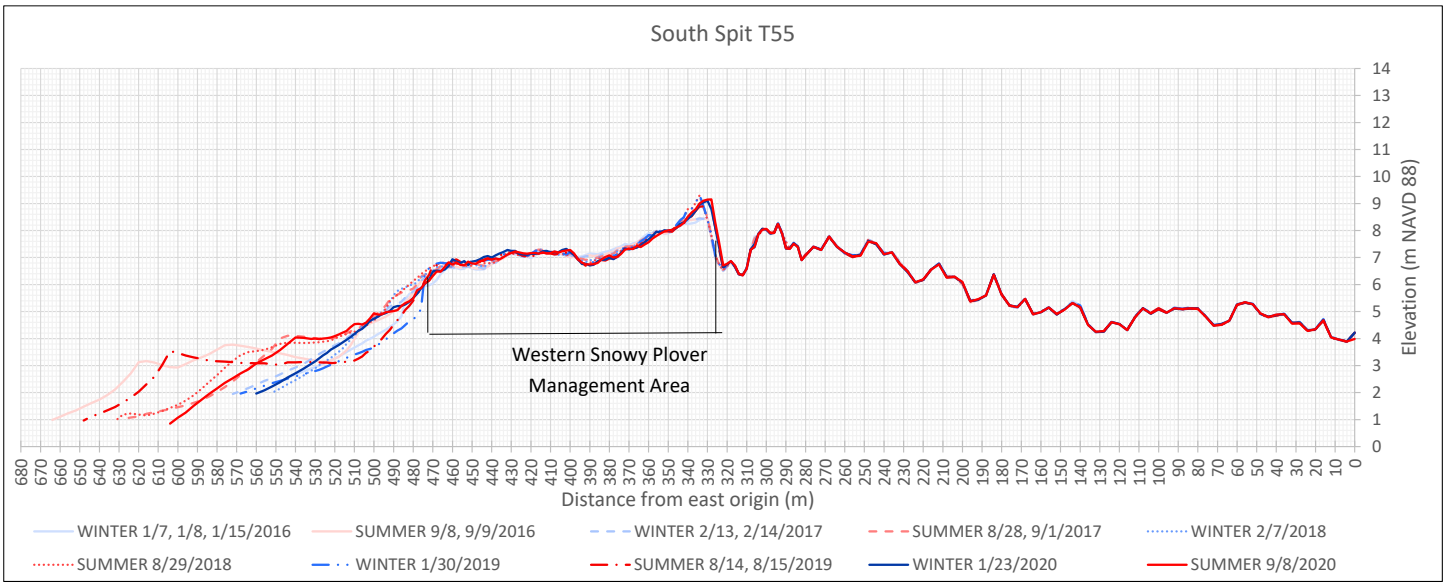


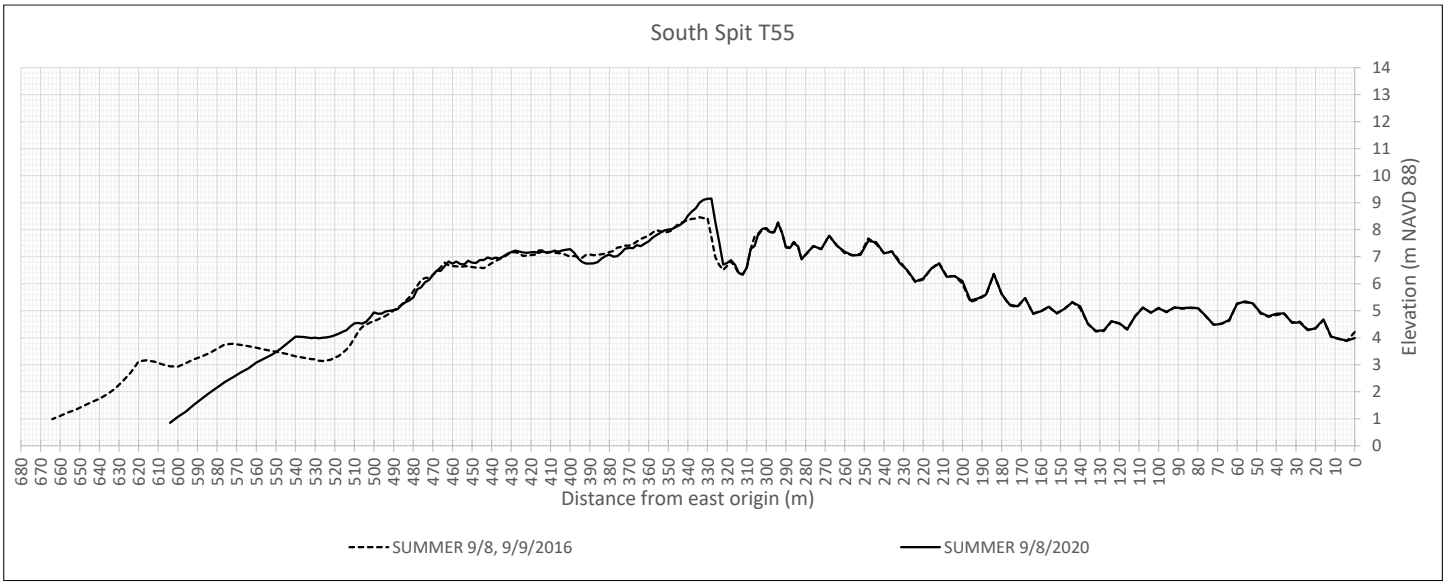
Notes: This transect intersects the South Spit at its widest point, in an area that vegetation is not managed. The profile demonstrates multiple, relict *Ammophila* foredune ridges from shoreline accretion. Data are not available for winter 2016. From summer 2016 through summer 2017 the upper beach increased 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 upper beach 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. Between summer 2019 and summer 2020 there was significant erosion of the backshore. Over the course of the study an incipient foredune formed, but retreated 10.0 m, while the backshore eroded.

South Spit Transect 54

View northwest along transect at 322 m (incipient foredune)

South Spit Transect 55



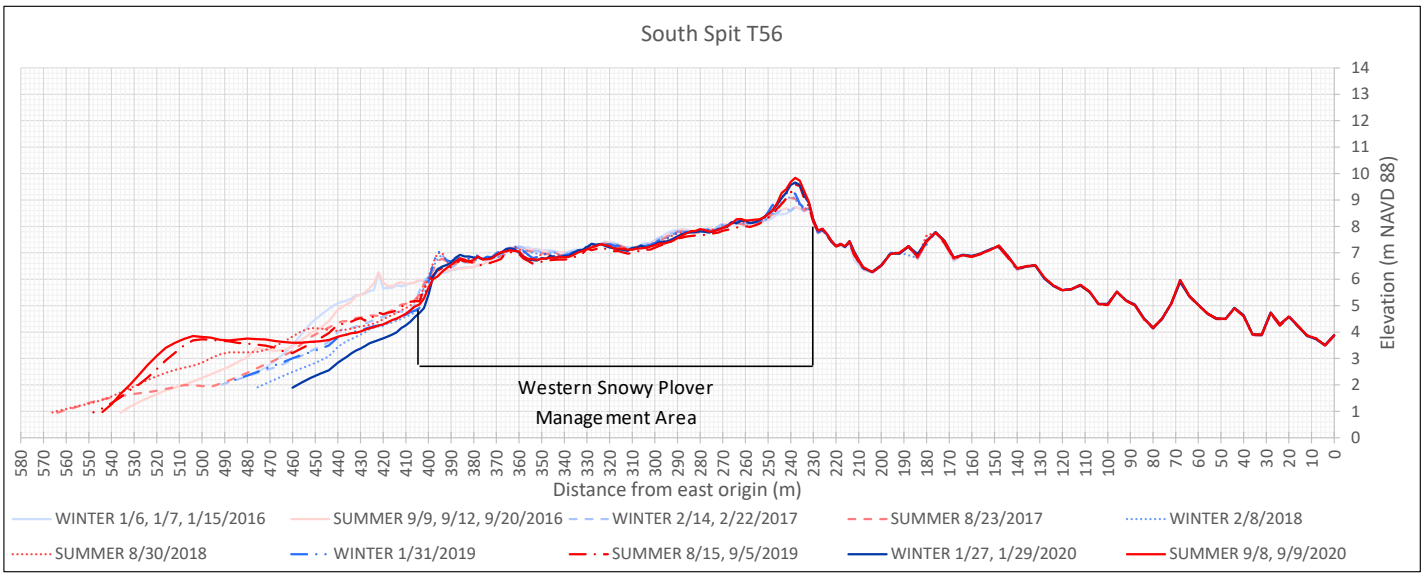


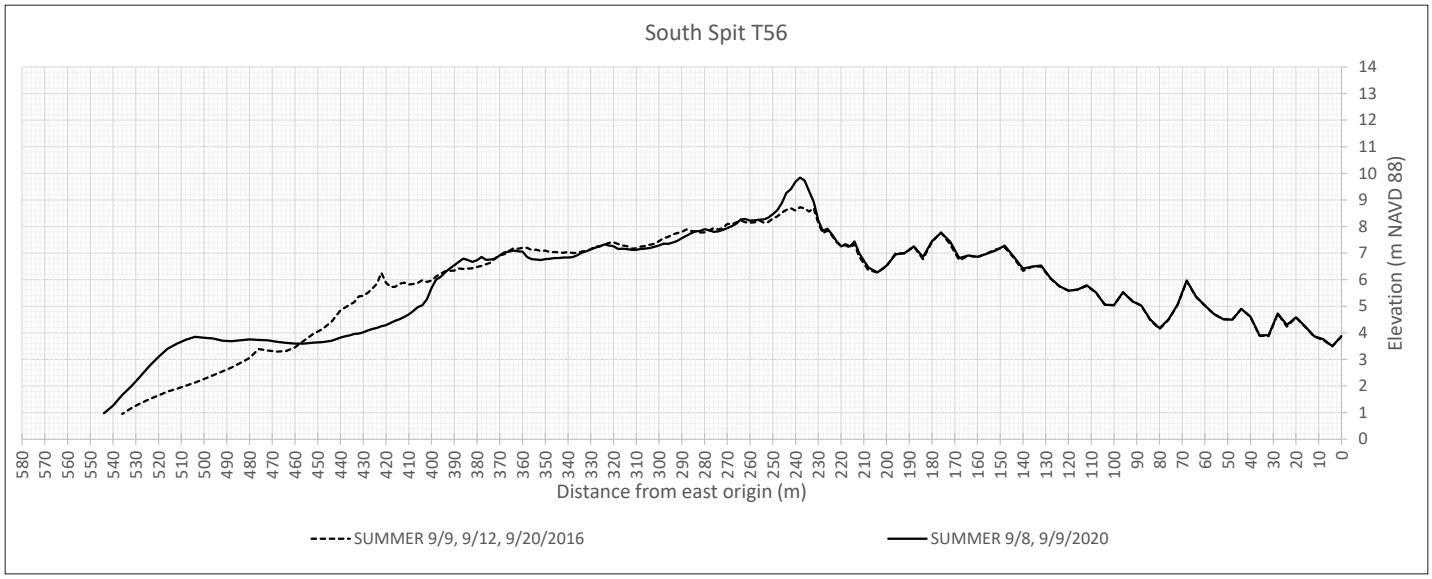
Notes: This transect intersects the BLM's Western Snowy Plover Management Area, which was bull-dozed to decrease vegetation cover and is maintained through dozing and/or disking annually. As a result, there is no distinct foredune feature, and the profile in the managed area shows shifting sand, as can 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, where dense *Ammophila* causes deposition. Over the course of the study the eastern boundary of the bull-dozed area increased in height, while the backshore lowered. The flattened foredune maintained its elevation over the course of the study.

South Spit Transect 55

View north at 480 m (foredune base)

South Spit Transect 56



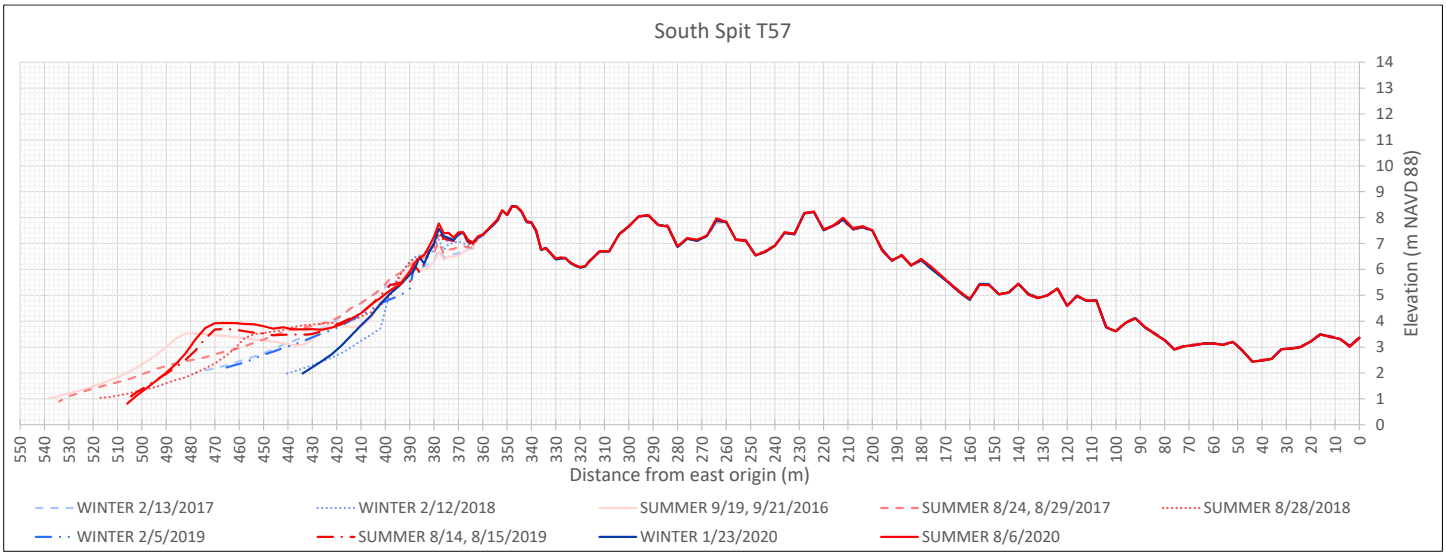


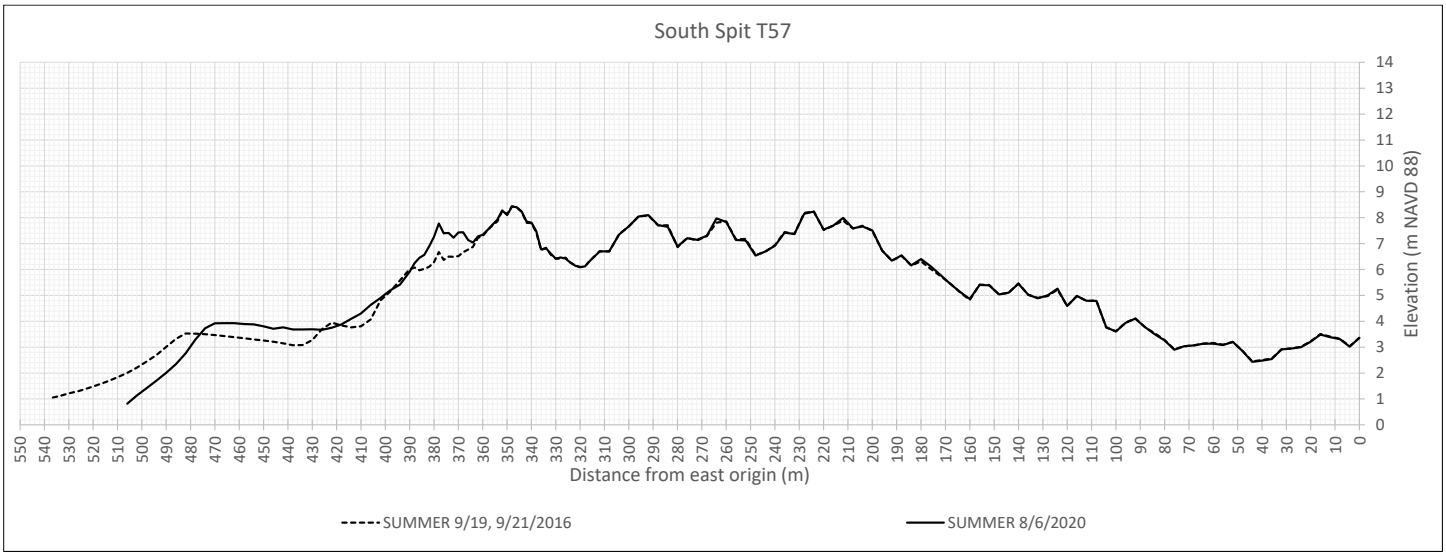
Notes: Similar to Transect 55, Transect 56 intersects the BLM's Western Snowy Plover management area. There was more of a foredune in this profile (with a similar feature visi-ble to the north in the photograph which is taken northwest along the transect from the base of the ridge). This feature originated 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 erod-ed. By summer 2020 the foredune feature 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. Over the course of the study, the flattened foredune retreated 40.0 m.

South Spit Transect 56

View northwest along transect at 406 m (foredune)

South Spit Transect 57



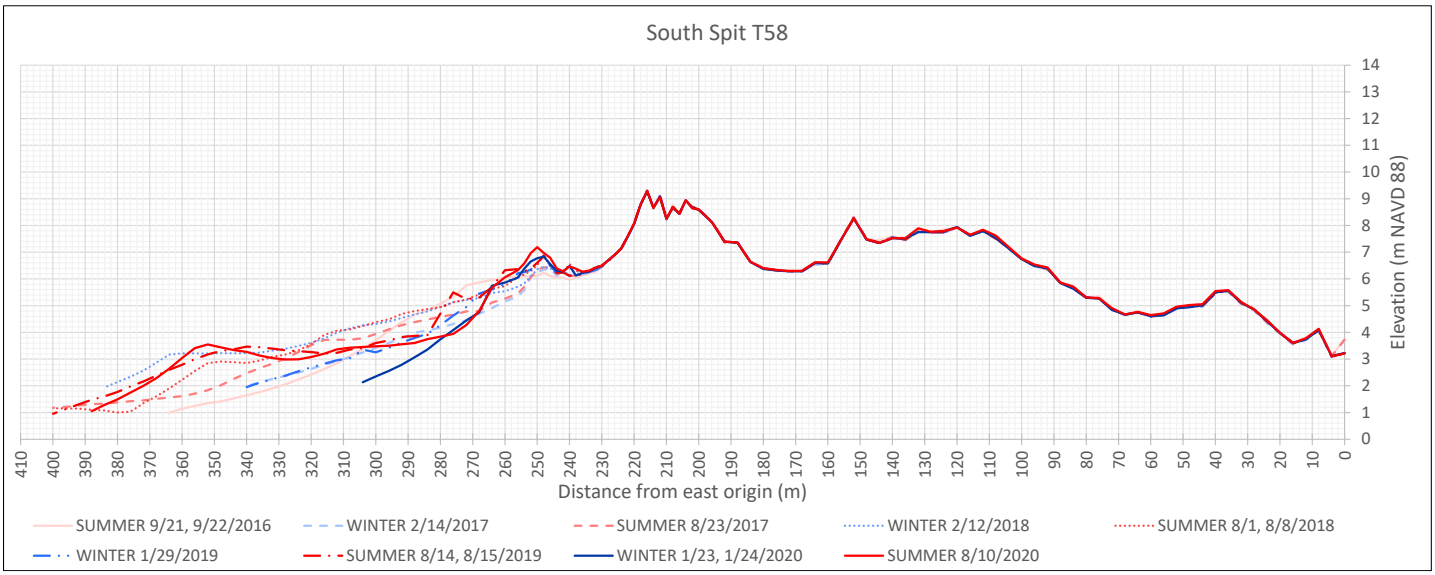


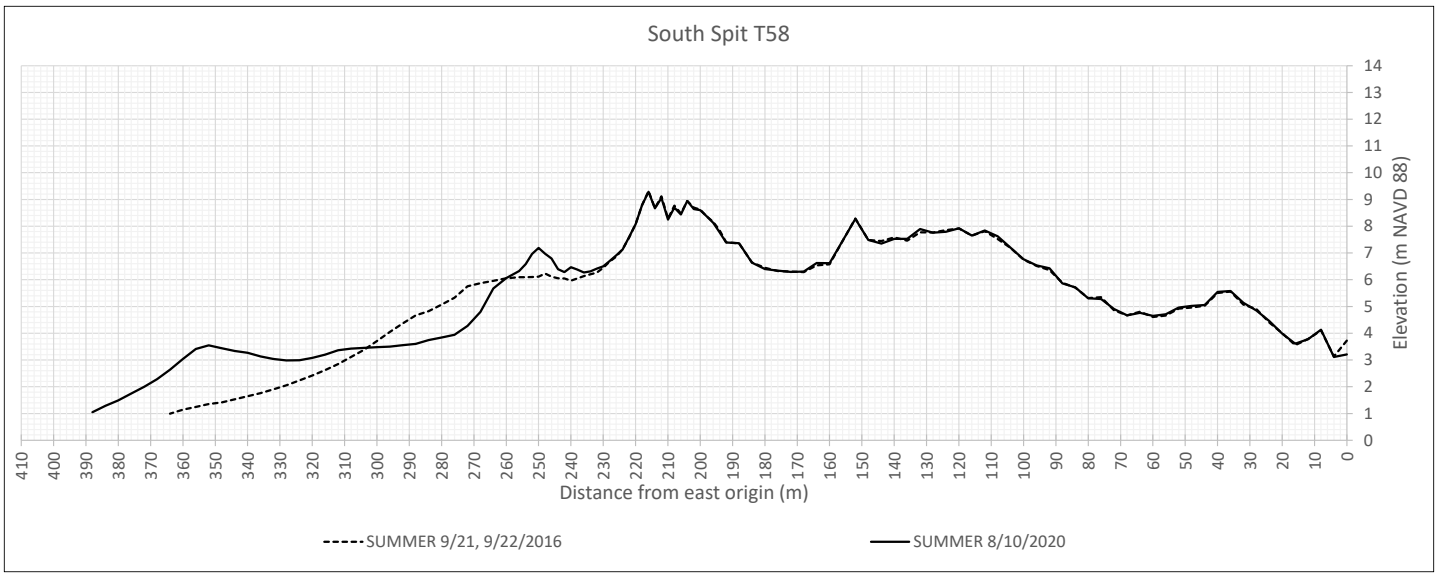
Notes: There are no data available from winter 2016, but the upper beach was relatively steep in summer 2017, and underwent significant deposition by winter 2017. By summer 2017 deposition had also occurred on the incipient foredune, visible in the upper left of the 2017 photograph below (taken from 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 and summer 2020 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. Over the course of the study, the area east of the incipient foredune was stable. The incipient foredune was formed over the 4-year period, with deposition of 1.2 m. No retreat or progradation occurred.

South Spit Transect 57

View northwest along transect at 352 m (foredune crest)

South Spit Transect 58



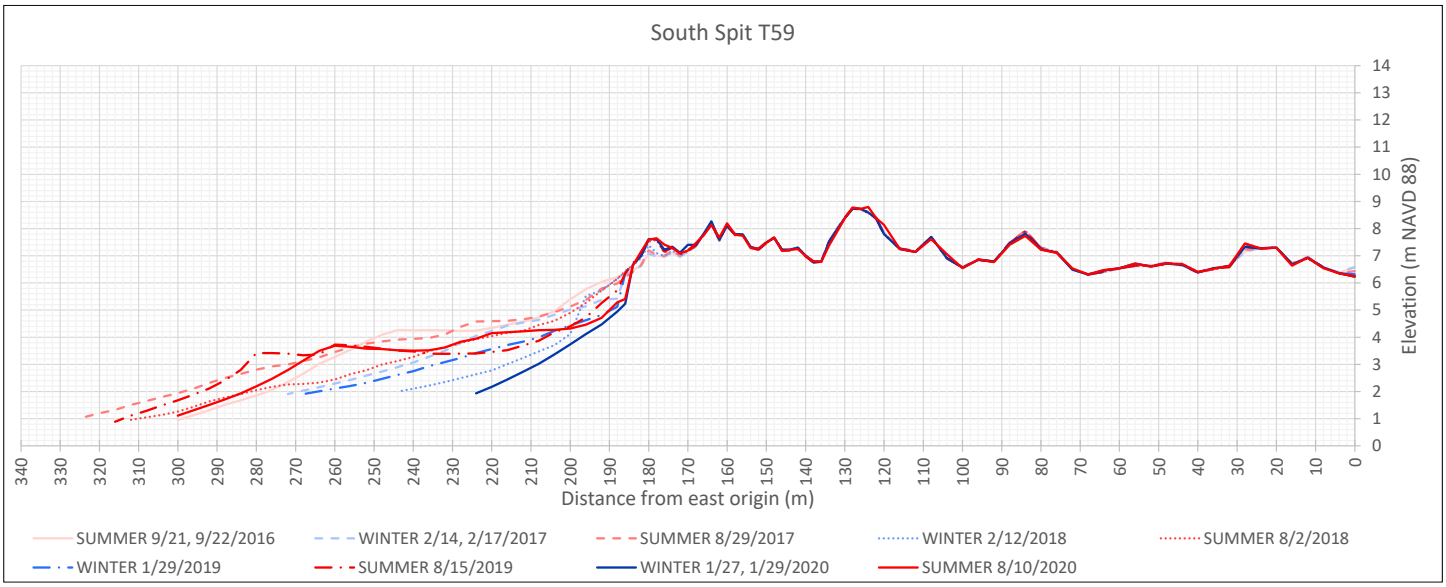


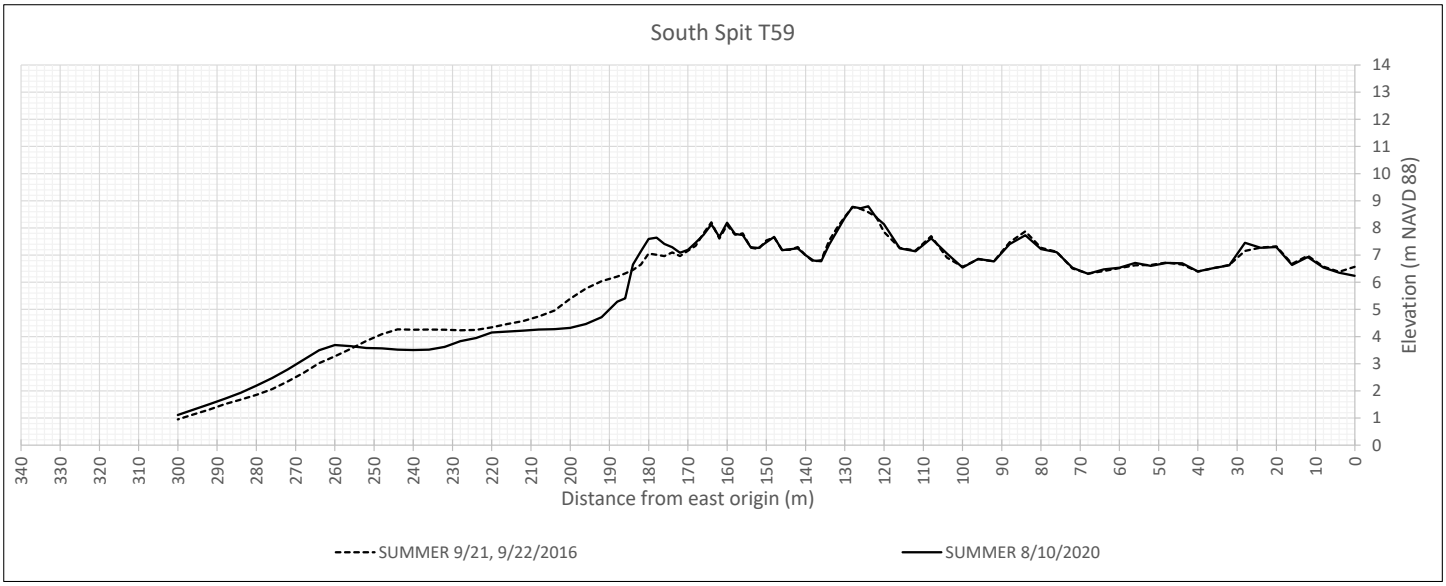
Notes: There are no data available from winter 2016. The transect is located in a portion of the South Spit in which vegetation is not managed and *Ammophila* is dominant. An incipient foredune topography was forming and was scarped during high water events in winter 2017. The scarp emphasized the incipient foredune morphology, and a driftwood deposit was placed in the swale of the incipient foredune, remaining through summer 2019 and visible in the photographs below 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. By summer 2020 the incipient foredune was well developed. Over the course of the study the area east of the incipient foredune remained stable, and change was restricted to formation of the incipient foredune and beach. The incipient foredune resulted in deposition of 1.0 m, but the upper beach was eroded by 1.0 m and retreated landward.

South Spit Transect 58

View northwest along transect at 216 m (foredune crest)

South Spit Transect 59



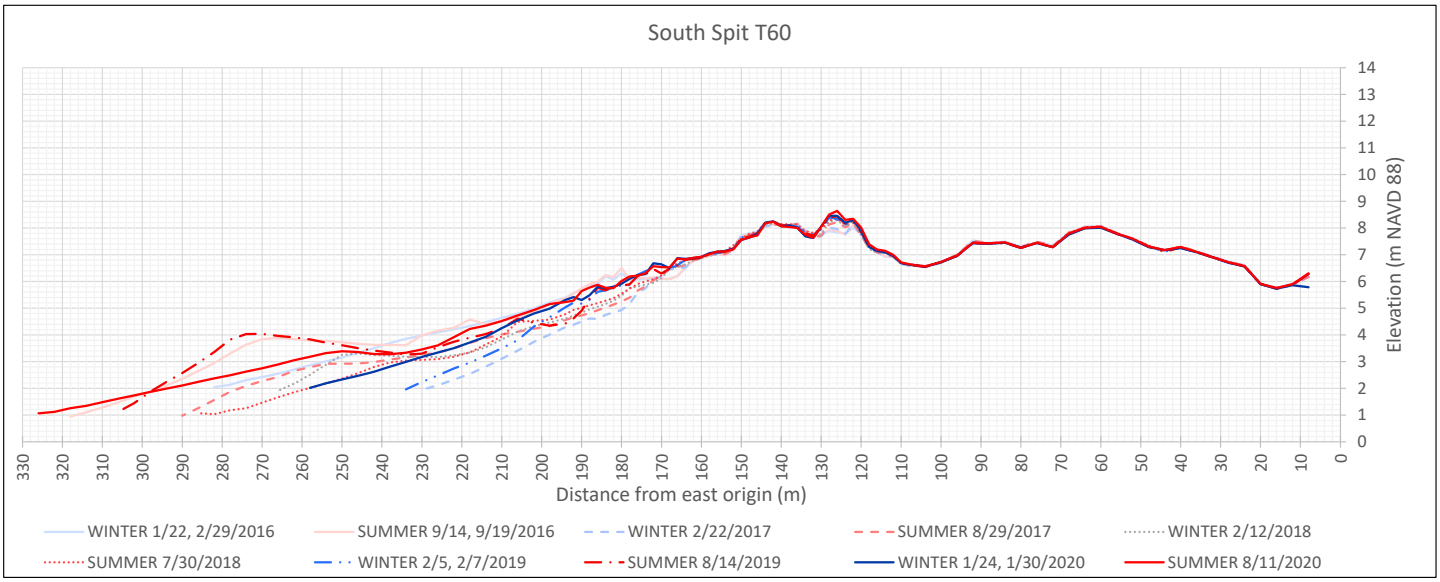


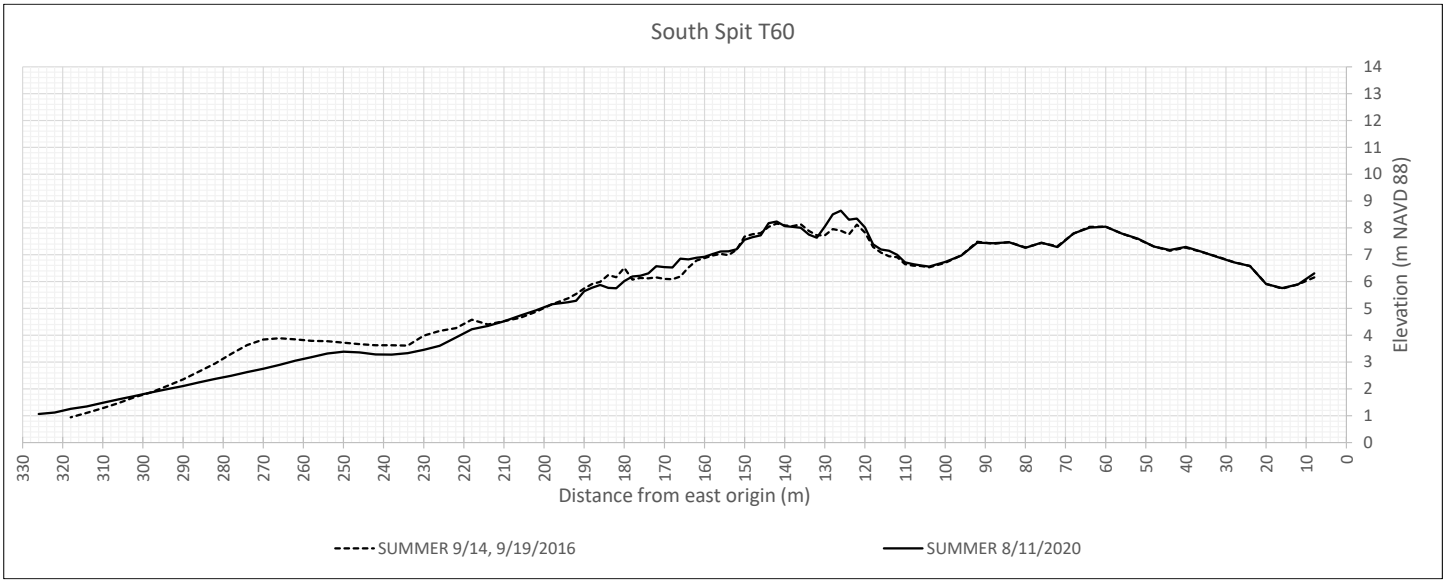
Notes: There are no data available from winter 2016. The profile is located on a portion of the South Spit that did not receive vegetation management until 2020. Multiple relict *Ammophila* foredunes are present resulting from accretion events. Between summer 2016 and winter 2017 the western edge of the incipient foredune scarped, but by sum-mer 2017 a scarp-fill ramp had formed as can be seen in the photograph below looking north-west along the transect from the incipient foredune towards the backshore. The beach regained elevation levels present in summer 2016. In winter 2019 the incipient foredune scarped, emphasizing its morphology. By summer 2019 the incipient foredune had gained in elevation and breadth (deposition can be seen in right rear of summer 2019 photograph below). During 2020 *Ammophila* was removed in this area, piles are visible in the photograph below. Over the course of the study an incipient foredune formed on the upper beach, resulting in deposition of 0.5 m, but causing retreat of 15.0 m.

South Spit Transect 59

View northwest along transect at 170 m taken at foredune base

South Spit Transect 60





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 high spot 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 four year period, there was some sediment movement on the established foredune, with 0.4 m of deposition at 126 m. There was no retreat or progradation.

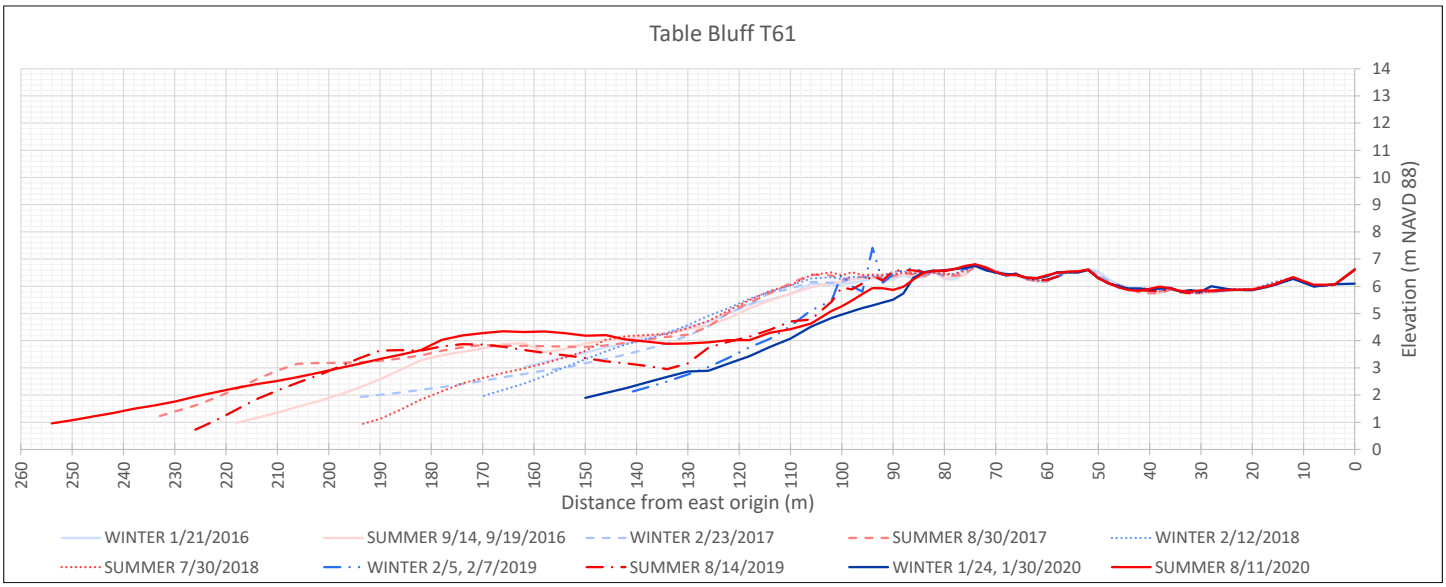
South Spit Transect 60

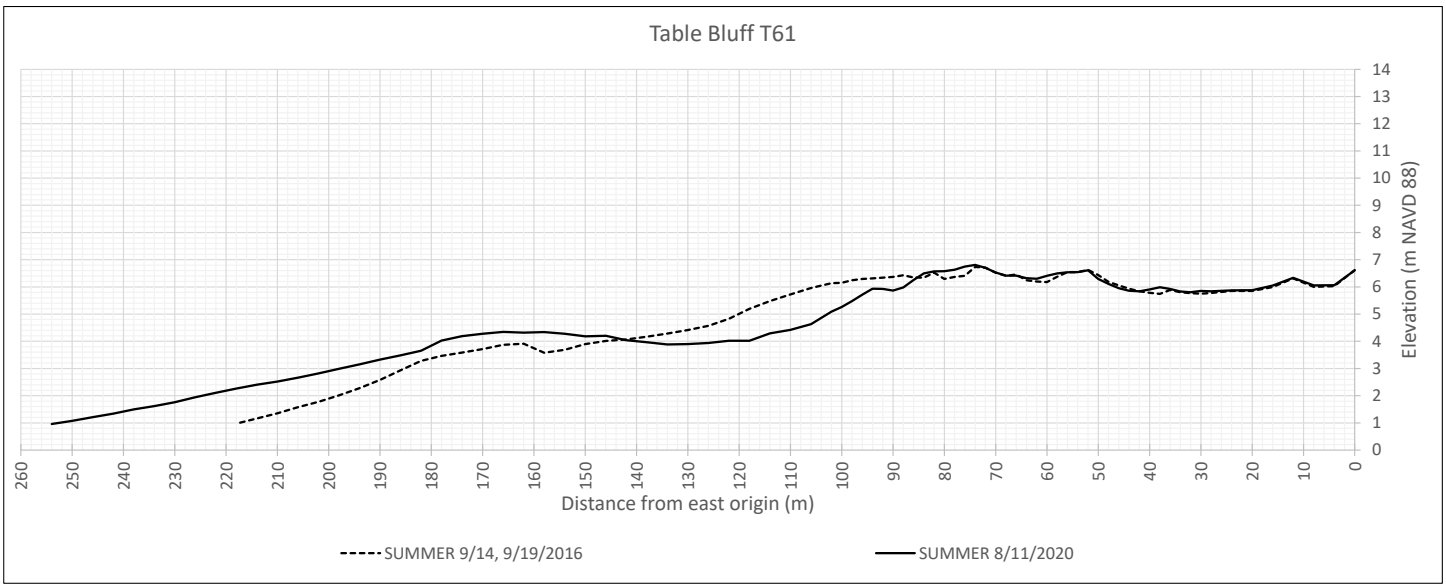
View northwest along transect at 138 m (foredune crest)

SOUTH SPIT SUMMARY. The northernmost transect (54) showed a dynamic upper beach. An incipient foredune formed over the course of the study. Transects 52-53 are located in the Western Snowy Plover restoration area, which is bulldozed annually. The transects reflect this, with a low gradient foredune terminating in a peak where *Ammophila* has historically been bulldozed. Transects 57-59 all exhibit an incipient foredune forming, but two of the three also experienced erosion, such that the incipient foredune is partly due to steepening from erosion. Transect 60 is located in an area in which *Ammophila* has been removed. It exhibits a gently sloping foredune. There was little net change to the profile over the course of the study, but significantly there was deposition of sediment behind the foredune. Overall, the site appears to be resilient and is located along a stretch of shoreline that has historically experienced medium accretion.

Table Bluff

Table Bluff Transect 61





Notes: This transect is located where the dune system narrows at the base of Table Bluff and restoration to native dune mat has occurred. Topography is low and no foredune is present. In winter 2019 the berm above the backshore was scarped, losing 1.0 m vertically. The vegetated backshore west of 76 m experienced deposition but later eroded to its present elevation. Large wood was deposited in this area in winter 2017. Between 2019 and 2020 there was additional erosion and much of the large wood washed out although some remains buried. Over the course of the study the foredune retreated 20.0 m.

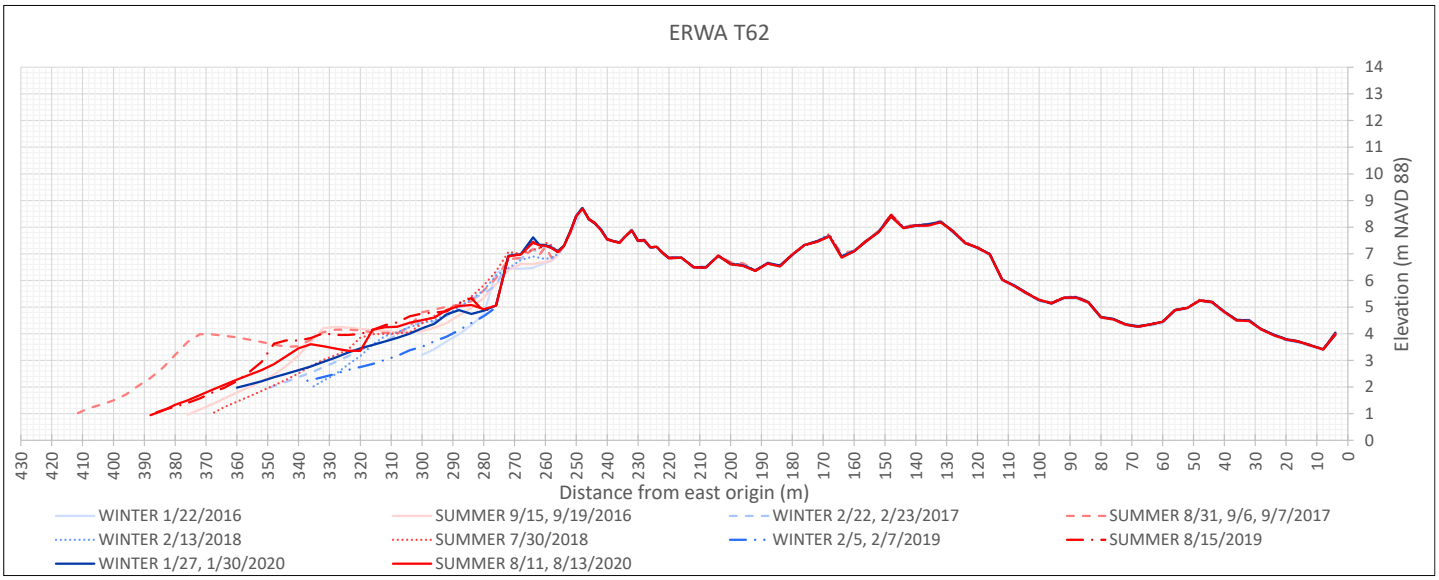
Table Bluff Transect 61

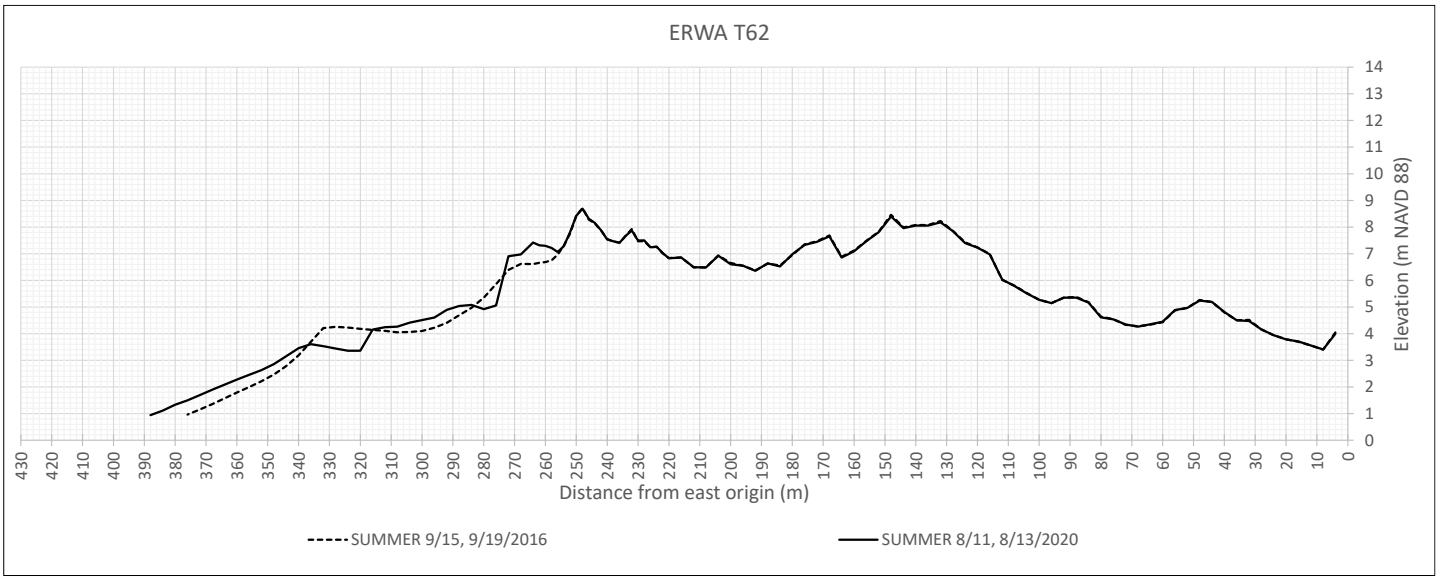
View northwest at 100 m (base of berm)

TABLE BLUFF SUMMARY. The barrier reaches its narrowest point here. There is a berm rather than a foredune and it is low and gradually sloping. There was net erosion on the berm, but net deposition on the upper beach. The narrowness of the barrier combined with net erosion of the foredune indicates a lack of resiliency. This site could not be characterized for long term trends due to a lack of statistical significance.

Eel River Wildlife Area

Eel River Wildlife Area Transect 62



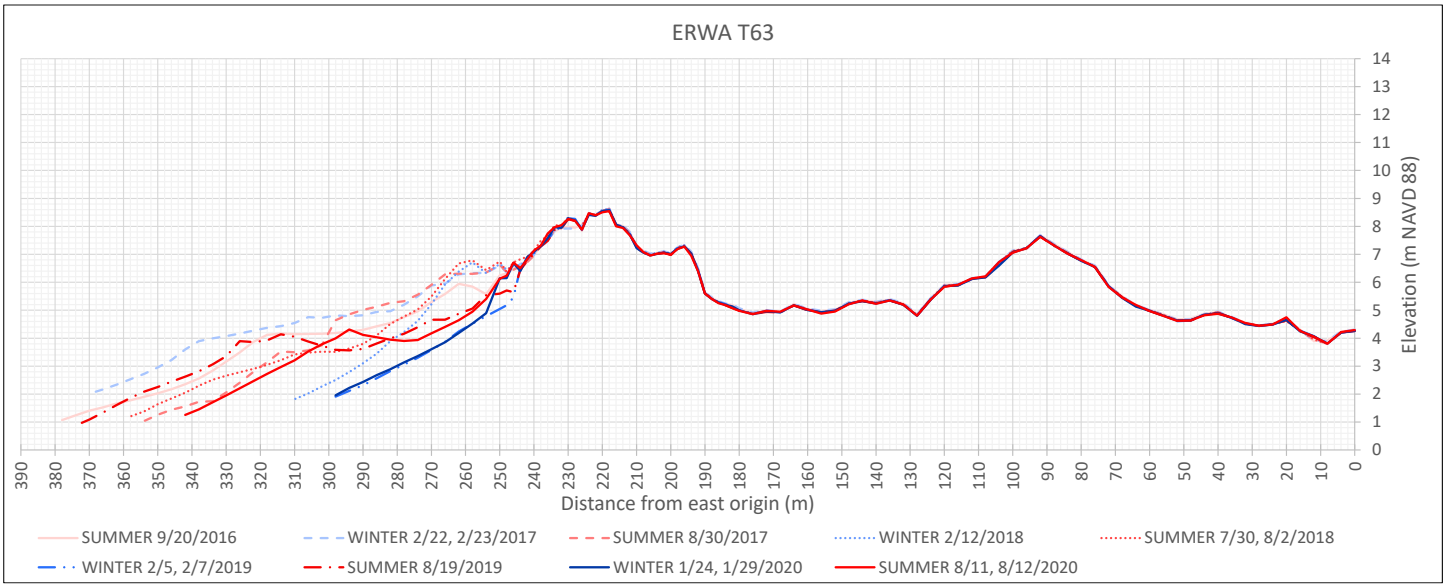


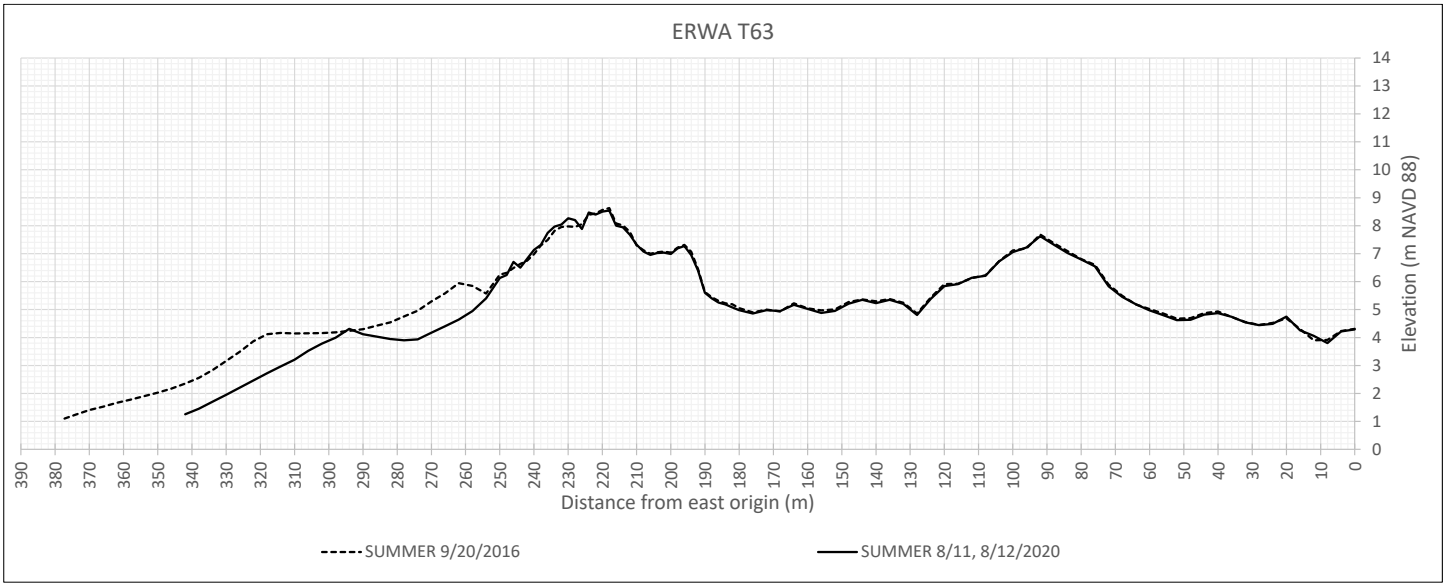
Notes: The transect is located on the north barrier of the Eel River in an unrestored system stabilized by *Ammophila*. The backshore had been scarped at 276 m prior to the winter 2016 survey. By the summer 2016 survey, scarp-fill ramping had occurred. In winter 2017 high water events deposited a large 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. Over the course of the study an incipient foredune formed, with a large wood component, but there was no retreat or progradation.

Eel River Wildlife Area Transect 62

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

Eel River Wildlife Area Transect 63



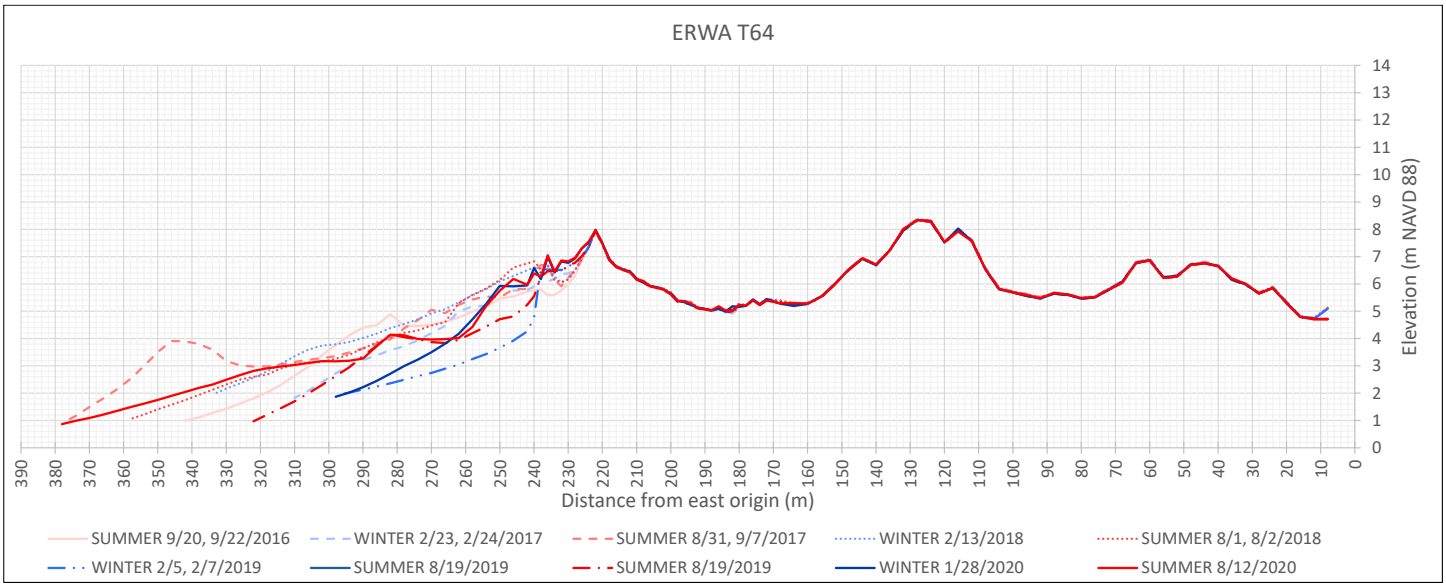


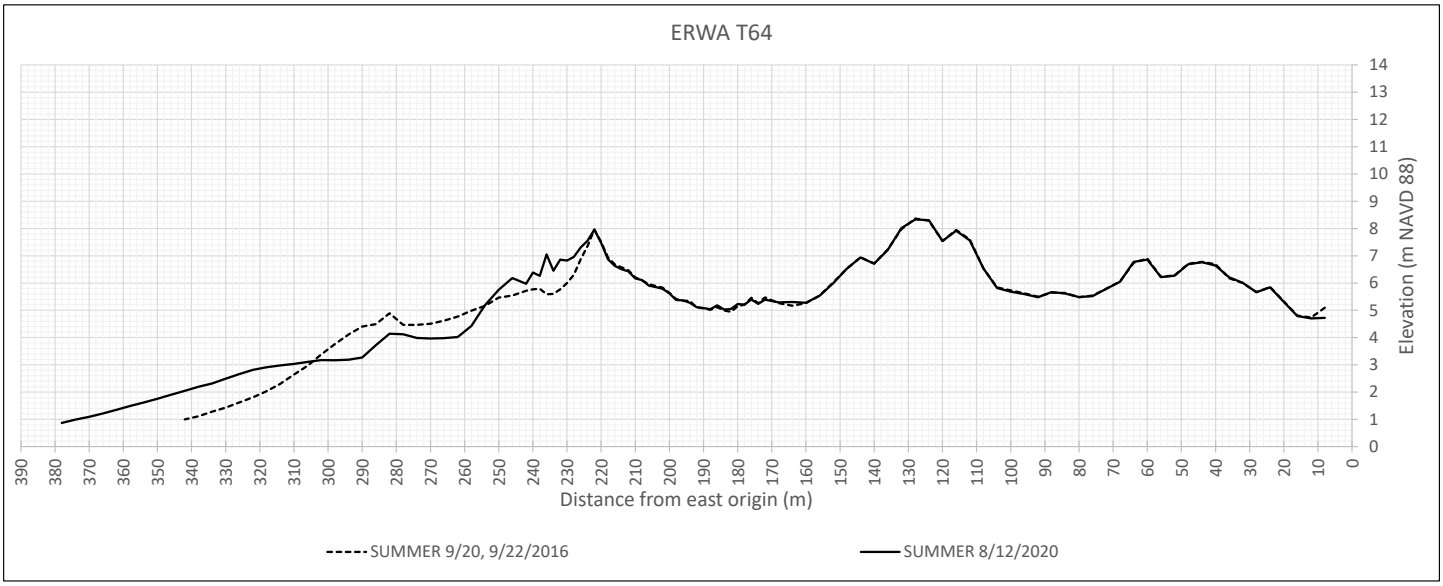
Notes: The transect is located on the north barrier of the Eel River in an unrestored system stabilized by *Ammophila*. Data from winter 2016 are not available. In winter 2017 a large amount of wood was deposited on the upper beach, and all points from 248-270 m were taken on top of wood. In summer 2017 the backshore was virtually unchanged, and the wood deposit can be seen in the photograph below 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 below). 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 a broad foredune swale between the relict and present day foredunes. Over the course of the study the upper beach underwent significant erosion, and the incipient foredune was removed, retreating at its base 20.0 m. The site is characterized by historic medium accretion.

Eel River Wildlife Area Transect 63

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

Eel River Wildlife Area Transect 64



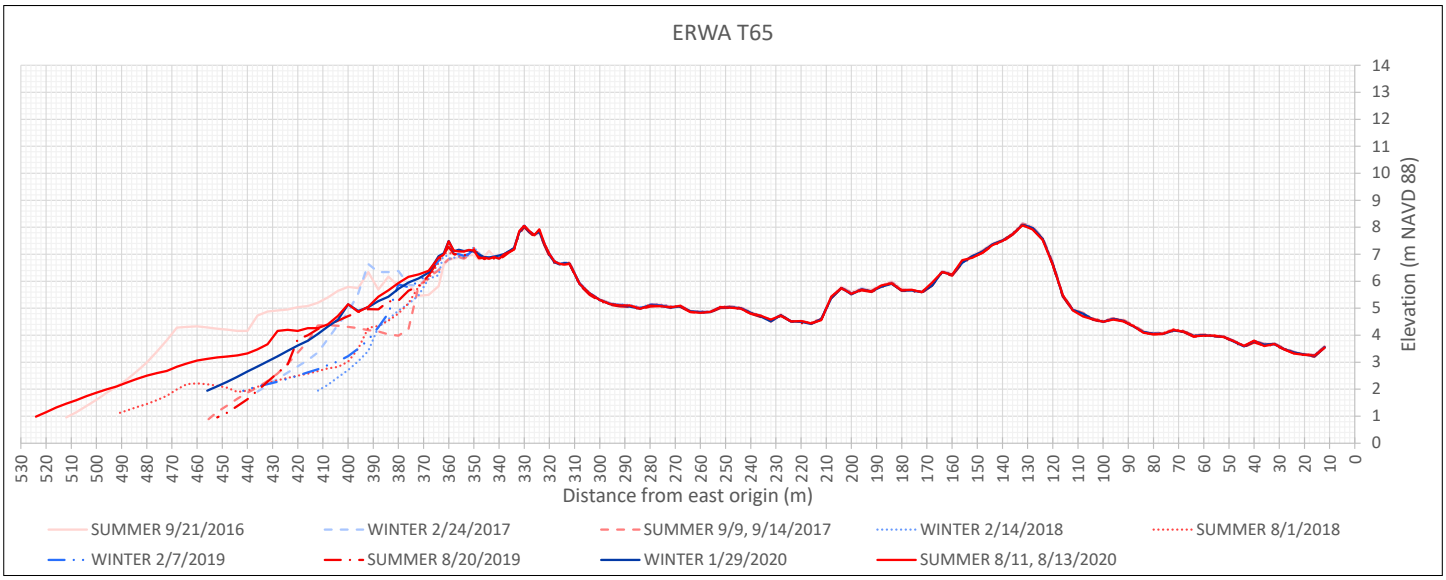


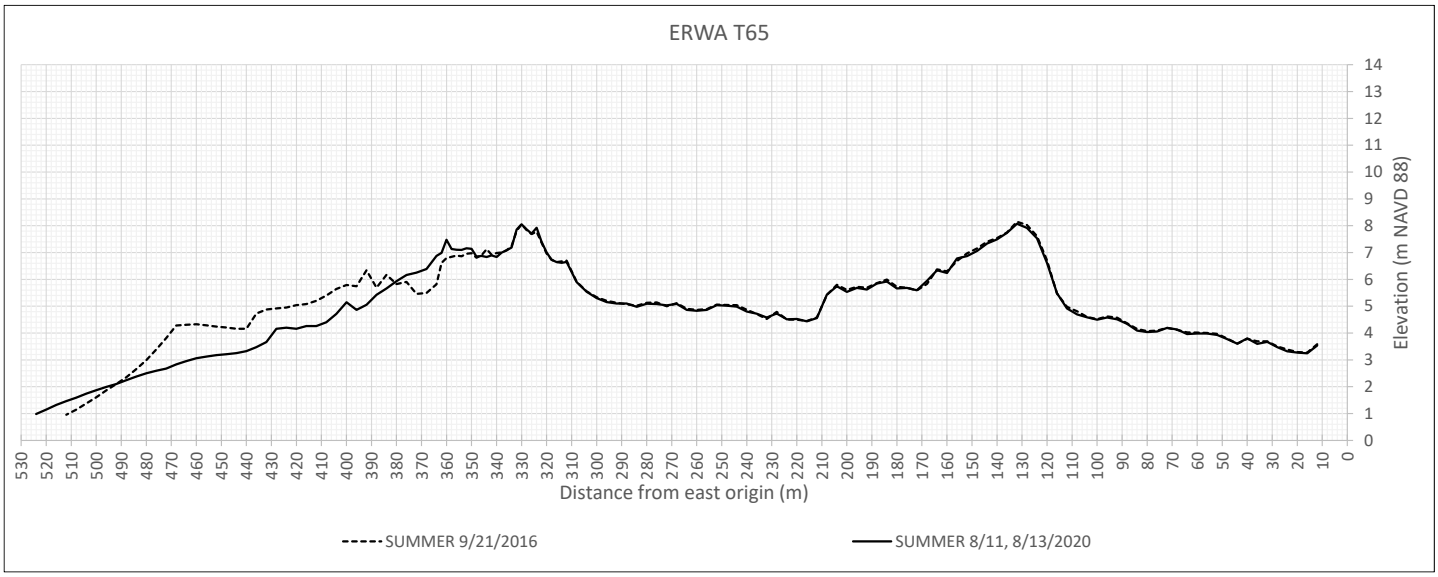
Notes: The transect is located on the north barrier of the Eel River in an unrestored system stabilized by *Ammophila*. Data from winter 2016 are not available. In summer 2016 a wood deposit was present in the vicinity of 282 m. In winter 2017 during high water events the beach eroded and a 1+ m vertical 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, 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 2.0 m of vertical loss. In summer 2019 approximately half of the elevation was regained and the incipient foredune received deposition that covered much of the wood. In winter 2019 there was another significant deposit of wood. Similar to the previous transect, the profile is distinctive in having a broad foredune swale between the relict and present-day foredunes. Over the course of the study, an incipient foredune with a significant large wood component formed, eventually merging with the foredune. This site is characterized historically by medium accretion.

Eel River Wildlife Area Transect 64

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

Eel River Wildlife Area Transect 65



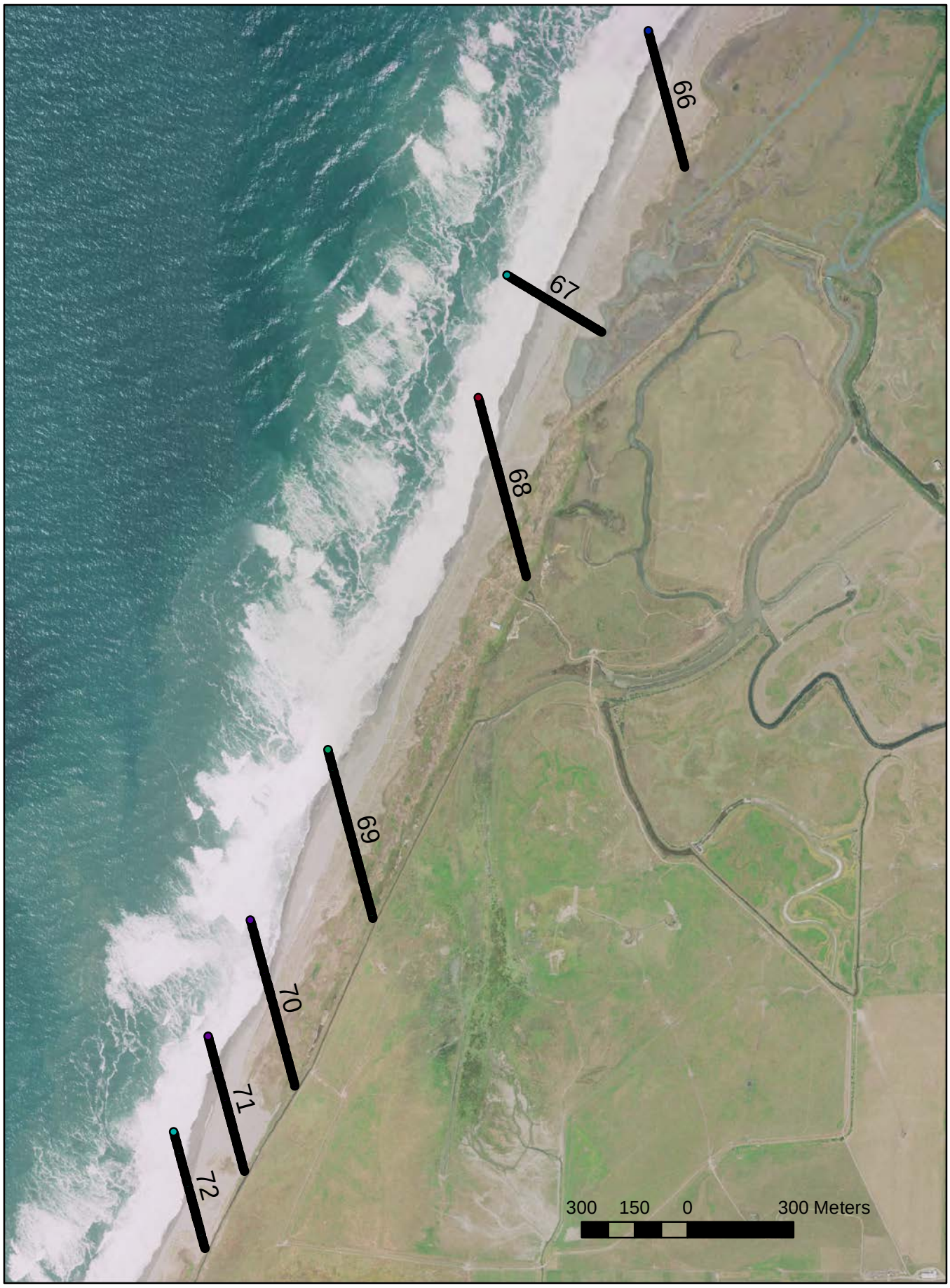


Notes: This transect is located near the dynamic spit at the mouth of the Eel River and exhibits high variability on its seaward side. Topographic data from winter 2016 are not available. The transect passes through a relict foredune scarp associated with mouth migration at 132 m. In summer 2016 the beach was wide. A wood deposit was present from 372-396 m. In winter 2017 during high water events the foreshore was eroded up to 3.0 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 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 .0 m of deposition that filled the scarp (see photo below on right). In winter 2019 there was scarping of the upper beach, with infilling the following summer. Over the course of the study the incipient foredune retreated eastward, 110.0 m, beginning to merge with the established foredune.

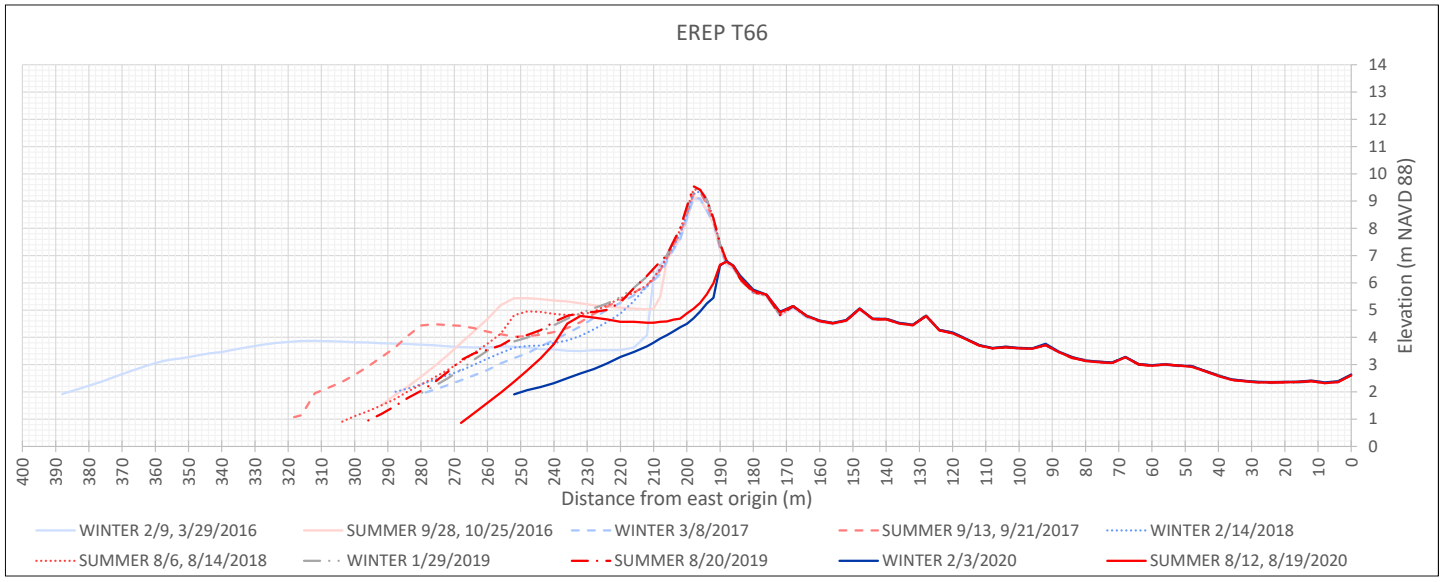
View southeast at 384 m (upper beach) looking towards incipient foredune

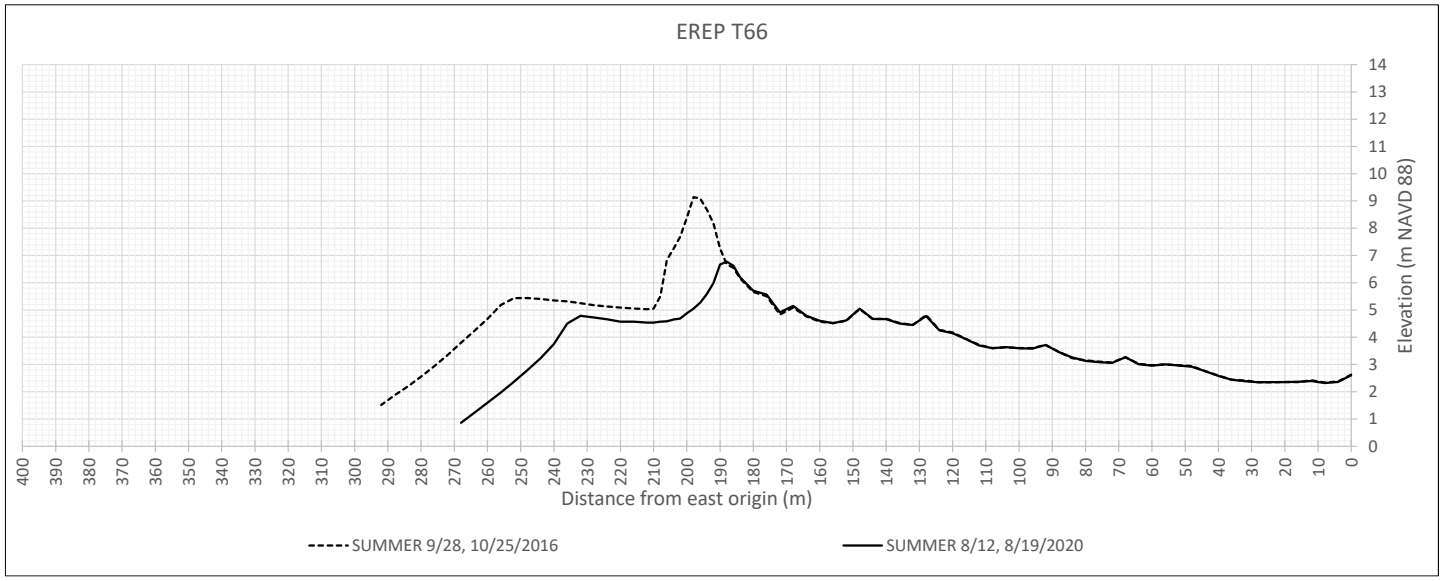
EEL RIVER WILDLIFE AREA SUMMARY. The Eel River Wildlife area transects were unique along the littoral cell in the amount of large wood deposited on the upper beach and foredune. In some cases the wood itself acted as an incipient foredune, in other cases sand was deposited in and around the wood. As a result, these transects tend to show depositional trends despite several large scarping events. Large wood is contributing to resiliency on this site. The site exhibits resiliency, and is located in an area of medium accretion historically.

Eel River Estuary Preserve



Eel River Estuary Preserve Transect 66



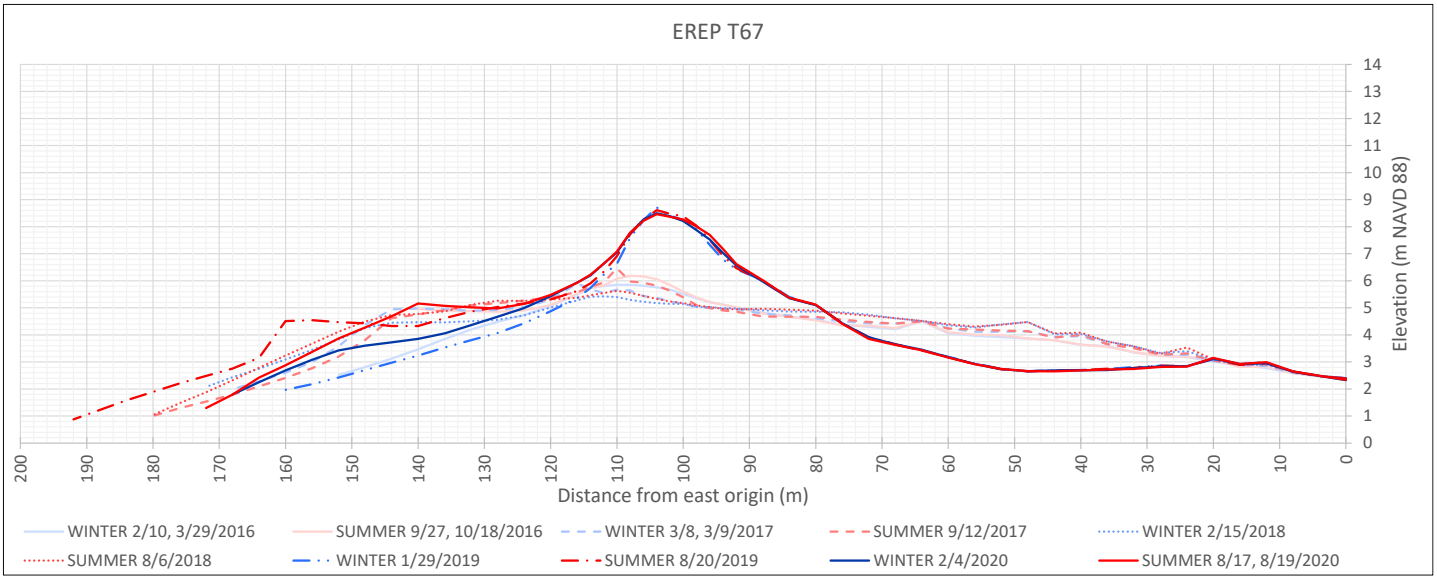


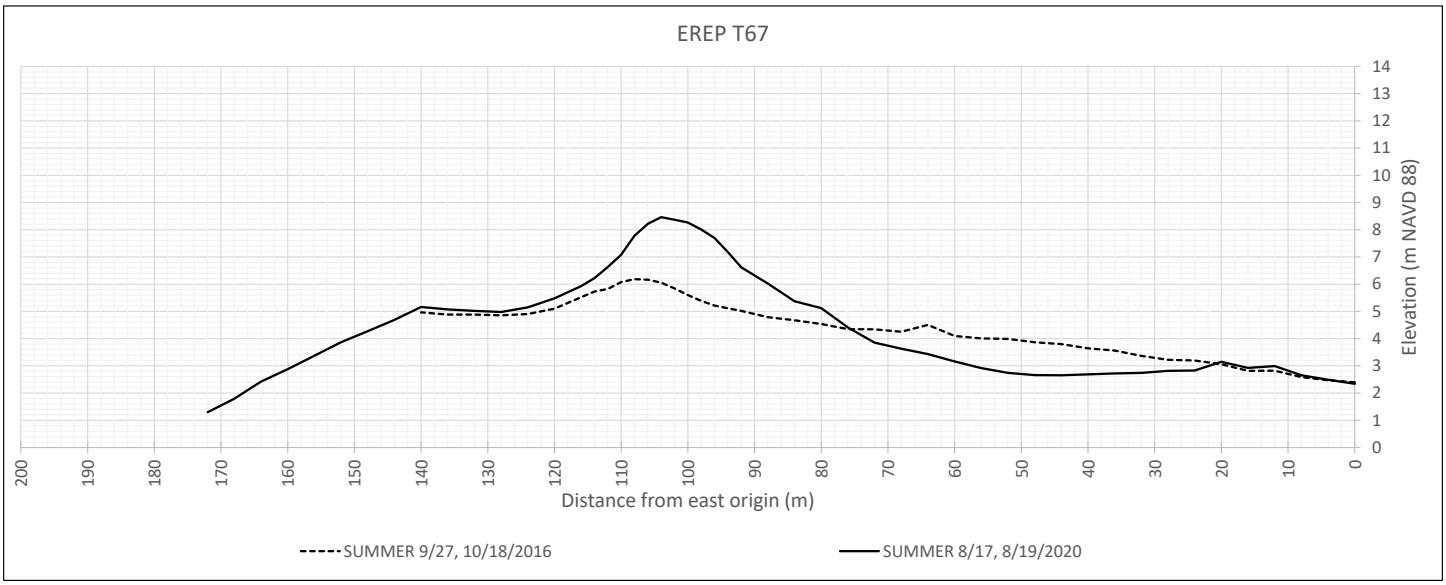
Notes: This transect is located on the Eel River southern barrier, south of the true spit, and consists of a dynamic beach and a narrow peaked *Ammophila* foredune in front of a low backdune area that slopes down to the estuary. The foredune was scarped in winter 2016 prior to the survey, creating a 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 below (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. In winter 2020 the foredune was severely scarped during winter storms, losing over 2.0 m in elevation. The profiles suggests a dynamic beach with high rates of annual volumetric change. Over the course of the study the foredune retreated 15.0 m, indicating low resilience and in keeping with the characterization of this stretch of shoreline as medium erosion historically.

Eel River Estuary Preserve Transect 66

View north at 210 m (foredune base)

Eel River Estuary Preserve Transect 67



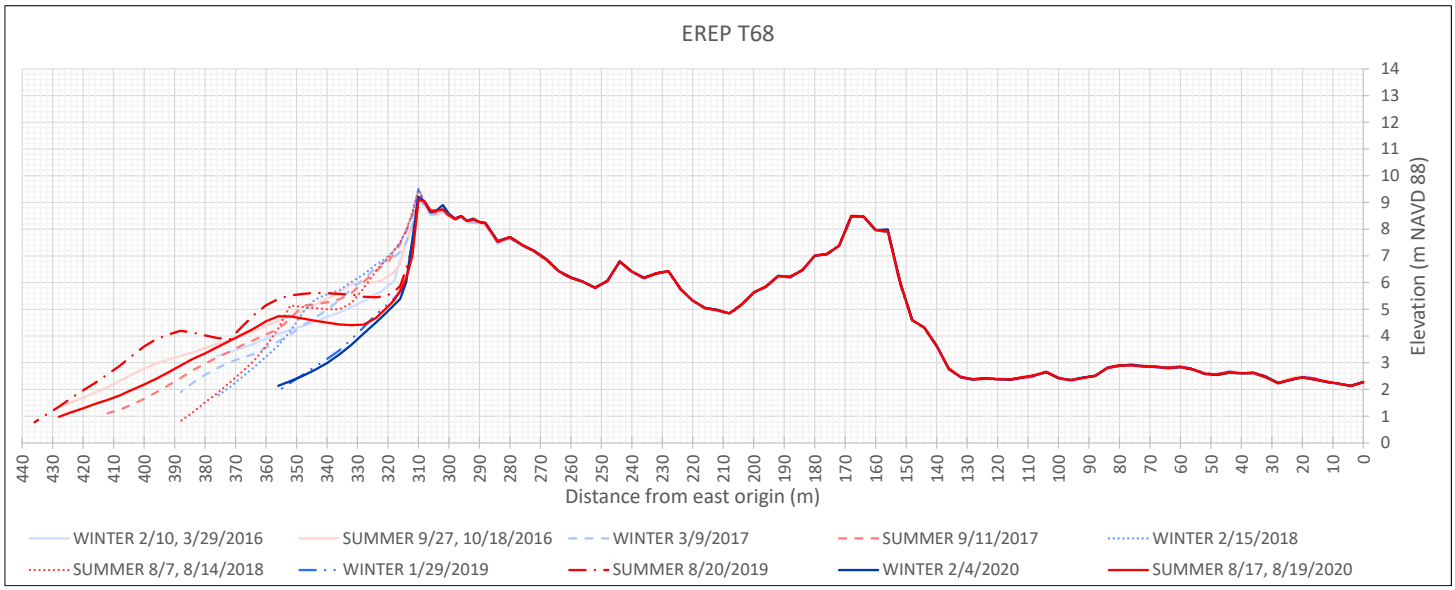


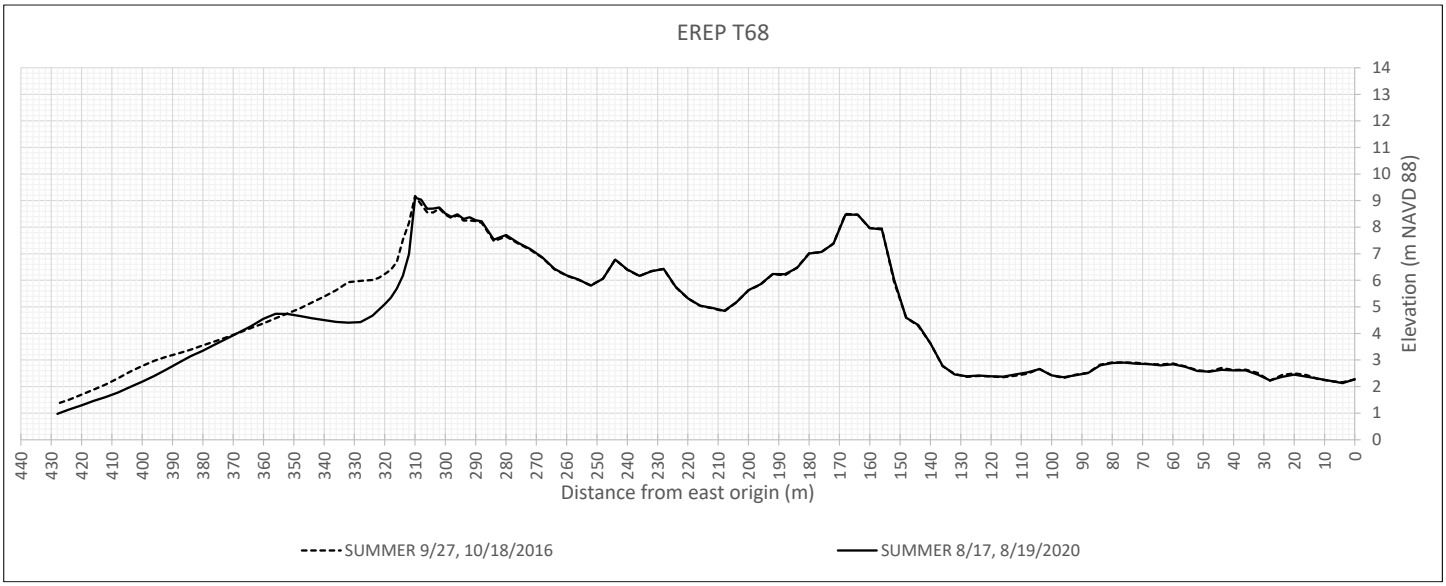
Notes: This transect was placed within a foredune breach that was overwashed during high water events. The transect was placed perpendicular to the shoreline (rather than parallel with predominant wind) in order to include the overwash lobe. The lack of foredune is apparent from the initial low profile. 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 what would be 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 2.0 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 Fall 2018 the foredune was rebuilt by borrowing sand from the overwash fan and creating a new foredune. There has been no significant erosion of the rebuilt foredune through summer 2020. and the foredune has neither retreated nor prograded.

Eel River Estuary Preserve Transect 67

View south at 102 m (foredune crest)

Eel River Estuary Preserve Transect 68



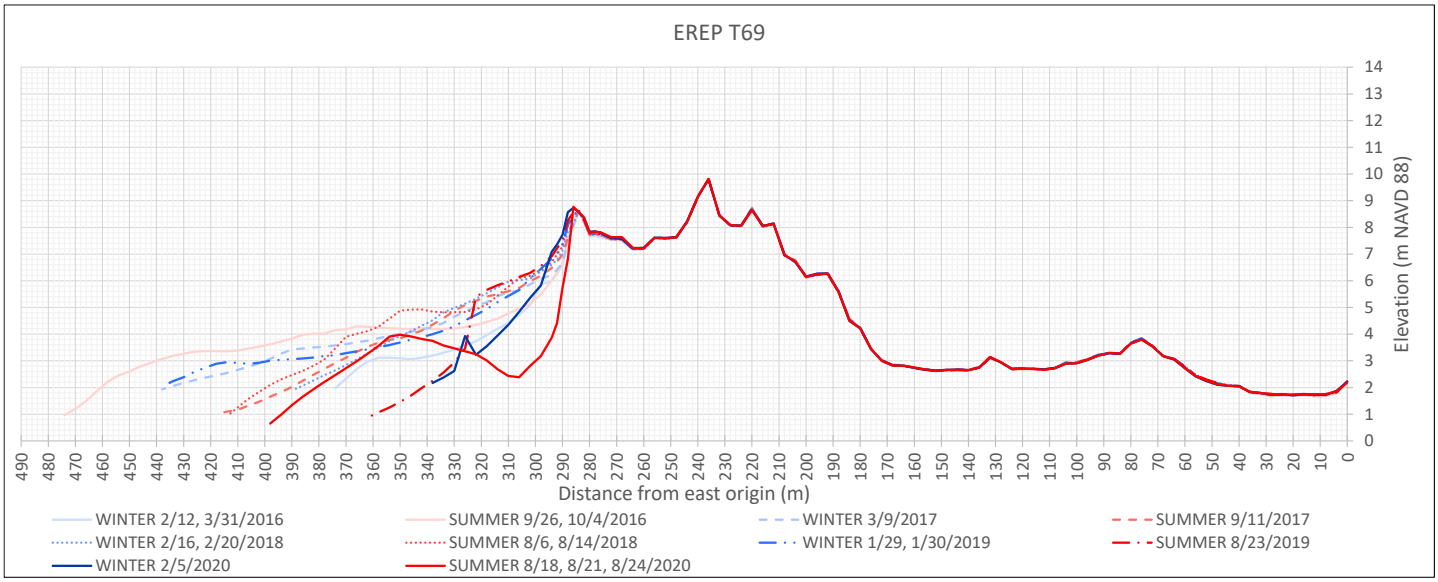


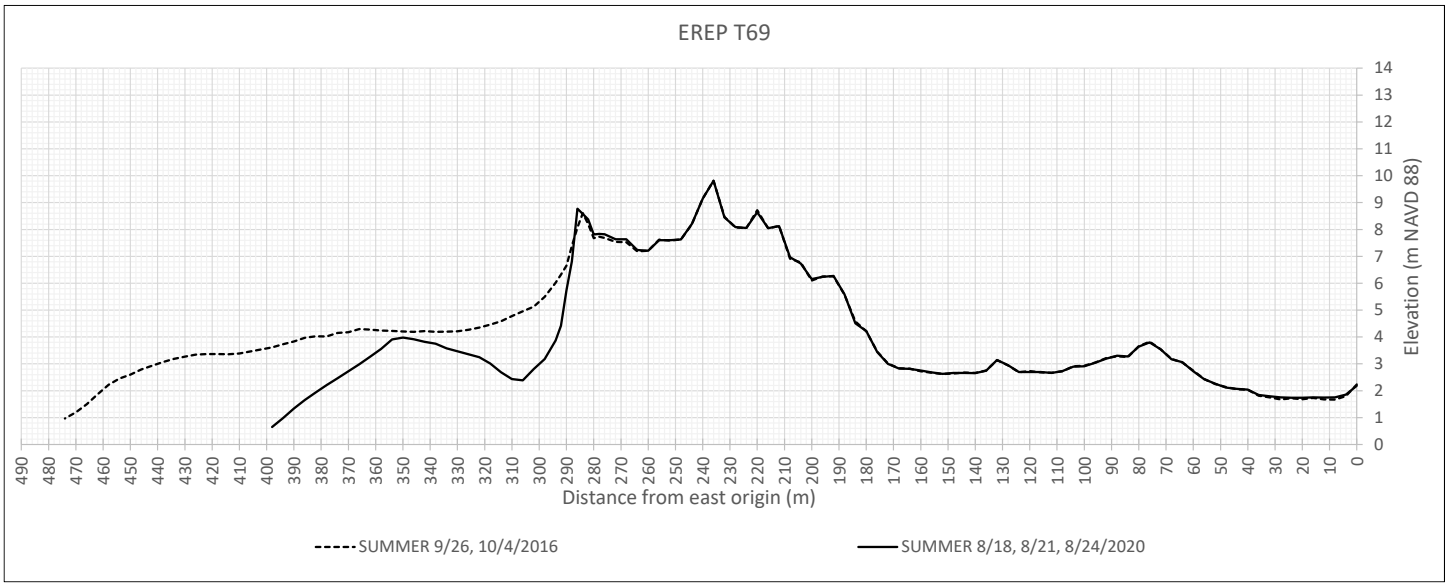
Notes: The transect intersects southern Eel River dune system at one of its widest points, and the profile depicts multiple relict *Ammophila* foredunes. The present-day foredune had been recently scarped, with up to 3.0 m of elevation loss, at the time of the 2016 survey. Between winter 2016 and summer 2017 a scarp-fill ramp gradually reconnected the backshore to the foredune crest. The beach lost 1.0 m of ele-vation in winter 2017 and regained only part of it in summer 2017, with additional loss of up to 2.0 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. In winter 2020 additional erosion at the base of the foredune lowered the beach by 1.0 m, but by summer2020 a ramp was forming. Over the course of the study, the foredune was steepened and the base retreated 30.0 m, suggesting low resiliency in keeping with the designation of historic medium erosion for this stretch of shoreline.

Eel River Estuary Preserve Transect 68

View south at 316 m (foredune base)

Eel River Estuary Preserve Transect 69



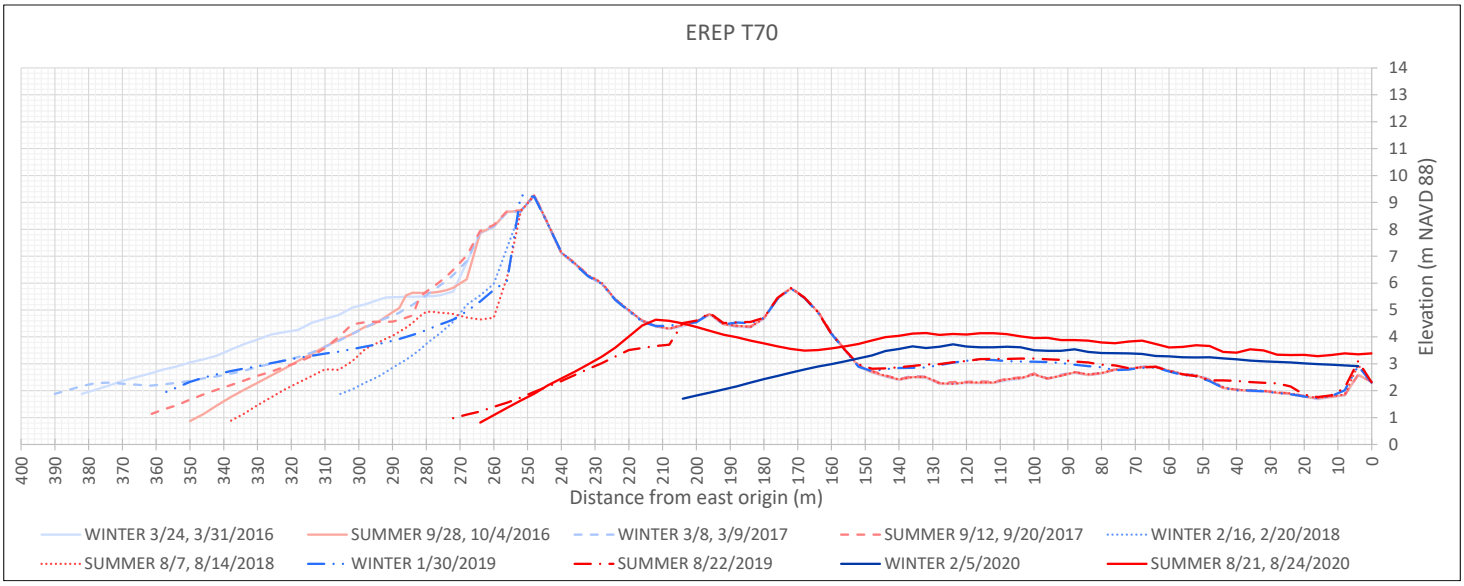


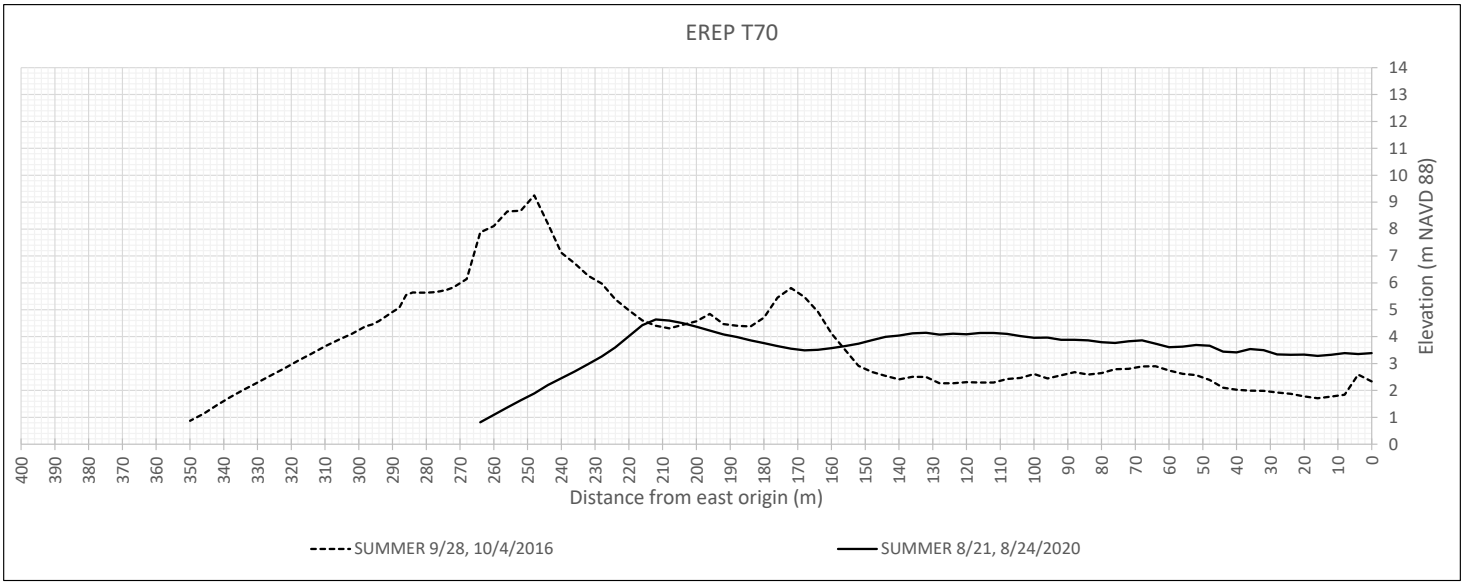
Notes: The profiles describe a peaked *Ammophila* foredune and foredune swale backed by a relict foredune, and a stable backdune area sloping down to the estuary. The foredune was scarped during winter 2016 prior to the survey. Between winter 2016 and summer 2016 significant deposition occurred in the mid to lower beach (up to 1+ m) while the beach at the base of the scarp changed little. By winter 2017 the beach had experienced deposition, which continued through summer 2017, resulting in a net gain of 1.0+ m. The resulting gently sloping backshore can be seen in the photograph taken from the transect and looking north (below). However, the beach was maintained at up to 2.4 m below summer 2016 levels. In summer 2018 the beach received up to 1.0 m of deposition. Between winter and summer 2019 the upper beach eroded, losing up to 2.5 m vertically, and an offshore bar formed. In winter 2020 the foredune eroded back up to 10.0 m and increased in steepness. Over the course of the study, the beach was lowered significantly and the foredune eroded and steepened, retreating 30.0 m at its base. These conditions suggest low resiliency, consistent with the historic designation of medium erosion for this stretch of shoreline.

Eel River Estuary Preserve Transect 69

View north at 294 m (foredune base)

Eel River Estuary Preserve Transect 70



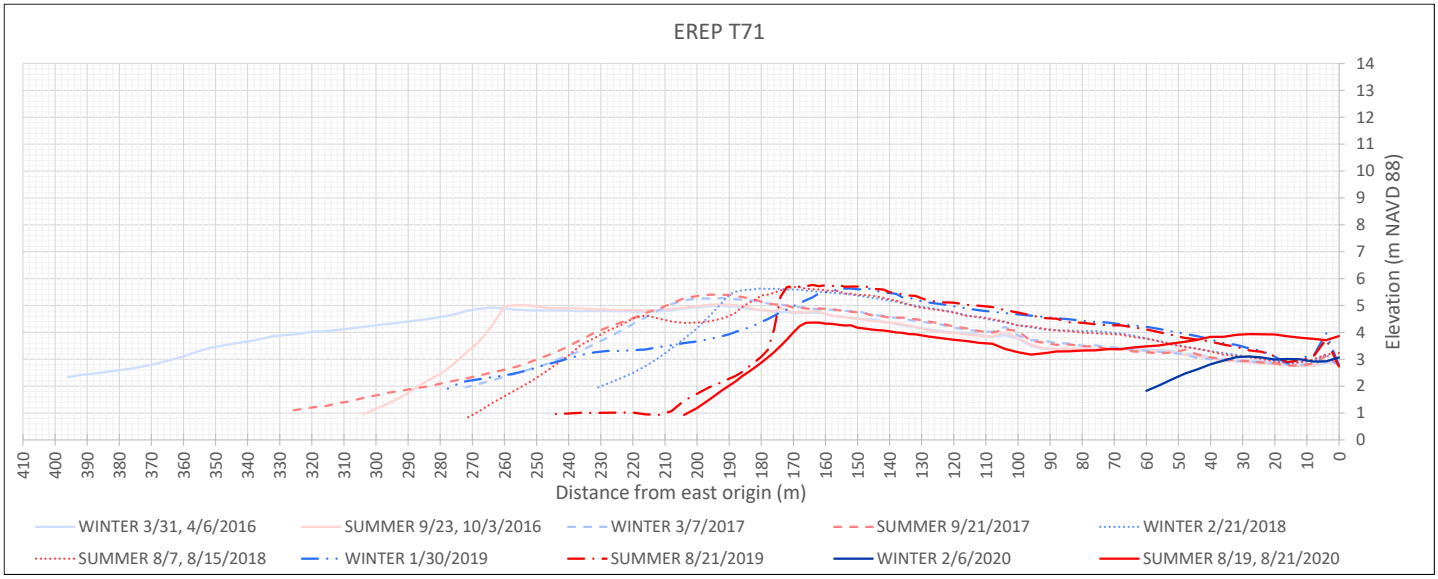


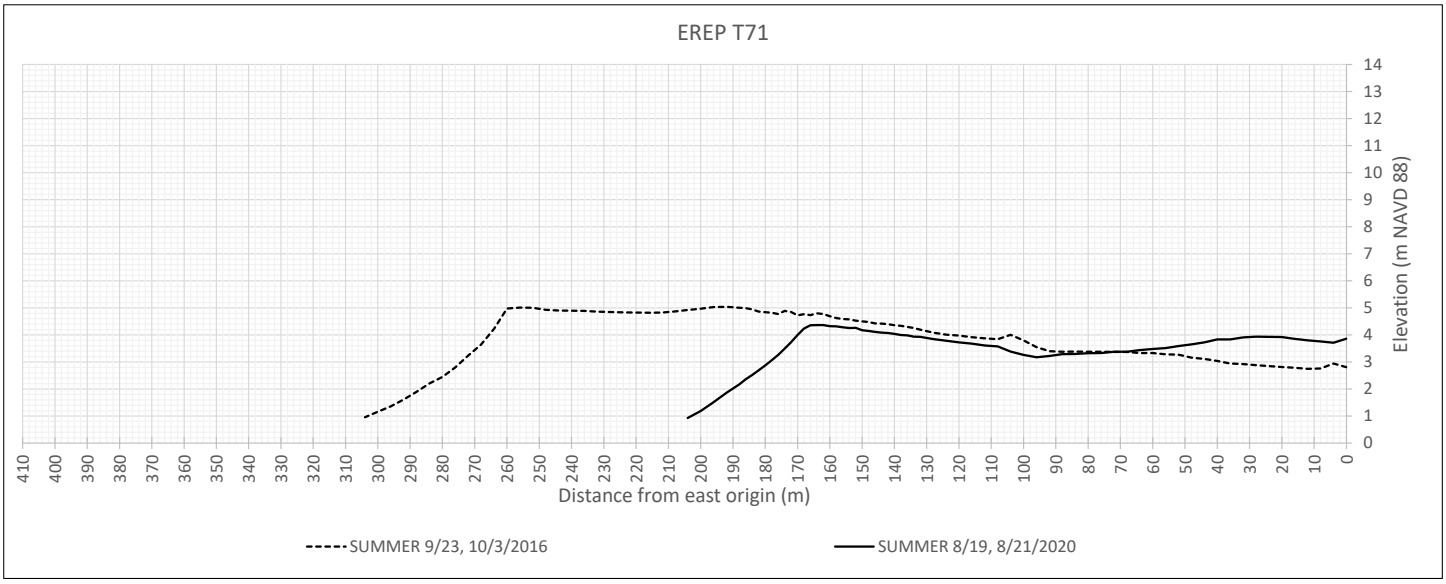
Notes: The transect is located near the south end of the barrier where the dune system narrows. At the start of the survey the transect was located just north of a foredune breach area. The *Ammophila* foredune was scarped during winter 2016 prior to the survey. By summer 2016 additional scarping had occurred and the beach 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 10.0m horizontally (see photos next page). By the summer 2018 survey the scarp had further eroded at the base but up to 1.0 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 below). Over the course of the study the foredune was completely removed, retreating 70.0 m, and an overwash fan formed behind it. This transect exhibits an extreme lack of resiliency, and the stretch of shoreline is characterized as medium erosion.

Eel River Estuary Preserve Transect 70

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

Eel River Estuary Preserve Transect 71



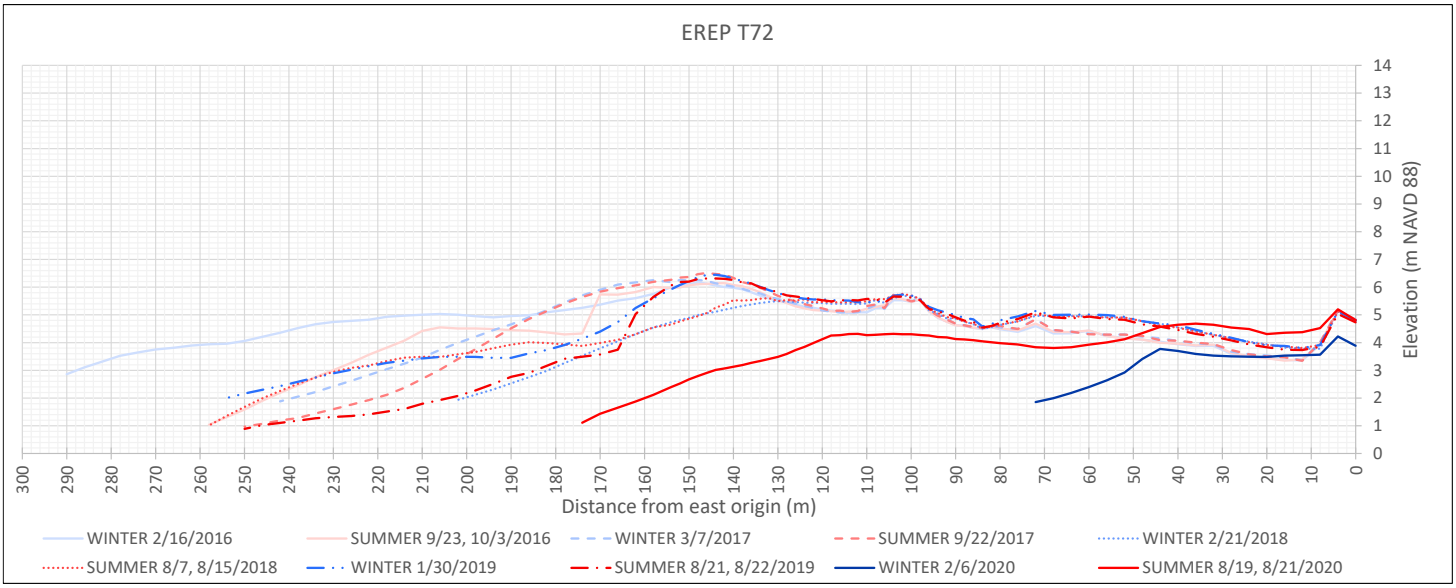


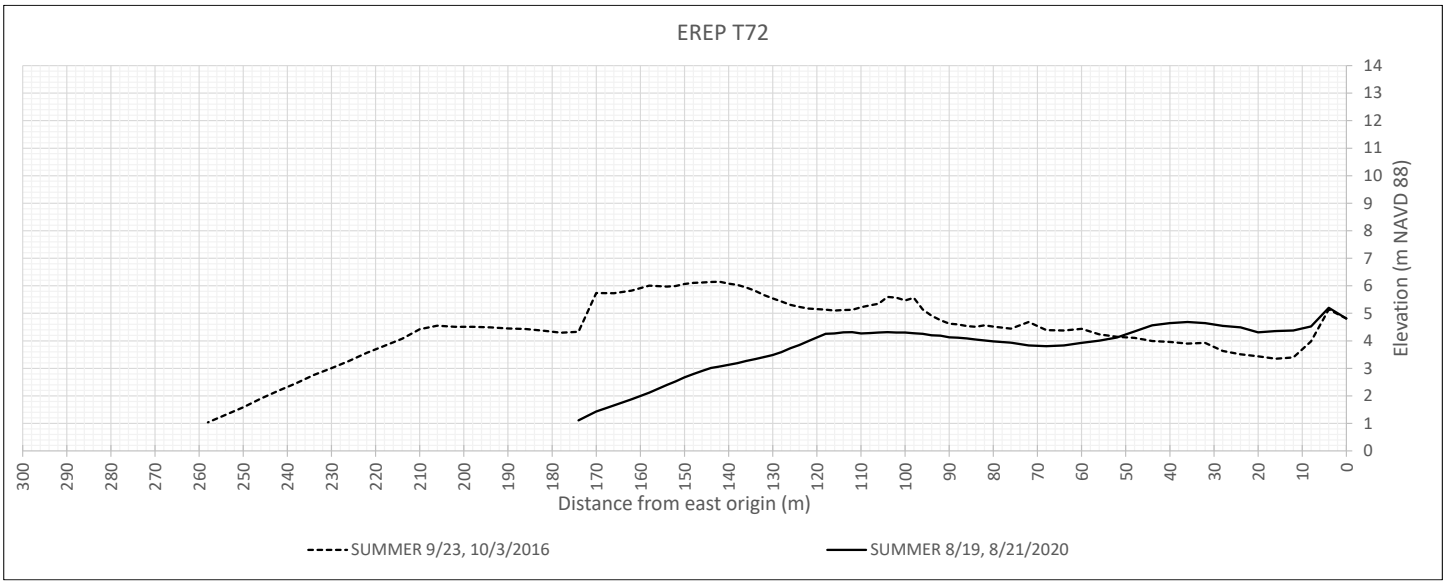
Notes: The transect passes through a large foredune breach area that is subject to washover during high water events. The profile describes a berm that is primarily influenced by waves in the winter months and modified by aeolian action in the summer, and is retreating inland. Extensive beach erosion 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 30.0 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. Over the course of the study the berm retreated 95 m, exhibiting extreme lack of resilience in keeping with the historic trend of medium erosion along this stretch of shoreline.

Eel River Estuary Preserve Transect 71

View north at 166 m (overwash area)

Eel River Estuary Preserve Transect 72





Notes: The transect passed 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 below 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 40.0 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 2019. In winter 2020 the berm was eroded back significantly, but shifted west in summer 2020 with new deposition. Over the course of the study the berm retreated 50.0 m, exhibiting a lack of resiliency in keeping with the designation of this shoreline historically as medium erosion.

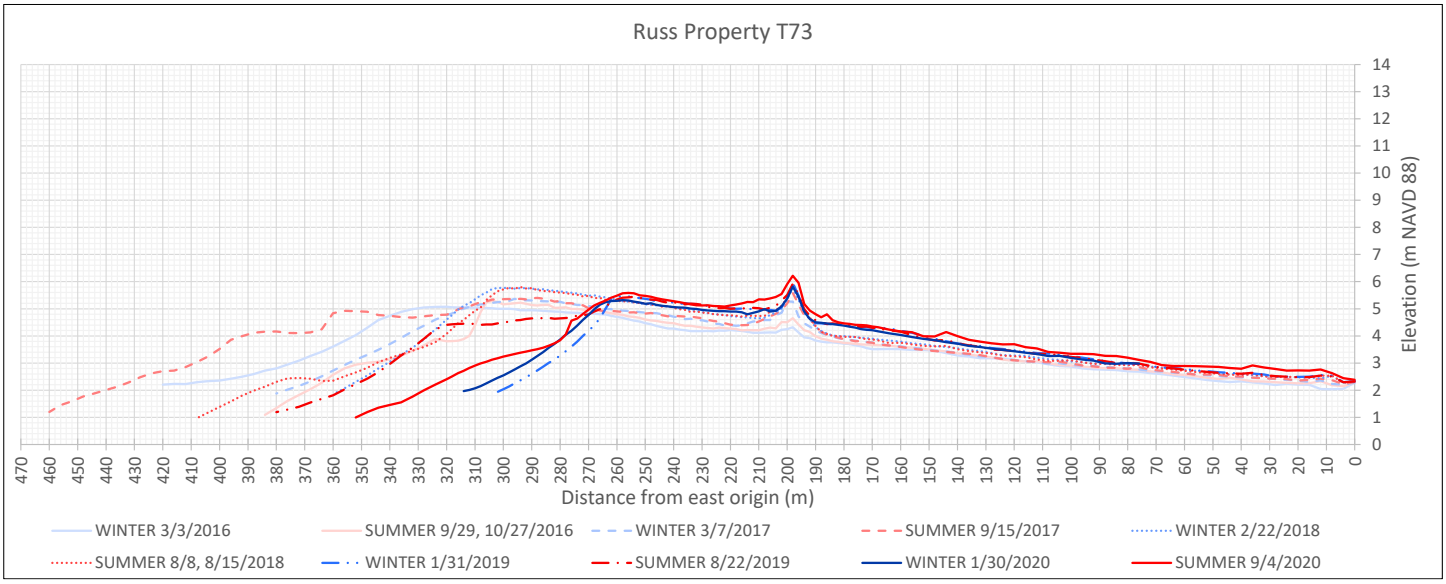
Eel River Estuary Preserve Transect 72

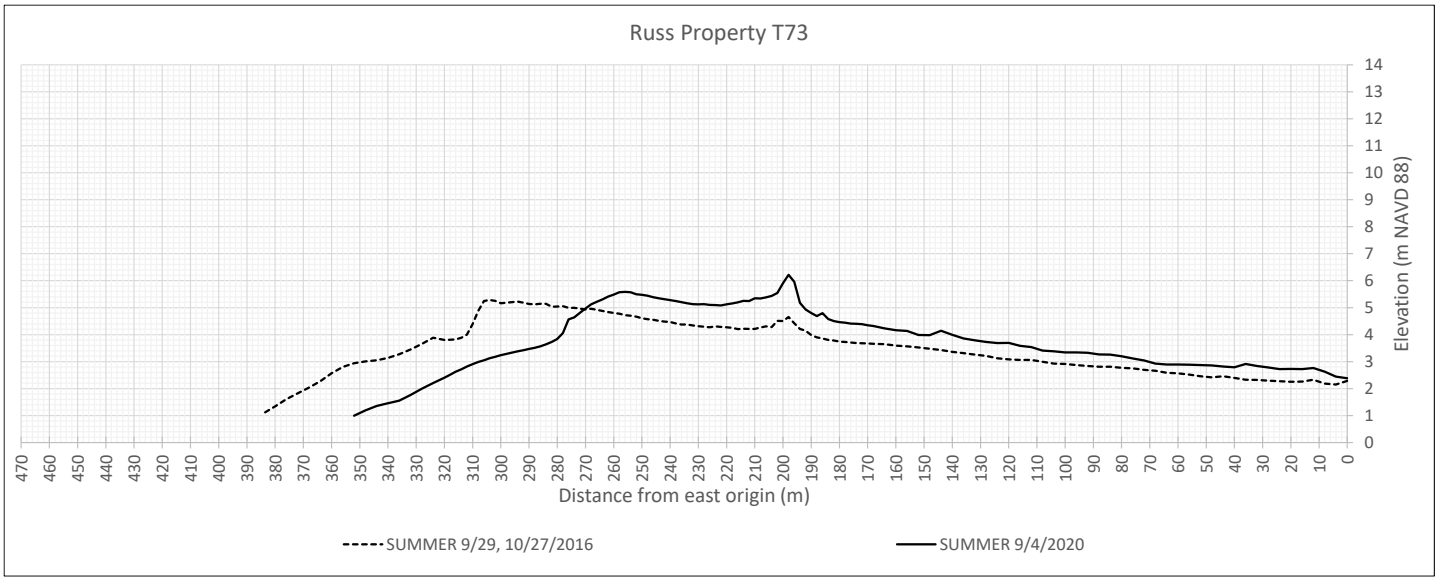
View southeast at 124 m (crest of berm) looking northwest along transect

EEL RIVER ESTUARY PRESERVE SUMMARY. This site is very dynamic and largely erosional. Transect 66, located near the north end, had its established foredune removed during the study. Transect 67 was placed in a historic foredune breach, and a new foredune was constructed using a bulldozer. The constructed foredune did not erode during its first winter. The previously scarped foredune in Transects 68 and 69 eroded at the base of the foredune, and the upper beach was lowered, causing a higher scarp. Transect 70 recorded a breach and overwash of the foredune. Transects 71 and 72 were located in pre-existing overwash areas, and the bench-like foredune retreated significantly in both. Overall this area showed low resiliency, and is located in an area of historic shoreline loss.

Russ

Russ Property Transect 73





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 30.0 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. Over the course of the study the beach berm retreated 30.0 m and the overwash deposit increased by up to 1.0 m, resulting in a translation of the barrier. This area shows an extreme lack of resiliency.

Russ Property Transect 73

View south at 296 (upper beach)

RUSS SUMMARY. This single transect is located in a largely unvegetated area that previously underwent erosion and removal of vegetation. The shoreline continues to retreat and this site exhibits an extreme lack of resiliency.

Conclusions

This report presents graphical data only. No quantitative analyses were carried out to measure volumetric change. Ultimately, the data will be used as a basis for modeling barrier response to sea level rise, storm events, and other climate impacts. The purpose of this report is to present property owners with the information collected on their lands, as well as to summarize observed trends along the entire littoral cell.

There were some overall patterns observed. The northernmost sites (Little River/Clam Beach) exhibited high resilience despite the fact that some lacked a foredune (those that were restored) and are located in an area of historic shoreline accretion. The significant amount of sediment delivery annually apparently prevents erosion at the shoreline. Despite being located in an area of medium accretion, the high steep foredunes of the Mad River, Long, and Woll sites south of the Mad River mouth were unable to recover from storm erosion and therefore lack resiliency. The steep cliffs caused by two or more highwater events prevented ramping from attaining a height that would allow sediment delivery to the upper stoss face and crest of the foredune. The restored Bair transects (Lanphere adaptation site) exhibited resiliency, while the adjoining unrestored transect to the north did not, suggesting that restoration increased resiliency by reconnecting beach-foredune-backdune sediment budgets through removal of invasive *Ammophila*. The Lanphere transects and Ma-le'l North transects commonly began with an incipient foredune which was eroded, but protected the established foredune, indicating some level of resiliency; these transects are located along a stretch of historically low accretion. The exception was two transects in Ma-le'l North located in an area of previous foredune loss. These transects indicated low resiliency. Ma-le'l South, an area of low accretion, included a section where the foredune has deteriorated to nebkha, indicating low resiliency. Other parts of Ma-le'l South showed a mixture of low to moderate resiliency. Friends of the Dunes and Manila Community Services District generally exhibited moderate resilience with loss of *Ammophila* incipient foredunes, and were characterized by historic low accretion. To the south, Samoa Pacific, Fairhaven Power, Cal Redwoods, and City of Eureka all underwent net erosion and indicate low resilience. Samoa Pacific transects were located in an area of low accretion, while the others were not classified due to a lack of statistical significance. The Samoa transects appear resilient, despite being located along a stretch characterized by high historic erosion of the shoreline. The South Spit generally showed a resilient trend and occurs along a stretch of historic medium accretion. Table Bluff, the narrowest point of the barrier, lacked resilience. The abundant large wood at the Eel River Wildlife Area conferred resiliency on this site, which has historically exhibited medium accretion. The Eel River Estuary Preserve and Russ sites were net erosional, with loss of foredunes, have very low resilience, and are located in an area of historic medium erosion.

Overall, the littoral cell exhibits variety in foredune type, vegetation, historic erosion/accretion patterns, and resilience. The area showing the greatest deposition as well as a history of high accretion, is at the north end of the cell at Little River/Clam Beach, and the area of greatest erosion, both currently and historically, was Eel River Estuary Preserve and Ross. Other areas of interest are Mad River, Woll and Long, which have historically had medium accretion, but had such high steep foredunes that they were unable to recover from the two years of high water events. The Bair site (Lanphere Adaptation Site), located adjacent to these, showed high resilience in the restored area. The Lanphere and Ma-le'l sites were characterized by incipient foredunes that had formed since 2012, and which eroded but protected established foredunes in these areas, conferring moderate resilience. it is unknown how these features will recover although historically this stretch of shoreline has intermittent incipient foredunes (Pickart and Hesp 2019). With exceptions, morphodynamic behavior reflected the historic condition of accretion or erosion. The extreme erosion of the south end of the littoral cell may also be related to subsidence.

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Acknowledgments

We thank the following individuals who assisted with field work over the five years of the project.

Susannah Ferson
Scott Christ
Michelle Forys
Lee Ann Morriss
Carol Vander Meer
Ezekiel Currier
Andrea Pickart
Candace Reynolds
Britta Countryman
Aliya McCarthy
Ana Carter
Alana Rader
Eric Nelson
Nathan Saltz
Elissa Blair
Alex Blessing
John Herrera
Kurt Roblek
David LeFever
Sam Flanagan
Mike Van Hattem
Kelsey McDonald
Kaleb Goff
Steve Harrison
Sean Binninger
Kim McFarland
Rose Dana
Sam Andres
Jess Barger
Ryan Arsenault
Joey Ferber
Danny O'Shea
Annie Eicher
Christine Cosby
Elizabeth Wu
Jenny Hutchinson
Laurel Goldsmith
Aaron Katz
Clint Pogue
Katie Siedel
Mackenzie Spencer
Jen Olson
Katelyn Southall
Emily Moloney
Kevin Landaw
Charlotte Hayes
Barbara Reisman
Madie Hassett
Nicole Bejar
Monique Sliva-Crossman
Riley Browing
Caitlin Ehnow
Steven La Pointe
Zach McKeown
Vladamir Berg
Andres Rodriguez
Ashley Disney
Katrina Henderson
Alex Mouritzon
Erica Siepker
Taylor Pantiga
Jason Leung
Shayden Fakhimi
Alyssa Suarez
Isaac Henderson
Mina Mayer
Tamara Yanin
Claudia Voigt
Matt Ford
Evelyn Lichwa
Tina Giudici
Veronica F?
Antoinette Esposito
Erika Burton
Jillian Zimmerman
Crystal Weld
Marena Yarnell
Marisa Parish
Ross Schaefer
Mike Leone
Brit Taylor
Cara Christensen
Mia Sundstrom
Wes Smith
Jack Ortega
Jolyon Walkley
Brenden Leigh
Conor Shea
Suzie Fortner
Emily Allee