HydroBio
Advanced Remote Sensing

April 13, 2012

2012 Assessment of Dune Movement Near Keeler, California

Prepared for Great Basin Unified Air Pollution Control District

Abstract

Dune movement on the northeast corner of Owens Lake shoreline near Keeler has given rise to a fugitive dust problem. This report is the fourth in a series of dune analyses initiated in 2008. This report provides the March 2012 update of dune surveys for four locations selected in October 2008. These transects were used to monitor the movement of the dune field to the southeast in all years since 2008. The position of the dunes in 2012 is compared to dune positions on satellite imagery in 2002. Dunes have moved faster in the south, a process that has led to reworking of the dune material, likely loss of fine particles and progression toward discrete barchan dunes. Vegetation cover has been lost during the past decade. Dune movement in the north has been much less than in the south.

1. Introduction

A preliminary assessment of the movement of the sand dunes near the community of Keeler, California was conducted in 2008. In that assessment, five tasks were established, (1) determine a sand budget to understand where the sand is moving, (2) evaluate wind data to assess how wind has influenced dune movement, (3) determine the direction and rate of dune movement through the Keeler dune field, (4) determine the rate of movement and winnowing of the dune material to determine whether fine particulate releases are a temporary or long-term problem, and (5) determine how to mitigate this problem.

As part of the first task in the assessment, the dunes were visited with staff from the Great Basin Unified Air Pollution Control District during October 2008 and a series of transects were established in order to provide a benchmark for assessing sand budgets. These sites were re-visited in October 2009 and 2010 to identify change within the dunes. This report is a continuation of the *Preliminary Assessment of Dune Movement, and Factors Influencing Air Quality and Potential Mitigation Near Keeler, California* and compares the data observed in 2008 through to the current early 2012 observations.

In addition, a 10-year examination is made of example dunes within the Keeler Dunes area. Using current aerial imagery and earlier satellite imagery, comparisons were made to plot the movement of the dunes over a longer time period than provided by the four years of transect measurements.

2. Field methods

Four sites selected for the analysis, which were described in more detail in the initial assessment (HydroBio 2009. Preliminary Assessment of Dune Movement, and Factors Influencing Air Quality and Potential Mitigation Near Keeler, California). These transects were placed in various locations around the dune field in order to determine the direction of dune movement and to gauge how much material was moving on the dunes through examination of inflation and deflation along the transects (Figure 1). These sites were visited during the same season for consecutive years 2008-2010. The current assessment occurred in late February while earlier evaluations were made during October. The February 2012 results are documented in this report and compared to earlier data.

2.1 Data Collection

Field data were collected using Global Positioning System (GPS) points to mark the beginning and end of each transect that were originally monumented using rebar stakes that were pounded into the ground. Elevation data were calculated from laser level measurements taken every 10 meters beginning and ending at starting monument locations on opposite sides of the dune or dune fields—many of the rebar monuments were buried by sand. These data sets were collected in October for three consecutive years to identify sand movement in and around the dunes. All datasets of elevation surveyed at the dunes were plotted for comparison to the 2012 data..

2.2 Aerial Photography

Nadir-look aerial photos were taken of the transect region with two Nikon D90 digital SLR cameras, flown at about 3000 ft above ground on March 9, 2012, to capture high resolution imagery of 11.18 inches. The high resolution imagery was then compared to imagery captured in 2009 and 2010 from the same camera setup.

Additional images were used where necessary to fill any missing data gaps in or around the transects. The additional imagery were taken in 2010 from altitudes of 500 and 1500 ft. Only two dunes had missing data gaps within the transect lines, dunes B and C.

Quickbird satellite imagery was also used to provide a longer frame of reference to monitor the dunes. Scenes from 10/16/2002 and 02/24/2005 were available that provided coverage of the Keeler Dunes, although the 2002 scene does not cover the extreme southern edge of the dunes.

3. Analysis

Noted in the initial assessment, transect sets B-E were intended to provide sufficient data to establish a sand budget within the dune field (Set A is located east of Highway 136, outside of the Keeler Dunes). In 2008 it was observed that the northern portions of the dune field had different characteristics than that found to the south. A series of initial hypotheses were formulated to be tested when the transects would be resurveyed. These hypotheses were:

- The dunes in the northern portion of the field are deflating and have been transported onto the alluvial fan to the east.
- As the dunes deflate, the coarser particles are left behind leaving a “lag deposit” that is resistant to erosion.
- The formation of dunes is inhibited by the upwind location of thick greasewood growth.
- Dunes are formed through reworking by the wind. Reworking of the dune material may winnow out the fine particles and thus, reduce air pollution concerns over time.

Subsequent surveys have now shown the northern dunes to be shallow but still capable of significant movement. This has become particularly visible in 2012, as the eastern transects of Dunes B and C have shown significant shift of mass from previous surveys. And while it is obvious that material is starting to accumulate on the eastern alluvial fan, the majority of the blown material is moving to the southeast.

Thick vegetation along the southeastern edge of the Keeler Dunes could provide some means of inhibiting the wind and acting as sand traps, but the existing greasewood and other shrubs are simply being overwhelmed by the encroaching dune face. The dune face at the most southern edge that is encroaching thick shrub cover is 6 feet high or greater, and this allows the saltating sand grains to fill in on the slip face of the dunes and then gradually bury the shrubs. Current movement rates of this leading face show no signs of slowing due to the vegetation it is burying.

The rate of movement across the entire dune field seems constant to the south and east with particular windy periods, such as between 2009 and 2012 contributing to an increase in sand movement. In particular the current examination shows a large amount of sand divorced of the dune field and instead deposited in a thin (less than 1 foot thick) sand sheet general sand sheet across the upper slopes of the east side of the valley. This includes deposits on the east side of Highway 136 which had been noted previously but is now present to a much greater degree.

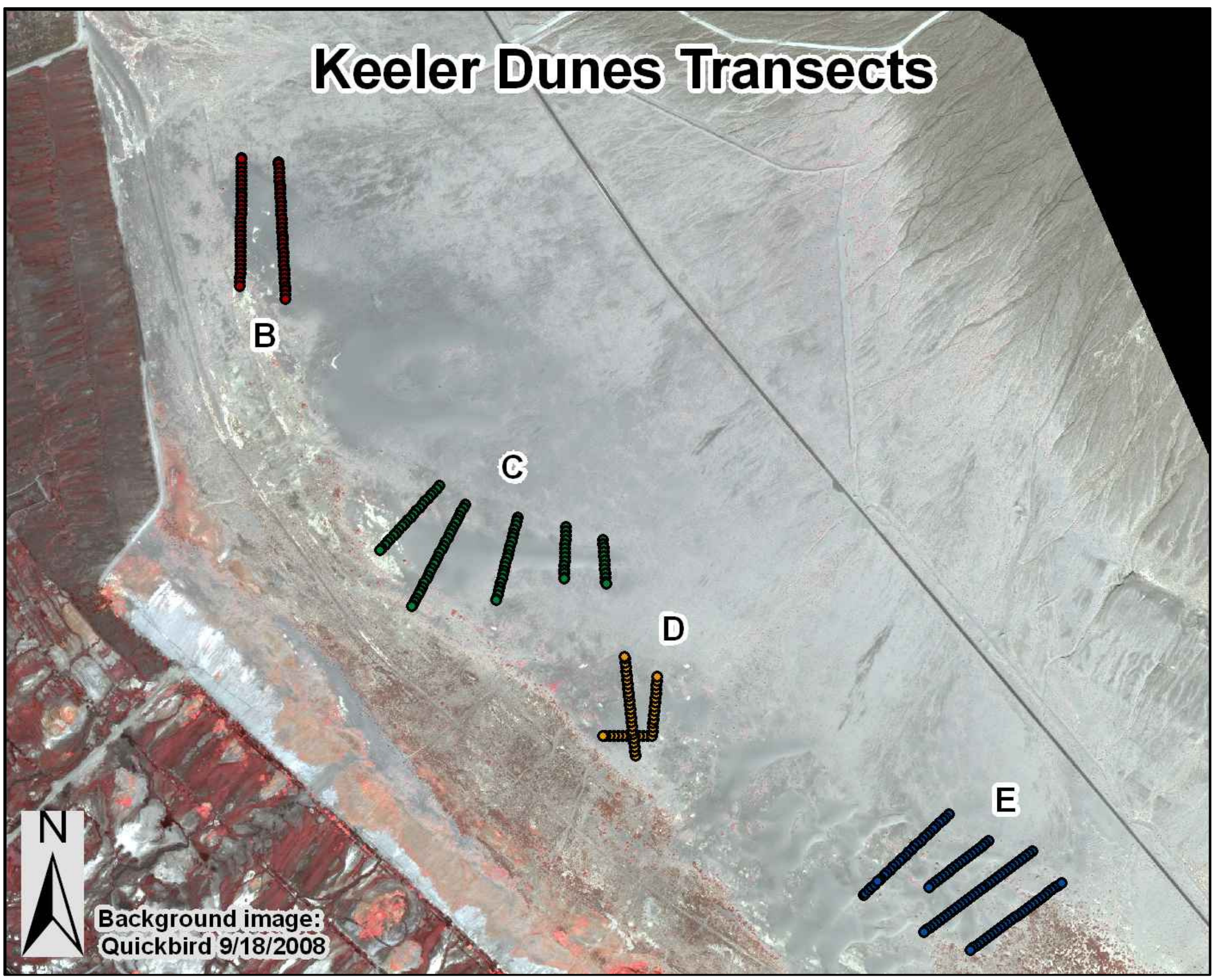


Figure 1. Locations of dunes for the 2008 – 2012 analysis displayed on the 2008 Quickbird image.

Dune B Analysis

Dune B, the northernmost of the studied dunes, is a shallow sheet of sand that lacks the discrete dune structure visible toward the south (Figure 2). Two transects have been used to monitor Dune B.

The transect analysis shows that Dune B elevations remained relatively stable until the last field visit (Figure 3). The 2012 results show scouring on the western transect and deposition on the central part of the eastern transect. Shrubs in the vicinity of Dune B experienced partial burying, mounding, and micro dunes trailing off toward the southeast (Figure 4). Transect 1 was scoured of sand that had built up around vegetation as at least three isolated spikes in elevation are now flat. Rather than moving from the region of Transect 1, the much greater depth of sand that aggraded on Transect 2 was likely transported from the region west of the dune.

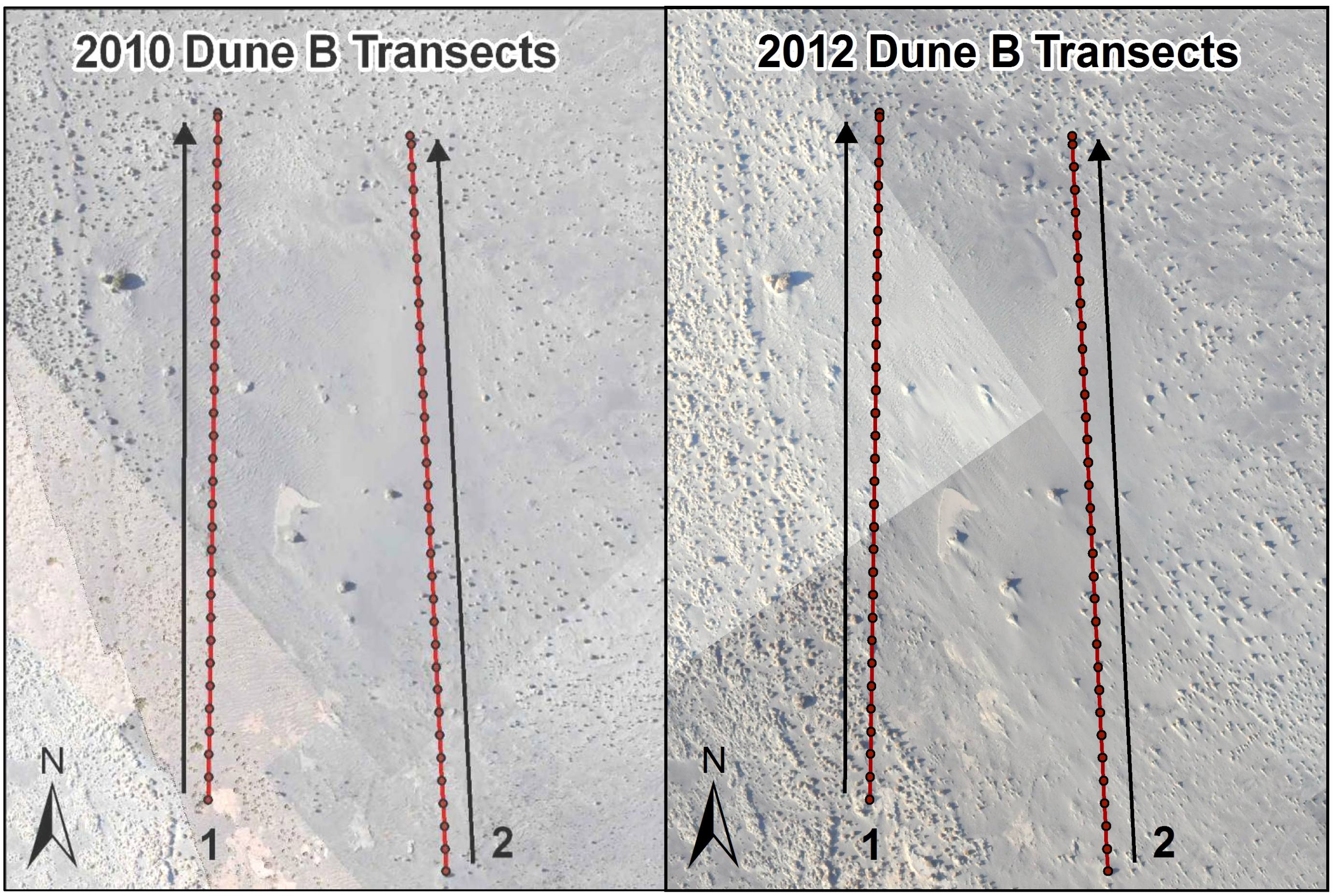


Figure 2. Comparison of aerial imagery collect over transects from Dune B data collected in October 2010 (left) and March 2012 (right). Note: 500 ft and 1500 ft imagery were included in the southwestern corner of transect 1 to fill missing data from the 3,000 ft imagery in 2010.

Figure 3. Transects from Dune B data collected in October 2008-2010 and in March 2012. A new pattern has developed in the 2012 data where previously this dune had been fairly stable. The western Transect 1 has become deflated in places along its northern half and Transect 2 has seen the deposition of up to an additional half meter of sand. Both signify movement of material from the north to the southeast.

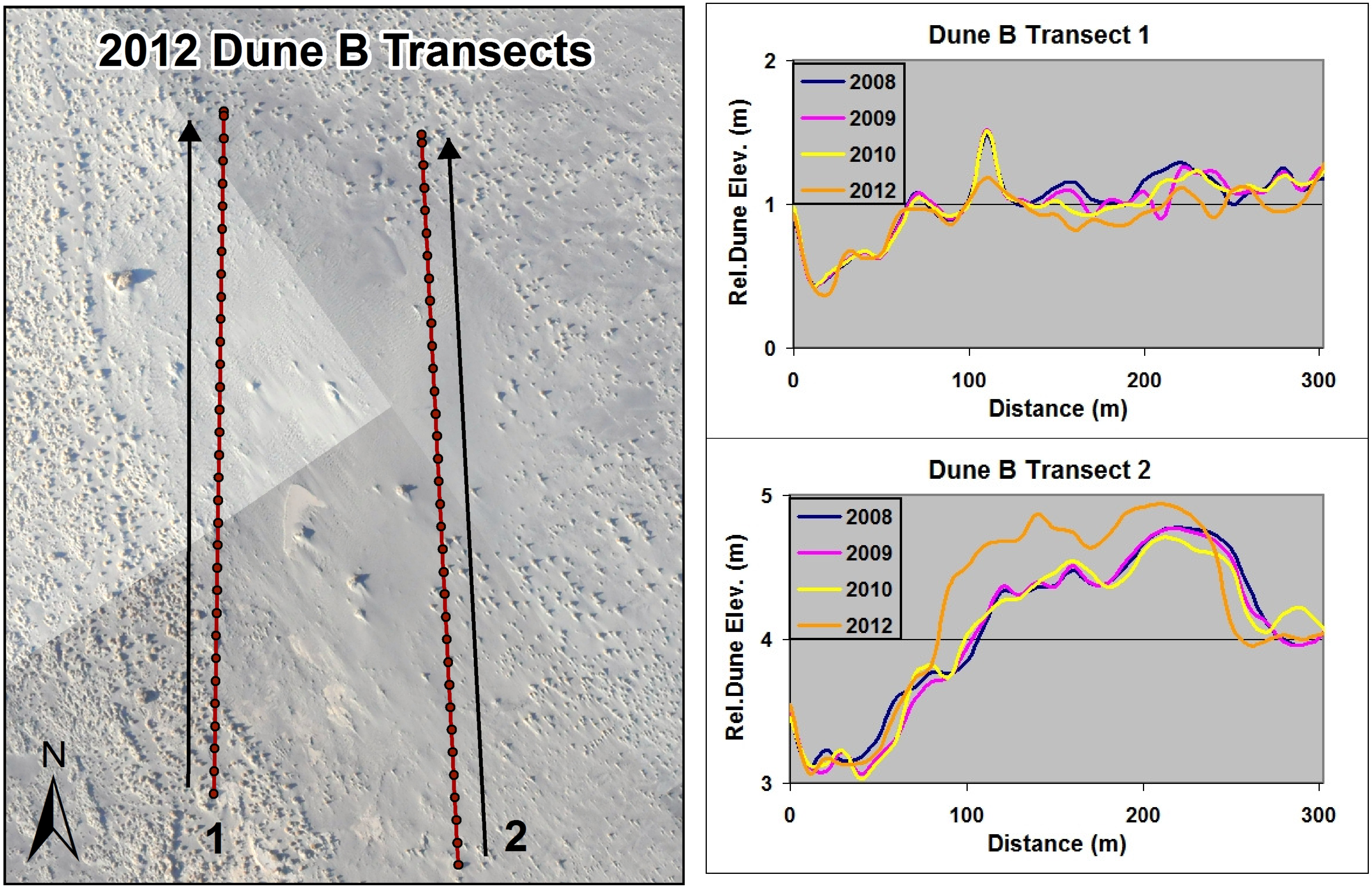
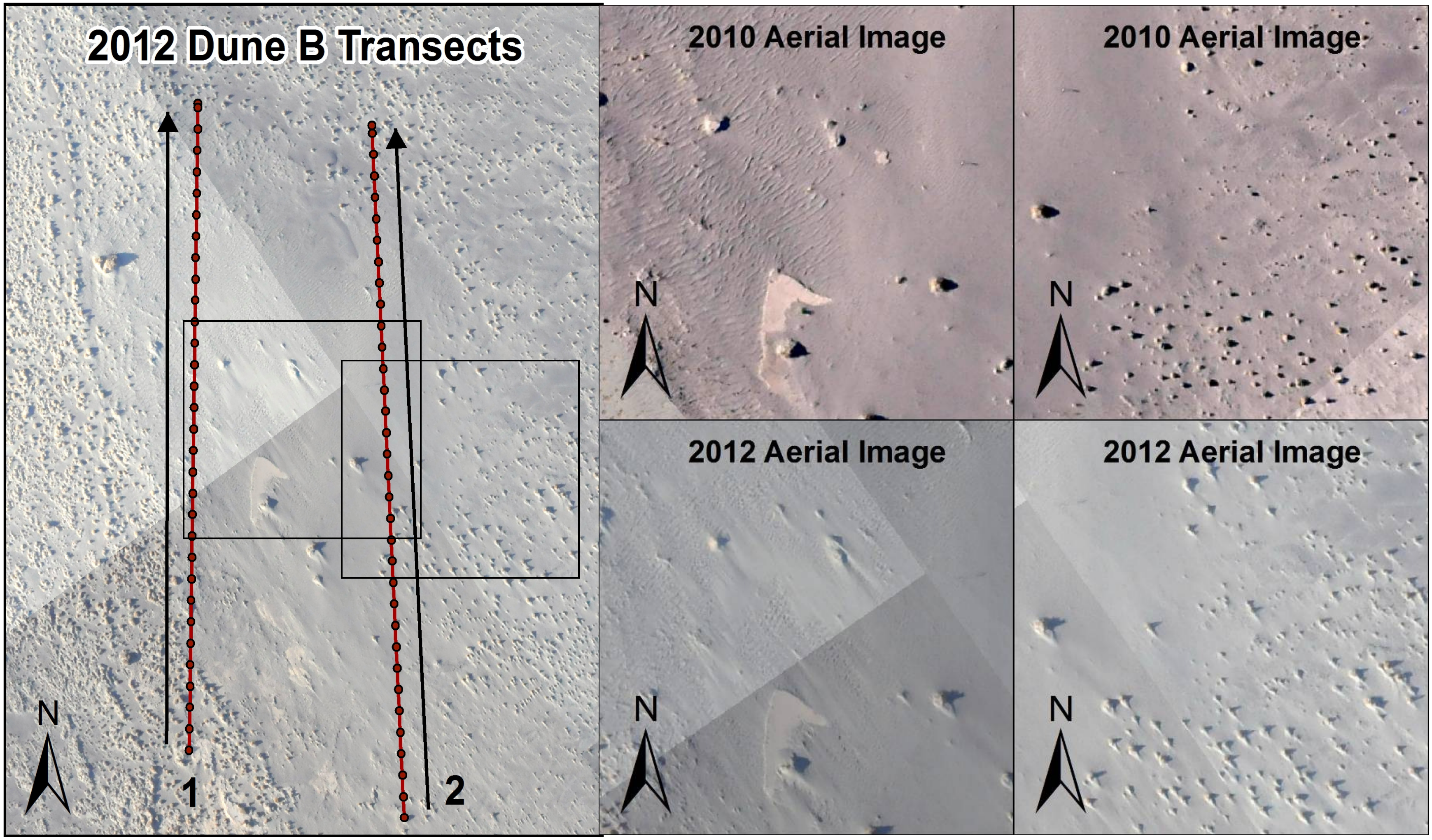


Figure 4. Examples of changes in Dune B from October 2010 to March 2012. Vegetation east of Transect 2 show signs of recent burial and dune tails evident of strong northwest winds. Previous ripple formations of sand in the center of Dune B are now buried in loose blown sand.



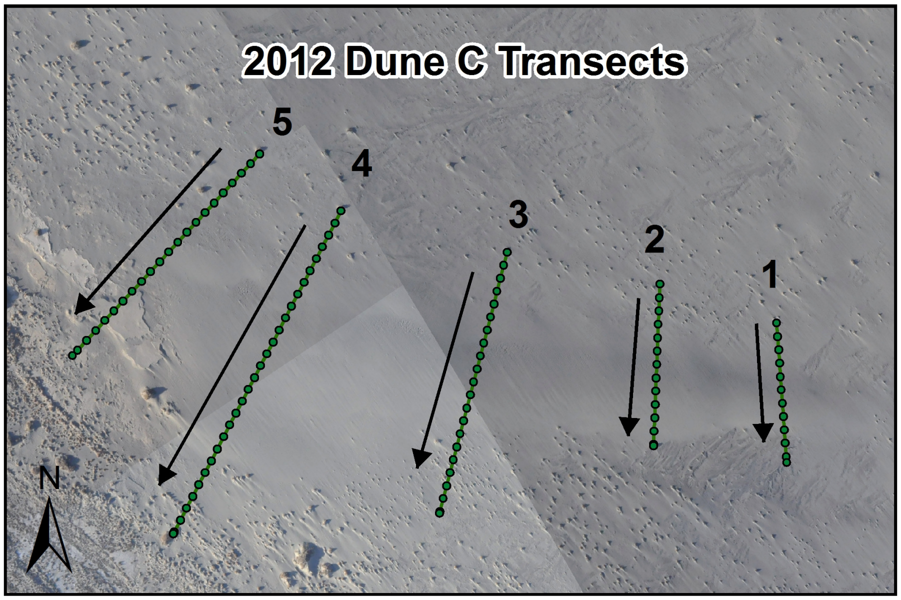
Dune C Analysis

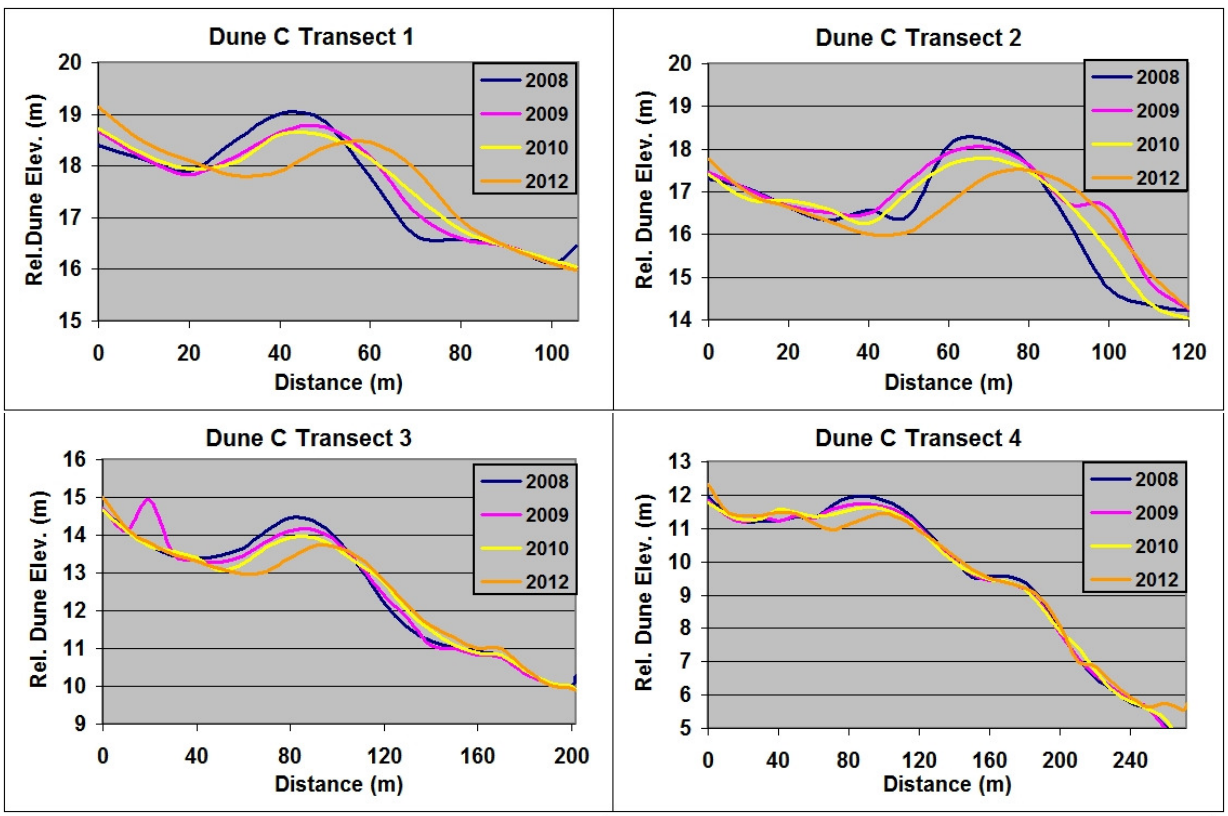
Dune C is a long linear dune that trends east-west ending in an eastern point. Dune C rises to its highest relative elevation in the center, and is wide and diffuse in the west (Figure 5). It is isolated from the larger, more active dunes to the south. Over the past 4 years it has progressed to the southeast matching general trends across dune field.

Dune C is losing elevation as it moves. Transects 1 through 3 show a drop of approximately one half meter as the dune apex has moved 15 m southward in the four years of monitoring (Figure 6). Over the past 10 years this movement has varied between 27 and 60 m along the entire face of the dune.

The west end of Dune C, Transects 4 and 5 have deflated. The volume of Dune C has reduced as it has moved to the south with evidence being the reduced cross sectional area through the majority of the transects. This reduction in volume suggests that particles have been lost from Dune C, perhaps, the removal of finer sands by saltation or winnowing (lofted fines).

Figure 5. Comparison f the October 2010 air photos (top) to the March 2012 air photos (bottom).





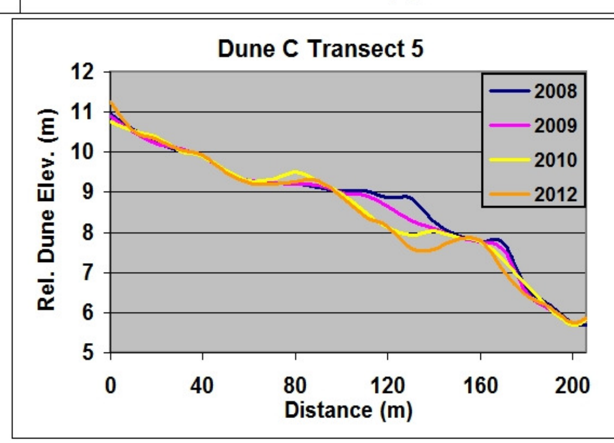


Figure 6. Transects collected for Dune C in October 2008-2010 and March 2012. Similar to Dune B, the Dune C data show slight deflation in the west (Transects 4 and 5) and significant movement in the east (Transects 1, thru 3).

Dune D Analysis

Dune D is a sand sheet that lacks discrete dune form and in this, is similar to Dune B. The 2012 analysis of Dune D also closely parallels the results found further north in Dune B. Here, the sand sheet has also shifted to the southeast (Figure 7). The origin points for both Transects 1 and 2 were buried by over a meter of sand since October 2010(Figure 8). This increased deposition is sourced by the scouring on the western half of Transect 1 and the middle portion of Transect 3. Buried vegetation is quite very evident to the southeast with large trailing dunes pointing windward. Surrounding the dune field there is a very thin sand sheet that seems to have developed over the surrounding landscape likely blowing off of Dune C to the north.

The future will likely see a continuation of the current trend of south and east movement. Additional sand is entering the vicinity from Dune C to the north. The rapid buildup of sand in the southeast could be signs of the incipient development of a formal dune, as this dune is just north of the series of formal Barchan dunes that incorporate Dune E.

Figure 7. Comparison of the aerial 2010 imagery (left) to the 2012 aerial imagery (right). Deposition of blowing sand sheets burying vegetation clearly evident along transect 2.

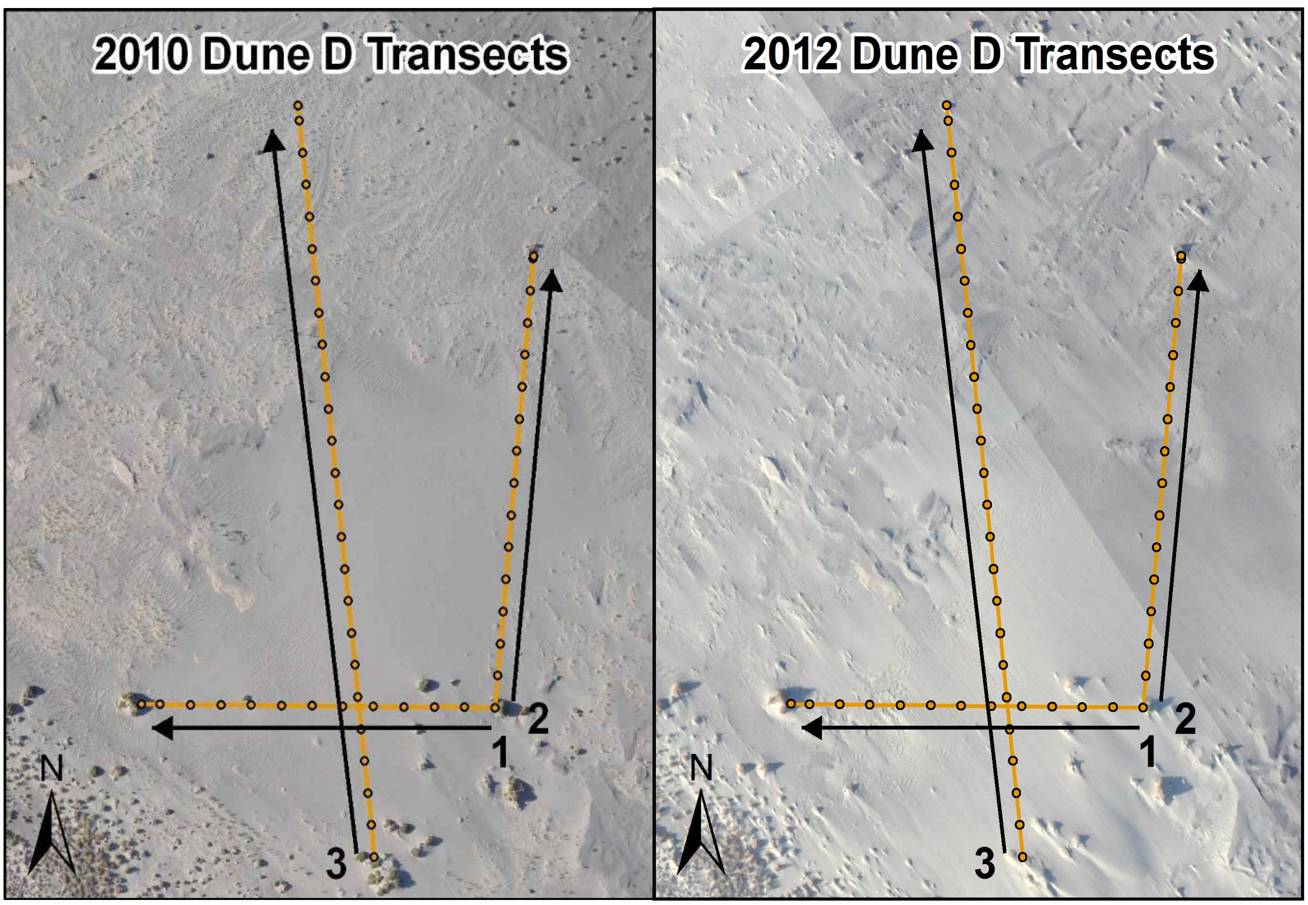
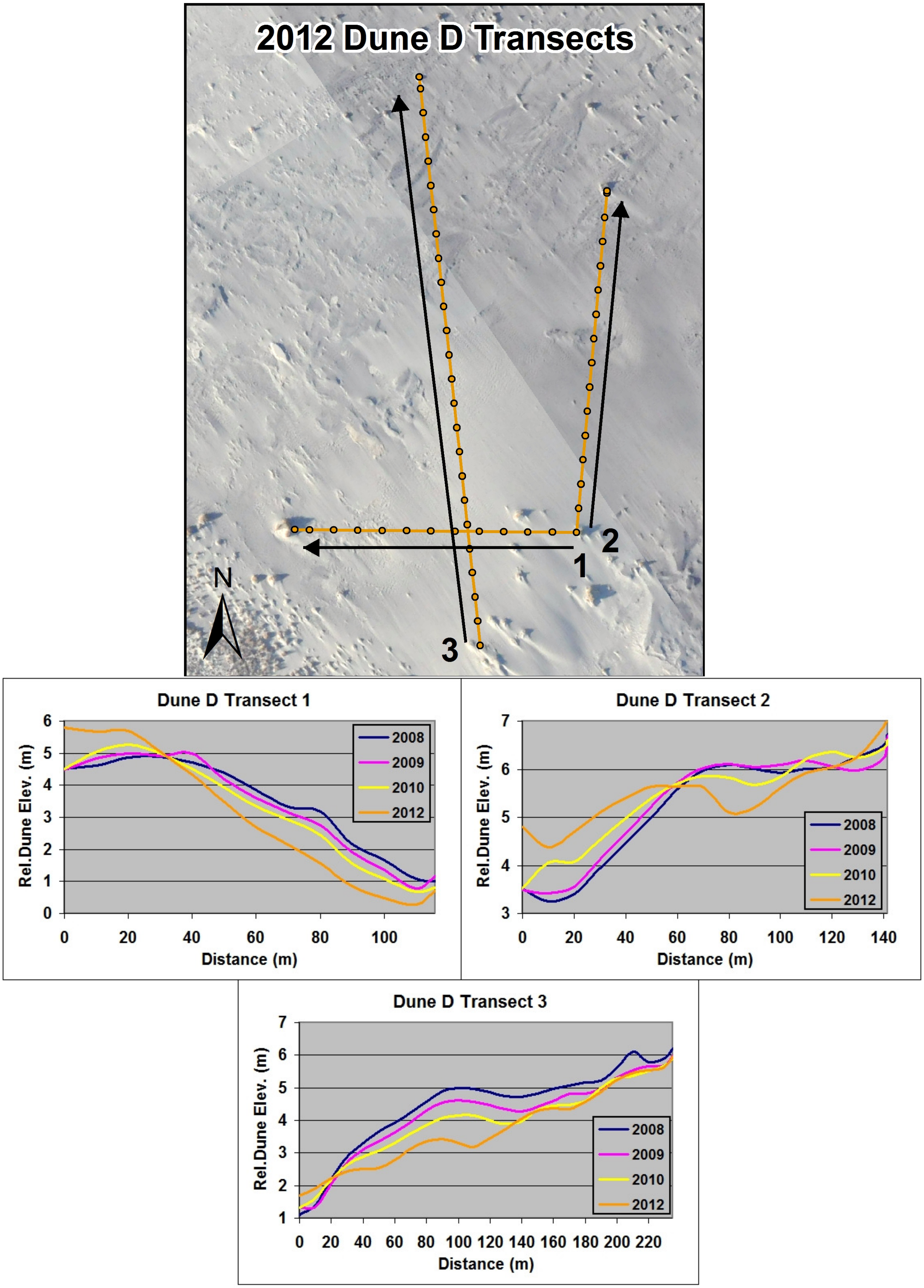


Figure 8. Transects for dune D collected in October 2008-2010 and in March 2012.



Dunes E Analysis

The Dune E region covers an active dune field of many discrete dunes and is the largest and most active portion of the Keeler Dunes. The majority of the Keeler Dunes' sand budget is contained in a series of large barchan dunes in this region. Dunes E have been moving consistently south and east for many years. Thick vegetation on the southern edge of the dune field has impeded the southeast dune movement, where sand is now encroaching and burying vegetation in sand up to several meters thick. This is displayed on Transect 1 (Figure 9).

The Transect 1 profile shows approximately two meters of sand have aggraded on this southern edge (Figure 10.), in addition to the southern face of the dune moving 50 m southeastward. Transects 2 and 3 are in area that forms a sand sheet that may be nascent barchan dunes. Transect 4 is located in a region of discrete barchan dunes. The southwestern edge of this transect recorded a drop in elevation resulting from passage of the dune crest to the southeast now leaving the end transect point on the sloped backside of the dune.

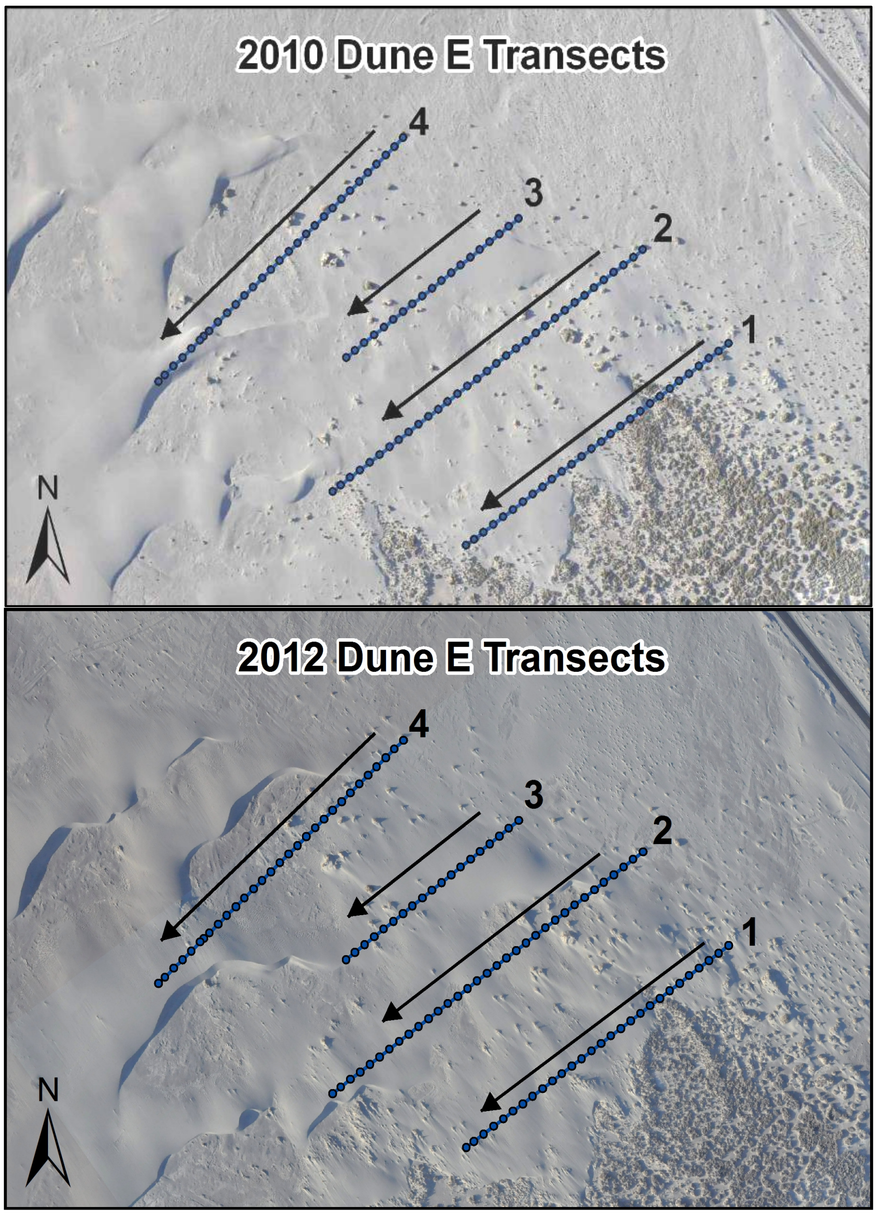
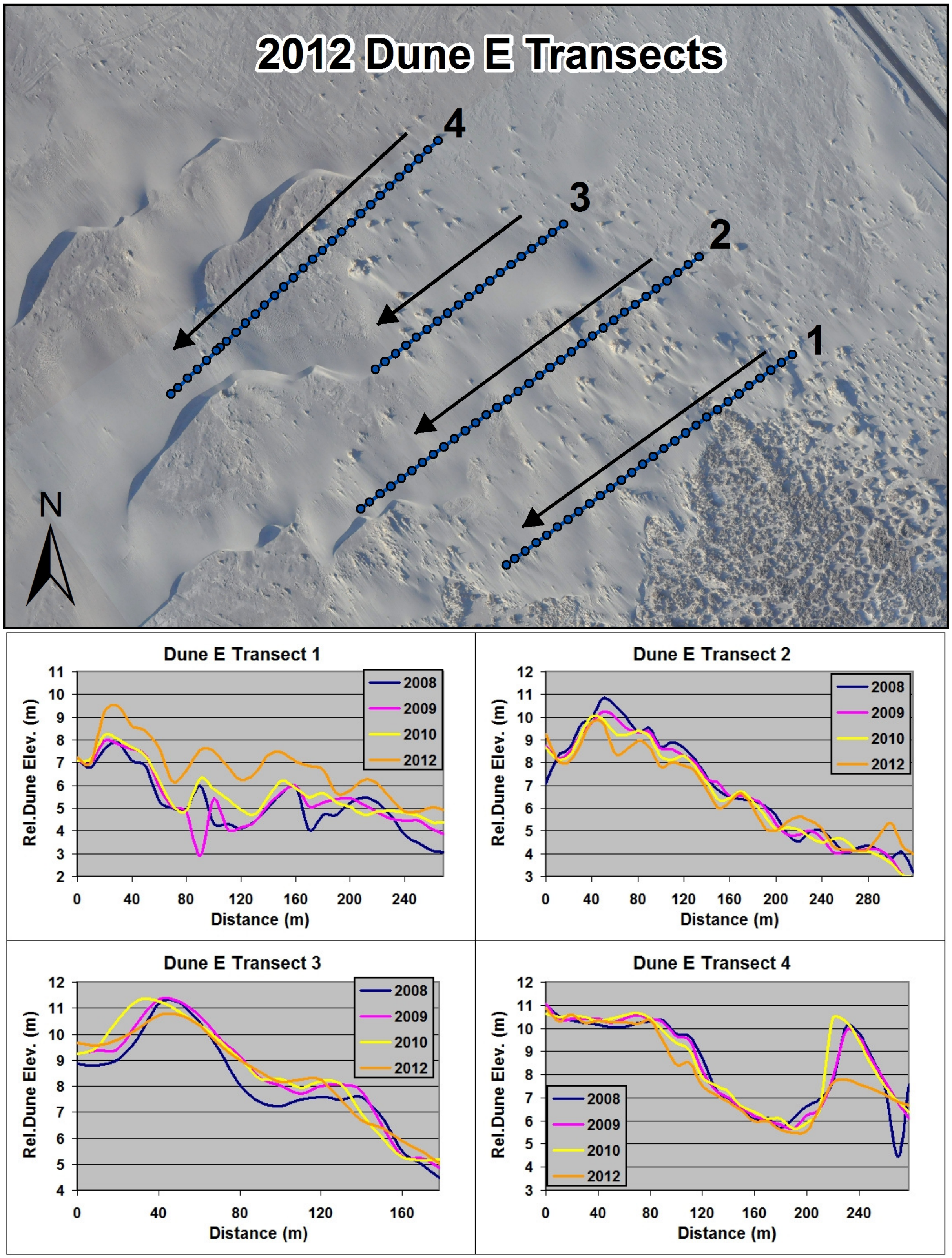


Figure 9. Comparison of the October image (top) to the March 2012 image (bottom). Large dune movement is clearly visible in the 16 months intervening period.

Note the vegetation at the SW end of Transect 1 that was inundated in the 16 months since the previous photo. Close examination of these air photos shows that the remaining shrub cover is being inundated by sand throughout the image.

Figure 10. Transects for Dune E collected in October 2010.



Long Term Dune Movement

As the Keeler Dunes are progress to the southeast the sand that is reworked by the wind in the progression is subjected to winnowing, separation and sorting of particles by size. The action of wind in the winnowing process exports finer particles while leaving the heavier sand behind in the dunes. In Figures 11 and 12, large barchan dunes on the southern edge of the dune field have been moving an average of about 10 m a year (Figures 11 and 12). Because the dunes themselves, are generally less broad than movement that has occurred, all the sand within the dunes has been reworked. This complete movement of dunes from one location to another means that all sand deposited in the previous location was eroded and deposited downwind. When dunes are reworked, the finer particles are winnowed from the sand mass and if the particles are sufficiently fine, silt sized or less, they will tend to depart the system as fugitive dust during wind storms. Dune movement is always episodic since high wind energy is necessary.

Figure 11. Ten-year dune progression (SW corner of Figure 10 image). The Dune face is marked with a colored lines for each snapshot.

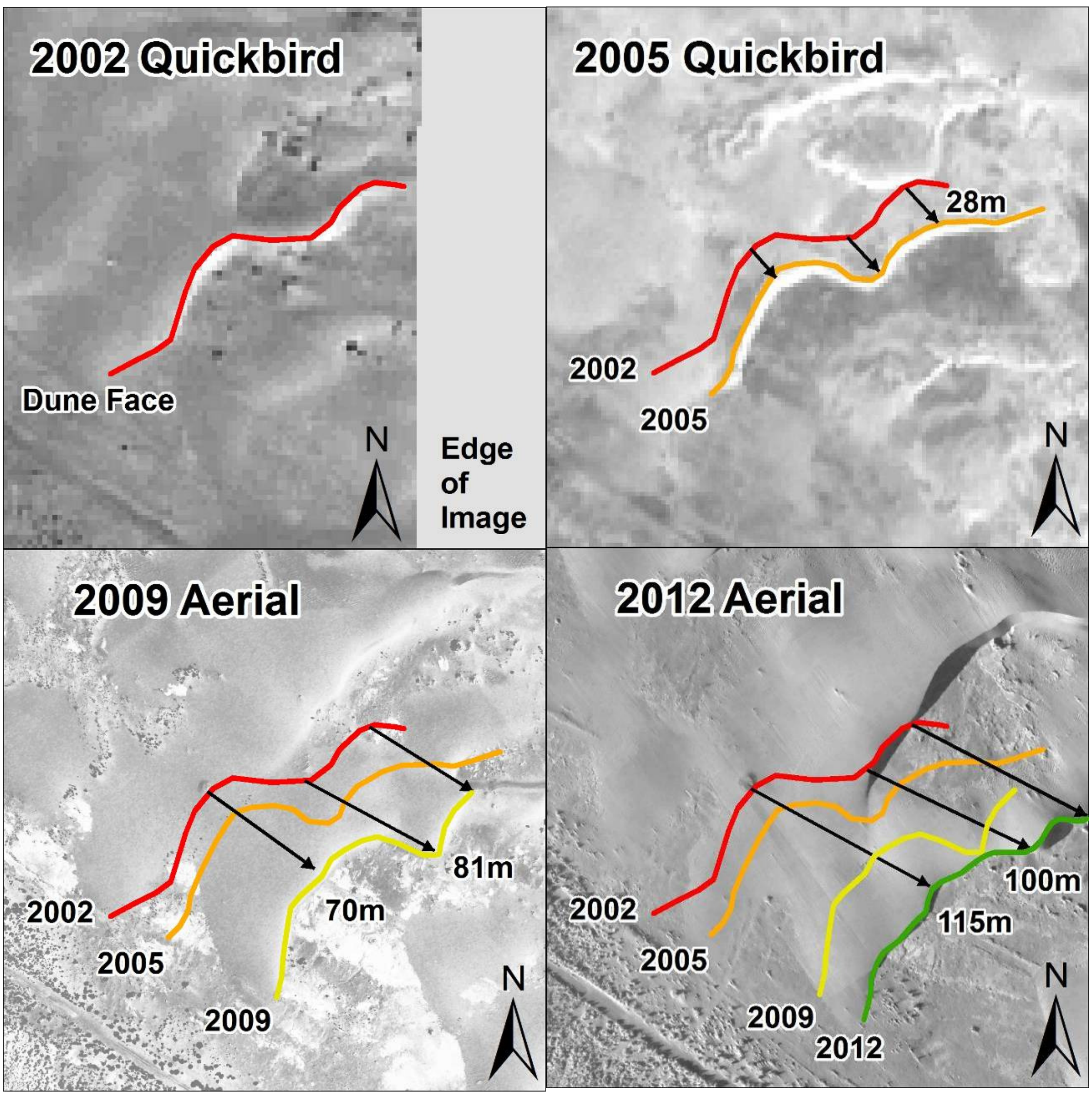


Figure 12. Ten year dune progression (W-center of Figure 10 image). The Dune face is marked with a colored line for each progressive year and the total advanced distance is noted.

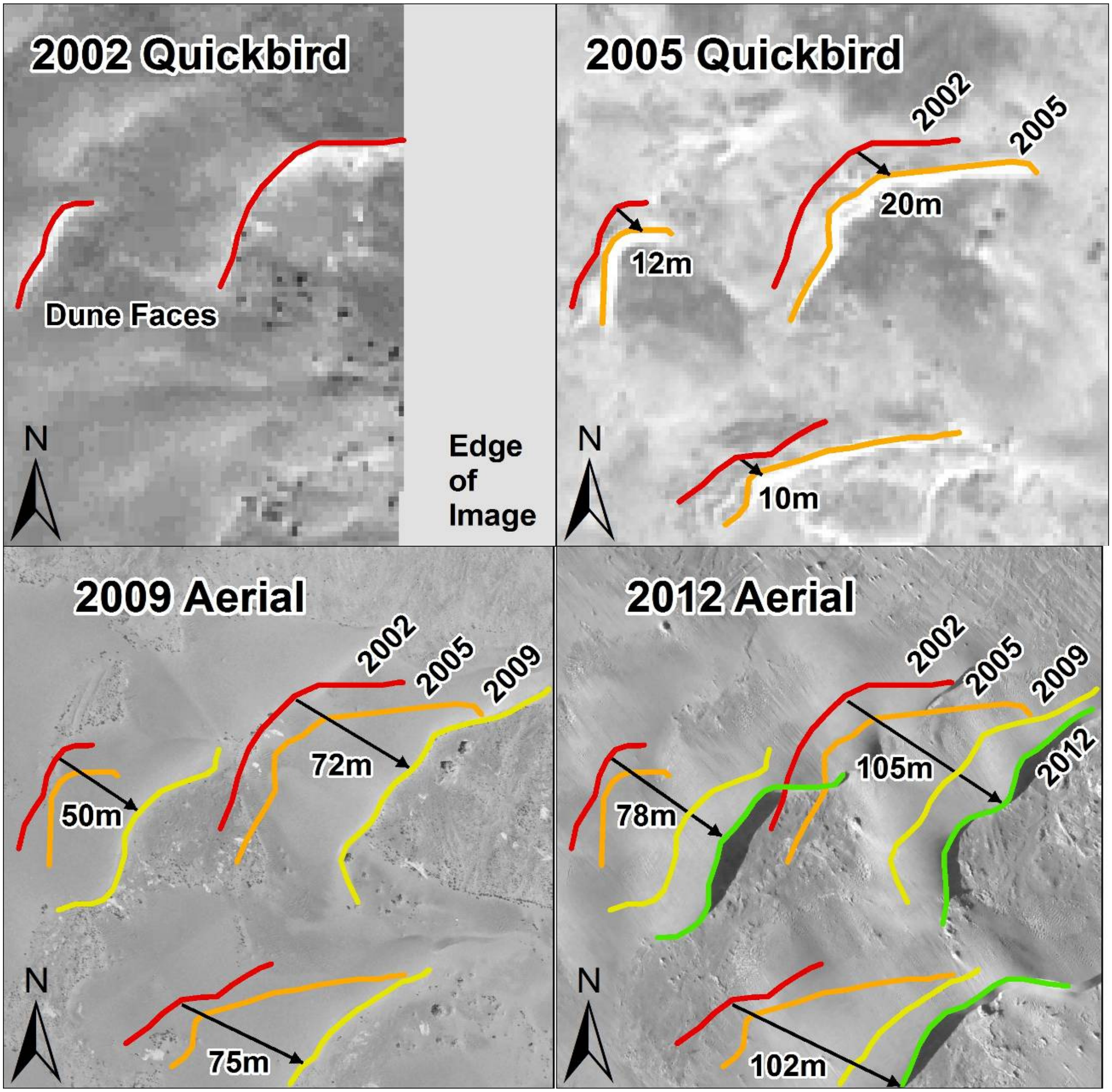


Figure 11 and 12 show three striking changes through the decade for the southernmost dunes: (1) coalesced and become more discrete; (2) moved a distance about equal to the sufficiently so that all or most of their material has been reworked; and (3) vegetation around the dunes has largely disappeared and those shrubs remaining are partially buried in sand.

Dunes have become more discrete over time and this fact has been noted in prior reports. The progression visible in both Figures 11 and 12 is from sand sheet to more discrete barchan dunes with the characteristic arcuate shape. One of the identifying characteristics for barchan dunes is having well-sorted grain size. Because all, or virtually all, of the material in each of the dunes has been reworked because they have moved completely or nearly so, the winnowing process noted earlier has occurred and presumably, the remaining material in the dunes has become well sorted—that is, all having about the same aerodynamic grain size. Wind-induced sorting is the likely factor that is governing the transition of dunes from sand sheets to barchan form.

Vegetation cover becoming severely reduced within the dune fields is an outgrowth of the time scales involved with dune movement and with shrub growth. Shrubs are the only permanent vegetation found within the Keeler dune field. The age of the shrubs may vary from a few years for small, rapidly growing species such as Parry's saltbush, to many decades and perhaps centuries for greasewood. Movement of dunes during the past decade have largely covered and then exposed locations where shrubs previously grew. Although shrub species such greasewood are associated with blowing dunes (for example the western shore of Mono Lake) and may benefit from the recharge of the water within dunes to grow, flourish and stabilize more sand, the rapid pace of dune movement near Keeler apparently overwhelms shrub growth capability. Hence, shrubs that may be multiple decades old have succumbed to the sand movement during only a decade of sand movement.

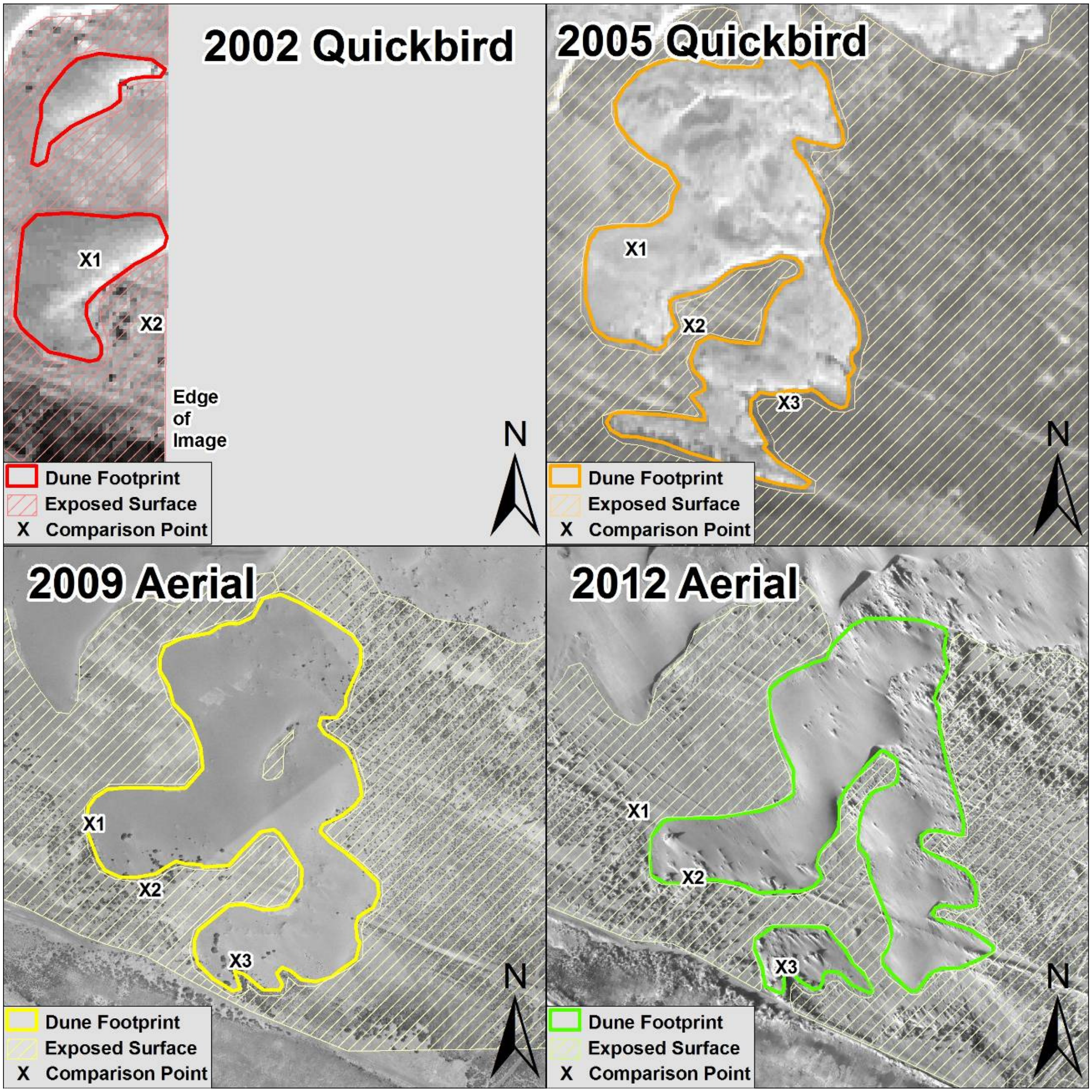
One factor that is notable for the dunes is that the sand sheets that have formed to the east have grown more pronounced and continuous. The effect of this sand sheet relative to perennial vegetation growth, again only shrub species, is a severe constraint. With exception of the vegetation along the former lake margin where water tables are close to the surface, the shrubs of the alluvial fan east of the dune field are being severely impacted by the sand that has moved out of the dunes. This impact is due to several factors: (1) burying and requirement for shrub regrowth through the deposited sand, (2) debriding of buds by saltating sand grains, and (3) sand transport that reduces water supply to the shrubs. Of these factors, probably (3) has the most effect for determining growth of shrubs.

The deposition and removal of sand within the sand sheet is an effective mechanism to restrict the water supply of the surviving shrubs. Consider recent deposition in an area proximal to a living shrub. The deposited sand does not contain roots of the shrub while root growth into this zone would require upward root growth, a rare occurrence in plants. Likewise, such layers, lacking roots, will be locations where rainfall will be held above the root zone and be unavailable. Finally, as wind action works on this near surface zone, it becomes an effective mechanism to transport the water out of the soil environment as successive layers dry and are removed. Thus, because of their instability, sand sheets are inhospitable to plant growth and will tend to cause the die off of any residual vegetation over time. This process is enhanced by the extremely arid climate of the Owens Lakeshore (ca 3 in/yr) since existing shrubs are operating near the lower limits of water availability for survival.

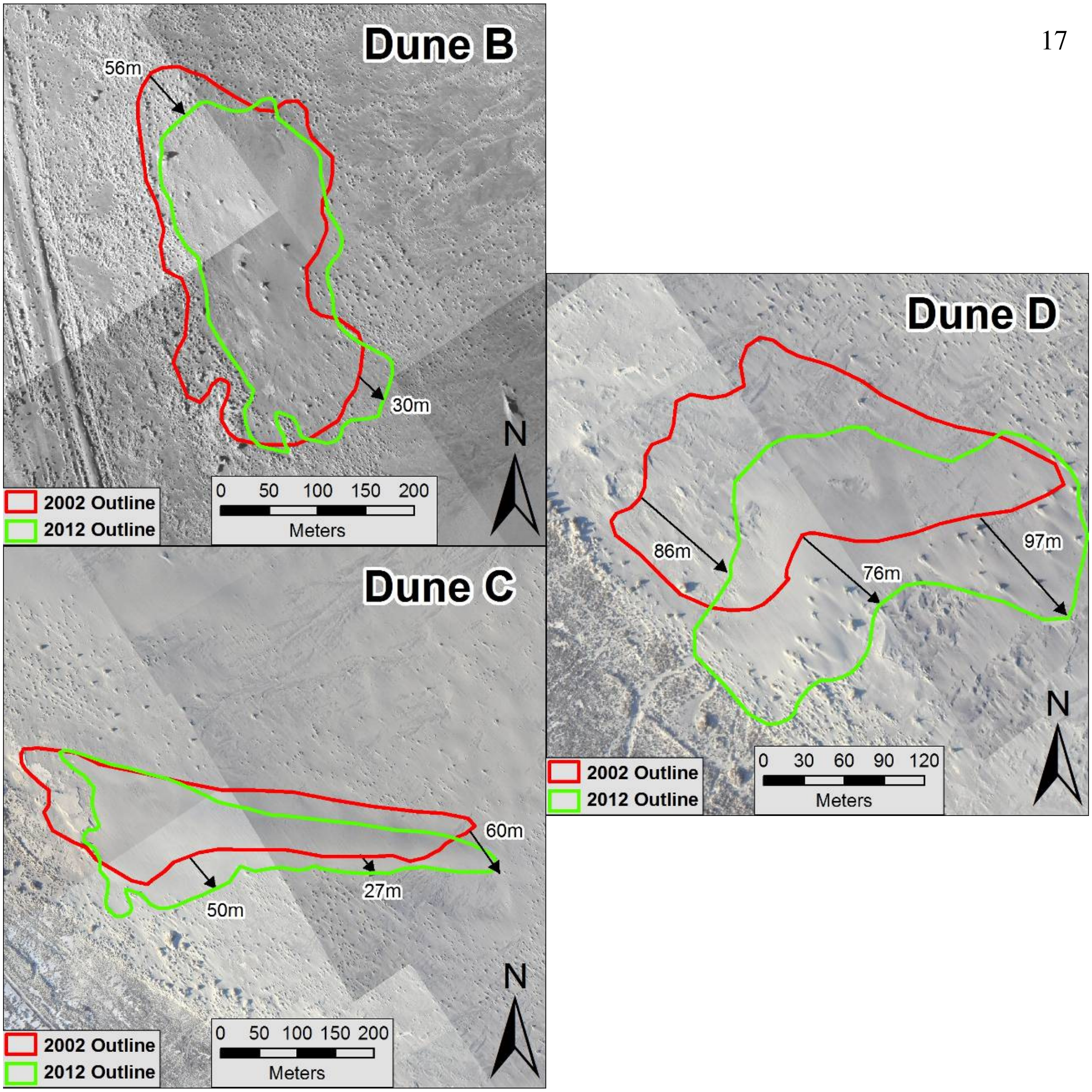
Figure 13 illustrates dune movement on the southern edge of Keeler Dunes in the vicinity of Dune E. The three highlighted point (X1, X2 and X3) demonstrate the cyclical nature of these dunes. Over a 10 year span, Point X1 went from being the center of a linear dune, to being the natural vegetated surface. Points X2 and X3 are the opposite in that they start as bare ground and within 10 years are buried.

The movement of dunes is highest in the south and much lower in the north. Figure 14 shows how the overall footprints of the individual northern dunes/sand sheets fields have moved in the past 10 years. Dune B has remained in about the same location with a comparatively small amount of movement. Dunes C and D, at their current rates, are likely to have the majority of their material moved completely beyond their original footprints during the next decade, but have not done so yet as has occurred in the southern portion of the dune field.

Figure 13. Located on the southeastern edge of the Dune E area (Figure 10), a 10 year progression. Points X1, X2 and X3 provide comparison of the relative dune locations.



The Dune E sample is a complicated field of dunes, but the overall movement rate and the general thicknesses of dunes indicates dune material recycling has occurred (Figure 15). The Dunes have progressed approximately 100 m in 10 years with several of the individual dunes only 40 to 75 m wide, demonstrating virtually complete movement of much of the Dune E complex during the past ten years.


Dune B
56m
30m
N
2002 Outline
2012 Outline
0 50 100 150 200
Meters
Dune C
60m
50m
27m
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2002 Outline
2012 Outline
0 50 100 150 200
Meters
Dune D
86m
76m
97m
N
2002 Outline
2012 Outline
0 30 60 90 120
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