Dr. R.A. Marston
Co–Editor–in–Chief, Geomorphology
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Raleigh, May 18, 2005

Dear Professor Marston,

please find enclosed 4 copies and CDROM with a revised manuscript entitled: "**GIS analysis of dynamic geomorphological features: Jockey's Ridge, North Carolina coastal sand dune field case study"** (the original title was: "Natural Processes and Human Impacts: The Dynamic Evolution of a Coastal Sand Dune Complex at Jockey's Ridge, North Carolina"). We have revised the manuscript according to the valuable comments of the reviewers and adjusted the formatting as required for the journal. The detailed description of the revisions is attached. Thank you for considering our paper for publication in Geomorphology,

sincerely,

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List of changes and answers to the reviewers comments

Editor
Formatting was adjusted for headings, table, references, and figures.
Metric units were used throughout the paper, with feet added in parenthesis when referring to the data on maps where feet were used.
Sentences with "it is" were reformulated.
Capitalization, commas and other changes were done as suggested in the manuscript, and llt was corrected to LLC.

Dr. Whittekar
Reference to US Coast and Geodetical Survey, 1955 is the same as Graber 1953, it was changed to Graber 1953 and added in the text where appropriate. References in press were published and proper information was added. Additional detail was added to on−line references where possible.

Units were fixed for Figure 4a,c (deg, m^2)

In Figures 6 and 7 the captions were changed to better explain the active dune subregion:
...area change for the active dune subregion with elevation z > 6 m and no vegetation.
...Overlay of active dune surfaces (subregions without vegetation where elevation z > 6 m),...

Darker figures were made lighter.

Dr. Havholm
Minor typographical and wording changes were made as suggested in the manuscript.

1. Title was changed to: GIS analysis of dynamic geomorphological features: Jockey's Ridge, North Carolina coastal sand dune field case study.

2. Abstract was completely rewritten to include the results.

3. The relevant section was modified as follows: For each month of the year, the 18 yr average of the mean monthly wind speed exceeded 4.5 m/s critical velocity needed to move the sand. In addition, the annual wind rose for 1982−1999 indicates that stronger winds (7−20 m/s) from the north and northeast are more frequent (USACE FRF, 2004), resulting in greater sand transport to the south and southwest. This conclusion is also supported by the sand transport rose for 1980−1991 (see Fig. 1 by Havholm et al., 2004).

4. Sentence was modified as follows: ... GIS database with multitemporal data layers representing topography and its properties (slope, curvature, peaks, etc.) was established.

5. After the NOAA reference to Historical Charts Archive was changed as follows,
no a,b was needed for NOAA references:
NOAA Office of Coast Survey, 2004. Historical Map & Chart Collection.
Online document, http://historicals.ncd.noaa.gov/historicals/histmap.asp

6. The sentence was simplified as follows: The published vertical accuracy of the data is 0.06

m for spot elevations and the horizontal accuracy is 0.30 m.

7. The sentence "Similar values ..." was removed – it was redundant.

8. (see also #18)
Section 3.3 Topographic analysis was modified to explain the 6m threshold, the first two sentences were changed to: Topographic analysis was used to extract features defining the location and geometry of individual dunes. These features – peaks, slip faces, active crests, windward side ridges, and active dune areas – are essential for measuring the dune migration and understanding its evolution.
A subsection was added for the active dune area derivation:
3.3.4 Active dune subregion
Visual analysis of contours, generated from the DEMs at 0.3 m interval and displayed along with elevation, slope and land cover maps, was used to identify a threshold elevation that defines the active dune subregion. Topography below this threshold flattens and includes only small, mostly stable vegetated features. Elevation surface above the threshold has typical dune geometry and bare sand. For all DEMs (1974 – 2001) this threshold elevation was found to be 6 m. For the 1999 DEM, the elevation threshold had to be combined with land cover derived from the 1998 aerial photography to eliminate trees and buildings. Map algebra was then used to compute the active dune DEMs as surfaces with elevation $z > 6$ m.

9. The color map of profile curvatures is draped over a DEM; however, the shading of the DEM is subdued to keep the focus on the curvatures, rather than topography. We have slightly enhanced shading, but to really show the draping would require and additional image with a different view.

10. Subsection about dune ridges was modified as follows (this also answers #27), the mathematical background is described in the references and is beyond the scope of this paper:

Therefore, an alternative approach based on the density of slope lines (lines in the direction of surface gradient, perpendicular to contours) generated uphill from each grid cell was used (Mitasova et al., 1996). This approach is an inverse version of the flow accumulation algorithm commonly used for extraction of streams (e.g., Tarboton, 1997), where slope lines are traced downhill from each cell and cells with slope line density (flow accumulation) exceeding a given threshold define the stream network. To extract ridges, slope lines were computed using a D–infinite (vector–grid) algorithm (Mitasova et al., 1996) to avoid artificial patterns produced by the standard D–8 methods on smooth surfaces typical for dunes. Dune ridges were then extracted as grid cells that had the number of slope lines passing through them (slope line accumulation) > 600 (Fig. 4C). The average slope of the windward side of the dunes was then computed by manually defining representative windward profiles along these ridges, extracting slope values along the profiles from the slope maps using map algebra, and computing the average value for each dune (Fig. 4C insert).

11. The suggestion to stay away from the discussion of controls on dune height was followed and the relevant sentences were removed.

12. Refrence was fixed to the Fig. 6A.

13. The first paragraph of section 3.4 Quantification of the dune change was simplified as follows and the Bailey and Bristow reference was removed:

Jockey's Ridge, as a complex dune field, has spatially and temporally variable migration, growth, and deflation rates (Fig. 6A). To quantify its evolution, an approach based on topographic analysis of elevation surfaces that involves extraction of dune features and measurement of the change in their location was used (Fisher et al., 2005). High resolution DEMs and GIS tools make such analysis feasible and effective.

14. The sentence was removed because it did not fit well with the rest of the text and the described method was not used in this paper.

15. Fisher et al. reference was fixed, the book chapter was published in 2005.

16. The sentence was modified as suggested.

17. To clarify, the sentence was modified as follows: Change in the shape and size of crests and ridges contributed to uncertainty in the measurements; therefore, each distance was measured six times and an average value was computed. The standard deviations of these averages did not exceed 3 m.

18. The 6m threshold is explained in methods, see #8.

19. The misplaced reference to Fig. 7 was fixed: ... confirms prevailing southern migration of the entire dune field (Fig. 7) accompanied by dune deflation.

20. Reference to the sand transport rose was added: Apparently, the overall direction of dune migration to the SW is not dictated by the long–term mean wind orientation (winds from the SE). Rather, as shown by the sand transport rose presented by Havholm et al. (2004), it is is the higher frequency of stronger winds from NE (see also USACE FRF, 2004) that lead to the prevailing SW direction of the potential sand transport.

21. USACOE was corrected to USACE FRF.

22. South dune was removed from the third sentence in this paragraph to avoid repetition.

23. The paragraph was modified to correctly reflect figure 5B:
(we are very grateful to Dr. Havholm for catching this mistake – for explanation, this paragraph was written before the horizontal shift in data due to different datums was fixed, we checked the rest of the text and figures to make sure that they reflect the corrected data).

The horizontal main peak migration followed the southeast direction between 1953 and 1995, with an eastward turn between 1995 and 1998, then continuing in south–southeast direction in the following years, with the exception of 2001–2002 time interval, when the main peak moved westward (Fig. 5B**).** The peak migrated 225 m over 50 yr period.

24. The paragraph was reformulated to more accurately describe the horizontal migration rates:

Between 1974 and 2004, the prevailing movement of slip faces was in the S/SW direction at average annual rates of 2.8 m/yr for the west dune and 6.3 m/yr for the fastest moving east dune. As expected, the lower east and south dunes moved faster than the higher main dune (Figs. 6A, 7A), reaching the rates of migration over 10 m/yr for the 1998 – 1999 time interval.

25. The sentence was modified to describe the evolution of the angle between the windward side ridges and the crests: The angle between the windward side ridges and dune crests, measured clockwise from the ridge line, was relatively stable for the main and west dunes, ranging between 110 – 120°. For the east dune, this angle changed gradually from 100 in 1974 to 130° in 2001.

26. We agree and the second part of the sentence implying that the ridges were loosing elevation was removed. The peak data show that while there was elevation loss on all windward sides, some peaks have grown recently (Table 1), due to deposition on the leeward side and in the "valleys" between the dune ridges.

27. The description of slope measurement was added to methods section (see #10).

28. The discussion was simplified and rewritten to indicate the anthropogenic influences: Collier Cobb, a University of North Carolina geologist, described the dramatic changes on the barrier islands in a 1906 National Geographic article as follows (Cobb, 1906): "The strong winds pile the sands into great barchans or medanos, crescentic sand dunes known locally as whaleheads which are moving steadily southward ... the origin of the sand forming the big dunes in this Nags Head area was released from an area that was deforested." The growth in the large sand dunes during this time period might have been a result of land management decisions in the late 1800s (i.e., excessive logging) that introduced instability to the landscape in the form of a hard–to–control, fast growing, and migrating dune field. The official 1915 surveyors descriptive report characterized the area as undulating, covered with sand dunes that drift amongst the woods, killing the timber as they move slowly along (Ferguson, 1915).

29. We agree, one needs to see more of these photos to get a sense how different (with many more active sand dunes) this section of Outer banks was at the beginning of the past century. We have taken out the Wright photos as they show a close but different area.

30. The following sentence was added: As the sand supply is reduced, transformation of the dunes into parabolic shape begins to take place, a process that has been documented for numerous locations (Havholm et al., 2004), including the False Cape dunes in Virginia (Hennigar, 1977).

31. We agree, but we did not have sufficient data about the sand piles to clarify this issue and nothing was changed in response to this comment.

References were fixed and the following two were added:

Tarboton, D. G., (1997), "A New Method for the Determination of Flow Directions and Contributing Areas in Grid Digital Elevation Models," Water Resources Research, 33(2): 309–319.

Hennigar, H.F., 1977. Evolution of coastal sand dunes: Currituck spit, VA/NC. In: Coastal Processes an Resulting Forms of Sediment Accumulation, Currituck Spit VA/NC, Virginia Institute of Marine Science SRAMSOE No. 143, pp. 403–422

Table 1. Reference to 1950 was changed to 1953 (the date when the data were published). We did not add the rates as they made the table harder to read, especially after the lower dunes' peaks were added.

Figures and figure captions

Figure 4. The units on the legend were fixed for slope and added for the slope line density (square m), the 2001 year was added. Shading in 4b was slightly enhanced and show that it is draped over topography. Insert was added to 4C to illustrate computation of average windward ridge slope.

Figure 6. Caption was modified to include more information about the migration measurements

Figure 7. More information was added to the caption, colors were changed in insets, peaks were added in legends, migration of peaks was indicated by arrows and the figure was re–organized.

Figure 8. Legend was repeated for A, B.

Figure 9. Wright photos were removed.

Figure 10. Map showing the location of management actions illustrated by the photos was added.

Additional changes:

In the subsection "3.3.1 Peaks" the reference should be to Fig. 5A.

We did not analyze the elevation of the peaks on any other dune and ridge besides the main dune in the original manuscript. We missed the fact that peak on the east dune and on the western ridge of the main dune have started to grown recently (over the past 6 years). To include this important observation we have added locations of additional peaks into Figure 2, elevations were added to Table 1 and comment was added to section 4.2 Peak change.