Aeolian Research 1 (2009) 63–73

Contents lists available at ScienceDirect

Aeolian Research

journal homepage: www.elsevier.com/locate/aeolia

Plants and ventifacts delineate late Holocene wind vectors in the Coachella Valley, USA

Peter G. Griffiths [a,*], Robert H. Webb [a], Mark Fisher [b], Allan Muth [b]

[a] U.S. Geological Survey, 520 N. Park Ave., Tucson, AZ 85719, USA
[b] Boyd Deep Canyon Desert Research Center, Box 1738, Palm Desert, CA 92261, USA

ARTICLE INFO

Article history:
Received 1 April 2009
Revised 21 July 2009
Accepted 22 July 2009

Keywords:
Aeolian transport
Wind direction
Ventifacts
Desert geomorphology
Desert plants

ABSTRACT

Strong westerly winds that emanate from San Gorgonio Pass, the lowest point between Palm Springs and Los Angeles, California, dominate aeolian transport in the Coachella Valley of the western Sonoran Desert. These winds deposit sand in coppice dunes that are critical habitat for several species, including the state and federally listed threatened species *Uma inornata*, a lizard. Although wind directions are generally defined in this valley, the wind field has complex interactions with local topography and becomes more variable with distance from the pass. Local, dominant wind directions are preserved by growth patterns of *Larrea tridentata* (creosote bush), a shrub characteristic of the hot North American deserts, and ventifacts. Exceptionally long-lived, *Larrea* has the potential to preserve wind direction over centuries to millennia, shaped by the abrasive pruning of windward branches and the persistent training of leeward branches. Wind direction preserved in *Larrea* individuals and clones was mapped at 192 locations. Compared with wind data from three weather stations, *Larrea* vectors effectively reflect annual prevailing winds. Ventifacts measured at 24 locations record winds 10° more westerly than *Larrea* and appear to reflect the direction of the most erosive winds. Based on detailed mapping of local wind directions as preserved in *Larrea*, only the northern half of the Mission-Morongo Creek floodplain is likely to supply sand to protected *U. inornata* habitat in the Willow Hole ecological reserve.

1. Introduction

In the northern Coachella Valley of the Sonoran Desert in southern California, aeolian processes dominate sediment transport, entraining fine-grained particles from alluvial plains and transporting these sediments east–southeast towards the Salton Sea (Fig. 1; Russell, 1932; Sharp, 1964; Beheiry, 1967; Lancaster et al., 1993; Griffiths et al., 2002). A strong, unidirectional wind field is created by westerly winds funneled eastward through the narrow San Gorgonio Pass that seasonally transports primarily fine sand eastward, depositing migrating aeolian landforms. Most alluvial sediment available for aeolian transport is deposited at the toes of alluvial fans and on the depositional plain of the Whitewater River and its tributaries, which drain the San Jacinto and San Gorgonio Mountains and lower-elevation desert ranges that ring the western and northern edges of the Coachella Valley (Fig. 1).

Several endemic species, notably the threatened Coachella Valley fringe-toed lizard (*Uma inornata*), inhabit active sand dunes in the northern Coachella Valley (Barrows, 1997). As urban development has expanded in recent decades in the Palm Springs area, aeolian habitat has been significantly reduced (England and Nelson, 1976; Barrows et al., 2008). In 1985, three reserves were established to protect *U. inornata* habitat (active dunes and their margins) (Nature Conservancy, 1985) and in 2007 preserved habitat was expanded and additional protection was conferred to the sand source areas and aeolian transportation corridors to the reserves (Coachella Valley Association of Governments, 2007). Griffiths et al. (2002) described the components of the transport system supplying sediment to the Whitewater Floodplain and Willow Hole Preserves, and identified alluvial sediment sources and general routes of aeolian transport. However, this work was based on generalized wind directions determined from a single wind station on Edom Hill at the northern edge of the wind field and outside of the Willow Hole lizard habitat.

The general direction of wind movement and aeolian transport in the Coachella Valley is determined by the large-scale topography of the valley, but local wind directions vary in response to changes in local topography as the wind is diverted around obstructions or routed through topographic constrictions (Laity, 1987). When considering aeolian transport over short distances (<10 km), local variations in wind direction are likely to have a large influence on which sediment sources and transport routes

* Corresponding author. Fax: +1 520 670 5592.
E-mail addresses: pggriffi@usgs.gov (P.G. Griffiths), rhwebb@usgs.gov (R.H. Webb), sandlizards@mindspring.com (M. Fisher), sandlizards@mindspring.com (A. Muth).

1875-9637/$ - see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.aeolia.2009.07.001

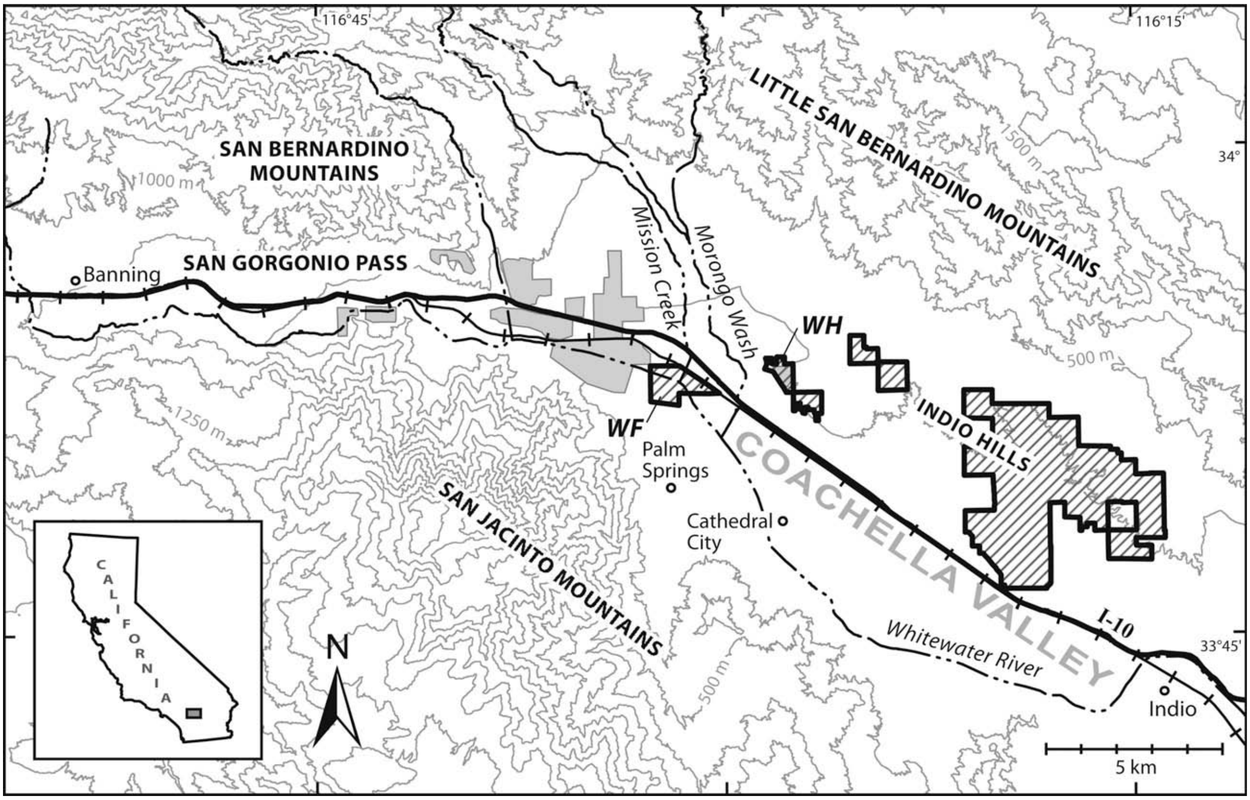

Fig. 1. Map of the northern Coachella Valley, Riverside County, California, from San Gorgonio Pass to Indio, California. Wind turbine locations are shaded gray and ecological preserves are cross-hatched (WH, Willow Hole Preserve; WF, Whitewater Floodplain Preserve). Contour interval is 250 m.

supply sand to specific aeolian habitats. Efforts to protect sediment sources and transport routes from development require knowledge of these local variations; general wind directions or data from distant weather stations are unlikely to provide reliable local information.

In this paper, we take advantage of flagging – the directional shaping of plant forms by wind – of the ubiquitous *Larrea tridentata* (creosote bush) to map the local direction of prevailing winds across the northern Coachella Valley. We use these plants to map the two-dimensional wind field emanating from San Gorgonio Pass as the field expands and dissipates eastward. We also use ventifacts – wind-eroded rock surfaces – to estimate wind direction and compare them to wind vectors from flagged *Larrea*. Finally, we re-evaluate the potential sources of sediment to ecological reserves in the valley in light of these findings.

2. Background

2.1. Setting

The Coachella Valley stretches for 75 km in a generally northwest–southeast direction, following the line of the San Andreas fault from San Gorgonio Pass to the Salton Sea (Fig. 1). The valley is bounded on three sides by the San Bernardino Mountains on the northwest, the Little San Bernardinos on the north, and the San Jacinto and Santa Rosa Mountains on the western and southwestern edges. San Gorgonio Pass, at the western edge of the valley, is a topographic low point between the San Bernardino and San Jacinto Mountains controlled by the San Andreas fault. San Gorgonio Pass narrows from west to east and drops 400 m in elevation into the Coachella Valley.

2.2. Climate

The Coachella Valley is dominated by seasonal winds flowing through San Gorgonio Pass. These winds are driven by the pressure gradient between the semi-permanent North Pacific High high-pressure cell and a thermal low-pressure cell that frequently forms over the inland desert during late winter and early spring (Laity, 1987). Westerly winds are typically strongest from late winter through early summer when the high-pressure cell is at its peak. The topography of San Gorgonio Pass intensifies winds as they flow down slope into the Coachella Valley. Wind speed varies diurnally, with the strongest winds occurring in late afternoon (Griffiths et al., 2002). Wind direction and intensity are sufficiently consistent to support numerous commercial electric-power wind turbines just east of San Gorgonio Pass (Fig. 1).

As wind courses through the Coachella Valley, its prevailing direction shifts to follow the general topographic alignment of the San Andreas fault, moving from west–northwest at the east end of San Gorgonio Pass to north–northwest near Palm Springs and Cathedral City (Fig. 1). The vector field diverges as the valley widens, and wind speed decreases to the southeast. As a result, aeolian processes are more active at the northern end of the valley, north of Palm Springs and west of Indio. By far the most common aeolian landforms are coppice dunes that form in the lee of desert shrubs, though larger parabolic and barchan dunes, and sand drifts, undulations, and veneers are also present (Russell, 1932; Beheiry, 1967; Lancaster et al., 1993).

Rainfall on the valley floor at Palm Springs International Airport averages about 100 mm/year (Fig. 2), and 69% occurs during the winter months from November through March in a seasonal pattern similar to the western Mojave Desert (Hereford et al., 2006). Precipitation in the mountains to the west is 4–5 times greater, generating winter floods in upland watersheds that flow down