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The influence of El Niño Southern Oscillation (ENSO) on fog oases along the Peruvian and Chilean coastal deserts.

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Abstract

Fog oases such as Lomas formation along the Chilean and Peruvian coasts are dependent on water inputs from oceanic fog. Vegetation is characterized by a marked seasonality which is often affected by climatic oscillations. Plant diversity and vegetation patterns are highly variable because of their fragmented spatial distribution. We hypothesize that ENSO could have influenced the spatial distribution of Lomas plant species. In particular we focus on two aspects: 1. The climate variables related to ENSO which likely affect the fog production and 2. The responses of Lomas vegetation to climate patterns during ENSO.

1. Introduction

Fog oases are found between ~6°S and 30°S in the western coasts of South America. The climate is characterized by a long dry period (austral summer) with a short and variable humid period from May to October (austral winter). This climatic pattern determines long periods of seed dormancy and short periods of growth.

Fog oases locally named “lomas” are considered “ecological islands” [6] as they are distributed in a kind of fragments or patchy way with a common climatic factor that is fog [8,21,23]. Although a floristic relationship was found between Peruvian and Chilean lomas due to some species in common [17,29,37] a floristic segmentation has been found [9,20] attributed to the hyper-arid barrier (ca. 18-20°S) between Peru and Chile that could have promoted isolation and limited plant dispersion [31].

EN (El Niño) has been observed to have positive influence in the present composition and productivity of desert flora [7,11,13]. Desert annual plants are strongly related to the rainfall availability [37], which during EN, increase primary productivity [33]. This could support the hypothesis that EN-like conditions in the past might have encouraged a continuous belt of vegetation along the Peruvian and Chilean coasts, but the enlarge of desertification fragmented such continuum [24,38]. We believed that continuous ENSO conditions may affect the lomas vegetation increasing their extension and connectivity, especially in rainy years.

To establish whether ENSO can influence the spatial distribution of lomas plant species we review two main aspects: 1. The climate variables related to ENSO event which likely affect fog production and 2. The responses of Lomas vegetation (composition, productivity, distribution) to climate patterns during ENSO.

2. Anomalies on fog seasonality

Anomalies in the fog season may be related to low-cloud anomalies associated to EN. A negative correlation between the marine Sc (Stratocumulus) amount and the warm SST (Sea Surface Temperature) has been demonstrated in the eastern Pacific [27] while convective clouds increase, especially during the austral summer. Thus, a lesser amount of Sc may reach the coast while precipitation increases.

In fact, Northern Peruvian sites receive more precipitation than southward because highly dominated by ENSO [5] while fog pattern is unknown. It is likely that fog have a negligible effect here during EN. Conversely, Southern Peruvian sites receive more precipitation in the late spring and early summer due to EN while fog and drizzle increase in winter. Northern Chile have similar pattern to south Peru but this changes south of ca. 25°S where the amount of low-clouds is negatively (positively) correlated to EN (LN) [10]. Thus, more cloud

amount in the north is related to EN and in the south with LN (La Niña).

Controversies still exist on fog-water collected during EN. Monitoring data from Chile and Peru lomas have shown more water collected during EN [14, 18]. But, whether is due to the high amount of low-clouds (fog) or more drizzle ("garúas" or "camanchacas") is not clear. The marine Sc region off the coast of Peru seems to be reinforced when unusually cool SST's are present [25]. Also colder SST and warmer air temperatures reinforce the temperature inversion and lead to a more persistent cloud deck and higher fog frequency at 30°S [10]. Thus, during EN years the fog frequency should decrease while during LN should increase. However, highest records of fog and water collection were obtained in both, northern Chile [3] and southern Peru [39] during the exceptional EN 1997-98 that depressed the thermocline in the eastern Pacific by more than 90 m in late 1997 [18] to the mid 1998 when almost instantaneously initiated LN. Apparently, the fog effect on coastal formations is higher during EN when the normal drizzle are intensified and small precipitations (during summer) may cause an impressive blooming of the desert due to the ephemeral plants establishment. Nevertheless, the coastal fog impact should be higher during the winter season when fog reaches its maximum.

3. Biological effects on fog oases

Floristic analysis have put in evidence three main groups [9,17] of lomas: North Peru (PE1, PE2, PE3), South Peru (PE4 to PE8) and Chile (CL9 to CL13). Divergence is likely due to the differences in the taxonomic relatedness between sites originated by isolation and long dry periods during the desert evolution [17] (Fig. 1).

At present, the more water availability triggered by EN (more precipitation in later spring and summer) produces extraordinary changes. During EN 1997-98, the primary productivity of southern Peru lomas reached thirteen times higher productivity (UNSA-PADOVA project report 1999) than the average value, around 1.4 g/m2/day [2,4,35] during the wet season, incrementing plant density and cover [14,21,30,33]. In some cases species that have disappeared for a long period of time reappeared [1]. Flowering and seed production increase [11,22] and so the life cycle and plant distribution following water availability [23,28,34]. More vegetation diversity has been attributed to southern Peru because more water collected from fog [21,26].

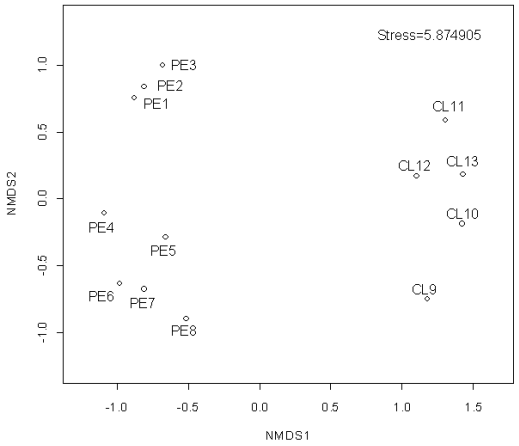

Figure 1: Divergence of lomas plant species composition (PE=Peru, CL=Chile) (from Manrique et al. 2010).

Permanent EN-like conditions in the past (3 Ma.) during the Pliocene [19] may have contributed to establish a fertile belt along the western coast of South America, which may explain the allied species found and the high quantity of endemism. Some studies showed that some species have descended in elevation due to more water availability [12,16].

According to the evidences and besides the desert barrier, it is likely that different precipitation (drizzle and fog) patterns influenced by ENSO periodic pulses may determine plant dispersion and survival of fog oases.

4. Conclusions

Contradictory results have emerged from studies on the low-cloud anomalies and the fog-collection related to EN. EN increase water availability in fog oases when fog should be less frequent due to the reduction of low-cloud amount and Sc. Because of a minor role of fog during EN is expected, especially in summer, it is likely that measurements of fog-water collection during EN are considering both, drizzle and fog at the same time. In turn the reinforced winds in winter, particularly during LN, would increase coastal low-cloud frequency and determine more fog occurrence and more fog-water collection.

Establishing which factor (drizzle or fog) is more significant to the persistence of fog oases is beyond the scope of this paper. However, we believe that the persistence of lomas is linked to both, fog (during winter) and drizzle (during summer), particularly during ENSO. Even though a short-term response in primary productivity is more related to the increase of rainfall, we assume that depending on how intense the effect is on rainfall and fog production, ENSO could modify the dynamics and plant distribution of fog oases.

Present fog-collection records are not temporally long and the latitudinal variability across the coast limits a correct interpretation of particular patterns observed in one specific site. The localized records may not have broad regional extent and may create some contradictions or unclear explanations. We believe that continuous monitoring in different points along the coast will help us to clarify some climatic patterns.

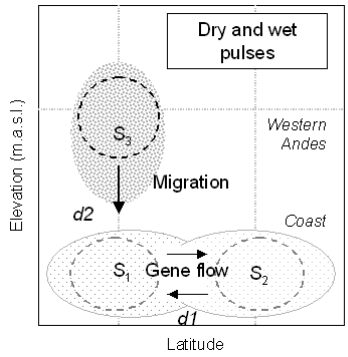

Figure 2: Divergence of lomas vegetation due to water pulses (S=species composition, d=distance). Dashed circles correspond to dry periods.

Plant composition and distribution of lomas or fog oases have changed through time. Based on the allied species found and the higher quantity of endemics, it was hypothesized that fog oases are fragments of a past continuous belt of vegetation. More paleobotanic and paleoclimatic studies are needed to clarify the real role of EN.

Two significant cases of vegetation fog-dependence show us the decline in fog frequency due to climatic anomalies such as ENSO: The Redwood forest (36°N-42°N) in California [15] and the relict forest of Fray Jorge (30°S) in Chile [10]. Thus, we infer that lomas may be influenced by ENSO events in two possible ways: 1) facilitating species migration and gene flow during wetter periods because more species abundance and 2) isolating plant communities particularly during long dry periods increasing genetic divergence (Fig. 2).

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