

BRISTOL SALT MARSH: VEGETAL HERITAGE, CONSERVATION STATUS AND RESTORATION PROPOSAL (CORRALEJO, FUERTEVENTURA, CANARY ISLANDS)

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I. INTRODUCTION

The island of Fuerteventura was declared a Biosphere Reserve in 2009 thanks to the richness of its natural heritage and good state of preservation. It has 12 protected areas under the figures of Natural Park (3), Natural Monument (6), Rural Park (1) and Protected Landscape (2); besides 1 Site of Scientific Interest (SSI), 9 SPAs and 12 SACs. The Saladar or Charco de Bristol is located in the north of the island near the town of Corralejo. It's a small coastal depression formed on aa lavas from Bayuyo volcano. Although it barely covers an area of 0.2 km², it has a big natural richness, composed of several biotopes formed at the contact between the sea and land surface. In addition, salt marshes are exceptional places in the Canary Islands by lack of coastal plains. However, it has undergone an extreme environmental degradation due to urban pressures and other threats that jeopardize wetlands and tourist coastal areas.

The salt marsh is located on a depression dug in the northern extreme of the Hoya del Caballo, where the thickness of the lava gradually decreases until it contacts with the sea in Bristol Bay and Corralejo. These lavas have fragmented surfaces and are chaotic with alternating small elevations of bare rock and depressions with thin materials. Aa lavas are gradually covering by marine bioclastic sands up to reach the coast. They are Pleistocene and Holocene sands with clays and Saharan dust that formed an aeolian sheet unbroken with the great *jable* of Corralejo (Natural Park of The Sand Dunes of Corralejo), before being sepa-

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rated by urban expansion of the town. The sands reach greater thickness in the plains and in depressions, often covering completely the basaltic lavas, while at elevations they are much less abundant or even disappear.

The position of the salt marsh, sheltered from the currents and the north winds, also favors the accumulation of sand and silt in the more sheltered part where the geo-environmental conditions are favorable. East of salt marsh there is also a small dune system attached by the vegetation and limited by a decorative cover of pyroclasts that links with the urban space. On the waterfront there is a deposited strip of boulders, flattened by wave action on the islands known as *Callao*. It forms a several meters wide edge and reaches heights of above two meters in the North of the salt marsh. There are also organic materials like calcareous algae (*confite*) and seashells. Finally, below the pebbles lies an abrasion platform where the Pleistocene basalts are cut at a bevel.

The climatic conditions are one of the main factors influencing the spatial distribution of vegetation and even in their physiognomic and floristic features. The most important features are: low rainfall which is even accentuated further in the northern coastal strip, where rainfall is less than 100 mm (Marzol, 1988); the high sunshine and mild temperatures; to which must be added in coastal areas like Bristol strong winds and high salinity, ie, a very restrictive environment that even hinders the development of halophytic vegetation adapted to these environments. According to data, the climate of the northern coastline of Fuerteventura can be classified as type *BWhsi'*, namely semi-isotherm warm desert (Lopez and Lopez, 1979).

The soil is another basic factor that explains the disposition of halophytic vegetation of Saladar de Bristol, distinguishing up to four of the major types present on the island. According to the classification of soils adopted by FAO / UNESCO, there are soils of the group of saline soils or solonchaks, very sandy soils or arenosols and rocky outcrops or leptosols. Finally, there are anthrosols at the areas used for small buildings or as tailings in the last decades of the twentieth century.

The main objective of this research focuses on the analysis of the plant heritage of the Saladar de Bristol and its environment, determining their condition and finally the development of restoration measures as a basis for proper environmental management and rational use.

II. METODOLOGY

The methodology consisted basically of field work and to a lesser extent, in the photo-interpretation of aerial images (1981, 1984 and 1989) and the PNOA orthophotomap and consultation of digitized information of the Canary IDE and the National Centre for Geographic Information. Such images, although having functionality for geomorphology mapping and, secondly, to distinguish different units according to vegetation texture, color, spatial arrangement, etc. (Hernández-Cordero et al, 2015), have proved less useful in the recognition and identification of some plant communities of the salt marshes, given its small size and, above all, for the low imprint of their plant tapestry of little size and low density.

For this reason, the field work has been very exhaustive, taking place through multiple itineraries made for a year, in particular between October 2013 and October 2014, covering all biotopes present in the study area. First, a sketch on aerial photography with the iden-

tification was made, a priori, the areas occupied by the main vegetation formations. Then for stratified random sampling different linear route transects a meter wide and different lengths were designed. After that, several plots of 2 x 2 meters were designated, where space permitted, in the most representative geomorphological units (front coastline, aeolian sheet, rocky, floodplain daily and occasional, degraded by human activities) to carry out through research. During sampling we proceeded to a deeper floristic inventory study of vascular plants strata, defining vegetation units based on criteria of abundance / dominance (Braun-Blanquet scale) and analyzing the most important ecological factors, with the aim of characterizing, interpreting and mapping the different plant communities (Beltran et al 1999; Arozena, 2000; Hernández-Cordero et al, 2015). Subsequently, we made an assessment of the conservation status and an identification of the threats to the vegetation units, analyzing for this the uses' evolution and tracking the recent impacts, in particular the transit of people and vehicles, control of hazardous liquids and solids discharges. For this aerial images were analyzed, solid waste found during the transects were related, carbides adhering to the rocks were identified, etc.

Finally interviews were performed to visitors of the salt marsh, to entrepreneurs from the construction sector of the town of La Oliva and to city officials of the Cabildo de Fuerteventura.

With all the obtained information we proceeded to develop a database which we included in a GIS using the ArcMap software, by which data have been digitized corresponding to the distribution of different plant communities. With that, we have obtained estimates of its surface as well as the final detailed mapping; laying the groundwork for future monitoring of the evolution of the salt marsh communities. This follow-up work is similar to another analysis made in the dunes of Maspalomas and the island of La Graciosa (Hernández, A. et al. Bristol, 2014. Garcia, L. et al., 2014).

III. VEGETAL HERITAGE

The plant heritage of the Charco de Bristol consists of hygrophile, halophyle, xerophyle and psamophile vegetation. The most significant plant communities are part of the ecosystem called "termo-atlantic halophytic scrub" underrepresented in Macaronesian European region by a shortage of flat coastal strips. It is an habitat of Community interest characterized by the plant association *Salicornietea fruticosae* Br.-Bl. & Tüxen 1943, where there are chenopodiaceae thickets with perennial woody formations on predominate saline soils (Rivas-Martinez et al., 2002, Arch et al, 2006; Del Arco et al, 2010). Its location in a coastal area affected by urban development explains the loss of part of its plant heritage: the potential extension of the Canarian salt marsh vegetation area is estimated in 362 ha of which more or less 304 ha are preserved (Del Arco et al, 2010). However, the strong anthropic pressure on this type of coastal areas in general, and in Bristol, in particular, makes this small enclave in a place very interesting for representation of other ecosystems and associated vegetation formations. This diversity is even much larger if we consider the existence of different biotopes.

So, to the west, on top of the pebbles of the hem coast and its rear edge is located the so-called Rocky coastal halophilous belt (*Frankenio ericifoliae* – *Zygophylletum fontanesii*). Behind them appear characteristic communities of salt marsh on the sandy-clay coating: *Zygophyllo fontanesii* - *Arthrocnemetum macrostachyi* and *Frankenio capitatae* – *Suadetum*

verae. An accumulation of lava about three meters high protects the depression that houses inside the salt marsh and despite being practically devoid of vegetation by the lack of soil and the edaphic dryness, it is covered with lichens, some specimens of *Suaeda vera* and own species of arid nitrophilous scrub of replacement.

A natural channel of more than 100 m long, where the sea breaks the abrasion platform carved in basalts, floods the small depression of Bristol. This inlet of seawater opens to the west where a minor influence of waves and prevailing winds of N, allows deposition of sludge in the intertidal space and the existence of *Sarcocornia perennis*. It corresponds to the association *Sarcocornietum perennis* (Fernandez and Santos, 1983) situated in the low marsh of the Charco de Bristol, resisting the partial flooding by twice a day. It prospers therefore on silty materials deposited by the sea and it is characterized by to configure a grass carpet, being a highly branched plant with fleshy stems articulated at the top, where the salts accumulate, and woody in base. This is a unique community in the whole island of Fuerteventura and it is also present in three other enclaves in the eastern Canary Islands. For this reason, it is included in the Catalogue of Endangered Species of the Canary Islands as a species of great interest.

It is estimated that the distribution of *Sarcocornia perennis* extends in four UTM grid of 500 m side, that is spread out over an area of 1,75 km² in Fuerteventura and Lobos (Morales, 2009). A follow-up investigation carried out by Santana and Naranjo (2002) pointed out, however, that it had an extension of 4,000 sqm on the island, ie, in the Saladar de Bristol, since this is the only enclave of Fuerteventura. A figure that seems excessive in terms of the area conducive to their development. However, the data that we have collected during field campaigns and GIS calculations provide a figure of 1,247 sqm².

To the south and west, following the first band of salt marsh vegetation, the most important areas of vegetation appear. They correspond again with *Zygophyllum fontanesii* – *Arthrocnemetum macrostachya* and *Frankenio capitatae* – *Suaedetum verae* that develop this depressed area of lava aa between 1 meter and 0 m elevation, covered with clay and sand and great saline content.

On the other hand, the increased energy of the waters on the southern edge of the channel allows the crossing of the belt of pebbles, producing a sand surface that connects with sand dune space located on the east. Anthropogenic alteration is very intense in this area, which explains the small dunes attached by replacement scrubs (*Chenoleoideo tomentosae* – *Suaedetum mollis*), coexisting with halophytes plants and ruderal communities. The location of the salt marsh in the urban area of Corralejo is manifested by the deposition of a layer of gravel for decorative purposes, in which the aforementioned communities and species of the associations *Salsolo kali* – *Cakiletum maritimae* y *Polycarpo* – *Nicotianetum glaucae* are present.

Finally, different substitution scrubs, like arid nitrophilous formations, increases as we move away from the core of the salt marsh to the urban perimeter.

The salt marsh vegetation has typical zoning of these wetlands directly related to the level of tolerance of plants to the flooding. Thus, the order from the center to the outside is the following: *Sarcocornietum perennis*, *Zygophyllo fontanesii* – *Arthrocnemetum macrostachyi* as. nova. y *Frankenio capitatae* – *Suaedetum verae*. Depending on the influence of *sea-salt* aerosol and the salt tolerance of plants it is possible to identify another spatial structure

of plant formations distribution where we find firstly the Rocky coastal halophilous belt, monospecific stands of *Suaeda vera* behind it and at the end, Sandy beaches and dune vegetation or Nitrophilous arid scrubs depending on the substrate and the level of human impact.

IV. STATUS OF CONSERVATION

In spite of the fact that the Bristol salt marsh has a wealthy plant heritage with regional relevance, this place has suffered negative activities to the conservation of its natural and cultural values. Almost all the recent territorial modifications in Fuerteventura, also in the salt marsh indirectly, have their origin in the increasing tourism and its repercussions on the demographic and economic dynamics and obviously, this has implicated very important landscape and ecological changes (Fernández-Cabrera *et al.*, 2011; Santana *et al.*, 2011) that have led to a loss of natural and cultural heritage (Pérez-Chacón *et al.*, 2007).

The urban territory of Corralejo has been extended over more and more space in all directions until affecting the Bristol salt marsh in the NE. Aerial photographs from 1981 show the first blocks of apartments near there and the utilization of the meridional area of this place as a landfill for construction waste. A little sand quarry at the eastern edge is observed also in subsequent pictures. After the cessation of these activities, the remains were extended over the ground covering the original sediments and disrupting the vegetation definitely. Moreover, the north end of the salt marsh also hosted a series of fishermen's huts of which remain some foundations, concrete milestones and access tracks.

In the 90's, a seawater desalination plant was built at the northwest of the Charco de Bristol, while to the south, some areas were used to deposit construction materials, rubble and trash; and a secondary school was edified. Anyway, the most striking element of the Saladar de Bristol is the track that crosses it, a not paved path but with enough traffic as it is the easiest way to reach the road which goes along the north of the island of Fuerteventura from Corralejo to Faro del Toston. This section coincides with a fringe included in the Important Bird Areas Program (IBAs).

V. CONCLUSIONS

The Saladar de Bristol, publicly owned, has undergone a major degradation and has no protection. It is a little natural enclave that has natural and cultural values with a great scientific interest. Some relevant elements are the geomorphologic components (lavas aa, strips of sea stones, sands, marine abrasion platforms, beach and coastal depression) and the wide plant communities diversity: *Zygophyllo fontanesii* – *Arthrocnemum macrostachyi*, *Frankenio capitatae* – *Suaedetum verae*, *Frankenio capitatae* – *Zygophyllum fontanesii*, *Chenoleoideo tomentosae* – *Salsoletum vermiculatae*, *Chenoleoideo tomentosae* – *Suaedetum mollis*, *Polycarpo* – *Nicotianetum glaucae* and other halophile and psammophile formations. However, the most important plant community is the *Sarcocornietum perennis*, unique on the island of Fuerteventura, whose area has been calculated by GIS tools and fieldwork for a necessary follow of its evolution. Its preservation can be possible if it is protected with an adequate environmental management. Instead of this, there is not a currently local neither regional policies based on sustainable development protecting the Bristol salt marsh, so the

suffering malpractices have been lasting for 4 decades. For this reason we have designed a restoration proposal that consists in the zonification of this space from different proposed measures aimed at the recovery and conservation of its landscape values and its original vegetation. Such measures must have as its ultimate goal the declaration of Charco de Bristol as Site of Special Scientific Interest. This can play an active role in the set of natural resources to promote the development of emerging sectors such as quality tourism, based on sustainability and specially interested in the knowledge of nature and landscape dynamics.