

De novo, neste número, incluímos investigação e propostas ligadas à protecção da Natureza. De novo com o fito de que quem de direito se há-de por elas interessar pois, discordando de abusos e maus usos, apregoamos que quem se arroga direitos, cumpra os deveres. De novo, com a esperança de que, acenando agora o estandarte da tradição, se desperte o orgulho de comunidade e se salve o que tão inconscientemente se descurou.

Cada dia nos chegam notícias dos milhões que se gastam para recuperar uma paisagem degradada ou salvar uma espécie em perigo. Desperdício ilógico, pois os actos que a tal levaram, na maioria dos casos, foram conscientes e trouxeram lucro apenas a muitos poucos! Não teria sido tão mais fácil prevenir? Não poderemos nós parvenir?

Pois bem, de novo a Sociedade Afonso Chaves tenta cumprir a sua função na sociedade dos Açores, alertando à sua maneira para a urgência de uma acção concertada para salvaguarda do nosso património natural que é, de facto, um pouco de cada um de nós.

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THE FORMER MARSH AT PAÚL, PRAIA DA VITÓRIA, TERCEIRA, AÇORES, AND THE CASE FOR THE DEVELOPMENT OF A NEW WETLAND BY REHABILITATION OF THE QUARRY AT CABO DA PRAIA

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ABSTRACT

There were once large wetlands at Paúl and Belo Jardim, Praia da Vitória, Terceira. Urban development and related pressures have resulted in their progressive destruction, probably since about 1929. Today, all that remains is a small, tidally replenished, pool at Paúl and a drained *Juncus acutus* stand at Belo Jardim. A general description of the present status of these two sites is given herein. The two locations retain little conservation value, although the pool at Paúl has historic and heritage significance and should be conserved within larger plans for the development of its former, broader, location as a public recreational and amenity facility.

During the course of this study, a new wetland was discovered within a largely worked out portion of the quarry at Cabo da Praia, just south of Praia da Vitória. Following but a few years disuse, a coastal wetland, attractive to wading birds and reminiscent of the situation that was once prevalent at Paúl, has become established. A description of the present, basic, structure, hydrology and ecology of the quarry is given and a case is made for its rehabilitation as an Açorean wetland, so that the former significance of Paúl can be sustained. Elsewhere, quarry rehabilitation has been shown to be effective for wetland conservation and suggestions are made as to how this might be achieved locally.

RESUMO

Existiram outrora extensas zonas húmidas no Paúl e Belo Jardim, Praia da Vitória, Terceira. O desenvolvimento urbano e as pressões com ele relacionadas resultaram na destruição progressiva daquelas zonas, provavelmente desde 1929. Hoje, tudo o que resta é uma pequena poça reabastecida pela maré, no Paúl, e uma mancha drenada de *Juncus acutus* no Belo Jardim. Aqui apresenta-se uma descrição geral da situação actual desses dois sítios. Os dois lugares têm pouco valor para conservação, embora a poça no Paúl tenha significado histórico e patrimonial e deva ser conservada dentro de um plano mais alargado de desenvolvimento da sua localização primitiva, mais extensa, como local público de recreação e parque de diversões.

No decurso deste estudo foi descoberta uma nova zona húmida dentro da parte abandonada de uma pedreira no Cabo da Praia, mesmo a sul da Praia da Vitória. Após apenas alguns anos de desuso, estabeleceu-se ali uma zona húmida costeira, atraente para as aves pernaltas e remanescente da situação que outrora prevalecia no Paúl. Faz-se aqui uma descrição da actual estrutura, hidrologia e ecologia básicas da pedreira e apresenta-se justificação para a sua reabilitação como zona húmida Açoriana, a fim de que a antiga importância do Paúl possa manter-se. Em outros locais a reabilitação de pedreiras tem demonstrado ser eficiente para conservação de zonas húmidas e avançam-se sugestões para como tal se possa conseguir localmente.

INTRODUCTION

Santos *et al.* (1995) review the potential for coastal conservation in the Açores, in broad terms, identifying for each of the nine islands, sites which might serve such a purpose. In more detailed studies of Açorean coastal wetlands, Morton & Tristão da Cunha (1993), made the case for continued protection of the lagoon at Santo Cristo, São Jorge, while Morton *et al.* (1995; 1996) make similar cases for the protection of Fajã dos Cubres, São Jorge and Lajes, Pico. Morton *et al.* (1997) have reviewed the case for coastal wetland conservation in the Açores, using the above locations as examples of areas worthy of either continued or new legislative protection. Such legislation has, for example, already been enacted for Fajã dos Cubres and Fajã do Santo Cristo, the former as a Partial Nature Reserve (Decreto Legislativo Regional N° 4/84/A) and the latter as a Special Ecological Area (Decreto Legislativo Regional n° 8/89/A), but not for Lajes do Pico.

Despite the protection afforded, access to Fajã do Santo Cristo has been facilitated recently by the

widening of the coastal trail sufficient to accommodate all-terrain vehicles. Similarly, a visit by the senior authors to Fajã dos Cubres in the summer of 1997, revealed extensive damage to this fragile ecosystem. The path to the lagoon at the side of the church and in front of a row of village houses had been sealed and a concrete dock constructed into the lagoon across the shallow *Ruppia maritima* platform to the edge of the drop-off into the lagoon itself. All the fringing *Juncus acutus* had been cut and burned. Most of the other elements of the complex botanical community associated with the marsh (Morton *et al.*, 1996) had also been destroyed. Workers were in the process of widening and sealing the two causeways connecting the lagoon sides and central islets. The purpose of the 'development' is apparently to provide a dock facility for recreational rowing boats and better access to the central islets. The consequences of such 'development' are grave. The lagoon community had suffered a severe ecological blow. The *Ruppia* population had been reduced by about 80% percent, with that which remained in evidence, either

dead or dying. Unlike in 1995 (Morton *et al.*, 1996), no coastal birds were seen in 1997. Only the prawn *Palaemon adspersus* was present in numbers comparable to that observed previously. The amphipods *Talitrus saltator* and *Gammarus locusta* and the isopod *Sphaeroma serratum* were still present underneath stones fringing the lagoon shore, but the fate of these species and the few other survivors of the 'improvements' to the lagoon at Fajã dos Cubres awaits the next onslaught, perhaps reminiscent of the pattern of destruction that has befallen other natural areas in the Açores.

The modern assault upon the lagoon at Fajã dos Cubres is matched over an even longer time scale by the progressive destruction of marsh habitats at Paúl and Belo Jardim near Praia da Vitória, Terceira. The larger Paúl marsh originally occupied several hectares in a coastal valley beside a fault escarpment and behind a large coastal sand dune (Fig. 1). The latter, in turn, accumulated at the other end of the enormous, in Açorean terms, three kilometre-long sandy beach which, even today, fringes the shore at Praia da Vitória and extends to Belo Jardim. Its light-coloured, carbonate-rich, sands attract locals and tourists on sunny days as an important recreational venue. The Paúl marsh, in its fullest expression, was favoured by many birds, with most historical records of Açorean wading species derived from this site (Bannerman & Bannerman, 1966).

Agostinho (*in* Bannerman & Bannerman, 1966) recalls the former richness of the Paúl marsh, how hunting was banned in it to protect its birds, including the endemic Açorean Moorhen *Gallinula chloropus correiana* and describes its destruction, especially from the 1950's. But, its demise actually began much earlier. It is said that, beginning in 1929, the fringes of the marsh were used as a local rubbish tip, following the initiation of urban garbage collection in Praia da Vitória. The marsh would have been filled and emptied of water at that time by percolation through the seaward sand dunes. The regular wetting of such garbage eventually must have made the marsh eutrophic and would, in turn, cause it to stink, as reported by Agostinho. Subsequent to 1929, however, holiday homes were constructed along the sides of the marsh and further pressure was put upon the city to reclaim it. This could not be accomplished easily, as the marsh continued to fill and empty under continued tidal pressures and, assisted by rain, it flooded regularly, as it still does today. Notwithstanding, reclamation of the dune and much of the marsh was accomplished progressively and in its place there is now a park, a garden, an outdoor pavilion and other amenities. When visited in the summer of 1997, additional reclamation was in progress from the seaward margin of the now much reduced marsh up to the line of an open drain that now channels seawater into and out of it with each tide. Pipe has

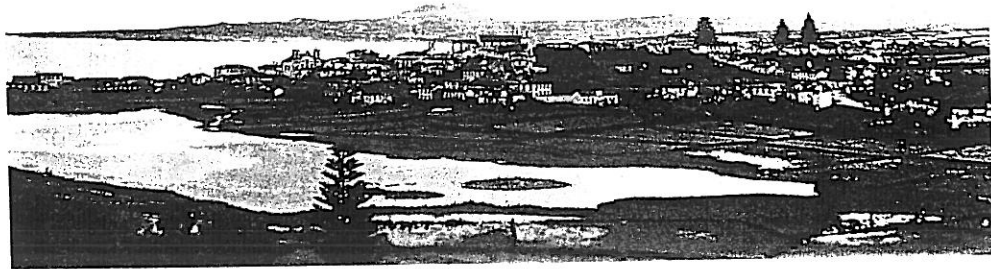


FIG. 1. A photograph of the marsh at Paúl probably taken in the 1930's or 1940's. (Courtesy of Francisco Jorge Ferreira, Provedor da Santa Casa da Misericórdia da Praia da Vitória, Terceira).

been laid in some of the drain and it will be eventually covered to provide a surface upon which a new road is to be constructed. The marsh at Paúl is now only a small fraction of its original proportions. In the summer (July and August) and autumn (October) of 1997, research visits were made to Paúl at Praia da Vitória, to Belo Jardim, the site of another residual marsh and part of the former, larger, Praia da Vitória wetland and, as it transpired, to a new wetland that has developed in a quarry and is evolving close to the

city at Cabo da Praia. This study was, thus, aimed at describing the basic geology, geomorphology, hydrology and ecology of the marsh at Paúl, the remnant at Belo Jardim and the new marsh at Cabo da Praia, with a view to making suggestions and proposals for the conservation of an Açorean wetland on Terceira.

GEOLOGICAL SETTING

The Terceira Rift, generally considered a secondary spreading centre (Krause & Watkins, 1970; Self, 1976;

Searle, 1980), forms the northeastern limb of the Açores Microplate, a submarine topographic high that arises near the Mid-Atlantic Ridge northeast of Flores and Corvo and trends east-southeast to near the African Plate, east-southeast of Santa Maria. It is not continuous but broken frequently by transverse faults, giving it the appearance of several, short, *en echelon* ridges separated by shallow troughs. The island of Terceira is roughly bisected by one of these ridges along a west-northwest to east-southeast-trending, four kilometre-wide, fissure zone positioned approximately along the line formed between the calderas of two volcanoes, the still active Santa Barbara and the extinct Cinco Picos. This elevated section of the Terceira Rift lies to the southwest of Praia da Vitória and north of Angra and is the focus of much volcanism, uplift and destructive earthquakes.

Praia da Vitória and Baía da Praia da Vitória occupy one of the basins adjacent to the Terceira Rift, bounded to the northeast by the Lajes Fault which marks another uplift zone. In the deeper waters surrounding Terceira, such basins accumulate fine oceanic sediments but, along the emergent coastline of the island, sand-sized particles eroded from the land accumulate within the shallow depression, or basin, of Baía da Praia da Vitória. The process is facilitated by southward-flowing currents sweeping against Ponta de Santa Catarina south of Praia da Vitória, depositing considerable

amounts of sand in Baía da Praia. This has produced the longest (three kilometre) beach in the Açores and the only shore once fringed by a 300 metre-wide dune field (Agostinho, *in* Bannerman & Bannerman, 1966). Much of the sand is derived from terrigenous igneous sources, but a thin veneer of calcareous debris upon the heavier volcanic sands gives the beach a distinctly white appearance. An analysis of five samples of the beach sand showed that it contained a mean of $65.6\% \pm 0.81\%$ of biogenic carbonate, comprised of shell fragments, bits of sea urchin spines, foraminiferan tests and the broken tests of bryozoans and calcareous algae, undoubtedly washed ashore from the shallow subtidal banks of the bay.

The low-lying nature of the shoreline, the protection afforded by the beach and former dunes, and the incursion of seawater through porous sediments behind the dunes were a natural setting for the development of a coastal wetland. Prior to human settlement, therefore, the region now occupied by the city of Praia da Vitória comprised the largest natural wetland in the Açores.

THE MARSH AT PAÚL, PRAIA DA VITÓRIA, TERCEIRA

The surviving marsh at Paúl, Praia da Vitória (Fig. 2), has been reduced to a small, shallow, pool fringed seaward by reclamation and, to the rear and its flanks, by agricultural land for livestock grazing although, at the moment, the north



FIG. 2. The marsh at Paúl, Praia da Vitória, Terceira, in the summer of 1997.

western flank has become an elevated wasteland dominated by the Castor bean *Ricinus communis*. The *Juncus acutus* component of the marsh lies to this side and is separated from the pool, lying on agricultural land, by barbed wire fences. Here also are many of the plants observed at other Açorean marshes, especially the Spear-leaved orache *Atriplex hastata*, but also Sea bindweed *Calystegia soldanella*, Watermint *Mentha aquatica*, Bramble (blackberry) *Rubus fruticosus*, Wild parsley *Petroselinum crispum*, Marsh dock *Rumex hydrolypium*, the Sea beet *Beta vulgaris*

and sparse stands of Seaside spinach *Tetragonia tetragonioides*. Several sedges stand amongst the other vegetation, most prominently Yellow nut-grass, *Cyperus esculentus* and the American rush, *Scirpus americanus*. Here also occurs the Slender rush *Juncus tenuis*, apparently recruited, like the two preceding sedges, from North America. The grass, *Holcus lanatus*, protected from livestock along the northwestern side of the pool by the fences, grows tall, producing large, showy, inflorescences. The same grass carpets the southeastern flank of the pool, just beyond

a muddy fringe disturbed by livestock, but here it takes the form of a prostrate creeper under the pressure of grazing. Interspersed among the cropped grass are solitary plants of Spear-leaved orache, *Atriplex hastata*, Ribwort plantain, *Plantago lanceolata* and young *Juncus acutus*.

The pool component of the marsh comprises a shallow, 50 metre-long, strip of water whose lateral dimensions change with the tide. The salinity of the water here was 34‰, determined on a rising tide and with no rain for the past few days. In the summer, at least, the surface of the pool is covered with a mat of *Enteromorpha intestinalis* and *Chaetomorpha linum*. Swarms of the ephydrid fly *Psilopa nitidula* crawl upon the algae and the surface of the water, making only short flights, even when disturbed. Fly pupae occupy the mud on the floor of the pool amid a few tiny *Assimineia eliae*, recorded only from Terceira (Backhuys, 1975). Also here, under mats of algae and the few stones, was the amphipod *Talitrus saltator*. When visited during a summer day, one Kentish plover *Charadrius alexandrinus* was feeding on the flies but, at dusk, three Coots *Fulica atra* had emerged from the *Juncus* and were also feeding on the pool. We observed a similar pattern in October, with one less Coot. Typically shy birds, they retreated quickly. The present poor status of the avifauna at Paúl reflects how significantly the marsh has deteriorated from its once proud reputation as the premier haven of Açorean

wading birds (Agostinho, in Bannerman & Bannerman, 1966). When the marsh was much more extensive, it supported, for example, a large population of small Mullet *Chelon labrosus* which local fishermen used to catch when taking to sea was a hazard.

THE MARSH AT BELO JARDIM, PRAIA DA VITÓRIA, TERCEIRA

Although some Terceirans are trying to preserve the pool and remnant *Juncus* community at Paúl, its fate is as uncertain as that of a second *Juncus* marsh at Belo Jardim, on the opposite side of the city of Praia da Vitória. Once part of what would have been an ecological continuum with Paúl, and which Agostinho (in Bannerman & Bannerman, 1966) described as a continuous marsh from Paúl to Ponta das Contendas, the marsh at Belo Jardim also occupied lowlands and a lagoon behind a large, 300 metre-wide, sand dune field near the southern terminus of the Praia da Vitória beach. This marsh was replenished at each tide by percolation of seawater through the loose sand, although it would also have received freshwater from rainfall and groundwater delivered from the adjacent highlands. Agostinho reported that gulls, terns and Kentish plovers roosted there as did visiting Lapwing *Vanellus vanellus*, Grey plover *Pluvialis squatarola*, Curlew *Numenius arquata* and Sanderling *Calidris alba*. Kentish plovers nested in the dune field.



FIG. 3. The marsh at Belo Jardim, Praia da Vitória, Terceira, in the summer of 1997.

The present *Juncus* marsh at Belo Jardim is considerably larger than that at Paúl, occupying at least 100 m² (Fig. 3). It appears, at least superficially, to be surviving but, in reality, its condition is, at best, precarious. The dune which once protected it has been removed and the marsh has been drained. Today, it is wetted only by rain which, except during the wettest winter storms, drains away quickly. As a consequence, although the *Juncus* plants survive, there is no other aquatic biota. The sole voice of a resident Quail *Coturnix coturnix* emerging from within the maze of *Juncus* attested to its dryness and

predominantly terrestrial nature as did the chirping of the Common field grasshopper *Chorthippus brunneus*. Several significant plants in addition to the *Juncus* are here, however, especially the Spear-leaved orache *Atriplex hastata*. Seaside spinach *Tetragonia tetragonioides* is more abundant here than at Paúl. As at Lajes do Pico, there is a second common rush, the bright green *Juncus maritimus* scattered among the *Juncus acutus*. The deadly poisonous Thorn apple *Datura stramonium* has invaded otherwise bare ground on the interior of the marsh, again attesting to the transition of this one time wetland to a terrestrially

dominated habitat. The exotic Russian thistle, or Tumbleweed, *Salsola kali*, with its numerous, sharp, prickles, dots low sand banks: all that remains of the once tall dune field which fringed the former marsh.

Like its contemporary at Paúl, the present stand of *Juncus* at Belo Jardim is a poor reflection of what once was a part of the most significant Açorean wetland. We have, however, discovered a third, emerging, wetland within a quarry outside the city of Praia da Vitória.

THE QUARRY AT PRAIA DA VITÓRIA, TERCEIRA

The construction of the harbour at Praia da Vitória necessitated quarrying large quantities of rock. This was initiated in 1983 at Cabo da Praia, south of the city, just beyond Belo Jardim. When landing at Terceira's Lajes airport from Praia da Vitória, the quarry is evident from windows on the left side of the aircraft, appearing as a rectangular precipitous escarpment surrounding a 300 m x 500 m scarred and sparsely vegetated bowl with large trucks entering and departing (Fig. 4). Its southern half appears greener and to have been worked out and abandoned, although it is now being used as a dump for construction debris, soil and household rubbish (Fig. 5). The reasons for the green in the quarry were investigated in July, August and October, 1997. At first, this portion of the quarry, approximately half of the entire site, seems unpromising and unproductive, its

ledged cliffs rising some twenty metres above the excavated floor and terminating, seaward, on the original, coastally-eroding, platform from which the quarry was dug. The landward, northwestern, portion of the quarry is still being used and here, with little vegetation, it resembles a boulder field on Mars.

The construction of the harbour and the Cabo da Praia quarry which facilitated it led to a number of mistakes in the absence, presumably, of a scientifically responsible environmental impact statement. The first was that the fate of the *Juncus* marsh at Belo Jardim was largely scaled. As the port and its associated activities grow, that marsh will disappear — it is already largely a relict. Second, at its southeastern end, the quarry was excavated too close to the sea. An even cursory examination of the original ledge presently separating the sea from the quarry floor reveals that its seaward face is actively eroding, probably facilitated by winter storms, with soil and rocks from it falling onto the coastal boulder shore below. The third mistake was that this end of the quarry was dug too deeply, penetrating the coastal water table. Each rising tide on the adjacent seashore pushes estuarine groundwater into the base of the quarry, partially filling depressions therein.

The collective consequence of these mistakes is that a unique Açorean wetland has been created, allowing the people and the government of Praia da Vitória to assuage

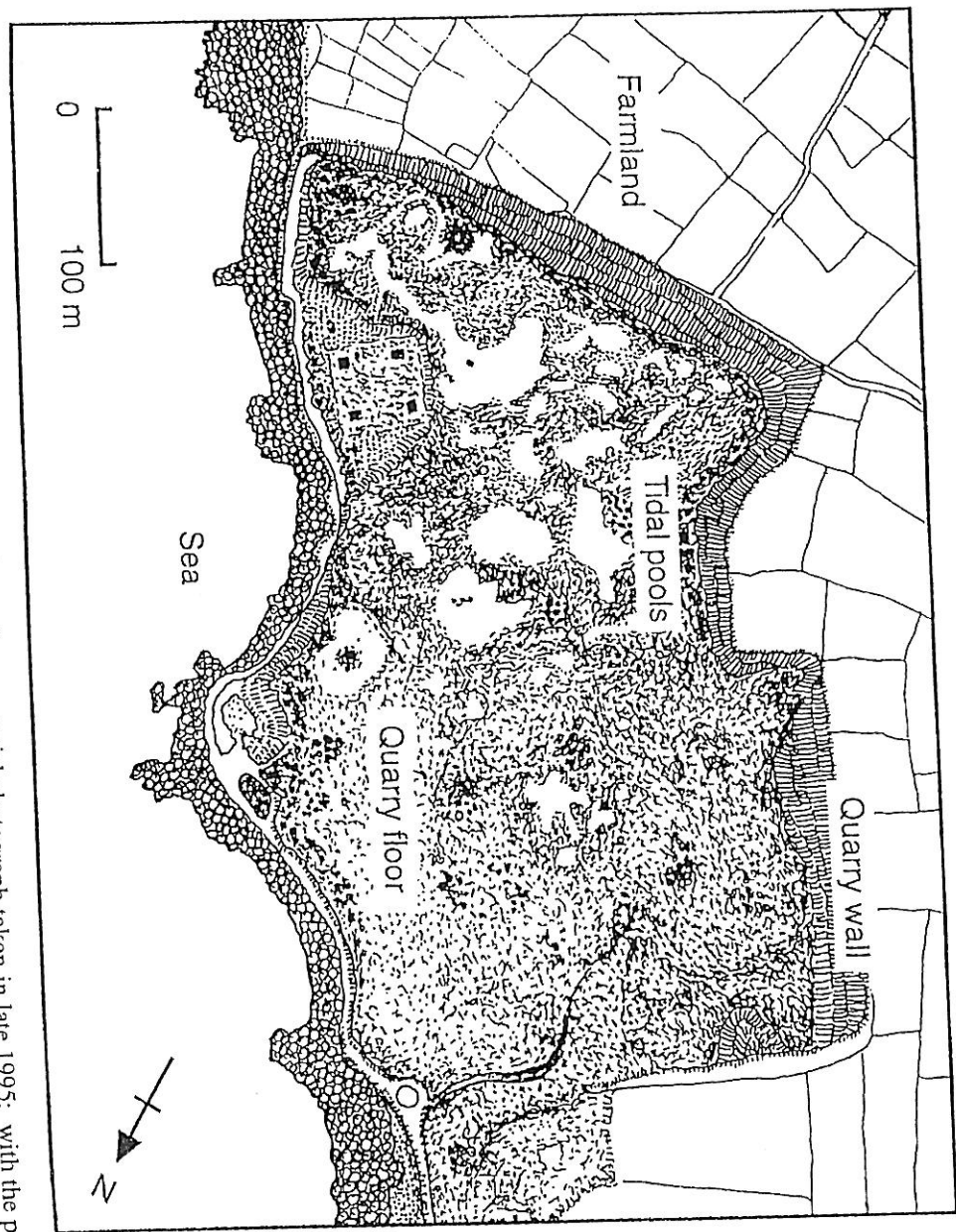


FIG. 4. A plan view of the quarry at Cabo da Praia. (Redrawn from an aerial photograph taken in late 1995; with the permission of the Direcção Regional do Ordenamento Urbanístico and the Instituto Português de Cartografia e Cadastro).

their consciences (where and if they exist) over the virtual loss of the formerly most significant marsh in the archipelago. The remains of the *Juncus* marsh at Paúl da Praia can now become what it actually is, a village pond, reminding every Terceiran resident of his and her coastal and cultural heritage. It can never again be a true wetland because it has been reduced to insignificant proportions. No matter. An accident of industry has created Paúl's successor, a wetland of manageable size in government-owned land that already has in place all of the infrastructural necessities for survival and public access.

The seaward ledge which surrounds that part of the quarry is characterized by scrub and the Cane *Arundo donax*. There are also Tamarisk trees, *Tamarix gallica*. This vegetation also fringes the internal ledges of the quarry cliffs and cane has invaded what appears to have been the quarry workmen's huts but, now, consists of a few tumbled brick buildings along the seaward margin of the quarry. In a few places, the Cane has already invaded the quarry floor. The floor itself comprises much dumped refuse and irregularly-terraced, boulder-strewn, crumbled ash depressions and elevations. These depressions flood with water periodically and, in so doing, interconnect to form broad, shallow, pools (Fig. 6). On spring tides, the entire floor of the southeastern end of the quarry floods to form a shallow lake.

Hydrology of the quarry pools

It is clear that the pools of the Cabo da Praia quarry are filling and emptying in rhythm with the tide, that is, flooding at high tide and draining on the ebb. The salinities of 16 pools were examined over a period of three days in July and August and one day in October at different tidal elevations, except low, when most of the pools drain. Salinity values ranged from between 21-28‰ (Table 1). Little variation occurred between the individual pools, although there is the suggestion that those at highest elevations (lower numbers) were slightly less saline (21-22‰) than those at lower ones (higher numbers) (27-28‰). Similarly, although the average salinity of the pools (25‰) varied little between falling, rising and flood tides, there is again the suggestion that the average salinity was slightly higher (25.4‰) than at the time of the falling tide (24.6‰). The salinity at the low ebb tide could not be measured because, at this time, the pools are largely drained.

We interpret these data to argue that a cell of groundwater occupies the porous spaces between rocks lining the bed of the quarry. It almost certainly varies in salinity with the frequency and duration of rainfall and groundwater supply from the land, probably being less saline apically and more saline basally, that is, a freshwater input settling on top of the marine one, accounting for the slight discrepancy in salinity values



FIG. 5. The wetland at Cabo da Praia, viewed from the landward cliff, in the summer of 1997.

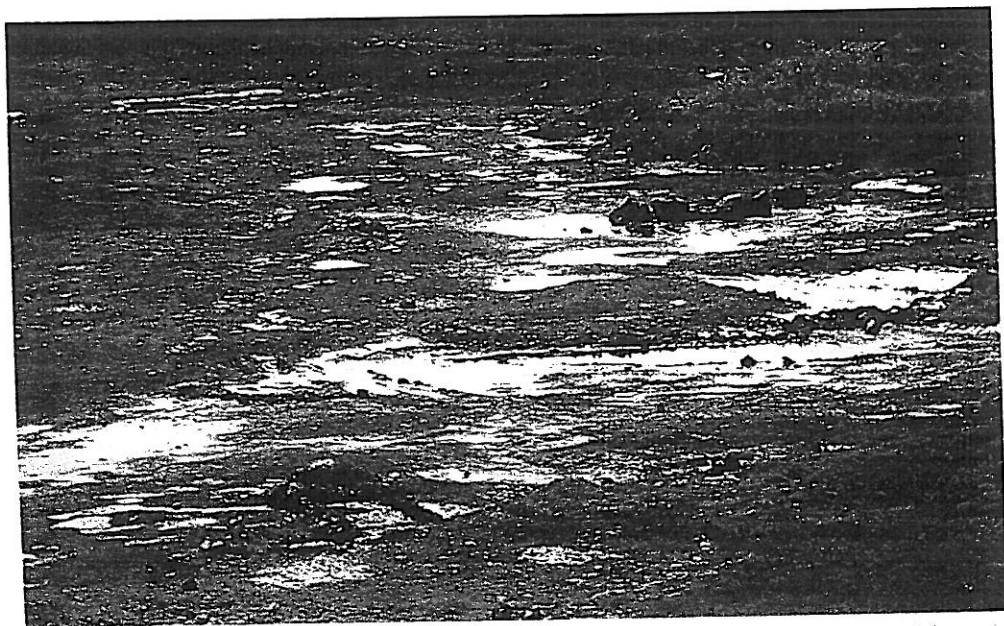


FIG. 6. The wetland at Cabo da Praia; ponds at a falling tide, near the abandoned huts, in the summer of 1997.

TABLE 1. The salinity of the pools in an approximate sequence from higher to lower elevations in the quarry at Cabo da Praia, Praia da Vitória, Terceira, taken over different stages of the external tide, in July/August and October, 1997.

Pool	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Mean
July/August 1997																	
	Salinity (‰)																
Falling tide	21	22	25	26	25	23	24	23	24	26	24	27	26	27	25	25	24.6
Rising tide	22	25	24	21	28	24	25	25	25	25	26	25	22	28	27	27	25.0
Flood tide	25	23	23	25	22	25	26	24	25	27	26	27	28	26	27	27	25.4
MEAN	22.7	23.3	24.0	24.0	25.0	24.0	25.0	24.0	24.7	26.0	25.3	26.3	25.3	27.0	26.3	26.3	25.0
October 1997																	
	Salinity (‰)																
Falling tide	25	25	25	23	25	26	26	22	21	22	25	24	25	27	27	28	24.8

between high and low elevation pools. This cell of water is pushed upwards by the hydrostatic pressure of the rising tide, eventually emerging from fissures and crevices in the quarry bedrock to flood much of its floor. As the tide ebbs, the water drains back into the rock.

Ecology of the pools at the Cabo da Praia quarry

Because the quarry floor depressions will be filled to an 'average' level over the course of a lunar year and higher elevations only on spring tides, a simple pattern of "intertidal" zonation has emerged around them. Moreover, a few of the pools, or portions of them, do not drain entirely. Patches of *Ruppia maritima*, recorded previously from the Açores only from São Jorge (Hansen & Sunding, 1985), in the lagoon at Fajã dos Cubres (Morton *et al.*, 1996), occur in these pools (Fig. 7). The vegetation surrounding the pools displays a distinctive zonation pattern. The Cane *Arundo donax* occupies higher ground at the quarry edges. Between adjacent tall plants and even within rusty, abandoned, oil drums

the large yellow and black spider *Argiope bruennichi* builds large orb-shaped webs. The cane is succeeded at lower levels, virtually everywhere, by the thin, erect, grey-green, Jersey cudweed *Gnaphalium luteofolium*. Below this, a dense bed of the Spear-leaved orache *Atriplex hastata* fringes the pools just above the influence of the highest spring tides. Lower still and covered by most average tides is another dense bed of vegetation consisting entirely of the Lesser sea spurry *Spergularia marina*, a delicate, low, fleshy, annual with leaves arising in groups up each stem. Tiny, 5-8 mm, five-petaled flowers crown the apices of most branches. The purple-pink flowers open when uncovered by water in bright sunlight, but close when either immersed or at night. The species has been recorded previously from Terceira, Pico, Graciosa, São Miguel and Santa Maria (Palhinha, 1966), but this is the first record of it as a mat. The fourth plant in this zonation sequence is *Ruppia maritima* occupying the bottoms of the non-draining pools. Elsewhere, however and even in the same pools as *Rup-*

pia, the depressions are covered by a mat of diatoms and blue green algae similar to that seen at Fajã dos Cubres and which at higher elevations cracks in the sun to form marginally up-curved saucer-shaped plaques. In the same low-level pools, a thin layer of pale pink pigment indicates the presence of chemosynthetic sulphur bacteria surviving in the presence of a highly reducing hydrogen sulphide environment, which gives off the faint odour of rotting eggs when the water is low (Fig. 8). Several pools had dense mats of *Enteromorpha intestinalis*, *Ulva rigida* and *Chaetomorpha linum*



which dry out in summer to form a grey-green crust covering pool floors at low tide and, indeed, to blanket the lower margin of Sea spurry.

The tidal range in the quarry may be as much as 50 cm on average, in comparison to the 2-3 cm at Lajes, Pico and Fajã dos Cubres and Fajã de Santo Cristo, São Jorge (Morton *et al.*, 1995, 1996; Morton & Tristão da Cunha, 1993) because of the proximity of the sea (although it can neither be seen nor heard) and the obviously highly porous nature of the basalt bedrock. Because the sea is so hidden, however, the impression is that one is observing a land tide!



FIGS. 7-8. The wetland at Cabo da Praia. 7, *Ruppia mariitima*; 8, sulphur bacteria.

The only invertebrates recorded from the quarry pools were the amphipod *Orchestia mediterranea*, under stones, three species of tiny prosobranch gastropods, *Assiminea eliae* (Backhuys, 1975), an unidentified species of *Assiminea* and *Paludinella littorina* and the fly *Psilopa nitidula*, its eggs and pupae resident in the mud and algal mats. The red dragonfly *Sympetrum fonscolombei* was patrolling the ponds hunting flies. This community is similar to that at Paúl da Praia, suggesting ecological continuity between the two.

Birds

The true wonder of the quarry lagoon, however, is its avifauna which, in its albeit reduced richness, stands out against the paucity of birds at Paúl da Praia and Belo Jardim and, further, recalls the former richness of the Paúl marsh remembered by Agostinho in Bannerman & Bannerman (1966) and, from here and elsewhere in Terceira and the Açores, by Le Grand (1983). The latter recorded 24 species of breeding birds from Terceira, including Cory's shearwater *Calonectris diomedea*, the Kentish plover *Charadrius alexandrinus*, the Common snipe *Gallinago gallinago*, the Herring gull *Larus argentatus* and the Common and Roseate terns *Sterna hirundo* and *Sterna dougallii*, respectively. Most significantly, the marsh at Paúl was home to the endemic Açorean Moorhen *Gallinula chloropus correiana*, but which, with the demise of the marsh at Paúl da Praia, is probably now

locally extinct (Agostinho, in Bannerman & Bannerman, 1966).

Today, the quarry cliffs are home to hundreds of Rock doves *Columba livia*. Also present in the quarry were the Canary *Serinus canaria*, the Black-cap *Sylvia atricapilla*, the Goldfinch *Carduelis carduelis*, the Blackbird *Turdus merula*, the Starling *Sturnus vulgaris*, the Grey wagtail *Motacilla cinerea* and the ubiquitous House sparrow *Passer domesticus*. Such birds are seen everywhere in the Açores but it was the seabirds which were a surprise.

Over a period of three days in July 1997, the following species were recorded from the quarry. Common terns *Sterna hirundo* and Roseate terns *Sterna dougallii* washed themselves and roosted on favoured, so soiled, pool rocks. There were two Whimbrel *Numenius phaeopus* and the site was being used as a roosting site by three Grey heron *Ardea cinerea* and, surprisingly, one Little egret *Egretta garzetta*. Single individuals of Sanderling *Calidris alba* and Green sandpiper *Tringa ochropus* were identified. There were pairs of Little-ringed plover *Charadrius dubius* and juvenile Grey plover *Pluvialis squatarola* present and flocks of approximately 12 Turnstones *Arenaria interpres*, turning stones and the dried algal plaques presumably in search of amphipods, and approximately 30 Kentish plover *Charadrius alexandrinus*, feeding on the flies. The flocks of both the latter species comprised adults and first summer birds, that is, those hatched

the previous calendar year. Turnstones do not breed in their first summer and remain far south of the breeding grounds (Hayman *et al.*, 1986). The presence of so many species attests to the newly discovered significance of the quarry and is a good reflection of what Agostinho (*in* Bannerman & Bannerman, 1966:7) recorded from the lagoon at Belo Jardim in the 1960's. The most interesting record from the quarry, however, was three individuals of the Black-tailed godwit *Limosa limosa* in breeding coloration, with a characteristic russet-coloured head and white underparts flecked with black. They were busy feeding, by probing, in the *Atriplex hastata* beds with their stout bills. Le Grand (1983) regards this species as a 'fairly common' winter visitor to the Açores although Bannerman & Bannerman (1966) think that it reaches the islands in 'some numbers'.

In a return visit to the quarry in late October 1997, an even bigger avian surprise was present. In addition to Herring gulls, there were three Black-headed gull *Larus ridibundus*, albeit in winter plumage and, thus, with a white head, 40 Common terns and two roseate terns. There were four Grey herons, two Little egrets, one Wimbrel, a flock of 30 Kentish plovers, some 20 Turnstones, six Grey plover in winter plumage, a flock of over 100 Sanderling and some 20-30 Little-ringed plover. Additional species recorded were eight Bar-tailed godwits *Limosa lapponica*, seven Knot *Calidris canu-*

tus and five Dunlin *Calidris alpina*, all in winter plumage, and two female Mallard *Anas platyrhynchos*. It was apparent that the roosting gulls and terns were using the quarry regularly and further that the resident and visiting waders were here feeding (Fig. 9). Although disturbed by our presence, they did not fly away but moved from one part of the quarry to the other. The autumn visitors, in particular, typically seen in the Açores as solitary individuals, were here as small flocks and clearly identified with the quarry and its various contained habitats. In the absence of *Juncus*, however, no Coots were recorded from the quarry.

DISCUSSION

In the introduction to this paper, we identified coastal areas and habitats of the Açores and their species that have been proposed for protection and conservation. In particular, we support all the suggestions of Santos *et al.* (1995), albeit with the provision that there is the possibility for flexibility with regard to different degrees of protection. For example, the sheer inaccessibility of the sea cliffs of Ilhéu de Baixo, off Graciosa, is effective in affording protection to the colonies of nesting Common and Roseate terns, both, uniquely, doing so on narrow ledges instead of the more usual coastal platforms. Conversely, as we have described herein, the lagoon at Fajã dos Cubres, one of the most ecologically sensitive and delicate of all local

intertidal habitats (Morton *et al.*, 1995), has, in 1997, been extensively perturbed. It is protected by legislation in theory, but not in practice. This is because the legislation does not have the accompanying regulations and, as a consequence, there is no means to enforce such legislative paperwork. Wetland destruction is, however, a global phenomenon, the word for the habitat too often being equated with 'wasteland'. It is precisely this attitude that led to the demise of the *Juncus* marsh at Paúl da Praia on Terceira but, in investigating the remains of this once thriving wetland, we discovered something that gives the conservation of such habitats in the Açores some cause for

hope. Before discussing this, however, we wish to point out several features of the Paúl marsh and new wetland at Cabo da Praia.

Morton *et al.* (1997) have shown that the Terceiran wetlands are ecologically fundamentally different from other Açorean wetlands on São Jorge and Pico. This is because, on Terceira, secondary productivity in the two sites seems to be principally based around the fly *Psilopa nitidula* and amphipods both being exploited by flocks of Kentish plovers and Turnstones, respectively, whereas at Fajã dos Cubres, for example, it is based around the prawn *Palaemon adspersus*. There are very few reports of an aquatic system with a fly-based source of secondary



FIG. 9. The wetland at Cabo da Praia; high tide, with flocks of roosting birds, in October 1997.

productivity. The best known such system is the Great Salt Lake in Utah, USA, where the ephydrid fly *Ephydra cinerea* is often the only benthic metazoan and creates an annual productivity of 50 g.m² (Collins, 1980). In freshwater Lake Malawi, Malawi, the larvae and pupae of the lake-fly *Cubers epulis*, feed on zooplanktonic crustaceans forming another unique food chain, the ultimate productivity of which is largely exported (Degnbol, 1993; Allison *et al.*, 1996). Of relevance to the situation at Cabo da Praia, however, Barnard (1993) showed that in a rehabilitated gravel quarry pit in England, the removal of fish resulted in an increase in the numbers of chironomid flies and a related increase in the breeding success of the Tufted duck *Aythya fuligula*. The fly at Cabo da Praia is likely the major source of food for the resident flock of Kentish plover. Feeding birds were observed stabbing rapidly at the mud surface on which the flies are the only invertebrates. This may, therefore, be a significant factor in the survival of Kentish plovers as a resident here. Another factor, however, is related to the propensity for the female to abandon her first clutch, leaving the male to hatch and rear it, while she produces a second one with another male which they then both raise. This appears to be unique among wading birds (Szekely & Williams, 1994). Kentish plovers are also highly vigilant, so that the combination of the unique food source, reproductive strategy (also

sustaining genetic diversity) and behaviour contribute to its continued survival here as long as the environment to support it persists.

We have recorded flocks of Turnstones from other locations in the Açores, for example, Lajes, Pico (Morton *et al.*, 1996). This species has a very catholic diet spanning many habitats (Gill, 1986), but is also recorded to eat flies (Smith & King, 1988). Like Kentish plovers, Turnstones are extremely vigilant (Metcalf, 1984). The continued survival of the Turnstone in the Açores, therefore, probably relates to its feeding opportunism, the species even being known to destroy tern colonies through egg predation (Loftin & Sutton, 1979), vigilance and, possibly, at Cabo da Praia, a secure roosting site. Here too it was turning stones, the only known occupant of the undersurfaces being *Orchestia mediterranea*. The Kentish plover and Turnstone are the only flocking waders we have observed at a number of locations in the Açores and, as discussed above, there may be good reasons for their continued survival locally. The other species of waders recorded from Cabo da Praia may be either vagrants or summer or winter visitors. Certainly the Dunlin, Sanderling, Knot, Grey plover and Black-headed gull were all in winter plumage. Le Grand (1983) records that the Grey heron *Ardea cinerea* used to breed on Santa Maria. The record of four at Cabo da Praia suggests to us that the species may be resident. Our reports of other birds

say nothing of their Açorean status although the three Coots in the *Juncus* marsh at Paúl suggest that they, too, are still resident.

Morton *et al.* (1997) have reported on the quarry at Cabo da Praia in more general terms and proposed that it be developed as a wetland reserve, catering for visitors, students, local community groups and tourists. How could this be achieved? Elsewhere in the world, quarries have been converted, either naturally or deliberately, into new wetland habitat, the most famous being the Sevenoaks, Kent, England Gravel Pit Reserve (Harrison, 1974). Andreas & Host (1983) have shown how an abandoned sandstone quarry in Ohio, USA, has developed into a weakly minerotrophic, freshwater, swamp, over a period of seventy years, based around five species of *Sphagnum* moss and with thirty-five other species of vascular plant present, six of which are on Ohio's rare plant list. Huebner *et al.* (1986) showed how aquatic birds returned to a rehabilitated inland quarry in Germany and Hill *et al.* (1987) showed how Mallard *Anas platyrhynchos*, bred successfully in a flooded, freshwater, quarry in England. Jaakson (1981), showed how five disturbed landform quarries in Canada, all close to urban areas, could be developed as outdoor recreational assets for city dwellers. This case study illustrated the positive value of a disturbed landform as a potential amenity in the open space system of a city and its surroundings. The author pointed out, however,

that hydrogeology and groundwater movement have to be considered in the process of landscape planning and design. Such would also have to be considered if and when the Cabo da Praia quarry is considered for rehabilitation. More related to the Açorean situation, Street (1976) discussed the ways in which a 300 hectare quarry in England had developed a fourteen hectare bird breeding reserve, particularly for ducks, that is, Mallard and Tufted duck *Aythya fuligula*. This involved the testing of different nesting structures and their sitings to determine their effectiveness. Most recently, Anderson & Brown (1991) studied a limestone quarry in the USA and showed how a half a square hectare of wetland was established on a stressed area of its floor and eventually comprised some 86% native species. All the more significant for the Cabo da Praia situation, however, was the observation that such a plant community had developed on an analogous substratum of a thin layer of topsoil and with fluctuating periods of inundation and flooding.

These studies all point to the potential for quarry rehabilitation as wetland reserves in many parts of the world. It thus seems at least possible that such a rehabilitation could take place at Cabo da Praia. Indeed, from the above description of the habitat which has already developed since work stopped in this part of the quarry, there would seem to be little restitution work necessary, save for, as pointed out by Jaakson (1981),

careful landscape planning within the present groundwater hydrogeographic regime of the quarry. The beauty of this proposal is that it would cost relatively little to achieve: the quarry is government owned, the wetland is essentially already there, the important habitats within it are easily identifiable, there are existing buildings for conversion to a temporary management and education centre. There would be an education centre, a guided walk around the cliff edge and within the quarry, bird watching hides strategically placed and a resident manager, wardens and education officers. The development would be seen by government and international fund-awarding bodies as a positive step to replace the original marsh at Praia da Vitória and which can now be allowed to end its existence as a wetland, but perhaps surviving as a village heritage pool. Gracefully. Kusler & Kentula (1990) provide a review of wetland restoration in the United States and provide a set of planning and implementation recommendations for persons and organisations preparing to undertake such rehabilitation work.

Medeiros *et al.* (1996) continued the search on Terceira for a habitat suitable for the endemic Açorean Moorhen *Gallinula chloropus correiana*. To be able to re-create such a habitat for such a species, if it is not locally extinct (Agostinho, in Bannerman & Bannerman, 1966), or, if it is, by the re-introduction of external stocks of the parent species,

would give added significance to the whole rehabilitation exercise and provide the quarry reserve with its species flagship.

This paper is also the first report of a *Spergularia marina* community in the Açores. It is, also, only the second record of a Widgeon grass, *Ruppia maritima*, community in the Açores (Hansen & Sunding, 1985; Morton *et al.*, 1995). The latter authors pointed out that the *Ruppia maritima* community at Fajã dos Cubres, São Jorge, was probably established from viable drupelets carried there in the intestines and faeces of wading birds. Bearing in mind, the very recent origin of the Cabo da Praia quarry, the likelihood is that it too was colonised by the seagrass in the same way, probably from Fajã dos Cubres, but a short flight away. The quarry at Cabo da Praia, therefore, is already a significant Açorean wetland.

There is, however, one important constraint to the proposal to establish Cabo da Praia as a rehabilitated wetland. There is already Açorean legislation which prohibits the hunting of sea birds, but such prohibition is, apparently, ignored. We were told, during our October visit, that two "geese" (probably Canada geese, *Branta leucopsis*) had been shot in the quarry. Legislation would have to be enforced at Cabo da Praia, if the newly-evolving wetland is to stand any chance of re-creating the wading bird environment of its predecessor, Paúl. Recognising that hunting constitutes one of the most

significant sources of disturbance for waterbirds throughout Europe, Madsen & Fox (1995) point out that quarry birds are potentially the most susceptible to disturbance by disrupting pair bonds and family structures to reduce reproductive success. Accordingly, if the quarry was to be developed as a new wetland, it would need not just protective legislation but also wardening and careful scientific monitoring with the gradual development of habitat suitable for the roosting, feeding and nesting of the greatest variety of species.

Throughout the world, community-based action groups, mindful of the destruction of their local wetlands, are either creating or rehabilitating disturbed marshland habitats. The formation of such a group would be a necessary development, too, in Terceira. Morton *et al.* (1996) also argue the need for the development of an Açorean ornithological society in the great tradition of Col. A. Chaves, Col. J. Agostinho and Álvares Cabral, to monitor and record bird numbers and species, especially at the different wetland sites so far identified but, especially, again at the newly-discovered quarry on Terceira. There is also a need for the establishment of a scientific research group dedicated to wetland ecology and which would through its activities and discoveries eventually finding their way into the local public and educational domain, lay the basis for the recognition of the need to protect such, so obviously endangered, coastal Açorean habitats.

ACKNOWLEDGEMENTS

The senior authors are grateful to the trustees of the Sociedade Afonso Chaves, Ponta Delgada, São Miguel, for the provision of finances which made this study possible. The authors are also grateful to Dr. Jorge A.P. Bruno, Instituto Açoriano de Cultura, Angra do Heroísmo, Terceira and Francisco Jorge Ferreira, Provedor da Santa Casa da Misericórdia da Praia da Vitória, Terceira, for hospitality and the benefit of discussions. David Melville (WWF, Hong Kong) kindly commented on our interpretation of the avian fauna of the quarry.

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