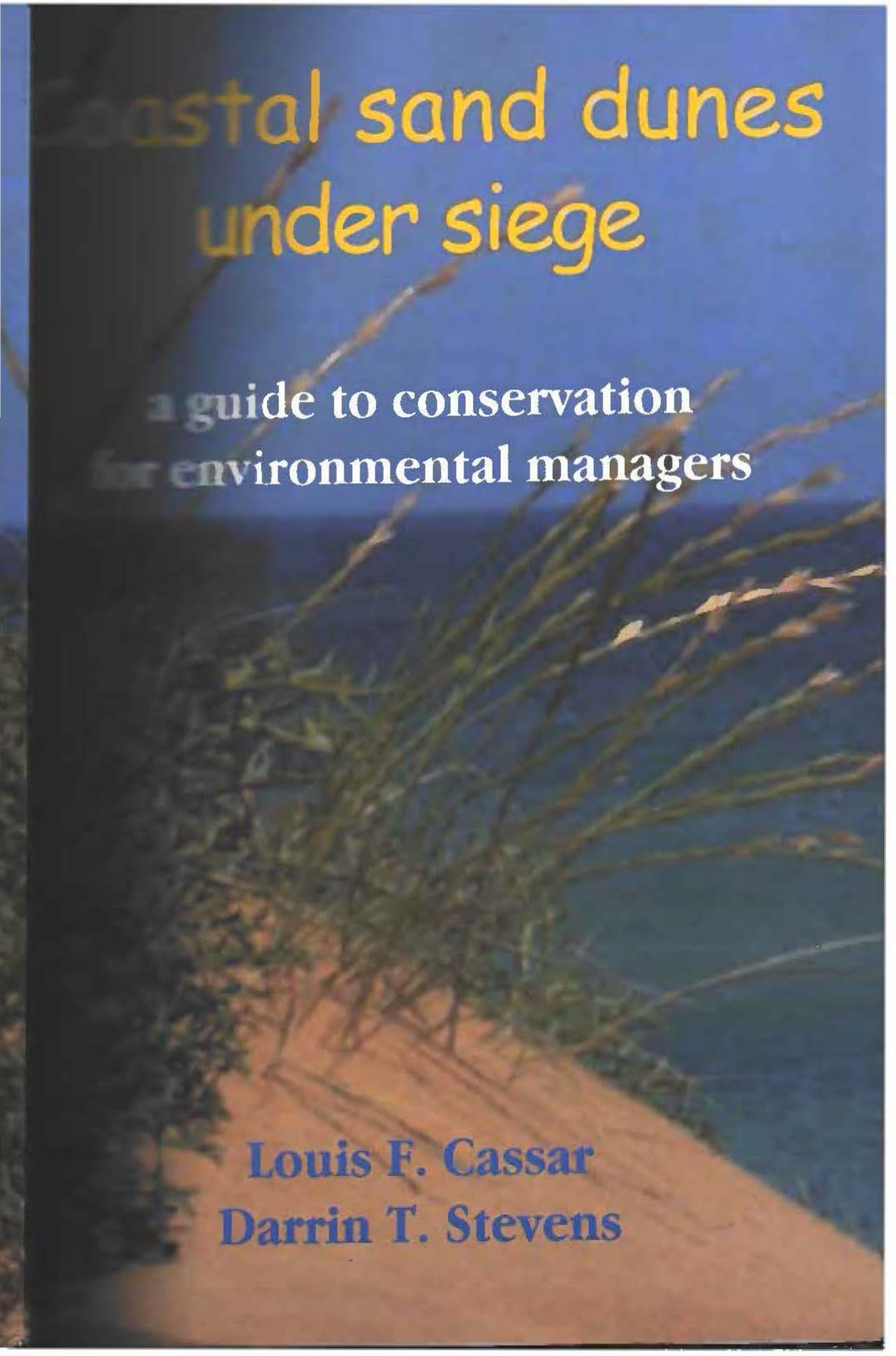
Coastal sand dunes
under siege
a guide to conservation
for environmental managers
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To

a paradise lost

a natural heritage that characterized Maltese coastal landscapes
and
to all those who genuinely strived to protect it

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The authors have had a long-standing interest in coastal dunes, having specialised in conservation management and floristics of sand dunes through their respective postgraduate studies. Louis F Cassar has travelled extensively in the Mediterranean region during the last two decades, in connection with conservation issues and, more recently, coastal management and dune conservation. Darrin T Stevens' interest in the subject was initiated following technical field visits to the San Rossore National Park and Parco dell'Uccellina in the Maremma in Tuscany.

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International Environment Institute: Established in 1987, the International Environment Institute aims to foster and disseminate respect and concern for humankind, and for the natural, urban and socio-cultural environment. The IEI, a conjoint Institute of the Foundation for International Studies and the University of Malta, conducts training, research and networking activities on environmental issues, and regards human resource capacity building in the fields of environmental science, and environmental planning & management as a priority. In this regard, the Institute organizes postgraduate and undergraduate courses in these areas. It also holds short intensive courses, research seminars and training workshops, often in collaboration with specialised international bodies, in areas such as environmental impact and strategic environmental assessment, environmental economics, integrated coastal area management and the use of GIS as a tool for environmental appraisal.

foreword

Coastal regions have for centuries been of benefit to humankind. Worldwide, human populations exploited the littoral and adjoining seas as a consequence to its relatively rich resource base. Particularly in an enclosed sea as the Mediterranean, demographic growth has had a marked effect on the region's resources. In recent decades, intensive shipping-related activities, industrial and infrastructural development, and other anthropogenic activities located close to the coast have led to an increased degradation of coastal ecosystems. The Maltese Islands are no exception and although numerous dune systems were obliterated during colonial times as a result of major developments along various parts of the coast, remaining sand dunes were further degraded during the decades that followed independence. This occurred, primarily, as Malta began to transform itself into a tourist destination.

Since sand dunes are much dependent on a variety of factors that lie further afield from the beach zone per se, they are among the most vulnerable coastal assemblages with respect to stability. For this reason, even topographical modifications of inland landscapes may have a severe negative influence on dune dynamics, consequent to alterations or disruptions of sediment fluxes. Sadly, only a few dune assemblages remain in the Maltese Islands, with *Ramla l-Hamra* being, so far, the best example, while others vary from highly impoverished to mere remnant sites.

Notwithstanding the protection measures undertaken by local agencies in recent years, conservation management of dunal sites in the Maltese Islands still lags behind. This publication recognises the importance of dunal systems and promotes their active conservation. The authors outline the various complex processes, which lead to the morphological development of dunes on the coast. Moreover, due emphasis is made upon the elements and zones that play a crucial role in maintaining dune field dynamics in a state of equilibrium.

No site is an island and coastal sand dunes require a broad and holistic approach to ensure their adequate conservation. This publication, made possible through UNESCO financial aid, should serve as a reference manual for coastal managers, environmental planners and conservationists. It may also serve as an eye-opener to all those who have natural heritage at heart. The further degradation of dunal habitats in the Maltese Islands and, indeed, elsewhere in the Mediterranean, shall leave us with a poorer genetic pool and a less diverse landscape, which, incoming and future generations have a right to enjoy.

Professor Charles J Farrugia
Chairman
Maltese National Commission for UNESCO

1 coastal sand dunes: an overview

contents

1.1 an overview

Coastal sand dunes, the result of a complex process involving aeolian sand transport and deposition, are formed through the interaction between sand movement, by means of wind action, and the characteristic vegetation cover which colonizes this type of coastal environment.

Coastal dunes are widely distributed across the globe and are to be found in arid, semi-arid and temperate climatic regions. They usually occur in a wide zone adjacent to the high-water mark and may extend inland for some kilometres. According to Cooper, coastal sand dune systems may extend inland for anything up to ten kilometres (COOPER, 1967; as quoted in PETHICK, 1984). Indeed, the coastal dune field at Zouaraa on the north-west coast of Tunisia, on which research is being carried out by one of the authors (LFC), extends beyond 12 kilometres inland to the Tabarka-Nefza thoroughfare.

The region of coastal sand deposition beyond the beach zone, that is, the sand dune area, may exhibit a relatively straightforward morphology of dune ridges deposited in parallel to the waterline and distanced from one another by a series of marked troughs. It may, on the other hand, develop into a system of sand ridges arranged at varying angles to the shore, sometimes forming "U-shaped isolated masses" (PETHICK, 1984) at right angles to the ridges.

Coastal sand dune ridges may vary in height from one to twenty and sometimes 30 metres, and are usually characterized by steep windward gradients and more gentle lee slopes. Dune crests are somewhat flat in appearance, often undulating with sparse shallow depressions. These semi-circular hollows within the dune ridge, known as blow-outs, do not usually support any vegetation cover and are the result of wind erosion. The age of an entire sand dune system can be estimated by noting the sequence of dune ridges developing (or, having developed) inland from the fore-dune area; the further landward the ridge formation, the older the dune. Goldsmith points out "the outstanding feature of these dune ridges is that each one represents a different stage in dune development rather like the growth rings with a tree-trunk" (GOLDSMITH, 1978; as quoted in DAVIES, 1978). Therefore, each dune ridge is a temporal stage in the development of the coastal dune system *per se.*

Sand dunes are as much a part of the coastal geomorphological process as any other landform dominated by the action of seawater and/or sediment movement. The time interval for development between each dune ridge varies from one location to another and is dependent on a number of factors. Pethick however, gives a broad estimate of between seventy and two hundred years, which he predicts by considering the morphology of an entire dune system and the development of each individual ridge; the result of the relationship between the rate of sand transport and the pattern of wind velocity streamlines (PETHICK, 1984). The rate of coastal dune formation is largely dependent on complex geomorphological processes. However, human agency may, at times, also play a role in dune development, although more often than not one finds that dune systems are affected negatively by anthropogenic influence. Engineering works to provide recreational facilities on the coast is a case in point.

In addition to onshore wind action, an abundant supply of sand and a vegetation cover, dune formation also depends on, what appear to be remotely related, climatic conditions. Although coastal dune systems occur throughout the world, they are more frequent on coasts experiencing temperate, arid and semi-arid climatic conditions, and are less likely to develop extensively in tropical and sub-tropical environments. The limiting factors in such environments include generally low wind velocities, damp sand conditions and a dense vegetation cover growing close to the waterline.

Coastal dunes differ from their desert counterparts in their somewhat different morphology. Although the basic processes of dune formation involving aeolian transportation of sand particles are similar, one of the principal elements that typically interacts with sand movement in coastal sand dunes, namely, vegetation-cover, is not present in desert dune systems.

1.2 the coastal zone from a socio-economic perspective

From time immemorial the coast has provided humankind with numerous benefits, primarily of a subsistence and economy-oriented nature. The marine environment has for centuries contributed to humankind's dietary requirements, while sea-salt (a natural resource derivative and an important basic need) has been produced since early civilization.

Humans have established urban centres near the sea since the earliest of times. From around the High Medieval to more recent times, in particular during the past one hundred and fifty years or so, increasingly more people have moved back to the coast. The reasons for this may be attributed to commerce and trade opportunities. However, improvements in social well-being and societal structures during the last eighty years or so and, closer still, with the advent of inexpensive travel possibilities (which seems to have had a catalytic effect since the fifties), are seen to be largely responsible for the pressures exerted on the littoral.

According to a United Nations agency estimate, some 66% of the globe's population lives within a few kilometres of the coast and, as a result, pressures stemming from human activity such as urban sprawl, food production, industry, communications and transport, and recreation, are concentrated in the region. For this reason, the coastal zone and adjoining marine habitats are potentially sites of extreme resource conflict.

In recent decades the coastal zone, or as it is popularly known 'the riviera', became the in-place for the masses. Sea-sports became increasingly popular and as the years went by, more diverse, while shore-based activities such as beachside camping, barbecues and beach picnics became more appealing with the result that round-the-clock disturbance increased significantly. One factor that has compounded the issue and, which has further attracted the masses to the sea, is the trend of acquiring a suntan. This, in some societies, has practically attained the level of a culture, notwithstanding the awareness of increased health risks due to exposure. These reasons and others have led to mass tourism, and worse still, to the trend of 'sun, sea and sand' holiday-making, which in broader terms translates to indiscriminate development of the littoral.

The devastating effects on the natural environment as a result of tourism and leisure, especially in those countries experiencing vacation-friendly climates, can result from insensitive development and an attitude for securing a quick source of income. This was particularly prevalent during the post-war period when the tendency to industrialize at the quickest rate possible was much in evidence. The unsustainable use of land and other natural resources, as though these were infinite, was at an exceptional high, principally during the fifties and sixties following the deprivation experienced during World War II. Privately owned seaside dwellings belonging to the affluent few, which once stood uncontested and relatively undisturbed, began to make way for, or rub shoulders with, resorts and holiday complexes. As the years went by, pristine sites were suffocated with concrete structures and hard-landscaping. Apart from mounting more pressures on existing infrastructure as well as contributing towards an overall escalation of domestic waste, tourism may also bring about a cultural disparity. In such context, the loss of cultural diversity could have as devastating an effect on a nation's heritage, as species extinction to ecosystems. Human relationships with the land are often rooted in cultural beliefs and practices, and ignoring or destroying those cultures is disruptive to many land management practices that have withstood the test of time.

The environmental education specialist Filho, in an account entitled "Education and public involvement in sustainable tourism in islands", in which Malta was included, argues that the presence of visitors from various cultural backgrounds and different habits, may cause cultural as well as social conflict (Filho, 1993). Since the cause of environmental degradation, whether directly through outright topographic modification, or indirectly through lack of planning, is primarily human-induced, the human factor or, more accurately the social fabric, has to be accounted for when appraising the 'state of the environment'; hence the stress on visitor impact. This does not necessarily mean that visitors are, in their own right, a negative element when away from home; it simply means that behaviour and attitudes may be somewhat different to indigenous lifestyles.

Apart from mass encroachment through physical presence as well as unplanned development and urban disarray, the coastal zone has yet another malady to cope with, that is, environmentally hazardous technology. Heavy industry, dockyards, power stations, waste treatment plants, marinas and even aquaculture projects are largely responsible for adversely affecting marine and coastal biota, and for applying added pressures to the littoral, leading to increased sea/land-use conflict.

1.3
the importance of protecting Mediterranean coastal ecosystems

The Mediterranean Basin features a variety of marine, wetland, and hinterland/mountain ecosystems, each unique in its richness and diversity. In fact, biological diversity is generally much richer in the Mediterranean (including southern Europe, North Africa and the Levant) than in the rest of Europe (Synge, 1993), and there is an incidence of endemism that is much greater than further north. Mediterranean coastal ecosystems are of special interest for a number of reasons, both biological and economic. The more notable biological reasons are:

- The Mediterranean Basin consists of a complex mosaic of habitats and assemblages, featuring many unique ecosystems supporting some 25,000 species, half of which are endemic (Leon *et al.*, 1985);
- these ecosystems are transitional between sub-tropical ecosystems and boreal ecosystems (Batisse, 1990); and,
- Mediterranean coastal ecosystems have long been associated with human activities, and may hence provide important baseline data on human impact on biodiversity. Such historical information is crucial for understanding and managing biodiversity (Mooney, 1988).

Yet, protected areas in the region, with some exception, are overall less extensive and, are afforded less protection than in the rest of Europe. Essentially, this is due to:

- shortage of funds for conservation;
- weak institutional backing; and,
- a lack of public support for the protection of nature.

As a result, many important sites are still not adequately protected and a number are under threat. Often, donor agencies' financial assistance has led to development projects being carried out without sufficient safeguards (such as legal instruments and monitoring mechanisms) for protected areas. In addition, due to constant change in land-use patterns over a short period of time, undisturbed natural areas are becoming more difficult to come by in the Mediterranean region and biodiversity is increasingly threatened. Furthermore, a burgeoning population, whose greatest demand is land area to develop, is subjecting the remaining areas of pristine beauty to intensified pressures.

It is estimated that as much as 43% of the Mediterranean's inhabitants live in coastal regions at present. Projections indicate that human pressure is expected to intensify, with coastal populations likely to reach between 150 and 170 million by the year 2025, while the number of tourists is expected to reach 260 million per year.

Population expansion has already had a notable effect on coastal zones, for example, urban sprawl and intensive land-use practices for tourism, as well as increasing industrialization. As the coastal zone is modified, the biodiversity of the region is, quite often, adversely affected. The richness and diversity of the flora and fauna of the Mediterranean, much dependent on maintaining stability of marine and terrestrial ecosystems, would thus diminish. As a result of human-initiated disturbance, habitats are degraded, food chains disrupted and entire ecosystems irreversibly damaged. This reckless degradation of Mediterranean Basin ecosystems may have serious and far-reaching effects, fundamentally, the loss of essential functions in the balance of ecosystems and species extinction; in economic terms, a reduction in goods and services provided.

Increasing pressures on natural areas can lead to a change in land-use patterns, and make demands on the ecological resources of the area that are unsustainable. Diminished regenerative capacities of natural coastal systems, that is, the capacity of Mediterranean ecosystems to replenish resources and absorb waste, will eventually be outpaced by population growth and accompanying activities, constraining future economic growth and development in the region.

Economic activities, such as tourism, which depend on the vitality of ecosystems, will suffer if unplanned and inadequate development is not contained. For instance, the destruction of habitats such as sea-grass meadows, vital to the early stages of the lifecycle of many species of fishes and crustaceans, will have significant repercussions on the fisheries industry if continued damage is not prevented. Further loss of species will diminish the aesthetic value of the region and may have an effect, which defies quantification or prediction.

1.4
Mediterranean coastal dunes

The Mediterranean region as a whole, in particular the coastal margin, is adorned with magnificent walled cities and historic sites, unique habitats and biota, and a vast number of coastal landscapes of spectacular scenic beauty. For the past three decades, the region has been subjected to a process of rapid change and degradation, while some ecologically important areas have been completely eradicated. This is mainly due to ever-mounting pressures brought about by non-sensitive development in this much sought-after region. This followed a marked change in lifestyle patterns and a general increase in disposable incomes. Given the post-Second World War revolution in aviation, air travel became by far the most convenient and efficient means of transportation for leisure.

Like most other coastal habitats in the region, Mediterranean coastal sand dunes also suffered a great deal from indiscriminate shoreline development. In a Council of Europe working document: "European dune and shoreline vegetation", it is estimated that during the past 30 years as much as 75 per cent of Mediterranean coastal dunes have been damaged or indeed destroyed, mainly as a result of tourism development (Gehu, 1985). This view is also shared by Salman and Strating in "European coastal dunes and their decline since 1900" (Salman & Strating, 1992). In their paper, which formed part of a report

The Environment in Europe: a Global perspective", commissioned by the Dutch National Institute of Public Health and Environmental Protection (RIVM), the authors reviewed the status of important Mediterranean sand dune habitats and attempted, through available data, to interpret changes which occurred in the landscape during the period 1900 - 1950, and which may have had a significant effect on coastal dunes. In an effort to determine possible trends and rates of change with a view to identifying conservation strategies for the future, the authors correlated their findings with present-day data.

In a parallel study largely based on the "Sand dune inventory of Europe" (Doody, 1991), van der Meulen and Salman describe four main types of coastal dunes for the Mediterranean[1], namely: mainland dunes; lagoon-bay barrier dunes; delta dunes; and, remnant dunes. The descriptions given for each dune-type are:

> **Mainland dunes**, including pocket or bay dunes as part of largely mountainous coasts, develop onshore as a part of a more or less elevated mainland. Examples are found in all Mediterranean countries. This type also includes "climbing dunes", which include sand dune formation over hill slopes. This type is characterised by a relatively low sand supply.
>
> **Lagoon-bay barrier dunes**, often develop as sand spits along the shoreline. Sand is predominantly supplied by longshore drift. Well-known examples are the Troia dune spit (Sado estuary, Portugal), the Mar Menor spit, the Devasa de Albufera (both Spain) and the French Languedoc coast. Associated environments include estuaries, lagoons and salt marshes. Quite often, some of these lagoons are partly reclaimed for agricultural land or salinas.

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[1] Reference made to Mediterranean coastal dunes in both the works is restricted to the area comprising the region's coast from Portugal and SW-Spain to the coasts of Turkey and Syria. The southern Mediterranean coastline from Lebanon to Morocco is not included in either work.

Delta dunes, develop in association with river mouths, where large amounts of sand are discharged into the sea. Delta dunes mainly consist of sand spits at the seaward margins of deltaic plains. Beautiful examples are found in the deltas of the Guadalquivir (Coto Donana), the Rhone (Camargue), the Ebro, the Archeloos (Mesolongi), the Gioksu (Silifke), the Seyhan and the Ceyhan (Cukurova) and the Nile.

Remnant dunes. This unclassified type mostly consists of dune islands as remnants of larger and older systems, developed in connection with estauries and river deltas. This type is almost entirely Atlantic and connected with extensive tidal areas (e.g. in some of the Portuguese estuaries and rias).

(adapted from van der Meulen & Salman, 1993)

As far as coastline morphology is concerned it appears that Mediterranean mainland, lagoon-bay barrier, and remnant dunes are visibly diminutive compared to their Atlantic counterparts. According to van der Meulen and Salman (1993), the lack of large amounts of sand in these dune-types is possibly due to a lower sand supply from the Mediterranean sea-bottom. When compared to numerous case examples of dunes in the Atlantic, these Mediterranean dune-types are less extensive, both in terms of individual ridge size and also as complete dune systems, and are markedly lower in height. Relatively narrow beaches also characterize Mediterranean dune fields. On the other hand, Mediterranean delta dunes, that is, those owing their physical formation to river-generated sediment transport and deltaic plains, are described as considerably larger dunes, primarily due to the vast supply of sand from rivers, so crucial to the very existence of this dune-type. In the event that the supply of sand from rivers is in some manner hampered, for example through the impact of projects involving river damming or even canalization and irrigation, this is likely to have a dramatic effect on delta dunes.

Referring to the process of parabolization, van der Meulen and Salman give reasons as to why parabolic dunes are uncommon along the Mediterranean coastline. Foremost is the fact that the Mediterranean has a limited sand supply when compared to the Atlantic, and for parabolization to occur, large amounts of sand are required together with strong unidirectional prevailing winds and broad dune systems. Another reason given is the fact that Mediterranean vegetation is "*less developed*" [2] than in the more humid, temperate Atlantic climates, with the result that the former is less capable of stabilizing sand particles (refer to - The influence of vegetation on coastal dune development in Two: Coastal dune dynamics). Furthermore, soil development is less pronounced than in the Atlantic area, while soils with high humus content (which are more resistant to erosion) are less common in the Mediterranean. For these reasons, dune ridge mobility is more prevalent in the Mediterranean than in the Atlantic (VAN DER MEULEN & SALMAN, 1993).

1.5 dune-type classification - a heterogenic nomenclature

Notwithstanding the many valid points that support every nomenclatural scheme that has been put forward by various researchers, it appears that no one-and-only uniform classification system for Mediterranean dune-types is widely accepted. The reason is that, since the study of coastal dune systems is an interdisciplinary one, references made to particular dunes also depend on the researcher's academic background. Thus, dune systems are often described by their physical characteristics or in terms of the dominant vegetation, while others are simply named after the locality in which they occur, with the different morphological formations, which occur within the dune system being referred to as a sub-unit.

For instance, ecologists will often characterize dunes on the basis of their vegetation communities. Moreover, dune systems may be further sub-categorized by giving descriptive labels according to colour

[2] less luxuriant (VAN DER MEULEN, pers. comm./LFC)

variation which occurs as a consequence to organic matter content in a particular sand; all three colour variants associated with dunes, that is, yellow, grey and brown, may occur within the same dune system (ANGUS & ELLIOTT, 1992). Botanists will also tend to identify dune sites in relation to predominant vegetation communities, for example: fescue grassland dune, bryophyte-rich dune, etc., (BINGGELI *et al.*, 1992), or may distinguish one dune from another by according species-specific categories, for example: Ammophila dunes [*A. arenaria* - Marram Grass]; Carex dunes [*C. arenaria* - Sand Sedge]; Corynephorus dunes [*C. canescens* - Grey Hair-Grass]; and Ammocalamagrostis dunes [*A. baltica* - Baltic Marram Grass] (SCHULZE DIECKHOFF, 1992).

Some researchers, in particular those studying the relationships between aeolian formations and the geology of the locality in which these are found, tend to classify dune-types according to the $CaCO_3$ (Calcium Carbonate) content, or lack of it, in the sandy soil. A case in point is the Sefton Coast, reputed to be one of the largest dune systems in the United Kingdom, and one which is sometimes referred to as a calcareous dune-type (ATKINSON, 1992). Lammerts *et al.*, in reviewing natural dune stabilization processes, examine the links between the pH of the top-soil (at a depth of 0 to 0.1m) and the dune vegetation. In this context, the classification of dune-types is based on a hierarchical model with divisions based on characteristics of surface water, lime content of the top-soil and calcium concentration of the groundwater, all regarded as main controlling factors. Dune-types, therefore, may be classified as **calcareous** or **non-calcareous**. Identification of these afore-mentioned categories can also be made, the authors add, by noting the vegetation communities, that is, whether the dune supports a calcicole (calciphilous species) or calcifuge vegetation cover (LAMMERTS *et al.*, 1992)

Pethick bases his dune-type classification and sub-divisions entirely on aeolian processes, referring to a particular dune according to its peculiar morphological expression: dune orientation and profile. He distinguishes parabolic dune systems, barchan dunes, U-shaped dunes and incipient blow-out formations. Dune ridges are termed in conformity with their sequential development - embryo dunes, foredune ridge, second dune ridge, third dune ridge, oldest dune ridge (PERSACK, 1984). A similar morphological classification, according to dune profile (transverse, longitudinal, parabolic, barchan) was used to classify dunes in a study in Alexandria (BATE & DOBKINS, 1992).

From the representative selection of literature outlined above it appears evident that, even for an area as geographically compact as the Mediterranean Basin, there is a prevalent lack of coherence in the use of a common classification for dune-types. The reason, therefore, why no unified homogenous coastal dune classification system exists, is, as outlined earlier, because different disciplines look at dunes from different perspectives. The study of coastal dunes, their dynamics, ecology and management for a conservation scope is an interdisciplinary affair, much dependent on an exceedingly varied background of interests. Moreover, the Mediterranean Region, notwithstanding its relative compactness, exhibits a diverse range of environmental situations and conditions from which the unique physical richness of the region has evolved.

Furthermore, in addition to the scientific mode of classification based on relationships (whether biological or geological), there also exists a geographical system, mainly nomenclatural. Some of the larger and scientifically interesting coastal sand dune systems in the region are referred to, in scientific literature, by their geographical name rather than by any respective dune-type classification. Some notable examples include: the **Coto Donana** (the former hunting reserve of Dona Ana), a national park in the SW Spain comprising 50,720 hectares of mobile dunes, seasonal wetlands (the *marismas*) and forests at the mouth of the river Guadalquivir (= from Arabic, *Wadi el Kabīr*); the **Camargue** on the SE coast of France, consisting of low dune systems and extensive marshlands; the coastal dunes of **Seyhan Delta** situated on the coast between Mersin and Adana; and finally, in an account on the dunes of the **Valencian coast** (eastern Spain), no less than fifteen dune systems, ranging from Pleistocene fossil dunes to Holocene dunes, are mentioned in the inventory of Valencian coastal dunes. All these important dune systems are all known by the proper names of the respective locality in which they occur (SANJAUME & PARDO, 1992).

There is no reason why the two systems, that is, the scientific classification based on relationships and the geographical system, should not coincide. To cite a local example, the dunes at Ramla are:

(i) *Elytrigia* dunes (fore-dunes) - **ecologically**;
(ii) dunes of Quaternary blown sand - **geologically**;
(iii) Ramla l-Hamra dunes - **geographically**.

2 Coastal dune dynamics

contents

2.1 key elements for dune formation

Coastal dunes are predominantly marine sedimentary systems with significant terrestrial interaction; their entire formation process is dependent on prevailing climatic factors. Essentially, therefore, the supply of sediment (abundant sand supply), and sand transport (through the occurrence of strong onshore winds), together with a vegetation cover, form the basic components of the principal processes for dune formation. A typical active coastal dune area consists of an **offshore zone** or **foreshore** [sediment bank]; a **transit zone** [that area which covers the wet/dry transition beach boundary, and the active fore-dunes' area]; and a **resting zone** [the area which comprises the stable dunes]. The extent of dune development depends largely on the relationship between the various key elements described above, and it is crucial that their interaction remains in a stable state of equilibrium.

2.2 sediment budgets in fore-dune development

Sediment is supplied as a result of longshore drift from eroding headlands, cliffs and other coastal geomorphological formations including dune systems, as well as by fluvial sources such as rivers and seasonal valley flow, and directly via the sea bed. In areas experiencing healthy longshore sediment transport, coastal fore-dunes will develop in a sequence that is related to the gradient of the longshore sediment supply. Thus, the complexity of fore-dune development may be considered a product of the rate of the longshore supply of sediment. Natural interruptions in the supply may be spatial, causing displacements of the input sites or changes in the direction of sediment transport, or, they may be temporal, that is, related to the sequences of sediment availability at a particular location. Variation in dune/beach sediment budgets may encompass both spatial and temporal changes. thereby increasing the complexity of coastal dune assemblages.

When considering coastal dune development, the importance of fore-dunes (that is, that portion of the dune profile that is actively exchanging sediment with the beach) cannot be overstressed. Compared to the vast range of existing dune types, the coastal fore-dune is a unique morphological assemblage in that it has a restricted spatial association, and is defined by the dynamics which characterize the beach zone as well as the 'traditional' dynamics of aeolian processes that give rise to subsequent dune forms. Coastal fore-dune development is thus closely related to sediment budget variation in the dune and beach components of the profile. Optimal conditions for fore-dune development occur when the beach budget is slightly negative and, concurrently, when there is a constant supply of sediment being transferred from the lower part of the beach onto the higher portion of the profile, that is, the fore-dune. Evidence from many of the world's coastal zones suggests that despite long-term shoreline erosion, coastal fore-dunes continue to exist in the beach/dune profile. Such occurrences show that dune forms may be able to amass sediment while shifting inland as beach erosion takes place. It is suggested that the fore-dune may be conceptually separated in 'sediment budget' context from the beach (Psuty, 1992). Movement of sediment, known as sediment transfer, from the beach position to the fore-dune area and beyond, contributes to the mass of the dune-field proper, besides the inland shift of the fore-dune position.

Psuty adds that the longer an active beach loses sediment to its adjacent fore-dune area (assuming the fore-dune accumulates the sediment transfers), the larger will the fore-dune become. One scenario that gives rise to an enlarging fore-dune is a slightly negative beach budget causing fluctuatory scarping of the dune face. As a result, sand is transported landward from the seaward dune slope-face, gradually leading to the transfer inland of the fore-dune crestline, as part of an on-going erosional and recovery process in fore-dunes.

Enhanced fore-dune development is best noted during the early stages of a negative beach budget. As erosion continues however, and consequently the beach budget deficit grows, it is likely that the fore-dune would begin to lose mass. Under a prolonged negative budget, the fore-dune would eventually decrease in size and subsequently undergo morphological modifications such as deflation of its ridge structure. In sum, it may be concluded that whereas there may be a situation where the dune *per se* may continue to experience a positive budget as the beach budget situation shifts from positive to negative, under an increasing negative beach budget situation, the dune will eventually begin to lose its mass and subsequently pass through a sequence of attenuation stages that will lead to loss of the fore-dune structure coherence.

The spatial association of dune morphologies [e.g. back-beach deposits, active fore-dune, parabolic zone, etc.] is regulated by the longshore gradient in sediment supply that, in turn, is highly dependent on the physical location of the (sediment) source. The sequential development of fore-dune morphologies therefore, is portrayed in the longshore balance between beach and fore-dune sediment budgets. A local case in point, and one which to-date may still be considered to be morphologically active, is the Ramla l-Hamra coastal dune system. Sediment is transported seaward from a number of seasonal fluvial sources, that is, Wied il-Pergla and from the Wied tar-Ramla valley system itself, and discharged respectively at Ghajn Barrani and Ramla Bay at points west of the fore-dune. Subsequently, sediment is transported by longshore drift as a result of prevailing north-westerly wind/sea action.

Modelling of cross-shore topographic/morphologic situations can be performed on a case-by-case basis, the reasons being two-fold:

(i) On the micro scale, fluvial sources of sediment supply (e.g. rivers, and seasonal valley flows) are exceedingly variable, both in terms of (a) **fluvial discharge** [i.e. susceptibility to fluctuations in sediment flux] and (b) **point source location** [physical changes of discharge point from dune site as well as variation in the number of discharge points, as a result of distributory shifts].

In view of the foregoing, the longshore sequence of fore-dune morphologies will shift spatially. The transitions from one combination of beach/dune budgets may occur at differing distances from the sediment source and, as a result, cause differing morphological manifestations in the fore-dune. Such episodes of fluctuation in fluvial discharge are related to 'complexity of development' stemming from the occurrence of different cycles in sediment budget combinations (each cycle will lead to the development of independent dune crests). Significant changes in the sediment supply in cases of distributory shift and massive alterations in the sediment flux, which can cause coastal *expansion* (build-out) or *retreat*, may in effect characterize the entire coastal zone experiencing such phenomena.

(ii) On the macro-level, the physical characteristics of the particular sediment system should be considered. The point source of sediment as well as the general morphology of the area under observation must be closely understood since these are the key components, in the spatial context, which have a strong influence on the development process.

Psuty identifies four types of active sediment supply sources and attempts to explain the development processes of each, using where possible, both simple and multiple stage scenarios.

2.2.1 Fluvial Delta Sediment System:

Where the source of sediment is a river or seasonal valley flow with a well-defined discharge point, that is, the river or valley mouth. In such cases, the spatial association begins adjacent to the sediment source where there is a highly positive beach budget and low dune budget. The longshore gradient however, will show a decreasing beach budget accompanied by an increasing dune budget. In morphological context, the fore-dune is usually very low at the point adjacent to the fluvial source and increases in dimension in the longshore direction due to a growing dune budget. If however, at some point in this continuum, the dune's sediment supply decreased, then the fore-dune would begin to lose its accumulated mass.

The formation of deltaic dunes, resulting from spatial shift due to the migration of fluvial discharge points, can be explained by means of a multiple-stage scenario with the following combination: a negative-beach/positive fore-dune budget which will eventually be transformed to a positive beach/negative-dune budget, and subsequently returned to a negative-beach/positive-dune budget. The morphological expression of this combination in a temporal setting is the creation of two distinct lines of dune ridges, one of which is the active dune-beach profile and the other is that which is stranded inland. The latter type of dune form represents periods of distributory abandonment, erosion of the shoreline and inland migration of the enlarging fore-dune (Psuty, 1992).

2.2.2 Spit Elongation Sediment System:

In general spits are formed through complex development related to cyclical episodes of updrift erosion supplying sediment to support a downdrift outbuilding of the spit. In terms of sediment budget, there is a gradient from negative beach and negative dune, to a positive dune with a negative beach, and eventually to a neutral dune with a positive beach. In a morphological sequence, the base of the spit may have the largest dunes, leading to a well-developed coherent fore-dune crest that normally diminishes in size towards the extremity of the spit.

2.2.3 Barrier Island Sediment System:
As the name suggests, dune morphology in such situations depends on the holistic spatial characteristics of:

(a) the position of the island/s;
(b) the mainland's coastline topography; and,
(c) the lagoon-type formation lying in between.

Barrier island forms have such a varied developmental history that, it is unlikely that one fore-dune model will apply in all cases. However, there is one general condition that tends to apply in a number of instances that is represented by an longshore gradient of sediment budget from the updrift extremity of the islands to their respective downdrift end, whereby sediment is transported, in the longshore direction, from deteriorating older dunes to form beach-ridge topography at the downdrift end. Also, in this case there are opportunities for development from a simple scenario with one fore-dune, to a complex scenario with longshore variations and shifts of the transitional forms in the longshore direction as well as major shifts in beach/dune topographic development.

2.2.4 Baymouth Barrier Sediment System:
A variant of the preceding dune type, where the barriers that are found at the mouths of estuaries or at seaward margins of alluvial plains may have several dune lines and, which may have gone through several combinations of beach and fore-dune budgets. (Psuty, 1992).

Fore-dune development, therefore, may have a sequential morphological variation determined by the temporal balance of sediment available, or, the variation may be spatial and related to the gradient of the sediment budget in its longshore direction. The most suitable criterion, however, is the concept of morphological sequence based upon changes in the beach/dune budget relationship. It is worth adding that this combination can vary spatially as well as temporally. Whatever the mode of variation, these are processes which influence the development of future dune topography.

2.3 sand/wind interaction

The influence of wind action, in the formation and development processes of sand dunes, is extremely important and, in a sense, crucial. Pethick describes this process, responsible for the formation and morphology of sand dunes, as one which is highly complex. He further quotes Bagnold as having, in 1941, formulated the theory on "*the intricate relationship between the physics of sand movement and the final shape of the dune*" (Pethick, 1984).

As a consequence to wind action, the most extensive dune development takes place in locations where the prevailing air-flow is onshore. In fact, local changes in wind or sea-currents have led to the erosion of entire sections of established dune systems. In exposed areas, continual high winds deposit only the larger sand particles, and this, together with a high evaporation rate, means that vegetation would establish itself with difficulty. A more moderate wind deposits smaller particles, which, in turn, have greater water-retention capabilities, while the evaporation rate would be lower. The lighter material deposited usually includes animal and plant remains which, in addition to organic matter, may include mollusc-shell and crustacean exoskeleton fragments which significantly increase calcium content in the substrate and, as a result, encourage the activities of root nodule and other bacteria[3] (Bennett & Humphries, 1965).

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[3] Increase in calcium content is particularly important in 'silica' sand dunes, known to be Ca poor. This, however, does not apply to 'carbonate' sand dunes.

2.3.1 Movement of sand:

The force of air-flow is decreased through the impact on the beach surface, that is, as the wind blows across the sand grains lying on the surface, its velocity is reduced through frictional resistance between it and the sand surface. Bagnold, in his analysis of sand-wind interaction, assumes that the result of the wind force (power) on the sand surface is equivalent to the amount of expended power (i.e., if the action is 100 per cent efficient):

Power in x efficiency = Power out

When wind begins to flow over the sand mass, two opposing forces are set up: the air-flow force, and the resisting force due to the gravitation effects on the sand grains. The resisting force is said to be brought about by the weight of the sand (mass x gravity) and the frictional resistance between the loose surface layer and the more compacted grains beneath. As movement of the sand comes about, it can be said that work is performed. The power expended in mobilizing the upper layers of sand can thus be calculated as follows:

{weight = force (mass x acceleration)} x velocity

The decrease in wind velocity, caused by frictional resistance as a result of air-flows and sand surface interaction, is "transmitted up through the flow producing a velocity profile". Pethick plots empirical values on a log-arithmetic graph featuring **height** (in metric scale) against **wind velocity**: (m/s) to illustrate "that zero velocities are produced by the frictional drag at a small, but very significant, height above the sand surface". This height is dependent on surface sand grain diameter or coarseness of the surface, and is estimated at circa one-thirtieth of the average surface sand grain diameter, e.g. 0.03mm for a one millimetre sand grain. This characteristic of the upper sand surface is known as 'effective surface roughness'. Therefore, the bigger the average sand grain size, the rougher the surface and, the higher the frictional drag.

The relationship between wind velocity and effective surface roughness, and the actual movement of sand grains can best be appreciated through air-flow velocity modelling, the varying effects of which will have a direct bearing on the sand grains lying on the surface due to the force (by the wind) exerted upon them. In this case it is the wind (air-flow) velocity gradient, which causes a force to be applied to the surface sand. The curvature quantum of the wind profile can be regarded as an accurate measure of its gradient, referred to as the **shear velocity**. In this case, the larger the shear velocity value, the greater the (wind) force on the sand surface. High shear velocity values, therefore, imply the application of greater force, or *shear stress*, on the sand surface layer. Inversely, by increasing the wind velocity or the effective surface roughness, or both, a higher shear stress would result. Sand grain movement, therefore, would be induced as the shear velocity increases to a critical level. A series of chain reactions will take place once a given shear velocity is applied to the sand grains (occupying the upper levels of the surface layer), the diameters of which range from critical size or below. As acceleration of the smaller sand grains commences, in the form of rolling and sliding, these collide with larger, immobile grains, which on impact cause the smaller grains to ricochet into the air. It is this series of events that will activate the most important developmental process in the formation of dunes known as **saltation.**

To the casual observer at a distance, the process of saltation will seem like a blur not unlike a stationary patch of mist, about a metre or so high. This is the result of the impact of moving grains with the larger stationary ones, which cause the former to be flicked high into the air and subsequently into the wind. As the sand grains get caught in the higher horizontal wind velocity zone, these are accelerated, eventually reaching the same velocity as the wind acting upon them and almost concurrently they begin to descend, forming a trajectory as they return to the ground surface. Their impact with stationary grains on the ground will cause the whole process to be repeated until the entire beach is in motion via this process of saltation.

Sand movement, apart from saltation, also takes place by another means known as **surface creep**. This process occurs through the direct action of saltating sand grains; as the descending grain impacts the surface, it may well collide with other grains too large and heavy to be flicked into the air, which will instead roll into motion. It is estimated that sand grains up to six times the size of the descending saltating grain can be subjected to this type of movement, while of the total sand in motion approximately seventy five per cent moves by saltation and the remainder by surface creep (Pethick, 1984). As a result, the finer saltating sand grains will shift at a quicker rate and further inland (and downwind). On the other hand, larger grains, incapable of uplift, will move at a slower rate and cover shorter distances. Evidence of this can be seen through the examination of sand grain size from samples taken from the extremities of the beach/fore-dune profile.

2.4
the influence of vegetation on coastal dune development

This component in the coastal dune developmental process is what causes aeolian formations on the coast to differ from desert counterparts. Fundamentally, dune vegetation plays two roles, both of which are responsible for reducing the sand transport rate considerably: first, vegetation provides the beach surface with a marked surface roughness element; second, it acts as an interception medium for descending saltating sand particles and serves to absorb much of the sand grains' energy as a consequence of the vegetation's soft and springy composition. The vegetation cover's springy characteristics also cause sand deposition to take place. As a result of energy losses, saltation will experience a lower transport rate, thus leading to high deposition levels within the vegetation zone.

Dune vegetation may vary both with time and space, and although coastal dune flora usually presents a characteristic zonation with low open plant communities nearer the beach (often characterized by a maritime assemblage) and taller shrubs and woodlands on the inner mature dunes, it can be said that every dune development stage has its own characteristic typology and plant community (see 2.5 below). This is due to a number of factors, notably, prevailing winds and sea-currents (and any subsequent directional fluctuations), topography (vis-à-vis shelter/exposure conditions), sediment sources and discharge, and the particular region's hydrology.

A typical dune profile exhibits a well marked succession of plant communities from, or close to, the shoreline, colonized by salt tolerant species, all the way inland to the main dune lines. Throughout the Mediterranean, the most important species, mainly due to its stabilizing influence, is marram grass (genus: *Ammophila*). This species, once native of some of the dunes in the Maltese Islands, has possibly been eradicated through the human agency, coupled by a lack of adequate protection measures by local authorities. Plants on the strand-line act as wind-breaks and, very often, accumulate sand mounds to form 'miniature dunes'. Most species that colonize this exposed portion of the beach have little stabilizing influence since their root systems do not bind the sand effectively. There exists an important exception however, and that is sand Couch-grass (*Elytrigia juncea*), which, under optimal conditions, prepares the way for the colonization of other species including marram grass. Unlike *Ammophila, Elytrigia juncea* is highly resistant to hyper-saline situations, to the extent that it can tolerate occasional immersion in seawater. Its extensive rhizome system binds the sand and, although it spreads more readily sideways, it is able to develop new aerial shoots when buried by sand.

As the sand level rises, through the formation of miniature dunes, conditions are said to be favourable for the growth of marram grass, since this thrives in the drier wind-blown sand and is not known to do too well in very damp conditions. Marram is capable of spreading in all directions by means of a branching system of rhizomes. It is by upward growth that the species is generally able to keep pace with the deposition of wind-borne sand, while its underground systems of roots and suckers hold the sand in a compacted state, although it cannot fix the air-dry surface sand which is thus liable to be blown away. Dunes formed in this manner are known as 'mobile dunes' because sand is continually being removed and replaced by fresh sand from the beach. The presence of high mobile dunes reduces wind speed over the lower fore-dunes, which leads to continued seaward growth of the dune system. Vegetation is able to establish itself on the dunes' sheltered side where the sand is less mobile. Many of these plants consist of common wind-dispersed inland species, their distribution depending on the location of the seed source (parent plant) and on suitably damp conditions during the period immediately following germination. In effect therefore, a great many species of plants may exist over an entire dune system, some characteristic of coastal dune habitats, while others are simply capable of adapting to maritime influences. The majority of these assist in the fixation (i.e. stabilization) of the sand, either by being deep rooted or by having an elaborate and branching root system, creeping stolons, etc. As time goes by and the dune becomes more stable, other plants will become established whose decaying material will add humus to the surface soil which in turn increases in fertility and water-retention capability, thus providing favourable conditions for an even wider variety of plant species. Should the 'inland' vegetation on the landward dunes eventually crowd out the marram grass and other pioneer species, such situation would give rise to 'fixed dunes', which in time may eventually support a higher vegetation succession.

2.5 zonation and succession in sand dunes

As indicated above, sand dune ecosystems illustrate zonation patterns as a consequence to the spatial segregation of different species and communities. Developmental phases of community succession are usually referred to as seres, with different seres leading to the **climax**, which zone is referred to as the highest vegetation potential of an area over a period of time. The complete succession occurring on a sand dune is called a **psammosere**. A psammosere is considered a form of developmental zonation, in which the vegetation grades from one dominated by pioneer species closest the shoreline, to climax communities, frequently characterised by highly competitive mesophytes, on the landward margin, where they merge imperceptibly with inland vegetation.

Vegetation patterns on coastal dunes are much dependent on the temporal sequence of the beach/dune profile. Thus, the distribution of flora will vary, depending on whether it occurs nearest the strand-line zone (driftline), the low embryo dunes and back-beach deposits, the more mobile fore-dune and yellow dunes, or the fixed (grey) dunes and mature (brown) dunes. This classification system, explained in further detail below, is based on the descriptions of POLUNIN & WALTERS (1985); MAYER (1995); LANFRANCO (1996) and PACKHAM & WILLIS (1997).

2.5.1 Driftline or strand-line:

Waves slow down along the rising profile of the sandy beach where organic residues are deposited the length of the high water mark that indicates the furthest extent of waves during winter storms. Species of the *Cakiletea maritimae* are dominant in this area; in the Maltese Islands, the most characteristic include the Sea Rocket (*Cakile maritima* s.l.) and the Prickly Saltwort (*Salsola kali*), together with Purple Spurge (*Euphorbia peplis*) and Sea Knotgrass (*Polygonum maritimum*).

2.5.2 Embryo dunes:

Occurrence of perennial plants within this zone form an 'obstacle' for the interception and subsequent accumulation of sand. Such embryo dunes tend to develop at the back of small pioneer tufts of perennial Sand Dropwort (*Sporobolus pungens*) or Sand Couch (*Elytrigia juncea*), which characterise the **Elytrigio juncei-Sporoboletum pungentis** association. The **Cakiletea maritimae** is also well-represented, and includes the presence of Sea Spurge (*Euphorbia paralias*), Sea Rocket (*Cakile maritima* s.l.) and Prickly Saltwort (*Salsola kali*). Less frequent, but also effective for the establishment of embryo dune are the Sea Holly (*Eryngium maritimum*) and the Sand Cottonweed (*Otanthus maritimus*).

2.5.3 Fore-dunes:

In favourable conditions embryo dunes may stabilize and increase considerably in size. This dune strip receives considerable amounts of sea spray since it forms the row of frontal dunes, usually parallel to the shoreline. Fore-dunes *or* first dune ridge assemblages are most vulnerable to storm surges, including strong waves and terrestrial run-off, and, as a result, are prone to partial erosion during wet season storms.

Fore-dunes can vary significantly in their shape and size, with the number of plant species increasing on the lee side of the fore-dune when compared to the vegetation cover on embryo dunes. Depending on the extent of embryo dunes, the vegetation is usually dominated by various species of the **Cakiletea maritimae** community and the more 'developed' **Eryngio maritimi-Elytrigetum juncei**. Common Mediterranean species found on this part of the beach include *Elytrigia juncea*, Sand Fern-grass (*Cutandia maritima*), Sand Cottonweed (*Otanthus maritimus*), Sea Medick (*Medicago marina*) and the Mediterranean Marram grass (*Ammophila littoralis*).

2.5.4 Yellow dunes or white dunes:

The second dune ridge and possibly other older ridges within the dune field sequence are often referred to as yellow or white dunes. according to the colour of their surface as a consequence to the patchwork of sand and sparse vegetation (Mayer, 1995). The plant cover on this dune belt is less influenced by salt spray when compared to fore-dune vegetation. The sand is still mobile, although it gradually stabilizes towards the back of this zone.

In the Mediterranean, this area is characterised by plant communities of the **Echinophoro spinosae-Ammophiletum arundinaceae** based on *Ammophila littoralis*, and the **Crucianelletum maritimae** based upon the Sand Crosswort (*Crucianella maritima*). In the Maltese Islands, owing to the absence and/or extirpation of *Crucianella maritima* and *Ammophila littoralis*, the **Eryngio maritimi-Elytrigetum juncei** association is predominant.

2.5.5 Semi-consolidated dunes:

Depending on the extent of sand consolidation, yellow dunes are sometimes subdivided, with a higher sere occurring on semi-consolidated sands. Dune grasslands based on Dune Fescue (*Vulpia fasciculata*) and Ripgut Brome (*Bromus rigidus*) and other **Malcolmietalia** and **Brometalia** vegetation tends to develop in this zone, depending on the extent of disturbance.

2.5.6 Fixed dunes or grey dunes:

The term 'grey dune' is an indication of the greyish tone of the sand as a result of the increased amount of humus in the sand, caused by the decomposition of plant matter, as also an increased amount of silt. In areas such as the Maltese Islands, where topographic changes have occurred over the years to accommodate infrastructural growth, fixed dunes have long given way to development.

In the area of fixed dunes, the speed of the wind, sand grain size and the influence of the salt spray decrease, while the number of plant species increase as a consequence of a marked decline in environmental stresses. Sand is largely stabilised and shows little capacity to 'migrate'.

Mediterranean fixed dunes are represented by various communities, such as the **Helichryso-Crucianelletalia** and **Cisto-Micromerietea** associations (Mayer, 1995). In the Maltese Islands, the community is typified by the **Centaureo-Ononidetum ramosissimae** community made up of Bush Restharrow (*Ononis natrix* ssp. *ramosissima*), Grey Birdsfoot Trefoil (*Lotus cytisoides*), Southern Scabious (*Scabiosa maritima*) and Sand Storksbill (*Erodium laciniatum*), and, in the case of areas in close proximity to wetlands, **Nerio-Tamaricetea** communities with African Tamarisk (*Tamarix africana*) and Chaste-tree (*Vitex agnus-castus*)[4].

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[4] The oleander (*Nerium oleander*) a characteristic feature of the **Nerio-Tamaricetea**, is unusually absent from the Maltese Islands, with the exception of naturalised individuals, possibly due to the extensive damage made to riparian and coastal woodlands (Stevens & Baldacchino, 2000).

2.5.7 Brown dunes or mature dunes:
These dunes support the 'oldest' in natural succession, representing the climax of the psammosere. They are termed brown dunes owing to the colour of the soil in which humus or compost accumulates. In the Mediterranean, one may encounter either an ericaceous maritime formation, which develops on acidic soil, or a juniper scrub dominated by *Juniperus oxycedrus* s.l. (POLUNIN & WALTERS, 1985). Such areas may eventually be taken over and colonised by woodland species like oaks (*Quercus* spp.) [especially *Q. ilex* s.l. and *Q. coccifera* s.l., with *Q. suber* in the western Mediterranean] and pines, (*Pinus* spp.) [like *P. pinaster* and *P. halepensis* s.l.] or accompanied by different types of maquis vegetation, characterised by *Arbutus unedo*, *Juniperus* spp., *Myrtus communis*, *Pistacia* spp., *Phillyrea latifolia* s.l., etc. (DEL PRETE & TOSI, UNDATED; MOSSA *et al.*, 1988). Mature dune communities are not known from the Maltese Islands, and were probably exterminated over the years.The zonation pattern outlined above is found only in 'typical' systems. Eroding dunes may lack embryo dunes or well-formed fore-dunes. Moreover, some dune fields in the Mediterranean may lack yellow, fixed or mature dunes due to restricted geographical extent or recent coastal development. Some dunes, as in the case of *Ghadira* (NE Malta) and *Il-Qala ta' Santa Marija* (N-NE Comino), are backed by marshlands, thus limiting the formation of true fixed or mature dunes. Furthermore, dune systems are often 'stabilised' on the inland side by afforestation schemes, through the planting of entire artificial, often coniferous, woods or by invading allochthonous species. This vegetation-type is vulnerable to various elements ranging from storm-driven sediment loads, overgrazing, fire, excessive trampling and offroading activities. Whenever this occurs, the natural succession that follows is usually termed **secondary succession**.

Natural 'litter' is also invariably important in dune formation and zonation. Seeds are often brought in as sea-borne 'litter', during the winter. This 'litter', which includes sea-grasses remains (especially *Posidonia oceanica* and *Cymodocea nodosa*) and macro-algal

...ns, frequently entraps viable seed. Moreover, this litter is ...gically important in providing nutrients as well as controlling the daily temperature variation on the sand surface; temperatures beneath litter are considerably lower than those on open sand. This is particularly important in the Mediterranean region, where driftline, embryo dunes and fore-dunes develop in a "sandwich-structure" of *Posidonia* residues and sand layers (MAYER, 1995), as at *Ramla ta' l-...ier* and *Ramla tat-Torri* in Malta, *Ramla* in Gozo, and *Il-Qala ta' Santa Marija* in Comino.

2.6 the hydrological balance

Pioneer vegetation in coastal dunes is especially vulnerable to disturbances. Its development or otherwise, that is, its successful growth or decline, is dependent on soil processes which control pH levels. Processes influencing soil-buffering mechanisms are decalcification, desalinisation and accumulation of organic matter. Fluctuations in the hydrology of a particular dune system will have an ill-effect on these processes and may lead to a decline in vegetation cover, primarily of the calciphilous pioneer-vegetation.

Lammerts *et al.*, (1992) identify the following environmental factors as essential in determining the developmental features of coastal dune vegetation: (i) the characteristics of surface water, that is, the frequency of sea water flooding throughout the annual cycle, leading to chloride concentrations; (ii) the lime content of top-soil; a main controlling factor in the development of calciphilous pioneer vegetation; and (iii) the ground water composition, i.e., its calcium concentration and its effect on the top-soil.

With regard to infrequent but regular inundation of seawater, a good local example, until some years ago, was the Ghadira sand dune/ saltmarsh area. Prior to construction of the initial road across the back of the bay, the dune system may well have been more extensive due to an unhindered sand supply (although land conversion for agricultural purposes may have also had a negative impact on aeolian development). Flooding during strong north easterlies was almost certainly prevalent then, particularly since this phenomenon also occurred after construction of the original road linking the Mellieha side with Marfa Ridge *(see below)*.

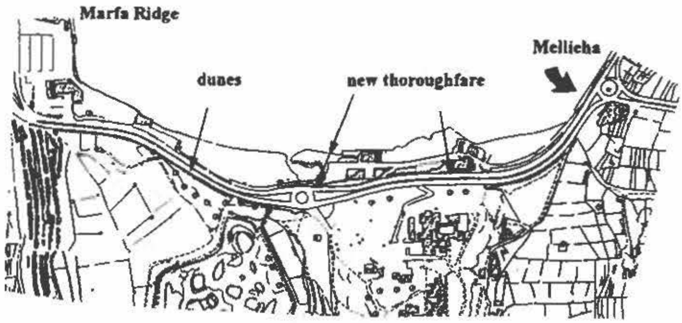


Figure 1. Map indicating the road linking Mellieha with Marfa Ridge.

As marked hollows develop between and around dune ridges as a result of wind action and, concurrently, sea water flooding occurs at a somewhat high frequency (while at the same time fresh water is also present near or at the surface), wet hollows begin to form, known as dune slacks, and later, as the frequency of surface water increases, saline marshes will prevail. In the initial phase of dune slack development, if flooding by seawater ceases, the influence of fresh water will predominate unless there is a constant seepage of seawater (LAMMERTS *et al.*, 1992). This model appears to fit the Ghadira scenario relatively well, although such developments may well have occurred before historic times.

Groundwater levels in sand dune habitat types depend largely, as in other situations, on the underlying strata or medium (the latter in the case of naturally occurring seawater beneath or salt water intrusion into low lying terrain further inland from a dune system). Its fluctuation is an important controlling factor in the development of dune vegetation cover. Lowering, for whatever reason, of the body water or freshwater lens within the dune could lead to the inland movement and subsequent decline of certain dune vegetation types, while the consequent increase of salinity will have a negative influence on the dune woodland-ecosystem located on the older mature dune fields (VAN DER MEULEN & SALMAN, 1993).

2.7 Dune morphology

A typical well developed coastal dune system should thus consist of **embryo dunes**, the youngest aeolian development nearest the strand line, in close proximity of which form the **fore-dunes** also referred to as the **first dune ridge**. These formations are located within the transit zone, which covers the wet/dry transition beach boundary and the active fore-dunes' area. The older dune formations, each a temporal stage in the development of the entire dunal system, extend sequentially inland, and are referred to as the second, third, fourth dune ridge and so on. The furthest dune formation, often one which appears quite flat and which has lost its aeolian dynamism (such areas may provide the ideal habitat for dune woodland ecosystems), is referred to as the **oldest dune ridge** and may be composed of dune slacks[5] - as a result of excessive wind erosion (i.e. blow-out formations), and **parabolic dunes**. These parabolic dunes are in fact small-disjointed dunes, which form within a larger body of sand - in this case, the oldest dune ridge. The orientation of coastal parabolics is much dependent on wind direction and although, in appearance, they resemble a smaller version of **desert barchans** (crescent-shaped desert dunes), the fundamental difference is that coastal parabolic formations support a vegetation cover while their desert counterparts are, in contrast, entirely mobile and therefore

[5] The vegetation of dune slacks is usually adapted to brackish water and can originate from several related vegetation classes. The main constituents of dune slack vegetation include rushes, represented by **Juncetea maritimae**, although the **Sarcocornietea fruticosae**, **Thero-Salicornietea** and **Spartinetea** can also be observed in this environment (MAYER, 1995), essentially forming an adjacent saline marshland community.

do not support any vegetation.

Other important components in coastal dune development are, as mentioned in more detail earlier in the text, the presence of a sediment bank, incorporating an offshore zone and foreshore, as well as an inland sediment supply source, which together with a 'favourable' topography will provide the material needed for onshore aeolian development.

3 The local scene

contents

3.1 Maltese coastal habitat-types

The coastline of the Maltese Islands totals some one hundred and ninety kilometres in length, the bulk of which includes the main inhabited islands: Malta (136.8km); Gozo (42.6km); and, Comino (11.1km). The larger uninhabited islands and islets include: *Kemmunet*, *Filfla*, *Selmunett* and *Il-Gebla tal-General*. There are also a number of minor rocks, some of which bear a vegetation cover. The more prominent among these are *il-Gebel tac-Cawl,* and *il-Gebel tal-Halfa*, respectively on the SE and ESE-coast of Gozo and the Blue Lagoon Islets at Comino.

The coast of the Maltese islands has, in recent years, been identified with that terrestrial land/sea margin where maritime influence is significant. Schembri and Lanfranco (1989) have defined the littoral (for purposes of ecological study) as that terrestrial area which extends from the shoreline to the limits of the zone of maritime terrestrial vegetation. One of the most frequent plant species around the Maltese coast, and the one most commonly used as a bio-marker of the terrestrial extent of the coastal zone, is the halophytic *Inula crithmoides* (Golden Samphire). These authors further classify Maltese coasts into three broad geomorphological types. These include: *(i)* beaches, having a mobile substratum; *(ii)* rocky shores with gentle gradients; and, *(iii)* sheer and vertical cliffs (SCHEMBRI & LANFRANCO, 1994). From an ecological standpoint, the coastal zone supports a number of important habitat types, essentially coastal cliffs, low-lying rock platforms, sand dunes, saline marshlands, and transitional coastal wetlands, of which some are of prime scientific importance. It is due to their scarcity in the Maltese Islands, and because they support specialized biota which, in view of its uncommon and localized habitat, is itself rare and, often, exceedingly vulnerable (SCHEMBRI, 1991).

3.2 effects of landscape changes on dune development in the Maltese Islands

Sand dune systems in the Maltese Islands are somewhat different to the dune-types that occur on northern Mediterranean shores, as categorized by, for example, van der Meulen and Salman (see Two: Coastal dune dynamics). Although similar in terms of formation processes, present-day Maltese coastal dunes are small compared to their European counterparts. Coastal dune systems in the Maltese Islands were, over the years, subjected to a degradation process, first by natural factors and then through human agency. As the climate in the central Mediterranean became progressively drier, the sediment supply that once discharged liberally from terrestrial fluvial sources diminished considerably, to the extent that fresh water flowing seaward through a *wied* (plural = *widien;* geographically: a seasonal watercourse) rarely reaches the coast in any significant amount, thereby disrupting the spatial association between the foreshore/transit zones and the resting zone, more specifically, between the beach and the dune. The morphological expression of these changes, as a result of a declining sediment budget, relates to loss of fore-dune coherence and, as erosion sets in, severe loss of the dunes' accumulated mass. Moreover, every accessible piece of land along the slopes adjacent to a *wied* (in itself a water catchment) was, over the centuries, levelled and converted for agricultural purposes.

The construction of retaining rubble walls and the transportation, and subsequent deposition, of huge amounts of soil on a previously sloping landscape altered the topography significantly. Consequently, much of the run-off from precipitation, which formerly used to flow laterally down gentle limestone slopes and eventually through the valleys, was being absorbed by the anthropogenically installed soils. As a result, the small percentage of water reaching the valley floors had little effect in the seaward sediment transport process. Exceptions to this are alluvial plains such as *Burmarrad*, and a number of valleys, despite damming activity, such as the *Fiddien/Wied il-Ghasel* catchment and Ramla Valley. Significant fluvial discharge from the latter may be one reason why the Ramla dunes are still geomorphologically active.

In recent decades road construction and recreation-oriented development have had a negative impact on the Maltese coasts. With the advent of the tourism era in the late fifties, efforts were made by every Administration to maximize on the recreational value of the islands' few sandy beaches. Accessibility was greatly enhanced, be it by road or by foot-paths and stairways, to the detriment of the existing coastal ecosystems. In view of the complex processes upon which dune development relies, Maltese coastal dune systems were among the first victims of unplanned spatial development. These patterns may well explain some of the reasons why coastal dune systems of the Maltese Islands are unlike their northern Mediterranean counterparts.

3.3
a review of Maltese sand dune systems

Only the three larger islands of the Maltese group, that is, Malta, Gozo and Comino, support sandy beaches of any significance. Although *Kemmunet* also has sandy beach development, this is limited to a mere patch measuring no more than a few square meters, which bears no vegetation cover. Lack of vegetation is mainly due to the fact that this minor patch of accumulated sand is too low, and therefore almost permanently under the influence of wave action.

This sandy area at *Kemmunet* is also extremely narrow because of the presence of low backing rocks which impede the formation of sand mounds and subsequent sand climbing processes.

From a total of 189.6km, which make up the entire length of the coastline of Malta, Gozo and Comino, only a mere 2.4 per cent (= 4.6km) is sandy (Schembri, 1991). Without doubt, this meagre portion of the islands' land area experiences intense pressure from human activities due to its high recreational land-use value. Apart from pressures by the local population, tourism also plays a role directly by further swelling visitor numbers in coastal locations, and, indirectly through construction of beach concessions and other recreation-related facilities.

Before the advent of tourism-oriented development and before various works were carried out for coastal defence by the British services, most of the islands' sandy beaches had aeolian formations, which supported a characteristic dune vegetation. During the past three decades or so, as a result of post-war economic prosperity, the spate of uncontrolled development, which went on around the coast, has had an adverse effect on the physical structure of numerous sand dunes.

Road construction and other development on the coastal fringe, in particular across valleys situated at the rear of sandy beaches, as well as construction of various structures in bays, has in some cases restricted natural sediment supply mechanisms and subsequently led to the gradual erosion of the sand mass. Smaller scale human activities that have negatively affected dunes, include trampling, picnicking and camping, agricultural activities, as well as the installation of 'temporary' beach concessions, and intrusion by off-road vehicles.

Such is the extent of dune deterioration in the Maltese Islands, that at present only a handful of dune systems still persist, and a high percentage of these have been much degraded. In 1991, Schembri noted that only some thirteen localities still supported some form of dune ecosystem, of which only five localities supported dunes with a relatively intact characteristic dune vegetation community. These were three localities on mainland Malta: *Ghadira*, *ir-Ramla tal-Mixquqa*, and *ir-Ramla tat-Torri*; one locality on Gozo: *ir-Ramla l-Hamra*; and, one locality on Comino: *Bajja ta' Santa Marija*. According to Schembri, although these dune systems may be regarded as the better examples within the islands, each of them exhibited signs of degradation of varying extent. The other remnant dune sites were much too degraded and it was expected that some of these will disappear entirely within a few years. Schembri further reported that a number of dune ecosystems had indeed lost all their typical floral community (SCHEMBRI, 1991) (see Four: Status of Maltese dunes). In view of the foregoing, sand dune ecosystems may be rated among the least common of local ecosystems, and certainly as highly threatened natural communities.

3.4 reports relating to conservation and management of local dunes

Prior to a number of survey reports commissioned in connection with the preparation of "The Structure Plan for the Maltese Islands", only limited information had been available, and this mainly consisted of publications and reports by individual researchers working on specific groups of organisms occurring within sand dune habitats.

Published work on the conservation value of dunes before the 'Structure Plan era', was limited to news items, which appeared sporadically in the local press and popular/semi-scientific grassroots magazines, very often as part of on-going[6] conservation and environmental education (EE) campaigns.

One of the earliest reports of the last century, in which Ramla l-Hamra

[6] Conservation efforts in the Maltese Islands can be considered to have commenced in the early sixties, when two voluntary nature-oriented organizations were set-up in 1962. Grassroots campaigning peaked between the late seventies and mid-eighties - c.1977-86, after which (around 1989 and later), the conservation movement seemed to have changed tact on a number of fronts.

was mentioned, was written by Laing and Norton in 1912 and published in the Bulletin of the Archaeological Institute of America. Although the paper dealt primarily with the discovery of Roman ruins (described as an ancient Roman villa), the authors, apart from recording the removal of sand, due to excavations, from the back of the beach where the ruins are located, made suggestions for preserving the area in question (LAING & NORTON, 1912). A personal communication with Capt. C. Zammit[7] revealed that following the intervention by the American researchers, much attention was drawn to the site and subsequently pilfering was reported to have taken place, probably by locals from outlying villages. Laing and Norton also reported that the *"farmers have been in the habit of picking up potsherds from a mound near the sea and of using them to make a kind of artificial stone or cement used here for roofing" (= defun*. As a result, Temi Zammit decided to bury the entire ruins site with sand, which was brought from the *"sand mounds behind roman villa"* (C. ZAMMIT, pers. comm./LFC, 1995). These 'sand mounds' which Zammit mentions may indicate the presence of aeolian formations also on the west sector of Ramla l-Hamra.

In 1962, an article entitled *"Ir-Ramla l-Hamra"* in *Il-Helsien* series *Dawra ma' Ghawdex*, by a certain J.A.B., described the area as desolate and without any amenities *"Haga ta' min jithassarha hi li f'dan il-post ma ssibx minn mnejn tixrob u ghalhekk min jiddeciedi li jmur jghum f'dan il-post ghandu jahseb ghal kollox minn qabel."* [*transl*. It is such a pity that there is no access to refreshments at Ramla and, for this reason, anyone planning an outing to this locality should, beforehand, consider taking provisions.] It is evident, from the article that it had only recently been made possible for light vehicles to reach Ramla. *"Ghal din il-bajja ... kienet bdiet issir triq min-Nadur, imma li sal-lum ghadha ma hix lesta ghal kollox. Minkejja dan hafna huma dawk il-karozzi zghar li bdew inizzlu n-nies sa isfel"*. [*Transl.* The construction of a road from the village

7 Former Director of Museums (and son of the late Sir Temi Zammit).

of Nadur had been initiated. However, to-date this has not been completed. Notwithstanding, numerous light cars have been known to ferry people down to Ramla Bay.] It was then, in the early sixties, that the area's recreational value was being realised, with the result that the locality was then being frequented by organized groups of individuals, probably from further afield than from just neighbouring Xaghra and *Nadur*. The article is concluded with the following *coup de grace "Hi tassew hasra li din ma tigix zviluppata ghax tassew tixraq il-ghajn ta' dawk kollha li jigu fi Gziritna"*. (IL-HELSIEN, 1962). [*Transl.* It is a truly a pity that such a unique location is not henceforth developed.]

In 1984, a preliminary report proposing a habitat management plan for the Ghadira coastal dune system was prepared by an *ad hoc* group of members of a local environmental non-governmental organization (NGO), of which one of the authors (LFC) formed part, that was attempting to manage the reserve. The unpublished report was submitted to this NGO's governing council for consideration. However, in a follow-up report submitted by other quarters, the proposed management strategy was countered with a list of reasons why the dune rehabilitation project should not be pursued.

Schembri *et al.*, in 'Localities with Conservation Value in the Maltese Islands' listed four coastal dune sites (two in Malta: Ramla tat-Torri and Ghadira; one in Gozo: *Ramla l-Hamra*; and, one in Comino: *Santa Maria*), and outlined their conservation value (SCHEMBRI *et al.*, 1987).

During a parliamentary debate, as reported in the press, the then Infrastructure Minister stated that a 510-bed tourist complex proposal for Ramla l-Hamra was submitted for consideration and that to-date (21 December, 1988) a permit had not been issued by the Planning Areas Permits Board (PAPB). The Minister further announced that a request to extend an already existing restaurant, overlooking Ramla Bay on the *Xaghra* side, and construct lodging facilities to take up as many as 144 beds had been turned down (L-ORIZZONT, December 1988).

3.5 studies on sand dunes during coastal zone surveys and post-Structure Plan[8]

In their report of the coastal zone survey, which took place over a six-week period during the summer of 1989, Anderson and Schembri reported on the immense pressures exerted on the coast through tourism-oriented development and other recreational facilities. The authors also reported that marram grass (*A. littoralis)*, an important sand-binder, was extinct from the Maltese Islands and further stressed on the need to conserve unique coastal habitats such as sand dunes (ANDERSON & SCHEMBRI, 1989).

Schembri, in a report on natural resources, included a section on the current status of sand dune systems in the Maltese Islands and outlined reasons for their degradation. The section lists a total of thirteen localities, which support dune ecosystems or remnants thereof. It adds however, that only three localities on mainland Malta, one in Gozo, and one in Comino still support dune systems with a relatively intact dune vegetation (SCHEMBRI, 1991).

The Ghadira sand dune system was afforded legal protection by the fact that the Ghadira Nature Reserve was declared a protected area under the Environment Protection Act of 1991. (Environment Protection Act, 1991). However, the EPA did not provide any legal framework to protect elements so vital in aeolian development, which fall outside the delineated boundaries of the reserve, such as the offshore zone (sediment bank) and the transit zone (wet/dry transition beach boundary), both important components in any typical active coastal dune area.

[8] The Structure Plan for the Maltese Islands (1992) is a legal instrument concerned with the efficient and effective management and coordination of the country's resources.

A report on the state of trees and the environment in general was prepared by the environmental NGO Arbor. During the survey, trees and reed beds were mapped at Ramla (ARBOR, 1991).

The Society for the Study and Conservation of Nature, in a memorandum on *ir-Ramla l-Hamra*, identified six possible causes for sand dune habitat degradation and made proposals to conserve the area (SSCN, 1991).

The Structure Plan for the Maltese Islands and supplementary planning documents, which may be described as planning policy and implementation tools of the Development Planning Act of 1992, outline a number of policies concerned with conservation and of direct relevance to the coastal zone. In particular, Policy RCO 10 specifies which habitats are to be designated as Areas of Ecological Importance (AEIs); this clearly includes sand dunes. The Structure Plan has also a number of other policies that have a direct bearing on sand dune habitats, the constituents that make them up (e.g. sand-binding vegetation, sand) and their conservation (PLANNING AUTHORITY, 1992).

In an overview of the ecology of the Maltese Islands, Schembri refers to coastal dunes as being among the most rare and highly threatened of local ecosystems (SCHEMBRI, 1993).

In an account on the environmental conditions at Ghadira Bay, Lanfranco evaluates the situation of the floral communities in the region and includes the dune area adjacent to the reserve; the author also reports on the human impact on the bay (LANFRANCO, 1994).

Schembri and Lanfranco, in a survey of sandy beaches of the Maltese Islands, identified areas of ecological importance, in particular dune vegetation and banquettes, and assessed their status and conservation importance. In turn, these features were mapped on survey sheets. The authors also made recommendations concerning beach-cleaning activities in sensitive areas (Schembri & Lanfranco, 1994).

An emergency conservation order for Ramla Bay (extending 100 metres offshore) was issued by the Planning Authority on July 08 1994. The ECO prohibited the passage of motorized vehicles; camping in the area; removal and/or collection of sand, cobbles and stones; and, the taking, killing, capture, collection, trapping of any species of flora and fauna (Gazzetta tal-Gvern, Govt. Notice 460 of 1994).

Micallef *et al.* (1994), in "An Ecological Survey of Ramla Bay, Gozo", describe the coastal biotic communities and features of ecological and scientific importance present in the area, identify existing land-use conflicts and impacts, and outline suggestions for minimizing these impacts.

A number of studies were undertaken in recent years in connection with research leading to the degree of Master of Science. One included a quantitative study on the macroflora and macrofaunal species present at *Ramla l-Hamra*. The purpose of this study was to investigate distribution patterns of the shore biota and determine whether any seasonal variations in these patterns occur and, if so, their cause (Sammut, 1995: MSc., unpublished dissertation). Another such study primarily dealt with conservation strategies for coastal zone habitats and involved the assessment of dunal sites within the Maltese Islands (Cassar, 1996: MSc., unpublished dissertation). A recent study dealt on the status of Maltese sand dunes and their flora, with a case study on *Ramla* (Stevens, 2001: MSc., unpublished dissertation).

In 1998 some fifty tamarisk trees located on the dune peripheries at White Tower Bay were chopped down, some even burnt according to a report, which appeared in a local newspaper (The Times, April 13, 1998). Moreover, the ecologically important *Torri l-Abjad* dunes, have periodically fallen victim of senseless and insensitive so-called clean-up operations.

From the mid-nineties onwards, the Planning Authority commissioned a series of studies in connection with Local Plan reports for the Maltese Islands. In particular, the North-West Local Plan and the Gozo & Comino Local Plan included studies of the various sand dune sites present within their respective geographical jurisdictions. The Marfa Ridge dunes as well as the *Ghadira* and *Mixquqa* sites were integrated in the former study (MALTA UNIVERSITY SERVICES, 1995), while *Ramla l-Hamra* was researched for the Gozo Local Plan between the latter months of 1999 and the initial part of 2000 (CASSAR & LANFRANCO, 2000).

In 1998, a European Union (EU) funded three-year project was initiated to study coastal locations in the Maltese Islands, Morocco and Tunisia. The project consortium, made up of various academic institutions and technical agencies from the Mediterranean region and beyond, selected a number of Maltese coastal sites to be researched in the three-year study; these included *ir-Ramla l-Hamra*, *ir-Ramla tat-Torri* (White Tower Bay), *ir-Ramla ta' l-Armier*, *Il-Bajja tal-Mellieha* (Ghadira Bay) and *ir-Ramla tal-Mixquqa* (Golden Bay). The findings of this study were published following completion of the project.

3.6 case studies

Representative coastal dune areas have been selected to highlight the importance of such habitat-types; these are the *Ramla l-Hamra* (island of Gozo) and *Ghadira* (island of Malta) sites. A number of reasons underpin the choice of these sites, namely: both areas, in particular *Ramla l-Hamra*, support a biota that is of high conservation value, while *Ramla* is one of the few sites which still boasts of relatively unhindered aeolian dynamism; they occur within recreational locations and are therefore prime examples of land-use conflict. Ramla Bay is located in a relatively remote setting and therefore attracts mobile kiosks, for lack of permanent amenities, and campers, apart from hundreds of bathers/sun-seekers who travel to Ramla by private or *ad hoc* organized transport. Ghadira Bay is the most extensive sandy beach in the Maltese Islands, easily accessible by both private and public transport, and has a multitude of permanent and mobile food and beverage retail outlets. It is well and truly a site that attracts the masses.

Furthermore, both sites have a strong potential for environmental education (EE). The *Ghadira* site lies adjacent to a saline marshland now converted into a bird reserve, which attracts regular organized student groups to its day-centre; *Ramla l-Hamra* is the only quasi-intact dune system in the Maltese Islands, and provides the opportunity for research in ecology, botany and geomorphology. Seen in a broader context, both sites, including the areas altered through human agency, offer good fieldwork opportunities for ecology, geography, environmental science, and, environmental planning and management.

3.6.1 Ghadira:

As far as habitat is concerned, *Ghadira*, situated on the northeast coast of the Island of Malta, is best known for its *circa.* six hectare saline marshland - the largest such habitat in the Maltese Islands. The saline marshland is located some one hundred metres from the sea at Mellieha Bay (on which lies the longest sandy beach within the archipelago), facing in a north-easterly direction. In the opposite direction the sea is approximately one kilometre away at ic-Cumnija, a predominantly rocky coastline on the west coast. Adjacent to the saline marshland lies a degraded dune remnant, rendered so by years of mismanagement and a lack of sensitive planning of this habitat-type. This once flourishing coastal dune system has been reduced to sparse patches of much degenerated dunal elements.

The saline marshland and sand dune system are located on the north-eastern (terrestrial) extremity of a downthrown limestone block

... two SE to NW running parallel faults - defining Marfa Ridge ... and Mellieha Ridge to the south. According to Pedley *et al.* the Ghadira/Mellieha Bay graben tilts downwards towards the ... the land/sea interface is represented by a sandy shore, *Ir-...-Mellieha*. This beach is surrounded by elevated ground - ... for the deposition of alluvial and colluvial materials ...ing at *Ghadira* and on which the saline marshland has ...ed (PEDLEY *et al.*, 1976). Towards the northeast the ...'s substratum consists of beach sand, while towards its ... the substratum becomes predominantly alluvial deposit (... *et al.*, 1990). The sand dune system has, with land-use change ... years, experienced fluctuations in its physical extent. In ... times at least two consecutive road constructions took place ... Mellieha Ridge with Marfa Ridge. This coastal stretch of road ... across the back of the beach thus affecting a previously ...ered land/sea sediment exchange, which, as a result had a ...e effect on the dune system's sediment supply. Following ...ction of the initial asphalted road, an extensive piece of land, ...ising a seasonal pool of water and a substantial part of the ...ne, was levelled to make way for a car park-*cum*-bus terminus.

... least the mid-sixteenth century, the area has been subjected ...ous land-use alterations. The site's initial use is indicated on ... cartographic material as a salt-making area - *Saline*. When the ... moved to a new locality, namely Salina Bay, the *Ghadira* ... gradually became inundated with alluvial material, carried ... from the surrounding soil-covered hillside through the ...bined action of precipitation and run-off (SULTANA, 1990) as well ... other physical forces. During the years that followed, the area ... left to develop (or presumably, re-develop) into a marshland ...at with adjoining dunes. It is further assumed that the land, which ... the site, was taken over for agriculture in subsequent years ... it became reasonably safe to frequent coastal areas.

During the mid-sixties, the government had planned to construct an asphalted road along the coast to link Marfa Ridge, since the which then existed at the back part of the beach was often dam by wave action in addition to its being completely covered, du strong north-easterlies, by mounds of sand carried from the be zone. This proposed construction was planned across the s marshland, thus posing a threat to the habitats present in the However, following the intervention of a then embryonic na conservation lobby, government revised the project and shifted proposed road construction further seaward, very likely across existing back-beach deposit/fore-dune zone. In the months followed, the Malta Ornithological Society published a " Report the natural and historical features of Ghadira" (MOS, 1967), wh was presented to the House of Representatives urging that the be converted into the *"first nature reserve"* for the Maltese Islan (SULTANA, 1990).

Throughout the first half of the seventies, the area becam increasingly popular during weekends as a picnic site. From May September cars were driven over most of the area, while footb and other outdoor recreational activities took place on the dry be of the seasonal pool. Meanwhile, the marshland and environs we leased to a private individual for the purpose of shooting game. In so doing, Government had, to a certain degree, been the initiator a classic case of land-use conflict. While the area was not acces restricted and, in fact, was being utilised for recreational purpos by the public at large, an individual was granted the right to pursu game shooting, which right granted the tenant the facility to discharg a firearm in a popular public place.

With a view to limiting public access on the forefront of the mars and adjacent area, i.e., the sand dune area, a local environmenta NGO organized a series of tree planting activities with the result tha the main dunal area was gradually transformed into an afforestatio site. Originally the Ghadira dune supported a dunal community wit marshland elements. However, following the initiation of the afforestation scheme, almost the entire dune area was planted with both indigenous (*Tamarix africana* but also other *Tamarix* spp., *Pinus halepensis*) and alien trees (*Acacia cyanophylla*, *A. cyclops* and *Eucalyptus gomphocephalus*). In April 1984, it was estimated that about eighty percent of the dune area was 'shaded' by the tree canopy (unpublished survey report by a team, of which one of the authors [sic] formed part). Afforestation strategies included the planting of saplings in the following manner: tamarisks were planted to complement existing trees of the same genus, thus forming a line parallel to the shore. As these developed to form a hedge-like growth, their very presence hindered sand transport from the beach to the dune, with the result that the dune gradually began to lose its mass. Aleppo pines were planted to form an irregular wide band, behind the tamarisks, along much of the entire dune length. Notwithstanding, the central part of the main dune-line, where two patches (one colonized by clumps of *Juncus acutus* and the other, more sparsely vegetated with a variety of dune and inland flora) were not extensively planted. The back and northern sectors of the dune, however, were heavily planted with alien species, mainly Acacia and Eucalyptus. As the trees grew, the hours of shade increased thus altering the microclimate of the ground around them, while their shed leaves altered soil conditions. As a result, in a relatively short time after the planting exercise, dune flora began making way for opportunistic species such as the invasive Cape Sorrel (*Oxalis pes-caprae*) and Crown Daisy (*Chrysanthemum coronarium*) as a consequence of altered environmental conditions.

In 1978, the marshland and adjoining land were declared a bird sanctuary. Soon after plans were made to modify the existing habitats to (*i*) enlarge the surface area of the pool; (*ii*) create small islands so as to increase the 'feeding edge' for wading bird species; (*iii*) excavate a deep depression that would serve as reservoir at the back of the reserve; and, (*iv*) dig a protective ditch all the way around the reserve perimeter and construct an embankment on the inner side of the ditch. This work schedule was planned over three consecutive summers (1980-82), while additional work such as the construction of a bird-watching hide and a resource centre as well as the planting of scores of trees, was carried out during this period and the years that followed.

No doubt, engineering and other works to modify the area, particularly *(i)* the haphazard introduction of trees on the dune area and, *(ii)* the conversion of the transitional zone, containing both dune and saline marsh elements, to make way for a larger pool surface area, must have had some effect on the physical characteristics of the site as well as on the flora and fauna present. In addition, a new thoroughfare, which was higher and wider than the older one, was constructed during the second half of the eighties. Its elevation, compared to that of its predecessor, varied from one to almost three metres, while the extra width was taken from the landward side, primarily the fore-dune zone, in order not to compromise the width of the beach.

The elevation of the new road had a negative effect on the dune sediment budget (pers. obs./LFC). Sand blown from the beach in the dune's direction was obstructed by this new construction, with the result that less sand was eventually reaching the dune area. It was only during exceptionally strong north-easterlies that notable amounts of sand are transported across the road and reach the dune. This effect is such that an embryonic fore-dune has begun to form at the back of the beach, just beneath the road. However, its condition varies, normally improving between autumn and spring, and degenerating during the summer months due to a massive human presence.

In 1991, the Ghadira Nature Reserve was afforded legal protection under the Environment Protection Act, as a result of which the adjacent afforested-*cum*-sand dune area benefited insofar as trampling by the public was concerned.

In the early nineties (c.1993), a shallow pit was excavated on one of the last remaining patches supporting a dune vegetation, to accommodate a shallow freshwater pool. The technique used to retain the water was by means of a polythene membrane placed some six inches beneath the surface and recharged, by hose, with water. Furthermore, many more trees and shrubs were planted in the remaining open areas and perimeter of the former dune site. The saplings mainly consisted of Mediterranean Evergreen Oak (*Quercus ilex*), Aleppo Pine (*Pinus halepensis*), Tamarisks (*Tamarix* spp.), Pomegranates (*Punica granatum*) and Shrubby Orache (*Atriplex halimus*). Without any shadow of doubt, these trees will have some effect on the remaining dune elements at Ghadira, apart from the fact that some of the species used are not altogether suitable for coastal fore-dunes.

Several important biotic elements have been reported from the Ghadira dune system. These include the Sand Broomrape (*Orobanche densiflora*), which occurs as the endemic form *melitensis*. In the Maltese Islands, it is also recorded from *Ramla tat-Torri* dunes, and is otherwise known only from parts of the western Mediterranean. Fauna which has a limited distribution in the Maltese Islands and is known to occur at the Ghadira sand dune site includes a species of land snail *Cochlicella conoidea* (Mollusca); a semi-subterranean sand-dwelling earwig *Labidura riparia* (Dermaptera); a large subterranean cricket *Brachytrupes megacephalus* (Orthoptera), essentially of North African distribution; and, a number of coleopterans: *Erodius siculus melitensis* - endemic to the Maltese Islands and known only from the Ghadira dune; *Pimelia rugulosa melitana* - also endemic, *Scarites buparius* and *Anoxia matutinalis* (Coleoptera).

From observations carried out from 1983 to-date on population numbers of *Brachytrupes megacephalus*, the number of individual crickets on the dune proper was noted to have decreased following the construction of the new thoroughfare flanking the Ghadira dune system. Although the number of stridulating male crickets, in the general area of *Ghadira* (including: the surrounding agricultural land, the back of the beach, the reserve and dune areas) has remained relatively constant over the years, the species seems to have become more widespread within the entire locality while less frequent on the former dune zone. It has been noted in previous research that *B. megacephalus* is particularly sensitive to fluctuations in air temperature and ground humidity (CASSAR & Bonett, 1985). The various topographic modifications, leading to induced alterations of the hydrological regime, coupled with an evident change in the vegetation cover of the area are likely to have been the cause of the species' decline from its preferred habitat.

3.6.2 Ramla l-Hamra:

The dunes at *Ramla* are the best example of such a habitat-type in the Maltese Islands. Although these too have suffered from anthropogenic disturbance during the last three decades or so, the Ramla dune system is *quasi*-intact and still supports most of the typical dune flora together with a suite of fauna characteristic of coastal dunes. On the basis of species richness, ecosystem stability and active morphological dynamics, the *Ramla l-Hamra* coastal dunes are the most important dune system in the islands.

Ramla l-Hamra (or *Ir-Ramla l-Kbira*) lies on the northern coast of the island of Gozo, at the mouth of a fluvially-eroded valley complex known as *Wied tar-Ramla*. The *wied* is located between two headlands, each having a plateau formation, on which the villages of *Xagbra*, to the west, and *Nadur*, to the east, are established. Both settlements lie on Upper Coralline Limestone, the uppermost and youngest rock stratum (of marine sedimaentary origin), while each of the plateaux exhibits a fair amount of the stratigraphic sequence of the Maltese Islands. The basal member of the Upper Coralline Limestone (Ghajn Melel Member) and the less resistant Greensand beneath are the source of the rock fragments and somewhat large boulders (which 'migrate' down-slope from the plateaux escarpments boulder screes) found on either side of Ramla's sandy shore and further offshore. It is the relatively active erosion process that is responsible for the geomorphological features of the *Ramla* environment and its surroundings.

It is in fact the erosion of these rock-types [*Ghajn Melel* Member - the basal member of the Upper Coralline Limestone and Greensand] (Pedley, 1978) through climatic factors and wave action, which, in addition to terrestrial run-off, are the source of sediment supply for the Ramla dunes system. In a report on the coastal communities of the area, Micallef *et al.*, stressed that "the beach at Ramla is very dynamic in terms of the sediment budget and supply of sediment comes partly from terrestrial run-off through the valley system which opens on the coast at Ramla" (MICALLEF *et al.*, 1994). The valley systems responsible, in-part, for the Ramla dunes' sediment supply are *Wied tar-Ramla*, which joins with the inland *Wied il-Hanaq*, itself ramifying with a number of minor tributaries, and *Wied il-Pergla* further to the west, lying between the ridges of *Il-Pergla* and *Ghajn Damma*, its mouth being less than a kilometre (approx. 0.8 km) from Ramla Bay.

The predominant prevailing wind in the Maltese Islands is the North-westerly (*Majjistral*), while the principal sediment sources, namely *Wied tar-Ramla* and *Wied il-Pergla*, are located respectively within a short distance of some metres and less than one kilometre to the west of the dune site. Thus, the combination of prevailing north-westerly winds and the physical location of sediment sources explains the reason for the present position of the *Ramla l-Hamra* dune system on the eastern sector of the beach. As the watercourses of *Wied il-Pergla* and *Wied tar-Ramla* carry quantities of terrigenous sediment as well as scoured beach sand seaward, the *Majjistral* causes wave action to carry seaborne particles towards the eastern segment of the arcuate zone of Ramla Bay, that is, in the direction of the dunes. Subsequently, the sediment particles reach the shore and are transported from the beach towards the dunes through aeolian processes *(see Two: Coastal dune dynamics)*.

Micallef *et al.,* reported that "the present beach consists of Modern Beach Sands of Holocene age, backed by wind-blown dunes and raised beach deposits which extend a considerable distance inland (at least 200 metres)". Quoting Pedley (P.J. Schembri, pers. comm. LFC, 1995), the authors added that "these are of an earlier origin thought to have formed during the late Pleistocene (Tyrrhenian c. 347,000 years BP)" (MICALLEF *et al.*, 1994).

During the rainy season much of the run-off of the *Wied tar-Ramla* watercourse reaches the sea, and in doing so forms a shallow gully which, for many weeks, carries sediment into the bay. As a result of exceptionally heavy rainstorms, severe gullying has often taken place on the Ramla fore-dunes consequent to considerable run-off descending from the *Ta' Venuta/Ta' Ghajn Qasab* hillside. A case in point was the storm of 5th March 1994, the effects of which were still visible for some years following this climatic event. The vegetation, mainly made up of Sea Daffodil (***Pancratium maritimum***) and Dropseed grass (***Sporobolus arenarius***) but also Sea Medick (***Medicago marina***) and Spiny Echinophora (***Echinophora spinosa***), regenerated slowly in the affected area of the fore-dune.

Habitat disturbance, which has left its mark at *Ramla l-Hamra* is that occurring through the human agency. Ever since the area was made more accessible, following the construction of reasonable roads leading from the villages of *Xagbra* and *Nadur*, human presence in the *Ramla* region became, over the years, more and more frequent. During the last three decades this coastal area literally became a catchment zone for various activities connected with recreation, including bathing, rambling, sea-sports, barbecues and camping. These, in turn, attracted retail kiosks, which until some years ago were located on the beach proper. As a result, the threat of large scale trampling could be seen in the context of accelerated erosion. In the last decade or so, four-wheel drive vehicles aggravated the level of disturbance on the dune system by occasionally driving over

...dune area. In addition, the sand at *Ramla* has, for decades ... used in making concrete as it is said to have better binding ... than quarried aggregate. Large quantities (often by the truck-... were apparently removed, normally under the cover of darkness ... removal of sand, to be used domestically or commercially, is ... Until a few years ago, at least one hardware store owner in a ...bouring village held quantities of Ramla sand in the back yard ... eventual sale. In 1992 public works employees were utilizing ... sand for construction purposes during the rehabilitation of ... promenade at *Marsalforn*. It was apparently only after the ...ention by an environmental agency official that the beach sand ... substituted by its quarried counterpart.

...the summer of 1993, a local firm was assigned to conduct beach-...ing operations on popular sandy beaches in Malta and Gozo; ...a Bay was among the selected beaches for the trials. ...withstanding notable concern by members of the scientific ...munity that these potentially damaging trials should be averted ... *Ramla l-Hamra*, the beach-cleaning exercise was, regrettably, ... as scheduled. The weeks that followed were characterized by ...lemic that ensued in some quarters of the local press on the lack ...appropriate supervision as well as on responsibilities and priorities ... the authorities concerned.

...e *Ramla l-Hamra* dunes still support a relatively good ...presentative floral community, typical of coastal dunes. The dune ...stem's main sand binders are the Sand Couch *(Elytrigia juncea)* ...d the Sand Dropseed (*Sporobolus pungens*). Vulnerable, rare or ...dangered dune flora that also occur at Ramla, and which have a ...stricted range in the Maltese Islands include: Spiny Echinophore (*Echinophora spinosa*), Sea Daffodil (*Pancratium maritimum*), Sea Holly (*Eryngium maritimum*), Sea Spurge (*Euphorbia paralias*), Coast Spurge (*Euphorbia terracina*), Purple Spurge (*Euphorbia peplis*), Sea Medick (*Medicago marina*), Sea Knotgrass (*Polygonum maritimum*), Sand Galingale (*Cyperus capitatus*), Sea Rape

(*Raphanus maritimus*), Spanish Golden Thistle (*Scolymus hispanicus*), Sand Fern Grass (*Cutandia maritima*), Sand Storksbill (*Erodium laciniatum*), Two-leaved Allseed (*Polycarpon diphyllum*), Gum-Chicory (*Chondrilla juncea*) [not observed during recent surveys], Sea Ragwort (*Ambrosia maritima*) [not observed during recent surveys], Sea Carrot (*Pseudorlaya pumila*) [not observed during recent surveys], Sand Birdsfoot Trefoil (*Lotus halophilus*) [possibly extinct], Sand Restharrow (*Ononis variegata*) [possibly extinct], and a very rare sand-dwelling mushroom (*Montagnites arenaria*). Other species include the Prickly Saltwort (*Salsola kali*), Sea Rocket (*Cakile maritima*), Dune Fescue (*Vulpia fasciculata*), Hairstail grass (*Lagurus ovatus*), Red Campion (*Silene colorata*), Sea Scabious (*Scabiosa maritima*), Bush Restharrow (*Ononis natrix* ssp. *ramosissima*), Sweet Alison (*Lobularia maritima*), Littoral Medick (*Medicago littoralis*), Yellow-horned Poppy (*Glaucium flavum*), Ripgut Brome (*Bromus rigidus*) and Grey Birdsfoot Trefoil (*Lotus cytisoides*).

The phytosociological assemblages forming the vegetation on the sand dunes at *Ramla l-Hamra* has only been recently analysed (Stevens, 2001), and are mainly characterised by five types of associations:

- a **Salsolo-Cakiletum maritimae** fore-dune community with *Cakile maritima* and *Salsola kali*, which is well-developed in some parts of the dune ecosystem, especially where accompanied by *Elytrigia juncea* and *Tamarix africana*. The latter acts as a dune-building hemicryptophyte, forming a mound-like dune (sometimes referred to as hedgehog dunes). A similar association, the **Salsolo-Euphorbietum paralias**, based upon *Euphorbia paralias*, *Cakile maritima* and *Salsola kali* is present along the western part of the bay;

- an **Eryngio maritimi-Elytrigetum juncei** yellow dune association, with a dune assemblage based upon *Elytrigia* *juncea*, *Medicago marina*, *Eryngium maritimum*, *Echinophora spinosa*, *Euphorbia terracina*, *Medicago littoralis*, *Cutandia maritima* and *Pancratium maritimum*;

- a **Brometalia** semi-consolidated dune grassland community dominated by *Bromus* spp., (typified by *Bromus rigidus*, but with *B. diandrus* and *B. madritensis* in more disturbed areas), *Vulpia fasciculata* and *Silene colorata*, together with *Ononis natrix* ssp. *ramosissima*, *Sporobolus pungens* and *Pancratium maritimum*;

- a **Centaureo-Ononidetum ramosissimae** semi-consolidated to fixed dune vegetation, typified by *Ononis natrix* ssp. *ramosissima*, accompanied by *Bromus* spp., *Erodium laciniatum* and *Scabiosa maritima*;

- a fixed dune area dominated by *Asparagus aphyllus* and *Ononis natrix* ssp. *ramosissima*, with *Prasium majus* and *Rubia peregrina*, as well as *Senecio bicolor* and *Lathyrus clymenum*. This community is very often replaced by a reed-dominated assemblage based upon the invasive *Arundo donax*, which is accompanied by *Vitis vinifera* s.str., *Asparagus aphyllus* and *Rubia peregrina*.

Along parts of the sand dunes, the fore-dune and the yellow dune communities are separated by an area of bare sand or little if no vegetation, probably because of sand loss as a result of processes leading to blow-out formations on the lee side of dune ridges. The vegetation of this area includes few individuals of *Cakile maritima*.

On the eastern part of the bay, the semi-consolidated part of the sand dunes is divided by an area with planted *Tamarix africana* and *T. gallica* [c. 70-80m from shore]. *Cakile maritima* is an important constituent of this spatially restricted area.

The dune slack present along the eastern part of the bay, apparently of relatively recent origin, is often flooded during occasional winter rains. As a consequence, it is characterised by a number of ruderal species typical of such natural disturbance, especially *Astragalus boeticus*, *Convolvulus arvensis*, *Dittrichia viscosa*, *Foeniculum vulgare* and *Galactites tomentosa*. Other species include *Avena* spp., *Lathyrus clymenum* and *Papaver rhoeas* subsp. *strigosum*. *Oxalis pes-caprae* and *Ranunculus muricatus* have been noted to become seasonally dominant in the dune slack area.

The fauna on the Ramla dunes includes both species that are characteristic of sandy environments and related maritime habitats and species, which also occur in other habitat-types. Among the more important species recorded from the Ramla dunes are: the amphipod (*Talitrus saltator*) and the burrowing isopod (*Tylos latreilli*); two endemic collembolans known only from *Ramla l-Hamra* (*Odontellina sexoculata* and *Mesophorus schembrii*); the large subterranean cricket of North African distribution (*Brachytrupes megacephalus*) known only from Ramla l-Hamra, Ghadira and, more recently, Armier; histerid beetles (*Hypocaccus dimidatus*, *Xenonychus* sp., *Hypocaccus* sp.); an anthicid beetle (*Anthicius fenestratus*); a number of species of carabids belonging to the genera *Harphalus, Masoreus, Eurynebria and Ophonus*; the endemic curculionid beetle *Othiorynchus ovatulus*; and, the tenebrionid beetles *Xanthomus pallidus*, *Nalassus aemulus* and the endemic *Pseudoseriscius cameroni*. Most of these coleopterans are known only from the Ramla dunes. In addition, the halictid bee (*Psuedoapis unidentata*); the sphecid wasps (*Prionyx lividocinetus, Sphex pruinosus, Philanthus raptor siculus, Bembix oculata* and *Bembecinus tridens*); and, the ants (*Trachymesopus darwini* and *Leptothorax* sp.) are also found (Schembri *et al.*, 1987, 1999; Sammut, 1995; Cassar, 1996; Mifsud, 1999).

Apart from the sand dune habitat, a number of other biotic communities exist in the Ramla region. These include:

- freshwater wetland community
- **Crithmo-Limonietea** assemblage
- Inter-dunal area, where clay slopes, rocky outcrops and sand meet.

- On the west sector of *Ramla l-Hamra*, at the point where the beach and agricultural land converge, the Wied tar-Ramla watercourse has developed into a **Scirpetum maritimi wetland community**, with relatively well-established beds of Great Reed (*Arundo donax*), Common Reed (*Phragmites australis*), the rush (*Bolboschoenus maritimus*) and the relatively more restricted Southern Reed Mace (*Typha domingensis*) [not observed during recent surveys] can be found in this habitat. This community is bordered by a **Nerio-Tamaricetea** community, characterised by *Tamarix africana*. During particularly wet years, valley water regularly erodes a funnel-shaped and often moderately deep canal into the sandy surface, which channels access run-off across the western sector of the bay and into the sea. Consequently, during strong north-easterly spells, seawater is often forced inland via this low-lying breach in the beach surface.

- The low-lying rocky coastline of Ramla Bay supports a biotic community typical of Mediterranean rocky shores. It is dominated by salt-tolerant vegetation, i.e., halophytes, and is phytosociologically described as **Crithmo-Limonietea**. The *Ramla* community is dominated by Golden Samphire (*Inula crithmoides*) and Maltese Sea Lavender (*Limonium melitensis*). Maltese Salt-tree (*Darniella melitensis*) is also present, dominant in some areas, within this assemblage.

- The western side of the bay is typified by an interdunal area, where the clay slopes, rocky outcrops and sand meet. The following communities occur:

(i) the community on mixed and exposed clayey/sandy soil that occurs on the plateau and hill slopes of the area is similar to the **Plantago weldenii-Parapholisetum incurvae** community described by Géhu *et al.* (1986) and reported for continental Greece and southern Italy. This is characterised by a high abundance of taxa of the *Plantago coronopus* group including *P. commutata* and *P. weldenii*, as well as *Parapholis incurva*, *Spergularia bocconei* and *Hainardia cylindrica*, together with *Beta maritima*, *Frankenia pulverulenta* and *Hordeum marinum*.

(ii) the community located along the disturbed clayey sand lower interdunal areas of the same zone is based upon *Cynara cardunculus* and *Scolymus hispanicus*, with *Beta maritima*, *Glaucium flavum*, *Inula crithmoides*, *Ammophiletalia* species and small populations of *Carthamus lanatus*, *Centaurea melitensis*, and *Hedysarum coronarium*, and an accumulation of dead *Posidonia oceanica* leaves. The habitat description and the vegetation structure are similar to the **Glaucio-Scolymetum hispanici** community described by Bartolo *et al.* (1988) for the island of Lampedusa, although the community at *Ramla* lacks the characteristic cover of *Glaucium flavum*, and is infiltrated by the **Sporoboletum** dune species such as *Sporobolus* and *Pancratium*, as a result of sand in the area. Moreover, *Cynara cardunculus*, *Centaurea melitensis* and *Hedysarum coronarium* are typical of the clay slopes, which surround the bay.

The region manifests other important ecological and geomorphological assemblages, notably the various minor *widien* throughout the largely sloping landscape; the Blue Clay coastal slopes and associated plateaux and screes; and, the maquis-type assemblages (comprising both archaeophytic and indigenous species) that literally dot the terrain within the embayments beneath the *Nadur* and *Xaghra* escarpments. This is not to mention the considerable amount of land under active cultivation, which complements the sheer beauty of the region's landscape and provides a physical link between the various habitats and assemblages, thus serving as biodiversity corridors. However, agriculture also impacts the supporting habitats and biota through direct competition for land and through the negative influence of agricultural by-products such as leachates, pesticides and so on.

4 Status of Maltese dunes

contents

4.1
extant dunal sites

A review of extant dune sites is carried hereunder, each assessed in terms of the flora present.

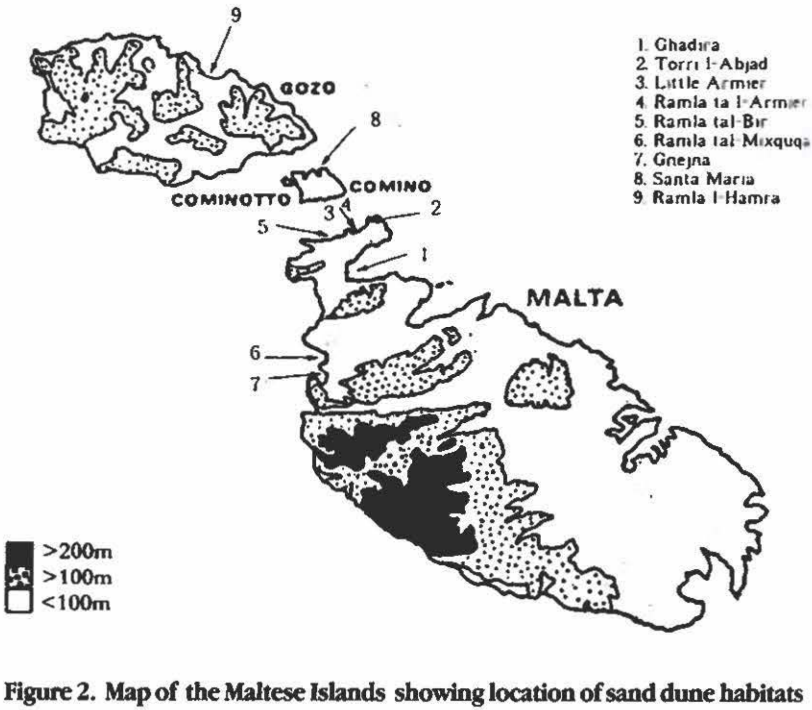
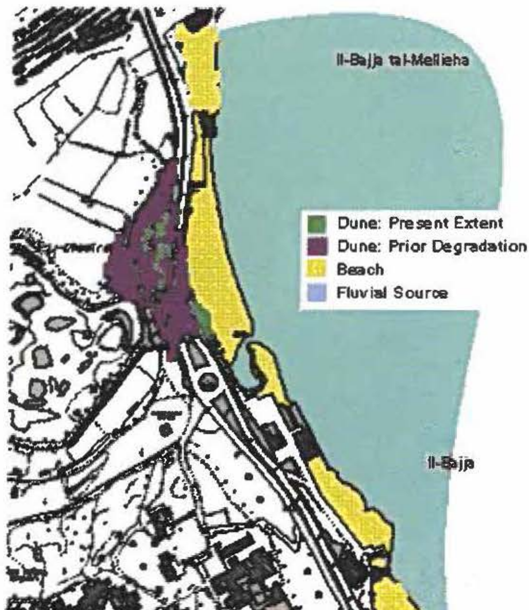


Figure 2. Map of the Maltese Islands showing location of sand dune habitats

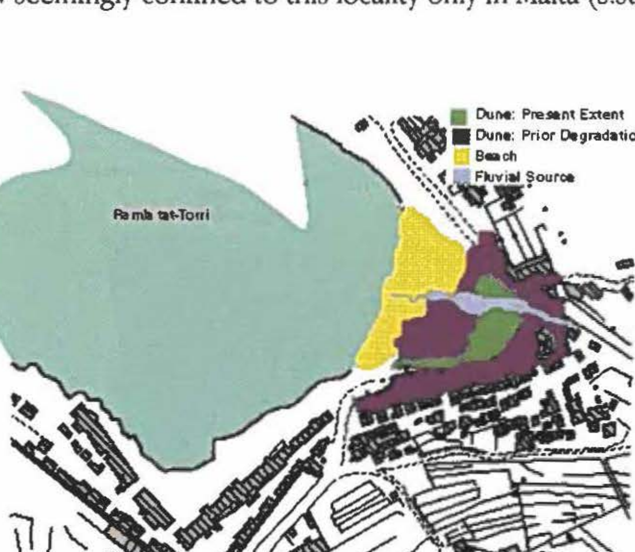
Ghadira (Mellieha Bay)

With the exception of a dune field at *Marsa*, information on the extent of which is unavailable, the sand dunes in the region of Mellieha Bay represented the largest dunes of the Maltese Islands. These are now largely degraded and restricted to mere mounds of sand; pocketed by a multitude of anthropogenic activities, notably road construction across the fore-dune zone, tourism and recreation-oriented development, overall mismanagement, inappropriate tree planting schemes (with *Acacia saligna*, *Pinus halepensis*, *Tamarix* spp., etc.) and invasion by *Arundo donax*. However, despite such activities, various species still persist, including the dune-building *Elytrigia juncea*, *Cakile maritima*, *Pancratium maritimum*, *Sporobolus pungens*, *Lotus cytisoides*, the endemic *Orobanche densiflora* forma *melitensis*, *Euphorbia terracina* and possibly *Chondrilla juncea*. *Ghadira* may represent the last Maltese (s.str.) station for *C. juncea* (*see also case study*).



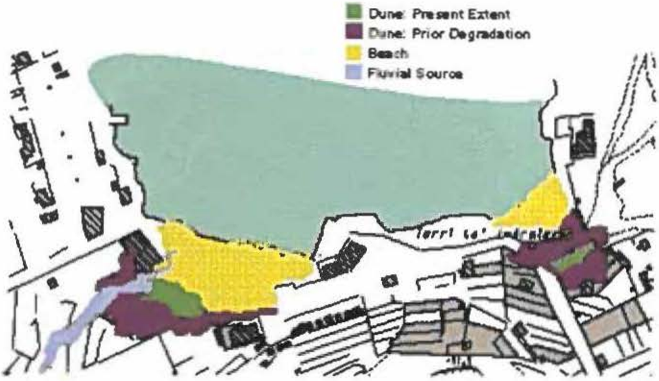
Ramla tat-Torri (Marfa promontory)

The most important of the extant Maltese (s.str.) sand dunes. Until recently, the bay "supported the best sand dune ecosystems in the Maltese Islands" (Schembri & Lanfranco, 1994), which, in the past, was more species-rich and diverse than *Ramla* in Gozo; it was characterised by a similar zonation, with dune grasslands based on *Vulpia fasciculata* and back-dune vegetation of the **Centaureo-Ononidetum ramosissimae** association. In recent years, this dune site was grossly degraded, primarily as a result of various activities, namely: inappropriately-conceived afforestation strategies based on *Acacia saligna*, construction of beachside dwellings, road construction, mismanaged beach clean-ups and other works in the area. A number of species known from this locality are now considered extinct from the islands. Examples include *Ammophila littoralis* and *Valerianella microcarpa* (Lanfranco, 1989, 1999; Stevens, 1998). Nonetheless, a varied array of dune species still persists in the area, including the endemic *Orobanche densiflora* forma *melitensis*, *Euphorbia peplis* and *Echinophora spinosa*; the latter two species are now seemingly confined to this locality only in Malta (s.str.).



Little Armier (Marfa promontory)

The small sandy enclave, forming part of the Armier embayment, may well have formed discrete dunes beyond the beach remit. What is left of the former dune within this area is presently taken up by an asphalted road and parking area. Although *Elytrigia juncea*, *Scolymus hispanicus*, *Erodium laciniatum*, *Lotus cytisoides* and *Medicago littoralis* still persist together with an array of other species, including *Cakile maritima*, *Beta maritima*, *Echium arenarium*, *Plantago macrorhiza*, *Salsola kali* and *Sporobolus pungens* (these latter species characterise the more exposed assemblages), some patches are largely dominated by invasive species such as *Arundo donax*, *Carpobrotus edulis*, *Oxalis pes-caprae* and planted *Atriplex halimus*. Although the dune *per se* is in a pitiable state, the potential for colonization by dunal flora does exist. This is evidenced by *Sporobolus* growing in thin sand layers deposited by aeolian processes on the asphalted surface.

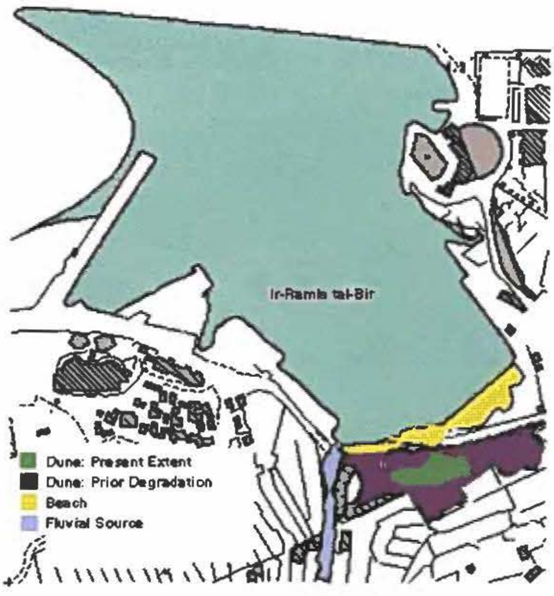


Ramla ta' l-Armier (Marfa promontory) - [see above]

In the past, Armier Bay apparently supported a fairly sizeable coastal dune system with *Ammophila littoralis*. However, it is currently quite degraded and small in size due to considerable recreational activity that takes place within the area, together with construction on the former dune area, clearance of vegetation and invasion by *Arundo donax*, *Oxalis pes-caprae* and *Vitis vinifera*. Some species, including *Ammophila littoralis*, are extinct, and only dune remnants remain, with *Cakile maritima*, *Sporobolus pungens*, *Erodium laciniatum* and *Scolymus hispanicus*, together with *Elytrigia juncea*, *Euphorbia terracina* and the last known haunt for *Calystegia soldanella* (CASSAR, 1996).

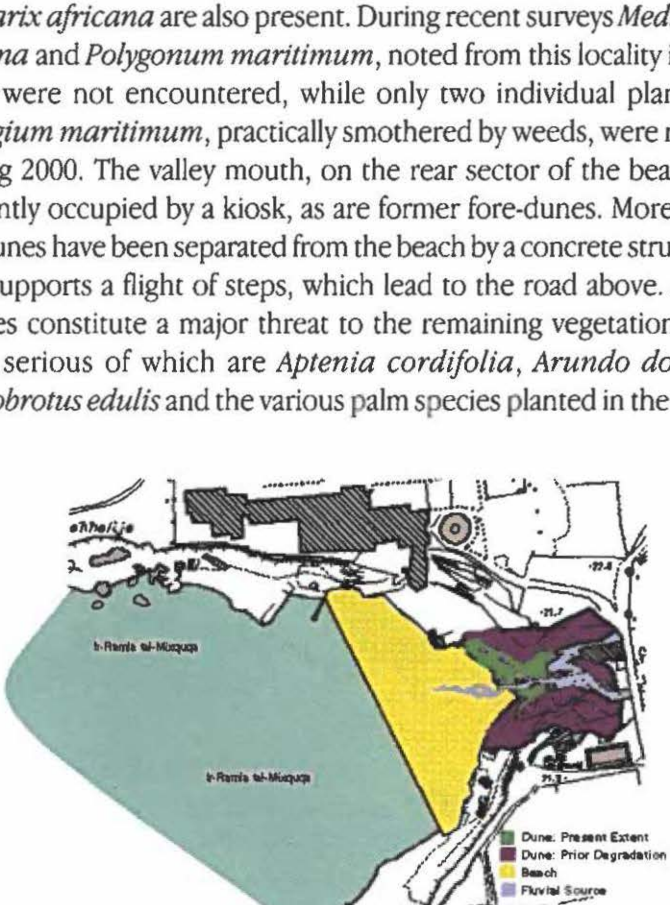
Ramla tal-Bir (Marfa promontory)

This beach, located within the Marfa embayment, used to support a discrete dune ecosystem, of which some patches still persist on the eastern segment of the sandy beach. These vestiges are characterised by *Cakile maritima* and *Salsola kali*, together with *Elytrigia juncea*, *Pancratium maritimum* and *Inula crithmoides*, together with *Phragmites australis*, a wetland species. Unfortunately, this assemblage thrives among considerable degradation and dumping, as well as invasive carpets of *Carpobrotus edulis*.



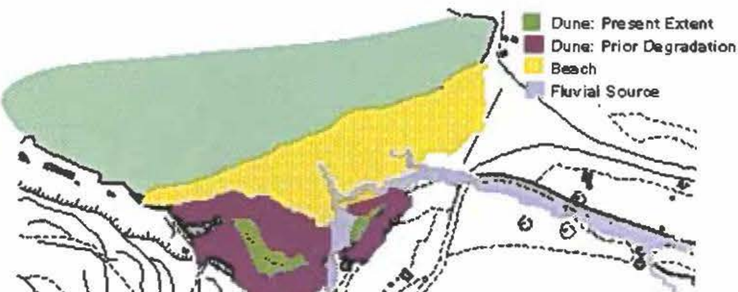
Ramla tal-Mixquqa (Ghajn Tuffieha, l/o Manikata)

Located at Golden Bay, this sand dune is peculiar in respect to the other extant dunes, especially with regard to its geographical orientation and species associations. The dunes are characterised by a zonation comprising *Glaucium flavum*, *Inula crithmoides*, *Matthiola tricuspidata* and *Limonium melitensis* on the northwest-facing exposed side. The dunes proper are colonized by a combination of *Arundo donax* and *Scolymus hispanicus*, together with *Elytrigia juncea*, *Medicago littoralis*, *Pancratium maritimum*, *Cakile maritima* and *Sporobolus pungens*. *Lavatera arborea* and *Tamarix africana* are also present. During recent surveys *Medicago marina* and *Polygonum maritimum*, noted from this locality in the past, were not encountered, while only two individual plants of *Eryngium maritimum*, practically smothered by weeds, were noted during 2000. The valley mouth, on the rear sector of the beach, is currently occupied by a kiosk, as are former fore-dunes. Moreover, the dunes have been separated from the beach by a concrete structure that supports a flight of steps, which lead to the road above. Alien species constitute a major threat to the remaining vegetation, the most serious of which are *Aptenia cordifolia*, *Arundo donax*, *Carpobrotus edulis* and the various palm species planted in the area.



Gnejna (l/o Mgarr)

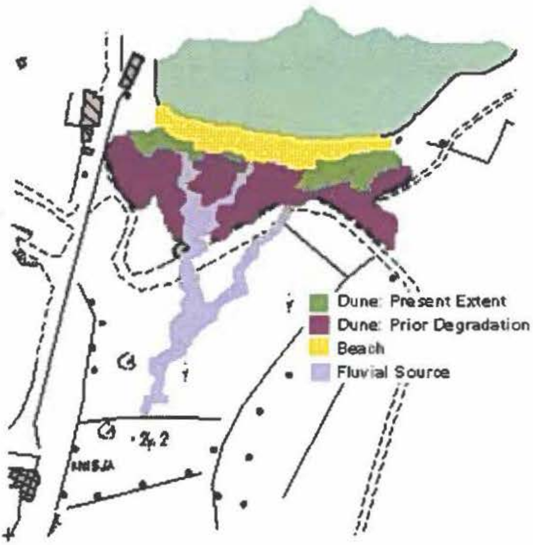
The Gnejna sand dunes have practically disappeared as a result of various human-induced activities. The area where the former yellow and semi-consolidated dunes once stood is now occupied by a car park, a main road leading directly to the popular bay, agricultural fields, *Arundo donax* beds and a dirt track across the rear portion of the beach leading to the boat-houses located on the southern flank of the embayment. According to Schembri & Lanfranco (1994), the remaining dunal embankment, currently dominated by *Arundo donax*, was created artificially through the bulldozing of sand and debris onto the reed beds that abut onto the beach. The remaining dune vegetation is confined to a few open spaces, as yet not invaded by *A. donax*, and are characterised by *Sporobolus pungens*, *Scolymus hispanicus*, *Cakile maritima*, *Beta maritima*, *Plantago macrorhiza*, *Salsola kali*, *Spergularia bocconei* and various weedy species.



Il-Qala ta' Santa Marija

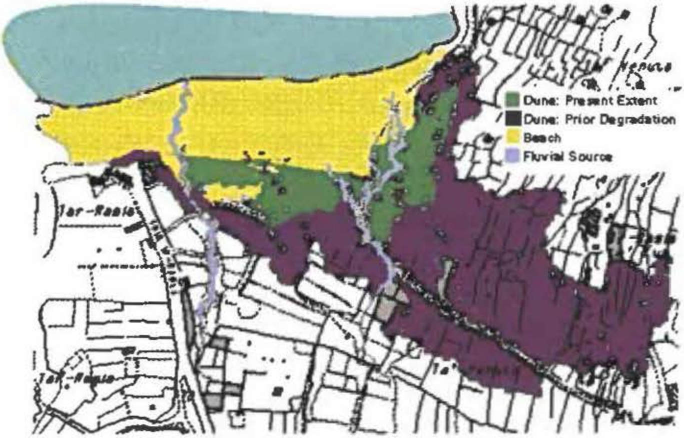
This is the only sand dune assemblage on the island of Comino. The site comprises a popular beach backed by a tamarisk stand, dune vestige and former marsh area, which endure considerable visitor pressure and overnight camping activity. Apart from human disturbance such as trampling, the dune remnant is also threatened by the excessive planting of tamarisk trees (supposedly to augment the local native stock), which have altered the microclimate somewhat through the provision of excessive shade, as well as nitrophilic conditions, favouring opportunistic weed species.

Some dune species still persist in the area; these include *Cakile maritima* (including var. *latifolia*), *Echium arenarium*, *Polycarpon diphyllum*, *Lotus cytisoides*, *Inula crithmoides*, *Ononis natrix* subsp. *ramosissima* and *Pancratium maritimum*, together with *Lotus halophilus*, which was recently re-discovered in the area and for which this Comino site is the last known locality in the Maltese Islands (LANFRANCO & STEVENS, 2000).



Ramla l-Hamra (l/o Nadur/Xaghra)

This site is currently the best example of dunal formation in the Maltese Islands with regard to both sediment dynamism and extent, and floral species richness. Most sand dune species known from the Maltese Islands are now confined to this area. Examples include *Euphorbia paralias*, *Medicago marina*, the sand-dwelling mushroom *Montagnites arenaria* and possibly *Ononis variegata* and *Pseudorlaya pumila*; the latter two species were, however, not encountered in recent years (see also case study).



4.2
a cursory evaluation

Currently, sand dune ecosystems or remnants thereof occur in nine localities in the Maltese Islands. Of these, only one site in Malta and one site in Gozo still support a significant dune vegetation cover (STEVENS, 2001). The other sites support only traces of coastal dune ecosystems, ranging from much degraded dune remnants to as little as single dune plants. Until a few years ago, four sites were considered as having a reasonable dune vegetation cover and relatively healthy dune morphology (CASSAR, 1996), while a decade or so ago, as many as thirteen localities supported dune ecosystems or their remnants, five of which were reported to have *"a more or less full dune flora"* (SCHEMBRI, 1991). Schembri further reported *"in the recent past, four previously flourishing dune ecosystems in Malta have lost all traces of the typical dune vegetation"*. In the span of a few years the total number of dunal habitats decreased to 69 percent, while if one considered the present remaining extant dune ecosystems as a percentage of the overall number of dunes recorded by Schembri in 1991, the situation is rather much bleaker: 15 percent. The percentages given relate to coastal dune and sand-bearing environments, supporting a dune flora - the latter refers to much degraded dunal areas whose sediment supply has experienced a significant decline. The only quasi-intact dune system in the Maltese Islands, that is, having a sustained sediment supply and flourishing dune-type vegetation is, in effect, Ramla l-Hamra in Gozo.

Below is a synthesis of recent findings, focusing on the current status of sand dune habitats in the Maltese Islands. The scores given are based on ratings described below.

Site	Dune ridge morphology	State of dune vegetation	Protection measures	Future prospects
Ghadira	3	3	2*	4
Ramla tat-Torri	2	2	2	2
Little Armier	3	3	2	3
Ramla ta l-Armier	3	3	2	3
Ramla tal-Bir	4	4	2	4
Ramla tal-Mixquqa	2	3	2	3
Gnejna	2	3	2**	3
Il-Qala ta' Santa Marija	3	4	2	3
Ramla l-Hamra	1	2	1	1

Table I. Status of Maltese sand dunes.

* Although in the case of Ghadira, legal protection has been afforded to the site, it is nonetheless only protected as a bird sanctuary and <u>not</u> because of its sand dune habitat.

** Gnejna dunes are scheduled as a buffer zone for nearby coastal cliffs.

Ratings	1	2	3	4
Dune ridge morphology	Dynamic dune activity	Potentially threatened sediment source	Sediment transport severely hindered	Beach/foredune sediment supply: insignificant net rate
State of dune vegetation	Extensive dune vegetation	Extant but potentially threatened	Degraded remnants	Sparse dune vegetation
Protection measures	Effectively protected: legal instruments/monitoring & enforcement	Afforded protection however, no adequate monitoring & enforcement	No legal protection, with signs of degradation setting in	No protection, mismanaged/neglected
Future prospects	Relatively secure	Relatively sustained, however under serious threat	Severely degraded however, still in a position to be managed	Likely to become extinct in the near future

4.3 sites with a potential for aeolian formation and/or extinct coastal dunes:

A number of sites, known to have supported coastal dune vegetation alongside a dynamic dune formation or remnants thereof, include Ramla ta' Bahar ic-Caghaq, Qalet Marku, Ghadira s-Safra, Salini, Bugibba area, Ramla tal-Pwales, Il-Qala tal-Mistra, Dahlet ix-Xilep, Ramla tal-Qortin, Ramla tac-Cirkewwa, Ramla ta' Qassisu, Ramla ta' Ghajn Tuffieha, Ramla ta' San Gorg, Marsaxlokk-Birzebbuga area, Ramla ta' San Tumas, Ramla ta' Marsaskala, Marsa, the Bieb il-Gzira-Ta' Xbiex system, Bajja ta' Spinola and Bajja ta' San Gorg in Malta; San Niklaw in Comino; and, San Blas, Marsalforn, Qbajjar, Ramla tax-Xlendi and Xatt l-Ahmar in Gozo [see map on page xx]. Although these sites no longer support coastal dune assemblages, they are nevertheless reviewed hereunder.

Ramla ta' Bahar ic-Caghaq

A much degraded dune remnant with traces of dune vegetation in the area; the dune flora was practically obliterated during a major 'clean-up' in the early 1990s. Various species of the **Ammophiletea** are reported from *Bahar ic-Caghaq*, which, however, seem to have disappeared, probably as a result of the construction, during the latter part of the previous century, of the coastal road that connects the urban centre of Malta to northern parts of the island. Schembri & Lanfranco (1994) noted that some dune vegetation (*Cakile maritima*, *Polygonum maritimum*, *Sporobolus pungens* and *Lotus cytisoides*) had re-appeared, although many species have since been obliterated, following clean-up operations and inappropriate afforestation with *Agave* and *Tamarix* spp. Nonetheless, despite considerable disturbance and invasion by planted *Carpobrotus edulis*, this beach is still particularly interesting, even though it does not support a true sand dune.

Qalet Marku

A relatively narrow sandy beach, with no dunal development.

Nevertheless, some interesting sand-associated species are known from the area, including the dune-building *Sporobolus pungens* and *Cakile maritima*, together with the vulnerable *Triplachne nitens* and the endemic *Orobanche densiflora* forma *melitensis*, parasitic on *Lotus cytisoides*.

Ghadira s-Safra (Ghallis, l/o Naxxar)

A transitional coastal wetland in which a number of sand-associated species have been reported, including *Polygonum maritimum* and the sand-binding species *Elytrigia juncea* (Borg, 1927). These species were not observed in the area in recent years, possibly as a consequence of habitat alteration following the construction of the coastal road and other works carried out in the area, which have altered the physical characteristics of the site.

Salini

Some sand-associated species, including *Euphorbia paralias* and *Pancratium maritimum* were recorded from this site (Grech Delicata, 1853). However, by the time Sommier & Caruana Gatto (1915) studied the area, these were already extinct. It is probable that *Salini* maintained some form of dune flora, either due to the presence of mobile substrates or as a dune remnant. At present, excluding two very small patches of sand, no appropriate habitat exists for either of these two species. *Salini* nowadays represents the largest extant (but degrading) saline marshland in the Maltese Islands.

Bugibba area (l/o San Pawl il-Bahar)

Various dune species (*Ambrosia maritima*, *Polygonum maritimum* and *Sporobolus pungens*) were recorded from an unspecified beach (or beaches) in the *Bugibba* area (Borg, 1927). At present, no such dune vegetation exists in the area, while sandy beaches are very much reduced in extent.

Ramla tal-Pwales (Xemxija)

Dunal vegetation, based upon *Ammophila littoralis* (Sommier &

CARUANA GATTO, 1915), used to occur in the area known as Xemxija Bay; at the back of this beach was a coastal wetland (now a nature reserve) known as *Simar*. Owing to the construction of a main thoroughfare along the seafront, most of the sand was removed and the area asphalted. Today, only two small patches of sand remain, both of which too narrow to support any sand dune vegetation.

Il-Qala tal-Mistra

This represents an extinct dune. According to Schembri & Lanfranco (1994), the beach at *Mistra* still supported typical dune elements until the 1970s. However, except for solitary *Cakile maritima* plants, no trace of these remain. The reason for this dune's disappearance is directly due to human disturbance, including construction and excavation works in the recent past along the coastal strip. Furthermore, asphalting of the valley-bed of *Wied il-Mistra* and 'clean-ups' of the valley sector leading to the beach zone will have had, no doubt, a negative effect on the sediment supply which will almost certainly disrupt the dune's potential to regenerate.

Dahlet ix-Xilep (Slugs Bay, l/o Mellieha)

This site has sparse dune vegetation, however, with no evidence of dunal formation. The small sandy beach is characterised by a small-scale dune assemblage, characterised by *Cakile maritima*, *Eryngium maritimum* and *Pancratium maritimum*. Owing to its limited size, typical sand dune zonation cannot develop; nonetheless, as observed by Camilleri (1996), "these species appear to be locally thriving and have spread to nearby sandy pockets amongst the boulders at *Rdum il-Hmar*".

Ramla tal-Qortin (Marfa promontory)

Located within Ta' Kejli Bay, this highly degraded dune is practically surrounded, on the landward side, by various constructions. Although it still supports remnants of the former *Ammophila*-based community, with dune elements such as *Sporobolus pungens*, *Elytrigia juncea*, *Cakile maritima* and *Pancratium maritimum* together with *Crithmum maritimum*, *Inula crithmoides*, *Glaucium flavum*, *Salsola soda* and *S. kali*, the Ramla tal-Qortin dune is likely to become extinct in the near future. At most, it may support sparse pockets of dune flora. However, the Ramla tal-Qortin dune seems far too degraded for rehabilitation. Invasive allochthonous species such as *Agave americana* and *Carpobrotus edulis* are also present (CAMILLERI, 1996).

Ramla tac-Cirkewwa (Paradise Bay – Marfa promontory)

Although this popular sandy beach may have supported a dunal community in the distant past, currently, there is no trace of any dune elements and nor has there been in the recent past (CASSAR, 1996). The sand-associating species *Cakile maritima*, which was recorded from this site was also absent during recent surveys; other halophytes are however present. The fringe of halophytic vegetation is backed by reed beds of both *Arundo donax* and *Phragmites australis*, together with a native stand of *Tamarix africana*; moreover, the vegetation leading to the beach supports a well-developed maquis community (SCHEMBRI & LANFRANCO, 1994).

Ramla ta' Qassisu (Marfa promontory)

Only rudiments of sand dune vegetation seem to persist in this area, mostly characterised by *Cakile maritima* and *Salsola kali*. The original extent of this sandy beach is however not known.

Ramla ta' Ghajn Tuffieha (l/o Mgarr)

Although *Elytrigia juncea* and *Sporobolus pungens* are present, there is no trace of dune formation. This beach is nonetheless included here mostly because of confusing literature records, which suggest a relatively interesting dune community within this locality, even if such records are questionable for a variety of reasons. Foremost among which is the fact that the topography does not lend itself too favourably for the formation of coastal dunes; the beach is exceedingly narrow and relatively steep clay slopes colonized by Esparto Grass back it. Moreover, it is apparent that Borg (1927), who mentions a good number of dune species from this locality, has probably confused this beach with the nearby *Ramla tal-Mixquqa*, which he does not mention at all. As is the case with Ramla l-Hamra in Gozo, viz. Wied tar-Ramla and Wied il-Pergla, Ghajn Tuffieha Bay may, in effect, be a sediment source for the Mixquqa dunes.

Ramla ta' San Gorg (l/o Birzebbuga)

A number of dune species have been reported from the area, including *Polygonum maritimum* and *Medicago marina* (BRENNER, 1838; GRECH DELICATA, 1853; SOMMIER & CARUANA GATTO, 1915; BORG, 1927). The records of *Muscari parviflorum* from "*arenosis herbosis*" (dune grassland?) by Grech Delicata (1853) may also indicate the possible presence of a back-dune in the area, where such 'grassland' could develop, a feature also confirmed by his own record of *Ononis natrix*. Moreover, the dynamics of the area and its vast catchment suggest that there was considerable potential for sand dune formation prior its 'development'.

Marsaxlokk-Birzebbuga area (excluding *Ramla ta' San Gorg*)

Some dune species have been reported from the area of *Marsaxlokk*, an area previously rich in sandy beaches. With the exception of *Eryngium maritimum* and *Euphorbia peplis*, which are apparently extinct from the locality, most sand-associated species are at present confined to the narrow, actively eroding, sandy beach off *Il-Ballut* nature reserve. It is unclear from where *E. peplis* was recorded, since other areas apart from *Il-Ballut* may have supported some sand-associated species; such areas include beaches at the *Qrejten* Point, at *Il-Qajjenza*, the area of *Kalafrana* and Pretty Bay. The first three beach areas are now quite restricted but all, with the possible exception of Pretty Bay, are known to have been colonized by an interesting sand-associated flora. Species reported from *Il-Qajjenza* and *Kalafrana* include, besides *Matthiola tricuspidata*, the now possibly extinct *Malcolmia maritima* (GRECH DELICATA, 1853; GULIA, 1874; BORG, 1927). All beaches in the area have been adversely affected by coastal and maritime constructions, which have altered the maritime offshore currents of the area, thus modifying the dynamics regime involved in dunal formation.

Ramla ta' San Tumas (l/o Marsaskala)

The dune vegetation of this bay has been totally obliterated. The beach is now dominated by extensive, well-developed *Posidonia* banquettes and a vegetation with generalised halophytes such as *Suaeda vera*, which occur on a mixture of sand and shingle, with some boulders, the result of the dumping of rubble in the area (SCHEMBRI & LANFRANCO, 1994).

Ramla ta' Marsaskala

The remains of a beach, which previously existed in the area, still persists in the form of a small sandy patch. Some now endangered dune species were reported from the area by various naturalists; examples include *Calendula maritima* by Gulia (1869), *Salsola kali* by Gulia (1874), *Ononis variegata* by Gulia (1875), and *Ambrosia maritima* and *Pseudorlaya pumila* by Borg (1927), indicating dune remnants at the time. Presently, the beach supports no vegetation. This might have been an important sand dune, considering the extensive catchment and sediment possibly derived from the *Wied il-Ghajn* system, and the saline marshland present at *Il-Maghluq*. However, agriculture and various constructions in the area have, most probably, negatively affected the beach, dune dynamics and sedimentation processes.

Marsa

Little is known of the sand dunes (and associated saline marshland) that are likely to have occurred in this area. The Marsa region represents the mouth of one of the most extensive catchments in the Maltese Islands that drains a significant land area via *Wied il-Kbir* and its tributaries. Regrettably, due to health reasons primarily (e.g., malaria), but also as a result of agricultural activities, construction and infrastructural development, this ecologically important area was drained, dredged and almost completely obliterated since the writings of Grech Delicata (1853). This was also confirmed by Sommier & Caruana Gatto (1915) who wrote, in an entry on *Pseudorlaya pumila*: "*dalla Marsa dove l'indicava Delicata, in seguito ai lavori ivi eseguiti non esiste più*" ("it has disappeared from *Marsa*, where it was indicated by Delicata, following works carried out in the area").

Bieb il-Gzira & Ta' Xbiex

This area must have supported an extensive vegetation cover prior to the various works and urban development undertaken within the area in general. Considering that it represents the estuarine zone of a significantly large, but almost completely urbanized, valley system (which includes *San Gwann ta' l-Gborgbar/Wied Gbollieqa*, as well as other obliterated valleys in the *Sliema-Msida* area), the wetland and dunal area may well have been considerable in size. The *Ta' Xbiex* sandy beach, which existed in Grech Delicata's time, may have extended up to the present *Rue D'Argens* region, where the same author reports the occurrence of saline grasslands on sand ("*arenosis herbosis salsis*", a possible reference to the occurrence of a back-dune or saline marshland). This could imply that some form of dunal assemblage and adjacent wetland existed in the area, in much the same manner as at *Gbadira* and *il-Qala ta' Santa Marija*].

Bajja ta' Spinola & Bajja ta' San Gorg (l/o San Giljan)

Considering the large extent of the catchment (the *Wied Gbomor-Wied il-Kbir* and *Wied Mejxu-Harq Hammiem-Pembroke* systems, respectively) and the potential beach coverage of either site, coupled by past records of species such as *Calendula maritima* and *Salsola kali* "*in arenosis maritimis*" of Spinola Bay (Grech Delicata, 1853), the presence of a sand dune ecosystem in the past cannot be excluded. Nevertheless, this must have disappeared upon development of the coastal area in the vicinity by the British Services, later enhanced by further road construction, domestic housing and holiday complexes. Owing to such constructions, sediment dynamics and maritime offshore currents may have been significantly altered in such a way that the sandy beach at Spinola Bay disappeared, while that at St. George's Bay (where sand is limited to a small patch with no significant vegetation) almost followed suit. Any marsh vegetation that may have occurred in the area probably suffered the same fate.

San Niklaw (Comino)

This small sandy beach may also have been characterised by some form of sand dune species in the past, although no dunal development is known for this locality. It is unlikely, however, that any vegetation should colonize this area, since this minute embayment is utilized as 'private beach' of the nearby hotel. Moreover, it is subjected to regular clean-ups, which involve the removal of *Posidonia* banquettes, raking of sand and, often, temporary removal of sand material during the winter months. Such a strategy, apart from disrupting the foreshore (sediment bank)-beach equilibrium, will impede the active development of dunal flora. In fact, very few halophytic plants were observed during recent visits to the locality, together with single dune elements, namely *Cakile maritima* var. *latifolia* and *Echium arenarium*.

San Blas (l/o Nadur, Gozo)

According to Schembri & Lanfranco (1994), this beach consists of bare sand with shingle and small to boulders at the back, where clay abuts onto the sand. The beach was apparently almost completely destroyed by a violent storm in December 1988 which carried away much of the sand together with its dune vegetation (Anderson & Schembri, 1989; Cassar, 1996). At present there is some minor regeneration of some dune elements.

Marsalforn

Whilst a sand dune community was known from the beach in Marsalforn Bay up to some fifty years ago, this seems to have been completely destroyed due to the urban and infrastructural works carried out in the area over the years. Nonetheless, despite the development within this popular bay, a number of dune species, mostly those typical of the embryo dune, still persisted. Among these was one of the finest populations of *Euphorbia peplis* known from the Maltese Islands. These were later eradicated subsequent to other works forming part of the '*Progett Marsalforn*' by the local Ministry. As a consequence of these recent works, the nature and constitution of beach material was significantly altered, with sand mixing with debris and rubble, thus resulting in a shingle beach surface (SCHEMBRI & LANFRANCO, 1994).

Qbajjar

The sandy beach in the area, located at the mouth of fairly large valley system, *Wied l-Infern*, has been practically obliterated but for a narrow strip of sand on the arcuate sector of the bay, as a result of works carried out in the area during the latter half of the 20th century. A coastal road connecting Marsalforn with Xwejni and Zebbug currently backs the extant beach. As a consequence of these works, all dune flora has long disappeared. Recent ill-conceived efforts to replenish beach sand using a clayey material, resulted in a muddy beach surface and highly turbid waters.

Ramla tax-Xlendi

A number of species, some exclusive to dunes, including *Cakile maritima*, *Erodium laciniatum*, *Lotus cytisoides*, *Ononis mitissima* and *Medicago arabica*, were reported from the area by Sommier & Caruana Gatto (1915) and BORG (1927), indicating some form of dune remnant at the time. At present, the sandy beach is separated from the wide gorge-type *wied* by an urbanized seafront. However, judging by the extent of the catchment and the potential for a vast amount of sediment accumulation, there is no reason why this area did not sustain a dune field and adjacent wetland. However, it appears that such an ecosystem was already negatively affected by the 20th century, when the afore-mentioned naturalists visited the area. At present, the beach is exceedingly narrow, with no significant vegetation.

Xatt l-Ahmar (l/o Mgarr)

These are two somewhat important sandy beaches, albeit small-scale, backed by clay slopes and low globigerina escarpments. A number of sand-associated species are known from this locality, some of which are vulnerable or endangered on a national scale, such as *Eryngium maritimum*, *Euphorbia peplis* and *Polygonum maritimum*, and the recently re-discovered *Otanthus maritimus* (TABONE, pers. comm., 2001).

4.4 sand dune flora - a synopsis

As outlined earlier in the text, sand dunes are a relatively harsh environment where plants are concerned. Sand dune flora, therefore, has to adapt to this environment in a variety of ways in order to survive. A brief account of such adaptations is given below, followed by an overview of the main sand dune flora of the Maltese Islands, mostly typical of dunal sites in Southern Europe and the Central Mediterranean.

4.4.1 Adaptations of dune flora:

Sand is highly porous and, therefore, has poor water-retention capacity. Essential mineral elements and organic matter are significantly lacking. These features, coupled by high evaporation rates, result in water shortage and high temperatures. Sand temperatures are known to rise to 50°C, implying that most dune species have to be tolerant of high daytime temperatures and considerable diurnal variation[9]. Additionally, as a substrate, sand material is loose and mobile, meaning that dune vegetation must be able to resist strong gales, waves and storms that often have an influence on these exposed coastal areas.

These parameters are reflected in distinctive morphological and anatomical features of the psammophytes (sand-inhabiting flora). These features are indeed very similar to the various adaptations apparent in plants living in Mediterranean-type ecosystems. These

[9] This also explains why the dune flora is remarkably uniform throughout the globe, although some exceptions, of course, do occur (PACKHAM & WILLIS, 1997).

similarities arise from convergent anatomical modifications, and are summarised below:

Various sand dune species exhibit **thick cuticles**. Such is the case with *Eryngium maritimum*, *Echinophora spinosa*, *Scolymus hispanicus* and *Crucianella maritima*, (BOURNÉRIAS *et al.*, 1988, 1991). In *Ammophila arenaria* and allied taxa, cuticles tend to be thick on the lower (abaxial) leaf surface, where the abaxial epidermis has a cuticle about 8mm thick, whilst the thickness of the upper (adaxial) epidermis is about 3mm. In *Euphorbia paralias* the thickness is much greater; about 30mm (abaxial) and 15mm (adaxial). Thick cuticles protect the plant from the effect of 'sand-blasting', as a result of saltation, as well as limiting water loss (PACKHAM & WILLIS, 1997).

Hairiness is another adaptive feature that protects the plant from drought, wind and sand-blasting. The hair coating is characteristically lightly coloured. This is beneficial to the plant in terms of temperature regulation. Such plants include *Medicago marina*, *Matthiola sinuata* and *Otanthus maritimus* (BOURNÉRIAS *et al.*, 1991). Some species have a coating which is also **viscous and sticky.** The stickiness reduces the impact of sand-blasting in that it agglutinates the saltating sand. Some examples include *Echium arenarium*, *Ononis natrix*, *Rhodalsine geniculata* and *Silene nicaeensis*.

Leaf Rolling is also important in many dune grasses. Certain grass species roll their leaves in periods of drought. In *Ammophila* spp., this restricts transpiration losses, even though stomata possibly remain open in the rolled leaf (RUTTER, 1981). Substantial reduction (50% or more) in transpiration rate as a result of leaf folding has been reported in *Cynodon dactylon* as well as in other species (WALTER, 1971).

Due to water limitations, many psammophytes have developed various other strategies for the storage of water, such as **succulence**, which is found in most dune species, such as *Cakile maritima*, *Salsola kali*, *Euphorbia paralias*, *Ononis variegata*, *Silene colorata* and others.

Well-developed and extensive **root systems** are also important for water uptake, better anchorage and nutrient uptake; the root/shoot ratio is higher in many psammophytes than in mesophytes (plants that due to their ecological requirements do not need to evolve special adaptations for water and nutrient availability). However, this varies from species to species, and according to life form. Hence therophytes (annuals) have average rooting depths from 5-20cm, while small herbaceous perennials have roots extending more than 1m (PACKHAM & WILLIS, 1997). The rooting systems of larger perennials reach even greater depths, as in *Eryngium maritimum* and *Euphorbia paralias* (BOURNERIAS *et al.*, 1991).

Tuberous or **bulbous** life-forms are also important. Hence the deeply-buried bulbs of *Pancratium maritimum* and the tubers of *Aetheorrhiza bulbosa*, apart from protecting these forms from the impact of sand, herbivores and the human agency, are also important for the accumulation of reserves, including water (BOURNERIAS *et al.*, 1991).

A **spreading growth form** with rhizomes or runners and distinctive root systems, as in *Ammophila* spp., *Elytrigia juncea*, *Sporobolus pungens* and *Cynodon dactylon*, is important in resisting the influence of moving sand leading to burying. Concurrently, spreading growth helps to fix the sand. Similar behaviour is also exhibited by *Calystegia soldanella* and *Tribulus terrestris* (BOURNERIAS *et al.*, 1991).

Another aspect of Mediterranean dunes is the frequent presence of **annuals.** Their abundance is due to their general adaptation in avoiding the adversity of the dry season. Examples include *Cakile maritima*; *Erodium laciniatum* and various grasses (like *Cutandia maritima*, *Bromus rigidus*, *Lagurus ovatus*, *Vulpia fasciculata*).

Plants on sand dunes, especially those that occur along the drift-line, embryo dunes and fore-dunes, must also **tolerate**, grow and complete their life cycles within a **high salt concentration** environment. These plants tend to be halophytic and show succulence, and tend to take up salts and use them to maintain low water potential. The high internal salinity is well tolerated by close regulation of ion uptake and internal concentration. Some species also have **specialised salt-exclusion structures** like salt glands, noted in several families (including the Poaceae) and *Tamarix* spp., and salt-bladders (as in the Chenopodiaceae).

Sand dune plants also depend on **seasonal variations in soil salinity** (which may be considerable), and have developed interesting germination patterns, with some species not germinating under saline conditions, while others exhibit a tendency towards **seed dormancy** (BOCCHIERI & MULAS, 1984, 1986; PACKHAM & WILLIS, 1997). Examples include, amongst others, *Elytrigia juncea* and *Euphorbia paralias*.

Some species have also **adapted to the input of organic matter** from the sea. Primary production and the competitive abilities of sand dune plants are usually limited by the availability of mineral nutrients, particularly phosphorus and nitrogen, which are frequently low in sand dunes. Local variations in soil nutrient concentration can lead to marked differences in growth. For example, low levels of nitrogen, rather than potassium or lack of water, are known to restrict the growth of the two annual halophytes: *Cakile maritima* and *Salsola kali*, in some fore-dunes, where these plants remain small and stunted, unlike the large, rapidly growing plants of these species in embryo dunes near the driftline, where the concentration of nitrogen in the sand (largely derived from macro-algal and *Posidonia* litter) is much higher than in the foredune. All these features favour the establishment and survival of psammophytes on sand dunes (PACKHAM & WILLIS, 1997).

4.4.2 Adaptations of driftline, embryo dune and exposed foredune species:

Colonisation of the driftline by plants may be transient or it may mark the initiation of the dune seral sequence outlined earlier in the text. The driftline is a physically demanding 'hostile' habitat (PACKHAM & WILLIS, 1997):

- it is susceptible to disturbance by wind and waves, considering that strong winds in the Mediterranean (like the north-westerly gales in the Maltese Islands) are often severe and accompanied by significant wave activity;
- its porous sediments retain little water;
- it offers little protection from the sun;
- its surface is essentially dry for long periods;
- its surface may be subject to large diurnal temperature fluctuations;
- nutrient capital (apart from that released by mineralization of organic detritus) is usually low (the availability of nitrogen from organic detritus is a major determinant of success in this area).

Owing to the above, the area occupied by driftline vegetation may vary considerably from year to year according to the weather, particularly during spring and early summer. Plants are adapted to live in such habitats by adaptations that fall within the following strategies:

- seeds and vegetative propagules of dune species may be dispersed over short distances within the landcover occupied by the local community or may extend the range of a species, thus colonising new sites through the action of wind or sea. The disseminules of driftline species are frequently buoyant and long-lived in seawater, as is the case with *Polygonum maritimum*, which occasionally colonises various beaches in the Maltese Islands, and that of *Beta* *maritima*, whose seeds can develop successfully following long-distance transport by sea;

- seeds tend to be large, providing reserves sufficient to allow germination from considerable depths in the sand;
- extensive root systems may exploit deep groundwater, which may move upwards as 'internal dew', thus helping to ameliorate this harsh and variable environment [10];
- some species, like perennials such as *Elytrigia juncea*, are often able to grow from vegetative fragments.

The driftline colonists are very diverse. In the Mediterranean these include ephemeral or annual species such as *Cakile maritima*, *Euphorbia peplis* and *Salsola kali*, and perennials like *Beta maritima*, *Euphorbia paralias*, *Polygonum maritimum*, and the dune builders as *Elytrigia juncea* and *Sporobolus pungens*.

The more typical driftline species are, however, the annuals. Notably *Cakile maritima* and *Salsola kali*, with *Atriplex glabriuscula* and *Atriplex laciniata* (= *A. arenaria*), are more characteristic in NW and W Europe (Tutin *et al.*, 1993). These species pass the dry season as seed stock. The perennials require more adaptations to survive these unfavourable months, and often become increasingly important inland, commencing on embryo and foredune formations. Indeed, some perennials act as pseudo-annuals, in that they lie dormant during adverse seasons, as is the case in *Elytrigia juncea*; however, their external 'skeleton' of roots and dormant shoots still enables them to function in their capacity as dune 'builders'.

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[10] The occurrence of dew in the summer months is of considerable significance for the survival of shallow-rooted plants on dune slopes during drought. In fact, the dew may be sufficient to meet the transpiration needs of the smaller annuals that are rooted near the surface of the sand, which is often very hot and dry in periods of drought (Packham & Willis, 1997).

4.4.3 Pioneer Dune Grasses:

Two growth habits are particularly effective in dune-forming plants. *Elytrigia juncea*, like *Ammophila* spp., produces horizontal rhizomes of potentially unlimited growth[11]. The potentially unlimited horizontal and vertical rhizome growth of *Ammophila* has enabled the various *Ammophila* species (like *A. arenaria* and *A. littoralis*) to create many of the highly vegetated dunes known in the region. *Ammophila arenaria*, *Elytrigia juncea* and *Sporobolus pungens* are rhizomatous sand-binding (also known as sand dune-building or sand-fixing species) grasses, whose leaves roll up, thus reducing transpiration and leaf damage by sandblasting, when the relative humidity of the air is low. *Cynodon dactylon*, another member of the family Poaceae, may also be an equally important sand-binding species, owing to its creeping stolons and profusely branched rhizomes; nevertheless, unlike the preceding species, is not sand-exclusive, and is considered a serious weed in many parts of the world.

Invasion of driftline communities by *Elytrigia juncea* and *Sporobolus pungens* is often the first sign of permanent establishment of dune-forming plants, though the ability of these species and of *Ammophila* to establish populations on the open sand of the back-shore means that even the latter may be considered a driftline species. *Ammophila arenaria* s.l., frequently succeeds *E. juncea* in the embryo dunes. In some dunes, formation is often initiated directly by *Ammophila* even though *Elytrigia* is present.

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[11] Though lacking this capacity, species such as *Salix repens* and *Tamarix* spp., readjust to sand burial by oblique or vertical rhizome or stem growth - in the case of *Tamarix africana* and other woody species, this may be almost unlimited as long as accretion is not too rapid. These plants have a tight growth form resulting in steep-sided hummock dunes (as in the case of *T. africana* dunes at *Ramla*), rather than the broad-based dunes resulting from the spreading growth of *Ammophila*.

4.4.4 Germination, accretion rates and survival of dune builders - the case of Sand Couch:

Dune builders do not necessarily maintain vegetative growth throughout the year, and some cases, among them *Elytrigia juncea*, show dormancy features. Nonetheless, their dead shoots, as has been previously stated, often persist and, thus, help to retain sand. Moreover, viable buds of this species have been found at a depth of 60cm, which also have similar tolerance to sand accretion up to rates of about 60cm a year. *Ammophila* spp., have been known to survive an absolute accretion limit of 1m sand per year, though plant density soon diminishes if these conditions persist (LAING, 1954; RANWELL, 1958).

As in other sand dune taxa, germination in this species is governed by a synergistic effect of temperature and salinity. Germination may commence within 2-4 days of seed deposition if the sand is moist and the temperature adequate[12]; germination often follows heavy rain when the seeds imbibe water and leaching of salts occurs. Germination is completely inhibited by seawater, and reduced, in terms of rate and amount, upon increase in sodium chloride concentration. Moreover, *E. juncea* seeds also have relative dormancy periods, which protect them from inopportune and simultaneous germination (BOCCHIERI & MULAS, 1986).

Where moisture conditions are favourable, the primary root quickly reaches a depth of about 15cm, but the initially formed lateral roots grow horizontally and close to the sand surface. After a rosette of tillers is formed, short rhizomes extend for 5-30cm, with new groups

[12] The optimal germination temperature for *Elytrigia juncea*, based on experimental work by Bocchieri & Mulas (1986), is within a temperature range of around 20°C, with the germination being reduced at lower and higher temperatures (10°C and 30°C respectively).

of tillers arising [see figure below].

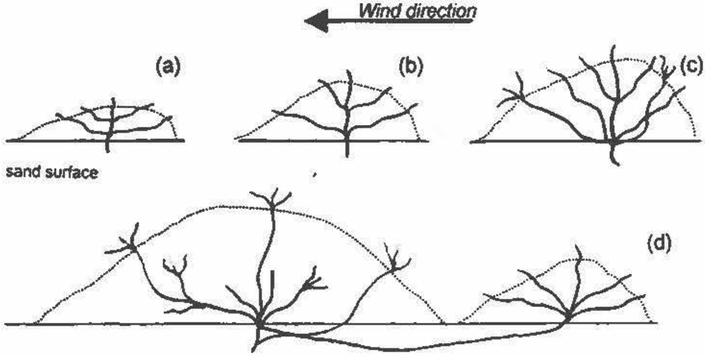


Figure 3: Stages (a)-(d) in the development of an embryonic dune round a plant of *Elytrigia juncea*. The upper broken line represents the surface of the dune.

Such growth may continue for two seasons but ultimately it is the long horizontal rhizomes that increase the spread of the plant. In autumn their tips often turn upwards, breaking the surface and forming new shoots in spring. If sand accretion is slight, such development sometimes continues indefinitely; elongation of shoots can bring them to the surface from depths of over 20cm. If, however, burial is very rapid, shoots are usually killed and rhizomes extend vertically rather than laterally until the surface is reached, when tillering occurs. This sympodial development can keep pace with sand accretion up to depths of 1.8m or more. Consequently, by lateral extension *Elytrigia juncea* can stabilize the foreshore region, stabilizing blown sand and acting as a dune-builder, if accretion is not too great. This may be seen, for example, at *Ramla l-Hamra* in Gozo, where *Ammophila littoralis* is locally absent.

Multi-node rhizome fragments of *Elytrigia juncea* have an important advantage over single-node fragments and seeds, since these are more liable to produce viable shoots following burial, though all three types of propagules were found by Harris & Davy (1986; 1987) to be effective in colonizing bare areas. When buried experimentally at various depths, shoots from newly-germinated seedlings and single-node rhizome fragments were able to emerge from 127mm but not from 178mm. Shoots from multi-node fragments, which have greater reserves, made it to the surface from greater depth. The driftline of a study site in the UK, was highly disturbed in comparison with adjacent fore-dunes, but was rapidly recolonised by seedlings and rhizome fragments following complete removal of the driftline community by the catastrophic storm surge (PACKHAM & WILLIS, 1997). This was much the case with the dunal elements at *San Blas*, a north-eastern coastal locality on the island of Gozo. Following a violent storm that practically destroyed the relatively well-established dune at *San Blas*, dune flora began to re-establish itself years later.

As previously stated, the capacity of *Elytrigia juncea* to tolerate salinity and seawater enables the plant to dominate in foredunes and initiate dune development. This enables *Ammophila arenaria* s.l., (i.e. including *A. littoralis*) to enter the next seral stage, owing to its increased efficiency and vigour with respect to sand accretion (BOCCHIERI & MULAS, 1986).

4.4.5 Zonation and Effectiveness of Dune Builders, with reference to Marram Grass:

Ammophila arenaria s.l., the marram grass, is perhaps one of the most effective dune-builders known, and functions in much the same way as *Elytrigia juncea*, with which it often occurs in foredunes. However, though tolerant to moderate salinity [up to almost 1% sea salt in the substratum (PACKHAM & WILLIS, 1997)]— it is not such an effective halophyte as *Elytrigia juncea*. In fact, it often establishes itself in more inland areas than *Elytrigia juncea*, usually from rhizome fragments, but may also arise from seedlings, especially on more inland dunes.

Marram grass is most vigorous in mobile dunes, frequently forming large dome-shaped tussocks in *Ammophiletum* assemblages, over 60cm in diameter. Extensive tillering leads to tussock formation, with horizontally growing rhizomes extending the area of stabilized dune.

The leafy shoots of *Ammophila* slow the wind speed above ground level considerably, causing sand grains to fall to the ground, accreting the dune which tends to grow higher as the marram expands upwards through the fresh sand.

Under conditions of appreciable sand supply, dense tall growth can be achieved (mostly about 75cm, but leaves may exceed 1m), often with 100-200 tillers of living marram per metre. The majority of the rhizomes and roots, which help to stabilize pioneer dunes, ramify throughout the top 1m of sand, but also extend to depths of 2m or more; tillers of this plant reach high densities when moderate amounts of sand are being deposited round it (PACKHAM & WILLIS, 1997). However, *Ammophila* can just withstand accretion rates of 1myr^{-1}, and may be overwhelmed by sudden heavy deposition, such as with sudden depositions of more than 120cm (ANWAR MAUN & PERUMAL, 1999). Growth is very slow when accretion of sand is minimal, with root failure occurring.

This is also important for the zonation development of dunes, whereby in the usually more inland semi-consolidated dunes with more evenly spread pasture-type marram, other species are found in the mixed *Ammophiletum*, which help to stabilize the surface. In fixed dunes, with little sand supply and mobility, the vigour of marram grass (and other dune builders) is low; such grasses often die out and, as a result, make way for a denser vegetation cover. This also occurs when sand accretion is too slow. As a consequence, other grasses may take its place.

Many reasons have been advanced for the known decline in the vigour of old dunes. Loss of vigour has been attributed, for example, to poor aeration, mineral content deficiency, competition for nutrients and water, toxicity, the presence of nematodes [like the nematode *Longidorus kuiperi* which is found exclusively on roots of *A. arenaria* (BRINKMAN *et al.*, 1987)], and natural senescence (WILLIS *et al.*, 1959). In *A. arenaria* s.l., old roots become decorticated but new roots may arise from the nodes of newly buried shoots (often three or four roots to a node). In fact, dilapidated marram areas have been known to regenerate by producing substantial sand accretion artificially (PACKHAM & WILLIS, 1997).

4.5 sand dune flora

A list of some of the more important dune species occurring in the Maltese Islands, in alphabetical order, is given hereunder. Each data sheet comprises: an interpretation of the scientific names applied to the species listed (e.g. *Ammophila arenaria*, based on the Greek words *ámmos* [sand] and *philos* [loving] and the Latin *arenarius* [of sand, sandy] = sand-loving plant that grows on sand); a list of the main scientific synonyms, if any; and, the common vernacular names of the species in question. A brief description of each plant, outlining general distinguishing features (including its habit, stems, foliage and flowering), is included, although complex botanical terms have, as much as possible, been avoided.

The information on geographical distribution follows that of the *Flora Europaea* and the Med-Checklist (Greuter *et al.*, 1984), whilst that on the Maltese Islands is based on literature records and studies made by the authors. Important unpublished findings by other authors are quoted as personal communication.

Extinct and doubtful species are treated separately at the end of this chapter. Their status and data about their former distribution, if known, is also included.

Ambrosia maritima L.
Family Asteraceae [= Compositae]

Name Derivative – Maritime Ambrosia; *ambrosia* = food of the gods that gave immortality [Gr.], from *ambrotos* = immortal, divine, excellent [Gr.]; *maritima* = maritime [Lt.]

Vernacular Names – English: Sea Ragwort; Maltese: *Mentna*; Italian: *Ambrosia maritima*

An annual or biennial plant. The entire plant has a whitish or ashy green appearance and has a pleasant aromatic smell. The stem is erect and branched, reaching heights of up to 60 cm. The lower leaves are opposite each other, whilst the upper leaves are alternate in arrangement. The leaves are ashy-green and tomentose on the lower side, but dark green and sparsely hairy on the upper side. The leaves vary in shape and size, and are usually incompletely divided into lobes that are roughly toothed along the margins. It produces tubular flowers enclosed within hemispherical, cup-shaped, flower heads, which is essentially an envelope made of fused sterile involucral bracts. The flower heads are in a terminal spike on a raceme (i.e., an inflorescence stalk holding the flower heads). The raceme bears numerous pendulous yellowish male flowers, with the one-flowered, female heads below the male heads, at the base of the raceme. The female flower heads are simply composed of a style surrounded by an oval involucre in the form of a capsule protecting the ovary.

Flowering: essentially a summer-flowering species, mostly between July and September, although it occasionally also flowers as early as June and up to late October. The fruit is ovoidal and spindle-shaped/fusiform, borne close to the upper leaves, with 4-5 almost erect spikes located centrally and slightly above the centre. The seeds lack the pappus typical of many composite flowers.

Distribution: Europe and throughout the Mediterranean region.

Distribution & Status in the Maltese Islands: formerly a frequent species in most sand dunes and sometimes also inland along some valleys. Amongst sand dunes and sandy habitats, it used to occur in *Bahar ic-Caghaq*; *Marsa*; *Gnejna*; *Ghadira*; *Ramla tal-Mixquqa*; *Ramla tal-Pwales* and the various beaches of the *Marfa* Peninsula in Malta; at *Qbajjar*, *Marsalforn* and *Ramla l-Hamra* in Gozo; and at *Il-Qala ta' Santa Marija* in Comino. This species seems to persist only at *Ghadira*, where it is very rare and localised, although young aromatic plants observed in February 1998 on dumped sand in the area of *Bejn il-Kmiemen* in Comino were possibly attributable to this species. *Ambrosia maritima* is therefore considered as endangered with a restricted distribution in the Maltese Islands.

***Ambrosia maritima* L.**
Sea Ragwort — **Mentna** *(drawing: Andrew Micallef)*

Ammophila littoralis (Beauvois) Rothmaler
Family Poaceae [= Graminae]

Name Derivative – Sand-loving plant of the littoral zone; *ammos* = sand (Gr.); *philos* = loving (Gr.); *littoralis* = of the littoral/sea-shore zone (Lt.)

Main Synonyms –*Ammophila arenaria* (L.) Link subsp. *arundinacea* H. Lindb. fil.; *Ammophila arenaria* (L.) Link subsp. *australis* (Mabille) Tutin; *Ammophila arundinacea* Host; *Psamma littoralis* Beauvois; *Psamma arenaria* (L.) Roemer et Schultes p.p.; *Arundo arenaria* L. p.p.

Vernacular Names – English: Mediterranean Marram Grass; Maltese: *Birrun* [13]; *Qasba tar-Ramel*; Italian: *Sparto Pungente*.

A robust, rhizomatous, hairless, perennial reed, with long creeping rhizomes submerged in sand. The plant is overall greyish-green, with erect tufted stems, 50-120 cm high. Its leaves are stiff and rigid, spiny and in-rolled. Flowers held in a cylindrical whitish spike-like inflorescence called a panicle, bearing various densely overlapping spikelets. These spikelets are relatively large, about 10-15 mm, flattened and short-stalked, with each spikelet bearing one hermaphrodite floret.

Flowering: between May and August.

As already stated, this is one of the most important Mediterranean dune-builders and sand binders of the Mediterranean region. The potentially unlimited horizontal and vertical rhizome growth of *Ammophila* rhizomes and its ability to re-establish itself from rhizome fragments and seeds has enabled the various *Ammophila* species (like *A. littoralis*, *A. arenaria* and *A. breviligulata*) to form a relatively dense growth and colonise various dunes.

Distribution: throughout the Mediterranean region.

Distribution & Status in the Maltese Islands: was reported from the island of Malta only, where it is possibly extinct, since it has not been observed for more than a decade. Last reported from *Ramla ta' l-Armier*; it was also present at *Ramla tat-Torri*, *Ramla tal-Qortin*, *Ghadira* and *Ramla tal-Pwales*. Previous records from *Ramla tal-Mixquqa* and *Ramla l-Hamra* (Gozo) are probably misidentifications for the sand couch, *Elytrigia juncea*.

[13] This term is utilised in *Mellieha* to describe this species (CAMILLERI, pers. comm.).

Ammophila littoralis **(Beauvois) Rothmaler**
Mediterranean Marram Grass — **Birrun** *(photo: Louis F. Cassar)*

Cakile maritima Scopoli
Family Brassicaceae [= Cruciferae]

Name Derivative – Maritime sea-rocket; *cakile* = generic name of obscure significance used for sea-rockets (probably Ar.); *maritima* = maritime (Lt.)

Main Synonyms – includes *Cakile maritima* Scopoli var. *maritima* [= *C. maritima* var. *australis* Coss.; = *C. maritima* var. *typica* Fiori] and *Cakile maritima* var. *latifolia* Desfontaines [= *Cakile aegyptica* Willdenow; *C. maritima* subsp. *aegyptica* (Willdenow) Nyman ex P.W. Ball]

Vernacular Names – English: Sea-Rocket; Maltese: *Kromb il-Babar*; Italian: *Ruchetta di Mare/Ravastrello/Baccherone*.

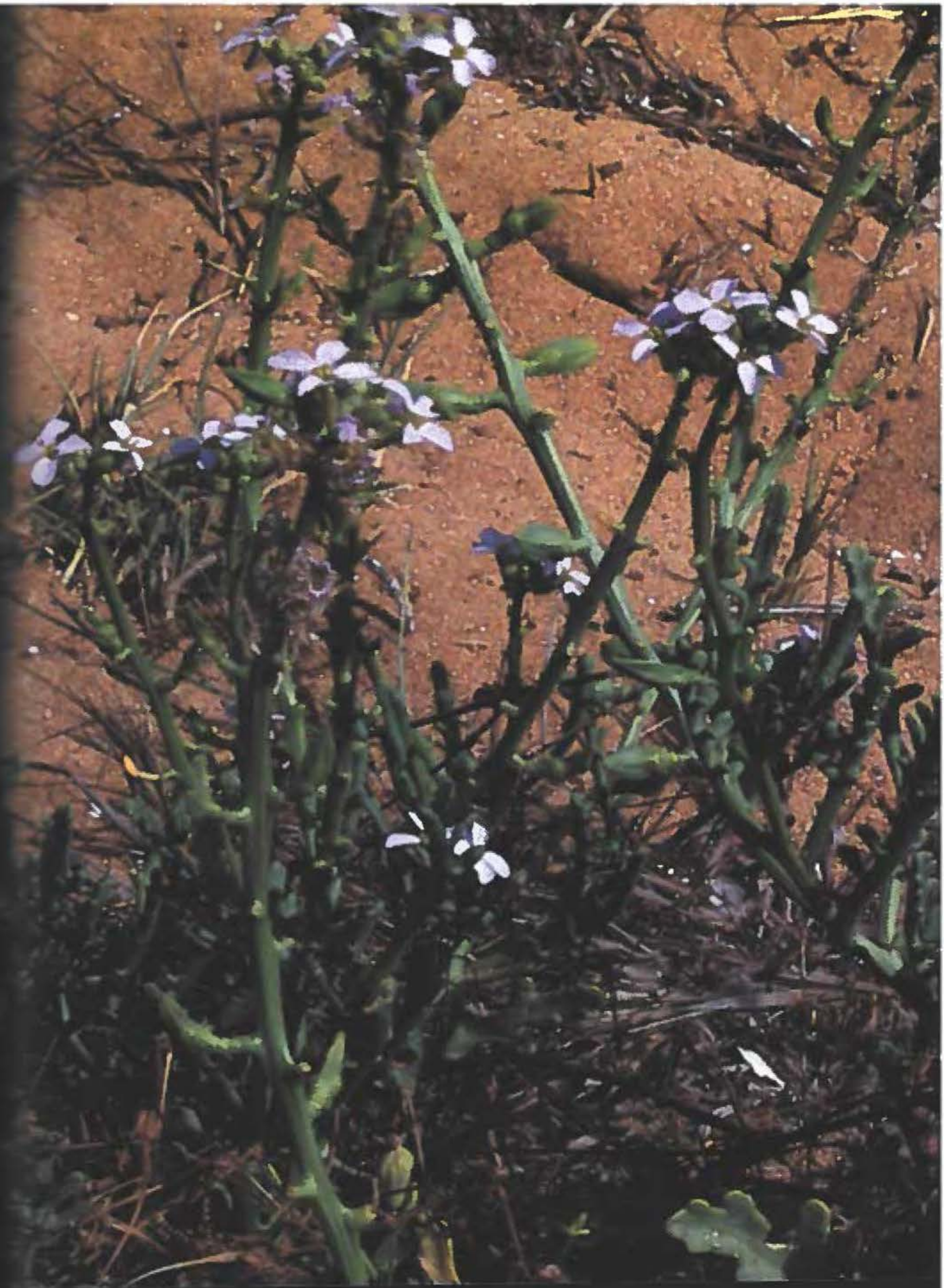
A glabrous herbaceous annual with succulent leaves. The leaves may be entire or almost so (var. *latifolia*) or, more frequently, pinnatisect (var. *maritima*), although some plants show features of both. It produces white to pink or violet flowers.

Flowering: mostly between March and June, although this depends on climatic and other abiotic factors; some plants may flower as early as December or as late as August-September. Once pollinated, these flowers give rise to characteristic pod-like fruit referred to as silicules.

This species is typical of exposed parts of sand dunes, especially drift lines, foredunes and embryo dunes close to the sea, but is also present in shaded areas, especially underneath trees, due to the species' nitrophilic nature.

Distribution: throughout Europe.

Distribution & Status in the Maltese Islands: both the var. *maritima* and the var. *latifolia* are present in the Maltese Islands, with the former being more frequent. Overall frequent in areas with sandy or similar sediment substrates, and is known from all the main islands and most of the islets.



Cakile maritima **Scopoli**
Sea-Rocket — **Kromb il-Baħar** *(photo: Louis F. Cassar)*

Calystegia soldanella (L.) R. Brown
Family Convolvulaceae

Name Derivative – Plant with two large persistent bracts at the base of the flower protecting the flowers and with small-coin-like leaves, due to the rounded form of the leaves. The generic name *Calystegia* is composed of the words *kalix* = calyx [Gr.] and *stege* = roofed [Gr.]; *soldus* = coin [Lt.]; *ellus* = diminuitive [Lt.]

Main Synonyms – *Convolvulus soldanellus* L.

Vernacular Names – English: Sea Bindweed/Sea Bells; Maltese: *Leblieb tar-Ramel*; Italian: *Soldanella di Mare/Vilucchio Maritimo/Cavolo di Mare.*

A rhizomatous perennial. The plant is glabrous and usually prostrate with succulent reniform (kidney-shaped) leaves. It produces relatively large flowers relative to its leaf size; these are solitary and are usually two-coloured, generally deep or pale pink with white. These flowers are also characterised by broad persistent bracts (called bracteoles), partly obscuring the sepals of the flower, hence the name roofed-calyx (*Calystegia*).

Flowering: mostly between the end of April till August, sometimes extending the flowering period to October. The seeds are enclosed in an oval capsule. Typical of exposed parts of sand dunes, and capable of withstanding sand deposition via its efficient rhizomatous system.

Distribution: a cosmopolitan species, whose primary area is considered to be the Mediterranean region.

Distribution & Status in the Maltese Islands: critically endangered, being perhaps one of the most threatened dune species of the Maltese Islands. This species is now confined to the sand dunes of *Ramla ta' l-Armier*, but was previously reported from other sand dunes of the *Marfa* Peninsula, including *Ramla tal-Qortin* and *Ramla tat-Torri*.

Other species: other bindweed species may be found on sand dunes. The most frequent bindweed species in Maltese dunes is the Field Bindweed [*Convolvulus arvensis*, Malt.: *Leblieb tar-Raba'*], a herbaceous perennial with climbing habits, with arrowhead-shaped foliage and whitish, pink, or striped pink and white flowers that are produced from late spring until autumn. This species tends to invade dunes and dune slacks from nearby agricultural fields and is essentially a ruderal species. The Narrow-Leaved Bindweed [*Convolvulus lineatus*, Malt.: *Leblieb tax-Xatt*], which is a small prostrate shrublet with white or pink flowers and slender narrow, olive-leaved, silvery foliage; and, the similar Olive-Leaved Bindweed [*Convolvulus oleifolius*, Malt.: *Leblieb tax-Xatt*], which is a larger shrub [reaching up to 50-60 cm in height] than the narrow-leaved bindweed and has larger but similar flowers, tend to grow on some inter-dunal areas close to rocky coasts.

Calystegia soldanella **(L.) R. Brown**
Sea Bindweed — **Leblieb tar-Ramel** *(drawing: Andrew Micallef)*

***Chondrilla juncea* L.**
Family Asteraceae [= Compositae]

Name Derivative – Rush-Leaved Chicory; *chondrille* = a kind of endive or chicory [Gr.]; *juncea* = like a rush [Lt.], from *juncus* = a rush, a kind of plant with straight, stiff and erect foliage [Lt.], because of the straight, stiff, rush-like stems characteristic of this species.

Vernacular Names – English: Gum-Chicory/Rush-Leaved Sow-Thistle; Maltese: *Tfief tar-Ramel/Tfief ta' l-Għadira*; Italian: *Lattugaccio Comune*.

A biennial or perennial plant with stiff, erect, spreading, almost leafless, green stems that are often quite branched at the base. The stem is fine-haired below and hairless above. The lower leaves are spear-shaped and shallowly lobed, and dry up when the plant is in flower, whilst the upper leaves are linear or spear-shaped, with entire or finely toothed margins. Flowers are borne in flower heads, as is typical of flowers of the composite family, protected by a whitish fine-haired involucre. The yellow stalkless flower heads are borne in clusters of 2-5 on slender stems.

Flowering: the flowering period of this species is exceedingly variable, extending from mid-spring to early autumn. Different plants in different areas flower during different periods, mostly depending on whether the plant occurs as a biennial or a perennial. The seeds are characteristic of the composite family with compressed seeds (achenes) to which is attached a short stalk bearing the fine hairs (the pappus) that enhance wind-dispersal. This species is opportunistic in many parts of the world, but is essentially a 'sand species' that has extended its range to other sandy soils and sometimes also stony soils. It is able to persist in fields, footpaths and waysides and disturbed ground.

Distribution: throughout most of Europe, extending to the Pontic regions and including the non-European parts of the Mediterranean region.

Distribution & Status in the Maltese Islands: this species was reported only at *Għadira* and *Ramla l-Hamra*[14]. However, it has not been recently observed in any of these two localities. Nonetheless, it may still persist at *Għadira*. The species is therefore considered to be critically endangered with a restricted distribution in the Maltese Islands.

Other species: other sow-thistles occur in some of the Maltese sand dunes, but it is difficult to confuse these with *Chrondrilla juncea*. The Smooth Sow-Thistle [*Sonchus oleraceus*, Malt.: *Tfief Komuni*] is annual with smooth, divided (not to the midrib) leaves; the Mediterranean Sow-Thistle [*Sonchus tenerrimus*, Malt.: *Tfief Fin*] is annual but sometimes perennial and has leaves that are very finely divided down to the midrib and, the Prickly Sow-Thistle [*Sonchus asper*, Malt.: *Tfief Car*], which produces stiff leaves with slightly spiny margins and flower heads with a paler yellowish colour.

[14] Recorded from *Ramla l-Hamra* by Michael Briffa (pers. comm.; for further information refer to STEVENS, 2001).

Chondrilla juncea **L.** — Rush-Leaved Sow-Thistle — **Tfief tar-Ramel**
b) ***Sonchus oleraceus*** **L.** — Smooth Sow-Thistle — **Tfief Komuni**
(drawing: Andrew Micallef)

Cyperus capitatus Vandelli non Burmann
Family Cyperaceae

Name Derivative – A headed galingale, due to its characteristic 'headed' inflorescence. *kypeiros* = a generic term used by the Greek to describe sedges, of which this species is one type [Gr.]; *capitatus* = having a head, derived from *caput* or *capitis* = head [Lt.].

Main Synonyms – *Cyperus kalli* (Forskåal) Murbeck; *Schoenus mucronatus* L.; *Cyperus mucronatus* (L.) Mabille non Rottb.; *Galilea mucronata* (L.) Parlatore; *Cyperus aegyptiacus* Gloxin; *Cyperus schoenoides* Grisebach.

Vernacular Names – English: Sand Galingale; Maltese: *Bordi tar-Ramel*; Italian: *Zigolo delle Spiaggie*.

A rhizomatous perennial. The rhizome is creeping, long and stoloniferous, enabling the spreading of the species in an adequate area. The species is characterised by recurved bluish-green leaves at ground level; these leaves are usually keeled (i.e. have a dorsal ridge along the leaves).

The inflorescence is quite characteristic in that it has a brown globose shape (like a head, hence, the scientific name) that is borne on a slightly tilted cylindrical stem of about 5-50 cm. This inflorescence is protected by means of a set of about six bracts (the involucre), of which the outer are leaf-like and longer than the inner scale-like bracts.

Flowering: mostly between April and July, although this may commence as early as March or extend until September.

C. capitatus is characteristic of semi-consolidated and stabilised sands.

Distribution: Mediterranean and Macaronesian region.

Distribution & Status in the Maltese Islands: according to records, this species was never widespread, and was only reported from the dunes of *Gnejna*, *Ghadira*, the various beaches of the *Marfa* Peninsula and *Ramla l-Hamra*. Unfortunately, it has disappeared from *Gnejna* and a number of *Marfa* dunes (due to human influence), and has declined in extent at *Ghadira*. Nevertheless, it still maintains fairly strong populations at *Ramla l-Hamra* and *Ramla tat-Torri*, although it is particularly threatened in the latter locality. The species is thus considered vulnerable, with a restricted distribution in the Maltese Islands.

Cyperus capitatus Vandelli
Sand Galingale — **Bordi tar-Ramel** *(photo: Louis F. Cassar)*

Echinophora spinosa L.
Family Apiaceae [= Umbelliferae]

Name Derivative – Hedgehog-bearing and spiny; *echinos* = hedgehog or sea-urchin [Gr.]; *phéro* = bearing (Gr.); *spinosa* = spiny [Lt.]

Vernacular Names – English: Spiny Echinophore/Prickly Parsnip/Prickly Samphire; Maltese: *Busbies Xewwieki tar-Ramel*; Italian: *Pastinaca Marina/Finocchio Litorale*

A much branched shrub reaching heights of about 10-50 cm, with robust rigid stems bearing triangular segments each ending with spines; these 'segments' are actually highly adapted succulent and spiny leaves. Despite its spines, this species is highly ornamental when in flower, producing white to rosy flowers held in umbrella-shaped inflorescences, called umbels, with 5-10 involucral bracts ending in spikes. Each inflorescence holds a single hermaphrodite flower (i.e. one bearing both male and female parts), surrounded by male flowers. These inflorescences are in turn held together to form a larger umbrella-shaped bunch or umbel.

Flowering: mostly between early April and late September. It produces rounded seeds of about 3-4 mm in diameter, which are greyish-white in colour.

This species has well-developed root systems, and in view of this and its bushy nature, it is an important sand stabiliser. The tender shoots and roots are often utilised for culinary purposes, and are sometimes candied in some Mediterranean countries. Owing to its spines, it used to be removed by individuals or local agencies, in order to minimize any inconvenience to bathers.

Distribution: the Mediterranean region, including Southern Europe, North Africa and Asia Minor.

Distribution & Status in the Maltese Islands: According to past records, it has always had a restricted distribution in Maltese sand dunes, and was reported only from the *Marfa* Peninsula at *Ramla ta' l-Armier* (from where it has since disappeared) and *Ramla tat-Torri* (where only two individuals still persist) and from *Ramla l-Hamra*, where it appears to be declining. The species is thence critically endangered.

Echinophora spinosa L.
Spiny Echinophore — **Busbies Xewwieki tar-Ramel** *(photo: Louis F. Cassar)*

Elytrigia juncea (L.) Nevski
Family Poaceae [= Graminae]

Name Derivative – rush-like leaves with a cover/sheath, typical of grasses; *elytron* = covering [Gr.]; *junceum* = rush-like [Lt.], from *juncus* = a rush [Lt.], a kind of plant with straight, stiff and erect foliage [Lt.], because of the straight, stiff, rush-like stems characteristic of this species.

Main Synonyms – *Triticum junceum* L.; *Agropyron junceum* (L.) Beauvois; *Elymus farctus* (Viviani) Runemark ex Melderis

Vernacular Names – English: Sand Couch; Maltese: *Sikrana tar-Ramel*; Italian: *Gramigna delle Spiaggie*; French: *Agropyre Jonc*.

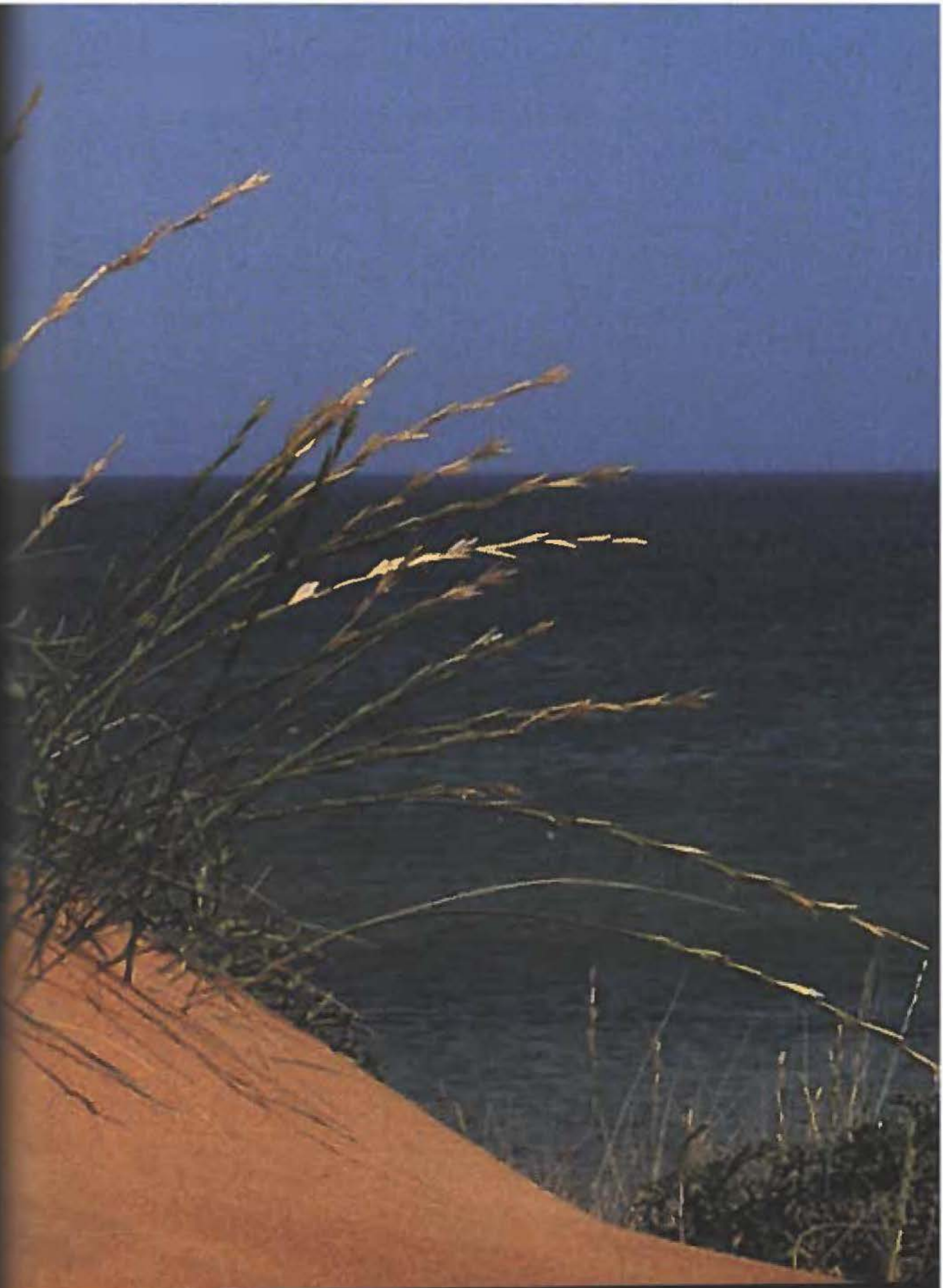
A rhizomatous perennial typified by long underground creeping rhizome and erect stems 30-80 cm long. Its leaves are glaucous, stiff, erect, prickly and in-rolled, minutely velvety on the upper surface, with usually glabrous sheaths. The inflorescence is about 10-20 cm long, bearing 7-9 (sometimes more) stalkless spikelets of about 17-30 mm in length, each with about 5 florets, all of which attached, at an angle, to the main axis. The main axis tends to become very fragile at maturity.

Flowering: between April and June.

Distribution: throughout the Atlantic coasts of Europe, and the Mediterranean.

Distribution & Status in the Maltese Islands: scarce and vulnerable, with a restricted distribution in the Maltese Islands. However, it used to be more widespread, and was reported from, amongst others, *Bahar ic-Caghaq*, *Ghadira*, *Ghadira s-Safra*, *Ghajn Tuffieha*, *Marsa*, *Ramla tal-Mixquqa*, and the various sandy beaches at the *Marfa* Peninsula in Malta, as well as *Ramla l-Hamra* in Gozo. This species has declined in extent in many localities, especially at *Ghadira* and at almost all the sandy beaches of the *Marfa* Peninsula, e.g. few individuals persist at *Little Armier*. It maintains a stronghold at *Ramla tat-Torri* and *Ramla l-Hamra*.

Note: the populations of the European Atlantic coasts are said to refer to subsp. *boreoatlanticum* Simonet et Guinochet. Two subspecies are reported from the Mediterranean, namely subsp. *mediterraneum* Simonet et Guinochet in the western and central Mediterranean, and subsp. *junceum* [= subsp. *sartorii* (Boissier et Reut.) Richter] in the eastern Mediterranean.



Elytrigia juncea (L.) Nevski
Sand Couch — **Sikrana tar-Ramel** *(photo: Louis F. Cassar)*

***Erodium laciniatum* (Cavanilles) Willdenow**
Family Geraniaceae

Name Derivative – Cut-Leaved plant with the nature of a heron; The generic name is derived from the Greek *erodios* = a heron, i.e. a bird with a long beak [Gr.] and *-ium* = having the quality nature of [Lt.], from the beak-like fruit typical of this group of plants; *lacinia* = fringe, lappet (Lt.) and the aforementioned *–ium* [Lt.], due to the extensively cut foliage.

Vernacular Names – English: Sand Storksbill/Cut-Leaved Storksbill; Maltese: *Miskta tar-Ramel*; Italian: *Becco di Grù Laciniato*.

An annual species, although it may also biennate depending on environmental conditions. Hispid or almost glabrous, with prostrate to ascending stems and leaves of varying size and shape: the basal leaves are usually oval-shaped, whilst the upper leaves that are usually reddish along the margin, range from tri-lobed to extensively divided leaves, with many toothed and cut lobes. The flowers are long-stalked, and borne in clusters on a hairy stem. The petals are usually purplish to pink, occasionally white.

Flowering: between February and June. The fruit is very characteristic, and includes a long beak-like structure from which the various names of this and allied species are derived (hence the names *Erodium*, storksbill and *becco di grù*). The beak is 35-90 mm long and is composed of five twisted corkscrew-shaped sections with the seeds attached at the base. This species is an important constituent of semi-consolidated to fixed dunes, and is rarely found on very mobile sands.

Distribution: Mediterranean Region.

Distribution & Status in the Maltese Islands: According to past records, it used to be more widespread in distribution and was reported from *Bahar ic-Caghaq*, *Ghadira*, *Ramla tal-Mixquqa*; *Ramla tal-Pwales* and the various beaches of the *Marfa* Peninsula, and at *Qbajjar*, *Ramla l-Hamra* and *Ramla tax-Xlendi* in Gozo. Nowadays, it has declined greatly in extent, and has disappeared from most of the aforementioned localities; it seems to maintain strongholds at *Ramla l-Hamra* and *Ramla tat-Torri* only. The *Ramla l-Hamra* populations seem to be different from those of the *Marfa* Peninsula; the latter, according to Sommier & Caruana Gatto (1915), belong to a variant known as "*E. bispidum* Presl.". The species is vulnerable and on the decline, with a restricted distribution in the Maltese Islands.

Other species: other storksbill species may be found on sand dunes. The most frequent intruder storksbill species in Maltese dunes are the Musk Storksbill [*Erodium moschatum*, Malt.: *Haxixa tal-Misk*] and the Glandular or Soft Storksbill [*Erodium malacoides*, Malt.: *Moxt*]. Both are hairy annuals with purplish flowers, and are essentially opportunistic species that are typical of steppes, cultivated ground and disturbed areas, and are distinguished from the sand storksbill from their foliage and shorter beaks. The musk storksbill has oval heart-shaped leaves that are shallowly cut into lobes with rounded teeth and beaks of 20-45 mm long, whilst the glandular storksbill has simple rounded to oval-shaped leaves and smaller beaks [18-35 mm long].

Note: old 19th century records of the Mediterranean Storksbill [*Erodium chium*, Malt.: '*Miskta tar-Raba*'] from Maltese sand dunes are very probably referable to the closely related sand storksbill, a species formerly included within *E. chium*. The Mediterranean storksbill, a very rare species in the Maltese Islands, is more typical of fields and uncultivated ground, and has never been reliably observed on sand dunes in the Maltese Islands.

***Erodium laciniatum* (Cavanilles) Willdenow**
Sand Storksbill - **Miskta tar-Ramel** *(photo: Edwin Lanfranco)*

Eryngium maritimum L.
Family Apiaceae [= Umbelliferae]

Name Derivative – Maritime Eryngium; The generic name is derived from the Greek *'eryngion*, which is seemingly derived from *'erygma* = a belching [Gr.], from the supposedly belching properties of the plant; *maritima* = maritime [Lt.].

Vernacular Names – English: Sea Holly/Sea Holm; Maltese: *Xewk tar-Ramel*; Italian: *Calcatreppola Marina*/*Erba di San Pietro*.

A tough herbaceous perennial reaching heights of about 20-60 cm, appearing more as a shrub rather than a herb due to its rigid stems and foliage. The stems are striated and much branched, whilst the leaves are thick and sinuated (i.e. wavy-edged) with spines along the margin. The stems and foliage are glaucous in colour, with the bluish tinge being more evident in its upper parts, giving a greyish-blue appearance to the whole plant, an important adaptation against water loss. The root system is rhizomatous. As for the spiny echinophore, this species is highly ornamental, especially when in flower. It produces small white or whitish-blue flowers forming white ovoid bunches that are surrounded by spiny bracts, which are either bluish-green or purple.

Flowering: essentially a summer-flowering species, flowering between mid-June until the end of September. Due to its rhizomatous root system and shrubby habit, this species plays an important role in fore-dune and yellow dune stabilisation. The rhizome is utilised for culinary purposes in some parts of the Mediterranean, due to its carrot-like taste, and for medicinal purposes, such as against pulmonary infections and as a diuretic. Moreover, the Oyster Mushroom, *Pleurotus eryngii*, grows on the roots of this species in many Mediterranean countries, where it appears in late summer and autumn. This mushroom species, although present in the Maltese Islands, occurs as a different variety (var. *ferulae*) that does not grow on the sea holly. Owing to its spines, it used to be wholly removed in order to minimise any inconvenience to bathers.

Distribution: Central and Southern Europe and other parts of the Mediterranean region, including North Africa and Asia Minor.

Distribution & Status in the Maltese Islands: according to past records, it used to be frequent in practically all the sand dunes of the Maltese Islands. Nowadays, it has declined greatly in extent, and seems to maintain a stronghold only at *Ramla tat-Torri* and *Ramla l-Hamra*. At the time of writing, only two specimens were noted at *Ramla tal-Mixquqa*. Also known from *Dahlet ix-Xilep*. The species is vulnerable and on the decline, with a restricted distribution in the Maltese Islands.

Eryngium maritimum L.
Sea Holly — **Xewk tar-Ramel** *(photo: Louis F. Cassar)*

Euphorbia peplis L.
Family Euphorbiaceae

Name Derivative – Peplis Spurge; *euphorbion* = spurge [Gr.), a term derived, according to Plinius from the name of a doctor who has discovered the toxic properties of spurges. *peplis* = this word corresponds to the name used by Dioscorides to describe this plant.

Vernacular Names – English: Purple Spurge/Hyssop Spurge/Wild Purseane; Maltese: *Gemmugha tar-Ramel*; Italian: *Euforbia delle Spiaggie/Peplide/Erba Mora*.

An annual glaucous plant. It has a flat prostrate habit and regularly branched stems. The stems are usually slightly reddish (although it maintains the green colour in some individuals or populations), and bear opposed leaves at regular branches. The leaves are succulent and ovate in shape. It produces small solitary flowers. The male parts are held within four reddish-brown to purplish structures called glands. The purplish colour of these glands and the reddish stem are the main features for which this species has been attributed the common name 'purple spurge'.

Flowering: mostly between May and late September, although this is dependent on climatic and other factors. In fact some plants have been observed to flower as early as April or as late as November. It produces rounded greyish seeds.

This species is particularly adapted to grow in exposed harsh dunal environments and is one of the first plants to colonise beaches. It also helps to stabilise sands in such areas due to its flat and branched habit.

Distribution: a seashore species known from the Mediterranean region and the Atlantic coasts of Europe, including the Azores and Canary Islands.

Distribution & Status in the Maltese Islands: The species is at present endangered with a restricted distribution in the Maltese Islands, where it is known from some two or three localities in Malta and Gozo. The most relevant extant population appears to be that at *Ramla tat-Torri*, where it is, however, declining due to the general degradation of the area. It was formerly more frequent and present in almost all dunal areas of Malta, Gozo and Comino.

Euphorbia peplis L.
Purple Spurge — **Gemmugha tar-Ramel** *(photo: Sandro Lanfranco)*

Euphorbia terracina L.
Family Euphorbiaceae

Name Derivative – The Spurge of Terracina; *euphorbion* = spurge [Gr.], a term derived according to Plinius from the name of a doctor who has discovered the toxic properties of spurges; *terracina* = the name of the town Terracina (in the Lazio region, Italy) [It.].

Vernacular Names – English: Coast Spurge; Maltese: *Tengħud tax-Xtut*; Italian: *Euforbia delle Spiaggie.*

A herbaceous plant but with stems that are usually woody at the base. It has erect rigid stems reaching heights of about 5-70 cm. Its leaves are slightly succulent and set close together, and are usually long and narrow. It is glabrous, somewhat glaucous, and branched at the base. It may be annual or perennial depending on the environmental factors to which it is subjected. It produces small 2-5 flowers at the tip of each stem set in umbrella-fashion, in bunches, with the reproductive parts [with four yellowish glands, semi-lunar in shape, containing the male part and a larger single capsule (the female) above them] held within special oval-shaped leaves.

Flowering: mostly between early April and late September. It produces ovoid seeds that are grey, sometimes mottled, in colour. It tends to thrive better on less dynamic sands, although it also occurs within yellow dunes. It is an important component of semi-consolidated to fixed dunes in the Maltese Islands.

Distribution: a dune species known from the Mediterranean region, the Azores and Canary Islands and Arabia.

Distribution & Status in the Maltese Islands: reported mostly from *Għadira*, and various sandy beaches of the *Marfa* Peninsula in Malta and *Ramla l-Ħamra* (Gozo). It has disappeared from most *Marfa* beaches, except *Ramla ta' l-Armier*, where it has declined dramatically. Still persists in small numbers at *Għadira* and at the *Ramla l-Ħamra* dunes. The species is vulnerable with a restricted distribution in the Maltese Islands.

Other species: the critically endangered Sea Spurge or Seaside Spurge [*Euphorbia paralias*, Malt.: *Tengħud tar-Ramel*] is very similar, but has a greener foliage with the leaves inserted at an acute angle. It grows in more dynamic dune environments than the coast spurge (such as embryo, fore-dunes and other exposed and mobile parts of dunes) due to its ability to withstand saline conditions. The sea spurge was formerly more frequent and was present in almost all main sand dunes of Malta (*Ġnejna*, *Għadira*, *Ramla ta' San Tumas*, *Salini* and the various sandy beaches of the *Marfa* Peninsula), Gozo (*Ramla l-Ħamra*) and Comino (*Il-Qala ta' Santa Marija*). However, it is now confined to three small exposed patches within the *Ramla l-Ħamra* dunes (Gozo).

Euphorbia terracina **L.** — Coast Spurge — **Tengħud tax-Xtut**
Euphorbia paralias **L.** — Sea Spurge — **Tengħud tar-Ramel**
(photos: Louis F. Cassar)

Glaucium flavum Crantz
Family Papaveraceae

Name Derivative – Glaucous plant with Yellow flowers. *Glaucos* = glaucous, i.e. bluish-green [Gr.], with reference to the colour of the entire plant; *flavum* = yellow [Lt.], from the colour of the flower.

Main synonyms – *Glaucium luteum* Scopoli

Vernacular Names – English: Yellow Horned Poppy/Sea Poppy; Maltese: *Pepprin Isfar*; Italian: *Papavero delle Spiaggie/Papavero Cornuto*.

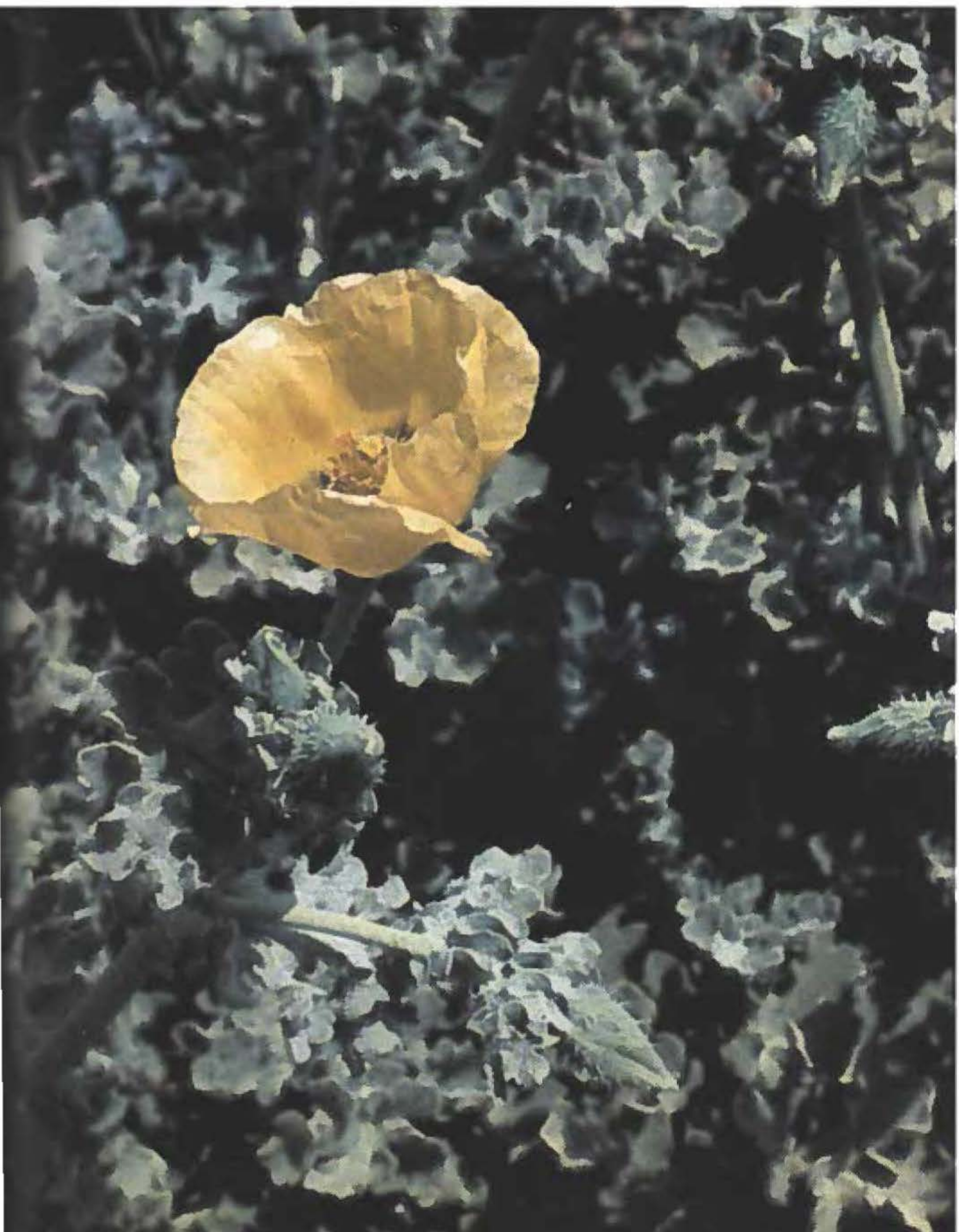
A biennial or a shortly-lived perennial. Glaucous, with bushy, ascending, hairy stems. The leaves are hairy, rough and fleshy, and are deeply lobed, with the lobes being further toothed. The upper leaves are similar, but are generally stalkless and encircling the stem. It produces large (5-6 cm in diameter), rounded, very conspicuous, solitary, terminal golden-yellow flowers.

Flowering: usually between May and the end of September. The fruit of the species consists of various hairless, rough, linear to slightly curved pods, 15-30cm long. This psammo-halophytic species prefers gravel and sandy habitats, although it occasionally penetrates inland areas and other coastal habitats, becoming a ruderal. Within sand dunes, it colonises both exposed dunes and the more inland dune sectors. The yellow horned poppy produces colourless latex that has been used in various parts of the Mediterranean as a traditional cure for skin ulcers.

Distribution: Western Europe, along the Atlantic coasts, the Mediterranean Region and Central Asia.

Distribution & Status in the Maltese Islands: a coastal species, particularly frequent along disturbed areas, but not frequent in all Maltese sand dunes. It is not exclusive to sand dunes, but is a very important component of the *Ramla tal-Mixquqa* dunes, where it forms the dominant component of exposed dune vegetation with *Matthiola tricuspidata*.

Other species: the yellow horned poppy can be confused with the Red Horned Poppy [*Glaucium corniculatum*], which has smaller (25–60 mm in diameter) scarlet to orange flowers, with the petals often bearing a blackish basal mark. The pods are usually straight with stiff hairs. However, this species is absent from the Maltese Islands, and is not typical of sand dunes. Other poppies do occur on disturbed sand dunes and within recent dune slacks in the Maltese Islands [at least six species of *Papaver* occur, Malt.: *Pepprin* or *Xabxieb*], but all are annual and all easily distinguishable from horned poppy, owing to their different habit, different flower colour (usually different tones of red or violet) and fruit (usually capsules not pods).



Glaucium flavum **Crantz**
Yellow Horned Poppy — **Pepprin Isfar** *(photo: Alfred E. Baldacchino)*

Lotus cytisoides L. s.l.
Family Fabaceae s.str. [= Leguminosae]

"*L. cytisoides* s.l." is essentially a group of closely-related species that includes *Lotus cytisoides* L. itself and the related *Lotus creticus* L., *Lotus commutatus* Gussone and *Lotus drepanocarpus* Durieu.

Name Derivative – Resembling/in the shape of a shrubby legume, due to its shrubby nature of this leguminous plant; *lotos* [Gr.], a generic name applied by the Greek (and Romans) to several different kinds of plants, including some members of the pea family (i.e leguminous plants, family Fabaceae), such as the birdsfoot-trefoils; *kytisos* = a shrubby legume [Gr.] and *–eides* = resembling [Gr.], from *eidos* = shape; likeness [Gr.].

Main Synonyms – *Lotus prostratus* Desfontaines.

Vernacular Names – English: Grey Birdsfoot Trefoil; Maltese: *Għantux tal-Blat*; Italian *Ginestrino delle Scogliere*.

A group of perennial bushy shrubs. Stem woody, especially at base. The leaves are small and usually covered with fine hairs, giving a greyish silvery-white colouration to the foliage. It produces flowers typical of the pea family (leguminous plants), to which it belongs. The flowers are yellow, sometimes with a reddish tinge, and are borne solitary or in clusters.

Flowering: usually between March and June, although this depends on the habitat it occupies. The pods (also called legumes) containing the seeds are typically linear in most species belonging to this group, except in *Lotus drepanocarpus*, which has curved legumes.

Members of this group are present in most sand dunes all over the Mediterranean and are some of the most important components of semi-consolidated and fixed dunes, especially in the Central Mediterranean.

Distribution and systematics: The group is widely distributed in the Mediterranean region, but its taxonomy is still unclear; it is often not easy to distinguish the different species, rendering the delineation of distribution patterns a difficult task. *Lotus cytisoides* is an important maritime garrigue and cliff component in the Mediterranean, sometimes also present on sand dunes. *Lotus creticus* is also a widespread Mediterranean coastal species, but is reported as an important component of Sicilian dunes, whilst *L. commutatus*, typical of sand dunes, is also present in Southern Italy and Sicily.

Distribution & Status in the Maltese Islands: The status of this group in the

Maltese Islands is uncertain due to confused systematics. Two species are reported in literature, *Lotus creticus* and *L. cytisoides*, although the occurrence of the former is still unsubstantiated. According to Edwin Lanfranco, an eminent Maltese botanist, two entities are present: *Lotus cytisoides*, on cliffs and maritime garrigue, and a 'different' plant found exclusively on sand dunes, which, however, appears to be attributable to *Lotus cytisoides* according to current botanical systematics. Hence, *Lotus cytisoides* as a species *per se* is frequent along the coastal areas of the Maltese Islands, but the sand dune 'variant' is endangered, with a restricted distribution in the Maltese Islands, with its best population being on semi-consolidated sands at *Ramla tat-Torri*.

Other species: at least other four other birdsfoot trefoils occur on sand dunes. The rarest is definitely the Sand Birdsfoot Trefoil [*Lotus halophilus*, Malt.: *Ghantux tar-Ramel*), a minute annual plant with yellowish flowers and smaller linear legumes, slightly curved at the apex. This species was quite widespread, being known from the main dunes of Malta, Gozo and Comino, but was considered as probably extinct for decades, until its rediscovery on the sandy beach of *Il-Qala ta' Santa Marija* in Comino, where it is exceedingly rare, and critically endangered.

The other species include the Edible Birdsfoot Trefoil [*Lotus edulis*, Malt.: *Qrempuc*], the Common Birdsfoot Trefoil [*Lotus ornithopodioides*, Malt.: *Qrempuc tal-Mogboz*] and the Eastern Sand Birdsfoot trefoil [*Lotus peregrinus*, Malt.: *Qrempuc tar-Ramel*]. These are also annuals with yellow flowers, and mostly differentiated from the pods, which are larger, fleshy and edible in *L. edulis*, but much thinner in the other two, although it is usually linear in *L. peregrinus* and usually curved in *L. ornithopodioides*. *L. peregrinus* is essentially Eastern Mediterranean species, also known from North Africa and the island of Linosa in Italy (but apparently absent from the Maltese Islands). The other two species are mostly weeds, also present in steppes and disturbed areas, including areas under cultivation.

Other notes: At least two broomrape species (family Orobanchaceae) are known as parasitic plants on grey birdsfoot trefoils. Broomrapes are plants bearing no chlorophyll, the green pigment which plants utilise to feed by photosynthesis from the sun. These live on the roots of other green plants, 'sucking' their food products. They are mostly recognised from the aerial erect inflorescences they produce in order to reproduce and disperse. The Sand Broomrape [*Orobanche densiflora*, Malt.: *Budebbus tar-Ramel*] and the Blood Broomrape [*Orobanche sanguinea*, Malt.: *Budebbus Ahmar*] are both known as parasites of *Lotus cytisoides*. The sand broomrape is a species known from Malta, Morocco, Portugal and Spain, and occurs in Malta as an endemic form [forma *melitensis*] – it is locally very rare, vulnerable and on the decrease, mostly due to human activities; its best populations are at the *Ramla tat-Torri* dunes and the nearby *Ahrax* garrigue. The blood broomrape was also reported from the Maltese Islands, but probably a mistaken identification for the sand broomrape. Both species are not confined to dunes.

Orobanche densiflora **Salzm. ex Reuter**
Sand Broomrape — **Budebbus tar-Ramel** *(drawing: Andrew Micallef)*

Lotus cytisoides L. s.l.
Grey Birdsfoot Trefoil — **Għantux tal-Blat** *(drawing: Andrew Micallef)*

Matthiola tricuspidata (L.) R. Brown
Family Brassicaceae [= Cruciferae]

Name Derivative – Three-Pointed Stocks. The generic name *Matthiola* is a general botanical term used to define scientifically stocks, and is actually derived from the name of an Italian botanist P.R. Mattioli (1500-1577), to whom this genus was dedicated; *trias* and *triados* = in three's [Lt.], from *treis, trion* [Gr.] and *cuspidatus* = pointed [Lt.], because of the three horns on the siliquae of this species.

Main Synonyms – *Cheiranthus tricuspidatus* L.

Vernacular Names – English: Mediterranean Stocks/Three-Horned Stocks; Maltese: *Gizi tal-Bahar*; Italian: *Violaciocca Selvatica/Violaciocca di Mare*.

An annual with prostrate to trailing habits, spreading and covering sand in the process. It has a bushy nature due to its numerous leaves. The undulated leaves and stem have a greyish to ashy-green appearance due to the presence of fine hairs. The shape of the leaves and their size varies considerably, but is invariably either entire but finely divided and sinuated (wavy-edges), or divided into lobes with rough toothed margins. The flowers are very attractive and ornamental, and are characterised by four pink, rosy or violet-coloured petals, with a whitish centre, although they may be occasionally completely white.

Flowering: March-May. The seeds are enclosed within typical elongate pods, called siliquae, which in these species possess three characteristic and conspicuous conical stiff horns at its apex, forming a triangular 'star'. This species dries in summer and disperses its seeds by breaking away at the base. This species is not confined to sand dunes only, but can also be found in sandy beaches and disturbed localities close to the sea (but with sandy or similar substrates).

Distribution: Mediterranean region.

Distribution & Status in the Maltese Islands: scarce. An important component of the *Ramla tal-Mixquqa* dunes. It still persists along the coastline of the areas of *Ghajn Tuffieha, Il-Qaliet, Tigne* and some of the beaches of *Marsaxlokk-Birzebbuga* area.

Other species: The Sand or Sea Stock [*Matthiola sinuata*, Malt.: *Gizi tar-Ramel*] is similar, but is a densely-haired perennial (sometimes biennial), with narrow, spear-shaped leaves, with slightly larger purplish and scented flowers (in *M. tricuspidata* the flowers are unscented) and elongate siliquae with conspicuous yellow, brownish or black stalked glands (lacking in *M. triscuspidata*), and two gibbosities instead of the three horns. This sand stock has also been reported from the cliffs of the Maltese Islands; nonetheless this species is not known from cliffs, suggesting that such records were very probably misidentifications for the Maltese Stock [*Matthiola incana* subsp *melitensis*, Malt.: *Gizi ta' Malta*], an endemic cliff taxon.

Matthiola tricuspidata (L.) R. Brown
Mediterranean Stocks — **Giżi tal-Baħar** *(photo: Sandro Lanfranco)*

Medicago marina L.
Family Fabaceae s.str. [= Leguminosae]

Name Derivative – Medick of the Sea; The generic name *Medicago*, meaning medick, is derived from the term *herba medica* [Lt.], which means the herb from Media or Mede (in Persia), i.e. *Medike* [Gr.], with reference to the lucerne, a plant whose supposed origins were in Media; *marinus* = of the sea [Lt.].

Vernacular Names – English: Sea Medick; Maltese: *Nefel tar-Ramel*; Italian: *Erba Medica Marina/Medicagine Marina*.

A herbaceous perennial with a silvery green appearance attributable to a thick covering of velvety whitish hairs that cover the whole plant. The species has a deep tap-root. The leaves are typically trifoliate (i.e. divided in three). The plant is usually prostrate, although exceptionally it might develop into a low cushion-like shrub. It produces typical flowers of pea family (leguminous plants), to which it belongs. These flowers are golden yellow and borne in small dense bunches.

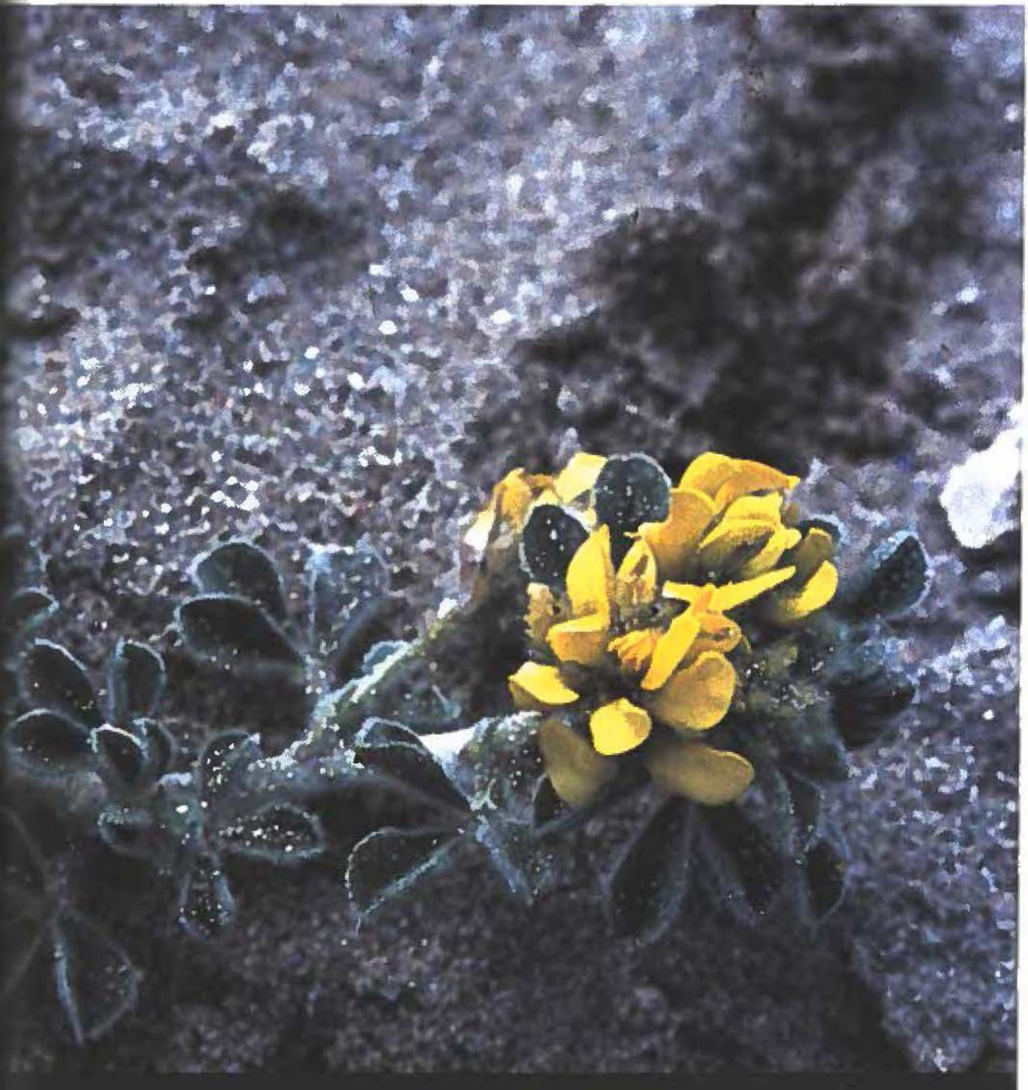
Flowering: a true spring-flowering species, flowering between April and June, although its flowering may extend from March till August. Following pollination, the flowers give rise to cylindrical pods with short spines. Its prostrate habit and fine hairs also help in stabilising sand; the hairs have a cohesive property, 'trapping' saltating sand grains as they collide with the plant. The occurrence of nitrogen-fixing bacteria in its roots and other leguminous plants growing on sand dunes, is important in that these bacteria are able to fix atmospheric nitrogen into nitrates, thus rendering the otherwise unavailable atmospheric nitrogen accessible to the plant. These adaptations allow the plant to grow profusely along various parts of sand dunes, including embryo dunes, yellow dunes and semi-consolidated sands, as at *Ramla l-Hamra* in Gozo.

Distribution: Mediterranean region.

Distribution & Status in the Maltese Islands: this species was quite widespread in the Maltese dunes, since it has been reported from Malta (*Gnejna*; *Ghadira*; *Ramla tal-Mixquqa*; *Ramla ta' San Gorg*; *Ramla ta' San Tumas* and the beaches of the *Marfa* Peninsula); Gozo (*Ramla l-Hamra*) and Comino (*Il-Qala ta' Santa Marija*). Nonetheless, it is possibly extinct from Malta and Comino, and seems to persist only at *Ramla l-Hamra*, where it maintains an important stronghold, with no apparent indication of decline. The species is vulnerable, with a restricted distribution in the Maltese Islands.

Note: other medicks occur on sand dunes, of which the most frequent are the Littoral Medick (*Medicago littoralis*, Malt.: *Nefel tax-Xtut*) and the Toothed Medick

(*Medicago polymorpha*, Malt.: *Nefel Komuni*). Both are annual species with trifoliate leaves producing yellow flowers, which upon pollination develop into spirally-coiled pods bearing hooked teeth along their outer margin.



***Medicago marina* L.**
Sea Medick — **Nefel tar-Ramel** *(photo: Edwin Lanfranco)*

Ononis natrix L. subsp. *ramosissima* (Desfontaines) Battandier
Family Fabaceae s.str. [= Leguminosae]

Name Derivative – Much-Branched Restharrow; *ononis* = a generic term to describe restharrows [Gr.]; *ramosissimus* = having many branches, from the combination of *ramosus* = many branches, full of branches [Lt.] and *-imus* = having the quality of [Lt.].

Vernacular Names – English: Bush Restharrow/Goat-Root/Large Yellow Restharrow; Maltese: *Broxka ta' Għawdex*; Italian: *Ononide Bacaja/Erba Bacaja*.

A dense, much-branched perennial shrub with dense foliage. Leaves trifoliate and toothed, with a short stalk. They are covered by small hairs, which give the plant a sticky texture, important to trap sand and reduce the impact of sand when this is falling over the plant via wind action. The whole plant is aromatic, emitting an odour that is pleasant to some and foetid to others. It produces solitary golden yellow flowers and streaked with red or purple, that are typical of pea family (leguminous plants), to which this shrub belongs.

Flowering: a spring-flowering species, between the end of March and June. Following pollination, the flowers give rise to linear, pendulous and hairy pods bearing several seeds. This species is typical of more inland, less mobile, semi-consolidated and fixed dunes of the Central and Eastern Mediterranean region, which it may dominate. This species was formerly collected for firewood, and was amongst the first protected plants of the Maltese Islands; in the 17th century, the Grandmaster De Rohan had issued a decree banning its collection prior to a fortnight after the feast of St. John (24th June) in order to allow seed formation and dispersal.

Distribution: Mediterranean region and Western Europe.

Distribution & Status in the Maltese Islands: a scarce, but widespread species known for Malta, Gozo, Comino and Cominotto, which is not exclusive to dunes; it is also found on coastal garrigues, in disturbed coastal localities and along footpaths, especially in Gozo and represents the dominant component of the semi-consolidated and fixed dunes of *Ramla*. It appears to have been important at *Il-Qala ta' S. Marija*, where few individuals still persist on the sandy area.

Note: other restharrows have been reported on Maltese sand dunes. The Sand Restharrow [*Ononis variegata*] is a very branched prostrate annual, with sticky foliage, yellow flowers and a spindle-shaped/fusiform pod; it is critically endangered, if not possibly extinct, and has long disappeared from the sandy beaches of *Marsaskala* due to habitat alteration. It was not recently observed in its last known haunt, *Ramla l-Hamra*. The White Restharrow [*Ononis mitissima*] is similar, in that it is a prostrate to ascending branched annual, with fine hairs but nearly glabrous and not sticky, and produces pink flowers and an oval pod; this dune species is overall scarce, mostly because of its occurrence on clayey soils, but is otherwise extremely rare on local sand dunes.

Ononis natrix **L. subsp.** ***ramosissima*** **(Desfontaines) Battandier**
Bush Restharrow — **Broxka ta' Ghawdex** *(photo. Louis F. Cassar)*

Otanthus maritimus (L.) Hoffmannsegg et Link
Family Asteraceae [= Compositae]

Name Derivative – Maritime Ear-Shaped Flower; The generic name *Otanthus* is composed of *ùsotos* = ear [Gr.] and *ànthos* = flower [Gr.], because of the auricle-shaped flower; *maritimus* = maritime [Lt.].

Main Synonyms – *Filago maritima* L.; *Diotis maritima* Desfontaines; *Diotis candidissima* Desfontaines

Vernacular Names – English: Cottonweed/Sea Cudweed; Maltese: *Santolina/Bajda tar-Ramel*; Italian: *Santolina delle Spiaggie*.

An aromatic woody tufted perennial with very fine hairs giving the plant a velvety greenish-white appearance. The leaves are alternate and directly attached to the stem and vary from entire to denticulate (i.e., with fine teeth along their margin). It produces yellow tubular flowers held within flower hemispherical heads with a white-felted involucre.

Flowering: a summer-flowering species, from the beginning of June until September. The fruits are single-seeded, bearing whitish and oblong seeds, without the characteristic pappus or hairs so typical of members of the composite family (family Asteraceae).

This species is typical of fore-dunes, embryo dunes and other forms of exposed dunes in the Mediterranean, often forming whole assemblages dominated by it.

Distribution: Mediterranean region, Atlantic coasts of Europe up to the British Isles, and the Macaronesian region.

Distribution & Status in the Maltese Islands: this species was recently re-discovered in the Maltese Islands. It was known only from *Ramla tat-Torri*, from where it disappeared a few years after its discovery due to illegal bulldozing works in 1998 and other related human activities. Recently re-discovered by Tabone at *Xatt l-Ahmar* (Gozo), where it appears to be confined. The species is critically endangered with a restricted distribution in the Maltese Islands.

Otanthus maritimus (L.) Hoffmannsegg et Link
Cottonweed — **Santolina tar-Ramel** *(photo: Louis F. Cassar)*

Pancratium maritimum L.
Family Amaryllidaceae

Name Derivative – Maritime All-Power; The generic name *Pancratium* is composed of *pan* = all [Gr.] and *kratos* = power [Gr.], because of the supposed 'powerful' medicinal properties; *maritimus* = maritime [Lt.].

Vernacular Names – English: Sea Daffodil/Sea Pancratium/Mediterranean Lily; Maltese: *Pankrazju/Narcis il-Bahar*; Italian: *Narciso Marino/Giglio di Mare/Pancrazio*.

A bulbous plant with glaucous, thick, flat, linear and spirally-twisted leaves and a deeply-buried bulb which provides adequate anchorage. The leaves are maintained for most of the year, with new leaves to replace the old ones developing every year, in late summer and early autumn, often after the first rains. The plant produces a stem-like stalk, 5-12 cm long, on which it bears 3-10 flowers held in umbels. The flowers are white, fragrant and relatively large.

Flowering: a summer-flowering species, between July and September, with most plants flowering early in the summer. The seeds are blackish and very evident. This species is quite widespread in sand dunes and is able to persist in relatively disturbed regions. In the Maltese Islands, it occurs on most dunes, although it is more frequent on semi-consolidated and fixed dunes.

Distribution: Mediterranean region, Atlantic coasts of Europe up to the British Isles, and the Macaronesian region.

Distribution & Status in the Maltese Islands: important dune component, which was known from many sandy beaches and dunes of the Maltese Islands, but has disappeared from some localities, like *Gnejna*, *Little Armier*, *Ramla tal-Pwales* and *Qbajjar* owing to human interference, including habitat alteration or destruction and/or the impact of alien species. It is on the verge of extinction in a number of localities, like *Ramla ta' l-Armier*, *Ramla tal-Qortin* and *Il-Qala ta' Santa Marija*, where few specimens still persist. Over all the species is scarce and considered vulnerable and on the decline, with restricted distribution in the Maltese Islands.

Note: another sea-daffodil, the Stinking Sea-daffodil [*Pancratium foetidum* Pomel, Malt.: *Pankrazju tal-Harifa*] has been recently reported by Edwin Lanfranco from the Maltese Islands. This species was apparently confined to the *Ghadira* sand dunes, from where it disappeared following the obliteration of the dunal area where this species used to thrive. It produces smaller whitish flowers, also held in umbels, but flowers later, in autumn; it produces an unpleasant smell. Its status is indeterminate, and requires closer investigation of the existing sea-daffodil populations, including those persisting within the relict dunes of *Ghadira*.

Pancratium maritimum **L.**
Sea Daffodil — **Narċis il-Baħar** *(photo Louis F. Cassar)*

***Polygonum maritimum* L.**
Family Polygonaceae

Name Derivative – Many-seeded Maritime Plant; The generic name *Polygonum* is composed of *polys* = many [Gr.] and *gonos* = seed, offspring [Gr.]; *maritimus* = maritime [Lt.].

Vernacular Names – English: Sea Knotgrass; Maltese: *Lewza tal-Bahar*; Italian *Poligono Marittimo*.

A prostrate perennial with thick woody rhizomes and rough, spreading stems densely furnished with leaves. The leaves are leathery and fleshy, elliptical and glaucous in colour, with well-marked nerves and in-rolled margins. At the base of the stem, a structure composed of joined leaf bases (called ochrea) occurs; it is very dark brown at the base, and silvery and scarious above. Flowers are conspicuous, white or rosy-pink, set in axillary clusters.

Flowering: between spring and summer, usually between April and July, and sometimes August. The fruit is trigonous, shining dark brown and slightly projecting from the floral parts. These are buoyant and are therefore able to travel by sea and colonise other beaches where the seeds are beached and subsequently deposited.

This species is typical of the most exposed and mobile sands, and is able to tolerate high salt concentrations. It is often one of the first plants to colonise beaches and characterizes driftline communities.

Distribution: Cosmopolitan.

Distribution & Status in the Maltese Islands: formerly quite widespread in Maltese dunes, and was known from Malta (*Bahar ic-Cagbaq*; *Gnejna*; *Ghadira*; *Marsa*; *Ramla tal-Mixquqa*; *Ramla tal-Pwales*; *Ramla ta' San Gorg*; and the various beaches of the *Marfa* Peninsula); Gozo (*Ramla l-Hamra*) and Comino (*Il-Qala ta' Santa Marija*), but is rapidly declining and has disappeared from many localities, owing to habitat alteration/destruction and/or the impact of alien species. Small populations apparently still persist at *Ramla tat-Torri* in Malta, *Xatt l-Ahmar* in Gozo and possibly at *Il-Qala ta' Santa Marija* in Comino. It occurs sporadically in other areas such as at *Exiles* (l/o *Sliema*). Previously also reported from *Bugibba* and *Ghadira s-Safra*, although it has not been recently observed in such areas. The species is endangered with a restricted distribution in the Maltese Islands.

***Polygonum maritimum* L.**
Sea Knotgrass — **Lewża tal-Baħar** *(drawing: Andrew Micallef)*

Pseudorlaya pumila (L.) Grande
Family Apiaceae [= Umbelliferae]

Name Derivative – Dwarf False-Orlay's Carrot; The generic name *Pseudorlaya* is composed of *pseudo* = false [Gr.] and *Orlaya*, which is a generic name of carrot species called Orlay's Carrot; the name *Orlaya* is in turn derived from the name of a Russian botanist, Orlay, of the 18th century. *Pseudorlaya* thence means that this species is similar to the *Orlaya* plants, representing a false *Orlaya*; *pumilus* = dwarf, pygmy [Lt.].

Main Synonyms – *Caucalis pumila* L.; *Daucus pumilus* (L.) Hoffmannsegg et Link; *Daucus muricatus* (L.) L. var. *maritimus* L.; *Daucus maritimus* Gaertner non Lamarck; *Orlaya maritima* (L.) Koch

Vernacular Names – English: Sand Carrot; Maltese: *Zunnarija tar-Ramel*; Italian: *Lappola Marina*.

A minute annual belonging to the carrot family. It has a prostrate habit, and the stem is either simple or branched from the base, ranging from 5-20cm in length. The leaves are finely divided. The plant is covered with fine hairs, rendering it greenish-white in appearance. This carrot produces white or pinkish flowers in umbels; the plants are often very minute and become conspicuous only when in flower.

Flowering: a spring-flowering species, between March and May. The fruit is characteristic and is elliptical, hairy and spiny, with the spines being always wider at the base or site of 'attachment' to the fruit. This species is more profuse on inland parts of dunes, especially among semi-consolidated sands and dune grasslands.

Distribution: Mediterranean region.

Distribution & Status in the Maltese Islands: formerly quite widespread in Maltese dunes, known from Malta (*Gnejna*; *Ghadira*; *Marsa*; *Marsaskala*; *Bahar ic-Caghaq*; *Ramla tal-Mixquqa* and the various beaches of the *Marfa* Peninsula; Gozo (*Qbajjar*; *Ramla l-Hamra*); and, Comino (*Il-Qala ta' Santa Marija*), and was also reported from other sandy beaches and sites with fine sediments, such as *Dwejra* (Gozo). It used to be an important component of the dune grasslands at *Ramla tat-Torri* prior to their destruction as a result of the construction of illegal boathouses and various other human activities. It is now seemingly confined to *Ramla l-Hamra*, its last known haunt, where it is critically endangered.

Note: other sand carrots occur in the Mediterranean, which includes a subspecies of the Sand Carrot [subsp. *microcarpa* (Loret et Barr.) Lainz] which almost invariably produces white flowers and has smaller fruits than the typical sand carrot [subsp. *pumila*]; and, the African Sand Carrot [*Pseudorlaya minuscola* (Pau ex Font Quer) Lainz], which is different from the sand carrot from the shape of the spines on the fruit, which are not wider at the base, as in *P. pumila*.

In the Maltese Islands, apart from *Pseudorlaya pumila*, other carrot species are known from sand dunes, especially the Wild Carrot [*Daucus carota* L. s.l., Malt.: *Żunnarija Selvagga*], which is essentially a very variable opportunistic species capable of growing also on steppes and disturbed ground; and the Sea Carrot [*Daucus gingidium* L. s.l., Malt.: *Zunnarija tax-Xtut*], which is mostly confined to coastal localities. Both produce similar whitish or pinkish flowers held in umbels, but are quite different in foliage, umbel shape and fruit.

***Pseudorlaya pumila* (L.) Grande**
Sand Carrot — ***Zunnarija tar-Ramel*** (photo: Edwin Lanfranco)

Salsola kali L.
Family Chenopodiaceae

Name Derivative – Potash-bearing plant growing in saline areas; the generic name *Salsola* is the diminutive of *sálsus* = salted, salty, saline [Lt.], indicating the saline conditions in which plants belonging to this genus grow; *qali* = potash [Ar.], also *kalium* = potassium [Lt.] and *al qali* = alkaline [Ar.], with reference to the former use of the ashes of this and other saltwort species.

Vernacular Names – English: Prickly Saltwort/Sandwort/Spiny Saltwort; Maltese: *Haxixa ta' l-Irmied Xewwikija*; Italian: *Riscolo/Erba Cali/Soda/Bacicci*.

An annual herbaceous plant. It has an erect habit, with the stem usually being branched from the base. It has cylindrical, fleshy and spine-tipped (hence prickly) leaves. The stems and leaves are glaucous green or, often, reddish, forming red 'carpets' on the sand. The flowers are green and stalk-less and are usually solitary or in clusters of 2-3, forming more or less dense spikes.

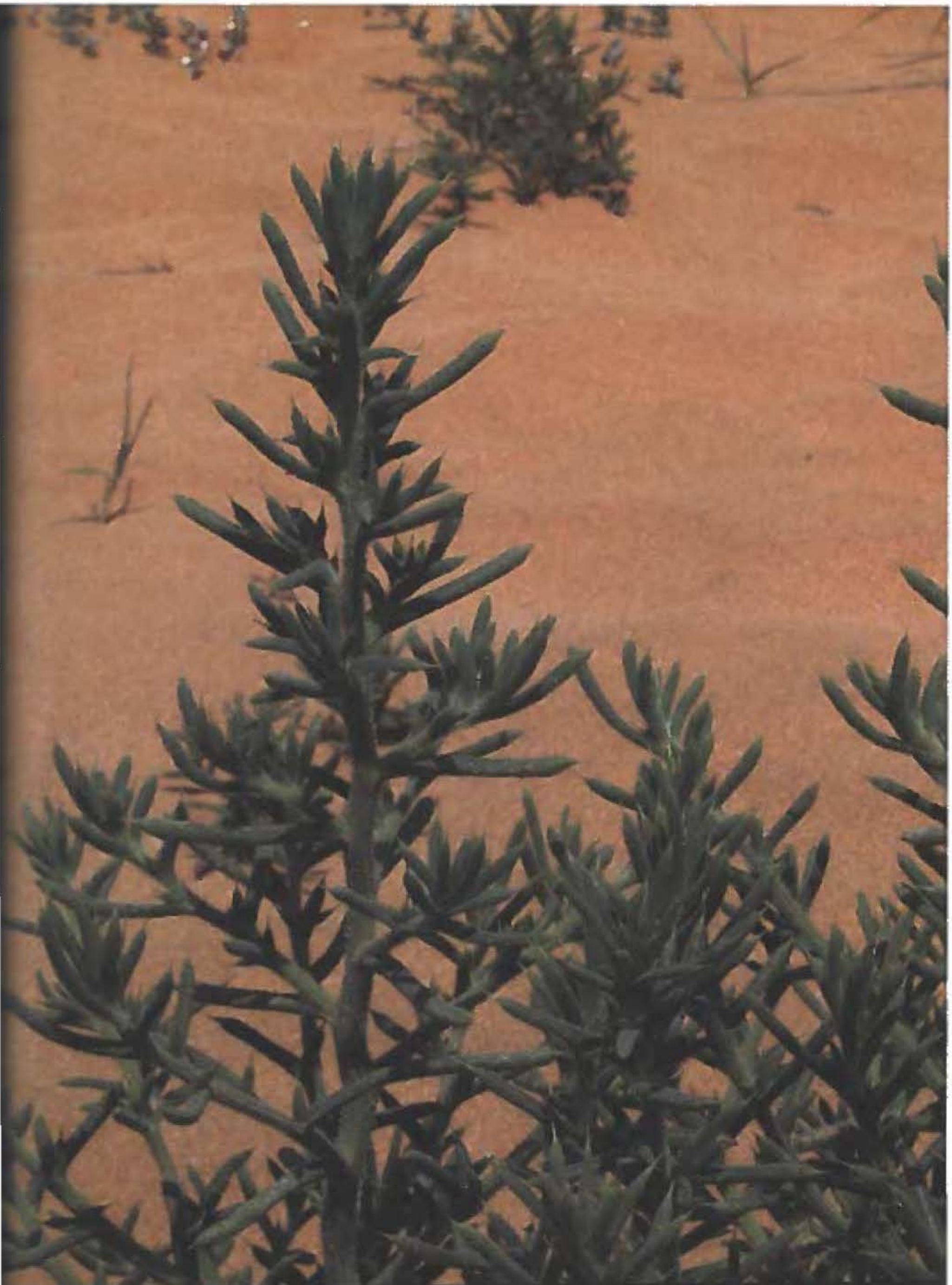
Flowering: mostly from May to October, although its flowering is quite irregular, and often depends on the environmental conditions it is thriving in. The fruits are tough with a broad transverse wing or ridge. In autumn, when the fruits mature, it dries up, breaks at the base and is blown away by the wind, dispersing the seeds in this manner.

This is one of the characteristic pioneer species, growing in the more sea- and wind-exposed dunal parts of beaches, often being among the first plants to be encountered on the beach. In this respect, it considered a coloniser, with modest properties of sand stabilisation, due its growth habit and much branching. This plant was in the past burnt for its ash, which is rich in soda (alkaline, hence *kali*), and was formerly used for soap and glass-making.

Distribution: almost cosmopolitan.

Distribution & Status in the Maltese Islands: a common coastal salt-loving species, found in almost all sand dunes and sandy beaches of the Maltese Islands.

Note: another saltwort species, the Smooth-Leaved Saltwort [*Salsola soda*, Malt.: *Haxixa ta' l-Irmied*] is also found in sand dunes and sandy beaches, although it usually occurs in areas with a higher supply of nutrients, such as in beaches with an adequate supply of Sea Neptune-Grass [*Posidonia oceanica*, Malt.: *Alka/ Posidonja*] residues.



Salsola kali L.
Prickly Saltwort — **Ħaxixa ta' l-Irmied Xewwikija** *(photo: Louis F. Cassar)*

Scolymus hispanicus L.
Family Asteraceae [= Compositae]

Name Derivative – Spanish Edible Thistle; *skólymos* = a term used for edible thistles, like artichoke [Gr.]; *hispanicus* = of Spain [Lt.], with reference to the former culinary use of this species in that country.

Vernacular Names – English: Sand Oyster Thistle/Spanish Golden Thistle; Maltese: *Xewk Isfar tar-Ramel*; Italian: *Cardo Colino/Barba Gentile/Piccolo Carciofo/Cardaburdue*.

A biennial erect and branched thistle, growing up to a height of 30-120cm. It has very stiff leaves that are divided into narrow, spiny-tipped lobes. The leaf blades continue all along the stem forming a 'winged' stem, whose 'wings' are similarly divided into spiny-tipped narrow lobes, thus rendering the plant extremely thorny. The golden yellow flower heads are borne terminally or laterally and are encircled by spiny leafy bracts.

Flowering: mostly from May to August. The fruits are one-seeded and bear 2-4 slender bristles to aid in wind dispersal.

This species is particularly resilient and is capable of growing in very disturbed and/or nutrient-enriched sand dunes, thereby colonising many disturbed sand dunes. It is especially frequent among dune grasslands on semi-consolidated and fixed dunes, but can also be found on "wasteland".

Distribution: Mediterranean countries and Macaronesian region.

Distribution & Status in the Maltese Islands: this species is present in most sand dunes and sandy areas of Malta, Gozo and Comino, and on dumped sand or sandy sediments more inland, as at *Il-Hazina* (Comino). However, it has declined or disappeared from a number of dunes due to habitat alteration or destruction, as at *Ramla ta' l-Armier* and *Ramla tal-Pwales* respectively. The species is considered scarce and vulnerable.

Note: another golden thistle, the Large-Flowered Golden Thistle (*Scolymus grandiflorus*, Malt.: *Xewk Isfar Kbir*) has been observed in the past in some Maltese sand dunes, although it is much rarer and is not exclusive to sandy localities. *S. grandiflorus* is differentiated from the Spanish golden thistle in being perennial, having larger flower heads (hence *grandiflorus*) and a continuous 'winged' stem (except at the base), unlike in *S. hispanicus*.

***Scolymus hispanicus* L.**
Sand Oyster Thistle — **Xewk Isfar tar-Ramel** *(photo: Louis F. Cassar)*

Silene colorata L.
Family Chenopodiaceae

Name Derivative – Coloured Catchfly; *silene* is a generic term of uncertain origin used for catchfly plants; *colorata* = coloured [Lt.], with reference to its coloured flowers.

Vernacular Names – English: Red Campion/Mediterranean Catchfly; Maltese: *Lsien l-Ghasfur*; Italian: *Silene Colorata*.

An annual herbaceous hairy plant. It usually has an erect habit, with the stem generally branched from the base. Its leaves are linear to spoon-shaped (called spathulate) and are often fleshy, although the extent of succulence depends on where it is growing. The stems and leaves are glaucous green or, often, reddish, forming red 'carpets' on the sand. The flowers are conspicuous, about 1-2 cm across, and are usually bright pink in colour, although occasionally, white or pink with white flowers do occur. These are composed of five petals, all of which are dissected into two parts (bifid), so appearing as if composed of ten petals, which are held on a cylindrical purple-striped tube of about 11-13 mm (sometimes more) in length.

Flowering: varies considerably, since the species is known to flower from late autumn (November) until early summer (June), with the bulk of flowering occurring in spring, between April and June. The fruits are in the form of a cylindrical capsule held on a stalk of approximately similar size (called the carpophore). The seeds held within the fruit are dark chestnut-brown and kidney-shaped, with two wavy ridges (or better, undulate wings) separated by a deep dorsal groove. This species is quite opportunistic, in that it is capable to grow in most habitats, not only sand dunes, but has probably originated from sandy areas. The forms growing on sand dunes tend to be more hairy and succulent than those growing in less harsh and more inland habitats.

Distribution: Mediterranean region.

Distribution & Status in the Maltese Islands: a common species, found in all sand dunes of the Maltese Islands.

Note: other important dune catchfly species include the Sand Catchfly [*Silene sericea*] and the Succulent Catchfly [*Silene succulenta*, Malt.: *Lsien l-Ghasfur tar-Ramel*]. *S. sericea* is a Western Mediterranean species that is very similar to *S. colorata*, with which it was often confused in Maltese dunes; it is mostly differentiated from *S. colorata* by a less pronounced groove and the absence of wings on its seeds. *S. succulenta* is also found on sand dunes elsewhere in the

Mediterranean region, as in parts of Italy and Tunisia, but is absent from the Maltese Islands. It is easily differentiated from the other two catchflies; it is a sticky/viscous perennial with a prostrate-ascending habit, succulent foliage and whitish-green flowers streaked with purple.

***Silene colorata* L.**
Red Campion — **Ilsien l-Għasfur** *(photo: Sandro Lanfranco)*

Sporobolus pungens (Schreber) Kunth
Family Poaceae [= Graminae]

Name Derivative – A plant with pointed leaves and seeds that are cast freely from the fruit wall; The generic name *Sporobolus* is composed of *sporá* = seed [Gr.] and *bállo* = throw, cast [Gr.]; *pungens* = sharp, pointed [Lt.].

Main Synonyms – *Sporobolus arenarius* (Gouan) Duval-Jouve

Vernacular Names – English: Sand Dropseed/Sand Dropwort; Maltese: *Nigem tar-Ramel*; Italian: *Gramigna delle Spiaggie*.

A creeping perennial grass, glaucous in colouration. Stems compressed, bearing stout, erect branches from which short, rigid, pointed leaves emerge in a distichous fashion (i.e., occurring in ranked patterns along two rows). These leaves are convolute at the apex, i.e. they roll up to avoid water loss and sand blasting. The species is rhizomatous, bearing long horizontal creeping rhizomes that are capable of spreading extensively beneath sand, and releasing, at intervals, new stems. The minute hermaphrodite flowers occur in small ovoidal panicles of 3-4 cm.

Flowering: essentially a summer-flowering species, between June and September. The seeds are eventually cast away freely from the fruit wall (hence the names dropseed or dropwort). *Sporobolus pungens* colonises the exposed parts of dunes and grows in dense stands on flat patches in front of mobile embryonic dunes, fore-dunes and exposed yellow dunes, often representing the first perennial vegetation strip on sandy beaches.

Distribution: Mediterranean and Macaronesian region.

Distribution & Status in the Maltese Islands: this species is widespread and found on all three main islands of the archipelago, being frequent on almost all areas with sandy or similar loose substrates.

Note: a similar grass, the Bermuda Grass [*Cynodon dactylon* (L.) Persoon, Malt.: *Nigem*], is also present in Mediterranean sand dunes and is especially important in some sand dunes of the Maltese Islands, as at *Ramla tat-Torri*, where it characterises some of the back-dune areas. This grass, which is a low creeping greyish perennial with greyish foliage, forms extensive 'carpets' and is also efficient in sand stabilisation. It is recognised from *Sporobolus* from its inflorescence, which is typified by 3-7 narrow and spreading terminal branches, each about 25-50 mm by about 2 mm wide. Moreover, the Bermuda Grass is not exclusive to sandy areas, and is essentially a weed, capable of growing in most habitats, including cultivated fields.

Sporobolus pungens (Schreber) Kunth
Sand Dropseed — **Niġem tar-Ramel** *(photo: Edwin Lanfranco)*

Tamarix africana Poiret
Family Tamaricaceae

Name Derivative – African Tamarisk. *tamaricis* = tamarisk [Lt.] and *africanus* = of Africa, African [Lt.], because of its predominant North African distribution.

Vernacular Names – English: African Tamarisk; Maltese: *Bruka*; Italian: *Tamarice Africana*

A medium-sized tree or large shrub, 2-6 m high that is usually semi-deciduous. The trunk is woody, with a rough, greyish bark and numerous branches, forming bushes when the species is younger. The leaves are small, scale-like and glabrous. Flowers usually white, on short pedicels, forming dense thick spikes of 4-8 mm in diameter. The flowers are borne laterally from woody branches of the previous year, sometimes appearing before the leaves.

Flowering: Spring-flowering, between February and May, although sometimes its flowering period extends until August. At the end of the flowering period, the dense white inflorescences turn into wool-like, dull yellow to brown spikes, due to the presence of tufts of hair on the seeds. The species grows mostly along watercourses (including valley bed streams and saline marshlands), especially near the sea. In the Maltese Islands it characterises the local back-dunes, where it occurs at ecotones between saline marshlands and sand dunes. It tolerates sea-spray considerably, also because of the presence of salt glands that exude excessive salt collected from available groundwater sources.

Distribution: South-western Mediterranean, including North Africa and Dalmatia.

Distribution & Status in the Maltese Islands: the only native tamarisk of the Maltese Islands, found in Malta, Gozo and Comino. It is overall rare in the Maltese Islands in its native form, and is found backing most of extant sand dunes, as at *Ghadira*, *Ramla tat-Torri*, *Ramla tal-Mixquqa* (Malta); *San Blas* and *Ramla l-Hamra* (Gozo); and *Il-Qala ta' Santa Marija* (Comino). The extant trees at *Ramla tat-Torri* are very old, although they are often vandalised.

Other species: The non-native French tamarisk [*Tamarix gallica*, Malt.: *Bruka Franciza/Bruka r-Roza*] and the Feathered Tamarisk [*Tamarix parviflora*, Malt. *Bruka r-Roza*] also occur on Maltese sand dunes, and are recognised in the Maltese Islands from the native *T. africana*, via their smaller pink inflorescences and different flowering period. *T. gallica* is more glaucous in colouration and has five pink petals on each of its flowers, whilst *T. parviflora* only four. Both are in full bloom in early summer [May-June], when *T. africana* is past its flowering period and is shedding its seeds. Moreover, *T. africana* may be in full bloom when the two other tamarisks are still in the deciduous phase.

Note: all tamarisks are legally protected in the Maltese Islands via Legal Notice 12 of 2001, published by virtue of the Environment Protection Act (Act XX, 2001).

Tamarix africana **Poiret**
Tamarisk — **Bruka** *(photo: Alfred E. Baldacchino)*

Other dune grasses

Apart from the aforementioned *Ammophila littoralis*, *Elytrigia juncea*, *Sporobolus pungens* and *Cynodon dactylon*, a number of other grasses [Family Poaceae (= Graminae)] may also occur on sand dunes, many of which are quite characteristic.

Cutandia maritima (L.) Richter

[= *Sclerochloa maritima* (L.) Sweet; *Triticum maritimum* L.]
English: Sand Fern-Grass; Maltese: *Kutandja*
A minute annual grass, 10-40 cm high, with prostrate to ascending stems and small, usually linear, leaves. The inflorescences bear branches that are triangular in section with 5-9 flowered spikelets, some 8-12 mm long. Flowers between March and June. It is known from *Ghadira*, *Ramla tal-Mixquqa*, *Ramla tat-Torri* and *Ramla l-Hamra*, but has declined in extent, particularly in the former locality. Rare and vulnerable with a restricted distribution in the Maltese Islands.

Lagurus ovatus L.

English: Harestail-Grass, Maltese: *Denb il-Liebru/Denb il-Fenek*
An annual grass with one or few erect stems and an unmistakable dense, oval, whitish, hairy panicle not unlike a rabbit's tail (hence the vernacular names). Flowers between March and May. Very common in the Maltese Islands; although it is essentially an opportunistic species elsewhere, it appears to form part of the Maltese sand dune community.

Triplachne nitens (Gussone) Link

[= *Agrostis nitens* Gussone]
English: Sea Nit-Grass; Maltese: *Mustacc il-Qattus tal-Bahar*
An annual grass with caespitose stems and a dense, cylindrical panicle. Flowers between March and May. It is very rare, vulnerable and is on the decline, with a restricted distribution in the Maltese Islands and the Mediterranean. It has been reported from *Ghadira*, *Bahar ic-*

Cagbaq, *Ramla ta' l-Armier*, *Ramla tal-Bir*, *Ramla tal-Qortin* and *Ramla tat-Torri*, but has disappeared from most of these localities. It is also known from other localities with sandy substrates.

***Bromus* spp.**

English: Bromes; Maltese: *Bunixxief*

Various species present on dunal areas. In general, bromes have multi-flowered spikelets that are more-or-less flattened. At least three annual brome species occur in Maltese sand dunes: the Great Brome [*Bromus diandrus* Roth, Malt.: *Bunixxief Kbir*]; the Compact Brome [*B. madritensis* L., Malt.: *Bunixxief Vjola*] and the Ripgut Brome [*B. rigidus* Roth, Malt.: *Bunixxief tal-Bahar*], the latter being a particularly important dune component, especially at *Ramla l-Hamra*. These brome species are frequent to very common and are characteristic of disturbed areas; indeed, these are also typical of semi-consolidated sands, often forming dune grasslands.

***Vulpia fasciculata* (Forsskål) Fritsch**

English: Dune Fescue; Maltese: *Hortan tar-Ramel*

An annual grass, 10-60 cm high, with ascending to erect stems and small, linear, often in-rolled leaves. The inflorescences are very narrow and elongated, simple or branched in the lower part, bearing 2-3 flowered spikelets, about 12-16 mm long and arranged one-sidedly. Flowers between March and May. This grass is somewhat frequent in the Maltese Islands and, although it shows a marked preference for sandy soils, it is not confined to sand dunes. Nonetheless, it is often under-recorded due to superficial resemblance with *Bromus rigidus*. The species has been reported from the dunes of *Gbadira*, *Ramla tal-Mixquqa* and the various dunes of the *Marfa* Peninsula in Malta, *Ramla l-Hamra* in Gozo and *Il-Qala ta' Santa Marija* in Comino.

A note on extinct and doubtful species

Ammophila littoralis (Beauvois) Rothmaler

English: Mediterranean Marram Grass; Maltese: *Birrun/Qasba tar-Ramel*
Status: Possibly Extinct

The possible extinction of *Ammophila littoralis* from the Maltese Islands is quite a complex issue. *Ammophila littoralis* was known from *Ghadira*, the sand dunes within the *Marfa* Peninsula (like *Ramla ta' l-Armier*, *Ramla tal-Qortin* and *Ramla tat-Torri*) and *Ramla tal-Pwales*. The sand dune of the latter locality was probably destroyed or heavily degraded upon construction of the coastal road through the dune, which no doubt led to altered beach-dune dynamics with a consequent loss of sand and, consequently, habitat.

Ammophila disappeared from *Ghadira* well before the 1970s and way before sand deposition was interrupted by the construction of the new thoroughfare, as also prior to considerable human-associated disturbance and severe habitat modification that took place in the eighties. Its disappearance from the *Marfa* Peninsula, however, seems attributable both to human interference and a reduction in sand deposition, particularly since this species had already naturally declined in extent throughout the area prior to its complete disappearance (Lanfranco, pers. comm., 2001). *Ammophila littoralis* is most vigorous in mobile dunes, but if sand supply is suddenly interrupted or sand accretion is too slow, its growth is known to slow down due to root failure. Subsequently, the plants may die soon after, later to be replaced by other grasses (Packham & Willis, 1997; Bird, 2000); this loss of vigour has been attributed to various reasons, notably poor aeration, mineral content deficiency, competition for nutrients and water, toxicity, natural senescence, etc. (Packham & Willis, 1997). Bulldozing and other works, coupled with an *Acacia saligna* afforestation plan in the late 1970s and early 1980s has removed the best remaining population of *Ammophila littoralis* at *Ramla tat-Torri*. The species was last reported from *Ramla ta' l-Armier* (Briffa, pers. comm., 2001), where it disappeared due to human influence. It has not been seen for over a decade.

Calendula maritima Gussone

English: Sea Marigold; Maltese: *Suffejra tal-Bahar*
Status: Possibly Extinct
Calendula maritima [= *C. suffruticosa* Vahl subsp. *maritima* (Gussone) Meikle] was reported from *San Giljan* and *San Pawl il-Bahar* by GRECH DELICATA (1853) and from *Marsaskala* by GULIA (1869), and not found again since. SOMMIER & CARUANA GATTO (1915) remarked that the material found in the indicated areas belonged to the related *Calendula fulgida* Rafn. [= *C. suffruticosa* Vahl subsp. *fulgida* (Rafinesque) Ohle]. Unfortunately, due to lack of herbarium material, it is difficult to ascertain which species was actually recorded by GRECH DELICATA (1853) and GULIA (1869), especially since the dunal habitats in question must have either disappeared or were already degrading during the time of Sommier & Caruana Gatto (1915).

Calendula maritima is very distinct from *C. fulgida* and other marigolds of the *C. suffruticosa* group in that its leaves are succulent and conspicuously glandular-pubescent, which features are absent from other Central Mediterranean marigolds of the *C. suffruticosa* group[15]. Moreover, *Calendula maritima* is known from beaches with algal depositions and *Posidonia* banquettes in Sicily (PIGNATTI, 1982c), a habitat similar to the "*arenosis maritimis*" of Grech Delicata, while *C. suffruticosa* s.l.[16] (excluding *C. maritima*) does not occupy the same habitat; therefore, the Grech Delicata identification is likely to be the correct one.

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[15] Excluding the Maltese records, *Calendula maritima* Gussone is a threatened Sicilian endemic (Conti *et al.*, 1997; Pavan Arcidiaco & Pavan, 1992; Pignatti, 1982c; Walter & Gillett, 1998).

[16] Including, the shrubby marigold [*Calendula fulgida* Rafinesque, Malt: *Suffejra-Kbira*] and the Sicilian marigold [*Calendula sicula* Gussone non DC. (= C. *suffruticosa* Vahl subsp. *gussonii* Lanza; *C. fulgida* Rafinesque var. *melitensis* Sommier & Caruana Gatto), Malt.: *Suffejra ta' Malta*], a Hyblaeo-Maltese endemic.

Crucianella maritima L.

English: Sand Crosswort; Maltese: *Krucanella tar-Ramel*
Status: Possibly Extinct/Possibly Doubtful
Recorded by Forsskål (1775) and Brenner (1838), without any mention of locality, by Grech Delicata (1853) from the "*arenosis maritimis*" of *Sliema* and Lanfranco (1971) from "rocky places near the sea", as at "*Abrax*". The records by Brenner and Lanfranco are certainly referable to the Rock Crosswort [*Crucianella rupestris*, Malt.: *Krucanella ta' l-Irdum*].

This species, which is conspicuously absent from the Maltese Islands, is characteristic of back-dune areas, together with *Ononis natrix* subsp. *ramosissima* in the Central Mediterranean region. However, no herbarium specimens of Grech Delicata's *Crucianella maritima* could be located (Lanfranco, pers. comm., 2000) and the records of Forsskål (1775) could not be verified through this study. In this sense, Sommier & Caruana Gatto (1915) ascribed the records of Grech Delicata (1853) from a 19th century *Sliema* sandy beach [i.e. before the area was significantly developed] to the frequent, and closely related, *C. rupestris* Gussone. However, *Crucianella rupestris* is not a dune species but a rupestral one, and is never found on sand, but only in contiguous rocky zones (unlike the indication for *C. maritima* of Grech Delicata: "*in arenosis maritimis*").

Helichrysum sp.

English: Everlasting; Maltese: *Sempreviva*
Status: Doubtful
Penza *in* Haslam *et al.* (1977) refers to the occurrence of the Cliff Everlasting [*Helichrysum rupestre* (Rafinesque) DC., Malt.: *Sempreviva ta' l-Irdum*] at *Balluta*. This species is not known from the Maltese Islands, where it is vicariated by the rupestral endemic Maltese Everlasting [*H. melitense*, Malt: *Sempreviva ta' Għawdex*]. Owing to the lack of appropriate habitat for both the aforementioned *Helichrysum* in *Balluta*, the record possibly refers to the related *H. italicum* (Roth) Don s.l. or *H. stoechas* (L.) Moench s.l., which may

have occurred there as planted, or as relicts of the dunes that might have characterised that area.

Launaea resedifolia **(L.) Kutze**

Status: Possibly Extinct

This species was reported as rare, from Gozo, by Gulia (1869), without any mention of any specific locality, although these records are possibly attributable to *Ramla l-Hamra*. It has probably disappeared due to disturbance or obliteration of its habitat, although the possibility of a misidentification cannot be excluded; unfortunately, no herbarium specimens are available. The records of Borg (1935), fide *Penza*, from *Wied Babu*, which are also unsubstantiated (no herbarium specimens were located), are probably a misidentification in that this locality, a coastal coralline limestone *wied* fringed by sheer cliffs, does not support any sandy habitat.

Matthiola sinuata **(L.) R. Brown**

English: Sea Stock/Sand Stock; Maltese: *Gizi tar-Ramel*

Status: Doubtful

A coastal species, also known from sand dunes in many European countries, which, although recorded, is conspicuously absent from the Maltese Islands. Its habitat is referred by GULIA (1874c: 379) as "sandy sea coast" and by SOMMIER & CARUANA GATTO (1915: 80) as "*nelle arene marine*" (i.e. in maritime sands).

Its records from Malta, by BRENNER (1838), GRECH DELICATA (1853), DUTHIE (1874), GULIA (1874b) and BORG (1927) are from areas as diverse as *Dwejra*, *Hagret il-General* and *Wied Hesri*. At least in the former two localities, the Maltese Stock [*M. incana* subsp. *melitensis*, Malt.: *Gizi ta' Malta*] is particularly frequent. SOMMIER & CARUANA GATTO (1915) did not observe this species, whilst HASLAM *et al.* (1977) limit themselves to previous records. Hence, these records are possibly a misidentification for the recently described *Matthiola incana* subsp. *melitensis*, an endemic rupestral species not known from sand dunes.

Ononis variegata **L.**

English: Sand Restharrow

Status: Possibly Extinct

This species was previously reported from *Marsaskala* (GULIA, 1875b) and *Ramla l-Hamra* (DUTHIE, 1874, 1875a,b; and subsequent authors). It has disappeared from *Marsaskala* long ago, since SOMMIER & CARUANA GATTO (1915) did not record it. It was lately known only from *Ramla l-Hamra*, but was not recently encountered, and was last observed reliably in 1984, when it was last reported by Michael Briffa (pers. comm. 2001).

Orobanche clausonis **Pomel**

English: Glandular Broomrape; Maltese: *Budebbus ta' San Pawl*

Status: Possibly Extinct

Found by SOMMIER & CARUANA GATTO (1915: 244) at "*San Paolo a mare*", without any reference to its host or habitat. Whilst very probably collected from the littoral zone, it is uncertain whether this was within the sandy beach [*Ramla tal-Pwales*?] or rocky area. According to Beck (in Sommier & Caruana Gatto) our plants refer to the forma "*parviflora*".

Paronychia **spp.**

English: Nailworts

Status: Possibly Extinct

Includes the Silvery Nailwort [*Paronychia argentea* Lamarck] and the Capitate Nailwort [*P. macrosepala* Boissier],both of which have not been reported for decades. These plants are known from sand dunes and rocky coastal localities. *P. argentea* was also reported from the maritime sands of *Sliema* by GRECH DELICATA (1853).

Pteranthus dichotomus **Forsskål**

English.: African Pteranthus

Status: Endangered in the Maltese Islands, Possibly Extinct from Sand Dunes

This species, for which Malta is the only known European station has been recorded "*in arenosis et argillosis*" (in sands and clays) by GRECH DELICATA (1853), who reported the species from the, presently non-existent, *Marsa* dune. Although extinct from Maltese sand dunes, it was recently rediscovered by Tabone along clay slopes in the limits of *Mgarr* (Gozo).

Trigonella maritima Delile

English: Sea Fenugreek/Sea Trigonella; Maltese: *Fienu tal-Bahar*
Status: Possibly Extinct
Found by GRECH DELICATA (1853) from the "*campis maritimis*" of *Bieb il-Gzira*. No herbarium records exist.

Valerianella microcarpa Loiseleur

English: Small-Fruited Cornsalad; Maltese: *Valerjanella tar-Ramel*
Status: Possibly Extinct
This species was previously recorded from the sandy beaches of the Marfa Peninsula as *V. puberula* (SOMMIER & CARUANA GATTO, 1915), and was recently known only from *Ramla tat-Torri*, its last haunt, from where it has seemingly disappeared in the late 1980s (LANFRANCO, 1989) as a consequence to the construction of illegal buildings and general disturbance which affected the dune in question.

Other taxa

Apart from the above taxa, a number of dune species are conspicuously absent from the Maltese Islands; these include, amongst others, the Sand Catchfly [*Silene succulenta* Forsskål s.l.] and the Sand Star-Thistle [*Centaurea sphaerocephala* L. s.l.]. The absence of the latter is also anomalous, because of the presence in Maltese semi-consolidated to fixed dunes of the *Centaureo-Ononido ramosissimae* association, which is locally based on *Ononis natrix* subsp. *ramosissima*, *Lotus cytisoides* s.l., *Scabiosa maritima*, *Euphorbia terracina*, *Pancratium maritimum* and *Erodium laciniatum*, and is characterised by the absence of *Centaurea sphaerocephala* and *Crucianella maritima*.

5 threats, management constraints & conservation of Maltese dunes

contents

5.1 threats, risks and impacts

Like much of the Mediterranean region, the coastal zone in the Maltese Islands has been subject to anthropogenic activities since its settlement by humans. Various anthropic activities have affected the biota of coastal locations over the seven thousand or so years of colonization through agricultural activities. Notably, the clearance of sclerophyllous vegetation for crops and reclamation, grazing of sheep, goats and pigs, terracing of the slopes, irrigation, the deliberate use of fire, leaching of animal waste, fertilizers and pesticides, are foremost among those activities that have impacted negatively on the ecology of the Maltese Islands.

Only a mere handful of sites, of a formerly much larger number of known dune sites, are considered extant, of which only one locality in Gozo, *Ramla*, still supports a fairly complete sand dune vegetation, with a relatively complete zonation pattern. Another locality, *Ramla tat-Torri*, still supports a variety of dune species, with a similar, but reduced and much degraded, zonation. The other extant dunes are all highly degraded, mostly due to human interference. Other sandy beaches are known or have been known to harbour some form of dune flora; in some cases, the past extent of these dunes is not well known. Of these areas, a considerable number are either heavily eroded or have been totally obliterated as a result of human influence.

Indeed, the human agency is a key factor that has had a considerable influence on the islands' ecology over the millennia. In more recent times, the relatively high population density of the islands, coupled by a large number of overseas visitors (more than three times the resident population in recent years) has had a profound negative impact, where land-use is concerned. In particular, the use of sandy beaches for recreational purposes, practically round the clock in the summer months, by both locals and visitors alike, is one of the main reasons for the overall degradation of local sand dunes.

The main threats and impacts identified on Maltese sand dunes are highlighted below. These are largely similar throughout Europe and the Mediterranean region (BEJARANO PALMA, 1997; BOURNÉRIAS *et al.*, 1990, 1991, 1996; MAYER, 1995), although, in a sense, amplified in the Maltese Islands due to the significantly high population density coupled by a considerable visitor transient population. It may be pointed out that risks, threats and impacts affecting sand dunes may include any activity that alters the sensitive equilibrium of the beach-dune system or lead to a change in its dynamics. Topographic alteration, landscape modification or changes in the hydrology of the region may affect adjacent marshland, valley systems and sediment fluxes, and, as a consequence, negatively influence dunal habitats since they are inter-dependent with the afore-mentioned elements. Moreover, a number of beach-cleaning methods are known to disrupt beach-dune interaction, as also damage sand dunes *per se* and the supporting floral community.

5.1.1 Agriculture:

Related activities have had a negative impact on dunes wherever cultivated fields competed for space with coastal dune components and sandy beaches. Examples include *Ramla* (Gozo), *Ghadira*, *Gnejna* and the Marfa Peninsula; all the retro-dunal zones are nowadays predominantly agricultural, although some have since been abandoned or 'developed'. The practice of reclamation for agriculture must date back considerably, considering that dunes (and marshes) occur in relatively productive catchments. Indeed, Abela (1647) and Agius De Soldanis (undated, however, between 1712 & 1770) confirm that this practice existed during the 17th and 18th centuries respectively. For example, whilst writing about the island of Comino, Abela (1647) adds that *"l'isoletta 'e ridotta 'a coltura"* [*translation*: the island is reduced to cultivated land]. A recent study confirms that cultivated fields lie at the back of the dunes and marsh of *Il-Qala ta' Santa Marija* (CASSAR *et al.*, 1999). On the other hand, when referring to *"Ginen tà Ramla"* (Gozo), Abela (1647) refers to *"vigne, canneto, e ficaie"*. De Soldanis (undated), writing about *"Ramla"* (Gozo), states that "in 1729, Grand Master Manoel, planted in this sandy region a large number of grapevines which produced six hundred Italian *scudi* worth of grapes annually" (as quoted from the translation by MERCIECA, 1999).

Agriculture is probably the main cause for the absence of mature dunes with coastal woodlands in the Maltese Islands. Stevens & Baldacchino (2000) ascribe to agriculture, among other factors, the lack of junipers and coastal woodlands (typical of mature dunes) from the Maltese Islands. Sommier (1916), also ascribed the lack of *Juniperus phoenicea* to the human agency.

Intensive agriculture may also explain the absence of other vegetation types typical of retro-dunal communities, such as those typified by *Centaurea sphaerocephala*, *Crucianella maritima* and *Helichrysum stoechas* s.l. Moreover, agriculture may also be responsible for the increase in nitrophilic vegetation in Maltese dunes due to the uncontrolled use of fertilisers by farmers that leads to the 'eutrophication' of sand, favouring nitrophilic species.

5.1.2 Tourism-related development:

A major economic activity for the Islands "generating one third of the island's hard currency revenue" (MAP, 2000) which is directly as well as indirectly responsible for much of the degradation on the coastal zone, including dunal regions. As much as 94% of tourist accommodation facilities are located in coastal areas (MALLIA *et al.*, 1999; MAP, 2000), with most developments being concentrated along coastal stretches in the areas of *San Pawl il-Bahar*, *Sliema*, *San Giljan*, *Paceville* (the latter includes *Il-Bajja ta' San Gorg*) and *Marsaskala* in Malta, and *Marsalforn* and *Xlendi* in Gozo (MALLIA *et al.*, 1999; MAP, 2000).

5.1.3 Inappropriate land-use:

Another important aspect that has affected sand dunes and sandy beaches in the Maltese Islands is improper land utilisation. This can be noted over practically all the Maltese dunes. As stated earlier in the text, many sandy beaches together with their accompanying dune assemblages have been almost totally obliterated, as a result of landscape alteration or interference with elements important to dune dynamics and development.

5.1.4 Road construction:

Roads to facilitate access to sandy beaches have also had a negative impact on beaches and related nourishment processes. Testimony of this is *Ghadira*, where a main thoroughfare, which connects the Mellieha region with the Marfa promontory further north, separates the beach from the dune. The road that skirts *Ramla tat-Torri* has also facilitated aeolian erosion, particularly after works carried out in March 1998 (STEVENS, 1998). Many sandy beaches bearing dune flora found along the NE coast of Malta, like *Bahar ic-Caghaq* and possibly *Ghadira s-Safra* and *Salini* have been very negatively affected by the construction of the coast road in the mid 20th Century. Roads were also constructed on former sand dunes as at *Little Armier* and *Ramla ta' l-Armier*.

In addition, whole beaches have been practically obliterated as a result of the construction of high rampart-like embankment walls, built around natural embayments as supports for coastal roads. Apart from deflecting waves, these smooth-surface embankments do not allow sediment to reach the shore and instead allow sand particles to move offshore. Possible cases include *Balluta*, *Il-Bajja ta' Spinola*, *Il-Bajja ta' San Gorg* (l/o *San Giljan*), *Ramla tal-Pwales*, *Ramla ta' San Gorg* (l/o *Birzebbuga*), and *Qbajjar*, among others. A number of beaches have also been adversely affected by structures, which obstruct sand movement and dune formation. Such is the case at *Ramla tal-Bir*, *Il-Qala tal-Mistra* and *Ramla tal-Mixquqa*. These structures (e.g. kiosks) often impede the movement of terrigenous sediment so vital for beach-dune nourishment. Kiosks were also a problem at *Ramla* prior to their re-location by the then Environment Protection Department some years ago.

5.1.5 Urbanisation:

Urban development, particularly during the last four decades, has been responsible for the despoliation of various interesting valley systems, either as a result of direct construction or through dumping of building waste. In the more distant past, other valleys with associated sandy beaches and possible dunes, especially those in the areas of *Sliema*, *Gzira*, *Msida*, *Valletta* and the Three Cities, were practically obliterated. The *Ta' Xbiex–Bieb il-Gzira* dune-marsh system probably disappeared following the urbanisation of the *Sliema-Gzira-Msida* area. Sandy beaches at *Bugibba* may also have suffered the same fate. The construction of coastal fortifications during the time of the Knights and, later, British rule, must have caused a dramatic reduction in the supply of sediment via valley systems to the sea.

5.1.6 Trampling:

Although dune vegetation is usually avoided, because of the spiny foliage of, for example, *Eryngium maritimum* and *Echinophora spinosa*, it is largely still negatively affected by trampling. Dune crests stabilised by *Elytrigia juncea* are sensitive to excessive trampling; in fact, dunes are subject to erosion if the plants, which stabilize the sand are not allowed to recover (Mayer, 1995). Trampling pressures can mostly be evidenced at *Ramla tat-Torri*, *Ramla tal-Mixquqa* and *Ramla* in Gozo, owing to considerable number of visitors during the summer season.

5.1.7 Offroading & access to motor vehicles:

The destructive effect of trampling is often coupled with the disastrous effect of offroading vehicles, especially in the dry season. Four-wheel drive vehicles and motorcycles occasionally cause havoc to dunal areas. In recent years, such activities were noted at *Gnejna* and *Ramla* in Gozo, despite the fact that the practice is illegal in these areas.

5.1.8 Camping activities and caravans:

Caravans, semi-permanent and permanent, as well as temporary camping activity are among the most damaging of activities, where dunes are concerned. The very fact that vegetation is removed or covered by temporary or permanent structures and trampled upon leads to a loss of flora, often important for dune forming processes or for their intrinsic value.

Caravans, owing to their semi-permanent or permanent nature, are relatively more damaging to dune or garrigue communities. This practice is evident at *Ramla tat-Torri* and *Little Armier*. Some caravans are placed on wooden or concrete platforms that are utilized to level off the ground, as a consequence of which, dune flora is crushed beneath and destroyed.

Official camping sites also result in the direct loss of natural habitat, as has been the case at *Il-Qala ta' Santa Marija* in Comino, where the original marsh-dune vegetation was cleared to make way for a camping site.

5.1.9 Car parking:

Car parking also poses a serious threat. For example, the sand dunes at *Ramla tat-Torri* have, in some peripheral areas, been transformed into a parking lot. Other dunal areas have, over time, also been converted into parking facilities so as to cope with the flood of motorised beach visitors during the summer months. A case in point is the mouth of *Wied ix-Xlendi* up to *Ramla tax-Xlendi*, which have been practically built over and developed into a car park/urban promenade. Other coastal locations that were affected in a similar manner include *Bahar ic-Caghaq*, *Little Armier*, *Ghadira* and *Gnejna*.

5.1.10 Dumping and fly-tipping:

The amount of litter that finds itself on sandy beaches and sand dunes, as well as in the countryside in general, is often of considerable proportion. Despite the presence of litterbins, used barbecue charcoal, for instance, is frequently left semi-buried in the sand. Although this is much the case with most beaches and accompanying dunes, the problem is more acute at *Ramla tal-Mixquqa*, *Gnejna*, *Ramla ta' l-Armier* and *Little Armier*. Perhaps the worst situation is that faced by the *Ramla ta' l-Armier* dunes, where the flora is characterised by few resilient dune species and opportunistic taxa, mainly because of the impact of dumping and fly-tipping.

5.1.11 Sand removal:

Although not apparently a major problem in Malta (with the possible exception of *Ramla ta' l-Armier*), this was apparently common practice at *Ramla* in Gozo until recently and may still occur on an irregular basis. Cases of sand removal have been reported from *Ramla* in the past, as is the case cited in Anon. (1992), where the illegal removed sand was reported to be "used to make cement for works carried out on a public garden under construction at Qbajjar Road, *Marsalforn*".

5.1.12 Facilities to collect valley run-off:

Any topographical alteration, which impacts negatively on fluvial sources, may have serious implications on dune development and dynamics. The farming community is often responsible for the construction of dams across valleys or the excavation of large pits for artificial pools, usually on clayey substrates, within catchment areas.

No doubt, this practice, which entraps freshwater runoff, will limit the amount of water and sediment reaching the beach-dune system. Although this is prevalent in most beach systems, it is considered to be a major problem at *Gnejna*. A prolonged imbalance in sediment budgets may thus affect the delicate equilibrium on which dune dynamics depend. Changes in a region's hydrology may also influence vegetation patterns. A case in point is *Ramla* in Gozo, where marshland vegetation with various *Juncus* and *Carex* spp., was known to occur in the past. This has seemingly disappeared, probably due to altered hydro-dynamics in the region, possibly as a result of over-extraction of water.

5.1.13 Banquette removal:

Posidonia banquettes are, in themselves, very important habitats, but are also crucial in providing organic nutrients to sand dunes, and often provide an adequate substrate for driftline and embryo dune development. According to Mayer (1995) *Posidonia* banquettes are important for the structure and the construction of the beach itself. This is primarily the case at *Ramla*, *Ramla tat-Torri* and *Ramla tal-Mixquqa* dunes, where sandwich-like layers of *Posidonia* remains and sand form the substrate for seaward-most dune communities.

Unfortunately, some beaches, known for their rich biodiversity, are often 'cleared' of their banquettes; examples include *Ramla tal-Mixquqa*, and *Ramla ta' l-Armier*. This regrettably destroys many rare plant and animal communities.

5.1.14 Plant removal:

Owing to their spines some plants, such as *Echinophora spinosa* and *Eryngium maritimum*, were removed in the past so as to make beaches more amenable to bathers, visitors and locals alike. Sporadically, such acts still occur as has happened in March 1998, when dune vegetation was cleared illegally, at *Ramla tat-Torri* and *Ramla tal-Mixquqa*, through the use of bulldozers. Moreover, flowers, and quite often the entire plant, of *Pancratium maritimum* are picked due to their ornamental nature (unfortunately, their flowering period coincides with the peak bathing season); this occurs particularly at *Ramla tat-Torri* and *Ramla*. Flower removal inhibits seed formation and may therefore be detrimental to local *Pancratium* populations. Removal or hard pruning of other species, including tamarisk trees, also occurs, as was the case at *Ramla tat-Torri* recently.

5.1.15 Beach-cleaning machines:

Beach-cleaning machines can have a severe impact on the vegetation as well as the fauna of the drift line, embryo dunes and foredunes, affecting plant and animal communities colonizing these areas. This method of non-selective cleaning may marginally favour annual plants, which set seeds before the first cleaning exercise takes place. The skimming rake and shovel of such machines have a lesser effect on plants with deep-lying rhizomes, such as *Sporobolus pungens* (MAYER, 1995), however, it is not so with numerous other plants whose rooting system is closer to the sand surface. Within some years, this treatment usually results in a strong reduction in biodiversity.

In the Maltese Islands, beach cleaning activities are mostly carried out manually, although small machines are sometimes used to level off sand, as at *Ramla ta' l-Armier*. The issue of mechanical beach cleaning at *Ramla l-Hamra* in Gozo was debated in 1993, as evidenced from various newspaper articles on the issue (e.g. ANON., 1993; CASSAR, 1993; SCHEMBRI, 1993; VELLA, 1993).

5.1.16 Drainage, dredging & alteration of habitat: Drainage of marshland regions has had a marked influence on sand dune dynamics in the Maltese Islands. Being topographically flat, marsh areas tend to be ideal for coastal development (urban and industry-related) and are also somewhat productive agriculturally (MAYER, 1995). These characteristics have favoured the reclamation of significant tracts of land through subsequent draining; *Marsa* and *Salini-Burmarrad* former marshes are a case in point. No doubt, the disruption of the dynamic processes would have had a negative impact on nearby beaches and supporting dune areas.

The same goes for urbanization. Habitat alteration resulting from urban sprawl poses yet another major threat to marsh-dune-beach systems. For example, the development of the *Sliema-Gzira-Msida* region would have negatively affected the *Bieb il-Gzira–Ta' Xbiex* marsh-dune-beach system, and possible similar systems in the *Sliema* and *Msida* areas.

In more recent times, the dunal area at *Ghadira* was negatively affected as a result of a suite of developments. The road construction, tourism-related development, kiosks, and inappropriate afforestation and management schemes at *Ghadira* have grossly degraded the sand dunes, which now constitute a mere fraction of a past flourishing dunal system. Moreover, inadequate management has led to the setting up of a tree nursery within the former dune remit, which forms a part of the nature reserve.

5.1.17 The impact of alien species:

Various alien species have been introduced into the Maltese Islands, some of which succeeded in naturalising and, in some cases, even invading sand dune areas. Perhaps the most serious invaders include *Arundo donax*, *Carpobrotus edulis*, *Oxalis pes-caprae* and *Vitis vinifera*. *Arundo donax* infiltrates sand dunes from nearby catchment areas, either by way of run-off waters that transport rhizome fragments or as a result of abandonment of agricultural land. In such situations, this species displaces native plants and associated wildlife as a consequence of the massive stands it forms.

Invasion by *Arundo donax* is particularly serious at *Gnejna*, *Ramla l-Hamra* and *Ramla ta' l-Armier*, and has recently appeared at *Ramla tat-Torri* following some excavations to facilitate seepage of water to the sea.

Carpobrotus edulis, a native of the Cape Peninsula, South Africa, was introduced mainly due to its ornamental nature (Fox, 1990; Quezel *et al.*, 1990). It is often planted in coastal regions where it tends to form large carpets that are quite attractive when in flower. This species and the related *Carpobrotus acinaciformis* are a serious threat to the flora of many Mediterranean coasts, including cliffs (Schembri & Lanfranco, 1996). According to Bournérias *et al.* (1991): "*constituent une grave menace pour la flore côtiere, litteralement étouffee puis éliminée*". This species has colonized Maltese sand dunes through a number of ways. This includes deliberate planting (as in the case of *Ramla tal-Mixquqa* and *Bahar ic-Caghaq*) and vegetative propagation via valley-water run-off or discarded garden remains (as at *Ramla tat-Torri*). It may also be dispersed by birds in seed form (Mayer, 1995).

Oxalis pes-caprae, by far the commonest plant in the Maltese Islands (Schembri & Lanfranco, 1996), is another invader from the Cape (South Africa) (Fox, 1990; Quezel *et al.*, 1990). This geophyte is particularly aggressive, and reproduces mostly vegetatively via bulbils (Guillerm *et al.*, 1990), displacing nearby native vegetation in the process. It is quite frequent in most sand dunes, although it does not from extensive carpets as in other, more inland, habitats.

Vitis vinifera is extensively cultivated worldwide, wherever the climate is conducive to grape production. Once naturalised it colonises various habitats owing to its climbing/clambering mode of growth and tends to cover dune vegetation with ease. At *Ramla* in Gozo, it has been known to suffocate natural vegetation over relatively large tracts of land. American vines utilised as grafting stock, including *Vitis vulpina*, have also become naturalised in a number of areas, including *Ramla* in Gozo.

Other species, like the various *Acacia* spp. (mainly *A. saligna*) and *Agave* spp. (mainly *Agave americana*), are also particularly invasive. especially on the *Marfa* promontory and *Bahar ic-Caghaq* respectively. *Acacia saligna* is quite a serious threat to the dune vegetation at *Ramla tat-Torri*, where regenerating seedlings are often removed by Malta Environment and Planning Authority staff. *Lavatera arborea* is also on the increase and is particularly invasive at *Ramla tal-Mixquqa*. *Chrysanthemum coronarium*, an indicator of disturbed areas, is dominant in some degraded dunes, as at *Gnejna*.

5.1.18 Afforestation:

Inappropriate or badly planned and managed afforestation schemes are as damaging as the introduction of alien species, even though the species may not necessarily be alien to the area involved. Most afforestation schemes on sandy beaches were perpetuated in the past mostly in an attempt to stabilise sand. Lately, a number of ornamental trees have been planted, especially alien species such as *Washingtonia filifera* and *Phoenix canariensis*, on or near sandy beaches with a view to create a pseudo-tropical ambience.

Species utilized to stabilize sand usually include various *Acacia* spp. and *Tamarix* spp., the former being mostly of Australian origin. Hence, *Tamarix africana*, *Tamarix parviflora*, *Elaeagnus* cf. *angustifolia* and *Acacia saligna* were introduced into *Ramla tat-Torri*, which, in the process, eradicated *Ammophila littoralis*.

Similarly, *Tamarix gallica* and *T. africana* were planted on the sand dunes of *Ramla* in Gozo and *Il-Qala ta' Santa Marija* in Comino to augment the existing native *T. africana* and *Vitex agnus-castus* stands. *Acacia saligna* and various *Tamarix* spp., among many others, were analogously planted at *Ghadira*, while *Pinus halepensis*, *Cupressus sempervirens* and *Tamarix africana* were used for *Ramla tal-Mixquqa*.

Introduced trees alter soil nutrient and pH conditions, and create a high degree of shade thus altering the microclimate of an area. In terms of dune dynamics and biodiversity conservation, the introduction of trees on dunal areas poses a serious threat. In fact, afforestation of sand dunes often "results in almost total exclusion of the original vegetation" (STURGESS, 1992). At *Ramla tal-Mixquqa* and *Il-Qala ta' Santa Marija*, where trees were planted along most of the former dune, sand is rapidly being lost through erosion. This is probably due to the inability of main sand-binding species to grow or compete with other species in areas shaded by the introduced trees, also as a result of nitrophilic conditions created by the pines and tamarisks.

5.1.19 Fire and grazing:

Fire is a major problem for most local sand dunes, although it is most accentuated at *Ramla* and *Ramla ta' l-Armier*. In the former locality, fire was responsible for the decimation of a good population of *Ononis natrix* subsp. *ramosissima* in 2001.

Grazing by domestic animals, once very important due to the high number of goats and sheep on the island (BUSUTTIL, 1993), is now very limited and is mostly confined to *Ramla* in Gozo. Nonetheless, grazing pressure in the area is low, and certainly less than the values cited by Carter, of 0.3 - 0.6 sheep ha^{-1} (CARTER, 1988; as quoted by SAMMUT, 1995), as the optimum densities to retain a vigorous, diverse ecology.

5.1.20 Natural disasters:

Storms in the Mediterranean region can occasionally be quite violent, and may lead to the removal of stabilised sand. Such was the case at *San Blas* in Gozo, where the sand dunes of the area were practically destroyed by a violent storm in December 1988 (ANDERSON & SCHEMBRI, 1989). Strong wave surges together with valley waters carried away most of the sand, together with its dune flora. Storm impact is often exacerbated by certain constructions or consequent to vegetation clearance in nearby valley systems. A classical example of sand erosion by storm waters may be observed at *Balluta* and *Il-Bajja ta' San Gorg*. The little sand that remains in these localities is most susceptible to flood waters flowing downstream via the quasi-cleared beds of the *Wied Balluta* and *Wied Mejxu-Harq Hamiem* systems respectively. *Ramla* in Gozo is also susceptible to sand loss as a result of violent storms.

5.2 restoration and rehabilitation

Most of the above-listed activities largely stem from the fact that there is a general lack of enforcement (despite legal protection afforded), essentially, but not exclusively, due to limited human resources on the ground; this is coupled by a lack of environmental awareness across different strata of local society. In response to the rapid rate of development that has taken place in the Maltese Islands in recent decades, concurrent with widespread habitat degradation, there is an undisputed need for habitat restoration and rehabilitation to be undertaken with some urgency. The constant reminder that agriculture, urbanization and industry have dramatically reduced and fragmented the natural and semi-natural environment has initiated a belief that urban fringes, rural areas and degraded habitats can be revitalized by re-creating semi-natural areas that resemble natural ones, which over the years were lost. The idea would be to *reconstruct* if the character of the site had been dramatically altered, for example in the case of intensive farmland, or *restore* if the site still retains much of its original communities, but has experienced degradation.

Until recent years, opportunities for habitat reconstruction were usually limited to embellishment projects of small-scale areas, like derelict land restoration or urban renewal schemes. However, a much wider potential now exists as a result of a region-wide phenomenon that is agricultural land abandonment. In this respect, ecological communities can be 'engineered' so as to resemble natural or semi-natural assemblages of plants and wildlife, which are valued for their attractiveness or high conservation value. Likewise, in the towns and villages, particularly on the rural-urban fringe, there is an equally challenging scope for innovative landscaping using indigenous species, which carry conservation as well as aesthetic value. In addition, important habitats that have, over time, been restricted to mere pockets may be extended in size by encouraging land located adjacent to high quality communities to diversify through natural colonization and appropriate management. This method is known as the *duplication solution* (NEWBOLD in BUCKLEY [Ed.], 1989), whereby heavily degraded adjacent areas, such as intensively farmed land or land that has experienced significant disturbance, are rehabilitated through the recreation of 'near-to-natural' habitats. It is important to consider that these rehabilitated areas are, initially, no more than a supporting network for naturally existing habitats and communities. Such restored zones can be engineered to perform the function of *biodiversity corridors*, so badly needed in degraded and heavily frequented areas like, for example, the Marfa promontory where a number of small dunal sites occur.

Habitat restoration work may take place at either of two levels: *(i)* that of the single plant population, that is, transplanting plants of a single species (this, however, often fails to reproduce the site conditions desired or fails to integrate with other communities occurring on site); and, *(ii)* that of planting groups of species, which usually occur together in nature as part of a larger ecosystem.

Moreover, there are numerous reasons for habitat 'creation'. The aim is generally to establish semi-natural vegetation communities, which in some way resemble their natural counterparts, although not necessarily to re-create their full diversity. Widely differing views exist on how far this process should be taken. Objectives include the creation of visually attractive vegetation; the provision of educational and possibly scientific interest; the safeguard of rare species or scarce ecological communities; and, the construction of low maintenance landscapes. In either of these cases, the starting point is the habitat stereotype, that is, an image of the type of ecological community to be reproduced. The closer this corresponds to the original, the more complicated it will be to achieve.

Habitat reconstruction or restoration cannot only be applied to repair damaged habitats and accompanying assemblages (for instance, within and around quarry sites), or, on a wider scale, for landscaping schemes following urbanization, but can be fully utilized in nature conservation projects and within protected areas through, for example, the re-introduction of rare and localized species or of locally extinct species in reserves.

There are a number of habitat reconstruction techniques currently in use. These may be summarized as follows: ***habitat creation***, in this context used to indicate the *a priori* construction of interesting ecological communities; ***habitat transplantation***, where an original habitat is moved from a donor to a receptor site; and, ***habitat enhancement*** or ***diversification***, in which attempts are made to maximize the ecological potential of existing but degraded or impoverished habitats.

Sand dunes and the entire Maltese countryside for that matter have suffered considerable damage in the past years resulting in a significant loss of natural, cultural and historical heritage. As a habitat, Maltese sand dunes are critically endangered. Although also somewhat disturbed, *Ramla* is the best remaining example of local sand dunes. Notwithstanding this, the site requires sound management and regular monitoring in order to ensure its long-term conservation and protection. Other areas may be saved from further degradation through appropriate rehabilitation and restoration techniques. A number of sites such as *Gnejna* and *Ramla ta' l-Armier* may still be rehabilitated, while sites at *Ramla tal-Mixquqa* and *Ramla tat-Torri* qualify for urgent restorative action. Undeniably, more work would be needed for most other areas. Various rehabilitation and restoration techniques and methods may be utilized and experience in this area is rapidly growing.

Surrounding areas tainted by asphalt or concrete, such as at *Gnejna*, *Little Armier*, *Ramla tal-Mixquqa* and *Ramla tat-Torri*, can also be rehabilitated and/or restored, much in the same manner as has been done at *Devesa de l'Albufera* dunes in Valencia (Spain), where dunes had been partially recreated over an area that was practically flattened and covered with concrete (SANJAUME, 1992). Another site worthy of rehabilitation is *Il-Qala ta' Santa Marija* in Comino, where the need for some clear-felling (i.e. controlled thinning of the extensive tree cover) is evident. Resulting studies by Sturgess (1992), show that such processes are not so straight-forward and short-term, and may take a number of years until restoration of the 'natural' dune system is complete. This may be due to altered soil conditions (like pH and nutrients) and the increase of 'weed' species in the seed bank as a result of changed micro-climatic conditions caused by a somewhat dense tree canopy.

Rehabilitation of the *San Blas* dunes may also be attempted, although detailed site analysis may be required to decide upon the extent of intervention needed in the area. A similar experience occurred at *Ille-et-Vilaine* in France (REGNAULD & KUZUCUOGLU, 1992), where partial dune retreat and sand erosion came about following a severe storm in 1990.

Where restoration of dunal vegetation is concerned, many dune species can be propagated *ex-situ* with relative ease, and re-planted where these have become extinct (SCHULZE DIECKHOFF, 1992). Hence *Ammophila littoralis* can be reintroduced from Hyblean Sicily (which probably offers the closest genetic match with the Maltese Islands), while searches for seeds may be carried out in areas where certain species were known to exist and have recently disappeared.

Nevertheless, the overall lack of public awareness remains a major obstacle. Rehabilitation and restoration will have to be accompanied by strict law enforcement and regular site monitoring. Regrettably, the success of environmental projects is often compromised by a general lack of respect and awareness towards the sensitivity of coastal habitats. Unless urgent action is undertaken, most of our sand dunes, including *Ramla*, risk further degradation and possibly even their outright loss, particularly if current trends persist. In this respect, the numerous extinct sand dunes and dune species should be an eye-opener.

Regrettably, the foremost reason as to why nature conservation is insufficiently valued by society in general is due to the lack of adequate awareness, created through education systems, about the importance and benefits in sustaining ecosystems. Learning about nature conservation, that is, the appreciation and protection of natural landscapes and habitats, and supporting ecosystems, may be incorporated within the curricula of primary, secondary and tertiary education systems, as well as in public information and awareness programmes.

5.3 Integrating coastal zone conservation with socio-economic priorities

The problems that arise when planning for protected areas and their biota on small islands are as diverse as the islands themselves. In particular, when considering protection measures in an over-populated country such as Malta, and where partisan politics, at the various levels, play an important part in the local power arena of everyday life, conservation matters, often, do not feature too favourably on the socio-political agenda. However, it is because environmental problems are even more amplified in small island states, such as Malta, that conservation issues must be pursued with added vigour. It should, therefore, become an essential requirement within conservation programmes, given that the human population is constantly competing with the natural environment and its resources, that both conservation and the relationship of people to the environment is addressed in a manner which guarantees the use of criteria other than those based solely on socio-economic values.

Like their inland counterparts, coastal zone habitats cannot be divided into discrete segments to be conserved in isolation from their surroundings. Probably even more so than inland protected areas, coastal habitats are intimately connected to and affected by a large region of influence, including activities on both land and sea. On small islands in particular, development which takes place at inland locations may very well have an impact on coastal habitats; some examples of such inland activities include industrial and agricultural activity, road construction, tourist developments, etc. Likewise, adverse environmental impacts at sea (oil spills, dumping of waste at sea, etc.) can also have an effect on coastal habitats such as sand dunes. In this respect, one cannot ignore the wide range of impacts which may occur from further afield.

5.4 economics and management of conservation areas

Viewed only in economic terms, conservation may not compare favourably with other short-term exploitative alternatives, such as, for instance, tourist resorts and golf courses. However, if viewed as part of an integrated regional development scheme that includes qualitative values as well, a conservation area may have much greater long-term value. Qualitative analysis show that many well planned, and subsequently well managed, conservation areas prove to be the better long-term option for local economy and welfare (HEYMAN & BOB, 1993).

Another method of valuing conservation areas is to show how these can be utilized in a responsible manner as an alternative to the dominant economic model's method of extracting revenue through natural resources. One of the most promising economic benefits to be derived from conservation areas is ecological and cultural tourism. Where such tourism is feasible and managed well, it can generate a sustainable source of income for both local as well as national economies. A country like Malta, which has invested much in tourism and which can boast of a wealth of cultural heritage and, to a lesser extent, natural sites, can benefit enormously, given that its spatial/environmental planning and tourism strategies are interlinked through some degree of streamlining.

Environmental economics plays a key role in identifying natural resource management options for sustainable development. It is an essential bridge between the traditional techniques of decision-making and the more environmentally sensitive approach, now emerging (Munasinghe & McNeely, 1994). Just as public information programmes are used to build political support, environmental economics is increasingly used in policy analysis. It should be added however, that although economic analysis offers great potential for the setting of priorities objectively, it is nonetheless difficult to analyse an array of problems. In particular, this is because priority setting is a political element, and although socio-economic factors often influence the political process, in real-life situations, they do not carry much weight in the face of political and financial interests.

The use of cost-benefit analysis, where possible, and cost-effectiveness exercises when benefit estimates are not available, strengthen the analytical process. This is where monitoring and evaluation play an important role. By monitoring progress, one will begin to understand the magnitude of existing constraints and, as a result, implementation could be more effective. Consequently, existing strategies and/or policies may be revised as necessary. In this regard, it is important to ensure that environmental strategies as well as decision-making are consistent.

The conservation of endangered habitats, such as sand dunes, and the biota they support, can essentially be achieved if criteria for the selection of protected areas, as well as their consequent planning and management, are based on the systems approach. This methodology strongly encourages the concept of inter-disciplinarity, combining the natural sciences with the humanities and applied in practical ways by specialists in the field. Far from the historical, passive role of protection and control, environmental planning and management emerges as a professional activity, which demands integrative skills from the various disciplines involved. Well planned and meaningfully managed, conservation areas have an important role to play, for society at large, in raising an awareness of the interconnectedness between our natural and cultural heritage, and our future welfare.

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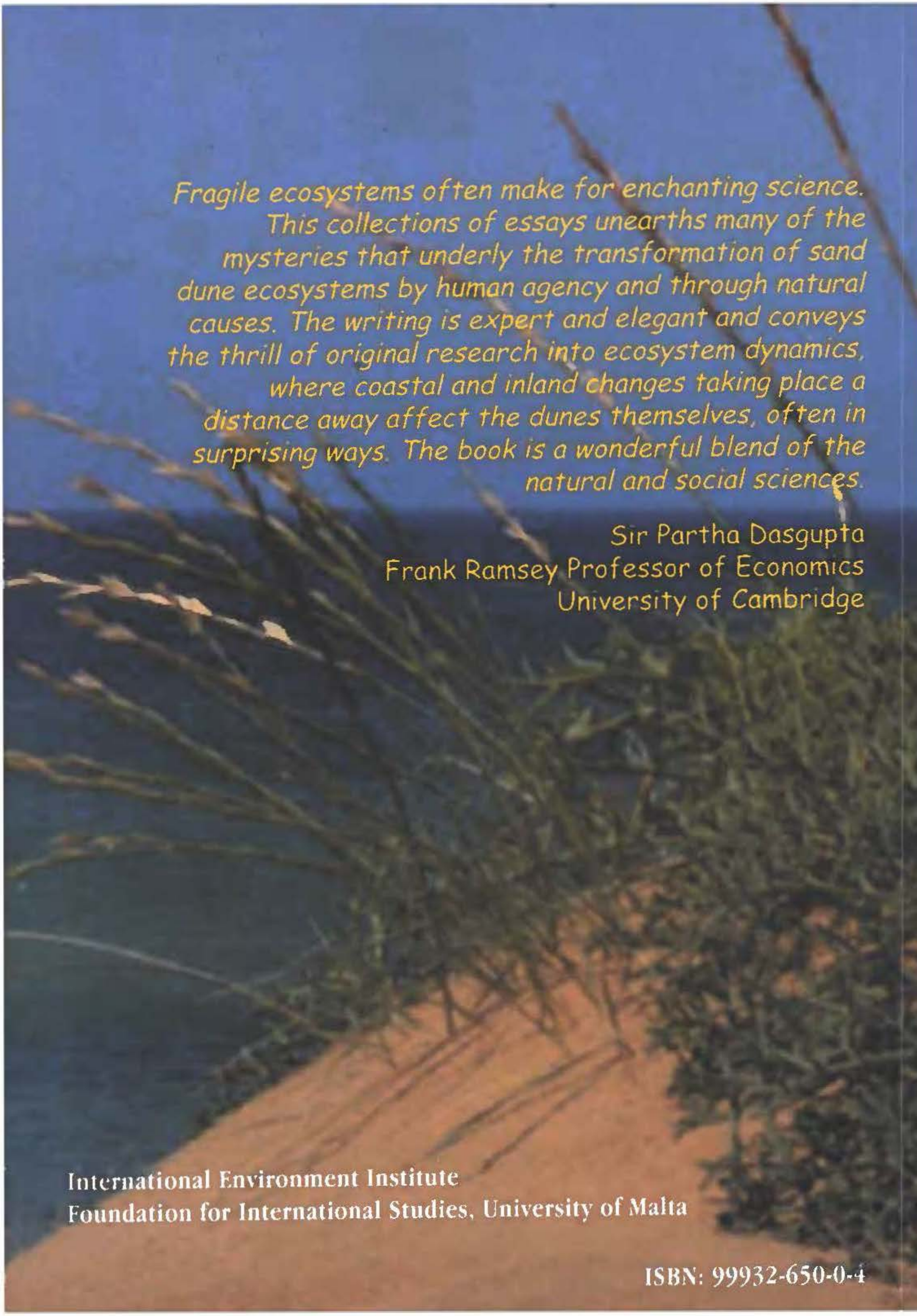

Fragile ecosystems often make for enchanting science. This collections of essays unearths many of the mysteries that underly the transformation of sand dune ecosystems by human agency and through natural causes. The writing is expert and elegant and conveys the thrill of original research into ecosystem dynamics, where coastal and inland changes taking place a distance away affect the dunes themselves, often in surprising ways. The book is a wonderful blend of the natural and social sciences.

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