VALLEYS

DISCOVERING MALTA & GOZO'S WATERCOURSES & THEIR VALUE TO SOCIETY

GOVERNMENT OF MALTA
MINISTRY FOR ENERGY, ENTERPRISE AND SUSTAINABLE DEVELOPMENT

RBMP LIFE MALTA

Life

PARKS MALTA

VALLEYS

DISCOVERING MALTA & GOZO'S
WATERCOURSES & THEIR VALUE TO SOCIETY

Foreword

It is an honour and distinct pleasure, on behalf of Parks Malta to release this book after three years of teamwork by many dedicated individuals, to bring together a collection of information and vivid pictures as we discover Malta and Gozo`s treasures through our watercourses and their value to society.

The idea of publishing such a book was to instigate more awareness, with regards to our natural geological and botanical wonder, as in life, when one becomes aware and appreciative of anything which is invaluable and priceless, one tends to be more conscious and caring in trying to conserve, preserve and enjoy what is so dear for the longest duration possible.

It is with such a notion, that Parks Malta through its team efforts, have embarked on taking the opportunity presented under the LIFE IP Project *Optimising the Implementation of the 2nd RBMP in the Malta River Basin District* (LIFE 16 IPE MT 008)[1], together with some of the nations most informed experts in the various natural scientific fields of study, present a comprehensive and informative appreciation of the invaluable gems our island is adorned with, better known by our Maltese locals as *Widien*. It is the main purpose of this book to showcase our *Widien*, together with the different historical artifacts and impressive structures, and the variety of flora and fauna species, housed within. Thus attaining a key deliverable within this project , that is to 'Sensitize the public on the intrinsic values of valleys and the importance of conserving their ecosystem-based functions and services'.

As a firm believer that education is the major catalyst in ensuring a broader contribution towards the protection of an ecosystem befitting the *Widien*`s environment, the idea of publishing this book with astonishing photographic pictures to provide a vivid experience, had my undoubted support and commitment to reach its objective - awareness.

[1] https://www.rbmplife.org.mt/

Such a publication aims to provide a sneak peek at our gems which one could encounter while walking past such watercourses, or even oversee what is not quite visible with the naked eye, such as the diverse habitat species. The intended message that this publication hopes to deliver is to make the society at large more aware and appreciative of the invaluable wealth of the natural diversity and historical structures for us to protect for generations to come as our ancestors have done previously for our enjoyment.

Finally, I would like to take this opportunity to extend my appreciation for the professional contribution to the respective authors, together with my dedicated colleagues both still engaged at Parks Malta and those that have moved on to other endeavours, but in any way have contributed to making this mission possible. Without their commitment, this publication could have never been achieved and to this I am immensely grateful.

To the reader, I hope it is to your satisfaction and enjoyment as it inspires a sense of pride and marvel in becoming more aware of the number of *Widien* hosting a variety of flora and fauna species snaking their way on one of the smallest islands in the Mediterranean Sea.

Adrian Attard

Director General
Parks Malta

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Contents

Damselfly species

Chapter 1

INTRODUCTION

An interconnected labyrinth of valleys, referred to locally as 'widien', meander their way through the Maltese Islands. They vary from broad, gently sloping formations, born out of tectonic movements, to narrow, deep, and steep-sided ravines that largely result from erosion. The widien are essentially seasonal watercourses, fed by runoff during the wet season and lying dry for most of the summer. There are a few exceptions, such as Wied il-Baħrija, where spring-flow supports a trickle of freshwater all year round.

These valleys provide a home for different species of fauna and communities of vegetation that are found only within watercourses and their immediate vicinity. These plant communities are known as riparian flora. There are two major types of riparian flora: hydrophytes, which are species that need to be fully or partially submerged in water, and non-submerged littoral flora, which grow mainly on the banks of the watercourses. Maltese valleys also host a number of other specialist plant species, such as those that thrive in rocky environments.

Throughout history, water in valley beds has attracted human settlement and agricultural activity. Malta's valleys have long been used as a source of irrigation and drinking water, as well as convenient waste disposal sites. Other common uses include transport routes, grazing and recreation.

The publication of this book, co-financed through the LIFE IP Project *Optimising the Implementation of the 2nd RBMP in the Malta River Basin District* (LIFE 16 IPE MT 008)[1], is intended to guide the reader to discover the Maltese islands' watercourses and their value and contribution to society.

The information provided is not only to create awareness of the rich diversity of flora and fauna but also on their vulnerability, and will hopefully raise awareness to reverse negative trends. Only through education and awareness to the greater public in hand with the authorities could such gems be preserved for future generations to enjoy.

To ensure a varied and holistic approach in the educative, appreciative and informative intentions of this book, a number of renowned professionals in the natural scientific field have come together to contribute from their different perspectives information on these unknown wonders that can be found throughout the Maltese islands.

Wied ta' l-Imselliet, Malta

[1] https://www.rbmplife.org.mt/

Spanish Sparrow

Wasp Nest

Moorish Gecko

Robin

Azure Stonecrop

Spurge Hawkmoth

Snails

Japanese Cheesewood

Wied tal-Ġnejna, Malta

Wied tal-Lunzjata, Gozo

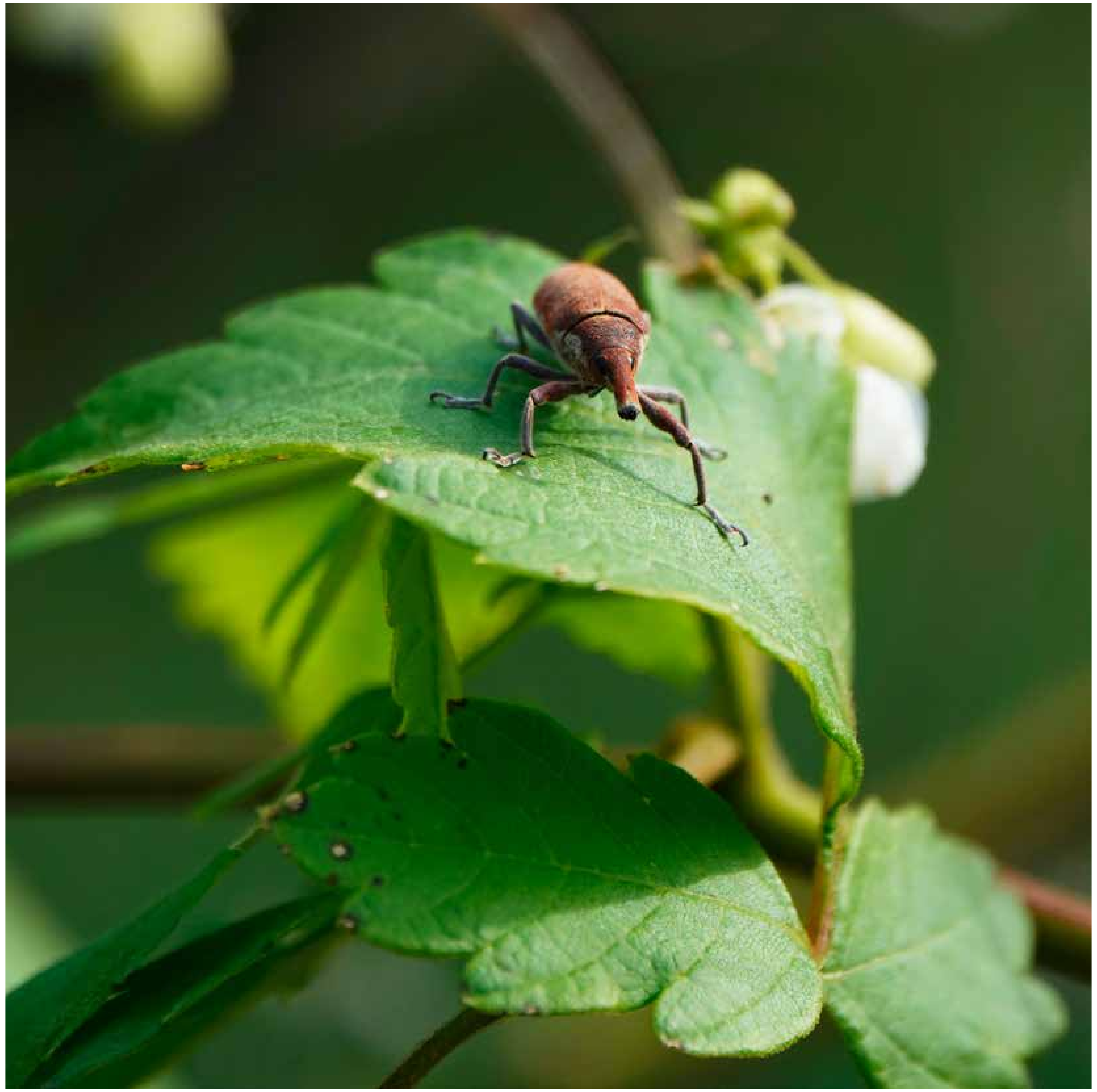
Banded Argiope Spider

French Daffodil

Native Flora and Fauna

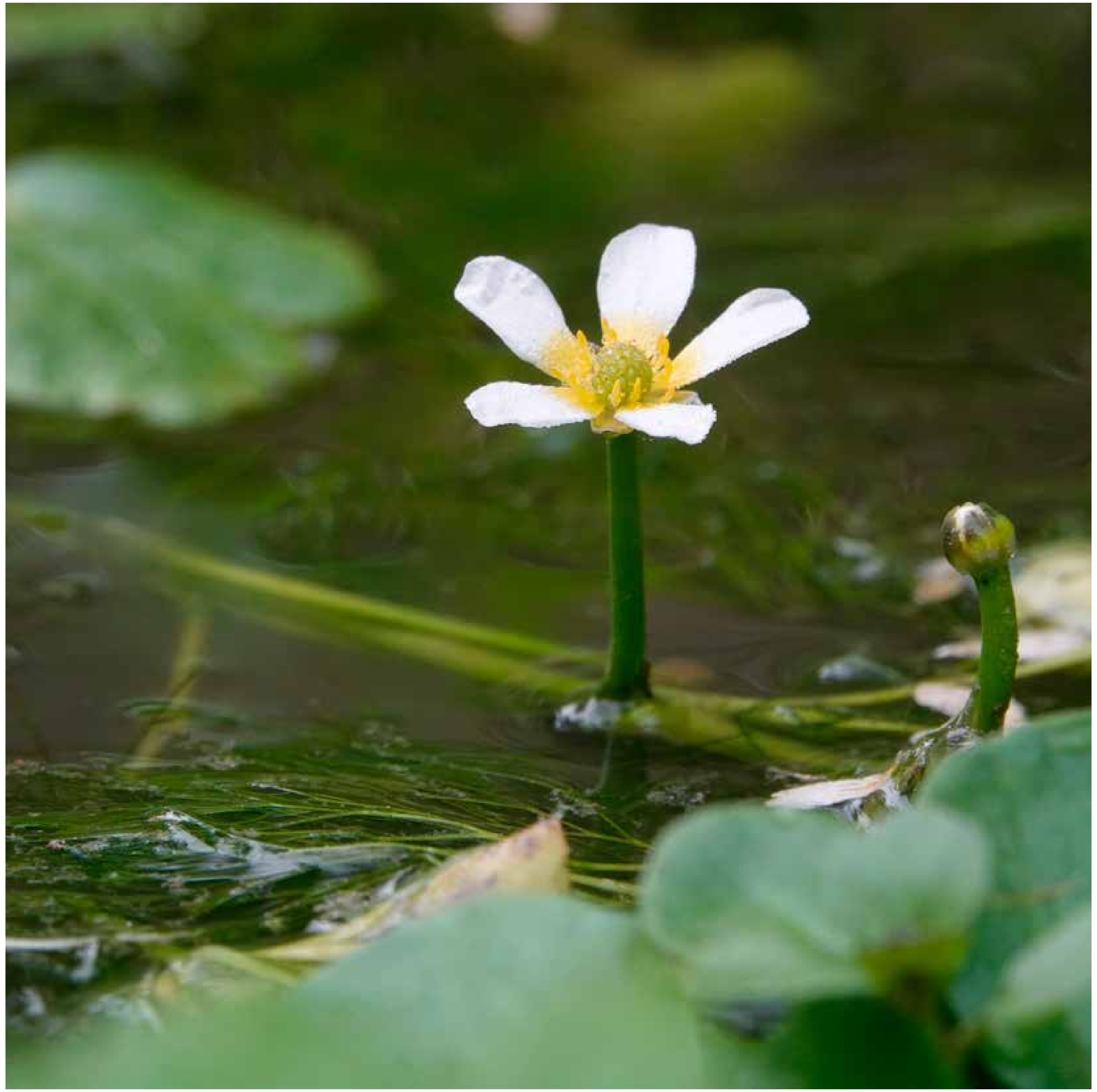
Maltese Freshwater Crab

Wied tal-Ġnejna, Malta



Elongated Bean Weevil

Native Flora and Fauna



Sanicle-leaved Water Crowfoot

Chapter 2

HOTSPOTS OF VEGETATION DIVERSITY WITHIN THE MALTESE ISLANDS

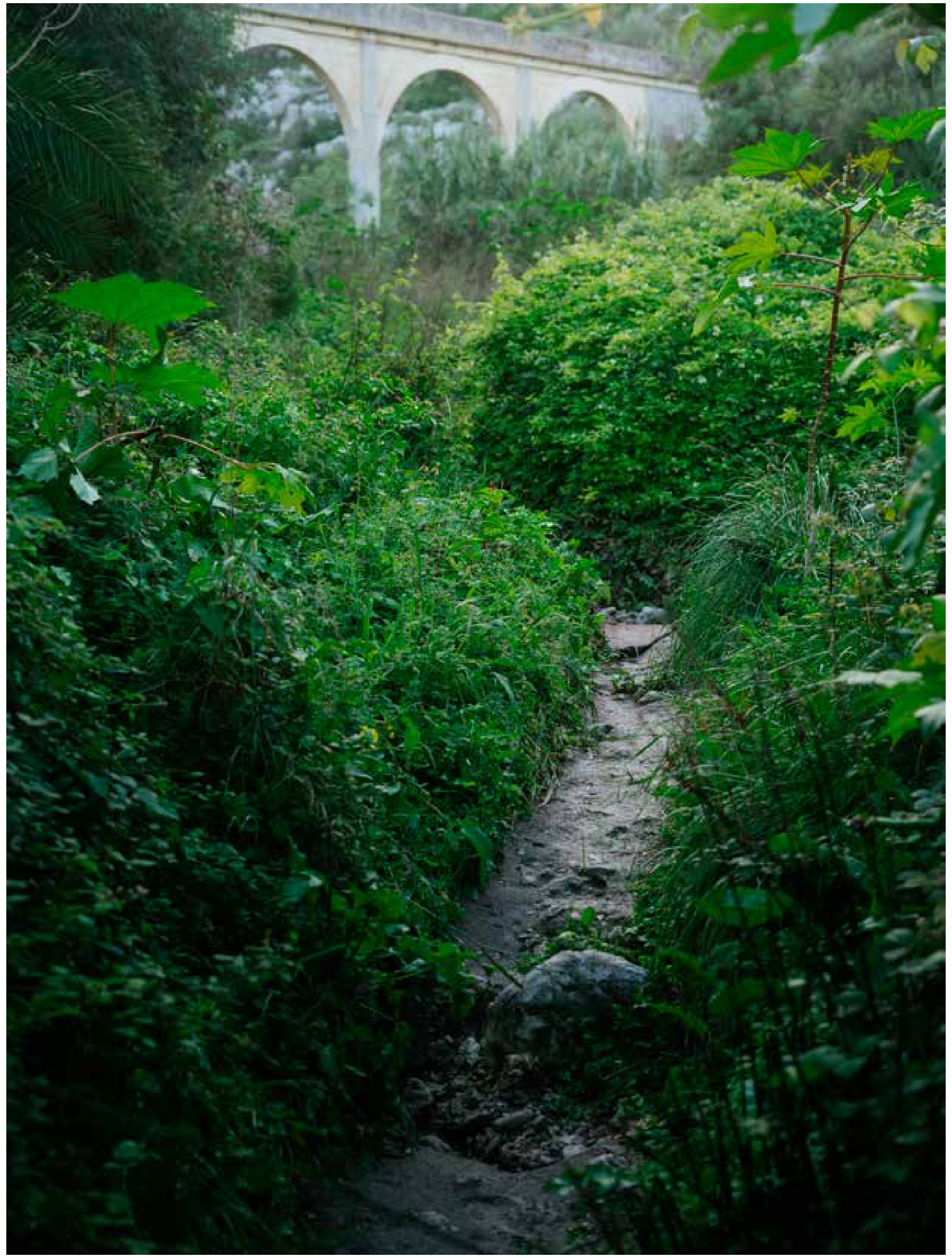
Dr Sandro Lanfranco and Ms Andrea Francesca Bellia

Plant growth and diversity are controlled by a large number of factors, including water availability, light intensity, soil depth, pH and salinity, the level of exposure to wind and the degree of human disturbance. The interaction between these factors creates a set of local conditions that favour certain species over others. Malta's valleys present a broad range of environmental conditions, where these factors vary dramatically over short distances. Changes in conditions along the length and across the width of the valleys interact with each other to form complex ecological units, capable of supporting a wide variety of plant species.

The nature of plant communities found along the valley sides is determined by two interconnected characteristics: the angle of slope and the land use. Gently sloping valley sides, such as those found in Wied Liemu, Wied tal-Imselliet and Wied il-Luq, have generally been transformed into agricultural land through terracing. This process eradicates the natural valley-side plant communities and replaces them with agricultural species. Conversely, valleys with steeper, rockier sides, such as Wied Żnuber, Wied Moqbol and Wied Babu, have typically never been agricultural. The valley side plant communities are therefore dominated by a natural mix of shrubs and cliff-dwelling specialists such as the Maltese Salt-Tree (*Salsola melitensis*), Maltese Sea Lavender (*Limonium melitense*), Maltese Cliff-Orache (*Atriplex lanfrancoi*) and Maltese Rock-Centaury (*Cheirolophus crassifolius*).

The valley bed is the most sheltered part of the system and where most water accumulates. Depending on the valley form, land uses, and the presence of dams or other modifications, streams or freshwater pools may form. Most Maltese valley beds can support a flowing stream for a period of days or weeks following heavy rainfall, but not usually for a whole wet season. Undergrowth species found along valley beds include Italian Lords-and-Ladies (*Arum italicum*), Friar's Cowl (*Arisarum vulgare*) and Bear's Breeches (*Acanthus mollis*), while the most humid and shaded areas may support Mediterranean Pellitory (*Parietaria lusitanica*). In some valleys, such as Wied il-Luq, the valley bed also hosts populations of White Poplar (*Populus alba*).

Aquatic habitats in valley beds promote a gradient of plant life, reflecting the adaptations of individual species. The central parts of the bed are covered with water most frequently, and for the longest durations. These zones are colonised by species with high water requirements, such as sedges, rushes, and reeds. Towards the margins of the valley bed, the frequency and duration of inundation drops. Aquatic plants are gradually replaced by amphibious species, and then by terrestrial plants tolerant of high soil moisture, such as Pennyroyal (*Mentha pulegium*) and Autumn Buttercup (*Ranunculus bullatus*). Further from the centre of the valley bed, soil moisture levels continue to fall, promoting colonisation by terrestrial plants unable to cope with prolonged periods of submergence.



Wied il-Għasel, Malta

Wied Għajn Riħana, Malta

Tree Spurge

Valley bed vegetation also differs between valleys. At Wied tal-Imselliet for example, the banks of the watercourse are colonised by Round-Headed Club Rush (*Scirpoides holoschoenus*) and Spear-Leaved Orache (*Atriplex prostrata*). The central portion of the watercourse hosts Common Water-Plantain (*Alisma plantago-aquatica*), Southern Cattail (*Typha domingensis*), Clustered Dock (*Rumex conglomeratus*), Scilly Buttercup (*Ranunculus muricatus*), Knotgrass (*Polygonum aviculare*), and Creeping Loosestrife (*Lythrum junceum*). Deeper areas contain submerged vegetation, including plant-like (*Chara)* algal species.

At Wied Żnuber, the valley bed is constrained by the very steep relief, leading to more shading. Valley bed vegetation includes dense stands of the invasive Great Reed (*Arundo donax*) interspersed with patches of maquis, which are dominated by Carob (*Ceratonia siliqua*) and Olive (*Olea europaea*), along with less common Lentisk (*Pistacia lentiscus*), Almond (*Prunus dulcis*), Fig (*Ficus carica*), Azarole (*Crataegus azarolus*) and Hawthorn (*Crataegus monogyna*).

Changes in the nature of plant communities along the length of the valleys are generally more subtle than those across their widths because the gradients in environmental conditions are less marked. In some of the shorter, coastal valleys, distance from the sea creates a noticeable gradient. In such cases, vegetation close to the valley mouth is characterised by salt-tolerant species. Often, human activity is the key factor leading to changes in the composition of plant communities along the length of a valley. Agriculture, rock quarrying, waste disposal, residential development, and many other activities create pockets of disturbance that are colonised by species differing from those in more natural, undisturbed parts of the valley. The plateaux flanking valley systems also exert an important ecological influence, by providing a pool of potential colonisers. This is of concern when the natural cliff plateaux have been modified into agricultural land or harbour alien species, which may then infiltrate valley communities.

Vegetation survey data show that almost half of the 1,306 higher plant species reported in the Maltese Islands[2] can be found within valleys[3]. When looking on the scale of a few square meters, the number of species per unit area does not differ significantly between valleys and the areas outside. However, because of the large variation in habitat types found within the valleys, when taken as a whole, valleys have a significantly higher number of plant species, and markedly different species compositions, when compared with the surrounding areas. This characteristic makes Malta's valleys important repositories for plant diversity, and therefore key targets for conservation and environmental management efforts.

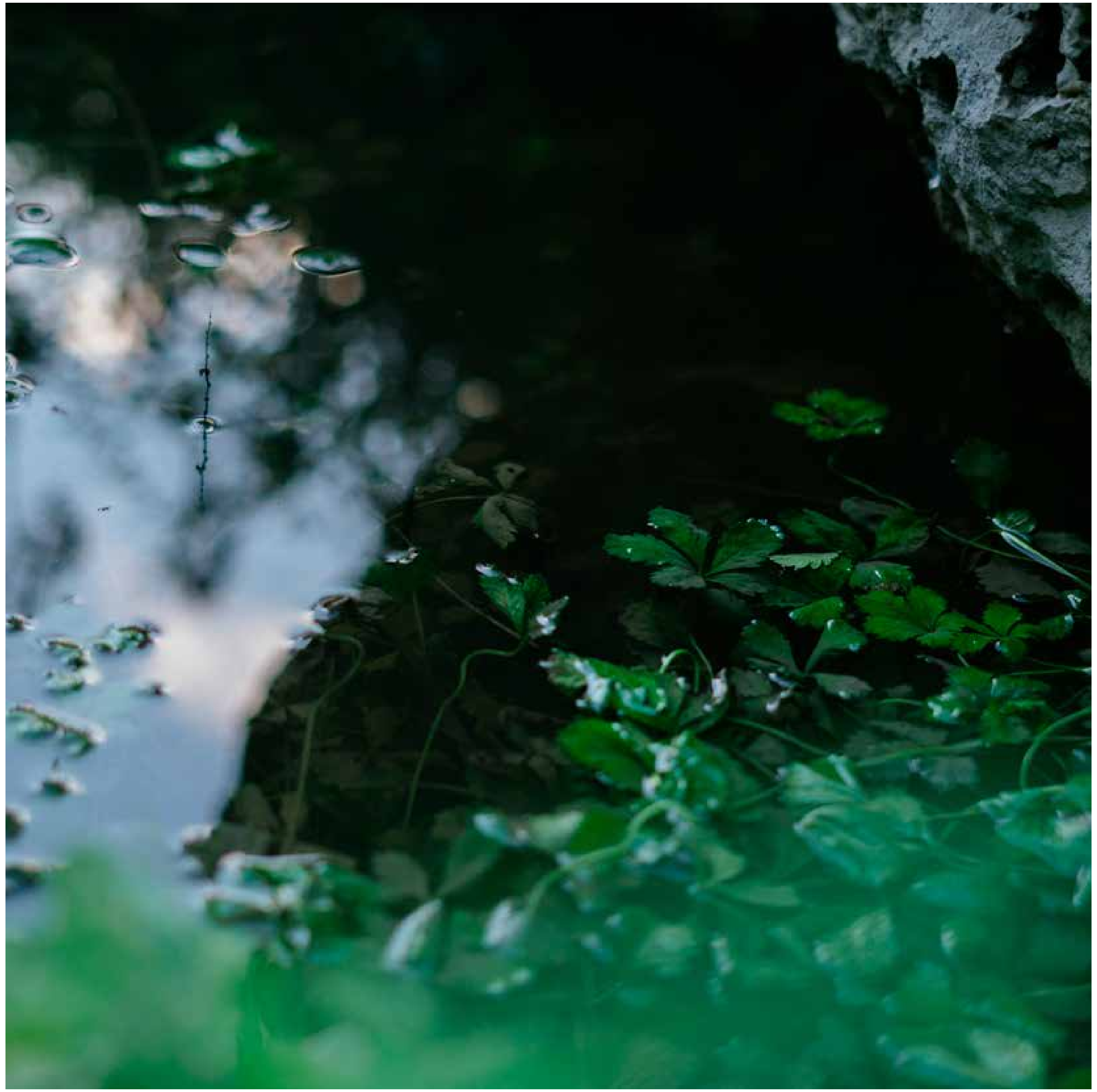
[2] Ellul, M. A. (2014). An annotated checklist of the vascular flora of the Maltese Islands. (MSc). University of Malta, Malta.

[3] Lanfranco, S. (1994-2019). Unpublished species lists; Lanfranco, S. and Bellia, A. F. (2019). Unpublished species lists.

Wied ta' San Niklaw, Malta

Indigenous Hawthorn

Invasive Flora



Watercourse at Wied il-Ghasel

Mastic Tree

Hawthorn at Wied il-Ghasel

Typical riparian vegetation

Wied tad-Dwejra, Gozo

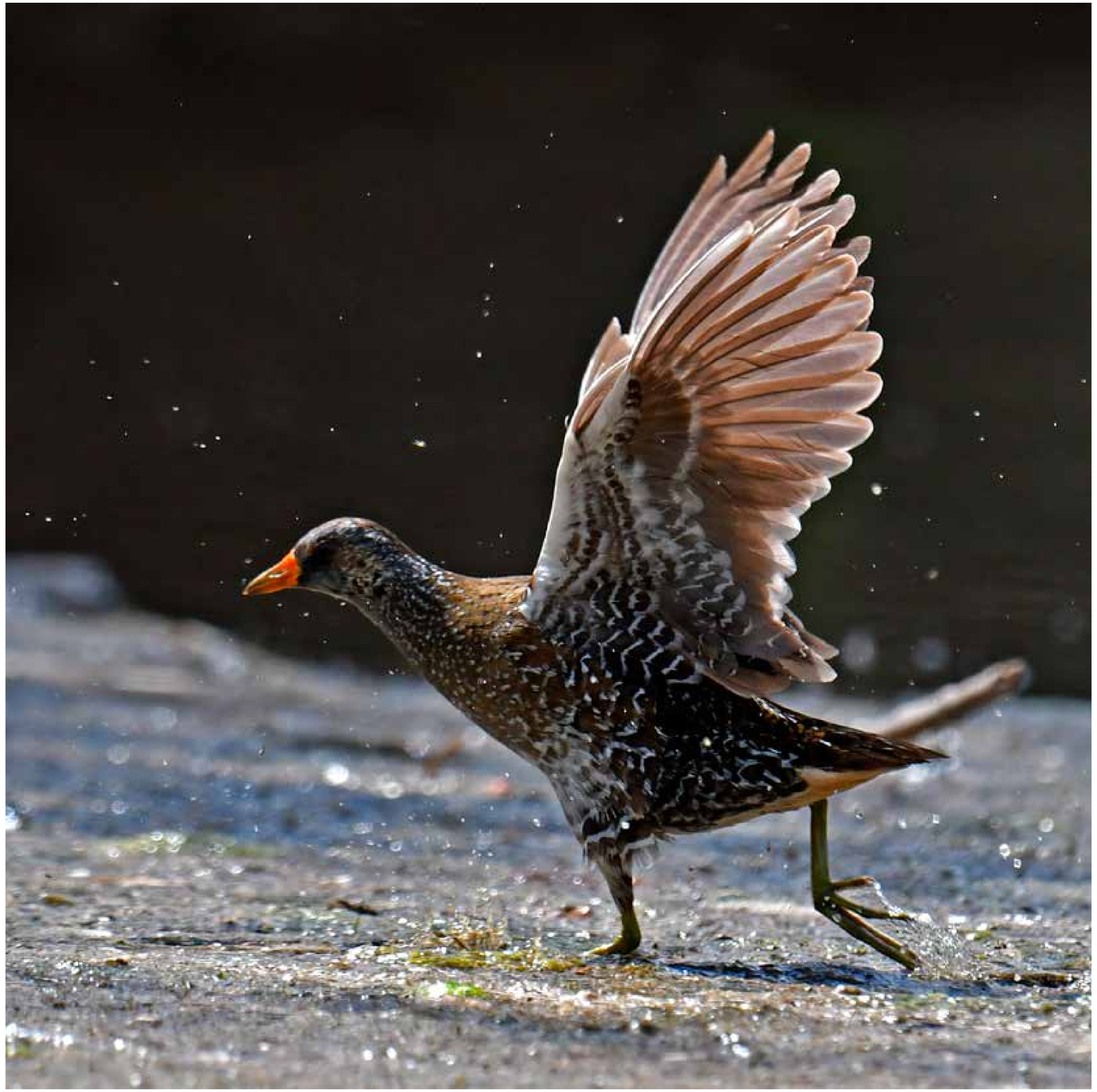
Wied tal-Mistra, Malta

Wied tal-Ġnejna, Malta

Almond Blossoms

Friar's Cowl

Southern Bullrush


Spotted Crake

Chapter 3

THE IMPORTANCE OF MALTA’S VALLEYS FOR BIRDS

Dr Natalino Fenech

A bird's eye view of the Maltese Islands reveals a large network of valleys, snaking their way across the landscape. The geomorphological and environmental characteristics of the valleys provide important features not available elsewhere. For instance, Carob trees (*C. siliqua*) are widespread in the Maltese countryside, but often found at higher concentrations within valleys. This provides significantly better habitat for birds than the individual, scattered trees more often found outside. Water, whether in ephemeral or perennial streams, or captured in ponds for irrigation purposes, contributes to make these habitats even more unique. Valleys therefore offer some of the richest and most important habitats for birds in the country and host a larger diversity of bird species than any neighbouring environment.

The importance of Malta's valleys for birds has been documented in several historical works. For example, in 1647, Gian Frangisk Abela described Wied ta' Dejr is-Saff, Girgenti, as being ideal for catching *beccafichi* (Garden Warblers), *tortore* (Turtle Doves) and *tordi* (thrushes)[4]. The long association between birds and Malta's valleys is also borne out in some valley names, such as Wied Għoxx il-Ħida (Valley of the Kite's Nest), Wied is-Seqer (the Hawk's Valley) and Wied il-Merill (Blue Rock Thrush Valley). However, as yet, no scientific study has focused on this association.

To address this gap in knowledge, an extensive programme of field surveys has been carried out, and the survey data analysed in combination with relevant published information and personal observations dating back to 1978. This information reveals that over 45% of all 468 bird species recorded in Malta to date[5] can be found actively using valleys.

Birds make use of the diverse habitats that valleys provide in a number of different ways. Some directly use the water within them, feeding from the waters' surface or below. Others make use of the aquatic and water-side vegetation, to feed on or seek shelter in. Still others use the valley sides, rock formations or the aerial space of the valley in which to feed. Herons catch insects, other invertebrates and amphibians from the water, both day and night. Waders and crake species feed on aquatic and other insects, larvae and tadpoles, and in some cases also seeds and plant material.

[4] Abela, G.F. (1647). Della descrittione di Malta, isola nel mare Siciliano con le sue antichita, ed altre notitie, Malta.

[5] Fenech, N. (2017). Birds of the Maltese Islands. BDL Publishing, p.288; Fenech, N. and Sammut, M. (2015). Eleven new species of birds for the Maltese Islands, Uccelli d'Italia XL, p.69-77; and Fenech, N. and Sammut, M (2020) New species and noteworthy records from Malta, Uccelli d'Italia 45: 105-115.

Chiffchaff

Dunlin

Some passerines, such as the Common Chiffchaff (*Phylloscopus* collybita), catch insects in flight and from in amongst the valley vegetation, while others, such as wagtails, also feed on tadpoles and insects on the waters' surface. Hirundines, such as Swift (*Apus apus*), swallows and martins are aerial feeders, catching insects in flight in broad daylight. The Nightjar (*Caprimulgus europaeus*) also catches insects in flight, but only at dawn, dusk and at night.

Malta is an important staging post for many migrant birds, both while travelling outward from their breeding areas in Europe to resting grounds in Africa, and again during the return journeys[6]. Valleys support roughly half of the migrant bird species seen in Malta. Various species of waders and crakes, such as Dunlin (*Calidris alpina*), Wood Sandpiper (*Tringa glareola)* and Green Sandpiper (*Tringa ochropus*), can be found spending several days in suitable valley habitats in the spring, before continuing with their migrations. The Spotted Crake (*Porzana porzana)* has been observed spending more than seven weeks in the same locality at Wied Għajn Riħana [7]. In September, passerines such as the Garden Warbler (*Sylvia borin*) and Common Redstart (*Phoenicurus phoenicurus*), may spend anything from two days to over a fortnight in the same valley. The Kingfisher (*Alcedo Atthis*) occurs regularly in Malta's valleys from mid-August onwards, in some cases up until March. A survey of water-holding Gozitan valleys, carried out between August and September 2019, revealed the presence of Kingfishers in every one.

Valleys, such as the ones at Girgenti and Lunzjata in Gozo, are very important historic roosting sites. Hirundines, including large numbers of Common House Martin (*Delichon urbicum*), Barn Swallow (*Hirundo rustica*) and Western Yellow Wagtail (*Motacilla flava*), regularly roost in the Great Reed (*A. donax*) beds in several valleys between February and May, and again between August and October or early November. The Great Reed bed at the lower end of Wied il-Luq, and the ones at Mtaħleb, Miġra l-Ferħa and Wied il-Fiddien, are also important for the Western Marsh Harrier (*Circus aeruginosus*), particularly in September and early October.

[6] De Lucca, C. (1969). A revised check list of the birds of the Maltese Islands. EW Classey Ltd., p.95; De Lucca, C. (1969). Bird Migration over the Maltese Islands, Ibis, 111, p.322-337; Roberts, E.L. (1954). The Birds of Malta. Progress Press, p.168; De Lucca, C. and Wain, N.C. (1960). Notes on the migration through Malta of birds on the British list (unpublished paper), p.14.

[7] Fenech, N. and Sammut, M. (2019). Migratory restlessness and other behaviour of two species of crakes in the Maltese Islands, British Birds, 112, p.295-297.

Malta's valleys also provide a breeding habitat for at least 28 bird species, including 19 species that breed regularly within the valleys. This equates to almost 75% of the bird species that regularly breed in the Maltese Islands. Some species, such as the Moorhen (*Gallinula chloropus*) and Reed Warbler (*Acrocephalus scirpaceus*), make use of the reed beds and flowing water for breeding sites. Others, such as the Scopoli's and Manx Shearwater (*Calonectris Diomedea* and *Puffinus puffinus*), and the Kestrel (*Falco tinnunculus*), use only the hard-to-access, steep, rocky valley sides in which to breed. Swift (*A. apus*) and Pallid Swift (*Apus pallidus*) breed under the bridge between Vjal Raguza and Triq id-Difża Ċivili in Wied il-Għasel. The birds began using this site a number of years ago, and their numbers have since increased following the installation of nest boxes[8].

Of the bird species regularly found within Malta's valleys, 20 are of global conservation concern, meaning they are critically endangered, and vulnerable or near threatened at a global level. All of these are migrant species, including the European Turtle Dove (*Streptopelia turtur*), Great Snipe (*Gallinago media*) and Meadow Pipit (*Anthus pratensis*). A further 73 species found within the valleys are of European conservation concern. While some of these are rare vagrants, such as the Smew (*Mergellus albellus*), others are frequent visitors, including the Kingfisher (*A. atthis*), Eurasian Coot (*Fulica atra*), Black Kite (*Milvus migrans*) and Short-eared Owl (*Asio flammeus*).

The importance of Malta's valleys for birds, and the precarious conservation status of many of the species using them, means that factors such as disturbance and the management of roosts should be considered in future valley management strategies. The level of disturbance, by human activity, dogs or feral cats, can play a key role in determining how long birds stay in suitable valley habitats. Roosting sites are used year after year. Management practices such as burning or complete removal of reeds, especially in places known to be roosts for birds, can have a negative impact on migrants, who would not find their usual roosting place when they arrive.

[8] Leone Ganado, P. (2018). Nesting boxes being installed by hunters to encourage bird breeding [Online]. Available at https://timesofmalta.com/articles/view/nesting-boxes-being-installed-by-hunters-to-encourage-bird-breeding.683475 (Accessed 12 September 2019).

Spotted Crake

Kingfisher

Short-eared Owl

Moorhen

Ashy-headed Wagtail

Blue Rock Thrush

Swallow

Black Redstart

Night Heron

Verdala castle at Wied il-Luq, Malta

Chapter 4

TRANSFORMATION OF THE CULTURAL LANDSCAPE IN THE VALLEYS OF NORTHERN MALTA

Dr Keith Buhagiar

Malta has an exceptionally rich cultural and archaeological heritage, with the artefacts and impressive structures dating from the prehistoric Temple period and the time of the Knights being particularly prominent in the public consciousness. However, there is much less public awareness about the cultural evolution of the Maltese landscape and its hydrological development between AD 1000 and 1530. Scientific research for this period does not come without its drawbacks. Extensive ploughing and cultivation of the shallow soils found within Malta's valleys has led to the destruction of several high or late medieval sites located within. Furthermore, an official ceramic typology, typically used to identify the period to which a cultural site or object belongs[9], is yet to be fully established for medieval Malta[10].

Because of these issues, the best way to investigate the development of the cultural landscape within Malta's valleys is to apply what is known as a retrogressive analytical approach. This involves starting at a relatively recent period in time and then working backwards, removing known, dated features from the landscape to gain a better understanding of its components during earlier times[11]. The valleys of northern Malta, including the Pwales Valley, Wied ir-Rum, Wied Ħażrun and Wied il-Fiddien, have been studied because of the availability of historical documentation, which, when combined with field research, can reveal the landscape transformations these sites have undergone.

Tentative dating suggests that the valleys were subject to a major agricultural intensification during the eleventh or twelfth centuries, through the development of a series of *viridaria* or *giardini*. There is no exact English translation for the term '*giardini*'. The closest modern equivalents include orchards, plantations, market gardens and small-holdings. The development of the *giardini* involved the excavation of subterranean water galleries, tapping into the shallow perched aquifer, and the construction of rubble walls and field terracing. These works appear to have formed part of a concerted, centralised effort to improve the water-yield and agricultural output of an otherwise semi-arid environment, which was dependent on seasonal rainfall.

[9] Gagné, M. (2013). *Dating in Archaeology* [Online]. https://www.thecanadianencyclopedia.ca/en/article/dating-in-archaeology#:~:text=Typology%20is%20a%20method%20that,a%20specific%20context%20or%20period (Accessed 27 March 2021).

[10] Luttrell, A.T. (2002). *The Making of Christian Malta: from the Early Middle Ages to 1530*. London: Routledge, p.352; Molinari, A., and Cutajar, N. (1999). Of Greeks and Arabs and of Feudal Knights. *Malta Archaeological Review*. 3, p.9-16.; Cutajar, N. (2001). Recent discoveries and the archaeology of Mdina. *Treasures of Malta*. 8(1), p.79-85; Bruno, B., and Cutajar, N. (2013). Imported amphorae as indicators of economic activity in Early Medieval Malta. In D. Michaelides, P. Pergol, and E. Zanini (Eds.), *The Insular System of the Early Byzantine Mediterranean: Archaeology and History*. Oxford: BAR Publishing, p.201; Hahs, D.G. (2010). *Medieval Malta: Abandoned Villages, Chapels and Farmhouses*. Unpublished M.A. thesis, Florida State University, USA.

[11] Rippon, S. (2012). *Historic Landscape Analysis: Deciphering the countryside*. Oxford: Council for British Archaeology.

Wied tal-Baħrija, Malta

A traditional stone 'Girna'

The *giardini* also contained hamlet-type settlements, which were mostly rock cut. Cave houses excavated into the Upper Coralline Limestone were typically set on the sides of ridges and valleys, allowing people to live directly above the land they cultivated. Mortared and un-mortared stone walls were commonly built across cave entrances, with an arched or square-headed doorway as the only means of access. Dry-stone walls generally partitioned the cave interior into a serious of individual spaces. Windows piercing the exterior wall were rare and, where available, these always assumed the form of narrow slits placed out of reach in the upper portion of the external screening wall. Access to many of these cave settlements was facilitated by cobble paths, connecting the cave houses to the underlying fields and the overlying garigue areas, which were used for rough grazing and the collection of brushwood fuel.

Several cave settlements in north and north-west Malta were serviced by small communal churches, many of which were similarly rock excavated. These medieval cave churches were fitted with either masonry or wooden altars and, in some cases, a flagstone floor. Some contained fixed seating, in the form of a rock cut or masonry bench, and a number also contained murals or frescoes, which indicate a Sicilian-Byzantinesque tradition and inspiration[12].

Giardini first appear in the historical record during the thirteenth century. In 1241, the Maltese *secrezia*, the entity responsible for the administration of royal rights and properties, received a total of 11,457 *tari*, the prevailing late medieval currency unit, for leasing *giardini*. Other documentary evidence reveals that in 1270, the castellan and the captain of the Malta were instructed to investigate the reinstatement of lands, including an estate and a *giardino* at Pwales, which had been confiscated during the reign of King Frederick II[13]. This indicates the presence of a *giardino* framework in the Pwales Valley as early as the first half of the thirteenth century. *Giardini* at Dejr il-Bniet, Gomerino, Għajn Tuffieħa and Ġnien is-Sultan are first mentioned in either late thirteenth or fourteenth century documentation and a significant corpus of historical documentation similarly indicates how an established *giardino* framework existed in both Wied ir-Rum and the adjoining Wied Ħażrun prior to AD 1530.

[12] Buhagiar, M. (2005). *The late medieval art and architecture of the Maltese Islands*. Malta: Fondazzjoni Patrimonju Malti; Buhagiar, M. (2007). *The Christianisation of Malta: Catacombs, cult centres and churches in Malta to 1530*. Oxford: BAR International Series 1647, Archaeopress; Vella, C. (2013). The Mediterranean artistic context of late medieval Malta: 1091-1530. Malta: Midsea Books.

[13] Dalli, C. (2006). *Malta: the medieval millennium*. Malta: Midsea Books.

Malta's close ties with Sicily during the high and late medieval periods make it likely that *giardino* development and perched aquifer gallery technology were imported through these connections. Personal fieldtrips to Sicily and southern Italy have identified various aquifer galleries, including at Ferla, in the territory of Syracuse, and at the late medieval rock cut settlement of Zungri, in the Calabria region. Similarly, cave dwellings and rock cut churches flourished in south-east Sicily during the high and late medieval periods[14].

Cave dwellings, rock-excavated churches, subterranean water galleries, terraced field cultivation and masonry-carved irrigation canals all form part of Malta's rich cultural heritage. However, most Maltese cave houses and cave churches are in a poor state of preservation, and their cultural value grossly underestimated. Many of the sites, including the *giardini* found in the Maltese valley systems, require continuous preservation and maintenance in order to increase the cultural value of such structures. There can be future plans to make some of these sites available and accessible to the public. The safeguarding of these sites, along with the preservation of the medieval fabric of several select *giardini*, could add value to and further diversify Malta's cultural heritage product.

Ancient apiaries at Wied tal-Mistra

Wied il-Luq, Malta

[14] Buhagiar, K. (2012). Malta, an island satellite in the lee of Sicily: investigating the troglodytic context for the late medieval and the early modern periods. In I. Contino, and F. Buscemi (Eds.) *L'Insediamento Rupestre di Monte S. Antonio a Regalbuto: Alle Origini del Rahal di 'Abbûd.* Enna: Paruzzo.

Ghar San Brinkaw, Malta

Wied tal-Baħrija, Malta

Wied tal-Baħrija, Malta

Simblija, Aerial View

Wied Ħażrun, Malta

Wied ta' San Niklaw, Malta

Maidenhair Fern

Wied tal-Baħrija, Malta

View over the Għasel catchment

Wied ta' San Niklaw, Malta

Ghar San Pietru, Malta

Wied ta' San Niklaw, Malta

Wied il-Qlejgħa Watercourse

Chapter 5

MAPPING VALLEYS FOR SUSTAINABLE PLANNING AND MANAGEMENT

Ing. Inês Félix & Ms Elena Portelli

National-scale spatial datasets collected consistently over long periods of time are vital to enable the sustainable management of natural capital, including valley systems. They provide a baseline of environmental conditions, evidence of trends and help to understand the drivers of change. For example, ten to fifty years' worth of stream gauge data are needed to understand stream status and to track trends in water availability[15]. Likewise, understanding trends in habitat extent and condition requires multi-season and multi-annual assessments[16]. Carrying out effective environmental management without this information was a major challenge.

While an increasing variety of global, remotely sensed datasets are freely available, these cannot generally be used in any meaningful way in Malta because of the scale of the data. For example, the globally renowned the CORINE Land Cover service[17] has a minimum mapping unit for areas of 25 hectares and a minimum width of linear elements of 100m. This scale means that none of Malta's watercourses, which typically vary between 0.5m and 20m in width, are included within the dataset.

Furthermore, although national public imagery base maps, such as that provided by the SIntegraM[18] project, are adequate for analysis at the scale of whole catchments, they do not provide the detail needed to understand and manage individual valleys. While they can be used effectively for some purposes, such as identifying areas of intensive agricultural land and urban features, they do not provide the detail required to accurately map natural habitats across seasons.

In 2018, as part of the RBMP LIFE Project[19], the Valley Management Unit within Parks Malta began the journey towards filling these information gaps by creating a collection of environmental information relating to Malta's valleys. This currently covers sixteen catchments, thirteen in Malta and three in Gozo, and has the potential to be expanded further in the future. These initial catchments cover some 148km^2, or just under half the landmass of the Maltese islands.

Work began with the creation of a central geographical information system (GIS) geodatabase, which is essentially a collection of various geographic datasets, held together in a common file system[20]. All relevant publicly available data were collected, and data gaps identified. Meetings were held with local stakeholders, including topic experts and various government entities, to ensure all potential sources of information were consulted. Non-GIS information were also collated, including published research papers, reports, surveys, Natura 2000 site forms and academic theses.

[15] González Del Tánago, M., & García De Jalón, D. (2011). Riparian Quality Index (RQI):
A methodology for characterising and assessing the environmental conditions of riparian zones. Limnetica, 29(2), 235–254.

[16] Asiantaeth Yr Amgylchedd Environment Agency, & Scottish Environment Protection Agency. (2003).
River Habitat Survey in Britain and Ireland - Field Survey Guidance Manual

[17] Copernicus Land Monitoring Service https://land.copernicus.eu/

[18] Spatial Data Integration for the Maltese Islands by Planning Authority.
The 2018 SIntegraM Imagery Service provides orthomosaic with 15 cm resolution covering the entire Maltese territory - https://sintegram.gov.mt/sintegram/#/pages/intro

[19] https://www.rbmplife.org.mt/

[20] https://pro.arcgis.com/en/pro-app/latest/help/data/geodatabases/overview/what-is-a-geodatabase-.htm

Drone image capture of agricultural crop fields

Wied Liemu Aerial View

Next, field surveys were designed to address the most pressing data gaps. A bespoke field survey method was developed, which was designed to map the key features of Malta's valleys in a consistent way. This method built on widely used European habitat and hydromorphological assessments[21 22 23 24], adapting them to the local context. Whenever possible, EU-wide categorisations and terminology were used to ensure replicability and comparability.

In-house modelling of the stream network was carried out and the main channels[25] selected for field mapping. These amounted to around 80km of watercourse. A 50m buffer was delineated on either side of the main channels as the boundary for the detailed survey area, in accordance with other European river habitat assessments[26]. The resulting area of around 10km^2 was then surveyed intensively using the project's bespoke methodology.

Collection of GIS data in the field was divided in two main activities. Firstly, to address the lack of detailed base maps, drones were used to capture high-resolution imagery of the selected valley areas. The images acquired through these photogrammetric drone surveys provided very recent, clear orthomosaics, which are geometrically corrected maps compiled from a series of individual aerial photographs. This type of drone survey also allows the construction of Digital Terrain and Digital Surface Models (DTMs and DSMs) and generates a series of other products such as contours, hillshade, slope, terrain orientation and solar radiation. The orthomosaics, along with the collated pre-existing datasets, were used for desktop mapping and interpretation of valley features, which were then validated through field surveys.

Survey data collection consisted of three separate, but interconnected elements: ecology, hydrology and geology. The ecology fieldwork primarily collected data on the presence, distribution and condition of natural habitats. Due to the accumulation of water, valleys are some of the greenest areas in the islands, where a wide variety of sensitive terrestrial habitats can be observed. The ecological survey also noted the presence and distribution of protected tree species, the presence of alien and invasive species, and variations in the freshwater habitats found along the watercourse.

[21] Stubbington, R., Chadd, R., Cid, N., Csabai, Z., Miliša, M., Morais, M., ... Datry, T. (2018). Biomonitoring of intermittent rivers and ephemeral streams in Europe: Current practice and priorities to enhance ecological status assessments. Science of the Total Environment, (618), 1096–1113. https://doi.org/10.1016/j.scitotenv.2017.09.137

[22] Rinaldi, M., Surian, N., Comiti, F., & Bussettini, M. (2015). Guidebook for the evaluation of stream morphological conditions by the Morphological Quality Index (MQI). Retrieved from https://www.researchgate.net/publication/286443202

[23] González Del Tánago, M., & García De Jalón, D. (2011). Riparian Quality Index (RQI): A methodology for characterising and assessing the environmental conditions of riparian zones. Limnetica, 29(2), 235–254.

[24] CNR-ISA Water Research Institute. (2008). CARAVAGGIO - Core Assessment of River Habitat Value and Hydromorphological Condition - Field Key. Brugherio, Italy.

[25] The Strahler method was used. The highest order for our network is 8 – these are the main channels with the most complex connections of tributaries. Order 1-4 were excluded as their significance is limited.

[26] CNR-ISA Water Research Institute, 2008; Gallart et al., 2018; González Del Tánago & García De Jalón, 2011; Rinaldi et al, 2013

Hydrological fieldwork surveyed both the physical characteristics of the stream channel and the flow state. This information gives an indication of the suitability of the channel for different species, the amount and pattern of water present, the susceptibility of the channel to deterioration from erosion, and the potential for water provision to people and the natural habitat.

The project's geological fieldwork described the human influence in the islands' valleys and mapped the land use, artificial modifications and pressures observed. The presence of artificial constructions and human use of the riparian landscape can alter the volume, speed and direction of water flow within channels. Human intervention within the channels themselves can affect the distribution of species, change erosion rates and impact on the potential for recharging freshwater from streams into groundwater reserves through infiltration.

Along with the field surveys, six water level dataloggers were installed at representative sites along selected watercourses, to improve understanding of stream flow and extent. The dataloggers monitor the height of the water column, known as the 'stage height', using readings of barometric pressure, and have been consistently monitoring changes since the winter of 2019. This information along with additional readings from other projects and sources will enable accurate categorisation of each monitored stream section as either intermittent, ephemeral, or perennial. The categorisation of streams into one of these groups is essential for proper understanding and management of the catchments.

The key data outputs from the project are freely available to view and download from the LIFE IP RBMP Geoportal[27]. These outputs include GIS maps of the catchment and sub-catchment boundaries, as well as the stream network. These products are routinely requested by researchers and governmental entities and can become the standard for related works locally. The project team endeavoured to confirm the local names for these hydrological features, to enable better communication with the public, particularly native Maltese speakers.

More than 25,000 individual geographic objects were mapped during the field surveys. To incorporate all the data requirements, the information was categorised into 16 feature classes, with more than 100 attribute fields, 32 subtypes and more than 400 values of domains. As an example, in the "Ecology" category, "habitat" is a feature class and the "habitat type" is one of the attributes. A subtype of this habitat type is "woodland", and "broadleaved deciduous woodland" is the domain.

[27] https://lifeip-rbmp-geoportal-valleymanagement.hub.arcgis.com/

Wied tad-Dwejra, Gozo

Wied tal-Ġnejna, Malta

Wied tad-Dwejra, Gozo

The data produced through the project can be summarised in a variety of interesting ways. For example, the percentage area with different land cover, the area colonised by invasive species, and the relative lengths of natural and modified channels can quickly provide a good indicator of the condition of a site. The diversity of habitat types or species found within a given area is also commonly used as an indicator of ecological quality. Connectivity tools within GIS can describe whether point features, such as the "notable trees" layer mapped through the field surveys, are connected with each and with natural habitats. The connectivity of habitat areas with each other is also an indicator of ecosystem quality. Connected natural areas provide wildlife corridors, and the larger the connected area is, the higher its presumed conservation value.

Spatial interpolation tools can also be applied to the project data. For example, during the hydrology fieldwork, the cross-sectional measurements of the channel at each accessible 200 metre point were collected. These, along with readings of stage height, can be interpolated to estimate the volume of the channel within selected areas, or across an entire network. This is valuable information in establishing a baseline and monitoring changes to the watercourse.

The key ecosystem services, or benefits to humankind, provided by each of the sixteen mapped catchments have also been assessed through the project. An external consultancy was engaged to develop a methodology that could be used to identify, quantify and where possible economically valorise these services[28]. Seventeen ecosystem services were investigated, with these broadly categorised into either provisioning, maintenance and regulation, or cultural services.

The provisioning services examined included cultivated crops, reared animals and their outputs, groundwater for drinking and non-drinking purposes, and surface waters for non-drinking purposes. Maintenance and regulation services studied included micro and regional climate regulation, global climate regulation by reduction of greenhouse gases, regulation of the chemical condition of freshwaters, flood protection, maintenance of nursery populations and habitats, pollination, and mass stabilisation and the control of erosion. With regards to cultural services, aesthetic, scientific and educational, physical and experiential, heritage and cultural services were considered.

The available spatial data alone was generally insufficient to describe many of these services. Sourcing a recent land cover map of sufficient detail, which covered the study area in its entirety, proved particularly challenging. To address these data gaps, a group of experts in the fields of hydrology, ecology and environmental management ranked the land use categories from two key national data sources[29] according to their perceived provision of ecosystem services. This process resulted in a matrix of mean rankings of values between 0 (no perceived supply of service) and 5 (very high perceived supply of service).

[28] Verhagen, Verburg, Schulp, & Störck, 2015
[29] The Environment and Resources Authority land cover map (2014) and the Land Parcel Identification System data from the Agriculture and Rural Payments Agency (2018).

It was possible to estimate the economic value of a limited number of ecosystem services in terms of their potential service provision to the local population. Total crop production value, and the value of crops per kilometre squared, were quantified using publicly available information. Crops dependent on pollinators were used as an indicator of the contribution of pollinators to crop production in kilos, and the economic value of these crops was derived from statistics produced by the National Statistics Office. Soil erosion has been studied previously at a national scale, making it possible to recalculate off-site costs of soil erosion, costs of soil recovery and projected costs of losses in agricultural production over the next 50, 100 and 500 years[30].

Taking the Ghasel catchment as an example, the total crop production value was estimated at 3.8 million euro annually, 688,400 euro of which are pollination-dependent crops. Costs of agricultural production losses due to soil erosion were estimated at 469.4 euro, 66,184 euro and 4,693.96 euro annually for 50, 100 and 500 years respectively. Annual off-site costs of soil erosion were estimated at 838,100 euro and annual costs of soil recovery estimated at 349,320 euro.

A preliminary assessment of the ecological status of the mapped valley areas was also carried out, using various indicators. These included indices related to land take, land cover and ecosystem area, population, the presence of alien and invasive species, riparian habitat area, protected area designation, hydromorphological alterations to the channel, artificial barriers to water flow, and the presence of artificial modifications within the channel. This provided an in-depth analysis of pressures present within the valleys, based primarily on data collected by Parks Malta during the field surveys.

While acknowledging that there are inherent limitations to the type of fieldwork carried out within this study, and that a number of data gaps remain, the information generated through this project has made a substantial contribution to the national environmental evidence base. Furthermore, the methods and geodatabase developed can act as a foundation for ongoing survey and monitoring efforts to establish the long-term, consistent datasets needed to underpin the effective implementation of integrated river basin management in Malta's valleys. The data collated through the project is available for free download at lifeip-rbmp-geoportal-valleymanagement.hub.arcgis.com

[30] Panagos et al., 2015; Sultana, 2015

Wied tad-Dwejra, Gozo

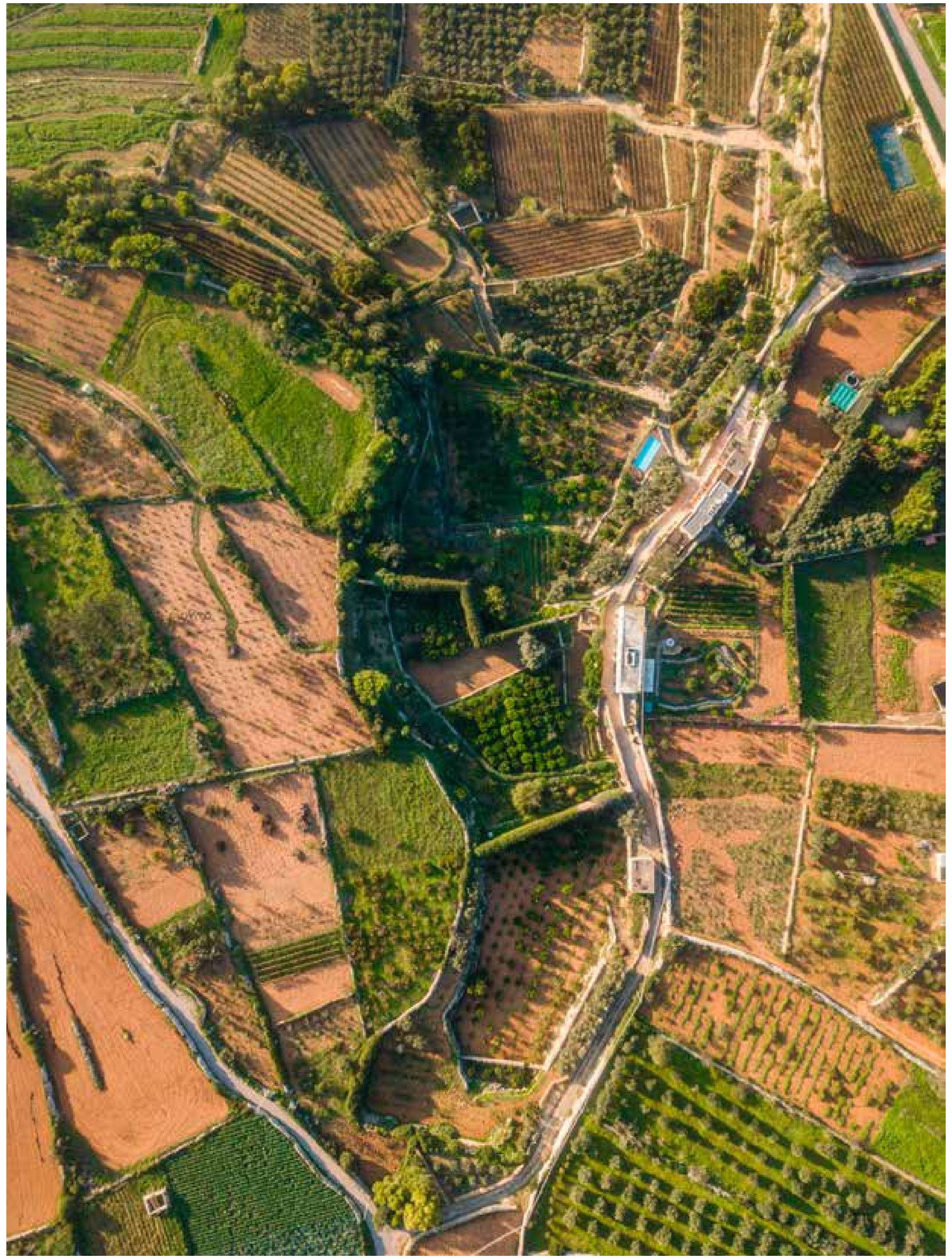
San Brinkaw Area

Wied Liemu Aerial View

Wied Harq Hammiem, Malta

Wied tax-Xlendi, Gozo

Wied Liemu Aerial View



Simblija Aerial View

Wied Għomor, Malta

Wied tal-Lunzjata, Gozo

San Niklaw Area

Marvel of Peru

Chapter 6

THE CHALLENGE OF NON-INDIGENOUS SPECIES

Prof Alan Deidun, Mr Arnold Sciberras & Mr Jeffrey Sciberras

Non-indigenous species have the potential to transform natural environments by establishing populations in areas where they would not otherwise be found[31]. Introductions of such species into Maltese freshwater environments are increasingly adding to the pressures these habitats already face from an array of human and climatic impacts. A particularly worrying group of non-indigenous species are referred to as 'invasive and alien species'. These species are highly likely to spread beyond the area in which they were first introduced, substantially changing habitats and pushing out native species. They can significantly impact on biodiversity and lead to large economic costs. They have therefore been identified as one of the major components of human-induced, global environmental change[32].

The most notorious invasive and alien species recorded in Maltese freshwater environments in recent years include a number of crayfish species[33]. By far the most widely distributed and locally abundant is the Red Swamp Crayfish (*Procambarus clarkii*), which has been recorded in five different valleys as well as within natural and artificial ponds[34]. Other species less commonly found in Malta's freshwater habitats include the Marbled Crayfish (*Procambarus virginalis*, different European populations of which have just been subjected to a genetic assessment[35]), Signal Crayfish (*Pacifastacus leniusculus)* and the Australian Redclaw (*Cherax quadricarinatus)*. These invaders were most likely released deliberately.

Freshwater terrapin species, including the Mississippi Map Turtle (*Graptemys pseudogeographica kohni*) and the Yellow-bellied Slider (*Trachemys scripta scripta*), have been recorded in Wied il-Għasel and Wied il-Qlejgħa, while the Red-bellied Slider (*Trachemys scripta elegans*) has been found in a pond and reservoir in Gozo. These invasive terrapin species have been introduced over the last two decades[36]. The Levant water frog (*Pelophylax bedriagae*) was first detected in Maltese freshwater ecosystems in the early 2000s, from its distinctive croaking, and has since been identified at Ta' Sarraflu pond and several artificial aquatic environments in Gozo[37].

[31] Occhipinti-Ambrogi, A. and Savini, D. (2003). Biological invasions as a component of global change in stressed marine ecosystems. Marine pollution bulletin, 46(5), p.542-551.

[32] Westphal, M.I., Browne, M., MacKinnon, K. and Noble, I. (2008). The link between international trade and the global distribution of invasive alien species. Biological Invasions, 10(4), p.391-398.

[33] Vella, N., Vella, A. and Mifsud, C.M., 2017. First Scientific Records of the Invasive Red Swamp Crayfish, Procambarus clarkii (Girard, 1852)(Crustacea: Cambaridae) in Malta, a Threat to Fragile Freshwater Habitats. Natural and Engineering Sciences, 2(2), pp.58-66.

[34] Deidun, A., Sciberras, A., Formosa, J., Zava, B., Insacco, G., Corsini-Foka, M. and Crandall, K.A. (2018). Invasion by non-indigenous freshwater decapods of Malta and Sicily, central Mediterranean Sea. Journal of Crustacean Biology, 38(6), p.748-753.

[35] Maiakovska, O., Andriantsoa, R., Tönges, S., Legrand, C., Gutekunst, J., Hanna, K., Pârvulescu, L., Novitsky, R., Weiperth, A., Sciberras, A. and Deidun, A., 2021. Genome analysis of the monoclonal marbled crayfish reveals genetic separation over a short evolutionary timescale. Communications biology, 4(1), pp.1-7.

[36] La Mantia T., Badalamenti E., Carapezza A., Lo Cascio P. & Troia A. (Eds.)2020. Life on islands. 1. Biodiversity in Sicily and surrounding islands. Studiesdedicated to Bruno Massa. Edizioni Danaus, Palermo, 492 pp

[37] Sciberras, A. and Schembri, P.J. (2006). Occurrence of the alien Bedriaga's frog (Rana bedriagae Camerano, 1882) in the Maltese Islands, and implications for conservation. Herpetological Bulletin, 95, p.2-5.

Brazilian Peppertree

Garden Nasturtium

A number of non-indigenous gastropod species have been identified in both watercourses and artificial freshwater locations. These include the Red-rimmed Melania snail (*Melanoides tuberculata*), the Seminole Ramshorn snail (*Planorbella duryi*) and the freshwater limpet *Ferrissia fragilis* [38 39 40]. At least two non-native, range-expanding dragonfly species (*Calopteryx haemorrhoidalis* and *Calopteryx virgo meridionalis)* have also become established in the Maltese Islands[41].

Several non-indigenous bird species have been deliberately introduced into the wild in recent years, especially within aquatic habitats. Most established among these are the domestic goose (*Anser anser domesticus*), the Muscovy duck (*Cairina moschata*), the Mallard duck (*Anas platyrhynchos*) and the Black-bellied Whistling-duck (*Dendrocygna autumnalis*).

The most glaring impacts these introduced species have on Malta's valley ecosystems include the predation of native species. For instance, invasive crayfish have been observed feeding on land snails, the Scarlet Darter nymph (*Crocothemis erythrae*), the Painted Frog (*Discoglossus pictus*), Western Mosquitofish (*Gambusia affinis*) and the larvae of the Lesser Drone Fly (*Eristalinus taeniops*). Invasive terrapins have been observed predating several species of insect larvae, including Odonata (dragonflies and damselflies) nymphs and Coleoptera (beetle and weevil) larvae, as well as Painted Frog tadpoles. Arguably the 'worst invader' of riparian ecosystems is the feral cat, which has been observed preying on the largest native terrestrial mammal species in Malta, the Least Weasel (*Mustela nivalis*), as well as on Odonata nymphs, Painted Frog adults and on the nests of native bird species.

In terms of plant species, the situation is even more dire. Several annual and perennial invasive species are already well established, including the Nasturtium (*Tropaeolum majus*) and Marvel of Peru (*Mirabilis jalapa*). Invasive alien trees and bushes, such as the Caster Oil Tree (*Ricinus communis)* and Tree of Heaven (*Ailanthus altissima)*, are widespread within valley ecosystems. The Caster Oil Tree, or Siġra tar-Riġnu, produces a constant supply of poisonous seeds, which can

[38] Cilia D.P. (2009). On the presence of the alien freshwater gastropod *Ferrissia fragilis* (Tryon, 1863) (Gastropoda: Planorbidae) in the Maltese Islands (Central Mediterranean). *Bollettino Malacologico*, 45, p.123– 127.

[39] Cilia, D.P., Sciberras, A. and Sciberras, J. (2013). Two non-indigenous populations of *Melanoides tuberculata* (Müller, 1774) (Gastropoda, Cerithioidea) in Malta. *MalaCo. Journal électronique de la malacologie continentale Française*, 9, p.447-450.

[40] Cilia, D.P. (2017). Contributions to the malacology of Malta, III: First record of *Planorbella duryi* (Wetherby, 1879) (Gastropoda Planorbidae) for Comino. *Biodiversity Journal* 8(2), p.769-771.

[41] Sciberras, A. and Sammut, M. (2013). The occurrence of the Copper Emerald *Calopteryx haemorrhoidalis* (Vander Linden, 1825), records of rare species, changing population trends of some hitherto common species and recent colonisers in the Maltese Islands. *J. Br. Dragonfly Society*, 28(1), p.1-9.

survive for ten years in dry conditions, but then easily germinate within a week. Other less well-known species with the potential to be equally invasive include the Lead Tree, or Gazzja Bajda (*Leucaena leucocephala*), which produces numerous viable seeds and grows quickly, potentially to a large size.

Alien hydrophytes in Malta are much less known, but nonetheless problematic. The Narrow-leaved Aster, or Settembrina Selvaġġa (*Aster squamatus*), easily invades the valley bed where water flows. Common Duckweed, or Lemna Komuni (*Lemna minor*), can cover the entire surface of standing water bodies, with this issue further exacerbated where nitrate pollution has caused eutrophication.

Some non-indigenous plants that were introduced to Malta decades ago are becoming increasingly rapid invaders in valley ecosystems due to changes in climate. Examples include the Californian Fan Palm, or Palm tal-Imrewħa (*Washingtonia filifera*), and the Love-in-a-puff, or Balloon Vine (*Cardiospermum hirsutum*), a creeper mostly identified from its lantern-shaped fruit capsules that can smother shrubs and even large trees.

Given their potential to dramatically alter ecosystems, the management of invasive and alien species is a national and international environmental priority. The 'National Strategy for Preventing and Mitigating the Impact of Invasive Alien Species in the Maltese Islands'[42] includes a number of actions to prevent species introductions, and also envisages more comprehensive intervention measures following the identification of a new alien species within Malta's native ecosystems.

[42] https://era.org.mt/national-strategy-for-preventing-and-mitigating-the-impact-of-invasive-alien-species-ias-in-the-maltese-islands/

Great Reed

Crayfish

Balloon Vine

Levant Frog

Red-eared Slider


Acacia


Castor Oil Plant

Eucalyptus

Fountain Grass

Garden Nasturtium

Balloon Vine

Reeds

Chapter 7

INFLUENCE OF ENVIRONMENTAL CONDITIONS ON THE GREAT REED INVASION

Dr Belinda Gambin & Mr Rylan Patissier

Commonly referred to as the Great Reed or Giant Reed[43], and locally as Qasba l-Kbira[44], *Arundo donax* has become a familiar sight in the Maltese islands. This resilient plant thrives in riparian habitats and has become an invasive species in many regions of the world with Mediterranean-type climates[45]. Usually found in dense stands along stream beds, it typically grows to a height of three to six metres[46] and can replace all other plant species for stretches of one kilometre or more. It has become dominant in many sensitive sites throughout Malta, which are already under threat due to human influence. Negative impacts resulting from this invasion include increased fire risk[47], removal of nutrients, the uptake of substantial quantities of water[48] and reduced species richness and diversity in colonised habitats[49].

Research has been carried out in three Maltese valleys, Wied il-Qlejgħa, Wied il-Luq, and Wied il-Buskett, to help develop an understanding of the conditions that lead to the Great Reed's success or otherwise in the Maltese context. The aim was to determine what was similar or different between sites where the Great Reed is dominant and where it is not, what conditions promote its success and what measures could potentially be used to suppress its growth.

Within each of the study areas, three sites were chosen: one where the Great Reed population was dense, one where it was scattered, and one where none was observed. At each site, soil samples were taken, and the light intensity and average plant length were measured. Other observations were recorded, including the presence or absence of large shade-creating trees. The soil samples were then analysed in a laboratory for pH, conductivity, nitrate and potassium levels and water holding capacity.

[43] https://era.org.mt/national-strategy-for-preventing-and-mitigating-the-impact-of-invasive-alien-species-ias-in-the-maltese-islands/

[44] Weber, H. C. and Kendzior, B. (2006). Flora of the Maltese Islands: a field guide. Leiden: Backhuys Publishers, p.630.

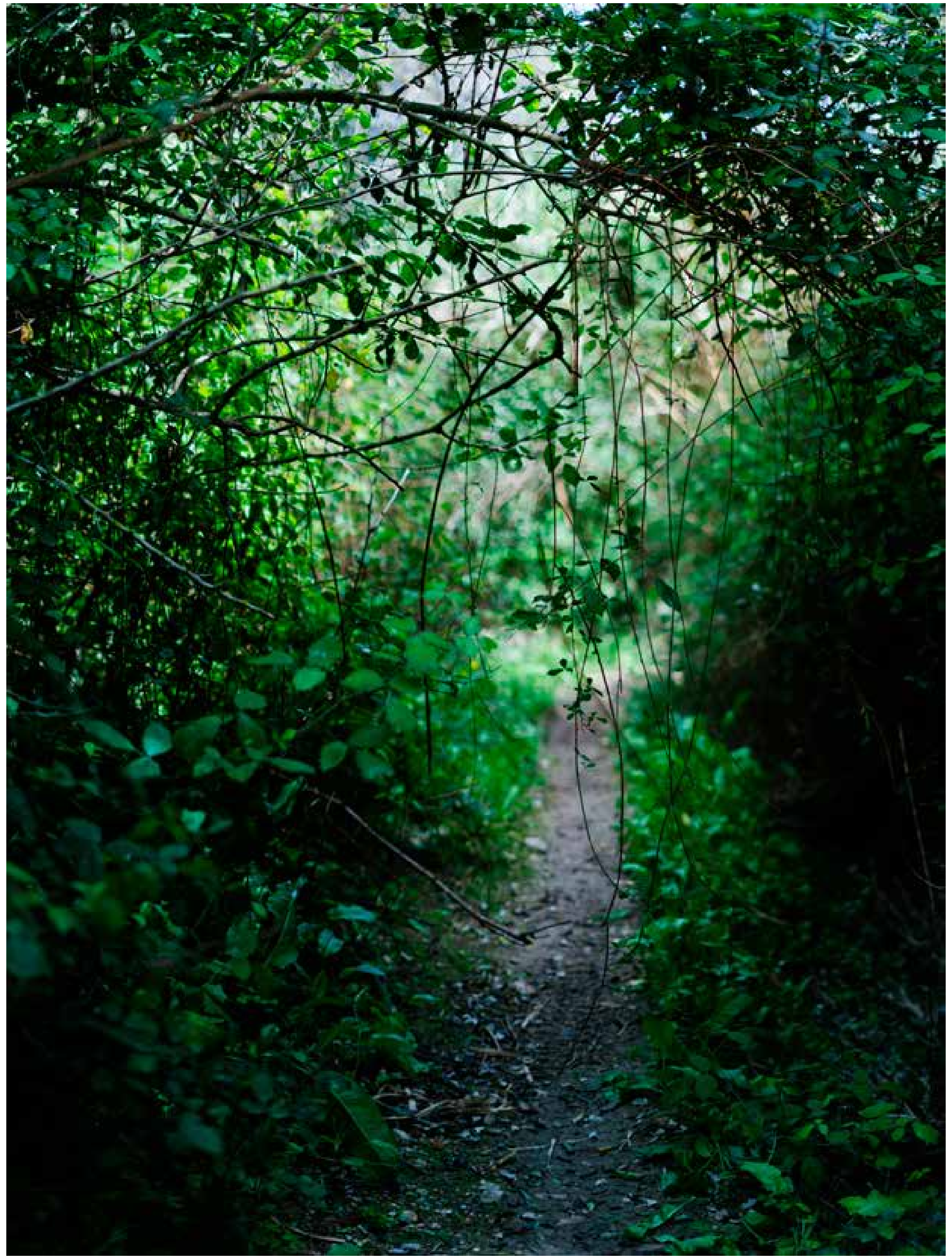
[45] Coffman, G. C. (2007). *Factors influencing invasion of Giant Reed (Arundo donax) in riparian ecosystems of Mediterranean-type climate regions.* Unpublished Doctoral dissertation, University of California, Los Angeles; Odero, D. C., Vollmer, K., Rainbolt, C. and Ferrell, J. (2011). Giant Reed (Arundo donax): Biology, Identification, and Management. [online] EDIS. Available at: https://edis.ifas.ufl.edu/pdffiles/AG/AG30700.pdf [Accessed 25/04/2021].

[46] Csurhes, S. (2009). Weed Risk Assessment: Giant Reed (*Arundo donax*). The State of Queensland, Department of Employment, Economic Development and Innovation. [online] Available at: https://www.daf.qld.gov.au/__data/assets/pdf_file/0006/59973/IPA-Giant-Reed-Risk-Assessment.pdf [Accessed 25/04/2021].

[47] Bell, G.P. (1997).; Spencer, D. F., Liow, P., Chan, W. K., Ksander, G. G. and Getsinger, K. D. (2006). Estimating Arundo donax shoot biomass. Aquatic Botany, 84(3), p.272-276

[48] Csurhes, S. (2009).

[49] Bassam, N. (2010). *Handbook of bioenergy crops: A complete reference to species, development and applications.* UK: Routledge, p.572.; Herrera, A. M., and Dudley, T. L. (2003). Reduction of riparian arthropod abundance and diversity as a consequence of Giant Reed (*Arundo donax*) invasion. *Biological Invasions*, 5(3), p.167-177.; Rieger, J. P., and Kreager, D. A. (1989). Giant Reed (*Arundo donax*): A climax community of the riparian zone. *Protection, Management, and Restoration for the 1990s: Proceedings of the California Riparian Systems Conference.* US Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA, p.222-225



Buskett, Malta

Buskett, Malta

The Great Reed appears to thrive in full sunlight, while suppressing other plants beneath its thick canopy. Sites where the plant was not present or was scattered were all shaded to some degree by established trees, such as the White Poplar (*Populus alba)* and *Eucalyptus* species. While not conclusive, these results support observations in earlier studies[50] and indicate that the Great Reed is most dominant in full sunlight. Reed density was also higher in areas of higher soil water holding capacity but did not show any relation with nutrient levels. This may reflect the fact that all areas sampled had high levels of nutrient enrichment, as is common throughout Malta.

The potential of large, shade-creating trees to outcompete the Great Reed warrants further investigation. Given the known difficulties with mechanically removing the plants rhizome network, including the potential for further accidental spreading in the process[51], this may provide an alternative, nature-based approach to address the impacts of the Great Reed invasion over the long-term.

[50] Simberloff, D. and Von Holle, B. (1999). Positive interactions of nonindigenous species: Invasional meltdown? Biological Invasions, 1, p.21-32.

[51] Bell, G.P. (1997).

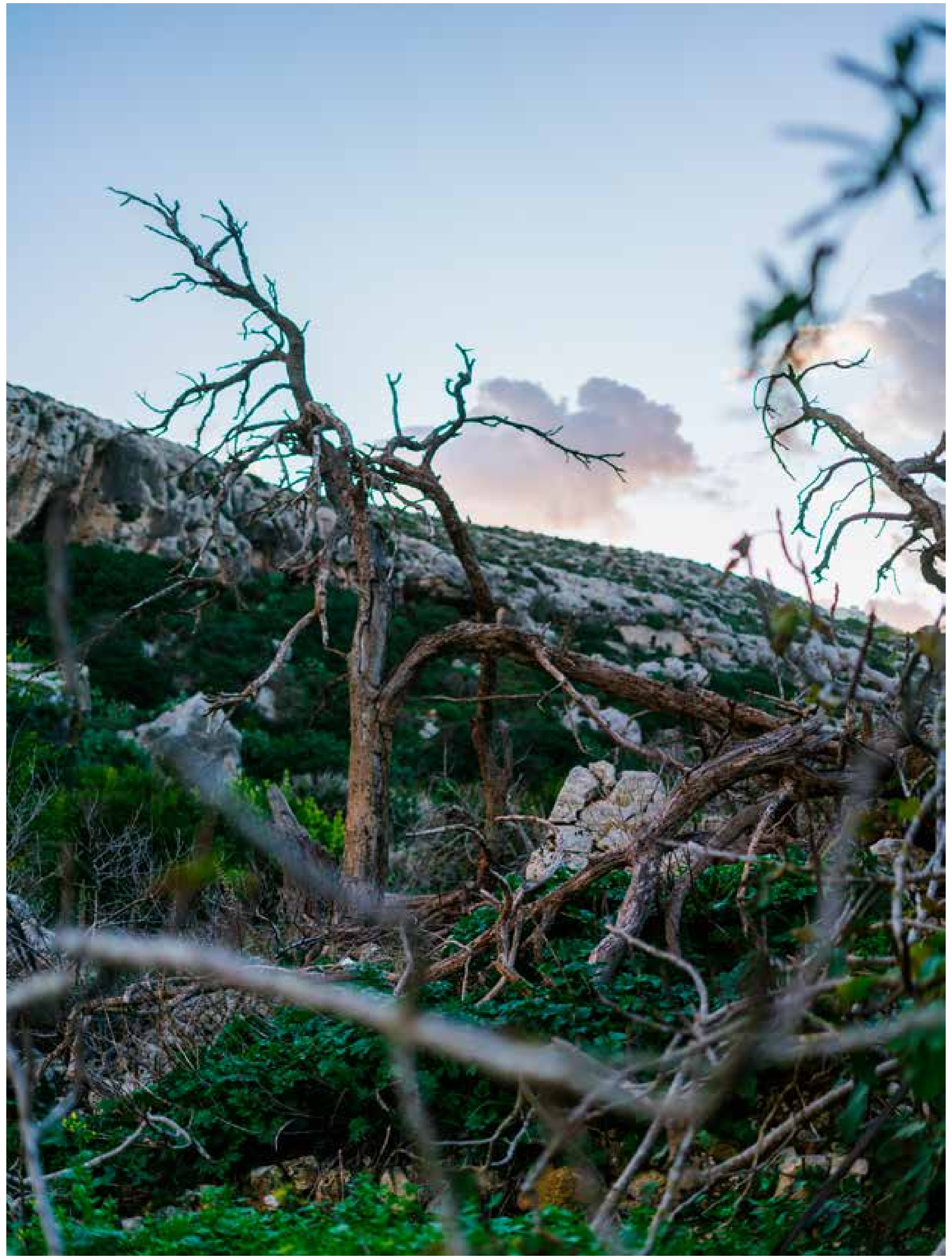
Wied il-Qlejgħa, Malta

Wied il-Qlejgħa, Malta

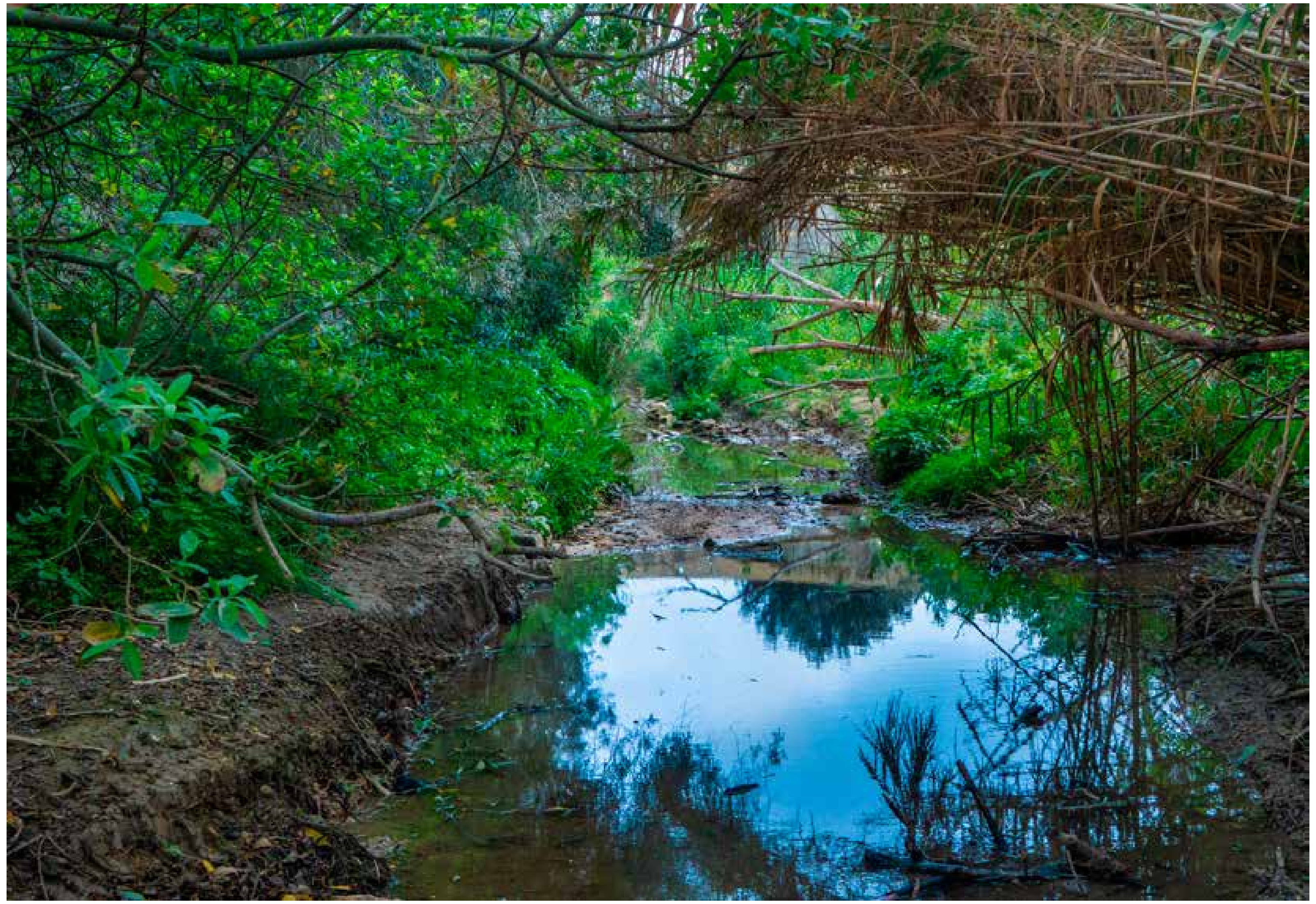
Wied il-Qlejgħa, Malta

Buskett, Malta

Wied il-Qlejgha, Malta



Wied il-Qlejgha, Malta



Wied il-Luq Watercourse

Great Reed

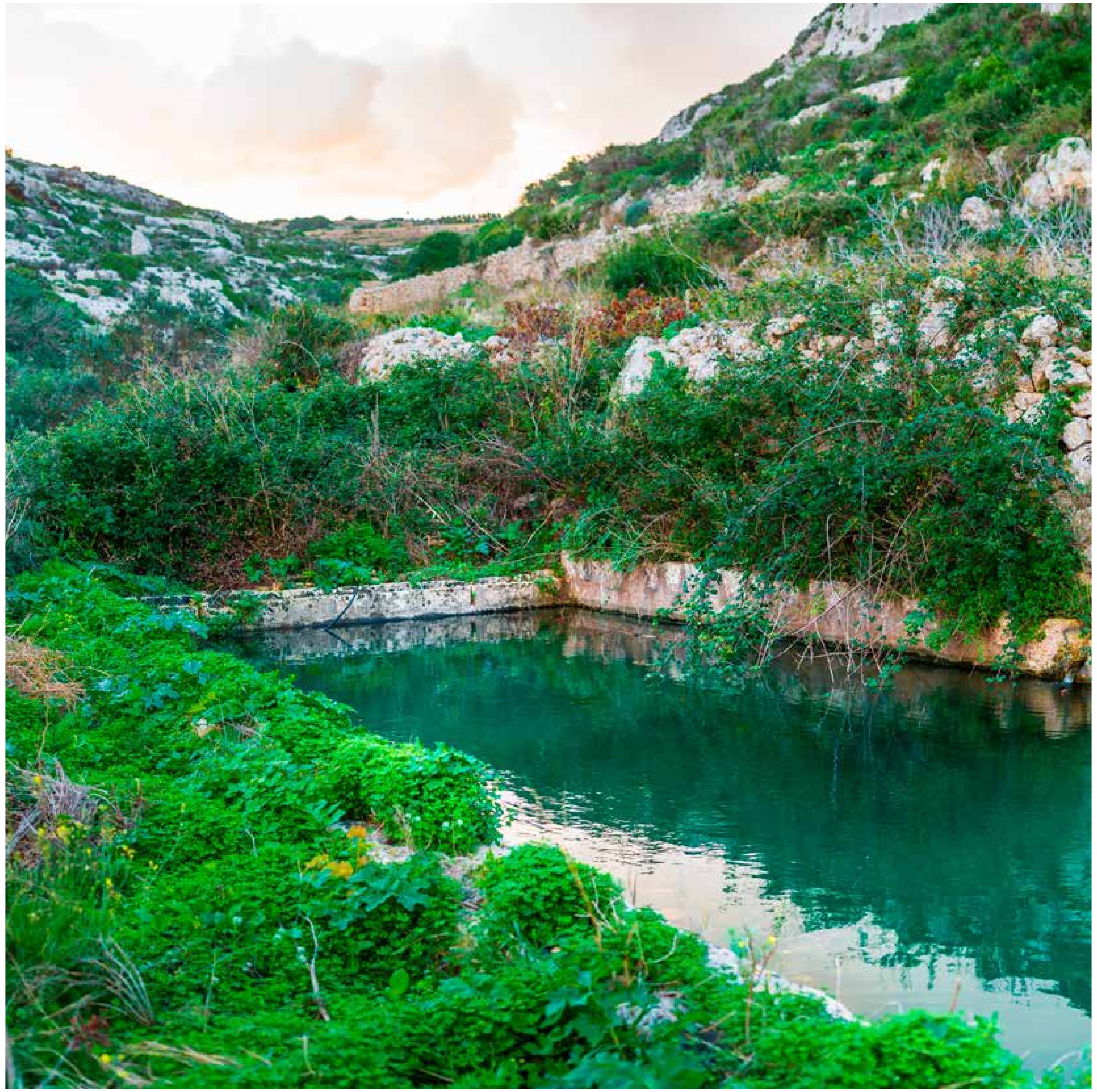
Wied tal-Lunzjata, Gozo

Buskett Hiking Trails

Wied il-Luq Watercourse

Wied il-Luq, Malta

Buskett, Malta



Open reservoir, limits of Mellieha

Chapter 8

STRENGTHENING THE CLIMATE RESILIENCE OF WIED IL-FIDDIEN THROUGH ECOLOGICAL RESTORATION

Dr Eman Calleja, Dr Manuel Sapiano & Mr Aaron Cutajar

Among the many impacts expected to result from the climate change is a decrease in the permanence of flow in European river systems. Freshwater habitats will be increasingly pressured from a reduction in flow permanence and gradually replaced by more xeric habitats. This, along with existing issues such as over exploitation of ground and surface water, may put the very survival of these riparian habitats at risk. Such is the case for Wied il-Fiddien, one of the largest and longest-flowing intermittent streams in Malta. Stream flow in the valley begins in autumn, often after the first heavy rains, and continues through until early spring. Flow then progressively reduces to pools of standing water and eventually to a dry stream bed with only localised flow through sediments under the surface. The channel then lies fully dry throughout the summer months.

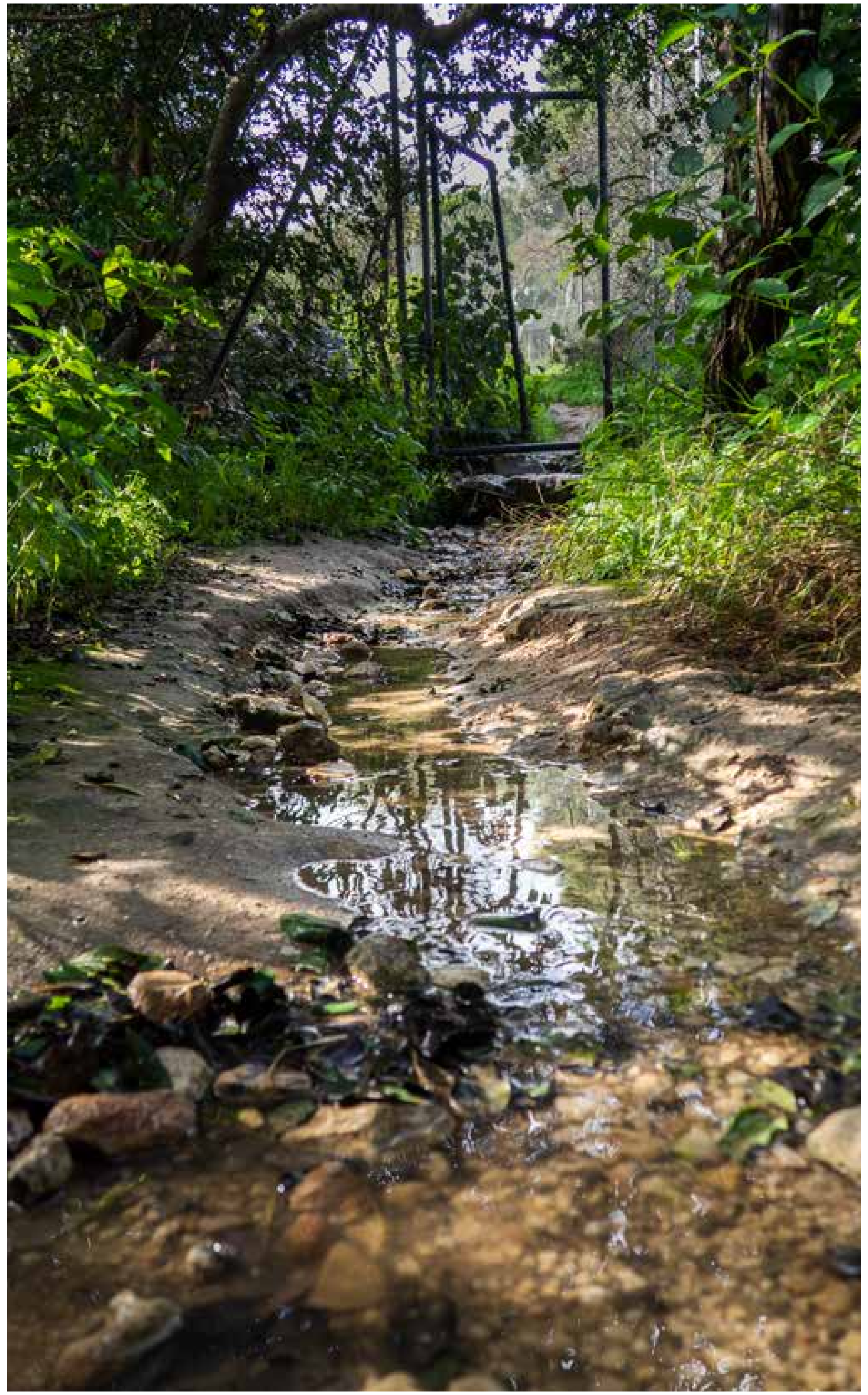
The watercourse is greatly affected by human activities. In 2017, 50 private abstraction boreholes were identified in an area within 500m of the channel[52]. Water is pumped from the shallow perched aquifer, reducing the volume of water available to feed into the stream. A large part of the valley has also been modified through the construction of dams and impoundments. These further reduce the permanence of flow in the valley, as the stream needs to fill up each successive reservoir before downstream flow can continue.

Throughout the catchment, water flowing into the stream from nearby agricultural land has a high nutrient content. This affects vegetation along the watercourse and encourages the growth of species that thrive in high nitrate conditions, such as the Giant Reed. These reedbeds replace the typical hydrophytic plant species and substantially reduce the space available for water flow within the channel.

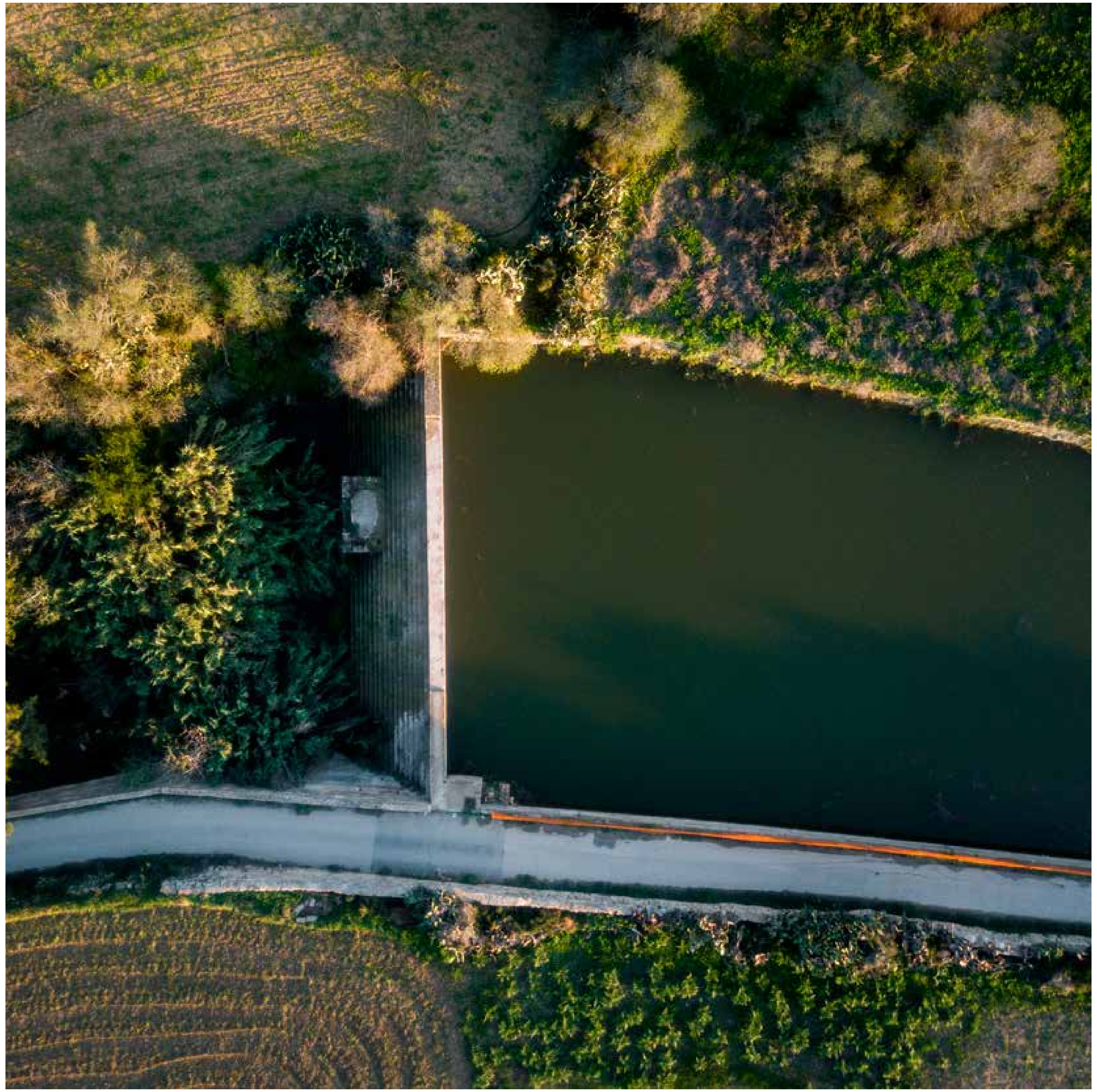
The habitats present in Wied il-Fiddien and the adjacent Wied il-Qlejgħa (Chadwick Lakes) were surveyed in 2017[53]. The majority were found to be degraded and dominated by opportunistic or alien species. However, around 30% of the valley contained a mix of rare and endangered habitats that exist in few other places in the Maltese Islands. These rare habitats were concentrated in an area of willow trees and scrub, largely present in the valley as a result of earlier restoration efforts.

[52] Adi Associates Environmental Consultants Ltd. (2017). *Assessment of the Ecological and the Environmental Status of Wied il- Qlejgħa Study Area – Environmental Restoration Plan*. San Ġwann, July 2017, vii + 260 pp. SEWCU294/2015.

[53] Ibid.



Wied Ghollieqa channel



Dammed Watercourse Aerial View

Two different species of willow were identified, with evidence indicating that they had fared very differently during recent periods of drought. The White Willow (*Salix alba*) was severely impacted with many trees dying out or showing signs of branch abscission, while the Mediterranean Willow (*Salix pedicellate*) showed no signs of water stress[54]. Other species found within this area included the White Poplar (*Populus alba*), Italian Lords and Ladies (*Arum italicum*) and Pellitory-of-the-wall (*Parietaria judaica*).

The survey results also demonstrated that earlier projects carried out in the valley had varying levels of success in re-establishing natural riparian habitats. Restoration efforts appeared to have been less successful when Great Reed beds were not removed prior to the re-planting of native trees, and also when restoration works took place in areas that are easily accessible and heavily impacted by trampling and off-roading.

In July 2019, the Energy and Water Agency began a project[55] to return Wied il-Fiddien to a more natural condition, based on a vision for the valley and detailed restoration plan developed by external consultants. The project used a variety of methods to improve the ecohydrology of the valley, including re-establishing the natural channel morphology, stabilising the soil and stream banks with bioengineering structures, slowing down the flow of water to increase groundwater replenishment and removing invasive reedbeds and other alien species and replacing them with riparian species. These works which were done by a contractor, were followed by the establishment of a management agreement between the Environment and Resources Authority, the Energy and Water Agency and Nature Trust Malta. This agreement arranged for Nature Trust to manage the site and continue establishing the target habitats.

While some of the target habitats were already established in parts of the valley, others were present only in a rudimentary form or were missing entirely. Absent species therefore had to be planted, including several hundred willow cuttings, shrubs such as the Common Elder (*Sambucus nigra*), Common Myrtle (*Myrtus communis*) and Spanish Broom (*Spartium junceum*) and ground cover plants such as the Bracken Fern (*Pteridium aquilinum*), False Broom (*Brachypodium sylvaticum*) and Spreading Hedge Parsley (*Torilis arvensis*). Given the rarity of some key species, a specialist propagation programme had to be set up to increase their numbers. The project favoured the use of the Mediterranean Willow over the White Willow because of its greater drought tolerance. This will help to ensure that the restored habitats are resilient to an increasingly intermittent water flow, resulting from the changing climate.

[54] Calleja, E.J. (2017). *Wet and dry season ecological survey for Wied il-Fiddien.* Unpublished report for ADI Environmental Associates, 90 pp.

[55] Part-funded by the European Union under the European Regional Development Fund – European Structural and Investment Funds 2014-2020.

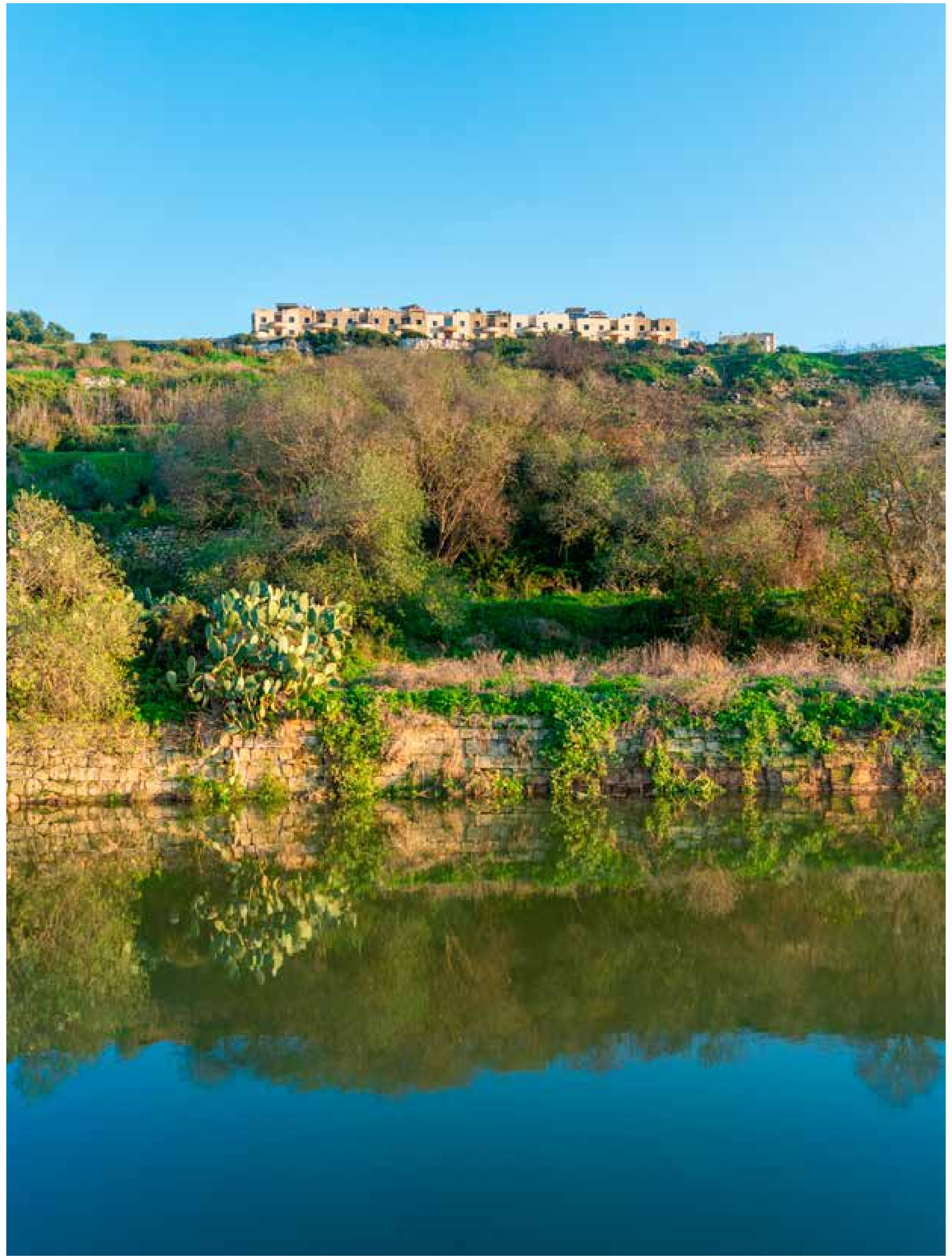
Intermittent and ephemeral streams are among the most vulnerable habitats in the Maltese Islands. Following the completion of this restoration project, Wied il-Fiddien should host the largest extent of riparian habitats in the country, giving it the potential to act as a refuge for riparian species in Malta.

During the course of the project, a number of challenges had to be overcome. Most of the bioengineering systems used were new to Malta, meaning that training had to be provided for all those involved in their installation. Unpredictable weather delayed works to restore the morphology of the stream in some areas. Drought conditions also meant that irrigation had to be introduced to enable newly planted cuttings to survive. Controlling alien and invasive species, including the Great Reed and Caster Oil trees was a major challenge. To address this, the plants and their seed bank were removed from areas upstream of the project site to reduce the chance of them becoming re-established.

The issue of conflicting demands from different local stakeholders was overcome by providing reservoirs for water retention intermittently along the stream between successive stretches of restored habitat, thereby striking a balance between local anthropic needs and the needs of the environment. Illegal use of the valley by off-roaders will continue to damage re-planted vegetation unless access can be stopped. Other problems will surely arise, however the key to solving such issues is having a strong vision that is shared by all parties. As long as the vision is clear, the road to achieve it will always be created or modified to ensure the overall success of the project.

Wied tal-Fiddien, Malta

Wied tal-Fiddien, Malta



Wied il-Qlejgħa, Malta

Wied Għollieqa watercourse

Sanicle-Leaved Water Crowfoot

Wied il-Qlejgħa Dammed Watercourse

Chaste Tree Flowers

Castor Oil Plant Leaf

Riparian Vegetation

Stone dam

Castor Oil Plant

Dammed Watercourse at Wied il-Qlejgħa

Reed Plume

Wied Għajn Żejtuna, Malta

Chapter 9

REHABILITATION AND REGENERATION OF WIED GĦAJN ŻEJTUNA

Mr Saviour Vella

Wied Għajn Żejtuna was once a fertile agricultural oasis, nestled between inland cliffs and fed by ephemeral springs. Over the centuries, farming communities conserved the soil through terracing systems, harnessed the springs and made comprehensive use of every resource that the land provided. The valley was often referred to as the 'fruit basket' of Malta. All this came to an abrupt end in the mid-sixties, when parts of the valley were developed into a villa estate. Today, the entire valley has been assigned for development, with only the actual watercourse excluded. The riverbed was treated as a dumping ground for many years, with the accumulated garbage becoming engulfed in brambles and wild vines.

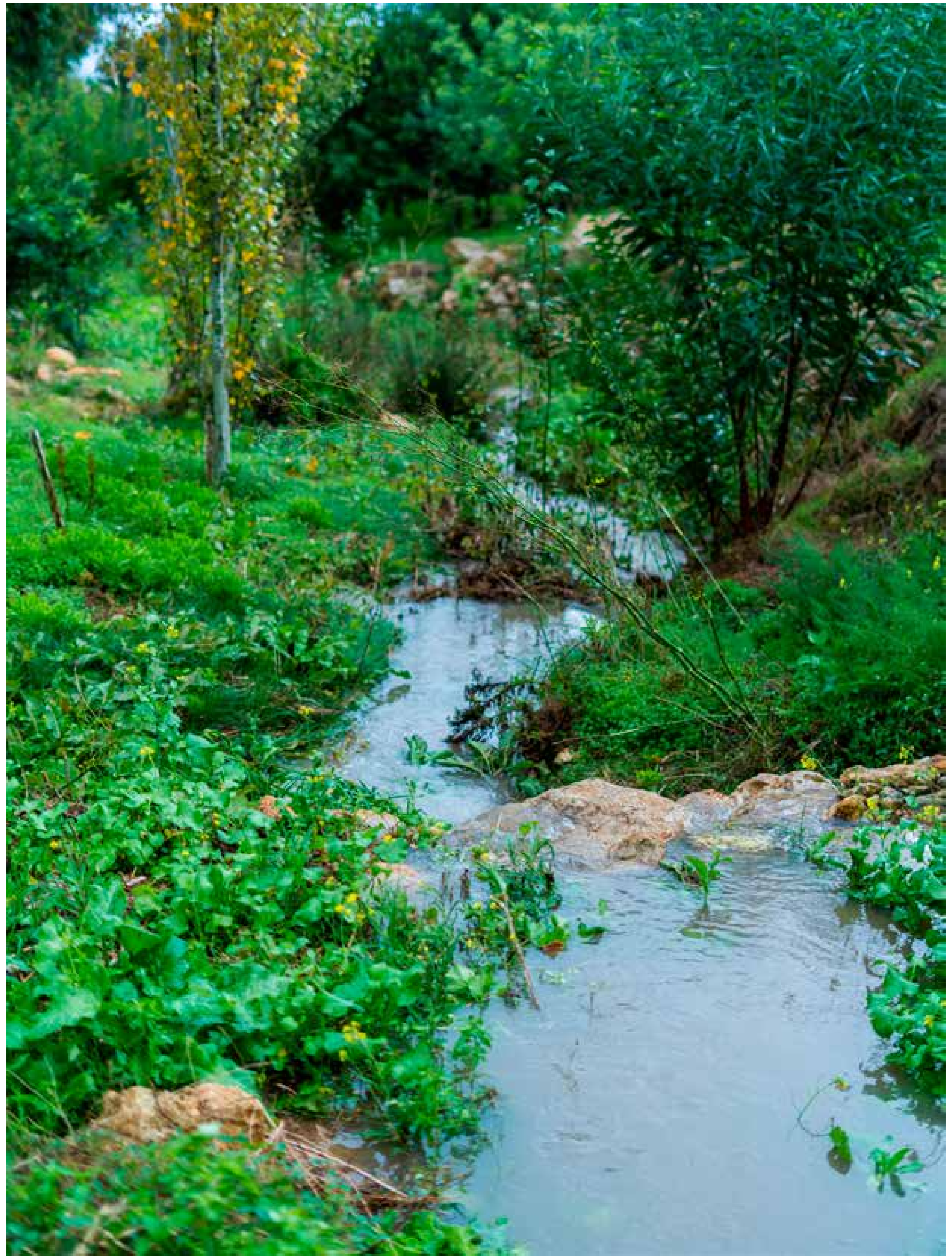
In an effort to regenerate the valley into an ecosystem befitting its environment, a group of residents in the Santa Maria Estate re-established the Residents' Association with a new statute that included the sustainable stewardship of the valley, and with a vision to reverse the damage that society had inflicted on this watercourse. An essential part of the vision was to involve young people, especially children challenged with varying degrees of ability, in order to establish the very important concept that the environment belongs to us all, and that we can all do our bit to conserve it, to protect it and to regenerate it wherever it has been degraded or compromised.

An ecological profile of the valley was established by conducting a detailed survey all the way from Triq iż-Żebbuġ to Santa Maria Bay. Survey findings indicated that, despite the severe degradation and rampant colonisation by alien and invasive species, there were large swathes of the valley that still manifested a vibrant biodiversity which warranted restoration and regeneration.

The Għaqda tar-Residenti ta' Santa Marija Estate identified one stretch of the watercourse as a pilot area for rehabilitation. To begin with, the area was cleared of accumulated rubbish. This was not carried out merely for aesthetic reasons. Some of the waste constituted serious hazards for volunteers working in the valley, being either very heavy, highly inflammable, or toxic. Mellieħa Local Council provided vehicles for waste removal and arranged for its proper disposal.

Next, invasive species were removed from the pilot area, including Acacias, Mediterranean Smilax (*Smilax aspera*), American Carob (*Prosopis pallida*), Canary Palm (*Phoenix canariensis*) and the ubiquitous Bramble (*Rubus ulmifolius*), where this threatened the survival of planted indigenous trees. Plant material above ground was cut back and heaped into mounds to dry, before being shredded and turned into a mulch. All roots or stumps of invasive species were then painstakingly dug up.

Wied Għajn Żejtuna, Malta



Wied Għajn Żejtuna Watercourse

Some members participated in an ongoing propagation programme, generating a stock of indigenous trees and shrubs with which to re-plant cleared areas and develop woodland habitats. A major challenge has been that germination and rooting take place mainly in late winter to early spring, after which the new plants face at least five months of formidable drought. The relatively steep banks of the valley create a shaded environment that plays a crucial role in helping the new trees to establish themselves, especially during these long, dry summer months. The mulch produced from valley clearance has also been used to offer a level of protection for the newly planted saplings, as well as to improve soil structure and help to conserve moisture.

Inflowing stormwater and freshwater springs ensure that the watercourse and associated banks maintain a level of soil moisture that supports the new saplings. The regular flow of stormwater brings in a considerable amount of soil and sediment, which provides an excellent medium for propagation and cultivation. The stormwater also brings in seeds and plants fragments, allowing both indigenous and alien invasive species to colonise the watercourse. Great pains have therefore been taken to remove the alien species before they establish themselves, while allowing the indigenous species to gain a foothold in the valley.

In this kind of venture, noble intentions alone are not enough to achieve successful restoration outcomes. Volunteers often start out unable to distinguish between an indigenous species and an alien one, and with a desire to obtain an aesthetically appealing result equivalent to creating a park inside a residential area. They may refrain from uprooting alien invasive plants because they consider them beautiful, while viewing some indigenous species as drab, colourless, and unappealing. Furthermore, ecosystem rehabilitation requires meticulous, patient, and, invariably, very slow work. There is no way you can hurry up the processes of nature.

Motivation is essential and so, to inject a sense of purpose into volunteers' endeavours, the project focussed on fostering a comprehensive understanding of the importance of indigenous species and their contribution to the dynamics of an ecosystem. Members were also shown how indigenous species were propagated from seed, from cuttings, or from division. This understanding of the techniques required to produce new seedlings or saplings led to the realisation that the loss of any one of them meant three- or four-years' work down the drain.

The most effective approach was found to be in associating indigenous trees and plants with their history, their folklore, and their medicinal properties. The narratives about these properties never failed to captivate audiences. Suddenly, volunteers would start taking a very keen interest in learning the names of these species and insisted on learning not only their English names but also their Maltese names and the botanical terms. Members started to buy name plaques to fix next to these trees so that they would be reminded of their names and could pass on their knowledge to visitors and acquaintances. A seed fostering initiative was also set up, asking volunteers and members to nurture a few potted plants in their own gardens in the shade of a tree until they were sufficiently developed to be planted in the valley.

Looking back, all of those involved in the project would likely admit that we had no idea what we were getting ourselves involved in. We were not prepared for the logistical, bureaucratic, legal, social, and financial hurdles the project would spawn. Nevertheless, we persevered in our determination to demonstrate that the project was not only ecologically but also legally sustainable. A key aspect of our endeavours was to inoculate in our members, and in the public that followed our progress, an unwavering respect for environmental laws and regulations. As a result, we managed to retain the support and endorsement of key administrative bodies, including the Mellieħa Local Council, the Valley Management Unit, the Environment and Resources Authority, the Ministry for the Environment, and several environmental non-governmental organisations. Without this support and assistance, we would never have managed to nurture the trees that we have planted. In fact, we can safely say that this project has succeeded because several entities have believed in our vision and have provided assistance when we needed it most.

It is now most gratifying to see how this stretch of degraded wasteland has been transformed into a vibrant oasis of biodiversity and lush shade. Already nature is taking over and proving that, with just a little determined assistance, it can very rapidly start healing itself.

Established Native Trees

Carob tree flowers

Fennel seedpods

Wild grass

Caper bush

Bramble branches

Bracket fungus spp.

Wied Għajn Żejtuna channel

Chaste tree flowers

Broomrape species

Mastic tree

Ivy

Love-in-a-mist Flower

Traveller's Joy Flowers

Glossary

Alien and invasive species: Species that have been introduced, either accidentally or deliberately, outside their natural geographic range and have the potential to cause major environmental and/or socio-economic impacts within their new environment.

Aquifer: A body of rock or sediment that holds groundwater and allows the water to flow through and be extracted from it. A perched aquifer is one that sits above the regional groundwater level and is held in this relatively elevated position by an impermeable base layer.

Biodiversity: The total variety of different life forms found in the world, or within a particular region or habitat.

Bioengineering: An approach that combines engineering and biology. In the case of ecological restoration works, this involves making use of plants to help protect and regenerate a natural area.

Catchment: The area in which, were it not to evaporate, any water falling as rain would eventually drain into the same watercourse.

Conductivity: The ability of a material to transmit an electrical current. In soil science, this gives an indication of the physical and chemical properties of the soil.

Digital Surface Model (DSM): A digital map layer that shows the elevation above mean sea level of both the natural and built features of an environment.

Digital Terrain Model (DTM): A digital map layer that shows the elevation above mean sea level of the natural features of an environment only.

Ecohydrology: The relationship between water and ecological systems, either in a particular place or as a branch of hydrological study.

Ecology: The study of the relationships between plants, animals, people and their environment, or the nature of these relationships in a particular place.

Ecosystem: A single environment, including all of its living and non-living components.

Ecosystem services: The benefits that ecosystems provide to humankind.

Ephemeral stream: A stream that only flow for short periods of time, usually after heavy local rainfall.

Garrigue: An open scrubland habitat with low-growing vegetation found in dry Mediterranean regions.

Gastropod: The group of animal life including slugs and snails.

Geodatabase: A collection of geographic datasets, held together in a common file system.

Geographical Information System (GIS): A framework for gathering, managing and analysing geographic data.

Geology: The scientific study of rocks and Earth systems.

Geomorphology: The study of the physical features of the Earth's surface and their development, or the nature of these features at a particular place.

Habitat: A particular group of plants, animals and the non-living parts of their environment or, when referring to the habitat of a particular species, the area and resources used by that species.

Hillshade: A digital map layer showing a three-dimensional representation of a surface using the sun's relative position to shade the image.

Hydrology: The study of water properties, distribution and movement in the environment in general, or as found in a particular place.

Hydromorphology: The physical characteristics of waterbodies, and the scientific study of their development.

Hydrophyte: A plant that grows either totally or partly submerged in water.

Intermittent stream: A stream that dries up for some portion of the year.

Knights period: The Early Modern period during which Malta was ruled by the Knights Hospitaller of the Order of St John, between 1530 and 1798.

Maquis: A habitat characterised by the presence of large shrubs and small trees found in dry Mediterranean regions.

Medieval: The High Medieval period comprises the late tenth till early thirteenth centuries AD, and in Malta involved the Muslim and Norman periods. The Late Medieval period encompasses the late thirteenth century until the arrival of the Knights Hospitaller of the Order of St John to Malta in AD 1530.

Non-indigenous species: Species that have been introduced, either accidentally or deliberately, outside of their natural range.

Orthomosaic: A digital map layer compiled from a series of individual aerial photographs.

Perennial stream: A stream characterised by permanently flowing water.

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pH: The scale used to measure the acidity or alkalinity of a substance.

Photogrammetry: A technique used to create accurate maps and measurements of physical features using photographs.

Remotely sensed data: Data collected from a distance, without any physical contact. This often refers to information collected by satellites.

Rhizome: A modified plant stem running horizontally underground that can produce new plant shoots.

Riparian: The area of land bordering rivers and streams, or the species typically found within these areas.

Tectonic: Relating to the large scale structure and movements of the Earth's crust.

Terrestrial: Something belonging to the Earth. In ecology, this typically means a plant or animal found on dry land, as opposed to in water or the air.

Upper Coralline Limestone: The youngest and uppermost geological layer found in Malta, composed of hard, pale-grey limestone.

LIFE IP Programme 2014-2020

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