LIFE Integrated Projects 2016

Optimising the implementation of the 2nd RBMP in the Malta River Basin District

LIFE 16 IPE MT 008

Action D.3 - Assessment of the LIFE Integrated Project's impact on the Ecosystems Services

Interim assessment of the existing ecosystem services contribution for the LIFE 16 IPE MT 008 project actions

Ref: EWA/CFT/11/2018

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Aims

The aim of this report is to carry out an interim assessment of the project's contribution towards ecosystems services improvement and restoration.

Background

This report carries out an interim assessment of the project's contribution towards ecosystem services and improvement. This report is based on a characterisation of ecosystem types impacted by the LIFE 16 IPE MT 008 and it assesses ecosystem service using guidance by the European Commission Mapping and Assessment of Ecosystem Services (MAES) initiative[1]. This report uses data for specific ecosystem service indicators to assess the baseline conditions for ecosystem contributions.

The hierarchical structure of CICES, and indicators for each category as proposed by the MAES initiative, has been adopted within the baseline assessment of ecosystem services (Figure 1). As explained in the guidance document on Assessing ecosystems and their services in LIFE projects[2], the hierarchical structure of CICES is adaptable to different scale and geographical contexts and to the varying detail in respective assessment. In general, if aggregated indicators are available or reporting is carried out at larger scales it is cost-effective to consider an assessment of ecosystem services at a high CICES level (e.g. group or division). At finer geographical scales, these broader categories of services might be represented by the specific classes that make sense at the local level.

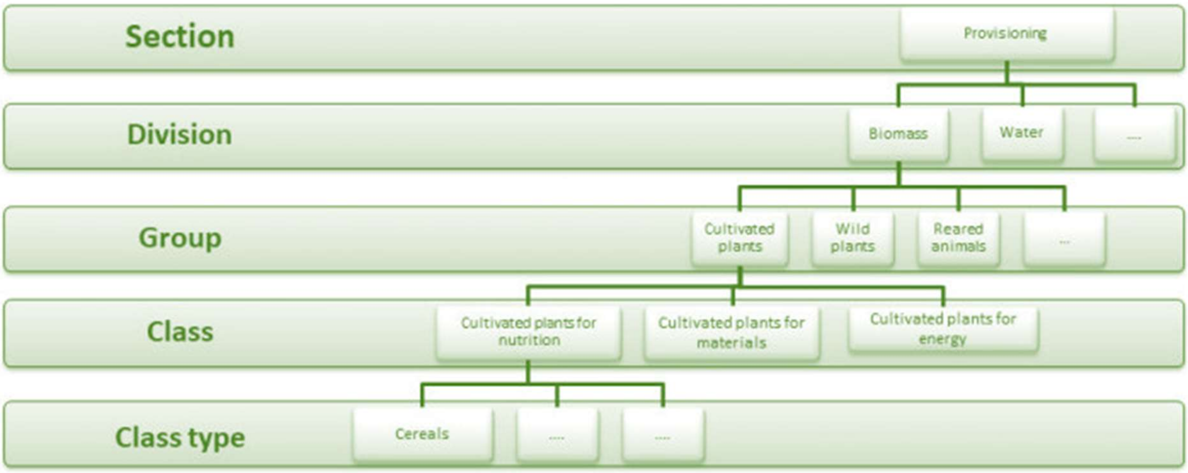

Figure 1: CICES structure (Source: https://cices.eu/cices-structure/)

The assessment is based on the outcomes of consultation meetings held with each beneficiary of the LIFE 16 IPE MT 008 project to ensure that all the activities that have an impact on ecosystem service and which are being carried out as part of the LIFE 16 IPE MT 008 project, are included in the baseline and interim assessments, and the relevant spatial and temporal scales of their impacts identified. During the consultation with the different partners, existing information and data owners, including geodata about ecosystems, ecosystem functions and services and their value, which are of relevance to the implemented actions and the MAES ecosystem types and services, were identified.

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[1] https://biodiversity.europa.eu/maes

[2] Assessing ecosystems and their services in LIFE projects: https://ec.europa.eu/environment/archives/life/toolkit/pmtools/life2014_2020/documents/life_ecosystem_services_guidance.pdf

Methodological Framework and Ecosystem Service Indicators

Direct Contributions to Ecosystem Services

In this interim assessment of the project actions ecosystem services contributions an analysis of the project actions is carried out, and actions that were identified as potentially having a direct contribution are identified.

Based on previous baseline assessment, the following actions were therefore identified as potentially having a more direct impact on ecosystem services:

- C.4. – Water educational campaign
- C.6. – Demonstration site for the application of new water resources - Gozo
- C.7. – Sustainable Urban Drainage Systems
- C.8. – Development of a managed aquifer recharge scheme in the Pwales Groundwater Body
- C.9. - Valley Management Plan
- C.13 - Restoration of one of the coastal wetlands
- C14 – Anchoring and mooring surveys

Through reference to regional and international initiatives about the assessment of ecosystem services assessment in wetlands and other ecosystems (e.g. de Groot et al., 2006; Grizzetti et al., 2016a; MAES, 2018; Maes et al., 2014; Mehvar et al., 2018; Russi et al., 2013) and following consultation with the Environment & Resources Authority, as the authority responsible for national ecosystem services assessment in Malta, ecosystem services indicators for the project actions were identified and presented in the baseline assessment of ecosystem services. The ecosystem services indicators were classified according to the three stages of the ecosystem services conceptual framework, linking ecosystem services capacities, flows and benefits to communities, and shown in Figure 2.

The ecosystem services conceptual framework distinguishes between the capacity of the ecosystems to deliver the service, the actual flow of the service, and the arising benefits and values. Ecosystem service capacity refers to the potential of the ecosystem to provide ecosystem services and relies on biophysical data. Ecosystem service flows provide information about the actual use of the ecosystem service and rely on socio-economic data. On the other hand, benefits are associated with human well-being and the value system. Values can be expressed in a number of different ways, including monetary, moral and spiritual criteria (Grizzetti *et al.*, 2016; Potschin and Haines-Young, 2016).

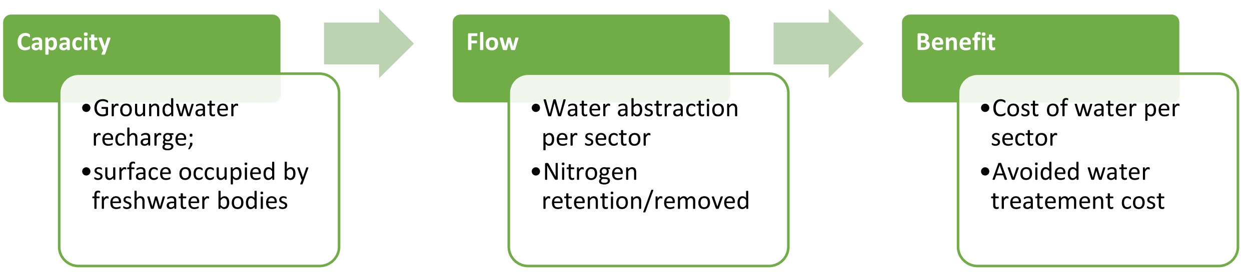

Figure 2 – Conceptual framework to classify indicators (adapted from Grizzetti et al., 2016).

Table 1 lists the ecosystems and ecosystem services that may be impacted by the project actions and identifies ecosystem service indicator and indicator type that will be used to assess the project contributions to ecosystem services.

The baseline assessment of the current environmental status and ecosystem services was intended to provide the necessary information that will be used to measure and assess the impact of the project's implementation towards the improvement of ecosystem services. This baseline assessment was carried out through consultation with the beneficiaries of the LIFE 16 IPE MT 008 project and subsequently through further data elaboration and analysis for different types of datasets.

The baseline assessment of ecosystem services was implemented according to the described methodological framework and using data relating to the ecosystem service indicators identified in the previous section for sites of implementation. Consultation about the ecosystem service indicators was also carried out with the Environment & Resources Authority, as the authority responsible for national ecosystem services assessment in Malta.

Some of the actions (e.g. actions C.7, C.9 and C.14) were at the initial phases of implementation, or will be implemented at a later phase in the project, and have therefore not yet identified the sites of intervention and the specific measures that will be carried out since these depend on the environmental and socio-economic characteristics of the sites and assessment of the interventions. These measures will also carry out monitoring that provides important data for the assessment of the improvement in environmental conditions. This is considered a critical input in assessing the contributions of these actions to ecosystem services.

During the preparation of this interim assessment, meetings were held with the authorities coordinating each of the actions having an impact on ecosystem services, and information about the status of the action, works carried out in specific sites, and ongoing monitoring was collected. It has, therefore, been possible to collect new data and update the indicator data collected during the baseline study while in other cases, for example when actions are in the planning phase, an overview of the potential contributions to ecosystem services is provided in this report.

Indirect Contributions to Ecosystem Services

In addition to the direct contributions to ecosystem services identified and assessed in this report, during the consultation with LIFE 16 IPE MT 008 beneficiaries, several actions were identified as leading to improved knowledge or capacity which, subject to the use in follow-up implementation actions, can lead to impact on ecosystem services. These potential indirect impacts arising from the implementation of these actions are also described briefly in this report.

Table 1 – An overview of the potential contributions of the LIFE 16 IPE MT 008 project to ecosystem services according to the ecosystem and the spatial extent of the action, and a list of ecosystem service indicators that may be used to assess these contributions.

Action	Action Start	Spatial Extent	Ecosystem	Ecosystem Services	Identified Ecosystem Service Indicators	Type of indicator (Capacity/Flow/Benefit)
C.4. – Water educational campaign	2018	Various schools		Intellectual and representative interactions with the natural environment	Number of projects by schools	Flow
					Number of participants	Flow
C.6. – Demonstration site for the application of new water resources - Gozo	2020	Gozo Experimental Farm, Gozo	Cropland	Cultivated terrestrial plants for nutrition, materials or energy	Crop production (surface area/production)	Capacity/Flow
C.7. – Sustainable Urban Drainage Systems	2020	Stormwater harvesting areas	Urban	Hydrological cycle and water flow regulation (flood control)	Recharge/Infiltration rates	Capacity
					Water retention or Reduction of surface runoff	Capacity
C.8. – Development of a managed aquifer recharge scheme in the Pwales Groundwater Body	2022	Pwales Valley	Cropland	Groundwater used for nutrition, materials or energy	Volume of water used for aquifer recharge;	Capacity
					Chemical status (chloride concentration)	
C.9. – Valley Management Plan	2020	*Not determined at this stage*	Streams, Cropland, Riparian Habitat	Cultivated crops Reared animals and their outputs Surface water for non-drinking purposes Groundwater for drinking purposes Groundwater for non-drinking purposes	Crop Area Livestock Density Number of reservoirs and storage capacity Infiltration rates Freshwater abstracted within water catchment Cover management Soil loss per unit area Density of rubble walls in moderate and good state	Capacity/Flow Capacity/Flow Capacity/Flow Capacity Flow Capacity Capacity

				Mass stabilisation and control of erosion rates Hydrological cycle and water flow regulation (flood control) Pollination Maintenance of nursery populations and habitats Scientific and educational Heritage Aesthetic	Off-site costs of soil erosion Costs associated with soil recovery Costs associated with loss of agricultural production Total area of permeable surfaces Population living in flood risk areas Bee Habitat Honeybee hive density Number of habitats of community importance Number of species of community importance Number of scientific and educational publications Number of heritage sites Area of high landscape value	Benefit Benefit Benefit Capacity Benefit Capacity Capacity/Flow Capacity/Flow Capacity/Flow Flow Capacity Capacity
C.13 - Restoration of one of the coastal wetlands	2021	Ballut Coastal Wetland, Marsaxlokk	Wetland	Water conditions	Chemical status	Capacity
				Lifecycle maintenance, habitat and gene pool protection;	Ecological Status	Capacity
					Habitat cover (biotope map)	Capacity
				Mediation of wastes, or toxic substances of anthropogenic origin by living processes;	Nutrient Concentration	Capacity
				Control of erosion rates	Rate of erosion	Flow
				Physical and experiential	Site visitation	Flow

				interactions with natural environment		
C14 – Anchoring and mooring surveys	2021	Marine vessel and mooring areas	Coastal	Lifecycle maintenance, habitat and gene pool protection	PREI (*Posidonia oceanica* Rapid Easy Index)	Capacity
					Area of *P. oceanica* and other sensitive benthic habitats from which the impact of anchoring/mooring is removed	Capacity
					Extent of *P. oceanica* (coastal sites)	Capacity
				Regulation of chemical composition of atmosphere and oceans	Carbon Storage	Capacity
					Estimated value of long-term C Storage	Benefit
				Physical and experiential interactions with natural environment	Site visitation (number of vessels)	Flow
					Number of divers	Flow
					Expenditure of tourists engaging in diving activity	Benefit

C.4. – Water educational campaign

Intellectual and representative interactions with natural environment

Ecosystem service indicator: Number of projects by schools (Flow)

Ecosystem service indicator: Number of participants (Flow)

Action C.4. has created an educational strategy targeting students attending the 'Għajn - The National Water Conservation Awareness Centre'. Measures carried out by the Centre include the provision of free transport for educational visits to the Centre and support for the development of small projects relating to water harvesting and management in schools.

This action develops and implements a water educational programme for children in Malta to raise awareness on the scarcity of natural water resources in the Maltese Islands and to promote water conservation in the younger generations.

The experiential use of water, as an ecosystem good, is considered as an intellectual and representative interaction with the natural environment (CICES Division 3.1.2). This ecosystem service category includes educational, scientific, cultural and aesthetic benefits derived from ecosystems.

This interim assessment presents a baseline (2018) and interim assessment of the participation of school children in activities carried out by the Centre. Data presented here is based on an assessment of visits to the Centre carried out by schools during the academic year and the number of water conservation projects that have been funded by the Centre (Table 2).

The participation in the educational activities organised by the Centre has been impacted by the COVID19 global pandemic which has, to varying extents and according to the restrictions set by the authorities, limited visitation to the Centre from 2019 onwards. The Centre has, therefore, through collaborations with other entities co-organised and participated in online training and awareness raising activities.

Table 2 – Ecosystem service indicators for Action C.4 – Water Educational Campaign.

Action	Ecosystem service	Ecosystem service indicator	Type of indicator	2018	2019	2020	2021
C.4.	Intellectual and representative interactions with natural environment	Number of projects by schools	Flow	11 projects	10 projects	8 projects	
C.4.	Intellectual and representative interactions with natural environment	Total number of participants of the Water Conservation Awareness Educational Programme	Flow	1589 participants	1705 participants	624 participants	112 participants

C.6. – Demonstration site for the application of new water resources – Gozo

Cultivated terrestrial plants for nutrition, materials or energy

Ecosystem service indicator: Crop production (Capacity/Flow)

Action C.6. develops a demonstration site at the Government Experimental Farm in Gozo for the application of New Water to agricultural irrigation. The tasks carried out as part of this action involve the construction of a bi-partitioned reservoir for the storage of New Water and groundwater, the installation of infrastructure and pumping equipment to cater for the distribution of the irrigation source to different sections of the farm, and the carrying out of crop trials at the Government Experimental Farm in Gozo. Recent work carried out within Action C.6. has focused on developing the required infrastructure for the implementation of the crop trials. The trials will test whether the new water quality is equivalent or better than borehole water in terms of its salinity and other chemicals present. The trials are expected to include three treatments, namely new water, borehole water, rainwater, and a control. Testing will be carried out in 3 demonstration areas: glasshouse, open field with citrus, and open field with crops.

The main contribution to ecosystem services is expected to be associated with crop production. It is expected that the contributions of the LIFE 16 IPE MT 008 project to this ecosystem services will be measured during these crop trials, and, amongst others, records of water use for irrigation, crop production, taste, quality of produce and other variables will be kept. This data will allow for a comparison on the impacts of water type on crop production.

In addition to production data measured these trials, greenhouse crop production at the Gozo Experimental Farm during the two years preceding the start of the action has been provided by the Rural Gozo Directorate. This data may be used to allow for a long-term comparison of the impact of New Water availability on crop production within the farm. However, it must be noted that the main purpose of the propagation of the crops in the greenhouses during the baseline years (2018 and 2019) is mainly for research. The crops propagated in open fields are mainly local varieties, with production being very low. Similarly, production from fruit trees is very low as these are also used for research trials, with the water supply being limited.

Table 3 – Greenhouse crop production at the Gozo Experimental Farm during the years 2018 and 2019.

Crop	Year	Total Production (Kg)	Yield (Kg/m^2)
Tomatoes	2019	3480	6.4
Cucumbers		6230	11.45
Aubergines		441	3.24
Peppers		479	3.52
Total Production (2019)		10630	
Tomatoes	2018	999	0.96
Cucumbers		5879	10.81
Aubergines		1143	4.2
Peppers		681	2.5
Cherry Tomatoes		408	9.07
Melon		1916	7.04
Watermelon		1132	4.16
Total Production (2018)		12158	

C.7. – Sustainable Urban Drainage Systems (SUDS)

Hydrological cycle and water flow regulation (flood control)

Ecosystem Service Indicator: Recharge/Infiltration rates (Capacity)

Ecosystem Service Indicator: Water retention or Reduction of surface runoff (Capacity)

Action C.7. will implement demonstration sustainable urban drainage systems (SUDS) to increase runoff generation time and promote the infiltration and percolation of water, thus leading to natural recharge. It is expected that soft landscaping, permeable pavements and green roofs will be used as demonstration SUDS within this action.

MTIP, together with a contractor engaged for this task, is carrying out the following steps forming part of a decision-making framework for this action: 1. to perform project scoping and preliminary planning for green stormwater infrastructure, 2. to select best management practice types and locations, 3. to conduct locations' investigations and analysis to confirm best management practices selection and sizing, and, 4. to design to construct and maintain best management practices. The steps translated into the following project tasks: 1. organise and conduct meetings with stakeholders, 2. project scoping and preliminary planning for green stormwater infrastructure, 3. Preparation of green stormwater infrastructure best management practices fact sheets, green stormwater infrastructure estimation methods selection and interpretation guide, 4. Identification of locations, types, and potential footprints of the best management practices and the overall conceptual design of each best management practice, 5. conducting locations' investigations and analysis to confirm best management practices selection and sizing, 6. design to construct and maintain best management practices, 7. prepare best management practices case studies, 8. draft guidance manual, 9. organise one conference on behalf of MTIP and prepare proceedings, and, 10. final reporting.

The contributions of this action to ecosystem services will depend on the selection of the case-study projects, the baseline environmental and socio-economic conditions within the site and the type of SuDS that are implemented in the case-studies, but the following list of environmental benefits has been identified (LIFE16IPE MT 008 Interim Report Covering the project activities from 01/01/2020 to 31/12/2021):

- Replenishing and augmenting groundwater by capture, treatment, and recharge of runoff,
- Trap pollutants, reduce water treatment need and can release water back to the water system and underlying ground, hence contributing to improve water quality,
- Provide corridors and habitats for wildlife species,
- Urban cooling from heat island effect, and
- Carbon sequestration, which might reduce climate change impacts fuelling energy demand.

The pilot SuDS will include information elements to highlight the application of these practices and the potential wider benefits associated with their application. In this respect, these information elements will also present the results achieved (rainwater runoff generation reduction) to highlight the eventual successful application of such techniques.

Other social and economic benefits arising from the implementation of SUDS include:

- Flooding losses avoided, cost savings, and increased property values,
- Calming traffic and traffic noise reduction,
- Reducing stress for drivers,
- Increasing streets' walkability and bikeability,
- Provide spaces for physical activities and relaxation,

- Enhancing neighbourhood aesthetics and livability,
- Provide space for socializing, and,
- Reducing the strain on stormwater infrastructure by decreasing the amount of stormwater that flows through it.

C.8. – Development of a managed aquifer recharge scheme in the Pwales Groundwater Body

Ground water used for nutrition, materials or energy (CICES 4.2.2)

Ecosystem service indicator: Chemical status (Chloride concentration; Capacity)

The Pwales groundwater body occurs within a downthrown syncline of Upper Coralline Limestone which sits over clay at an altitude of 21m in the western side near Ghajn Tuffieha whilst it dips below sea-level to a depth of around 30m at the eastern side along Xemxija bay. Saltwater intrusion is quasi-horizontal spreading from east to west, and therefore the wells located at the western edge of the valley are least susceptible to seawater intrusion (SEWCU, 2015).

Figure 3 – Satellite image of the Pwales valley (Source: Google Earth)

Water quality monitoring in the Pwales is carried out as part of the requirement of Article 8 of the Water Framework Directive. The established national framework for qualitative and quantitative monitoring is described in the 2nd Water Catchment Management Plan for the Malta Water Catchment District. The Groundwater Directive under Annex II requires Member States to establish threshold values for all pollutants and indicators of pollution which characterise bodies or groups of bodies of groundwater as being at risk of failing to achieve good groundwater chemical status. The threshold value determination was based on historical and current groundwater quality data and the environmental characteristics of the groundwater body. For Malta's coastal groundwater bodies, such as the Pwales aquifer, a threshold value of 500 mg/L has been established.

Data from groundwater monitoring shows that the chloride concentration is higher than the set threshold value of 500 mg/L. No significant increase in chloride concentration over the monitoring period, starting in 2009, and shown in Figure 4 is detected.

An average recorded concentration of 403.5 (±158.3) mg/L of nitrates was recorded within the Pwales ground water body. The data presents some variation in nitrate concentration, and while an overall increase in nitrate concentration can be observed, no significant trend could be detected using regression analysis for this dataset over the monitoring period (Figure 5).

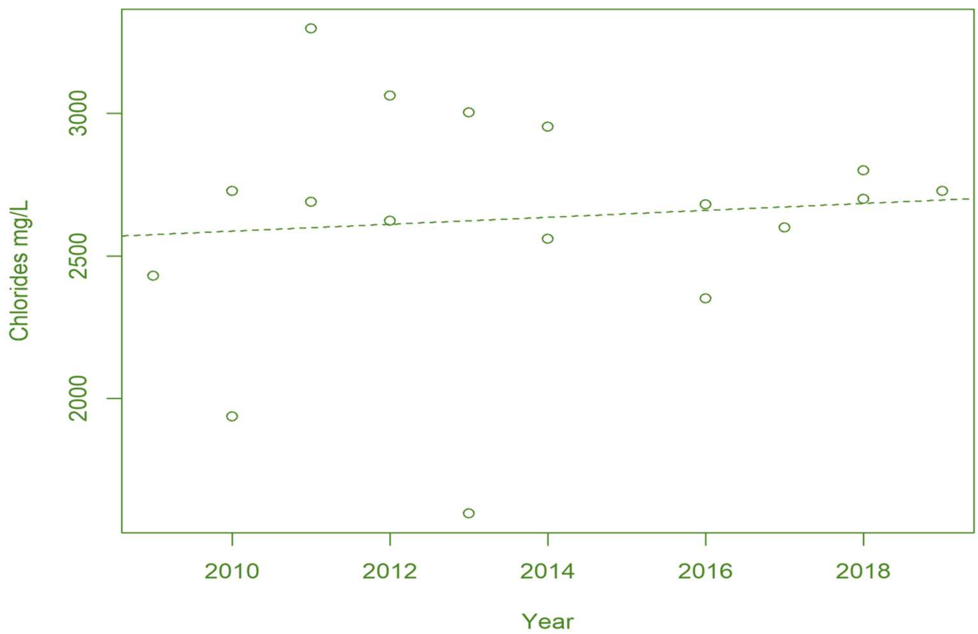

Figure 4 – Scatterplot for change in chloride concentration (mg/L) with time in the Pwales Ground Water Body (coefficient of determination $R^2 = 0.0089$; p-val = 0.72; df=15).

Action C.8 implements a managed aquifer recharge scheme for the Pwales aquifer system. The Pwales valley is one of the most fertile agricultural areas in northern Malta, and in this valley intensive agriculture is dependent on irrigation. This aquifer system had been identified in studies leading to the formulation of Malta's 2nd River Basin Management Plan as one of the ideal sites for undertaking managed aquifer recharge techniques as it is considered as being hydrologically isolated and there are strong anthropogenic impacts on the water body. During consultation with the LIFE 16 IPE MT 008 beneficiaries, the high salinity of the Pwales groundwater was identified as main threat, impacting on its current and potential use for crop production in the Pwales area.

This action is highly linked with the ongoing work in the 'new water' project, in which dispensing points will be created for the use of new water for irrigation purposes within the Pwales Valley. The quality of the new water is currently being studied. During the action six boreholes will be used for the injection of new water and another seven boreholes will be used for monitoring purposes.

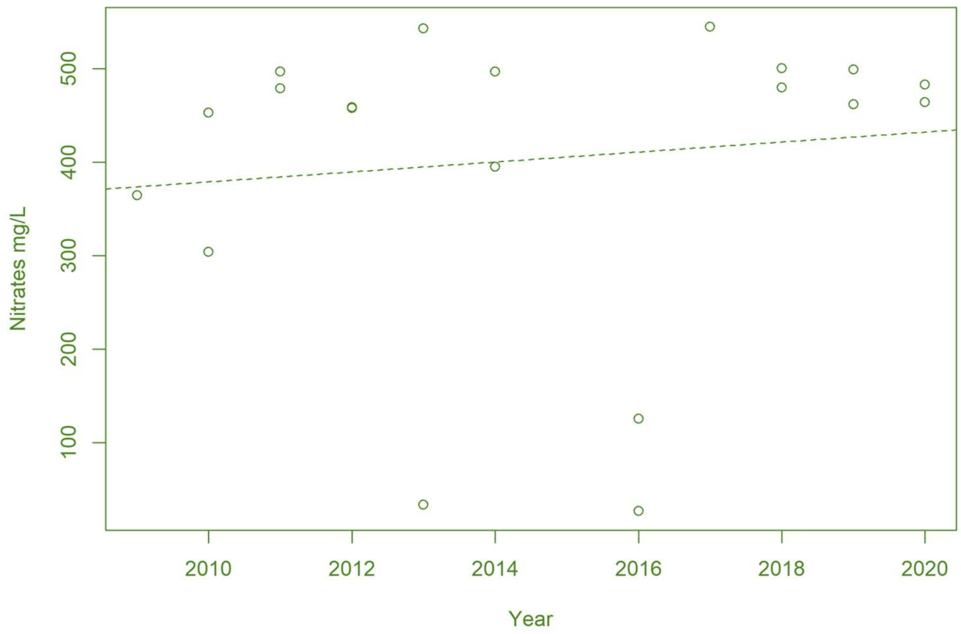

Figure 5 – Scatterplot for change in nitrate concentration (mg/L) with time in the Pwales Ground Water body (coefficient of determination R^2 =0.015; p-val=0.61; df=18)

During discussions with EWA, it was ascertained that groundwater recharge will commence in 2023 and that monitoring of the water quality will thereafter be carried out. Since the assessment carried out and presented in D3 - Baseline assessment, efforts have focused on gathering baseline data on the groundwater body condition and use, which include the implementation of a geophysical survey, data collection from farmers regarding water level, and depth of the water source, and usage.

During the identification of the impacts of the action on ecosystem services, one intermediate ecosystem service has been identified as being impacted by this action (Table 4). Intermediate ecosystem services are defined as ecological functions or processes not used directly by a beneficiary but which underpin those final ecosystem services which are used directly (Potschin-Young *et al.*, 2018). Groundwater storage is therefore considered as intermediate ecosystem services that is required for crop provisioning ecosystem services within the Pwales valley. Two ecosystem service indicators have been proposed, namely the volume of water used for aquifer recharge and the chemical status (Chloride concentration). Since no significant long-term change in chloride levels is detected (Figure 4), and given the long-term variability in chloride concentrations, two baseline values for chloride concentration are presented to represent the short term and long-term averages for chemical status, as shown in Table 4.

Ecosystem service indicator: Volume of water used for aquifer recharge (Capacity);

Aquifer recharge will be carried out as part of the action and the baseline value for this indicator is therefore consider as being nil (Table 4).

Table 4 – Ecosystem service indicators for Action C.8 - Development of a managed aquifer recharge scheme in the Pwales Groundwater Body.

Action	Ecosystem service	Ecosystem service indicator	Type of indicator	Ecosystem service baseline
C.8.	Ground water used for nutrition, materials or energy	Volume of water used for aquifer recharge (litres);	Capacity	Nil
C.8.	Ground water used for nutrition, materials or energy	Chemical status (chloride concentration – mg/L)	Capacity	Short-term (2-year) average (2018-2019): 2742.67 ± 42.12 mg/L
				Long-term average (2009 – 2019): 2631.69 ± 392.16 mg/L
		Chemical status (nitrate concentration – mg/L)	Capacity	Short-term (2-year) average (2018-2019): 477 ± 17.45 mg/L
				Long-term average (2009 – 2020): 403.48 ± 158.32 mg/L

C.9. – Valley Management Plan

Action C.9. develops two pilot projects, one in Malta and another in Gozo, which will serve as case-studies to monitor the effectiveness of the guidelines provided in the Master Plans developed in Action A.8. The two selected valleys are Wied Speranza (Malta) and Wied tal-Grixti, Xlendi (Gozo).

As part of Action A.8. work has been carried out to assess ecosystem services and value associated benefits in identified catchment areas (Figure 6). This work was based on data collected by Parks Malta and has also used other environmental dataset relating to ecosystem services quantification and valuation and has been carried out by Ecostack Innovations Limited (engaged by Parks Malta). This work has now been finalised and a total of 15 ecosystem services have been mapped and assessed using ecosystem service indicators (Table 1) and expert scoring. The expert scores were used to create an ecosystem service matrix with an average score for each ecosystem service capacity according to the ecosystem. This dataset consists of a look-up table with assigned ecosystem service scores for each ecosystem type, with each of the scores being based on ranks assigned by expert and stakeholders during a consultation workshop.

During the stakeholder/expert workshop the experts were asked to rank ecosystems and different land use land cover categories to ecosystem services by ranking ecosystem service capacities on a scale from 0 to 5. At the end of the workshop the data submitted by each participant was compiled and used to extract the mean and standard deviation for each score. This data is the presented in the form a matrix that lists mean rankings (and their standard deviation) for every ecosystem service-land cover category interaction considered.

The ecosystem service assessments carried out by the consultant for all valley catchments considered in Action A.8. have been published on a dedicated geoportal and are summarised briefly below:

- **Economic Valuations:**
    - *Total Economic Value of Annual Crop Production:* Using national annual data for fruit and vegetable production and for the utilised agricultural land (UAA), as collected by the NSO for the years 2019 and 2016 respectively, the economic value of agricultural production per square kilometre of UAA was calculated. Market value of agricultural production within the study area was estimated at € 11,943,826, with the largest contributions made by the Wied il-Kbir and Wied il-Għasel catchments
    - *Cost of Off-Site Soil Erosion*: National data for soil erosion has been used to calculate the off-site costs of soil erosion, associated with the clearing of eroded soil sediment from the catchments areas and deposited in valleys and other water bodies. The direct costs associated with the dredging of the material were calculated using cost data for the year 2020, as obtained from the Valley Management Unit, for the removal of eroded sediment from the catchments in the AoS and disposal off-site. An average unit price of 25€/m3 of soil dredged was calculated accordingly. Similar to previously reported trends, the highest off-site cost of soil erosion is recorded in the largest catchments but when the values are standardised per unit area, the Ġnejna, Dwejra Gozo and Wied Għomor catchments had the highest soil erosion off-site costs. The lowest values were obtained for the Wied Blandun, Wied Dalam and Ħarq Ħamiem catchments had the lowest off-sites costs, in line with previously documented trends indicating lower soil erosion rates in these catchments.
    - *Cost of Soil Recovery:* Eroded soils need to be restored to ensure continued sustainable agriculture. The costs of soil recovery was used as an indicator of the required spending to restore soil ecosystems. The cost associated for the restoration of the soil was calculated at catchment level using estimated soil erosion volumes and average cost data for 1m^3 of soil. The latter was based on actual cost data for soil purchases by Ambjent Malta in 2017 and amounted to an average of 8.54€/m^3 of purchased soil (including VAT). The Ġnejna, Dwejra Gozo and Wied Għomor catchments had the highest soil erosion off-site costs per unit area whilst Wied Blandun, Wied Dalam and Ħarq Ħamiem catchments had the lowest costs for soil recovery.
    - *Economic Value of Pollinated Crops per Km^2:* The value of pollination ecosystem services may be assessed using pollinator dependency values, as carried out by Balzan et al. (2018) who downscale national fruit and production data to calculate the production dependence on biotic pollination. Using average crop pollination dependency data (Balzan et al., 2018) and crop area in different catchments, the value of crop pollination within each catchment was estimated. Total annual crop production dependent on biotic pollination within the study area was estimated to be €2,171,388, with substantial variation between the various catchments. Crop pollination dependence follows on the distribution of agricultural land cover (Balzan et al., 2018), and accordingly the highest values of crop production and associated economic benefits of crop pollination were recorded in the Wied il-Kbir and Wied il-

Għasel catchments whilst the lowest values were recorded for more urbanised catchments, that is the Ħarq Ħamiem and Blandun catchments.

In addition to measuring crop pollination, beehive density and bee habitat indicator data were mapped for the study area. The Zonqor, Għomor and Mġarr (Gozo) catchments had the highest beehive density whilst the lowest densities were recorded in the Sant'Antnin, Wied Blandun and Ġnejna catchments. On the other hand, the highest relative pollination potential scores for bee habitat were recorded in the Wied il-Kbir and Wied il-Għasel catchments, but this is strongly influenced by the area of the catchment. Relative Pollination Potential scores per square kilometer indicate that Mistra, Baħrija and Ġnejna have the highest scores whilst the Wied Għomor, Wied Sant'Antnin and Wied Blandun catchments had the lowest relative pollination scores.

- **Provisioning Services:**
    - *Groundwater for Non-Drinking Purposes:* the capacity of different ecosystems to provide groundwater for non-drinking purposes was mapped using expert ranking during a dedicated workshop and is presented as an ecosystem service matrix and map.
    - *Groundwater for Drinking Purposes:* the capacity of different ecosystems to provide groundwater for drinking purposes was mapped using expert ranking during a dedicated workshop and is presented as an ecosystem service matrix and map
    - *Surface water*: the capacity of different ecosystems to provide surface water for non-drinking purposes was mapped using expert ranking during a dedicated workshop and is presented as an ecosystem service matrix and map.
    - *Crop production*: the capacity of different ecosystems to provide cultivated crops was mapped using expert ranking during a dedicated workshop. Additionally, crop area was used as a proxy for crop production. The catchment system having the largest surface area dedicated to crop area is Wied il-Kbir with 21.0 square kilometres, closely followed by Wied il-Għasel, with 20.2 square kilometres of crop area. These catchment areas are the largest ones under review, and therefore they host the largest crop area. Other smaller catchment systems host much smaller crop areas, with the next in line, Sant'Antnin hosting only 4.2 square kilometres. At the bottom end of the spectrum, one can find Wied Blandun and Ħarq Ħamiem, with 0.1 and 0.08 square kilometres respectively. The latter two valley catchment systems are rather urbanised, with a high population density and limited crop area. Out of a total crop area of 63.3 square kilometres, 45.5 square kilometres consist of arable land and 9.0 square kilometres consist of permanent crops. Wied il-Kbir and Wied il-Għasel encompass the largest surface are of arable land and permanent crops. Greenhouses cover the relativity small surface area of 0.5 square kilometres, with Wied il-Kbir and Wied il-Għasel, between them, hosting approximately 70 percent of all the area dedicated to glasshouses.
    - Wild plants: the capacity of different ecosystems to provide habitat for wild plants was mapped using expert ranking during a dedicated workshop and is presented as an ecosystem service matrix and map.

- **Regulating and Maintenance Services:**
  - *Local and microclimate regulation:* the capacity of different ecosystems to regulate the local climate was mapped using expert ranking during a dedicated workshop and is presented as an ecosystem service matrix and map.
  - *Global climate regulation*: the capacity of different ecosystems to regulate the global climate through carbon sequestration was mapped using expert ranking during a dedicated workshop and is presented as an ecosystem service matrix and map.
  - *Control of soil erosion:* mass stabilisation and control of erosion rates capacities were mapped using expert ranking during a dedicated workshop and is presented as an ecosystem service matrix and map.
    Additionally, indicators for cover management (C-factor) and soil loss using the Revised Universal Soil Loss Equation (RUSLE) were measured for all catchments. Substantial variation in the C-factor exists between the AoS catchments, with the Blandun catchment identified as having the highest C-factor whilst the Ħarq Ħamiem and Baħrija catchments having the lowest average C-factor value. The highest total soil loss were recorded in the largest catchments, or the Wied il-Għasel and Wied il-Kbir catchments, whilst the lowest is in Wied Blandun, Wied Dalam and Ħarq Ħamiem catchments.
  - *Flood protection*: the capacity of different ecosystems to provide flood regulation ecosystem services was mapped using expert ranking during a dedicated workshop and is presented as an ecosystem service matrix and map.
    Additionally, the estimated number of individuals benefiting from flood protection ecosystem services has been used a proxy for the measurement of the number of people benefiting from any water reduction runoff by permeable surfaces. High resolution human population distribution data for Malta (Tatem, 2017) was used to calculate the human population in residential areas that are prone to flood risk as identified in Malta's Flood Risk Maps. Flood risk areas overlapped with two catchments from the study area. For Wied il-Għajn, the estimated affected population adds up to 772 whereas for Wied il-Kbir, the population is larger, adding up to 7,307.
  - Regulating the chemical condition of freshwaters: the capacity of different ecosystems to regulate the chemical condition of freshwater was mapped using expert ranking during a dedicated workshop and is presented as an ecosystem service matrix and map.
  - Maintaining nursery populations and habitats: the capacity of different ecosystems to maintain nursery populations and habitats was mapped using expert scoring during a dedicated workshop and is presented as an ecosystem service matrix and map.

- **Cultural services:**
  - Aesthetic: The area of sites designated as Area of High Landscape Value is used as a proxy for aesthetic value. The area of these sites is calculated for each water catchment using the latest national submission to the Common Database on Designated Areas (CDDA) report. Nine of the catchments had areas designated as being of high landscape value. The Baħrija, Ġnejna and Dwejra (Gozo) had the highest proportion of the catchment designated as Area of High Landscape Value.
    The aesthetic value of ecosystems was also mapped using expert scoring.

- *Experiential interactions with natural environment*: Data about site visitation to Heritage Malta sites for the year 2019 was obtained and then mapped for the entire AoS. This dataset was then used to extract the number of heritage sites in each catchment and the number of visitors to each of these sites. Among six out of the sixteen valley catchments under review, one can find eleven heritage sites that are managed by Heritage Malta. In each of the two largest valley catchment systems, namely Wied il-Kbir and Wied il-Għasel, one can find three such sites. On the other hand, Dalam hosts two such sites whereas Wied Blandun, Wied il-Ġnejna and Zembaq-Saptan each host one site managed by Heritage Malta. Wied il-Kbir sites received 202,957 visitors in 2019. Wied Blandun received 73,318 visitors in its Heritage Malta site. Dalam, with 50,952 visiting its two sites, has the third highest number of visitors. Wied il-Għasel and Wied il-Ġnejna received almost 12,000 visitors, but spread between 4 different sites. The site in Zembaq-Saptan area (Ta' Mintina Catacombs) is usually not open to the public. The experiential interactions with the environment were also mapped using expert scoring.
- *Scientific and educational:* Publications about the natural and cultural heritage of the different catchments have been recorded by the Valley Management Unit. This dataset was used to calculate the number of publications for each catchment as a proxy for the scientific and educational value of the different ecosystems and catchments within the AoS.

  With a total of 49 and 39 publications respectively, the Wied il-Kbir, Wied il-Għasel and Xlendi catchments had the largest number of publications whilst the Zonqor catchment had the lowest number of publications and no publications were recorded for Wied il-Għajn and Mġarr (Gozo). The results shown here may be biased because of the variation in the area of the different catchments, and when standardised per unit area a different picture emerges as Ħarq Ħamiem, Għomor and Blandun catchments had the highest number of publications per square kilometer.

  The scientific and educational value of ecosystems was also mapped using expert scoring.

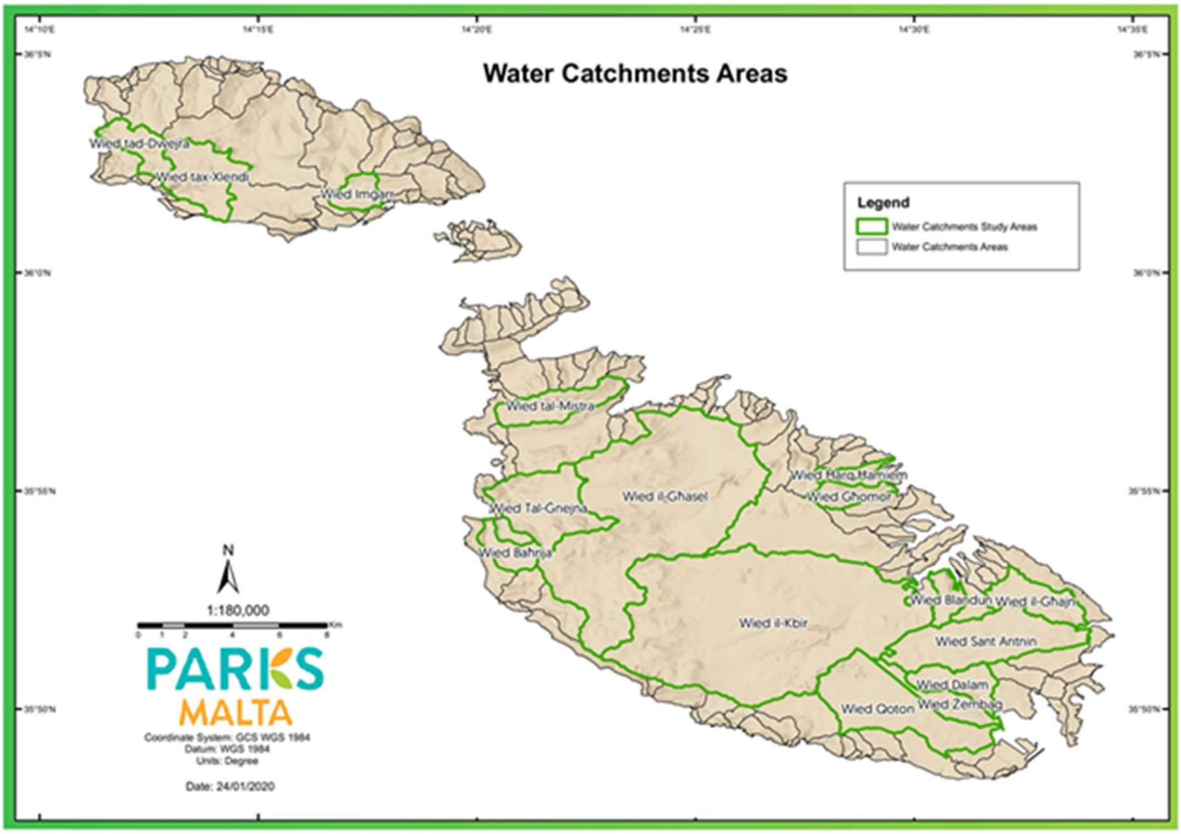

Figure 6 – Water catchment areas for which an ecosystem service characterisation is being carried out in Action A.8. (source: Parks Malta, 2022)

Action C.9. is expected to contribute to the delivery of ecosystem services but these contributions will depend on the actions carried out within these case-studies sites. The following actions have been identified for the two case-study sites:

1. actions identified for the Wied l-Isperanza, a sub-catchment of Wied il-Għasel, will involve a general clean-up, installing measures to stop off-roading in the valley bed, removal of invasive alien species such as *Arundo donax, Cardiospermum halicacabum, Ricinus communis, Leucena leucocephala, Rubus ulmifolius*; establishing a nature/walking trail between the Chapel of San Pawl tal-Qlejgħa and the Chapel of ta' L-Isperanza and planting of a Woodland on the eastern side of Wied il-Għasel.
2. the master for the Xlendi catchment identifies the clean-up of il-Wied ta' Grixti and planting along the road in the upstream part of il-Wied ta' Grixti with *Populus alba* and *Fraxinus angustifolia* trees.

C.13 - Restoration of one of the coastal wetlands

Action C.13. involves a series of actions for the restoration, management and monitoring of the il-Ballut ta' Marsaxlokk coastal wetland, which is located within the boundaries of a Natura 2000 Site (site MT0000014[3]; Figure 7). Activities carried out within this action are expected to contribute to several regulation and maintenance and cultural ecosystem services (Table 5). The following section presents baseline indicator data from the study area but there are a number of studies supported by the LIFE 16 IPE MT 008 that would be expected to lead to an improved understanding of the ecosystem condition and links to ecosystem services capacities and flows.

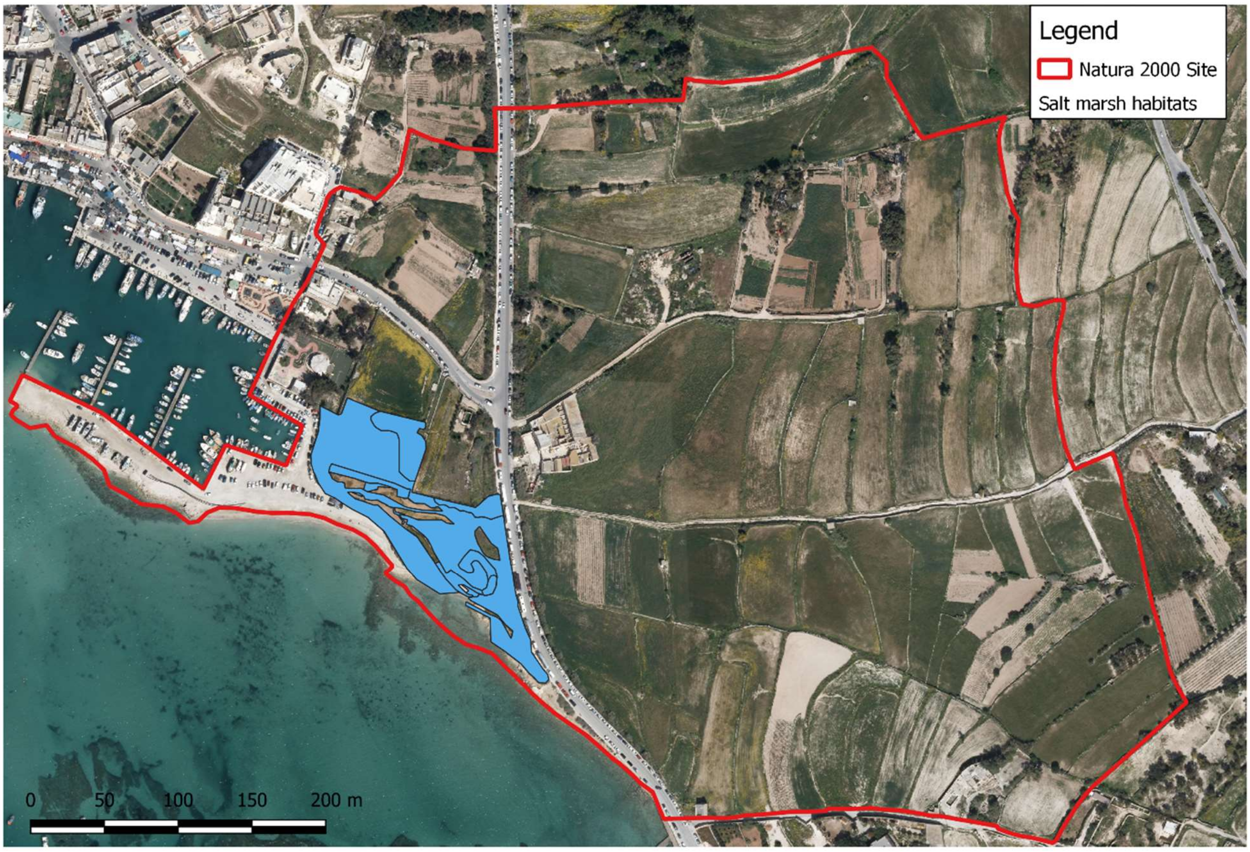

Figure 7 – Boundaries of the Ballut ta' Marsaxlokk coastal wetland and the Natura 2000 site plotted on an orthophoto from 2016 (source: Planning Authority).

[3] Il-Ballut ta' Marsaxlokk Natura 2000 Standard Data Form: https://era.org.mt/en/Documents/20180601_MT0000014-Ballut-Marsaxlokk-SAC.pdf

Table 5 – Ecosystem service indicators for Action C.13.

Action	Ecosystem service	Ecosystem service indicator	Type of indicator
C.13.	Water conditions	Chemical status	Capacity
C.13.	Mediation of wastes, or toxic substances of anthropogenic origin by living processes	Nutrient Concentration	Capacity
C.13.	Lifecycle maintenance, habitat and gene pool protection	Habitat cover	Capacity
C.13.		Ecological Status	Capacity
C.13.	Control of erosion rates	Rate of erosion	Capacity
C.13.	Physical and experiential interactions with natural environment	Site visitation	Flow

Water Conditions Ecosystem Service (CICES 2.2.5)

Ecosystem service indicator: Chemical Status (Capacity)

Monitoring of priority substances and certain other pollutants as listed in Annex I of the Environmental Quality Standards Directive (2008/105/EC) in inland surface and transitional waters in Malta has been carried out in the il-Ballut ta' Marsaxlokk wetland between 2011 and 2012, as part of the monitoring of small inland surface and transitional waters identified in Malta's 2nd Water Catchment Management Plan, while further monitoring is currently ongoing. During the assessment for priority substances and other pollutants, a total of 47 chemicals were analysed (Ecoserv and CADA, 2012). No trace (below detection limits) was found for 40 chemicals, and only 7 chemicals were detected in one or more waterbodies assessed. A total of 4 chemicals were recorded at the il-Ballut ta' Marsaxlokk wetland, namely di(2-ethylhexyl) phthalate, lead, and nickel. Concentrations for these 3 parameters for the 3 consecutively surveyed months at il-Ballut ta' Marsaxlokk are presented in Table 6, and mean contaminant concentration and the respective Environmental Quality Standards are presented in Table 7.

During the survey of the 10 inland surface and transitional water bodies, the most ubiquitous chemical was di(2-ethylhexyl)phthalate (DEHP), which occurred above detection limits in all samples monitored (i.e. 6 samples from 10 WB). This chemical has also been recorded in all samples from the il-Ballut ta' Marsaxlokk wetland but its level was below the Environmental Quality Standards as stipulated in the Directive on Environmental Quality Standards (Directive 2008/105/EC).

During the baseline survey, nickel was the second most ubiquitous contaminant, and was recorded at moderately high levels at il-Ballut ta' Marsaxlokk with a maximum recorded in December 2011 that reached 26.5 µg/L. The MEPA Baseline Surveys for Inland Surface and Transitional Waters for Priority Substances and Certain Other Pollutants suggests that the background level of nickel in local inland waters is between 3-6 µg/L. Therefore, the ubiquitous nature of this chemical may be explained due to natural factors but higher concentrations, such as that reported at il-Ballut ta' Marsaxlokk, indicate release from industrial activities.

Table 6 - Mean (± SD) values of chemical parameters recorded from samples collected from Il-Ballut ta' Marsaxlokk (Station 3 in Ecoserv and CADA, 2012). Values denoted by < were below the method detection limit in both replicates. All levels are shown in µg/L. NA = not applicable. Only the 3 parameters detected in at the il-Ballut ta' Marsaxlokk wetland are shown.

Month	Parameter	Mean	SD
Dec-11	Di(2-ethylhexyl) phthalate	0.28	0.18
Jan-12		0.38	0.05
Feb-12		0.28	0.04
Dec-11	Lead	3	0
Jan-12		<0.1	NA
Feb-12		3	1.4
Dec-11	Nickel	26.5	0.7
Jan-12		14	1.4

Lead was recorded in the il-Ballut ta' Marsaxlokk at levels that were considered as being relatively high and close to the EQS by the MEPA Baseline Surveys for Inland Surface and Transitional Waters for Priority Substances and Certain Other Pollutants (Table 7). Moderate levels of lead were occasionally recorded at il-Ballut ta' Marsaxlokk and the Marsaxlokk fisheries harbour, indicating that the use of fossil fuel and lubrication oils may feature well as releasing sources for this contaminant. A moderately strong (but not significant) correlation with the extent of the basin coverage with natural vegetation and agricultural land was recorded, which may indicate that lead shot arising from bird shooting may play a role as an additional sources of this contaminant (Ecoserv and CADA, 2012).

Table 7 - Mean levels of various contaminants in the il-Ballut ta' Marsaxlokk wetland monitored over the period December 2011 to February 2012 and the Environmental Quality Standards for the respective contaminants. All levels are shown in µg/L (Source: Ecoserv and CADA, 2012).

Parameter	Di(2-ethylhexyl) phthalate	Lead	Nickel
AA EQS Inland surface waters (µg/L)[1]	1.3	1.2	4
Il-Ballut ta' M'Xlokk	0.308	2.017	14.667

[1]Values obtained from the EQS Directive (2013/39/EU). AA = Annual Average

Mediation of wastes, or toxic substances of anthropogenic origin by living processes

Ecosystem service indicator: Nutrient Status (Capacity)

Monitoring of nutrient concentration at the il-Ballut ta' Marsaxlokk wetland has been carried out as part of the monitoring of small inland surface and transitional waters identified in Malta's 2nd Water Catchment Management Plan (AIS Environmental, 2011).

Total content of inorganic nitrogen compounds at the il-Ballut ta' Marsaxlokk was considered as being low but varying with time (Figure 8). The concentration of nitrites and nitrates was generally below the detection limits, except for February (nitrates = 0.6 mgL^{-1}) and October (nitrites = 0.11 mgL^{-1}). The concentration of ammonium was also below detection limit for 10 months, but higher levels were detected in September (0.78 mgL^{-1}) and October (1.55 mgL^{-1}). Monthly variation of total nitrogen (N) generally followed similar patterns, with the highest level being recorded in October (3.7 mgL^{-1}; Figure 9). Total phosphorus was also low with the highest concentration being reached in October (1.3 mgL^{-1}; Figure 10).

Based on the established baseline, average nutrient levels for the wet season, i.e. excluding April to August when then water body was dry, are provided in Table 8.

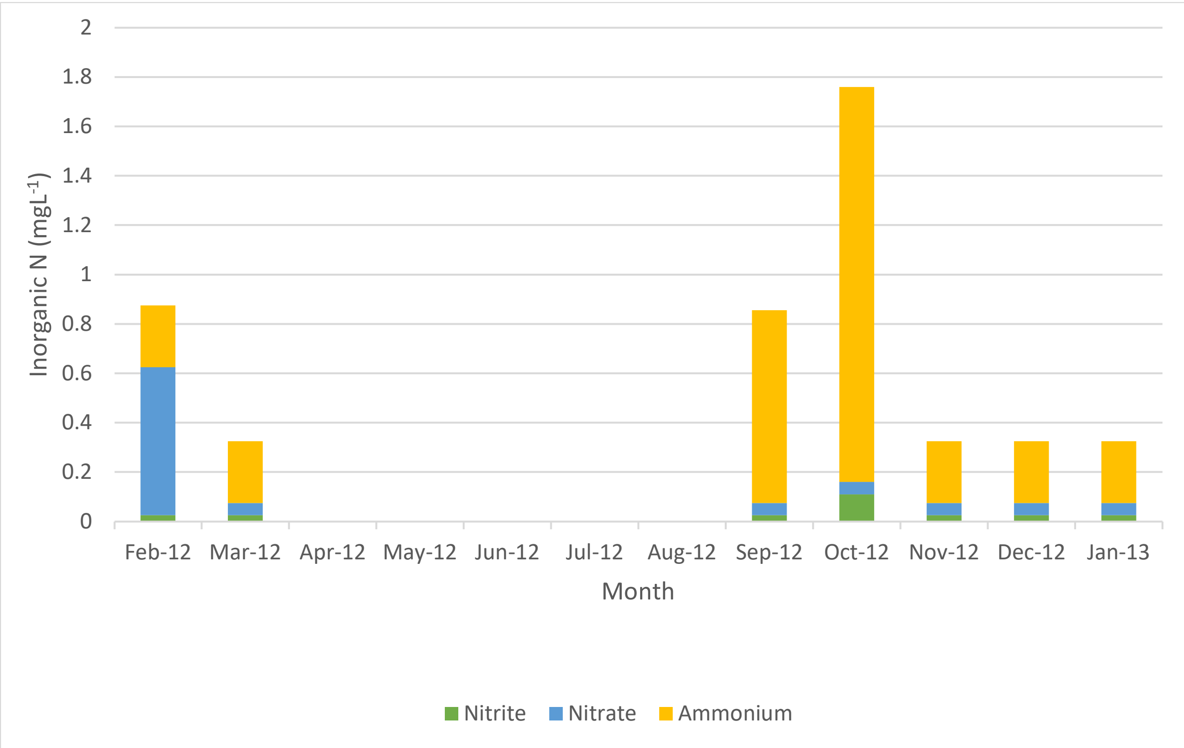

Figure 8 – Monthly variation of nitrites (NO_2^-), nitrates (NO_3^-) and ammonium (NH_4^+).

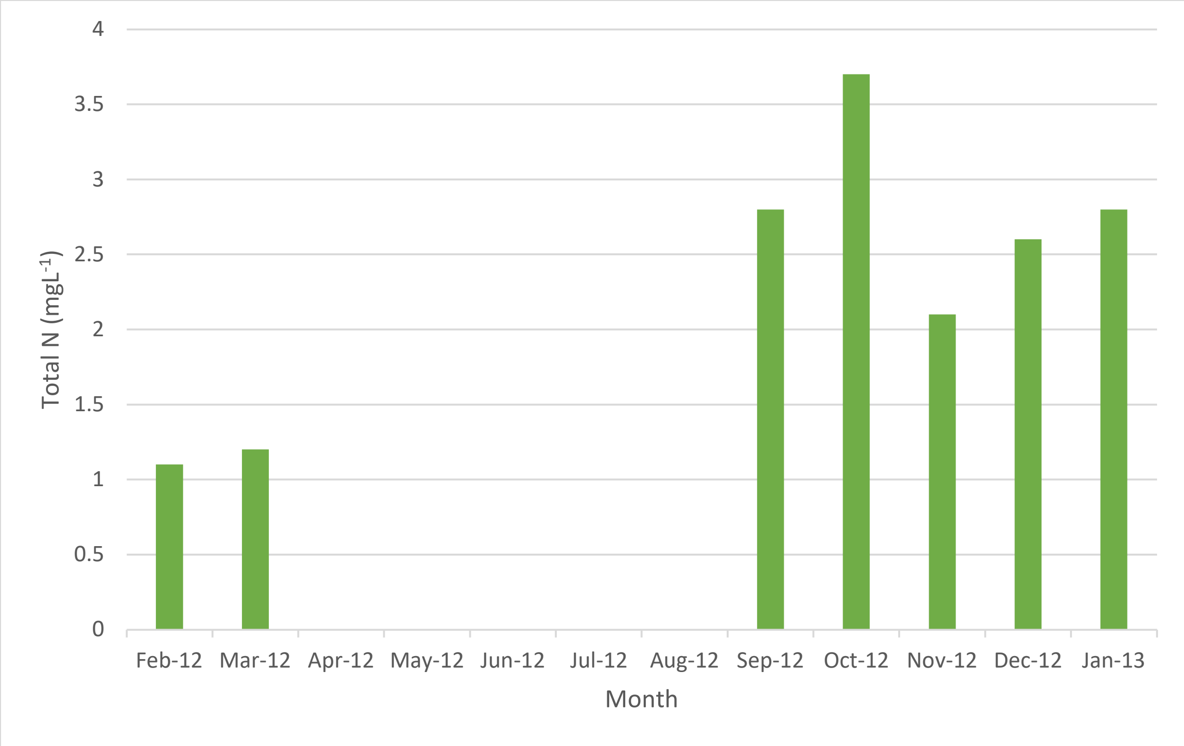

Figure 9 – Monthly variation of total nitrogen (N).

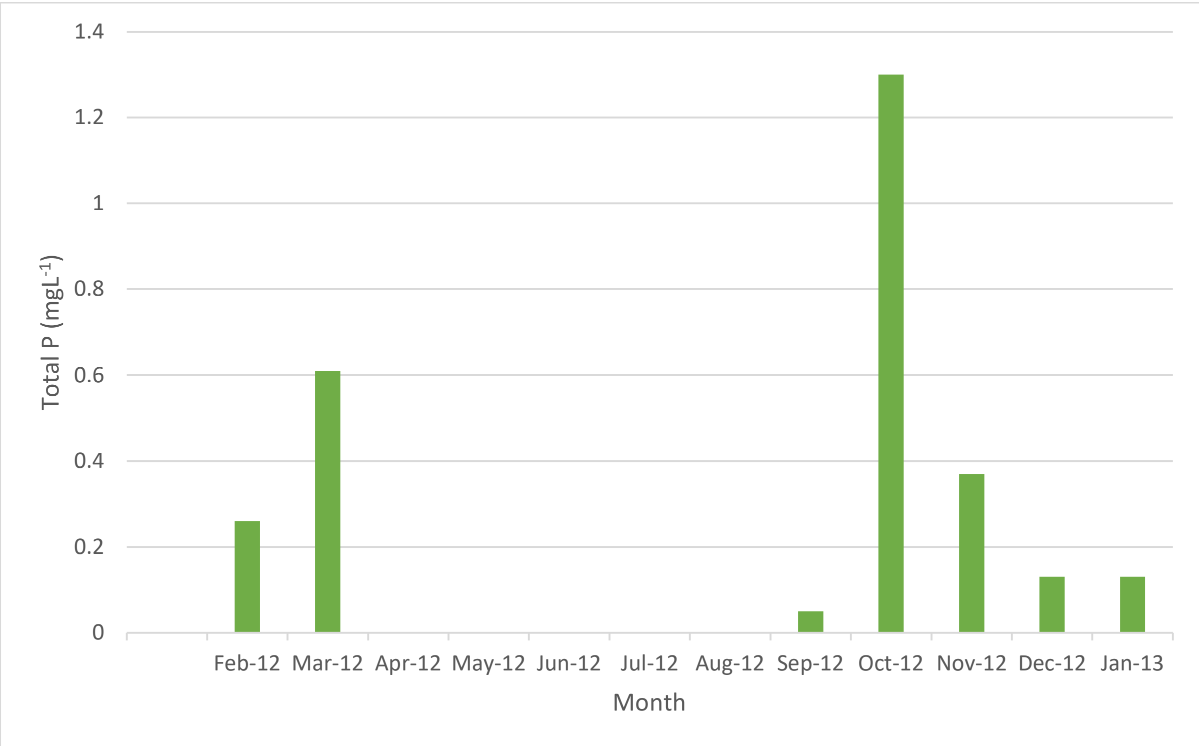

Figure 10 – Monthly variation of total phosphorus (P).

Table 8 – Mean nutrient levels during the wet period (data based on 7 months)

	Mean	Max
Nitrite	0.04 ± 0.03	0.11
Nitrate	0.13 ± 0.19	0.6
Ammonium	0.52 ± 0.48	1.6
Total Nitrogen	2.33 ± 0.86	3.7
Orthophosphates	0.25 ± 0.00	0.25
Total Phosphorus (as P)	0.41 ± 0.40	1.3

Lifecycle maintenance, habitat and gene pool protection

Ecosystem service indicator: Habitat Cover

Figure 11 - Il-Ballut ta' Marsaxlokk marshland.

The indicators developed for the assessment of the lifecycle maintenance, habitat and gene pool protection ecosystem services within the study area are based on data presented in the Natura 2000 Standard Data Form for il-Ballut ta' Marsaxlokk (Site Code: MT0000014; update: 2018-05), which was prepared by the Environment & Resources Authority.

Figure 12 provides a map for the Habitats Directive Annex 1 habitats for the salt marsh area as updated during field surveys. The following Annex 1 habitats are recorded:

- **1420 – Mediterranean and thermo-Atlantic halophilous scrub** (area = 7445.2 m^2): Habitat 1420 is composed of scrub and perennial species, including *Atriplex portulacoides, Inula chritmoides, Arthrocnemum macrostachyum and Suaeda vera.* This habitat has the widest distribution within the site, dominates the site from the lagoon banks throughout the rest of the marshland area, and is currently outcompeting habitats 1310 and 1410 as hydrological conditions at the site favour its establishment. The Natura 2000 management plan of the il-Ballut ta' Marsaxlokk identifies the improvement of the structure of this habitat and its expansion to disturbed lands at the periphery of the wetland as being desirable.

- **1410 – Mediterranean salt meadows** (area = 754.5 m^2): Habitat 1410 is fragmented and mainly limited to the lagoon banks. *Juncus maritimus* is the most dominant species in Habitat 1410 whilst *Carex extensa* has a more sporadic distribution. The Natura 2000 management plan of the il-Ballut ta' Marsaxlokk site identifies the improvement of the habitat structure, area and integrity as being desirable, and may be achieved through recession of the competing habitat 1420 and through the exploitation of former wetland grounds.

- **1310 – Salicornia and other annuals colonising mud and sand** (area = 194.5 m^2): Since *Salicornia ramosissima* grows at the edge of the lagoons and is partly submerged, Habitat 1310 is located within and at the bank of the lagoons. The Natura 2000 management plan of the il-Ballut ta' Marsaxlokk site identifies the conservation of this habitat and improvement in terms of area and structure as being desirable and dependent on the maintenance of open mudflats that may be colonised by this habitat.

- **92D0 – Southern riparian galleries and thickets** (area = 1183.3 m^2): habitat 92D0 is dominated by *Tamarisk africana* trees at the border of the marshland, representing a *Nerio-Tamaricetea* community.

The area and habitat conservation status assessment is presented in Table 9, and is based on the following measures:

- **Representativity**: the degree of representativity of the natural habitat type on the site, as presented using the following categories:
  A: excellent representativity; B: good representativity; C: significant representativity
- **Relative Surface**: the area of the site covered by the natural habitat type in relation to the total area covered by that natural habitat type within the national territory:
  A: $100 \geq p > 15\%$; B: $15 \geq p > 2\%$; C: $2 \geq p > 0$
- **Conservation**: the degree of conservation of the structure and functions of the natural habitat type concerned and restoration possibilities:
  A: excellent conservation; B: good conservation; C: average or reduced conservation
- **Global**: A global assessment of the value of the site for conservation of the natural habitat type concerned:
  A: excellent value; B : good value; C: significant value

Ecosystem service indicator: Habitat conservation Status (habitat condition and change)

The assessment of the habitat conservation status is based on 2 indicators, namely:

- *Habitat Condition: habitat having good or excellent value (m^2)*: the baseline conditions for the habitat condition indicator are based on the survey data as reported in the Natura 2000 Standard Data Form for il-Ballut ta' Marsaxlokk (update: 2018-05). The area of each habitat having good or excellent value in the global assessment criteria is used as a measure for this indicator.
- *Habitat Change: area showing improvement in the global assessment of the value of the site from baseline conditions (m^2)*: improvement in the value of the site for conservation of the natural habitat concerned (in comparison to the 2018-05 ERA survey) is used as a proxy for the capacity of ecosystems to provide lifecycle maintenance, habitat and gene pool protection ecosystem services, and may provide a direct measure of the impact of the LIFE 16 IPE MT 008 Action C.13 on this ecosystem service.

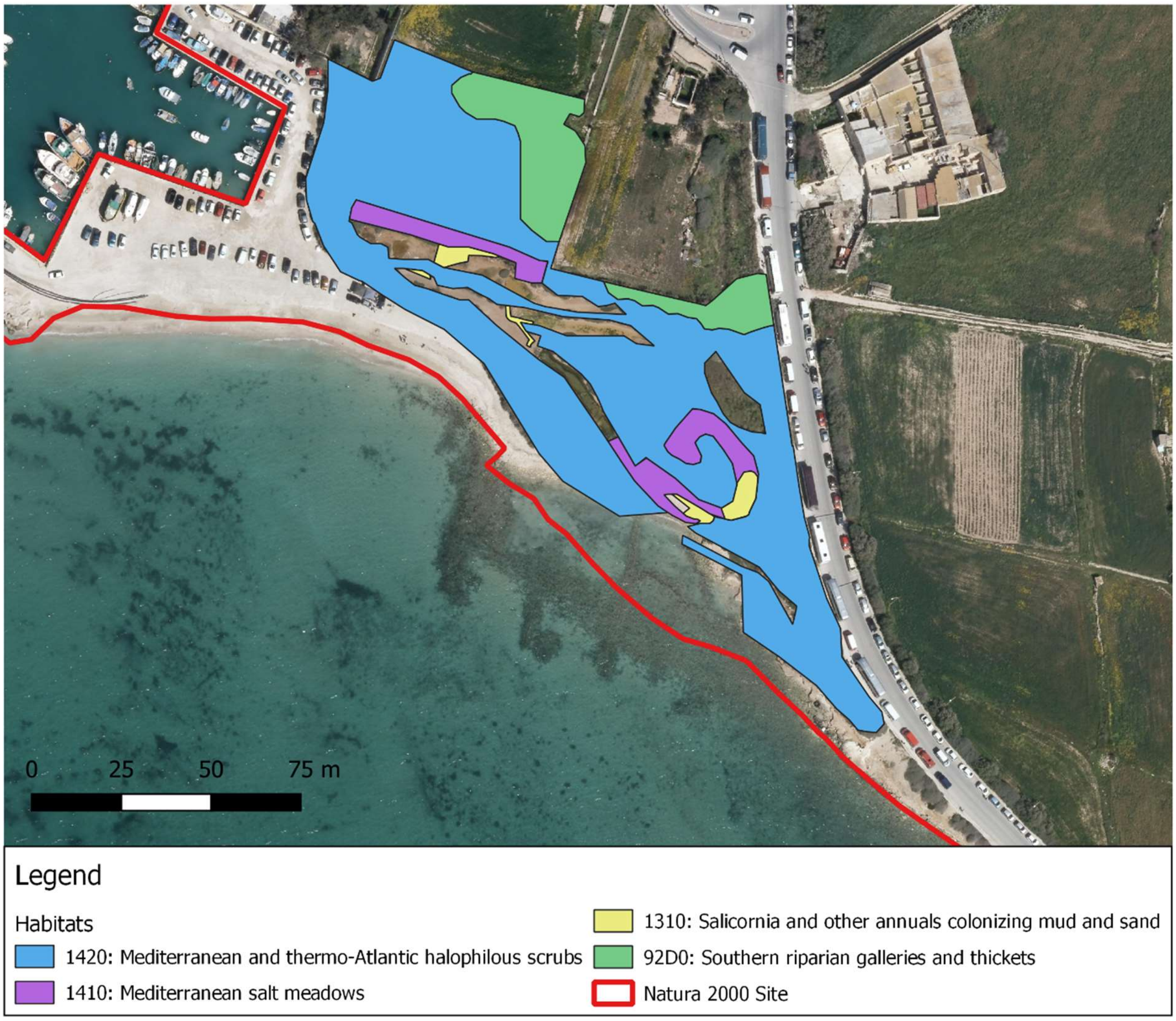

Figure 12 – Il-Ballut ta' Marsaxlokk Annex 1 habitats (data source: ERA, 2019)

Table 9 – Area and habitat conservation status of Annex I habitats at il-Ballut ta' Marsaxlokk wetland

Annex I Habitat	Code	Site Assessment				Ecosystem service baseline conditions		
		Representativity	Relative Surface	Conservation	Global	Habitat Cover (m^2)	Habitat Condition: habitat having good or excellent value (m^2)	Habitat Change: area showing improvement in the global assessment of the value of the site from baseline conditions
Salicornia and other annuals colonizing mud and sand	1310	B	C	C	C	194.5	0	Nil
Mediterranean salt meadows	1410	B	B	B	B	754.5	754.5	Nil
Southern riparian galleries and thickets	92D0	B	C	B	B	1183.3	1183.3	Nil
Mediterranean and thermo-Atlantic halophilous scrubs	1420	B	B	B	B	7445.2	7445.2	Nil

Control of erosion rates

Ecosystem service indicator: Rate of erosion (Capacity)

A change in the outline of the coast is noticeable when comparing satellite photos, indicating that coastal erosion may be happening at the il-Ballut ta' Marsaxlokk saltmarsh area. It has also been suggested that some of the major projects carried out along the coastline could have also affected the dynamics of wave action at Marsaxlokk Bay.

Figure 13 - The erosion of the narrow beach separating the marsh from the sea has greatly narrowed this natural barrier and the marsh is now inundated during rough weather.

The saltmarsh is surrounded by a human constructed embankment consisting of material excavated during the construction of the Power Station, which is located some metres away from the marsh. The embankment is stabilised by *Tamarix africana* trees together with *Atriplex halimus*, whilst supporting several ruderal species such as *Lavatera arborea*, *Oxalis pes-caprae*, *Galactites tomentosa* and *Sonchus oleraceus*.

The embankment has a critical role in safeguarding the marshland ecosystems from wave action and inundation, and thus providing important coastal protection ecosystem services. The area covered by the embankment and its vegetation was mapped using orthophotos from 2012 and 2016 (source: Planning Authority). The embankment was delineated through the use of the orthophotos and following a site visit to the marshland. During the digitisation, breaches to the embankment and areas showing signs of severe erosion and loss of vegetation cover were not considered to contribute to ecosystem service capacity. Similarly, in order to calculate the rate of coastal erosion within the il-Ballut ta' Marsaxlokk marshland during this reference period, the area of the marshland was also mapped.

Results indicate a general reduction in the marshland habitat area, with a total loss of 552.5m^2 of marshland habitat between 2012 and 2016. Most of this habitat loss appears to be going on in the embankment, and a reduction of 407.4 m^2 in the embankment area was recorded. This reduction accounts for 73.7% of the total habitat loss from the marshland area. Based on the dates of the orthophotos it is possible to calculate the baseline average erosion rate for both the embankment area and the marshland habitat, as shown in Table 10.

Table 10 – A reduction in embankment and marshland area is observed between 2012 and 2016.

Year	Area in 2012 (m^2)	Area in 2016 (m^2)	Difference (m^2)	Average Erosion rate (m^2/year)
Embankment area	1,855.99	1448.58	407.41	107.14
Marshland area	10649.38	10096.85	552.53	145.3

Figure 14 – A section of the perimeter of the saline marshland showing impacts arising from wave action and potentially leading to coastal erosion.

Figure 15 – Difference between the embankment extent based on orthophotos from the years 2012 and 2016 (Source: Planning Authority).

Figure 16 – Difference between the extent of the il-Ballut ta' Marsaxlokk marshland based on orthophotos from the years 2012 and 2016 (Source: Planning Authority).

Physical and experiential interactions with natural environment

Ecosystem service indicator: Site visitation Flow)

Nature Trust Malta (NTM), which manages the site in collaboration with the ERA, has organised various clean-ups over the years and organises group site visits (James Gabarretta and Vincent Attard, personal communication, 2019). Data about individual site visitation has not been recorded for 2020 but baseline data for 2019 has been made available by Nature Trust Malta. During 2019 a total of 305 individuals visited the site during organised events. A total of 110 individuals have attended an open day at the site, while a total of 3 organised group site visits and 10 clean up events have been carried out and were attended by 59 and 86 participants respectively (Figure 17).

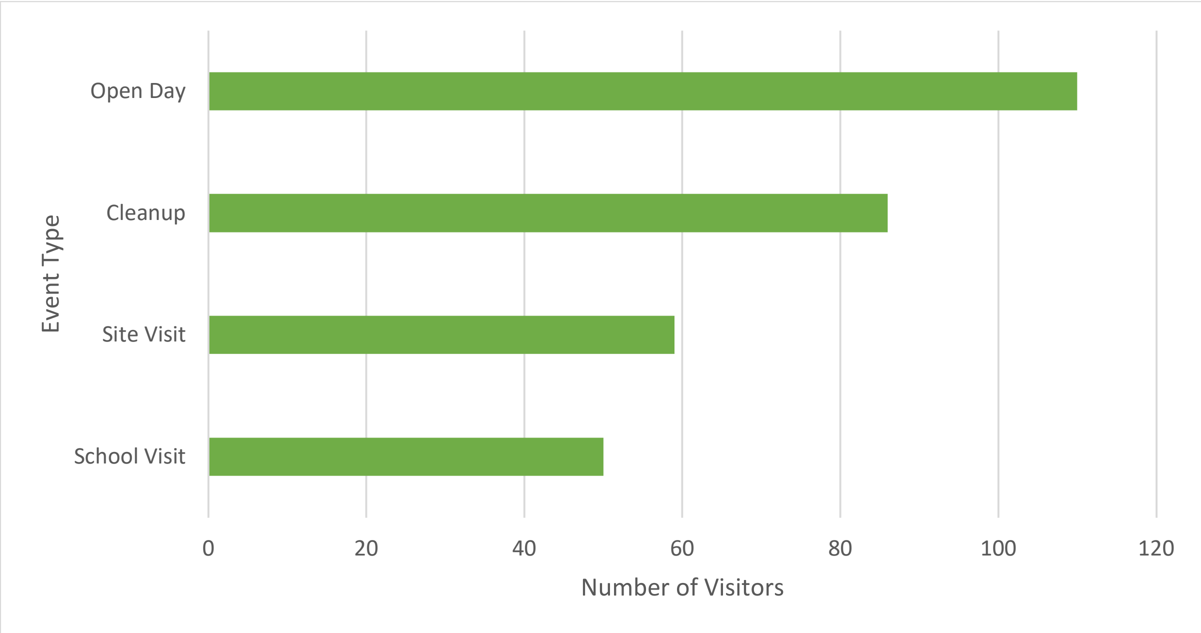

Figure 17 -Number of visitors to the il-Ballut ta' Marsaxlokk by event type.

Organised site visits had an average duration of 1.83 hours whilst clean ups and school visits had an average duration of 2.67 and 3 hours respectively (Figure 18).

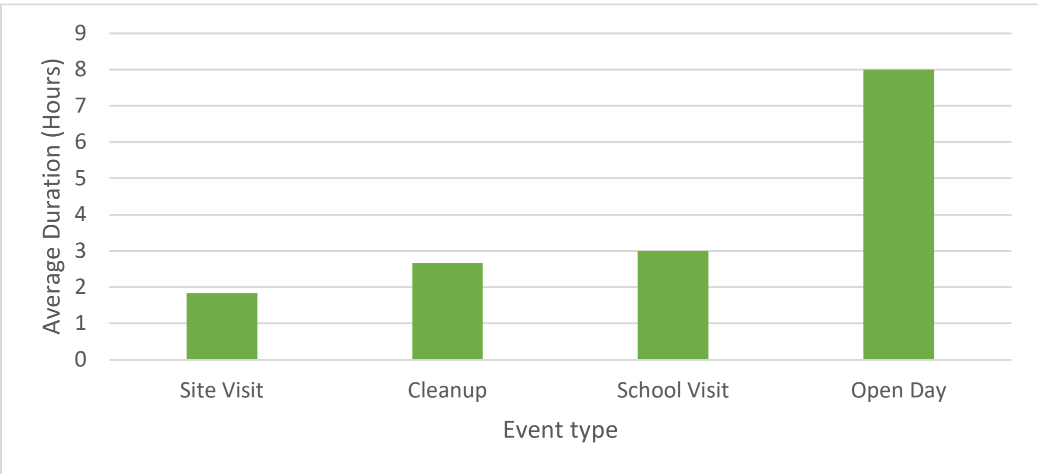

Figure 18 - Site visit duration in hours by event type.

C14 – Anchoring and mooring surveys

Action C.14 seeks to assess the extent of anchoring and mooring activities in the territorial waters and develop management measures to address verified impacts on seabed habitats.

Action C.14 will include a mapping exercise of marine areas that are subject to anchoring/mooring activity by different types of vessels. This exercise will provide important baseline information for subsequent deliverables.

Based on the mapped mooring and anchorage areas, the habitat types that are likely to be significantly affected by these activities will be identified. A quantitative assessment of the impacts associated with different anchoring/mooring practices in relation to sensitive habitats will be undertaken through localised and targeted surveys within selected marine areas. This action is also expected to lead to the identification of technically feasible and cost-effective management options to address the impacts from mooring/anchoring activity on seabed habitats.

The aforementioned quantitative assessment and consultation with stakeholders will lead to the implementation of selected management options on a pilot basis. The outcome of the management actions as implemented in pilot sites will be monitored to assess whether ecological objectives and the demands of the users can be met and to inform management in the longer term.

The implementation of pilot management actions is expected to contribute to several regulating and maintenance ecosystem services, including lifecycle maintenance, habitat and gene pool protection and carbon sequestration (Table 1). Moreover, changes in the use of the sites by vessels may be associated with impacts on the experiential use of ecosystems (cultural ecosystem service).

The extent to which Action C.14 contributes to ecosystem services will be impacted by the selection of the pilot sites, the baseline environmental conditions and socio-economic benefits derived from the site and the type of actions that are implemented within these case-studies sites.

Monitoring carried out as part of this action will also generate important biophysical and socio-economic data that will be used in the assessment of the baseline contributions to ecosystem services and the contributions arising from the project action itself. More specifically, data relating to the present level of anchoring/mooring activity by different types of vessels and the impacts of these activities on the seabed habitats will be collected. The implementation of management actions and monitoring at pilot sites will also provide important data that may be used to assess the contributions of the action to ecosystem services. Given the reasons above, the baseline assessment of ecosystem services relating to this action needs to be phased with the selection of the pilot sites for the implementation of management actions during this project action. An overview of the methods used for the assessment of the baseline and action contributions to ecosystem services is provided in the next sections.

Lifecycle maintenance, habitat and gene pool protection

Ecosystem service indicator: Posidonia oceanica Rapid Easy Index (PREI; Capacity)

Ecosystem service indicator: Area of P. oceanica and other sensitive benthic habitats from which the impact of anchoring/mooring is removed (Capacity)

Ecosystem service indicator: Extent of P. oceanica (coastal sites; Capacity)

The assessment of the contributions of the project actions to the lifecycle maintenance, habitat and gene pool protection ecosystem services is strongly dependent on the choice of the pilot sites and habitat types. However, based on the consultation carried out as part of the baseline assessment of ecosystem services, and given their important role and their significant conservation value (Vassallo *et al.*, 2013; Campagne *et al.*, 2014), data for *Posidonia oceanica* meadows, which include information about extent and condition, can be used as a proxy for ecosystem service delivery.

Regulation of chemical composition of atmosphere and oceans

Ecosystem Service Indicator: Carbon Storage (Capacity)

Ecosystem Service Indicator: Estimated value of long-term Carbon Storage (Benefit)

P. oceanica is considered as an important long-term carbon sink, as it forms a carbon stock with a residence time of 4 to 6 thousand years. Based on recent assessments of carbon sequestration by different seagrasses, it was estimated that seagrass carbon sequestration makes up 15% of the blue carbon within the biosphere, while *P. oceanica* is considered as being the most effective of considered sea grasses in terms of carbon storage (Pergent-Martini et al., 2020). The analysis of *P. oceanica* parts can be carried out to quantify the primary production and the carbon content of different tissues. However, several recent studies already provide primary production data at different sites, including locations, depths, meadow structure and human pressures, and have made it possible to estimate a mean value of the amount of carbon fixed by *P. oceanica* in the Mediterranean Basin (e.g. Vassallo et al., 2013; Campagne et al., 2015; Pergent-Martini et al., 2020; Rigo et al., 2021).

In a recent study of one of the largest *P. oceanica* meadows in the Mediterranean Sea (100 km of coastline, 20,425 ha), the mean total carbon fixation (blades, sheaths, and rhizomes) per year varied according to depth, and between 33.5 and 426.6 g C.m^{-2}. The mean carbon sequestration, corresponding to the sheath and rhizome tissues, varied between 7.7 and 84.4 g C.m^{-2}. When these values are used to estimate the carbon fixation and sequestration rate throughout the Mediterranean basin, according to the depth, average proportion of different tissues (blades, sheaths, rhizomes), and average concentration for these tissues, a total fixation rate of 1 302 t C ha^{-1}yr^{-1} and sequestration rate (dead sheaths and rhizomes) of 278 t C ha^{-1}yr^{-1} was obtained (Pergent-Martini et al., 2020). The contribution of *P. oceanica* to carbon sequestration ecosystem services can be valued using market prices from CO_2 emissions trading schemes or based on damage cost avoided based on the costs that would be incurred if the impacts of climate change were not mitigated through the carbon sequestration service provided by the seagrass (e.g. Campagne et al., 2015).

Physical and experiential interactions with natural environment

Ecosystem Service Indicator: Site visitation (number of vessels; Flow)

Ecosystem Service Indicator: Number of divers (Flow)

Ecosystem Service Indicator: Expenditure of tourists engaging in diving activity (Benefit)

The baseline assessment of the physical and experiential interactions with the natural environment (cultural) ecosystem services depends on the existing use of the sites will depend on the use of the sites selected for pilot actions. Data about the use of the sites for anchoring/mooring by different vessels will be collected in Action C.14. This may be complemented with other visitation data collected directly from the users of the sites (e.g. divers, tourists, etc.).

Indirect contributions of the LIFE 16 IPE MT 008 project actions to ecosystem services

In addition to the direct contributions to ecosystem services described and assessed in this report, during the consultation with LIFE 16 IPE MT 008 beneficiaries, a number of actions were identified as leading to improved knowledge or capacity building which, subject to their use in follow-up implementation actions, can lead to impact on ecosystem services. As such, the actions shown below can be considered as having a potential indirect impact on ecosystem services, but this depends on the actions carried out at a follow-up stage which use the knowledge and capacities developed in the LIFE 16 IPE MT 008 project:

- ***Action A.6. 'Development of a monitoring strategy for contaminants of emerging concern'*** has carried out a risk-based assessment of the potential presence of anthropogenic contaminants of emerging concern. The action will lead to the development of a monitoring strategy and programme for each water category. ***Action 'C.18. - Monitoring for emerging pollutants of potential concern'*** builds on the results obtained in A.6, will start in June 2022 will entail investigative monitoring for the identified emerging pollutants and diffused sources of pollutants. Knowledge and capacity generated from this action are expected to indirectly impact positively on water conditions and the mediation of pollutants by ecosystems.
- ***Action A.7. 'Development of a hydrographic model for Malta's marine waters'*** identified data input and offshore monitoring needs and has developed a hydrographic model for Malta's marine waters. This collaboration with the Geosciences Department, University of Malta, is intended to facilitate the implementation of the Action A.7. Following up on the results obtained in A.7., ***Action 'C.16 – Hydrographic model simulations for Malta's marine waters to quantify and investigate pressures in the marine environment'*** will set up and run basic elements of modelling and observation systems to determine the baseline hydrographical conditions for coastal and offshore Maltese waters. This baseline data will be then used to characterise pressures and impacts on the marine environment. The developed hydrographic models in Actions A.7. and C.16. are expected to improve the characterisation of the hydrographic conditions of Malta's nearshore and offshore waters, help in the assessment of hydrological dispersion of pollutants and sediment and understand the potential transboundary sources of contaminants.
- ***Action C.3 'Remote sensing for agricultural water demand'***: Sentinel 2 satellite imagery will be used as a baseline for the creation of an online tool for the management of water in the agricultural sector. This decision support system will be used to better understand how to use water more sustainably. The utilisation of generated data and decision support system by key stakeholders would be expected to contribute to sustainability of crop and water provisioning ecosystem services, hydrological cycle and water flow maintenance, and the regulation of chemical conditions of surface and coastal water bodies when implemented, for example, in the implementation of nutrient management strategies
- ***Action C.11 'Exploitation of deep saline aquifers'***: The objective of this action is to develop a pilot abstraction, treatment and discharge system to enable the exploitation of deep saline grounwater. The model developed in ***Action* A.9. 'Groundwater modelling'** will be used to analyse potential extraction of saline water from below the mean sea level aquifer. Subsequent application of this knowledge may lead to an improved conditions of groundwater bodies, and potentially impacting on water provisioning and the maintenance of hydrological cycle and water flows.
- ***Action 'C.10. – Industrial Discharges – Enforcement Augmentation & Sustainability'*** will build up the technical capacity of the DPU in order to allow the unit to direct its efforts towards those areas which are contributing to lowering of the quality of the sewage. Indirect impacts

on ecosystem services arising from the implementation of Action C.10 may lead to improved water conditions but the magnitude of change depends on the implemented policy and technological interventions.

- ***Action 'C.15 - Impact of Reverse Osmosis discharges on the marine environment'*** will investigate the impact of brine discharge from the Reverse Osmosis plants to the marine environment. More specifically, this action will develop and implement a monitoring programme to understand the impacts of brine discharges in the marine environment. This monitoring programme will assess dispersion rates and the spatial extent and distributions of the impacts. Results provide information about salinity gradients and profiles that may be created because of the brine discharges. This action provides important baseline information about the brine discharges into the marine environment. The subsequent implementation of technological measures to reduce the impact of brine discharges on the marine environment may lead to contributions to improved water conditions and lifecycle maintenance, and habitat and gene pool protection ecosystem services, but this depends on the baseline environmental conditions of the site and any implemented interventions.

Conclusions

This report has carried out an interim assessment of the project's contribution towards ecosystems services improvement. Direct contributions to ecosystem services were identified from a total of 7 actions implemented in the project while another 9 actions are expected to lead to indirect contributions to ecosystem services by favouring evidence-based actions and management of the ecosystems. Actions that are currently in planning phase require further, and longer-term, monitoring to provide a more comprehensive assessment of their impact on ecosystem services.

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