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**Towards effective management of Malta's marine waters**

# LONG-TERM MONITORING STRATEGY REPORT

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This report is Deliverable 3 of the

**TENDER FOR THE ESTABLISHMENT AND IMPLEMENTATION OF A LONG-TERM MONITORING STRATEGY FOR BREEDING SEABIRDS IN MALTA**

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Cover image: Scopoli's Shearwater *Calonectris diomedea*; by B. Metzger.

## EU Monitoring and Reporting Requirements

### Reporting requirements according to the MSFD

Art. 17, Marine Strategy Framework Directive 2008/56/EC (Commission 2020)

**Descriptor and criteria relevant to seabirds**
The long-term strategy report at hand covers the monitoring of five (C1-C5) criteria listed under **Descriptor D1 – Biodiversity** of the EU Marine Strategy Framework Directive (MSFD). Below, all relevant criteria are listed and briefly described:

- **D1C1** (primary): The mortality rate per species from incidental by-catch is below levels which threaten the species, such that its long-term viability is ensured.
- **D1C2** (primary): Data collection on the (breeding) population abundance, reflecting the effects of anthropogenic pressures, such that its long-term viability is ensured.
- **D1C3** (secondary): Data collection on the populations' demographic characteristics and anthropogenic pressures to assess whether the population demographic characteristics are indicative of a healthy population which is not adversely affected due to anthropogenic pressures.
- **D1C4** (secondary): Data collection on the species' distributional range i.e. presence/ absence within mapped suitable nesting habitat, to assess whether the species distributional range and, where relevant, pattern is in line with prevailing physiographic, geographic and climatic conditions.
- **D1C5** (secondary): Collection of quantitative and qualitative data on the habitat of the seabird species to assess whether the habitat for the species has the necessary extent and condition to support the different stages in the life history of the species. Relevant here are the different life history stages on land linked to breeding (including egg, chick, fledgling, adult breeder, prospecting bird) as well as the anthropogenic pressures of influence to the habitats' condition. Relevant are also quantitative and qualitative data on the habitat at sea, here within the 25nm FMZ as well as the anthropogenic pressures influencing them.
- **Pressures:** data on relevant pressures will be collected/assessed and applied in the assessment of all the above criteria as relevant (European Union 2017).

*Overall aim of the MSFD monitoring scheme is the data collection to support the assessment of whether Good Environmental Status (GES) is achieved and/or maintained.*

## Reporting requirements according to the BD

### Indicators assessed under Birds Directive

The long-term monitoring strategy also covers the EU Birds Directive monitoring and reporting requirements in line with the following parameters, as described in the Article 12 reporting guidelines (European Commission 2018) and according to the specific reporting sheets[1]:

- **Population size:** The status of the three pelagic seabird species breeding in Malta and listed in Annex I of the EU Birds Directive, assessed as the breeding population size in breeding pair numbers of each of the three species in the Maltese islands, as specified in the Article 12 guidelines (European Commission 2018). If a precise estimate of population size does not exist, as is the case with all three seabird species in Malta, with estimates only available as a range (i.e. minimum–maximum), these two values should be reported.
- **Population trend:** The population trends (direction and magnitude) of the three Annex I listed pelagic seabird species breeding in Malta will be assessed in the
    - Short-term as the trend in the number of breeding pairs per species in the last 12 years.
    - Long-term as the trend in the number of breeding pairs per species since 1980.
- **The breeding distribution map and size (surface area).** This will be assessed for all three Annex I listed seabird species for the Maltese islands on a grid of 1x1 km², as recommended for small member states and as opted for by MT in the last Art. 12 report (Epsilon 2019). The surface area of distribution is the total area covered by the representative grids.
- **The breeding distribution trends.** This will be assessed for all three Annex I listed seabird species including direction and magnitude both short-term (in the last 12 years) and long-term (since 1980).
- **The main pressures and threats.** The main pressures and threats to the three pelagic seabird species nesting in Malta will be listed per species and characterized as laid out in the Article 12 reporting guidelines (European Commission 2018). In this respect, latest updates to reporting requirements would need to be considered within the official monitoring program.
- **Progress made in international Species Action Plans (SAPs). The long-term data collection processes will contribute to the implementation of the SAP** for *P. yelkouan* (Gaudard 2018). For all three species the long-term data collection processes will inform how the relevant N2K Sites and their management contribute to the conservation of the species.

[1] https://cdr.eionet.europa.eu/Converters/run_conversion?file=mt/eu/art12/envxztaea/MT_birds_reports.xml&conv=612&source=remote#A464_B

- **The conservation measures for these bird species as taken by the member state and their effectiveness.** This will entail the preparation of a list of the main conservation measures that have been implemented to improve or maintain the status of the three pelagic seabird species breeding in Malta. It will also include the status and location of the measures as well as the response of the seabird populations per species to these measures, thus informing on their effectiveness.

*Overall aim of the Birds Directive monitoring scheme is to allow an assessment on whether the concerned Annex I species achieved and/or maintained population levels which corresponds to their ecological, scientific and cultural requirements. The guidelines for the 2019-2024 reporting period are currently under revision and will be published by the European Commission on the reference portal once finalized. The final guidelines should be consulted as they could require adjustments to the long-term monitoring strategy regarding the Article 12 reporting.*

## Reporting cycles of the directives

### Monitoring and assessment cycle under the MSFD

The monitoring and assessment under the MSFD are reviewed every six years. The current monitoring cycle covers the period 2019 to 2024, with the next assessment due in October 2024.

### Monitoring and assessment cycle under the BD

The reporting cycle under the EU Birds Directive is six years. The current monitoring cycle covers the period 2019 to 2024.

## Synergies in reporting requirements under the MSFD and the BD

The significant overlap in the reporting requirements of the two directives resulting in synergies for the monitoring and assessment have been analysed for deliverable 1 of the tender, the Seabird Monitoring Strategy Report. However, they did not include the criterion D1C1 which is now included in the table below.

**Tab. 1:** Comparing monitoring parameters and reporting requirements between the MSFD and BD as well as links between the parameters.

| **Parameter MSFD** Relevant biodiversity (D1) descriptors for GES | **Parameter BD** Article 12 reporting guidelines | **Links between parameters** |
|---|---|---|
| **D1C1 (primary):** The mortality rate per species from incidental by-catch is below levels which threaten the species, such that its long-term viability is ensured. | **Main pressures and threats** Characterisation of main pressures and threats | MSFD but not BD requires an assessment of the specific indicator bycatch mortality rate. Both require assessment of pressures (BD additionally requires assessment of threats) |
| **D1C2 (primary):** Breeding populations' **abundances** and anthropogenic pressures on these populations; ensuring long-term viability | National breeding **population size** of seabird species in breeding pairs (min., max., or range). | National breeding populations' abundances (MSFD) equivalent to breeding population size (BD). MSFD: assessment of pressures; BD pressures and threats. As per Commission Decision 2017/848/EU, MSFD criterion D1C2 is deemed to equate to 'population size' under the BD. |
| | Breeding **population trends** including direction and magnitude: Short-term (last 12 years); long-term (since 1980) | A trend-based approach is recommended for reporting under MSFD, especially in case threshold values for the assessment of GES have not yet been defined |
| **D1C3 (secondary):** Populations' **demographic characteristics** indicative for healthy populations, not adversely affected by anthropogenic pressures | | MSFD but not BD requires an assessment of demographic parameters. Both require assessment of pressures |
| **D1C4 (secondary):** Species' **distributional range and pattern (where relevant) is** in line with prevailing physiographic, geographic and climatic conditions | Breeding **distribution map and size** (surface area); grid sizes due to small member state size: 5x5km² or 1x1km² | Geographic distribution required by both directives; MSFD requires comparison with expected distribution according to prevailing conditions |
| | Breeding **distribution trends** including direction and magnitude: Short term (last 12 years); long-term (since 1980) | The BD but not the MSFD requires trends in the distribution (map and size). However, trends help in the assessment of GES. As per Commission Decision 2017/848/EU, criterion D1C4 is deemed to equate to 'range size' under the BD. |
| **D1C5 (secondary): Extent and condition of habitat** adequate to support the species' different life history stages | **Natura 2000 (SPAs) coverage** Population size inside Natura 2000: type of estimate and method used; Short-term population size trends within network: direction and method used | |

| | | |
|---|---|---|
| | | |
| | **Main pressures and threats** Characterisation of main pressures and threats | Both directives require assessment of pressures. BD additionally asks for assessment of threats |
| | **Progress made in international Species Action Plans (SAPs) and Management Plans (MPs); short management statement** | No direct link between MSFD and BD |
| | **Conservation measures** List of main measures; status, main purpose, and location of measures; response to measures | Assessment of conservation measures as part of PoMs reporting under Art. 13 of the MSFD (ERA 2017: https://era.org.mt/topic/msfd-programme-of-measures/). |

## Preliminary Note on Budgets

Throughout the report a breakdown of costs is presented per criteria and method. Where applicable costs are additionally broken down by species. All estimated costs are in Euro. Costs related to travel and transport are not included in the separate budget tables but are included and presented as lump sums in the final budget estimation.

## Criteria and Indicators of the MSFD and the BD

### Bycatch mortality

**D1C1 (primary):** Monitoring and assessment whether the mortality rate per species from incidental by-catch is below levels which threaten the species, such that its long-term viability is ensured. Bycatch mortality is expected to be of major concern for *P. yelkouan* and *C. diomedea*. There is currently no indication that *H. pelagicus melitensis* is susceptible to bycatch. However, we propose that bycatch monitoring entails data collection on all species that are accidentally caught, also including birds foraging in the area outside the breeding period such as *Ichthyaetus audouinii*. Although bycatch mortality is not a specific indicator to be monitored under the Birds Directive, it is believed to be a major pressure and/or threat for populations of *P. yelkouan* and *C. diomedea*, thus creating the requirement to be monitored as part of the pressure and threat assessment under Art. 12 of the BD, especially as the seabird species of major concern are listed in Annex I. Where mitigation measures to reduce bycatch are implemented, the Birds Directive would also require the monitoring of these as part of the assessment of conservation measures.

The risk of a seabird to be accidentally caught in fishing gear depends on a variety of factors, such as species, gear type, food availability, time of day and year, location, weather conditions, among others (Cortés, Arcos, and González-Solís 2017). Relatively rare and stochastic events with a large number of birds caught e.g. on a single long-line were suspected to occur in the Mediterranean (Arcos, Louzao, and Oro 2008). Such events have a significant negative impact on population level but require a relatively high effort to be detected.

**Suggested monitoring and assessment scheme for seabird mortality caused by accidental bycatch**

**Monitoring**

The monitoring and assessment of criterion D1C1 'incidental mortality of seabirds from bycatch' has not been part of the tender at hand. Furthermore, seabirds are only one taxonomic group among various others for which bycatch mortality rates need to be assessed under MSFD D1C1. To reduce redundancies, excessive effort incurring unnecessary costs, as well as a potential data-collection fatigue among relevant stakeholders (specifically fishers) it is highly recommended to establish one comprehensive bycatch monitoring program for the Maltese fleet that includes all relevant taxonomic groups i.e. seabirds, marine mammals, marine reptiles (sea turtles), and non-target fish species such as protected elasmobranchs. Such a program should also consider and incorporate existing projects in the field (e.g. LIFE PanPuffinus) and start with a review of comparative programs implemented in the region by other member states. Here we can only outline ways forward and propose methodologies that should be developed and implemented to assess D1C1 regarding seabirds.

*It has to be emphasized that the monitoring and assessment scheme for seabird mortality caused by accidental bycatch has to be seen as a preliminary suggestion and all proposed approaches would require further discussion with the Maltese Department for Fisheries and Aquaculture (DFA) to ensure alignment with the control regulations and the existing data collection procedures as carried out by the fisheries.*

- Development and implementation of obligatory reporting (e.g. via e-logbook, with fishers logging the location, time, date, gear and also take a photo of bycaught birds) of all bycaught birds occurring, in the FMZ with a focus on marine SPA by the end of 2023, irrespective of fleet and/or gear. The detailed methodology of such a program would be developed and tested including training sessions of fishers during 2022/3 and is thus not further elaborated here. However, the program would focus on vessels of less than 12m in length since these are currently not covered by e-logbook obligations (as opposed to larger vessels). Logbooks would need to be filled in by fishers for each trip. The development phase would also include questionnaires, as currently implemented by LIFE PanPuffinus, aiming at a representative subsample of the entire fishing fleet operating from Maltese harbours. Questionnaires and logbook surveys should be carried out annually throughout the monitoring cycle.

- Development and implementation of an obligatory seabird bycatch landing program, comparable to the EU's regulation on landing obligations (LO) of discard (Regulation (EU) No 1380/2013). All fishers operating in the Maltese FMZ would be obliged to land any bycaught seabirds that are not in a condition in which they can be immediately released back into the wild. In all cases, fishers should be encouraged to take an image of the bycaught bird for species confirmation. Fishers would report bycaught birds which would then be picked up at landing by dedicated staff. Bycaught seabirds which are injured but still alive are handed to a government vet for treatment and then sent for rehabilitation. Dead birds are sent to be further examined by trained staff (e.g. at National Museum for Natural History (NMNH), Malta University, environmental NGO), i.e. identification (species ID, age-class, sex) and analyses linked to other relevant descriptors (e.g. to pollution: plastic ingestion, bioaccumulation of pollutants, etc.). Relevant samples would be frozen/ prepared appropriately for further analyses.

- Implementation of a continuous onboard observer scheme on selected commercial fishing vessels (full-timers) of the Maltese fleet fishing with a focus but not restricted to marine SPA and the MFZ and specifically targeting gear that poses the highest by-catch risk such as surface and bottom-longlines, gillnets and trammel nets. Onboard observations should take place annually throughout the monitoring cycle.

**Analyses and assessment**

*It has to be emphasized that the methodology proposed here for the analyses and assessment of incidental bycatch is preliminary. Apart from the requirement to be robustly tested, it would need to be consulted further with the DFA prior to implementation and any publication of results.*

The estimation of the number of bycaught seabird individuals in the Maltese MFZ per species will be obtained by extrapolating analysed bycatch reported by fishers obtained from e-logbooks, questionnaires, and onboard observers (subsamples), factoring the overall fishing effort per gear in the FMZ provided by the MFA. To collect data with high temporal resolution it is recommended to carry out such data collection every 3 month with each participating fisher. Due to high stochasticity of bycatch events, it is questionable that calculations of bycatch per set hook from subsamples would lead to robust results (Burgess et al. 2010; Cortés et al. 2017; Dimech et al. 2009). Therefore, other BirdLife partners monitoring bycatch in the Mediterranean use the combined approach of logbooks and questionnaires compared to the overall fishing effort to obtain more robust data on incidental bycatch induced mortalities. These are still considered to be minimum estimates due to the random occurrence of bycatch, meaning that rates are believed to be actually higher than those reported or estimated. The minimum bycatch-induced annual adult mortality of the Maltese populations of *P. yelkouan* and *C. diomedea* will be calculated as proportions of the overall annual mortality rates, as revealed from Capture-Mark-Recapture (CMR) and modelling in selected sub-colonies (for the first time towards the end of the current assessment cycles in time for the reporting deadlines; BD and MSFD: 2024). It is widely assumed that by-catch induced mortality of long-lived seabirds can be considered excess (i.e. added to the natural) mortality. For the assessment of the excess mortality caused by incidental bycatch within one reporting cycle, the average of the proportions of the annual mortality of the latest 5-6 years will be calculated, leaving out the final year of monitoring due to methodological constraints.

When and where implemented, the quality, scale and impact (i.e. effectiveness) of mitigation methods will be monitored and assessed additionally, however, this will be part of the monitoring and assessment of conservation measures under the program of measures (PoMs).

**Costs**

Up-to-date statistics on active fishers and effort per vessel in the Maltese fishing fleet are currently not available to the authors of this report. Therefore, the estimates provided here (Tab. 2) are minimum estimates thought to provide the minimum data required to estimate by-catch rates. However, questionnaire, logbook and on-board observations might need to be increased to cover a representative sample of the Maltese fishing fleet.

**Tab. 2:** Estimated costs for monitoring seabird bycatch under D1C1

| Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| Questionnaires with fishers* | 1920 | person hours | 15 | 28,800 |
| On-board observations with/without mitigation** | 8640 | person hours | 15 | 129,600 |
| Logbook follow up with fishers*** | 1920 | person hours | 15 | 28,800 |
| Compilation of data | 350 | person hours | 15 | 5,250 |
| Analysis in relation to national fishing effort | 60 | person hours | 18 | 1,080 |

*Assuming 4 questionnaires (every 3 months), overestimated at taking 2 hours because some visits will not be successful, with 40 fishers (vessels >12m), annually throughout the 6-year cycle
**Assuming 20 on-board surveys per year lasting an average of 3 days, annually throughout 6-year cycle
***Assuming follow up every 3 months with 40 fishers (<12m vessels), overestimated at taking 2 hours because some visits will not be successful, annually throughout the 6-year cycle.

## Population abundance, breeding population size and trends

**MSFD D1C2 (primary):** Data collection on the (breeding) **population abundance**, reflecting the effects of anthropogenic pressures, such that its long-term viability is ensured. **BD:** The national breeding **population size** estimates of seabird species in breeding pairs, as a range from minimum to maximum. The short-term (last 12 years) and long-term (since 1980) breeding **population trends** including their direction and magnitude. The methodologies for

D1C2 (primary) to be implemented long-term include the monitoring intensity, frequency, timing, and where relevant sites per species.

## Monitoring and assessment of the abundance of *P. yelkouan*

### Colony monitoring with Automatic Sound Recorders (ARUs)

### Monitoring Locations

For the annual assessment of the breeding population abundance/size and trends 15 to 20 automatic sound recording devices should be deployed across all colonies in the Maltese islands (Tab. 3). The colonies which have been monitored at the same location using ARUs since LIFE Arċipelagu Garnija in 2018 are included, having the currently longest-term acoustic datasets for Maltese colonies. Moreover, these are representative sample of the *P. yelkouan* colonies, including the larger colonies such at MT09 L-Irdum tal-Madonna and MT24 Majjistral, but also smaller colonies such as G1 Ta' Isopu and MT24 Rdum id-Delli. However, long-term trend estimation from acoustic data, would benefit from a larger sample size of sites as per conclusions drawn in the Deliverable 2 report of this tender. Therefore, 5-10 ARUs or added to increase sample size and colony coverage. Sites are selected on the basis of suitability of ARU placement and ensuring wide coverage across the archipelago's colonies. Furthermore, ARUs should be placed in the same location each year.

Devices are deployed either next to, on top of or inside *P. yelkouan* colonies, avoiding setting up devices in direct vicinity of active nests. This deployment strategy aims at predominantly recording birds in flight around the colony and avoiding strong influence on recordings from stationary birds in nests directly adjacent to ARUs.

### Timing

The period covered is suggested to span over three months (three moon cycles), from January to April, when calling activity of breeding birds is high, few nests have been lost (e.g. to predation) and the majority of vocal, non-breeding prospectors hasn't arrived. The time span will yield sufficient recordings with high call activity and low ambient noise from waves and wind. Moreover, *C.diomedea* only arrives in the colonies in February/March, which means that recordings in January solely contain *P. yelkouan*, facilitating assessment of colonies with both species. Ideally, for comparability and inference of trends, the recording time span is close to identical across all sites and between years.

The recording schedule of 5 minutes every 30 minutes (5 minutes ON; 25 minutes OFF) throughout the night and the settings of 0dB gain and 24kHz sampling frequency have proven to be effective and thus should be kept.

**Tab. 3:** Proposed monitoring locations by ARUs for *P. yelkouan* in the Maltese Islands. Sites are separated by those with previous data collected under LIFE Arċipelagu Garnija or MSFD monitoring or those that are added to increase sample size.

| | Site | Years of data | Aim | Requirements |
|---|---|---|---|---|
| 1 | MT0000009 Rdum tal-Madonna, RM01 | 2018-2021 | Trend estimation | |
| 2 | MT0000017 Cominotto | 2018-2021 | Trend estimation | |
| 3 | MT0000017 Comino, Santa Maria caves | 2018-2021 | Trend estimation | |
| 4 | MT0000024 Cumnija | 2018, 2020-2021 | Trend estimation | |
| 5 | G1 (not N2K) Ta' Isopu | 2018-2021 | Trend estimation | |
| 6 | MT0000024 Majjisral, above main colony | 2018-2021 | Trend estimation | |
| 7 | MT0000024 Majjistral, Rdum id-Delli | 2018-2021 | Trend estimation | |
| 8 | Ras in-Newwiela – MT0000027 | 2019 & 2020 | Trend estimation | Species specific algorithm/temporally separated recording from *C. diomedea* |
| 9 | MT0000022 Selmunett | 2018 & 2020 | Trend estimation | |
| 10 | MT0000031 Blue Grotto | 2019 | Increase sample size for future estimates | Species specific algorithm/temporally separated recording from *C. diomedea* |
| 11 | MT0000032 Miġra l-Ferħa | NA | Increase sample size for future estimates | Species specific algorithm/temporally separated recording from *C. diomedea* |
| 12 | MT0000024 Qammieħ | 2020 | Increase sample size for future estimates | |
| 13 | MT0000030 Għarb | NA | Increase sample size for future estimates | Species specific algorithm/temporally separated recording from *C. diomedea* |
| 14 | MT01 Għajn Barrani | 2020 | Increase sample size for future estimates | |
| 15 | MT0000033 Ħal Far | NA | Increase sample size for future | Species specific algorithm/temporally |

| | | | | |
|---|---|---|---|---|
| | | | estimates | separated recording from *C. diomedea* |
| 16 | MT0000037 San Dimitri | NA | Increase sample size for future estimates | Species specific algorithm/temporally separated recording from *C. diomedea* |
| 17 | MT0000031 Għar Lapsi | NA | Increase sample size for future estimates | Species specific algorithm/temporally separated recording from *C. diomedea* |
| 18 | MT0000027 Ta' Ċenċ | NA | Increase sample size for future estimates | Species specific algorithm/temporally separated recording from *C. diomedea* |
| 19 | MT0000029 Wardija | NA | Increase sample size for future estimates | Species specific algorithm/temporally separated recording from *C. diomedea* |
| 20 | MT0000029 Fungus Rock | NA | Increase sample size for future estimates | Species specific algorithm/temporally separated recording from *C. diomedea* |

**Frequency across monitoring cycle**

With two visits to each site, one for deployment and one for retrieval of ARUs, remote monitoring with sound recorders requires relatively low effort. Therefore, it is recommended to carry out this type of monitoring annually at all sites, alternatively at least every other year. Trend analysis would take place once per monitoring cycle.

**Analysis**

The analyses of the sound data to reveal bird abundances followed Austad et al. (2019). After filtering out recordings at higher wind speeds (25km/hr) to avoid the most extreme effects of wind, and subsequent wave noise, the 'soundecology' package in R was utilised to analyse the sound recordings. So far, the indices used to estimate bird abundance at colony sites is the Bioacoustic Index (BIX) and the Acoustic Diversity Index. Both indices were positively correlated to the number of *P. yelkouan* calls counted manually in a small subset of recordings.

However, one of the shortcomings of acoustic indices is that they do not differentiate between specific types of sound recorded by the ARUs, such as wind, waves, bird calls of different species etc. Therefore, it is planned to develop sound classifiers to be utilised on the ARU sound files, e.g. via AI applications currently developed by BirdNET (https://birdnet.cornell.edu/about-us/) or Conservation Metrics (https://conservationmetrics.com/). Sound classifiers would then be able to detect wind and wave noise to be filtered out and then to label and count calls specifically of *P. yelkouan* in each recorded sound file. In a transition exercise, acoustic indices and differentiated call-counts by the classifiers would be calibrated against each other. Archived sound files from previous assessments could be utilized as well to reduce the potential bias caused by a change in methodology and to estimate trends. Therefore, any new sound analysis method would be applied for the complete stored dataset of sound files.

Alternative models additional to RandomForest algorithms should also be considered, especially for the aim to determine trends in calling activity. An alternative model for trend estimation could include a Generalised Linear mixed model (GLMM), with a mean annual site-specific calling activity as dependent variable and year as predictor variable, while keeping site as a random effect to take into account non-independence of observations.

**Costs**

Devices utilized in previous assessments and during the 2021 field season were SM04 by Wildlife Acoustics (https://www.wildlifeacoustics.com/). Alternatively, devices that come at a fraction of the costs of the SM04 such as AudioMoth by Open Acoustic Devices could be used (https://www.openacousticdevices.info/audiomoth) or new smaller versions of the SM04 (https://www.wildlifeacoustics.com/products/song-meter-mini). The microphones of the smaller Wildlife acoustics are identical to the SM04 units, the recording quality would be identical. However, since the units are smaller, battery capacity is reduced, meaning more frequent visits might be required to ensure the same recording period is reached. Audiomoths have different microphone quality which might affect comparison between years with SM04 recordings. However, these differences can be incorporated into AI models if sufficient training data is at hand i.e. a soft transition to Audiomoths with both types of units used for a few years before any complete transition.

**Tab. 4:** Costs for Acoustic monitoring and analysis for *P. yelkouan across a 6-monitoring cycle.*

| **Item** | **Number per monitoring cycle** | **Unit type** | **Unit cost [€]** | **Total [€]** |
|---|---|---|---|---|
| Deployment & Retrieval of ARUs* | 480 | person hours | 15 | 7,200 |
| Acoustic trend analysis | 80 | person hours | 18 | 1,440 |
| Replacement units: Audiomoth including waterproof case | 10 | equipment | 115 | 1,150 |
| Replacement units: Wildlife acoustics mini | 10 | equipment | 445 | 4,450 |
| Batteries (AAx4 rechargeable) | 20 | consumables | 8 | 160 |
| SD cards | 20 | consumables | 4 | 80 |
| Replacement batteries for SM04 (D cell X4) | 20 | consumables | 14 | 280 |
| Cloud computing space for AI** | 5000 | external assistance | 1 | 5,000 |
| Hard Disk 1TB | 6 | equipment | 50 | 300 |

*Assuming 1 hour per deployment/retrieval, 20 units, 2 visits per year for deployment & retrieval, 2 persons per visit, annual deployment for a 6-year cycle.

**highly variable depending on AI algorithm complexity, minimum estimate provided by expert opinion.

**Colony monitoring via capture mark recapture (CMR)**

It is recommended to continue the breeding population size assessment by means of CMR and population modelling with a combined approach of capture by means of mist-netting and capture of birds by hand on the ground in front of the nest or cave entrance

**Monitoring Locations**

To date, the CMR approach has been repeated regularly (annually) at accessible sub-sites of four areas inside Natura 2000 sites, including Malta's two major colonies for the species (in bold): **L-Irdum tal-Madonna (MT0000009)**, Cominotto (MT0000017), St Paul's Island (MT0000022), **Majjistral (MT0000024) (Tab. 5). Monitoring of all subsites listed in Table 5 should be continued.** The number of colonies where CMR is carried out should be increased. To cover a larger range in the distribution of the species one colony in Gozo (e.g. Torri ta' Isopu) and one in the south of Malta (e.g. Wied Babu) should be added in future monitoring.

**Tab. 5:** All subsites that have been covered in the period 2012-2021 for CMR of *P. yelkouan* in four representative and accessible colonies. The type of capture technique is mentioned per subsite; whether by hand in cave entrances, handing at the nest for accessible nests or by mist net.

| Colony | Subsite | Technique | Remarks |
|---|---|---|---|
| MT09 Rdum tal-Madonna | RM01 | Hand; Nest; Mist net | 40ft above 'big crack' |
| | RM03 | Mist net | 80ft in front of NS1 to NS18 |
| | RM04D | Hand; Nest | |
| | RM04C | Hand; Mist net | 40ft in front of Cave 2 |
| | RM04A; RM04B | Hand | |
| | RM05 | Hand | including South, Central & North ledges of RM05GC and Upper & lower ledges of RM05BT |
| MT24 Majjistral | EC | Hand | |
| | TC | Hand | |
| | NS2-NS3 | Hand; Nest | |
| | SC 4 | Hand | |
| | SC 1 | Hand | |
| MT17 Cominotto | Cave 1 | Hand; Mist net | 6ft optional |
| | Cave 2 | Hand; Mist net | 9ft |
| | Cave 3 | Hand | |
| | Cave 4 | Hand | |
| | Cave 9 | Hand | |
| MT22 Selmunett | Main Cave | Hand, Mist net | 80ft |
| | West Cave | Hand, Nest | |

**Timing**

At least two, but ideally three, CMR visits per subsite and per year would be necessary to collect adequate data for modelling. The focus should be on nights with high bird activity and during the period February to June.

**Frequency across monitoring cycle**

If it is not feasible to carry out annual CMR monitoring programs, it should be carried out at least every other year. However, for the best result all colonies should be covered within the same seasons.

**Analysis**

The analyses of CMR data should follow Austad et al. (2019), using Jolly-Seber models in a Bayesian framework (Kéry and Schaub 2011).

One additional advantage of the CMR approach for bird abundance assessments is the opportunity to use the collected data on demographic parameters (D1C3, secondary), specifically adult survival rates (see below). Depending on the timing, it is also possible to combine the CMR visits with nest-checks for the earlier monitoring visits of reproductive performance.

Analysis of abundance and adult survival should be carried out on colonies of comparable size, therefore if small colonies are included in future analysis (e.g Wied Babu), obtaining the estimates for these can perhaps be attempted by modelling with subsites of the larger colonies.

**Costs**

Costs for CMR analysis for *P. yelkouan* are presented in Tab. 6.

**Tab 6:** Costs estimated for carrying out CMR for *P. yelkouan* across a 6-year monitoring cycle under D1C2. Results also contribute to D1C3.

| Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| CMR at *P. Yelkouan* sub-sites* | 2304 | person hours | 15 | 34,560 |
| CMR data input and cleaning | 288 | person hours | 15 | 4,320 |
| CMR analysis | 40 | person hours | 18 | 720 |
| Mist nets | 2 | consumables | 100 | 200 |
| Mist net poles | 3 | consumables | 40 | 140 |
| Ringing kit (pliers, callipers,...) | 2 | consumables | 70 | 140 |

| | | | | |
|---|---|---|---|---|
| Rings | 2000 | consumables | 0.175 | 350 |

*Assuming 4 hours per visit, 2 persons for 16 subsites (some adjacent subsites can be combined); 3 visits per year; annual monitoring for the 6-year monitoring cycle

**Colony monitoring via camera traps**

**Monitoring Locations**

Over the past years, camera traps have been proven to be very useful tools to get reliable abundance estimates for sub-colonies of *P. yelkouan* in caves with communal nest entrances (Tab. 7). Additional caves should be added if discovered during future monitoring, taken safe access is possible to reach the cave entrance for camera deployment and maintenance.

**Tab. 7:** Locations of subsites suitable for monitoring using trail cameras for purposes of obtaining abundance estimates of *P. yelkouan*.

| Site | Sub-Site Code | Site | Sub-Site Code |
|---|---|---|---|
| G1 Ta' Isopu | G1_Isopu_lowercrack | MT17 Cominotto | MT17_Cominotto_Cave_1 |
| MT09 Rdum tal-Madonna | MT09_RM01_above_big_crack | | MT17_Cominotto_Cave_2 |
| | MT09_RM01_underboulder | | MT17_Cominotto_Cave_3 |
| | MT09_RM02_caves | | MT17_Cominotto_Cave_4 |
| | MT09_RM02_lower | | MT17_Cominotto_Cave_5 |
| | MT09_RM03DC_NS14_15_16 | | MT17_Cominotto_Cave_6 |
| | MT09_RM03DC_NS19 | | MT17_Cominotto_Cave_7 |
| | MT09_RM03DC_NS20_22 | | MT17_Cominotto_Cave_9 |
| | MT09_RM03DC_NS3_4 | | MT17_Cominotto_Cave_10 |
| | MT09_RM03DC_NS8_9 | MT22 Selmunett | MT22_StPaul_East_Cave |
| | MT09_RM03_Spiderman | | MT22_StPaul_West_Cave |
| | MT09_RM04A | MT24 | MT24_Cumnija_South_Cave |
| | MT09_RM05BT_lower | | MT24_Majjistral_TC |
| | MT09_RM05GC_Cave_1 | | MT24_Majjistral_EC |

| | | | |
|---|---|---|---|
| | MT09_RM05GC_Cave_2 | | MT24_Majjistral_S_Cave_1 |
| | MT09_RM05GC_Cave_3 | | MT24_Majjistral_S_Cave_2 |
| | MT09_RM05GC_Cave_4 | | MT24_Majjistral_S_Cave_3 |
| | MT09_RM05GC_Cave_6 | | MT24_Majjistral_S_Cave_4 |
| MT17 Comino | MT17_Comino_Shelf_Cave_lower_south | | MT24_Majjistral_S_Cave_5 |
| | MT17_Comino_Shelf_Cave_Upper_north | | MT24_Majjistral_ontop_cave |
| | MT17_Comino_Shelf_Cave_Upper_south | | MT24_Delli_Cave |
| | MT17_Treasure_Cave_NS2 | MT27 Ta' Ċenċ | MT27_RasNewwiela |
| | MT17_Treasure_Cave_NS4 | MT31 Għar lapsi | MT31_Lapsi_SeaCaves |

**Timing**

To use resources efficiently, these camera traps should focus on the early chick-rearing period late April to May. To estimate biases caused by early nest-loss during the egg-laying and incubation periods, some camera traps should be operational from February to May.

**Frequency across monitoring cycle**

Camera use can be economized via rotation between caves between years within one assessment cycle. Overall trail cameras should be deployed annually or at least every other year to generate sufficient and robust data. To reduce the number of site visits and economise the work, setting up, maintaining and retrieval of camera traps is recommended to be combined with site visits for other purposes.

**Analysis**

Camera traps are not suitable for accurate trend detection but currently provide the only method to reveal cave specific estimates of abundance for caves or cave entrances too small to be surveyed by a human observer, making nest counts in such places impossible. Cameras are equipped with a motion sensor and an infrared light source emitting no visible light to avoid any disturbance. Cameras are set to capture a still image whenever the motion sensor is activated, e.g. by birds entering or leaving the cave. For comparability reasons, the analyses of camera trap data should follow Austad et al. 2019 with dates in which the five to 10 nights with highest number of images taken per night and site to be used for the analyses. The number of images was found to correlate with the number of birds entering caves.

Currently, the analysis of camera trap images requires significant manpower as birds are counted by trained personnel in a large number of images. Technological advancement of visual recognizer software including trainable AI solutions (Islam and Valles 2020) should be considered for automatization of future image analyses. However, due to large variation in caves, and hence positioning of cameras, it is likely that for the foreseeable future the direction of movements (birds entering or leaving) would be determined by human observers.

### Costs

Up to 20 units should be allocated for work on *P. yelkouan,* surveying suitable cave entrances (Tab. 8). However, it is recommended to keep several additional cameras as spares for replacement during the season in case of loss or technical issues.

**Tab. 8.** Estimated costs for monitoring *P. yelkouan* using trail cameras under D1C2 for the duration of a 6-years monitoring cycle.

| **Item** | **Number per monitoring cycle** | **Unit type** | **Unit cost [€]** | **Total [€]** |
|---|---|---|---|---|
| Trail Camera deployment* | 480 | person hours | 15 | 7,200 |
| Trail Cameras | 30 | equipment | 150 | 4,500 |
| Counts of shearwaters in images** | 240 | person hours | 18 | 4,320 |
| Batteries (AA x 8) | 120 | consumables | 6 | 720 |
| Sd Cards | 30 | consumables | 4 | 120 |

*Assuming 1 hour per visit (will be combined with nest monitoring and other actions); 2 persons per visit; 20 cameras per year; a deployment and a retrieval visit per camera; annual monitoring throughout the 6-year cycle

**Assuming annual monitoring at 20 sites and analysis by experienced observer

### Colony monitoring via thermal imaging and audial counts, photomapping

### Monitoring Locations

Counts of *P. yelkouan* entering the colony at night using a thermal imaging camera (FLIR) at inaccessible colony entrances as well as audio-visual assessments should be carried out across **all colonies.** A thermal imaging camera is either handheld or fitted on a tripod but is not left unattended for several nights due to battery and cost limitations, in contrast to trail cameras described above. Thermal imaging cameras also have a longer detection range compared to trail cameras, making them suitable to monitor inaccessible sites where trail cameras cannot be deployed. In fact, this method is specifically important at those colonies that are largely not accessible by other means due to difficulty in access (Tab. 9). At most sites, audio-visual monitoring is carried out from a RIB, but should be performed from land where the topography allows. In boulder scree habitat, *P. yelkouan* often nest in the Upper globigerina limestone layer, above the scree. In such habitats surveys are best done from land by walking through the boulder scree. In largely accessible colonies where CMR and trail cameras can cover a majority of subsites, thermal imaging counts are still recommended to cover inaccessible subsites (Tab. 10).

**Tab. 9**: Colonies which are to a large extent inaccessible, and where abundance estimation for D1C2 relies on thermal imaging and audial counts from land and/or sea.

| N2K Colony site | Count from Land and/or RIB | Remarks |
|---|---|---|
| MT0000037 W. Għasri to San Dimitri | both | |
| MT0000001 Għajn Barrani | land | |
| G1 - Għar il-Mixta to D. Qorrot | land | includes one accessible section within AFM base |
| MT0000017 Kemmuna | both | cliffs south of Santa Marija caves |
| MT0000024 Qammieħ | land | |
| MT0000024 Rdum id-Delli to Majjiesa | land | includes a few accessible sections |
| MT0000032 Fomm ir-Riħ | both | |
| MT0000032 Miġra l-Ferħa | both | includes one accessible section |
| MT0000032 Dingli & Fawwara | sea | |
| MT0000031 Għar Lapsi | both | includes two accessible sections |
| MT0000031 Blue Grotto | sea | includes one accessible section |
| MT0000031 Wied Fulija | both | |
| MT0000033 Ħal Far & Bengħisa | sea | includes one accessible section |
| MT0000027 Ras in-Newwiela | both | includes one accessible section |
| MT0000027 Ta’ Ċenċ | sea | includes two accessible sections |
| MT0000028 Sannap | sea | |

| | | |
|---|---|---|
| MT0000029 Xlendi to Wardija | both | |
| MT0000030 Dwejra to Għarb | both | includes one accessible section |

**Tab. 10:** Inaccessible sections within otherwise accessible colonies, for which abundance estimates are best obtained using thermal imaging counts

| N2K colony site | Subsite |
|---|---|
| MT000009 Rdum tal-Madonna | Inaccessible section between RM05BT to RM05GC |
| | Upper inaccessible section between RM04B to RM04D |
| | RM03 upper |
| | RM02 upper to RM01 |
| | RM01 upper |
| MT0000022 Selmunett | Main Cave upper |
| MT0000017 Kemmunett | Section between Cave 7 and Cave 8 |
| | Section east of Cave 1 & 2 |
| MT0000024 Majjistral | Upper North, Central and South caves (above EC to South 4) |
| | Section between North of wall & EC |

**Timing**

The general assessment is ideally carried out early in the breeding season of *P. yelkouan*, in the time between January and March, before significant numbers of non-breeders/ prospectors and numbers of *C. diomedea* arrive in the colonies. Especially the assessment from a RIB at this period of the year is often constrained by unfavourable weather conditions. Furthermore, as the activity of birds entering the colony peaks between one hour after darkness maximum until midnight or until the moon is up, assessments during whole nights can create strong biases.

In cases of inaccessible cave entrances (and hence the deployment of camera traps is not viable), in otherwise accessible colonies (Table 10), thermal imaging counts can be carried out in conjunction with CMR visits, by which the FLIR is set on a tripod and records for circa 30min intervals. Birds entering caves can be counted at a later stage from footage by a human observer, providing estimates for specific sub-sites.

**Frequency across monitoring cycle**

For reasons presented above, an annual assessment of the entire breeding range (Tab. 9) is unlikely to be feasible and the assessment should be spread over the critical time periods each year of one entire assessment cycle (six years). At least three visits should be made to each colony due to stochastic activity at colonies. On the other hand, Tab. 10 sub-sites can be incorporated with CMR fieldwork as described above and therefore can be repeated annually.

**Analysis**

Sections of cliff faces with suitable nesting habitats should be monitored for incoming birds via FLIR (direct counts or from footage) in short time intervals (3-5 minutes per section). Call counts during these intervals add information on bird abundance per site.

The nocturnal monitoring of all suitable habitat via FLIR counts is also seen as currently the best method available for an overall assessment of breeding range (under D1C4), size and trends.

To date, most suitable nesting habitats for *P. yelkouan* have been successfully photo-mapped. However, for the current assessment cycle the photomaps should be finalized and as much as possible overlayed with *P. yelkouan* breeding pair estimates per site as revealed by an integration of the above-mentioned methods. Such overlay should then be repeated once per assessment cycle in the future.

For the remaining time of the current assessment cycle (until 2024), breeding pair estimates should focus on the areas in category 1 and 3 of distribution range certainty, making use of audio-visual assessments and thermal imaging, to further close knowledge gaps and increase certainties regarding the overall size of the Maltese breeding population (as well as the overall distribution – see relevant chapter). In case access to any additional larger colonies appears feasible, employment of the other methods presented above, e.g. camera trapping, should then be considered for future assessment periods.

**Costs**

Costs for audio-visual surveys for *P. yelkouan* are presented in Table 11.

**Tab. 11:** Estimated costs for audio-visual monitoring of *P. yelkouan*, including by use of a thermal imaging camera, under D1C2 for the duration of a 6-year monitoring cycle.

| Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| Audio-visual counts* | 504 | person hours | 15 | 7,560 |
| Thermal imaging camera (Thermal Imaging Camera: IR camera-FLIR T420 25 camera- IR lens 15 and | 1 | equipment | 14500 | 14,500 |

| | | | | |
|---|---|---|---|---|
| FLIR tools+software | | | | |
| Drone including licenses & training | 1 | equipment | 1800 | 1,800 |
| Photomapping (Deskbased) | 40 | person hours | 15 | 600 |
| Counts of shearwaters in footage** | 120 | person hours | 15 | 1,800 |
| Compiling of population abundance data | 16 | person hours | 18 | 288 |

*Assuming 2 persons per trip; an average of 6 hours per trip; 14 sites (by combining nearby sites into one survey) and 3 visits per site within the monitoring cycle

**Assuming 10 thermal imaging video recordings of 2-hour duration per year of the 6-year annual cycle

***Puffinus yelkouan* population abundance estimates by integration of methods**

For all accessible colonies, each colony is subdivided into subsites based on different ledges, caves and burrows. All encountered cave entrances and nest sites are assessed for the presence of *P. yelkouan* footprints, faeces, smell and/or visible nests with adults (incubating) or chicks. Population estimates, with lower and upper estimates, are assigned to each subsite according to the different methods most suited to each subsite.

For each colony, the estimates of each subsite are summed to give the total estimate for the colony. This results in a higher resolution and accuracy compared to estimating the population on the colony level.

For completely inaccessible colonies, estimates are largely less accurate and are based on methodologies that can be applied on a larger scale, mainly audio-visual counts during surveys carried out from land or sea and based on modelling of calling activity in ARU recordings.

Costs for the integration of results from methods in order to obtain abundance estimates for the whole of the Maltese Islands are included in compilation of data under respective methods above.

## Monitoring and assessment of the abundance of *C. diomedea*

### Colony monitoring with Automatic Sound Recorders (ARUs)

#### Monitoring Locations

For the annual assessment of the breeding population abundance/size and trends 20 automatic sound recording devices should be deployed across all colonies in the Maltese islands (Table 12). Devices are deployed in a way as described under the relevant section for *P. yelkouan* (see above).

**Table 12:** Recommended sites for ARU deployment for long-term monitoring of *C.diomedea*

| Site | Years of data | Aim | Requirements |
|---|---|---|---|
| MT0000009 Rdum tal-Madonna, RM02 | 2019;2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000016 Filfla NW boulders | 2019;2021 | Trend estimation | |
| MT0000017 Comino, Santa Maria caves | 2019;2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000031 Wied Fulija | 2019;2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000029 Ta' Riefnu | 2019;2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000028 Sannap Cliffs | 2019;2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000032 Fomm ir-Riħ | 2021 | Increase sample size for future estimates | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000027 Ras in-Newwiela | 2019-2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000033 Bengħisa | 2019;2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000031 Blue Grotto | 2019;2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000032 Miġra l-Ferħa | 2019;2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000032 Dingli | 2019;2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000030 Għarb | 2019;2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000030 Dwejra | 2019;2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. Yelkouan* |

| | | | |
|---|---|---|---|
| MT0000033 Ħal Far | 2019;2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000037 San Dimitri | 2019;2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000031 Għar Lapsi | 2021 | Increase sample size for future estimates | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000027 Ta' Ċenċ | 2019;2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000029 Wardija | 2019;2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. yelkouan* |
| MT0000029 Fungus Rock | 2019;2021 | Trend estimation | Species specific algorithm/temporally separated recording from *P. yelkouan* |

**Timing**

The period covered is suggested to span over three months (three moon cycles), from June to August. The time span will yield sufficient recordings with high call activity and low ambient noise from waves and wind. Ideally, for comparability and inference of trends, the recording time span is close to identical across all sites and between years.

The recording schedule of 5 minutes every 30 minutes (5 minutes ON; 25 minutes OFF) throughout the night and the settings of 0dB gain and 24kHz sampling frequency have proven to be effective and thus should be kept.

**Frequency across the monitoring cycle**

With two visits to each site, one for deployment and one for retrieval of ARUs, remote monitoring with sound recorders requires relatively low effort. Therefore, it is recommended to carry out this type of monitoring annually at all sites, alternatively at least every other year. Trend analysis would take place once per monitoring cycle.

**Analysis**

After filtering out recordings at higher wind speeds (circa 25km/hr) to avoid the most extreme effects of wind, and subsequent wave noise, the ‘soundecology’ package in R was utilised to analyse the sound recordings. So far, the indices used to estimate bird abundance at colony sites is the Bioacoustic Index (BIX) and the Acoustic Diversity Index. A small-scale test in 2019, found that BIX correlated positively with the number of shearwaters counted in flight on Filfla. However, one of the shortcomings of acoustic indices is that they do not differentiate between specific types of sound such as wind, waves, bird calls of different species etc. Therefore, it is planned to develop sound classifiers to be utilised on sound files collected by ARUs for the long-term monitoring, e.g. via AI applications currently developed by BirdNET (https://birdnet.cornell.edu/about-us/) or Conservation Metrics (https://conservationmetrics.com/). Sound classifiers would then be able to detect wind and wave noise to be filtered out and then to label and count calls specifically of *C.diomedea* in each recorded sound file. In a transition exercise, acoustic indices and differentiated call-counts by the classifiers would be calibrated against each other. Archived sound files from previous assessments could be utilized as well to reduce the potential bias caused by a change in methodology and to estimate trends. Therefore, any new sound analysis method would be applied for the complete stored dataset of sound files.

Alternative models additional to RandomForest algorithms should also be considered, especially for the aim to determine trends in calling activity. An alternative model for trend estimation could include a Generalised Linear mixed model (GLMM), with a mean annual site-specific calling activity as dependent variable and year as predictor variable, while keeping site as a random effect to take into account non-independence of observations.

**Costs**

Devices utilized in previous assessments and during the 2021 field season were SM04 by Wildlife Acoustics (https://www.wildlifeacoustics.com/). Alternatively, devices that come at a fraction of the costs of the SM04 such as AudioMoth by Open Acoustic Devices could be used (https://www.openacousticdevices.info/audiomoth) or new smaller versions of the SM04 (https://www.wildlifeacoustics.com/products/song-meter-mini) (Tab. 13). Information comparing SM04, SM04 mini and Audiomoths is presented under P. yelkouan.

**Tab. 13:** Costs for Acoustic analysis for *C.diomedea* under D1C2 for a 6-year monitoring cycle

| Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| Deployment & Retrieval of ARUs* | 480 | person hours | 15 | 7,200 |
| Acoustic trend analysis | 80 | person hours | 18 | 1,440 |
| Replacement units: Audiomoth including waterproof case | *same as P. yelkouan* | | | |
| Replacement units: Wildlife acoustics mini | same as P. yelkouan | | | |
| Batteries (AAx4 rechargeable) | 20 | consumables | 8 | 160 |
| SD cards | 20 | consumables | 4 | 80 |
| Replacement batteries | 20 | consumables | 14 | 280 |

| | | | | |
|---|---|---|---|---|
| for SM04 (D cell X4) | | | | |
| Cloud computing space for AI** | 1 | external assistance | 5,000 | 5,000 |
| Harddisk 1TB | 6 | equipment | 50 | 300 |

*Assuming 1 hour per deployment/retrieval, 20 units, 2 visits per year for deployment & retrieval, 2 persons per visit, annual deployment for a 6-year cycle.

**highly variable depending on AI algorithm complexity, minimum estimate provided by expert opinion.

**Colony monitoring via capture mark recapture (CMR)**

After increasing the ringing effort of the species during the 2021 assessment, it is recommended to add a CMR approach of the *C. diomedea* breeding population including population modelling, like the approach taken for *P. yelkouan* and *H. pelagicus melitensis,* to the portfolio for future monitoring of population size.

**Monitoring Locations**

With the CMR approach it is envisaged to systematically cover a representative sample of nests (ideally pairs of >300 nests), and distribution (all important colonies) across the Maltese islands. Except for Filfla, where a significant number of *C. diomedea* is caught in mist nets set for the monitoring of *H. pelagicus melitensis,* CMR for the data collection in order to model relevant population parameters should focus on breeding pairs of individually marked nests and birds encountered in the colonies on the ground. Colonies in seven Natura 2000 sites should be covered (Table 14). In 2021 at these locations 151 occupied nests from a total of 222 accessible nesting sites were identified, but the sample could be increased further by for example abseiling to the wide ledges at Ta’ Ċenċ colony. Further information on the number of nests per sub-site and colony is provided under D1C3 (Tab. 26.

**Tab. 14:** Natura 2000 sites, colonies for CMR monitoring of *C. diomedea*.

| Natura 2000 site number | Colony site names |
|---|---|
| MT0000016 | Filfla |
| MT0000027 | Ta' Ċenċ (ideally including the main colony) |
| MT0000029 | Xlendi |
| MT0000030 | Dwejra, Fungu Rock, Għarb |
| MT0000031 | Għar Lapsi |
| MT0000032 | Fomm ir-Riħ, Miġra l-Ferħa, Ta’ Żuta |
| MT0000033 | Bengħisa, Ħal Far |

**Timing**

It is recommended to catch and ring/ recapture the birds mainly at the beginning of the breeding period in April and May (before incubation) when partners meet in the nest for pairing. One to two visits per season are to be carried out, ideally at the beginning of the first nights following the full moon, i.e. periods when colony attendance of breeding birds is expected to be high.

**Frequency across monitoring cycle**

Each nest in the sample of monitored nests should be visited annually or at least every second year throughout the monitoring cycle. If a bi-annual approach is taken it is recommended to visit all sites within the same year.

**Analysis**

The advantage of the CMR approach for bird abundance assessments is the opportunity to combine the visits and use the collected data also for monitoring of demographic parameters (D1C3, secondary), specifically to determine adult survival rates (see below). A Jolly-Seber model without splitting data by colony is deemed suitable (Kéry & Schaub 2011), where effort will be the number of nests monitored in addition to visits made.

**Costs**

A budget for CMR of *C. diomedea* is presented in Table 15.

**Tab. 15:** Estimated costs of CMR of *C. diomedea* under D1C2 for a 6-year monitoring cycle.

| Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| CMR at nests* | 792 | person hours | 15 | 11,880 |
| Ringing kit (pliers, callipers,...) | 2 | Consumables | 70 | 140 |
| Rings | 1000 | consumables | 150 | 150 |
| CMR data input and cleaning | 144 | person hours | 15 | 2,160 |
| CMR analysis | 40 | person hours | 18 | 720 |

*Assuming 1 visit per year dedicated to this action, while additional visits will be combined with other monitoring methods (D1C3 nest checks); all nests covered with 11 separate visits involving an average of 6 hours; 2 persons; annual across 6-year cycle

**Colony monitoring via thermal imaging and audial counts, photomapping**

**Monitoring Locations**

Counts of *C. diomedea* entering the colony at night using a thermal imaging camera (FLIR) at inaccessible colony entrances as well as audio-visual assessments should be carried out across **all colonies** and specifically at those that cannot be assessed by other means due to difficulty in access. At most sites, this monitoring has to be carried out from a RIB but should be performed from land where the topography allows (Tab. 16). Despite some accessible locations and nesting sites a wider assessment of all colonies is recommended for abundance estimates of this species.

**Tab. 16:** Colonies where audio-visual assessments for *C.diomedea* should be carried out from land and/or sea.

| N2K Colony site | Count from Land and/or RIB | Remarks |
|---|---|---|
| MT0000037 W. Għasri-Dimitri | Both | |
| MT0000017 Kemmuna | Both | includes one accessible section |
| MT0000009 Rdum tal-Madonna | Both | includes one accessible section |
| MT0000032 Fomm ir-Riħ | Both | includes one accessible section |
| MT0000032 Miġra l-Ferħa | Both | includes accessible sections |
| MT0000032 Dingli & Fawwara | Both | includes one accessible section |
| MT0000031 Għar Lapsi | Both | includes accessible sections |
| MT0000031 Blue Grotto | Both | |
| MT0000031 Wied Fulija | Both | |
| MT0000033 Ħal Far & Bengħisa | Both | includes accessible sections |
| MT0000027 Ras in-Newwiela | Both | includes one accessible section |
| MT0000027 Ta' Ċenċ | Sea | includes accessible sections |
| MT0000028 Sannap | Sea | |
| MT0000029 Xlendi to Wardija | Both | includes one accessible section |
| MT0000030 Fungus Rock | Both | includes accessible sections |
| MT0000030 Dwejra to Għarb | Both | includes accessible sections |

**Timing**

The assessment is ideally carried out early in the breeding season of *C. diomedea*, in the time between April and May, before significant numbers of non-breeders/ prospectors arrive in the colonies but considering the pre-laying exodus of the birds in May. However, the activities can be extended into August if the presence of non-breeders is considered.

**Frequency across the monitoring cycle**

As the activity of birds entering the colony peaks between one hour after darkness maximum until midnight or until the moon is up, assessments during whole nights can create strong biases. Therefore, an annual assessment across the entire breeding range is unlikely to be feasible and the assessment should be spread over the critical time periods each year of one entire assessment cycle (six years).

**Analysis**

Sections of cliff faces with suitable nesting habitats should be monitored for incoming birds via FLIR (direct counts or from footage) in short time intervals (3-5 minutes per section). Call counts during these intervals add information on bird abundance per site.

The nocturnal monitoring of all suitable habitat via FLIR counts is also seen as currently the best method available for an overall assessment of breeding range (under D1C4), size and trends.

To date, only a part of the suitable nesting habitats for *C. diomedea* has been photo-mapped. Therefore, monitoring in the coming years should focus on finalizing the photomaps during the current assessment cycle (until 2024). Photomaps should then be overlaid with *C. diomedea* breeding pair estimates per site as revealed by an integration of the above-mentioned methods. Such overlay could then be repeated once per assessment cycle in the future.

For the remaining time of the current assessment cycle (until 2024), breeding pair estimates should focus specifically on the areas in category 1 of distribution range certainty, making use of audio-visual assessments and thermal imaging, to further close knowledge gaps and increase certainties regarding the overall size of the Maltese breeding population (as well as the overall distribution – see relevant chapter).

**Costs**

Table 17 presented the costs estimated for audio-visual surveys of *C. diomedea*.

**Tab. 17:** Estimated costs for audio-visual monitoring of *C. diomedea*, including by use of a thermal imaging camera, under D1C2 for the duration of a 6-year monitoring cycle.

| Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| Audio-visual counts* | 432 | person hours | 15 | 6,480 |
| Thermal imaging camera | same as *P. yelkouan* | | | |
| Drone including licenses & training | same as *P. yelkouan* | | | |
| Photomapping (Deskbased) | 40 | person hours | 15 | 600 |
| compiling of population abundance data | 16 | person hours | 18 | 288 |

*Assuming 2 persons per trip; an average of 6 hours per trip; 12 sites (by combining nearby sites into 1 survey) and 3 visits per site within the monitoring cycle

## Monitoring and assessment of the abundance of *H. pelagicus*

### Colony monitoring via capture mark recapture (CMR) on Filfla

The intensive CMR approach covering six locations around the islet with a spatially explicit population modelling repeated once per assessment cycle has been carried out already three times, in 2013, 2019 and 2021. The six subsites (North, North-East, South-East, South; West and North-West) and typically used mist-net length required per sub-site is presented in Table 18. West 1 and West 2 can be used interchangeably depending on rock stability in the year of survey. North-East includes two mist netting sites next to each other (Net_ID 2). South-East includes two mist netting sites next to each other (Net_ID 3 and 9). Net_ID 8 was trialled in 2019 and does not need to be included in future surveys.

The boulder scree of Filfla is constantly changing, and future surveys are not expected to be affected if a sub-site has to be entirely removed. Moreover, if a mist-net site is moved within the same area, a new Net_ID can be created to take into account this change in statistical model.

**Tab. 18**: Filfla CMR sub-sites for *H. pelagicus* abundance estimation. Net_ID is used for modelling purposes and should be kept consistent for future analysis. All sites, except NET_ID 8, presented in this table are recommended for future surveys while Net_ID 5 and 6 can be used interchangeably depending on the safety of the boulder scree.

| Net_ID | LAT | LONG | Sub-site | Mist-nets | Remarks |
|---|---|---|---|---|---|
| 1 | 35.787869 | 14.409892 | North | 2*40ft together | |

| | | | | | |
|---|---|---|---|---|---|
| 2 | 35.78781 | 14.41084 | North-East | 2 *40ft together (NE2) and 1*40 separate (NE0) | includes both NE2 (24m site) and NE0 (12m net site) |
| 3 | 35.787234 | 14.410946 | South-East | 1*40ft | |
| 4 | 35.78693 | 14.409712 | South | 1*40ft | 2*40ft can also be used |
| 5 | 35.787491 | 14.408336 | West 1 | 2*40ft together | |
| 6 | 35.787421 | 14.40854 | West 2 | 2*40ft together | |
| 7 | 35.78775 | 14.40921 | NW | 2*40ft together | |
| 8 | 35.78791 | 14.41022 | North | 20ft in cave entrance | trialled once in 2019 |
| 9 | 35.78695 | 14.41085 | South-East | 2*40ft together | lower down than 3, below clay cliff |

**Timing**

Each sub-site on Filfla should be at least visited twice (i.e two separate complete mist-netting nights) as part of a complete CMR survey of the islet. Nets should be up at dusk until dawn.

However, ideally the effort is even increased to 3-5 nocturnal mist-netting sessions per sub-site, especially because the recapture probability remained low in the 2021 analysis. Nevertheless, to meet the model criteria the period in which the visits are carried out would need to be kept as short as possible (ideally within 2 months, 3 months maximum). Beyond the obligatory and minimum two visits per sub-site, since effort is included in the model, a different number of additional visits can be made to the subsites (i.e 5 visits to North-West, 4 visits to North-East, 3 to South-West etc…). Moreover, different sub-sites can be covered on the same night, taking a sufficient number of ringers, to limit the total number of visits to Filfla islet.

All visits should be made between mid-May until the end of July, with the possible extension to mid-August if visits are not accomplished before due to unfavourable weather.

An increase of effort in future CMR surveys is expected to increase the accuracy of estimation, while still allowing for inclusion of data collected in 2013, 2019 and 2021 in the CMR model.

**Frequency across monitoring cycle**

It is highly recommended to continue with the setup of one thorough assessment covering all 6 sub-sites within one season per monitoring cycle. It is planned to further explore the possibility of an additional CMR approach with lower effort during the other five years, e.g. two to three visits covering only one site and potentially changing location from one year to the next. While it is expected that such a setup will increase the individual recapture probability and thus improve the accuracy of the population estimates, it will need to be explored how the model to calculate the population estimates needs to be modified.

**Analysis**

We recommend data from all years (2013, 2019, 2021 and any future surveys) to be analysed together in a robust design model (Kéry & Schaub, 2011). In such a model, each year is regarded as a primary occasion, with the different sessions held within a year regarded as secondary occasions. The robust design model utilised was a spatially explicit capture–recapture (SECR) model and therefore abundance estimates are given as density. The R package ‘openpopscr’ has been used (Glennie & Borchers 2019) with data preparation carried out using R package ‘secr’ (Efford, Borchers, & Byrom, 2009). Finally, effort for each occasion and sub-site, in net length multiplied by hours, is controlled for in the robust design model as a covariate to the detection parameter.

For the spatial analysis carried out the part of the boulder scree of Filfla that provides actual breeding habitat for the species is considered, meaning a polygon of 2.75 ha, which excludes the plateau and the outer rocks in the splash zone of the islet where Storm-petrels do not breed.

For the estimation of the population size in breeding pairs we followed the assumption that the overall population constitutes of up to 50% non-breeding individuals, including prospecting birds (Sanz-Aguilar et al., 2010). Therefore, the population numbers in individuals as revealed by the CMR and modelling approach were divided by four to obtain the population size in breeding pairs.

**Costs**

Each 40ft mist-net should be attended by two experienced ringers at busy sub-sites (NW, N, NE). At less busy subsites (SE, S, W) one experienced ringer should suffice. Costs are estimated for one complete CMR survey of Filfla islet Table 19.

**Tab. 19:** Estimated costs of CMR monitoring for *H. pelagicus* on Filfla islet.

| **Item** | **Number per monitoring cycle** | **Unit type** | **Unit cost [€]** | **Total [€]** |
|---|---|---|---|---|
| CMR survey on Filfla* | 1344 | person hours | 15 | 20,160 |
| Vessel trip to Filfa boulder scree ** | 18 | external assistance | 140 | 2,520 |
| Mist nets | 4 | Consumables | 100 | 400 |
| Mist net poles | 5 | Consumables | 40 | 200 |
| Ringing kit (pliers, | 4 | Consumables | 70 | 280 |

| | | | | |
|---|---|---|---|---|
| callipers,...) | | | | |
| Rings | 5000 | consumables | 0.15 | 750 |
| CMR data entry | 72 | person hours | 15 | 1,080 |
| CMR data analysis | 40 | person hours | 18 | 720 |

*Assuming an average of 4 persons per visit, each visit taking 14 hours, 4 visits per sub-site, 6 sub-sites and 1 complete survey per monitoring cycle

**Mist-netting at two different sub-sites can take place on the same night so even if 4 visits per sub-site is made this does not necessarily equate to 24 total visits to the islet.

**Colony monitoring via capture mark recapture (CMR) at other colonies**

It would be certainly interesting to carry out CMR monitoring visits and potentially also take a population size modelling approach for the smaller *H. pelagicus melitensis* colonies. It is recommended to trial such an approach at least for the sea-cave in Ta'Ċenċ, and potentially also for the colony at Rdum tal-Madonna during one season of the current assessment cycle and repeat such set-up once per assessment cycle if successful. Unfortunately, due to difficulties in accessing the actual colony site in the large sea cave at Gharb, a CMR approach with use of mist nets for capture appears unfeasible.

Such a trial is not additionally budgeted, because it would be incorporated into other visits carried out for the species.

**Colony monitoring via thermal imaging (and audial counts, photomapping)**

Thermal imaging by FLIR from RIB and/or land appears currently as the main feasible method to assess and monitor the population size of the smaller *H. pelagicus melitensis* colonies in the Maltese islands.

**Location**

All smaller *H. pelagicus* colonies, being MT000009 Rdum tal-Madonna, MT0000030 Għarb and MT0000027 Ta' Ċenċ.

**Timing & Frequency**

Several visits per site during calm nights at the peak of the breeding season (May to July) are necessary at least during one season per assessment cycle to reveal reliable population estimates.

**Costs**

The costs related to monitoring of *H. pelagicus* at the smaller colonies in the Maltese Islands are presented in Table 20.

**Tab. 20**: Estimated costs of audio-visual monitoring of *H. pelagicus* at colonies other than Filfla islet.

| **Item** | **Number per monitoring cycle** | **Unit type** | **Unit cost [€]** | **Total [€]** |
|---|---|---|---|---|
| Audio-visual counts* | 108 | person hours | 15 | 1,620 |
| Thermal imaging camera | same as *P. yelkouan* | | | |
| Compiling of population abundance data | 8 | person hours | 18 | 144 |

***Assuming 2 persons per visit; 6 hours per visit; 3 visits for each 3 sites; 1 complete survey per monitoring cycle

**Colony monitoring of *H. pelagicus* via camera traps**

Motion sensors from most of-the-shelf camera trap models are usually built to be triggered by larger organisms and are expected to miss detections especially of storm-petrels passing more distanced from the camera and hence can lead to an underestimation of the colony size. For a camera trapping trial during the current assessment cycle, it is therefore recommended to test cameras with modified motion sensors which also trigger for smaller organisms such as *H. pelagicus*.

**Locations**

The sub-sites presented in Table 21 are foreseen as suitable for testing camera trap monitoring for *H. pelagicus*, and if successful can be included in future monitoring cycles.

**Tab. 21:** Locations suitable for testing and monitoring *H. pelagicus* abundance estimates with camera traps

| **Site** | **Sub-Site** | **Number of cameras** |
|---|---|---|
| MT0000017 Filfla | Northeast Cave 1 | 1 |
| MT0000027 Ta' Ċenċ | Horizontal nesting crack inside main cave | 2 |
| MT000009 Rdum tal-Madonna | RM05L | 1 |
| | RM04C | 1 |
| MT000033 Għarb | Cave south of main cave | 1 |

**Timing**

Due to the high variation in the *H. pelagicus* breeding cycle the cameras might need to be deployed for a long period to capture the period of highest activity. Deployment period can be further refined with better knowledge obtained through camera trap and nest monitoring surveys. As a preliminary period we recommend camera traps to be active from mid-May to the end of August.

**Frequency**

If successful, such camera trapping could then be repeated at least for one season per assessment cycle, but ideally more frequently. Due to the small number of locations rotation between sites might not be required and all sites can be monitored within the same season.

**Analysis**

As described under corresponding section for *P. yelkouan* (see above).

**Costs**

If in future monitoring cycles this method was to be included as a standard assessment method for the species, it is expected that the costs estimated here (Tab. 22.) will vary proportionally to the number of cameras included and years of assessment. Deployment and retrieval of cameras can be carried out in conjunction with other monitoring activities.

**Tab. 22:** Estimated costs of using camera traps with high motion sensor sensitivity for *H. pelagicus* monitoring for one year within a 6-year monitoring cycle.

| Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| Camera traps with high motion sensor sensitivity | 450 | equipment | 6 | 2,250 |
| Counts of petrels in images | 40 | person hours | 15 | 600 |

**Conclusion**

As a concluding remark for D1C2 it needs to be emphasized that even with high effort and an integration of various methods, population size estimates for all three species will remain to some extent unprecise with a relatively wide range between minimum and maximum numbers estimated. This in turn makes it more difficult to reveal reliable trend estimates as required for reporting under the Birds Directive. For this reason, Birdlife International states in their position paper on GES for threshold criteria under D1 that *'Criterion D1C3 (population characteristics) should be adopted as primary criterion instead of D1C2 under certain circumstances'* (BirdLife International 2019). Irrespective of using D1C3 as primary or secondary criterion, we underline the importance of the demographic parameters collected under D1C3 for the GES assessment of all three Maltese procellariiform seabird populations and especially for the two shearwater species as we believe that this more integrated approach helps drawing a more precise picture of the status of the populations than abundance or population size alone.

## Demographic parameters

**D1C3 (secondary):** Data collection on the populations' demographic characteristics and anthropogenic pressures to assess whether the population demographic characteristics are indicative of a healthy population which is not adversely affected due to anthropogenic pressures. The monitoring of demographic characteristics is not a requirement for reporting under the Birds Directive.

## Monitoring and assessment of the population demography of *P. yelkouan*

### Adult annual survival rates of *P. yelkouan*

**Survival rate monitoring via capture mark recapture:**

The same CMR approach as described for the species under D1C2 can provide adequate data to model adult annual survival rates of the *P. yelkouan* breeding population if sufficient effort is allocated to ring and recapture a representative subsample of the population. It is recommended to continue the CMR with a combined approach of capture by means of mist-netting and capture of birds by hand on the ground in front of the nest or cave entrances.

**Locations**

Locations should be the same as those covered under D1C2 CMR for *P. yelkouan* (Tab. 5).

**Timing**

At least two, but ideally three, CMR visits per subsite and per year would be necessary to collect adequate data for modelling. The focus should be on nights with high bird activity and covering the period February to June. The same visits as those under D1C2.

**Frequency across monitoring cycle**

CMR monitoring for the assessment of adult survival is ideally carried out annually at each site. However, if it is not feasible to carry out annual CMR monitoring programs, it should be carried out at least every other year. In that case, all colonies should be covered within the same seasons to achieve best results possible. The frequency selected is the same as that for D1C2.

**Analysis and assessment**

The analyses of CMR data should follow Austad et al. (2019), using Jolly-Seber models in a Bayesian framework (Kéry and Schaub 2011).

Analysis of adult survival should be carried out on colonies of comparable size, therefore if small colonies are included in future analysis (e.g Wied Babu), obtaining the estimates for these can be attempted by splitting the larger colonies into sub-sites and modelling with these subsites.

For the reporting it is recommended to calculate the average value from the six annual survival rates over the MSFD assessment cycle. However, due to methodological constraints leading to an underestimation of the annual survival rate in the last year of assessment (as pointed out and described in deliverable 2a), it is recommended to omit the latest assessment year and calculate the average from the 5-6 previous years instead (i.e. 2018/19-2023 for the current assessment cycle). To assess whether GES is reached, adult annual survival rates will be compared with the baseline and threshold values proposed in the International Species Action Plan for *P. yelkouan* (Gaudard 2018) until such values are developed and implemented specifically for Malta.

**Costs**

Equipment needed and costs for CMR monitoring of *P. yelkouan* are covered by D1C2 (Tab. 6). Costs for the analyses and assessment for D1C3 are listed in Table 23. It has to be noted that depending on the timing, it is also possible to combine the CMR visits to some extent with nest-checks for monitoring visits of reproductive performance of the species (see below).

**Tab. 23:** Estimated costs for the analysis of P. yelkouan adult survival under D1C3 for a 6-year monitoring cycle.

| **Item** | **Number per monitoring cycle** | **Unit type** | **Unit cost [€]** | **Total [€]** |
|---|---|---|---|---|
| CMR analysis and assessment | 40 | person hours | 18 | 720 |

**Monitoring and assessment of reproductive success rates of *P. yelkouan***

To determine reproductive success of the Maltese *P. yelkouan* population, it is necessary to monitor an adequate number of nests distributed over a representative sample of sub-colonies during each breeding period.

**Monitoring Locations**

All the visible *P. yellkouan* nests located in 2021 per colony are presented in Table 24 (see also Deliverable 2 Fieldwork Report Table 13). The number of nests varies from year to year with different occupation rates and any new nests found during the incubation period can be added to the sample of that year.

However, not all nest sites listed here are occupied and suitable for the monitoring of reproductive success at each given year. The use of “burrow-scopes” i.e. video endoscopes (e.g. https://www.nhbs.com/video-endoscope) in future seasons could further increase the number of nests for the monitoring of reproductive success.

**Tab. 24**: Number of nest sites per site and subsite of *P. yelkouan* breeding colonies, suitable for nest monitoring and reproductive success under D1C3.

| N2K site number | Name of site and subsite | total nests | of which in nest boxes |
|---|---|---|---|
| MT0000009 | Rdum tal-Madonna RM01 | 22 | 18 |
| | Rdum tal-Madonna RM02 | 3 | |
| | Rdum tal-Madonna RM03 | 14 | |
| | Rdum tal-Madonna RM04 | 23 | |
| | Rdum tal-Madonna RM05 | 20 | |
| MT0000017 | Comino and Cominotto | 15 | 1 |
| MT0000022 | St Paul's Island | 10 | 2 |
| MT0000024 | Majjistral NHP | 39 | |
| | Ċumnija | 8 | |
| MT0000027 | Ta' Ċenċ and Ras in-Newwiela | 4 | 2 |
| MT0000030 | Għarb | 1 | |
| MT0000031 | Għar Lapsi and Blue Grotto | 9 | |
| MT0000033 | Għar Ħasan | 3 | |

**Timing**

As part of the reproductive success monitoring, at least three visits per breeding season would have to be carried out, a first one in the period shortly after egg-laying in the second week of March, a second one shortly after hatching in the period of the second half of April to early May, and a third visit when the shearwater chicks are at an adequate age to be ringed at the end of May into the beginning of June. If feasible, two additional visits are to be carried out, one pre-breeding in January to early February to reveal **nest occupancy rate**, and another one very late just before the fledging period in the second half of June to mid of July to determine **fledging success** (and to ring additional fledglings from inaccessible nests when they come out at night to train their wings).

**Frequency of monitoring**

As reproductive performance can vary significantly between years (and sites), monitoring is recommended to be carried out annually for all suitable nests.

**Analyses and assessment**

Reproductive success will be calculated from the number of chicks reaching the age to be ringed (alternatively: reaching fledging age) compared to the number of occupied nests (under incubation during the first visit). Only nests with clear fate will be included in the final analyses which might lead to a slight bias and, together with a bias created by nests lost before the first visit, an overestimation of reproductive success. Therefore, it is recommended to include the very early and late visits (for nest occupancy and fledging success, as outlined above) in the analyses if feasible. As reproductive output can be expected to fluctuate significantly between years, it is recommended to monitor this parameter annually and to assess and report the six-years average (including the range) for each reporting cycle. To assess whether GES is reached, the reproductive success values will be compared with the baseline and threshold values proposed in the International Species Action Plan for *P. yelkouan* (Gaudard 2018) until such values are developed and implemented for Malta.

**Equipment and costs**

Reproductive assessment costs for *P. yelkouan* are presented in Table 25.

**Tab. 25:** Estimated costs for nest monitoring of *P. yelkouan* under D1C3 for a 6-year monitoring cycle.

| Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| Monitoring of P. yelkouan nests | 1248 | person hours | 15 | 18,720 |
| Data input and cleaning | 96 | person hours | 15 | 1,440 |
| Analysis and assessment | 10 | person hours | 18 | 180 |
| Burrow scopes | 2 | consumables | 350 | 700 |
| Rings | 600 | consumables | 0.175 | 105 |

*Assuming an average of 2 hours per visit, 2 persons for 13 subsites (some adjacent subsites can be combined); an average of 4 visits per year; annual monitoring for the 6-year monitoring cycle.

## Monitoring and assessment of the population demography of *C. diomedea*

### Annual adult survival rates of *C. diomedea*

**Monitoring Locations**

Due to limited and non-systematic ringing effort of the species in recent years, it has not been possible to adequately estimate the adult annual survival rate of the Maltese Scopoli’s Shearwater population. However, over 200 accessible nest sites across most relevant colonies have been identified for monitoring of adult breeding birds (and for reproductive success monitoring) during the 2021 breeding period, leading to a total number of approximately 150 *C. diomedea* couples of occupied nests (Tab. 26). It is recommended to increase the amount of nest sites with accessible adults to at least 300 nests (or at least 200 occupied nests) until the end of the current assessment cycle for the following reasons: (i) except for Filfla, the CMR for annual survival monitoring (as for abundance assessment) relies mainly on adult birds caught on the nest; (ii) larger overall population size as compared to P. yelkouan; (iii) currently lack of knowledge on demographic parameters as compared to *P. yelkouan*; (iv) the species is known to carry out sabbaticals[2] which also might need to be reflected in the models to not underestimate annual survival rates. The overall target of 300 monitored couples appears feasible with limited additional effort.

**Table 26:** Currently monitored locations as numbers of accessible nests per N2K area and site or sub-site.

| N2K number | Site name | Nest count | Occupied nests under incubation check |
|---|---|---|---|
| **MT0000016** | Filfla | 21 | 16 |
| **MT0000027** | Ta' Ċenċ | 17 | 13 |
| **MT0000029** | Xlendi | 24 | 21 |
| **MT0000030** | Dwejra | 1 | 0 |
| | Fungus Rock | 29 | 19 |
| | Għarb | 36 | 22 |
| | **Total MT30** | **66** | **41** |
| **MT0000031** | Għar Lapsi | 18 | 14 |
| **MT0000032** | Fomm ir-Riħ | 4 | 3 |
| | Miġra l-Ferħa[3] | 10 | 4 |
| | Ta' Żuta | 5 | 4 |
| | **Total MT32** | **19** | **11** |

[2] Among other procellariform seabird species, *C. diomedea* can skip a year leaving their nest site empty during the breeding season of a given year but would return the following year. This has implications for the modelling of adult annual survival rates because an adult bird not encountered on their nest in any given year cannot be assumed dead.

[3]

| | | | |
|---|---|---|---|
| **MT0000033** | Bengħisa | 12 | 6 |
| | Ħal Far | 45 | 29 |
| | **Total MT33** | **57** | **35** |
| **Grand Total** | | **222** | **151** |

**Timing**

To determine adult annual survival rates of the species, it is recommended to visit all accessible nest sites at least once on suitable nights during the pre-breeding season (April to May) to handle (ring or recapture) both adults of each pair occupying a nest for the nest based CMR approach. Additional data can then be collected when handling adults during two further nest-checks, carried out for nest monitoring (after egg-laying in the first half of June and after hatching in mid to end of July). Especially on Filfla (MT0000016), additional birds of the species would be handled during the mist netting sessions mainly aimed at *H. pelagicus melitensis*, in the period between May and August. These CMR data would lead to additional data for the survival analyses.

**Frequency across monitoring cycle**

It is highly recommended to carry out the adult survival monitoring on an annual basis. Because the species is known to carry out sabbaticals, annual survival rates are likely to be underestimated otherwise. If however, this appears unfeasible, it is recommended to carry out the adult survival monitoring every second year, covering all sites in the same year.

**Analyses and assessment**

The modelling of the annual survival rates of adult Scopoli's Shearwaters from nest based CMR will follow a similar methodology as described in (Oppel et al. 2011) and Austad et al. (2019) for *P. yelkouan*. However, adjusting the analyses to a specific nest-based CMR approach should be considered, e.g following (Sanz-Aguilar et al. 2010). Therefore, a Jolly-Seber model without splitting data by colony is deemed suitable (Kéry & Schaub 2011), where effort will be the number of nests monitored in addition to visits made.

The species is moderately sexually dimorphic, and in most couples, males can be separated from females in the hand via certain morphometric measurements (Wink, Wink, and Ristow 1982; Navarro, Kaliontzopoulou, and González-Solís 2009), especially when both partners of a pair are encountered together. If enough adult birds are monitored via CMR it will be possible to assess the adult annual survival rate differentiated by sex.

**Costs**

Equipment needed and costs for CMR monitoring of *C.diomedea* are covered by D1C2 (Tab. 15). Costs for the analyses and assessment of under D1C3 are presented in Table 27. It has to be noted that depending on the timing, it is also possible to combine the CMR visits to some extent with nest-checks for monitoring visits of reproductive performance of the species (see below). Travel costs are estimated in total for the complete budget.

**Tab. 27:** Estimated costs for *C.diomedea* adult survival modelling

| **Item** | **Number per monitoring cycle** | **Unit type** | **Unit cost [€]** | **Total [€]** |
|---|---|---|---|---|
| CMR analysis and assessment | 40 | person hours | 18 | 720 |

**Monitoring and assessment of reproductive success rates of *C. diomedea***

**Monitoring locations**

To determine the reproductive success of the Maltese *C. diomedea* population, the above mentioned up to 150-200 occupied nests from sub-colonies across the Maltese islands should be utilized (Tab. 26). It is recommended to increase the number of monitored nests to at least 200, spread across the various colonies in the Maltese islands. This increase can be achieved by a combination of slightly increasing effort, including additional colonies or sub-colonies, and especially by making use of burrow-scopes.

**Timing of monitoring**

Each breeding season at least three visits would be carried out, with the first one in the period shortly after egg-laying in the second week of June, a second one shortly after hatching in mid of July and a third visit when the shearwater chicks are at an adequate age to be ringed, which would be end of August to mid of September. If feasible, additional visits would be carried out, one pre-breeding in April to May to reveal nest occupancy rates, and another one very late just before the fledging period in the second half of September to mid of October to determine fledging success.

**Frequency across monitoring cycle**

As reproductive output is expected to fluctuate significantly between years, especially as many larger procellariiform seabird species, including *C. diomedea*, are known to perform sabbaticals (Weimerskirch et al. 2015; Mougin, Jouanin, and Roux 1997), it is strongly recommended to monitor this parameter annually.

**Analyses and assessment**

Reproductive success will be calculated from the number of chicks reaching the age to be ringed (alternatively: reaching fledging age) compared to the number of occupied nests (under incubation during the first visit). Only nests with clear fate will be included in the final analyses which might lead to a slight bias and, together with a bias created by nests lost before the first visit, an overestimation of reproductive success. Therefore, it is recommended to include the very early and late visits (for nest occupancy and fledging success, as outlined above) in the analyses if feasible. It is recommended to monitor this parameter annually and to assess and report the six-years average (including the range) for each reporting cycle. As soon as baseline and threshold values have been identified for the species, it is envisaged to compare these with the assessment results in order to identify whether GES is reached.

**Costs**

Costs for monitoring of *C. diomedea* nests for reproductive success parameters of D1C3 are presented in Table 28.

**Tab. 28:** Estimated costs of reproductive success monitoring of *C. diomedea* under D1C3

| **Item** | **Number per monitoring cycle** | **Unit type** | **Unit cost [€]** | **Total [€]** |
|---|---|---|---|---|
| Monitoring of *C. diomedea* nests* | 2376 | person hours | 15 | 35,640 |
| Data input and cleaning | 96 | person hours | 15 | 1,440 |
| Analysis and assessment | 10 | person hours | 18 | 180 |
| Rings | 600 | consumables | 0.15 | 90 |

*Assuming 3 visits per year; all nests covered with 11 separate visits involving an average of 6 hours; 2 persons; annual across 6-year cycle

## Monitoring and assessment of the population demography of *H. pelagicus*

**Annual adult survival rate**

Monitoring of the annual adult survival rates will be carried out along the CMR approach set up for the population abundance monitoring (D1C2) of the species on Filfla. The methodology is well established and has been carried out already three times, including once during the current assessment cycle. Therefore, it is highly recommended to continue with this setup of at least one thorough assessment season with high mist-netting effort per cycle.

It would be certainly interesting to carry out CMR monitoring visits to model annual adult survival rates for birds of the smaller *H. pelagicus melitensis* colonies. This would inform on the viability of these smaller colonies and might provide additional information such as informing on potential sources and sinks on a metapopulation level and exchange with the Filfla population.

**Locations**

At least six defined mist-netting locations, set up in the boulder scree spread around the islet of Filfla, detailed information provided in the relevant section, including the Tab. 18 under D1C2.

It is further recommended to trial such an approach at least for the sea-cave at Ta'Ċenċ during the remaining seasons of the current assessment cycle and then repeat such set-up in future assessment cycles if successful. Unfortunately, due to difficulties in accessing the actual colony site in the large sea cave at Għarb, a CMR approach with use of mist nets for capture appears unfeasible.

**Timing**

Each sub-site on Filfla should be at least visited twice (i.e two separate complete mist-netting nights) as part of a complete CMR survey of the islet. Nets should be up at dusk until dawn.

Ideally the effort is increased to 3-5 nocturnal mist-netting sessions per sub-site, especially because the recapture probability remained low in the 2021 analysis. However, to meet the model criteria the period in which the visits are carried out would need to be kept as short as possible (ideally within 2 months, 3 months maximum). The same effort and occasion number conditions described under D1C2 apply for modelling of survival under D1C3.

All visits should be made in the period between mid-May and end of July, with the possible extension to mid-August if visits are not accomplished before due to unfavourable weather.

An increase of effort in future CMR surveys is expected to increase the accuracy of estimation, while still allowing for inclusion of data collected in 2013, 2019 and 2021 in the CMR model.

**Frequency**

It is highly recommended to continue with the setup of one thorough assessment covering all 6 sub-sites on Filfla within one season per monitoring cycle. However, as indicated and reasoned above, the effort is ideally increased with more than two nocturnal mist-netting sessions per site. However, to meet the model criteria the period in which the visits are carried out would need to be kept as short as possible. It is planned to further explore the possibility of an additional CMR approach with lower effort during the other five years, e.g. two to three visits covering only one site and potentially changing location from one year to the next. While it is expected that such a setup will increase the individual recapture probability and thus improve the accuracy of the survival estimates, required modifications of the model to cater for such a set-up would need to be explored.

**Analyses and assessment**

In analogy to the assessment of the population abundance, we recommend data from all years (2013, 2019, 2021 and any future surveys) to be analysed together in a robust design model (Kéry & Schaub, 2011). In such a model, each year is regarded as a primary occasion, with the different sessions held within a year regarded as secondary occasions. The robust design model utilised was a spatially explicit capture– recapture (SECR) model. The R package 'openpopscr' has been used (Glennie & Borchers 2019) with data preparation carried out using R package 'secr' (Efford, Borchers, & Byrom, 2009). Finally, effort for each occasion and sub-site, in net length multiplied by hours, is controlled for in the robust design model as a covariate to the detection parameter. Adult survival is estimated as annual survival irrespective of the elapsed number of years between primary occasions.

**Equipment and costs**

Equipment and costs for the monitoring of the Filfla population including data entry are already covered in the respective section for species under D1C2 (Tab. 19). The CMR analysis specifically for the annual adult survival is the only item that would need to be budgeted additionally (Tab. 29).

**Tab. 29:** Estimated costs for estimated adult survival of *H. pelagicus* under D1C3.

| Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| CMR analysis and assessment | 40 | person hours | 18 | 720 |

**Reproductive success rates of *H. pelagicus melitensis***

**Monitoring methodology**

During the 2021 assessment and previous field seasons it has been proven difficult to find enough accessible/ visible nests to monitor reproductive performance of *H. pelagicus melitensis*. Moreover, natural nests identified in a particular season are unlikely to remain visible for monitoring for sufficient seasons due to shifting rocks and substrate. This applies to the largest colony on Filfla, but also to the smaller colonies in Malta and Gozo. However, the number of wooden nest-boxes for the species on Filfla has been increased to 34 during the 2021 breeding period and it is planned to increase this number further to at least 50 within the current assessment cycle. One wooden nest box was already successfully occupied in the 2020 and 2021 breeding seasons and others were prospected. Together with several known natural nests, the number of which should be further increased by nest searches early in each breeding season (April-June) and the use of burrow-scopes, the aim is to achieve at least 50 and up to 100 nests across all colonies suitable for monitoring towards the end of the current assessment cycle. If at the end of the current assessment cycle the number of nests available for monitoring is still too low (<20), it should be considered to use solely adult annual survival rate together with trends from abundance modelling for the assessments (at least as long as the trends indicate a favourable conservation status for the species).

For the remaining breeding periods of the current assessment cycle, it should also be assessed annually if the accessible smaller breeding colonies (Rdum tal-Madonna, Ta’ Ċenċ) provide sufficient accessible nests for monitoring reproductive performance.

**Timing**

With regards to the onset of the breeding period, *H. pelagicus melitensis* is much less synchronised than the two Maltese shearwater species. This means, several visits (approximately at least 2 per stage) for each of the three relevant stages to be monitored (early post-laying for baseline of occupied nests, early chick-rearing for hatching success, (pre-fledging for ringing of nestlings) are believed to be necessary to cover the extended breeding period of the species (March – October).

As nest monitoring can be carried out during hours with daylight, early visits can be combined with the monitoring of *Larus michahellis* for the threats assessment.

**Frequency across monitoring cycle**

Ideally, the reproductive success monitoring is carried out annually for the remaining period of the ongoing assessment cycle, which can be seen as a test phase. However, if this is not feasible or if the disturbance caused in the colony is deemed too high, less frequent monitoring (e.g. every other year) could be considered. If the effort required or disturbance caused is believed to be too high, it should be considered to carry out the monitoring of reproductive success only once during the assessment cycle. This would be carried out in the same year as the intense, spatially explicit CMR assessment as linking both would require only two additional visits early during the incubation period.

**Analyses**

Reproductive success will be calculated from the number of chicks reaching the age to be ringed (alternatively: reaching fledging age) compared to the number of occupied nests (under incubation during the first visit, natural and in nest boxes). Only nests with clear fate will be included in the final analyses. If this parameter is monitored annually with a sufficient number of nests, the six-years average (including the range) should be calculated for each reporting cycle. As soon as baseline and threshold values have been identified for the species, it is envisaged to compare these with the assessment results in order to identify whether GES is reached.

**Costs**

Given here are maximum estimated costs with at least 6 independent visits annually for reproductive success assessment of *H. pelagicus* (Table 30).

**Tab. 30:** Estimated costs of monitoring reproductive success of *H. pelagicus* under D1C3 for a six-year monitoring cycle.

| Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| Monitoring of *H. pelagicus* nests* | 720 | person hours | 15 | 10,800 |
| Data input and cleaning | 12 | person hours | 15 | 180 |
| Analysis and assessment | 10 | person hours | 18 | 180 |
| Marker pens | 12 | Consumables | 5 | 60 |
| Handheld GPS | 1 | Consumables | 200 | 200 |
| Burrow scopes | same as *P. yelkouan* | | | |

*Assuming 6 visits to Filfla per year; all nesting areas with all potential nest sites covered, involving an average of 6 hours; six visits to two additional colonies (Malta, Gozo), involving an average of 2 hours; 2 persons; annual across the 6-years assessment cycle.

*On a side note: to date, the assessment of demographic parameters in all three species has focused on two main lifecycle stages, namely adult breeding birds and their nests (egg to fledgling). Survival rates of a third important cohort,* ***immature birds (from fledglings to recruitment)*** *have been widely neglected. This bias creates a knowledge gap which can be easily explained by difficulties in accessibility to monitor immature birds. However, as inexperienced, immature individuals in a population are likely to face increased mortality risks as compared to adults, this could have strong implications for the assessment of the overall demographic structure of the Maltese seabird populations. With a continuation in monitoring efforts of nests and adults, specifically the recapture of recruiting adults that were ringed as nestlings, it is believed that data quality concerning immature birds will increase. Therefore, future monitoring strategies might be in the position to address this shortcoming with adequate assessment methods and analyses.*

## Distributional range, range size and trends

### General background

Due to the relatively small size of the member state and a comparably high effort of seabird population assessments and monitoring across suitable breeding habitat in recent years, specifically for *P. yelkouan* and as part of various EU-LIFE funded projects (LIFE10 NAT/MT/090; LIFE14 NAT/MT/000991), the current overall breeding range is believed to be relatively well known for all three species. However, the certainty of breeding is not equally distributed across the range and certainty categories have been assigned to the breeding areas of each of the three species with two main categories following the methodology and definitions as per the latest MSFD assessment (Environment and Resources Authority 2020):

> "1" –Complete possible range based on adult birds calling in flight at night and suitable habitat. This category represents the total breeding range for the species. It has a medium confidence level in comparison to category 2.
>
> "2" –Known nests or adults entering (seen on thermal imaging camera) or heard calling from inside nests. This category represents the distributional range where breeding was confirmed, and therefore has the highest confidence level.

## Monitoring and assessment of distributional range for *P. yelkouan*

### Monitoring methodology

It is recommended to assess the entire suitable *P. yelkouan* nesting habitat across the archipelago. The general assessment should follow the methodology as described in Austad et al. (2019) and in the tender's fieldwork report.

For areas with suitable habitat that have not been assessed under D1C2 or D1C3, the use of the FLIR for nocturnal observations paired with audial monitoring is believed to be required for most sites that can't be accessed physically. Monitoring in calm dark nights from the sea along the cliffs by means of a RIB as a platform appears to be the most effective way to do so. All surveyed areas where birds are seen or heard on the ground or entering nest cavities or heard from inside are mapped by means of a handheld gps.

### Monitoring locations

All areas with suitable nesting habitat for the species. Areas that are accessed physically and/or already monitored for D1C2 and D1C3 can be easily mapped from information gathered under these criteria and do not require additional monitoring effort for range assessment. Only areas that are believed to provide suitable habitat but are not assessed under the above-mentioned criteria are listed here (Tab. 31) and budgeted below (Tab. 32).

**Tab. 31:** Specific sites with (potentially) suitable breeding habitat for *P. yelkouan* which require surveys under D1C4 additional to abundance estimate surveys carried out under D1C2.

| N2K number | Site name |
|---|---|
| **MT0000016** | Filfla |
| **MT0000030** | Dwejra |
| | Fungus Rock |
| **MT0000024** | Qammieħ |

| | |
|---|---|
| | Ras il-Pellegrin |
| **MT0000026** | Daħlet Qorrot to Ramla Valley (excluding Ta’ Isopu) |
| **MT0000017** | Comino: Santa Marija Tower area |
| **MT0000032** | West of Blue Grotto |

**Timing**

Monitoring work will ideally focus mainly on calm, dark nights at the beginning of the breeding period of P. yelkouan (January to March). Especially areas where the two shearwater species co-occur it is believed to be most important to cover the period before *C. diomedea* becomes more active in the colonies. As bird activity often drops with the progress of the night and/ or with moonlight, only the first hours of dark nights are suitable for surveying.

**Frequency across monitoring cycle**

For the long-term monitoring it is envisaged to carry out one entire range assessment (actual range and overall suitable habitat) as described above, spread over the breeding seasons of each six-years assessment cycle. A higher frequency of assessment does not appear feasible, as this type of assessment widely requires calm seas for surveys by means of a RIB and time windows are limited (see above under timing). However, a higher frequency of assessment is not believed to be necessary.

**Costs**

**Tab. 32:** Estimated costs of surveying *P. yelkouan* range in the complete area with suitable habitat in addition to surveys carried out under D1C2

| **Item** | **Number per monitoring cycle** | **Unit type** | **Unit cost [€]** | **Total [€]** |
|---|---|---|---|---|
| Audio-visual counts* | 90 | person hours | 15 | 1,350 |
| Mapping, plotting of range | 10 | person hours | 15 | 150 |
| Compiling of range size data for entire range | 10 | person hours | 18 | 180 |

*Assuming 2 persons per trip; an average of 3 hours per trip; 5 sites (by combining nearby sites into 1 survey) and 3 visits per site within the monitoring cycle

### Analyses and assessment

All surveyed areas that are deemed suitable will be delineated by coordinates from aerial imagery. Only areas where birds have been clearly identified as *P. yelkouan* and seen on the ground or entering caves or burrows or heard calling from the ground or from inside nest cavities (see above) are then to be mapped (as range category 2) as part of the breeding range of the species. Areas where birds are seen or heard in flight only should be assigned category 1 temporarily and assessed subsequently at least in one additional occasion with suitable conditions, repeated if necessary up to two times, to confirm category 2. Areas, in which after repeated visits in suitable conditions no activity is noticed, are then assigned category 0 (not part of the actual breeding range within the given assessment cycle). However, they should be re-visited and monitored in the following assessment cycle.

The actual range is mapped in relation to Natura 2000 sites (SPA) and also overlaid with the 1x1km² grid provided by the EEA in accordance with reporting requirements under the Directives. The actual breeding range is then overlaid with the total area of suitable habitat for the species, allowing to calculate the percentage of suitable habitat being occupied. It remains to be decided whether such areas should also include potentially suitable habitat that would only be suitable after the implementation of conservation management and restoration work. Distributional range trends and range size trends between assessment cycles will be provided (short-term and long-term) for the breeding distribution e.g. as change in occupied 1x1km² squares. Additionally, the trends in the range of suitable habitat (distribution and size) can be provided.

## Monitoring and assessment of distributional range for *C. diomedea*

### Monitoring methodology

It is recommended to assess the entire suitable *C. diomedea* nesting habitat across the archipelago. The aim would be to move current category 1 areas as well as all remaining areas with suitable habitat but currently not in any category either into category 2 (part of the breeding range) or 0 (suitable habitat but no species not present/ nesting).

The general assessment should follow the methodology as described in the tender's fieldwork report.

For areas with suitable habitat that have not been assessed under D1C2 or D1C3, the use of the FLIR for nocturnal observations paired with audial monitoring is believed to be required for most sites that can't be accessed physically. Monitoring in calm dark nights from the sea along the cliffs by means of a RIB as a platform appears to be the most effective way to do so. Only areas where birds are seen on the ground or entering caves or burrows or heard calling from the ground or from inside nest cavities should be included in the breeding range assigned category 2. The use of the FLIR for nocturnal observations is believed to be required for most sites that can't be accessed physically. All surveyed areas where birds are seen or heard on the ground or entering nest cavities or heard from inside are mapped by means of a handheld gps.

**Monitoring locations**

All areas with suitable nesting habitat for the species. Areas that are accessed physically and/or already monitored for D1C2 and D1C3 can be easily mapped from information gathered under these criteria and do not require additional monitoring effort for range assessment. Only areas that are believed to provide suitable habitat but are not assessed under the above-mentioned criteria are listed here (Tab. 33) and budgeted below (Tab. 34).

**Tab. 33:** Specific sites with (potentially) suitable breeding habitat for *C. diomedea* which require surveys under D1C4 additional to abundance estimate surveys carried out under D1C2.

| N2K number | Site name |
|---|---|
| **NA** | Ġebla tal-Ħalfa (Gozo) |
| **MT0000024** | Qammieħ to Majjistral |
| | Ras il-Pellegrin |
| **MT0000026** | Daħlet Qorrot to Ramla Valley (excluding Ta' Isopu) |
| **MT0000017** | Comino: Santa Marija Tower area |
| **MT0000001** | Għajn Barrani |

**Timing of monitoring**

Monitoring work will ideally focus mainly on calm, dark nights during the earlier part of the breeding period of *C. diomedea* (April to July). As bird activity in the colonies often drops with the progress of the night and/ or with moonlight, only the first hours of dark nights are suitable for surveying.

**Frequency of monitoring and assessment**

For the long-term monitoring it is envisaged to carry out one entire range assessment (actual range and overall suitable habitat) as described above, spread over the breeding seasons of each six-years assessment cycle. A higher frequency of assessment does not appear feasible, as this type of assessment widely requires calm seas for surveys by means of a RIB and time windows are limited (see above under timing). However, a higher frequency of assessment is not believed to be necessary.

**Costs**

**Tab. 34:** Estimated costs of surveying *C. diomedea* range in the complete area with suitable habitat in addition to surveys carried out under D1C2

| Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| Audio-visual counts* | 54 | person hours | 15 | 810 |
| Mapping, plotting of range | 10 | person hours | 15 | 150 |
| Compiling of range size data for entire range | 10 | person hours | 18 | 180 |

*Assuming 2 persons per trip; an average of 3 hours per trip; 3 wider sites (by combining adjacent sites when surveying) and 3 visits per site within the monitoring cycle

**Analyses and assessment**

All surveyed areas that are deemed suitable will be delineated by coordinates from aerial imagery. Only areas where birds have been clearly identified as *C. diomedea* and seen on the ground or entering caves or burrows or heard calling from the ground or from inside nest cavities (see above) are then to be mapped (as range category 2) as part of the breeding range of the species. Areas where birds are seen or heard in flight only should be assigned category 1 temporarily and assessed subsequently at least in one additional occasion with suitable conditions, repeated if necessary up to two times, to confirm category 2. Areas, in which after repeated visits in suitable conditions no activity is noticed, are then assigned category 0 (not part of the actual breeding range within the given assessment cycle). However, they should be re-visited and monitored in the following assessment cycle.

The actual range and the suitable habitat of each species are mapped in relation to Natura 2000 sites (SPA) and also plotted on the 1x1km² grid provided by the EEA in accordance with reporting requirements under Art. 12 of the Birds Directives. The actual breeding range as occupied grid cells can then be overlaid with the total area of suitable habitat for the species, allowing to calculate the percentage of suitable habitat being occupied. It remains to be decided whether such areas should also include potentially suitable habitat that would only become suitable after the implementation of conservation management and restoration work.

Distributional range trends and range size trends between assessment cycles will be provided (short-term and long-term) for the breeding distribution e.g. as change in occupied 1x1km² squares. Additionally, the trends in the range of suitable habitat (distribution and size) can be provided.

## Monitoring and assessment of distributional range for *H. pelagicus melitensis*

### Monitoring methodology

It is recommended to assess the entire suitable *H. pelagicus melitensis* nesting habitat across the archipelago. The general assessment should follow the methodology as described in Austad et al. (2019) and in the tender's fieldwork report.

Especially the largest colony on Filfla is adequately monitored under D1C2 and D1C3, thus range data for the islet can be revealed from these criteria. For the rest of the suitable habitat the use of the FLIR for nocturnal observations paired with audial and olfactory monitoring is believed to be required. Monitoring in calm dark nights from the sea along the cliffs and into sea caves by means of a RIB as a platform appears to be the most effective way to do so. Only areas where birds are seen on the ground or entering caves or burrows or heard calling from the ground or from inside nest cavities should be included in the breeding range and assigned category 2. The use of the FLIR for nocturnal observations is believed to be required for most sites that can't be accessed physically. All surveyed areas where birds are seen or heard on the ground or entering nest cavities or heard from inside are mapped by means of a handheld gps.

### Monitoring locations

All areas with suitable nesting habitat for the species. Areas that are accessed physically and/or already monitored for D1C2 and D1C3 can be easily mapped from information gathered under these criteria and do not require additional monitoring effort for range assessment. Only areas that are believed to provide suitable habitat but are not assessed under the above-mentioned criteria are listed here (Tab. 35) and budgeted below (Tab. 36).

**Tab. 35:** Specific sites with (potentially) suitable breeding habitat for *H. pelagicus* which require surveys under D1C4 additional to abundance estimate surveys carried out under D1C2.

| N2K number | Site name |
|---|---|
| **MT0000031** | Għar Lapsi |
| | Blue Grotto sea caves |
| **MT0000032** | Dingli sea caves |
| | Miġra l-Ferħa sea caves |
| | Fomm ir-Riħ sea caves |
| **MT0000033** | Ħal Far to Bengħisa sea caves |

| | |
|---|---|
| **MT0000017** | Comino Santa Marija Caves |
| **MT0000022** | Selmunett |
| **MT0000028** | Xlendi to iċ-Ċnus |
| **MT0000029** | Wardija |
| **MT0000037** | W. Għasri to San Dimitri |

**Timing**

Monitoring work would focus mainly on calm, dark nights during the earlier part of the breeding period of *H. pelagicus melitensis* (April-July) in combined monitoring surveys for *C. diomedea* (see above) and where applicable, namely MT22 Selmunett, with *P. yelkouan* surveys during the same period.

**Frequency across monitoring cycle**

For the long-term monitoring it is envisaged to carry out one entire range assessment (actual range and overall suitable habitat) as described above, spread over the breeding seasons of each six-years assessment cycle. A higher frequency of assessment is not believed to be necessary.

**Costs**

**Tab. 36:** Estimated costs of surveying *H. pelagicus* range in the complete area with suitable habitat in addition to surveys carried out under D1C2.

| Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| Audio-visual counts | Same as *C. diomedea* surveys listed above, due to overlap in range and timing | | | |
| Mapping, plotting of range | 10 | person hours | 15 | 150 |
| compiling of range size data for entire range | 10 | person hours | 18 | 180 |

**Analyses and assessment**

All surveyed areas that are deemed suitable will be delineated by coordinates from aerial imagery. Only areas where *H. pelagicus melitensis* are seen entering caves or burrows or heard calling from the ground or from inside nest cavities are included (as range category 2) into the breeding range of the species. Areas where birds are seen or heard in flight only should be assigned category 1 temporarily and assessed subsequently at least in one additional occasion with suitable conditions, repeated if necessary up to two times, to confirm category 2. Areas, in which after repeated visits in suitable conditions no activity is noticed, are then assigned category 0 (not part of the actual breeding range within the given assessment cycle). However, they should be re-visited and monitored in the following assessment cycle.

The actual range and the suitable habitat of each species are mapped in relation to Natura 2000 sites (SPA) and also plotted on the 1x1km² grid provided by the EEA in accordance with reporting requirements under Art. 12 of the Birds Directives. The actual breeding range as occupied grid cells can then be overlaid with the total area of suitable habitat for the species, allowing to calculate the percentage of suitable habitat being occupied. It remains to be decided whether such areas should also include potentially suitable habitat that would only become suitable after the implementation of conservation management and restoration work.

Distributional range trends and range size trends between assessment cycles will be provided (short-term and long-term) for the breeding distribution e.g. as change in occupied 1x1km² squares. Additionally, the trends in the range of suitable habitat (distribution and size) can be provided.

## The extent and condition of habitat

**D1C5 (secondary):** The extent and condition of the habitat of each species is adequate to support the species' different life history stages.

### Monitoring methodology of terrestrial breeding habitat

The extent of overall available versus currently occupied terrestrial breeding habitat for each species is to be mapped as part of D1C4 assessment once per assessment cycle. Additional monitoring specifically for D1C5 regarding the extent of the terrestrial breeding habitat is not required.

The condition of the terrestrial breeding habitat will be monitored for each species as part of the assessment of the threats, pressures and conservation actions active in these habitats in accordance with the monitoring program listed in the relevant chapter (see below), for which the costs are presented in Table 37. It is believed that no additional monitoring is required specifically for the assessment of the condition of terrestrial habitat under D1C5.

### Monitoring locations

All relevant monitoring locations are listed under D1C2 to D1C4. In summary they entail the entire suitable nesting habitat for each of the three seabird species.

### Timing

The timing for the monitoring activities can be found under the relevant sections above (D1C4) and below (Pressures, Threats and Conservation Actions).

**Frequency across monitoring cycle**

The assessment of the extent and quality of available breeding habitat for each of the three seabird species will be carried out once within the six years assessment cycle.

**Costs**

**Tab. 37:** Estimated costs related to terrestrial habitat suitability mapping and assessment under D1C5 for all three seabird species

| Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| preparing all data re habitat extent and condition for the model; modelling habitat suitability, creating habitat suitability maps for each species | 90 | person hours | 18 | 1,620 |

**Analyses and assessment**

To assess the condition (i.e. quality) of the habitat it is suggested to spatially overlay the seabird breeding distribution maps (both occupied and suitable habitat) for each species with mapped pressures (such as light pollution, problematic invasive species) but also conservation actions (e.g. predator control schemes, local notices to mariners, N2K coverage). This desk-based exercise should be carried out once per assessment cycle, thus averages would be used from monitoring data that are collected more frequently. It should further be considered to utilize all data in a habitat suitability modelling exercise (e.g. following Troy et al. 2017).

Comparison between assessment cycles would reveal trends. How pressures, threats and conservation actions should be assessed, mapped, and monitored is detailed in the specific chapter below.

**Monitoring the extent and condition of marine habitat**

The collection of primary data on the extent and condition of the marine habitat during the current assessment cycle has not been part of the tender at hand. However, it is considered to play an important role in the assessment of GES of this secondary criterion. Furthermore, the regular assessment of the marine SPAs as designated for the Maltese seabird species in coastal and offshore waters of the Maltese FMZ (and the proportions of each population that are protected by them) is also required as part of Art. 12 reporting under the Birds Directive (Art. 12 Reporting Guidelines Section 8: SPA coverage and conservation measures). Therefore, it is believed that the extent and condition of the marine habitat need to feature in the long-term monitoring strategy accordingly.

Still within the current assessment cycle and then once per future assessment cycle the data collection of seabird distribution and abundance at sea is recommended:

- Standardized distance sampling (sightings) of all three seabird species along transect lines (vessel-based or aerial) covering the FMZ but with a focus on the marine SPA, following ESAS methodology. Wherever suitable and feasible this should be carried out together with data collection on other biota such as marine mammals and sea turtles, as such a creation of synergies would help to reduce overall costs for MSFD monitoring under D1. Seabird data collection should follow the ESAS protocol and importantly should not be carried out from a fishing vessel (Garthe 2004).

**Locations**

The Maltese FMZ and the Marine SPAs should be surveyed, with a minimum of 6 separate full day transects but ideally up to 14 transects to fully cover the whole area (Metzger et al. 2015).

**Timing**

Three surveys for each of the transects should be carried out during a year, to obtain a representative sample across the species' breeding period. The first survey can take place in March/April, the second in May/June and the third in July/August.

**Frequency**

At-sea surveys are proposed to be carried out within a year, once per monitoring cycle.

**Cost**

Costs for a minimum number of at-sea surveys of all three seabird species in the Maltese FMZ are presented in Table 38. Efficiency and outputs might be improved if incorporating data collection for other taxa.

**Tab. 38**: Estimated costs for assessing at-sea distribution and marine habitat suitability under D1C5 using distance sampling

| **Item** | **Number per monitoring cycle** | **Unit type** | **Unit cost [€]** | **Total [€]** |
|---|---|---|---|---|
| Vessel day at sea* | 18 | external assistance | 800 | 14,400 |
| At-sea observers** | 480 | person hours | 18 | 8,640 |
| Handheld GPS | 1 | consumables | 200 | 200 |
| Binoculars | 2 | consumables | 500 | 1,000 |
| Data entry | 40 | person hours | 15 | 600 |
| Data cleaning, analyses, mapping | 120 | person hours | 18 | 2,160 |

*Assuming 6 days to cover FMZ with focus on mSPA, 3 repetitions spread over breeding season, once per assessment cycle, price includes vessel, fuel and captain

**Assuming 10 hours per day, 2 persons

- Assessment of rafting areas including range, location, and condition, for *C. diomedea* via land-based counts, for all three species via vessel-based assessments, potentially including aerial counts via UAV and from tracking data (see below.). Costs for this assessment are presented in Table 39.

**Locations**

A minimum number of locations for land-based raft counts of *C. diomedea* are proposed as follows:

- MT0000027 Ta' Ċenċ
- MT0000030 Għarb/San Dimitri Point
- MT0000033 Ħal Far
- MT0000031 Għar lapsi
- MT0000032 Miġra l-Ferħa

Vessel-based assessments of rafting areas can be combined with the above at sea distribution surveys. However, some locations can benefit from additional surveys using a smaller vessel such as RIB. The proposed areas include the SPAs MT0000108 (especially in proximity to the fish farms which might attract *H. pelagicus*, MT0000112 (especially off Rdum tal-Madonna) and MT0000111 (especially off Filfla).

**Timing**

Three surveys each (Land-based and vessel-based) should be carried out during a year, to obtain a representative sample across the species' breeding period. The first survey can take place in March/April, the second in May/June and the third July/August.

**Frequency**

Rafting assessments through land-based and vessel-based surveys are proposed for once per monitoring cycle. Assessments from tracking data will take place in both years in which tracking data is obtained.

**Costs**

**Tab. 39:** Estimated costs for assessing at sea distribution and marine habitat suitability under D1C5 using rafting area assessments

| Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| Land Based Raft Counts* | 30 | person hours | 15 | 450 |
| Identification of rafting areas from tracking data | 40 | person hours | 18 | 720 |
| Rafting area surveys by RIB** | 108 | person hours | 15 | 1,620 |
| Data entry | 20 | person hours | 15 | 300 |
| Data cleaning, analyses, mapping | 40 | person hours | 18 | 720 |

*Assuming 5 locations, 2 hours each survey, 3 surveys per year, once per monitoring cycle

**Assuming 3 locations, 4 hours each survey, 3 personnel including skipper, 3 surveys per year, once per monitoring cycle

- GPS tracking of sub-samples of adult seabirds (all species) during the breeding season to monitor habitat use and use of marine SPA, but also for risk monitoring, e.g. by-catch risk and risk of plastic ingestion, when overlaid with spatial data on fishing effort and from marine litter surveys. *C. diomedea* and *P. yelkouan* have been intensively GPS-tracked during the last assessment cycle, while *P. yelkouan* are also tracked during the current one as part of LIFE PanPuffinus. In the future, effort should specifically aim at GPS-tracking of *H. pelagius melitensis* for which no high-resolution foraging trips of the Maltese population exist to data. The importance of a tracking approach is underlined by the fact that due to the size *H. pelagicus melitensis* is underrepresented in data collected through vessel-based surveys. GPS-tracking data appear crucial to monitor main range and range size of important foraging and rafting areas of the species in the Maltese FMZ and beyond. Advancements in technology, especially further miniaturization of devices and use of GPS-GSM loggers which do not require retrieval for acquiring logged data, should be considered in future tracking projects to further minimize the impact on tracked individuals. Estimated costs for this assessment are presented in Table 40.

**Location**

Obtaining tracking data efficiently with high chances of retrieval for the least amount of effort and disturbance requires a large number of nests in a small area. Ideally the nests are accessible and visible. Ease of access to the colony or sub-site is beneficial.

*P. yelkouan* have successfully been tagged at L-irdum tal-Madonna and Majjistral. With higher effort tagging can take place at Blue Grotto and St Paul's Island but requires calm sea for access.
*C. diomedea* have been successfully tagged at Għarb, Ħal Far and Filfla. Xlendi and Fungus Rock would also be suitable but are subject to higher effort to access and the need for calm seas.
Filfla and Ta' Ċenċ sea cave are currently the only feasible locations for tagging *H. pelagicus* but both involve a certain element of risk because calm sea is required during the retrieval period. Higher occupancy of nest boxes on Filfla would increase the chances of successful retrieval.

**Timing**

Tracking should focus on the early chick-rearing period. This equates to late-April, beginning of May for *P. yelkouan* and mid-July for *C. diomedea*. Hatching in *H. pelagicus* is less synchronised and frequent nest monitoring would be required to time the tagging successfully.
Additionally tracking during the incubation period, the second half is recommended to avoid unnecessary disturbance, can be carried out for *P. yelkouan* and *C. diomedea* at accessible nests.

**Frequency**

It is recommended that tracking takes place in two consecutive years for each species within each monitoring cycle. This would ensure the best use of any retrieved gps-units from the first year of tagging. Foraging areas might vary with seasonal conditions and therefore two-years of data are needed to discern such effects. Due to the high financial costs, but more importantly to limit any disturbance to breeding seabirds, it is not recommended to repeat tagging more than two years per cycle.

**Costs**

**Tab. 40:** Estimated costs for assessing at sea distribution and marine habitat suitability under D1C5 using gps-tracking for each species

| Species | Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|---|
| *P. yelkouan* | GPS-GSM devices | 30 | consumables | 1,000 | 30,000 |
| *P. yelkouan* | GSM data transmission | 120 | external assistance | 20 | 2,400 |
| *P. yelkouan** | GPS deployment | 192 | person hours | 15 | 2,880 |

| | | | | | |
|---|---|---|---|---|---|
| *P. yelkouan*** | GPS retrieval | 640 | person hours | 15 | 9,600 |
| *C. diomedea** | Data cleaning and mapping | 60 | person hours | 18 | 1,080 |
| *C. diomedea*** | GPS-GSM devices | 30 | consumables | 1,000 | 30,000 |
| *C. diomedea* | GSM data transmission | 120 | external assistance | 20 | 2,400 |
| *C. diomedea* | GPS deployment | 192 | person hours | 15 | 2,880 |
| *C. Diomedea* | GPS retrieval | 640 | person hours | 15 | 9,600 |
| *H. pelagicus* | 1g GPS tags | 40 | consumables | 600 | 24,000 |
| *H. pelagicus**** | GPS deployment | 320 | person hours | 15 | 4,800 |
| *H. pelagicus***** | GPS retrieval | 960 | person hours | 15 | 14,400 |
| *H. pelagicus* | Data cleaning and mapping | 60 | person hours | 18 | 1,080 |
| All | TesaTape | 2 | consumables | 70 | 140 |

*Assuming 2 years per monitoring cycle, 24 hours for all deployments, 4 persons
**Assuming 2 years per monitoring cycle, 10 visits of 8 hours each for retrieval, 4 persons
***Assuming 2 years per monitoring cycle, 5 visits of 8 hours for deployments, 4 persons
****Assuming 2 years per monitoring cycle, 15 visits of 8 hours each for retrieval, 4 persons

### Analysis

The analyses would overlay updated seabird distribution (as revealed applying the methods above such as at-sea-transects and tracking plus modelling) with habitat suitability parameters e.g. prey availability[4], climatic conditions and pressures, threats, and SPA boundaries as well as data on conservation activities collected as primary data and more importantly as secondary data provided by relevant bodies. At-sea observation-based data and gps-data should be analysed spatially in GIS software and methods described in for example Metzger et al. (2015) and Gatt et al. (2019) used to identify areas particularly frequented by foraging seabirds.

## Pressures, threats, and conservation actions

### Methodology

[4] While tracking can reveal where the birds forage, prey availability can be obtained either (i) directly from surveys carried out by the DFA or (ii) modelled indirectly making use of remote sensing data (SST, ChlA,…) available free of charge. Furthermore, prey identification from regurgitate samples collected at tag retrieval can link foraging areas to prey species.

**Collection of primary data**

Primary data are defined here as data that would be collected directly as part of monitoring activities by staff while in the field and are budgeted below. Such primary data include:

- Light pollution levels via Sky quality meters
- Monitoring of the *L. michahellis* population nesting on Filfla
- Any pressures encountered and documented while carrying out monitoring activities under the various criteria (this means no additional person hours to be budgeted for this type of monitoring)

**Collation of secondary data**

Secondary data are defined here as relevant additional data on pressures, threats and conservation activities that are (or have been) collected outside the direct scope or budget of the tender or by other entities. Due to uncertainties concerning the availability of such data (see below) and their costs, they are not budgeted here. However, such data would need to be provided to be included for complete analyses and assessments.

The collection of systematic secondary data on the pressures (threats as these pressures projected into the future) and conservation actions has been carried out as part of the tender where possible (e.g. data collected by BirdLife Malta on problematic invasive species and their control and rescued grounded fledglings). However, acquiring additional data on pressures and conservation activities from relevant bodies (such as Transport Malta, Armed Forces of Malta, The Malta Police Force, Ambjent Malta, and any entity managing Natura 2000 sites which host seabird species) as part and during the implementation period of the tender at hand has been shown to be of very limited success. The acquisition of such data therefore would either require more time or, more likely, an alternative approach. As a potential way forward to solve this issue and receiving the data in the remaining period of the current assessment cycle and more importantly for future assessment cycles we suggest the following ways forward:

- Creation of a task force formed by relevant bodies (see also below).
- Extraction of suitable and relevant data on pressures and conservation actions from annual management reports as well as concerning all nature permitting reports of all managed N2K sites which hold seabird colonies submitted to ERA.
- Official requirement of all activities (creating pressures, conservation actions) taking place inside Natura 2000 sites holding seabird colonies (plus a buffer area) and marine SPA to be reported annually to ERA by the entity responsible for these activities (e.g. boat traffic, bunkering, breaches of relevant local notices to mariners: Transport Malta; road and other development increasing light pollution: Infrastructure Malta, the Planning Authority; by-catch, fishing effort in marine SPA: The Maltese Fisheries Department).
- The collection of additional data where data quality or quantity appears insufficient, including setting up of autonomous surveillance units e.g. webcams, additional sky-quality meters (SQM).

- Creation of a template format for site management reports, (this could be on a platform e.g. App, webtool, e-logbook) in which Natura 2000 site managers are enabled to enter relevant information standardized and compliant to Art. 12 and MSFD reporting of pressures, threats and conservation actions. To reduce redundancies, the reporting template could also be developed to cater for the same reporting of pressures under the HD.
- Implementation of a site ranger scheme for all Maltese SPA which host seabird colonies, with rangers not only implementing and enforcing conservation actions, but also collecting data on pressures and conservation actions systematically and in a standardised manner during regular patrolling visits.

**Primary data collection**

**Monitoring light pollution levels with Sky Quality meters**

**Monitoring Locations**

Sky Quality meters are placed facing cliff faces at colony sites to record light levels to which nesting seabirds are exposed to at night. The same locations (Tab. 41) used during this tender are recommended in order to continue building a long-term dataset. Additionally, Filfla is another recommended site (Tab. 41). Moreover, new sites can be added if the need arises for comparison to existing monitoring sites. For existing monitoring locations, similar deployment ensures the highest compatibility with previous years of data (i.e facing the same section of cliff face).

**Tab. 41:** Monitoring locations for light pollution at seabird colonies using Sky Quality meters

| N2K site | Location name | Target species | Latitude | Longitude |
|---|---|---|---|---|
| MT0000009 | Rdum tal-Madonna | *P. yelkouan* | 35.994122 | 14.371269 |
| MT0000017 | Cominotto | *P. yelkouan* | 36.013041 | 14.321426 |
| MT0000024 | Majjistral NHP | *P. yelkouan* | 35.954726 | 14.339868 |
| MT0000027 | Ras in-Newwiela | *C. diomedea* | 36.011528 | 14.261965 |
| MT0000033 | Ħal Far | *C. diomedea* | 35.809828 | 14.505697 |
| MT0000016 | Filfla | *H. pelagicus* | 35.787788 | 14.409767 |

**Timing**

Each unit should be deployed for a minimum of 3 months to acquire sufficient data across moon cycles. Units where the target species is *P. yelkouan* (Tab. 41), should be deployed between at least February and May. Units where the target species is *C. diomedea* and *H. pelagicus* (Tab. 41) should be deployed between May and July. When set on 10-minute reading frequency the SQM can last on new batteries for the whole period recommended here.

**Frequency monitoring**

Due to the low costs of this monitoring method and the possibility to combine deployment and retrieval with other monitoring visits, annual monitoring of light pollution is recommended. However, lower frequency is also possible and not all meters have to be active in the same year for analysis of change within each given site.

**Costs**

All costs related to primary data collection under D1C5 are presented in Table. 42.

**Analysis**

Nocturnal light readings (i.e between the time the sun is 18 degrees below the horizon at dusk on date i and at dawn on date i+1) are plotted against time for each location. Temporary light pollution events such as ship bunkering are identified as peaks in light readings. Higher permanent light pollution is identified as higher means in readings across the monitoring period.

**Monitoring impact of *L. michahellis* on the *H. pelagicus* population on Filfla**

The breeding population and trend of *L. michahellis* on Filfla is assessed via systematic nest- and egg-counts on the islet's plateau and boulder scree while the collection and quantification of *H. pelagicus* remains from gull regurgitates will be assessed to estimate the predation pressure related to the *L. michahellis* population.

**Tab. 42:** Estimated costs for primary data collection and assessment

| Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| handheld cameras to document pressures/threats | 2 | equipment | 300 | 600 |
| Unihedron SQM and casing | 6 | equipment | 320 | 1,920 |
| SQM placement and retrieval | 144 | person hours | 15 | 2,160 |
| SQM batteries AA | 216 | consumables | 5 | 1,080 |
| light pollution graph analysis | 48 | person hours | 15 | 720 |
| Vessel trip to Filfa boulder scree for assessment of *L. michahellis* | 12 | external assistance | 140 | 1,680 |
| assessment of *L. michahellis* boulder scree | 144 | person hours | 15 | 2,160 |
| assessment of *L. michahellis* Filfla plateau | 120 | person hours | 15 | 1,800 |
| Access to Filfla Plateau via AFM | 12 | external assistance | provided free of charge | |

| | | | | |
|---|---|---|---|---|
| helicopter (return trips) | | | | |
| Data analyses and assessment | 120 | person hours | 18 | 2,160 |

*Assuming 2 visits per unit for deployment and retrieval, 1 hour per unit due to combining with other actions, 2 persons per visit, annual monitoring across 6-year cycle.
**External collection of secondary data (externalized) not budgeted

## Baseline and threshold values

### Background and considerations

To date, Malta has not established the methodology to define concrete baseline and threshold values for any of the criteria of Descriptor 1 Biodiversity (D1C1-D1C5) regarding the three procellariiform seabird species. However, these values are believed to be crucial to evaluate whether GES for each of the species and for the entire species community is achieved.
Neither the development or adaptation of the methodology nor the establishment of the actual baseline and threshold values per species and criterion have been the scope of the tender at hand. However, they will have to form an integral part of any long-term monitoring strategy and it is strongly advised to establish them still during the current assessment cycle so that GES can be adequately examined. This would be carried out as a desk-based study and should take the results of the current and previous assessments into account. Furthermore, developing these values for seabirds should also consider the methodologies that are/will be utilized in Malta for other marine taxa evaluated under Descriptor 1 and include information on the methodologies used and baseline and thresholds established in relevant EU member states and other signatories to the regional sea convention under UNEP (Barcelona Convention). Effectively, the baseline and threshold values and the methodologies to establish them should be in line with the overarching values and processes for the relevant Common Indicators currently developed for various species, including the three procellariiform seabird species (all part of the pelagic feeding functional group) for the entire Mediterranean by UNEP/IMAP. Taking such a harmonized approach between various states, entities, subregions, and conventions is believed to be necessary to establish baseline and threshold values that are scientifically sound, feasible, and allow for comparison of assessments along different scales and across the region as part of UNEP/IMAP's integrated Ecosystem Approach (EcAp).
Finally, when establishing a methodology for defining baseline and threshold values it is advised to adapt or at least to consider approaches that have already been proven successful as part of other regional sea conventions such as OSPAR and HELCOM and consider recommendations from relevant position papers (e.g. BirdLife International 2019) and reports (e.g. report from the EU's Joint Research Centre - JRC: (Palialexis and Boschetti 2021).

### Methodology

Baseline and threshold values for the Maltese breeding populations of each species should be developed taking a desk-based approach. This would entail a thorough review of methodologies used and established approaches implemented by other EU member states but also by the various Regional Sea Conventions (SPA/RAC UNEP-IMAP, HELCOM, OSPAR). After deciding on the approach suitable for the Maltese seabird populations, the actual baselines and thresholds would then be developed for each criterion and each species.

**Timing**

The proposed aim is to have baseline and threshold values for each criterion and each species within the current assessment cycle in order to be decided on and implemented at the start of the next assessment cycle.

**Frequency across monitoring cycle**

The definition of baselines and thresholds is foreseen as a singular exercise; however, revisions might become necessary in future assessment cycles.

**Costs**

**Tab. 43:** Estimated costs for the development of baseline and threshold values for all relevant criteria and all three seabird species breeding in the Maltese islands

| Item | Number per monitoring cycle* | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| Development of baseline and threshold values for GES assessment (desk based) | 150 | person hours | 18 | 2,700 |

*Carried out once. However, revisions might become necessary in future assessment cycles.

## Complete budget and strategy overview

The budget estimations provided in this monitoring strategy for seabirds, have given a summary of the required costs for essential and specific equipment as well as experienced fieldworkers including an estimation of number of person hours per monitoring method and species.

Budget estimations in all cases have been calculated to cover costs and not to create any profits. Moreover, seabird monitoring involves several risks inherent to the difficulty of access to colonies and the dependence on weather and sea conditions. The numbers of hours and visits required have been estimated with a certain safety margin considering and on the experience with such risk, a margin increased with the contingency budget. Moreover, the number of hours required can vary with the potential of combining several actions and sites within the same visits. It is likely that the costs for a team lacking prior experience working with the colonies in the Maltese Islands and the techniques used would be substantially higher.

It is highly recommended that the frequencies of monitoring implementation proposed in this document are followed, but the strategy is to some degree flexible. The detailed overview of each method's time budget should allow for adapting the strategy. However, reducing the number of visits or sites substantially might reduce the quality of data and the method of its interpretation and analysis. In cases where reduction in frequency could be reduced from annual to bi-annual this has been clearly indicated. At the same time, it is acknowledged that as technology advances certain methods might become redundant or less efficient than emerging ones. The strategy has been written keeping in mind the most feasible and economically viable methods currently at hand and used during monitoring in the Maltese Islands.

Further costs, not specific to any monitoring action, are provided in Table 44. Such costs include report writing, management, as well as equipment and consumables required for transport and access.

**Tab. 44:** Estimates for additional costs per assessment cycle, which are not budgeted specifically for any monitoring action.

| Item | Number per monitoring cycle | Unit type | Unit cost [€] | Total [€] |
|---|---|---|---|---|
| Writing up reports | 640 | person hours | 18 | 11,520 |
| Fuel for the motor vehicle | 6 | Consumables | 1000 | 6,000 |
| Fuel for RIB | 6 | Consumables | 833 | 4,998 |
| Ferries to Gozo | 395 | other costs | 20.35 | 8,038.25 |
| Maintenance for the powerboat once per year (6 years) | 6 | external assistance | 640 | 3,840 |
| 4x4 motor vehicle | 1 | equipment | 1 | 15,000 |
| Maintenance for the motor vehicle once per year (6 years) | 6 | external assistance | 500 | 3,000 |
| Abseiling course for 2 persons | 2 | external assistance | 400 | 800 |
| First Aid course for 6 persons | 1 | external assistance | 300 | 300 |
| Abseiling equipment for 4 persons | 1 | equipment | 1 | 1,800 |
| Inflatable kayak (paddles and pump) | 1 | equipment | 1 | 1,290 |
| Travel time, boat preparation hours etc | 5148 | person hours | 15 | 77,220 |
| Insurance for the motor vehicle | 6 | Other costs | 740 | 4,440 |
| Insurance for the powerboat | 6 | Other costs | 210 | 1,260 |
| 1x Rock Core i7 Desktop PC Custom | 1 | Equipment | 1 | 1,100 |

*Assuming an average of 2 persons per visit and an average of 2 hours travel time per visit

**All prices exclude shipping and VAT.**

**The total budget as estimated for one entire 6-years monitoring and assessment cycle is:**

| | |
|---|---|
| Total without overheads | 767,401.25 |
| Overheads 7% | 53,718.09 |
| **Total Budget** | **821,119.34** |

The budget figures are calculated with the prices known as realistic for the year 2021. Prices tend to inflate by 3% per annum. Such inflation is not reflected in the budgets presented here.

All figures in the budgets are exclusive of VAT.

The budgets do not include a contingency which would be calculated between 10 to 15% of total amount.

## Conclusion and Outlook

Due to the re-evaluation of the MSFD itself every six years, any strategy for the long-term monitoring of Maltese seabirds, including the one presented here, is certainly not to be cast in stone. Instead, the strategy should allow for a degree of flexibility, while not compromising continuity and hence the comparability in monitoring data to be collected.

The adequate monitoring of all Descriptor D1 - Biodiversity criteria of colonial, burrow nesting procellariiform seabirds from the offshore pelagic group that are nocturnal at the breeding sites is expected to remain a challenging task. The nesting sites have been pushed mainly towards the least accessible places in steep sea cliffs, sea caves, and onto offshore islets due to centuries of human persecution. Predation by problematic invasive species is likely to have further contributed to the distribution pattern found today. Increasing urban developments in recent decades can be expected to be pushing seabird colonies even further into places difficult to monitor. This is certainly adding to the challenges of adequately monitoring seabirds in the Maltese islands.

Various strong efforts, mainly as part of larger, EU-co-funded conservation projects (LIFE10 NAT/MT/090; LIFE14 NAT/MT/000991; LIFE19 NAT/MT/000982) have been a gamechanger in the recent past. With specific scopes but all requiring some sort of monitoring to assess the success of such projects, the knowledge of most colony locations, their size and breeding pair abundance across the Maltese islands has widely improved. As a side effect, local expertise has increased significantly. Smaller projects like the assessment for the previous monitoring cycle and the latest short-term assessment for the tender at hand have further improved the knowledge. Nevertheless, such short-term monitoring projects have covered less than one entire breeding cycle of the species to be assessed. They were also limited in scope, not allowing for the monitoring of at-sea distribution and pressures and threats acting on the foraging grounds offshore. This clearly highlights a shortcoming of the current situation.

Therefore, the most important conclusion regarding the current assessment is that the implementation of any long-term monitoring strategy requires planning ahead and should follow the 6-years reporting cycles. Such a strategy requires a real commitment to adequate, continuous monitoring effort, including securing the necessary resources to be truly sustainable and effective in delivering results long-term.

On the way towards a viable long-term monitoring strategy, some intermediate and more short-term steps are proposed, aiming at closing persisting knowledge gaps, and addressing current shortcomings. These are ideally carried out in the remaining time of the current assessment cycle and are listed as follows:

- Deciding on the methods to be used for and then defining baseline and threshold values against which GES can be assessed, according to this methodology for all criteria and for all three procellariiform seabird species.
- Increasing the certainty of the breeding distribution range where necessary for the D1C4 assessment (see above).
- Increasing the total number of accessible nests for an adequate breeding success monitoring for criterion D1C3 'Population Demography' of *C. diomedea* and *H. pelagicus melitensis.*
- Developing and implementing a conclusive by-catch assessment program for the fishing fleet operating in Maltese waters for monitoring D1C1.
- Developing and implementing a strategy and program (e.g. including a webtool) for the collection and sharing of secondary data on pressures and conservation activities effectively across all sites (focus on Natura 2000 areas).

Furthermore, part of the long-term monitoring strategy, ideally still to be carried out during the current assessment cycle, should be the development of an **emergency response program**. Such a program would be able to provide resources quickly and fast-track for example required permitting with the ERA when needed. The program would allow for swift intervention actions as soon as a relevant pressure is detected, or an acute threat can be anticipated from the monitoring activities. Such interventions could for instance include a quick response to biosecurity breaches and invasion of colonies by problematic species (rats, cats), or the dimming or switching off of lights in certain areas ahead of expected fall-out events of fledglings close to colonies as done on various islands across the globe (e.g., on the Azores).

Monitoring threatened seabirds can obviously never be an end in itself but must always be a means to an end: informing on the pressures as well as necessary conservation activities and their effectiveness timely and adequately. Allowing direct approach and handling in their colonies on land, long-lived seabirds are ideal model organisms. They have great potential to be used as sentinels, able to inform of remote pressures on the environment (e.g. plastic pollution, impact of fisheries) active in far-away offshore areas which in general are costly to monitor otherwise. Their role as sentinels for the state of the sea highlights the importance of monitoring activities in seabird colonies, even irrespective of their conservation status.

This aspect of direct accessibility also highlights the great chances of creating synergies between different descriptors within the MSFD monitoring requirements. Taking an integrated Ecosystem Approach (EcAp), seabirds (their eggs, tissues, regurgitates, faeces) can be sampled inside the colonies for pressures they are exposed to on their feeding grounds offshore (e.g. plastic ingestion, heavy metals and other persistent and bio-accumulative pollutants, invasive prey species). Creating such synergies with monitoring programs for other descriptors under MSFD in an integrated approach would increase the cost-effectiveness of monitoring programs significantly, apart from providing chances for a more holistic assessment of GES.

However, also within the same descriptor D1 and even within the same criterion, any long-term monitoring strategy should aim towards an integrated monitoring approach to make use of limited resources efficiently. A more obvious example has been provided above, proposing an integrative by-catch monitoring program under D1C1, combining data collection and assessment on bycatch across the various affected taxa, such as seabirds, marine mammals, and sea turtles. Additionally, at-sea abundance monitoring under D1C2 and range monitoring under D1C4, e.g. via aerial or vessel-based transect surveys could to some extent cater for the assessment of different taxa simultaneously. Creating synergies through combining monitoring survey work for different taxa where possible will ultimately reduce costs and increase the data harvest per unit effort.

## Annex I

Annex I provides a detailed overview of the entire budget estimate in excel datasheets format.

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