EU LIFE+
MALTA SEABIRD PROJECT

LIFE10 NAT/MT/090
Creating an inventory of marine IBAs for
Puffinus yelkouan, Calonectris diomedea &
Hydrobates pelagicus in Malta

Malta Marine IBA Inventory Report

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November 2015

MINISTRY FOR SUSTAINABLE DEVELOPMENT, THE ENVIRONMENT AND CLIMATE CHANGE
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1. Introduction

The EU-Life Malta Seabird Project (LIFE10 NAT/MT/090) aims at creating an inventory of Marine Important Bird Areas for three seabird species nesting in the Maltese islands for which the country hosts internationally important populations namely, the Yelkouan Shearwater *Puffinus yelkouan*, the Scopoli's Shearwater *Calonectris diomedea*, and the Mediterranean Storm-petrel *Hydrobates pelagicus melitensis*.

Quantitative, standardised, globally agreed criteria, developed by BirdLife International are used across countries, institutions and organisations for the identification of Important Bird Areas (IBA). To serve this aim, BirdLife International developed the Marine IBA Toolkit (BirdLife International 2010) to identify IBAs for seabirds by applying comparable methods and quantitative criteria in the marine environment. Various tools and methods are applied and combined to confirm that a significant proportion of a species of conservation concern or otherwise threshold numbers of global populations (≥ 1%) of sea- or waterbird species are making use of a sea area on- or off-shore, and coastal or inland areas (e.g. for nesting), or are crossing certain bottlenecks on migration. The tools include colony size assessments, standardised, repeated land- and boat-based bird counts, tracking individuals of known colonies during the breeding season and outside the reproductive period, and modelling expected occurrence including various oceanographic data.

In the report at hand, we present the background, methods and results of the work carried out during the last four years to create an inventory of marine IBAs for the Maltese populations of the three above mentioned species.

The main focus is set on the Maltese Exclusive Fishing Zone (25nm). This is the area in which the Maltese Government will designate marine Special Protected Areas (mSPA) as part of the Natura 2000 Network, on the basis of the marine IBAs presented here.

2. Methods

2.1. IBA categories, aggregation activity types and threshold numbers

2.1.1. mIBA Categories

According to the marine IBA toolkit, the following two categories are applicable in the identification process of marine IBAs for Maltese seabirds:

Category A1 - Globally Threatened Species: The site regularly holds significant numbers of a globally threatened species, or other species of global conservation concern. The site qualifies if it is known, estimated or thought to hold a population of a species categorized on the IUCN Red List as globally threatened (Critical, Endangered and Vulnerable). The list of globally threatened species is maintained and updated annually by BirdLife International. For Maltese seabirds, this category applies to the Yelkouan Shearwater *P. yelkouan*, listed as vulnerable (BirdLife International (2015) Species factsheet: *Puffinus yelkouan*).

Category A4 - Congregations: ii) The site is known or thought to hold, on a regular basis, ≥ 1% of the global population of a congregatory seabird or terrestrial species. For Malta, this category applies to all three tubenose species, nesting in the Maltese islands.

2.1.2. Aggregation and activity types

Four main types of areas for seabirds' aggregation and activities are recognized by BirdLife International in the identification process of marine IBA:

(I) Seaward extensions to breeding colonies: Coastal seabird species such as terns tend to forage relatively close to their colonies. Pelagic seabirds from the *Procellariiformes* order might forage far away from their nesting sites.

In general, the boundaries of the breeding colonies can be extended to include sea areas in the proximity of the colonies which are used by colony members for feeding, maintenance behaviours and social interactions. They are limited by the foraging range, depth and/or habitat preferences of the species concerned (BirdLife International 2010). The species of concern make use of sea areas in front of their colonies mainly for gathering, rafting, comfort behaviour etc. Additionally, sea areas in front of colonies have been shown to be important aggregation zones for non-breeders, especially for prospecting birds. Additionally, birds concentrate on the approach to the colonies (comparable to (IV) bottlenecks, see below), and therefore these areas are ideally kept free of any obstacles (solid, visible, audible and olfactory). The nesting sites also have to be kept free from negative impact of light pollution (sky glow, stray-light, etc.) coming from sea areas of the proximity.
The size of the seaward extensions used by seabirds around the colonies are considered to be species-specific. The size of these areas are usually achieved combining knowledge on the species biology with land-based and boat-based observations as well as with tracking of breeding birds. *P. yelkouan* and *H. pelagicus* were underrepresented in land-based observations. Therefore, we relied on literature data (e.g. Sultana et al. 2011, Raine et al. 2010, Borg, J.J. in MSFED Initial report on Seabirds 2012) regarding the seaward extension areas when modelling the hotspot areas for the three Maltese tubenose species (see below). Radii around seabird colonies were chosen as follows: 1 km for *H. pelagicus melitensis*, 4 km *C. diomedea* and 7 km for *P. yelkouan*.

(II) Coastal congregations of non-breeding seabirds: Many sea- and waterbird species such as divers, grebes and benthos-feeding ducks form large congregations in coastal waters outside the breeding season (e.g. during moult, for refuelling on migration, over-wintering). For all three Maltese tubenose species, these congregations do not to seem very relevant in Maltese waters, except for prospecting birds in front of colonies, as mentioned under **(I)**.

(III) Migration bottlenecks: Topographic features such as headland and straits can funnel seabirds regularly e.g. in the course of their bi-annual migrations. In the Maltese islands the only geographic feature which creates a significant bottleneck situation is the Gozo Channel. Apart from the shearwaters, it is additionally important for migrating Ferruginous Ducks *Aythya nyroca* (Near Threatened, BirdLife International 2015) which funnel here in large numbers and has already been identified as a marine IBA by the EU-Life Yelkouan Shearwater project. Furthermore, two major migratory bottlenecks are important for Maltese and other Mediterranean seabirds on migration: The Bosporus for *P. yelkouan* and the Strait of Gibraltar for *C. diomedea* (e.g. Raine et al. 2013, Sahin et al. 2012, http://maps.birdlife.org/marineIBAs, own data).

(IV) High seas sites for pelagic species: As other strictly pelagic seabirds, Maltese shearwaters and storm-petrels often forage at high sea sites and can gather in large numbers to exploit pelagic food sources in marine areas remote from Malta, in international waters and in national waters of other countries. Although the distribution of pelagic food sources is rather patchy in space and time, they often coincide with predictable, specific oceanographic features, such as shelf-breaks, fronts, eddies and upwellings - areas in which biological productivity is high. To research and monitor large sea areas to identify marine IBAs and other biodiversity hotspots is logistically challenging and costly. Therefore, vessel-based seabird surveys and tracking techniques are combined with remote sensing approaches collecting data on biological and physical features.

2.1.3. Evaluating the numbers and species priorities

To apply the Congregation Category (A4ii) and the relevant numbers criterion (≥ 1% of global population threshold), we compared the latest global/ geographical breeding pair population estimates of *C. diomedea*, *P. yelkouan* and *H. pelagicus (melitensis)* with numbers of their Maltese breeding populations. For the global and bio-geographical populations we were using data published on BirdLife International's Species Factsheets (2015). All data concerning Maltese populations of seabirds were taken from Sultana et al. (2011) and from Malta's MSFD Initial report on seabirds (Borg, J.J. 2012), respectively. We added own, unpublished data for sites with new breeding records (e.g. *H. pelagicus* in Gozo), re-discovered breeding sites (e.g. *P. yelkouan* on Saint Paul's Island) or where we were able to gather additional data (e.g. *P. yelkouan* at Majjistral Nature and History Park).

2.2. Vessel-based surveys

Standardised vessel-based seabird counts, one of the core methods to identify marine IBAs, were carried out over a period of two years between 2012 and 2013, eight months each (March to October) covering the entire Maltese Exclusive Fishing Zone (EFZ), a radius of 25nm around the Maltese Islands and covering an area of 6735 km^2.

Seabird counts were carried out along 14 previously set-up transect lines, laid out petal-like around the Maltese Archipelago. Each of these transect lines was surveyed once per month (Mar-Oct), resulting in a total of 224 days spent at sea, 112 days for each sampling year.

The vessel-based seabird surveys followed strictly ESAS methodology (Camphuysen & Garthe 2004, Camphuysen et al. 2004), a distance sampling approach along transect lines. All transects were carried out with at least two trained observers on board a sailing yacht (36-42ft). Whenever the weather conditions allowed, foresail and/ or main sail were used to stabilize the course, tilt and heel of the vessel and to reduce the carbon footprint of the project. A total sea area of 4785.94 km^2 was surveyed. See map (Fig. 1) for the transects' distribution around the Maltese islands.

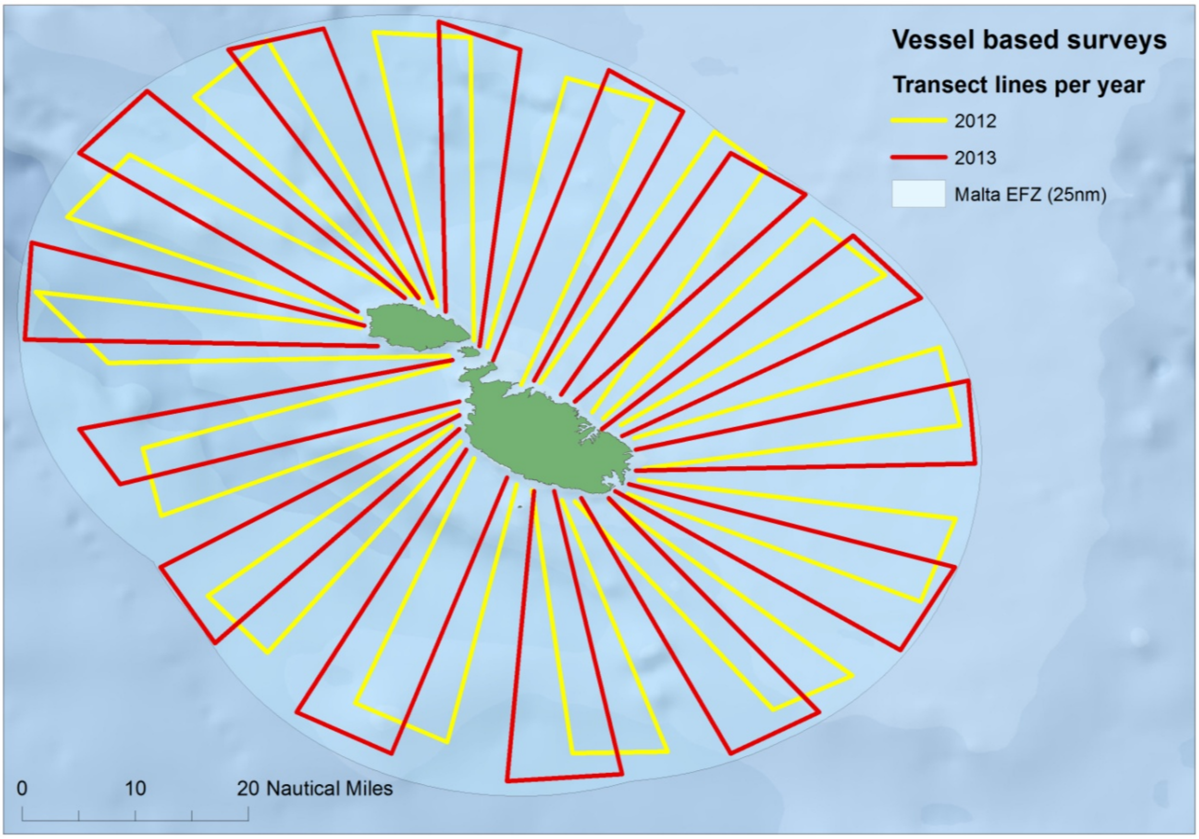

Fig. 1: Map of the 14 transect lines around the Maltese islands, each sampled once per month from March to October, yellow lines in 2012 and red lines in 2013.

2.3. GPS-tracking of Scopoli's Shearwaters and Yelkouan Shearwaters

Like vessel-based seabird counts, GPS tracking of adult birds is an important method to identify core areas the birds make use of, during the reproductive period. Between 2012 and 2014 we were GPS-tagging adult breeding and chick rearing Shearwaters to track their movements and whereabouts. Scopoli's Shearwaters were tagged in three colonies: San Lawrence (Gozo), Filfla and Hal Far; and Yelkouan Shearwaters in two colonies: Rdum tal-Madonna and Majjistral (see Fig. 2). Tags were programmed to store a position fix every 20 minutes.

2.4. GLS-tracking of *Calonectris diomedea*

During the 2012 and 2013 breeding seasons, a total of 30 geolocators Mk13 (Biotrack)[1] were deployed on adult Scopoli's Shearwaters from three different colonies: San Lawrence, Filfla and Hal Far. GLS were attached to the metal ring of the birds' tarsometatarsus with a cable tie. Two additional GLS tracks of adult Scopoli's Shearwaters, which had been tagged in 2010 and recaptured in 2011 were included into the analyses. In general, data generated by GLS devices are less accurate (mean error of 186 km; Phillips et al., 2004), than e.g. GPS data. Furthermore, they provide only two fixes per day and suffer from problems defining latitude values, especially around equinoxes. GLS data therefore have to be processed (filtered and standardised) prior to their inclusion in the analyses, following procedures detailed elsewhere (e.g. Phillips et al., 2004).

2.5. GLS-tracking of *Hydrobates pelagicus*

During the 2012 and 2013 breeding seasons, a total of 25 GLS devices, provided by the Swiss Ornithological Institute (SOI), were deployed on Mediterranean Storm-petrels on Filfla using a modified harness adapted from systems used on swifts.

2.6. Radio-tracking of Mediterranean Storm-petrels

During the 2012 and 2013 breeding season, a total of 76 adult Storm-petrel recaptured from Filfla, were equipped with radio-tags (pico-pip, Biotrack) after being mist-netted during the night in the chick-rearing period,

[1] Also referred to as Global Location Sensor (GLS) tag.

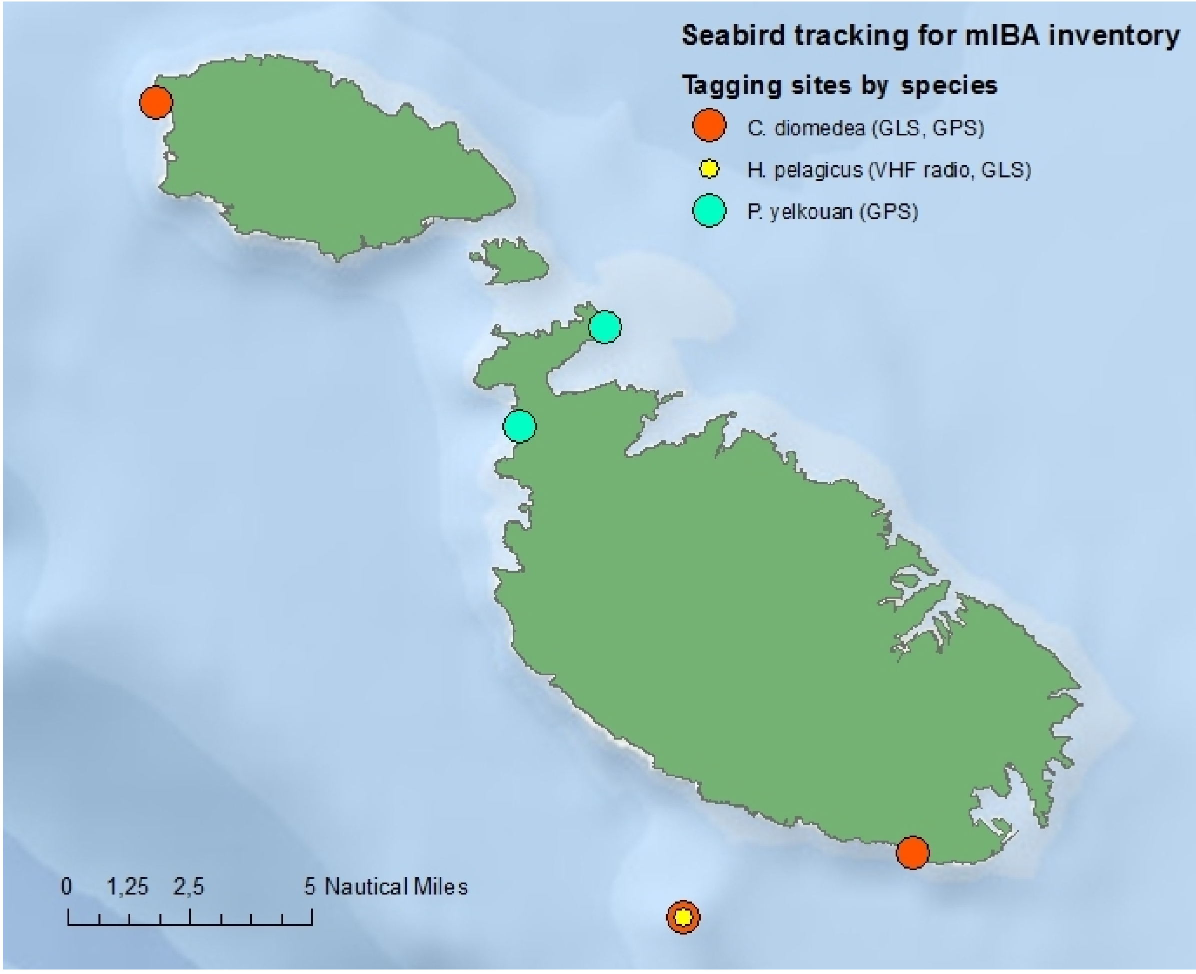

Fig. 2: All tagging site locations of the project in the Maltese islands by species and types of tracking devices used.

2.7. Monitoring seabird colonies and seaward extensions

Seabird monitoring including capture-mark-recapture and land based observations was carried out in and in front of selected colonies. Land-based seabird counts were carried out at a minimum of three sites once per month, from March to September, two to three days after the full moon, during the 2012 and 2013 breeding seasons. As *C. diomedea* was the only seabird that could be counted from land in representative numbers, we relied on the seawards extension buffers for all three seabird species and did not take the results of the land-based observations into account when modelling seabird distribution for the mIBA inventory.

We used published colony areas and breeding pair numbers (Raine et al. 2009, Sultana et al. 2011, Borg, J.J. in MSFD Initial Report on Seabirds 2012, together with own, unpublished data) as the basis to create species-specific maps for all colonies, including seawards extension buffers. Buffers used were 1 km for *Hydrobates pelagicus*, 4 km for *Calonectris diomedea* and 7 km for *Puffinus yelkuoan* (see Fig. 5-7).

2.8. Acquisition of oceanographic data for the modelling

Bathymetry line data of the Maltese EFZ (Fig. 3) were plotted on a raster of 4km by 4 km, see below). For the same raster we calculated distance to coast.
Raster data on the monthly averages of Sea Surface Temperature during the day and Chlorophyll-A (see examples on maps in Fig. 4) were downloaded for the relevant area and relevant months (December 2011 to December 2013) from:
(*http://coastwatch.pfeg.noaa.gov/browsers/cwbrowser_global180.html*).
In detail:
SST, Aqua MODIS, NPP, 0.05 degrees, Global, Daytime, Science Quality; Chlorophyll-A, Aqua MODIS, NPP, 0.05 degrees, Global, Science Quality
Where datasets were not available from NOAA (SST for June 2013; ChlA and SST from October to December 2013), we used datasets provided by OCEANCOLOR:
(*http://oceancolor.gsfc.nasa.gov/cms/*).

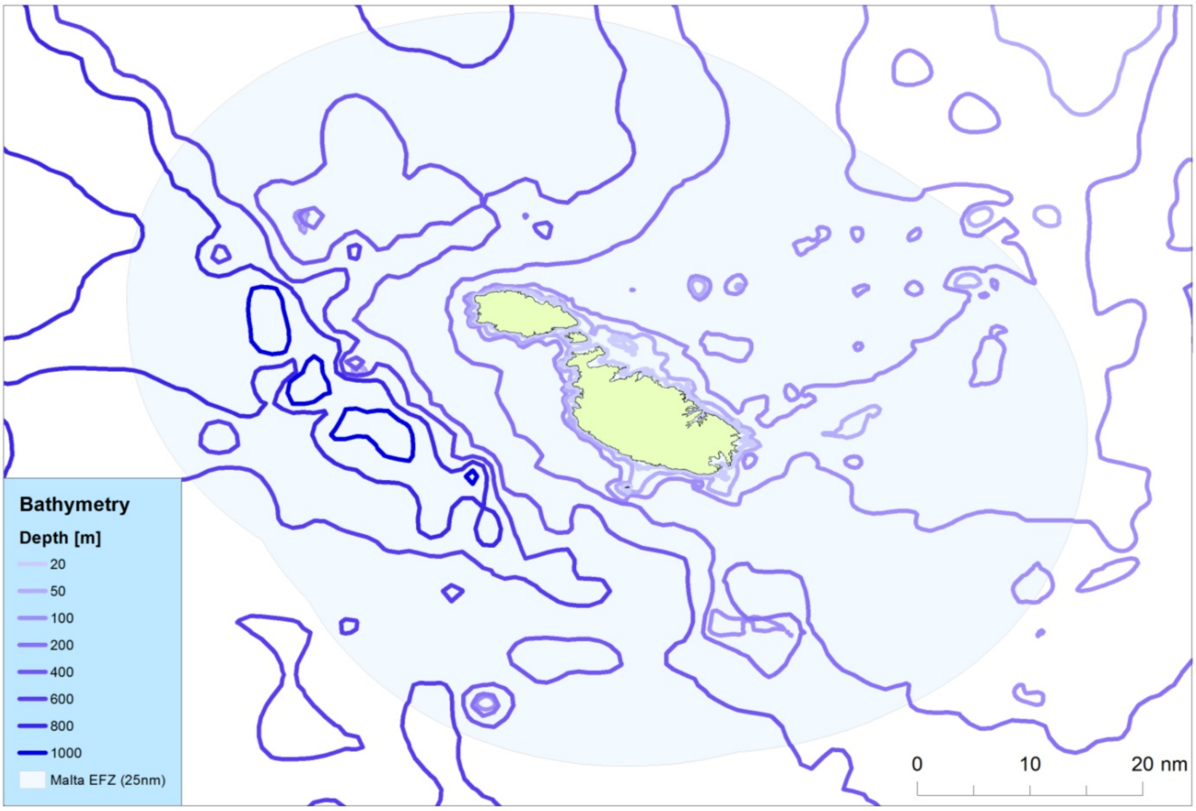

Fig. 3: Bathymetry data for the Maltese EFZ (25nm). Data were plotted on centres of grid cells with other oceanographic data prior to modelling.

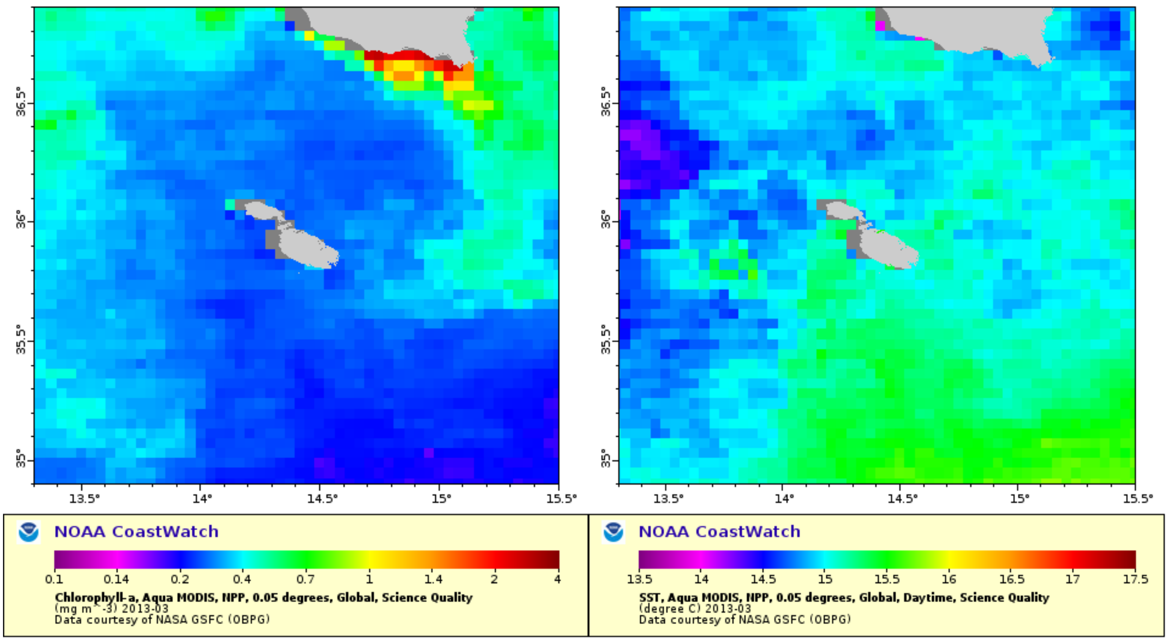

Fig. 4: NOAA raster data of the area, examples for monthly averages Chlorophyll-a (left), Sea Surface Temperature (right).

Sea Surface Height data (altimeter products) were produced by Ssalto/Duacs and distributed by Aviso, with support from Cnes*:*
(*http://www.aviso.altimetry.fr/duacs/*).
Data were downloaded from open-access sources free of charge.

2.9. Data processing (ArcGIS database)

All vessel-based observation data were entered in a database (PARADOX 11.0, 2003) and processed further in Excel 2007 before they were imported into an ArcGIS database (ArcGIS 10.2 for desktop).
In preparation for the modelling, all vessel-based survey data for the three relevant species including the survey effort (monthly, area surveyed), bathymetry, distance to land, monthly SST, monthly ChlA and SSH were plotted in ArcGIS on centres of a rectangular grid (top left: 36.9 N, 13.3 E, bottom right: 34.9 N, 15.5 E; 55 x 50 cells, cell-size: 4 km x 4 km).

2.10. Modelling seabird distribution in the Maltese EFZ (25nm)

2.10.1. Modelling from vessel-based surveys

The seabird distribution modelling from vessel-based survey data followed the methods described in Oppel et al. (2012). Where possible, oceanographic variables were used as published there. All modelling was carried out by Matthew Caroll and Steffen Oppel (RSPB) using the free software R (The R Foundation for Statistical Computing). The only variables that could not be used were the ocean fronts variables (due to data access limitations) and SST anomaly (because the data were not available for the appropriate time period). Because surveys were carried out every month, a ‘month’ predictor was used instead of ‘season’. Oceanographic variable values were calculated from the raw variables for SST and ChlA. These were calculated for every map cell as follows:

- The mean value of the variable was calculated over the three preceding months (e.g. for June 2012, the mean included March, April and May 2012). This was done to account for lags in the response between conditions and the birds' distributions.
- A temporal gradient was calculated as a percentage. This was calculated over the three preceding months and the focal month. It was calculated as ((maximum value-minimum value)*100)/maximum value. It indicates the degree of change over that period.
- A spatial gradient was calculated as a percentage. This was calculated using data just from the focal month. For each cell, a 20km x 20km window was used with the focal cell in the centre; within this window, the gradient was calculated as ((maximum value-minimum value)*100)/maximum value. This indicates the degree of change within that area. This spatial gradient was also calculated for bathymetry.

For the modelling, bird observation data were split into training and testing data in a 70:30 ratio. To do this, data were first split into presences and absences. A random 70% was selected from each, then recombined into a single training data set. The remaining 30% were used for testing model performance. This approach was taken to ensure that the proportion of presences and absences remained consistent in each dataset.

Using the training data, models were fitted describing presence/absence as a function of the oceanographic variables. The following five model types were fitted:

- Boosted regression tree
- Random Forest
- GLM (Generalized Linear Model with subsequent stepwise selection of variables using Akaike Information Criterion AIC)
- Generalized Additive Model
- Maximum Entropy Model

All models described the observed presence/absence as a function of the following predictor variables:

- Year, month
- Latitude, Longitude
- Area of cell surveyed
- Bathymetry spatial gradient
- Distance to coast
- ChlA mean from preceding 3 months, ChlA temporal gradient, ChlA spatial gradient
- SST mean from preceding 3 months, SST temporal gradient, SST spatial gradient
- Sea surface height

The performance of each model was tested by calculating a range of test statistics, primarily using the area under the curve (AUC) from a ROC curve. The quality of this prediction ranges from zero to one, with one being perfect prediction. The testing was carried out for the testing datasets (i.e., the 30%) to give a better indication of the model performance in comparison to a testing that is based on the same data the models were fitted with.

Based on the AUC scores, a weight was calculated for each model type (weights sum to 1, and indicate the relative performance of each model – a higher value indicates better performance).

For the final ensemble predictions, predictions were made from each model and weighted using the model weights, then summed. This means that a better-performing model contributes more to the final ensemble prediction.

The same approach was also taken for modelling abundance instead of presence/absence. For this approach, models were Boosted Regression Trees, Random Forest, Generalized Linear Model, Generalized Additive Model, and a Zero-inflated Poisson model. However, model performance scores (indicated by the correlation between predicted and observed abundances) were low, indicating that models could not reliably predict abundances. Also, not all models would fit for Storm-petrel. Therefore, presence-absence and not abundance models were used in the final zonation exercises (see below) for the three different species.

2.10.2. Modelling seabird distribution from tracking data

The modelling of the seabird distribution from GPS- and GLS-tracking data was carried out by Maria Dias (BLI), following a protocol published in BirdLife International's Marine IBA Toolkit (BirdLife International 2010), using a compilation of customized R-scripts (http://www.r-project.org/) described in a forthcoming paper (Lascelles et al. 2016). Here, we present a short description of the procedure:

The tracking analyses applied here identify areas based on regular use by high proportions of trips. Using measures of the data's representativeness, estimates and assessments of site population can be determined and used to assess sites that qualify against IBA criteria and thresholds. If the tracked birds belong to a small population (less than 1%) of a non-threatened species, the hotspot areas identified with this approach would not meet any of the IBA criteria. Therefore, we did not include this exercise for the radio-tracking data of *Hydrobates pelagicus* from Filfla. The approach is based on the identification of the geographic areas most intensively used by a certain species, using Kernel Density Estimation (KDE; e.g. Wood et al. 2000). Simple dataset with a unique identifier for each individual bird and colony with a split into single foraging trips, including the locations provided by the tracking devices (latitude and longitude, in decimal degrees), corresponding dates and times (all in GMT) are used for the analyses to locate the areas which are most intensively used by the tracked birds. In a next step, the representativeness of the tracked birds is assessed in relation to the entire population. Sites used by a higher proportion of birds are highlighted and finally, the proportion of the species using the several sites identified, based on the population estimations in each colony, is calculated. On a global scale, the sites meeting the IBA criteria are proposed mIBAs (http://www.birdlife.org/datazone/info/ibacritglob).

For a more detailed description of the analyses used read also: Methods for identifying marine IBAs using seabird tracking data, Birdlife International, 2015, Version: 25th September.

Data from GPS (Global Positioning Systems) devices have a much higher accuracy (several meters) than other tracking devices. Therefore, only tracking data from

GPS-devices were used for the seabird distribution modelling to identify the important areas used by Maltese seabirds within the Maltese EFZ.

Due to lower accuracy (scale default 186 km, i.e. the error of the device, Phillips et. al, 2004) but longer lifespan, GLS-devices (geolocators) were used to detect the birds' large scale movements during the annual cycle and to detect the whereabouts during the non-breeding season.

2.10.3. Prioritising areas based on multiple sources of information

To identify priority areas for conservation within the Maltese EFZ, we used our predicted probabilities of occurrence from shipboard survey data combined with information on the location of the seabird colonies of the three species and the information derived from tracking data in the spatial prioritization algorithm 'Zonation' (Moilanen, 2007; Moilanen *et al.*, 2005), which has been used successfully in large-scale marine applications (Leathwick *et al.*, 2008; Oppel *et al.*, 2012). The 'Zonation' algorithm ranks areas according to their priority for conservation and is thus ideally suited for conservation planning. The ranking is achieved by sequentially removing grid cells from the study area that have low predicted probabilities of occurrence, and thus the lowest conservation value. The sequential removal also considers proximity of cells to areas of high conservation priority and thus results in a spatially constrained set of priority areas most relevant for conservation (Moilanen, 2007; Moilanen *et al.*, 2005). The approach is designed for the use with multiple species, and marine reserve designation generally requires consideration of multiple species (Ainley et al. 2009; Nur et al. 2011). Here, we used predicted probabilities of occurrence for the three species (*Puffinus yelkouan, Calonectris diomedea* and *Hydrobates pelagicus melitensis*) separately, in each of 8 months (March-October), plus the location of known breeding colonies of each species, and information from tracking data for the two shearwater species during incubation, brood-guarding, and the post-guarding chick-rearing period.

For each of the three data sources (predictions derived from vessel-based survey data, colony locations, tracking data), we created monthly input data for spatial prioritisation reflecting the temporally variable importance of marine areas for each of the three focal species over the course of the breeding season. While monthly occurrence probability could be modelled explicitly with the vessel-based survey data, we interpolated colony and tracking data to match the temporal resolution of the vessel-based survey data. Each known seabird colony was buffered with a radius of 7 km for *Puffinus yelkouan*, 4 km for *Calonectris diomedea*, and 1 km for *Hydrobates pelagicus melitensis*, based on typical aggregation and rafting areas around colonies (Fig. 5-7). These buffer radii were discarded outside the breeding season, i.e. for *Puffinus yelkouan* from August onwards. Tracking data were also interpolated to provide monthly distribution files, with data derived from tracking *Calonectris diomedea* during incubation considered representative for the months of May and June, brood-guarding distribution representative for the month of July, and post-guarding distribution representative for August-October. For *Puffinus yelkouan*, tracking data during brood guarding were considered representative for April, and tracking data from the post-guarding stage were considered representative for May through July.

To avoid emphasising the importance of those seabird colonies from which birds were tracked with GPS devices, which might introduce bias due to the accessibility of birds and the amenability for tracking work, we excluded information derived from tracking data from within the buffer radius around each known colony. This ensured that the tracking data provided information mostly for pelagic foraging areas rather than for the known location of colonies.

We weighed all three sources of information equally in our spatial prioritisation.

We used a simple core-area prioritisation in Zonation 2.0 to guarantee the retention of high-quality areas that were either consistently important in all months or had outstanding importance in some months. We ran the algorithm without boundary quality penalties and a boundary length penalty (BLP) of 0.01 to provide the biologically most detailed map of hotspot areas for each of the three species.

3. Results

3.1. Seabird colonies, breeding pair numbers and seaward extensions

3.1.1. Yelkouan Shearwater *Puffinus yelkouan*

The Yelkouan Shearwater is currently IUCN-listed as 'Vulnerable' (BirdLife International Species Factsheet 2015). Therefore the mIBA category A1 applies. All known Maltese Yelkouan Shearwater colonies are of a significant size regarding their relevance for the conservation of the species.

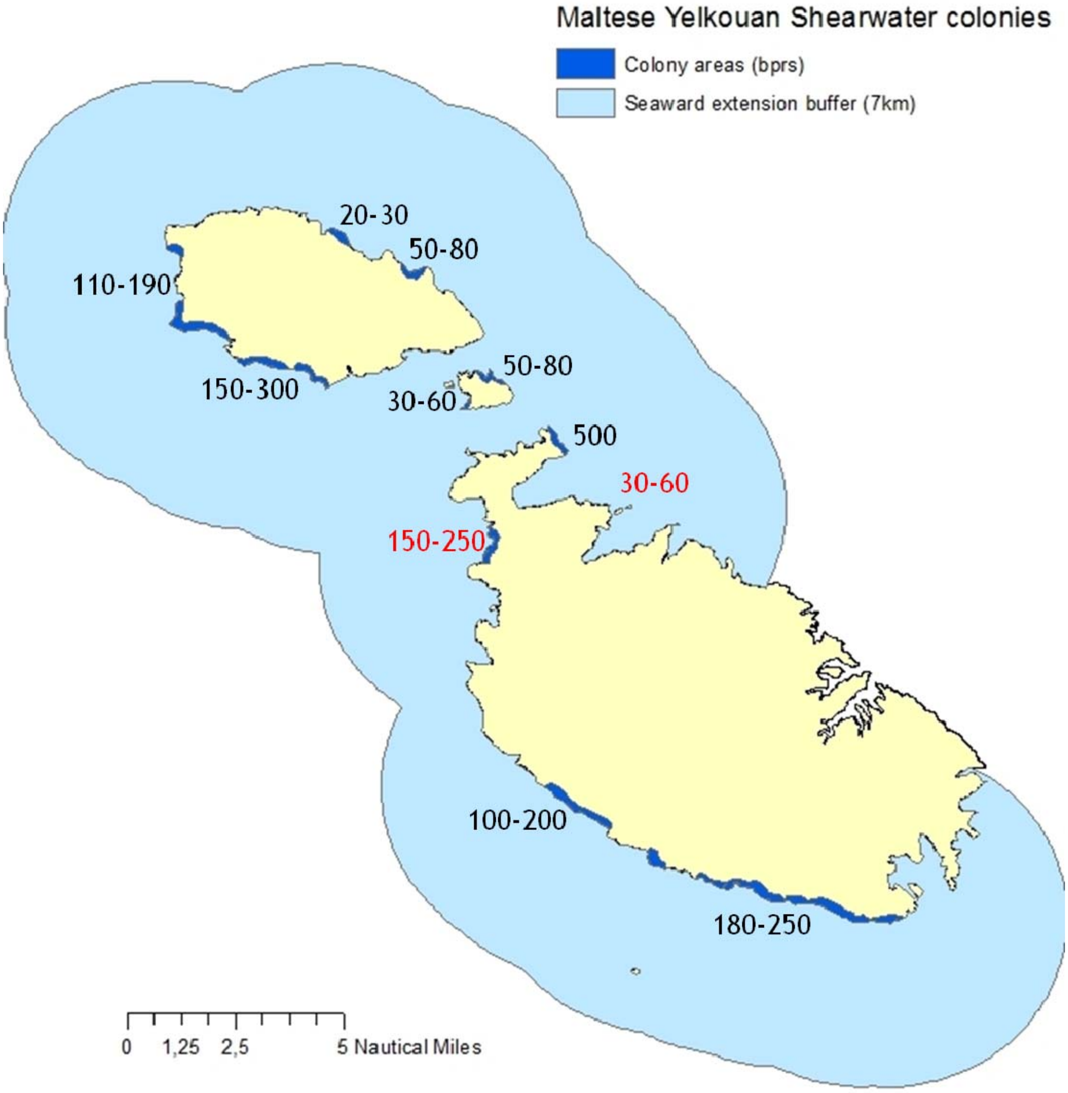

Fig. 5: *Puffinus yelkouan*, areas, breeding pair number estimates and seawards extension buffers (7km) for all Maltese colonies (breeding pair estimates for re-discovered or recently assessed colonies on Selmunett and in Majjistral shown in red).

3.1.2. Scopoli's Shearwater *Calonectris diomedea*

In a Meta-population approach, we consider the various sub-colonies stretched along the western and south-western coast of Gozo and Malta to form two large colonies: (I) San Dimitri to Ta' Cenc, (II) Ras il-Pellegrin to Benghajsa. Regarding breeding pair numbers, to both of them the Congregation Category (A4ii) and the relevant numbers criterion (≥ 1% of global population threshold) apply. Only the relatively small colonies on Filfla, on Comino and at Rdum tal-Madonna do not fall under the A4ii criterion.

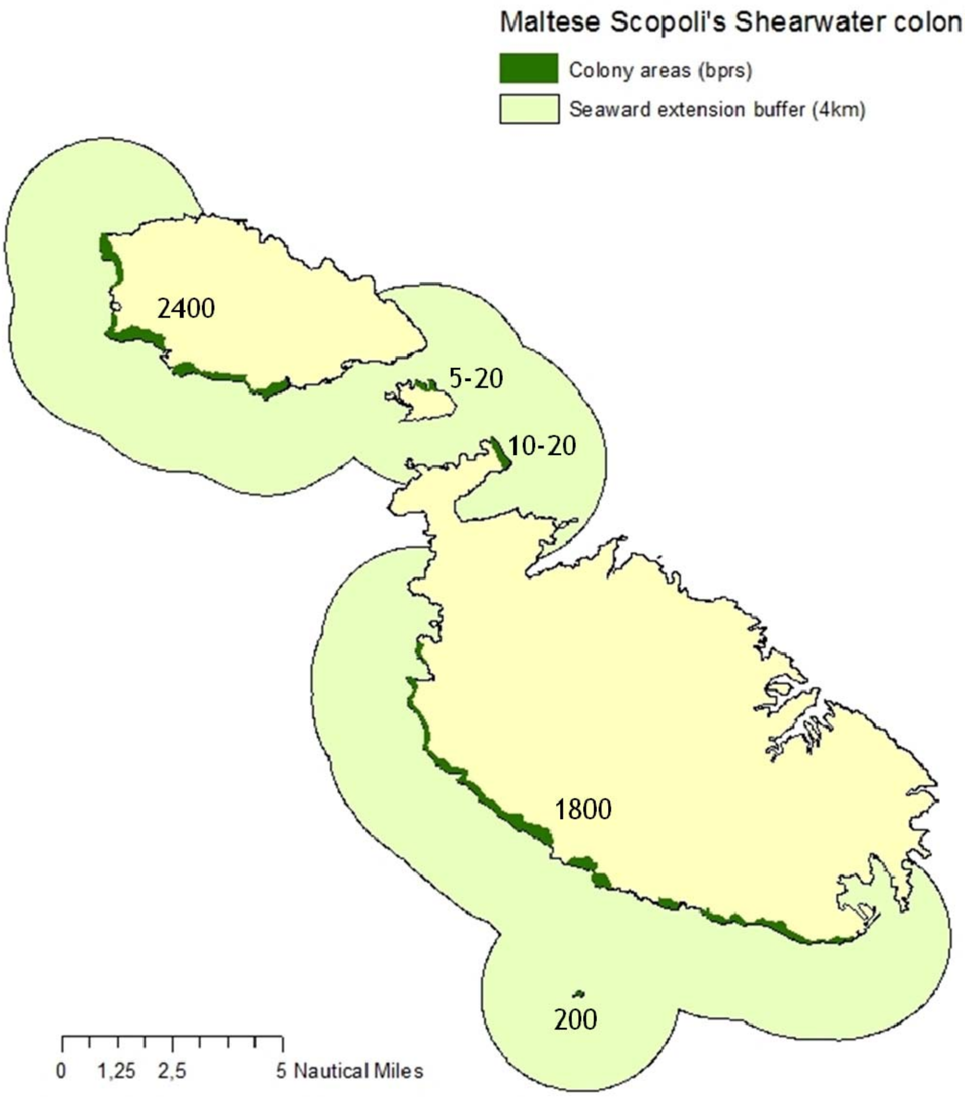

Fig. 6: *Calonectris diomedea*, areas, breeding pair number estimates and seawards extension buffers (4km) for all colonies of the Maltese archipelago (aggregated numbers for meta-colonies on Gozo and Malta).

3.1.3. Mediterranean Storm-petrel *Hydrobates pelagicus melitensis*

The Mediterranean Storm-petrel *Hydrobates pelagicus melitensis* is currently listed as a subspecies of the European Stormpetrel *H. pelagicus* (Clements et al. 2015). BirdLife International lists *Hydrobates pelagicus* of 'Least Concern' (BirdLife International Species Factsheets 2015). According to past (Sultana et al. 2011) and current (SPACECAP modelling) population estimates, Filfla is the only site in the Maltese Archipelago, to which the Congregation Category (A4ii) and the relevant numbers criterion (≥ 1% of global population threshold) apply. However, two new colonies were discovered during the project and need further assessment.

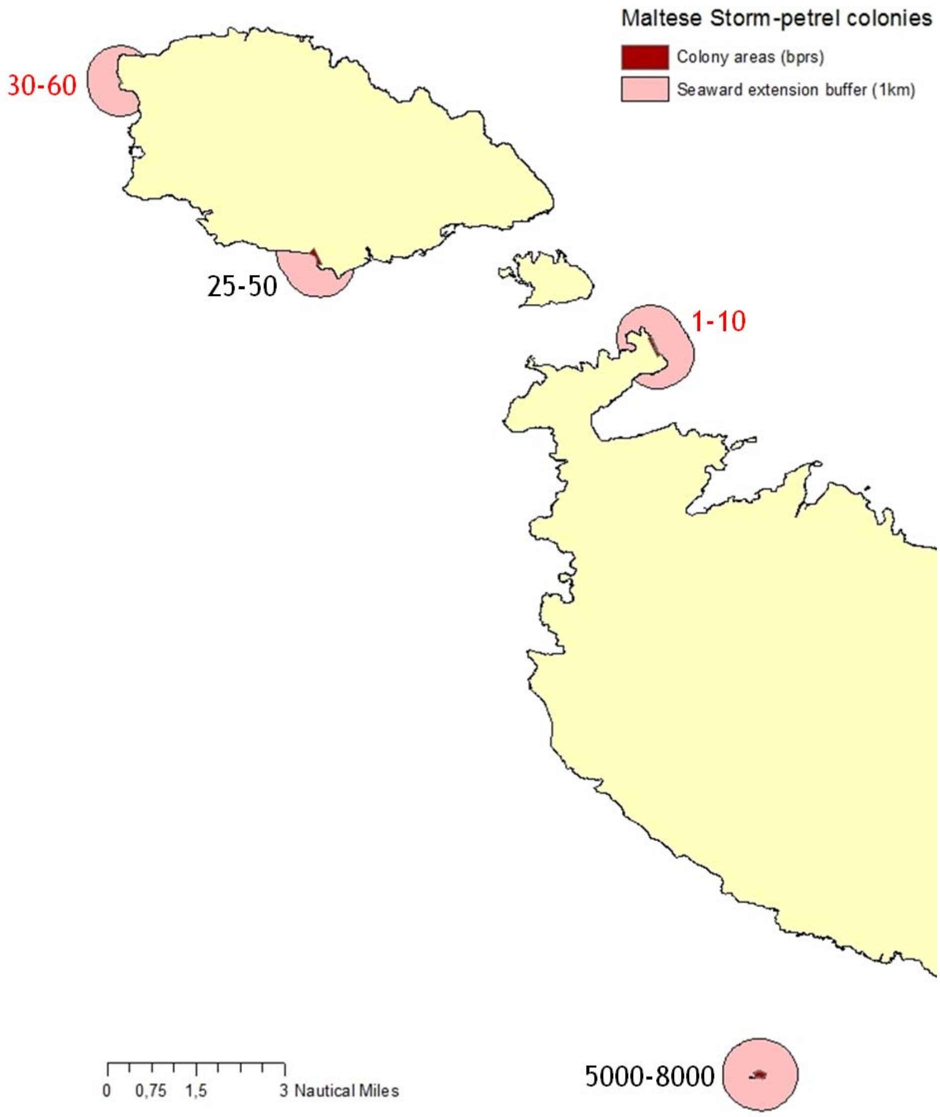

Fig. 7: *Hydrobates pelagicus*, areas, breeding pair number estimates and seawards extension buffers (1km) for all Maltese colonies (breeding pair estimates for newly discovered colonies at Rdum tal-Madonna and San Dimitri, Gozo shown in red).

3.2. Results from boat based observations

Figures 8-10 present as raw data the number of birds per Poskey (5min interval) of the three target species counted along the 28 transect lines in the Maltese EFZ, during the 8 month periods (March to October) in 2012 and 2013.

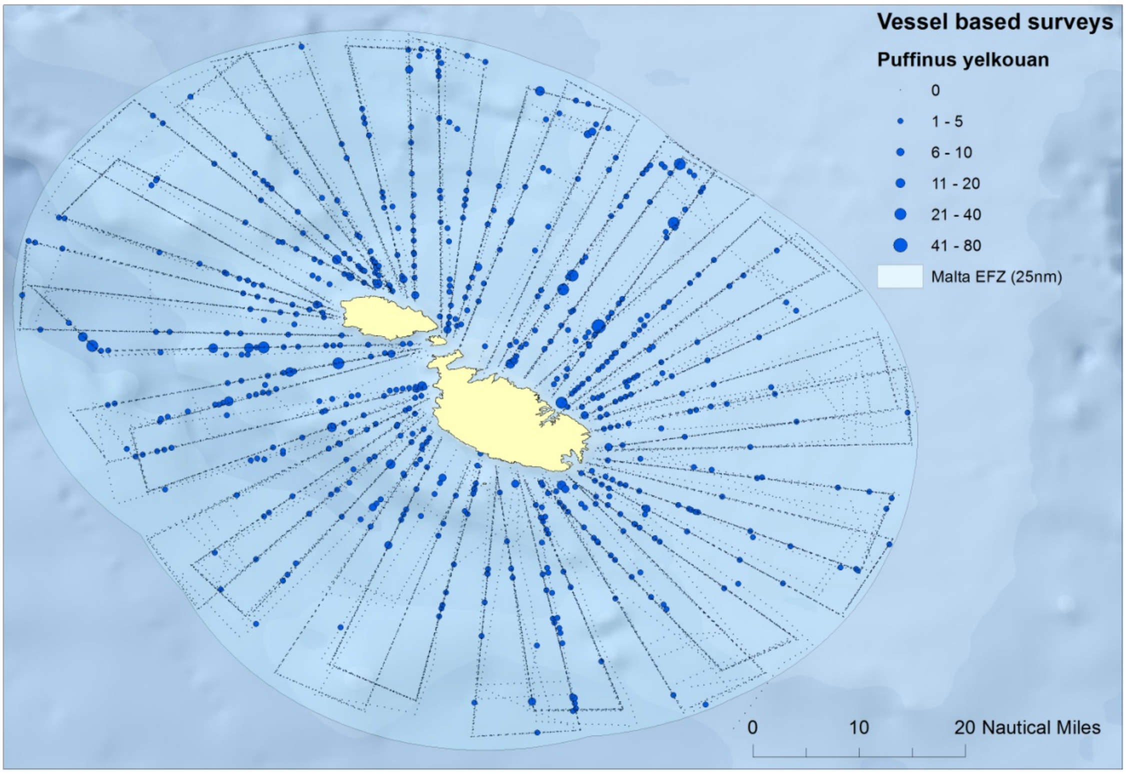

Fig. 8: Raw distribution numbers of Yelkouan Shearwaters *P. yelkouan* counted during vessel based surveys in the Maltese EFZ in 2012 and 2014.

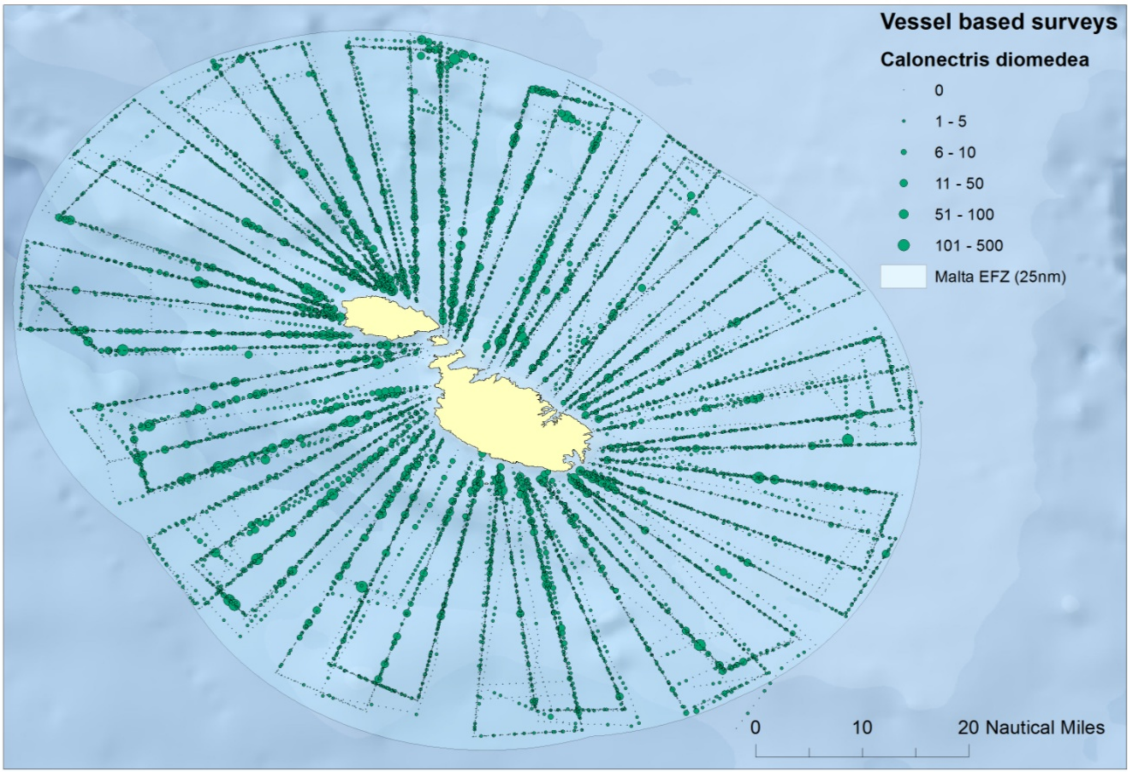

Fig. 9: Raw distribution numbers of Scopoli's Shearwaters *C. diomedea* counted during vessel based surveys in the Maltese EFZ in 2012 and 2014.

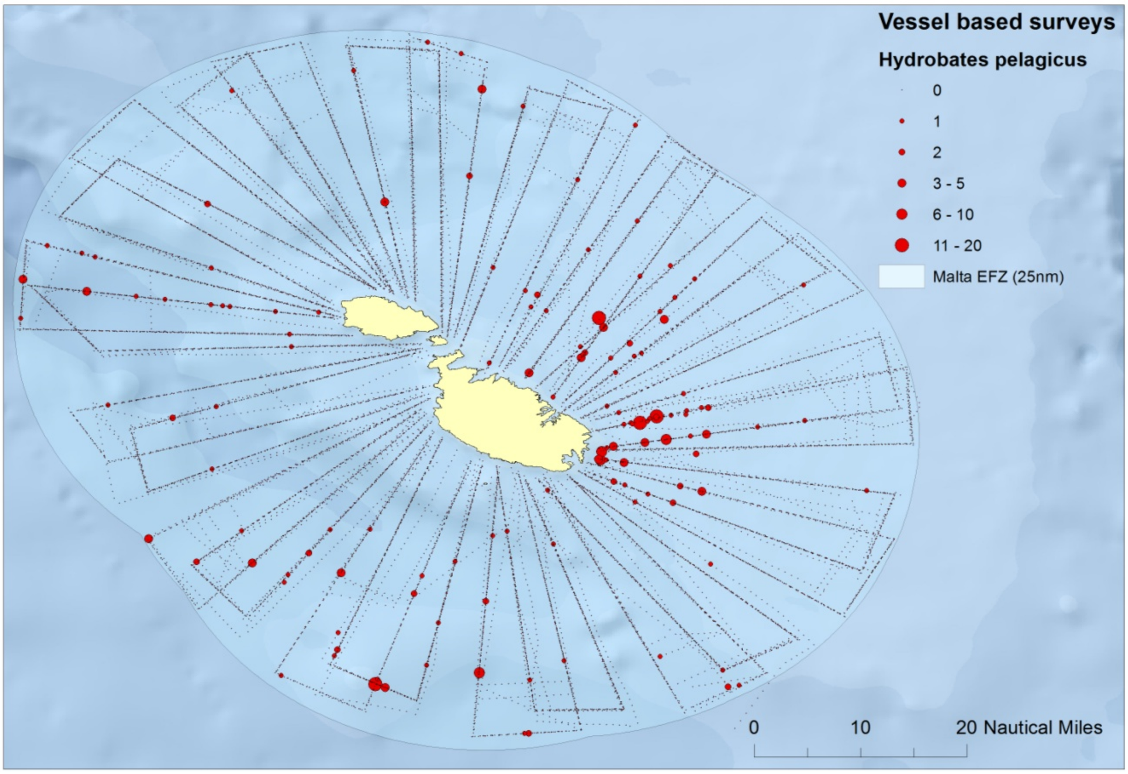

Fig. 10: Raw distribution numbers of Mediterranean Storm-petrels *H. pelagicus melitensis* counted during vessel based surveys in the Maltese EFZ in 2012 and 2014.

3.3. Results of GPS-tagging *P. yelkouan* and *C. diomedea*

Figure 11 and Figure 12 show all GPS-tracks of adult *P. yelkouan* and *C. diomedea*, tracked as part of the Malta Seabird Project differentiated by colony.

Overall, GPS-tagging of adult *Puffinus yelkouan* and *Calonectris diomedea* during three reproductive periods (2012-2014) revealed a total number of 280 foraging trips that were included into the analyses (see Tab. 1). Maps in figure 13 and figure 14 present the core areas used as the 50% Kernel Density Estimates for each of the two species separated by colony and reproductive stage.

Tab. 1: Number of GPS-tracks by species, colony location and reproductive stage.

Species	Colony	Reproductive stage	Tracks [n]
P. yelkouan	Majjistral	brood-guarding	10
P. yelkouan	Majjistral	post-guarding	15
P. yelkouan	Rdum Tal Madonna	post-guarding	30
C. diomedea	Filfla	incubation	13
C. diomedea	Filfla	brood-guarding	47
C. diomedea	Gharb	incubation	14
C. diomedea	Gharb	post-guarding	41
C. diomedea	Hal Far	incubation	63
C. diomedea	Hal Far	post-guarding	47

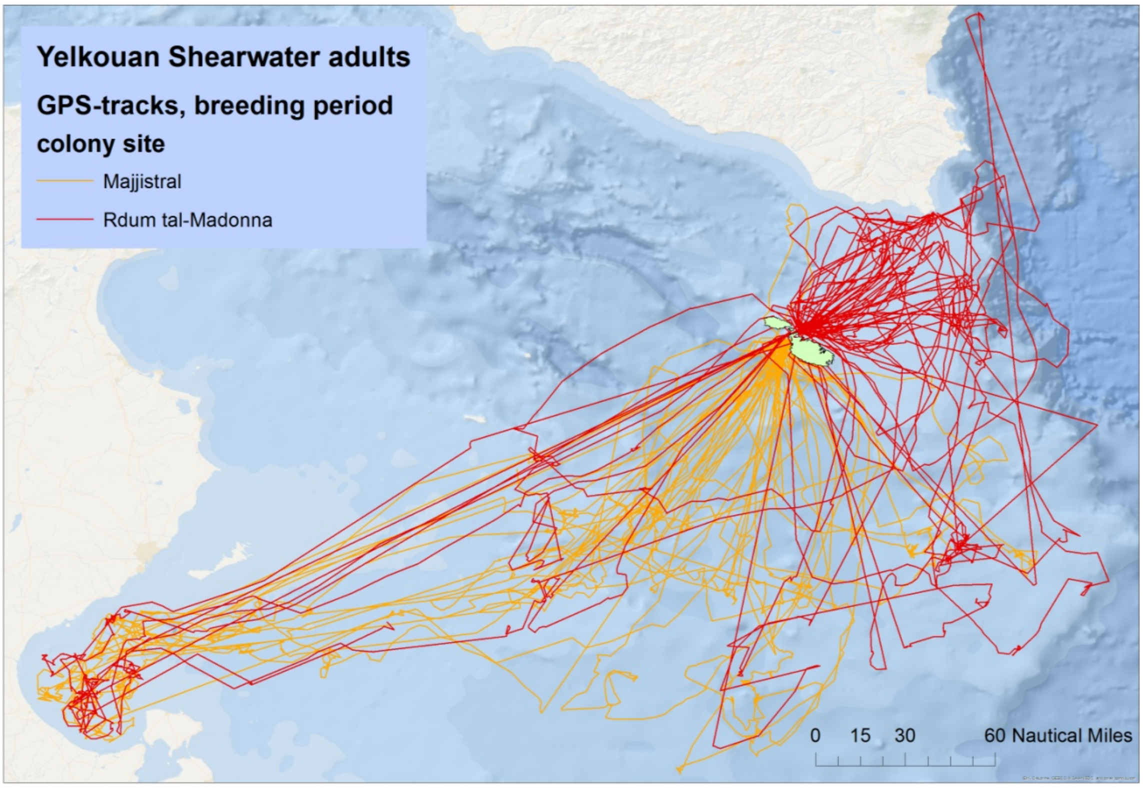

Fig. 11: GPS tracks of adult Yelkouan Shearwaters from two Maltese colonies, orange: Majjistral NHP, red: Rdum tal-Madonna.

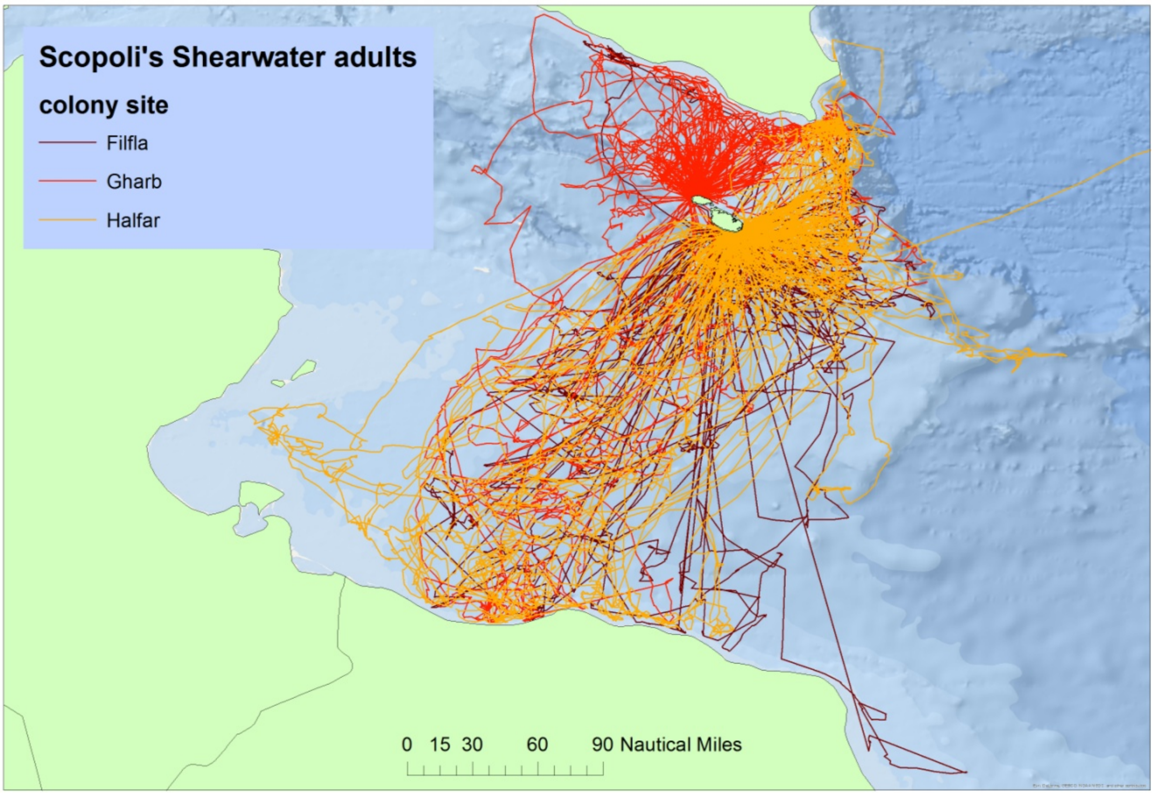

Fig. 12: GPS tracks of adult Scopoli's Shearwaters from three colonies of the Maltese islands, dark red: Filfla, light red: Gharb (Gozo), orange: Hal Far (Malta).

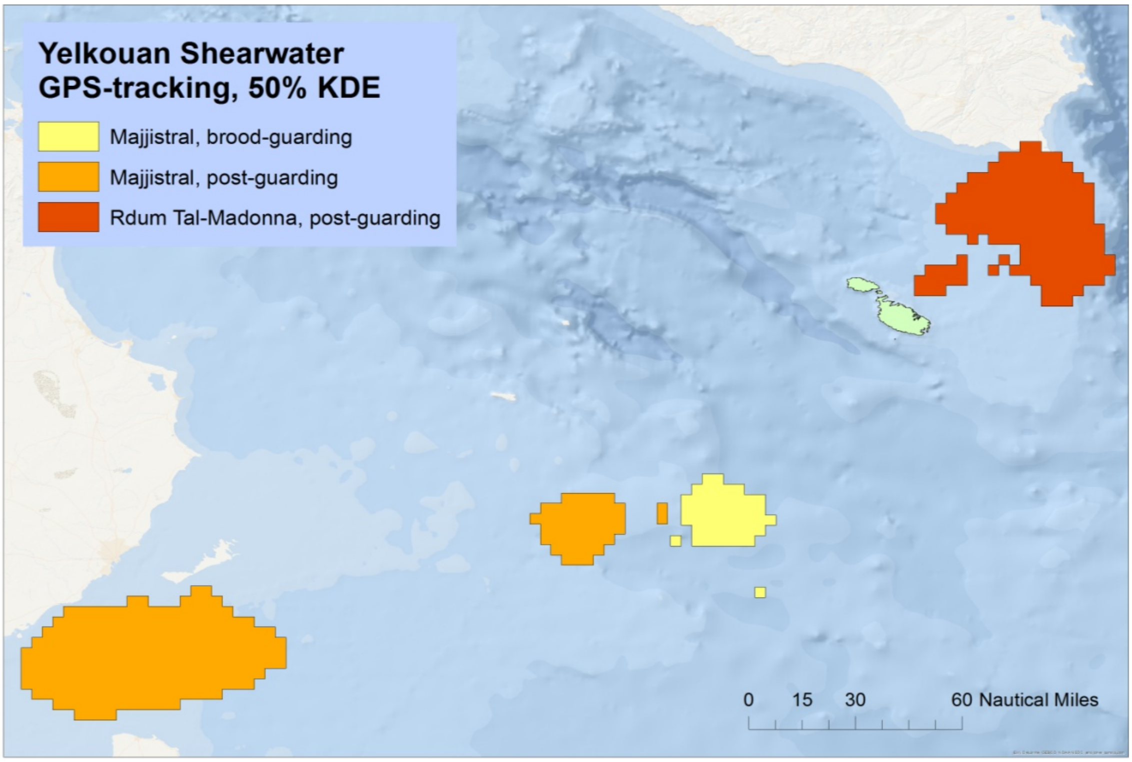

Fig. 13: Core foraging areas (50% KDE) of adult Yelkouan Shearwaters from GPS tracks. Birds from two different colonies and reproductive stages.

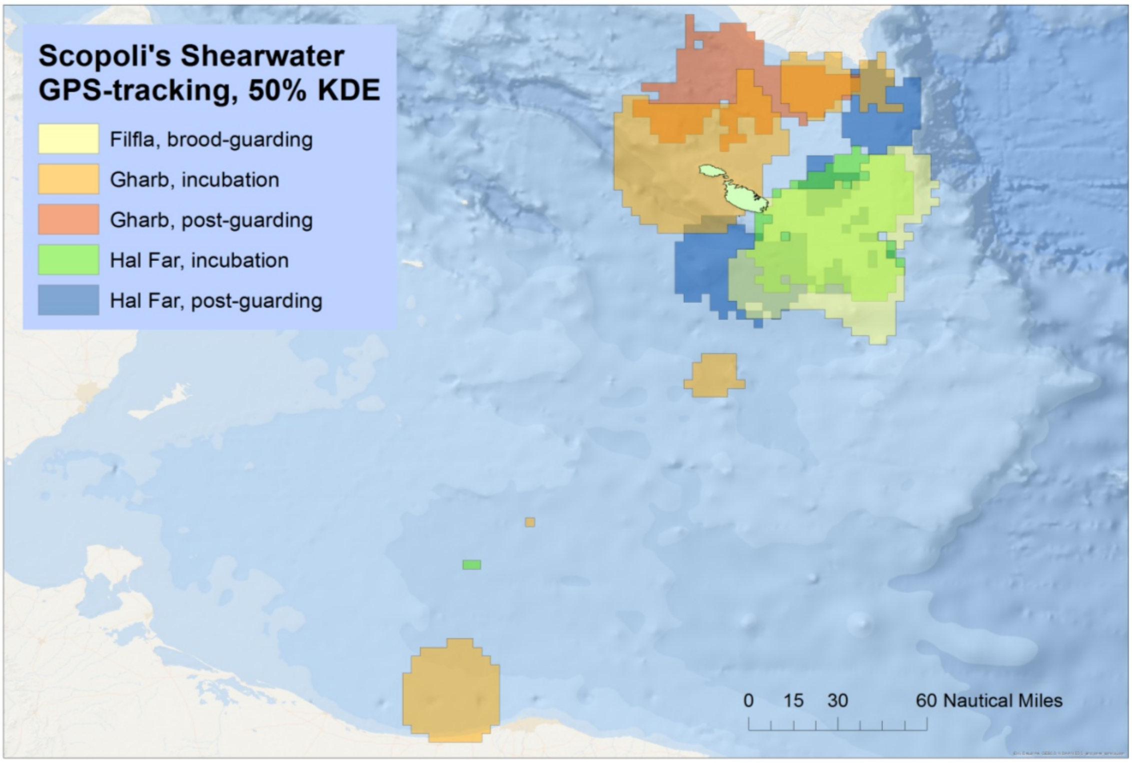

Fig. 14: Core foraging areas (50% KDE) of adult Scopoli's Shearwaters from GPS tracks. Birds from three different colonies and reproductive stages.

3.4. Results from GLS-tracking *Calonectris diomedea*

We recorded 20 complete migration cycles of adult Scopoli's Shearwaters *C. diomedea*, GLS-tagged at three different sites in the Maltese islands. The cleaned fixes are presented in Figure 15, while the main wintering grounds and areas used during the breeding season (KDE) are shown in Figure 16.

All GLS-tagged Scopoli's Shearwaters left the Mediterranean through the Strait of Gibraltar during the last week of October and the first week of November to winter in front of the Western African coast (Mauritania, Senegal, Gambia). Three females from Filfla continued their migration to winter further south in front of the Congo river mouth and off the coast of Angola and Namibia, respectively.

All birds returned into the Mediterranean in February to March, after having performed a large clockwise circle route through the Central Northern Atlantic.

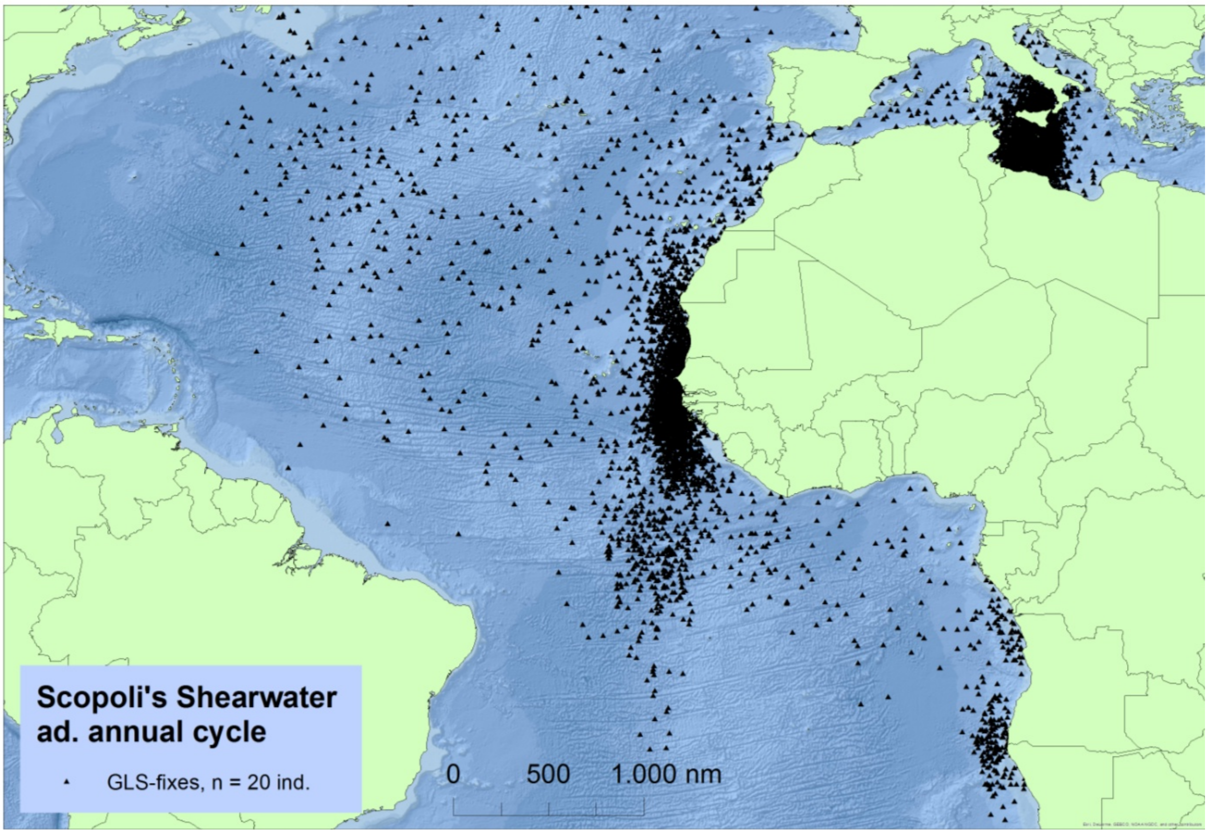

Fig. 15: Cleaned GLS-fixes of 20 adult Scopoli's Shearwaters of the Maltese islands during the annual cycle.

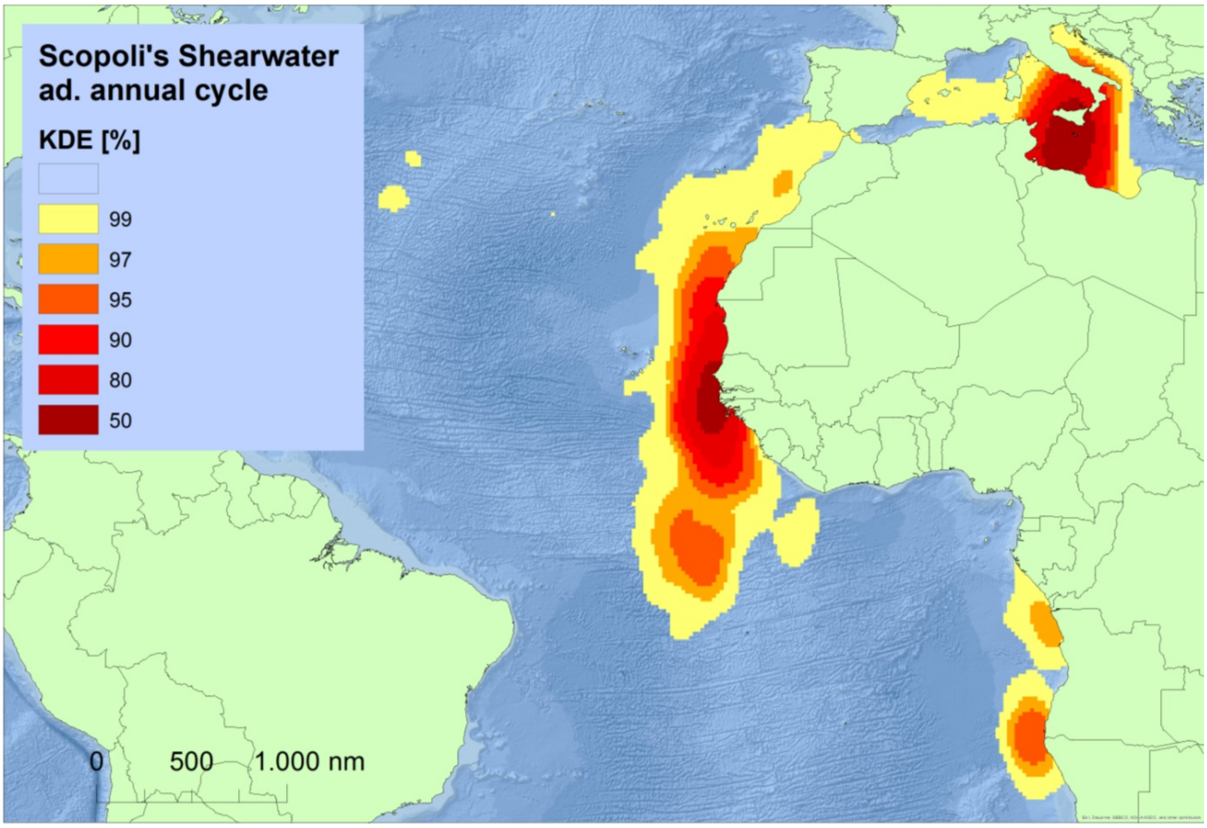

Fig. 16: Core wintering areas (and the breeding area) of Scopoli's Shearwaters, derived from KDE of GLS-fixes from 20 adult individuals from the Maltese breeding population.

3.5. Results from GLS-tracking *Hydrobates pelagicus melitensis*

Of the 35 Storm-petrels that had been equipped with SOI geolocators, one was caught back after one year, while another one was caught back after two years. Both birds were in good body conditions, the devices were still properly attached, but had failed and no data could be recovered.

3.6. Results from radio-tracking *Hydrobates pelagicus melitensis*

We registered 183 radio-fixes from 43 individuals out of the total of 76 radio-tagged Storm-petrels. The majority of 114 signals (30 individuals) were picked up from the Cessna 172 aircraft, 40 signals (17 individuals) were picked up from the research yacht while performing vessel-based surveys (ESAS), and 29 signals (19 individuals) were picked up from land, mainly during mist-netting sessions on Filfla in nights post-tagging. Figure 17 shows the transect lines flown with the Cessna aircraft during the radio-tracking flights, as well as the locations from where the signals were picked up, differentiated by platform: plane, boat and land, respectively.

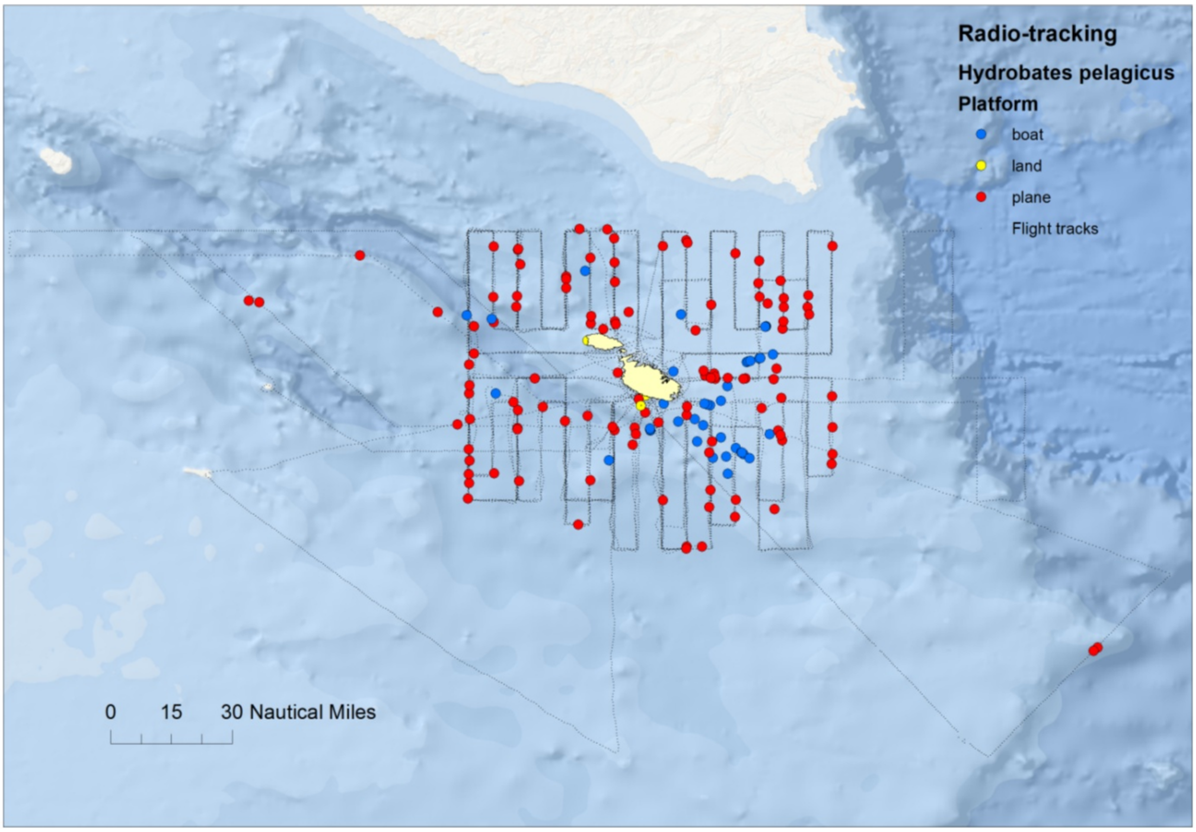

Fig. 17: Radio-tracking flight surveys (black lines) carried out during two Storm-petrel chick rearing periods (2012 and 2013) and locations were radio-signals were picked (dots), red: from plane, blue: from the research yacht, yellow: from land.

3.7. Results from prioritisation and zonation modelling

Figure 18-20 present the results of the prioritisation modelling of core areas of seabird distribution inside the Maltese EFZ, including the zonation approach with a moderately low 0.01 border length penalty. Shown are the 10% and 15% core areas within the Maltese EFZ resembling the areas of highest importance for each of the three species.

For the Maltese breeding population of *P. yelkouan*, three main hotspot areas are identified, one around Gozo, including the Gozo Channel and along the west- and southwest coast of Malta, a second one offshore in the northeast of Malta and a third one offshore in the southwest of Malta (see Fig. 18). For the Maltese breeding population of *C. diomedea*, we identified five priority areas in the Maltese EFZ, the first one around and north of Gozo and a second one along the west and southwest coast of Malta. Additionally to that, three offshore areas are found east, southeast and south of Malta (see Fig. 19). For *H. pelagicus melitensis* breeding in the Maltese islands the core area is covering a coastal zone around Malta and a larger area of sea east of the island. Additionally, a small area is found in the Pantelleria channel northwest of Gozo and several fragmented squares are spread over an area southwest of Malta (see Fig. 20).

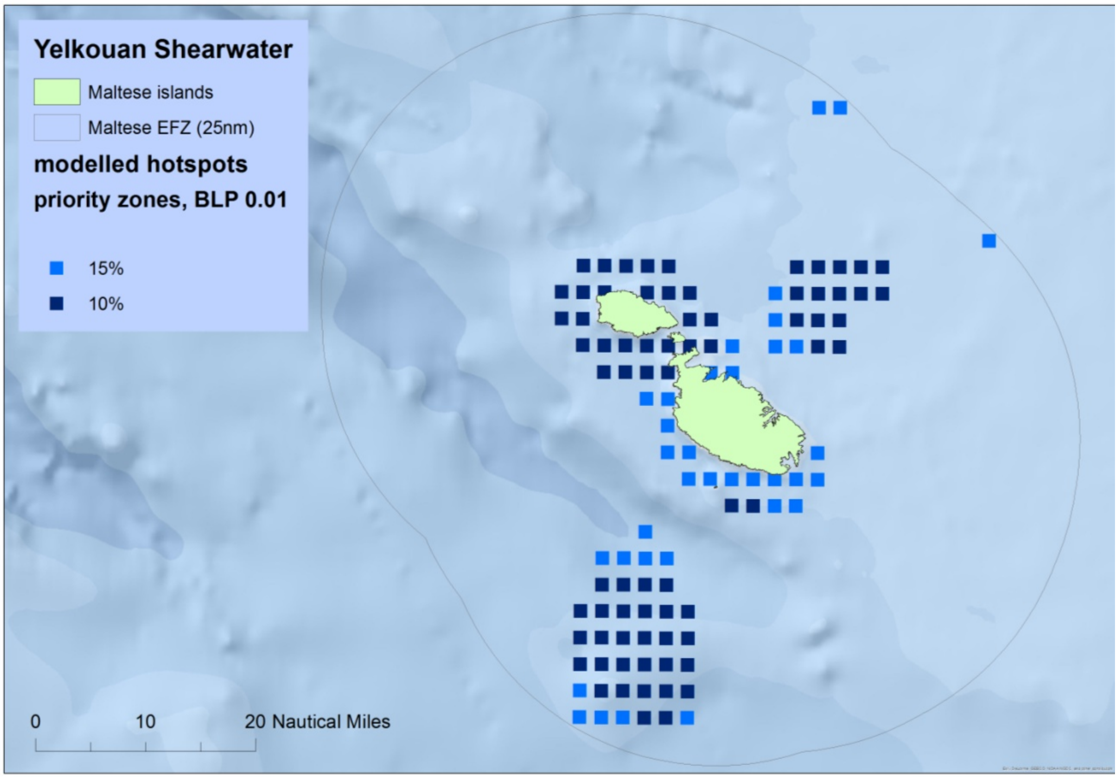

Fig. 18: Priority areas for *P. yelkouan* within the Maltese EFZ, dark blue squares: 10%, light plus dark blue squares: 15%.

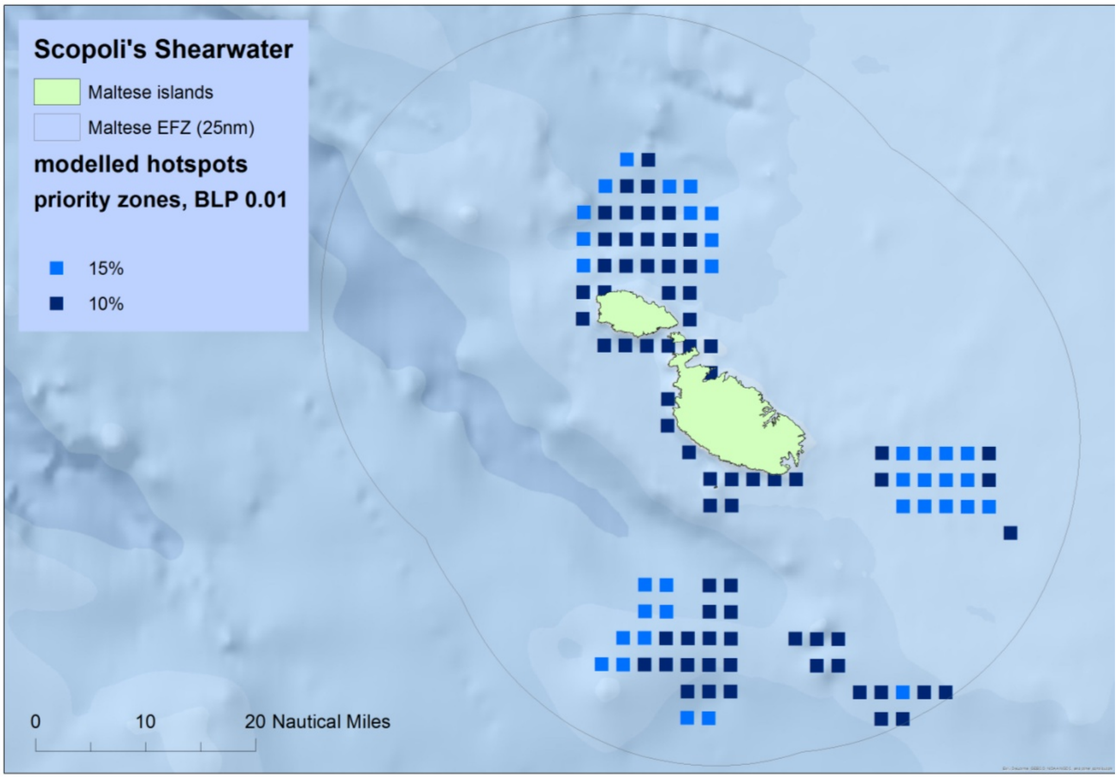

Fig. 19: Priority areas for *C. diomedea* within the Maltese EFZ, dark blue squares: 10%, light plus dark blue squares: 15%.

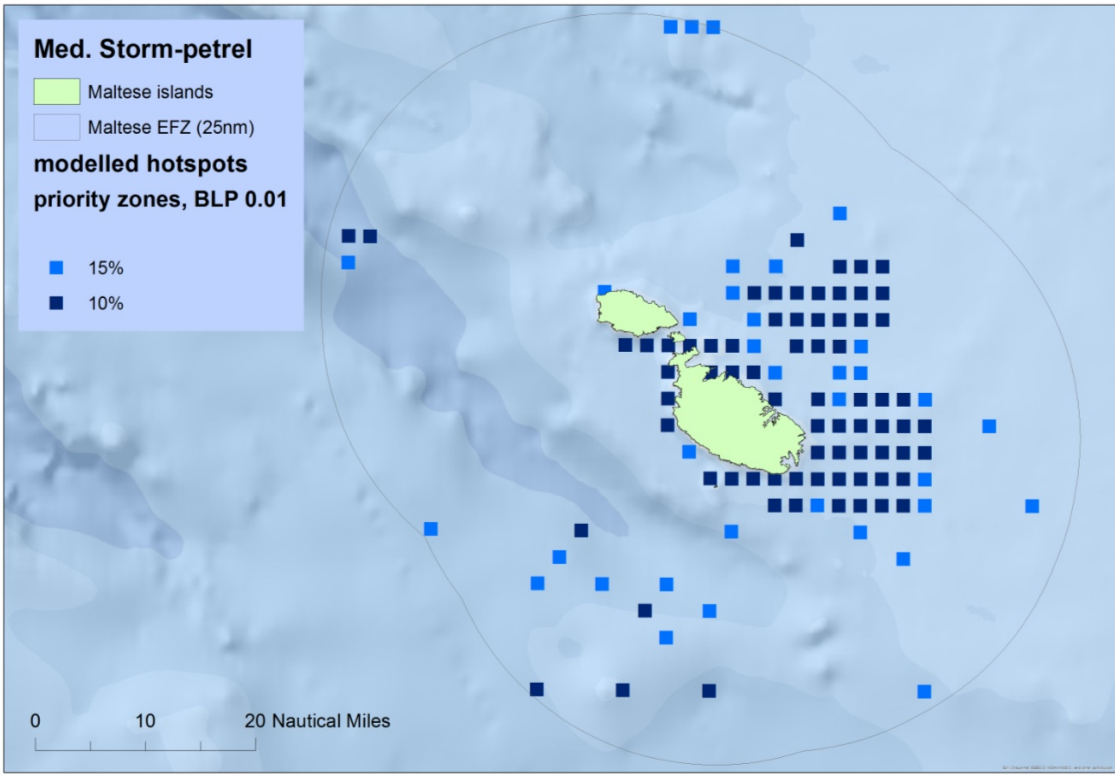

Fig. 20: Priority areas for *H. pelagicus melitensis* within the Maltese EFZ, dark blue squares: 10%, light plus dark blue squares: 15%.

3.8. Proposed marine Important Bird Areas in Maltese waters

On the basis of the above-modelled mentioned priority areas for the three species, we created the proposed marine Important Bird Areas as polygons, along and diagonal to the raster lines, discounting single priority raster squares on the grid (see Fig. 21-22).

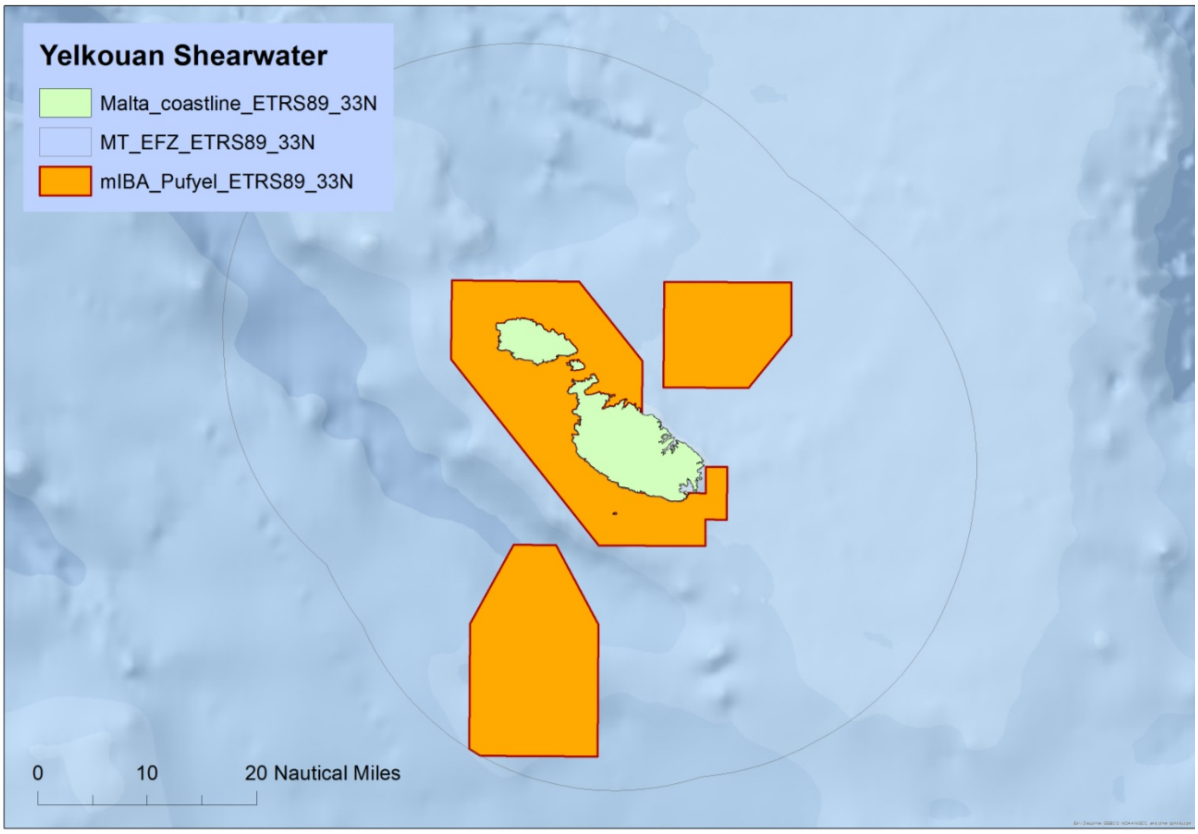

Fig. 21: Proposed marine IBAs for *P. yelkouan* within the Maltese EFZ.

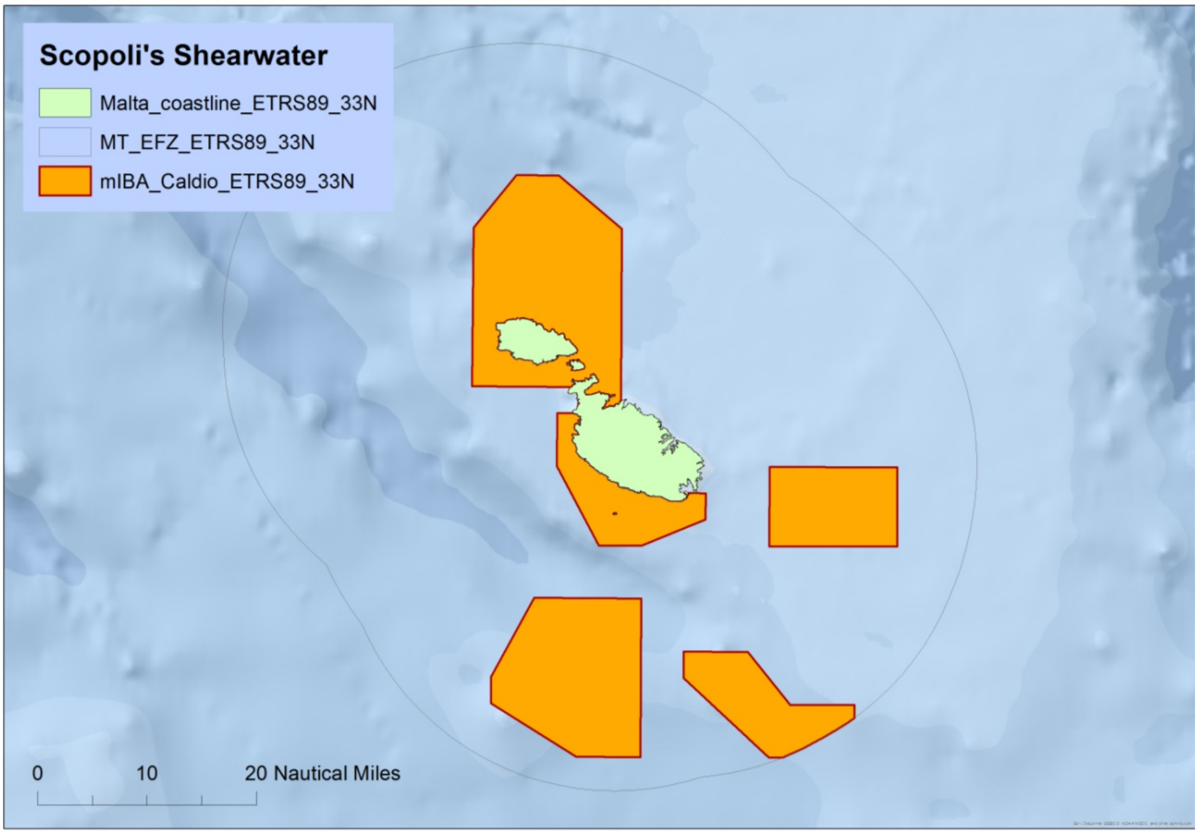

Fig. 22: Proposed marine IBAs for *C. diomedea* within the Maltese EFZ.

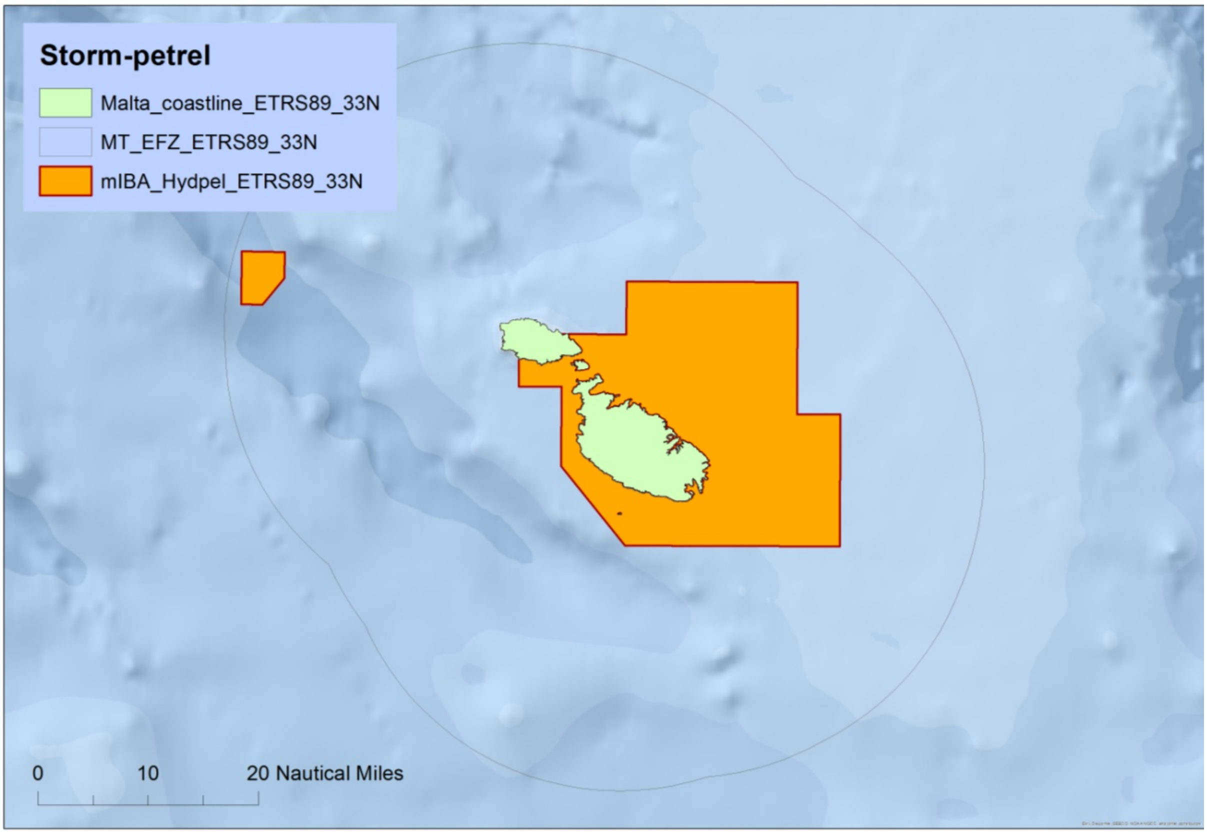

Fig. 23: Proposed marine IBAs for *H. pelagicus* within the Maltese EFZ.

4. Discussion

Using multiple sources of information, core areas of the at-sea distribution during the breeding period were identified for each of the three Maltese tubenose species. With the marine IBA inventory proposed, we have focused on the Maltese EFZ, the area, where the Maltese authorities can declare, implement and enforce marine Special Protected Areas within the European Nature 2000 network.

This multiple sources of information approach, combining data collection with modeling to identify the hotspots of seabird distribution at sea has been widely used in the Mediterranean and elsewhere, and has been deemed very successful in the process of creating an inventory of mIBAs worldwide (BirdLife Internationals marine IBA e-atlas). This is also the basis for a coherent network of marine protected areas in Europe (e.g. Ramirez et al. 2008) and elsewhere.

The prioritisation and zonation exercise which was applied here could be easily repeated in a modified way, identifying the core areas for all three focal species together and/ or including a larger penalty for the boundary length, which would result in fewer, more coherent areas recommended for protection. The algorithm could also incorporate economic costs (fisheries, transport) of declaring protected areas if raw data of such costs were to be made available. This would allow for a more coherent and integrative approach regarding marine spatial planning.

Results from GPS-tracking data of *P. yelkouan* and *C. diomedea* show that additional important foraging areas during the breeding season are situated outside the Maltese EFZ, in international waters and in national waters of Italy, Tunisia and Libya (Fig. 13 and 14).
These data have been submitted to BirdLife International and incorporated into the Seabird Tracking Database (http://www.seabirdtracking.org/) and will be shared with BirdLife partners and national authorities of the respective countries to feed into marine protected area designation outside Maltese waters.
GLS-tracking of *P. yelkouan* as part of the previous project has revealed the non-breeding distribution of the species (Raine et al. 2013) and the important bottleneck the Bosphorus, as well as larger areas of the Black Sea, were these birds go to perform their moult, are already (proposed) mIBA (see Marine IBA e-atlas).

With GLS-tracking of Maltese *C. diomedea,* we could unravel the movements and whereabouts of these birds during the non-breeding period. As in *P. yelkouan*, some areas of the wintering grounds of *C. diomedea* in the East Atlantic as well as the Strait of Gibraltar, the main migration bottlenecks, are already part of the mIBAs (see Marine IBA e-Atlas).

Regarding the identification of non-breeding areas and annual movements of the Maltese population of the Mediterranean Storm-petrel, we recommend a second trial of GLS-tracking in the future, using the latest generation of devices, which have in the meantime improved regarding weight and performance.

As part of the project's intensive monitoring and tagging work in seabird colonies, several important sites for seabirds were newly discovered or their importance re-assessed. The recently rediscovered *P. yelkouan* colony on Saint Paul's island and the better assessed colony at Majjistral, will be included into the mIBA network and need to get mSPA status. However, both sites have already Natura 2000 protection status as they are situated inside existing Maltese SACs. We also were able to confirm breeding of *H. pelagicus* at two previously unknown sites (Gozo, Rdum tal-Madonna). Together with one previously known site (Ta'Cenc) these areas will be carefully assessed in detail in the future regarding population numbers to incorporate them into the existing SPAs.

5. Next steps

All marine IBAs in the Maltese EFZ that are proposed in this report as a result of four years of intensive research, will be uploaded into the marine IBA e-atlas of BirdLife International, where the proposals will be assessed by experts. All data layers and meta-data will be shared in the formats required with the relevant Maltese authorities (MSDEC, MEPA, WBRU) to assist the eventual declaration of marine Special Protected Areas within the Natura 2000 Network by June 2016.

The mSPAs will then need to have their pressures and threats analysed and management plans for the sites to be drawn, implemented and enforced to make sure that the Maltese marine environment will reach Good Environmental Status by 2020.

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