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An evaluation of risk from sea level rise and storm surge on subpopulations of *Brachytrupes megacephalus* (Lefèbvre, 1827) on the island of Malta

Louis F. CASSAR[1]*, Charles GALDIES[1] & Nicholai XUEREB[1]

ABTRACT. *Brachytrupes megacephalus* (Lefèbvre, 1827) is a relatively large gryllid with predominant but not exclusive distribution across northern Africa, favouring sandy habitats in coastal and Saharan hyper-arid regions. The crepuscular species is also known to occur in certain areas of Europe's central Mediterranean littoral. The species' distribution in the Maltese Islands is restricted to fragmented populations on northern coastal sites in Malta and one site in Gozo. The present contribution focuses on the vulnerability of the species' habitat due to sea level rise and storm surges and estimates that habitat loss on the basis of three modelled inundation scenarios at 5 m, 10 m and 15 m contour heights would be 28.1%, 49.7% and 65.9% respectively. Furthermore, the models developed serve to provide insights for conservation management, specifically through elucidating the potential for linkages that ensure ecological connectivity for subpopulations on elevated terrain.

KEY WORDS. Biodiversity conservation, vulnerability, ecological connectivity, gryllid, inundation, habitat loss.

INTRODUCTION

Brachytrupes megacephalus is known from a number of established populations in both Malta and Gozo, having first been discovered in Gozo in 1955 (Lanfranco, 1957) and subsequently at Għadira, Malta in 1977 (Cassar, 1979). Further research confirmed the species' presence in other locations within the Aħrax promontory on mainland Malta (Cassar & Conrad, 2008; Cassar, Galdies & Xuereb, 2017; Cassar, Conrad & Galdies, 2018; Cassar, *in press*).

Within the southern shores of the Mediterranean basin, *B. megacephalus* is distributed across northern Africa from Algeria to Libya (Bonnet & Finot, 1885; Forel, 1893; Finot, 1896; Krauss, 1902; Jannone, 1938; Chopard, 1943; Valdeyron-Fabre, 1955; Gentry, 1965; Scortecci, 1971; Cassar & Stevens, 2002; Massa, 1998; 2009; Lakhdari *et al.*, 2015; Cassar, *in press*). Within the EU, where the species' IUCN conservation status is noted as 'vulnerable' (Buzzetti *et al.*, 2016), it occurs in Italian and Maltese territories. The species is afforded legal protection in both countries and benefits from the designation of over 20 Natura 2000 sites within the EU territory (European Commission, 1992). In Italy, the species has been reported from Sicily, the Aeolian Islands (Lipari and Vulcano), Linosa and Sardinia (Lefèbvre, 1827; Serville, 1838; Escherich, 1893; Zanardi, 1964; Alicata *et al.*, 1982; Baccetti, 1991; Baccetti *et al.*, 1995; Schmidt & Hermann, 2000; Galvagni, 2010; Massa, 2011; Massa *et al.*, 2012; Conti *et al.*, 2014; Prazzi *et al.*, 2014), and more recently from Lampedusa (Prazzi *et al.*, 2014; Cassar & Galdies, 2018). In the Maltese Islands, the species is known from at least 12 sites, all of which, except for one at Ramla in Gozo, are located

[1]Institute of Earth Systems, University of Malta, Msida MSD 2080, Malta.
*Corresponding author: E-mail: louis.f.cassar@um.edu.mt

in proximity to Għadira and the Aħrax promontory (Cassar, Galdies & Xuereb, 2017; Cassar, Conrad & Galdies, 2018; Cassar, *in press*); some subpopulations form part of a metapopulation at Aħrax.

Among the prevailing threats, habitat fragmentation is perhaps one of the most significant. Topographic modification of the terrain through land reclamation, terracing and tillage, as well coastal development in the form of boathouses, roads, parking facilities and lighting has resulted in severe negative impact. Furthermore, physical disturbance and predation, by anthropogenic activities and stray cats respectively, are among the foremost threats to the species' long-term survival in Malta (Cassar, Conrad & Galdies, 2018). In addition to these threats, coastal locations on which populations of *B. megacephalus* thrive are vulnerable to sea level rise and the effects of storm surge. Global mean sea level rise during the 21st century will very likely occur at a higher rate than during the period between 1971–2010. Climate models used for the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5) project a rise in sea level over the 21st century in the range of 0.52–0.98 m, based upon a high greenhouse gas (GHG) emissions scenario (RCP 8.5 - Representative Concentration Pathways). However, substantially higher values of sea level rise cannot be ruled out and the values previously referred to would increase substantially if future projections for the ice melting in Antarctica were to be included. Based on the expected continued high GHG emissions until 2100 and the incorporation of highly important sea ice modelling in climate models, authoritative climatologists such as Hansen *et al*., (2016) predict a 9 m rise in sea level as early as 2060. Increases in meteorologically-driven storm surges could also play a significant role in increased coastal flooding (Galdies, 2017).

MATERIALS AND METHODS

In an effort to evaluate the level of vulnerability to sea level rise and storm surge of this stenoecious gryllid occurring in Malta at Għadira and Aħrax, direct field observations during stridulation activity were conducted with a view to investigate the species' spatial habitat extent. Aerial Data Collection (UAV) survey technologies were employed, using a DJI Phantom 4 (quadrotor drone), to obtain high-resolution aerial photography in order to cartographically delineate the extent of each subpopulation, followed by ground truthing. Sea level rise visualisation, by way of an island-wide contour dataset, was further utilised to provide topographical information, following which, three contour heights above current sea level, each with a 5 m interval, were selected. The vector lines, at 5, 10 and 15 metres respectively, represented three projected scenarios of sea level rise due to climate change and storm surge over known *B. megacephalus* subpopulation distribution areas. High resolution satellite imagery (ERDF 156 data, 2013) was used as a basemap to facilitate visualisation of spatial impact, while landmarks and road networks were vectorised to enable area recognition. A digital elevation model (DEM) for terrain analysis was constructed using LiDAR data [grid resolution: 1 m x 1 m] (ERDF 156 data, 2013). The DEM was subsequently imported into a geographic information system (GIS) for spatial analysis. Pixel values with an elevation exceeding 15 m were nulled.

RESULTS AND CONCLUSIONS

Results showing the spatial impact of projected sea level rise and storm surges on the subpopulations of *B. megacephalus* serve to elucidate linkages within the landscape to ensure connectivity with suitable habitat on elevated terrain. The total area calculated to support subpopulations of the species at Għadira and Aħrax, at 2017, (Fig. 1a) totalled 312,248 m^2.

1. L-Għadira
2. Daħlet ix-Xilep
3. Tax-Xmajjar
4. L-Aħrax tar-Ramel
5. L-Aħrax tal-Madonna
6. Ta' Frawla (l/o Wied tar-Ratal)
7. Ta' Damma
8. Little Armier valley (l/o tal-Għozlien)
9. Wara l-Għarmier (Wied ta' l-Armier)
10. Qortin it-Twil road
11. Ramla tal-Qortin road (Wied ta' Tutti)

Figure 1a: Habitat areas at Għadira and Aħrax in 2017 (yellow polygons).

The model illustrates that inundation at 5, 10 and 15 m would flood 28.1% (Fig. 1b), 49.7% (Fig. 1c) and 65.9% (Fig. 1d) of the cricket's habitat respectively. In turn, these percentages equate to the respective land areas inundated, as indicated in Table 1.

Table 1: Spatial impact on the habitat of subpopulations as a result of inundation.

Contour height	% of inundated habitat	Habitat loss (area inundated)
5 m	28.1%	87, 638 m^2
10 m	49.7%	155, 065 m^2
15 m	65.9%	205, 855 m^2

The three contour height inundation maps overlaying delineated locations of the species' subpopulations were created by GIS to highlight selected sea level rise (SLR) scenarios of five, ten and fifteen metres above current mean sea level. The resultant graphics are reproduced in Figures 1b, 1c and 1d.

Figure 1b: Inundation map (at 5 m) highlighting SLR and storm surge impact over habitat areas.

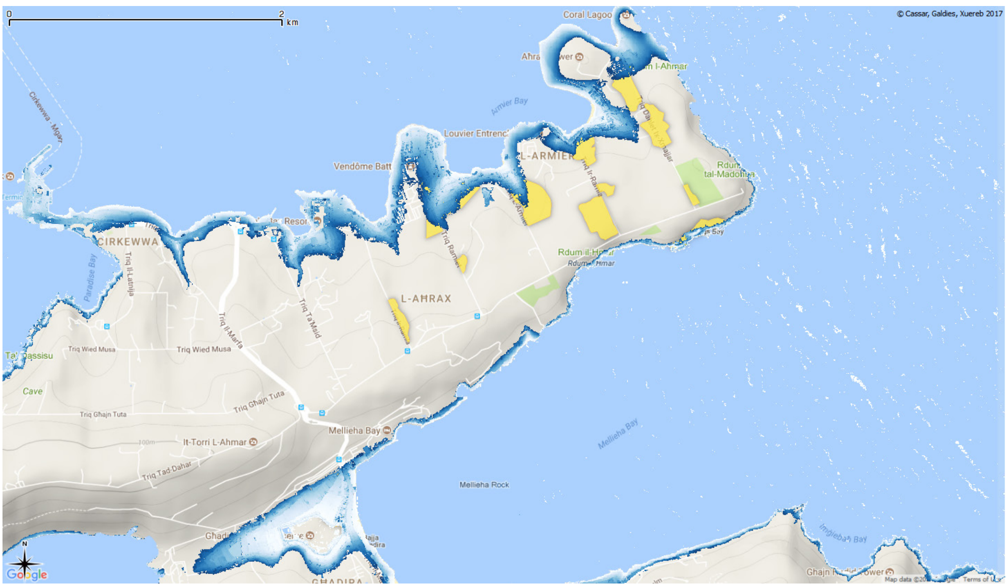

Figure 1c: Inundation map (at 10 m) highlighting SLR and storm surge impact over habitat areas.

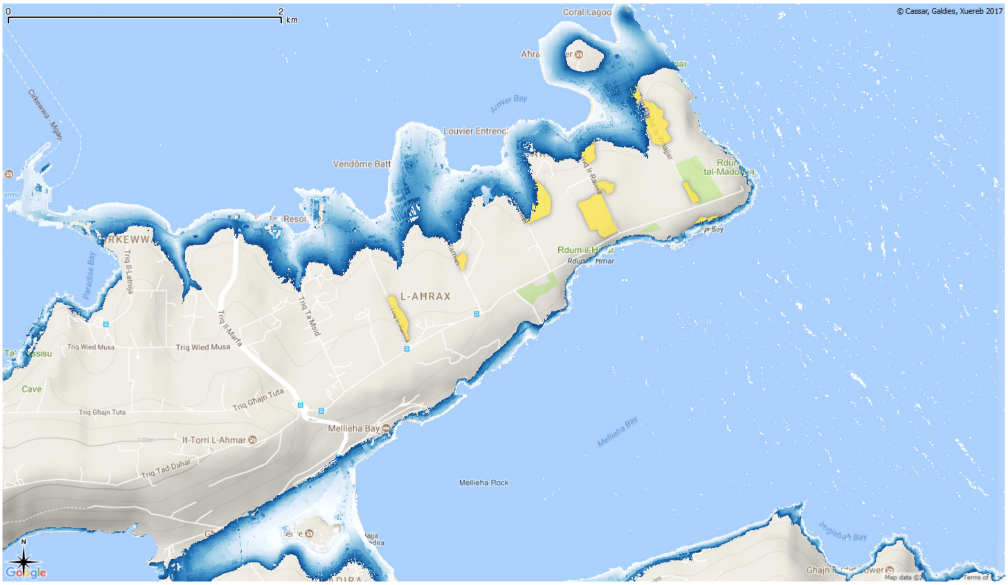

Figure 1d: Inundation map (at 15 m) highlighting SLR and storm surge impact over habitat areas.

There is no doubt of the considerable negative impact from inundation on some of the subpopulation habitats. In particular, the Għadira population would almost be completely submerged at 5 m (lowest contour height modelled scenario), with slivers of suitable habitat remaining at the two extremes of its current extent. Other populations on the coastal fringe, close to the current strandline, would also be influenced by a surging sea level; this is especially pertinent to the populations at Daħlet ix-Xilep, Tax-Xmajjar, Little Armier valley (l/o tal-Għozlien) and Wara l-Armier (Fig. 1b). At 10 m the Għadira population's habitat would be completely obliterated, while the aforementioned locations, together with the subpopulation at Ta' Frawla, would suffer heavily from inundation (Fig. 1c). The highest contour height modelled scenario, at 15 m, would inundate all low-lying regions with predicted consequential impact, leaving only four subpopulation habitats intact and others considerably diminished in extent (Fig. 1d).

The increased vulnerability of the species and its habitat due to fragmentation stems from a combination of sources. As described above, topographic modification due to a variety of land-uses, coupled by anthropogenic disturbance and predation by stray cats not only results in habitat breakup into smaller, isolated patches with ensuing consequences (smaller total habitat area; less area per patch; lengthier distance between patches) but also leads to a higher potential for 'edge effect' impacts and a decline in subpopulation numbers. The risk of SLR and storm surge further exacerbates the level of risk to this species and its habitat. Further research is therefore essential in order to explore opportunities for ecological connectivity between habitat patches with a view to minimise the risk of metapopulation breakdown. The possibility of engaging with stakeholders, notably farmers and landowners, should not be overlooked. The notion of connecting habitat fragments across the Aħrax landscape matrix may involve: (i) the identification of suitable adjoining habitat; and, (ii) the need for engineering solutions, possibly involving topographic and habitat restoration, albeit at a small scale. The scope of such interventions would thus reduce the patchy distribution of unsuitable habitat, in turn reducing the chances for subpopulation bottlenecks to occur and increasing connectivity potential for 'dispersers' across the metapopulation-occupied matrix.

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