

LOUIS F. CASSAR, ELISABETH CONRAD, JOHN J. BORG & CHARLES GALDIES

FIELD NOTES ON TWO STENOTOPIC ORTHOPTERANS FROM
THE CENTRAL MEDITERRANEAN:

BRACHYTRUPES MEGACEPHALUS (*Grylloidea Gryllidae*)
AND *PAMPHAGUS ORTOLANII* (*Acridoidea Pamphagidae*)

SUMMARY

Brachytrupes megacephalus (Lefebvre, 1827) and *Pamphagus ortolanii* Cusimano & Massa, 1977 are two stenoecious species of Orthopterans that occupy psammophilic and rocky shrubland biotopes, respectively. Field investigations conducted in Sicily and on Lampedusa Is., in 2018/19 and 2019 respectively, highlight the species' vulnerability, mainly due to habitat fragmentation. A total of 20 sites are investigated for the presence of *B. megacephalus*, on the north-west and south-east coast of Sicily, and on Lampedusa. Of these, presence is confirmed from three locations. Potential presence, due to the occurrence of tunnel entrances comparable to the 'sky chamber' typical of male burrows, is detected at three other dunal sites, although further field investigations are proposed. The occurrence of *P. ortolanii* is confirmed from four locations on Lampedusa. Patch occupancy for the Cala Francese site was noted to be significantly higher than that of the larger *P. tunetanus* on the north African mainland. Preliminary findings indicate that while *B. megacephalus* is reasonably well protected, further efforts are required to ensure satisfactory conservation of *P. ortolanii* in Lampedusa.

Key words: Sicily, Lampedusa, island biogeography, endemic, stenoecious, ectothermic, connectivity, conservation

RIASSUNTO

Note di campo su due ortotteri stenotopici del Mediterraneo centrale: *Brachytrupes megacephalus* (*Grylloidea Gryllidae*) e *Pamphagus ortolanii* (*Acridoidea Pamphagidae*). *Brachytrupes megacephalus* (Lefebvre, 1827) e *Pamphagus ortolanii* Cusimano & Massa, 1977 sono due specie di Ortotteri stenoeci che vivono rispettivamente in biotopi psammofili e rocciosi. Alcune ricerche di campo effettuate in Sicilia e nell'isola di Lampedusa, rispettivamente nel 2018/19 e 2019, mettono in evidenza la vulnerabilità delle specie, dovuta soprattutto alla frammentazione degli habitat. In

totale sono stati controllati 20 siti per la presenza di *B. megacephalus* nel nord-ovest e sud-est della Sicilia e a Lampedusa. La presenza è stata confermata in tre siti. In altri tre siti in habitat dunale è stata notata la presenza potenziale di *B. megacephalus*, presunta dalla presenza di entrate di tunnel simili a quelli tipici costruiti dai maschi della specie, sebbene siano necessarie altre ricerche in proposito. È inoltre confermata la presenza di *P. ortolanii* in quattro siti di Lampedusa. A Cala Francese è stata osservata una densità significativamente più alta della specie *P. tunetanus* vivente nel vicino Nord Africa. Le osservazioni preliminari indicano che mentre *B. megacephalus* è ragionevolmente ben protetto, sono richiesti ulteriori sforzi per assicurare una soddisfacente conservazione di *P. ortolanii* a Lampedusa.

Parole-chiave: Sicilia, Lampedusa, biogeografia insulare, specie endemica, specie stenoece, ectotermico, connettività, conservazione

INTRODUCTION

Islands are commonly regarded as biodiversity hotspots in view of the significant number of endemic taxa they support, frequently coupled with a high level of threat to their habitats and biota (BROOKS *et al.*, 2002). The influence of islands on evolutionary biology has been documented since at least the 18th century (FORSTER, 1778; BROWN & LOMOLINO, 1998) and an interest in insular biogeography and phylogeny has since attracted considerable attention (e.g., MACARTHUR & WILSON, 1967; LOMOLINO, 2000; FARKAS *et al.*, 2015; LINDGREN & COUSINS, 2017). As a consequence of their insularity, islands play a crucial role as ecological refugia for fragmented populations of species, often affording an important living demonstration of evolutionary processes and endemism. Islands within the central Mediterranean area are similarly important from the biogeographical standpoint (HUNT & SCHEMBRI, 1999; CASSAR *et al.*, 2007).

The various marine regressions that occurred within the Mediterranean Basin (as a result of both continental drift and climate change) led to intermittent physical connections, which facilitated the dispersal of terrestrial biota from surrounding continental landmasses. The Messinian Event at the end of the Miocene epoch was characterised by one such major marine regression, when the Basin, to a large extent dried up (HSU, 1983; KRIJGSMAN *et al.*, 1999; GARGANI & RIGOLLET, 2007). Subsequently, during the Pleistocene, when eustatic sea levels continued to fluctuate, the Mediterranean Sea experienced a series of Quaternary lowstands during extensive continental glaciations (facilitating dispersal via terrestrial corridors), which were successively followed by prolonged periods of isolation during the interglacials, when elevated landforms of significant altitude were cut off (as sea levels within the Basin rose), effectively forming islands. The ensuing inter-

mittent isolation gave rise to sequential development of various endemic forms (HUNT & SCHEMBRI, 1999; CASSAR *et al.*, 2007; CASSAR, 2010). Moreover, the presence of certain species that lack the capacity to travel significant distances over open bodies of water (either due to their apterous nature or because there is no evidence of nomadic dimorphism and associated migratory morphing behaviour), is particularly interesting from an island biogeographical context. The two species of stenoecious Orthoptera, on which the present communication focuses, fall within these categories.

Brachytrupes megacephalus is a relatively large gryllid, which, within European territory, occurs exclusively in coastal locations on the islands of Sicily, Sardinia, Linosa, Lampedusa, Lipari, Vulcano, Malta and Gozo (LANFRANCO, 1957; CASSAR, 1979, 1990, 1996; CASSAR & BONETT, 1985; BACCETTI *et al.*, 1995; CASSAR & STEVENS, 2002; CASSAR & CONRAD, 2008; MASSA *et al.*, 2012; PRAZZI *et al.*, 2014; CASSAR & GALDIES, 2018). The species is also known from a number of coastal and inland locations in North Africa (FOREL, 1893; CHOPARD, 1943; VALDEYRON-FABRE, 1955; LA GRECA, 1957; MASSA, 1998; 2009; LAKHDARI *et al.*, 2015). The European Environment Agency lists the conservation status of the species as 'Unfavourable-Bad' (EUROPEAN COMMISSION, 1992), while its IUCN threat status for Europe is 'Vulnerable' (BUZZETTI *et al.*, 2016). Consequently, more than 20 locations within which the species occurs have been designated Natura 2000 sites (EUROPEAN COMMISSION, 1992); a number of these protected areas, together with other potential coastal habitats in close proximity, were investigated in the present study.

Pamphagus ortolanii is a fairly large micropterous grasshopper species endemic to the island of Lampedusa (CUSIMANO & MASSA, 1977; MASSA & LO VERDE, 1991; MASSA *et al.*, 2012). The species occurs simultaneously in both adult and nymph phases throughout much of the year, and unlike other closely related species of Pamphaginae, *P. ortolanii* is known to occur in fairly high population densities (MASSA & LO VERDE, 1991; MASSA *et al.*, 2012). Mobility is somewhat sluggish, largely due to its relatively heavy disposition and its vestigial wings, which makes the species especially vulnerable to predation; in fact, it has been observed to be Eleonora's Falcon's *Falco eleonora* preferred prey when the said raptor, at the time of observation, arrived on Lampedusa between May and June (MASSA, 1978). *P. ortolanii* colonises stony, semi-arid shrubland and grassy steppe environments, and is reported from at least two locations, one of which lies within a protected area. Its IUCN Red List status is 'Near Threatened' (BUZZETTI *et al.*, 2016).

APPROACH

Field observations were made during a number of dedicated visits with the aim of:

- i. mapping the distribution of *Brachytrupes megacephalus* within selected sites in Sicily. Field surveys were carried out during the cricket's mating seasons of 2018 and 2019, when presence can be detected by means of the distinctive male stridulation at dusk (such method also limits the necessity of disturbance by researchers), or through the occurrence of the likewise characteristic sand mounds with accompanying subterranean tunnel entrances that the burrowing crickets are known to produce;
- ii. verifying its sustained presence or otherwise on the island of Lampedusa;
- iii. collecting material for molecular dating as per: *Protocollo nr: 7442 (2019) PNM - Direzione Generale per la Protezione della Natura e del Mare* (see note below¹).

Site visits were conducted in April and May of 2018 (Sicily), and in April of 2019 (Lampedusa and Sicily) (Fig. 1). Sites investigated comprised sandy coastal areas at or in close proximity of Alcamo Marina, Balestrate, Isola delle Femmine and Mondello on the northwest coast of Sicily, Vendicari, sandy stretches between San Lorenzo and Marzamemi, the beach and dunes located east of Pantano Morghella, dunes at Capo Passero in the vicinity of Portopalo, the extensive dunal system near Pantano Ponterio and sandy pockets between Pozzallo and Marina di Modica on the southeast coast of Sicily, and all sandy beaches on the island of Lampedusa. The latter included the following pocket beaches: Spiaggia dei Conigli, Cala Galera, Cala Greca, Cala Madonna, Cala Croce, Cala Guitgia, Cala Francese, Cala Pisana, and Cala Creta.

As noted above, evidence of *B. megacephalus* was searched for on sandy beaches and dunal biotopes, while seemingly appropriate habitats for *P. ortolanii* on Lampedusa, that is, rocky outcrops and/or ground armour (unattached surficial stony material) on karstic steppe, were reconnoitred through walk-over searches. Specific locations comprised the karstland on the extensive northwest coast between Albero Sole and Capo Ponente, the

¹ Note: collection of live material for DNA analysis was only carried out in 2019, subsequent to the issuance of relevant permits by the appropriate Italian authorities on the basis of derogation DPR 357/97 and subsequent advice from ISPRA.



Fig. 1 — General location of areas surveyed (base map source: IUCN map server).

steppic areas south of Albero Sole (where one of the authors [JJB] had observed two adults and a nymph in April of 2009 and one adult in October of 2017), the Faro di Levante promontory, and the immediate karstic hinterland at Cala Francese.

RESULTS

Based on field observations on *Brachytrupes megacephalus* in Sicily and on Lampedusa:

Study sites on the northwest coast of Sicily – Four study sites with coastal sands at or close to Alcamo Marina, Balestrate, Isola delle Femmine, and Mondello were inspected in 2018 and 2019. Field investigations were carried out both during daytime in both years (for evidence of burrowing activity) and after dusk in 2018 (for stridulating males); on each occasion no evidence of the cricket’s presence was registered.

Study sites on the southeast coast of Sicily – A total of seven study sites were examined for the occurrence of *B. megacephalus* on this segment of the Sicilian coast. Of these, Vendicari and the pocket beaches between Pozzallo and Marina di Modica were inspected in both years (in 2019, the latter habitat site was investigated by a local collaborator) and on each occasion, the species was recorded. Site observations at Vendicari in April 2018 and April 2019, were made over an area of study (AoS) of approximately 8900 m² (Fig. 2); at the time of survey, the prescribed AoS yielded evidence of eleven and nine stridulating males, respectively.

The dunes at Capo Passero, near Portopalo, and those in the immediate vicinity of Pantano Morghella were inspected in both years, however, only during daytime, for tunnel entrances and sand mounds. In both sites, potential evidence of the species' presence was noted only in 2019. In the case of the dunes near Pantano Morghella, two shallow burrows were discovered, with lengths measuring 14 cm and 22 cm, respectively. The site at Capo Passero also yielded two burrow entrances; both tunnels were substantially longer and deeper than those at Pantano Morghella. Careful excavation demonstrated lengths of approximately 43 cm and 65 cm, respectively, at depths from the beach surface of 28 cm and 42 cm. In both of these two localities, neither sand mounds nor crickets were encountered.

No evidence of the species' presence was registered on the dunes abutting Pantano Ponterio or within the sandy enclaves between San Lorenzo and Marzamemi in either of the two years during which the study was conducted.

Island of Lampedusa – Of the nine sandy beaches investigated for the presence of *Brachytrupes megacephalus* on Lampedusa, only one yielded a potentially positive outcome. A singular burrow was discovered at Spiaggia dei Conigli (Fig. 3), and, albeit very shallow on examination (<20 cm deep), it assumed a strong resemblance to the tunnel entrance typically excavated by male crickets during the breeding season, inclusive of the 'sky chamber' (a convex formation to enhance acoustic output). No other tunnel entrances, nor any characteristic sand mounds (evidence of burrowing activity), were observed at this site or at any other study site on the island. In addition to a thorough examination of each of these potential habitat sites during daytime, each location (with the exception of Spiaggia dei Conigli) was also visited after nightfall with the intention of checking for stridulating males; no such activity was detected.

Based on field observations on *Pamphagus ortolanii* on Lampedusa, we report the following findings.

In view of the limited published information on the precise habitat loca-



Fig. 2 — Left: location of area of study at Vendicari (Base map source: IUCN map server); right: Vendicari dunal site where field observations were carried out in 2018 and 2019, delineation of which is indicated by an approximated polygon (base map source: Google Earth).



Fig. 3 — Left: General area at Spiaggia dei Conigli where a burrow was discovered; right: entrance to a shallow burrow, which bears manifest resemblance to the ‘sky chamber’ typically created by male crickets during the breeding season.

Table 1
Sites investigated for the presence of Brachytrupes megacephalus in 2018 and 2019, where C = confirmed presence; P = possible presence; N = no detected presence.

Locality	Presence of burrows	Presence of mounds	Stritulation detected	Year of investigation	
				Daytime	Dusk
Northwest coast of Sicily (field investigation: 2018/19)					
Alcamo Marina	N	N	N	2018/19	2018
Balestrate	N	N	N	2018/19	2018
Isola delle femine	N	N	N	2018/19	2018
Mondello	N	N	N	2018/19	2018
Southeast coast of Sicily (field investigation: 2018/19)					
Marina di Modica	C	C	C	2018/19	2018/19
Areas between Pozzallo and Marina di Modica	C	C	C	2018/19	2018/19
Dunes near Pantano Ponterio	N	N	N	2018/19	2018
Capo Passero (dunes near Portopalo)	P	N	–	2018/19	–
Dunes East of Pantano Morghella	P	N	–	2018/19	–
Areas between San Lorenzo and Marzamemi	N	N	N	2018/19	2018
Vendicari	C	C	C	2018/19	2018/19
Island of Lampedusa (field investigation: 2019)					
Spiaggia dei Conigli	P	N	–	2019	–
Cala Galera	N	N	N	2019	2019

Continued on following page

Follows from previous page: Table 1

Cala Greca	N	N	N	2019	2019
Cala Madonna	N	N	N	2019	2019
Cala Croce	N	N	N	2019	2019
Cala Guitgia	N	N	N	2019	2019
Cala Francese	N	N	N	2019	2019
Cala Pisana	N	N	N	2019	2019
Cala Creta	N	N	N	2019	2019

tions of *Pamphagus ortolanii*², the species was actively searched for via walk-over surveys across a relatively large overall area, totalling some 1.2 km² (collectively forming a perimeter exceeding >12 km), comprising four seemingly suitable localities (refer to Approach above). The species was recorded from two of the locations investigated, notably Cala Francese, where a sizeable population was observed on April 6th on gently sloping coastal karst characterised by steppic vegetation, and on the shrubland-dominated cliff-top region (at 104 m amsl) east of Punta Parise (west of Albero Sole), where a single female specimen, a nymph (fourth instar), was found on thistles.

A thorough assessment of a virtual band transect of approximately 2000 m² at Cala Francese yielded four adult males and three adult females, along with four nymphs of varying size, ranging from 1.7 cm to just over 4 cm. A further adult female specimen was observed on west side of the arcuate segment of the pocket beach, again, on somewhat elevated karstic terrain (Fig. 4).

Apart from the obvious disparity in overall dimensions between *P. ortolanii* and *P. tunetanus*, the population density of the latter species in Tunisia (at Djebel Dyr near El Kef and around the Lac de Rades et Salines wetlands), where one of the authors [LFC] has carried out field research on the species, was noted to have been significantly lower. When compared with the population density at Cala Francese (Lampedusa), individual numbers within the Tunisian sites (over similarly sized habitat patches) were found to vary between 25% and 42%. Moreover, it was an uncommon occurrence for adults and early instars of *P. tunetanus* to occur concurrently in Tunisia,

² A dearth of published information on the precise locations of *Pamphagus ortolanii* is available. However, the species is known to inhabit steppic biotopes on open karstland where the terrain is typically stony. Since much of the surficial constitution of the island of Lampedusa is basically karstic, the field investigation was essentially based on good judgment and on previous experience by two of the authors respectively, on Lampedusa [JJB] and in North Sicily [LFC] researching other species of Pamphagidae.



Fig. 4 — Study site at Cala Francese – recorded occurrence of *Pampbagus ortolanii* within virtual band transect (approx. 2000 m²) and at indicated point, respectively on the eastern and western sides of the embayment (base map source: IUCN map server).

whereas on Lampedusa, various instar phases and adult forms of *P. ortolanii* have been encountered simultaneously, as verified during the present and previous studies (CUSIMANO & MASSA, 1977; MASSA & LO VERDE, 1991; field obs. by one of the authors [JJB] in 2009 and 2017). *Pampbagus ortolanii* is now confirmed from at least four locations (Fig. 5), that is, at Cala Galera (BREITSCHOPF, 1987; MASSA *et al.*, 2012), near Albero Sole, on the cliff-top east of Punta Parise, and at Cala Francese. The population within the investigated area at Cala Francese is unlikely to come into contact with any individuals on the opposite promontory across the bay where a single female was discovered, due to the fragmentation of habitat by walled properties at the back of the embayment. Once any physical linkages between small, fragmented subpopulations cease to exist, adjacent habitat patches will no longer be re-colonised and metapopulation breakdown is expected to occur.

Meteorological conditions during field observations on Lampedusa. Weather conditions during fieldwork on the island of Lampedusa can best be described as variable, with light winds and relatively clear skies typifying the afternoon of arrival, followed by few to scattered clouds during the



Fig. 5 — Indicative locations of four *Pamphagus ortolanii* populations on Lampedusa; these are (from west to east), Punta Parise, Albero Sole, Cala Galera, and Cala Francese (base map source: IUCN map server).

first and second full days of fieldwork, together with relatively mild to moderate winds. The third full day of fieldwork was characterised by a significantly increased cloud cover, varying from scattered to broken clouds³, rain showers, and thunder storms. The final day on Lampedusa saw quasi-cloudless skies and by generally moderate north-westerly winds. Although ambient temperatures did not vary noticeably over these days, insect life was conspicuously more prevalent during the last day when the sun shone for significantly long periods, albeit with some insignificant interruption by cloud cover.

The focus of field observations during the first evening [EO1] was primarily on stridulating *Brachytrupes megacephalus*, a crepuscular species, within practically all the island's sandy beaches. The evening was characterised by light northerly winds (5.6 km/h), while temperatures descended from 16 to 12.7 °C between 19:00 and 21:00 hours (GMT+2); this two-hour window is generally when the male of the species is typically known to emerge from its burrow to stridulate in order to attract a female. Although the lower range of temperatures recorded at the time of observation could well be considered as borderline for stridulatory activity, wind intensity was low and its direction (N-NE) provided shelter to the mostly south-facing embayments; stridulation should therefore not have been impeded. The following evening [EO2] saw the wind direction shift to the south, with speed of 17 km/h, subsequently decreasing to 16.7 km/h by 21:00 hours, while temperatures remained quite stable at 15 °C throughout the entire two-hour observation period of EO2.

³ Half-hourly METAR weather reports were used for the present study. These reports are used by aviators in partial fulfilment of pre-flight weather briefings, and by meteorologists for weather forecasting. 'Scattered' and 'Broken' cloud cover refer to 3-4 oktas and 5-7 oktas respectively.

On this evening, wind speed/direction, ambient air temperatures, and a critically adverse wind-chill could have potentially impeded stridulatory activity. During the third evening of observations [EO3], the wind maintained a southerly direction (S–SSE) and decreased steadily from 12 to 5.5 km/h during the observation period, while temperatures remained somewhat constant at 16 °C, subsequently decreasing to 15.8 °C by 21:00 hours. Such meteorological conditions ought to have been favourable to stridulatory activity. The fourth evening [EO4] was characterised by a gentle breeze, the direction of which was predominantly N–NNW, with speed increasing from approximately 11.0 km/h (at 19:00 hours) to 13 km/h by 21:00 hours. Variations in ambient temperatures were minor, from approximately 15 °C (as at 19:00) to 14 °C by 21:00 hours. With such borderline temperatures and fairly strong winds as those registered on EO4, it would appear unlikely for males to emerge from their subterranean burrows, with the exception of those areas in south-facing embayments sheltered from northerly winds. As indicated above, notwithstanding favourable meteorological conditions on at least two of the evenings [EO1 and EO3], no stridulatory activity was registered within the potentially suitable sandy environments investigated.

Another, albeit secondary, aim of the field visit on the island of Lampedusa was to map the distribution of *Pamphagus ortolanii*. Since this species is diurnal, specific searches were made during daytime across seemingly suitable habitats (see Approach above) over a period of four days. Interestingly, although daytime ambient temperatures did not vary significantly (Table 3), *P. ortolanii* was nowhere to be seen during the initial three days when skies were quite dull with scattered or broken cloud cover, occasional rains with thunder storms (on one of the days) and relatively gusty winds. It was during the final day, which was bright, sunny and largely devoid of clouds, that *P. ortolanii* was finally encountered. The Cala Francese locality on the island's

Table 2

Field observations in connection with Brachytrupes megacephalus, between 19:00 and 21:00 hours (GMT+2), on Lampedusa in April, 2019. (Source: SYNOP WMO: 16490).

Evening Observation session	Wind speed (Km/h)	Wind direction	Temperatures
EO1	5.6	N - NE	16 - 12.7 °C
EO2	17.0 - 16.7	SSW - SSE	15.0 °C
EO3	12.0 - 5.5	S - SSE	16.0 - 15.8 °C
EO4	11.0 - 13.0	N - NNW	15.0 - 14.0 °C

south-eastern coastline, where numerous individuals of Lampedusa's endemic Pamphagid were encountered, was completely sheltered from the prevailing northerly winds blowing on the day in question. Evidently, refuge from the wind, coupled by warm temperatures and sunny skies, provided ideal environmental conditions for ectothermic fauna such as *P. ortolanii*.

Table 3
 Highest and lowest temperatures registered between 10:00 and 17:00 (GMT+2) during the Lampedusa field visit. (Source: SYNOP WMO: 16490)

Daytime Observation session	Highest temperature registered	Lowest temperature registered
DTO1	15.8 °C	15.0 °C
DTO2	17.3 °C	16.5 °C
DTO3	15.5 °C	15.3 °C
DTO4	16.4 °C	15.5 °C

DISCUSSION AND CONCLUSIONS

Islands provide a remarkable setting within which to study insular biogeography, given they are typical microcosms of larger regions and, therefore ideal models for researching the impacts of human activities and resulting perturbations on both habitats and biota. The theory of island biogeography has important implications for conservation management, of which one notable development was the conceptualisation framework for ecological corridors to link 'habitat islands'. Islands also provide a suitable backdrop for researching both spatial and temporal dimensions of behaviour and adaptation.

In the case of *Pamphagus ortolanii*, one such manifest biological adaptation to a spatially restricted insular environment in which predation appears to be extraordinarily higher (due to the seasonal presence of *Falco eleonora*), is its seemingly high fecundity (compared with its appreciably larger relative, *P. tunetanus*), coupled by an ability to produce year-round generations (CUSIMANO & MASSA, 1977; BUZZETTI *et al.*, 2016). This was also clearly evidenced by findings at Cala Francese (present contribution), where both adults and instars of varying levels of development were observed concurrently.

Notwithstanding the species' capacity to adapt to insular environments, the species remains quite vulnerable due to its relatively sluggish mobility and, as a result, slower rate of active dispersal. Habitat fragmentation further

restricts its ability to exploit new habitat areas, with the Cala Francese *P. ortolanii* population being a well-defined example. It is strongly anticipated that the construction of walled properties will minimise connectivity and potentially break-up the species' habitat into smaller, isolated patches, while undermining the prospect of any increase in spatial distribution via dispersers. The smaller and narrower the residual habitat fragments (often with long, exposed boundaries), the more vulnerable they are to edge effect-induced impacts. Moreover, in the longer term, there is an underlying risk posed by sea-level rise to low-lying habitat patches on the coast, such as the coastal fringe at Cala Francese.

In the case of *Brachytrupes megacephalus* on Lampedusa, no evidence of its presence was noted during the April 2019 field research visit, albeit for a single burrow at Spiaggia dei Conigli, which may or may not have been excavated by the species, and which, as a result, provides a somewhat flimsy evidence base to assume the species' presence. On the other hand, at least five specimens of the species have been recorded from Lampedusa in the past (PRAZZI *et al.*, 2014; pers. comm. B. Massa, 2018), all of which, it is worthy of note, were found in urban areas rather than within a psammophilous environment where the species typically occurs. Such occurrence, therefore, begs the question as to whether the recorded presence on Lampedusa was accidental (CASSAR & GALDIES, 2018). Although at present there does not seem to be an established population on the island, there is no doubt that further monitoring is warranted.

Three of the four locations from which *P. ortolanii* has thus far been recorded in Lampedusa lie within a protected Natura 2000 site (ITA040002: Isola di Lampedusa e Lampione). Cala Francese, from where most specimens were observed during this observation period, does not currently fall within this protection network. Nevertheless, even the presence of the species within the Natura 2000 site is somewhat incidental, given that *P. ortolanii* is not currently listed in Annex II of the Habitats Directive, i.e., it is not considered a species of community interest whose designation requires the designation of Special Areas of Conservation (SACs). At present, the species is merely listed within the datasheet for this Natura 2000 site under an optional list of *Other Important Species of Flora and Fauna*, where its presence is noted and its inclusion in national Red Data Lists is recorded. Its endemic status is not reflected within this data sheet listing. This weak protection status does not accord well with the species' restricted distribution and recognized near threatened IUCN status. Further studies of the species' distribution and population status could provide valuable information on a thus-far poorly-understood species that could potentially contribute to strengthening its regional protection status. At the same time, it is recognized that, even if the species were to

be formally listed in Annex II, designation of the Cala Francese sites could be challenging, given the very close proximity of Lampedusa airport.

The protection status of *B. megacephalus* is comparatively more robust, given that this is included in both Annexes II and IV. Within the data sheet for the above-mentioned Lampedusa Natura 2000 site, it is listed as a *permanent* species by virtue of it being non-migratory, even if, as noted above, the permanence of its status on Lampedusa remains questionable. No other information on its abundance is provided. Its status in Sicily is comparatively better documented, particularly within Natura 2000 sites in the south and south-east of the island. The status of populations in other parts of Sicily is being evaluated in more detail in separate work.

Both species treated in this communication are subject to *r*-selection. Nonetheless, they are still affected by the dynamics of minimum viable population (MVP) size. It is predicted that if metapopulation patch boundaries shrink, due to habitat loss and a consequential decrease in connectivity, dispersal opportunities may be reduced, leading to a marked decline in the species' home range. Unless adequate proactive measures are taken, it is anticipated that the more isolated subpopulations of *B. megacephalus* and of *P. ortolanii* will experience patch occupancy reduction events; necessary measures include zoning and related enforcement as well as interventions to ensure (i) conservation of suitable habitats, and (ii) ecological linkages across habitat patches. Whatever the drivers of loss, degradation, or fragmentation of these stenotopic species' habitat, it is imperative that every effort is made, by both the authorities concerned and the scientific community, to forestall the potential occurrence of population bottlenecks and attendant impacts.

Acknowledgements — We would first like to thank the University of Malta for financial support through research grants, which facilitated this research. We are indebted to Toni Puma and Elena Prazzi, for assisting our research in Sicily and Lampedusa, respectively. We acknowledge with gratitude the support rendered by the Direzione Generale per la Protezione della Natura e del Mare of the Ministero dell'Ambiente e della Tutela del Territorio e del Mare, and by the Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA) in granting necessary permits to carry out fieldwork within protected areas and on *Brachytrupes megacephalus*, a protected species. In relation to permit acquisition, grateful thanks are also due to Bruno Massa for his support. Finally, we would like to thank Lt. Col. Marcel N. Cassar [Rtd.] for useful logistical tips during the planning phase of our field mission to Lampedusa, as also Ms Christa-Marie Pisani, Projects Officer at the Institute of Earth Systems (University of Malta), for logistical support.

REFERENCES

- BACCETTI B., MASSA B. & CANESTRELLI P., 1995. Dermaptera, Isoptera, Blattodea, Mantodea, Phasmatodea, Orthoptera. Pp. 163-194 in: Massa B. (ed.), Arthropoda di Lampedusa, Linosa e Pantelleria (Canale di Sicilia, Mar Mediterraneo). *Naturalista sicil.*, 19 (suppl.).

- BREITSCHOPF, T. 1987. Abwehrverhalten von *Pamphagus ortolanii* Cusimano-Massa. *Articulata*, 2 (10): 406.
- BROOKS T.M., MITTERMEIER R.A., MITTERMEIER C.G., DA FONSECA G.A.B., RYLANDS A.B., KONSTANT W.R., FLICK P., PILGRIM J., OLDFIELD S., MAGIN G. & HILTON-TAYLOR C. 2002. Habitat Loss and Extinction in the Hotspots of Biodiversity. *Conservation Biology*, 16 (4): 909-923.
- BROWN J.H. & LOMOLINO M.V., 1998. Biogeography. 2nd ed. *Sinauer Associates, Inc.*, Sunderland, Massachusetts, xii + 691 pp.
- BUZZETTI F.M., HOCHKIRCH A., MASSA B., FONTANA P., KLEUKERS R. & ODÉ B., 2016. *Pamphagus ortolanii*. *The IUCN Red List of Threatened Species* 2016: e.T47696611A47696629. <http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T47696611A47696629.en>.
- CASSAR L.F., 1979. Occurrence of *B. megacephalus* Lefevre in the Maltese Islands. *Central Medit. Naturalist*, 1(1): 22-23.
- CASSAR L.F., 1990. Notes on rare and infrequent Orthoptera of the Maltese Islands. *Central Medit. Naturalist*, 2(1): 1-4.
- CASSAR L.F. 1996. Coastal Dunes: Form and Process. Geomorphology, ecology and planning & management for conservation. University of Malta: Unpublished dissertation published in part fulfillment of the requirements for the degree of MSc (Environmental Planning & Management). viii+136 pp.
- CASSAR L.F., 2010. A landscape approach to conservation: integrating ecological sciences and participatory methods. *UNESCO – Int. Envir. Inst.*, Msida xxxi+210 pp.
- CASSAR L.F. & BONETT G., 1985. Weitere Nachweise von *Brachytrupes megacephalus* Lefevre auf den Maltesischen Inseln (Orthopt.: Gryllidae). *Neue Entomol. Nach.*, 14: 27- 29.
- CASSAR L.F. & CONRAD E., 2008. New populations of *Brachytrupes megacephalus* (Lefevre, 1827) on mainland Malta and some notes on its adaptive capacity (Orthoptera: Gryllidae). *Bull. Ent. Soc. Malta*, 1: 59-62.
- CASSAR L.F., CONRAD E. & SCHEMBRI P.J., 2007. The Maltese archipelago. Pp. 279-322 in: Vogiatzakis I.N., Pungetti G. & Mannion A.M. (eds.) Mediterranean Island Landscapes: natural and cultural approaches. *Springer Landscape Series*, 9, Dordrecht.
- CASSAR L.F. & GALDIES C., 2018. On the recent occurrence of *Brachytrupes megacephalus* (Lefevre, 1827) (Orthoptera Gryllidae) on Lampedusa. *Naturalista sicil.*, 42: 153-158.
- CASSAR L.F. & STEVENS D.T., 2002. Coastal dunes under siege: a guide to conservation for environmental managers. *Int. Env. Inst., University of Malta*, Valletta, x+194 pp.
- CHOPARD L., 1943. Orthopteroides de L'Afrique du Nord. *Larose*, Paris, 450 pp.
- CUSIMANO G. & MASSA B., 1977. Panfagidi nuovi delle isole circumsiciliane (Orthoptera Acridoidea). *Atti Accad. Sc. Lett. Arti*, Palermo, 35: 1-22.
- EUROPEAN COMMISSION, 1992. Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora.
- FARKAS T.E., HENDRY A.P., NOSIL P. & BECKERMAN A.P., 2015. How maladaptation can structure biodiversity: Eco-evolutionary island biogeography. *Trends Ecol. & Evol.*, 30(3): 154-160.
- FOREL A., 1893. Zur lebensweise der W stengrille (*Brachytrupes megacephalus* Serv.). *Mitt. Schweiz. Ent. Ges.*, 8: 247-250.
- FORSTER J.R., 1778. Observations Made during a Voyage Round the World, on Physical Geography, Natural History, and Ethic Philosophy. *G. Robinson*, London, UK.
- GARGANI J. & RIGOLLET C., 2007. Mediterranean Sea level variations during the Messinian Salinity Crisis. *Geophys. Res. Lett.* 34: L10405.
- HUNT C.O. & SCHEMBRI P.J., 1999. Quaternary environments and biogeography of the Maltese Islands. Pp. 41-75 in: Mifsud A. & Savona Ventura C. (eds.), Facets of Maltese Prehistory. *The Prehistoric Society of Malta*, Malta.

- HSU K.J., 1983. The Mediterranean Was a Desert. *Princeton Univ. Press*, Princeton, New Jersey.
- KRIJGSMAN W., HILGEN F.J., RAFFI I., SIERRO F.J. & WILSON D.S., 1999. Chronology, causes and progression of the Messinian salinity crisis. *Nature*, 400 (6745): 652–655.
- LAKHDARI W., Doumandji-Mitiche B., Dehliz A., Acheuk F., Hammi H., M'lik R. & Soud A., 2015. Some elements of the bio-ecology of *Brachytrupes megacephalus* (Lefebvre, 1827) (Orthoptera, Gryllidae) in the Region of Oued Righ (Algerian Sahara). *American-Eurasian J. Agric. & Environ. Sci.*, 15 (6): 1082-1089.
- LA GRECA M., 1957. Blattoidea, Mantoidea, Orthoptera (Risultati delle Missioni entomologiche dell'Istituto di Entomologia dell'Università di Bologna nel Nord-Africa). *Boll. Ist. Ent. Univ. Bologna*, 22: 51–62.
- LANFRANCO G., 1957. Notes on the Orthoptera of the Maltese Islands. *Entomologist*, London, 90 (1126): 75-76.
- LEFÈBVRE L-F., 1827. *Gryllus megacephalus* Lef. *Ann. Soc. Linn. Paris*, 6: 10.
- LINDGREN J. & COUSINS S., 2017. Island biogeography theory outweighs habitat amount hypothesis in predicting plant species richness in small grassland remnants. *Landscape Ecol.*, 32(9): 1895-1906.
- LOMOLINO M.V., 2000. A Call for a New Paradigm of Island Biogeography. *Global Ecol. and Biogeography*, *J. Macroecol.*, 9 (1): 1–6.
- MACARTHUR R.H. & WILSON E.O., 1967. The Theory of Island Biogeography. *Princeton Univ. Press*, Princeton, New Jersey.
- MASSA B., 1978. Observations on Eleonora's Falcon *Falco eleonora* in Sicily and surrounding islets. *Ibis*, 120(4): 531-534.
- MASSA B., FONTANA P., BUZZETTI F.M., KLEUKERS R. & ODÉ B., 2012. Fauna d'Italia – Orthoptera. XLVIII. *Calderini ed.*, Milano, ccxiv+563 pp. & dvd.
- MASSA B. & LO VERDE G., 1991. Ciclo biologico delle specie del genere *Pamphagus* Thunberg 1815 (Orthoptera Pamphagidae). *Frustula entomol.*, 13: 213-224.
- PRAZZI E., BILLECI V., MARAVENTANO G., SANGUEDOLCE F. & SORRENTINO G., 2014. Presenza di *Brachytrupes megacephalus* (Lefebvre, 1827) (Orthoptera Gryllidae) e *Schistocerca gregaria* (Forskål, 1775) (Orthoptera Acrididae) nell'Isola di Lampedusa (Pelagie, Canale di Sicilia). *Naturalista sicil.*, 38 (1): 121-123.
- VALDEYRON-FABRE L., 1955. Observations sur la biologie de *Brachytrupes megacephalus* Lef., en Tunisie. *Rev. Path. Vég. Entom. Agri. France*, 34 (3): 136-158.

Authors' Addresses — L.F. CASSAR*, E. CONRAD, C. GALDIES, Institute of Earth Systems, University of Malta, Msida; J.J. BORG, National Museum of Natural History, Vilhena Palace, Mdina; e-mail: louis.f.cassar@um.edu.mt, elisabeth.conrad@um.edu.mt, john.j.borg@gov.mt, charles.galdies@um.edu.mt

*corresponding author.