Zootaxa 5231 (1): 065–078
https://www.mapress.com/zt/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

https://doi.org/10.11646/zootaxa.5231.1.5
http://zoobank.org/urn:lsid:zoobank.org:pub:D630EE18-5206-4BDF-A73D-6C06D3E41CBA

A new subspecies of *Papilio saharae* Oberthür, 1879 (Lepidoptera: Papilionidae) from Lampedusa, Italy

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Abstract

An investigation into the only representative of the genus *Papilio* on the island of Lampedusa, the largest island of the Pelagian group, was conducted as part of a broader Mediterranean-wide study on the *machaon* complex. Over a three-year period, adults, larvae and ova were collected for further research during field visits, while an in-house breeding programme involving wild-collected gravid females was initiated with a view to examine an adequately sized series of specimens. A total of 38 adults, including 23 male specimens, >150 ova, 233 larvae, and 220 pupae were examined. In addition to a thorough morphometric assessment, statistical tests were performed using one-way ANOVA and multivariate analysis. Results demonstrate morphological characters of *P. saharae* and, to a lesser degree, of *P. machaon*, suggesting that the taxon is plausibly the outcome of a hybrid swarm whose occurrence on the island was facilitated by Pleistocene lowstands (when the island was physically connected with the north African continental landmass, the taxon's centre of origin). Based on results, involving all four stages of metamorphosis, it is proposed to 'anchor' the taxon to *Papilio saharae* Oberthür, 1879 and assign it subspecific status, *aferpilaggi* **ssp. nov.**

Key words: Central Mediterranean, Pelagian Islands, island biogeography, *machaon* complex, hybrid swarm

Introduction

The island of Lampedusa is the largest of the Pelagian island group, with a total area of >20 km2. It is located ≈130 km east of Mahdia on the coast of Tunisia, >150 km WSW of Malta and ≈207 km to the south of Sicily. Lampedusa forms part of the Pelagian Block, together with the Hyblean plateau of south-eastern Sicily and the Maltese Islands, among other emergent segments of the structure on the northern periphery of the African plate. During Quaternary lowstands, the opportunity for sporadic physical connectivity between Lampedusa and the north African mainland would have presented itself (Giraudi, 2004). As a result of a fairly similar, albeit more recent geotectonic past, Lampedusa is topographically comparable to the Maltese Islands, currently comprising a maximum altitude of 133 m amsl. (Grasso *et al.*, 1985; Grasso & Pedley, 1988). Under the present climatic regime, Lampedusa does not sustain any natural bodies of water of significant extent, nor any perennial fluvial sources. The island's climate is classified as subtropical/low-latitude semi-arid hot steppe (Köppen-Geiger category: Arid Steppe, hot – *BSh*), supporting natural and semi-natural biotopes, characteristic of the Thermo-Mediterranean zone, across the island's pervasive karstland landscapes. The island's floral formations are of central Mediterranean-Maghrebi provenance, which together with a suite of endemic species (including aerohaline associations *Limonietum lopadusani* and *Chiliadenetum lopadusani*), rely on precipitation during the wet season (average registered annual rainfall: 300 mm) and, presumably, on aerosol particles from the sea (albeit saline). As a consequence, the vegetation of Lampedusa is well adapted to an arid, wind-swept terrain, where soils are typically shallow. Given there are no perched aquifers on the island, spring-line seepage is virtually non-existent.

Accepted by H. Chiba: 24 Dec. 2022; published: 26 Jan. 2023

The occurrence of *Papilio machaon* Linnaeus, 1758, assumed as the sole representative of the genus on the island, has been reported in a number of scientific contributions (Romano & Romano, 1995; Vodă *et al*. 2016; Romano, 2020). Vodă *et al.* (2016) assigned the taxon to the north African clade, however noting a "*substantially diverged lineage*". Meanwhile, Cassar & Catania (2022) drew attention to the listing of *Papilio saharae* Oberthür, 1879 from Lampedusa on Paolo Palmi's website, which according to Palmi (pers. comm. Palmi/Cassar June 2021), was based on a sighting by Luigi Racheli. Following a 2021 field visit by two of the authors (LFC/AC), the presence of '*a taxon with perceptible morphological traits of Papilio saharae on Lampedusa*' was reported (Cassar & Catania, 2022, p. 305). This initial work drew its preliminary conclusions based on the morphometrics of wild-caught specimens, inclusive of all four major life cycle stages of metamorphosis, as well as framing the line of discussion in the context of the Quaternary sea-level fluctuations-habitat nexus. A comprehensive overview of Lampedusa's geography, geology, climate and biotopes is incorporated in Cassar & Catania (2022). A number of field research visits to the island of Lampedusa were organised with a view to collect specimens of *P. machaon* for taxonomic analysis. These visits were held between 2019 and 2022, during which time three stages, notably adults, larvae and ova, were collected. Larvae and ova were found on both *Foeniculum vulgare* and *Ruta chalepensis*. Material collected in the field thus comprised adult specimens that were appropriately processed for subsequent dry setting and living specimens, including gravid females, larvae and ova, which were transported back for breeding and further related observations (refer to detailed Methodology below).

Methodology

Three five-day field research visits were organised in April 2019, May-June 2021 and April 2022, with the purpose of collecting *Papilio machaon* specimens for taxonomic examination and, separately from the focus of the present contribution, for subsequent DNA analysis. During each of the visits, adult specimens were collected with kite or standard nets by means of conventional stalking. During the second and third visits, specific effort was made to collect a gravid female as well as early stages for rearing with a view to examine a series of voucher specimens for morphological variability. The second field visit (May-June 2021) yielded a number of ova and larvae (first and second instars), collected from among the florets of *Foeniculum vulgare*, and one gravid female (which featured a narrow longitudinal abdominal black line, normally indicative of the brood associated with the onset of the hot season). During the third visit (April 2022), four gravid females (with a wide black longitudinal abdominal line, presumed to have emerged from overwintering pupae) were collected from various locations across the island, together with two ova on *F. vulgare* filiform foliage and two first instar larvae found on an inflorescence of *Ruta chalepensis*. All living material was transferred to butterfly breeding cages or larval boxes, as applicable. Based upon the biotope on which the adult females were taken, *F. vulgare* or *R. chalepensis* was introduced into the rearing cage. Similarly, in the case of the ova and larvae, the choice of foodplant offered depended on the species of hostplant each one was collected from. Eventually, the early stages that were collected on *R. chalepensis* were transferred to cultivated *Ruta graveolens*.

Adult specimens were subsequently spread (dry preservation), with male specimen claspers set in manner to permit examination of the harpe under the microscope. A thorough photographic record was also kept of the various larval instars in order to document any phenotypic variation. Morphometric analysis for diagnostic assessment was carried out via both naked-eye and microscopic examination, while DNA analysis is currently underway; the latter work forms part of a separate study that also involves taxa of the *machaon* complex from across the Mediterranean. Recent DNA analysis of the Palaearctic *machaon* complex, particularly of the COI mitochondrial gene, has not been published due to poor resolution of the trees (AMC observation). Domagala & Lis (2022) published analysis results of two mitochondrial genes for many taxa in the *machaon* complex, but not including *P. saharae*, with similar poor resolution between samples. The process of selection of the holotype comprised a thorough examination of all wild-caught adults and specimens that emerged from wild-collected larvae, with particular attention accorded to both biometrics and colour markings. Due attention was afforded to the number of antennal segments of each specimen, as well as the length of the forewing and the general size and shape of the red colouration of the ocellus on the hindwing's jugal area. The forewing was measured from its base, in a straight-line, to the apex. In view of the existence of an additional identification character solely found in males, specifically the teeth on the harpe, particular emphasis was attributed to the number of teeth on this organ. Attention was also paid to specific characters of immature stages, notably the size of ova (overall volume), the colour and size of the larval osmeterium, and the general shape of the pupa in terms of cuticular protuberances. A number of paratypes have also been assigned. In total, 38 adult specimens were examined, of which 23 were males, in addition to >150 ova, 233 larvae (of which >60 were specifically examined for the length of their osmeterium), and 220 pupae. One-way ANOVA and multivariate analysis were used to explore the significance of differences in selected parameters in respect to male and female subgroups. A series of plots, useful for data visualisation, were as a result also rendered. Terminology of the wing venation and cells follows Smith & Vane-Wright (2001).

Results and Discussion

The decision to 'anchor' the proposed new subspecies to *Papilio saharae* Oberthür, 1879 is based on established morphological characters that are distinct from those of *Papilio machaon* Linnaeus, 1758. Notably, in the adult, these include the number of antennal segments, the number and configuration of the teeth on the male harpe, the size and shape of the ocellus on the hindwing, and the overall size. In the immature stages, the morphometrics are also different; in '*saharae*' the size of the ovum is smaller, the larval osmeterium is much longer, while the pupa is smooth and lacks the protuberances typical of most '*machaon*' forms.

P. saharae saharae is an eremic form that occurs in numerous locations across northern Africa, particularly but not exclusively where altitudinal gradient is prevalent. Its distribution is mostly defined by a mosaic of microclimates that characterise desert fringe environments on the northern edges of the Sahara, the dynamics of which play a crucial role in landform processes and floral distribution. Although the species is mostly confined to arid environments, it is also known to maintain a sympatric co-occurrence with *P. machaon* in several locations within the Maghreb - the Tunisian Sahel, where the landscape is dominated by a broad plain-type terrain, is a case in point - albeit with limited niche overlap in view of distinctly diverse biotope/larval host-plant preferences on the north African mainland (Pittaway, 1985; Pierron, 1990; Pittaway *et al*., 1994; Tennent, 1996; Tolman & Lewington, 1998; Moonen, 2012; Cassar, 2018). This sympatric association is, to a degree, analogous to the case of *Papilio hospiton* Géné, 1839 and *P. machaon* in Corsica and Sardinia, where the two taxa tend to follow a distribution pattern that is influenced by elevational diversity gradient but where some overlap is known to occur (Strobino, 1970; Higgins & Riley, 1978; Marini & Trentini, 1989). Although Lampedusa's topography is much too limited to afford an altitudinal gradient, the island's fairly homogenous karstic landscape nonetheless supports a number of larval host-plant species that *P. saharae* can potentially exploit, given (i) it is not strictly an oligophagous species, and (ii) the occurrence of several plants of the families Apiaceae and Rutaceae, among others. Incidentally, a male specimen of *P. saharae* was confirmed from Lentini in Sicily (20.IX.1978, leg. H.v.Oorschot). This specimen, considered a first for Europe, was discovered in the collections of the Zoological Museum Amsterdam (ZMAN), University of Amsterdam (Moonen, 2012). Coutsis *et al*. (2018) contested both this record as well as claims by Leraut (2016) that *P. saharae* was present in Sicily (after discovering several specimens in the natural history museum in Paris), and Leraut's assertion that the taxon occurring in Malta should be referred to as *P. saharae melitensis* Eller, 1936. The authors of the present work are of the opinion that the merits by which assertions were made, and methods employed for determination by both Leraut (2016) and Coutsis *et al*., (2018) extend beyond the scope of this contribution and may thus deserve a separate dedicated response. In 2018 a female specimen with morphological characters of *P. saharae* was taken in Giarratana, Sicily (31.V.2018, leg. L-F.Cassar), at 473 m amsl (Cassar, 2018). Both Lentini and Giarratana lie on the Hyblean Plateau (part of the Pelagian Block, which is effectively the foreland area of the African plate), where the terrain can tend to become fairly arid, especially during the dry season.

In the case of the Lampedusa taxon, the size of the ovum (>150 ova examined, including wild-collected ova and those laid by wild-caught female specimens) is distinctively smaller than that of *P. machaon*, while its shape bears a spherical profile, typical of the *machaon* (s.l.) complex; both these traits have been previously reported (Pittaway *et al*., 1994; García-Barros, 1996; Cassar & Catania, 2022). The osmeterium of all the larvae examined (>60) was, without exception, substantially longer than that of the typical '*machaon*' larva (estimated to be more than twice as long), though orange in colour rather than brown, as characteristic in *P. saharae saharae*. Moreover, all reared larvae (233), whether initially collected as ova, wild-collected early instars, or resulting from gravid female specimens, exhibited the typical colouration of *P. saharae*, that is, a general whitish colour that replaces the green background colouration of *P. machaon* larvae (see description below and in Cassar & Catania, 2022). In 93% of cases (220 examined), pupae were smooth, lacking protuberances common in '*machaon*' pupae. Phenotypic plasticity in pupal colour (including seasonal polyphenism) was not evident, as all pupae, with a single exception of a green morph pupa, exhibited a range of brown hues, mostly quite uniform in colouration and some with darker brown or greyish markings. Pupal length ranged between 2.1 to 2.9 cm, with males predominantly on the smaller end of the scale. The Lampedusa taxon pupa, in contrast to those of *P. machaon* and *P. hospiton*, varies appreciably. Compared to that of *P. machaon*, the former is far smoother, with a light texture and significantly less defined cephalic projections and thoracic segment. In comparison to both *P. machaon* and *P. hospiton*, the tubercles on the latero-dorsal region of the Lampedusa taxon are considerably less evident. Adult males can be markedly smaller than the females, with the HW ocelli of the former, more often than not quite small, slightly ovoid or roundish, sometimes assuming the shape of a curvilinear triangle. Ocelli on the female's hindwing are somewhat larger (mostly in congruence with the larger wing area), generally assuming a more curvilinear appearance.

Morphometrics of all the three early phases of metamorphosis (ovum, larva and pupa) provide compelling evidence that points to *Papilio saharae*. A total of 57% of adult individuals examined also possessed characters common to *P. saharae*, notably the number of antennal segments (across all specimens examined) and the teeth on the harpe of male specimens [*P. saharae* range for antennal segments and harpe teeth, respectively: 30-31; 7-10]. However, a number of the individuals examined tended to fall into a category of biometric variance, with a cohort of 14.3% bearing characters typical of both '*machaon*' and '*saharae*' taxa, and another, yet smaller, group of specimens (8.6%) that bore anomalous morphological characters that belonged to neither '*machaon*' nor '*saharae*'. Morphologically, this latter cohort was intermediate between the two taxa and was consequently categorised as being comprised of outliers. Two individual male specimens had an intermediate number of antennal segments (32) but a number of harpe teeth that fell within the '*machaon*' range. Five individual female specimens had 33 antennal segments, the lowermost end of the '*machaon*' range [antennal segment range for *P. machaon*: 33-36]. If only male individual specimens were to be considered for investigation (in order to have employed the use of two relatively reliable characters to separate the taxa, that is, harpe teeth and antennal segments), then the percentage of specimens with *P. saharae* traits increases to 70% (Figures 1-3). There is no doubt that the taxon has a dominance of '*saharae*' expression in morphological terms, notwithstanding the lesser degree of '*machaon*' and other outlier characteristics in a percentage of the specimens examined. Another interesting observation, which tends to correspond with *Papilio saharae*, is diapause duration. Although *P. machaon syriacus* has been known to diapause for two years (Benyamini, 2008), *machaon* subspecies from the central Mediterranean (Malta, Sicily and southern Italy) are not habitually known to resort to such physiological process, at least in the long term. Intriguingly, many pupae resulting from reared offspring of wild-collected adults (May-June 2021) are, at the time of writing, still in diapause, while reared offspring of wild-collected (April 2022) adults have emerged from their pupae, albeit gradually, in significant number. The only adults, originating from the 2021 field visit which emerged were those of wild-collected ova and larvae (see list of paratypes below).

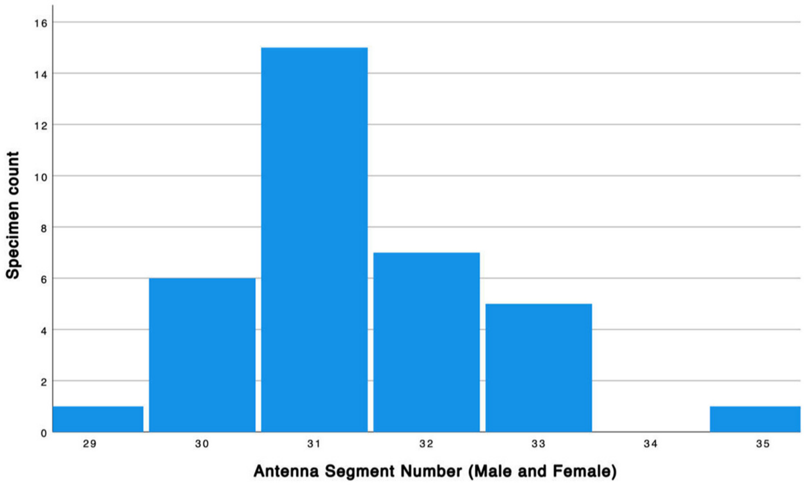

FIGURE 1. Frequency analysis of antennal segments (male and female).

In terms of dimensions, often suggested as a characteristic of *P. saharae saharae* (Larsen, 1984; Pittaway *et al*., 1994; Tarrier, 2020), it may be surmised that overall size is not an entirely reliable descriptor in respect to this taxon. The morphometrics of two male specimens examined, emerged between the last week of July and the first week of August 2022, underpin this assertion quite clearly. Although their general appearance and size tallies reasonably well with that of a typical northern African *P. saharae saharae* (FW length from base to apex, based on six male specimens ex-Morocco, Algeria, and Tunisia: x̄ 33.40 mm), the specimens in question, which have a FW length (base – apex) of 34.35 mm and 34.98 mm, respectively, were in fact found to have 33 and 35 antennal segments, and 13 and 14 harpe teeth, respectively. Conversely, a sibling individual of similar size (FW length of 35.30 mm) that emerged in June 2022 has 31 antennal segments and 10 harpe teeth.

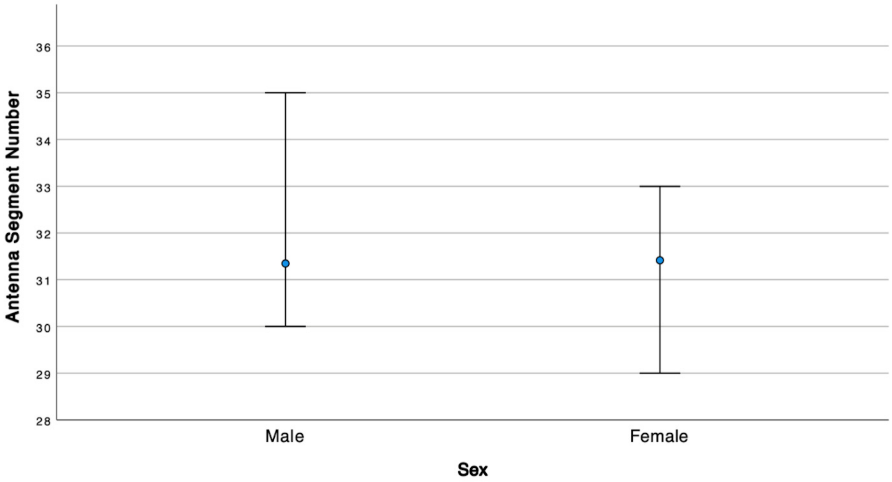

FIGURE 2. Mean antennal segment number for male and female subgroups, with error bars showing the range of values.

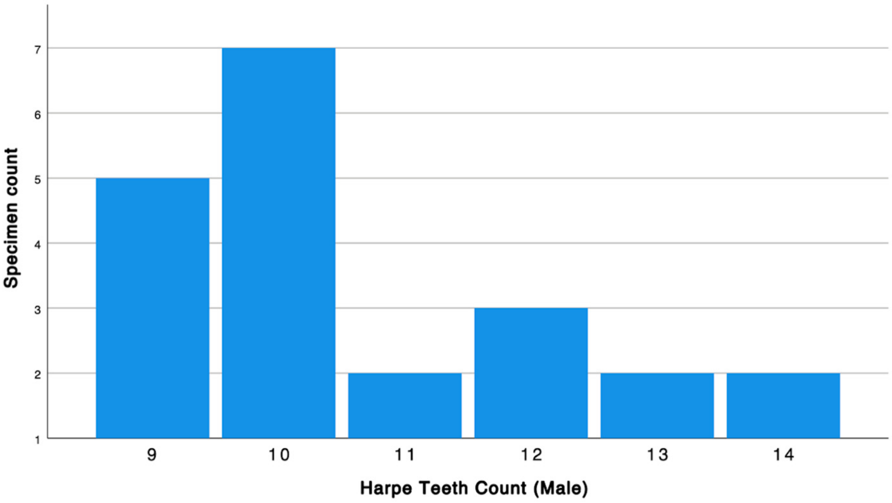

FIGURE 3. Frequency analysis of harpe teeth (males).

It is thus clear that the population on the island of Lampedusa possesses morphological traits of both *P. saharae* and *P. machaon*, plausibly the result of a hybrid swarm whose occurrence on the island was facilitated by Pleistocene lowstands, when Lampedusa was physically connected with the centre of origin, that is, the continental landmass represented by present-day Tunisia (Figure 4). The island's eventual isolation during ensuing interglacials, consequent to eustatic sea-level change, would have made possible the formation of a hybrid zone. Whether this is a reticulation event or a case involving introgression as a result of intermittent connectivity with the African landmass as sea levels continued to fluctuate during the Pleistocene, or to varying extent a combination of both, remains to be seen. Whichever the circumstance, the Lampedusa taxon appears to be, quite literally, a species in the making through the process of natural hybridization. *Papilio saharae* and *P. machaon* are known to hybridise naturally in

Israel (Benyamini, 2017; Benyamini & John, 2020), where the two species maintain a contemporary sympatric association, contrary to the case of the Lampedusa taxon, which has been isolated for millennia.

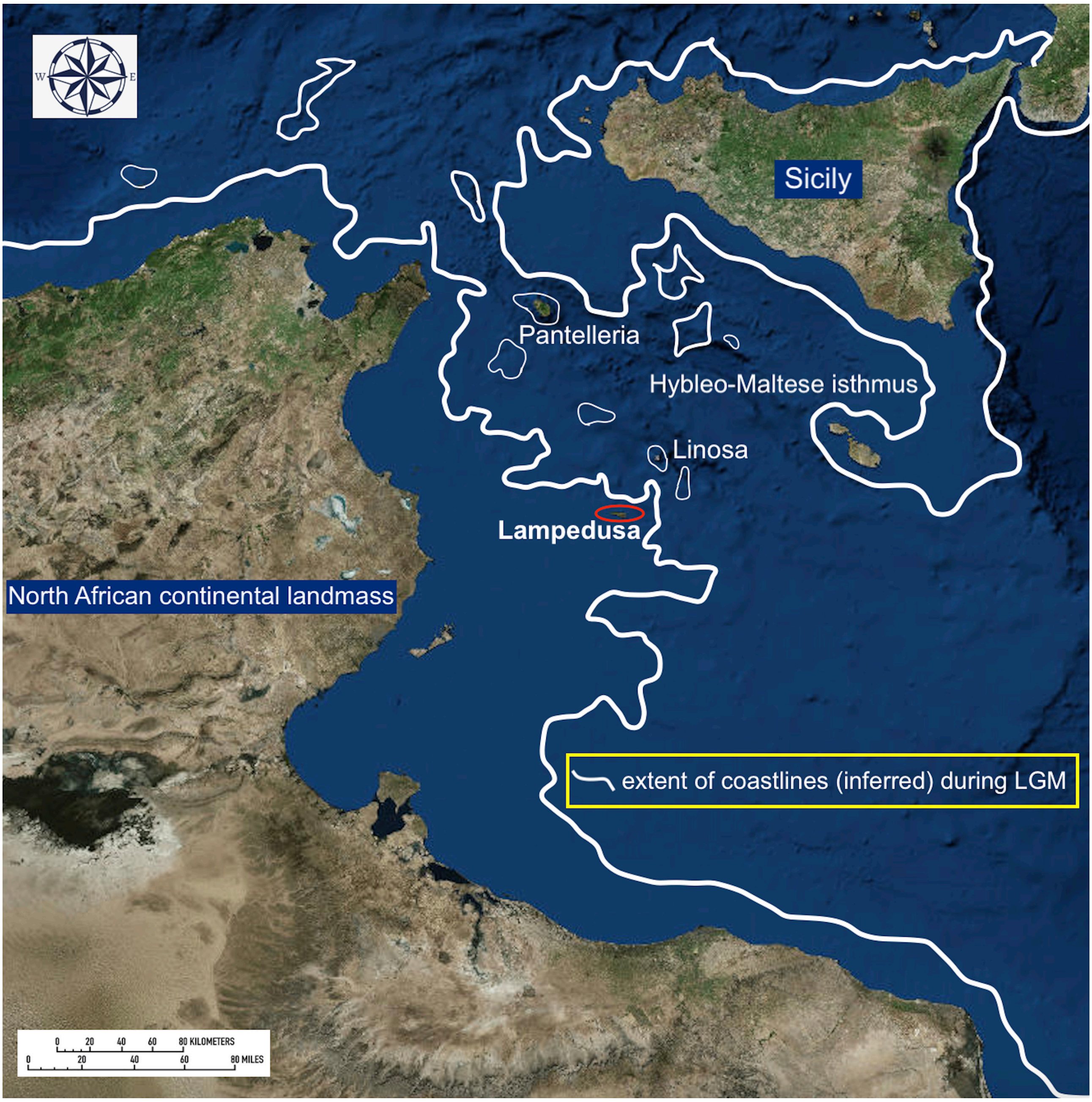

FIGURE 4. Inferred extent of coastline in the central Mediterranean area during Pleistocene lowstands at the peak of the Last Glacial Maximum (approx. 18 ka BP) at ≈120 m contour (base map source: IUCN map server).

Papilio saharae aferpilaggi ssp. nov.

Holotype. Adult male, collected 05 April 2022, *leg*. Aldo Catania and Louis F Cassar (Figure 5). The holotype will be deposited in the Museo Civico di Storia Naturale 'G. Doria', Genoa, Italy.

Type locality. Contrada di Cimitero Vecchio [35.51473, 12.56600], island of Lampedusa (Isola di Lampedusa), Sicily, Italy (Sicilia, Italia).

FIGURE 5. [Top] *Papilio saharae aferpilaggi* **ssp. nov.** ♂ holotypus (underside and upperside), Contrada di Cimitero Vecchio (on plateau between Tabaccara and Cala Galera valley), Lampedusa. **[Bottom]** Holotypus – scale bar increments: mm/in. (Photos: L-F. Cassar).

Morphometrics of the holotype

Antennal segments: 31; number of harpe teeth: 9; FW length: 36.30 mm.

Description

Forewing (FW): distal margin slightly concave from vein CuA_1 to M_1, with yellow crescents between each black vein tip providing a serrated appearance.

FW Upperside: ground colour black with two yellow bands across the discal cell. A yellow post discal band consisting of a rectangular spot in cell 1A at the lower margin with a rhomboid spot above it in cell CuA_2 and a series of arrow-head shaped spots in the cells above. The first four arrow-head spots shortening towards the apex, the fifth spot in cell R_5 longer than the fourth in cell M_1. A further arrow-head spot in cell R_4 with a large black spot completely separating the tiny tip from the base. The tip of the triangular spot in cell R_3 in line with the points of the arrow-head spots in cells R_5 and M_1, parallel to the apex of the discal cell. An elongate ephemeral spot composed of yellow scales not completely covering the black background above the triangular spot in cell R_3. Spots in the postdiscal band clearly separated by black scales along the veins, narrowest at vein 1A. Submarginal band consisting of a row of half-moon shaped submarginal yellow spots between each vein between cells CuA_2 and R_3, those in cell CuA_2 to R_5 half-moon shaped. Black band between the post-discal and submarginal bands finely irrorated with yellow scales, not reaching the yellow bands, merging with the ephemeral spot in cell R_3. Base of the discal cell and cells 1A and CuA_2 distinctly peppered with yellow scales, not quite reaching the yellow spot in each cell. Narrow cell between the radial vein and subcostal vein strongly covered with yellow scales from base, becoming diffuse above the first yellow spot in the discal cell. Costal wing edge black without yellow scales from base to apex.

FW Underside: pattern similar to upperside, yellow scales in discal cell dense near base and between the submarginal band and the distal margin, reaching the margin in cells CuA_2 and R_3; denser than the upperside between the post discal and submarginal bands except in cell CuA_2.

Hindwing (HW): margin distinctly concave between veins M_3 and R_s, with a uniformly narrow tail at vein M_3 curving slightly downwards. Margin between tail and vein CuA_2 strongly concave, protruding slightly at vein CuA_1. Lobes present at veins CuA_2 and 1A+2A. Upperside covered with fine hairs near base, extending down inner marginal area, more sparsely present in discal cell and below cell. Fine hairs forming a fringe on the inner margin, sparsely present in cell CuA_2 on the underside, mainly along vein 1A+2A.

HW Upperside: base and discal area yellow, black scales covering the base extending into the anal cell and cell CuA_2, not reaching as far as the anal ocellus along vein 1A+2A but narrowing along vein CuA_2, forming a yellow triangle in cell CuA_2 above the anal ocellus. Veins in the yellow discal band strongly covered by black scales, particularly broad at the apex of the discal cell and on the posterior discocellular vein. A broad black postdiscal band well separated from the apex of the discal cell, discal edge irregular. Cobalt blue scales forming amorphous spots with diffuse greenish scales distad from the outer margins not reaching the crescent shaped yellow submarginal spots. Outer margin yellow between broadly black veins, except at the tip of vein CuA_1 which is narrowly yellow, the black scales on the vein produced to a point before the tip of the vein. Yellow scales extend along the margins of the black tail on vein M_3 to ¾ of the tail length. The lobe at the tip of vein CuA_2 black, forming a teardrop. The anal ocellus in the lobe of cell CuA_2 ringed by a black extension of the discal band above and along vein 1A+2A, narrowly extending along the lower edge of the ocellus from the tip of vein 1A+2A enclosing ¾ of the ocellus and terminating in a slightly swollen tip. Ocellus consisting of a curvilinear triangular red spot with a crescent of bright blue scales above, appearing violet where these scales extend into the red spot. Margin of cell CuA_2 below the ocellus yellow from inside vein 1A+2A, extending up the edge of the ocellus along vein CuA_2 almost to the blue scales above the red spot.

HW Underside: mostly similar to upperside; basal area and cell CuA_2 yellow, not covered by black scales except along all veins, more broadly than on the upperside. Inner margin of the black postdiscal band narrower than upperside, with blue scales coalesced into distinct spots centrally just distad of the margin. Yellow scales, appearing greenish due to the black scales below, thickly peppering the whole band almost to the distinctly enlarged yellow submarginal crescents, separated by a thin black line; veins of the postdiscal band thinly scaled black. Yellow scales extending into the red ocellus near vein CuA_2 and merging with the blue scales above; a thin yellow line between the red ocellus and black margin parallel to vein 1A+2A below the blue crescent.

Head: covered by yellow scales; palpi yellow; frons centrally black with yellow edges.

Body: dull yellow with broad black dorsal band from centre of frons to tip of pseuduncus on abdominal tergite

VIII above yellow valvae; tegulae dull yellow, fringed with hairs; thorax and abdomen distinctly pilose, especially ventral surface covered with dull yellow hairs; hairs also present on the dorsal surface, but generally sparse and shorter, except for long yellow hairs on the third thoracic segment covering the base of abdomen.

Differential diagnosis

Forewing upperside: distal margin slightly concave from vein CuA$_1$ to M$_1$ [in *P. s. saharae* concave from vein CuA$_2$ to M$_2$]; outer margin with distinct yellow edge between veins [either absent or only indicated in *P. s. saharae*]; narrow cell between the radial vein and subcostal vein strongly covered with yellow scales from base to the first yellow spot in the discal cell [tends to be black in *P. s. saharae*].

Hindwing tail thin and curved distinctly inwards [tail of *P. s. saharae* straight].

Hindwing upperside: ocellus shape and size – ovoid or curvilinear, small in males and larger in females [round in *P. s. saharae*]; postdiscal band pitch black, with strikingly conspicuous broad cobalt blue suffusion in cells across postdiscal area, extending from tornal area above ocellus to cell R$_1$ [blue colouration in *P. s. saharae* significantly reduced].

Hindwing underside: postdiscal band thickly peppered with yellow scales over a black base, with an intense pale blue suffusion bordering the discal area in each cell and defined black lunules bordering the submarginal area [markings ill-defined and somewhat hazy, blue scales minimal to absent in *P. s. saharae*].

In addition to these distinctive characters in the adult, the one morphological characteristic which stands out in the larval stage is the colour of the osmeterium, which, in contrast to the characteristically brown organ of *P. saharae saharae*, the osmeterium of *P. saharae aferpilaggi* **ssp. nov.** is orange.

Observed at a distance, the adult butterfly bears a resemblance to a typical Old World '*machaon*'. A closer naked-eye examination of the ocelli will indicate a degree of noticeable disparity between the Lampedusa taxon and *P. machaon*. The ocellus on the male hindwing is small and slightly ovoid or roundish, often assuming the appearance of a curvilinear triangle; the ocellus of the female is larger (consistent with a larger wing area) and generally assumes the shape of a curvilinear triangle (Figures 6 and 7). Male forewing length (base to apex) range: 34.35-45.80 mm ($\bar{x}$36.85 mm); female forewing length range: 37.55-46.86 mm ($\bar{x}$42.52 mm). Microscopic examination of antennal segments and the number of teeth on the harpe, although not entirely conclusive due to the degree of variance among individuals, will further provide a fair indication. However, a holistic appraisal of the taxon's diagnostic morphological characters needs to be considered across all stages of metamorphosis for a definitive determination (for a description of the taxon's immature stages see below). Male and female specimens of the various *machaon* subspecies that occur within the Mediterranean Basin, together with a pair of *P. saharae saharae*, are illustrated with a series of five specimens of *P. saharae aferpilaggi* **ssp. nov.** for comparative purposes (Figure 8). In addition, Table 1 compares antennal segments and forewing length between taxa, with results quite similar to those obtained by Pittaway *et al*., (1994) and Cassar (2018). Notwithstanding the sizeable sample size across all taxa listed in Table 1, there remains the limitation of unequal assortment of males and females, where forewing length is concerned.

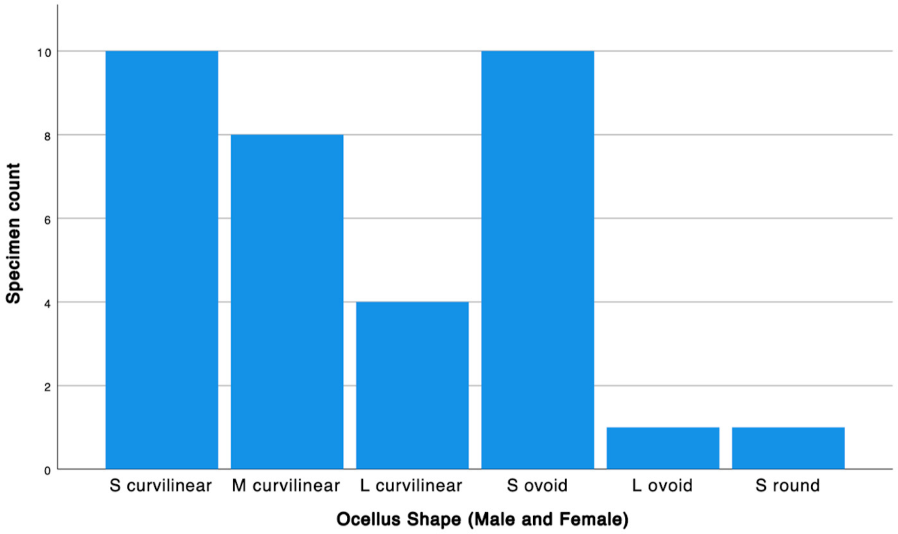

FIGURE 6. Frequency analysis of ocellus shape (all adults); S, M and L refer to small, medium and large, respectively.

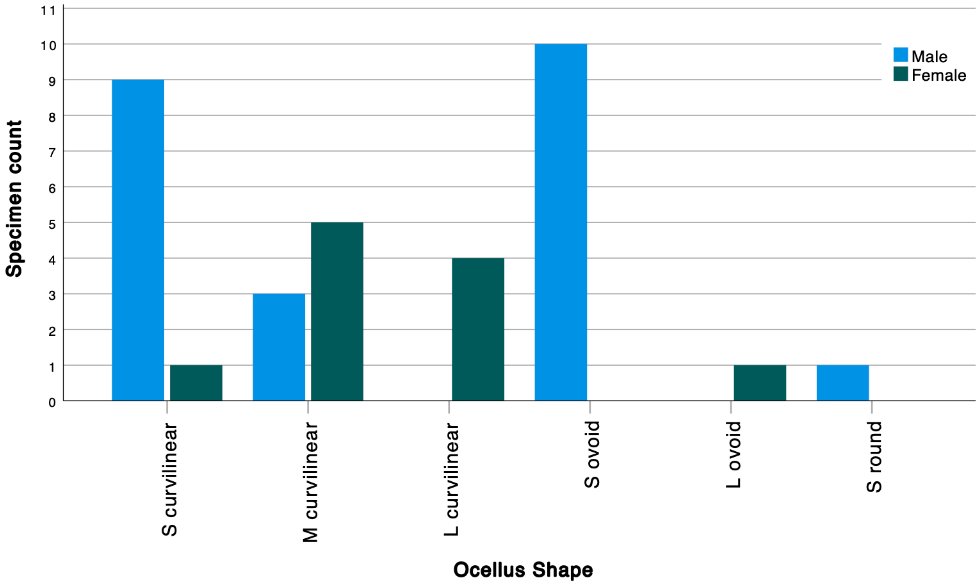

FIGURE 7. Frequency analysis of ocellus shape, for male and female subgroups; S, M and L refer to small, medium and large, respectively.

FIGURE 8. A series of *Papilio saharae aferpilaggi* **ssp. nov.** specimens with pairs of *Papilio machaon* subspecies from the Mediterranean Basin and of *P. saharae saharae*. From the left, first column: *P. machaon hispanicus*, Spain, Teruel, ♂ and ♀ VI.2015 (Coll. LFC); *P. s. saharae*, Morocco, Tizi-Tazouguart, ♂ IV.2018 and Azgour, ♀ VI.2018 (Coll. LFC); second column: *P. m. sphyrus*, Italy, Sicily, Il Pagliaio delle Madonie, ♂ and ♀ VI.2019 (Coll. AC); *P. m. mauretanica*, Morocco, Azrou, ♂ and ♀ VI.2018 (Coll. LFC); third column: *P. s. aferpilaggi* **ssp. nov.** Italy, Lampedusa, ♂ VIII.2022, ♂ VII.2022, ♂ IX.2022, ♀ IX.2022 and ♀ VI.2021 (Coll. LFC); fourth column: *P. m. melitensis*, Malta, Selmun, ♂ I.2019 and ♀ V.2019 (Coll. LFC); *P. m. syriacus*, Greece, Samos, ♂ VII.2018 (Coll. LFC) and Israel, Moshav Kidron, ♀ V.2008 (Coll. AC) – scale bar increments: mm/in. (Photo: A. Catania).

Immature stages

Ovum. Spherical, creamy-yellow in colour when deposited, eventually developing a brownish ring around the crown together with fine spots, subsequently becoming very dark prior to hatching.

Larva. L1 and L2 instars quite dark with characteristic small but restricted white dorsal saddle-like patch spread across two abdominal segments (A3 and A4); pronounced black spiny setae on subdorsal scoli of L3 and L4, and subspiracular orange bulbous verrucae producing a quasi-continuous longitudinal row that extends laterally from mesothoraxic segment (T2) to preanal segment (A9); prominent bright orange subdorsal protuberances at base of scoli of L3 instar; discontinuous black encircling patches, conspicuous mostly in L5 (final) instar but also present in L3 and L4. Segmental divisions in L5 larva very pale pastel green (not velvety black as in numerous *machaon* subspecies); external body surface of final instar generally smooth and velvety with the intense orange markings (present in L3 and L4) much reduced; osmeterium of L5 instar larva orange and very long (Figure 9), extending to metathoracic segment (T3); when protracted, odour emitted distinctly different to that of *machaon* larvae.

Pupa. Fine-textured and relatively quite smooth, with discreet protuberances, if any; cephalic projections, thoracic segment (T2 region) and latero-dorsal tubercles not pronounced.

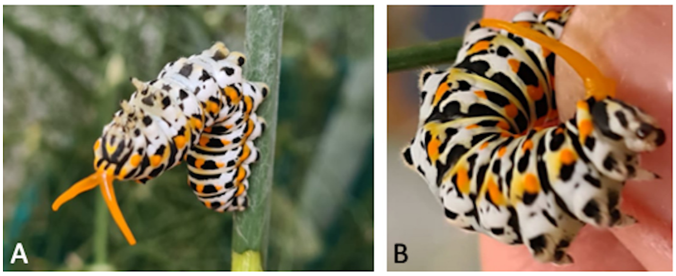

FIGURE 9. Osmeterium (A) partially extended; (B) fully extended.

Paratypes. A total of 38 adult specimens were examined as per the methodology described above (including the holotype), comprising 26 wild-caught adults and imagines that emerged from wild-collected ova and larvae, and 12 randomly selected reared, first- and second-generation individuals (= offspring of wild-caught and 1st generation adults). In addition to the specimens examined, a series of other specimens, notably a number of those that have been bred from wild-caught parent specimens and some that have been reared from first generation bred material, all of Lampedusa stock, have been selected as paratypes.

Italy, Sicily, island of Lampedusa:

05.IV.2019. Cala Creta (1♂), L-F. Cassar.

31.V.–04.VI.2021. NE main town periphery, off via Firenze (1♂, 1♀); Clifftop above Grotte Solaro (1♂); main town near harbour – wild-collected L2 and L3 larvae, reared and emerged as adults on: 21.VI.2021, 26.VI.2021, 26.VIII.2021, 04.IX.2021, 25.IX.2021 and 28.IX.2021 (1♂, 5♀♀); Cala Francese (1♂); NNE segment of main town (1♂); NW fringe of main town (2♀♀), A. Catania/L-F. Cassar.

01-06.IV.2022. NW fringe of main town (1♂, 3♀♀); Cala Creta (1♀); Albero Sole (1♀); Contrada di Cimitero Vecchio – TL: plateau between Tabaccara and Cala Galera valley – (3♂♂, 1♀); NNE segment of main town (1♂); NW fringe of main town (2♂♂); main town near harbour – wild-collected L2 larva, reared and emerged as adult on: 25.V.2022 (1♂); Cala Francese (1♂, 1♀); *Bred 1st generation (offspring of four ex-Lampedusa ♀♀ taken in April 2022)* – emerged as adults on: 30.IV.2022 (1♀), 21.V.2022 (3♂♂), 22.V.2022 (2♂♂), 23.V.2022 (3♂♂), 24.V.2022 (1♂), 25.V.2022 (2♂♂, 2♀♀), 26.V.2022 (2♂♂, 2♀♀), 28.V.2022 (1♂), 29.V.2022 (3♀♀), 31.V.2022 (1♂, 1♀), 05.VI.2022 (2♂♂, 1♀), 06.VI.2022 (3♂♂), 07.VI.2022 (1♂), 13.VI.2022 (1♂, 1♀), 14.VI.2022 (1♂, 1♀), 16.VI.2022 (1♀), 17.VI.2022 (1♂), 19.VI.2022 (2♂♂, 1♀), 24.VI.2022 (1♂, 1♀), 27.VI.2022 (1♀); *Bred 2nd generation (offspring of 1st generation that originated from ex-Lampedusa ♀♀ taken in April 2022)* – emerged as adults on: 19.VI.2022 (1♂), 22.VI.2022 (1♂, 1♀), 30.VI.2022 (5♂♂, 1♀), 02.VII.2022 (6♂♂, 3♀♀), 03.VII.2022 (2♂♂, 1♀), 12.VII.2022 (1♂, 3♀♀), 19.VII.2022 (1♂, 2♀♀), 27.VII.2022 (3♂♂, 1♀), 28.VII.2022 (1♂, 1♀), 29.VII.2022 (2♀), 01.VIII.2022 (1♀), 02.VIII.2022 (2♂♂, 2♀♀), 04.VIII.2022 (1♂, 4♀♀), 05.VIII.2022 (1♀), 06.VIII.2022 (1♂), 12.VIII.2022 (1♂, 1♀), A. Catania/L-F. Cassar.

The paratypes will be deposited in various museums of natural history and in private collections.

Distribution. Known only from the island of Lampedusa.

Etymology. The subspecies name makes reference to the fact that the taxon originated in Africa, hence, the use of the adjective *âfer* which implies "of Africa", while *pilaggi* is derived from the Sicilian name of the island group, namely, Ìsuli Pilaggî.

Description of the locus typicus. South-facing karstic plateau (elev. 47 – 68 m) overlooking Baia della Tabaccara. The vegetation comprises a garrigue-steppe mosaic characterised by a lithophilous floral assemblage typically on shallow soils, exposed bedrock and an extensive 'ground armour' (scattered, loose stone fragments), which demonstrates the influence of erosional processes that operate in such exposed coastal environments over time. Predominantly, the flora is represented by the following associations: *Coridothymo capitati-Cistetum parviflora, Triadenio-Chiliadenetum* (with a significant presence of the endemic *Chiliadenus lopadusanus*), and *Limonietum lopadusani*, together with an Ermes community, as well as widespread stands of *Ruta chalepensis* (Figure 10).

Note: as is typical of taxa of the *machaon* complex, these butterflies are known for their characteristic hill-topping behaviour, where males tend to congregate on high, exposed terrain in search of a female, and where they may be observed engaging with other, potentially competitive, males. It may therefore be pertinent to note that although the butterflies were relatively abundant during the time of survey, their presence within the type locality should be considered transient.

FIGURE 10. General view of the ***locus typicus***, highlighting the landform and presence of *Ruta chalepensis* (Photo: A. Catania).

TABLE 1. A comparison of antennal segments and forewing length between taxa that occur in the Mediterranean Basin and North Africa.

Taxon	Locality	Antennal segment range	Antennal segments (average number)	FW length range (mm)	FW length average (mm)
Papilio s. saharae (n:12)	Algeria, Morocco, Tunisia	28 – 32	30.66	28.00 – 44.00	35.27
Papilio s. aferpilaggi (n:38)	Lampedusa (Italy)	29 – 35	31.37	32.40 – 46.86	39.20
Papilio m. melitensis (n:16)	Malta	33 – 36	34.18	34.00 – 45.50	40.25
Papilio m. sphyrus (n:12)	Sicily (Italy)	33 – 36	33.66	36.00 – 45.50	41.99
Papilio m. hispanicus (n:12)	Spain	33 – 36	33.83	36.35 – 52.40	41.28
Papilio m. mauretanica (n:10)	Morocco	33 – 36	33.90	33.00 – 45.85	39.12
Papilio m. syriacus (n:12)	Samos, Crete (Greece), Israel, Lebanon	32 - 36	34.42	37.60 – 45.00	41.48

Acknowledgements

The authors are indebted to Adam Gauci (Department of Geosciences, University of Malta) for his help with the statistical analysis. A special word of thanks is due to Bruno Massa (Department of Agriculture, Food and Forest Sciences, University of Palermo) for the provision of photographs and field data pertaining to *Papilio 'machaon'* records on Lampedusa, to Martin Caruana (Institute of Earth Systems, University of Malta) for technical support in the field and logistical arrangements, and to Elena Prazzi and Gerry Sorrentino (Legambiente, Lampedusa) for the issuance of relevant permits to collect material from within the protected area on the island. The authors are grateful to Elisabeth Conrad (Institute of Earth Systems, University of Malta) for her insightful comments that improved the manuscript, to Moira Catania for assisting one of the authors [A.C.] with sorting out paratype specimen data, and to John J Borg (ornithologist and senior curator at the Natural History Museum – Heritage Malta), who accompanied the teams on all three visits to the island, for his companionship. Finally, the authors would like to express their sincere thanks to the three reviewers for their valuable suggestions and insights which helped improve the final version of the manuscript. Financial support through research grants by the University of Malta is acknowledged.

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