

# Preliminary findings on the presence of a taxon with morphological traits of *Papilio saharae* Oberthür, 1879 in Lampedusa (Italy) (Lepidoptera: Papilionidae)

L.-F. Cassar & A. Catania

## Abstract

Research visits to the island of Lampedusa yielded a number of adult specimens belonging to the “*machaon*-complex”, which, on closer examination of specific diagnostic features (including antennal segments, ocelli and number of teeth on the male harpe) have been found to possess morphological characters akin to *Papilio saharae* Oberthür, 1879, as well as to *P. machaon* Linnaeus, 1758, and including intermediate forms. Early stages, comprising ova and larvae, were also collected and reared, while several ova deposited by a gravid female taken in the field subsequently reached pupal stage. Ova are noticeably smaller, while larvae and pupae exhibit characters atypical of *P. machaon*. The present work examines a number of potential scenarios and provides a critique based on morphometric features of a suite of specimens examined, as well as on the history of eustatic sea-levels changes during the Quaternary Period that may potentially have abetted the species to reach Lampedusa during low-stands, before being left isolated during interglacial high-stands as sea-levels fluctuated during the Pleistocene epoch.

KEY WORDS: Lepidoptera, Papilionidae, Morphometrics, *Papilio machaon*, Thermo-Mediterranean zone, Pelagian Islands, Italy, North Africa.

## Hallazgos preliminares sobre la presencia de un taxón con rasgos morfológicos de *Papilio saharae* Oberthür, 1879 en Lampedusa (Italia) (Lepidoptera: Papilionidae)

## Resumen

Las visitas de investigación a la isla de Lampedusa produjeron un número de ejemplares adultos que pertenecían al complejo “*machaon*”, que, en el examen más detallado de las características de diagnóstico específicas (incluyendo los segmentos antenales, los ocelli y el número de dientes sobre el harpe del macho) hemos encontrado que poseen características morfológicas semejantes a *Papilio saharae* Oberthür, 1879, así como también respecto a *P. machaon* Linnaeus, 1758, e incluyendo las formas intermedias. Etapas tempranas, comprendiendo huevo y larva, también fueron recogidos y criados, mientras que algunos huevos dejados por una hembra grávida tomada en el campo posteriormente alcanzaban el estado de pupa. Los huevos son perceptiblemente más pequeños, mientras que las larvas y crisálidas exhiben unos caracteres atípicos de *P. machaon*. El presente trabajo examina un número de escenarios potenciales y provee una crítica sobre la base de las características morfométricas de un grupo de especímenes revisados, tanto como sobre la historia del eustatismo que los cambios del nivel del mar en el período Cuaternario que podría haber facilitado la llegada de la especie a Lampedusa durante los periodos de baja intensidad, antes de quedar aislada durante los periodos interglaciares de alta intensidad al fluctuar el nivel del mar durante el Pleistoceno.

PALABRAS CLAVE: Lepidoptera, Papilionidae, morfometría, *Papilio machaon*, zona termomediterránea, Islas Pelagias, Italia, Norte de África.

## Introduction

Field research visits to Lampedusa were held for the specific purpose of collecting *Papilio machaon* Linnaeus, 1758 specimens for DNA analysis. The first field visit was held in April of 2019, during which one male specimen was taken. During a more recent research visit to the island, held between May 31<sup>st</sup> and June 4<sup>th</sup> 2021, a number of adult specimens, including a gravid female and a host of larvae and ova were collected. Regrettably, other field visits in the interval were not possible in view of the prevailing public health restrictions and travel bans associated with the COVID-19 pandemic.

The presence of *Papilio machaon* in Lampedusa has been reported by various authors (ROMANO & ROMANO, 1995; VODÁ *et al.*, 2016; ROMANO, 2020). Until recently, it was assumed that *Papilio machaon* was the sole representative “Papilio” species present in Lampedusa, although Paolo Palmi, in his website entitled “Farfalle Italiane” (<http://www.farfalleitalia.it/sito/202/index.php>), lists *Papilio saharae* Oberthür, 1879 as having been reported from the island. Palmi attributes credit to Luigi Racheli for the sighting (pers. comm. Palmi/Cassar June 2021), which Tommaso Racheli corroborated via e-correspondence with one of the authors (T. Racheli/Catania, June 2021). However, the precise details of this occurrence do not appear to have been published. VODÁ *et al.* (2016) report the presence of *Papilio machaon* in Lampedusa, assigning it to the north African clade, and further citing what the authors describe as a “substantially diverged lineage” of 0.8%.

Geography, geology, and climate: Lampedusa is the largest of the Pelagie (Pelagian island group), with a total area of just over 20 km<sup>2</sup>. It lies some 130 km east of the Mahdia coastline (Tunisia), just over 150 km WSW of Gozo - *Malt*. Ghawdex - (Maltese Islands) and around 207 km south of the Sicilian coast near Agrigento. Structurally, the island of Lampedusa forms part of the Pelagian Block, representing one of its emergent segments. Notwithstanding its Italian sovereignty, it lies on the foreland domain of the African plate’s northern margin. Geologically, the island comprises depositional sequences of Meso-Cenozoic succession, forming a carbonate shelf that projects above the central Mediterranean to an altitude of 133 m amsl. Lampedusa is characterised by horst formations, the age of which extend across the late Tertiary (Neogene) - Quaternary Period boundaries. Stratigraphic exposures consist of a complex of sedimentary limestones, notably lithoclast breccias and bioclastic grainstones, and aeolian formations (GRASSO & PEDLEY, 1988a; LOMBARDO *et al.*, 2014). Topographically, Lampedusa is not unlike the Maltese islands, as a result of a relatively analogous yet more recent geo-tectonic history (GRASSO *et al.*, 1985; GRASSO & PEDLEY, 1988b). Similarly, karstic features are largely pervasive across the 11 km length of the island, as are sea-cliffs, raised beaches, and wave-cut platforms. However, in contrast to the Maltese Islands, Lampedusa does not support perched aquifers and registers an average of around 300 mm of rainfall annually. This dearth of freshwater, coupled by the island’s geographical position (latitude 35.30° N and proximity to the Tunisian mainland) and its considerably shallow and exposed soils, renders Lampedusa significantly more arid. According to the Köppen-Geiger classification, Lampedusa’s climate is subtropical/low-latitude semi-arid hot steppe (K-G category: Arid Steppe, hot - *BSh*, which is too arid to sustain a forest environment but not hot enough to be termed a desert).

Biotopes: The natural and semi-natural vegetation that colonises the island’s extensive karstland is made up of biotopes typical of the Thermo-Mediterranean zone, characterised by a suite of floral formations of central Mediterranean-Maghrebi provenance, together with a host of endemic assemblages (resulting from the island’s prolonged isolation), including the aerohaline associations *Limonietum lopadusani* and *Chiliadenetum lopadusani*. The vegetation climax on the island is represented by the *Periploco angustifoliae-Juniperetum turbinatae* association, which also occurs on the Tunisian mainland (BRULLO *et al.*, 2008). Other low maquis and garrigue floral associations resulting from degradation, or simply lower stages in the succession sequence due to abiotic conditions, consist

of the *Periploco angustifoliae-Euphorbietum dendroidis*, and the labiate *Coridothymo capitati-Cistetum parviflori* (often occurring with the endemic *Chiliadenetum lopadusani*). These and numerous other biotopes form mosaics with steppic communities, grading into one another (largely a function of edaphic factors, exposure, and slope aspect). Among the more common floral assemblages on the island, one encounters mosaics formed of elements of some of the above-named floral associations, together with other associations, namely *Triadenio-Chiliadenetum*, *Pegano-Salsoletum* and *Oryzopsis pauciflora-Hyparrhenietum hirtae*, various xerophilous grassland vegetation, including the *Lygeo-Stipetea*, *Stipo-Trachynietea* and *Tuberarietea guttatae* classes, as well as ruderal and ermes communities. In fact, although the human population of Lampedusa is relatively small (approximately 6,550) and contained within a single main conurbation, the impact of ribbon development, agricultural land abandonment, domestic dumping, and grazing, albeit limited, has contributed towards a relatively extensive spread of ruderal assemblages. This has led to the formation of a fairly well established synanthropic environment colonised by extensive stands of *Foeniculum vulgare* Mill. and other ruderal and roadside assemblages, notably represented by vegetation typical of classes such as the *Chenopodietea*, *Artemisietea* (particularly the alliance *Onopordion illyrici*), *Polygono-Poetea annuae*, and *Parietarietea judaicae* (BARTOLO *et al.*, 1988).

*Papilio saharae*: rank, range, and diagnostic features: The taxon was initially treated as a variety and, later, as a subspecies of *P. machaon* (Oberthür, 1879; 1888). While some authors continued to regard it as such (SEITZ, 1908; TURATI, 1942; PELLACCHIA *et al.*, 2002), several others regard *Papilio saharae* as a distinct species (LARSEN, 1990; PITTAWAY *et al.*, 1994; TENNENT, 1996; TOLMAN & LEWINGTON, 1998; TARRIER & DELACRE, 2008; TSHIKOLOVETS, 2011; LERAUT, 2016; CASSAR, 2018). The nominotypical *P. saharae saharae* is present along the northern fringes of the Sahara, from the Maghreb to Egypt's Siwa oasis, extending across the eastern desert towards the Red Sea, into the Negev and the northern Hejaz. Although it is typically found in hyper-arid locations, it has also been known to occur in arid environments in relative proximity to the Mediterranean (CLARKE & SHEPPARD, 1956; LARSEN, 1990; PIERRON, 1990; TENNENT, 1996; MOONEN, 2012; CASSAR, 2018). In contrast, *P. saharae rathjensi* Warnecke, 1932, a subspecies restricted to Yemen and the adjacent Asir region of Saudi Arabia, inhabits mesic environments within rocky, montane regions (LARSEN, 1983, 1984, 1990; PITTAWAY, 1985; MEERMAN & BOOMSMA, 1986). Various diagnostic features have been proposed to separate “*machaon*” and “*saharae*” (ELLER, 1936; SEYER, 1974; LARSEN, 1980, 1984; CLARKE & LARSEN, 1986; PIERRON, 1990), which notably rely upon coloration and markings, on anatomical characters (e.g., antennal segments; teeth on valva or harpe), and on dimensions and shape (e.g., wings or part thereof; male valvae). Beyond doubt, biometric consistency is of the essence and a reliance on morphometric analysis, both through naked-eye examination and microscopy, is noted to be more dependable for certain characters than for others (PITTAWAY *et al.*, 1994).

The aim of this contribution is to report the presence of a taxon with perceptible morphological traits of *Papilio saharae* on Lampedusa, recognized on the basis of morphometrics of wild-caught specimens, including imagines and reared lower stages (ova, larvae and pupae). It also discusses its ecology in relation to Lampedusa's geographical location and its proximity to northern Africa, as well as to the vegetation present on the island, specifically larval hostplants.

## Methodology

Two five-day field visits were organised in 2019 and 2021, with the aim of collecting *Papilio machaon* specimens for DNA analysis. Adult specimens were taken via customary pursuit, using short-handled kite nets. During the second, more successful visit, ova and larvae were collected from among the florets of *Foeniculum vulgare*. Adult male specimens had their respective thorax pinched in the conventional manner of despatching most butterfly species, while a female specimen and a suite of larvae were kept alive; these, together with a number of wild-collected ova, were transported to Malta. The intention was to rear the larvae and ova to adult phase, while concurrently attempting to induce the

female specimen to oviposit in captivity, the reason for which was to examine a series of voucher specimens for morphological variability. All living material was maintained in appropriate butterfly breeding cages or larval boxes, both during fieldwork (collapsible butterfly enclosures were used for this purpose) and following the team's return to Malta. Based upon an established breeding protocol, the wild-caught larvae (including hatchlings of wild-collected ova) were reared on *Foeniculum vulgare*, while both *Foeniculum vulgare* and *Ruta graveolens* L. were introduced into the breeding cage containing the gravid, wild-caught female. Each larval instar was photographed for comparative purposes. Adult specimens were set (dry preservation) on standard spreading-boards for subsequent naked-eye and microscopic examination, while relevant body parts were extracted for eventual DNA analysis. The diagnostic assessment that follows is based on morphometric analysis.

## Results and Diagnostics

A total of six adult specimens were examined, including four wild-caught specimens (3 ♂♂, 1 ♀) that were collected during the 2019 and 2021 field trips, and two specimens (2 ♀♀) reared from larvae collected on *Foeniculum vulgare* that was growing on the roadside in the main town, during the June 2021 visit. A total of 12 larvae (three: L3; six: L2; three: L1) and three ova were collected during the second field trip, of which all, except for one, reached pupal stage. Moreover, 82 ova were deposited by the wild-caught female specimen, of which 12 larvae hatched (< 15%); these were reared on *Foeniculum vulgare* and all eventually pupated. It may be of interest to add that deposition commenced after the sixth day in captivity, when the vast majority of the ova were deposited on *Ruta graveolens*, while only three ova were deposited on *Foeniculum vulgare*.

The four wild-caught adult specimens were taken in flight by means of conventional stalking with a kite net, at the following localities: limits of Cala Creta (♂); NE edge of main town, off Via Firenze (♂ ♀); and, on the cliff-top above Grotte Solaro (♂). The larvae and ova were collected from and in the vicinity of Via delle Grotte, in the main town. These were reared and two females emerged weeks later, while the rest appear to have entered pupal diapause, as did the batch reared from the wild-caught gravid female specimen; high temperatures due to a prevailing heatwave at the time may well have instigated this.

ITALY: LAMPEDUSA: Limits of Cala Creta [35°30'47.80" N, 12°37'15.21" E], 35 m amsl, 1 ♂, 05-IV-2019, leg. and coll. LFC. North-eastern periphery of main town [35°30'25.30" N, 12°36'44.10" E], 17 m amsl, 1 ♂, 03-VI-2021, leg. and coll. AC. North-eastern periphery of main town [35°30'27.60" N, 12°36'45.35" E], 17 m amsl, 1 ♀, 03-VI-2021, leg. and coll. AC. North-facing sea-cliffs above Grotte Solaro [35°31'18.43" N, 12°35'11.68" E], 72 m amsl, 1 ♂, 03-VI-2021, leg. and coll. AC. Main town at Via delle Grotte [35°30'06.00" N, 12°36'22.07" E], 13 m amsl, 2 ♀♀, 01-VI-2020, - reared from L3 larvae which emerged: 21-VI-2021, leg. AC; coll. LFC; 26-VI-2021, leg. and coll. AC.

Diagnosis: The list above (Table I) comprises selected morphological features deemed appropriate to distinguish *Papilio saharae* (LARSEN, 1980, 1983, 1990; CLARKE & LARSEN, 1986; PIERRON, 1990; PITTAWAY *et al.*, 1994; TENNENT, 1996; TOLMAN & LEWINGTON, 1998) from *Papilio machaon*. These are based on the number of antennal segments, the length and number of teeth on the harpe, and the size and general shape of the red ocellus on the hindwing's jugal area (Figure 1a and b. - specimens s2 and s3), among other features that have been proposed over the years. Although the length of the forewing is given (measured in a straight-line from the base to the apex), such dimensions may vary from individual to individual, as well as seasonally and across species, since size (within range limits of a given species) is a function of nutritional opportunities at larval stage. All adult specimens examined had a marked smattering of yellow scales over the dark regions on the forewing (FW) basal and postbasal areas, and on the hindwing (HW) basal and dorsum areas, which rendered each individual seemingly lighter in colour (note: such characteristic is also present in a number of *P. machaon* subspecies and appears to be particularly evident in, although not exclusive to, latter broods of *P. machaon hispanicus* Eller, 1936, *P. machaon mauretanicus* Verity, 1908 and *P. machaon syriacus* Verity, 1908).

**Table 1**– Biometric data of specimens examined. (sn = specimen-allocated code number; Flt = taken in flight; W-cL = reared wild-collected larva).

Specimen	Biotope type	Antennal segments	FW length (mm)	Red ocellus dimensions (mm)	General shape of ocellus	Teeth on harpe
♂ (Flt) s1	Habitat patch colonised by ruderals, dominated by <i>Galactites tomentosa</i>	31	38.90	3.58 x 2.45	ovoid and fairly compressed horizontally	10
♂ (Flt) s2	Synanthropic environment characterised by stands of <i>Foeniculum vulgare</i>	32	37.55	3.26 x 1.64	ovoid but very compressed horizontally	10*
♀ (Flt) s3	Synanthropic environment characterised by stands of <i>Foeniculum vulgare</i>	32	n/a**	4.73 x 3.55	domed upper part and a more horizontal bottom edge	n/a
♂ (Flt) s4	Coridothymo capitati-Cistetum parviflori and Chiliadenetum lopadusani on karstic clifftop	31	39.30	3.64 x 3.02	irregular curvilinear	12
♀ (W-cL) s5	L3 larva collected on <i>Foeniculum</i> florets in an urban environment and reared	32	45.26	3.95 x 3.28	curvilinear triangle with rounded lower edges	n/a
♀ (W-cL) s6	L3 larva collected on <i>Foeniculum</i> florets in an urban environment and reared	33	43.80	4.39 x 2.71	curvilinear triangle with rounded lower edges	n/a

\* s2 harpe contains 10 well-developed teeth, together with three significantly smaller notched edges protruding from three of the teeth. \*\* Forewings were severely damaged as this specimen was used for rearing purposes. Measurement was, therefore, not possible.

Early life cycle stages: In comparison to the ovum of *Papilio machaon melitensis* Eller, 1936, both wild-collected ova and those deposited by the captive specimen were significantly smaller, approximately 80% of the former, but similar in shape, characteristically spherical. Initially, the yellowish coloration of freshly deposited ova was also similar to those of the Maltese subspecies. However, the “Lampedusa ova” (wild-collected and fertile ones deposited in captivity) subsequently developed hazy brown markings (after three days), unlike the distinctly uniform brown rim around the crown that typically develops on *P. machaon melitensis* ova. The fertile ova which were deposited in a rearing cage hatched after five days.

The larvae, compared with each corresponding instar of *P. machaon melitensis*, were generally smaller, while coloration and morphology were also noticeably different. The overall colour of older instars of the Maltese subspecies is green, whereas the general background coloration of the Lampedusa larvae of comparable lifecycle stage was white (Figure 2a). While it should be noted that coloration and markings in larvae of the genus *Papilio* Linnaeus, 1758, among other groups, is not necessarily a firm verification of specific status (PITTAWAY *et al.*, 1994) but potentially a function of environmental conditions and/or available food-plant, the markedly different morphology is striking and worthy of note. In particular, the black spiny setae on the subdorsal scoli of the Lampedusa L3 and L4 instars were remarkably pronounced, while the subspiracular orange bulbous verrucae formed a quasi-continuous longitudinal row (separated only by segmental divisions), which extended laterally from the mesothoracic segment (T2) to the preanal segment (A9). Likewise prominent on the L3 instars were the bright orange subdorsal protuberances at the base of the scoli (Figure 2b). L3 and later instars had discontinuous black encircling patches, mostly conspicuous in final instar (L5) larvae. Segmental

divisions of the Lampedusa L5 instar larvae were a very pale pastel green and not a velvety black as in *P. machaon melitensis* and numerous other *machaon* subspecies. The external body surface of the final instar was generally smooth and velvety to the touch, with the intense orange markings, present in L3 and L4 instars, much reduced. The white saddle, which characteristically extends from the dorsal area to the subdorsal region and across a number of segments in L1 and L2 instar larvae of *P. machaon melitensis*, was restricted to only two abdominal segments (A3 and A4) in the Lampedusa larvae of equivalent developmental stage (Figure 2c). The osmeterium of the L5 instar larva was orange in colour, similar to that of *Papilio machaon*, but much longer (Figure 3), extending to the metathoracic segment (T3). PIERRON (1990) maintains that the osmeterium of *P. saharae* is brown (as opposed to orange, as in *P. machaon*) and twice as long. The osmeterium of the Lampedusa larvae thus includes morphological traits of both taxa; however, the odour emitted when the organ was protracted was distinctly different to that of *P. machaon melitensis*.

The pupae of both wild-collected ova and larvae, and those reared from deposited ova in captivity were strikingly different to those of *P. machaon*. Compared to pupae of *P. machaon melitensis*, the “Lampedusa pupae” were fine-textured and far smoother, with less obvious protuberances. In particular, the cephalic projections, the thoracic segment (T2 region) and the latero-dorsal tubercles of “Lampedusa pupae” are significantly less pronounced than those of *P. machaon*, with the pupae of offspring of the captive female being noticeably smoother than those of wild-collected individuals (Figure 4). In comparison to the pupa of *Papilio hospiton* Gené, 1839 (a parallel also drawn by PIERRON (1990) and PITTAWAY *et al.* (1994), among others), the Lampedusa pupae are similar only insofar as the cephalic projections and thoracic segment are concerned, since the tubercles on the latero-dorsal region of the specimens under investigation are far less prominent than those of the Sardo-Corsican endemic.

## Discussion and Conclusions

The closest landmass to the island of Lampedusa is the Tunisian mainland, which lies some 130 km westward. This may be regarded as a fair distance for a typically non-migrant butterfly species, considering the expanse across open Mediterranean waters, with no prospect of nectaring enroute. Preliminary findings of separate on-going studies by the present authors and colleagues, using telemetry on *Papilio machaon*, indicate a travel speed of approximately 18.3 km/hr over a distance of 2.14 km across an inter-island sea channel - in this instance, particular attention ought to be given to two divergent factors, namely, the short island-to-island distance being tested and the payload of .15gr derived from the electronic transmitter. Generally, in addition to distance, another key aspect to consider is the fact that islands, compared to continental landmasses, tend to make poor targets for immigrant organisms. Given their relatively small size, the physical location of isolated islands would make it vastly more difficult for insects to achieve landfall. That said, although seemingly implausible for non-migrant butterfly species to reach small remote islands, it is not an impossibility, and exceptional instances have been known to occur (potentially abetted by extraordinary meteorological events), as has been a case on Madeira (pers. comm. Teixeira, Silva, Cotton, Wiemers/Cassar, July, 2021). Notwithstanding such remote possibility, the probability that such an occurrence will (i) lead to the establishment of a nascent population of an immigrant species or (ii) augment an already existing population via influxes of immigrant individuals, however, remains significantly small.

Climatically, Lampedusa’s environment can best be described as arid steppe with a varying degree of dryness, as a result of the existing diverse landform and topographic relief. Its relatively low altitude (maximum height 133 m) and narrow width (3.6 km at its widest points) render the island entirely coastal. As described above, the vegetation is characteristic of the Thermo-Mediterranean zone, so, predictably, traditional and potential *Papilio saharae* larval hostplants of hyper-arid (often high altitude) environments, for example, *Deverra denudata* (Viv.) and *D. scoparia* [Family: Apiaceae] and *Haplophyllum tuberculatum* (Forssk.) A. Juss. [Family: Rutaceae], are not present. However, representative species of these two families, notably, *Foeniculum vulgare* (also listed as *F. piperitum*



Mill. by some authors - BARTOLO *et al.*, 1988), *Ferula communis* L. (a known hostplant of *P. saharae* in Yemen - LARSEN, 1983; MEERMAN & BOOMSMA, 1986) and *Ruta chalepensis* L., on the other hand, do occur in relative abundance; these latter species are known larval hostplants of *Papilio machaon*. It is also a known fact that different populations of *P. saharae* are manifestly well adapted to distinctly different habitats. These include the eremic marginal lands of the Tunisian Sahel (including coastal steppe and higher topography) and hyper-arid Moroccan highlands, occupied by *P. saharae saharae*, as well as the mesic habitats in montane regions at its easternmost range, where *P. saharae rathjensi* occurs.

Given the foregoing and the fact that the island of Lampedusa was last physically connected with the Tunisia mainland during late Pleistocene low-stands (GIRAUDI, 2004), it is not unreasonable to contemplate the possibility that a population of *Papilio saharae* was left isolated after sea-levels rose during subsequent inter-glacials. There is also no evidence contrary to the possibility of a sympatric association with *Papilio machaon*, which may account for the presence of intermediate forms. If, indeed, such coexistence still occurs, further field investigations will need to assess whether the two species have divergent lifecycle timelines (pers. comm. Cotton/Cassar, July, 2021) or whether some phases coincide with a degree of overlap and, as a result, potentially lead to natural hybridisation, including introgression. Unlike *Papilio hospiton* and *P. machaon* on Corsica and Sardinia, where the two taxa occupy somewhat different habitat niches (former flies in mountainous regions at mid to high altitude, while latter is known to occur closer to the coast), even if the two are known to occasionally hybridize, the relatively low elevation of Lampedusa does not provide for such altitude-related habitat diversity. If, on the other hand, the presence of *P. machaon* per se on the island is in question, then it would be interesting to delve deeper into the genetic make-up of the taxon that occurs on Lampedusa - (although some individuals encountered during either of the field research visits bore characteristics atypical of *P. machaon* - at larval or imago stage, or both - this does not necessarily imply that the species is not present on the island). Another plausible avenue to explore would be whether the two taxa reached the island during Quaternary low-stands and remained isolated as eustatic sea-levels rose, leading to the development of a hybrid swarm (between *P. machaon*, most likely, ssp. *mauretanicus*, and *P. saharae*), but more evidence is required at this juncture. To-date, morphometric examination suggests that some of the specimens analysed demonstrate taxonomic characters, to a varying degree, of *Papilio saharae*, but the fact that some individuals examined also possessed morphological features characteristic of *P. machaon*, however minor, and therefore atypical of *P. saharae*, warrants further investigation; in fact, this is the subject of on-going research by the present authors. Might the waterway between the north African mainland and Lampedusa (which effectively brought about the island's relatively prolonged isolation), have acted as an extrinsic barrier leading to some level of taxonomic differentiation?

## Acknowledgements

The authors are indebted to Adam Cotton for sharing his views on hybridisation and for his advice on such rearing strategies. Grateful thanks are due to botanists Darrin Stevens and Edwin Lanfranco for their insights on phytosociology and botanic nomenclature. The authors would like to express their sincere gratitude to Christa M Pisani and Elisabeth Conrad of the Institute of Earth Systems (University of Malta), for logistical and field support and for critical and helpful comments on early drafts, respectively. A special word of thanks is due to Bruno Massa, Paolo Palmi, and Tommaso Racheli for sharing relevant information based on primary observations and/or secondary sources, as well as to Elena Prazzi and Gerry Sorrentino of Legambiente for facilitating the relevant permits for access into the protected area. The research visit of 2019 was authorised via "Protocollo nr: 7442 (2019) PNM - Direzione Generale per la Protezione della Natura e del Mare", based on derogation DPR 357/97 and on subsequent advice from ISPRA; Legambiente (Lampedusa) granted access to the reserve, during the 2021 field visit, through "Autorizzazione per ricerca scientifica N. 2 del 27/5/2021, trasmessa con nota Prot. N. 152/RN/LAM del 27/5/2021". The first author is grateful to Sergio Teixeira, Adam Cotton, and

Martin Wiemers for sharing their views and unpublished data pertaining to the island of Madeira. Financial support through research grants by the University of Malta, which supported the first author during both field visits, as also in-part funded some of the logistics in the field, is acknowledged.

## BIBLIOGRAPHY

- BARTOLO, G. & BRULLO, S., MINISSALE, P. & SPAMPINATO, G., 1988.– Flora e vegetazione dell'Isola di Lampedusa.– *Bollettino dell'Accademia Gioenia di Scienze Naturali*, **21**: 119-255.
- BRULLO, S., GIANGUZZI, L., LA MANTIA, A. & SIRACUSA, G., 2008.– La classe *Quercetea ilicis* in Sicilia.– *Bollettino dell'Accademia Gioenia di Scienze Naturali*, **41**(369): 1-77.
- CASSAR, L. F., 2018.– *Papilio saharae* Oberthür, 1879 (Lepidoptera Papilionidae) on the Hyblean Plateau, Sicily: Case of a relict population due to climate-driven phenomena?.– *Naturalista siciliano*, **42**(1): 21-29.
- CLARKE, C. A. & LARSEN, T. B., 1986.– Speciation problems in the *Papilio machaon* group of butterflies.– *Systematic Entomology*, **11**: 175-181.
- CLARKE, C. A. & SHEPPARD, P. M., 1956.– A further report on the genetics of the *machaon* group of swallowtail butterflies.– *Evolution*, **10**: 103-112.
- ELLER, K., 1936.– Die Rassen von *Papilio machaon* L.– *Abhandlungen der Bayerischen Akademie der Wissenschaften. Mathematisch-Naturwissenschaftliche Abteilung*, **36**: xiv + 1-96, 16 pls.
- GIRAUDI, C., 2004.– The Upper Pleistocene to Holocene sediments on the Mediterranean island of Lampedusa (Italy).– *Journal of Quaternary Science*, **19**: 537-545.
- GRASSO, M., PEDLEY, M. H. & REUTHER, C. D., 1985.– The geology of the Pelagian Islands and their structural setting related to the Pantelleria rift (central Mediterranean Sea).– *Centro*, **1**(2): 1-19.
- GRASSO, M. & PEDLEY, H. M., 1988a.– *Carta Geologica dell'Isola di Lampedusa*. Ministero della Pubblica Istruzione e Regione Sicilia.
- GRASSO, M. & PEDLEY, H. M., 1988b.– The sedimentology and development of the Terravecchia Formation carbonates (Upper Miocene) of north-central Sicily: possible eustatic influences on facies development.– *Sedimentary Geology*, **57**: 131-149.
- LARSEN, T. B., 1980.– The status of *Papilio machaon rathjensi* and its relationship to other Arabian populations (Papilionidae).– *Journal of the Lepidopterist Society*, **34**: 365-367.
- LARSEN, T. B., 1983.– Insects of Saudi Arabia; Lepidoptera, Rhopalocera (a monograph of the butterflies of Arabia).– *Fauna of Saudi Arabia*, **5**: 333-478.
- LARSEN, T. B., 1984.– The zoogeographical composition and distribution of Arabian butterflies (Lepidoptera; Rhopalocera).– *Journal of Biogeography*, **11**: 119-158.
- LARSEN, T. B., 1990.– *The Butterflies of Egypt*: 112 pp.+8 pls. Apollo Books, American University Press, Cairo.
- LELAUT, P., 2016.– *Butterflies of Europe and neighbouring regions*: 1113 pp.+ 655 pl. N. A. P. Editions. Verrières-le-Buisson.
- LOMBARDO, G., PANZERA, F., SALAMANCA, V., SICALI, S., BALDASSINI, N., BARRECA, G., DI STEFANO, A., MONACO, C. & D'AMICO, S., 2014.– Detailed geophysical and geologic study in the Lampedusa Island: SIMIT Project. 33° Convegno Nazionale.– *Atti Tema 2: Caratterizzazione sismica del territorio*: 203-209.
- MEERMAN, J. & BOOMSMA, T., 1986.– Der wenig bekannte Schwalbenschwanz aus Nordjemen, *Papilio saharae rathjensi* Warnecke, 1932 - Freilandbeobachtungen und Zucht (Lepidoptera: Papilionidae).– *Entomologische Zeitschrift*, **96**(13): 177-182.
- MOONEN, J. J. M., 2012.– Notes on the *Papilio machaon* group (Lepidoptera: Papilionidae) from the Palaearctic Papilionidae collection of the Zoological Museum of Amsterdam.– *Entomologische Berichten*, **72**(3): 184-186.
- OBERTHÜR, C., 1879.– Faunes entomologiques. Descriptions d'insectes nouveaux ou peu connus. Catalogue raisonné des Papilionidae.– *Etudes d'entomologie*, **4**: 117 pp., 6 pl. Rennes.
- OBERTHÜR, C., 1888.– Faunes Entomologiques. Descriptions d'insectes nouveaux ou peu connus. III. Lepidopteres d'Europe et d'Algerie.– *Etudes d'entomologie*, **12**: 21-46.
- PELLECCHIA, M., MARINI, M. & SCALI, V., 2002.– Diversità mitocondriale nel *Papilio machaon* species complex (Papilionidae): evidenze dai geni COI e NADH 4.– *Atti XIX Congresso Nazionale Italiano di Entomologia*: 131-134.
- PIERRON, M., 1990.– Contribution a la connaissance de la biologie de *Papilio machaon saharae* Obth. Differences



- avec *Papilio machaon machaon* L. et hybridations experimentales (Lep. Papilionidae).– *Alexanor*, **16**(6): 331-340.
- PITTAWAY, A. R., 1985.– Lepidoptera Rhopalocera from western Saudi Arabia.– *Fauna of Saudi Arabia*, **7**: 172-197.
- PITTAWAY, A. R., LARSEN, T. B., CLARKE, C. A., SMITH, C. R., CRNJAR, R. & CLARKE, F. M. M., 1994.– *Papilio saharae* Oberthür, 1879, specifically distinct from *Papilio machaon* Linnaeus, 1758 (Lepidoptera: Papilionidae).– *Entomologist's Gazette*, **45**: 223-249.
- ROMANO, F. P. & ROMANO, M., 1995.– Lepidoptera, pp. 693–722.– In B. MASSA (Ed.). Arthropoda di Lampedusa, Linosa e Pantelleria (Canale di Sicilia, Mar Mediterraneo).– *Il Naturalista Siciliano*, **19** (Suppl.): XII + 899 pp.
- ROMANO, M., 2020.– Insects of Lampedusa, Linosa and Pantelleria: Addenda to the 1995 Checklist.– In T. LA MANTIA, E. BADALAMENTI, A. CARAPEZZA, P. LO CASCIO & A. TROIA (Eds.). *Life on Islands. Biodiversity in Sicily and surrounding islands. Studies dedicated to Bruno Massa*: 492 pp. Edizioni Danaus, Palermo.
- SEITZ, A., 1908.– *Grossschmetterlinge der Erde. Die palaearktischen Tagfalter*, **1**: 379 pp.+ 89 pl. A. Kernen Verlag, Stuttgart.
- SEYER, H., 1974.– Versuch einer Revision der *Papilio machaon* subspezies in der westlichen Palaarktis.– *Mitteilungen aus der Entomologischen Gesellschaft, Basel*, **24**: 64-90, 93-117.
- TARRIER, M. R. & DELACRE, J., 2008.– Les papillons de jour du Maroc. Guide d'identification et de bio-indication.– *Museum national d'Histoire naturelle*: 1-480. Meze, Paris.
- TENNENT, J., 1996.– *The Butterflies of Morocco, Algeria and Tunisia*: xxxvi + 217 pp. Gem Publishing Co., Wallingford.
- TOLMAN, T. & LEWINGTON R., 1998.– *Die Tagfalter Europas und Nordwestafrikas*: 536 pp. Verlags-GmbH & Co., Stuttgart.
- TSHIKOLOVETS, V.V., 2011.– *Butterflies of Europe & the Mediterranean area*: 544 pp. Tshikolovets Publications, Pardubice.
- TURATI, E., 1924.– Spedizione Lepidopterologica in Cirenaica 1921-22.– *Atti della Società Italiana di Scienze Naturali e del Museo Civile di Storia Naturale*, **63**: 21-129.
- VODĀ, R., DAPPORTO, L., DINCĀ, V., SHREEVE, T. G., KHALDI, M., BARECH, G., REBBAS, K., SAMMUT, P., SCALERCIO, S., HEBERT, P. D. & VILA, R., 2016.– Historical and contemporary factors generate unique butterfly communities on islands.– *Scientific reports*, **6**: 28828. <https://doi.org/10.1038/srep28828>.

\*L-F. C.

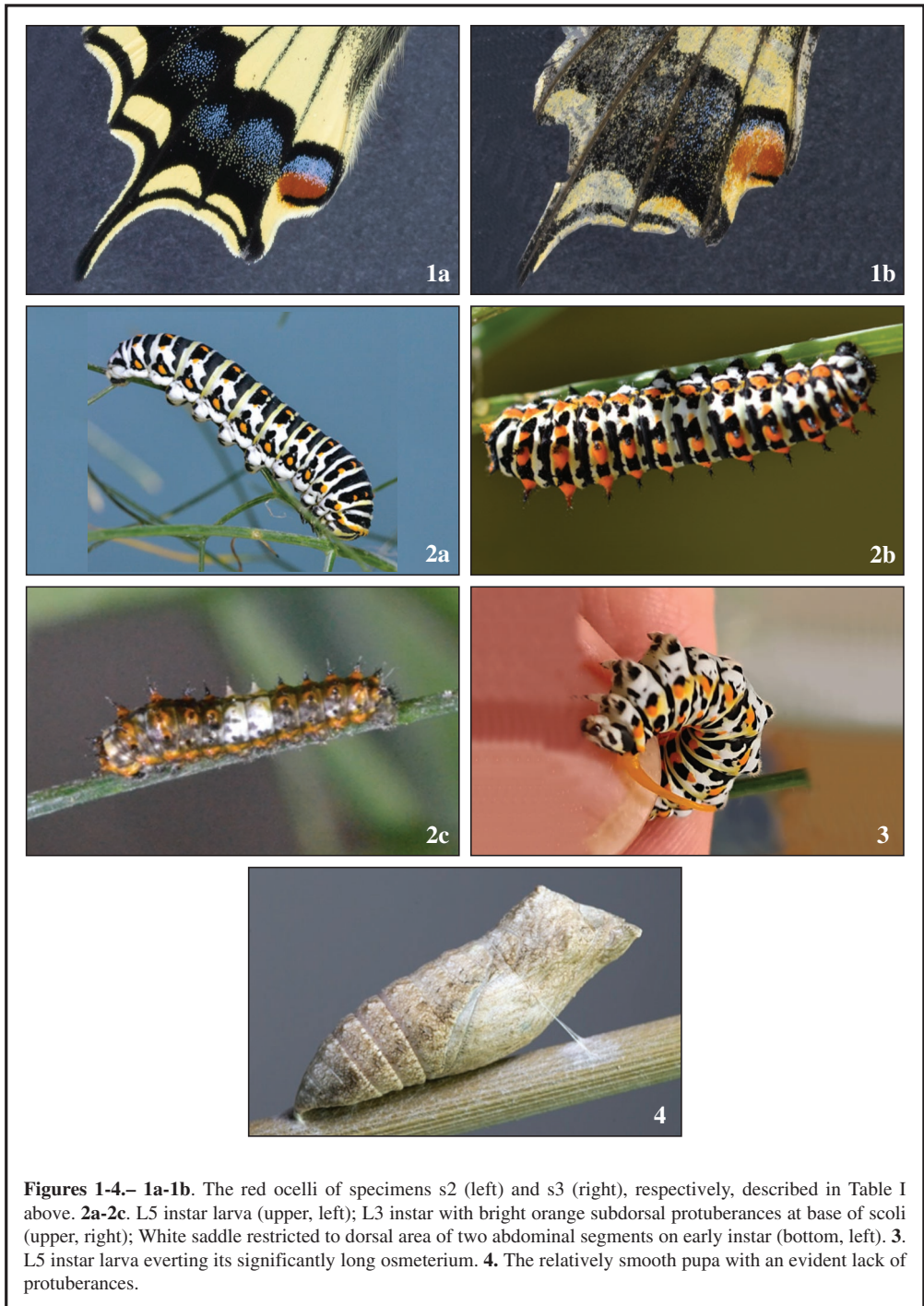
Institute of Earth Systems, University of Malta  
Chemistry & Pharmacology Building  
Floor 3, Office suite 311A  
MT-Msida MSD 2080  
MALTA / MALTA  
E-mail: louis.f.cassar@um.edu.mt  
E-mail: louis.f.cassar@gmail.com  
<https://orcid.org/0000-0001-6459-3931>

A. C.

27, Rama-Rama  
Triq Monsinjur Anton Cilia  
MT-Zebbug ZBG 3140  
MALTA / MALTA  
E-mail: aldocatania47@gmail.com  
<https://orcid.org/0000-0001-7559-143X>

\*Autor para la correspondencia / *Corresponding author*(Recibido para publicación / *Received for publication* 7-VIII-2021)(Revisado y aceptado / *Revised and accepted* 15-IX-2021)(Publicado / *Published* 30-VI-2022)

**Derechos de autor:** El autor(es). Este es un artículo de acceso abierto distribuido bajo los términos de la Licencia de Reconocimiento 4.0 Internacional de Creative Commons (CC BY 4.0), que permite el uso, distribución y reproducción sin restricciones en cualquier medio, siempre que se cite al autor original y la fuente. / **Copyright:** The author(s). This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.



**Figures 1-4.– 1a-1b.** The red ocelli of specimens s2 (left) and s3 (right), respectively, described in Table I above. **2a-2c.** L5 instar larva (upper, left); L3 instar with bright orange subdorsal protuberances at base of scoli (upper, right); White saddle restricted to dorsal area of two abdominal segments on early instar (bottom, left). **3.** L5 instar larva everting its significantly long osmeterium. **4.** The relatively smooth pupa with an evident lack of protuberances.