

Research article

[urn:lsid:zoobank.org:pub:C9BAD342-B492-42FD-B7CD-E810D76A82AF](https://zoobank.org/C9BAD342-B492-42FD-B7CD-E810D76A82AF)**Assessing the distribution of the Andalusian endemic
Berberomeloe payoyo Sánchez-Vialas et al., 2020 (Coleoptera: Meloidae),
with comments on its ecology****Fernando Cortés-Fossati** *EcoEvo Group, Area of Biodiversity and Conservation, Universidad Rey Juan Carlos, c/ Tulipán s/n,
E-28933, Móstoles, Madrid, Spain**Email: fernando.cfossati@urjc.es*[urn:lsid:zoobank.org:author:F3D8E2DD-58F0-4116-80D4-A6A9248464B6](https://zoobank.org/author/F3D8E2DD-58F0-4116-80D4-A6A9248464B6)

Abstract. Thanks to recent molecular studies, it was revealed that one of the biggest European beetles, the red-stripped oil beetle *Berberomeloe majalis* (Linnaeus, 1758) (Coleoptera: Meloidae) comprised a complex of nine different species. To improve the knowledge of this threatened group, chorology of the newly described microendemic *B. payoyo* Sánchez-Vialas et al., 2020 is updated in pursuit of a better knowledge and future adequate conservation strategies. 252 field sampling events were performed between 2012–2021. 668 specimens were studied. In the framework of the study, two citizen science projects were carried out. The first detailed distribution map and notes about the species' biology are provided.

Keywords. Biodiversity, blister beetles, entomology, Iberian endemism, insect conservation.

INTRODUCTION

Berberomeloe Bologna, 1989 is an endemic genus from the Ibero-Maghrebian region and includes some of the biggest European, which can reach a body length of up to 7 cm (Bologna 1989; García-París 1998; Cortés-Fossati 2018a). This genus has remained unchanged for thirty years including two species, the red-stripped oil beetle *Berberomeloe majalis* (L., 1758) and *B. insignis* (Charpentier, 1818). Recent molecular studies focused on *B. majalis* revealed a complex of nine morphologically and phylogenetically distinct species (Sánchez-Vialas et al. 2020). Among these nine species the new south-western Iberian microendemic *B. payoyo* Sánchez-Vialas et al., 2020 (Fig. 1) was described, being distributed in Cádiz province, Málaga, and Granada provinces (Andalusia, Spain) (Sánchez-Vialas et al. 2020). Currently, there are hardly any data and only scarce studies available about the natural history and biology of *B. payoyo* (Cortés-Fossati 2018a, b; Cortés-Fossati & Cervera 2018; Sánchez-Vialas et al. 2020). However, this information is crucial to design appropriate and specific conservation strategies. In this case – even though no Spanish oil beetle species is protected under any legal framework – it was important to consider that the only catalogued species within the genus, *Berberomeloe insignis*, was classified as vulnerable (VU) in the Andalusian and Spanish Red Book of Invertebrates (Barea-Azcón et al. 2008; Verdú et al. 2011). The species is affected by several impacts, mainly related with environment transformation (García-París & Ruiz

2008, 2011). These threats are observed for *B. payoyo* in some areas (Cortés-Fossati 2018a, b; Cortés-Fossati and Cervera 2018, sub *B. majalis*) but the information we have on the species is outdated and scarce, including its distribution range. Up-to-date distribution information and a georeferenced map are key tools in conservation (D'Amen et al. 2013; Della Rocca et al. 2020), especially in the cases of complexes of closely related species. This could reveal potential cases of sympatry or allopatry and clarify the geographic distribution ranges of each of the species of the *B. majalis* complex, improving knowledge and contributing to decrease the Wallacean shortfall, i.e., the lack of knowledge about the geographical distribution of species (Lomolino 2004; Cardoso et al. 2011). Therefore, the aim of this study is to provide a better understanding of the chorology and ecology of the Iberian *B. payoyo*.

MATERIAL AND METHODS

The dataset has been generated by 1) own sampling campaigns; 2) citizen science programs, and 3) available literature, from the oldest reported observation to the most recent, covering the period 1921–2021.

1) Field sampling campaigns were carried out from 2012 to 2021, from January to August to safely cover the time interval in which imagoes of the species are present in the field (from March to July in southern Spain: Bologna, 1989). Specimens were identified according to Sán-

chez-Vialas et al. (2020). The species presents distinctive morphological and biogeographical characteristics that allowed all individuals to be identified (Sánchez-Vialas et al. 2020). The first is that the taxonomic identity of the species is very clear in most of the area it occupies, being restricted to the south-west of the Iberian Peninsula. Secondly, *B. payoyo* presents among other characteristics (for more details, see identification key and description in Sánchez-Vialas et al. 2020) narrow, coloured post-tergal bands (Fig. 1A), poorly impressed punctures on the head (Fig. 1B), and anterior angles of the pronotum are not expanded (Fig. 1C). These features differentiate *B. payoyo* from the other species of the complex present in eastern Andalusia (*B. indalo* Sánchez-Vialas et al., 2020 and *B. tenebrosus* Sánchez-Vialas et al., 2020). Specimens that could not be reliably determined based on their morphology, as happened in four cases, were excluded from the study. 252 samplings events were carried out in 86 different sampling points. 668 specimens were studied in the field in 29 different locations. All populations/records were georeferenced. The number of individuals, colouration of post-tergal bands, and biological/behavioural observations were also noted.

2) Additional observations were received by the author by mail, or were uploaded by citizens to two different Citizen Science Programs in which the author was administrator (“Proyecto Biodiversidad de Andalucía”, hosted in collaboration with [iNaturalist.org](https://www.inaturalist.org) and the “Proyecto Meloidata”, hosted in collaboration with [Observation.org](https://www.observations.org)), and were also included in the database. Likewise, the veteran Spanish nature conservation association Biodiversidad Virtual ([biodiversidadvirtual.org](https://www.biodiversidadvirtual.org)) provided their observations concerning the species from its internal database. Only those observations were considered, in which the specimens could be reliably identified from photographs that had georeferencing and date.

3) The only seven publications that provided location data were considered for this study (Bologna 1989; García-París 1998; Pérez-Moreno et al. 2003; García-París et al. 2003; Percino-Daniel et al. 2013; Cortés-Fossati 2018, Sánchez-Vialas et al. 2020). In most cases, due to the age of these works, there was not a very high spatial precision in them, so the locations have subsequently been referenced estimating their position with the data provided in these works. On the other hand, in works before 2020, only locations have been considered in which, according to Sánchez-Vialas et al. (2020), the taxonomic identity of the species *B. payoyo* is clear, that is, the province of Cádiz, and certain areas of Malaga and Granada.

The resulting distribution map was generated with software QGIS ver. 3.16.1-Hannover (GIS Development Team 2020) using a EPSG:4326-WGS 84 coordinate system and the layers “Terrestrial 10×10 km grid” from Ministerio para la Transición Ecológica y el Reto Demográfico ([miteco.gob.es](https://www.miteco.gob.es)) and “Líneas límite

provinciales” from the Instituto Geográfico Nacional (centrodedescargas.cnig.es). In a complementary way, notes about ecology and conservation of the populations studied were registered.

RESULTS & DISCUSSION

An updated chorology of the species is provided based on 154 different locations (Appendix: Table S1), allowing to establish a well-represented distribution map, since a large part of its potential distribution area has been covered (Fig. 2). This total number has been formed by data from fieldwork, citizen science and literature. During field sampling, the species was present in 29 locations of 86 sampled, belonging to 14 different municipal districts. Citizen science programs functioned satisfactorily, obtaining 84 valid observations from this source, belonging to 84 different locations. It could be noted that, especially in rural areas, villagers generally have a good knowledge about genus *Berberomeloe*, a phenomenon already observed for the Cádiz region (Cortés-Fossati 2018a, Cortés-Fossati & Cervera 2018) and for the Iberian Peninsula (García-París et al. 2016) probably due to the ethnopharmacological uses that the hemolymph of these animals has historically developed (Percino-Daniel et al. 2012). This fact may be the main reason why this program has given reliable results. Finally, the literature review provided 41 locations, only eight of them georeferenced.

According to previous literature (Bologna 1989; García-París 1998; Cortés-Fossati 2018a, b) *Berberomeloe payoyo* is a diurnal xerophilous species, inhabiting diverse Mediterranean habitats (see Sánchez-Vialas et al. 2020), being also distributed in suburban landscapes with degraded vegetation (Cortés-Fossati 2018a, b). Nevertheless, the species seemed to have preference on open areas, steppe lands and meadows with presence of bare soil patches and not very dense, pioneer vegetation where females oviposit (Cortés-Fossati 2018; Fig. 3). Here, its presence can be massive (up to 200 individuals registered in 0.27 ha in a single day). During evening time individuals have been observed on several occasions to leave the foraging area to hide under leaf litter or grass in areas of denser vegetation where they spend the night (pers. obs.). Adults are present in the field from the end of February to mid-July, being very rare outside this period (e.g., one single adult record in January cited by Sánchez-Vialas et al. 2020). Highest abundance occurred between end of March and end of May (Fig. 4). Earliest oviposition was observed at the end of March (03/21/2017 in Puerto Real). Offspring hatched between 20 and 26 days later (three replicates carried out in March 2014, March 2017, and May 2017 in the laboratory in translucent 10L terrariums in sand substrate with natural conditions of light, humidity, and temperature). Characteristic of first instar

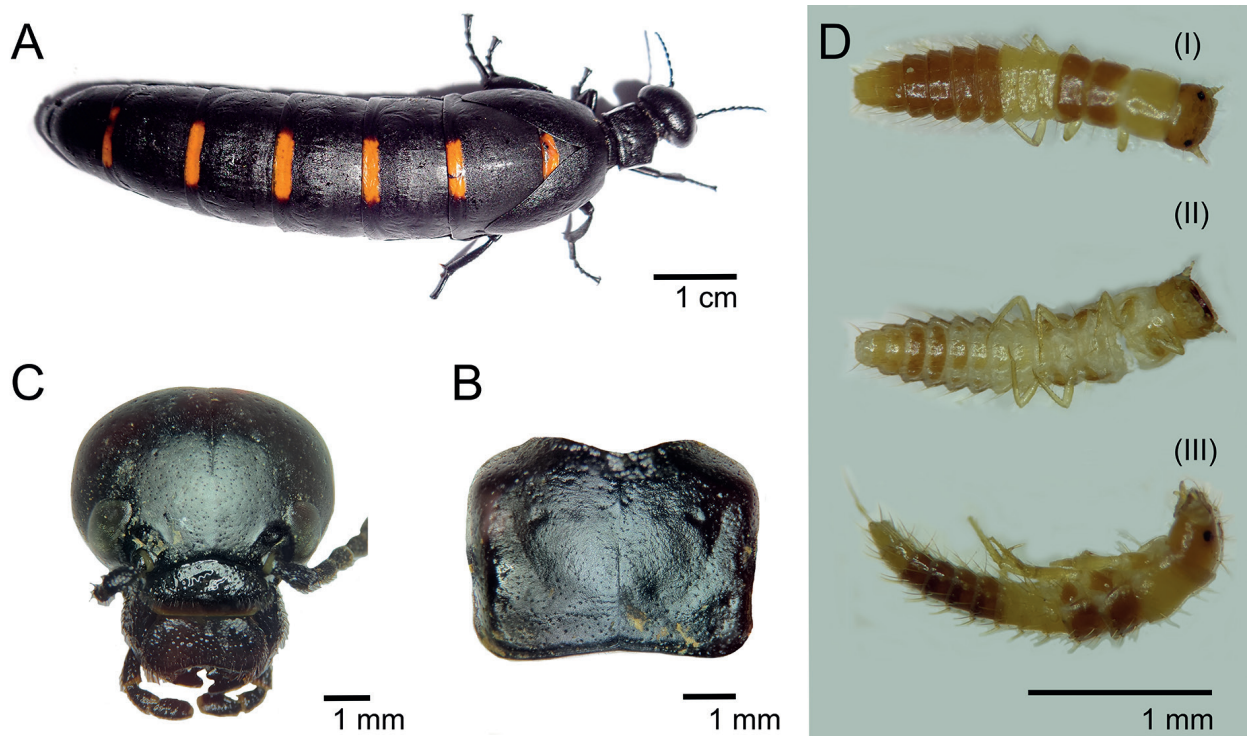


Fig. 1. *Berberomeloe payoyo* Sánchez-Vialas et al., 2020. **A.** Imago from Puerto Real, Cádiz. Dorsal view. **B.** Pronotum. **C.** Head front view, with characteristic punctures. **D.** First instar larva in dorsal (I), ventral (II) and lateral view (III). Instars were damaged during collection, lacking their terminal long chaetae, partially visible in III.

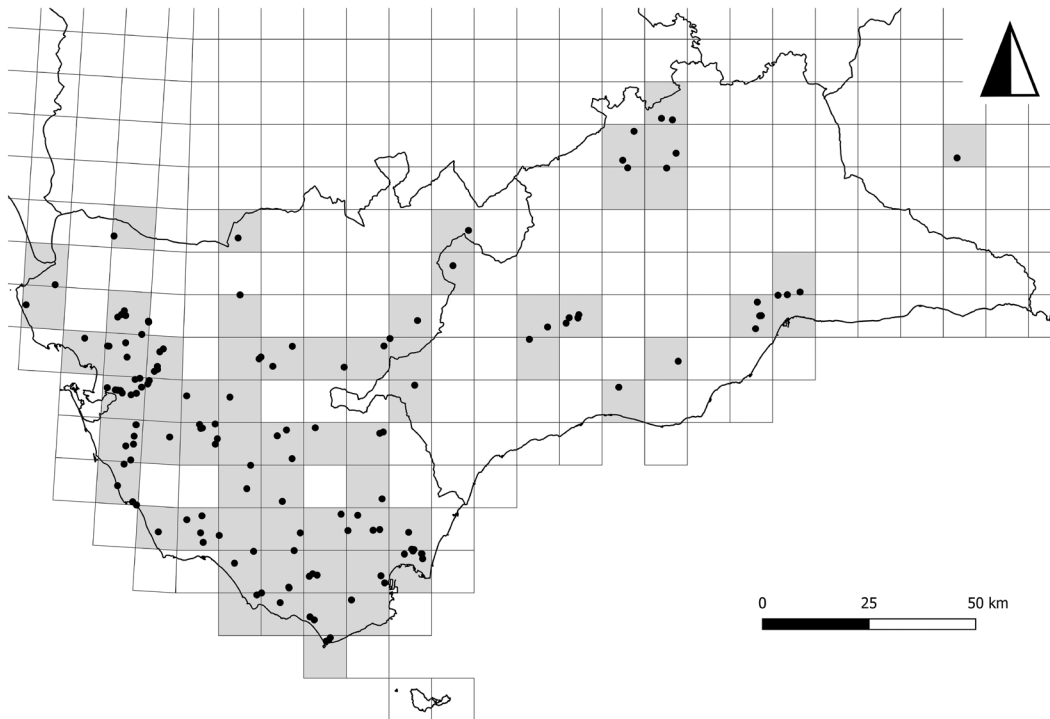


Fig. 2. Distribution of *Berberomeloe payoyo* composed with data from sampling campaigns, citizen science records and literature records.



Fig. 3. Typical environment where the species seems to have preference, consisting of open areas with no dense vegetation (Medina Sidonia, Cádiz).

larva (Fig. 1D) corresponds to the description made by Bologna (1989) for the larvae from the *B. majalis* complex, not observing appreciable differences.

Based on the findings, it is also possible to conclude the absence of this species in the coastal strip and marshy ecosystems, at least, in tidal influence areas and beach sand substrate (after 113 samplings and studying all the data provided by third parties, absent in the tidal zone and marshes of Algeciras, Barbate, Cádiz, Chiclana de la Frontera, Chipiona, Conil de la Frontera, Puerto Real, Puerto de Santa María, Sanlúcar de Barrameda, Tarifa).

As expected, no sympatry cases with other *Berberomeloe* species were detected in Cádiz, but a genetic study of the possible contact areas is necessary, in this case, the limit zone of distribution in the east, since there may be cases of introgressive hybridization that do not allow the individuals to be correctly identified morphologically, and even, hybrid populations may be present.

Intraspecific variation of the populations was detected, in terms of the post-tergal band colouration, which can range from light orange to reddish orange and even vermilion red, the orange-coloured form being probably the most common in Cádiz province (Appendix: Table S2,- Fig. S2). No populations with mixed specimens of different band colours have been detected. No completely black morphotype specimens were observed.

According to personal observation, imagos feed on leaves of different pioneer and herbaceous plants species as well as young shoots. However, they seem to show preference on flower petals of certain plants species such as those of the genus *Echium* L. (Boraginaceae). Throughout this study, also repeated feeding on diverse Asteraceae (highlighting *Carduus* L., *Galactites* Moench, and *Pallenis* Cass), and on *Oxalis pes-caprae* L. (Oxalidaceae) has been observed. *Berberomeloe payoyo* has also been observed feeding on *Erodium* L'Hér. ex Aiton (Geraniaceae), *Plantago* L. (Plantaginaceae) and *Lysimachia* (L.) U. Manns and Anderb. (Myrsinaceae).

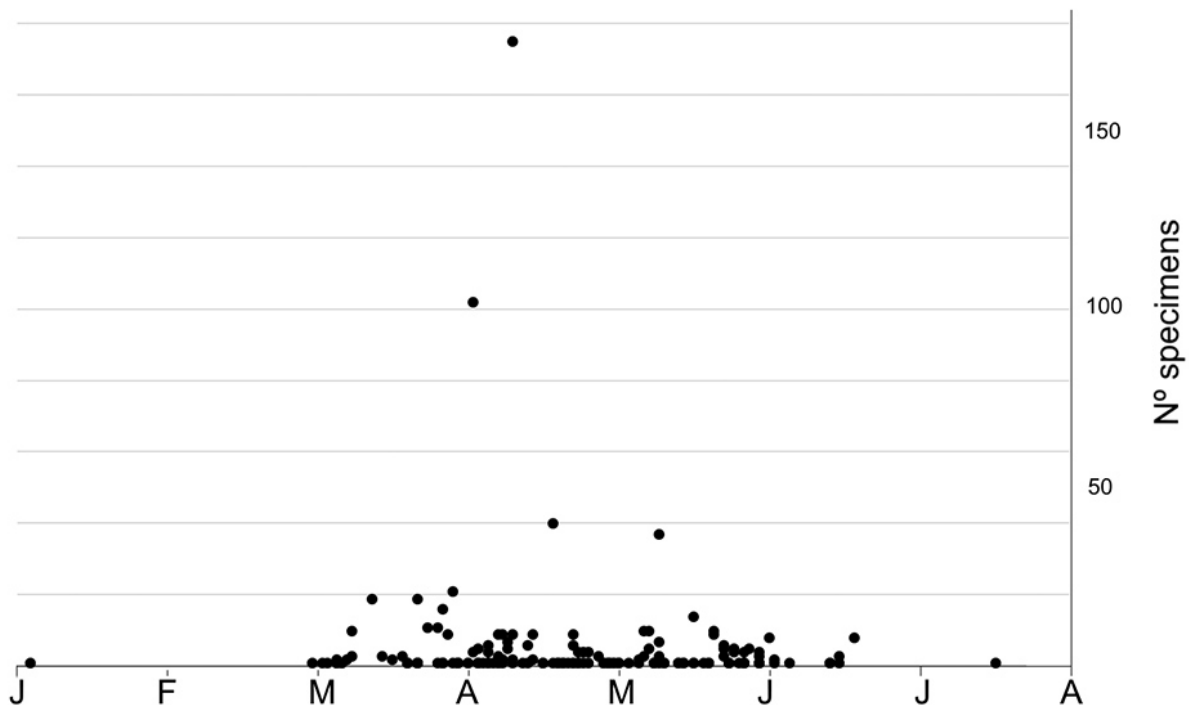


Fig. 4. Phenology of imago of *Berberomeloe payoyo*, built from the database generated for the study. Literature or citizen science data that lacked the number of observed individuals by date have been plotted as $n = 1$.

No studies have been conducted on the conservation status of the species. However, data collected during this work suggest that populations near cities undergo a negative anthropogenic pressure. The ecosystems of the Cadiz and Málaga provinces are highly transformed and fragmented, except for some well-preserved natural cores such as Grazalema, Los Alcornocales or Sierra de las Nieves Natural Parks. Agriculture and an aggressive urbanistic process occupies most of the area, increasingly taking ground in its development over the years. In this way, in Cádiz it is very frequent to observe populations of *B. payoyo* located on croplands and peri-urban regions with a clear degree of deterioration (Cortés-Fossati 2018a). Totally or quasi-isolated populations due to human infrastructures have been observed (e.g., diverse populations in Chiclana de la Frontera, Puerto Real, Jerez de la Frontera, Sanlúcar de Barrameda) since the species has a very low dispersal rate and a low capacity to colonize new areas (García-París 1998; Sánchez-Vialas et al. 2020). Use of steppe lands or zones dominated by colonizing pioneer r-strategist plant species as uncontrolled waste dumps, urban pressure, and the agricultural fields as well as the use of chemicals are probably affecting populations, threats already proposed as impacts for other Meloidae (García-París & Ruíz 2008a, b, 2011; Ruíz & García-París 2008a, b). In these zones, populations seem degraded and with lower population densities. Also, road kills have been observed very frequently, a phenomenon also observed for the Madrilénian *Berberomeloe* populations (García-París et al. 2006; pers. obs.). Even possible local extinction of some populations has been observed during this work. In 2012, an expansion to a mega commercial area was carried out in Jerez de la Frontera (Area Norte and Area Sur, see Appendix: Table S1). The species has no longer been observed there since 2016, also not appearing again in the adjoining crop fields. Moreover, a population located in a cropland in Torre del Puerco (see Appendix: Table S1), completely disappeared in 2017 after changes in land use in the area. However, geographical situation of this population suggests it could be derived from another nucleus, located on a semi-natural shrubland in front of the sampling point, found behind several linear structures that fragment the area (two walkways and a road). So, if transformation will not continue, there could be a possibility that the beetle will return to the area. Finally, during 2017, in Puerto Real: Parque Entrevías (see Appendix: Table S1), the species apparently disappeared after diverse human interventions, e. g., illegal deposit of debris and the installation of a pipeline that flooded the study area. As of 2018, a large decline in number of individuals was observed. After that season, no specimen has been observed in the area. However, there are no data on dynamic populations that allow calculating possible regressions or the real status of the species, so it would be necessary to carry out studies focused on conservation ecology.

CONCLUSIONS

Berberomeloe payoyo Sánchez-Vialas et al., 2020 is a microendemic restricted to the south-west of the Iberian Peninsula that is well represented throughout its area of distribution. Information collected provides an update on the distribution of *B. payoyo* and some ecological notes that improve the knowledge about the species. The information regarding its ecology and biological cycle seems to fit very well to what was already stated by Bologna (1989) when the genus was described (Bologna 1989; García-París 1998; García-París et al. 2003; Cortés-Fossati 2018). At least, peri-urban populations seem to suffer from negative human impacts, e.g., habitat fragmentation and change in land use. Future works on the conservation ecology of the species are needed.

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Ethical & legal aspects. This study was framed under the legal regulations and laws for the collection and ethical treatment of animals and has been endorsed by Andalusian government.

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APPENDIX I

(electronic supplement, available at www.zoologicalbulletin.de)

Table S1. Location dataset composed by data from field work (F), citizen science programs (CS) and Literature (L: authors, year). Dates indicated in intervals pertaining to the field campaigns represent a sustained work in the period between January and August of those years.

Table S2. List of specimens studied in the field in which the color of the banding was noted. The observations are divided between two classes, Orange (O) which is represented on the map with orange dots and Red (Red) represented on the map with red dots. Only those individuals from the sampling campaigns were included in the study as the colors could not be standardized from photographs provided by third parties.

Fig. S2. Mapping of specimens studied on field divided by coloration in the post-tergal banded pattern. The observations are divided between with orange dots (populations with orange bands and black dots (populations with red bands) represented on the map with red dots. Only those individuals from the sampling campaigns and Cortés-Fossati, 2018 were included in the study as the colors could not be standardized from photographs provided by third parties. According to citizen science data, which have not been taken into account in the plot because it cannot be corroborated – since despite having testimonies and photos the colors have not been normalized with a scale – the red individuals would be confined to the northern part of the province and the southern part of the same Strait Zone), leaving the central strip of the province dominated by populations of orange coloration, thus being probably the most widespread coloration.

Assessing the distribution of the Andalusian endemic *Berberomeloe payoyo* Sánchez-Vialas et al., 2020 (Coleoptera: Meloidae), with comments on its ecology

Fernando Cortés-Fossati

Appendix Fig. S2

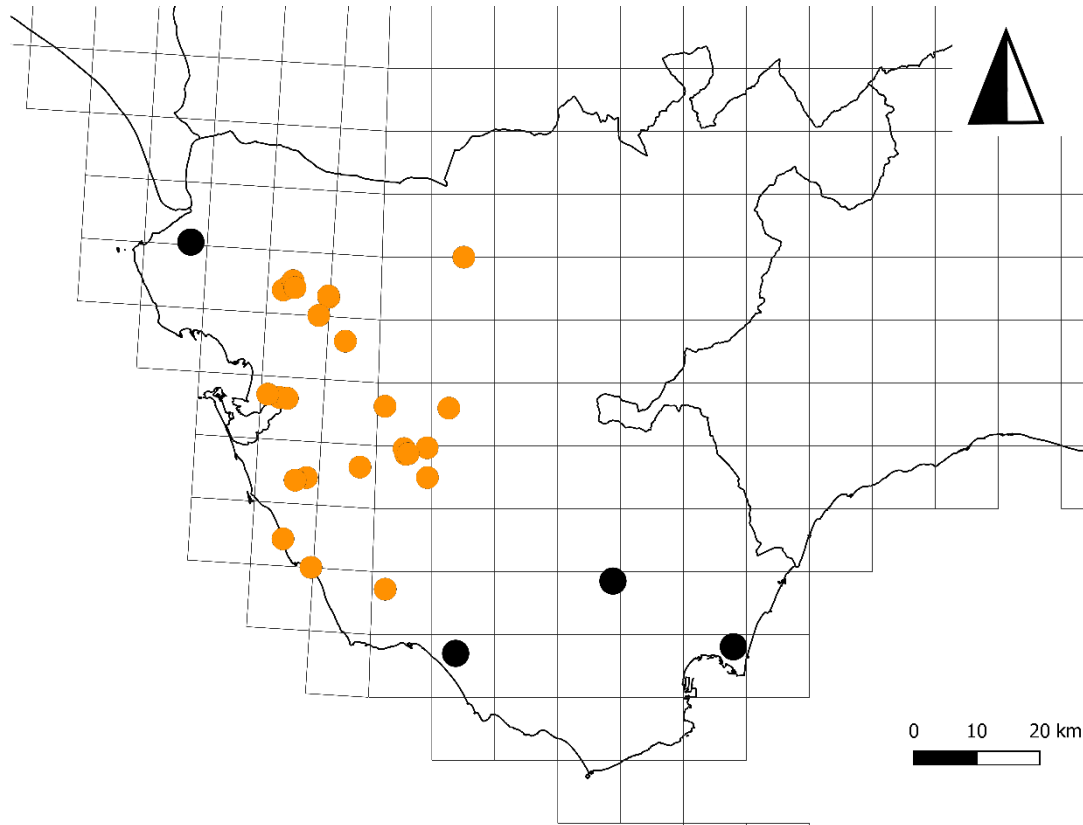


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Source	Province	Locality (Municipal D.)	Location	X, Y	MASL	Date obs.
F	CADIZ	Alcalá de los Gazules	El Algibe	36.44570, -5.74695	48	2016-2017
F	CADIZ	Algeciras	Sierra de la Plata	36.11251, -5.77617	388	2018-2019
F	CADIZ	Arcos de la Frontera	Arroyo del Salado	36.74120, -5.85514	50	22.05.16
F	CADIZ	Barbate	Sierra del Retín	36.17378, -5.84883	285	2018-2019
F	CADIZ	Chiclana de la Frontera	East peri-urban area	36.41881, -6.12198	15	09.04.17
F	CADIZ	Chiclana de la Frontera	South-West peri-urban area	36.41452, -6.14204	6	09.04.17
F	CADIZ	Chiclana de la Frontera	Torre del Puerco	36.33004, -6.16010	21	2016-2017
F	CADIZ	Conil de la Frontera	Fuente del Gallo	36.29054, -6.10900	13	01.05.13
F	CADIZ	Jerez de la Frontera	Area Sur Shopping centre	36.69224, -6.15621	44	2013-2019
F	CADIZ	Jerez de la Frontera	Arroyo Canaleja, South stretch	36.67779, -6.09269	14	2015-2017
F	CADIZ	Jerez de la Frontera	Arroyo Canaleja, East stretch	36.67972, -6.09339	12	2015-2017
F	CADIZ	Jerez de la Frontera	Arroyo de la Loba	36.69169, -6.16478	11	2016-2017
F	CADIZ	Jerez de la Frontera	Campaña del Área Norte	36.68620, -6.17414	26	2016-2017
F	CADIZ	Jerez de la Frontera	Campaña del Área Sur	36.69996, -6.15733	35	2013-2019
F	CADIZ	Jerez de la Frontera	Cartuja Santa María Defensa	36.65135, -6.10955	5	09.05.14
F	CADIZ	Jerez de la Frontera	El Pedroso	36.52443, -5.98691	110	2016-2017
F	CADIZ	Jerez de la Frontera	Laguna de Medina	36.61580, -6.06087	36	17.03.17
F	CADIZ	Jerez de la Frontera	Zoological Park parkings	36.69006, -6.15332	62	2014-2019
F	CADIZ	Línea la Concepción	Sierra Carbonera	36.19398, -5.35895	220	2018-2019
F	CADIZ	Los Barrios	La Teja, Alcornocales Nat. Park	36.28370, -5.57462	263	07.04.17
F	CADIZ	Medina Sidonia	Arroyo del Azúcar	36.46683, -5.91008	114	01.06.17
F	CADIZ	Medina Sidonia	Arroyo Golondrina/Croplands	36.42423, -5.90806	53	2017
F	CADIZ	Medina Sidonia	Colada de la Espartera	36.43629, -6.02801	29	24.05.17
F	CADIZ	Medina Sidonia	Croplands near Saltillo	36.45661, -5.94742	92	2016-2017
F	CADIZ	Medina Sidonia	Croplands near Saltillo (2)	36.46475, -5.95086	96	2016-2018
F	CADIZ	Paterna de Rivera	Arroyo Pozomedina/ croplands	36.52451, -5.87369	106	19.05.17
F	CADIZ	Puerto Real	Peri-urban area	36.53215, -6.17407	21	2017

F	CADIZ	Trebujena	South croplands	36.85740, -6.19088	14	2016-2017
F	CADIZ	Vejer de Frontera	Arroyo Montecote/ Croplands	36.26264, -5.97657	20	01.06.17
CS	CADIZ	Alcalá de los Gazules	Embalse de Barbate	36.39830, -5.70650	37	14.06.18
CS	CADIZ	Alcalá de los Gazules	Near Mirador de los Tallones	36.46497, -5.64809	138	19.04.19
CS	CADIZ	Algeciras	Urban zone	36.14075, -5.45623	23	03.04.17
CS	CADIZ	Barbate	Near Arroyo Mondragón	36.21585, -5.93205	2	29.04.17
CS	CADIZ	Benalup-Casas Viejas	Embalse del Celemín	36.30733, -5.72880	45	NA
CS	CADIZ	Castellar de la Frontera	Puerto Juan Alonso/Guadarranque	NA	NA	NA
CS	CADIZ	Castellar de la Frontera	Sierra Montecoche	36.28233, -5.53112	273	NA
CS	CADIZ	Chiclana de la Frontera	Cañada Picapollos	36.45983, -6.11653	35	26.05.15
CS	CADIZ	Chiclana de la Frontera	El Marquesado	36.46005, -6.11715	33	22.04.18
CS	CADIZ	Chiclana de la Frontera	Pago de Humo	36.40732 -6.08526	13	12.04.21
CS	CADIZ	Chiclana de la Frontera	Pinar del Hierro	36.38523, -6.12780	19	18.04.21
CS	CADIZ	Chipiona	Urbanización Costa Ballena	36.70557, -6.41539	10	23.05.18
CS	CADIZ	Espera	Cañada Jerez-Utrera	36.86150, -5.86470	113	19.05.18
CS	CADIZ	Jerez de la Frontera	Near Arroyo de la Gallina	36.59469, -5.57690	212	26.05.18
CS	CADIZ	Jerez de la Frontera	Laguna de Medina	36.62210, -6.05190	44	29.05.17
CS	CADIZ	Jerez de la Frontera	Laguna del Tejón	36.57407, -6.07349	60	29.05.17
CS	CADIZ	Jerez de la Frontera	Las Canteras y el Tejón	36.57845, -6.06554	60	29.05.17
CS	CADIZ	Jerez de la Frontera	Las Canteras el Tejón Croplands	36.58476, -6.06608	68	29.05.17
CS	CADIZ	Jimena de la Frontera	Arroyo de los Hoyones	36.45684, -5.47904	171	29.05.17
CS	CADIZ	Jimena de la Frontera	Río Hozgarganta	36.45979, -5.47008	406	26.05.15
CS	CADIZ	Los Barrios	Embalse de Almodóvar	36.15347, -5.63273	121	16.05.15
CS	CADIZ	Los Barrios	Embalse Zanona	36.24179, -5.67973	181	NA
CS	CADIZ	Los Barrios	Near Garganta del Cabrero	36.25150, -5.48990	283	12.06.13
CS	CADIZ	Los Barrios	Near Garaganta Curtidora	36.25330, -5.47260	291	30.03.17
CS	CADIZ	Los Barrios	Sendero Palancar	36.24939, -5.55560	89	NA
CS	CADIZ	Manzanete	Manzanete	NA	NA	NA
CS	CADIZ	Medina Sidonia	Croplands	36.43572, -5.90323	69	03.04.20
CS	CADIZ	Puerto Santa María	El Martillo Industrial area	36.62448, -6.19817	14	20.04.13
CS	CADIZ	Puerto de Santa María	Peri-urban croplands	NA	NA	NA
CS	CADIZ	Puerto de Santa María	Rancho Linares	NA	NA	NA

CS	CADIZ	Puerto de Santa María	Sierra San Cristóbal	36.63250, -6.15120	115	07.03.21
CS	CADIZ	Puerto Real	Arroyo del Castaño	36.54700,-6.08969	67	29.05.17
CS	CADIZ	Puerto Real	Arroyo de la Zarza	NA	NA	NA
CS	CADIZ	Puerto Real	Arroyo de las Yeguas	NA	NA	NA
CS	CADIZ	Puerto Real	Camino Torrealta	36.52619, -6.15571	22	16.04.21
CS	CADIZ	Puerto Real	Camino Los Barreros	36.53163, -6.16760	24	22.03.10
CS	CADIZ	Puerto Real	East peri-urban forested area	36.55845,-6.11097	22	NA
CS	CADIZ	Puerto Real	Forested-shrubby area	36.55426,-6.08621	86	29.05.17
CS	CADIZ	Puerto Real	La Chacona	36.52646, -6.11869	56	30.03.18
CS	CADIZ	Puerto Real	Peri-urban cropland	36.53978,-6.10563	42	29.05.17
CS	CADIZ	San José del Valle	Arroyo del Palmetín	36.63580, -5.71410	111	23.04.16
CS	CADIZ	San José del Valle	El Acebuchal	36.59244, -5.76379	205	NA
CS	CADIZ	San José del Valle	Peri-urban ring	36.60721, -5.80027	137	14.05.17
CS	CADIZ	San Roque	Estación Ambiental Madre Vieja	36.20270, -5.40670	6	25.04.15
CS	CADIZ	San Roque	Monte bajo	NA	NA	NA
CS	CADIZ	San Roque	Peri-urban area	36.20974, -5.38457	111	07.04.09
CS	CADIZ	San Roque	Pinar del Rey	NA	NA	27.03.85
CS	CADIZ	San Roque	Sierra Carbonera	NA	NA	01.04.82
CS	CADIZ	Tarifa	Arroyo del Molino	36.20403, -5.69441	83	NA
CS	CADIZ	Tarifa	Arroyo Cagancha	36.15347, -5.63273	118	16.05.15
CS	CADIZ	Tarifa	Camino de la Pista	36.06480, -5.64840	68	08.05.21
CS	CADIZ	Tarifa	Campaña Tarifeña	NA	NA	NA
CS	CADIZ	Tarifa	Cerro de Bartolo	36.09313, -5.72697	368	05.05.08
CS	CADIZ	Tarifa	Near Cortijo Aguilón	36.12480, -5.70490	75	01.05.17
CS	CADIZ	Tarifa	Embalse de Almodóvar	36.15057, -5.65305	90	10.05.18
CS	CADIZ	Tarifa	Pico Luna	36.10292, -5.54157	781	20.05.17
CS	CADIZ	Tarifa	Río de la Jara	36.05870, -5.63700	5	23.04.19
CS	CADIZ	Tarifa	Sierra la Plata	36.10799, -5.78828	348	29.04.18
CS	CADIZ	Torre Alháquime	Abandoned cropland	36.89050, -5.25950	604	01.05.17
CS	CADIZ	Ubrique	Los Alcornocales Natural Park	36.641672, -5.473934	NA	28.04.12
CS	CADIZ	Ubrique	South peri-urban area	NA	NA	01.05.17
CS	CADIZ	Vejer de la Frontera	Near Arroyo Donadillo	36.27180, -5.93740	8	26.05.18

CS	CADIZ	Vejer de la Frontera	Near el Ciruelo	36.23510, -6.04980	30	13.05.18
CS	CADIZ	Vejer de la Frontera	Near Río Barbate	36.23580, -5.93970	3	23.05.12
CS	CADIZ	Villaluenga del Rosario	Peri-urban area	36.69740, -5.38767	870	05.05.08
L: Bologna, 1989	CADIZ	NA	Bay of Cádiz Area, see Fig. 10	NA	NA	NA
L: Bologna, 1989	CADIZ	NA	La Janda Area, see Fig. 10	NA	NA	NA
L: Bologna, 1989	CADIZ	NA	Bay of Algeciras, see Fig. 10	NA	NA	NA
L: García-París, 1998	CADIZ	NA	N Bay of Cádiz Area, see Fig. 1	NA	NA	NA
L: García-París, 1998	CADIZ	NA	S Bay of Cádiz Area, see Fig. 1	NA	NA	NA
L: García-París, 1998	CADIZ	NA	Bay of Algeciras, see Fig. 1	NA	NA	NA
L: García-París <i>et al.</i> , 2003	CADIZ	Algeciras	NA	NA	NA	21.04.21
L: García-París <i>et al.</i> , 2003	CADIZ	Algeciras	NA	NA	NA	23.04.21
L: García-París <i>et al.</i> , 2003	CADIZ	Algeciras	NA	NA	NA	24.04.21
L: García-París <i>et al.</i> , 2003	CADIZ	Alcalá de los Gazules	NA	NA	NA	NA
L: García-París <i>et al.</i> , 2003	CADIZ	Jerez de la Frontera	NA	NA	NA	16.03.85
L: García-París <i>et al.</i> , 2003	CADIZ	Jerez de la Frontera	Laguna de Medina	NA	NA	27.03.83
L: García-París <i>et al.</i> , 2003	CADIZ	San Roque	NA	NA	NA	00/05/1973
L: García-París <i>et al.</i> , 2003	CADIZ	Tarifa	NA	NA	NA	00/04/1971
L: Pérez-Moreno <i>et al.</i> , 2003	CADIZ	Ronda	Sierra de las Nieves	NA	NA	10.04.87
L: Pérez-Moreno <i>et al.</i> , 2003	CADIZ	San Roque	NA	NA	NA	00/05/1987
L: Pérez-Moreno <i>et al.</i> , 2004	CADIZ	San Roque	NA	NA	NA	00/05/1971
L: Pérez-Moreno <i>et al.</i> , 2003	CADIZ	Tarifa	NA	NA	NA	20.03.89
L: Percino-Daniel <i>et al.</i> , 2013	CADIZ	Benalup-Casas Viejas	Benalup de Sidonia	NA	NA	NA
L: Percino-Daniel <i>et al.</i> , 2013	CADIZ	Chiclana de la Frontera	NA	NA	NA	NA
L: Percino-Daniel <i>et al.</i> , 2013	CADIZ	Vejer or Algodonales?	La Muela	NA	NA	NA
L: Percino-Daniel <i>et al.</i> , 2013	CADIZ	NA	3km S Alcalá de los Gazules	NA	NA	NA
L: Cortés-Fossati, 2018	CADIZ	Medina Sidonia	Arroyo del Saltillo	36.45757, -5.94340	37	2016-2018
L: Cortés-Fossati, 2018	CADIZ	Puerto Real	East croplands	36.53127, -6.16051	37	2016-2018
L: Cortés-Fossati, 2018	CADIZ	Puerto Real	Parque de Entrevías	36.53636, -6.19546	366	2014-2021
L: Cortés-Fossati, 2018	CADIZ	Sanlúcar de Barrameda	Las Dunas industrial area	36.75019, -6.34113	39	04.06.17
L: Sánchez-Vialas <i>et al.</i> , 2020	CADIZ	Conil de la Frontera	Fuente del Gallo	36.29691, -6.11925	28	13.04.13
L: Sánchez-Vialas <i>et al.</i> , 2020	CADIZ	Facinas (Barbate)	Facinas	36.12633, -5.70572	NA	19.06.16

L: Sánchez-Vialas <i>et al.</i> , 2020	CADIZ	Manzanete	Sierra del Retín	NA	NA	04.01.18
L: Sánchez-Vialas <i>et al.</i> , 2020	CADIZ	Manzanete	Sierra del Retín	36.20000, -5.80000	NA	24.03.11
L: Sánchez-Vialas <i>et al.</i> , 2020	CADIZ	Paterna de Rivera	NA	NA	NA	21.05.17
L: Sánchez-Vialas <i>et al.</i> , 2020	CADIZ	NA	2 km S Benalup Sidonia	NA	NA	19.04.01
L: Sánchez-Vialas <i>et al.</i> , 2020	CADIZ	NA	7 km SW Benalup Sidonia	NA	NA	19.04.01
L: Sánchez-Vialas <i>et al.</i> , 2020	CADIZ	NA	4km NE San José del Valle	NA	NA	19.04.01
L: Sánchez-Vialas <i>et al.</i> , 2020	CADIZ	NA	3km S Alcalá de los Gazules	NA	NA	NA
L: Sánchez-Vialas <i>et al.</i> , 2020	CADIZ	San Roque	NA	NA	NA	00/05/1973
CS	MALAGA	Alhaurín el Grande	Shrubby area	36.62300, -4.70160	3	29.04.07
CS	MALAGA	Antequera	Acuartelamiento Bobadilla	37.03120, -4.74121	307	NA
CS	MALAGA	Antequera	Cropland	37.06300, -4.71700	3	14.04.15
CS	MALAGA	Campillos	Sub-urban area	37.04603, -4.85733	460	25.05.19
CS	MALAGA	Campillos	Laguna Redonda	37.03010, -4.84400	3	25.05.19
CS	MALAGA	Ciudad Jardín	Arroyo Hondo	36.77359, -4.38472	394	05.04.12
CS	MALAGA	Ciudad Jardín	Near Jardines de San Telmo	36.76744, -4.41804	164	03.04.07
CS	MALAGA	Cortes de la Frontera	Loma de los Pinos	36.56040, -5.39080	3	04.04.15
CS	MALAGA	Fuente de Piedra	Sub-urban area	37.13343, -4.72823	335	NA
CS	MALAGA	La Roda de Andalucía	Mirador la Vicaría	37.13619, -4.75720	397	NA
CS	MALAGA	Málaga	Arroyo las Cañas	36.72195, -4.48979	354	04.03.15
CS	MALAGA	Málaga	Sub-urban area	36.722323, -4.485513	61	15.07.19
CS	MALAGA	Ojén	Sub-urban area	36.56567, -4.85609	100	06.04.08
CS	MALAGA	Parauta	Near Área Recreativa Conejeras	36.66316, -5.09306	1048	13.05.11
CS	MALAGA	Palma-Palmilla	Shrubby area	36.76606, -4.44250	360	22.07.17
CS	MALAGA	Puerto de la Torre	Camino Cupiana	36.75087, -4.49657	376	19.03.21
CS	MALAGA	Sierra de Yeguas	Near Camino de Campillos	37.107585, -4.829026	3	NA
CS	MALAGA	Tolox	Mirador el Cuco	36.71058, -4.98980	381	14.03.16
CS	MALAGA	Yunquera	Mirador Luis Ceballos	36.71734, -4.96470	3	25.05.13
CS	MALAGA	Yunquera	Near Puerto Saucillo	36.71040, -4.96685	1099	03.05.14
CS	MALAGA	Yunquera	Parque Natural Sierra las Nieves	36.71142, -4.96696	1189	26.03.16
L: Sánchez-Vialas <i>et al.</i> , 2020	MALAGA	NA	Sierra de las Nieves	NA	NA	25.04.91
L: Sánchez-Vialas <i>et al.</i> , 2020	MALAGA	Montecorto	NA	NA	NA	NA
L: García-París, 1998	MALAGA	NA	Near Málaga, see Fig. 1	NA	NA	NA

L: Pérez-Moreno <i>et al.</i> , 2004	MALAGA	Sierra de Ronda	NA	NA	NA	08.04.82
L: Sánchez-Vialas <i>et al.</i> , 2020	GRANADA	Santa Cruz Comercio	NA	NA	NA	NA

Table S2. List of specimens studied in the field in which the color of the banding was noted. The observations are divided between two classes, Orange (O) which is represented on the map with orange dots and Red (Red) represented on the map with red dots. Only those individuals from the sampling campaigns were included in the study as the colors could not be standardized from photographs provided by third parties.

Source	Province	Municipal district	Location	X, Y	Colour
F	CADIZ	Alcalá de los Gazules	El Algibe	36.44570, -5.74695	O
F	CADIZ	Algeciras	Sierra de la Plata	36.11251, -5.77617	R
F	CADIZ	Arcos de la Frontera	Arroyo del Salado	36.74120, -5.85514	O
F	CADIZ	Barbate	Sierra del Retín	36.17378, -5.84883	R
F	CADIZ	Chiclana de la Frontera	East peri-urban area	36.41881, -6.12198	O
F	CADIZ	Chiclana de la Frontera	South-West peri-urban area	36.41452, -6.14204	O
F	CADIZ	Chiclana de la Frontera	Torre del Puerco	36.33004, -6.16010	O
F	CADIZ	Conil de la Frontera	Fuente del Gallo	36.29054, -6.10900	O
F	CADIZ	Jerez de la Frontera	Area Sur Shopping centre	36.69224, -6.15621	O
F	CADIZ	Jerez de la Frontera	Arroyo Canaleja, South stretch	36.67779, -6.09269	O
F	CADIZ	Jerez de la Frontera	Arroyo Canaleja, East stretch	36.67972, -6.09339	O
F	CADIZ	Jerez de la Frontera	Arroyo de la Loba	36.69169, -6.16478	O
F	CADIZ	Jerez de la Frontera	Campiña del Área Norte	36.68620, -6.17414	O
F	CADIZ	Jerez de la Frontera	Campiña del Área Sur	36.69996, -6.15733	O
F	CADIZ	Jerez de la Frontera	Cartuja Santa María		
F	CADIZ	Jerez de la Frontera	Defensión	36.65135, -6.10955	O
F	CADIZ	Jerez de la Frontera	El Pedroso	36.52443, -5.98691	O
F	CADIZ	Jerez de la Frontera	Laguna de Medina	36.61580, -6.06087	O
F	CADIZ	Jerez de la Frontera	Zoological Park parkings	36.69006, -6.15332	O
F	CADIZ	Línea la Concepción	Sierra Carbonera	36.19398, -5.35895	R
F	CADIZ	Los Barrios	La Teja, Alcornocales Nat. Park	36.28370, -5.57462	R
F	CADIZ	Medina Sidonia	Arroyo del Azúcar	36.46683, -5.91008	O
F	CADIZ	Medina Sidonia	Arroyo Golondrina/Croplands	36.42423, -5.90806	O

F	CADIZ	Medina Sidonia	Colada de la Espartera	36.43629, -6.02801	O
F	CADIZ	Medina Sidonia	Croplands near Saltillo	36.45661, -5.94742	O
F	CADIZ	Medina Sidonia	Croplands near Saltillo (2)	36.46475, -5.95086	O
			Arroyo Pozomedina/ croplands		
F	CADIZ	Paterna de Rivera		36.52451, -5.87369	O
F	CADIZ	Puerto Real	Peri-urban area	36.53215, -6.17407	O
F	CADIZ	Trebujena	South croplands	36.85740, -6.19088	O?
L: Cortés-Fossati, 2018	CADIZ	Medina Sidonia	Arroyo del Saltillo	36.45757, -5.94340	O
L: Cortés-Fossati, 2018	CADIZ	Puerto Real	East croplands	36.53127, -6.16051	O
L: Cortés-Fossati, 2018	CADIZ	Puerto Real	Parque de Entrevías	36.53636, -6.19546	O
L: Cortés-Fossati, 2018	CADIZ	Sanlúcar de Barrameda	Las Dunas industrial area	36.75019, -6.34113	R

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