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43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

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Cover: Mixed media illustration of a Blue bird and Sunbird. © Lakshmi Niranjana.



Taxonomy and distribution of some orthopteran species (Orthoptera: Gryllidae, Trigonidiidae, Acrididae) from northwestern Morocco

Hanae El Harche¹ , Samiha Kaïoua² & Dalale Mansouri³

^{1,2,3} University Ibn Tofail, Faculty of Sciences, Department of Biology, Laboratory of Plant, Animal and Agro-Industry Productions, Kenitra, Morocco.

¹ hanae.elharche@yahoo.com (corresponding author), ² samiha.kaïoua@uit.ac.ma, ³ dalale.mansouri@uit.ac.ma

Abstract: Orthopterans have emerged as a crucial group of invertebrates for environmental monitoring and assessment. According to available literature the study of Moroccan orthopteran species remains limited in comparison to other countries. In recent years, the field of orthopteran classification has witnessed significant progress thanks to groundbreaking research in taxonomy and phylogeny that have shed new light on relationships and evolutionary history. In Morocco, there are many types of Orthoptera, including grasshoppers, crickets, and locusts, and different regions of the country have not been equally well sampled and studied. Notably the northwestern, particularly the Sidi Kacem region, are little studied. Here we present a taxonomic update of the most abundant orthopterans in Morocco based on field visits between spring and summer 2019. Five species were identified: *Dociostaurus maroccanus*, *Aiolopus strepens*, *Gryllus bimaculatus*, *Gryllus campestris*, and *Nemobius sylvestris*. We aim to use this publication as a baseline for future work on Orthopterans from northwestern Morocco.

Keywords: Caelifera, Ensifera, grasshopper, invertebrates, taxonomic update.

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Author details: Hanae El Harche, a PhD graduate from Ibn Tofail University in Morocco, specializes in animal ecology, entomology, systematics (taxonomy) and faunistics. Her research projects have focused on exploring spatial and seasonal variations, as well as the impact of human activities on arthropod communities. In particular, she has contributed to the establishment of a comprehensive checklist of terrestrial arthropods present in agroecosystems in northwest Morocco. Samiha Kaïoua, a PhD graduate from Ibn Tofail University, has a keen interest in the bioecology and systematic structure of molluscs and crustaceans. Her research focuses on the complex relationships and classifications of these marine organisms. Dalale Mansouri, a PhD graduate from Ibn Tofail University, studies biology, environmental chemistry, biochemistry and environmental pollution.

Author contributions: El Harche Hanae—conducted surveys, collected specimens, identified the species, and writing - review and editing the manuscript. Mansouri Dalale & Kaïoua Samiha—assisted with data collection.

INTRODUCTION

The order Orthoptera, comprising a vast array of species, holds a prominent position among insect orders (Bidau 2014). With approximately 28,000 species worldwide, it ranks as the sixth largest order, trailing only Hemiptera (Cigliano et al. 2022). These insects, commonly known as grasshoppers, locusts and crickets, are present in many terrestrial environments and exhibit remarkable diversity (Yadav & Kumar 2017). The composition of grasshopper communities serves as a valuable indicator, as their structure is highly responsive to environmental changes (O'Neill et al. 2003). Moreover, these insects play a crucial role in the functioning of ecosystems and can potentially serve as useful bioindicators for land disturbance (Saha et al. 2011). This order can be classified into two distinct suborders: the Ensifera, which includes crickets, katydids, and their relatives, characterized by their long antennae (longer than their bodies and consisting of more than 30 segments); and the Caelifera, which encompasses grasshoppers and their allies, distinguished by their short antennae (shorter than their bodies and comprising less than 28 segments) (Song et al. 2018).

Grasshoppers play a crucial role as ecological and biological indicators, providing valuable insights into ecosystem qualities and the effectiveness of ecological networks (Zhang et al. 2019). However, they have also garnered significant attention due to the extensive damage they inflict on crops and various forms of green vegetation (Dakhel et al. 2020). Despite the rich biodiversity of grasshoppers, Morocco has received little attention in terms of research, with only a few localities being studied. The first significant contribution to our understanding of Moroccan grasshoppers was made by Chopard (1936, 1943, 1949). Subsequently, several taxonomic studies were conducted such as: Badih & Pascual (1998), Latchinsky (1998), and Faucheux et al. (2013). More recently, some faunistic surveys have been carried out, including those by Defaut & Francois (2018, 2020, 2021), Mabrouki et al. (2021), Defaut (2022), and Aziz et al. (2023). Despite these efforts, our knowledge of the grasshopper fauna in many regions of Morocco remains insufficient, and further research is needed. There is a lack of published work or reports on the grasshopper fauna in the northwestern region of Morocco. This region remains poorly studied, presenting an opportunity for future research and exploration. The aim of this study was to improve our comprehension to the grasshopper fauna in Morocco, with a specific focus on the taxonomy, ecology, and distribution of the most

prevalent orthopteran species found in a poorly studied northwestern region. By conducting this research, we aimed to contribute valuable insights to the existing knowledge in this field.

MATERIAL AND METHODS

Study area

The study was conducted in three stations in the region of Sidi Kacem (34.13.00 N, 5.42.00 E) located in the northwest of Morocco (Figure 1). The climate of the region is classified as semi-arid, the temperature in autumn goes down to 6 °C while in summer it can exceed 40 °C, with a probability of daily precipitation above 13%.

Station 1: 34.2295°N; -5.7013°E. It is a field of *Vicia faba* L. beans (Fabaceae).

Station 2: 34.2402°N; -5.7094°E. This is a field of cereal crops: soft wheat: *Triticum aestivum* L. (Poaceae).

Station 3: 34.2302°N; -5.7055°N. This is an uncultivated area. The plant species dominate the area are *Nicotiana glauca* Graham tree tobacco (Solanaceae), *Ferula communis* L. fennel (Apiaceae), *Cynara humilis* L. thistle (Asteraceae), and *Ammi visnaga* L. toothpick weed (Apiaceae).

Sampling

The orthopteran specimens collected, studied, and documented during faunistic surveys between April and August 2019. The insects were captured by sweeping vegetation using an entomological net, to collect orthopterans from plants and by handpicking, seeking under stones and different substrates. After the collection, insects were transferred into specimen bottles containing 70% alcohol. Specimens were identified using a relevant, published key, and by referring to the Orthoptera collection at the Scientific Institute of Rabat (Morocco) and Data available in the Global Biodiversity Information Facility (GBIF) of Morocco. The nomenclature has been updated using the websites <http://orthoptera.speciesfile.org>, <https://www.gbif.org> and MNHN Paris website <http://acrinwafrica.mnhn.fr>.

Abbreviations used in the examined material are the following: CSIR—Collection at the Scientific Institute of Rabat (Morocco). GBIF—<https://www.gbif.org/country/MA>.

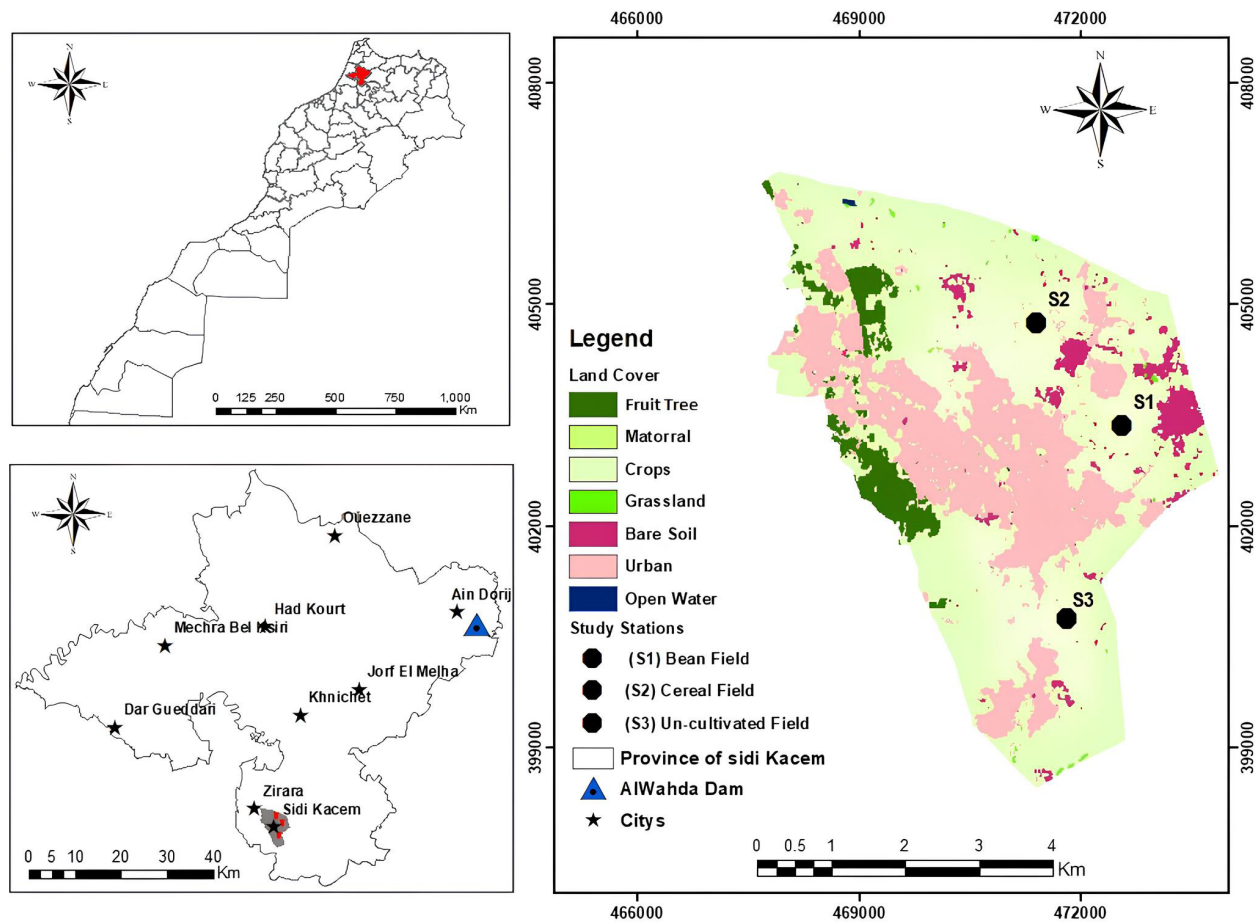


Figure 1. Map of Morocco showing the location of sampling stations.

RESULTS

Systematic Account

Suborder: Ensifera Chopard, 1922

Family: Gryllidae Laicharting, 1781

Subfamily: Gryllinae Laicharting, 1781

Tribe: Gryllini Laicharting, 1781

Genus: *Gryllus* Linnaeus, 1758

Gryllus (Gryllus) bimaculatus De Geer, 1773

Material examined: MOROCCO: Sidi Kacem (Station 1), 34.2295°N; -5.7013°E, 191 m; 15.v.2019, H. El Harche leg, 1 adult (♂), GBIF. Sidi Kacem (Station 3), 34.2302°N; -5.7055°E, 192 m, 20.vi.2019, H. El Harche leg, 2 adults (♂), CSIR.

Diagnosis: 17–23 mm. Black almost all over the body, males have a yellowish area between the pronotum and the elytra and light legs. This species can be differentiated from other cricket species by the two yellow/white spots on the dorsum of its thorax. Females have a tubular organ at the rear, the ovipositor, which is used to lay eggs in the ground.

Nutrition: Foliage, seeds, roots, and small insects

Habitat: Inhabits pastures, shrubs, dunes, grasslands and ruderal terrain (Bent et al. 2018).

Life cycle: Adults appear from June, July to autumn (Gawalek et al. 2014). This species, like other crickets, has an incomplete metamorphosis (hemimetabolous) with an egg, nymph, and adult stage (Donoughe & Extavour 2016; Watanabe et al. 2017). Females lay their eggs in humid soil or sand and hatchlings emerge from the eggs in about two weeks (Donoughe & Extavour 2016).

General distribution: A Palearctic species; occurs predominantly in the Mediterranean area (Ferreira & Ferguson 2010; Panagiotopoulou et al. 2016) northern Africa, Madagascar, the Indo-Malayan area, Ethiopia, and Central Asia (Gorochoff & Llorente 2001).

Distribution in Morocco: Recorded at Oued Cherrat, Korifla, Tafrata, Amizmiz (Chopard 1936), in the cork oak forest, Mamora (El Alami Idrissi 2013), and the Oriental region (Mabrouki et al. 2021).

***Gryllus (Gryllus) campestris* (Linnaeus, 1758)**

Material examined: MOROCCO: Sidi Kacem (Station 1), 34.12.35N, 5.42.31E, 191 m; 10.vi.2019, H. El Harche leg, 1 adult (♂), CSIR. Sidi Kacem (Station 3), 34.13.50N, 5.40.12E, 192 m, 18.vii.2019, H. El Harche leg, 1 adult (♂), CSIR.

Diagnosis: Male: range from 19–23 mm. Female: from 17–22 mm. Body: shiny black to rarely brown of compact cylindrical shape and with strong legs. Head: black, large, wider than the pronotum. Tegmina: brown with yellow spots at base, with rounded end not exceeding the abdomen. Wings not exceeding elytra: Inner side of hind femur red

Nutrition: Mostly plants (herbs, grasses), but also occasionally (dead) insects.

Habitat: inhabits nutrient-poor grasslands of all kinds, rather dry, extensive hay meadows, large embankments, heathland, and extensive, sunny pastures (Witzenberger & Hochkirch 2008).

Life cycle: The life cycle includes eggs, several instars of nymphs and adults. Nymphs can be found together with adults (Vrenozi & Uchman 2020). During growth, the nymph's males dig out the burrow and hibernate until late April and early May–July (Witzenberger & Hochkirch 2008; Gawałek et al. 2014). Mature females lay hundreds of eggs into the soil around May and June (Rodriguez-Munoz et al. 2010). Only eggs laid fairly early in the season (late May–early June) are robust enough to hibernate successfully.

General distribution: A Palearctic species, the distribution of *G. campestris* includes all of Europe, northern Africa (Morocco, Algeria & Tunisia), and western Asia (Gorochoy & Llorente 2001; Hochkirch & Adorf 2007; Panagiotopoulou et al. 2016).

Distribution in Morocco: Recorded in the cork oak forest, Mamora (El Alami Idrissi 2013).

Family: Trigonidiidae Saussure, 1874

Subfamily: Nemobiinae Saussure, 1877

Tribe: Nemobiini Saussure, 1877

Genus: *Nemobius* Audinet-Serville, 1838

***Nemobius (Sylvestris) sylvestris* (Bosc, 1792)**

Material examined: MOROCCO: Sidi Kacem (Station 3), 34.2402°N; -5.7094°E, 192 m, 28.viii.2019, H. El Harche leg, 1 adult (♂). GBIF.

Diagnosis 7–10 mm. Both adults and nymphs of *N. sylvestris* may be recognized by their unique color pattern golden brown to almost black body. **Head:** black with pale Y-shaped marking attached to the body with very short wings. **Pronotum:** very pale with dark

speckles. Male: Absence of glandular hind tibial spines.

Female: ovipositor shape and tooth dentation, straight, about as long as the hind femur, and without teeth. Straight ovipositors.

Nutrition: Omnivorous, feeding on a wide range of organic matter, including carrion, leaf litter, decaying plant parts, fruits & also fresh plants, and dead or living insects (Martín-Vega et al. 2013).

Habitat: It can be found at ground level in meadows, in leaf litter, shrubs, and woodland borders in which it looks for food (Brouwers & Newton 2008; Brouwers et al. 2011). It inhabits also boulders in grasslands, where they are hidden in the pore systems of the stones.

Life cycle: *Nemobius sylvestris* passes through two to three winters in its life cycle. The first winter is spent as eggs, and the second as nymphs of a medium size. These mature by the middle of the summer, and some of these adults may endure a third winter (Vahed 2020). Adults appear from July–October (Brouwers et al. 2011).

General distribution: A Palearctic species, found in the Iberian Peninsula, covers the southwestern Europe, the south of England, France, the south of Portugal, and Poland (Gorochoy & Llorente 2001). Also recorded in North America (Woo 2022).

Distribution in Morocco: Recorded in Tangier (Default et al. 2016).

Suborder: Caelifera Ander, 1939

Family: Acrididae MacLeay, 1821

Subfamily: Gomphocerinae Fieber, 1853

Tribe: Dociostaurini Mishchenko, 1974

Genus: *Dociostaurus* Fieber, 1853

***Dociostaurus (Dociostaurus) maroccanus* (Thunberg, 1815)**

Material examined: MOROCCO: Sidi Kacem (Station 1), 34.2295°N; -5.7013°E, 191 m; 16.viii.2019, H. El Harche leg, 2 adults (♂), GBIF. Sidi Kacem (Station 2), 34.2402°N; -5.7094°E, 190 m, 12.vi.2019, H. El Harche leg, 1 adult (♂), GBIF. Sidi Kacem city (Station 3), 34.2402°N; -5.7094°E, 192 m, 20.v.2019, H. El Harche leg, 1 adult (♂), GBIF.

Diagnosis: Body: 16.5–28.5 mm for males and 20.5–38.0 mm for females. Tegmina: are 17.5–27.0 mm for males and 23.0–36.0 mm for females, nearly transparent that extend far behind the tip of the hind femur can have sporadic, tiny brownish or gray patches. The pronotum: bears a pale cross-shape. Wings: longer than wide. Hind Femurs: femora slender. Hind femur male 13.2–17.4 mm, female 15.5–21.6 mm. Grayish-yellowish in color overall, with dark markings on the body. Depending on

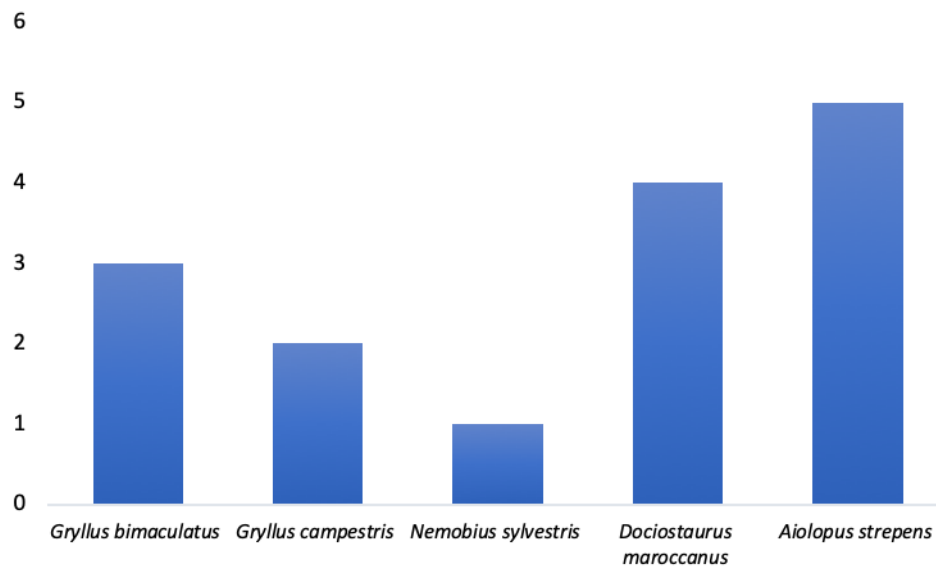


Figure 2. Number of orthoptera individuals caught in the study area.

the phase, the hind femora may or may not have black bands. Tibia: usually red, less often yellow, pinkish, or even whitish, with short striae that don't reach behind the transversal furrow. Pronotum: yellow or pale.

Nutrition: Polyphagous insect, mostly plants (herbs, grasses), but also occasionally insects.

Habitat: *Dociostaurus maroccanus* is a thermophilous and xerophilous species inhabiting open, well-lit areas (Victorovich & Zlatanov 2020). The species is mainly adapted to valleys and foothills with xerophytic vegetation at an altitude of between 400 m and 800 m (Song 2011).

Life cycle: This cricket species undergoes a single annual generation and exhibits an incomplete metamorphosis, known as heterometabolous development. Interestingly, during this process, the nymph closely resembles the adult form, eliminating the presence of a distinct nymphal stage. To ensure successful reproduction, female crickets require firm and exposed ground to lay their eggs. Once laid, these eggs hatch during the subsequent spring and the young crickets migrate towards vegetated areas to find nourishment. It is worth noting that the egg-laying activity primarily occurs in early summer. Each female lays between 18 and 42 eggs. Usually, a single female provides two egg-pods (Quesada-Moraga & Santiago-Álvarez 2001). Nymph development is quite rapid, lasting no more than 25–35 days. The adult stage actively migrates from the hatchling sites to humid depressions where the adults find a sufficient amount of food (Popova & Popov 2009). The breeding season starts in May (Victorovich & Zlatanov 2020).

General distribution: A Palearctic species; in Africa the species occurs in Morocco, Algeria, Tunisia, Libya, and Egypt (Latchininsky & Launois-Luong 1992). It is also present in west and central Europe, i.e., Portugal, Spain, France, Italy, countries of ex-Yugoslavia, Greece, Bulgaria, Moldova and southwestern Ukraine, as well as in the Caucasus, i.e., Armenia, Azerbaijan, and Georgia. The northern limits of its distribution area reached in Hungary and Rumania. The species is also found in countries of the Middle East and Minor Asia, i.e., Turkey, Syria, Lebanon, Jordan, Iraq, and Afghanistan (El Ghadraoui et al. 2003; Guerrero et al. 2017).

Distribution in Morocco: recorded in Al-Azagh of the Middle Atlas (El Ghadraoui et al. 2008) and the Oriental region (Mabrouki et al. 2021).

Subfamily: Oedipodinae

Tribe: Parapleurini Brunner von Wattenwyl, 1893

Genre: *Aiolopus* Fieber, 1853

***Aiolopus (Strepens) strepens* (Latreille, 1804)**

Material examined: MOROCCO: Sidi Kacem (Station 2), 34.2402°N; -5.7094°E, 190 m, 26.vi.2019; H. El Harche leg, 2 adults (♂), GBIF. Sidi Kacem city (Station 3), 34.2302°N; -5.7055°E, 192 m, 19.viii.2019, H. El Harche leg, 3 adults (♂), GBIF.

Diagnosis: Body: 19–24 mm for males while females reach 24–31 mm. *Aiolopus strepens* has a wide range of coloration (green, yellow, and brown). Their strong bodies are typically light brown, though occasionally they might be green, have green patches, or have reddish stripes. Females, can also be totally green in

color. Wings: translucent, slightly bluish, marked by a clear dark spot in the apical region. Antennae: 22–24 segmented, shorter than head and pronotum together. Eyes: ellipsoid, almost twice as long as wide. Pronotum: male 3.9–5.0 mm, female 4.5–7.0 mm, usually brown, the disc may occasionally have median longitudinal stripes that reach the vertex. Subtectiform, rather flat. Tegmina: male 16.7–23.6 mm, female 19.6–30.9 mm, relatively short and broad, exceeding end of hind femur. Hind femur: male 11.3–14.8 mm, female 13.4–19.2 mm, brown with testaceous spots, blackish at upper surface, reddish on inner surface. Wings: transparent with darkened brownish apex. Tibia: as long as hind femur, with 10 outer and 11 inner spines.

Nutrition: The insects feed mainly on grasses.

Habitat: It inhabits dry meadows, riverbanks, dry to mesophilic grasslands, woodland edges, shrubland with open soil spots, quarries. The species can be found over 1,500 m.

Life cycle: The presence of *Aiolopus strepens* adults for most of the year, with only one generation per year (univoltine) in imaginal hibernation. The imagines (= adults) can be found from August–May of the following year. Some of these animals hibernate and reproduce the following spring. There is therefore only one generation per year, but due to the extended lifespan of some individuals, they may still be alive when the nymphs from the eggs laid the previous year are already hatching (Baur et al. 2006). According to the work of Hamdi (1989) in the mid-northern region of Algeria, Benrima (1990) in the Koléa region, Guecioueur (1990) in the Lakhdaria region, Fellaouine (1989) in the Sétif region, Zergoun (1991, 1994), and Douadi (1992) in the Ghardaïa region, *Aiolopus strepens* is present as an adult throughout most of the year. The larvae begin to appear in April. These authors note that *Aiolopus strepens* has only one annual generation and spends the winter in the imaginal state.

Remark: In southern Spain, *A. strepens* exhibits a fascinating life cycle, characterized by two distinct generations per year. The first generation commences in March, when larvae make their initial appearance, followed by the emergence of adults in April. The second generation, on the other hand, commences from July and extends until December, during which a dense population is observed. Between these two periods, the species enters a state of hibernation. Notably, the two generations overlap, resulting in the presence of adult individuals throughout the year (Hernández et al. 1985).

General distribution: A west Palearctic species: widespread throughout the Mediterranean region until

Asia Minor, often reported throughout southern Europe and North Africa (Algeria, Morocco & Tunisia) (Defaut 1999).

Distribution in Morocco: Observed in Moroccan Middle Atlas (Sefrou at an altitude of 800 m and Mazdou at an altitude of 1,200 m) (Essakhi et al. 2014).

DISCUSSION

During the course of this study, five distinct species were collected from three sections of the Sidi Kacem region, representing three families: Acrididae, Gryllidae, and Trigonidiidae. These insect families are widely distributed and typically abundant in nature. However, it is worth noting that the level of biodiversity within the Sidi Kacem region is relatively low for these three families. This can be attributed to the prevalence of anthropogenic pressures in the area. The expansion of agricultural areas and the intensification of management practices are significant factors that contribute to the loss of terrestrial biodiversity at both local and global scales (El Harche et al. 2022). Specifically, the application of pesticides, tillage, and the timing of harvest periods have all had a detrimental impact on the fauna's biodiversity (El Harche et al. 2023). The current state of low biodiversity within these families highlights the potential ecological consequences of human activities. As agricultural areas continue to expand and management practices become more intensive, the delicate balance of the ecosystem is disrupted, leading to a decline in biodiversity (El Harche et al. 2023). Ecosystem alterations have a profound impact on the behavior of organisms, particularly poikilotherms like grasshoppers, which heavily rely on plant matter for sustenance (Bronwyn 2013). Latchinsky et al. (2011) have demonstrated that certain grasshopper species face significant threats from anthropogenic pressures, such as overgrazing and ploughing. The limited number of orthopteran species discovered in our study sites suggests that these species have developed adaptive strategies to withstand human disturbances (Havyarimana et al. 2013).

Orthopterans are widely recognized for their herbivorous habit and are generally regarded as a dominant group of insects in terrestrial habitats. They have a voracious appetite for various types of plants, often leading to significant economic losses. The extent of crop damage is contingent upon the populations and movements of orthopterans within the fields. This poses a significant threat to food crops in Africa.

In our current investigation, the orthopterans were

found to be omnivorous or phytophagous, exclusively consuming plants and seeds. This finding underscores the importance of understanding their feeding habits and preferences. The impact of orthopteran pests on agricultural productivity cannot be overstated. Their relentless feeding habits and ability to decimate crops pose a serious challenge to farmers' livelihoods. Consequently, it is crucial to develop effective strategies for managing and mitigating the damage caused by these insects.

Gryllus sp. and *Dociostaurus maroccanus* pose a significant threat to agricultural crops. These voracious locusts indiscriminately target a wide range of crops, including cereals, vegetables, forage crops, oilseed crops, fruit trees, date palms, and even conifers (Latchinsky 1998). The destructive impact of *D. maroccanus* on crops has been documented in more than 25 countries, often necessitating military intervention for effective control (Latchinsky 1998). This species feeds on over 150 plant species from 33 different families, with 50 of them being important agricultural crops (Latchinsky & Launois Luong 1992). However, despite its potential for devastation, the detailed study of this species has been limited due to its relatively low occurrence rate.

This investigation, conducted in the Sidi Kacem region, has enabled us to compile an initial inventory of the local orthopteran biodiversity of most frequent species that exists in this area. It is important to note that this list can be expanded and updated as new species could be discovered in the future. The Orthoptera, being highly sensitive to changes in vegetation structure, seasonal temperature, and humidity, play a crucial role in ecological studies. They serve as effective indicators of environmental changes (El Harche et al. 2023)

This comprehensive list serves as a valuable reference for future studies aimed at examining the development of biodiversity and determining the real impact of landscape change & degradation on entomofauna. The article focuses mainly on the description of the specimens collected and their distribution, providing an in-depth analysis of the subject. The article presents detailed observations and measurements of each specimen, highlighting its morphology, nutrition, habitat, and life cycle. In addition, this study examines the distribution patterns of these specimens in various locations in Morocco and abroad. This meticulous examination provides valuable information on the range and abundance of different species in a given area, revealing complex relationships within ecosystems. Overall, this article is a crucial resource for scientists in this field, documenting important results on specimen

collection and distribution patterns, while opening the door to further research opportunities.

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Mr. Jatishwor Singh Irungbam, Biology Centre CAS, Branišovská, Czech Republic.
Dr. Ian J. Kitching, Natural History Museum, Cromwell Road, UK
Dr. George Mathew, Kerala Forest Research Institute, Peechi, India
Dr. John Noyes, Natural History Museum, London, UK
Dr. Albert G. Orr, Griffith University, Nathan, Australia
Dr. Sameer Padhye, Katholieke Universiteit Leuven, Belgium
Dr. Nancy van der Poorten, Toronto, Canada
Dr. Kareen Schnabel, NIWA, Wellington, New Zealand
Dr. R.M. Sharma, (Retd.) Scientist, Zoological Survey of India, Pune, India
Dr. Manju Siliwal, WILD, Coimbatore, Tamil Nadu, India
Dr. G.P. Sinha, Botanical Survey of India, Allahabad, India
Dr. K.A. Subramanian, Zoological Survey of India, New Alipore, Kolkata, India
Dr. P.M. Sureshan, Zoological Survey of India, Kozhikode, Kerala, India
Dr. R. Varatharajan, Manipur University, Imphal, Manipur, India
Dr. Eduard Vives, Museu de Ciències Naturals de Barcelona, Terrassa, Spain
Dr. James Young, Hong Kong Lepidopterists' Society, Hong Kong
Dr. R. Sundararaj, Institute of Wood Science & Technology, Bengaluru, India
Dr. M. Nithyanandan, Environmental Department, La Ala Al Kuwait Real Estate. Co. K.S.C., Kuwait
Dr. Himender Bharti, Punjabi University, Punjab, India
Mr. Purnendu Roy, London, UK
Dr. Saito Motoki, The Butterfly Society of Japan, Tokyo, Japan
Dr. Sanjay Sondhi, TITLI TRUST, Kalpavriksh, Dehradun, India
Dr. Nguyen Thi Phuong Lien, Vietnam Academy of Science and Technology, Hanoi, Vietnam
Dr. Nitin Kulkarni, Tropical Research Institute, Jabalpur, India
Dr. Robin Wen Jiang Ngiam, National Parks Board, Singapore
Dr. Lionel Monod, Natural History Museum of Geneva, Genève, Switzerland.
Dr. Asheesh Shivam, Nehru Gram Bharti University, Allahabad, India
Dr. Rosana Moreira da Rocha, Universidade Federal do Paraná, Curitiba, Brasil
Dr. Kurt R. Arnold, North Dakota State University, Saxony, Germany
Dr. James M. Carpenter, American Museum of Natural History, New York, USA
Dr. David M. Claborn, Missouri State University, Springfield, USA
Dr. Kareen Schnabel, Marine Biologist, Wellington, New Zealand
Dr. Amazonas Chagas Júnior, Universidade Federal de Mato Grosso, Cuiabá, Brasil
Mr. Monsoon Jyoti Gogoi, Assam University, Silchar, Assam, India
Dr. Heo Chong Chin, Universiti Teknologi MARA (UiTM), Selangor, Malaysia
Dr. R.J. Shiel, University of Adelaide, SA 5005, Australia
Dr. Siddharth Kulkarni, The George Washington University, Washington, USA
Dr. Priyadarsanan Dharma Rajan, ATREE, Bengaluru, India
Dr. Phil Alderslade, CSIRO Marine And Atmospheric Research, Hobart, Australia
Dr. John E.N. Veron, Coral Reef Research, Townsville, Australia
Dr. Daniel Whitmore, State Museum of Natural History Stuttgart, Rosenstein, Germany.
Dr. Yu-Feng Hsu, National Taiwan Normal University, Taipei City, Taiwan
Dr. Keith V. Wolfe, Antioch, California, USA
Dr. Siddharth Kulkarni, The Hormiga Lab, The George Washington University, Washington, D.C., USA
Dr. Tomas Ditrich, Faculty of Education, University of South Bohemia in Ceske Budejovice, Czech Republic
Dr. Mihaly Foldvari, Natural History Museum, University of Oslo, Norway
Dr. V.P. Uniyal, Wildlife Institute of India, Dehradun, Uttarakhand 248001, India
Dr. John T.D. Caleb, Zoological Survey of India, Kolkata, West Bengal, India
Dr. Priyadarsanan Dharma Rajan, Ashoka Trust for Research in Ecology and the Environment (ATREE), Royal Enclave, Bangalore, Karnataka, India

Fishes

Dr. Neelesh Dahanukar, IISER, Pune, Maharashtra, India
Dr. Topiltzin Contreras MacBeath, Universidad Autónoma del estado de Morelos, México
Dr. Heok Hee Ng, National University of Singapore, Science Drive, Singapore
Dr. Rajeev Raghavan, St. Albert's College, Kochi, Kerala, India
Dr. Robert D. Sluka, Chiltern Gateway Project, A Rocha UK, Southall, Middlesex, UK
Dr. E. Vivekanandan, Central Marine Fisheries Research Institute, Chennai, India
Dr. Davor Zanella, University of Zagreb, Zagreb, Croatia
Dr. A. Biju Kumar, University of Kerala, Thiruvananthapuram, Kerala, India
Dr. Akhilesh K.V., ICAR-Central Marine Fisheries Research Institute, Mumbai Research Centre, Mumbai, Maharashtra, India
Dr. J.A. Johnson, Wildlife Institute of India, Dehradun, Uttarakhand, India
Dr. R. Ravinesh, Gujarat Institute of Desert Ecology, Gujarat, India

Amphibians

Dr. Sushil K. Dutta, Indian Institute of Science, Bengaluru, Karnataka, India
Dr. Annemarie Ohler, Muséum national d'Histoire naturelle, Paris, France

Reptiles

Dr. Gernot Vogel, Heidelberg, Germany
Dr. Raju Vyas, Vadodara, Gujarat, India
Dr. Pritpal S. Soorae, Environment Agency, Abu Dubai, UAE.
Prof. Dr. Wayne J. Fuller, Near East University, Mersin, Turkey
Prof. Chandrashekhar U. Rivonker, Goa University, Taleigao Plateau, Goa. India
Dr. S.R. Ganesh, Chennai Snake Park, Chennai, Tamil Nadu, India
Dr. Himansu Sekhar Das, Terrestrial & Marine Biodiversity, Abu Dhabi, UAE

Birds

Dr. Hem Sagar Baral, Charles Sturt University, NSW Australia
Mr. H. Byju, Coimbatore, Tamil Nadu, India
Dr. Chris Bowden, Royal Society for the Protection of Birds, Sandy, UK
Dr. Priya Davidar, Pondicherry University, Kalapet, Puducherry, India
Dr. J.W. Duckworth, IUCN SSC, Bath, UK
Dr. Rajah Jayapal, SAGON, Coimbatore, Tamil Nadu, India
Dr. Rajiv S. Kalsi, M.L.N. College, Yamuna Nagar, Haryana, India
Dr. V. Santharam, Rishi Valley Education Centre, Chittoor Dt., Andhra Pradesh, India
Dr. S. Balachandran, Bombay Natural History Society, Mumbai, India
Mr. J. Praveen, Bengaluru, India
Dr. C. Srinivasulu, Osmania University, Hyderabad, India
Dr. K.S. Gopi Sundar, International Crane Foundation, Baraboo, USA
Dr. Gombobaatar Sunde, Professor of Ornithology, Ulaanbaatar, Mongolia
Prof. Reuven Yosef, International Birding & Research Centre, Eilat, Israel
Dr. Taej Mundkur, Wetlands International, Wageningen, The Netherlands
Dr. Carol Inskipp, Bishop Auckland Co., Durham, UK
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Tamil Nadu 641006, India
ravi@threatenedtaxa.org

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