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The first evidence of breeding by *Crocothemis sanguinolenta* and *Zygonyx torridus* (Odonata: Libellulidae) in Iran

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ABSTRACT. For the first time, exuviae of *Crocothemis sanguinolenta* and *Zygonyx torridus* were collected from southern parts of Iran. Females of *Z. torridus* were also observed mating and ovipositing in two habitats. According to our data, these two species successfully breed in some suitable microhabitats and are neither immigrants nor vagrants. Our findings based on this research and recent information showed that habitat dispersal for these two species is not limited to the Hormuz Strait region, as previously thought. Suitable habitats for *Z. torridus* expanded from the Southwest to the East of the country. For *C. sanguinolenta*, the habitat range covers the far southeastern parts of the country near the Pakistan border area. Based on the geological history of the Persian Gulf region in the last glacial period and similar African coexisting species in these microhabitats, we suggest that these species are relict populations that survived in a few suitable habitats from a wider area in the past. This view seems more appropriate to explain the current distribution of these species than their recent migration from the UAE or Oman regions.

Key words: Autochthonous, distribution, dragonfly, relict, Anisoptera, exuviae

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INTRODUCTION

Zygonyx torridus (Kirby, 1889) (Ringed Cascader) is the largest libellulid species in Europe, Arabia, and Iran. This species can be recognized by its characteristic flight style, oviposition mode (with females perching on stones or vegetation while introducing the abdomen into the water; see Martens, 2015), and perching position, and by its pattern of colouration with dark navy or black background, marked with yellow spots and some metallic shining. This species is common in tropical Africa, the Middle East, Arabia, a few parts of Southern Europe, and Oriental regions (Fraser, 1936; Dumont, 1991; Askew, 2004; Kalkman, 2006; Kunz et al., 2006; Boudot & Kalkman, 2015; Martens, 2015; Schneider et al., 2018a; Dijkstra et al., 2020). *Crocothemis sanguinolenta* (Burmeister, 1839) (Little Scarlet) is another common Afrotropical species in most South Africa and some parts of the Arabian Peninsula as a relict species and recently was recorded from Iran (Schneider & Dumont, 1997; Schneider, 2004; Boudot et al., 2009;

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Schneider et al., 2018b; Tarboton & Tarboton 2019). Schneider (1982) described *C. sanguinolenta arabica* as a subspecies in the Arabian area with some different characters in body size, lack of dark stripe in the abdomen, and reduced yellow colour patch in the wing base. This taxon is no longer used today and is now regarded as a variation of the main species dispersed in the Arabian area. Different characters may be considered as an adaptation for hot and dry habitats (Schneider, 1982; Dijkstra & Dingemanse, 2000; Schneider et al., 2018b). Both species are regarded as vagrant species that immigrate across the Hormuz Strait to a limited area in the south of Iran (Heidari & Dumont, 2002; Ebrahimi et al., 2009, 2014; Schneider & Dumont, 2015; Schneider et al., 2018a; Schneider et al., 2018b; Schneider & Ikemeyer, 2019).

Previous research suggests that the low winter temperatures in the areas where these two species were first recorded are the reasons for unsuccessful breeding in the Kerman province. Additionally, all observed or captured specimens of *Z. torridus* in Iran until now were males only (Heidari & Dumont, 2002; Ebrahimi et al., 2009, 2014; Schneider et al., 2018a; Schneider et al., 2018b; Schneider & Ikemeyer, 2019). Thus, these arguments suggest recent immigration as the main reason to explain the presence of these species in Iran. On the other hand, in two references, the breeding sites for *Z. torridus* were suggested and predicted along the coastal regions of the Persian Gulf and hypothesized that from this area, they had spread to nearby regions and that these regions serve as a bridge between the Oriental and African/Arabian populations (Kunz et al., 2006; Boudot et al., 2021).

In this paper, we want to report on our records of Iranian reproductive populations in both species, *C. sanguinolenta* and *Z. torridus*.

MATERIAL AND METHODS

We investigated more than 800 aquatic habitats throughout Iran between 2009 and 2020. From these sites, a total of 12 localities in five provinces (Fars, Bushehr, Hormozgan, Kerman, and Sistan & Baluchestan) included suitable habitats for *C. sanguinolenta* and *Z. torridus* (Figs 1–2; Tables 1–4,). Adult specimens were collected using an aerial net and preserved in acetone or 75% ethyl alcohol. Collected exuviae were also preserved in 85% acetone. Some specimens were photographed directly at the habitats with a Canon EOS 80D camera and Sigma 150–600 C Lens. Habitat parameters such as water and air temperature, pH, salinity, elevation, and some riparian and aquatic vegetation species were recorded (Tables 1, 4). Adult and exuviae samples were identified by consulting the specialised literature (Schneider, 1982, 1986; Dumont, 1991; Samways, 2008; Suhling et al., 2014; Tarboton & Tarboton, 2019; Dijkstra et al., 2020). For some weather parameters (maximum temperature of warmest month, minimum temperature of coldest month, annual precipitation), the WorldClim data, 1950–2000 with the spatial resolution 2.5 minutes (~21 km^2) were used (Hijmans et al., 2005; Table 4). For more details, microscopic stacked images (Fig. 3), maps of localities (Fig. 5), as well as historical and recent species distribution maps (Figs 6, 7) are also provided. For base maps, the Natural Earth maps (www.naturalearthdata.com) are used. Odonata databases were downloaded from Odonata Database of Africa (Clausnitzer et al. 2012), IUCN spatial data for Odonata (www.iucnredlist.org/resources/spatial-data-download), Atlas of the Odonata of the Mediterranean and North Africa, Boudot et al. 2009, and Atlas of the European dragonflies and damselflies, Boudot & Kalkman, 2015). All specimens are deposited in the Zoology Museum in the Collection of the Biology Department of Shiraz University (ZM-CBSU). The investigated localities are listed in Table 1.

RESULTS

In total, six adult males and eight exuviae of *Z. torridus* (two ♂♂ and seven exuviae from location 2, one exuvia from location 8, two ♂♂ from location 5, one ♂ from location 6, and one ♂ from location 7) were collected, and females in a copulating pair and ovipositing in tandem were observed in locations 2 and 8. Adult males were also observed in all localities 1–10 (Figs 1–5, Tables 1, 3).

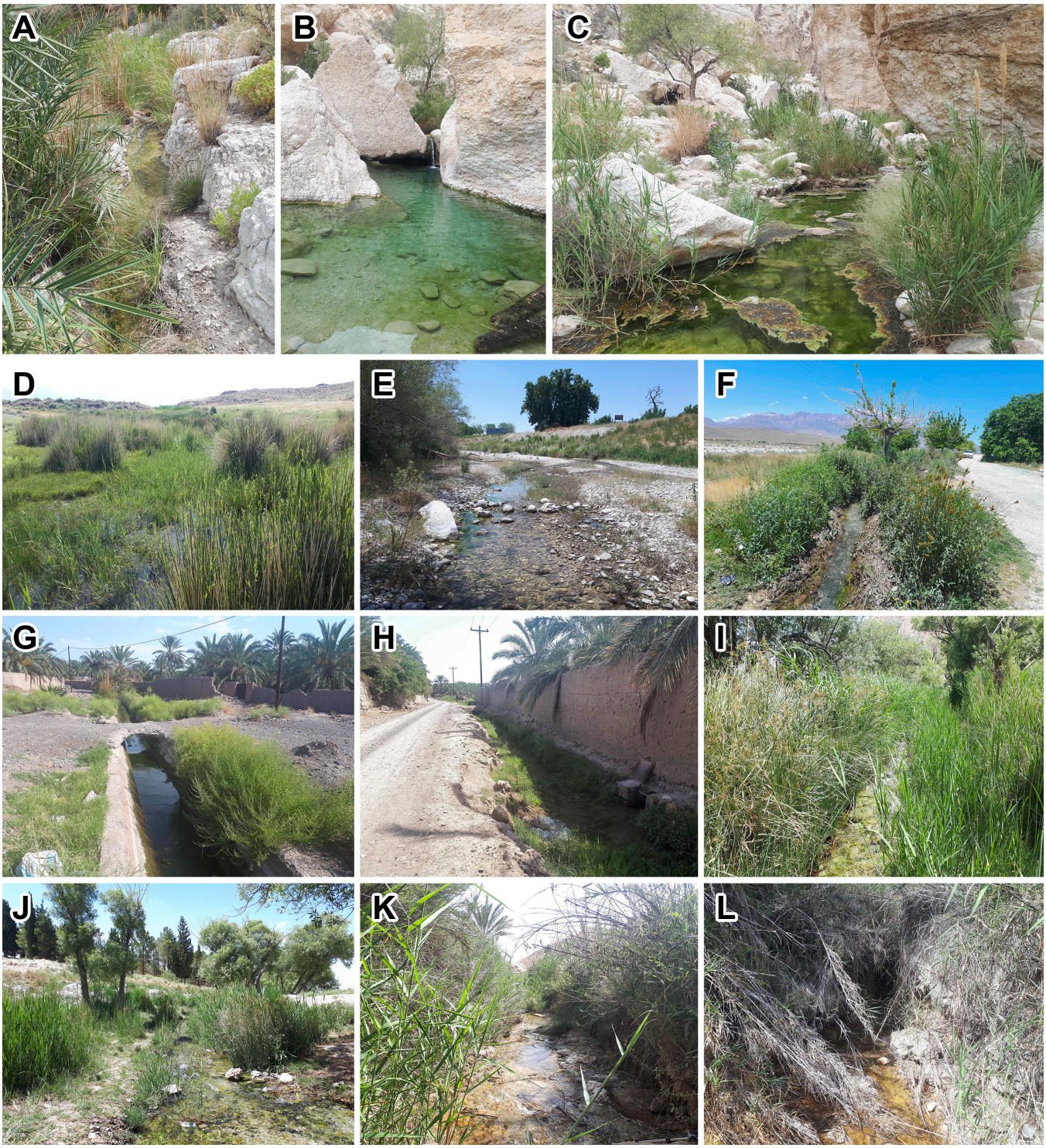

Figure 1. Habitats of *Crocothemis sanguinolenta* and *Zygonyx torridus* in Iran. **A.** Kalat mountainous small brook; **B–C.** Kalat mountainous spring and waterfall, Bushehr province; **D.** Springs and streams near Abad Sivandi village; **E.** Stream near Ahmad Khani Khabr; **F.** Kaht spring and brook; **G–H.** Kariz or Qanat in Imam Ali town, Bam, Kerman province; **I–J.** Sarcheshmeh Springs, Herat, Yazd province; **K–L.** Foumestan-Lamerd small mountain spring.

For *C. sanguinolenta* eight adult specimens and one exuvia, (two ♂♂, two ♀♀ and one exuvia from location 8, one ♂ from location 3, one ♂ from location 5, one ♂ from location 11 and, one ♂ from location 12) were collected, and females in oviposition were observed in locations 2 and 11. Adult males also were observed in locations 2, 3, 5, 8, 11, and 12 (Figs 1–5, Tables 1, 3).

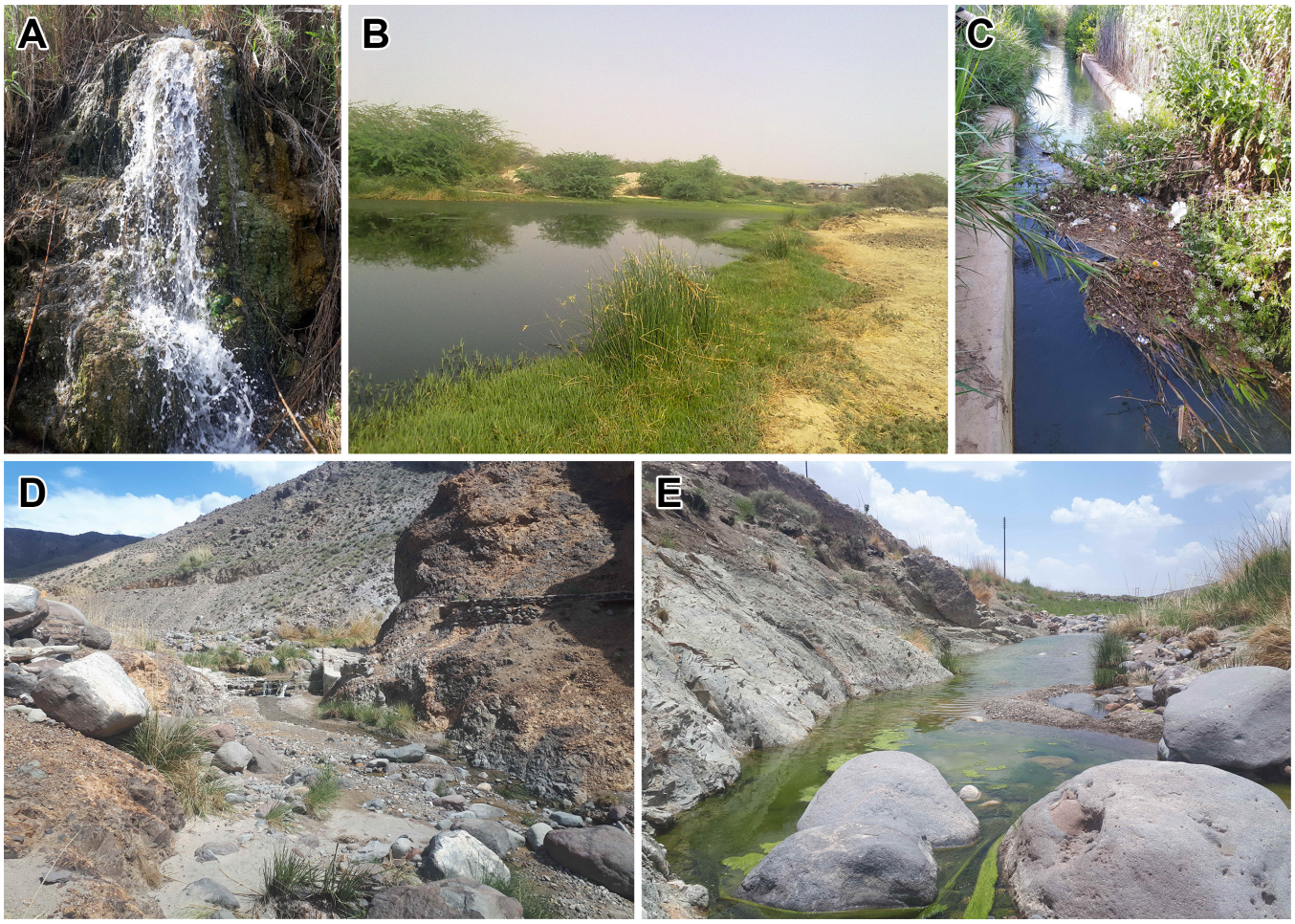

Figure 2. Habitats of *Crocothemis sanguinolenta* and *Zygonyx torridus* in Iran. **A.** Foumestan-Lamerd small mountain waterfall; **B.** Wetland and river, near Bandar Abbas, Hormozgan province; **C.** Spring and garden canals, Seyed Hosein, Kazerun, Fars province; **D.** Tamandan springs; **E.** Kooteh mountainous spring, Taftan, Sistan & Baluchestan province.

Table 1. Localities from throughout Iran for both species: *Crocothemis sanguinolenta* and *Zygonyx torridus*.

Provinces	Ref No.	Loc Name	Coordinates	Survey dates	Figs. Number
Bushehr	1	Kalat mountainous small brook	27°28'20.8"N, 52°44'17.6"E	09 May 2019	1A
	2	Kalat mountainous spring and waterfall	27°28'45.0"N, 52°44'17.3"E	09 May 2019	1B, 1C
Kerman	3	Spring and streams near Abad Sivandi village	28°49'34.9"N, 56°14'20.6"E	01 June 2019	1D
	4	Stream near Ahmad Khani, Khabr	28°49'25.2"N, 56°16'55.4"E	01 June 2019	1E
	5	Kaht spring and brook	28°43'26.0"N, 56°19'46.0"E	01 June 2019	1F
	6	Kariz (Qanat) in Imam Ali town, Bam	29°07'34.8"N, 58°17'08.4"E	29 May 2019	1G, 1H
Yazd	7	Sarcheshmeh Springs, Herat	30°00'56.0"N, 54°20'25.0"E	02 June 2019	1I, 1J
Hormozgan	8	Foumestan-Lamerd small mountain spring	27°15'10.9"N, 53°03'26.4"E	09 May 2019	1K, 1L 2A
	9	Wetland and river, near Bandar Abbas	27°17'22.8"N, 56°20'21.2"E	22 June 2010	2B
Fars	10	Spring and garden canals, Seyed Hosein, Kazerun	29°47'35.3"N, 51°34'14.4"E	27 Apr 2017, 25 Apr 2019	2C
Sistan & Baluchestan	11	Tamandan Springs, Taftan	28°34'36.4"N, 61°01'08.8"E	22 May 2019	2D
	12	Kooteh mountainous spring	28°34'20.6"N, 60°56'39.8"E	23 May 2019	2E

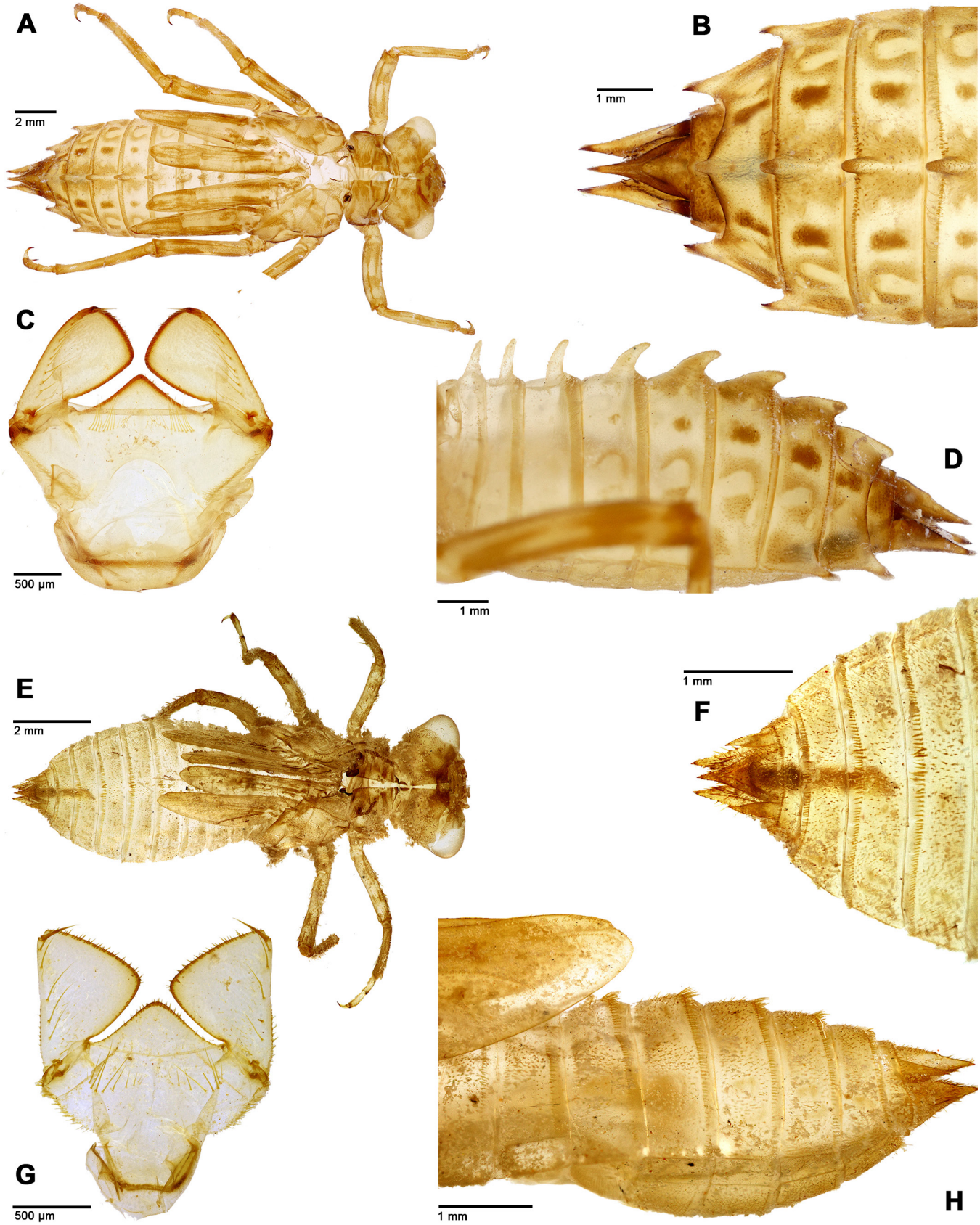

Figure 3. Exuvia of specimens. **A–D.** *Zygonyx torridus* (Kirby, 1889) ♂, **E–H.** *Crocothemis sanguinolenta* (Burmeister, 1839) ♂ from Location 08; **A, E.** Dorsal view; **B, F.** Caudal parts of abdomen s7–s10 and anal pyramid, dorsal view; **C, G.** Prementum and labial palpus, dorsal view; **D, H.** Abdomen, lateral view.

Table 2. Habitats specifications for *Crocothemis sanguinolenta* and *Zygonyx torridus*. **BHD** brief habitats description; **DR/AP sp.** dominant riparian/aquatic plants; **NC/O sp** number of collected/observed specimens.

Locations	BHD	DR/AP sp.	NC/O sp.
1, Fig. 1A	Small brook in the mountain, irrigating gardens & palm-grove, natural and concrete bed.	Riparians: *Phragmites australis*, *Saccharum* sp., *Juncus* sp.	*Z. torridus*, 2♂ patrolling above the brook
2, Figs 1B, 1C	Mountain springs, small cascades, ponds, and pools with max 1m depth in a shallow valley	Riparians: *Phragmites australis*, *Saccharum* sp., *Juncus* sp., *Adiantum* sp., *Nerium* sp., *Salix* sp., *Digitaria* sp	*Z. torridus*, 2 Pairs ♂♀ in tandem & oviposition, 1 Pair ♂♀ in heart position, 6♂ in patrolling, 7 exuviae in rocks and reeds. *C. sanguinolenta*, 1♂
3, Figs 1D, 4C	Springs with peripheral wetlands in a mountainous area near Khabr National Park with a small stream, small swamps, and ponds	Aquatics: *Ceratophyllum* sp., *Batrachium* sp., *Lemna* sp., *Nasturtium* sp. and alga *Chara* sp. Riparians: *Phragmites australis*, *Cyperus* sp., *Juncus* sp., *Cynodon* sp., *Poa* sp., *Digitaria* sp., *Schoenus* sp., *Mentha* sp. and *Typha* sp	*Z. torridus*, 3♂ patrolling above the streams. *C. sanguinolenta*, 3♂ sitting on the rocks or perching on vegetation
4, Fig. 1E	Stream in a shallow valley with gravels, rubble, and sandy bed with wide and shallow water in most parts	Riparians: *Phragmites australis, Mentha* sp., *Saccharum* sp., *Avena* sp., *Bromus* sp., *Juncus* sp., *Carex* sp. and *Cynodon* sp.	*Z. torridus*, 2♂ patrolling above the streams.
5, Fig. 1F	Spring with a small brook in the mountainous Khabr area	Riparians: *Mentha* sp., *Juncus* sp., *Cyperus* sp., *Plantago* sp., *Cynodon* sp., *Bromus* sp. and *Poa* sp.	*Z. torridus*, 4♂ patrolling above the brook. *C. sanguinolenta* 4♂ around brook.
6, Figs 1G, 1H, 4A	Old Kariz (Qnant) using for irrigating gardens and palm-grove, concrete, and natural beds in some parts	Riparians: *Saccharum* sp., *Cynodon* sp., *Salsola* sp., *Alhagi* sp., *Tamarix* sp. and *Mentha* sp.	*Z. torridus*, 3♂ patrolling over canals and gardens
7, Figs 1I, 1J, 4B	Roaring springs with dense vegetation and a heavy canopy of trees in some parts, in a desert area. An important and valuable habitat for desert species.	Riparians: *Phragmites australis, Mentha* sp., *Cyperus* sp., *Carex* sp., *Juncus* sp., *Cynodon* sp. and *Salix* sp	*Z. torridus* 5♂ patrolling in the open area
8, Figs 1K, 1L, 2A	Spring with small waterfalls and streams with dense vegetation in the mountainous area, irrigating downstream palm-grove.	Riparians: *Phragmites australis*, *Epipactis* sp., *Carex* sp., *Juncus* sp. and *Cynodon* sp	*Z. torridus*, 1 Pair ♂♀ in tandem & oviposition, 2♂ patrolling in the open area, 1 exuvia on reeds. *C. sanguinolenta*, 2♀ in oviposition, 3♂ around well-vegetated streams, 1 exuvia
9, Fig. 2B	River with dark and stagnant water with the wetland around it in a hot climate.	Riparians: *Paspalum* sp., *Juncus* sp., *Salsola* sp., *Cynodon* sp., and *Prosopis juliflora*	3♂ patrolling above the river
10, Fig. 2C	Large springs and irrigation channels with concrete and natural beds along with dense vegetation beside the channels	Aquatics: *Nasturtium* sp., *Potamogeton* sp., and *Ceratophyllum* sp. Riparians: *Phragmites australis, Mentha* sp., *Silybum* sp., *Avena* sp., *Juncus* sp.	*Z. torridus*, 3♂ patrolling above concrete channels.
11, Fig. 2D	Mountain spring with stream in foothills of Taftan volcano mountain with sandy and rubble bed, large rocks on the sides along the river. Small pools formed in some parts of the stream.	Aquatics: *Nasturtium* sp. Riparians: *Saccharum* sp., *Carex* sp., *Juncus* sp. *Glycyrrhiza* sp., *Mentha* sp. and *Hordeum* sp.,	*C. sanguinolenta*, 1♀ in oviposition, 3♂ cliffs along the creek.
12, Fig. 2E	Located near Location 11 in the foothills of Taftan Volcano Mountain at a lower altitude in a valley. Most parameters were the same	Identical to the location 11	*C. sanguinolenta*, 2♂ on large, sunny cliffs of the waterside.

According to our data, it is clear that the distribution area for these two Arabian-Afrotropical species is not limited to only the Hormuz Strait area. For *Z. torridus*, our recorded data from Kariz (Qanat) close to Bam (location 6) in Kerman province (Figs 1G, 1H, 4A) is the most easterly Palearctic-Oriental location for the species in Iran. The distance between this location and the Pakistan area is only about 300 km.

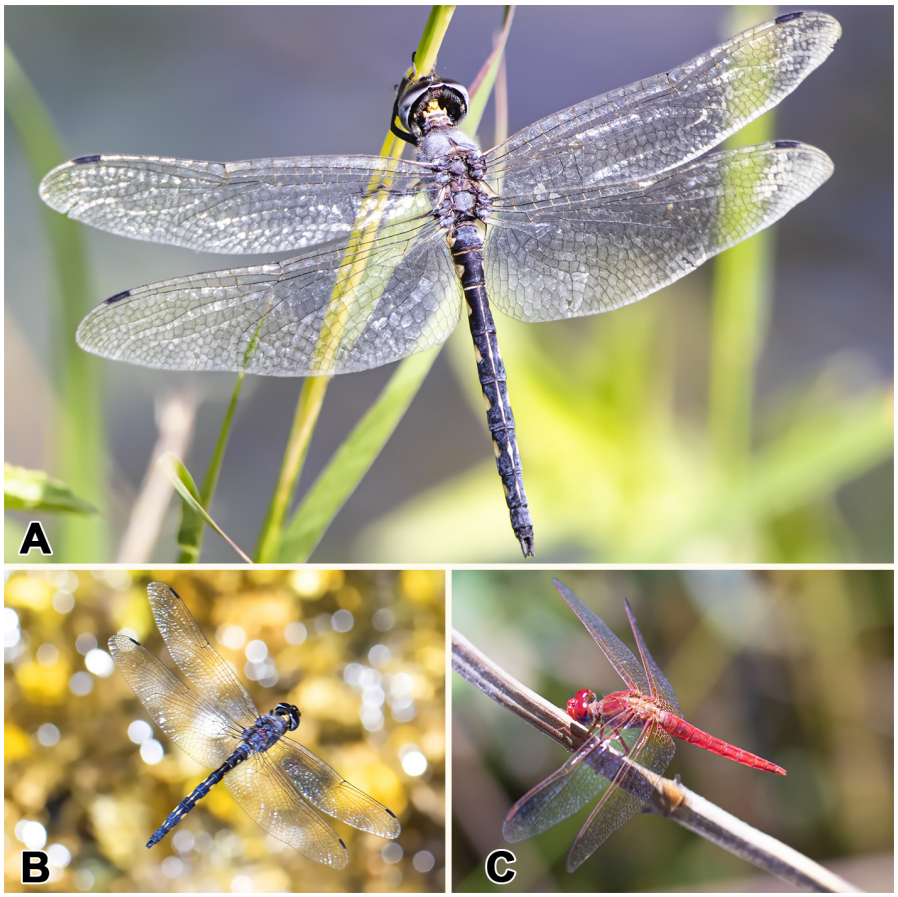

Figure 4. General habitus. **A.** *Zygonyx torridus* (Kirby, 1889) ♂, Location 06: Kerman province; **B.** Same species ♂, Location 07: Yazd province; **C.** *Crocothemis sanguinolenta* (Burmeister, 1839) ♂, Location 03: Kerman province.

Table 3. List of common species in each locality, indicated by an asterisk. Grey columns (2, 8) are breeding sites for both species (*Zygonyx torridus* and *Crocothemis sanguinolenta*)

Species	Localities											
	1	2	3	4	5	6	7	8	9	10	11	12
***Zygonyx torridus* (Kirby, 1889)**	*	*	*	*	*	*	*	*	*	*		
***Crocothemis sanguinolenta* (Burmeister, 1839)**		*	*		*			*			*	*
***Platycnemis dealbata* Selys, 1850**			*	*			*			*		*
***Ischnura evansi* Morton, 1919**		*					*		*	*		*
***Anax imperator* Leach, 1815**	*	*	*				*	*		*		
***Onychogomphus lefebvrii* (Rambur, 1842)**			*	*	*		*			*		
***Paragomphus lineatus* (Selys, 1850)**	*					*	*			*		
***Crocothemis erythraea* (Brullé, 1832)**	*		*	*	*	*	*			*		
***Orthetrum brunneum* (Fonscolombe, 1837)**			*	*						*	*	
***Orthetrum chrysostigma* (Burmeister, 1839)**	*	*		*		*		*		*	*	*
***Orthetrum coerulescens anceps* (Schneider, 1845)**			*		*		*			*		*
***Orthetrum taeniolatum* (Schneider, 1845)**	*					*				*	*	*
***Trithemis annulata* (Palisot de Beauvois, 1807)**	*	*		*		*	*	*	*	*		
***Trithemis arteriosa* (Burmeister, 1839)**		*					*	*				
***Trithemis festiva* (Rambur, 1842)**	*	*	*	*	*	*	*	*		*	*	*
Trithemis kirbyi				*			*			*	*	*

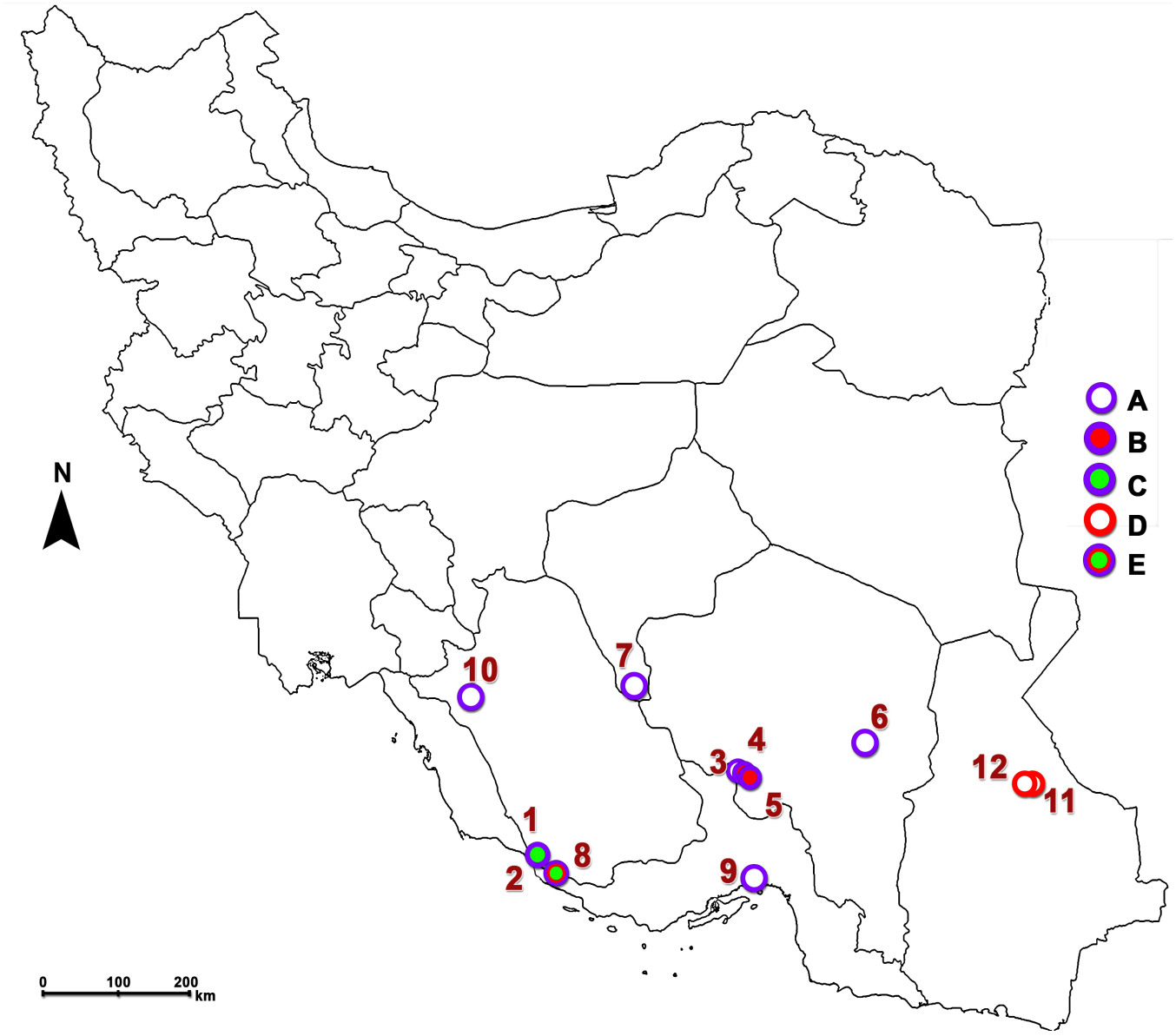

Figure 5. Map of localities in Iran. **A.** Habitats with only male records of *Zygonyx torridus* (Kirby, 1889); **B.** habitats with both species; **C.** Breeding sites with exuviae evidence for *Z. torridus*; **D.** Habitats of only *Crocothemis sanguinolenta* (Burmeister, 1839); **E.** Breeding habitat for both species with exuviae evidence, base map created with DIVA-GIS.

The breeding sites of *C. sanguinolenta* and the distance between these localities show that the range of distribution extends near the Pakistan border in the East of Iran (locations 11, 12), (Figs 2D, 2E). The middle area of the Persian Gulf in the West (Locations 8, 2) (Figs 1B, 1C, 1K, 1L, 2A) shows similar habitats, which resemble the habitats of *Z. torridus*.

In locations 2 and 8 in southern parts of Iran, the observed and collected exuviae (Figs 3, 5) and oviposition activities indicate successful breeding at these sites. In addition, some species such as *Trithemis arteriosa, T. festiva, T. annulata, Orthetrum chrysostigma,* and *Anax imperator* were also common at both sites (Fig. 7C–H, Table 3).

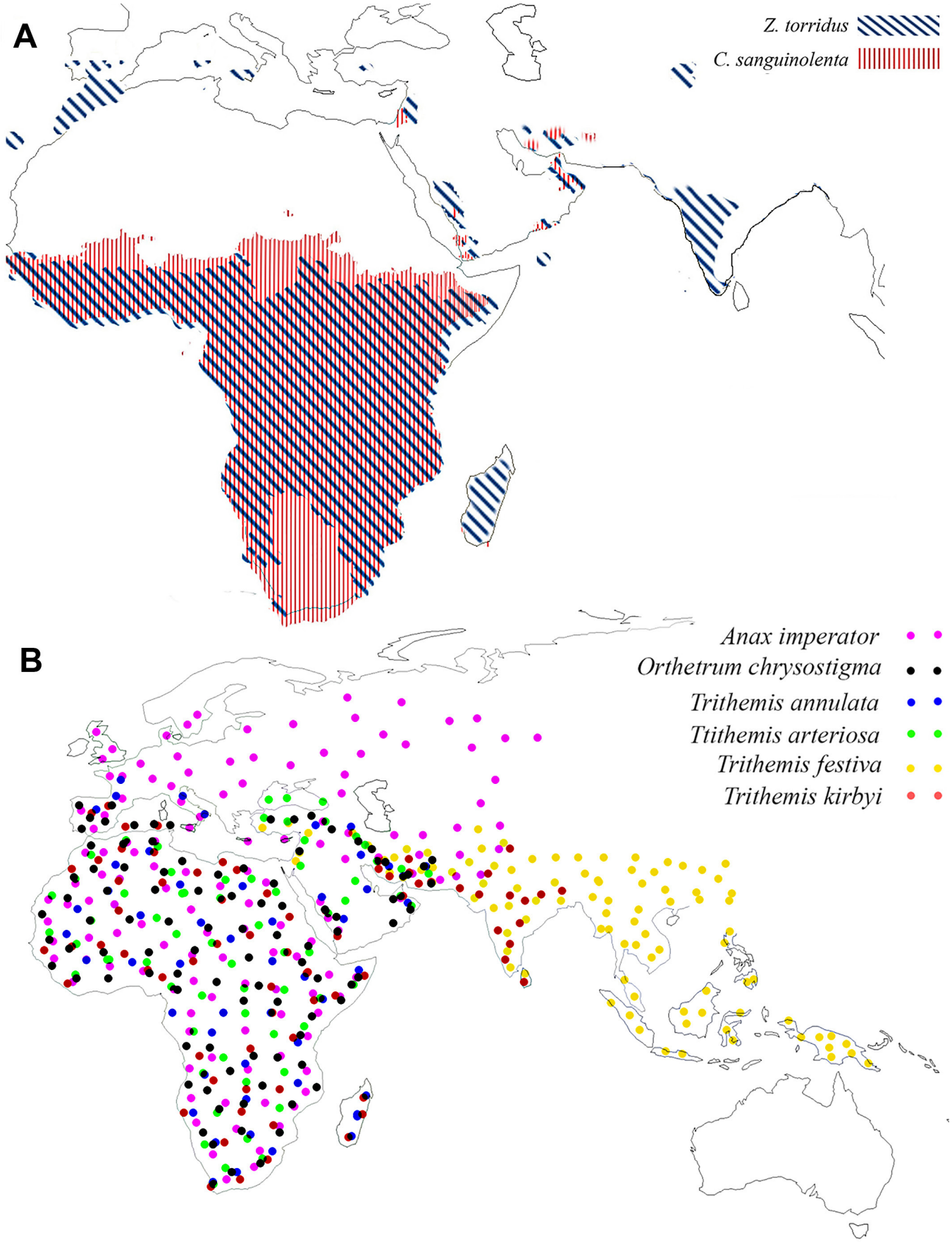

Figure 6. Distribution pattern of *Zygonyx torridus* (Kirby, 1889) and *Crocothemis sanguinolenta* (Burmeister, 1839). **A.** In the world; **B.** Coexisting species in breeding habitats.

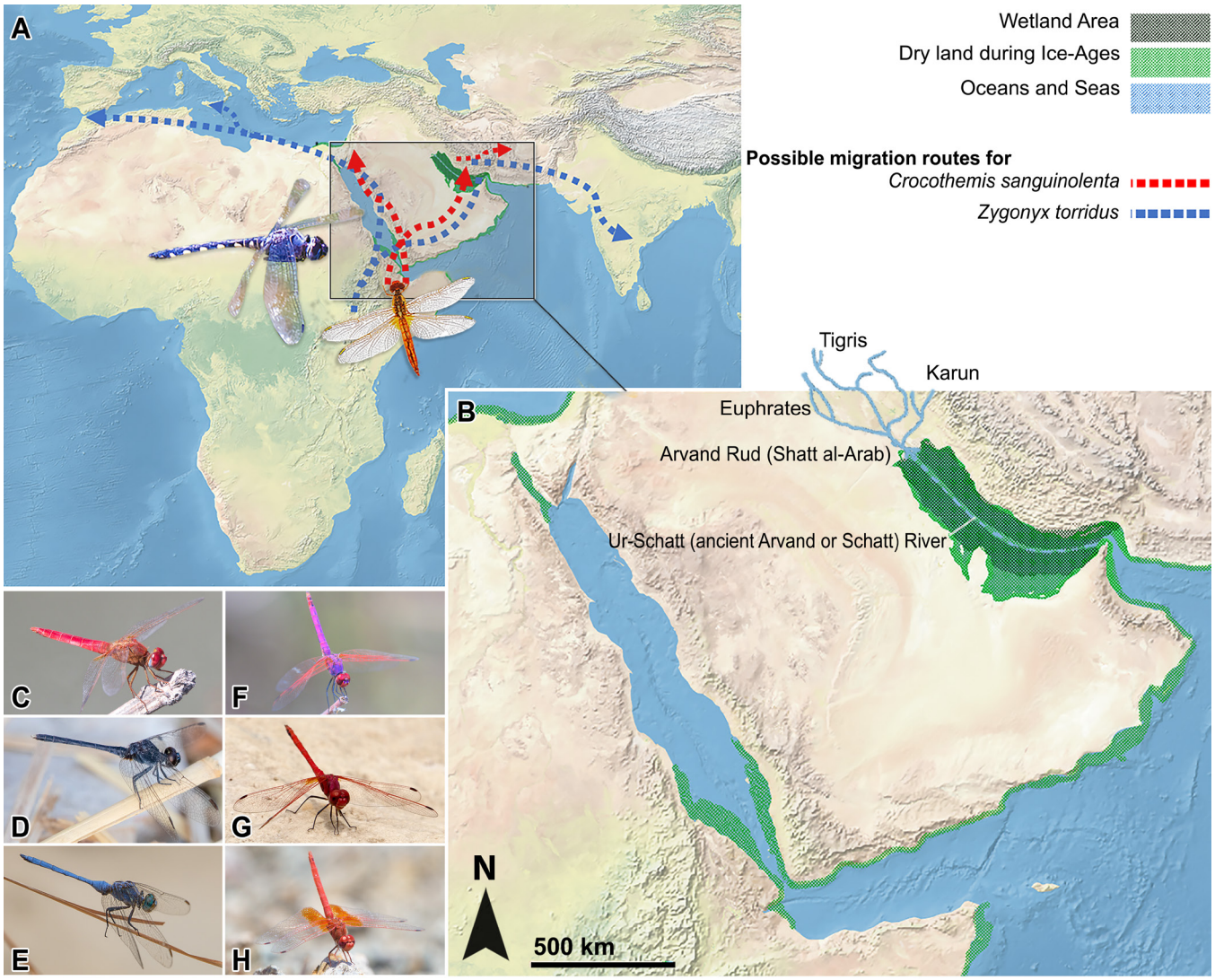

Figure 7. Possible historical paths of *Zygonyx torridus* (Kirby, 1889) and *Crocothemis sanguinolenta* (Burmeister, 1839) and their coexisting species **A.** Possible historical migration routes during the last glacial maximum in the Pleistocene; **B.** The enlarged part of the map shows the dry parts (green colour), land bridges, and the Persian Gulf with wetland areas during this time; **C–H.** The species that might have used the same routes for migration/distribution between Africa-Arabia-Iran or Oriental areas in the past, most of these species coexist in reproductive habitats. **C.** *Crocothemis erythraea*; **D.** *Diplacodes lefebvrii*; **E.** *Orthetrum chrysostigma*; **F.** *Trithemis annulata*; **G.** *Trithemis arteriosa*; **H.** *Trithemis kirbyi*. [Base map downloaded from: http://www.naturalearthdata.com/downloads/50m-physical-vectors]

DISCUSSION

According to our data, the most suitable habitats for breeding in both species are similar. Both habitats contain mountain springs with cool water and air temperatures (against the warm coastal lowlands), low alkaline brackish water, and medium to high vegetation diversity and density levels. For *Z.torridus,* some specific parameters existed, such as small cascades/waterfalls along the streams and an open area for patrolling. However, no fast-flowing water is found in streams (Tables 1, 4). As to the coexisting odonates, *Orthetrum chrysostigma* is widespread from Africa to Oriental regions with successful adaptation to various habitats. From the *Trithemis* genus, Oriental-Arabian-African species were found in these areas, including *T. annulata* and *T. arteriosa*, but limited to the eastern parts of Iran, and *T. festiva* was found in opposite directions, from the Oriental to the Mediterranean coast without

entering the Arabian-African parts. *Anax imperator* is abundant from Africa to Eurasia and also in India (Kalkman, 2006; Boudot & Kalkman, 2015; Dijkstra et al., 2020).

Occasional immigration is commonly proposed to justify the records of some rare or infrequently observed species. For example, in the most recent dragonfly studies in Iran, this is often the explanation for what happened during the species distribution history. The arguments refer to climatic conditions such as global warming, recent precipitations or floods, or unsuitable habitat conditions for the reproduction of species otherwise thought to be absent. However, these arguments may be incorrect if the species are searched for in limited areas or time spans (Ebrahimi et al., 2009, 2014; Schneider & Dumont, 2015; Schneider et al., 2018a; Schneider et al., 2018b; Ikemeyer & Schneider, 2020). As an example, the distribution of *Z. torridus* in the last checklist of Iran includes historical records in the northeastern region of Bandar-Abbas, and reports from Kerman province, without any new records (Heidari & Dumont, 2002; Ebrahimi et al., 2009, 2014; Schneider & Dumont, 2015; Schneider et al., 2018a). In other research from the southeastern region of Iran, the record of *C. sanguinolenta* was explained as a consequence of the influx of this species from the Hormuz Strait and confirmed that a kind of migration has occurred from the Arabian Peninsula to Iran (Schneider et al., 2018b). In fact, the observation of males only of *Z. torridus* and the cold winter of the mountainous habitat of *C. sanguinolenta* may suggest that these species are migrants and not reproductive in the region (Schneider et al., 2018b).

On the other hand, we face important geological and historical events that have played an important role in the distribution pattern formation of different species between Africa-Arabia and Oriental regions, through the southern part of Iran as a passage corridor or bridge. Historical events show the existence of an extensive wetland or a narrow waterway across the entire Persian Gulf to the Strait of Hormuz in 14000–15000 years BP when the Persian Gulf was not flooded by seawater. Instead of salty seawater, there were some freshwater rivers such as Tigris, Karun, Arvand Roud (Shatt al-Arab) and wetlands according to the climatic conditions of that period (Lambeck, 1996; Kennett & Kennett, 2006; Jagher et al., 2008; Fig. 7). In this case, exchanging and passage of species from the Arab-African region to Iran and further to Oriental regions is conceivable.

Table 4. Habitat parameters of localities from throughout Iran for both species: *Crocothemis sanguinolenta* and *Zygonyx torridus*. Type of habitats: mountainous brook **MB**, mountainous Spring **MS**, Kariz or Qanat **K**, river wetland **RW**, spring **S,** recorded time: middle spring **MS**, late spring **LS**, Early spring **ES**. vegetation: Medium-density **MD**, high-density **HD**, low-density **LD**. Maximum temperature of the warmest month **Max TWM**, minimum temperature of the coldest month **Min TCM**, annual precipitation mm **AP**. (3 parameters obtained from WorldClim Data, 1950–2000)

Parameters	Localities											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Type of Habitats	MB	MS	MS	MS	MS	K	MS	MS	RW	S	MS	MS
Altitude (m)	118	163	1801	1908	1960	1133	1629	384	32	807	2162	1990
Recorded Time	MS	MS	LS	LS	LS	LS	LS	MS	ES	MS	LS	LS
Air temperature °C	39	37	32	33	34	37	35	37	-	37	30	33
Water temperature °C	26	25	20	21	20	23	20	25	-	24	21	23
pH	8.4	8.3	7.8	7.9	8.1	7.8	7.7	8.6	-	7.9	8.2	8.0
Salinity (ppm)	828	810	430	550	390	510	350	1280		450	716	770
Vegetation	MD	MD	HD	MD	MD	LD	HD	HD	MD	HD	MD	MD
Max TWM	37.6	37.6	34.3	34	33.7	38.5	37.6	36	38.4	41.1	34.4	33.2
Min TCM	9.6	9.6	-1	-1.5	-1.6	2.7	-1	6.8	13	3.5	-2	-3.1
AP	159	159	184	188	193	79	157	186	134	260	135	145

A few species that now occur in scattered areas may be the relicts of the past, when the saltwater barrier did not yet exist. However, it seems, in this case, that most coexisting species in the same breeding habitats had/have the same historical/recent routes and dispersal patterns. For example, *Diplacodes lefebvrii* is another species with comparable features. Although this species has not been recorded during our research, it has a similar distribution range as other Afrotropical-Arabian-Oriental species that prefer warmer lowland or coastal habitats (Figs 6, 7). We might consider that populations of some species became relict after the Persian Gulf flooding in the Southern regions of Iran and adapted to new conditions and distributed over large areas or have survived only in limited areas and suitable habitats as relicts (Fig. 7). These species, *T. arteriosa*, *T. festiva*, *T. annulata*, *O. chrysostigma*, and *A. imperator,* were found in the reproductive habitats (Locations 2, 8) with both *Z. torridus* and *C. sanguinolenta* as coexisting species that need similar habitats for breeding (Tables 2, 3, 4).

With a powerful flight, species such as *Z. torridus* will have no problem crossing barriers and flying long distances, (Kunz et al., 2006). However, all specimens seen in previous records were males, which may refer to the second idea that in some species, most migrant members are males (Dumont, 1967). Sex-biased dispersal is observed across various species of Odonates. The ability and potential for females to disperse over long distances have been noted in several references, especially in damselflies (Beirinckx et al., 2006; McCauley et al., 2022). However, in certain instances, the dispersal has been discussed as being male-biased, particularly for species inhabiting desert conditions (Damm & Hadrys, 2012). This may also hold true for *Z. torridus*. These males migrate from their breeding sites to other habitats for various reasons, such as reducing their interaction with other males (Corbet, 2004).

Crocothemis sanguinolenta exclusively prefers undisturbed perennial habitats (Suhling et al., 2005) and is not known as a migrant. It is possible that this species was more widely distributed in the past and is now limited to appropriate and separated habitats. Thus, these patterns do not refer to recent migrations. However, because we did not find exuviae in Taftan (locations 11, 12), the easternmost occurrences are not considered to be reproductive so far. A future study should be conducted to confirm the existence of reproductive and vital populations there.

AUTHOR'S CONTRIBUTION

The authors confirm their contribution to the paper as follows: M. Kiany: Material preparation, data collection, analysis, photographing and drafting the manuscript; S. Sadeghi & M. Ebrahimi: Editing and revision of the manuscript. The authors read and approved the final version of the manuscript.

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AVAILABILITY OF DATA AND MATERIAL

The specimens listed in this study are deposited in the Zoology Museum in the Collection of Biology Department of Shiraz University (ZM-CBSU) and are available from the curator, upon request.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this paper.

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اولین شواهد زادآوری *Crocothemis sanguinolenta* و *Zygonyx torridus* (Odonata: Libellulidae) در ایران

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چکیده: برای اولین بار پوسته لاروی گونه‌های *Crocothemis sanguinolenta* و *Zygonyx torridus* از مناطق جنوبی ایران جمع آوری شدند. جنس ماده *Z. torridus* نیز در دو زیستگاه در حال جفت‌گیری و تخم‌گذاری مشاهده شد. بر اساس مشاهدات ما، این دو گونه با موفقیت در زیستگاه‌های کوچک داری شرایط مناسب تولید مثل می‌کنند و به صورت مهاجر و غیر بومی نیستند. یافته‌های ما بر اساس این پژوهش حاضر نشان داد که پراکنش و زیستگاه‌های این دو گونه، آن‌طور که در گذشته تصور می‌شد، تنها محدود به نواحی اطراف تنگه هرمز نیست. زیستگاه‌های مناسب برای *Z. torridus* از جنوب غرب تا شرق کشور گسترش یافته است. محدوده زیستگاهی *C. sanguinolenta* از جنوب غرب تا انتهای جنوب شرقی کشور در نزدیکی منطقه مرزی پاکستان را پوشش می‌دهد. با توجه به تاریخچه زمین‌شناسی منطقه خلیج فارس در آخرین دوره یخبندان و گونه‌های مشابه آفریقایی-عربی که به صورت هم‌زیستگاه هستند، پیشنهاد می‌کنیم که این گونه‌ها جمعیت‌هایی بازمانده هستند که از پراکنش گسترده در گذشته برخوردار بوده و امروزه تنها به زیستگاه‌های ویژه‌ای محدود شده‌اند. به نظر می‌رسد این دیدگاه برای توجیه پراکنش فعلی این گونه‌ها مناسب‌تر از مهاجرت‌های اخیر آنها از مناطق امارات یا عمان است..

واژگان کلیدی: بومزاد، انتشار، سنجاقک، بازمانده، ناهمسان‌بالان، پوسته‌لاروی