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Biogeography and ecology of sand-dwelling noctuids (Noctuidae: Lepidoptera) in Israel.

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ABSTRACT

All together 44 species of Noctuidae are specific to 5 sandy areas in Israel: Arava Valley, Rotem-Yamin Plain, Uvda Valley, Western Negev and Coastal Sand Dunes. The areas are different in temperature and moisture regimes and belong to different biogeographical districts in Israel (Mediterranean, Irano-Turanian and Saharo-Sindian). More than half of the species (26/44) are found only in one of these sandy areas. The highest number of these species is recorded from the sands of the Arava Valley (18 species) including all 8 Israeli species of *Anumeta*, no unique species were found in the Uvda Valley. Most of the sand-dwelling species are univoltine. On inland sands (Arava, Rotem, Uvda) they fly in November or February until April. On the Coastal Dunes and on adjacent sands of Western Negev the species fly in January because of warm nights (mean minimal temperature per month is 10.1ºC) compared to inland areas (mean minimal temperature of 4ºC). According to their general distribution pattern, most of the species inhabiting inland sands belong to eremic groups. Species inhabiting Coastal Sand Dunes and sands of the Western Negev are all circum-Mediterranean. The reasons for the association of these noctuids with sandy soils are discussed.

KEYWORDS: sand-dwelling, desert, sands, dunes, psammophilous, Noctuidae, Lepidoptera, Israel, biogeography.

INTRODUCTION

Sand covers about 20% of Earth's deserts (online at: http://earthsky.org/earth/how-did-the-sand-in-the-desert-get-there). Sandy areas are home for many species of

plants, animals, including many insects. For example, many plant species were described as specific to sandy areas in Greece (Sykora *et al*., 2003), in United Kingdom (UK) (Rodwell, 2000), and in Finland (Hellemaa, 1998). Many insects of different orders also occur only on sandy soils. In Norway 181 species of Coleoptera, 119 species of Hymenoptera, and 65 Lepidoptera species have been found to be specific to sand dunes (Ødegaard *et al*., 2010). Lepidoptera that are specific to sandy soils often comprise an essential part of the total number of species collected. On Coastal Sand Dunes in Cornwall (UK), for example, among 331 species of macro-Lepidoptera, 32 (9.7%) were specific to sand (Spalding, 1995). In the Vakhsh valley (Tajikistan) 28.9% of Lepidoptera species occurred only on sand (Shetkin, 1960; 1965), in the desert of western Uzbekistan this value is even higher 32% (Falkovich, 1968; 1979).

Biotopes characterized by sandy soils, especially Coastal Sand Dunes, are under strong pressure from development and recreation (Doody, 1991; Kutiel, 2001; Mun *et al*., 2011). Therefore, sand-dwelling (psammophilous) species are often at risk of extinction and included in the regional "red lists" (threatened species) of nature protection organizations. In Norway nearly 16% of all the threatened and near threatened species on the Red List are inhabitants of sandy areas (Ødegaard *et al*., 2010).

Israel is situated at a crossroads of four biogeographical regions: Mediterranean, Irano-Turanian, Saharo-Sindian and in Sudanian penetration (Fig. 1) (Zohary, 1966; Furth, 1975). Sandy areas in Israel are common and present in all the biogeographical regions. Species assemblages and the ecology of psammophilous plants in Israel were repeatedly discussed by botanists (Orshan and Zohary, 1963; Danin, 1978; Danin & Nokrian, 1991; Danin, 1996); however, there are no publications devoted to any group of sand inhabiting insects in the region. In this paper we consider species composition, distribution and the seasonal dynamic of flight of sand-dwelling noctuids in Israel.

Noctuidae is the most species-rich family of Lepidoptera, with 549 species documented in Israel (Kravchenko *et al*., 2007a; 2007b). In recent years the classification of Noctuidae has been the subject of permanent classification changes. For this study we follow the recent classification of Fibiger and Lafontaine, 2005; Fibiger and Hacker, 2005; Lafontaine and Schmidt 2010; Zahiri *et al*., 2012).

MATERIALS AND METHODS

Classification of biogeographical categories applied in this survey follows that for the Lepidoptera of Levant (Kravchenko *et al*., 2007a; 2007b) and Saudi Arabia (Wiltshire, 1994). The biogeographic term "Eremic" applied to species inhabiting the southern Palearctic desert belt from the African Atlantic coastal desert, through the Sahara to deserts of central Asia and northern India. Species are classified into four sub-groups, e.g. West-Eremic, East-Eremic, Central-Eremic and Pan-Eremic. We consider the circum-Mediterranean distribution a special group. Information about the hostplants, distribution of species within Israel and their phenology are taken from the literature mentioned above and from our records for desert noctuids (Kravchenko *et al*., 2006).

Method of collecting. Since 1986, in the context of an Israeli-German project for the study of the Israeli Lepidopteran fauna, a network of permanent automatic light traps (220V 20W black light UVB & UVC tubes) was maintained. Traps were relocated on an annual basis. Results were published in two monographs (Kravchenko *et al*., 2007a; 2007b).

Terminology. Some species occur exclusively on sand, while others prefer sandy soils. The terms psammophilous and ammophilous are used for sand-adapted and sand-associated terrestrial arthropods, respectively (Acorn, 2011). We apply the term psammophilous to species collected exclusively on sand and ammophilous for species in which more than 75% of the specimens were collected on sand. The term Levant is an imprecise term that denotes the area roughly bounded on the north by the Taurus Mountains, on the south by the Arabian Desert, and on the west by the Mediterranean Sea, while on the east it extends into Upper Mesopotamia (online at: http://www.glaphyridae.com/Biogeografia/NEL.html).

Description of sandy areas. We collected Noctuidae in five relatively isolated sandy areas that vary in temperature/moisture regimes (Tab. 1) (Jaffe, S., 1988; Stern *et al*., 1986; Danin, 1988) and belong to different biogeographical regions (Fig 1). The Arava Valley is a penetration of Ethiopian (Sudanian) elements into the Levant (Shmida and Aronson, 1986). This represents an extreme desert with average annual precipitation of less than 25 mm and an average daily maximum temperature in August (the hottest month) of 38ºC. The Northern Negev includes the Rotem-Yamin Sands and is in the Irano-Turanian region with a mean maximum temperature in August of 32ºC. The Southern Negev and Uvda Valley is a Saharo-Arabian region with an average daily maximum of temperature in August ranging from 34º-36ºC. Sands of Western Negev in the Saharo-Arabian region has an average maximum temperature in August of 34ºC. Coastal Sand Dunes in Israel extend along the shore of the Mediterranean Sea for about 190 km. This Mediterranean region has an average daily maximum temperature in August ranging from 28º-30ºC.

Tab. 1
Meteorological characteristics of the sandy areas.

Sandy areas	Annual precipitation in mm	Mean temperature in coldest month (January) in ºC	
		Lowest	Highest
Arava	< 25	4	25
Rotem-Yamin	100-200	7	17.5
Uvda Valley	~40	4.2	22.1
Western Negev	200-300	7.3	23.6
Coastal Sand Dunes	400-700	10.1	22.4

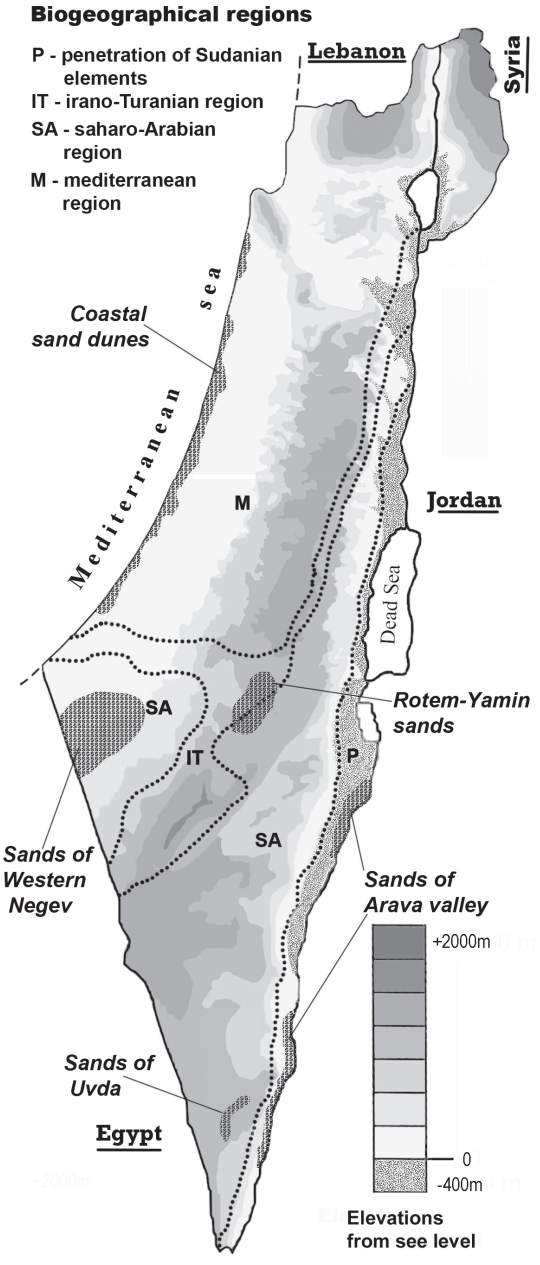

Fig 1. Israel biogeographical regions and sandy areas

RESULTS

Faunistic survey of sand-dwelling Noctuidae.

Family Erebidae
Subfamily Erebinae
Tribe Toxocampini

1. ***Anumeta spilota*** Ershov

Distribution: Pan-Eremic. From the Western Sahara to the Levant, Central Asia, Pakistan, and India. In Israel: Arava Valley.
Period of flight: multivoltine, flying from March to September with the greatest abundance from March to May; larvae observed in May.
Host-plants: in Israel, *Calligonum comosum* L. (Polygonaceae); in Turkmenistan, *Calligonum* spp.

2. ***Anumeta henkei*** (Staudinger)

Distribution: East-Eremic. European part of southern Russia, Central Asia, Levant, Iran, Iraq, and Afghanistan. In Israel: Arava Valley.
Period of flight: multivoltine, flying from March to October with the greatest abundance from March to May.
Host-plants: in Israel and elsewhere unknown. Congeners on *Calligonum* spp.

3. ***Anumeta atrosignata*** (Walker)

Distribution: East-EremicEast-Eremic. India, Iran, Iraq, Arabian Peninsula, and Levant. In Israel: Arava Valley.
Period of flight: multivoltine, March to July with the greatest abundance from March to May.
Host-plants: in Israel, *Calligonum comosum*; elsewhere unknown.

4. ***Anumeta straminea*** (A. Bang-Haas)

Distribution: West-Eremic. Throughout the Sahara and the Arabian desert to Bahrain, northern Oman, and the Levant. In Israel: Arava Valley.
Period of flight: univoltine, winter species, flying from December to March with the greatest abundance in January.
Host-plants: in Israel unknown; in Saudi Arabia on *Calligonum* spp.

5. ***Anumeta arabiae*** Wiltshire

Distribution: Endemic to Saudi Arabia and the Arava. In Israel: Arava Valley.
Period of flight: bivoltine, spring species, flying from January to April with the greatest abundance from January to February and in April.
Host-plants: unknown. Congeners on *Calligonum* spp.

6. ***Anumeta asiatica*** Wiltshire

Distribution: East-Eremic. Southwestern Iran, Iraq, Levant, Kuwait, Saudi Arabia, Oman, and United Arab Emirates. In Israel: Arava Valley.
Habitat: deserticolous, psammophilous.
Period of flight: multivoltine, summer species, flying from May to August with the greatest abundance in May.
Host-plants: in Israel, *Calligonum comosum*; elsewhere unknown.

7**.** ***Anumeta hilgerti*** Rothschild

Distribution: West-Eremic. From the deserts of North Africa, including the central Sahara, to the Arabian Peninsula, and the Levant. In Israel: Arava Valley.
Period of flight: univoltine, spring species, February to May with the greatest abundance in March.
Host-plants: unknown. Congeners on *Calligonum* spp.

8. ***Anumeta cestis*** (Ménétriès)

Distribution: Pan-Eremic. From the Sahara to the Levant, Central Asia, Kazakhstan, S.Urals. In Israel: Arava Valley.
Period of flight: univoltine, spring species, February to May with the greatest abundance in March.
Host-plants: unknown. Congeners on *Calligonum* spp.

Tribe Melipotini

9. ***Drasteria oranensis*** Rothschild

Distribution: West-Eremic. From Algeria to Libya, Egypt, Levant, and Saudi Arabia. In Israel: on sands of Rotem-Yamin.
Period of flight: so far collected only in March and in April; in Tunisia June to September.
Host-plants: in Israel *Helianthemum* sp.(Cistaceae); in North Africa and Saudi Arabia, *Calligonum comosum*.

10. ***Drasteria kabylaria*** (A. Bang-Haas)

Distribution: West-Eremic. From the western and central Sahara to the Arabian Peninsula, Iran, and the Levant. In Israel: on all sandy areas except Coastal Sand Dunes.
Period of flight: bivoltine, March to May and October.
Host-plants: in Israel *Helianthemum lippii* (L.)

Tribe Ophiusini

11. ***Cerocala sana*** Staudinger

Distribution: West-Eremic. Turkey, Iraq, Iran, Levant, Egypt, Libya, and Algeria. In Israel: all sandy areas.
Period of flight: probably bivoltine, flying from October through winter to April with the greatest abundance in November and March.
Host-plants: in Israel unknown, in Saudi Arabia monophagous on *Helianthemum kahiricum* Delile and *H. lippii* (L.) (Cistaceae).

Tribe Anydrophilini

12. ***Anydrophila stuebeli*** (Calberla)

Distribution: West-Eremic. Central Arabia, United Arab Emirates, and Levant. In Israel: Arava Valley.
Period of flight: univoltine, spring species, March to May.
Host-plants: in Israel, *Rumex* and *Calligonum* spp. (both Polygonaceae), elsewhere unknown.

Subfamily Acontiinae
Tribe Acontiini

13. ***Acontia biskrensis*** (Oberthür)

Distribution: West- and Central-Eremic. From the Canary Islands through North Africa and the Sahara to the Arabian Peninsula, Levant, Iraq, and Iran. In Israel: Arava Valley and Dead Sea Area.
Period of flight: in Israel univoltine, spring species, March to April.
Host-plants: unknown.

Tribe Armadini

14. ***Armada nilotica*** A. Bang-Haas

Distribution: probably endemic to southeast Mediterranean coast. Described from the coastal dunes of El-Arish oasis in Egypt. In Israel: sands of western Negev.
Period of flight: univoltine, collected so far only from March to May; in Egypt (Sinai) from May to June.
Host-plants: in Israel unknown; in Sinai, *Heliotropium luteum* Poir and *H. arbainense* Fresen..

15. ***Tarachephia hueberi*** (Ershov)

Distribution: East-Eremic. Iraq, Iran, Levant, Trans-Caspian region, Uzbekistan, Turkmenistan, and Afghanistan. In Israel: Arava Valley and Dead Sea Area.

Period of flight: univoltine, spring species observed so far only in March; in Central Asia flying from March to May.
Host-plants: in Israel unknown; in Central Asia, larvae found in May on leaves of *Arnebia decumbens* (Boraginaceae).

Subfamily Metoponiinae

16. ***Epharmottomena eremophila*** (Rebel,)

Distribution: West-Eremic. From Morocco and the western Sahara to the Levant. In Israel: Western Negev.
Period of flight: probably bivoltine, September through winter to April with the greatest abundance in October and March.
Host-plants: unknown.

17. ***Iranada turcorum*** (Zerny)

Distribution: West-Eremic. Egypt, Levant, southwestern Iran, Iraq, and Oman. In Israel: Coastal Sand Dunes and western Negev.
Period of flight: in Israel univoltine, spring species, January to March.
Host-plants: unknown.

Subfamily Cuculliinae

18. ***Cucullia macara*** Rebel

Distribution: West-Eremic. Egypt, Arabian Peninsula and Levant. In Israel: all sandy areas except Coastal Sand Dunes.
Period of flight: in Israel univoltine, winter species, December to February.
Host-plants: unknown. Congeners on *Scrophularia* spp. (Scrophulariaceae).

19. ***Cucullia strigicosta*** Boursin

Distribution: Iranian. Iraq, Turkey, Azerbaijan, Iran and Levant. In Israel: Western Negev.
Period of flight: in Israel univoltine, winter species, January to March.
Host-plants: in Israel unknown; in Iraq, probably *Scrophularia* spp. (Wiltshire, 1957).

20. ***Cucullia macewani*** Wiltshire

Distribution: Probably endemic to coasts of the Arabian Peninsula and east Mediterranean. Saudi Arabia, Yemen, and Levant. In Israel: Coastal Sand Dunes.
Period of flight: in Israel univoltine, winter species, January to February.
Host-plants: unknown. Congeners on *Scrophularia* spp. and *Verbascum* spp. (both are Scrophulariaceae).

Subfamily Oncocnemidinae

21. ***Lithophasia quadrivirgula*** (Mabille)

Distribution: West-Eremic. Throughout North Africa from Morocco to Egypt, also Levant and Iraq. In Israel: all sandy areas.
Period of flight: in Israel univoltine, winter species, November to February with the greatest abundance in December.
Host-plants: unknown.

22. ***Calophasia barthae*** Wagner

Distribution: north (Circum-)Mediterranean. Southern part of Balkans, Turkey and Levant. In Israel: sands of Western Negev.
Period of flight: in Israel univoltine,, spring species, collected so far only in March.
Host-plants: unknown.

23. ***Calophasia angularis*** (Chrétien)

Distribution: Pan-Eremic. From the western Sahara and Morocco throughout North Africa to Saudi Arabia, the Levant, Iraq and Turkmenistan along the Kopet-Dagh Mts. In Israel: all sandy areas except Coastal Sand Dunes.
Period of flight: in Israel univoltine, early spring species, February to March.
Host-plants: unknown.

24. ***Cleonymia chabordis*** (Oberthür)

Distribution: West- and Central-Eremic. North Africa, Saudi Arabia, Levant, Iraq and Iran. In Israel: all sandy areas.
Period of flight: in Israel univoltine, early spring species, January to April.
Host-plants: in Israel, *Helianthemum stipulatum*, elsewhere unknown.

25. ***Metopoceras omar*** (Oberthür)

Distribution: Pan-Eremic. From northwestern Africa to the Levant, Sicily and southernmost Italy, the Arabian Peninsula, coasts of the Caspian Sea, Turkmenistan, the Near and Middle East. In Israel: all sandy areas.
Period of flight: in Israel univoltine, early spring species, January to April with the highest rate of occurrence from February to March.
Host-plants: unknown.

26. ***Metopoceras kneuckeri*** (Rebel)

Distribution: Pan-Eremic. From northwestern Africa across the Arabian Peninsula to Pakistan. In Israel: all sandy areas except Coastal Sand Dunes.
Period of flight: in Israel univoltine, spring species, March to April.
Host-plants: unknown.

Subfamily Noctuinae
Tribe Caradrinini

27. ***Scythocentropus eberti*** Hacker

Distribution: probably endemic to sands of the Arava Valley. Collected in all sandy areas of Arava Valley, also on Jordanian side the Arava.
Period of flight: in Israel univoltine, autumn species, October to November with the highest rate of occurrence in November.
Host-plants: unknown.

28. ***Scythocentropus inquinata*** (Mabille)

Distribution: Pan-Eremic. Morocco, Algeria, Tunisia, western and central Sahara, Levant, Arabian Peninsula, Iraq, Iran, Turkey, Pakistan and northern India. In Israel: all sandy areas.
Period of flight: in Israel univoltine, autumn species, September to December with the highest rate of occurrence in November.
Host-plants: unknown.

29. ***Diadochia stigmatica*** Wiltshire

Distribution: West-Eremic. Western Saudi Arabia and Levant. In Israel: Arava Valley.
Period of flight: in Israel univoltine, autumn species, November.
Host-plants: in Israel unknown; larvae of Central Asian congeners develop from April to May on *Salsola arbuscula* Pallas and *S. richteri* (Moq.) (Amaranthaceae).

Tribe Xylenini

30. ***Polymixis epiphleps*** (Turati & Krüger)

Distribution: south (Circum-)Mediterranean. Libya and Levant. In Israel: Western Negev and Coastal Sand Dunes.
Period of flight: in Israel univoltine, winter species, November to January with the highest rate of occurrence in December.
Host-plants: unknown.

31. ***Mniotype compitalis*** (Draudt)

Distribution: south (Circum-)Mediterranean. Coastal Libya, Egypt and Levant. In Israel: Coastal Sand Dunes.
Period of flight: in Israel univoltine, winter species, November to December.
Host-plants: unknown.

32. ***Boursinia lithoxylea*** (A. Bang-Haas)

Distribution: West-Eremic. North Africa, western Arabian Peninsula, and Levant. In Israel: Arava Valley.

Period of flight: in Israel univoltine, autumn species, November.
Host-plants: in Israel unknown; elsewhere, *Retama raetam*. (Fabaceae).

Tribe Hadenini

33. ***Odontelia daphnadeparisae*** Krachenko, *et al*.

Distribution: East-Eremic. Arabian Peninsula, Turkmenistan, Afghanistan, Iran and Levant. In Israel: Arava Valley.
Period of flight: in Israel univoltine, winter species, December to March with the highest rate of occurrence in February.
Host-plants: unknown. Larvae in Israel were found living subterranean in sand dunes with *Haloxylon persicum* Bunge (Amaranthaceae)..

Tribe Leucaniini

34. ***Leucania punctosa*** (Treitschke)

Distribution: Mediterranean-Iranian. From Morocco to Libya, southern Europe, Turkey, Armenia, Levant, Iran, Iraq and Turkmenistan. In Israel: Western Negev and on Coastal Sand Dunes.
Period of flight: in Israel univoltine, autumn species, November to December.
Host-plants: in Israel, *Desmostachya bipinnata* Stapf (Poaceae=Gramineae); in Europe, undefined Poaceae (Gramineae).

Tribe Noctuini
Subtribe Agrotina

35. ***Euxoa oranaria*** (A. Bang-Haas)

Distribution: West-Eremic. Iberian Peninsula, one record in Sicily, also Morocco, Algeria, Saudi Arabia and Levant. In Israel: all sandy areas except Coastal Sand Dunes.
Period of flight: in Israel univoltine, autumn species, November.
Host-plants: unknown.

36. ***Euxoa anarmodia*** (Staudinger)

Distribution: West-Eremic. From Algeria to Tunisia, Libya, Egypt and Levant. In Israel: all sandy areas.
Period of flight: in Israel univoltine, autumn species, October to December with the greatest abundance in November.
Host-plants: in Israel and elsewhere unknown; in captivity reared on *Hyoscyamus muticus* L. (Solanaceae).

37. ***Euxoa canariensis*** (Rebel)

Distribution: Pan-Eremic. From the Canary islands throughout the arid and semi-arid

parts of North Africa to the Arabian Peninsula, the Levant, Iran, and Afghanistan. In Israel: all sandy areas except the Coastal Plain.
Period of flight: in Israel univoltine, spring species, March to May.
Host-plants: unknown; in captivity reared on *Atriplex halimus* L. (Chenopodiaceae).

38. ***Agrotis alexandriensis*** Bethune-Baker

Distribution: south (Circum-)Mediterranean. From Tunisia to Egypt and Levant. In Israel: Coastal Sand Dunes.
Period of flight: in Israel collected so far only in October, possibly univoltine, autumn species; in North Africa bivoltine, flying in April and November.
Host-plants: unknown.

39. ***Agrotis herzogi*** Rebel

Distribution: Pan-Eremic. North Africa, Arabian Peninsula, Levant, Iran, Pakistan and western India. Migrating to southern Europe, found in Sicily and Greece. In Israel: Arava Valley.
Period of flight: in Israel probably bivoltine, October to April with the greatest abundance in November and March.
Host-plants: in Israel, *Atriplex leucoclada* Boiss. (Chenopodiaceae); elsewhere unknown.

40. ***Agrotis haifae*** Staudinger

Distribution: West-Eremic. North Africa, Arabian Peninsula and Levant. In Europe restricted to one locality in northern Greece. In Israel: Arava Valley.
Period of flight: in Israel univoltine, autumn species, October to April with the greatest abundance in November.
Host-plants: in Israel and elsewhere unknown.

41. ***Agrotis sardzeana*** Brandt

Distribution: Pan-Eremic. North Africa, Arabian Peninsula, Levant, Iran, Pakistan and eremic parts of India. In Israel: Arava Valley.
Period of flight: in Israel univoltine, autumn species, October to December with the greatest abundance in November.
Host-plants: unknown. In captivity reared on *Atriplex halimus* L.

42. ***Agrotis pierreti*** (Bugnion)

Distribution: West- and Central-Eremic. Southeastern Spain, North Africa, Iraq, southern Iran and Levant. In Israel: all sandy areas.
Period of flight: in Israel univoltine, autumn species, October to November with the greatest abundance in November.
Host-plants: unknown.

43. ***Agrotis lasserei*** (Oberthür)

Distribution: Pan-Eremic. Widespread throughout the eremic zone of the Palearctic region. From southeastern Spain and the western Sahara to Turkey, the Levant, Iraq, Iran, and Turkmenistan. In Israel: all sandy areas except Coastal Sand Dunes.
Period of flight: in Israel univoltine, autumn species, October to November.
Host-plants: unknown.

44. ***Agrotis boetica*** (Boisduval)

Distribution: south (Circum-)Mediterranean. Southern Iberian Peninsula, North Africa (Morocco, Algeria and Tunisia), and Levant. In Israel: Western Negev and Coastal Sand Dunes.
Period of flight: in Israel univoltine, winter species, November to December.
Host-plants: in Israel unknown; in Spain on *Lithospermum* spp (Boraginaceae), *Echinops* spp (Asteraceae) and *Astragalus* spp, (Fabaceae).

Species composition on different sandy areas

More than half of the species (26/44 = 59.1%) occurred only in a single sandy area (Table 1). There are 18 species found exclusively in the sands of the Arava Valley including all 8 Israeli species of *Anumeta*. One species (*Drasteria oranensis*) has been found only in Rotem-Yamin sands. In the Uvda Valley no unique species has been found. Four species are found exclusively in the sands of the western Negev, and three species in Coastal Sand Dunes. Seven species inhabit all the sandy areas other than the Coastal Sand Dunes. Four species were common for the Coastal Sand Dunes and the Sands of the Western Negev and another seven species were found in all sandy areas.

Biogeographical composition

According to their general distribution pattern, most of the species inhabiting inland sands belong to the eremic group. There are 14 West-Eremic species; 5 East-Eremic; 5 Central-Eremic, 3 West- and Central-Eremic and 10 Pan-Eremic. Most of these species are widespread on sands in the Palearctic desert belt, e.g. 11 of them are a common component of sand dwelling Lepidoptera in central Asian deserts (Falkovich, 1979).

Species inhabiting the Coastal Sand Dunes and sands of the Western Negev are all circum-Mediterranean. There are four south Circum-Mediterranean species inhabiting coastal sands of the African Mediterranean coast: *M. compitalis*, *A. alexandriensis*, *P. epiphleps*, *A. boetica*. Also one Mediterranean-Iranian species: *L. punctosa* maintains a preference for sandy areas throughout its distribution (Hacker, 1999; 2001).

The endemic group includes four species with different types of distribution. *Armada nilotica* is known only from the type locality (Egypt, El-Arish oasis, Coastal Sand Dunes) and from the adjacent part of the Western Negev in Israel; *A. arabia* was

Table 2
Species assemblages according to their preference for different sandy areas

Species	Sandy areas					
	Arava	Rotem	Uvda	Western Negev	Coastal dunes	
Anumeta spilota	+					Inhabit one area
Anumeta henkei	+					
Anumeta atrosignata	+					
Anumeta straminea	+					
Anumeta arabiae	+					
Anumeta asiatica	+					
Anumeta hilgerti	+					
Anumeta cestis	+					
Anydrophila stuebeli	+					
Acontia biskrensis	+					
Tarachephia hueberi	+					
Scythocentropus eberti	+					
Diadochia stigmatica	+					
Boursinia lithoxylea	+					
Odontelia daphnadeparisae	+					
Agrotis herzogi	+					
Agrotis haifae	+					
Agrotis sardzeana	+					
Drasteria oranensis		+				
Armada nilotica				+		
Epharmottomena eremophila				+		
Cucullia strigicosta				+		
Calophasia barthae				+		
Cucullia macewani					+	
Mniotype compitalis					+	
Agrotis alexandriensis					+	
Drasteria kabylaria	+	+	+	+		Inhabit few areas
Euxoa oranaria	+	+	+	+		
Euxoa canariensis	+	+	+	+		
Agrotis lasserei	+	+	+	+		
Cucullia macara	+	+	+	+		
Calophasia angularis	+	+	+	+		
Metopoceras kneuckeri	+	+	+	+		
Iranada turcorum				+	+	
Polymixis epiphleps				+	+	
Leucania punctosa				+	+	
Agrotis boetica				+	+	
Cerocala sana	+	+	+	+	+	Occur everywhere
Lithophasia quadrivirgula	+	+	+	+	+	
Cleonymia chabordis	+	+	+	+	+	
Metopoceras omar	+	+	+	+	+	
Scythocentropus inquinata	+	+	+	+	+	
Euxoa anarmodia	+	+	+	+	+	
Agrotis pierreti	+	+	+	+	+	

described from Saudi Arabia and recorded from a few localities along the Arava Valley; *C. macewani* is probably an inhabitant of coastal dunes of the Arabian peninsula and east-Mediterranean; and *S. eberti* is probably endemic to the Arava Valley sands, recorded both in the Israeli and Jordanian part of this valley.

Host plants

Host plants for most species are unknown. Some noctuid genera can be associated with host plant genera. For example, desert plants of the genus *Calligonum* are known to be hosts for species of *Anumeta*. Larvae of *Cucullia* usually develop on *Scrophularia* spp. Larvae of Noctuinae are known to be polyphagous on roots and stems of various grasses.

Periods of flight

The only multivoltine species among the sand-dwelling noctuids were species of *Anumeta*, flying from February to July with 2-3 generations. Other species are univoltine and fly during a 2-3 week period once a year. On inland sands (Arava, Uvda, Rotem) species fly during two periods (Fig. 2), one in November (autumnal species) and another from February to April (spring species). In the Coastal Sand Dunes and adjacent Sands of the Western Negev, sand-dwelling species were collected only in winter (December and January).

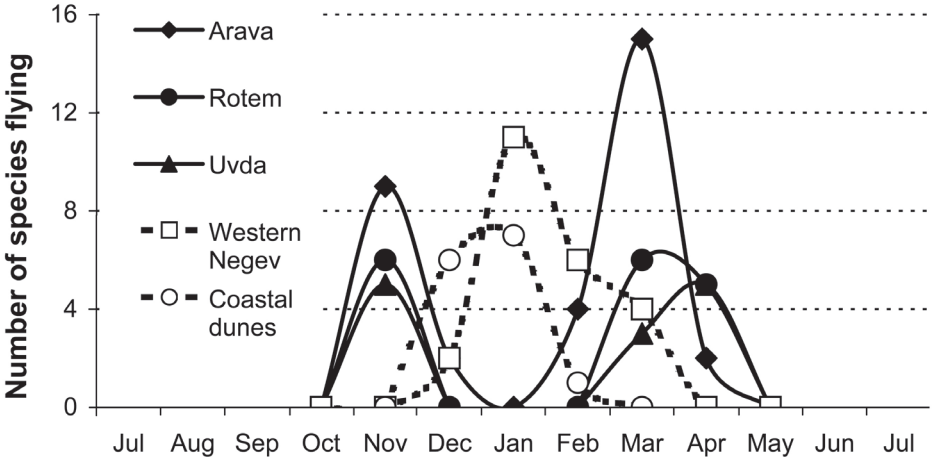

Fig 2. Periods of flight of the sand-dwelling species in different sandy areas

DISCUSSION

Aridisation and sand formation are inextricably linked. If there is no vegetation or water to hold the soil, the wind takes away the clay's particles and dried organic matter. The rest is desert sand (Lancaster, 2009). Probably sandy areas have become an independent center of speciation inside the desert; therefore, the vast majority of the sand dwelling species in Israel has an Eremic type of distribution.

Only seven species were found in all of the sandy areas, others showed preference for different sandy areas. The primary differences of species composition in biogeographical areas and in periods of seasonal flight are between species living in the inland and coastal sands. Species restricted to coastal dunes and to sands of the Western Negev belong to a Circum-Mediterranean type of distribution and fly in the winter. The minimal winter temperatures and moisture are different in coastal and inland areas. The coastal areas get more moisture (Table 1) in the form of precipitation and from fog (Goldreich, 2003). Relatively high winter temperatures allow moths to initiate flight activity in the winter in contrast to the Arava Valley, where the winter temperature often drops to 4ºC at night (Table 1).

Conformity of monophagous species to sandy soils most probably is a result of host plant specialization to sandy soils. Sand-dwelling species probably become host specific because of the low diversity of plants occurring on sandy soils. Mechanical characteristics of sand must be specific in order for the cutworms to be able to inhabit these types of habitats. In desert Lepidoptera larvae hide in the soil during hot and dry days and come out to feed only at night. Therefore, the relationship between soil type and species composition of Lepidoptera in the desert is derived not only through the relation of soil type and host plant, but also through the suitability of the soil as a shelter for the larva (Falkovich, 1968). Pupation of most sand-dwelling Lepidoptera also takes place in the soil. Sand-dwelling Lepidoptera are specifically adapted to successfully emerge from the pupa and make their way to the surface. That success depends on: a) hatching is under the control of a diurnal rhythm, allowing hatching only in the most humid night hours (for example Jacobson, 1970; Peng-Fei, *et al*., 2007); and b) many desert Lepidoptera possess special morphological structures for successful squeezing out that are strong spines on the tibia, or frontal tubercles of different shapes in order to push the soil (Falkovich, 1968). Psammophilous species of *Euxoa* without a frontal tubercle have less difficulty emerging from the soil as the non-psammophilous species (Lafontaine, 1981).

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