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Jordan Journal of Natural History

THE ROYAL SOCIETY FOR THE CONSERVATION OF NATURE

Conservation Monitoring Centre

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Scope

The Jordan Journal of Natural History is an open access scientific publication published by the Conservation Monitoring Centre at Royal Society for the Conservation of Nature. The aim of the journal is to enrich knowledge on the regional fauna and flora of the Arabian countries of the Middle East (Bahrain, Iraq, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, United Arab Emirates, and Yemen). This includes fauna, flora (Systematics, taxonomy, Phylogenetics, Genetics, Morphology, Conservation, Ecology, Biogeography, and Palaeontology) and Geology. Monographs will be published as supplementary issue.

Type of papers

The journal publishes high-quality original scientific papers, short communications, correspondence, books reviews, and case studies. Review articles are only by invitation. However, Review articles of interest and high standard will be considered.

Submission of Manuscripts

Manuscripts should be solely submitted to the Jordan Journal of Natural History and have not been published or submitted elsewhere. All manuscripts will be reviewed by at least two referees. Based on reviewers' recommendations, the Chief Editor will decide whether the manuscript will be accepted or rejected for publication.
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Manuscript format

Title page: the title page should include concise title; a short running title, author(s) full name(s), affiliation, complete postal address, e-mail addresses, phone, and fax numbers of the author to whom all correspondence should be addressed.

Abstract: an abstract not exceeding 300 words, summarised account of the subject, results and conclusions should be given.

Keywords: Three to seven keywords should be included for each paper. Use of abbreviations should be avoided, only standard abbreviations, well known in the established area may be used, if appropriate. These keywords will be used for indexing.

Introduction: Should include a short introduction to the background, a brief literature survey and the scope and aim of the work done.

Materials and Methods: Give adequate information to allow the experiment to be reproduced. Already published methods should be mentioned with references. Significant modifications of published methods and new methods should be described in detail. Subheading can be used.

Results: Results should be concise and should not include discussions. Text, tables and figures should not duplicate the same information. Newly described taxa must be distinguished from related taxa. For newly described species, the holotype should be deposited and numbered in a recognised museum.

Discussion: Concise discussion without repeating the results with the significance of the present work should be provided. Citations should be given in support of the findings.

Acknowledgment: A brief acknowledgment section may be given after the conclusion section just before the references. The acknowledgment of people who provided assistance in manuscript preparation, funding for research, etc. should be listed in this section.

References: should be listed in alphabetical order and cited according to the Harvard citation style.

Figures and Tables: It is in the author's interest to provide the highest quality figure format possible. Figures must be saved separate to text. Please do not embed figures in the file. Files should

be saved as one of the following formats: TIFF (tagged image file format), PostScript or EPS (encapsulated PostScript), and should contain all the necessary font information and the source file of the application.

All figures and tables must be numbered in the order in which they appear in the paper (e.g. Fig. 1, Fig. 2) and their position should be indicated in the text. In multi-part figures, each part should be labelled (e.g. Fig. 1(a), Fig. 1(b)). Tables should be numbered using Arabic numerals.

Both black and white and coloured photographs are accepted. However, these photographs need to be of high quality, and minimum of 300 dpi resolution. They should not to be submitted within the text, but as a separate attachment with a file name refers to the figure location within the text (e.g Fig. 1).

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Times New Roman font size 12 should be used. Lines should be doubled spaced. Titles and subtitles should be bold with first word and proper nouns cap only, and paragraphs should be indented.

After final acceptance of the manuscript, the author(s) should sign a copyright form for the journal. No page charges are due for publishing in the journal. The table below summarises the manuscript style:

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Author/s	An Author and Another Author (initials closed up for example if: J.B Hamad), centred, Regular, Times New Roman, size 14

Affiliation	[a]Department, University, City, Country; [b]Department, University, City, Country, Centred, Italic, Times New Roman, size 12
Abstract	Abstract: Text smaller, indented both sides, Centred, Regular, Time New Roman, size 11
Key words	Keywords: word; another word; lower case except names. Position aligned with abstract
Headings	A. Bold initial cap only (size 12 bold) *B. Bold italic initial cap only (size 12 bold, italic)* *C. Italic initial cap only (size 12 italic)* *D. Italic initial cap only (size 12 italic*) Text runs on after a punctuation mark All ranged left, numbers to be included if supplied, no indent below.
Paragraph	Indented Paragraph: use this for the first paragraph in a section, or to continue after an extract. New paragraph: use this style when you need to begin a new paragraph.

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Forward by Yehya Khaled

Director General
Royal Society for the Conservation of Nature

The Royal Society for the Conservation of Nature (RSCN) is a long-standing and active NGO, devoted to the conservation of Jordan's natural environment. It was established in 1966 under the patronage of late King Hussein, and it has an official delegation for biodiversity conservation across Jordan. RSCN's protected areas are the backbone of its nature conservation strategy. They represent the finest ecosystems remaining in the Kingdom.

For several decades RSCN managed its protected areas as isolated sanctuaries, fenced and guarded from the general public and with little role for scientific information in their management. In 1992 the Society pioneered the Region's first integrated conservation and development project in the Dana Nature Reserve. This project successfully demonstrated that protected area management could be linked to the socio-economic development of local people and ushered in a new era in conservation thinking, based on the proper use of ecological research in protected areas management; therefore RSCN witnessed the establishment of its first Research and Survey section to play this role. Since that time, the research information are collected and updated regularly, however there has been little sharing of this information with scientific community or even the public.

In 2011 RSCN's Transformation Strategy was completed, It was designed to address the serious problems stemming from the rapid growth of the organisation over the last 5 years; one of which is turning the Research and Survey section into a modern Conservation Monitoring Center (CMC). The main objective of the new center is to standardize the process for recording, categorising, analysing, archiving, and reporting of ecological data and sharing it with scientific community and the public in general in order to influence national polices and plans to become more biodiversity conservation friendly.

Today, I am really pleased to launch the first issue of RSCN's scientific journal, the *Jordan Journal of Natural History*, which represents RSCN's new tool designed to enhance proper documentation of biodiversity research and sharing this information with decision makers and scientific communities. This journal will serve researchers in biodiversity issues within the Middle East to exchange scientific knowledge. In this regard, I take the opportunity to thank all the reviewers who spent their valuable time to revise all the submitted manuscript and for their critical and professional comments.

Contents

The paleoclimate of Jordan during the Pleistocene as a possible indicator for future climate change: an overview

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ABSTRACT

Several fresh to brackish water paleolakes were formed and sustained in Jordan during the warmer and wetter periods of the Pleistocene: including Umari Lake during the Marine Isotope Stage MIS 9 at 330 Ka (thousand/year), Mudawwara and Samra Lakes during the MIS 5 130-70 Ka, Lisan and Jafr Lakes 30-33 and 25-27 Ka respectively, and the Burqu' Lake during the Holocene Optimum 9-6 Ka.

Studies on the mineralogy of the lake sediments and of their fossil remains all indicate that the water of the lakes was initially fresh but became more brackish at times depending on the climate change. Most of these lakes were more than 1000 km2 in area and from 10 to few hundred metres deep, with possible water temperature of between 15-20°C.

Present-day climate cannot account for the presence of such lakes in the arid to semi arid area of Jordan. Therefore more intense and wetter Mediterranean cyclones in winter coupled with Arabian monsoon or even Arabian-Indian monsoon in summer would have affected major parts of Jordan up to latitude 31° 32′ during the warmer periods of the Pleistocene and brought more rain to establish and sustain such lakes.

However, summer monsoon rains currently postulated for Jordan and adjacent areas remain controversial and are not fully accepted by other workers in this area of research. Consequently, more detail work on the paleoclimate of the Jordan is needed

Key words: Paleoclimate, Paleolakes, Monsoon rain, Jordan, Arabia, Sahara

INTRODUCTION

Paleoclimatology is a branch of Earth sciences which deals with determining the type of climate prevailing on Earth or certain area of it in the 'near' past. It tries to understand and explain the factors controlling those climates. Its overall aim is to help predict future trends in climate possibly associated with global warming either across the whole world or on smaller parts of it; e.g. the Sahara, Arabia or the Middle East.

Paleoclimate research work in Jordan and nearby countries is rather limited and cannot be compared with the volume of papers produced in other areas of the world like Europe. Only few papers have been published in the last two decades on the paleoclimate of Jordan. Abboud (2000) reported a humid period at the Holocene Optimum 10-6 ka in Wadi Muqat (Burqu' Lake) at site 1 (Fig. 1, L1), followed by dry conditions after 5 ka. Jericho first appeared as a village in the Jordan Valley at around 8 ka or slightly earlier (Kenyon, 1979; Neev and Emery, 1995). Huckriede and Wiesemann (1968) described a 1000-1800 km2 fresh water lake in the Jafr basin (Fig. 1, L6) in southern Jordan at 27-25 ka which subsequently disappeared completely during the Last Glacial Maximum (LGM). Abboud (2000) also recorded a humid interval at 25 ka and one dry interval at 21-15 ka in Wadi Muqat Basin (Fig. 1, L1). Abed (1983) and Abed and Yaghan (2000) demonstrated a shrinkage of the huge Lisan Lake in the Jordan Valley-Dead Sea (Fig. 1, L4) to a smaller sabkha during the last glacial maximum LGM. A fresh water area, Lake Damya (L4), reformed in the Jordan Valley around 14-12 ka (Abed, 1985).

Moumani (1996) documented the formation of a 4 km^2 shallow, fresh water lake at Al-Hisa (Fig.1, L5) between 182-82 ka based on 3 OSL (optically stimulated luminescence) dates. A *Cardium* fresh to brackish lake was recorded in the Mudawwara area (Fig.1, L7) at 130-70 ka (Marine Isotope Stages (MIS) 7–5a-e (Masri, 1987; Abed et.al., 2000; Yasin, 2001; Petit-Maire et al. 2002). At the centre of the Azraq Basin (Fig.1, L2), Davies (2000) and Khoury (2003) found that the central part of the Basin was occupied by a lake between 500-250 ka. Turner and Makhlouf (2005) investigated a 652 ± 47 ka, 15 m thick friable sandstone horizon with roots, beta calcrete and

gypcrete from the Azraq Formation at the southern periphery of the Azraq Basin (Fig. 1, L3).

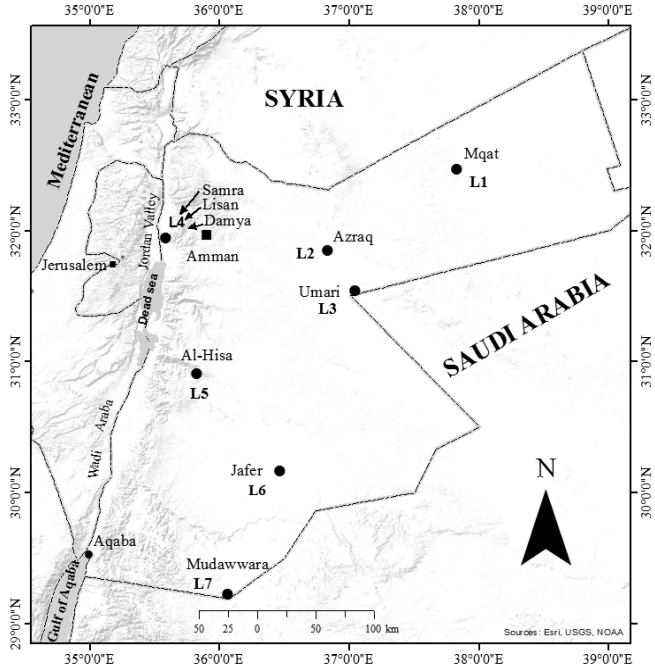

Fig. 1: Location map for the sites of paleolakes studied in Jordan.

They concluded that this sandstone correlates with MIS 17 at 659 ka, which was a wetter/warmer period. Abed et al. (2008) described a warm humid climate producing a fresh water lake or lakes which occupied the area between the Umari border post with Saudi Arabia and the Azraq during the marine isotope stage 9 (MIS 9).

All these works suggest that the climate was wetter and warmer in parts of Jordan during the late Pleistocene. More lakes were formed during those periods and areas with drier climates were less common. This notion is supported by paleoclimate findings in the Sa-

hara, Arabia, and SE Asia, with well-established evidence that previous climates during the glacial periods were cold and dry with the advance and expansion of deserts. By contrast the warmer interglacial periods were wetter with smaller areas of desert (e.g. the Sahara: COHMAP, 1988; Prell and Kutzbach, 1987; Gasse et al., 1987; Yan and Petit-Maire, 1994; Gasse, 2000; Larrosoana, et al., 2003), Arabia (McClure, 1976; Al-Sayari and Zotl, 1978; Fleitmann et al., 2003) and SE Asia (Petit-Maire and Guo, 1997; Zhuo et al. 1998).

On the other hand, several other workers maintained the idea that the area was cold and wet (pluvial) during the glacial periods of the Alps and Europe, and warm and dry (interpluvial) in the interglacial periods (e.g. Horowitz, 1979 to 1992; Bowman, 1990; Neev and Emery, 1995). Thus the aim of this work is provide an overview of the paleoclimate of Jordan and adjacent areas during the Pleistocene and suggest how it could influence our understanding of future climate change in the area.

CLIMATE

The locations of all the paleolakes in Fig.1 are, at present, in the arid areas of Jordan except the Samra, Lisan and Damya lakes which formed in the Jordan Valley-Dead Sea basin. Average annual rainfall, as short duration storms, is less than 150 mm in the north, with the southern ones having less than 50 mm/y (Fig. 2). The weather is characterized by two defined seasons; hot, dry, and dusty with relatively strong northwesterly wind in summer (May-October), and cold, semi dry, windy in winter (November-April) (National Water Master Plan, 2004).

The rainy season in Jordan extends from early October to late April. Figure 2 displays the temporal distribution of rainfall, most of which falls between November through March. During the months November through February, frontal depressions (cyclones) sweep across the Eastern Mediterranean producing westerly to southwesterly wind circulation, lower temperatures, and an increase in humidity and rainfall. Occasional snow events occur at higher elevations in the west. Annual rainfall tapers off towards the east. In February, occasional cold spells and dry easterly winds, driven by

the Siberian anticyclones, may cause frost conditions which can be potentially damaging to winter crops. Instability during the fall and spring months (interference between cold Mediterranean cyclones and warm Red Sea cyclones) can lead to torrential rain events and can cause flooding in low laying terrain.

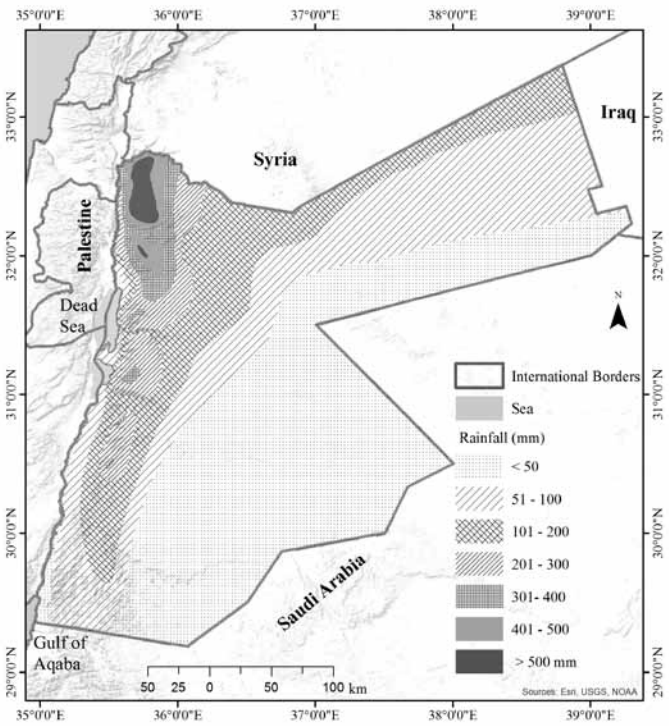

Fig. 2: Rain fall distribution in Jordan.

April and early May are dominated by the Khamaseen cyclones. These cyclones originate in the Mediterranean and pass through eastern North Africa and produce large amounts of dust associated with rains in Jordan. Furthermore, Indian monsoon cyclones affect Jordan and almost all the eastern Mediterranean for days at a time

each summer. The weather becomes very hot with maximum temperatures reaching as high as 42° C. Most of the vegetation in the area consists of desert shrubs (salt tolerant plants) and grass along wadis. Farms are developed near the two Azraq towns and east of the mudflat and are irrigated by shallow wells of acceptable salinity.

CASE STUDIES

A brief account of some of the best documented studies on the paleoclimate of Jordan is presented here to provide substance for the current review. Three case studies are presented here to reflect the paleoclimate conditions (temperature and precipitation) in Jordan during the Pleistocene: Samra/Lisan lakes, Mudawwara lake and Umari lake.

Samra/Lisan lakes

The Samra and Lisan are two successive lakes which were present in the Jordan Valley-Dead Sea basin. The Samra lake was a fresh water lake that lived between 135-70 thousand years before present; 135-70 Ka. The Lisan lake (Fig. 3) was of mixed salinities and spanned the period around 65-15 Ka (Picard, 1943; Begin et al. 1974; Abed, 1985; Abed and Yaghan, 2000).

The **Samra Lake** is approximately coeval with marine isotope stage 5 (MIS 5) 130-70 Ka. The MIS 5, especially MIS 5e or the Eemian period, is well known for being one of the warmest and wettest periods throughout the glacial period of 2.6 million years (Ma) (Ogg et al. 2008; Cronin, 2010). The deposits of the lake in Kherbet El Samra, some 6 km north of Jericho (Picard, 1943) and elsewhere in the Jordan Valley, consist of limestone, sandstone, clays and conglomerates with no evaporates. The lack of evaporites is clear evidence that the lake water was fresh. The Samra Lake was separated from the Mediterranean due to the continuous uplift of the mountains on both sides of the rift (Quennell, 1958; Bender, 1974; Powell, 1989). Thus the source of water for the lake was the rain fall from its catchment area on both side of the Jordan Valley-Dead Sea basin. Consequently, the precipitation at the Samra time must have been much higher when compared to that of today in order to produce

a fresh water lake several times larger than the Dead Sea and Lake Tiberias. In conclusion, the climate of Jordan was much wetter and warmer than that of today.

The **Lisan Lake** was studied in much more detail compared with the Samra Lake because of to its extensive sediment outcrops extending from Lake Tiberias in the north to northern Wadi Araba in the south, a distance of more than 200 km (Fig. 3). The life time of the Lisan Lake is around 65 – 15 Ka (Abed and Yaghan and the references therein).

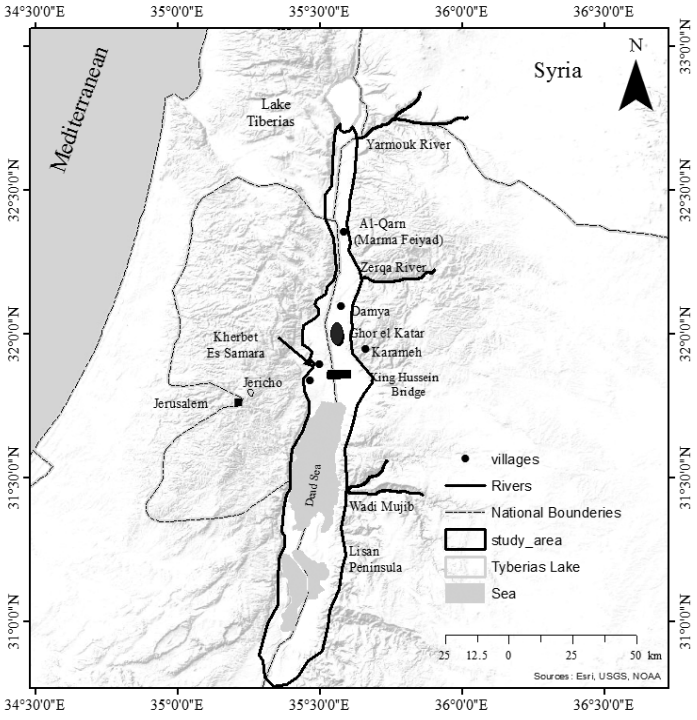

Fig. 3: The extent of the Lake Lisan occupying the rift valley from Lake Tiberias in the north to more than 25 km south of the Dead Sea. Also shown are the localities mentioned in the text.

There are three different and distinct types of lithologies of the Lisan sediments reflecting the prevailing salinities of the water body. They are from north to south:

1. The northern basin extending from Lake Tiberias in the north to the Qarn (Marma Fayad) in the north central Jordan Valley (Fig. 3). The Lisan sediments in this basin consists of alternating varves of aragonite and fresh water diatomites. No evaporates are reported and the lake water should be fresh (Begin et al. 1974; Abed, 1985). The presence of a fresh water lake in the northern most Jordan Valley can be understood by the fact that it is situated proximal to the main fresh water resources in the Upper Jordan and Yarmouk Rivers (Abed, 2014).

2. The middle area of the Jordan Valley from the Qarn in the north to the area opposite to the town of Karameh. The Lisan sediments in this area consists of alternating lamina (varves) of aragonite and clays with no evaporates up till the topmost few metres called the white cliff which consists of alternating gypsum and aragonite (Fig. 4). Abed and Yaghan (2000) demonstrated that the sediments below the white cliff (65-23Ka) were deposited from a fresh to brackish water bodies. The salinity of the lake at this time interval is indicated by the non presence of any evaporate minerals in addition to several fresh to brackish water fossil species. Abed and Helmdach (1981) studied the fossil content, especially the ostracods, of the Lisan sediment in a section near the Damya Bridge (Table 1).

Table (1) Example of fossil content, especially the ostracods, of the Lisan sediment.

Fresh to slightly brackish water environment	**Brackish water environment**
Cypredeis torosa	*Cyprinotus salinus*
Candona hartwigi	*Ilyocypris cf. gibba*
Darwinula sp	*Ilocypris dentifera*
Candonopsis kingsleweii	
Darwinula cf. stevensoni	

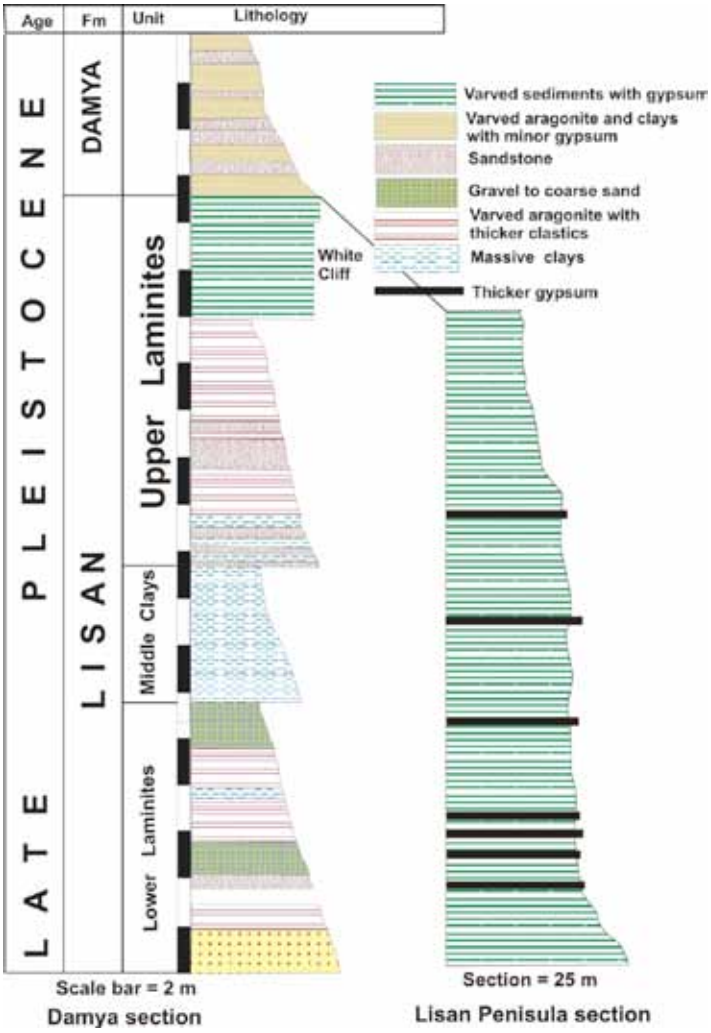

Fig. 4: Lithology of the Lisan Lake sediments in the intermediate area west of the Karameh town (left) and in the Lisan Peninsula (right) (Abed, 1983; Abed and Yaghan, 2000).

The white cliff itself (23-15 Ka), which has gypsum, was deposited from salt water with a salinity in the range of 100-120 % (part per thousand or ppt), much too high for organisms to live in. The time of deposition of the White Cliff is interpreted by Abed and Yaghan (2000) coincides with the Last Glacial Maximum (LGM); the last maximum glaciations during the Pleistocene. Obviously, the climate was globally cold and seemed to have less rain fall, thus, allowing for the higher salinities in this area of the Lisan Lake. It should be emphasized that Lake Lisan disappeared almost completely by about 15 Ka and became a sabkha; i.e. during the LGM cold period. This is confirmed by the absence of Lisan sediments above the white cliff in this area.

3. The southern basin involves all the Dead Sea area especially its central part. The Lisan sediments are well displayed in the Lisan Peninsula and consist completely of alternating varves of aragonite and gypsum (Fig. 5). This means that the water within this basin of

Fig. 5: Field photo showing the thin lamination (varves) in the Lisan Lake sediments in the Lisan Peninsula, Dead Sea.

the Lisan Lake was saline throughout. This is most probably due to less water arriving to the Dead Sea area from the north as well as to greater evaporation.

As explained above, Lake Lisan became drier at about 15 Ka during the LGM. A warmer climate prevailed after that, and a new smaller fresh water lake called Damya Lake formed and continued for about 2000 years from 14-12 Ka, indicating a warmer and wetter climate (Abed 1985). This is evident from the presence of 14 m laminated sediments in the Ghore El-Katar - Damya area representing the Damya Lake. Damya Lake also became smaller because of a short-lived cold period called the Younger Dryas at around 11 Ka which led to the formation of the Dead Sea with its present day shape at around 11-10.5 Ka. Again, changes to Lake Damya during the Younger Dryas period would indicate a cold and dry climate.

In the opinion of the author, but see also Begin et al. (1974) and Abed and Yaghan (2000) for more details, two reasons were responsible for the segmentation of the salinities of the Lisan Lake. The first reason is the presence of a paleohigh (natural dam) in the Qarn area which regulated the flow of water to the lake. The second, is that the source of water to the lake was from the Upper Jordan River and the Yarmouk River both in the north, as the situation is at present. The northern basin receives enough fresh water overtops the paleohigh and enters to continue as a fresh water lake, with the excess water the paleohigh enters the middle area and the Dead Sea basin in the south. Evaporation within the Dead Sea basin area can also be added to explain the precipitation of the evaporate gypsum facies.

The Lisan Lake water level was not the same throughout its history. Abu Ghazleh (2011) mapped and dated in details the fluctuations of the lake levels. She concluded that the Lisan Lake levels were highest during the warmer intervals between 33 – 25 Ka when conditions were wetter. This conclusion was supported by the work of Huckriede and Wiesemann (1968) on Lake Jafr, a fresh water lake that occupied the Jafr basin east of Ma'an at the same time with a surface area of 1000-1800 km^2, at around 27-25 Ka. Both lakes occurred during the same period of wet and warm climate in Jordan.

The Mudawwara Lake

The sediments of this lake were studied by Suha Yasin in her Ph. D thesis at the University of Jordan (Abed et al. 2000; Yasin, 2001; Petit-Maire et al. 2002). Masri (1987) named this Lake Halat Ammar Lake. The lake lies at the southern border with Saudi Arabia and includes parts of both countries (Fig. 6). The lake was about 1200 km^2 in

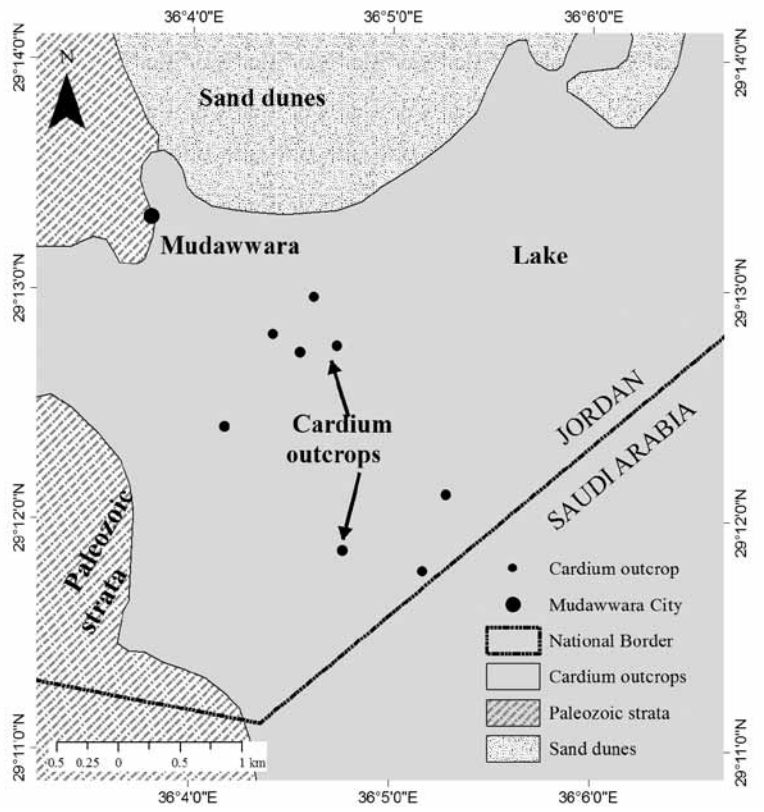

Fig. 6: The Mudawwara Lake at the extreme southern Jordan which includes Saudi Arabia. The limits of the lake are approximate.

area with a depth of between 10-12 m. It existed between 135-70 Ka with a peak being at the Eemian stage of the MIS 5. Consequently, it was coeval with the Samra Lake in the Jordan Valley. The macro and micro fossils recovered from the sediments show that it was a freshwater lake at that time.

The abundant rainfall for the Samra Lake may be explained by the Mediterranean cyclones which usually occur in winter, similar to those of today except possibly being more intense. The nearness of the catchment area, in Lebanon, Syria and Palestine to the Mediterranean Sea can help in this interpretation. However, the Mudawwara Lake is more than 300 km to the south and present winter cyclones rarely arrive to that area now. In fact, the annual rainfall cannot exceed 20mm/year and the Mudawwara area, at present, is a desert. The question is how a fresh water lake, 1200 km^2 and 10 m deep could be produced and maintained in such a desert environment unless the rainfall was many times higher than at present. For this reason, monsoon (summer rain) rain is advocated to have affected the area at the time of the Mudawwara Lake (Cohmap, 1988; Abed et al. 2000; Yasin, 2001; Petit-Maire et al. 2002). It seems possible that the Arabian monsoon was more intense during MIS 5, consequently it was able to bring summer rain to southern Jordan to a latitude of 30°. The Mudawwara area was probably affected by the Mediterranean cyclones in winter and the monsoon cyclones in summer, a pattern which could explain the rain fall needed to form and sustain a large fresh water lake during the Eemian stage of MIS 5.

The Umari – Azraq Lake

Two *Cardium* shell beds representing this lake are present at the Umari border point with Saudi Arabia, coordinates 31° 32' N, 37°06' E, and at about 10 km NE of the Azraq Druz town at the highway to Iraq, coordinates 31° 55' N, 36° 45' E (Fig. 7).

The shell beds form the uppermost part of Azraq Formation (Ibrahim, 1996; Raba'a, 1998; Turner and Makhlouf, 2005; Abed et al. 2008). Abundant macro and micro fossils making the shell beds are

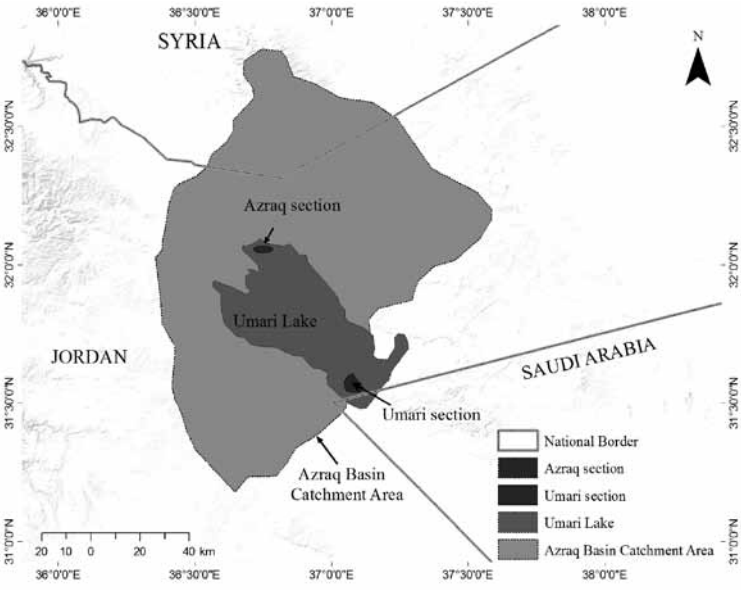

Fig. 7: The location and extent of Lake Umari.

shown in Fig. 8 and 9. Cardium shells dominate, but other fossils such as gastropods, ostracods, foraminifera and charophytes are also recorded. The fossil assemblage, and the absence of evaporite minerals, indicates a fresh to brackish water lake or possibly several smaller lakes that occupied the area between the Umari and Azraq (Gaillard and Testud, 1980; Feist et al. 1995; Abed et al. 2008).

The age of the shell beds is 330 Ka determined by U/Th method on the shells, which puts these beds within the MIS 9. The MIS 9 is the warmest and wettest isotope stage in the last half million years of the Earth history. Consequently, the *Cardium* shell beds provide another example of a warm and wet climate in Jordan during the Pleistocene.

The Umari-Azraq area now receives 150-60 mm of rain per year, a much wetter weather must have been prevailing at the area during

the warm MIS 9. Again, what is the source of such intensive rain fall? No exact answer can be provided except through more extreme Mediterranean cyclones and summer monsoons.

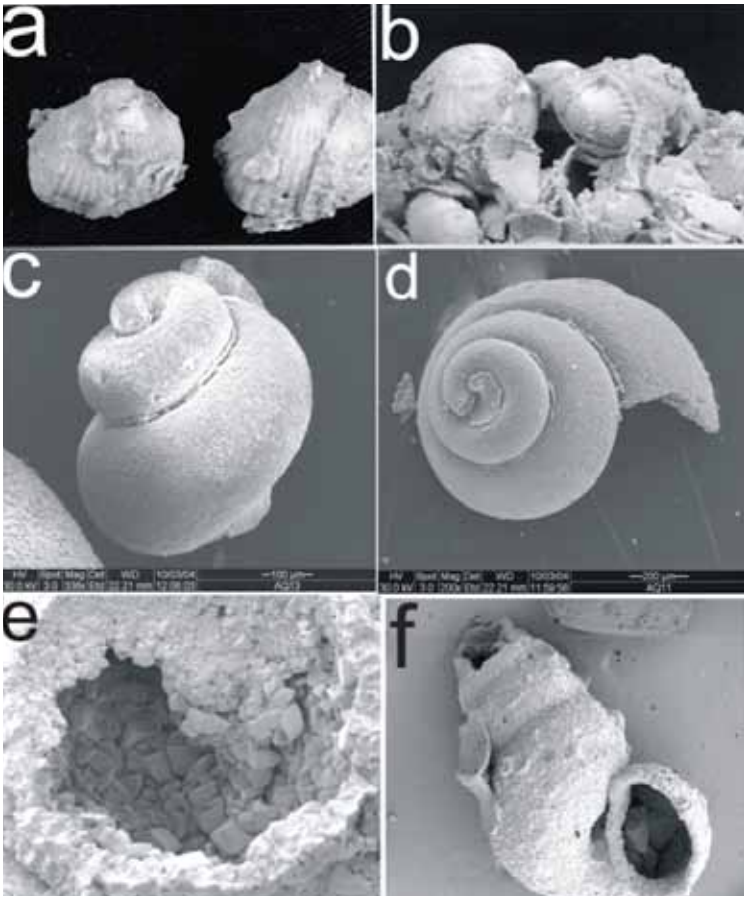

Fig. 8: Molluscan fossils from the studied sequence: a. *Cardium* shell from Azraq, b. *Cardium* shell from Al Umari, c. *Bythinia* sp, d. *Gyraulus* sp., Highly diagenetic gastropod shell, f. *Hydrobia* sp.

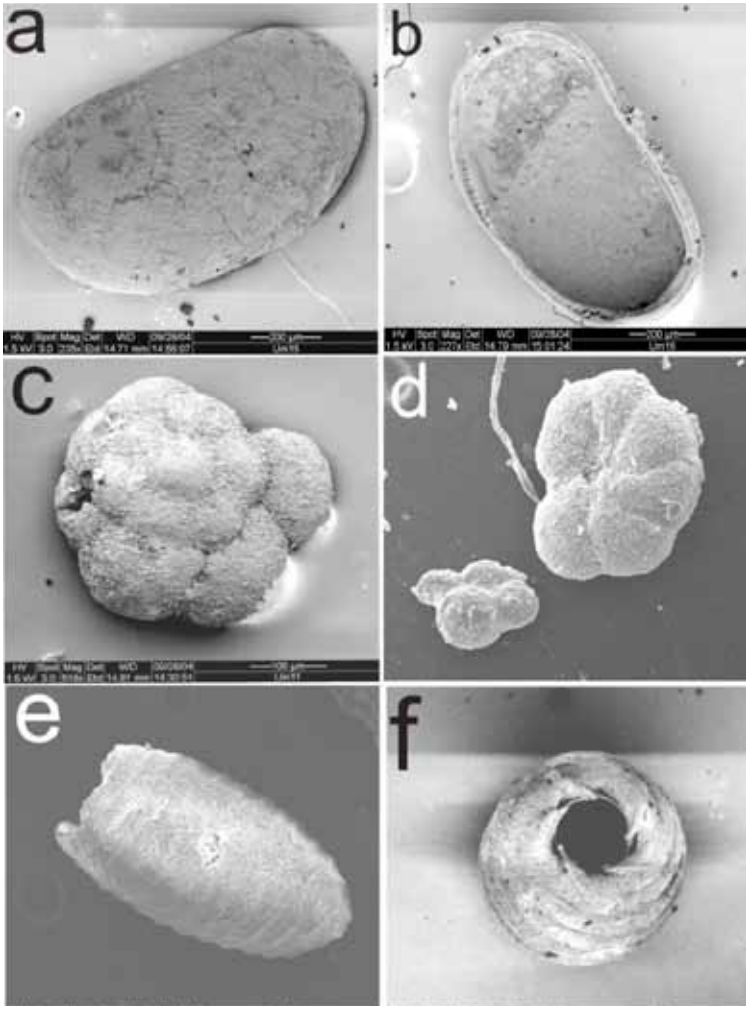

Fig. 9: Ostracods and Charophyte fossils: c. Ammonia beccarii tepida ventral view, d. Ammonia beccarii tepida dorsal view, a. Cyprideis torosa gr., smooth and sieve like, exterior right valve, b. Cyprideis torosa gr.enterior left valve, e. Charophyte gyrogonite of Croftiella cf escheri, f. Charophyte top view.

Arabia

Several works have been conducted on the paleoclimate of Arabia during the Pleistocene indicating that Arabia climate was wetter during the warmer periods. McClure (1976) and Sanlaville (1995, 1996) demonstrated a shrinkage of deserts in Arabia during the warmer periods and their expansion during the cold period with stronger wind deflation and dune forming processes.

Al-Sayari and Zötl (1978) investigated the Pleistocene (not exactly dated) surface calcareous duricrust in Arabia extending almost continuously from Rub Al-Khali (about 20° N) to the Sakaka in the extreme NW Saudi Arabia (30–31° N). They postulated semi-arid climatic conditions for its formation with precipitation ranging from 200 to 600 mm/y or more, a much higher range than the present day.

COHMAP (1988) placed the northern limit of the summer monsoon rain in Arabia at around 27°N during the Holocene Optimum. Thus, during the Holocene optimum, 9500-6500 years before present, Arabia up to latitude of 27°N was much wetter than today; i.e. up to 250 km south of the Jordanian border. Further south in Arabia, Fleitmann et al. (2003) studied the Hoti Cave speleothems in northern Oman and reported a rapid deposition during 5 warm MIS stages including the Holocene Optimum, Eemian, and MIS 9 due to the northward penetration of the monsoon rains. From these works, it seems reasonable to conclude that Arabia was much wetter during the warmer periods in the recent geological past.

North African Sahara

The Sahara in North Africa has received more studies of its paleoclimate by several European scholars (e.g. Kutzbach and Street-Perrott, 1985; Yan and Petit-Maire, 1994; Gasse, 2000; Emeis, et al. 1998; Larrasoana et al. 2003; Weldeap et al. 2007; Cole et al. 2009; Abouelmagd, 2012 amongst many others). Whilst it is difficult to review all these works fully some generalizations are given below.

The Sahara retreated northwards for a considerable distance during the warmer periods such as MIS 5 and the Holocene Optimum (Fig. 10). The Savanna expanded northwards and occupied for example, southern Libya and Algeria with abundant remains of large herbivores and the presence of human fire places. Then, the Sahara expanded southwards during the cold periods including the Last Glacial Maximum where the Savanna retreated towards the Equator. It is generally agreed that the increased rainfall was caused by an intensification of the monsoon rains that extended to 30°N or possibly further north during the warmer period.

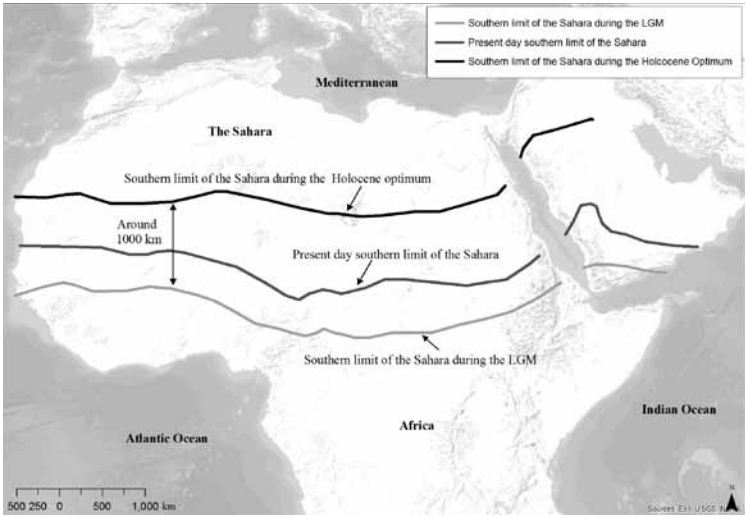

Fig. 10: A map of Africa and Arabia showing the northwards retreat of the Sahara during the warmer Holocene Optimum (9-6 Ka) and its advancement southwards during the Last glacial Maximum (LGM) at around 18 Ka. (Modified after COHMAP, 1988; Petit-Maire and Guo 1997)

DISCUSSION

From the above case studies and others, it is clear that several lakes were formed in Jordan during warmer interpluvial periods of the

Pleistocene. The presence of Charophytes and Planorbid snails in the Umari, Mudawwara, Umari and Jafr lakes (Brasier, 1980; Murray, 1991; Yasin, 2001; Petit-Maire et al. 2002), fresh water diatoms in the northern Lisan basin sediments (Begin et al. 1974) fresh to brackish water ostracods in the intermediate area of the Lisan sediments in the Jordan Valley (Abed and Helmdach, 1981) all indicate that these lakes were fresh to brackish water at some time in the past, or possibly more appropriate alternating fresh and brackish depending on the changes in climate during the life time of the lakes.

The area of each lake was in excess of 1000 km^2 with a depth varying from about 10 metre in the Mudawwara Lake (taken from the Charophytes and the *Ammonia beccarii tepida*) to few hundred metres as in the Lisan Lake (e.g. Abu Ghazleh, 2011). This clearly indicates that the climate at the time of each of these lakes must have been much wetter than present day climate in order to form and sustain such lakes for a considerable period of time for both. Consequently, the warmer interpluvial periods were much wetter than the cold pluvial periods.

Paleotemperature of the lake water may be estimated to have been about 20ºC at a minimum, since *Cardium* requires at least this temperature for reproduction and *Ammonia beccarii tepida* is best developed at temperatures of 15-20ºC. This is comparable to the average Eastern Mediterranean surface temperature during the interglacial sapropel formation times of 20-22°C (Kroon et.al., 2000; Emeis, et al. 1998).

With lakes established during the warmer interpluvial periods, a major question needs answering: what was the source of the increased humidity during those periods compared with present day climate? The source of precipitation, at present, is from the Mediterranean cyclones during the winter season (October-May). Figure 2 shows that this source provides the lake areas with <50 – 160 mm/y rain, except Samra and Lisan Lakes which can receive higher rain fall in the Upper Jordan River catchment area (up to 1200 mm/y).

Clearly, the present-day climate cannot sustain lakes in the investigated arid area such as the huge Samra and Lisan Lakes in the Jordan

Valley. The general trend in the distribution of rain throughout the Eastern Mediterranean decreases in amount from north to south and to a lesser extent from west to east (Fig. 2). However, the extensive Samra and Lisan Lakes that occupied the central Jordan Valley and the Dead Sea Basin were both fed essentially from the north; probably through the Mediterranean cyclones (Abed, 1983 amongst many others). It should be emphasized that the main source of water for both lakes was the Mediterranean cyclones located only a few tens of kilometers away.

When the area cooled down during the LGM, the Lisan Lake shrank to a sabkha, in response to a drastic decrease in rain with falling temperatures. Does that mean the increase in incoming solar radiation due to orbital forcing increases the atmospheric water vapor and causes the Mediterranean cyclones to become more productive? This contention would be supported by the work of Arz et al. (2003) who explained that the humid period for the early Holocene in the northern Red Sea-Gulf of Aqaba was sourced from the Mediterranean.

What about lakes hundreds of kilometers away from the Mediterranean such as Umari, Jafr and Mudawwara Lakes, had the Monsoon (Summer rain) rain participated in the formation of those lakes? More detailed work is required before this question can be answered conclusively. However, some insight can be gained from the small amount of existing research.

COHMAP (1988) placed the northern limit of the summer monsoon rain in Arabia at around 27°N during the Holocene Optimum. Abed et al (2000), Yasin (2001) and Petit-Maire et al. (2002) explained the 1200 km2, 20m deep, Eemian, fresh water Mudawwara Lake (L7 in Fig. 1) at 29°N by both winter rain from the north and monsoonal summer rain from the south. The 1000-1800 km^2 Jafr lake (L6) at 30oN disappeared completely during the LGM (Huckriede and Wiesemann, 1968). The authors did not discuss the source of humidity but further south in Arabia, Fleitmann et al. (2003) studying Hoti Cave speleothems in northern Oman reported a rapid deposition during five intervals including the Holocene Optimum, Eemian, and MIS 9 due to the northward penetration of the monsoon rains. See also the maps in Sanlaville (2000). From these examples, the

Arabian monsoon with summer rain seems to have reached 29°N and possibly 30°N.

Can Monsoonal summer rain be pushed further north to reach the Umari Lake at 31° 32´ during MIS 9, so that the Umari Lake was affected by both the monsoon from the south and the Mediterranean cyclones from the north? The evidence suggests that Jordan was wetter/warmer and drier/colder than today at times during the Late Pleistocene. Monsoon intensification is primarily related to the 'heat engine' produced by insolation forcing (Emeis, et al. 1998; Larrasoana, et al. 2003 amongst others). A better fit to paleoclimatic data, would require other factors beside the solar radiation forcing including oceanic, vegetation and soil moisture. The latter three factors would increase water vapor in the atmosphere and consequently precipitation (deMenocal, et al. 2000; Gasse, 2000; Liu, et al. 2003). Globally the MIS 9 period is documented as having more greenhouse gases and being warmer than any other stage during the last 420 Ka (Petit et al., 1999). MIS 9 is also recognized as a warm and wet interglacial period (Kroon et.al., 2000, Hodell et al., 2000; Fleitmann et al., 2003 amongst others). Furthermore, the Indian monsoon cyclones which is now affecting Jordan every summer, from May through August, with temperatures up to 39°C (e.g 2006) and dry conditions (Local daily weather forecasts, Jordan Meteorological Department). Thus, it seems possible that Arabian monsoons or even the Arabian-Indian monsoon had penetrated further north during the MIS 9 and produced summer rain in the study area, in addition to the winter Mediterranean precipitation.

However, it should be noted that we are the first group of workers that have advocated summer monsoon rains reaching Jordan during the warmer interpluvial periods (Abed and Yaghan, 2000; Abed et al. 2000; Yasin, 2001; Petit-Maire et al. 2002; Abed et al. 2008). This idea is further supported by the extensive research on the North African Sahara where the monsoon rains reached to latitudes of 30o and possibly 32o N (e.g. Larrasoana, et al. 2003). This idea is currently under review since other workers do not agree with our conclusions and maintain that the paleolakes discussed above are explained by a wetter climate during the cold pluvial periods (Begin et al. 1974; Neev and Emery. 1968, 1995; Horowitz, 1979, 1992).

CONCLUSIONS

1. Several fresh to brackish water paleolakes were established and sustained in Jordan during the warmer and wetter periods of the Pleistocene including Umari Lake during the MIS 9 at 330 Ka, Mudawwara, the Samra Lakes during the MIS 5 130-70 Ka, Lisan, the Jafr Lakes 30-33 and 25-27 Ka, and the Burqu' Lake during the Holocene Optimum 9-6 Ka.

2. Mineralogy of the lake sediments and their associated fossils indicate that the water of the lakes was fresh becoming brackish at times depending on the climate change.

3. The lakes were more than 1000 km^2 in area, and from 10 to few hundred metres deep, with possible water temperature of between 15-20°C.

4. Present-day Mediterranean rain cannot support the presence of lakes in such an arid environment. More intense Mediterranean cyclones during the warmer periods might have carried more rain than today. Because most of the lakes are far from the Mediterranean, intensified Arabian monsoons or even Arabian-Indian monsoons may also have penetrated further north into Jordan up to latitude 31° 32′ producing summer rain to establish and sustain such lakes.

5. Summer monsoon rains in Jordan and adjacent areas are still controversial and are not accepted by all workers in the field as is the case for events in the North African Sahara. Consequently, more detailed work on the paleoclimate of the area is needed.

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Vegetation Community Analysis in Mujib Biosphere Reserve, Jordan

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ABSTRACT

Field surveys of the plants and vegetation of the Mujib Biosphere Reserve in Jordan were carried out between 2005 and 2007. The study covered all areas of the reserve as defined by latitudes 7425000 W to 757000 E and longitudes 3501000 N to 3474500 S (total reserve area = 220 km^2). Plants and their vegetation were sampled both by area plots and line transects. Transect routes were directed from east to west across the reserve and defined as sectors (1-7). These generally included a range of altitudes from 900m down to -400m along the border with the Dead Sea. Various parameters were recorded during the study including the site name, its location (GPS coordinates), principle plant species present, and their life forms together with associated species and soil conditions. Various species were collected, photographed, and later deposited at the Herbarium of the Department of Biological Sciences, Faculty of Science, University of Jordan. From the various plant associations observed, three biogeographic regions were recognised, namely Mediterranean, Irano-Turanian and Tropical (Sudanian). In addition, five plant communities were identified and allocated to named classes as *Artemisia herba-alba; Retama raetam – Salsola vermiculata; Zygophyllum dumosum; hydric vegetation* and *tropical vegetation.* Differences within classes were grouped as sub-classes. The total number of plant species recorded during the survey was 408 which included several new and rare species to the flora of Jordan. An illustrated map showing the distribution of vegetation areas across the reserve is presented.

INTRODUCTION

The Mujib Biosphere Reserve is one of the largest reserves in Jordan. It situated within the mountain range of Jordan that extends with altitudes of 7425000 W to 757000 E and the latitudes of 3501000 N to 3474500 S. The reserve comprises rough terrain composed of a series of mountains, slopes and very deep valley formations with steep with inclinations extending to values in excess of 70% in some cases and often with inclinations ranging from 30 – 50 %. The reserve crosses a series of important wadis (valleys) including Zara, Zgara, Atoun, Wadi Abu Irteimeh, Wadi Um Ghreiba, Wadi Hidan, Wadi Um Zghaib and Wadi Mujib after which the reserve is named.

Mountain ranges in the study area vary in form and altitude. The higest altitude in Faqu' site is about 900 m at the southern borders of the reserve, while in Makawir at the southern border the height is 680 m. Again the mountains vary from 900-680 m in the eastern side and decline to about (- 400) m at the Dead Sea level in the West. Therefore, the reserve covers various stages geographical regions within which there are a series of microclimates. This kind of formation is reflected in the distribution of the flora and vegetation within the reserve, where three biogeographical regions are recognised, the Mediterranean, the Irano-Turanian and the Sub-tropical or Sudanian biogeographic region (Al-Eisawi, 1996) all of which occur within a relatively small area of about 220 km^2.

One of the earliest scientific studies of this region, before the area became a reserve, was a survey of plants carried out from the area of Ad-Daier near Makawer down to the west passing Zara and the Dead Sea (Al-Eisawi, 1983, unpublished work). The plants, which were collected there, are now deposited at the Herbarium of the Department of Biological Sciences, Faculty of Science, University of Jordan. Amman. One of the major references to Jordan is the work of Post, revised and published by Dinsmore (1932-1933) in the 'Flora of Syria Palestine and Sinai'. In his book 'Plant Life of Palestine' Zohary (1962) has covered most of the literatures related to the area until that date. Zohary's (1966-1972) work together with that of Feinbrun-Dothan (1978-1986) in the 'Flora Palaestina' are considered to be

the main references to the flora of Jordan. Zohary (1973) previously wrote the 'Geobotanical Foundation of the Middle East' in which he wrote extensively about the plant biogeographic regions, the major plant groups and formations across the whole area.

A major work related to Jordan and Mujib Biosphere Reserve is that of Al-Eisawi (1982), who published a list of vascular plants in Jordan in which more than 2000 species were recorded. Since then, various papers referring to the flora and biodiversity of Jordan have been published. A revised checklist including 2545 species has been recently published (Al-Eisawi, 2013). A few papers have been specifically concerned with the vegetation of Jordan including that of Al-Eisawi (1985). This latter work became the basis for the publication of a major reference entitled 'Vegetation of Jordan' sponsored by UNESCO (Al-Eisawi, 1996). An illustrated book (Al-Eisawi, 1998) also provides an account of more than 488 species of Jordan. Some of those species are also found in the Mujib Biosphere Reserve.

In 1996, The Royal Society for the Conservation of Nature (RSCN) conducted a survey of the water resources of the Mujib Biosphere Reserve. This was followed by surveys of birds and of mammals (carnivores) within the reserve (Hendig, 1998 and Nassar and Sabol, 1999 respectively). Details of the trapping methods developed during the latter study can be found in (Nassar and Sabol,1999). Nassar & Sabol (1999) studied the geology of Mujib Biosphere Reserve but also included details of location, access, topography, climate and vegetation and previous geological work. In that introductory study of the climate and vegetation, four main vegetation communities were identified with respect to elevation, namely:

i. Sudanian (with Saharo-Arabian) (15% of the total area)
ii. Saharo-Arabian (24.25% of the total area)
iii. Irano-Turanian (38.33% of the total area)
iv. Mediterranean transitional zone within Irano-Turanian (15% of the total area).

In 2000, the Research and Survey Section of the RSCN conducted a vegetation survey of Mujib as part of their Biosphere Reserve, Riverine

and Spring Vegetation Monitoring programme. This was based on a line transect along 2580 m of the River Mujib valley. Every twenty meters a record was made of the plants present across the water path. Species recorded included the following : *Saccharum ravenae (ravennae), Juncus maritimus, Inula crithmoides, Typha domingensis, Phragmites australis, Atriplex halimus, Tamarix sp., Nerium oleander, Blumea bovi, Sinapis arvensis, Ochradenus baccatus, Capparis spinosa (=Capparis cartilaginea)* and *Aaronsohnia factorovskyi.* However, this number of species represents only a relatively small proportion of the total biodiversity and richness of the area surveyed.

The RSCN (2001, 2002) submitted a report to the National Centre for Agricultural Research and Technology Transfer (NCARTT), under the title 'Inventory of Medicinal and Herbal Plants'. In this report a brief description of various areas of Jordan such as Ajloun woodlands, Safawi and Azraq study area, Mujib Biosphere Reserve and Feinan and Wadi Araba Study Area was given. Al-Noubani (2005), studied the distribution of *Teucrium polium* in addition to other elements of the flora of Mujib Biosphere Reserve in her thesis entitled: 'Productivity and Some Aspects of Phytochemical Analysis of *Teucrium polium* L. Grown in Different Environments'. In the study, she also recorded various counts of vascular plants from the sampling sites.

Although scientists (phytosociologists) currently have different views on the nature of the 'plant-community', most ecologists accept the existence of plant communities, which replicate themselves spatially within the two extremes proposed by Clements and Gleason. In practical terms, most plant communities are probably distributed according to a mosaic pattern. However, as human disturbances have become more intense, the boundaries of plant communities have become much sharper than under natural conditions. In some cases, vegetation components have been completely lost due to human impacts. Therefore, the main aims of this study were to re-define the vegetation communities within Mujib Biosphere Reserve and to produce a map of the distribution of these plant communities.

MATERIALS AND METHODS

Vegetation description

The method of description used here was based on the occurrence of species along a defined transect (floristics). Alternative methods based on physiognomic or structural features were considered inappropriate for the area. Where vegetation cover is scarce, as in the Mediterranean or arid or semi-arid desert, the most appropriate method of survey is the line transects method, which was used here. Initial surveys employed both 50m and 100m line transects due to the large areas to be surveyed.

Later, more systematic line transects were used to produce area based samples which could be allocated to a map. This method was used to produce small scale grid samples within a larger grid refernce system of survey. Where the terrain was too difficult to survey fully due to steep slopes or valley formations with rock beds, it was impossible to effect a survey based on a systematic selection of grid system. However, it was decided to make a survey along lines crossing the reserve from east to west to make sure that changes in vegetation with the drop in altitude was recorded.

Accordingly, the reserve was crossed from various parts of the reserve from east to west whenever possible, by walking and the use of a vehicle for ease of access. Various line transects and surveys were therefore completed by such means. The start and end points of each line were marked using a hand held GPS. Plant species along the lines were recorded and plant specimens collected for identification and preservation when necessary. Photographs of the plant communities and surrounding areas were taken, as well as individual plant species where appropriate. Particualr attention was given to hydric vegetation along the wadi formations during the survey.

Physical characteristic of the study area

Soil

Detailed soil surveys of the reserve have not been carried out to date, but from the observations made during this survey, the soils can be divided into one of the following groups:

i. Typical Mediterranean red soil or 'terra rosa'.
ii. Brown greyish clay like soil.
iii. Brown yellowish soil.
iv. Calcareous soil.
v. White chalk soil.
vi. Sandy soil especially, Kurnub (Cretaceous) formations
vii. Saline soil.

Vegetation types in relation to soil conditions were given for each line transect at the ten major sectors.

Temperature

Information related to temperature and rainfalls were extracted from RSCN reports (2001). The mean annual temperature ranged from 12.6 ºC at Fagu' to 29 ºC at Raddas on the Dead Sea. The hottest month was in July at Raddas 39 ºC and 29.6ºC in the eastern mountain side in Fagu'. In the coldest months temperatures were 3.7 ºC at Fagu' and 19 ºC at Raddas at a lower altitude in the west near the Dead Sea.

Rainfall

The rainfall is taken from RSCN (2001) records with an annual rainfall maximum of 326.5 mm in Fagu' and a minimum of 71.5 mm in Raddas. The month with maximum rainfall was recorded in Makawer in January with 83.5 mm, whilst in December it was 17.2 mm in Raddas. The period between June and September recorded no rainfall across all areas of study

RESULTS

A total of seven line transects crossing the reserve from east to west were surveyed. The length of the line transect varied less than 500m up to a few kilometers based on the road accessibility to walking on foot. The length of the line was calculated as a linear distance between the start and end point GPS coordinates of the transect. The start point of each transect was usually decided on the basis of a change in the vegetation structure. At other times the start and end points was sometimes based on the nature of the terrain.

Those areas surveyed were allocated to one of **seven** sectors, namely::

1. Sector 1 Makawir Dead Sea
2. Sector 2 Faqu' – Raddas
3. Sector 3 Al-Batheiah Dead Sea
4. Sector 4 Ad-Dair Makawir – Dead Sea
5. Sector 5 Dead Sea – Main
6. Sector 6 Bat-han, Mujib, Raddas
7. Sector 7 Wadi Shgaig – Dead Sea

Findings according to Sectors

The total number of areas surveyed, as previously mentioned, provides records for the seven major sectors crossing the reserve from east to west. Each sector includes many line transects varyiong from ten to 27 lines. In some cases specific detailed studies were made using parallel line transect for one of the lines up to times measuring various factors such as dominance, abundance, density, coverage, height and other factors to test our observation and recognition. In some other places the plant community was observed initially as an almost pure stand of one species but later became mixed with one or more other species such that the dominant species becomes replaced by another species.

However, the following example Makawer–Dead Sea line shows the details of obtained information in each line within one sector. Looking at the line transects and changing in altitude, a clear change in the plant species and their associated plant communities

is apparent. In this line, the starting point of the survey was 686 m and the end of the sector was 169 m with a declination of about 500 m unit as one reaches almost a stable type of ecosystem. Due to space limitation, it was not possible to put all the raw data collected from all sites. Sample of the vegetation survey for the various sectorts is represented in a similar way for Makawer sector. For all other sectors, actual data have been excluded from the account due to space limitations.

Sector 1 Makawir Dead Sea

Locality No 58/2005	**Line 1 Sector 1 (1/1)**
Locality	Makawir – Dead Sea
Vegetation	Mediterranean- Irano-Turanian vegetation
Dominant species	*Ballota undulata, Varthemia iphionoides, Artemisia herba-alba, Reaumuria hirtella, Noaea mucronata*
Community	*Artemisia herba-alba, Reaumuria hirtella, Noaea mucronata*
Soil	Clay soil, light brown becoming calcareous later on at lower altitudes
Coordinats	0748826 E 3496695 N
Altitude m	686-595
Notes	This line starts from Makawir Station down to the west for about 400 m. The terrain is rocky, rough and mostly covered by pebbles. The vegetation in the upper part is Mediterranean turning into mixed Mediterranean and Irano-Turanian elements. The density of the vegetation is about 35-40 %.
Date	11/10/2005
Collectors	D. Al-Eisawi
Line length	Variable

Coordinates	Starting E	Starting N	Ending E	Ending N	Inclination %	Height cm	Cover %	Altit
L1	0748826	3496695	0748439	3476089	40	40m	37	686-595

Recorded Species			
1.	*Aegilops sp*	25.	*Helianthemum salicifolium*
2.	*Allium desertorum*	26.	*Hippocrepis unisiliquosa*
3.	*Alyssum damascenum*	27.	*Hordeum glaucum*
4.	*Anthemis sp.*	28.	*Ifloga spicata*
5.	*Artemisia herba-alba*	29.	*Minuartia decipiens*
6.	*Ballota undulate*	30.	*Minuartia Formosa*
7.	*Bromus fasciculatus*	31.	*Noaea mucronata*
8.	*Bromus lanceolatus*	32.	*Ononis reclinata*
9.	*Bromus tectorum*	33.	*Onopordum sp*
10.	*Carex pachystylis*	34.	*Papaver argemone*
11.	*Carlina hispanica*	35.	*Paronychia argentea*
12.	*Carrichtera annua*	36.	*Phagnalon rupestre*
13.	*Carthamus tenuis*	37.	*Phlomis brachyodon*
14.	*Catapodium rigidum*	38.	*Plantago coronopus*
15.	*Centaurea hyalolepis*	39.	*Poa bulbosa*
16.	*Colchicum brachyphyllum*	40.	*Roemeria hybrid*
17.	*Crithopsis delileana*	41.	*Rostraria berythaea*
18.	*Crucianella ciliate*	42.	*Salsola vermiculata*
19.	*Cynosurus callitrichus*	43.	*Silene coniflora*
20.	*Daucus subsessilis*	44.	*Taeniathermum crinitum*
21.	*Echinops polyceras*	45.	*Torilis leptophylla*
22.	*Erucaria pinnata*	46.	*Urginea maritime*
23.	*Filago desertorum*	47.	*Varthemia iphionoides*
24.	*Filago pyramidata*	48.	*Verbascum fruticulosum*

Vegetation communities – descriptions

The major (recognisable) vegetation types are allocated to classes whilst variations within classes are called sub-classes, which represent a smaller plant community unit. Specific plant communities can be recognised within each line as part of the major transects profile. Such small communities can often represent a pure stand of one species or an alternative dominance of two to three different species. Since such findings are generalluy of a small scale restricted in size to m^2, they cannot easily be recorded on the map due to the large scale of the study area.

The hydric class can in fact be the frist of three major classes since it is restricted by the presence of water either as a continuous or with intermittent flow. While the tropical class is a deviation from the hydric vegetation and becomes recognised in location with hot springs such as those at Zara, or in habitats characterised by very low altitudes with hot temperature, similar to those wet habitats found along the road of the eastern side of the Dead Sea.

Within the Mujib Reserve, there are five major classes of plant communities and 18 very marked sub-classes, as shown in (Fig. 1). However, it is justified to say that some of the small communities (sub-classes) are often distributed between two major plant cover communities (classes). At other times, the leading species of one community (sub-class) becomes the second or the third most common in other communities. Some species such as *Salsola vermiculata,* and *Urginea maritima* occur in almost all parts of the reserve, while other species such as *Artemisia herba-alba, Teucrium polium, Ononis natrix,* and *Ballota undulata* are largely restricted to the highlands of the reserve, above 600m.

Similarly, the species of *Typha angustifolia, Phragmites australis, Nerium oleander, Arundo donax, Salix alba,* and *Tamarix spp.* are restricted to water availability and forming the major formation of the hydric vegetation. Again, *Moringa peregrina, Phoenix dactylifera, Imperata cylindrica* and *Saccharum spp.* Are only found in hot water springs and very hot wet conditions.

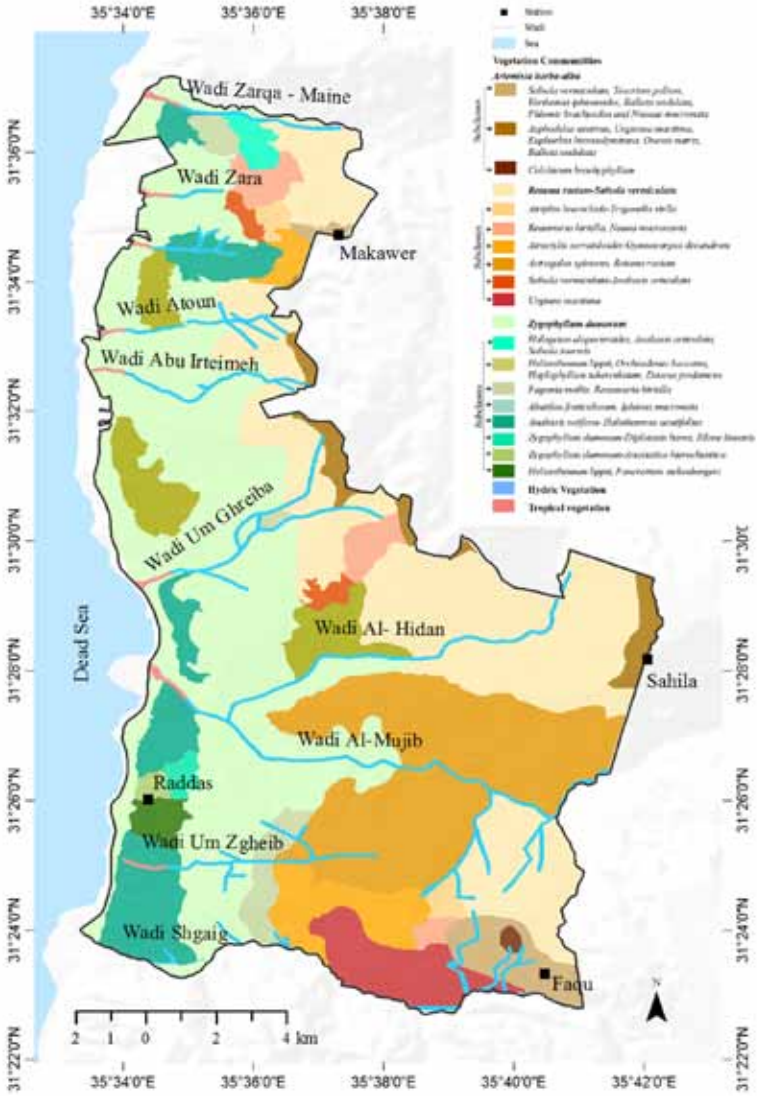

Fig. 1: Vegetation Communities at Mujib Biosphere Reserve

Therefore, it was clear that specific edaphic factors especially, soils type have played an important role in the distribution of other groups of species such as *Reaumuria hirtella* restricted to clay-salty soils. By contrast, *Haplophyllum tuberculatum, Daucus jordanicus, Helianthemum lippii* and *Ochradenus baccatus* are restricted to sandy soils of *Zygophyllum dumosum* class, which always occurs at an altitude of less than 400m.

Class 1. *Artemisia herba-alba* (Plate 1. A)

This type of vegetation is restricted to altitudes above 600 m. However, sometime penetration of one class with another class can be observed in a restricted area due to changes in rock or soil type. This class of vegetation is dominated by *Artemisia herba-alba* in combination with other plant species especially, *Salsola vermiculata, Teucrium polium, Varthemia iphionoides, Ballota undulata, Phlomis brachyodon, Noaea mucronata, Asphodelus aestivus, Urginea maritima, Ononis natrix,* and *Euphorbia hierosolymitana.*

When a new leading species within a restricted area appears even when the leading species of the class is still apparent then a new sub-class is recognised. This vegetation class is usually a Mediterranean type which occurs in the mountainous areas of south Jordan, especially when temperature is cold and rainfall is maximum in the local area, but generally less than that of the northern mountains of Jordan. The vegetation is dominated by perennial herbaceous and woody bushes and very low shrubs, with height ranging from 20 to 60 cm. Soil is usually of limestone origin and mostly of a brownish clay-loam type. This class has some variations of composition in the leading species leading to thesub-divisions:

Subclass: *Asphodelus aestivus, Urginea maritima, Euphorbia hiero solymitana, Ononis natrix* and *Ballota undulata*

Subclass: *Salsola vermiculata, Teucrium polium, Varthemia iphi onoides, Ballota undulata, Phlomis brachyodon,* and *Noaea mucronata*

Subclass: *Asphodelus aestivus, Urginea maritima, Euphorbia hiero solymitana, Ononis natrix* and *Ballota undulata*

Subclass: *Colchicum brachyphyllum*

Class 2. *Retama raetam- Salsola vermiculata* (Plate 1. B, Plate 2. A)

Retama raetam is typical of steppe vegetation, although it might extend its distribution to desert or marginal Mediterranean. It occurs in more humid places or in north facing slopes where the solar radiation is minimal to avoid soil dissection. In fact, *Salsola vermiculata* is a more dominant species in this class, but since *Retama raetam* is much higher plant, the name of class was given as *Retama - Salsola* rather than *Salsola – Retama*. The soil is mostly of soft limestone origin, with often calcareous to yellowish or gravelly features and a thin layer of clay like soil if present.

Salsola vermiculata know locally as *(Hamdh, Hamth)*, is a very important component of the grazing system in the dry ecosystem of Jordan. Wherever it is found it gives a good indication about the importance of the grazing land. As this plant is perennial and grows almost all the year round but especially during summer like most other members of the family Chenopodiaceae. Accordingly, the presence of this plant in most ecosystems of the reserve and at various altitudes is a good indicator of a highly palatable species. In fact, *Salsola vermiculata* was observed in almost all study sectors. This class varied in compostion so it is sub divided into the following subclasses:

Subclass: *Atriplex leucoclada – Trigonella stellata*

Subclass: *Reaumuria hirtella- Noaea mucronata*

Subclass: *Atractylis serratuloides- Gymnocarpos decandrum*

Subclass: *Astragalus spinosus- Retama raetam*

Subclass: *Salsola vermiculata- Anabasis articulata*

Subclass: *Urginea maritime*

Class 3. *Zygophyllum dumosum* (Plate 2. B, Plate 3 A)

This class is a typical low altitude tropical element of vegetation that dominates at the low hillsides of the Dead Sea and Arab Valley in Jordan. The class is characterised by having low woody shrubs of a height ranging from 30-70 cm and rarely more. The leaves are highly succulent, round and delicate flowers and winged pentangular fruits. All vegetative parts are palatable by local grazing animals especially, goats.

This class of vegetation is the leading species starting from about 400m above sea level becoming almost the single species at lower altitudes. If calcareous and lime stone condition change, where *Zygophyllum* is dominant, especially, when humid sand stone is available other members become clearly increasing and leading species such as *Ochradenus baccatus, Helianthemum lippii,* and *Daucus jordanicus.* This class has some variation in its composition and leading species resulting in the following sub-classes:

Subclass: Halogeton alopecuroides, Anabasis articulata, Salsola inermis

Subclass: Helianthemum lippii, Ochradenus baccatus, Haplophyllum tuberculatum and *Daucus jordanicus*

Subclass: Fagonia mollis - Reaumuria hirtella

Subclass: Abutilon fruticulosum - Iphiona mucronata

Subclass: Anabasis setifera- Halothamnus acutifolius

Subclass: Zygophyllum dumosum-Diplotaxis harra and Silene linearis

Subclass: Zygophyllum dumosum - Anastatica hierochuntica

Subclass: Helianthemum lippii - Pancratium sickenbergeri

Class 4. Hydric vegetation (Plate 3. B)

Hydric vegetation is a typical type of vegetation occurring along fresh water canals, wadis, rivers or water springs. Height, thickness and species composition of plant species varies according to the location of the fresh water passage. The altitude of the water passage and ecosystem often affect the occurrence of additional new species

or replacing exsisting species. The best examples of the fresh water ecosystem have been observed in Wadi Shgaig, Wadi Mujib especially at the exit leading to Raddas Station, and at Wadi Al-Batheiah. The vegetation may become very thick and difficult to penetrate due to the tree and high shrub dense formation especially when strong stream of running fresh water is available.

Vegetation components observed are usually the various species of *Tamarix, Nerium oleander, Arundo donax,* and *Phragmites australis.* In association with these dominant species, often, other important hydric elements become apparent such as *Ficus carica, Salix spp. Typha domingensis,* and many other herbaceous plants. This class has some variations of composition and leading species that are subdivided into the *Nerium oleander* and *Arundo donax subclass.*

Class 5. Tropical vegetation (Plate 4. A, B)

This type of vegetation is very much associated in the study area with hot springs, high humidity, low altitudes, and hot conditions. Such specific characteristics of this habitat have created almost a microclimate of hydric tropical vegetation within the study area, where dense vegetation dominated by few tree species. Other components of the vegetation are composed almost entirely of grasses. The trees and shrubs are largely made up of *Moringa peregrina, Phoenix dactylifera, Ziziphus spina-christi, Tamarix species* and by *Capparis deciduas respectively.* The remaining components of this vegetation group consist of often dense 'mats' of *Saccharum ravennae, Imperata cylindrica, Phragmites australis, Arundo donax* and of the fern *Adiantum capillus-veneris* together with the orchid *Epipactis veratrifolia.* Variations in the floral compostion of this class give rise to the sub-classes dominated by species including *Moringa peregrina, Phoenix dactylifera, Ziziphus spina-christi* and *Saccharum.*

DISCUSSIONS

The Mujib reserve contains a wide range and diversity of habitats. Much of this diversity reflects differences in altitude of over 1300m (range -400m to 900m below and above sea level). Additional species richness is generated by the presence of hydric habitats of fresh

water or hot spring, both of which are of particular interest to tourists. The reserve also spans three biogeographic zones within a limited area. This variation is of particular interest to ecologists and biologists with special interests in the variation of plant species, their distribution and evolution. Both the high temperature and altitudinal ranges provide opportunites for changes in slection pressures over relatively short distances.

The presence of these three biogeographic regions within such a limited area has caused a special pressure on the living organisms especially, at the meeting points and borders of zonation of the three regions. Such condition can produce certain plant and animal groups with specific sets of morphologic, genetic and ecological characters that can separate them as new endemic species, subspecies or varieties. Since the terrain is very rough in the Mujib reserve, sufficient time is needed to walk around carefully and safely trough the reserve to be able to observe the variety of species found growing within the boundaries of the reserve. This of course is very critical and true if the surveys are extended to include the various growth seasons and for a longer period. However, field survey and the observations of the vegetation types and species composition and distributions confirm that there are three biogeographic regions within the boundaries of the reserves as follows:

1. Mediterranean

This region in Mujib reserve, starts at the eastern boundaries of the reserve at an altitude of 900 to 600 m or a little less when the microclimate conditions permit the Mediterranean elements to develop which are identified as 'Mediterranean penetration', with an annual rainfall in excess of 250 mm. The Mediterranean region in Jordan is normally characterised by having a forest vegetation or a degraded forest vegetation, with soil types of Terra Rosa (red soil) or Rendzina (yellow soil). Although typical Mediterranean conditions have not been formerly observed within the reserve, Terra Rosa soils has been observed at the eastern borders of the reserve in Makawir and Faqu' areas which seesm to confirm its existence.

Most trees represented in the region consist of remants of a forest climax vegetation with a limited number of *Pistacia atlantica* at the eastern borders of the reserve west of Faqu' and Sarfa. This was the only proper element of forest formation but a very good indicator of degraded forest, which was present at one time within the past century or two. However, the widespread occurrence of *Artemisia herba-alba* in association with *Ballota undulata, Varthemia iphionoides, Eryngium glomeratum, Echinops polyceras* and *Phlomis brachyodon* are typical of a Mediterranean flora. The occurrence of *Artemisia herba-alba* in the Mediterranean region similar to the Mediterranean condition in Tafila, Shuabak, Ras an Nagab and other parts in Southern Jordan is an indication of high, cold, exposed and rather less rainfall typical of Mediterranean conditions. Due to this fact, some people recognise *Artemisia herba-alba* as *Artemisia seiberi,* since *Artemisia herba-alba* is a typical Saharo-Arabian element. *Euphorbia hierosolymitana* was the best example of the Mediterranean penetration within the Irano-Turanian conditions.

2. Irano-Turanian

This region is confined to the area ranging from 600 to 300 m above sea level with a rainfall ranging from betweee 250 and 100 mm. This area has calcareous soils and a vegetation consisting of small shrubs such as *Retama raetam* or *Astragalus spinosus*. The dominant vegetation is usually made of bushes of less than 50 cm height. This area is typical Irano-Turanian region of Jordan.

3. Tropical (Subtropical-Sudanian)

This region may start at an altitude of 400 m as an extension of penetration within the Irano-Turanian territory, but in general typical tropical region is well recognised at an altitude of 200 m above sea level down to - 400 m below sea level. Typical tropical vegetation includes trees and shrubs such as *Acacia sp. Salvadora persica, Maerua crassifolia, Moringa peregrina, Ziziphus spina-christi, Phoenix dactylifera, Balanites aegyptiaca* and *Calotropis procera.* Unfortunately, typical tropical (Sudanian) vegetation falls outside the reserve at the western borders of the reserve, where the majority of such conditions lie within private property. Typical tropical vegetation in Mujib is

characterised by the sudden appearance and dominance of a single species *Zygophyllum dumosum,* which is a low succulent shrub or bush, usually in association with other plants depending on the soil conditions.

Often, within the tropical area, the presence of streams, canals and or hot spring are very important for the presence of specific hydrophilic tropical elements such as *Imperata cylindrical, Saccharum ravennae, Capparis decidua, Moringa peregrina, Adiantum capillus-veneris,* and *Phoenix dactylifera* amongst others.

In addition to the above factors the Mujib Biosphere reserve also contaians at least two endemic plant species, *Iris edomensis* and *Daucus jordanicus* and a few rare species such as *Crocus cartwrightianus, Capparis decidua,* and *Epipactis veratrifolia.* Newly discovered species like *Pancratium parviflorum* are likely to be added to as the reserve as it receives further study. Thus, the reserve is important for its varied ecology and plant biodiversity but also as a venue for ecotourism

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Plate 1

A: *Artemisia herba-alba* vegetation

B: *Retama raetam* vegetation calss in association with *Urginea maritima*

Plate 2

A: *Astragalus spinosus* class of vegetation subclass *Astragalus spinosus- Retama raetam*

B: *Zygophyllum dumosum class*

Plate 3

A: *Zygophyllum dumosum class*

B: Hydric Vegetation

Plate 4

A: Tropical vegetation, showing a local orchid *Epipactis veratrifolia*

B: Wild Palm

Contribution to the Hawk Moths (Sphingidae: Lepidoptera) of Jordan

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ABSTRACT

Hawk moths (Sphingidae) have been collected from different parts of Jordan by light traps from 2007 to 2014. Unidentified specimens preserved at the Unversity of Jordan Insects Museum were examined. The following nine species are recorded from 38 localities across Jordan: *Acherontia atropos* (Linnaeus, 1758), *Agrius convolvuli* (Linnaeus, 1758), *Marumba quercus* (*Denus & Schiffermuller*, 1775), *Daphnis nerii* (Linnaeus, 1758), *Macroglossum stellatarum* (Linnaeus, 1758), *Hyles euphorbiae conspicua* (Rothschild & Jordan, 1903), *Hyles livornica* (Esper, 1779), *Hippotion celerio* (Linnaeus, 1758) and *Theretra alecto cretica* (Boisduval, 1827).

Key words: Jordan, hawk moths, Sphingidae, Lepidoptera.

INTRODUCTION

Hawk moths are stout-bodied moths with long narrow front wings. The family Sphingidae Latreille 1802, contains 1450 species after the adults of which are often seen feeding in front of flowers. Their larvae or caterpillars are large and have a distinctive horn at their rear. As a group they are widely distributed across the world except in Antarctica (Kitching et al. 2014).

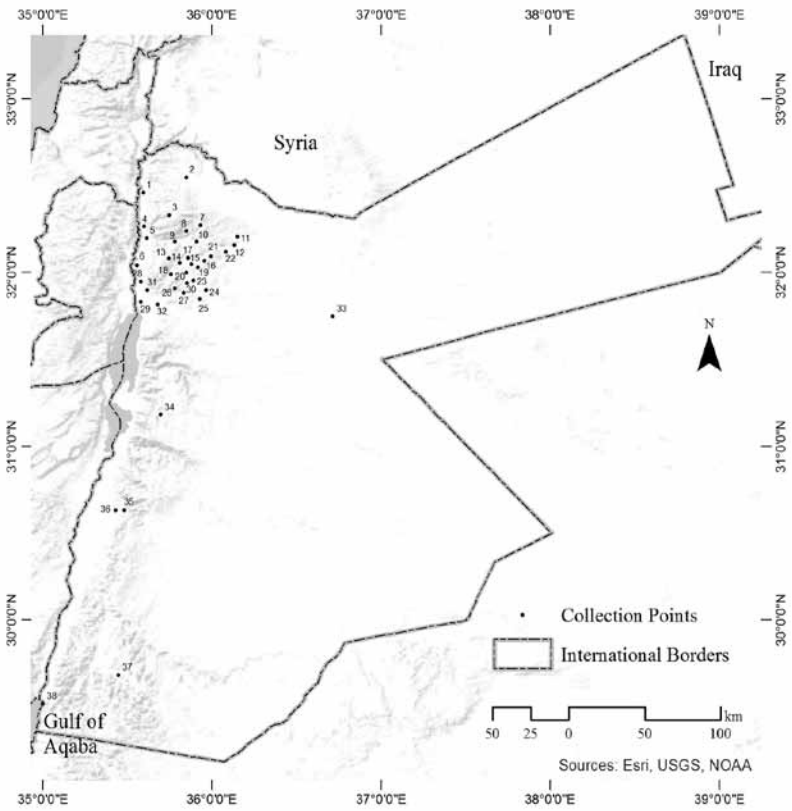
A number of studies have been carried out on hawk moths in the Middle East although few of these refer to Jordan. For example, several papers were published on the Sphingidae of Saudi Arabia

(Pittaway, 1979; Pittaway, 1981; Wiltshire, 1980a; Wiltshire, 1986; Wiltshire, 1990). Wiltshire (1957; 1980b) recorded 18 species of hawk moth from of Iraq and provided notes on those of Lebanon, Syria and Sinai. Talhouk (1997) recorded 16 species of hawk moth from Lebanon with colour photographs. Müller, et al. (2005b) recorded 21 species from Palestine. In Jordan, Müller et al. (2005a) recorded 21 species and described their distribution, phenology and ecology. A general review of the ecology and biogeography of hawk moths of the Western Palaeartic is provided by Pittaway (1995). A definite account of the species of the region including their nomenclature, biogeographical affiliations, descriptions, biology, photos of adults and immatures, host plants, parasitoids and geographical distribution can be found in his website (http://tpittaway.tripod.com/sphinx/list.htm) .

Given the limited information available on the hawk moths of Jordan, the main aim of this work is to document recent records obtained from trapping and identified with those in national museum collections.

MATERIALS AND METHODS

A survey of the moths of Jordan, including the Sphingidae began in 2007. Light traps were placed in localities across the Jordan Valley, Highland and the Desert (Fig. 1). In addition, specimens of hawk moths collected previously from Jordan (preserved at the University of Jordan Insects Museum) were examined and identified. For those species caught, the scientific name, common name, specimens examined, biogeographical affiliation, world distribution, remarks and colour photographs are given. The world distribution patterns follow those of (Pittaway, 1997-2014). Localities in Jordan (Fig. 1) were arranged alphabetically and dates were arranged chronologically according to the month. The number of specimens was placed after the date between brackets which was followed by the collector. Unless otherwise mentioned, the museum staff or the author of this article was the collector. All specimens were deposited at the University of Jordan Insects Museum.



1 Al Mashre
2 Irbid
3 Ajloun Reserve
4 Al Kurayyimah
5 Dayr Alla
6 Ain Ghazal
7 Jarash
8 Old Jarash Road
9 Al Mastabah (Near Jarash)
10 Al Qasabat (Al- Qasabah)
11 Al Hashimeyyah
12 Az Zarqa
13 As Salt, As Salalem
14 Abo Nusayr
15 University of Jordan Farm
16 Shafa Badran
17 University of Jordan
18 Suwayleh
19 Al Jubayhah
20 Khildah
21 Tabarbawr
22 Ar Rusayfah
23 Amman
24 Abo Alandah
25 Jawah
26 Marj Al Hamam
27 Naur
28 Wadi as Sayr
29 Al-Rameh Farm
30 Jabal Amman
31 As Shounah Al Janoubiyah
32 Hisban
33 Ash Shawmari
34 Al Karak
35 Dana Reserve
36 Finan
37 Rumm
38 Al Aqabah

Fig. 1: Map of collecting sites

RESULTS

A total of 169 specimens of hawk moths from 38 localities were examined during this study. They were identified and allocated to one of nine species as follows.

Acherontia atropos (Linnaeus, 1758)
Death's Head hawkmoth, (Plate 1)

Specimens: n = 3 specimens. Univ. of Jordan,?. X.2009, (1), Univ. of Jordan Farm 27.XII.200? (1); Amman 29.IV.1998 (1).

Biogeographical Affiliation: Palaeotropical; Afrotropical region. Has become part of the present-day Holomediterranean faunal element.

Distribution: An Afrotropical species which extends north to the Mediterranean (including the whole of North Africa and the Middle East) and across Cyprus, Turkey, the Republic of Georgia to north-eastern Iran, the Ukraine, Turkmenistan, Mesopotamia, Kuwait and western Saudi Arabia. It is also found in the Canary Islands, Madeira and on the Azores, and throughout Europe as a migrant, including Iceland. Recorded as a vagrant as far north as Izvail' in European Russia, and as Far East as Pavlodar in north-eastern Kazakhstan.

Remarks: Only three specimens were caught during this study which agrees with the findings of Müller et al. (2005) who described it as rare although it could be found in all phytogeographical zones of Jordan, including the desert. The specimens from the Jordan Valley were from a vegetable farm containing some fruit trees. Caterpillars were observed in large numbers within small-untreated sweet potato and tomato fields. Adults were recorded from early June to November; most specimens were collected from July to October (Müller et al., 2005).

Agrius convolvuli **(Linnaeus, 1758)**
Convolvulus hawkmoth (Plate 2)

Specimens: n = 4. Al Mashre'a, Irbid Gov. 9.XI.1995 9(1); Al Masta bah (Near Jarash), 20.XI.1997(1); Rumm 30.X.2010 (1); Univ. of Jordan Farm 12-14.IX.2008 LT(1).

Biogeographical Affiliation: Palaeotropical and Australasian.

Distribution: Resident in only the warmest areas of the western Palaearctic, but as a migrant to almost the entire region. Recorded as far north as Yaksha in European Russia and as far west as Ireland and the Azores. It is one of only three species of sphingid recorded from Iceland.

Remarks: The collected specimens come from the Jordan Valley, the highlands and the desert. Müller et al. (2005) stated that it was common in the Mediterranean zone and uncommon in the Irano-Turanian grasslands and few specimens were collected in the desert or in oases. Large numbers of caterpillars were seen in *Ipomoea* fields (Convolvulaceae). Other food plants include *Convolvulus* and *Zygophyllum dumosum* (Zygophyllaceae). Records were from early May through November. There were two flight peaks, one in June and a more pronounced one from August to September. All records from the desert were from September to October.

Marumba quercus **(Denus & Schiffermuller, 1775)**
Oak Hawkmoth (Plate 3)

Specimens: One specimen from Ajloun Reserve, 18.VIII-1IX.2009.

Biogeographical Affiliation: Holarctic; western Palaearctic region.

Pleistocene refuge: Polycentric – Holo-mediterranean refugia.

Distribution: From the Rif and Atlas Mountains of Morocco, Portugal and Galicia, Spain, across southern and central Europe to Turkey, Transcaucasia, the Republic of Georgia, western Kazakhstan, Lebanon, Palestine, western and northern Jordan, northern Iraq and

south-west Iran (Shiraz). Also from northern Iran to the lower Volga River and southern Turkmenistan.

Remarks: The only specimen was collected from Ajloun reserve in which oak trees are abundant. Pittaway (1997-2014) stated that this species occurs at low population densities so its presence may go undetected for long periods. However, Müller et al. (2005) found that the species was common in oak forests in the Northern Highlands and the Western Mountain range as far south as the Dana Nature Reserve. Jordan is considered the southern limit of this species in the East Mediterranean. The parasitic fly, *Drino (Palexorista) imberbis (Wiedemann)*, was reared from one caterpillar. Adults fly from late April to late September with a peak from May to June and another one from August to early September. This suggests that the species has two generations in Jordan (Müller et al., 2005).

***Daphnis nerii* (Linnaeus, 1758)**
Oleander Hawkmoth (Plate 4)

Specimens: n = 6. Abo Nusayr, 15.X.2002(1), Adnan Khateeb; Al Aqabah, larva pupated on 24.X.2009(1), emerged 18.XI.2009 reared by Wafa Naser; As Salt 7.V.2007(1); Finan 9.IX.2010 (1), Malek Awaji; no data (1),Wadi Shuaib, 8-9.VI.2013(1).

Biogeographical Affiliation: Palaeotropical.

Distribution: The southern Mediterranean region, North Africa and the Middle East to Afghanistan and Turkmenistan. Along the Mediterranean, there is no clear distinction between resident and migrant populations. Permanent populations exist in suitable locations in Sicily, Crete and Cyprus; however, over a number of favorable years further colonies may be established in those islands and in southern Italy and southern Greece, all of which may die out during a hard winter.

Remarks: This species was common on oleander (Apocynaceae) in the Mediterranean zone and in wadis within the Irano-Turanian area. However, in the desert, it occurred in irrigated settlements. In the Jordan valley, it is common but subject to large annual fluctuations.

Records from southern oasis and the Jordan Valley are from March to December. In the Mediterranean Hills, it was found from April to October with a pronounced peak in July and August (Müller et al., 2005). It probably feeds on *Ipomoea* (Convolvulaceae) and other plants.

***Macroglossum stellatarum* (Linnaeus, 1758)**
Hummingbird Hawkmoth (Plate 5)

Specimens: n = 39. Abo Alandah 21.III.1993(1), on flower; Al Jubayhah, 8.I.1977(1), 15.III.1978(1), 31.I.1983(1), 10.III.1993(1), 12.X.1983(1), 18.X.1977(1), 25.XII.1979(1); Al Qasabat 16.IV.1997 Akram Quay(1); Amman 8.III.2014(1), 12.XII.1987(1), 26.IX.1991(1), 8.X.1997(1), 10.XII.1992(1), 17.VIII.1990(1); As Salt, As Salalem, B. Gneimat, 13.VIII.1993(1) , 17.IV.1993(1); As Shoumari, 3145N 3643E, 18-24.V.2010(6); As Shounah Al Janoubiyah 7.XI.1985(1); Az Zarqa'a 25.X.1992(1); Irbid, 4.VIII.1992(1); Jawah 9.I.1993; Marj Al Hama, 14.XI.1992(1); 2.V.1992(1); Old Jarash Raod 18.IV.1979(1), Suwayleh 25.X1992(2), 16.V.1981(1), 24.III.1983(1); Tabarbour, 19.III.2010(1); Univ. of Jordan , 8.II.1982(1), 30.II.1993(1), 10.III.1993(1), 15.X.1993(1) , 19.IV.1992(1).

Biogeographical Affiliation: Holarctic; Palaearctic (both eastern and western subregions).

Pleistocene refuge: Polycentric – probably several refugia, from the Mediterranean to the Sinopacific.

Distribution: From southern Europe and North Africa to Central Asia, the Altai Mountains, the Middle East and Pakistan. A summer migrant to the north, with one example recorded from Syktyvkar in European Russia. In the southernmost part of its normal range, confined to mountains, as in Iran, Oman and the Hoggar of Algeria. This is only one of two species of sphingid to have reached the Azores.

Remarks: It was abundant in the Mediterranean, Irano-Turanian and in the Ethiopian zones while in the desert, it was fairly common in wadis. It may be seen hovering over flowers at sunset. Several thousand specimens were seen in late August, 1999, moving

within two hours in the Southern Mountain Desert in a north-west erly direction. The species was found all year but with with peaks from March to May and August to September (Müller et al., 2005). Larsen (1976) reported that this species in Lebanon spent the time from October to November until February and March hibernating in caves and crevices, though a few specimens were on the wing in the winter months. Often specimens were found dead on the windows of disused houses in spring. However, scores of hibernating *M. stellatarum* were found between the layers of stored goat-skins.

Hyles euphorbiae conspicua **(Rothschild & Jordan, 1903)**
Spurge Hawkmoth (Plate 6)

Specimens: n = 23. Ain Ghazal, 10.VII.1975(2), 31.V.1977(1), 10.VII.1975(1), 10.VII.1975(1); Al Jubayhah, collected 4.IX.1988 emerged 1.VI.1989(1), 4.VIII.1979(1); Amman, reared in museum, emerged 17.VII.1981 (1) R. Jado, 18.VII.1981 (2), 29.VI.1980(1), 20.VI.1981(1), 30.VIII.1980(2), 2.VII.1980(1), 7.VII.1980(2), 12.VII.1980(1), 21.VI.1988(3); Na'ur, 15.VII.2009(1); Old Jarash Road, 12.IV.1980(1).

Biogeographical Affiliation: Holarctic; western Palaearctic region.

Pleistocene refuge: Monocentric – Syrian and/or Syroeremic refuge.

Distribution: Palestine, Jordan, Lebanon, Syria, southern Turkey, Armenia and northern Iraq into northwestern Iran.

Remarks: All of our records come from the highlands mostly collected between June and August. However, Müller et al. (2005) found this species to be common in the Mediterranean and the Irano-Turanian grassland, uncommon above 1000 m in the Mediterranean Hills but rare in the desert and in Wadi Arabah. Caterpillars occur on *Euphorbia* sp. (Euphorbiaceae). The parasitic fly *Spoggosia aegyptiaca* (Tachinidae) was recorded from larvae collected near Irbid. Records were from late March to early November, with the highest numbers during late June to mid-September. The species has at least in two generations in Jordan.

*Hyles livornica (*Esper, 1779*)*
Striped Hawkmoth (Plate 7)

Specimens: n = 69. Abo Alandah, 3-5.IV.2009(1); As Salt 26.VII.1994(1); Al Hashimeyyah 21.V.1980(1);Al Jubayhah IV. 1997(1) Taymeyyah Dwood , 23.V.1990(1), 1.IV.1997(1); Al Kurayyimah 27.III.1994(1); Al-Rameh Farm 15.IV.2009 (1); Amman 4.V.1980(1), 6.V.1980(3), 29.IV.1996(1), 20.III.1997(1), 1.V.1997(1); Ash Shawmari, 14.IV.-6.V.2009(5), 10-16.V.2009(2), 18-24.V.2010(1), 24.V. 2010(1); Az Zarqa , 15.V.2010(1) Met'eb Al-Khalayleh, 19.IV.1993(1), 21.V.1980(10), 10.VII.92(1), 27.V.1994(1); Dana Reserve, 20.IV.1997(1), H. Quattous; Dayr Alla 12.IV.1997(1), 30.III.1997(1); Hisban, no date, Rami (3); Irbid 12.V.1992(1); Jabal Amman 16.V.1980(1); Nau'r 25.VI.2007(1) Rana Jado; Rumm 2941N 3527E, 27.III.2010(2) Dr. Luma Al Banna; Shafa Badran, 8-10.III.2009(1), 20.III.2009(1), 30.III-2.IV. 2009(1), 23.IV.2009(2), 2-4.IV.2009(1), 25-28.IV.2009(1); Tabarbawr 23.III.2009(1); Univ. of Jordan Farm 5.III.1995(1); 27.III.1994(1) M. Khawaldeh, 9.II.2009(1),23-24.III.2009(2), 4-11.V.2008(1), 13-20.V.2008(1), 15.III.?(1), 15.XII.1997(1), 27.II.1995(1), 4.III.1997(1), 22.III.1997(1); Wadi as Sayr 1.III.1997(1), 14.V.1993(1).

Biogeographical Affiliation: Palaeotropical (but not rainforest areas of Africa and Asia), Holomediterranean and Saharo-Arabian.

Pleistocene refuge: probably the Afrotropical region.

Distribution: Occurs throughout the region, but resident only in the south; a migrant elsewhere. Often found in very large numbers, except the extreme north. Recorded several times from Novosibirsk in western Siberia, Russia.

Remarks: Our records come from the Jordan Valley, the highlands and the eastern and southern deserts. Most of the specimens were obtained from March to May. Müller et al. (2005) found this species to be common throughout the country and abundant in the Irano-Turanian zone. The highest numbers were observed in Wadi Arabah and the Central Plateau. Large numbers of emergent larvae was observed in the spring of 1999 in Al Azraq Wadi. During the third

instar the larvae consumed most of the natural food plants available including *Rumex, Emex,* Euphorbia in an area of several square kilometers. Later the caterpillars migrated and invaded bushes of *Prosopis farcta* and *Atriplex halimus*. Local Bedouins said that they had observed this kind of mass development at intervals of about 10 years, especially after years with heavy rains and thick vegetation. More than 80% were parasitized by the flies *Spoggonia aegyptiaca* and *Nemorilla maculosa* (Tachinidae). Recorded all year round with a strong peak from late March to May.

***Hippotion celerio* (Linnaeus, 1758)**
Silver-striped Hawkmoth (Plate 8)

Specimens: n = 6. Amman 12.IV.1997(1); Shafa Badran 23.IV.2009(1); Univ. of Jordan Farm 27.X.2008(1), 4-7.IX.2008(1), 18.II.2009(1), Reared in museum, emerged 9.XI.1988(1).

Biogeographical Affiliation: Palaeotropical.

Distribution: A notable migrant in most years from tropical Africa and India to the western Palaearctic region. In warm years, new colonies may even be established in North Africa and Europe, so the delineation between resident and migrant ranges cannot be clearly defined. It is resident in the Canary Islands, and probably also in the Azores and along the Atlantic coast of Morocco. It is certainly resident in many areas of the Levant and the Arabian Peninsula, and Egypt.

Remarks: Our specimens were collected from the highland and the Jordan Valley. Müller et al. (2005) reported that this species was very common in the Irano-Turanian and Saharo-Arabian zone and less common in the Mediterranean parts of the country. The highest numbers were regularly seen in Wadi Arabah, and central Plateau. Numerous caterpillars were observed in the southern Mountain desert, especially in wadis with *Emex* and *Rumex* (Polygonaceae). From 10 caterpillars collected in a grape vineyard near Amman, one was parasitized by the fly *Drino (Zygobothria) atropivora* (Robineau-Desvoidy) (Tachinidae). Adults were found all year round with

a well-pronounced peak in April and May. Populations fluctuated highly from year to year and it was not clear if this was because of migration or local mass developments.

Theretra alecto cretica (Boisduval, 1827)
Levant Hawkmoth (Plate 9)

Specimens: n = 22. Al Fuhays, collected 2.VI.1978(1) pupated 6.VI.1978 emerged 18.VII.1978(1); Al Hashimeyyah 13.IV.1980(1); Al Jubayhah 28.VII.2008(1), 12.V.2008(1), 28.VII.2008(1) Riyad Zumar, 18.VIII.2008, 2.V.1991(1), 4.V.1991(1) Rana, 15.IX.2008 Riyad Zumar, 25.V.2008(1); Al Karak 2.IX.? Amman 14.V.1979(1), 6.VII.1979 larva, pupa 9.VII.1979, adult 29.VII.1979(1), 16.V.1980(1); Ar Rusayfah reared in Museum emerged 23.VI.1997(1); Irbid 14.VI.1993(1); Az Zarqa'a 6.X.1987(1); Jarash, no date, Dr. Luma Al Banna; Khildah 3.XI.2010(1); Marj Al Hamam 2.V.1992(1); Suwayleh 1.X.1975(1), 12.VIII.1981 larvae, emerged 7.IX.1981(1), 26.VII.1993(1), 1.X.1975(1), larva 22.VIII.1981 emerged 12.IX.1981; Univ. of Jordan Farm 7.V.1988(1).

Biogeographical Affiliation: Palaeotropical; Oriental region. Penetrates the warmest areas of the western Palaearctic region.

Distribution: A species which is partially migrant, individuals having been found as far west as Sicily and north to Romania; resident in south-western Bulgaria. It is regularly found in Corfu, where it may be a resident. It is a rarity in Romania. The main distribution stretches from Greece across southern and eastern Turkey, Cyprus to Transcaucasia, the Republic of Georgia, Daghestan and most of Iran, Turkmenistan, Uzbekistan, Kyrgyzstan and Afghanistan, and south to Iraq, Lebanon, Palestine, Jordan and the more fertile areas of Egypt.

Remarks: All of our records come from the highlands with two locations close to the eastern desert. Müller et al. (2005) found that the species was common in the Mediterranean Hills and the Irano-Turanian grassland and rare in the Saharo-Arabian zone in the south although some specimens were collected in Aqaba. Caterpillars are

pests in vineyards in the Jordan Valley. Records were from the end of March to December, depending on the year with an occasional spring and regular well-pronounced summer peak. Spring peaks, generally occur during May and summer peaks were from June to December.

DISCUSSION

This is the second published paper about the Sphingidae of Jordan after that of Müller et al. (2005). Nine species are recorded from Jordan collected from 38 different localities across the country. This number is less than half the number of species recorded from Jordan by Müller et al. (2005) (21 species) during a seven years project aimed to study the Middle East Lepidoptera from 1998-2004. They used a total of 850 nights of mobile light traps and several permanent light traps moved annually. The traps used in this study were 6-8 fixed light traps, which were also moved annually. Therefore, the study of Müller et al. (2005) was much more extensive in time and space. However, nine of their recorded species were recorded from Jordan for the first time, more than half of all species were rare, and the majority was found in three or fewer localities. This may explain the low number of species collected in our study.

All of the recorded species in this study occurred in the Mediterranean zone, though some of them were not restricted to this zone and occurred in the Jordan Valley, Eastern or Southern Desert or as far south as Aqaba. This agrees with the previous results of Müller et al. (2005) who also found almost all the species in Mediterranen Zone of Jordan.

Several species of Jordanian hawk moths have their limit of distribution in Jordan. The southern distribution limit is Jordan for *Akbesia davidi, Marumba quercus, Smerinthus kindermanni kindermanni, Sphingonaepiopsis gorgoniades pfeifferi and Proserpinus proserpina proserpina. Acheronia styx styx,* which is mainly found in the Oriental Region, was collected in the Al Azraq Oasis (Müller et al. 2005). This is currently the most westerly record for this species in Jordan. Its occurrence in Jordan may be as a migrant. Such outlying 'populations' may be of interest especially for molecular studies concerned with population variation or expansion.

Six species were recorded in Jordan from one or two specimens only, namely *(Acheronia styx styx, Dolbina elegance, Akbesia davidi, Hemaris alaiana, Hemaris (Cochrania) croatica croatica and Rethera komarovi drilon)* (Müller et al. 2005). The status of such rare species needs further research regarding their habitat or migration.

The species described in Eitschberger et al. (2005) as *Hemaris molli* from a single female from near Irbid looks superficially like *Hemaris fuciformis*, although the illustrated example lacks the dividing line of scales in the forewing cell. Intriguingly, the corresponding genitalial preparation appeared to be similar to that of *Hemaris* radians (Walker, 1856) from the eastern Palaearctic. Further studies, including DNA barcoding, have demonstrated that *Hemaris molli* appears to be an example of *Hemaris alaiana*. This raises an interesting question. The individual could be a mislabeled specimen from Central Asia or represent an isolated population resident in the Levant which requires further investigation (Pittaway, 1997-2014).

The study of the migration of *Macroglossum stellatum*, population fluctuations of *Agrius convolvuli* and *Hyles livornica*, and the host plant for the larvae and adults of many species could be interesting aspects of studying the Sphingidae of Jordan in the future. All parasitic flies that were found on the Jordanian Sphingids belonged to Tachinidae (Diptera). These were *Drino (Palexorista) imberbis* (Wiedemann), *Drino (Zygobothria) atropivora* (Robineau-Desvoidy), *Spoggosia aegyptiaca* and *Nemorilla maculosa* (Müller et al., 2005). The study of the parasitization of such flies, their host range and the presence of other species in Jordan may provide new and interesting data.

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Plate 1: *Acherontia atropos* (Linnaeus, 1758)
Wing span: 10.5 cm

Plate 2: *Agrius convolvuli* (Linnaeus, 1758)
Wing span 11.2 cm

Plate 3: *Marumba quercus* (Denus & Schiffermuller, 1775)
Wing span: 6.5 cm

Plate 4: *Daphnis nerii* (Linnaeus, 1758)
Wing span: 8.7 cm

Plate 5: *Macroglossum stellatarum* (Linnaeus, 1758)
Wing span: 5.5 cm

Plate 6: *Hyles euphorbiae conspicua* (Rothschild & Jordan, 1903)
Wing span: 7.7 cm

Plate 7: *Hyles livornica (*Esper, 1779)
Wing span: 6.3 cm

Plate 8: *Hippotion celerio* (Linnaeus, 1758)
Wing span: 6.5 cm

Plate 9: *Theretra alecto cretica* (Boisduval, 1827)
Wing span: 8 cm

Notes on the current and past freshwater snail fauna of Jordan

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ABSTRACT

Past and current distribution of the freshwater snils of Jordan is given. The freshwater snail fauna of Jordan belongs to two subclasses of the class Gastropoda (Prosobranchia and Pulmonata). Prosobranchians includes seven families (Bithyniidae, Cochliopidae, Neritidae, Hydrobiidae, Melanopsidae, Neritidae, Thiaridae and Valvatidae) with ten genera (*Bithynia, Globuliana, Heleobia, Melanoides, Melanopsis, Plotia, Pseudamnicola, Pyrgophorus, Theodoxus* and *Valvata*) representing 16 species. Pulmonates are represented by three families (Lymnaeidae, Physidae and Planorbidae) within six genera (*Bulinus, Haitia, Galba, Gyraulus, Lymnaea* **and** *Planorbis*) and six species.

Keywords: Prosobranchia , Pulmonata, Jordan, Invasive species.

INTRODUCTION

In spite of the limited range and size of freshwater habitats in Jordan, at least 19 species of snail have been recorded across the country (Burch et al., 1989). Particular attention has been given to those species, which are known to be the intermediate hosts of human parasitic diseases such as, schistosomiasis and fasciolosis (Abdel-Azim & Gismann, 1956, Saliba et al., 1976, Lutfy et al., 1978, Saliba & Othman, 1980, Arbaji et al., 1998). In 1950 and 1951 a study was commissioned by the World Health Organiza tion (WHO) to search for *Bulinus truncatus*, the intermediate host for

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schistosomiasis, across south-western Asia including Jordan (Azim and Gismann,1956). This study also provided records of *Melanopsis* sp. of various forms from the Jordan and Zarqa rivers. Additional information on the freshwater snails of Jordan can be found in Scates (1968) and Schütt (1983a & b). Outside Jordan, Tristram (1865) provides various records of the freshwater and land snails of Palestine, Jordan, Lebanon and Syria. He also found *Melanopsis ammonis* from "the streams of *Heshbon* and *Ammon*".

Within Jordan, the freshwater snails of the Azraq Oasis have received a considerable attention, especially in the 1960s. During an International Jordan Expedition, freshwater snails from Azraq were collected by M. Goerge and J. Rzoska and stored at the British Museum of Natural History, London. Some details from this collection were published by Brown and Wright (1980). Scates (1968) listed five definitely identified species of snail (*Melanoides tuberculatus, Melanopsis praemorsa, Theodoxus macrii, Planorbis planorbis philippii,* and *Limnea auricularia* [Sic]. She expressed some confusion about *Hydrobia* sp. and stated that this genus is represented by three forms, one of which is similar to that of *Hydrobia ventrosa*, although the other two forms were not clearly identified. Nelson (1973) listed six species of freshwater snails from Druze and Shishan ponds in Azraq. Perhaps he quoted Scates (1968), and included *Hydrobia ventroser* [Sic] (=*Hydrobia ventrosa* (Montagu, 1803)) in addition to other common species known from Azraq.

More recently, the collections made by Prof. Ragner Kinzelbach and his students between 1975 and 1980 from the Middle East were re-examined by Schütt (1983a). Although the surveys were confined to only a relatively few sites, seven species of snail were recorded then. Schütt (1983b) also examined the collection obtained by the German geologist Dr. Klaus Bandel made in 1978 while stationed in Jordan. He recorded 14 species of freshwater snails from several locations.

Between 1981-1983, the first comprehensive study on the freshwater snails of Jordan was carried out through efforts on Prof. Elias Saliba (University of Jordan) and the Ministry of Health in partner ship with Prof. John Burch (University of Michigan, Ann Arbor, USA)

and Prof. John Bruce (University of Lowell, USA). Two hundred and thirty nine freshwater sites were surveyed across the country. The results of this survey were published initially by Burch & Bruce (1985), and then by Burch et al. (1989). They listed a total of 17 freshwater snail species. Collected specimens are now held at the museum of Zoology, at the University of Michigan, Ann Arbor.

Previous studies on the freshwater snails of the Middle East, particularly on Syria and Lebanon were published by Germain (1921-1922) and Pallary (1929, 1939). More detailed studies on the freshwater snails of neighboring countries are given in Schütt (1983a and b) and Kinzelbach (1980) for Syria; Alouf (1998), Glöer & Bößneck (1997 a & b) and Bößneck (2011) for Lebanon, and Neubert (1998) for the Arabian Peninsula. Thus, the main aim of the current study was to re-examine the freshwater snails of Jordan through direct field surveys and where necessary to update the current taxonomic status of individual species.

MATERIALS AND METHODS

Eighty five freshwater sites representing several aquatic habitats (springs, dams, water collecting pools, swamps, rivers and streams, ponds and irrigation canals) were surveyed for the presence of freshwater snails between 2010 and 2013. Samples were collected by hand or by means of a 2 mm pore size sieve for small-sized and mud-dwelling species. Specimens were then preserved in plastic containers containing 70% ethanol. For each site, a standard snail survey form was completed including description of the site body is main features and surrounding landscape.

RESULTS

The freshwater snail fauna belongs to two subclasses of the class Gastropoda (Caenogastropoda and Pulmonata). Prosobranchians includes seven families (Bithyniidae, Cochliopidae, Neritidae, Hydrobiidae, Melanopsidae, Neritidae, Thiaridae and Valvatidae) with nine genera (*Bithynia, Heleobia, Melanoides, Melanopsis, Plotia, Pseudamnicola, Pyrgophorus, Theodoxus, Valvata*) representing 16 species. Pulmonates are represented by three families (Lymnaeidae, Physidae and Planorbidae) within six genera and species.

Prosobranchia

Family Neritidae Rafinesque, 1815

Theodoxus jordani (Sowerby 1844)

Description: Shell medium in size, up to 15 mm in length, with about 4 whorls, 'zebrated' (generally), or with white spots on a dark background, or uniform black or dark purple to yellow in color. Zebrated shells have red or brown to deep purple or black zig-zag stripes on a white or yellow background. The shell is imperforate, and has a wide, flat, white parietal callus. The spire is very short, body whorl large, elongate, and usually has a broad, shallow constriction. The aperture is D-shaped, and is tightly closed by an operculum of the same shape (Fig. 1 A).

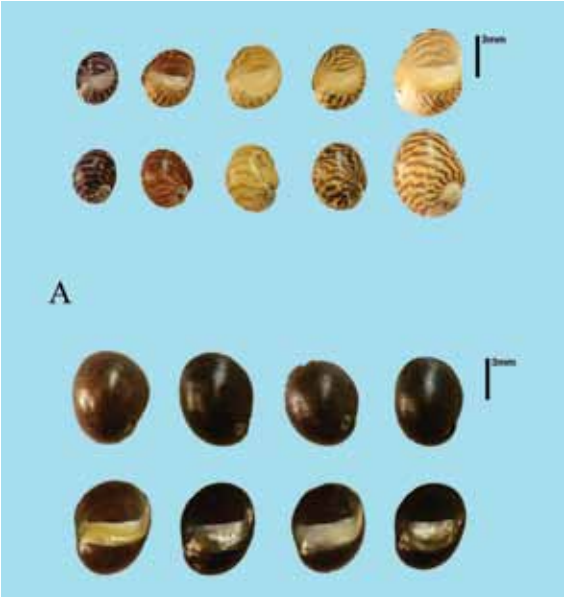

Fig. 1: A. Shell morphology of *Theodoxus jordani*. B. Shell morphology of *Theodoxus macrii*.

Range of distribution: Distributed in the Near East, except the Arabian Peninsula.

Distribution in Jordan: Present study: along the East Ghore Canal, Aqraba spring, Al-Ghazal spring (Yarmouk Reserve), Ghnyah and Khraisan springs in Zarqa. Previous records: Wadi Zaraq Ma'in (Near the Dead Sea), Azraq (Schütt, 1983a); Azraq, Rumeimin springs, Seel Hisban, Wadi Essir, Dhibin stream, Wadi Hidan, Elquneiya spring, Hemma, Yarmouk river, Wadi Azraq (Schütt, 1983b). Tawaheen Al Sokar, Dair Alla, East Ghore Canal, Yarmouk River, Abu Sedo, Shaikh Hussain Bridge, King Hussain Bridge, Ein Rahoub, Al Mogarin, Kufr Lahi spring, Abdou spring (Burch et al., 1989).

Habitat: This is one of the most ornamented freshwater snail species in Jordan. Within the same population, different patterns of striations as well as coloration were observed. *Theodoxus jordani* is confined to some localities in the Jordan Valley and along the Jordan and Yarmouk rivers. It prefers clear and fast running water. Snails are usually submerged and attached to stones located within turbulent parts of the water body. It was collected from the East Ghore Canal as well as from the secondary and tertiary irrigation canals. An isolated population in Azraq oasis was also recorded (Burch et al., 1989).

Remarks: The *jordani* complex consists of three isolated subpopulations; *Theodoxus niloticus* (Reeve, 1856) in the Nile River, *Theodoxus jordani* (*Sowerby*, 1844) in the Levant rift valley and *euphraticus* (Mousson 1874) in Mesopotamia (Roth, 1987). Furthermore, Roth (1984) showed that the characteristics of the operculum provide an effective characteristic for the systematics of this species. Schütt et al. (1983) discussed the relationships between the plio-pleistocene snails of the Jordan and the Orontes valleys. They stated that this species is very adaptive and variable, to the point that shells of the living forms cannot be grouped into geographical subspecies. Further studies discussed the biogeographic relationship of this species in the Middle East (Alouf, 1998).

Theodoxus macrii (Sowerby 1844)

Description: Shell with the same general characteristics as *Theodoxus jordani*, but somewhat smaller, uniformly black or dark purple in color, and without a constriction in the body whorl. The shell is ovate in 'apertural' or top view, and hemi-spherical in side view. Operculum as in *Theodoxus jordani* (Fig. 1 B).

Range of distribution: Jordan, Syria, Iraq, Palestine.

Distribution in Jordan: Present study Ajloun, Al-Zoughdyah, Bossat El Eraq, Ennab fish ponds (Kofranga), Al-Baida spring (North Shoonah), Al-Rmaimeen spring. **Previous records:** Swaimeh spring, Othaymat, Quasmiya, Barakat spring, Halaweh spring, Quanyah, Al-Diat, Azraq Druze, Damyah Bridge, Al-Deak Spring, Bayda spring, Tal Arbaeen spring, Wadi Ziglab, Shaikh Hussein spring, Jorf Wadi, Lakna spring, Tul Arbueen Outlet, Yarmouk River North, Salem Yousef spring, Amayrah Spring, Bast Al-Halabi, Al-Rasam spring, Abu-Azbi spring, Ganam southern spring, Sharhabeel Basa, Slikhat, Mageda spring, Al-Yabis Agricultural Station spring, Shouna Spring, Gholah spring, Zour Ambeerh, Al-Jarm Wadi, Sofsafa Spring, Abu Hajeer spring, Ben Hammadn spring, Sekeen spring, La'aban spring, Om Shrar Irbid, Eoon Om Ershid Al-Rafeed, Iraq Al-Ameer, Khillet Al-Ein Saham-Irbid, Ein Eish Al-Rumman Saham-Irbid, Ein Al-monqat Samar, Ein Al-Fatouha Kufr Soum, Aqraba spring, Doflah spring, Sa'ud spring, Hajala spring, Sofla spring, Wadi Al-Rmemin, Sultan spring, Wadi Alal-Irbid, Al-Ghadir springs-Kufr soum, Sheeha spring (Burch et al., 1989).

Habitat: This species inhabits clear springs and fast running water. It is most common in the springs and streams in the Mediterranean ecozone and the Jordan Valley.

Remarks: Burch et al. (1989) recognized Th. *macrii* as a separate species from Th. *jordani* since the two nominal species are clearly distinguishable among the examined Jordanian specimens. On the other hand, Degan (1971) considered Th. *jordani* and Th. *macrii* as the same species. His conclusion was based on the opercular apophyses and the shape of the central teeth of the *radula. Theodoxus macrii* is

smaller than Th. *jordani*, with uniformly black or dark purple colour and without a constriction of the body whorl (Burch & Amr 1990). Further studies are required to clarify its systematic status.

Family Valvatidae Gray, 1840

Valvata saulcyi Bourguignat 1853

Description: The adult shell is about 4 mm in diameter, has 3 1/2 to 4 whorls, is depressed helicoid, rather widely umbilicate, translucent, pale to tannish-horn, with well-developed transverse striae and faint spiral striae. The sutures are moderately deep. The round aperture is closed by a round, thin, corneous, multi-spiral operculum (Fig. 2 A).

Range of Distribution: Jordan, Syria, Palestine, Lebanon, Turkey, Egypt and Italy (Sicily).

Distribution in Jordan: Previous records: Azraq south pool, Jerash Roman Pools, Wadi Essir, Wadi Rum spring (Schütt, 1983b); Al-Hashra swamps (Burch et al., 1989).

Habitat: This species occurs in different types of standing water and springs, preferably with aquatic vegetation.

Family Bithyniidae Gray, 1857

Bithynia philalensis (Conrad 1852)

Description: The shell is horn or tannish-horn in color, moderately glossy, rather solid, translucent, smooth except for sculpture of fine growth lines, imperforate, perforate or rimately perforate, with impressed sutures and up to 5 whorls. Shells of the largest specimens reach nearly 10 mm in length. The spire height varies from being less than the height of the shell aperture to being noticeably greater than that of the aperture. The aperture is entire and is ovate in shape. The calcareous, concentric operculum has a small spiral nucleus, 1/6 to l/5 the width of the operculum. The operculum barely fits the shell aperture (Fig. 2 B).

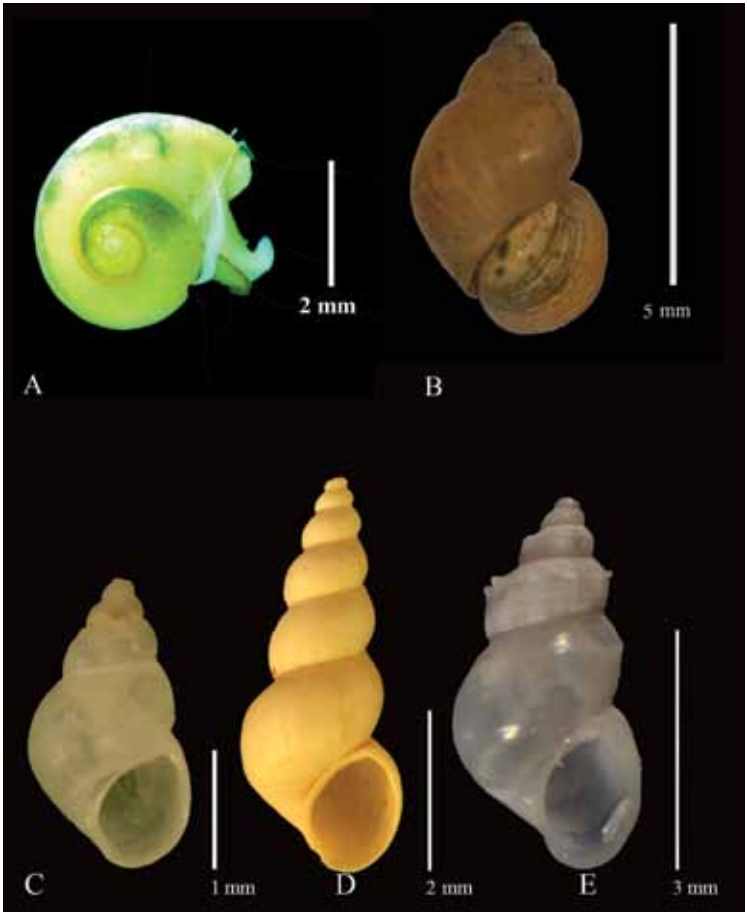

Fig. 2: A. Shell morphology of *Valvata saulcyi*. B. Shell morphology of *Bithynia philalensis*. C. Shell morphology of *Heleobia contempta*. D. Shell morphology of *Heleobia longiscata*. E. Shell morphology of *Pyrgophorus coronatus*.

Range of Distribution: Jordan, Palestine, Lebanon and Syria.

Distribution in Jordan: Previous records: Shaik Hussain spring,

Azraq southern, Jordan River Shaikh Hussain Bridge, Wadi Khaled Irbid, Al-Tarfeh Swamps Yarmouk River, Al-Hashra Swamps (Burch et al., 1989).

Habitat: This species inhabits swamps, in small groups around springs and small ponds. It was collected along swamps formed near the Yarmouk and Jordan rivers.

Remarks: Further studies on the penial morphology are required to distinguish species from the *Pseudobithynia species* known from Middle East, and clarify its generic affiliation (Glöer & Bössneck 2007; Glöer et al. 2012).

Family Hydrobiidae Stimpson, 1865

Globuliana gaillardotii (Bourguignat, 1856)

Description: Shell small, 2.5–3.5 mm in length, subovately to subglobosely conic, with about 4 1/2 to 5 1/2 whorls. The shell is narrowly umbilicate to perforate, glassy and transparent to translucent horn. The aperture is entire. Although the length of the spire is variable, its length is generally about the same as or a little more than that of the aperture.

Range of Distribution: Jordan, Lebanon, Syria and Palestine.

Distribution in Jordan: Previous records: Al Ma'alaka spring (Ruwaiha), Ein Om Ershid, Basat Al Faras (Ghore Kabed), Ain Al Amyreh (Saham), Wadi Al Kafer, Wadi Al Khoor, Wadi Al Mokaran, Barakat spring, Zarat spring, Beer Al Azraq (Burch et al., 1989).

Habitat: It was found in various freshwater habitats including spring, mineral springs and swamps along the Jordan Valley (Burch et al., 1989).

Remarks: This species was listed as *Globuliana gaillardoti* (Germain, 1911) by Mienis (2010). Burch et al. (1989) listed this species as *Pseudamnicola gaillardoti* for Jordan.

Pseudamnicola solitaria Tchernov, 1971

Description: Shell small, 1–1.5 mm in length, with four whorls, globose, glossy, near transparent, narrowly umblicate with entire aperture.

Range of distribution: Jordan and Palestine.

Distribution in Jordan: Previous records: Dead Sea springs, Zarqa Ma'in cool and hot waters, Tal spring (Schütt, 1983b), Wadi Al Kafer, Beer Al Azraq (Burch et al., 1989).

Habitat: This is another halophylic hydrobiid inhabiting swamps and streams around the Dead Sea area (Schütt 1983b, Burch et al., 1989). *Pseudamnicola solitaria* is an **endemic** species to Jordan and Palestine.

Remarks: This species was originally described from a few springs along the Dead Sea (Tchernov, 1971). It is considered Endangered according to the IUCN Red List of Endangered Species.

Pseudamnicola sp.

Description: Subovately to ovately conic shells, perforate and small (3-5 mm) length, 5 whorls and sculpture of fine growth lines, tannish horn color.

Distribution in Jordan: Present study: North Shunah. **Previous records:** Azraq Druze, Ein Om Ershid, Zour Al-Nees, Zour Al-Breej Yarouk River, Wadi Khalid Irbid (Burch et al., 1989).

Habitat: Located in brackish water, and occurs on sandy-muddy substrates. The shell morphology of this species is close to *Bithynia phialensis* but smaller in size. Further examination for live specimens for this form should be undertaken to reveal its identity.

Family Cochliopidae Tryon, 1866

Heleobia contempta (Dautzenberg 1894)

Description: Shell small, 2-3.5 mm in length, narrowly to elongately

conic imperforate shell that consists of 5 to 5.5 whorls, light white-yellowish color and translucent, sutures separating the whorls are mildly impressed (Fig. 2 C).

Range of distribution: Jordan, Palestine, Syria and Lebanon.

Distribution in Jordan: Present study: Al-Karamah dam. **Previous records**: Dead sea, Sail Hisban, Jerash Roman Ponds, Wadi Essir, Dhibin stream, Zarqa Ma'in cool and warm waters, Wadi Hidan, Elquneiya spring, Hemma, Yarmouk River, Wadi Na'ur spring, Kherbat Suweirat (Schütt, 1983b); Beer Al-Azraq, Rahib spring, Al-Maleh spring, Okla Wadi, Wadi Mokran spring, Al-Karn spring, Bast Al-Feleh Mashareh, Al-Kafer wadi, Debaa Spring, Rehab spring, Saham Irbid, Aqraba area, Ein Frouj Irbid, E'oun Al-Alka Saham, Ein Al-Habees Saham, Faroje Spring, Ein Om Ershid (Burch et al., 1989).

Habitat: It was found to inhabit springs, swamps and dams. Specimens were usually found attached to roots of aquatic vegetation.

Remarks: In previous reports, this species was placed as *Semisalsa contempta*. Molecular data suggests that species of the genus *Semisalsa* should be reassigned under the genus *Heleobia* (Wilke et al., 2001).

Heleobia longiscata (Bourguignat, 1856)

Description: Another brackish water living species, shell is 4-6 mm length only, shell is narrowly elongated conic with up to 6 1/2 whorls, torsion is right-handed, light of tan white-yellowish color with transverse bands on the body whorl impressed sutures separating the whorls and the shell is perforated (Fig. 2 D).

Range of distribution: The distribution range extends from Turkey to Jordan.

Range: Jordan, Syria, Libya, Israel and Turkey.

Distribution in Jordan: Present study: Azraq Oasis. Previous records: Asad spring (=Lion Spring Azraq), Dashah-Azraq (Burch et al., 1989).

Habitat: This small snail is only known from the swamps of Azraq oasis. It was reported from brackish waters of the Syrian coastal area (Schütt, 1983a).

Remarks: Schütt (1991) considered this species to be in the genus *Semisalsa* rather than *Heleobia*. The record of Schütt (1983b) of *Semisalsa musaensis (=Hydrobia musaensis)* from Azraq may probably erroneous and could be *Heleobia longiscata*. Also, the record of *Hydrobia lactea* from the Lion spring in Azraq by Brown & Wright (1980) and Scates (1968) for *Hydrobia ventrosa* could be also H. *longiscata*.

Pyrgophorus coronatus (L. Pfeiffer, 1840)

Description: shells very small, right coiling, ca.1.2-3.5 mm length; shell perforated with a slit-like umbilicus; teleoconch whorls strongly shouldered, shoulder often with conical or triangular spines; lower part of the whorls with fine spiral ridges; usually, penultimate whorl only slightly shouldered marked by a fine keel or step-like margin; shell light greyish to white-yellowish in color (Fig. 5 E).

Range of distribution: Coastal areas of the southern states of North America, both sides of Central America and the northern countries of South America. Introduced to Hawaii, Jordan and Palestine.

Distribution in Jordan: Present study: Al-Karamah Dam, Ayoon Al Tilal (Al Masharea'h), Northern Jordan Valley.

Habitat: Shells and living specimens were collected from four sites in the Jordan Valley, including a dam, irrigation ponds and a spring. This is an invasive species that was not collected during 1981-1983 survey. Recently *Pyrgophorus* sp. was reported in the Taninim River basin, Israel (Mienis et al., 2011).

Remarks: Hershler & Thompson (1992) reviewed the systematics of the genus. There is no current revision of the genus *Pyrgophorus*, as this genus is widely distributed in the American tropics with more than 20 described species proposed.

Family Thiaridae Gill, 1871

Melanoides tuberculata (Müller, 1774)

Description: Shells vary in size, the larger ones reaching nearly 50 mm in length and containing up to 15 whorls. The shell is imperforate, and has moderately rounded whorls, which are separated by moderately impressed sutures. The shell surface is sculptured with transverse ribs and spiral ridges and grooves (although in some regions of the species' distribution populations occur which contain shells that are almost or completely smooth). The shell is light horn or somewhat darker in color, with reddish-brown color patches. The anterior shell aperture is evenly curved. The posterior aperture is not narrowly constricted, as it is in *Melanopsis praemorsa* (Fig. 3 A).

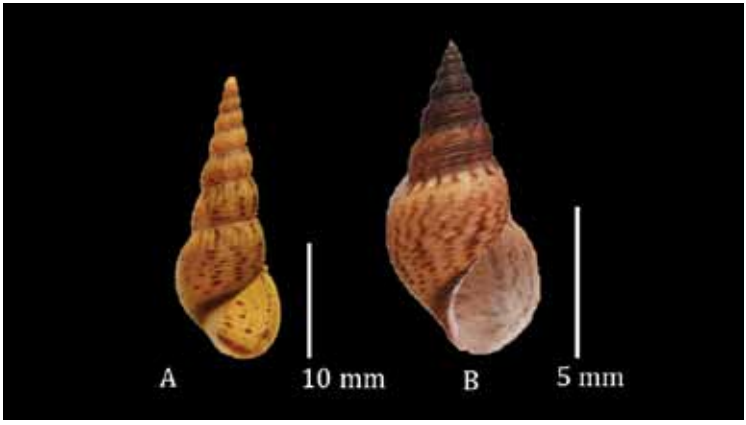

Fig. 3: A. Shell morphology of *Melanoides tuberculata*. B. Shell morphology of *Plotia scabra*.

Range of distribution: worldwide in distribution throughout much of Africa into Asia and Australia.

Distribution in Jordan: Present study: water collecting pools in South Shoonah, Ghore Al-Safi, Ghore Fifa, Al-Karamah Dam, Ennab

fish ponds in Kofranga, streams near Dead Sea, Irrigation canals in Swaimeh, Khraisan and Ghnayah springs in Al-Hashemyah (Zarqa). **Previous records:** Dead sea springs, Azraq Shishan and south pool, Zerqa ma'in cool water, El Quneiya spring (Al Hashimyah), Hemma, Yarmouk River, Hammam spring, el Sokhneh, Deir Alla, Wadi Azraq (Schütt, 1983). Swaimeh spring, Hamdi Al-Anees spring, Othaymat, Quasmiya, Mahateet spring, Wadi Dokhanya, Nakhlah spring, Barakat spring, Mahafeet spring, Draybeh, Halaweh spring, Kafreen Dam, Moasher farm, Quanyah, Jedyaab Wells, Al-Birkteen, Al-Waleh Wadi, Al-Deak Spring, Ma'an, Abu Zyad spring Halaka Spring, Aleyah spring, kofer Assad spring, Tal Arbaeen spring, Al-Maleh spring, Northern Maleh spring, Wadi Ziglab, Kasim spring, Abu Besseh spring, Tal Zarah, Jorf Wadi, East Jordan canal, Dokan spring, Lakna spring, Shater spring, Tul Arbueen Outlet, Bayda Spring, Wadi Zahar, Al-Maleh Southern spring, Al-Maleh med Spring, Yarmouk River North, Nakheel Wadi, Wadi Al-Ghore, Salem Yousef spring, Amayrah spring, Basat Al-Halabi, Al-Rasam spring, Bata spring, Abu Azbi spring, Ganam southern spring, Al-Khesa spring, Awad Hamod spring, Narjas spring, Sharhabeel Basa, Bast Rayahni, Abu Hani spring, Slikhat, Mageda spring, Al-Yabis Agricultural station spring, Shouna spring, Ghanam spring, Sa'ada spring, Tal Salman spring, Masbeerah spring, Zour Al-hamam, Gholah spring, Marazal Spring, Amayrah spring, Zour Ambeerh, Mnawer spring, Al-Jarm Wadi, Sofsafa spring, Abu Hajeer spring, Yatook spring, Arabeya spring, Ben Hammadn spring, Sekeen spring, La'aban spring, Azraq-southern, Jordan River King Hussain bridge, Om Sharar, Salleh spring, Sahab-Irbid, Ein Haroub Irbid, E'oun Al-Alka Saham-Irbid, Wadi Khaled Irbid, Qanat Al-Aqlat Saham, Ein Al-Amayreh Saham, Ein Al-Dellan Al-Mansoorah Irbid, Ein Deeb Saham, Ein Al-Sahn Al-Mansoorah, Eraq Al-Amir, Khiller Al-Ein Saham, Ein Al-magaren Kufr Soum, Ein Eish Al-Rumman Saham, Ein Al-Monqat Samar, Ein Al-Fatouha Kufr Soum, Ein Al-Tayyah Irbid, Ein Al-Habees Saham, Ein Issa Saham, Sheha and Sokar spring, Mokhibeh Yarmouk River, Hemma spring, Aqraba spring, Doflah spring, Sa'ud spring, Sab'ee spring, Hajala spring, Yobla spring Irbid, Kufr Lahi spring, Sofla spring, Wadi Al-Rmemin, Wadi Al-Wala Madaba, Ein Al-Safayneh Saham, Sultan spring, Sahal spring, Wadi Alal Irbid, Al-Ghadeer spring Kufr Soum, Abdou spring (Burch et al., 1989).

Habitat: One of the most common species in the Jordan Valley. This thiarid snail is associated with saline freshwater bodies, including springs, streams and swamps. This is a common species in the Jordan Valley and around the Dead Sea basin. It was also collected from Azraq oasis (Burch et al., 1989). This species is active mostly at night, hiding beneath decaying plants and stones or burying itself in the mud during the day (Livshits & Fishelson, 1983).

Plotia scabra (Müller, 1774)

Description: shell conical, turreted, with a maximum length of 23 mm; shell consisting of 8-12 whorls; usually, upper whorls shouldered, ribbed, often with upwards pointing spines at the shoulder, or with thickened knob-like ribs on the shoulder; teleoconch whorls with spiral threads; shell colour varying from reddish-yellowish to olive-green with an irregular pattern of red-brown spots or zig-zag like axial flames (Fig. 3 B).

Range of distribution: South and Southeast Asia, the Indo-Australian Archipelago extending westwards to the western Pacific Islands. This species has been introduced to many countries in the Arabian Peninsula, Jordan and Palestine.

Distribution in Jordan: Present study: North Shunah, near Al Adasyeha area, The East Ghore Canal.

Habitat: Considered as invasive tropical species, closely related in morphology and habitat to M. *tuberculata*.). In the Middle East, it became a dominant species in Lake Tiberius, reaching as much as 95% of the total freshwater snail fauna, causing almost eradication of four native species (Heller et al., 2013). It was also found in other adjacent water bodies (Roll et al., 2009; Mienis et al., 2011) and became established in many countries in the Arabian Peninsula (Brown & Wright 1980, Brown & Gallagher 1985, Neubert, 1998; Feulner & Green, 1999).

Remarks: Glaubrecht et al. (2009) moved *Thiara scabra* to the genus *Plotia Röding*, 1798 and suggested *Plotia scabra* for this species. Further clarification of the systematics of this species is given by Mienis (2012).

Family Melanopsidae Adams & Adams, 1854

Systematics: Olivier (1801 and 1804) considered two species of the genus *Melanopsis* in the Levant; M. *buccinoidea* and M. *costata*. Forty three species of *Melanopsis* have been described earlier, but later reduced to six species by Germain (1921) including M. *praemorsa*, M. *jordanicensis*, M. *bullio*, M. *saulcyi*, M. *bovieri* and M. *costata*. Some investigators suggested that all *Melanopsis* shell variations reflects ecotypes and all belong to a single species; *Melanopsis praemorsum* (Tchernov, 1975). Two species of M. *praemorsa* (smooth) and M. *costata* (rough) were considered by Bilgin (1983). Five species of *Melanopsis* were represented by Mienis & Ortal (1994) as M. p. *bucciniodea*, M. p. *eremita*, M. p. *jordanica*, M. *saulcyi* and M. *certhiopsis*. Schütt & Sesen (1989a) considered all *Melanopsis* of the Levant as M. *praemorsa* and M. p. *bandeli* from Jordan in addition to five subspecies derived from M. *praemorsa* from Syria. Burch et al. (1989) assigned Melanopsis in Jordan by two species; M. p. *bucciniodea* and M. p. *costata*. Glaubercht (1996, 1999) suggested that the two subspecies arise from the superspecies M. *praemorsa*, and have minor anatomical differences including radula and shell sculpture and they hybridized widely to produce polymorphic individuals. Heller & Sivan (2000) suggested, based on comparative studies of sperms, radula and allozymes, that four species occurred in the Jordan valley (M. *buccinoidea*, M. *costata*, M. *saulcyi* and M. *meiostoma*) and seven species in the Levant; all those of the Jordan Valley and another three species M. *doraie*, M. *sharhabili* and M. *ammonis* (Bandel, 2000).

Five smooth-shelled *Melanopsis* species were described; M. *buccinoidea*, M. *ammonis*, M. *dircaena*, M. *khabourensis* and M. *meiostoma* (Heller et al., 2005). M. *ammonis* is considered as a subspecies from the bucciniodae and significantly differs from M. *meiostoma* (Heller et al., 2005). Another five species with ribbed shells; four subspecies derived from M. *costata* found in north Orontes, upper Jordan, Sea of Galilee and south of Levant (Heller et al., 2005). According to fossil evidence, the M. *saulcyi* has released due to hybridization between M. *costata* and M. *bucciniodae* during the last 1.5 Million years. Therefore in morphology, M. *saulcyi* specimens have narrower shell and shorter, bumpier ribs compared with M. *costata*. Other ribbed shell snails in the Levant, including M. *germaini* have numerous ribs com-

pared with M. *costata*. M. *pachya* with shorter ribs. M. *infracincta* is characterized by its bumpy shells with each rib has huge tubercles with pronounced ridge flanking the columella.

Melanopsis ammonis **Tristram, 1865**

Description: Elongated and narrow shell, black or reddish brown in colour, apex acutely pointed. Shell body smooth with 7-9 high whorls, gradually increasing, separated by very shallow sutures, ribs or striae indistinct, simple and acute while callus around the shell mouth (Fig. 4).

Fig. 4: Shell morphology of *Melanopsis ammonis*.

Range of distribution: Endemic to the Jordan Valley, Palestine and Jordan.

Distribution in Jordan: Present study: Rumeimin waterfalls, Rumeimin spring. Previous records: Heshbon (=Hisban) and Ammon (=Amman) streams (Tristram, 1865); Rabat Ammon (=Amman), Wadi Al Walla, Hamam Yarmouk, Rumeimin (Heller et al., 2005).

Habitat: Found in clear running water around springs and waterfalls around Rumeimin.

Remarks: M. *ammonis* was considered as a subspecies from the bucciniodae and significantly differs from M. *meiostoma* (Heller et al., 2005). *Melanopsis ammonis* differs from M. *buccinoidea* of the Jordan valley in its higher penultimate whorl, as expressed in its higher values of the ratio f/mouth height.

***Melanopsis buccinoidea* (Olivier, 1801)**

Description: Two forms were; the Levant form (elongated) and the Jordan Valley form. Compared to the Levant forms, the Jordan Valley form. Compared to the Levant forms, the Jordan Valley form is 'stouter'. So the shell diameter compared to shell height (SD/SH) is relatively large in the Jordan Valley form with a larger mouth height relative to shell height (MH/SH) and lower (F/MH) ratio. For clearer discrimination between the two forms, cluster analyses have been made to study the relationship of the two ratios (f/Mouth Height) relative to (Mouth Height/Shell Height) with two clusters found as the Jordan Valley form has high a ratio of (MH/SH) and lower ratio of (f/MH) and vice versa for the elongated form (Fig. 5).

Fig. 5: Shell morphology of *Melanopsis buccinoidea*.

Melanopsis saulcyi (Bourguignat, 1853)

Description: Has more ribs than M. *costata*, the shell is elongated and the mouth height is small in relation to the shell height (MH/SH). The ribs are 'bumpier' and descend from the suture to about the middle of the lowest whorl; the rib usually consists of an upper tubercle, fused to the lower ridge. The color varies from pale brown to dark brown or black, each rib, on the penultimate whorls, has a waist (Fig. 6).

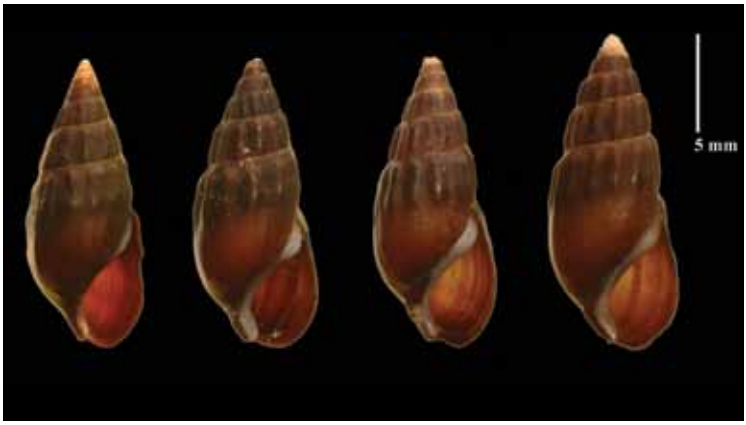

Fig. 6: Shell morphology of *Melanopsis saulcyi.*

Range of distribution: Jordan, Palestine and Syria.

Distribution in Jordan: Present study: Ghnayah and khraisan springs, Ennab fish ponds (Kofranga), Al-Baidah spring, Al-Rmaimeen spring, Um El-Ebr spring. Previous records: perhaps it was confused with M. *costata*.

Habitat: This species was found in slow running water courses and occurred close to aquatic vegetation.

Melanopsis costata jordanica (Roth, 1839)

Description: Shell is significantly 'stout', compared to the M. *saulcyi.*

The ribs are mildly pronounced, with rounded shoulders, the mouth is relatively large. Shell color varies, some shells are black but many are banded; the dark bands are broad and black. The last whorl of each banded shell has three dark bands and two pale ones (Fig. 7).

Fig. 7: Shell morphology of *Melanopsis costata jordanica*

Range of distribution: the Levant and Iran.

Distribution in Jordan: Present study: Yarmouk River.

Habitat: Like M. *saulcyi*, M. c. *jordanica* is found attached to rocks or concrete on both sides of the water canals. This species is a habitat generalist. It was found along irrigation canals, streams, swamps and ditches.

Melanopsis costata obliqua (Bourguignat, 1884)

Description: Ribs of the last whorl extend along the entire length of the whorl, the shell is conic to elongate in shape. Each rib has a very prominent tubercle fused to straight prominent lower ridge. The upper three whorls are smooth, while the lower whorls are ribbed; tubercle and the ridge are sometimes separated by a depression. The shell color is grayish yellow to almost black (Fig. 8).

Fig. 8: Shell morphology of *Melanopsis costata obliqua.*

Range of distribution: the Levant and Iran.

Distribution in Jordan: Present study: Jordan River, the East Ghore Canal.

Habitat: Inhabiting springs and swamps often found submerged in the mud. This species was known from the lower Jordan valley and the coastal plain of the southern Levant.

Melanopsis costata lampra Bourguignat, 1884

Description: Shell conical, ribs are mildly pronounced and their shoulders are rounded. M. c. *lampra* further differs from M. c. *costata* in that it has a larger mouth (higher mouth-height/shell-height), higher number of ribs, and these are closer together (Fig. 9).

Range of distribution: Known from the Hula valley, upper Jordan River, coastal plain of northern Palestine, and in the Azraq Oasis in Jordan.

Distribution in Jordan: Present study: Azraq marshes.

Fig. 9: Shell morphology of *Melanopsis costata lampra.*

Habitat: This species inhabits still water with dense vegetation of *Typha*.

Family Lymnaeidae Rafinesque, 1815

Galba *truncatula* (O.F. Müller, 1774)

Description: Shell dextral, small in size (10 mm or less), 'rimately' perforated, sutures deeply impressed, white-brownish or tan color and glossy. The spire is broader and less acutely pointed than Radix *auricularia*, and is about the same height as the shell aperture (Fig. 10 A).

Range of distribution: Widespread throughout the world.

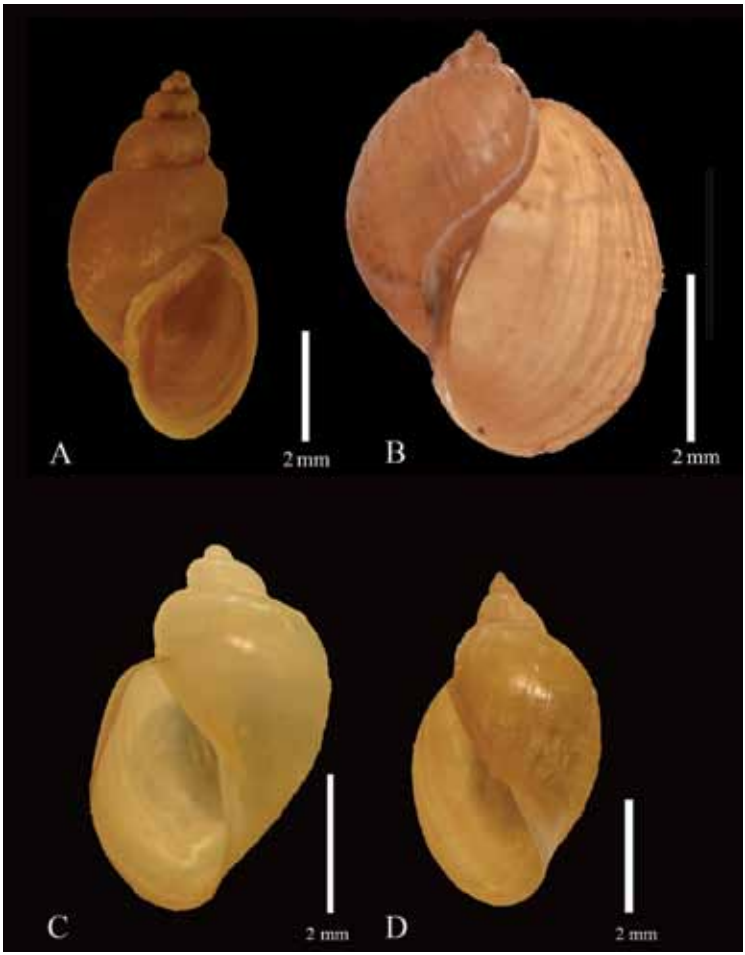

Fig. 10: A. Shell of *Galba truncatula*. B. Shell of *Lymnaea natalensis*. C. Shell of *Bulinus truncatus* D. Shell of *Haitia acuta*.

Distribution in Jordan: Present study: Ail spring (Ma'an), Um Al-Ebr spring (Ajloun), Jinin and Danah springs (Al-Tafilah). **Previous records:** Kherbat es Suweirat (Schütt, 1983b). Kafreen Dam, Mohr-

been spring, Abu Azbi spring, Hamed spring, Mageda spring, Debaa spring, Aymeh spring, La'aban spring, Lahtha spring, Ma'an spring, Aeil spring, Wadi Al-Sigin Hartha-Irbid, Saham Irbid, Na'our, E'oun Al-Alka Saham, Wadi Khaled Irbid, Mureihat kabed Al-Karama, Ein Al-Lataifeh Saham, Zizon spring, Mokhibeh Yarmouk River, Om Qreen spring, Quaibeh spring (Burch et al., 1989).

Habitat: This species inhabits stagnant and slow running waters, irrigation canals and swamps. It was found along the muddy edges of rivers and springs.

Remarks: Species of this genus have undergone various radical revisions. Previously, species of *Galba* in the Middle East were placed under the genus *Lymnaea*. *Bargues* et al. (2001) stated that the taxonomic status of this family remains unclear.

Lymnaea natalensis Krauss, 1848

Description: The shell is medium in size, 12 to 15 mm in length, thin (but not especially fragile), has a relatively large body whorl and a small and pointed spire, is tannish-brown in color, translucent, perforate, without spiral sculpture, lacks a columellar plait (or has only a slight trace of one), and has a thin and sharp 'apertural' lip. The shell surface is moderately glossy, with distinct (but not prominent) growth lines (Fig. 10 B).

Range of distribution: Tropical Africa, Yemen, Oman and Saudi Arabia.

Distribution in Jordan: Previous records Berjes/ Azraq, Azraq Southern, Om Khlal Irbid, Zour Al-Breej Yarmouk River, Al-Braig Irbid, Zour Abo Al-Ghosh Aqraba, Wadi Zeizon Irbid, Wadi Amrawa Irbid, Al-Hashra Bridge Swamps Irbid, Ein Om Ershid Irbid (Burch et al., 1989).

Habitat: This snail prefers swamps with dense vegetation on the margins. Recently, we found a small population in Al Shawmari Wildlife Reserve, living around animal watering area with limited vegetation. It used to be common in swamps in the Jordan valley,

but now it is known from very few locations.

Remarks: Previous records for this species from Jordan are referred to as *Lymnaea auricularia* (Lutfy et al. 1978; Saliba & Othman 1980), and *Lymnaea* (*Radix*) *auricularia* (Burch et al., 1989). Neubert (1998) pointed out the urgent need for a revision of the species within the family Lymnaeidae. *Radix natalensis* and Radix *auricularia* have both been found across the Arabian Peninsula.

Family Physidae Fitzinger, 1833

Haitia acuta (Draparnaud, 1805)

Description: Shell sinistral and ovate, small to medium size shell (8-15 mm), imperforated and forming 5 1/2 whorls. Pale white-yel lowish in color and translucent, smooth and moderately glossy. Shell with fine growth lines and faint spiral sculpture. Aperture is more than half the total shell length. The outer lip of the aperture is sharp and their shell has a sharply pointed apex (Fig. 10 C).

Range of distribution: widespread in northern America, Europe, Eurasia, and Africa.

Distribution in Jordan: Present study: Zarqa River, Wadi Shaib Dam, Al-Sader spring (Wadi Mussa), Khraisan and Ghnayah springs in Zarqa, Al-Ghazalat spring. **Previous records:** Deir Alla (Schütt, 1983), Kafreen Dam, Tawahen Al-Sokar, Arda Triangle, Kabed Lake, Ghour kabed canal, South shounah Dam, Al-Karamah wells, Moasher farm, Swalha, Al-Fazah, Dair Alla, Masri Triagle, Swalha, Tal Al-Dahab, Al-Diat, Fanosh Spring, University Farm Station, Shoeabe Dam, Damyah Bridge, Issa spring, Sokhnah spring, Aid spring, Nabaa› spring, East Jordan Canal, Yarmouk River North, Said Shameli spring, Al-Kafer spring, Shaheen spring, Bast Al-Halabi, Ahmed spring, Abadee spring, Hamed spring, Abdel Hadi spring Bast Hamdan, Tal Sliman Shamalih, Al-Karn spring, Sharhabeel Basa, Bajawi spring, Barghasha spring, Bast Rayahni, Bast Al-Feleh Mashareh, Abu Akeel spring, Al-Yabis Agricultural station spring, Abu Sedo, Zour Al-Hamam, Gholah spring, Shahadat Wadi, Tahtamoni Spring, Salem spring, Jordan River Shaikh Hussain Bridge, Zour Al-Nusayrah

Irbid, Zour Al-Breej Yarmouk River, Al-Braig Irbid, Wadi Khaled Irbid, Mureihat Kabed Al-Karama, Zour Abu Al-Ghosh Aqraba, Zour Al-Nees, Al-Tarfeh Swamps Yarmouk River, Wadi Zeizon Irbid, Ein Al-Sarayah, Zizon Spring, Wadi Amrawa Irbid, Al-Hashra Bridge Swamps Irbid, Ein Om Ershid (Burch et al., 1989).

Habitat: This is one of the most common species inhabiting water bodies in the Jordan valley. *Haitia acuta* does not occur in mountain range or the eastern desert of Jordan. In the Jordan valley, it inhabits sewage contaminated streams (i.e. Zarqa River and Wadi Sha'ib), irrigation ponds, swamps, slow running water along springs and streams.

Remarks: Taylor (2003) has assigned *Physella acuta* to the genus *Haitia* Clench & Aguayo, 1932. The taxonomic status of populations within the Middle Eastern remains poorly understood.

Family Planorbidae Rafinesque, 1815

Bulinus truncatus (Audouin, 1827)

Description: Sinistral, small shell reaching about 10 mm in length, perforated and translucent light white-yellowish in color, moderately glossy with depressed sutures. Similar to *Haitia acuta* but less pointed, more 'shouldered' and perforated rather than imperforated (Fig. 10 D).

Range of distribution: Africa, southwest Asia and Portugal, Sardinia and Corsica.

Distribution in Jordan: Present study: Ghore Fifa, Al-Tanoor Dam. **Previous records:** Jerash Roman pools (Schütt, 1983b); Al-Birkteen, Shaik Hussain spring, Ahmed spring, Tal Sliman Shamalih, Zour Al-Hamam (Burch et al., 1989); Ghadir Abu-Zeid, Zur Al-Khbeinah, Zur Al-Nasaireh, Tallat Khalid ben Al-Walid, Mahatat Khalid, Zur Al-Klea, Ar Ramtha, Jarash - The Roman pools, Jarash, Ghawr Kabid, El-Karamah, Ash Shunah, Wadi Batus, Al-Kufren Dam, Al-Kufren, Wadi Rama, Zur Shasha'a, Ghore As-Safi, Hammamat Burbaytah, Wadi Abo Dubana, Ad-Disah (Arbaji et al., 1998)

Habitat: *Bulinus truncatus* was found to inhabit all types of ecozones of Jordan. Since 1975 and until the present, a total of 60 sites were foumd in four Governorates with this snail species. Most of the known populations were concentrated along the Jordan valley and the Yarmouk River (Balqa and Irbid Governorates), other major sites includes Zarqa River, King Talal Dam and Jarash Roman Pools (Zarqa and Jarash Governorates). An additional site in the southeastern Wadi Rum desert was found with this snail (Arbaji et al. 1998).

It prefers still water as in dams, reservoirs, ponds, slow water running ditch canals and pools. Snails were found from underneath rocks, floating vegetation, submerged objects (plastic sheets and containers) or around the edges the areas sampled.

Gyraulus piscinarium (Bourguignat, 1852)

Description: Discoidal small shell (5mm with 4 whorls as adult), well developed growth lines but have no spiral striation and has a shallow depressed spire, umbilicate side is slightly curved (Fig. 11).

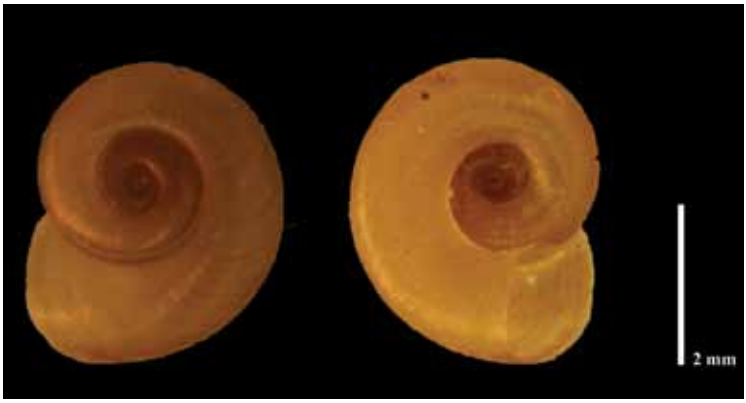

Fig. 11: Dorsal and ventral views for *Gyraulus piscinarium* collected from Ail spring.

Range of distribution: Bulgaria, Iran, Palestine, Lebanon, Syria and Turkey.

Distribution in Jordan: Present study: Ail spring, Lawrence spring

(Wadi Rum). Previous records: Wadi Rum (Schütt, 1983b); Ma'an spring, Wadi Al-Sigin, Eyoon Om Ershid, Wadi Khaled, Zour Al-Nees, Quaibeh spring, Hartha (Burch et al., 1989).

Habitat: Live specimens were recorded from small pools around springs and swamps.

Planorbis planorbis (L. 1758)

Description: Shell discoidal, up to 8 mm in major diameter, with about 4 1/2 slowly increasing whorls, pale horn in colour, with growth (transverse) lines, but without spiral striae. The inverted spire is flat, hardly depressed; the umbilical (upper-most) side is nearly flat. The whorls have a keel or sharp angulation at the periphery and this feature differentiates *P. planorbis* from *Gyraulus piscinarium.*

Range of distribution: This species is widely distributed across the Palearctic region, upper Egypt, Morocco and Algeria.

Distribution in Jordan: Previous records: Azraq (Brown & Wright, 1980); Al-Azraq (Burch et al., 1989)

Habitat: In Jordan, the distribution of this snail is known from the marshes of Azraq Oasis in the eastern desert of Jordan. It lives in shallow standing water densely vegetated by Typha . Its presence in Azraq may represent a relict of a formerly more widespread distribution.

Remarks: Glöer and Pešic´ (2010) gave a description of *Planorbis planorbis* along with the other species of this genus from the Balkans.

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Distribution and Cytogenetics of Amphibians from the Occupied Palestinian territories (West Bank of Jordan)

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ABSTRACT

The distribution of four species of amphibians (*Bufotes variabilis, Pelophylax bedriagae, Hyla savignyi / H. felixarabica,* and *Pelobates syriacus*) are given in the occupied Palestinian territories of the West Bank are recorded. Karyotypic data on *Bufotes variabilis* (2n=22) and *Pelophylax bedriagae* (2n=26) are reported

Keywords: Amphibians, Palestinian Territories, Karyotype.

INTRODUCTION

The order Anura is a group of amphibians with some 6000 described species which has been subject to significant taxonomic revision (Frost et al. 2006). Amphibians are an important component of ecosystems but increasingly threatened by human activities including global warming (Blaustein et al. 2010). Amphibians can also provide evidence of environmental health and resilience. Decline or loss of species can act as an early warning of global change (Gardner 2001). Thus environmental management of fragile habitats should be directed towards monitoring the diversity of amphibians to assist in their protection or recovery especially in wetlands (Storfer 2003). One species, the Hula painted frog, originally described by Mendelssohn and Steinitz in 1943 initially disappeared when the Hula lake and surrounding wetlands were first drained (Honnegger 1981) but has recently been rediscovered and assigned to the genus *Latonia* based on molecular and morphological data (Biton et al. 2013).

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Amphibian species in the Eastern Mediterranean region were studied by various authors via standard taxonomic, morphological and ecological methods (e.g. Werner 1988, Disi & Amr 2010, Degani & Didi 1999). However more modern methods now available were used by Gvoždík et al. (2010) to study the mitochondrial DNA of some species of Hylidae and a new cryptic species *Hyla felixarabica* was identified. This species is currently found in Palestine, Jordan and Yemen. Some species of Ranidae (Schneider & Sinsch 2001, Plötner et al. 2010) can also be differentiated by acoustic methods, but care must be taken in the interpretation of calls because of the effects of temperature (Huble & Schneider 1979). The aim of this study is to provide an initial assessment of anurans present in the Occupied Palestinian territories and their distribution, and to examine their karyotype.

MATERIALS AND METHODS

We surveyed several of locations in the occupied West Bank to survey location of permanent or seasonal bodies of water that could harbor amphibians. Table 1 shows localities from which material were collected. All animals caught were photographed in the field and in some cases preserved and deposited in the Palestine Museum of Natural History (PMNH), Bethlehem.

Table 1: localities from which materials were collected.

Locality	N	E
Al-Auja	31° 56’	35°27’
Artas	31° 41’	35° 11’
Beit Sahour	31° 70’	35° 22’
Ein Arik	31° 54’	35° 08’
Ein Fara	31° 49’	35° 18’
Ein Sinya	31° 58’	35° 13’
Fasayil	32° 01’	35° 26’
Husan	31° 42’	35° 07’
Wadi Quf	31° 33’	34° 58’
Jenin	32° 26’	35° 17’
Jericho	31° 51’	35° 27’

Jiftlik	32° 08'	35° 29'
Jinsafut	32° 10'	35° 07'
Kufr Dan	32° 28'	35° 15'
Mar Saba	31° 42'	35° 19'
Mikhmas	31° 52'	35° 16'
Nebi Saleh	32° 00'	35° 07'
Nuba	31° 36'	35° 02'
Salfit	32° 05'	35° 10'
Taffouh	31° 32'	35° 03'
Wadi Al-Qelt	31° 50'	35° 24'
Wadi Fukeen	31° 71'	35° 10'
Wadi Zarqa	31° 59'	35° 06'

Laboratory analysis

A number of those animals collected from the field (n=64) were also used for chromosomal analysis. Animals were first injected with 0.2 ml colchicine solution (1 mg/ml) for a 5-14 hours before bone marrow was removed for cytogenetic study. Blood was taken from the cardiac area and cultured in PHA medium (Al-Shehri & Al-Saleh 2005a,b; Amor et al. 2007) . A minimum of five metaphases were analyzed for each specimen and pictures taken using an Olympus MX41 microscope fitted with a digital camera.

RESULTS AND DISCUSSION

Three species of amphibians were collected from the study area. *Pelobates syriacus* was not collected during the present study. Figure 1 shows the current distribution of known amphibians in the Occupied Palestinian Territories. Karyotypic data was given for two *species; Bufotes variabilis* and *Pelophylax bedriagae.*

Family Bufonidae

Bufotes variabilis (Pallas 1769) Fig. 2

Material examined (n=13): **Jericho** (PMNH1856 ♂ 20.ix.2010; PMNH1870 ♂

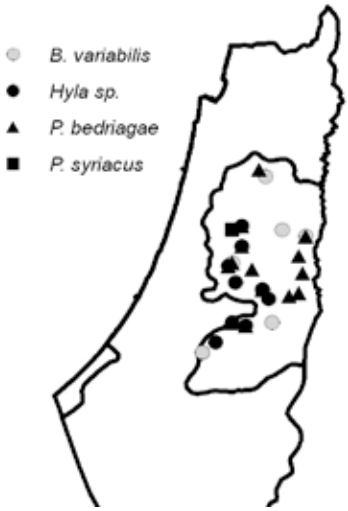

Fig. 1: Light trap sampling location in the period of the study.

25.ix.2010; PMNH1872 ♀ 25.ix.2010; PMNH1873 ♂ 1.x.2010; PMNH1874, ♂ 25.ix.2010); **Beit Sahour** (PMNH1841 ♀ 2.xiii.2010; PMNH1848 ♂ 4.ix.2010; PMNH1850 ♂ 4.ix.2010; PMNH1851 ♀ 14.ix.2010); **Jiftlik** (PMNH1979, ♀ , 27.iii.2013; PMNH1980, ♂ 27.iii.2013); **Mikhmas** (PMNH1700 ♂ 27.iv.2013); **Idnah** (PMNH1824 ♂ 26.vi.2012). Also we recorded it via observations in **Mar Saba, Nebi Saleh,** and **Jenin**.

Remarks: This species is distributed widely in the Arabian Peninsula (Degani and Kaplan 1999; Disi and Amr, 2001; Odierna et al. 2004). This is a common and highly adaptable toad found in different habitats. Previous records in the West Bank include from Wadi Malha northeast of Tubas (Odierna et al. 2004). It was found it in Palestine in temporary winter ponds during the rainy season and into early spring and at the edges of permanent waters year round especially common in the Jordan Valley. Hundreds of juvenile toads were noted in Mikhmas at a sewage stream. This was diluted sewage as we observed an abundance of other wetland species in the area. We

Fig. 2: *Bufotes variabilis* from *Beit Sahour.*

also reported this species from a cave at Idnah, Hebron district. Locals recognize this species as coming out after the initial winter rains.

Small pools that last sometimes merely few weeks act as breeding habitats. The toads have a very quick turnover with eggs developing to small toads able to aestivate in 3-4 weeks. Frost et al. (2006) describe a new genus *Pseudepidalea* which was considered a junior synonym of *Bufotes* (Dubois & Bour 2010; Frost 2013). The name etymology was in reference to the morphological similarity of this group to *Epidalea calamita.*

Below the genus level, the group of "*viridis*" clearly had some distinguishing clades by molecular phylogenetic methods. Stöck et al. (2006) stated that all Near Eastern and much of the northern Eurasian populations belong to a separate taxon suggested by molecular

clocks to have diverged from the nearest European *viridis sensu strictu* in Lower to Middle Pliocene. Because of the fact that the range of this clade included the type locality of *variabilis* in Lubeck, Germany, these authors tentatively suggested the use of the name *Bufo variabilis* for the populations that occur in our area (see also Stöck et al. 2001). Combined with the data of Frost et al. (2006, 2013) and Dubois and Bour (2010) we now use the name *Bufotes variabilis* (instead of the older name *Bufo viridis* in Palestine).

Karyotypic data: The diploid number of *Bufotes variabilis* we observed in Palestine is 22 with all metacentric and submetacentric chromosomes in three specimens examined (Fig. 3) and is identical to that seen in this complex elsewhere (Miura 1995, Odierna et al. 2004, 2007, Al-Shehri & Al-Saleh 2010). Stöck et al. (2013) showed that Low rates of X-Y recombination account for homomorphic sex chromosomes (difficult to distinguish because males and females have similar chromosomes).

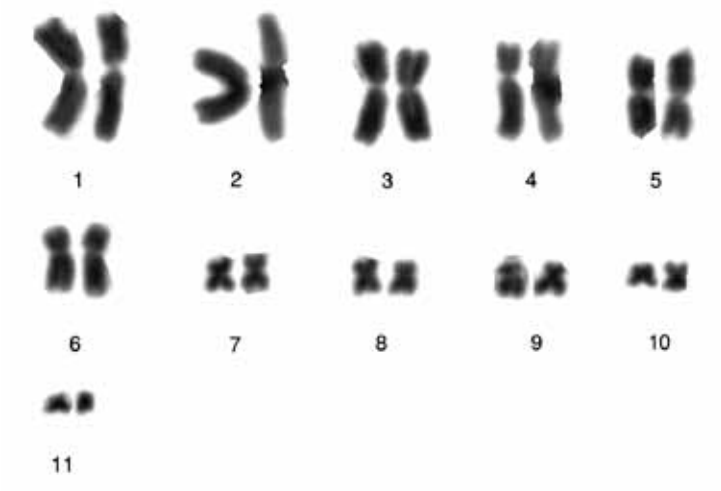

Fig. 3: *karyotype* of *Bufotes variabilis*

Family Pelobatidae

Pelobates syriacus (Boettger 1889)

Remarks: Munwes et al. (2010) collected this species from Jinsafut, the only known presence in the West Bank. We visited this locality in the northern part of the West Bank but not during the rainy season. Locals confirm the presence of this toad during the seasonal filling by rain of this pool. *Pelobates syriacus* prefer temporary ponds of Terra Rosa soil at high attitude according to Disi and Amr (2010). It digs in the humid sub-soil when not in the rainy season. *Pelobates syriacus* prefers open steppe-like habitats and also preys on snails following the rainy season. Cytogenetic studies of *Pelobates syriacus* showed 2n=26 from various countries (Belcheva & Ilieva 1977; Morescalchi et al. 1977; Schmid et al. 1987; Ugurtas et al. 2001).

Family Ranidae

Pelophylax bedriagae (Camerano 1882) Fig. 4

Material examined (n=30): **Wadi Zarqa, Beitullo** (PMNH1517 ♂ 30.v.2012; PMNH1518 ♀ 30.v.2012; PMNH1519 ♂ 30.v.2012; PMNH 1529 ♀ 30.v.2012; PMNH1530 ♀ 30.v.2012; PMNH 1533 ♂ 30.v.2012); **Nebi Saleh** (PMNH1725 ♂ 5.v.2013); **Fasayil**, (PMNH1577 ♂ 27.vi.2012); **Jiftlik**; (PMNH1981 ♂ 27.iii.2013; PMNH1982 ♂ 27.iii.2013); **Wadi Fukeen** (PMNH1832 ♂ 3.iv.2009; PMNH1853 ♂ 6.viii.2011; PMNH1860, ♀ ,8.viii.2011; PMNH1865 ♂ 29.ix.2010; PMNH1943, ♀ 6.viii.2011; PMNH1945 ♂ 6.viii.2011; PMNH1948 ♂ 8.viii.2011; PMNH1949 ♂ 8.viii.2011; PMNH1984 ♀ 6.viii.2011); **Husan** (PMNH1875 ♂ 28.ix.2010; PMNH1963, ♀, 29.ix.2010); **Artas** including **Solomon's pools** (PMNH1883, ♂ 28.ix.2010; PMNH1937 ♀ 1.x.2010); **Salfit** (PMNH1844 ♀ 3.viii.2010); Jericho (PMNH1933 ♂ 11.v.2011; PMNH1934 ♂ 11.v.2011); **Wadi Al Qelt** (PMNH1764 ♂ 20.xii.2012; PMNH1968 ♂ 18.ix.2011; PMNH1969 ♂ 18.ix.2011); **Kufr Dan** (PMNH1798 ♂ 19.vi.2013). We also recorded it in **Ein Sinya, Al-Auja,** and **Mikhmas.**

Remarks: The name *Rana ridibunda* was used for Palestinian populations for a long time. Nevo and Filippucci (1988) suggested that the populations in our area are distinct from European populations. This

Fig.4: Adult male of *Pelophylax bedriagae* from Wad Qana.

prompted Schneider et al. (1992) to describe *Rana levantina* but this is a junior synonym of *Rana bedriagae Camerano* (1882) (the type from Syria). Morphometric studies confirmed the designation of this species stretching from Turkey to Palestine and Jordan (Sinsch & Schneider 1999). Frost et al. (2006) showed that the valid generic name is *Pelophylax* and hence the proper name for our frog is P. *bedriagae*.

However, there is still some mitochondrial DNA data that suggest that some populations especially in Syria and Anatolia and possibly entering our region maybe of more than one species (Plötner et al. 2001, 2010).

Previous records of P. *bedriagae* from the occupied West Bank include Jericho (Sinsch & Schneider 1999). We found it in total 11 localities in the occupied West Bank. It is the most common species found in Palestine as in Jordan (Disi & Amr 2010). We collected 30 specimens of P. *bedriagae* or more than half of all amphibian specimens collected in the West Bank. We found this species almost everywhere near springs, agriculture ponds, and even seasonal pools.

Karyotypic data: Chromosomes analysis revealed the diploid number of this species in Palestine to be 2n= 26 all metacentric and submetacentric chromosomes (Fig. 5) in four specimens examined (5 metaphases each) similar to other parts of the range of this species and even related species of *Pelophylax* (*Rana*) (*Schmid* 1978, Miura 1995, Al-Shehri & Al-Saleh 2005a).

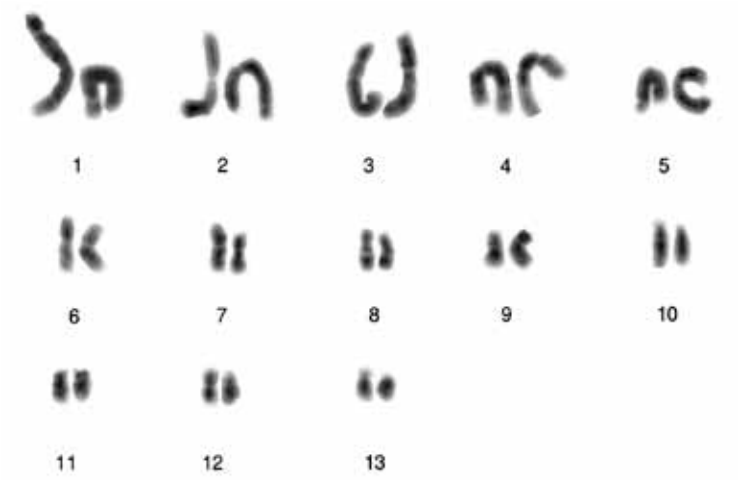

Fig. 5: Karyotype of *Pelophylax bedriagae*

Family Hylidae

Hyla sp. Fig. 6

Material examined (n=21): Husan (PMNH1835 ♂24.iv.2013; PMNH1845 ♂ 17.viii.2010; PMNH1846 ♀17.viii.2010; PMNH1866 ♂1.x.2010; PMNH1877 ♀ 1.x.2010; PMNH1935 ♂ 21.xiii.2010; PMNH1965 ♂ 1.x.2010; PMNH1964 ♂ 1.x.2010; PMNH1985 ♂ 21.viii.2010); Wadi Fukeen (PMNH1501♀ 27.iii.2013; PMNH1502 ♀ 27.iii.2012; PMNH1830 ♀3.iv.2009; PMNH1946, ♂6.viii.2011; PMNH1967 ♂1/10/2010); Nuba (PMNH1744 ♂18.iii.2013); Salfit (PMNH1833 ♂, 3.iv.2009); Ein Arik (PMNH1987 ♂ 7.vii.2013; PMNH1988 ♀ 7.vii.2013); **Mikhmas** (PMNH1999 ♂ 27.iv.2013);- **Rammalah district :Wadi zarqa –**

Beitullo (PMNH1524 ♂ 30.v.2012; PMNH1525 ♂ 30.v.2012). We also observed it in **Ein Fara** (also reported but under a misnomer by Grach et al. 2007). Also observed at **Solomon's pools at Artas.**

Fig. 6: *Hyla cf. savigniyi* from Idhna.

Remarks: Grach et al. (2007) described a *Hyla* from Jerusalem with distinct vocalization and morphology and called it a new sibling species of what was known as *Hyla savignyi* from Palestine and Jordan.

They named it *Hyla heinzsteinitzi*. However, Stöck et al. (2006; 2008) evaluated mitochondrial and nuclear DNA on samples referred to "*Hyla heinzsteinitzi*" and found them indistinguishable from *Hyla japonica* (also in vocalizations etc). It is also likely according to that work that a "paratype" from Ein Fara in the occupied areas also belongs to the common species.

The description of an introduced species as a new species emphasizes the need for larger studies perhaps with the use of mitochondrial and nuclear studies in evaluating phylogeny of amphibian species.

Based on mtDNA, rhodopsin, and tyrosinase sequences from specimens throughout the range of H. savignyi, Gvoždík et al. (2010) found that in our region two fairly distinct populations exist: 1) a traditional H. *savignyi* found in Lebanon, Syria, and northern Jordan (perhaps also parts of Palestine), and 2) a cluster that is similar to Yemeni specimens which he designated as a new taxon H. *felixarabica* found in areas of Palestine and Jordan near the rift valley (excluding the introduced H. japonica). This means that in our area of Jordan and Palestine, Hyla belong to two local (*H. savignyi* and *H. felixarabica*) and one introduced species, H. japonica (synonym *heinzsteinitzi*). But these authors found a mixed genome (*H. savignyi* and *H. felixarabica*) from a locality "Karkom, Israel" and suggested hybridization between the taxa. Until this is sorted out with further studies we use *Hyla* sp. for the taxon found in this area of Palestine and extending perhaps to Yemen.

The tree frog in this area was more common than we had expected for a threatened or even possibly endangered species. In fact, all the amphibians mentioned which were recorded in the literature from very few localities in the West Bank of Jordan were more widely distributed than we had anticipated. However, most of the permanent water sources have been depleted and springs dried in many places. As an example, Israeli authorities pumped water from the head stream of Al-Auja area which resulted in significant habitat changes in the area and we did not find tree frogs there. Karyotype of *Hyla felixarabica* from Saudi Arabia showed that it consists of diploid number of chromosomes 2n=24 which is conserved karyotype (Al- Sheri & Al- Saleh 2005b).

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Satellite Tracking of the Lappet-faced Vulture *Torgos tracheliotos* in Saudi Arabia

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ABSTRACT

Two Lappet-faced Vultures (*Torgos tracheliotos*), were fitted in early 1995 with Satellite transmitters at the Mahazat as-Sayd protected area located in Central west Saudi Arabia in order to track their movements. After release, the vultures left the reserve for approximately seven months, both returning in the autumn. Both birds visited areas to north-east or north of the reserve, though one tended to range over greater distances. The movements of these two birds supported observations of seasonal changes in the abundance of Lappet-faced Vultures in the Mahazat as-Sayd protected areas, and also indicated that some birds engage in short-distance migration within Saudi Arabia. In addition, the movements of these two birds suggest that there is a possibility of contact between other Lappet-faced Vultures populations within Saudi Arabia and those in neighbouring countries. This suggests that a single meta-population could range over the Arabian Peninsula.

Key words: Lappet-faced Vulture, Mahazat as-Sayd, migration, meta-population

INTRODUCTION

Satellite telemetry has in recent years, established itself as a highly effective method of investigating the migration of raptors (e.g. Grubb et al. 1994; Meyburg et al. 1998; 2002; 2003; Ueta et al. 1998, 2000; Martell et al. 2001; Gavashelishvili 2005; Newton 2004; McGrady and Gavashelishvili 2006). Birds of prey are well suited for satellite telemetry studies because many have extensive ranges and

migrations, and most species are also large enough to carry telemetry devices with a long battery life. Most studies to date have been on species with lengthy, often transcontinental, migrations (Strikwerda et al. 1986; Meyburg and Lobkov 1994; Merburg et al. 1995; 1996; 1998; 2003; Brodeur et al. 1996; Kjellen et al.1997; Newton 2008). However, regional movements of birds of prey have also documented (Griesinger et al. 1992; Grubb et al. 1994; Bahat 1995; Mendelsohn et al 2005; Phipps et al. 2013).

The Lappet-faced Vulture *Torgos tracheliotos* (Fig. 1) is amongst the species of conservation concern, both globally and in the Arabian Peninsula (Jennings 2010; Bird-Life International 2012). It is considered as globally threatened under the "Vulnerable category (VU)" (IUCN 2013). The population size in the Arabian Peninsula has been estimated to be about 600 breeding pairs with the majority found in Saudi Arabia (Jennings 2010). Studies at the Mahazat as-Sayd protected area, located in the central part of Saudi Arabia, showed that this protected area probably hosts one of the most important

Fig. 1: Lappet-faced Vulture with its check photographed in Mahazat as-Sayd Protected Area. (c) Shobrak

populations of this species, with the number of breeding pairs ranging from 28 to 37 (Shobrak 2011). Although some aspects of the breeding biology of Lappet-faced Vulture have been studied in Saudi Arabia, little information is available on their movements (Shobrak 2000; 2001; 2004; 2011; Jennings 2010).

Observations of marked birds in Africa have shown that they are far ranging, with birds having been re-sighted 700 km from their natal site, in their first year (Mundy et al. 1992). Newton and Newton (1996) have demonstrated that seasonal movements of full-grown birds occur in Saudi Arabia, with non-breeding birds vacating the core nesting area when large chicks are in the nest.

The mobility of species is an important aspect in their conservation planning (Newton 2008; 2013). Therefore, understanding the movements of threatened species like the Lappet-faced Vulture is important for the long term conservation of this species. Although the range of the species in Arabia is very extensive (Newton and Shobrak 1993; Jennings 2010), the extent of interchange between well used areas is unknown. Such information is clearly important in developing a management strategy for the species, given their virtual extinction at the northern edge of their range (Del Hoyo et al. 1994; Jennings 2010). Thus, the main objective of this study was to understand the movements of the Lappet-faced Vultures in Mahazat as-Sayd using satellite tracking.

MATERIALS AND METHODS

In late January and early February 1995 two Lappet-faced Vultures were captured and fitted with 95 g Platform Transmitter Terminals (PTT 100): Microwave Telemetry Inc., USA. The two birds were immature but more than three years old, and were captured in the Mahazat as-Sayd reserve in west central Saudi Arabia. The capture technique takes advantage of the large body size of the birds and their dependence on thermals to help them fly. Birds were caught by hand in the early morning and late evening when there were no thermals. Lone birds were selected to avoid disturbing large numbers of birds at communal roosts.

PTTs were fitted as back-packs and secured by a Teflon ribbon double-loop (Snyder et al. 1989). A 45 g conventional VHF transmitter and plastic wing-tag with letter code were also attached to one wing in following Wallace et al. (1994). The PTTs, which are 'received' by the Argos-Tiros satellite system (Argos, 1996) had been programmed to transmit for 20 hours every week (20 hours on and 148 hours off) to cover a period of approximately 75 weeks. The PTTs also were equipped with pressure sensors. Using a cure calibrated by the PTT manufacturer, the altitude at which the birds flew could be estimated. The range encompassed by the bird's movements was calculated for the period of transmission, using PC software package SEAS (Spatial Ecology Analysis System), and the Home Range Analysis program (CALHOME) based on the minimum convex polygon.

RESULTS

Transmission of PTT No 23628 (vulture no. 28) started on 25 January 1995, and stopped on 8th of October in the same year when the battery expired, covering a period of approximately 37 weeks, given 108 corrected locations. PTT No. 23629 (Vulture no. 29) started transmitting on 12 February 1995, but transmissions stopped, on 31st May 1995, for a three-month period, before it started again in early September, and continued transmitting until 12 December 1995. The reason for this transmission loss during the summer is unknown. The total period of transmission was approximately 31 weeks, with 82 corrected locations. Lappet-faced Vulture no. 28 left the reserve after its release, returning in the autumn of the same year after it had covered a total distance of 5500 km (Figure 2). It moved continually throughout the tracking period. The greatest linear distance moved away from the capture site was 400 km.

Vulture no. 29 covered 1325 km, moving to the north of the reserve and stayed there for more than three months, before the transmission ceased at the end of May (Fig. 3). During this period, the longest distance moved by this bird away from the release site was 450 km.

Fig. 2: The movement of Lappet-faced Vulture no. 28

Fig. 3: The movement of Lappet-faced Vulture no. 29

When transmission recommenced on 7th September, the bird had moved more than 400km to the north west of its last recorded position in late May, at a Protected Area called at-Tubayq in the north. A week later, the same bird had returned to the Mahazat as-Sayd reserve, having covered more than 900 km. It stayed in the reserve until late November 1995 then moved 400 km to the north.

The bird remained in this area for two weeks before it returned to the reserve in early December 1995 when the last transmission was received. The vulture was located in the reserve during conventional UHF tracking by plane over Mahazat as-Sayd on 31st September 1997. Table 1. Shows the rate of travel recorded (using SEAS) between successive locations. Both birds had similar maximum speeds. From 15 records when the birds were flying, the maximum altitude recorded was 8,825 feet (2,690 m) from ground level, for bird no. 28.

Table 1. Distances covered and range areas for the two birds fitted with PTT transmitters

Variable	**Bird no. 28**	**Bird no. 29**
Distance covered	5500 km (10 months)	1325 km in 1st period
Distance covered per month	724 km	361 km
Maximum distance moved per day	198 km	193 km
Average distance between locations	63.494 km	33.92 km in the 1st period 42.122 km in the 2nd period
Harmonic mean range	283,380 km^2	289,280 km2 in 1st period 277,840 km2 in 2nd period
Rate of travel	47 km/h	45 km/h
Maximum Altitude	8825 feet (2690 m)	5322 feet (1622 m)

The range calculated by SEAS during seven months from 25 January 1995 to 31 August 1995 was 92,881 km^2, also for bird no. 28. The Harmonic mean range calculated by Calhome was 283,280 km^2, with an average distance between locations of 63.5 km.

The second bird no. 29 spent more time in one area, and had two shorter periods during which the transmitter was operating. The range encompassed for this bird during the first period was 36,771 km^2 and the harmonic mean range of this bird in the first period until end of May was 289,280 km^2, with an average distance between locations of 33.9 km. In the second period, from September to early December of 1995, the harmonic mean range was 277,840 km^2, with an average distance between locations of 42.1 km.

DISCUSSION

Each satellite tracked lappet-faced vulture showed a different movement pattern. One moved continually, whereas the other underwent periods of long movement separated by more sedentary periods. These variations in behaviour may have been associated with differences between animals with respect to age or sex. However, both birds left the reserve after release in the winter but returned to the reserve again in the autumn. These findings help explain the annual variation in abundance of lappet-faced vultures in the protected area (Newton and Newton 1996; Shobrak 1996). The longest distances the two lappet-faced vultures moved from the capture site, ranged between 600-1000 km which is similar to the observations in Africa where birds have been re-sighted 700 km from the nesting site (Mundy et al. 1992)

Moreover, breeding Lappet-faced Vultures have been recorded at most of the areas in which the birds were tracked (Jennings 2010). This could be important for the species in the location of food resources as non-breeding birds were observed roosting together in the protected area. This suggests that the birds probably benefited from the presence of other birds in the location of food. In addition, the capture of the birds during the breeding season and the fluctua tion in the number of these vultures in the protected area increases the possibility of contact between individuals between different

breeding colonies. This type of contact has been recorded for several other bird species including birds of prey (Newton 2008).

Contact between birds in this way, is probably important in preserving the genetic diversity of the species. Furthermore, the large distances covered by the two birds suggests that there is the potential for contact between the population in Saudi Arabia and those in neighbouring countries. This contact between different highly dispersed populations, also suggests that the lappet-faced vulture populations in the Arabian Peninsula can be considered to be a meta-population. If the Lappet-faced Vultures from other colonies in the Arabian Peninsula have similar movement patterns, the species should probably be included in the list of species considered by the Memorandum of Understanding on the Conservation of Migratory Birds of Prey in Africa and Eurasia. However, more work is needed to understand the movements of breeding adults and fledglings in order to determine the threats on the species. Finally, genetic studies should be considered to identify the relation between the different breeding populations in Saudi Arabia and neighbouring countries.

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The numbers of breeding and migrant birds at the Royal Society for the Conservation of Nature (RSCN) Azraq Wetland Reserve 2004 to 2011

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ABSTRACT

The Azraq Oasis and Qa al Azraq Ramsar site were one of the most important and impressive wetlands in the Middle East, providing an invaluable resource to local people and wildlife. However, in 1993, the abstraction of water from the Azraq aquifer resulted in the oasis completely dying up. In 1994, the Royal Society for the Conservation of Nature (RSCN) secured a supply of water to establish the Azraq Wetland Reserve. RSCN has successfully restored part of the Azraq Oasis. This paper presents the results of a study to monitor the numbers of breeding and migrant birds using the Azraq Wetland reserve between 1999 and 2011. With a few exceptions, most species of breeding and migrant birds appear to have declined in numbers since 2004, probably as a result of the very dry conditions.

Key words: Azraq; wetland; RSCN; migrant; breeding;

INTRODUCTION

The Azraq Oasis and Qa al Azraq Ramsar site were one of the most important and impressive wetlands in the Middle East, providing an invaluable resource to local people and wildlife. However, in 1993, the abstraction of water from the Azraq aquifer for use both in cities and at local farms resulted in the world famous oasis completely dying up. In 1994, the Royal Society for the Conservation of Nature (RSCN) secured a supply of water from the Jordanian Water Authority to establish the Azraq Wetland Reserve. RSCN has successfully

undertaken a programme of management aimed at restoring at least a small part of the Azraq Oasis.

By obtaining a small supply of water (insignificant in national terms), RSCN has been able to restore about 2% of the original oasis. Although the Wetland Reserve is now probably only a shadow of its former glory as an oasis, it is still invaluable for wildlife. The Reserve also draws tourists to Azraq, provides employment in the area and is an extremely valuable educational facility with a programme of school-visits. The wetland provides an important habitat for a variety wildlife, but it is the migrant birds that use the reserve as an "island refuge" during their long spring and autumn movements over inhospitable desert terrain and provide an impressive spectacle within the area.

Between 1999 and 2011 the Azraq wetland reserve and Qa al Azraq were censused on six occasions during April, by RSCN staff working with volunteer staff from the Royal Society for the Protection of Birds (RSPB) based in the United Kingdom. These studies were intended to record migrant and breeding birds at Azraq and allow comparisons between the results of other years in an attempt to evaluate the success of the programme of habitat management work.

Surveys of birds were carried out across a number of habitats within the reserve during the spring period, between 1999 and 2011 (Melling 1999), 2000 (Strudwick 2000), 2004 (Ellis 2004) and 2006 (Ellis 2006), 2009 (Ellis 2009) and 2011 (Ellis 2011).

MATERIALS AND METHODS

During April in each of the survey years, censuses of birds were carried out on the Azraq Wetland Reserve. In years when Qa al Azraq was flooded, censuses were also carried out of the mud flat habitat. Methods were broadly similar each year. In the dry habitats on the reserve, two fixed transects were walked and all birds seen within 100 metres either side of the transect line were recorded. For some species, singing males were recorded separately in order to estimate breeding populations. Each of the two (3.5km) transects.

were walked on two to four (depending on the year) different days approximately nine days apart, and each census was carried out between 06.26 hrs and 09.46 hrs. This allowed an estimate to be made of the breeding and migrant birds using the dry habitats on the reserve. Using similar methods, bird censuses were also carried out in the wetland habitats on the reserve, referred to as the Boardwalk and Circular transects. Two new transects were introduced in 2006, the New Pools transect which ran around the perimeter of the pools and the New Marsh transect which ran along the length of the new ditch and flooded area, which runs east from the New Pools (Fig. 1).

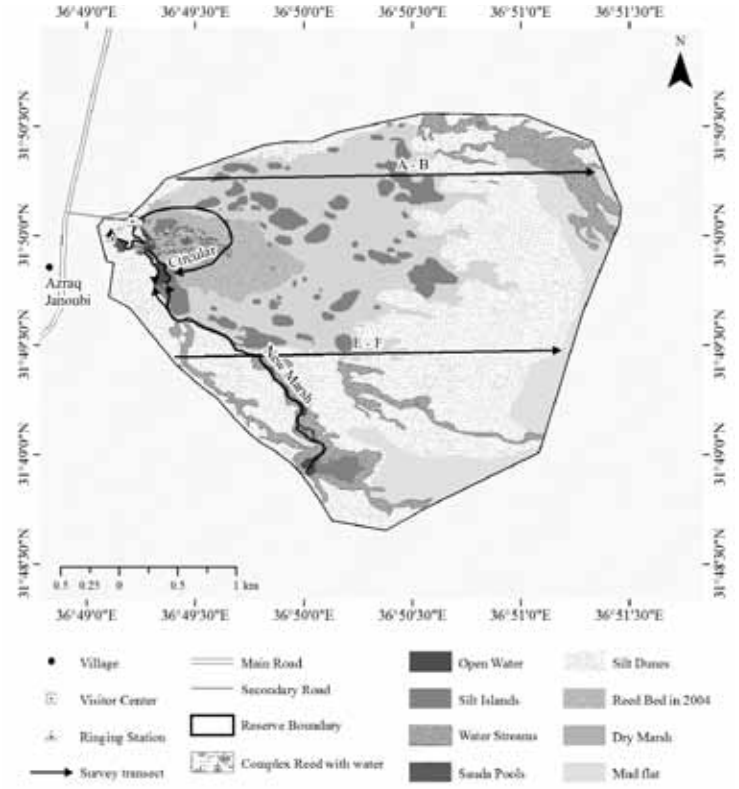

Fig. 1: Survey transects in the Azraq Wetland Reserve.

On these transects, birds within 10m either side of the water were recorded. The mapping of breeding birds began in 2006 and was continued in 2009 and 2011. Geographical positioning system (GPS) and satellite images were used to map several wetland breeding species along the Circular, Boardwalk, New Pools and New Marsh transects.

In addition, counts of birds were also made during the evening period from the roof of the Visitors' Centre in order to gauge the importance of the reserve for roosting birds. Counts were also made from the Hide in the evening in order to assess the importance of the Hide Pools and the areas of wet reedbed at the south end of the pools. However, in 2011, because a fire in 2009 had removed all the intervening tall, dry reed, counts from the hide, included the entire area visible from the hide, including the newly enlarged Sharq Soda Pool. Qa al Azraq was censused between 1999 and 2006, but did not flood in 2009 or 2011.

RESULTS

Many of the breeding species in the drier habitats on the reserve have declined. However, the populations of Crested Lark, Rufous Bush Robin and White-cheeked Bulbul in the drier habitats and Graceful Warbler and Reed Warbler in the wetland habitats have increased (Figures 1, 2, 3 and 4). Numbers of migrant birds feeding in the wetland areas of the reserve have mostly declined, with the exception of Chiffchaff and apparently migrant Reed Warblers, which have increased (Figure 2).

Those migrants that largely feed off the reserve, but roost in the reedbed have also declined. The most common migrant species that roosted in the reed bed, Sand Martin, Swallow and Yellow Wagtail, have declined considerably since 2004. However, their numbers have remained broadly stable, but much lower since then (Figure 5). The unauthorised burning of the reed bed in the vicinity of the board walk in 2009 and subsequent grazing by water buffalo, reduced the amount of available tall reed habitat for reed warblers in the area. Although reed warbler numbers declined substantially in this area, the numbers of singing males and apparent migrants on the reserve as a whole have increased (figures 1 and 2).

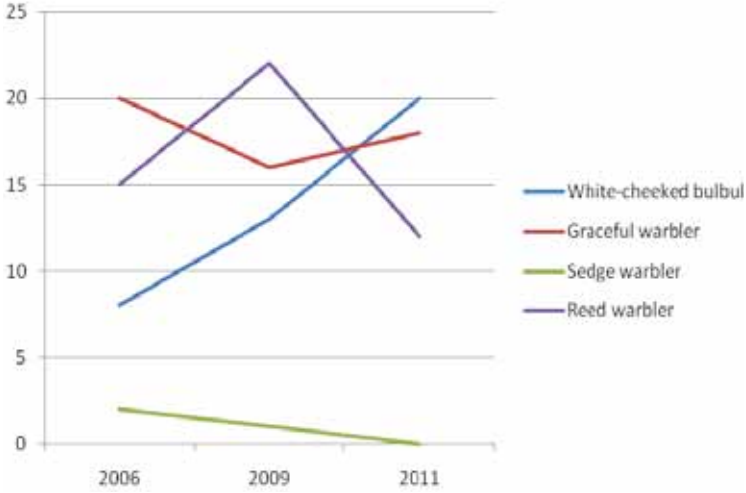

Fig. 1: Total numbers of singing male White-cheeked Bulbul, Graceful Warbler, Sedge Warbler and Reed Warbler recorded from the Boardwalk, Circular, New Pools and New Marsh Transects 2006 to 2011

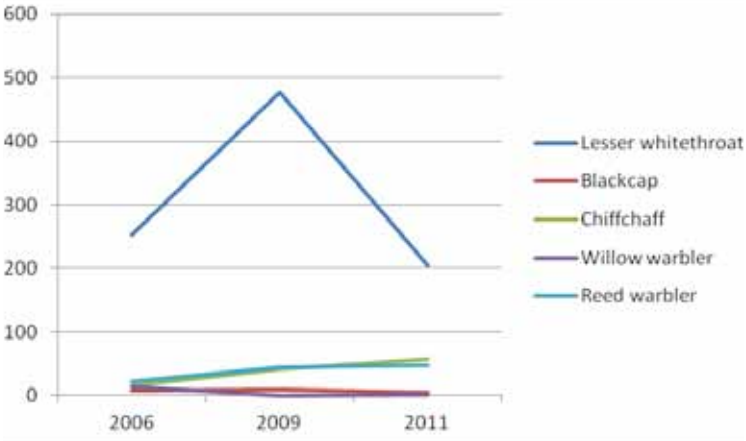

Fig. 2: Mean numbers of migrant warblers recorded on the Circular, Boardwalk, New Pools and New Marsh transects between 2006 and 2011

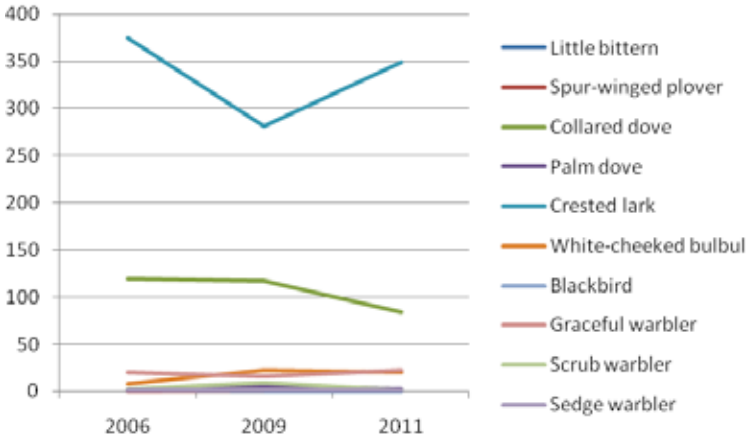

Fig. 3: Estimates of the numbers of singing/displaying males of those species thought to breed on the reserve in 2006, 2009 and 2011

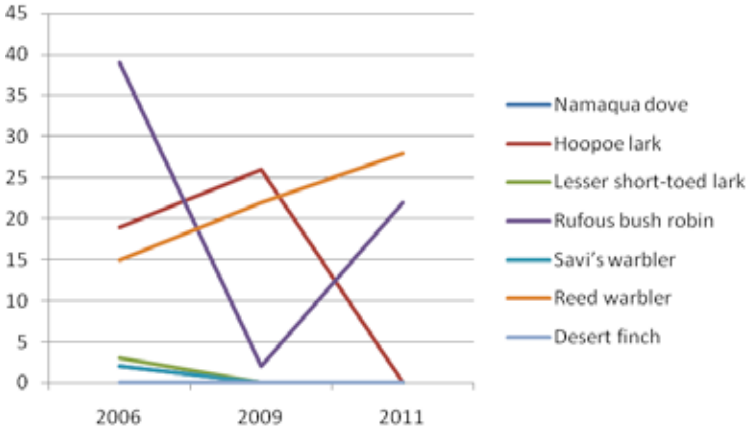

Fig. 4: Estimates of the numbers of singing/displaying males of those species thought to breed on the reserve in 2006, 2009 and 2011

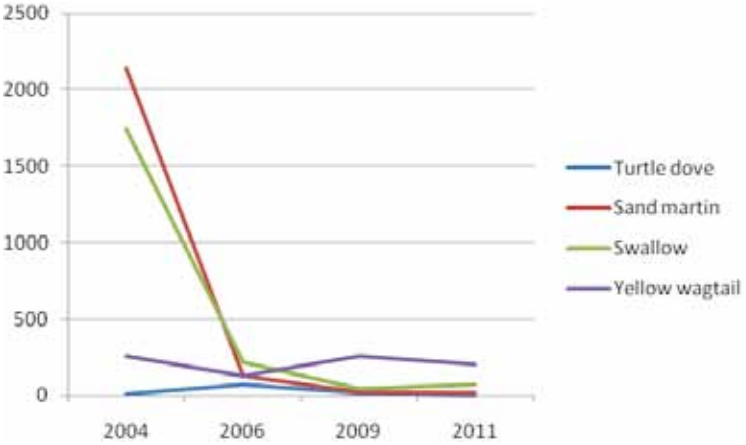

Fig. 5: Trends in the numbers (mean counts) of selected migrant species roosting in the reed beds between 2004 and 2011

DISCUSSION

The over abstraction of water from the Azraq Oasis and its resultant drying out has had a profound effect on the numbers of migrant and breeding birds that use it. The numbers of migrants that pass through the oasis and the number of species that breed there both appear to have declined substantially from those found by studies carried out before the oasis dried out in 1993 (Nelson 1973, Wallace 1982, Wallace 1983).

RSCN reflooded a small part of the oasis and created the Azraq Wetland reserve in 1994, this supported smaller but still significant numbers of migrant and breeding birds (Melling, 1999) and Strudwick (2000). However, since 2005, the winters have been considerably drier (Fig. 6). These dry conditions have had a substantial effect on the dry ground habitats on the reserve. Since 2006, there has been so little rain in the winter that Qa al Azraq has not flooded to any significant extent and no surface water has been observed in the qa during this study since then. These drier conditions have almost certainly resulted in a decline in the numbers of many of the

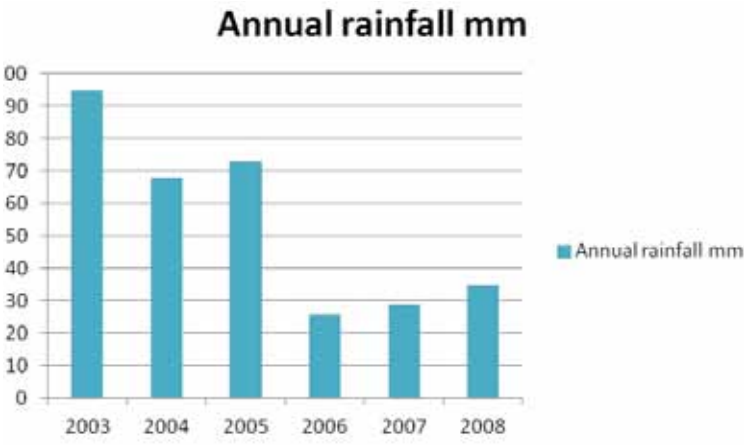

Fig. 6: Annual rainfall in mm recorded at the Azraq meteorological station

recorded and probable breeding species on the reserve, with a few exceptions.

In wetland habitats, the continued pumping of water, though proving politically difficult to continue, has been very successful and has largely maintained the quality of these habitats, which have been further enhanced by a pool creation programme. The increase in numbers of both breeding and apparently migrant reed warblers, despite the reduction in the area of tall reed in the area of the Boardwalk Transect by an unauthorised fire and subsequent grazing by water buffalo, may have been due to displaced birds moving into the New Pools area. This indicates that the recent programme of pool creation has made the reserve better able to adapt to unforeseen changes. The areas of green, short, grazed reed between the Visitors' Centre and the Hide did however prove attractive to Wagtails and a variety of other migrant species.

The numbers of migrant species that use the reserve as a staging post in their spring movements northwards will fluctuate annually depending on several factors, including changes in the size of the biogeographic population of each species, prevailing weather con-

ditions and in the timing of the spring migration. However, one of the most important influences on the numbers passing through the reserve each year is the condition of the habitats within the reserve, and how they relate to the condition of the surrounding habitats. The habitats used by most migrant species have been adversely affected by the continuing dry conditions and with few exceptions, the numbers of migrants feeding on the reserve and roosting in the reedbed have declined since 2004.

CONCLUSION

This study has confirmed the importance of the Azraq Wetland Reserve for several species of breeding birds and many species of migrants. Low winter rainfall and the failure of the Qa al Azraq to flood in recent years have undoubtedly reduced the numbers of migrant birds using the entire Azraq area including the reserve. However, the continuing enhancement of the wetland habitat on the reserve and the continuing pumping of water to different parts of the reserve have been very successful in maintaining and increasing the attractiveness of the wetland to a large variety of bird species, especially migrants. For migrant birds, the Azraq wetland reserve acts as an "island" of wetland habitat in the otherwise dry Eastern Desert. Consequently, it is essential that if breeding and migrant birds are to continue to find suitable habitat in the area, the quality of the wetland habitat must be maintained and preferably further enhanced.

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Monitoring, threats and conservation of hibernating bats roosts in Lebanon

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ABSTRACT

In this study up to 41 sites known to contain hibernating bats were surveyed during the winter of 2012-2013. There was a noted increase in the Egyptian fruit bat, *Rousettus aegyptiacus*, population in Berqayel cave. This increase was probably due to the effectiveness of the awareness program that was conducted in Berqayel after the 2010 disturbance; where thousands of R. *aegyptiacus* were shot or suffocated by fire in the cave and the destruction of the cave entrance. New roosting sites were reported for different species. However, there was a decrease in *Rhinolophus blassii* and *Miniopterus schreibersii* populations, mainly due to human disturbance. Proposed conservation measures including follow-up monitoring of bats, and broader public awareness programs are highly recommended for more effective bat conservation.

Key words: Bats, Lebanon, Conservation, Monitoring

INTRODUCTION

Bats are the only true flying mammals and include around 20% of all described mammal species. Many species of bat are closely associated with cave where they can be considered keystone species for such habitats. Bats also play an important role in dispersing seeds, pollinating flowers and controlling insect agricultural and forest pests (Gnaspini & Trajano 2000).

Currently bats are one of the most threatened mammal groups and

are declining across the world. (Hutson et al. 2001; Fujita & Tuttle 1991; Schipper et al. 2008). Bats face acts of vandalism, especially when they are hibernating or roosting in large colonies.

In terms of biodiversity the fauna and flora of Lebanon is enhanced by its geographical location to the east of the Mediterranean, moderate climate and wide range of geology, landscapes and habitats. Two-thirds of Lebanon is covered by Karst limestone formations with over 1000 natural caves. These caves provide suitable sites as bat roost during summer and winter.

In addition, Karst formations, characterized by subterranean limestone caverns carved by groundwater, which provide an immense potential of bat roosts and feeding grounds. Old information and literary records on the Lebanese bats are surprisingly scarce except for some early records in the 1960s to 70s summarized by Tohme & Tohme (1985).

The situation has changed during recent years and an intensive bat monitoring and survey programme was initiated in 2006-2007. A yearly monitoring of hibernating roosts is being carried out. This paper is intended to provide data on the present state of bats in Lebanon, identify threats they face, and recommendations for their conservation.

MATERIALS AND METHODS

The bat survey was initiated late between December 2012 and February 2013. A total of 41 caves and roosting sites were visited (Table 1). Members from caving clubs assisted in visiting the caves. Hibernating bats were identified and their numbers were estimated by direct observation. When populations were too big, the number was estimated either by taking a photo of the colony and counting them later; or by taking a small quadrate and then multiplying it by the appropriate scale to get the approximate size. All data including the name of the cave, date, location, species and number of bats were recorded.

Table 1: Caves inspected for the presence of bats.

Location/ Governorate	Cave name	Date of visit
North*	Akroum Cave	26.12.2012
North*	Zebdeen Cave	16.1.2013
Mount Lebanon	AlDaba'a Cave- Maaser	9.1.2013
Mount Lebanon	Naba'a Niha Cave	9.1.2013
Mount Lebanon	Alwataweet Cave- Besri	29.12.2012
Mount Lebanon *	Howet Wadi Aldayr Baakleen	9.2.2013
Mount Lebanon	Naba'a AlMghara	30.12.2012
Mount Lebanon	Mgharet Fakherdeen	10.2.2013
Mount Lebanon	Mgharet Al-Wataweet- Debbayeh	10.2.2013
Mount Lebanon	Naba'a Niha	9.2.2013
Mount Lebanon *	Bsayr-Chehim	14.2.2013
Mount Lebanon	Saleh– Amcheet	24.12.2012
Mount Lebanon	22-April-Antelias	24.12.2012
Mount Lebanon	Kenaan-Antelias	24.12.2012
Beqa'a	Kfarzabad	23.2.2013
North	Gallery Msailha-Chekka	28.2.2013
Mount Lebanon	Hiba – Jbeil	24.12.2012
North	Deir Mahwet – Koura	28.2.2013
Mount Lebanon	AlTarrash - Hrajel	30.12.2012
Mount Lebanon	Ser`aya – Hrajel	30.12.2012
Mount Lebanon	Afqaa	8.2.2013
Mount Lebanon	AlRwaiss	8.2.2013
Mount Lebanon	Salem Cave – Lasa	8.2.2013
Mount Lebanon	Marjaba Mine	30.12.2012
Mount Lebanon	AlHeskan- Abadieh	22.1.2013
Mount Lebanon	Old House-Chweet	22.1.2013
Mount Lebanon	Zaytoun	26.1.2013
North	Berqayel Cave	3.12.2012

North	Ras Al Chequa Cave	3.12.2012
North	Yousef Karam – Qezhaya	19.2.2013
North	Qnat Cave	19.2.2013
North	Joulman-Bhairet Toula	19.2.2013
North	Qadeesha	22.2.2013
North	Church in Kfarsghab	22.2.2013
South	Em Bazzez Aadloun	5.2.2013
South	Al alalieh Aadloun	5.2.2013
South	AlReehan	21.12.2012
South	Wadi Jilo	21.12.2012
Mount Lebanon	Fowar Dara – Tarchich	4.2.2013
North	Tripoli-Mtal Azraq - Tripoli	3.12.2012
North	Alhab Cave – Tripoli	2.2.2013

RESULTS AND DISCUSSION

Bat Species Observed in Caves

A total of 10 bat species were recorded during this survey. Table (2) shows bat species incountered, their estimated numbers and cave location. The Egyptian Fruit Bat, *Rousettus aegyptiacus*, was recorded in nine sites ranging from the coastal areas to Mount Lebanon but not exceeding an altitude of 850m above sea level. Additional new location was recorded in the Al Shouf area of Mount Lebanon. The total population size was estimated to be about 9000 individuals. An increase in the number of the Egyptian Fruit Bat in Berqayel cave, North Lebanon, was observed (Figure 2). This cave was exposed to a significant disturbance in 2010: The number has risen from ca. 1500 bat in 2011 winter census to ca. 5000 in 2013 year.

Four species of horseshoe bats were observed during the present survey. The Greater Horseshoe Bat, *Rhinolophous ferrumequinum*, was

Table 2: Caves under study with estimated number of bat species observed.

	Species									
Cave name	Mca	Mmy	Msc	Pku	Ppi	Rea	Rhb	Rhe	Rhf	Rhh
Akroum Cave		2							1	5
Zebdeen Cave	10	3								1
ALDabe'a Cave- Maaser										
Nabe'a Niha Cave		3								
Alwataweet Cave- Besri						1000				3
Howet Wadi Aldayr-Baakleen									4	1
Nabe'a ALMghara									7	5
Mgharet Fakherdeen									5	1
Mgharet Awateet- Debbayeh						850				
Nabe Niha	13									
Bsayr- Chehim						1				
Saleh– Amcheet			1			150			1	
22-April-Antelias						500				2
Kenaan						150				
Kfarzabad							17			
Gallery Msailha									3	2
Hiba – Jbeil						150				
Deir Mahwet – Koura									2	1
AlTarrash - Hrajel									1	
Seraya – Hrajel			20						15	5
Afqaa									43	9
Al Rwaiss			~600						4	5
Salem Cave – Lasa									2	4
Marjaba Mine									650	
AlHeskan						100		15	20	
Old House-Chweet					1				200	
Zaytoun						150				
Berqayel Cave						5000			1	2

Qadeesha									5	15
Yousef Karam – Qezhaya								3	2	2
Cave Qnat									3	10
Joulman-Bhairet Toula									2	
Church in Kfarsghab										300
Cave Ras AlCheqa'a						100				
Em Bazzez Aadloun				4		50				
Al alalieh Aadloun					3	200				
AlReehan										1
Wadi Jilo						20				
Fowar Dara – Tarchich										
Tripoli-Mtal Azraq						250				
Alhab Cave – Tripoli	100							15	35	
Total	**123**	**8**	**622**	**4**	**4**	**8671**	**17**	**33**	**942**	**374**

Mca: *Myotis capacinii*, Mmy: *Myotis myotis*, Msc: *Miniopterus schreibersii*, Pku: *Pipistrellus kuhlii*, Ppi: *Pipistrellus pipiitrellus*, Rea: *Rousettus aegyptiacus*, Rhb: *Rhinolophus blassii*, Rhe: *Rhinolophus euryale*, Rhf; *Rhinolophous ferrumequinum*, Rhh: *Rhinolophous hipposideros*

Fig. 2: A colony of the Egyptian Fruit Bat, Rousettus aegyptiacus in Berqayel Cave.

recorded from 21 sites across Lebanon with a total population size of approximately 1000 individuals. The Lesser Horseshoe Bat, *Rhinolophous hipposideros*, was recorded from 19 sites from all over Lebanon. The total population size is estimated to be ca. 400 individuals. This bat was encountered individually except for one big colony of ca. 300 individuals located in a church in *Kfarsghab*, North Lebanon. The Mediterranean Horseshoe Bat, *Rhinolophus euryale*, was only recorded from three sites including one new site from the North of Lebanon. The Blasius' Horseshoe Bat, *Rhinolophus blassii*, was recorded for the first time in 2007 in Kfar Zabad cave on the western slope of the Anti-Lebanon (Horacek et al., 2008). In this survey it was recorded from the same site, however with a smaller colony size of 17 individuals compared to the 2012 census.

The Greater Mouse-eared Bat, *Myotis myotis*, has been recorded from seven different sites in Lebanon (Harrison & Lewis 1961, Lewis & Harrison 1992, Harrison 1964, Atallah 1970, Tohme & Tohme, 1985, Spitzenberger 1996, Horacek et al.2008). Two new records were added during this survey from Akkar in the North of Lebanon on the Lebanese Syrian border. Their total recorded population size was eight individuals.

The Long-fingered Bat, *Myotis capacinii*, has been documented as existing in different parts of Lebanon in the summer but only two findings were made here (Horacek et al. 2008). However, three new records were documented from the winter census—two in the North of Lebanon (Akkar and Tripoli) and one from Mount Lebanon (Niha Cave). Their total population size estimated was ca. 123 individuals (Table 2).

The Common *Pipistrelle* Bat, *Pipistrellus pipiitrellus*, is the most common bat in Lebanon (Horacek 2008). In this study, it was recorded from two sites with a total of 4 individuals. Four individuals of the Kuhl's Pipistrelle Bat, *Pipistrellus kuhlii*, were found at one site in the South of Lebanon (Table 2). The Schreibers' Bat, *Miniopterus schreibersii*, was recorded from three sites during this study. In Al Rwaiss cave, more than 600 individuals were observed.

A number of differences were found in both the distribution and abundance of many of those bat species recorded here, compared with previous records available. In some case these represented reestablishment of old sites, in others loss of species from known sites. Data recorded during this survey shows a noticeable positive difference from previous years (2011-2012) in species composition, proportion of particular species, and population re-establishment of some species.

The positive increase in the population size of *Rousettus aegyptiacus* in Berqayel cave and the reappearance of *Miniopterus schreibersii* in the Al Rwaiss Cave could be attributed to the awareness programs that were executed in both sites. The programs included meetings with locals, seminars, workshops and pamphlet distribution on bats and their positive role in the environment. Likewise, in Kathmandu-Nepal a radio program and lectures about bats were effective in bat conservation (Thapa et al. 2012). Moreover, environmental education programs on three critically endangered species of fruit bats in western Indian Ocean islands have led to increased awareness about bats and their conservation (Trewhella 2005).

On the contrary to what was found in Palestine (Qumsiyeh 1996), there was no evident effect of fruit bats on the insectivorous bat population in caves where both species coexist. This could be attributed to the size of the cave as most fruit bats inhabited the entrance of the caves while insectivores went deep in the caves. Besides, most insectivorous bats are found in roosts of higher elevation where fruit bats cannot survive due to the cold winter.

Horacek et al. (2009) reported a large number of hibernating bats in 2009 in Lebanon, probably due to the cold and early winter. On the contrary, during this survey a small number of bats were recorded compared to previous years. Apparently the winter of 2013 has been undoubtedly warmer than that of previous years and the temperature in low altitudes was higher. In the same way, in south-central Texas bats emerged earlier in years with extreme drought conditions than during moist years (Frick et al. 2012). The heavy rain that occurred this year flooded some caves which affected the roosting sites of some species. This was the case in Al-Tarrash cave

of Mount Lebanon where the water level reached above three meters inside the cave.

Threats on Bats in Lebanon

Threats to bats can be in different forms: ecotourism, entering caves during hibernating season, putting fire and fireworks in caves, as well as shooting bats. In quite a few caves, tracks of bats were found on the ceiling of the caves or guano was found on the ground without the existence of bats (Figure 4). These caves might have been used as summer roosts or bats were disturbed enough to leave the roost. In Al Rwaiss cave, the colony of Schreiber's bats was relocated into a new chamber within the cave (far from the entrance pathway). This is probably due to disturbance by visitors. Lately, this cave accepts a significant number of visitors; hence bats have to relocate their hibernating site away from the disturbance of visitors. In addition, the winter was exceptionally mild, the colony would be seeking thermal stability deeper inside the cave, as *Miniopterus schreibersii* can detect small temperature differences and use this ability to select cold areas of the cave in order to enter torpor.

Fig. 4: Tracks of bats on cave ceiling and guano encountered in some visited caves.

On the other hand, the population of R. *blassii* has decreased and this is mostly caused by human disturbance, since during the survey study, an electric generator, ropes and other man-made materials were found beside the cave. Similarly in China, caves that were exposed to human disturbance in the form of recreational activities had a negative pronounced effect on the number of bat

species present (Luo et al. 2013). Similarly, Barber et al. (2009) found urban noises to have a negative effect on terrestrial vertebrates. The relative abundance and distribution of fruit bats in Malaysia was affected severely by hunting (Mohd-Azlan et al. 2001).

In summary, whilst this study has highlighted the current status of bats across many areas of Lebanon there is an urgent need to extended surveys to check on other roosts, their status, as well as a follow up on the ones under study. This will lead to better conservation of species and their habitats, hence insuring their protection. It is strongly recommended to take measures to prevent any disturbance of bats hibernating roosts. These include: routine visits from concerned locals; preventing any activity in caves during the hibernating season; the establishment of an intensive awareness program directed towards conservation of bats, their role in the ecosystem, their benefits to humans, and the importance of their conservation. Awareness programmes have proved their efficiency in saving a number of different animal species by changing human attitudes and resolving human-wildlife conflict. Similar awareness programmes should be introduced across Lebanon for bats.

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The use of multi-criteria evaluation and expert knowledge in developing protected area zoning plans in Jordan

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ABSTRACT

Protected areas (PAs) in Jordan are managed through scientifically based management plans (MPs). Zoning plans are created as supporting plans to MPs when different management procedures need to be applied in different parts of a PA. A GIS-based zoning plan model was developed using spatial multi-criteria evaluation technique (MCE). The model was created to provide a systematic repeatable approach to evaluate the conservation values and human threat, thus facilitating the decision making process for PA's zoning in Dibeen forest in the northwest of Jordan. Cartographic modeling was used to combine datasets with different attributes by reclassifying them according to a common comparison scale, and finally adding them according to their assigned relative weights. The resulting weighted summation rasters identified areas with high conservation values-high human threat, high conservation values- low threat, and low conservation values- high human threat. The PA was divided accordingly into three management zones: an intensive use zone where tourism and other human activities are allowed but restricted to a small area, a semi-intensive use zone where educational activities are allowed, and finally a wilderness zone that includes the most ecologically important and representative habitats of the PA where all human activities are prohibited except wildlife research and monitoring. The zoning plan model developed for Dibeen Forest Reserve can also be applied to other PAs in Jordan and within the region taking into consideration that the evaluation criteria and weights can be modified depending on the characteristics of each PA and the data available.

Key words: Protected Areas, Jordan, Forest, GIS, RSCN.

INTRODUCTION

The management of protected areas (PAs) has recently transformed to a wider and more inclusive approach. From isolated areas set aside for conservation and scientific research, PAs are now run as networks with social, economic and cultural objectives with local people more in mind (Phillips, 2003). The PAs network in Jordan was first proposed in 1979, modified and updated in 1997, 2005 and in 2008 (RSCN, 2008). The Royal Society for the Conservation of Nature RSCN is mandated by the Jordanian government to establish and manage PAs network according to scientifically based management plans (MoEnv., 2003). Management plans contain supporting documents, including zoning plans; which are created when different management actions and procedures need to be applied in different parts of a PA in order for its objectives to be met. It is a legal document that can be presented in a form of a map illustrating geographical boundaries between different zones (Phillips, 2003). Young and Young (1993) state that "Zoning defines what can and cannot occur in different areas of a park in terms of natural and cultural resources managements; human use and benefit; visitor use and experience; access; facilities and development; maintenance and operations. Through management zoning the limits of acceptable use and development in the PA are established".

For terrestrial and even marine PAs, planning has largely been based on common sense, and on simplistic approaches that have been used to provide guidance to decision makers (Villa et al., 2001). In Jordan, zoning plans were prepared by overlaying different map layers representing physical, ecological, social and other site characteristics using Geographic information systems (GIS). The layers were visually analyzed to identify the parts of the PA with high conservation value. This was applied in Wadi Rum PA (RSCN, 2003), Dana PA (RSCN, 2006), and Petra archeological park (Damhoureyeh et al., 2011). Visual analysis of different layers did not always produce satisfactory results when huge datasets with different levels of importance were involved in the analyses. It was therefore desirable to develop an objective and systematic GIS-based approach to enhance the decision making process when it comes to protected area zoning.

Geographic information systems applications have been frequently used in producing new information by combining information from different sources and by spatial analysis of existing data (Store and Kangas, 2001). Jiang and Eastman (2003) stated that 'Multi-criteria evaluation (MCE) is considered the most fundamental decision support operation in GIS'. One approach to MCE in a GIS environment is the 'additive' technique whereby the criterion scores are standardized and the total score for each alternative is calculated by multiplying each criterion score by its weight factor and then adding the results (Store and Kangas, 2001). This approach was used in GIS habitat suitability modeling (Store and Kangas, 2001), and in landscape ecological forest planning (Kangas et al. 2000), and in Marine Protected Area Zoning (Villa et al. 2001). Al-Bakri et al. (2011) used GIS database functionalities integrated with statistical analysis and 'expert' knowledge in analyzing the explaining variables that influence the spatial distribution of medicinal and herbal plants in the north western highlands of Jordan. In the same study they identified hotspots for medicinal plants with high priority for conservation by interpolating the total evaluation scores assigned for the sampled ground locations using expert chosen evaluation criteria.

This work aims at integrating spatial MCE and expert knowledge to develop a systematic GIS based model for terrestrial protected area multi-objective management zoning.

MATERIALS AND METHODS

Study area

The study area is Dibeen Forest Reserve (35° 48.95´ E, 32° 14.77´ N), which is located in the north western highlands of Jordan within Jerash District and covers about 850 hectares (Fig. 1). The area is located within the semiarid Mediterranean zone with precipitation ranging from 400mm – 500mm within the PA, the rainy season extends from November to April. The mean maximum temperature in the PA is around 33°C (occurring in August), and the mean minimum temperature is around 3 °C (occurring in January). The elevations range from 1060m a.s.l in the northern parts of the PA to 470 m a.s.l in the south.

The PA was established in 2004 in order to conserve the unique Aleppo pine forest, *Pinus helpensis*, that represents the south eastern limit of the species' distribution in the northern hemisphere (RSCN, 2004c). The size and shape of the PA represents a challenge for management since it consists of three small land blocks connected in the middle. The land of the PA is a treasury land, and managed by the RSCN. The PA is served by a network of paved and unpaved roads, and is surrounded by small villages. The forest suffers from illegal woodcutting, hunting and tremendous pressure resulting from the use as a recreational area.

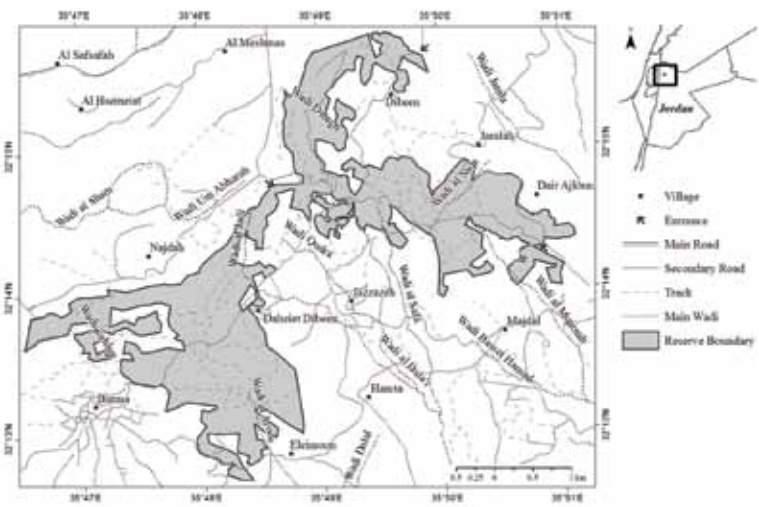

Fig. 1: General location of Dibeen Forest Reserve

According to the management plan of Dibeen Forest Reserve, its management vision was to retain a core of self-regenerating Aleppo pine habitat and become ecologically and financially sustainable, while continuing to provide an important recreational resource and valued forest habitat for local people (RSCN, 2009).

Datasets preparation and evaluation criteria

Flora and fauna baseline surveys and field data collection on land use and threats to biodiversity were carried out between 2004 and 2006 during the establishment of the PA. These surveys provided a spatial database, which represented the core for selecting evaluation criteria based on their relevance to the purpose of the zoning plan. The purpose of the zoning plan, in the context of this study, was to provide maximum protection to the parts with the highest conservation values and least disturbance due to human activities while permitting reasonable human use in limited areas. The PA evaluation criteria were in two categories: conservation values and human threats. Expert knowledge was used in defining the evaluation criteria, the type of impact and the relative weight for each criterion.

The conservation values were selected by conservation specialists based on their relevance to the aforementioned PA's purpose of establishment, thus the vegetation types was considered the most significant evaluation criteria. Other criteria representing the distributions of indicator plant and animal species were also selected as they indicate health of the habitat (RSCN, 2004c). Accordingly, high densities of indicator species were considered having positive impact on the conservation values. Table 1 includes the selected conservation evaluation criteria, and the data set collection source.

Table 1: Conservation evaluation criteria, data sets and data collection source

Category	Criteria/ Dataset	Dataset Source
Representation of habitats	Vegetation Types • Pine areas • Mixed Pine-Oak • Ever-green Oak • Deciduous Oak • Open Areas	RSCN (2004c) Dibeen Flora Baseline Survey

Indicator Species and species important to the forest	Plants Density Orchids and Irises	RSCN (2006a) Dibeen Flora Monitoring Survey
	Rodents Density Persian Squirrel, *Sciurus anomalus*	RSCN (2005) Dibeen Rodents and Bats Baseline survey Amr et al. (2006) Status and distribution of the Persian squirrel *Sciurus anomalus* in Dibeen nature reserve
	Birds Density • Short-toed eagle, *Circaetus gallicus* • Syrian Woodpecker, *Dendrocopus syriacus* • Blue Tit, *Cyanistes caeruleus* • Wren, *Troglodytes troglodytes*	RSCN (2004a) Dibeen Birds Baseline Survey
	Carnivores Density Stone Marten, *Martes foina*	RSCN(2004b) Dibeen Carnivore Baseline Survey
	Invertebrates Density Carabidae	RSCN(2006b) Dibeen Invertebrates Survey
	Reptiles Density • Greek Tortoise, *Testudo graeca* • Green Lizard, *Lacerta media*	RSCN(2004d) Dibeen Reptiles Baseline Survey

For the human threats evaluation, criteria representing threats or risk elements were defined by PA experts, rangers and biodiversity specialists. Anything identified by experts as having a negative influence on the health of a critical habitat or key species was considered a risk element (Schill and Raber, 2009). The relative weight of each human threat or risk element was decided based on the observed intensity of threat and its impact on biodiversity. Table 2 includes the human impact evaluation criteria and the collection source of each dataset.

Table 2: Datasets included in the human impact analysis

Dataset Category	Dataset	Dataset Source
Infra-structure	Major and secondary roads	RSCN (2004) PA's Basemap
Tourism	• Parking Areas • Picnicking Sites • Tourism and Educational trails • Tourism facilities	RSCN (2004e) Dibeen Reserve Tourism Management Plan
Threats	Woodcutting	RSCN (2006) GPS Coordinates
	Land encroachments/ private lands	RSCN (2006) GPS Coordinates
	Tree leaves Collection	RSCN (2006) GPS Coordinates
	Hunting	RSCN (2006) GPS Coordinates

The topographic basemap and main features were prepared by on screen digitizing of scanned 1:25000 topographic maps for the area produced by the Royal Jordanian Geographic Center. Field survey findings used as evaluation criteria were first collected by Global Positioning System (GPS) devices with positional accuracy of ±5 meters, and mapped in vector formats. All vector layers were converted to raster formats; distributions of plant and animal species were converted from point distributions to kernel density rasters with a spatial resolution of 5 meters using the quadratic kernel function as described by Silverman (1986). Human threat elements were also collected using GPS devices and mapped in vector formats. Threat elements were converted to Euclidean distance rasters with a spatial resolution of 5 meters where the value at each grid cell represented its proximity to the corresponding threat element. The Euclidean distance rasters were calculated within a neighborhood of 500m around each threat element as it was assumed that the impact of a threat element concentrates within this neighborhood.

Application of GIS analysis

The zoning plan GIS model was developed based on spatial MCE using ArcGIS software (ESRI, 2008). The model was divided into three parts; evaluation of conservation values, evaluation of human threats, and combining human threats and conservation values. Cartographic modelling, a process of solving problems by spatial layer combination using map algebra operations (Bolstad, 2012), was applied in reclassifying, weighting and combining map layers representing evaluation criteria. For the conservation values part, vegetation types of high importance and high priority were given high scores as advised by experts. Each species density raster was reclassified to five density ranges; relatively high density ranges were also given high scores indicating high conservation value thus high priority. Reclassified conservation values were summed according to their relative weights. A sample of this part of analysis is displayed as maps in figure 2.

Similarly each threat distance raster was reclassified to five distance ranges, each distance range was given a score; small distance ranges were given high scores indicating high threat impact. Reclassified threat maps were also summed according to their relative weights. The weighted summation for human threat evaluation was subtracted from weighted summation for conservation values to identify the areas with high conservation value-low threat, and low conservation value –high threat.

The final geographical boundaries of the zones were mapped considering the presence of physical features like roads and wadis to make the zone boundaries easily distinguishable on the ground to make the zones easily recognized by PA staff, visitors and the local community.

Validation of GIS analysis

Face validation, a method used to validate the behavior of a model and the input and output relationships based on consulting knowledgeable people (Edward and Rykiel, 1996), was used to validate the results of the GIS analysis. The resulting maps were presented to biodiversity experts who were not part of the consultation through

biodiversity experts who were not part of the consultation through the selection and weighting of evaluation criteria to see if they found the performance of the model and resulting analysis reasonable.

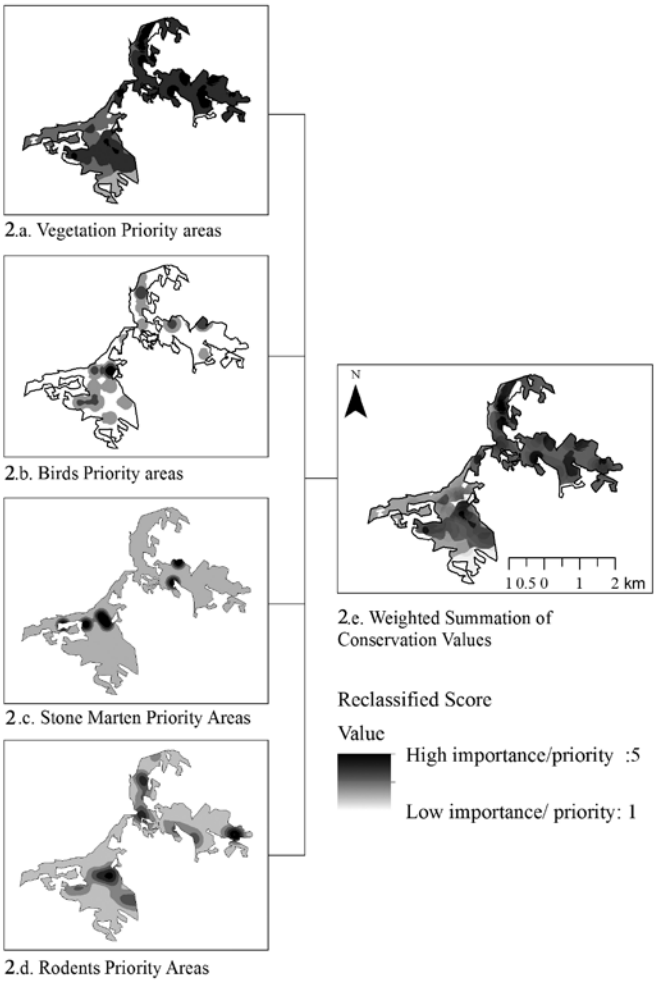

Fig. 2: A sample of the conservation evaluation analysis displayed as maps

RESULTS

The resulting weighted summation rasters (Fig. 3) were used to divide the PA to three management zones (Fig. 4) as follows:

1. Wilderness zone: This included the parts of the PA with the highest conservation values and low human threat. It is located in the pine forest areas in the middle of the northern and the south western blocks of the PA. Types of activities acceptable in the wilderness zone were restricted to ecological research and monitoring in order to preserve its critical highly important conservation values.

2. Intensive use zone: This included the area with the highest human threat located in the middle of the eastern block of the PA.

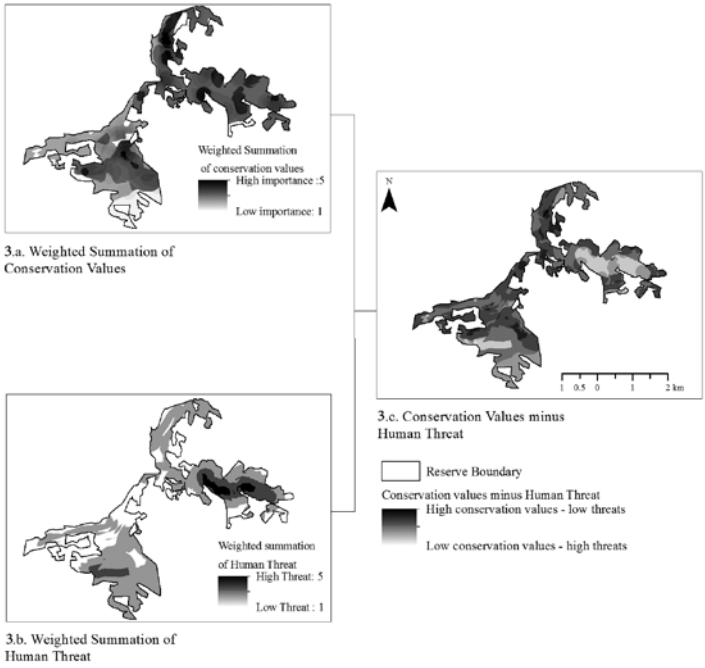

Fig. 3: The final resulting rasters of the three parts of the GIS model

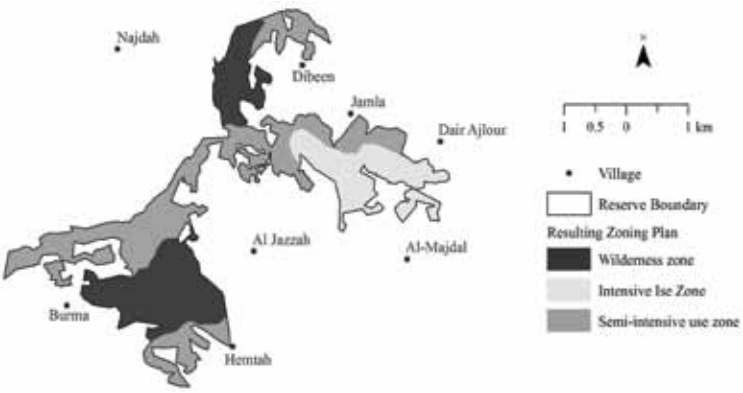

Fig. 4: The resulting zoning plan

This area included the recreation area used by local people. It already had the infrastructure and facilities constructed to serve recreational and educational activities. Types of activities allowed in this zone included recreation and picnicking, management facilities and infra-structure.

3. Semi-intensive use zone: This included the areas with medium to low conservation values and medium to low human impact. Limited human use and activities like ecological research and monitoring, bird watching. Only local people were allowed grazing access to this zone, grazing only by local people were permitted in this zone. Table 3 shows the area of each zone and the percentage it comprises of the total PA area.

Table 3: Area of each zone and the percentage it comprises from the reserve area

Zone Name	Area in sq km	Percentage of PA
Wilderness Zone	2.8	33%
Semi-intensive use zone	4.1	48.2%
Intensive use zone	1.6	18.8%

DISCUSSION

Spatial multi-criteria evaluation was used in other regions in habitat suitability modeling (Store and Kangas, 2001) and marine protected area zoning (Villa et al., 2001). The approach presented by (Villa et al., 2001) was based on the defining suitability factors that decide the suitability of an area to certain types of activities. The approach presented in this paper is more concerned with the identification and evaluation of conservation values, and human threat intensity within the site rather than its suitability to certain activities. The current paper deals with the zoning plan from a different perspective corresponding to the need to understand and evaluate the current status of the PA, and then planning the zones accordingly.

Other more simplistic approaches followed in Jordan in developing the zoning plans for Rum PA (RSCN, 2003), Dana PA (RSCN,2006), Petra archeological park (Damhoureyeh et al., 2011) did not involve advanced spatial analysis, and could be considered based on visual interpretation of available layers without demonstrating how datasets could be weighed, prioritized and combined to reach a decision on the zone boundaries.

Although the GIS model did not directly produce the final boundaries of the zones, the model enhanced the decision making process. Zone boundaries had to be slightly extended to physical boundaries like roads, tourism structures or other landmarks on the ground in order to be easily recognized by PA rangers, visitors and community members. The conservation value hotspots did not comprise large continuous zones rather than spots or patches with high conservation values. Small patches of high conservation values were merged into one zone as it was not practical to have isolated patches as different zones. The intensive use zone and the wilderness use zones were easily distinguishable and could be located on the weighted summation rasters of the conservation values and human threat respectively. The subtraction raster combined these two datasets and gave a clear idea on the relationship between them in each grid cell.

Dibeen PA was also found to be a hotspot in another study conducted on medicinal and herbal plants in the north western highlands

of Jordan with a different GIS based approach (Al-Bakri et al., 2011). Although that study used similar evaluation criteria to identify medicinal plants hotspots and conservation priorities, their approach was based on interpolating the total evaluation scores assigned at certain surveyed ground locations assuming that the total evaluation score is spatially auto-correlated. The approach presented in this study evaluates each layer separately within the analysis extent based on the value of each grid cell then sums the scores from all evaluation criteria. A future project could apply both approaches using the same set of evaluation criteria and compare the results.

The parts of the PA having high conservation values were mainly areas with pine forest vegetation as it was given the highest weight among other evaluation criteria. The locations where indicator plant and animal species were recorded within the pine forest had relatively higher conservation values than other pine areas because of the overlap of high densities of different indicator plant and animal species. These parts had low human impact thus qualified to be included in the wilderness zone. This result was consistent with the management vision and conservation priority of the PA. The eastern block of the PA where intensive tourism activities occur had the highest human threat as the tourism was given the highest relative weight among all other human threat criteria in addition to its overlap with other threat criteria like the presence of roads and other facilities. The management decision was to define this area as an intensive use zone where tourism activities can be sustainable and well organized as it already had the necessary infra-structure and it had already been used by visitors for picnicking for decades.

CONCLUSION

A major challenge for any organization managing a PA involves developing the management approach itself. The approach presented in this paper demonstrates how GIS can be used to provide guidance and support strategic decisions in managing protected areas. The GIS-based zoning plan model evaluated and quantified characteristics of the PA like conservation values and human threat in order to reach a decision on how the PA should be managed. The model development process enabled a wide range of stakeholders from man-

agers to executive staff and local community members concerned to have a comprehensive assessment and understanding of the PA, and developing a more reasonable zoning plan.

The zoning plan model developed for Dibeen Forest Reserve can also be applied to other PAs in Jordan and the region taking into consideration that evaluation criteria and weights can be modified depending on the characteristics of each PA and the data available. It is therefore hoped that this approach, will be adopted more widely by the RSCN in utilizing a spatial multi-criteria evaluation procedure in developing ecological and human impact hotspot maps in order to provide guidance for the PA zoning.

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