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Scope

The Jordan Journal of Natural History is an open access scientific publication published by the Conservation Monitoring Center at the 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 a supplementary issue.

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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.

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CONTENTS

An overview of the geology and evolution of Wadi Mujib

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ABSTRACT

The rock units exposed in Wadi Mujib range in age from the Late Cambrian Umm Ishrin Formation (~ 500 million year (Ma)) ago, to Recent (Holocene). They represent a good percentage of the geological history of the country. The lower part of the geological column consists of about 600 m of sandstones (Umm Ishrin Formation and the Kurnub Group), while its upper part is dominated by about 700 m of carbonates, bedded chert and phosphorite.Volcanic rocks, 6 Ma old, are present on the southern side of the wadi. Tectonically, the Mujib is bordered from the west by the Dead Sea Transform fault (DST), a plate boundary separating the Arabian Plate, representing here by Jordan, from the small Sinai-Palestine Plate. Jordan moves to the NNE relative to Palestine along this DST 4-5 mm/y, with a total displacement of Jordan the middle Miocene, of 107 km. The DST system caused the formation of the Dead Sea basin and its subsequent subsidence as well as the continuous uplift of the mountains on both sides of it. Both subsidence and uplift are still ongoing. Other major fault is the Sewaga faults, an E-W fault with a small dextral strike-slip movement along them, where the Shihan volcanics are associated with it. Wadi Mujib had started initiation by running water at 5-4 Ma ago along the fractured, E-W axial plane of Mujib anticline. Rate of erosion of the wadi ranges between 0.1-0.23 mm/y. The Mujib deepening is still ongoing because of the ongoing lowering of the Dead Sea basin and uplift of its area.

Keywords: Wadi Mujib, Stratigraphy, Evolution history, Formation age

INTRODUCTION

Wadi Mujib is possibly the most magnificent canyon in Jordan. It can be compared with the Grand Canyon of Colorado in the United States albeit being smaller with much less water flowing through it. It cuts and exposes various types of strata from Recent to the Late Cambrian at its western reaches at the Dead Sea shores. Differences in elevation between its top and base can exceed 1000 m.

For the above reason, Wadi Mujib preserves and exposes most of the geological history of Jordan. It deserves being conserved as a Jordanian geopark suitable for geotourism, adventure, education, and research. The geology of Wadi Mujib and its surroundings has been discussed, as part of the geology of Jordan, by many authors since the early 20th century (e.g. Blake and Ionides 1939; Wetzel and Morton, 1959, Bender, 1974; Powell, 1989). More detailed works on certain geological aspects of the Mujib have been also carried out (e.g. Abed and Schneider, 1982; Karaishan, 1988; Abed and Kraishan, 1993; Masri, 2003; De Jaeger, 2003). This overview will discuss, in brief, the geology and evolution of Wadi Mujib.

LOCATION

Wadi Mujib crosses west central Jordan from east to west, some 60 km south of the capital Amman (Fig. 1). It separates two governorates; Madaba in the north and Karak in the south. Three major highways cross Wadi Mujib: The Desert Highway in the east, the King's Highway in the middle, and the Dead Sea -Aqaba Highway in the west, along the eastern Dead Sea coast.

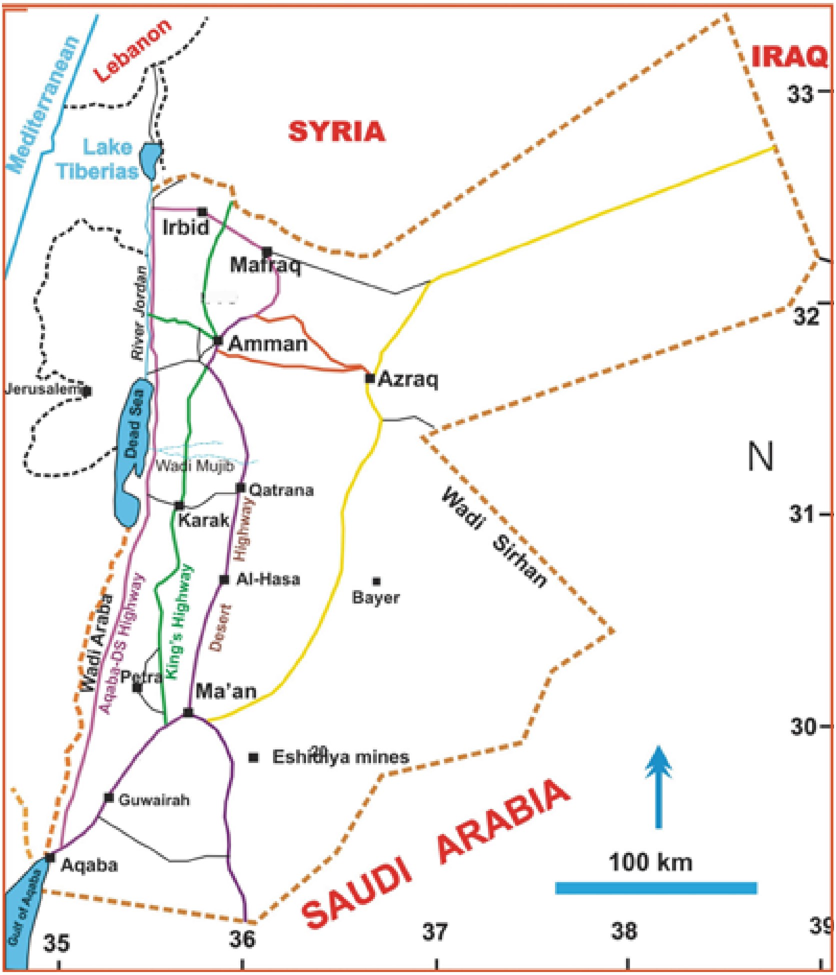
GEOLOGICAL SETTING

The geological framework of the Mujib area will be discussed in brief under two main subjects: stratigraphy and structural geology.

Straigraphy

Stratigraphy deals with the rock units (groups and formations) exposed in the study area. It thus gives an insight into the geological history of Wadi Mujib which extends for more than 500 Million years (Ma), from the Late Cambrian (~ 500 Ma) to the Recent (Holocene) time. The rock units are discussed from older to younger:

Umm Ishrin Formation (Late Cambrian)
Umm Ishrin Formation is the oldest rock unit exposed in Wadi Mujib. It belongs the Late Cambrian (~ 500 Ma) of the Early Paleozoic. It consists of around 300 m thick, brick red, fluvial, quartz sandstone. Excellent outcrops are present at the Mujib mouth in the west, into the wadi eastwards, and along the Dead Sea coasts from both side of its mouth, north and south (Fig. 2). Umm Ishrin Formation is characterized by its long vertical joints sets, at least in two orthogonal directions, cutting the whole length of the formation, very much the same as in Wadi Ram and Petra.

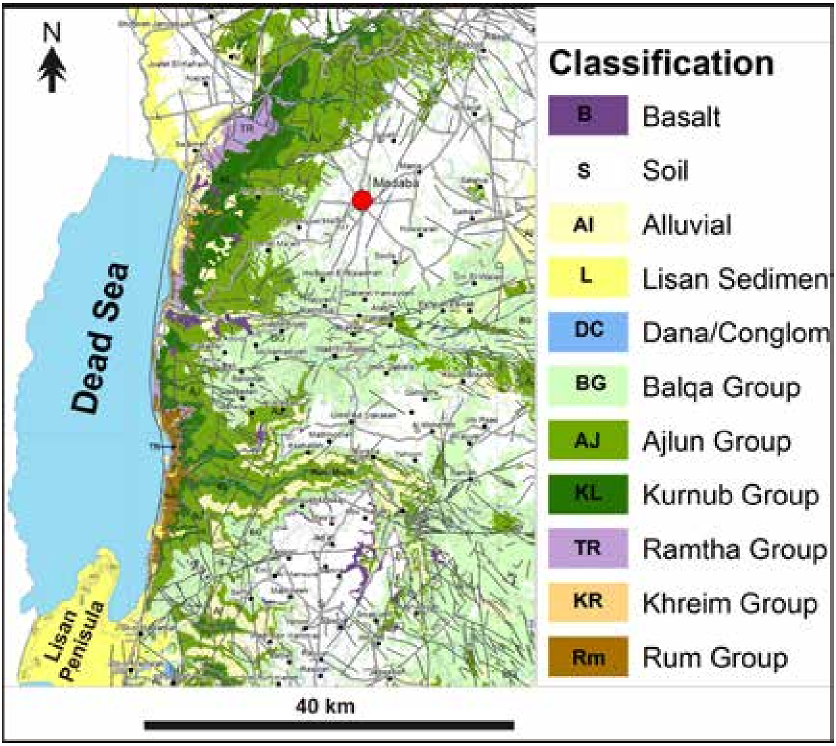


Figuer 1: Location map of Wadi Mujib area and its surroundings.

Figuer 2: Photo of the Umm Ishrin Formation south of the Mujib at the highway. Note the vertical joints and the brick red colour of the formation.

These joints are responsible for the formation of the narrow siqs (gorges) in the western reaches of Wadi Mujib (Fig. 3).The outcrops of the formation, are seen in the geological map (Fig. 4).

Figuer 3: Narrow gorges or siqs in the lower Mujib just east of the Dead Sea. The siq is formed through the erosion and widening of original wide open vertical joints in the Late Cambrian Umm Ishrin Sandstone Formation.



Figuer 4: Generalized geological map of the Mujib area

Long Time Unconformity

The upper surface of Umm Ishrin Formation is erosional. This surface represents a huge gap in the geological timescale of the Mujib extending from the late Cambrian (~ 500 Ma) to the base of the Kurnub Group of the Early Cretaceous (~ 135 Ma); i.e. around 365 million years of sediments were eroded/not deposited in the Mujib area. This huge gap and the lost sediments took place due to the erosion of the Paleozoic sediment associated with the Hercynian Orogeny at around the Middle Carboniferous (Andrews, 1991), non-deposition of the Permian Triassic and Jurassic Periods at this area because it was positive area relative to sea level, and the erosion associated with base of the Kurnub Group. Most of the lost sediments can be seen or drilled elsewhere in Jordan.

Umm Irna Formation

The Umm Irna Formation is 60 m in thickness, made of fluvial sandstone alternating with paleosoil containing iron pisolites. It is of late Permian age, uppermost Paleozoic and represents, with the overlying lower Triassic marine sediments, the first incursion of the Neo-Tethys Ocean into the area (Bandel and Khory, 1981;Stephenson and Powell, 2013).

Kurnub Group

The Kurnub Group is Early Cretaceous in age which consists of around 300 m offriable quartz sandstones of essentially fluvial origin. The Kurnub sandstones are massive white at the lower half of the group becoming varicoloured, dominantly violet, further up section. The Kurnub sandstones overly the Umm Ishrine Formation with a huge unconformity discussed above. See Fig. 4 for location of the Kurnub Group in Wadi Mujib.

Ajlun Group: A carbonate regime

The Ajlun Group represent the period when Jordan became submerged by the Neo-Tethys Ocean Between 100 – 88 Ma ago; that is during the Cenomanian- Turonian of the Late Cretaceous (Table 1). Jordan was part of the inner platform of that ocean (Powell and Moh'd, 2011; Abed, 2017), consequently a dominantly carbonate regime was deposited. The carbonate regime consists of limestone/ dolomite alternating with marl throughout the duration of the Ajlun Group. Total thickness of the Ajlun Group is ~ 450 m (Fig. 5). The exposures of the Ajlun Group are shown in the geological map (Fig. 4).

The Ajlun Group is subdivided into five formations (rock units) in north Jordan. They are from older to younger: Na'ur, Fuheis, Hummar, Shueib and Wadi Es Sir formation (Masri, 1963). In central and south Jordan, the middle three units are combined into one unit because of the difficulties of mapping the three units separately. The new unit has the name of the three original units combined; i.e. Fuheis/Hummar/Shueib (FHS) Formation. See Table 1 (El-Hiari, 1986; Powell, 1989) Thus, in the area in central Jordan, the formations from older to younger are Na'ur Formation, Fuheis/Hummar/Shueib (FHS) Formation, and Wadi ES Sir Formation.

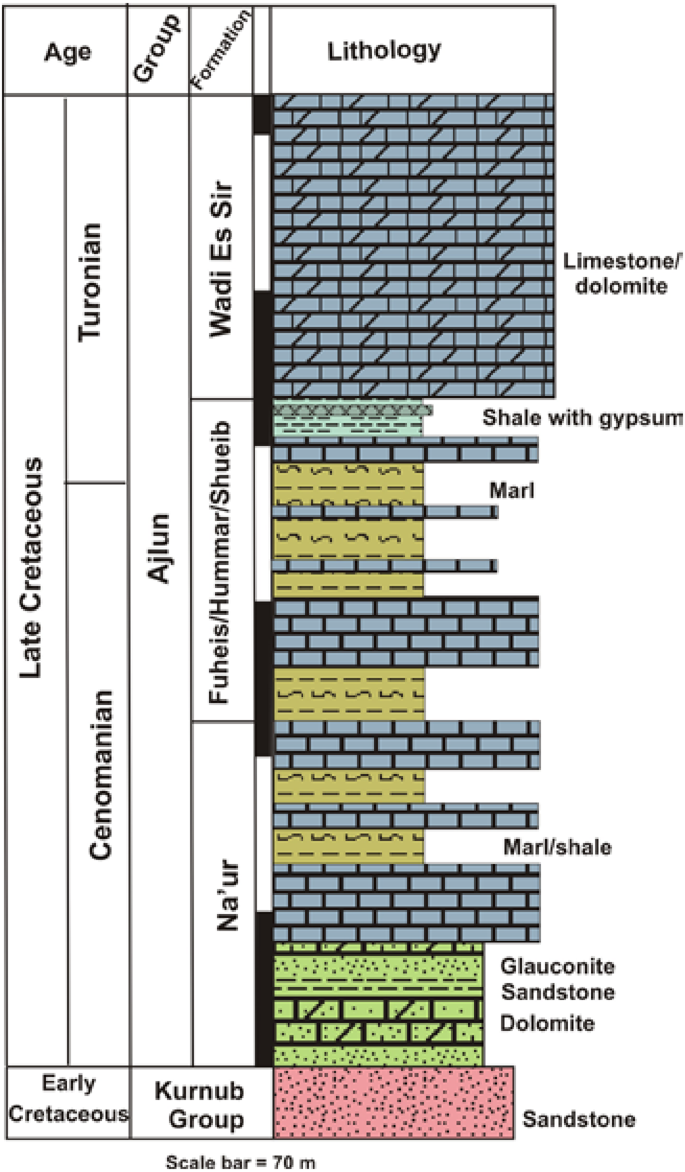
The **Na'ur Formation (A1-2)** forms the base of the Ajlun Group, is early Cenomanian in age, 150 m thick, and consists of hard limestone and/ or dolomite horizons alternating with similarly thick, soft marl to marly limestone horizons (Fig. 5). It is exposed at the base of the Mujib Dam and further west along the wadi course. The limestone beds are typically nodular due to burrowing (Abed and Schneider, 1982), while the soft marl horizons are the loci for landslides. There are evidences that the Mujib area formed a paleohigh (an island) during the lower Cenomanian (Abed, 1984).

Table 1: Nomenclature of the Ajlun and Belqa Groups (Powell, 1989).

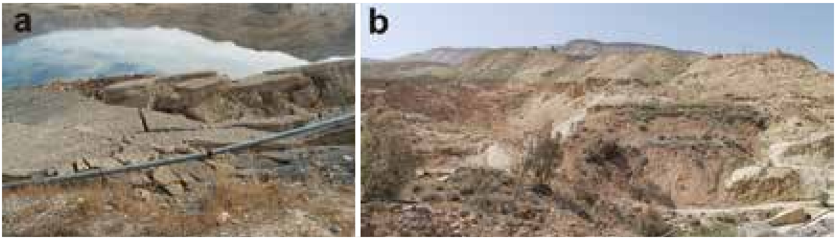
Age		Group	Formation	Member
Tertiary	Eocene	Belqa	Shallaleh	
			Umm Rijam Chert Limestone	
	Paleocene		Muwaggar Chalk Marl (MCM)	
Late Cretaceous	Masstrichtian		Al Hisa Phosphorite (AHP)	Qatrana Phosphorite
				Bahiyya Coquina
				Sultani Phosphorite
	Campanian		Amman Silicified Limestone	
	Santonian			
	Coniacian		Gudran	Dhiban Chalk
				Tafila
				Mujib Chalk
	Turonian	Ajlun	Wadi Es Sir	
			Shueib	
	Cenomanian		Hummar	
			Fuheis	
			Na'ur	
Early Createceous	Aptian-Albian		Kurnub (Hathira) Sandstone Group	

The **Fuheis/Hummar/Shueib (FHS) Formation (A3-6)** overlies the Na'ur Formation. It is Cenomanian-Turonian in age, 140 m thick, consisting of soft marl/ marly limestone and shale with much less thick, hard limestone interbedded with them (Masri, 2003). Some minable, primary gypsum beds are also present towards the top of the formation especially in Wadi Mujib.

In Wadi Mujib, the FHS succession is exposed from the Mujib bridge eastwards along the wadi course, thus the Mujib dam lake is within the outcrops of this formation. Westwards of the Mujib bridge, the formation becomes part of the lower slope. The fact that the FHS consists dominantly of soft marl, makes it the loci for continuous landslides, easily seen east and west of the Mujib bridge (Fig. 6).



Figuer 5: A generalized columnar section of the Ajlun Group in Wadi Mujib showing the lithology of the formations.



Figuer 6: Landslides in the lower FHS: a) 2013 when a major collapse took place, immediately east of the dam, b) just west of the Mujib Dam when it started during 2011.

The **Wadi ES Sir Formation (A7)** is the uppermost formation of the Ajlun Group (A7). However, Masri (2003) described 25 m of clayey limestone rock unit belonging to the Khurayj Formation overlying the Wadi Sir Formation and belong to the Ajlun Group. The age of the Wadi Sir Formation is Turonian (Upper Cretaceous).

Within the study area the Wadi Es Sir Formation is 125-150 m thick. It is dominantly a limestone formation. Micrite (microcrystalline limestone) dominates the rock type in the formation with relatively minor various types of limestone such as shelly packstone-grainstone, oolitic grainstone. Chert nodules and sometimes thin bedded chert are present. Dolomite and dolomitic limestone are also present especially towards the bottom of the formation. The formation has abundant fossil content especially the Molluscs and Echinoderms. Bed thickness is variable from massive, cliffy strata as seen towards the top of the formation and its bottom.

However, thinly bedded limestone, sometimes marly, are also present especially in the middle of the formation (Fig. 5). From a hydrogeological view point, the Wadi Es Sir Formation is an excellent aquifer throughout Jordan. Due to the predominance of limestone and the near lack of marls and clayey material within the formation, the whole formation can be considered as a continuous aquifer.

The **Khurayj Formation** is a 25 m thick rock unit, overlying the Wadi Sir Formation, newly described, by Masri (2003) in this area of central Jordan. Previously it was described as part of the Wadi sir Formation. That is why the previous authors gave the Wadi sir Formation a thickness of 150 m in the Wala-Mujib area. The Khurayj Formation is essentially a limestone formation, very much like the underlying Wadi sir Formation. However, there are some marly limestone horizons in the middle part of the formation. In my opinion, these minor marly horizons do not affect the continuality and connection of the Wadi Sir aquifer. The age of the formation is possibly Coniacian-Santonian.

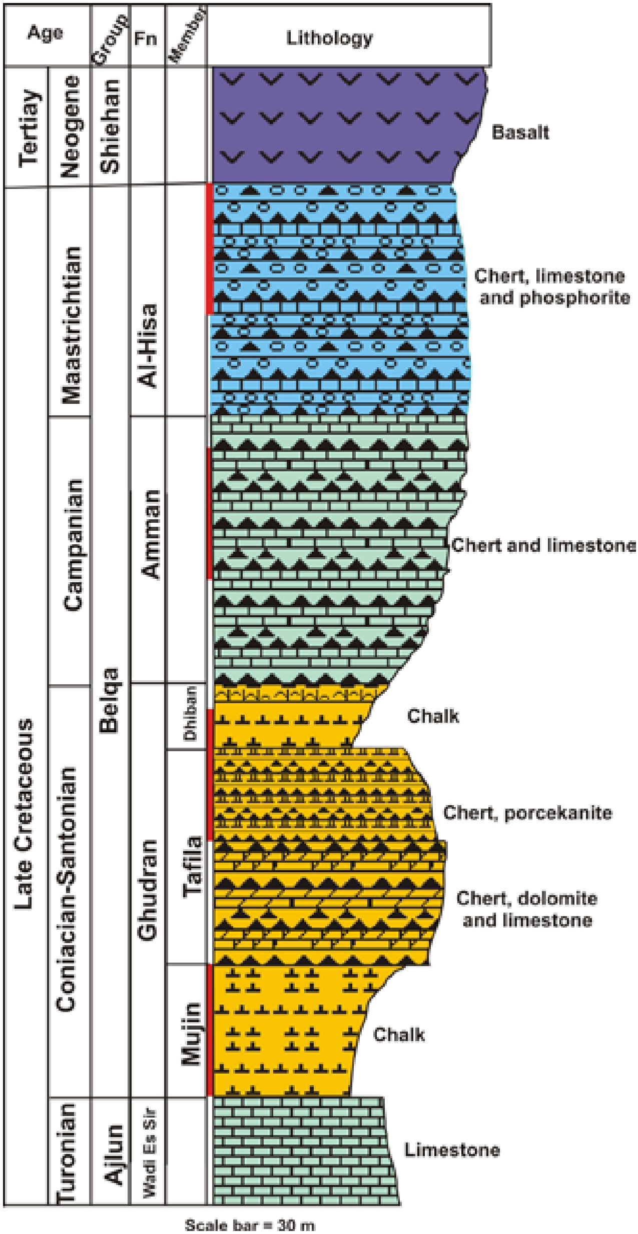
Belqa Group: A chert-dominated regime

The predominantly carbonate regime of the Ajlun Group changed into an exotic sedimentation regime during the Belqa Group. This exotic regime consists of bedded chert, chalk, limestone, phosphorite, dolomite and porcelanite. The back bone of this regime is the bedded chert, a rock type present in almost all the formations representing the Belqa Group. The reason for the dramatic changes in sedimentation and sediment types is, most probably, related to the tectonics associated with the closure of the Neo-Tethys, circum global oceanic currents and upwelling, and the associated biodiversity. These conditions were the cause for the deposition of the bedded chert and phosphorite in particular (Abed (2013). The Belqa Group overlies disconformably the Ajlun Group. It involves all the marine sediments deposited from the Neo-Tethys Ocean from the end of the Ajlun Group till the closure of this ocean in the late Eocene some 35 Ma ago. Figure 4 shows the outcrops of the Belqa Group in the Mujib area and its surroundings. Due to uplift and erosion of the upper part of the Belqa Group, three formations of this group crop out in the study area (Fig. 7).

The complete rock units making the Belqa Group are shown in Table 1. These formations are from bottom to top: **Ghudran (B1), Amman (B2a) and Al-Hisa (B2b)**. The other, younger, formations of the Belqa Group such as the **Muwaqqar (B3), the Rijam (B4) and Shallaleh (B5) formations** are eroded from the study area and can be seen much to the east.

Ghudran Formation (B1)

The Ghudran Formation is well developed in central Jordan and especially in the Wala-Mujib canyon complex. It is in excess of 100 m in the latter area compared with only 20 m in the Amman region and about 35 m in north Jordan. In the Amman area and north of it, the Ghudran Formation consists essentially of chalk. While in the Mujib area it consists of three formal members: a lower whit, homogenous chalk horizon called the Mujib Chalk, a middle heterogeneous horizonmade essentially of bedded chert called the Tafila Member, and an upperchalk horizon called the Dhiban Chalk (Fig. 7). The Ghudran Formation is exposed above mid slope of the Mujib canyon and can be easily seen in the northern flanks of the Mujib with its conspicuous white chalk horizons. It is thus higher up in the succession and is not involved in the wadi course unless one travels much to the east.



Figuer 7: A generalized columnar section showing the lithology of the Belqa Group exposed in the study area.

Amman Formation (B2a)

Amman Formation in the Mujib is a very conspicuous formation characterized by its abundant bedded chert. The bedded chert comprises about 50% of the formation. In other words, the chert: limestone ratio is roughly 1:1 (Fig. 8). This is the highest chert ratio in any chert-bearing rock unit in Jordan including the Tafila Member. Its thickness is about 60 m (Fig. 7). The bedded chert is either massive or brecciated. Chert nodules are also present. The chert beds are in many instances fragmented.

There is much evidence that the chert is early diagenetic as a replacement of other rock types like limestone. Bedded chert alternates with limestone of various types such as coquinoidal limestone, chalk, micrite, etc. Further up in the formation, some minor phosphorite beds are present. In Wadi Mujib, the Amman Formation is exposed along the upper parts of the canyon; e.g. the rest area at the beginning of the descend in the northern flank of the Mujib and similarly in the southern side.

Figuer 8: A field photo from the upper slope of Wadi Mujib showing the interbedded chert and limestone.

Al-Hisa Phosphorite Formation (B2b)

Al-Hisa Formation consists of phosphorite, bedded chert, limestone and oyster coquinoidal limestone. Intermediate lithologies of these rocks are also present. The lower part of Al-Hisa Formation makes the higher most topographic parts of the Wala-Mujib canyon system. The thickness of the formation in the study area is in excess of 60 m, but certainly parts of it are eroded from the plateau (Fig. 7).

From a hydrogeological view point, Al-Hisa and Amman Formations behave similarly. Both were one formation called the Amman Formation in the Masri (1963) nomenclature in the early 1960s.

Volcanic rocks

In Wadi Mujib itself and its immediate vicinity, volcanic rocks are present on both sides of the wadi, especially the southern side. Abundant basaltic rocks are present further north of the Wadi Mujib which are not included in this overview. The volcanic activities associated with Mujib proper had started around 6 Ma ago and stopped before the initiation of the formation of Wadi Mujib; i.e. they are older than the Wadi Mujib. Two separate volcanic basalt events took place in the Mujib – Heedan canyon complex and its surroundings. These volcanic rocks are extensively exposed south of the Mujib with minor occurrences north of it.

The older basalt or the **Shihan Group basalt** which is up to 6 Ma in age (uppermost Miocene/Pliocene) (Bareberi et al., 1979). This basalt is cropping out at the higher slopes of the Heedan west and southwest of Al-Shgaig. It is the northern continuation of the Mujib basalt originated from the flows of Jabal Shihan further south (Fig. 9). The Shihan Group consists of 4 formation with more than 20 flows, at least 6 of these flows can be seen along the Kings Highway at the southern flanks of Wadi Mujib. The Shihan Group basalt is in excess of 100 m in thickness south of the Mujib. This basalt predates the incision of both Wadi Mujib and Wadi Heedan; i.e. older than both canyons (De Jaeger, 2003). In other words, both Wadi Mujib and Heedan had cut and eroded these basalt flows. That is why the basalt can be seen on both sides of the Mujib. However, this basalt does occupy a wide area especially south of the Mujib canyon.

Figuer 9: Shihan basalt in the form of a paleo wadi predating the Mujib Formation some 6 Ma ago.

The younger basalt is present along the western course of Wadi Heedan. (Fig. 10). It is much younger than the plateau basalt with an age of around 1 Ma, most probably, at a fault running partially along Wadi Heedan. Due to its high resistance to water erosion, this basalt has formed high, nice waterfalls within Wadi Heedan.

Figuer 10: The Heedan basalt along the course of the wadi. Its age is around 1 Ma; i.e. younger than the Shihan basalt and post date the incision of the Heedan.

Recent and subrecent deposits

These deposits are of minor importance to the geology of the area. They include limestone, chert, dolomite, phosphorite and basalt rock fragments. They occupy the course of Wadi Wala-Heedan to a certain depth varying from one place to the other. They can reach several metres in the wider parts of the wadi course, and are reduced to a very thin veneer in the narrow gorges and the cliffy parts of the wadi course.

These deposits include wadi terraces and slope debris. They are gravelly or conglomeratic in nature. Their composition varies with position and age. However, their framework consists of limestone and chert rock fragments of various sizes. They are bound together, in several places, by soil material. The true terraces have smaller amounts of the binding soil and they are much indurated becoming a true conglomerate. De Jaeger (2003) had studied the Pleistocene terraces in Wadi Mujib and their implications in the evolution of the wadi and paleoclimate of the area.

Geological structures

Several major faults are present within the larger study area. However, the structures adjacent to the Mujib are discussed here.

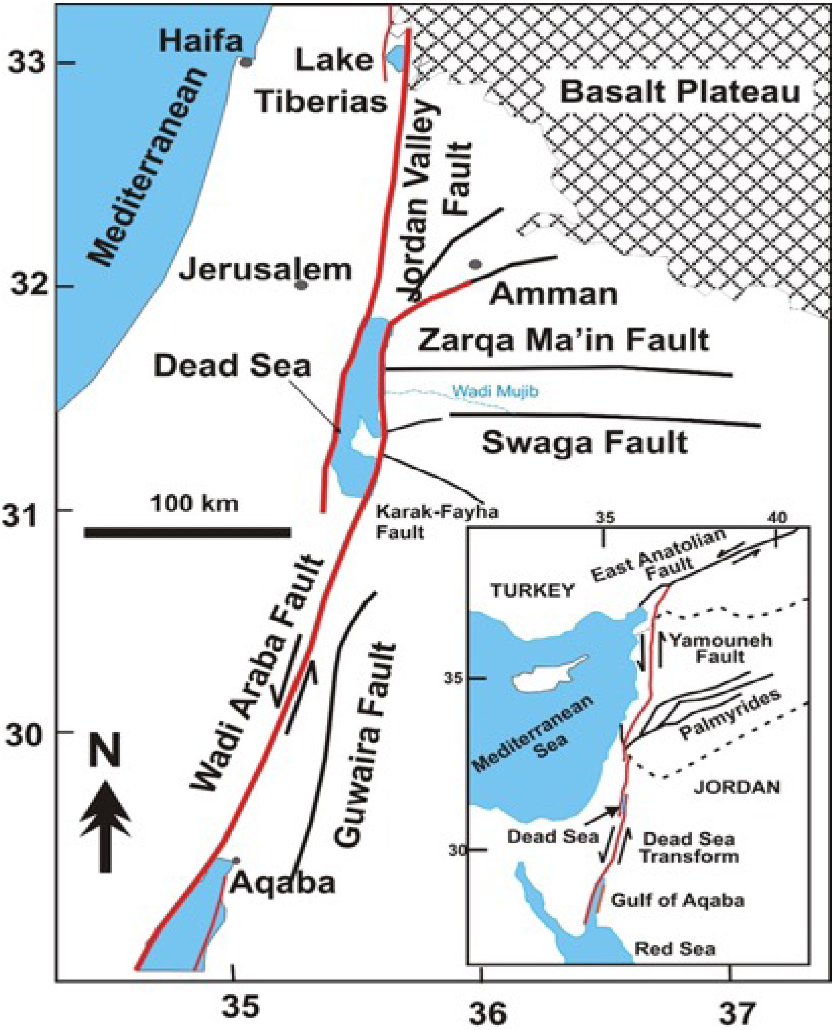
The **Dead Sea Transform fault (DST)** which bounds the area from the west along the Dead Sea shores and ends at the NE tip of the Dead Sea with the Amman-Hallabat structure (Fig. 11). The DST is a plate boundary separating the Arabian Plate, representing here by Jordan, from the small Sinai-Palestine Plate. Jordan moves to the NNE relative to Palestine along the DST with a rate of 5-4 mm/year. The total displacement of Jordan since the start of the activity of the DST in the middle Miocene some 17 Ma ago, is 107km. The DST system caused the formation of the Dead Sea basin and its subsequent subsidence as well as the continuous uplift of the mountains on both sides of it. Both subsidence and uplift are still ongoing. It is worth mentioning that the continuous deepening of the Dead Sea basin forced Wadi Mujib to dig deep to keep in equilibrium with the Dead Sea surface, its base level.

The **Sewaga and Zarqa Ma'in faults,** both are E-W faults with a small dextral strike-slip movement along them. The Sewaga fault starts slightly NE of the Lisan Peninsula, then passes by the Shihan volcano area and continues in an east direction to cross the borders with Saudi Arabia. The Zarqa Ma'in fault starts from the western parts of the wadi and continues eastwards until it joins the Sewaga fault nearby the Saudi borders (Fig. 11).

The Mujib anticline is a very broad anticline running along the canyon from the Dead Sea eastwards. Beds in the two flanks of the Mujib are very gently (several degrees) dipping away from each other, thus creating this broad anticline. Wadi Mujib seems to have created its course along the maximum curvature of this anticline. At the maximum curvature of the anticline, the strata are normally fractured, thus facilitating the movement of surface water to erode and form the Mujib canyon. The formation of the anticline seems to be due to the compression associated with the northward movement of Jordan, as part of the Arabian Plate, along the Dead Sea transform by a rate of around 5 – 4 mm/year (Galli , 1999). No one major fault has been identified running along the Wadi Mujib course or parallel to it in an E – W direction in the study area. However, E – W local faults are present within the flanks of the Mujib canyon.

EVOLUTION

The following discussion describes the evolution of Jordan and adjacent countries from the deep past up till the initiation of Wadi Mujib some 5 Ma ago, then the evolution of the Mujib will be discussed. For more details, see Abed (2005, 2017).



Figuer 11: Shows the DST in Jordan and the other major faults north and south of the Wadi Mujib.

Precambrian time

Pre 540 Ma ago, Jordan formed part of the Arabian-Nubian Shield (ANS) which now occupies western Arabia (Arabian Shield) and the area west of the Red Sea (Nubian shield). The ANS took about 700 Ma to form and stabilized from 1200-540 Ma, through island arcs subduction, collision, obducion and deformation. The resultant ANS consisted of plutonic and volcanic rocks of varying affinities, metamorphic and metasedimentary rocks, and sedimentary conglomerates, sandstones and carbonates. The Najd Fault system, 640 Ma onwards, had created highs and lows in the whole ANS where the highs were later eroded to create a thick sequence of conglomerates and sandstones in many parts of the Shield, such as the Saramouj Conglomerates in Jordan (595-605 Ma) (Fig. 12).

Figuer 12: A photo showing the Saramuj conglomerates near the SE tip of the Dead Sea (595-605 Ma).

This long period of erosion led to the peniplanation of the preexisting reliefs, which is nicely displayed in southern Jordan. The ANS is represented in Jordan by the igneous and metamorphic rocks around Aqaba and in Wadi Araba (800-540 Ma) (Abed, 2017, Al-Shanti, 1993).

The Paleozoic siliciclastics

By the end of the ANS, northern Arabia, including Jordan, subsided and became the scene of braided rivers running from south to north and depositing around 1000 m of sandstone rocks which are now forming Ram, Petra, parts of Wadi Araba and the coasts of the Dead Sea; e.g. Umm Ishrin Formation. This terrestrial period end by the Lower Ordovician (~465 Ma), after which the Paleotethys Ocean invaded Jordan, and the whole eastern Mediterranean, depositing marine shale and sandstone. By around 430 Ma (Late Ordovician), Jordan was within the arctic circle of the south pole and glacial deposits in south Jordan testify this location and environment (Abed et al., 1993). Permian, Triassic and Jurassic periods were deposited from the marine water of the Neo-Tethys Ocean in northern Jordan only, north of Wadi Mujib. It seems that Jordan became a positive relief during the Early Cretaceous (135-100 Ma ago), and rivers again had deposited a relatively thick sequence of Quartz sandstone throughout the country called the Kurnub Group.

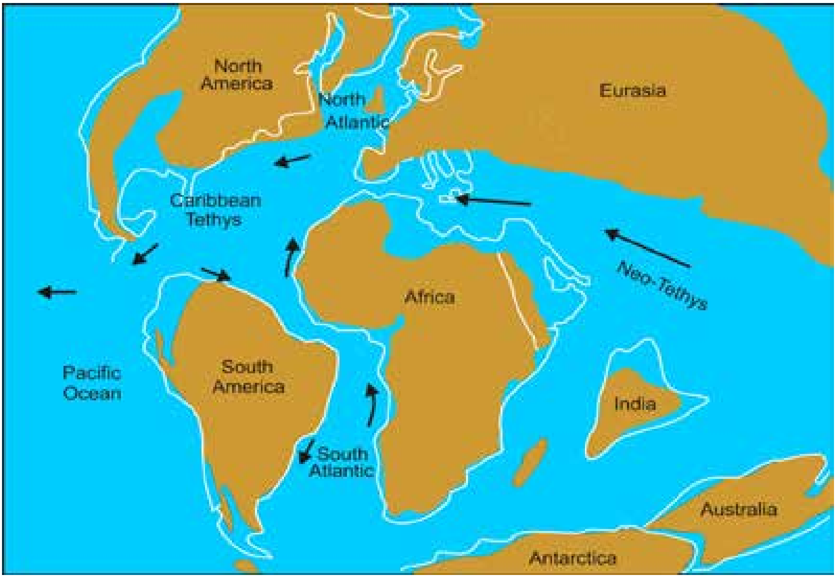
Marine submergence (100 Ma-35 Ma)

The onset of the Late Cretaceous, some 100 Ma ago, witnessed a major global sea level rise in excess of 100 m. This major global sea level rise was caused by the warm mid Cretaceous (Cenomanian – Turonian) green house climate event where all the ice sheets on the Earth poles and mountains were melted and returned to the oceans. Atmospheric temperature was several folds higher than present-day temperatures.
This green house event and the subsequent rise in sea level, led to the flooding of almost all the eastern Mediterranean including all Jordan except its extreme south. Jordan, thus, was submerged with shallow marine water of the southern continental shelf of the Neo-Tethys Ocean, and formed part of its inner shelf (Fig. 13). The shore line was far to the south, thus ensuring the deposition of a pure carbonate regime, several hundred metres thick in north and central Jordan including the Mujib canyon area, represented by the **Ajlun Group** described above.

By the beginning of the **Belqa Group**, base Ghudran formation of the Coniacian some 80 Ma ago, the ocean water transgressed due to a new sea level rise. The shoreline became several hundred kilometers to the south of the shorelines of the Ajlun Group, thus even southern Jordan was submerged. The Neo-Tethys Ocean became well connected to the global ocean currents which helped deep, cold, nutrient-rich upwelling currents to prevail all over Jordan. This regime is the one responsible for the deposition of several hundred metres of bedded chert, phosphorite, oil shale, chalk, porcelanite and limestone throughout the Belqa Group.

Neo-Tethys migration and Jordan exposure (35 Ma-present)

The above depositional conditions which led to the deposition of the Belqa Group continued up till the end of the Eocene of the Tertiary some 35 Ma ago. At around this date, late Eocene, the Neo-Tethys migrated from eastern Mediterranean including all Jordan, except for a small passage in northern Syria and into Iraq. The migration of the Neo-Tethys lead to the termination of marine deposition and to an end of the Belqa Group. The migration of the Neo-Tethys was due to the uplift of the eastern Mediterranean which in turn is due to the collision of the Afro-Arabian Plate, due to its northward movement, with the Eurasian Plate which took place at around the same time; i.e. late Eocene.



Figuer 13: Paleogeographic map of the world during the Late Cretaceous (Campanian Ma). Brown = land mass, white line = present day land mass, arrows = circumglobal currents. Note that Jordan was completely submerged.

Post Eocene, Jordan became emerged and terrestrial processes such as erosion of the previously deposited Belqa Group sediments commenced especially in western Jordan where uplift was, and still higher. At around 20 Ma ago, early Miocene, full-fledged collision and suturing of the Afro-Arabian Plate with the Eurasian Plate in Turkey and Iran, due to the continuous northward movement, took place and completely closed the remnants of the Neo-Tethys in northern Syria and Iraq. To release the stress mounting in the Afro-Arabian Plate because of that, at around 20 Ma ago during the Early Miocene, the Syrian–East African Rift formed, separating the Arabian Plate from the African Plate. This major structural event led to the formation of the Gulf of Aden, the Red Sea and the Dead Sea Transform system. A whole system of faulting formed associated with this Furthermore, the forevent, and some of these faulted areas were the scene of extensive basaltic fields throughout Arabia and the greater Syria; e.g. Harrat Esh Sham in NE Jordan.

Furthermore, the area along the DST started subsidence and became relatively lower than adjacent areas to the east and west; e.g. Dead Sea basin and the Jordan Valley. Several lakes, varying in size and salinity, formed and demised throughout this period (20 Ma) such as the Usdum Lake (Paleocene), Samra, Lisan and Damya Lakes (Pleistocene), and the Dead Sea, Lake Tiberias, and Lake huleh (Holocene).

Mujib formation

By around 6 Ma ago, the upper half of the Belqa Group was removed from the Mujib area by surface water erosion through smaller wadis draining the area. At this date 6 Ma ago, **Shihan volcano** became active sending its basaltic lava flows in all directions. One of these directions was towards the not-yet formed Wadi Mujib, sending the lava via a broad, shallow paleowadi where it crossed the Mujib area and reached to the Heedan NW of Shgaig. At least 6 basalt flows can be counted in this area separated by soil and calcrete; meaning 6 separate eruptions of Sihan volcano separated by a long period of time allowing the formation of soil between the flows. After the formation of the basalt flows across the Mujib, and sometimes about 4-5 Ma ago, Wadi Mujib started to form in its present day-course. This is possibly due to the deepening of the Dead Sea towards the mouth of the Mujib as well the formation of the E-W Mujib anticline. Running water selected the week E-W direction in the area, the axial plane of the Mujib anticline (Fig 14), and started the initiation of Wadi Mujib at around 5-4 Ma ago. It has to cut across the basalt flows first then to deepen its course with time, with an estimated rate of erosion of 0.23-0.1 mm/y. The presence of the basalt flows on both sides of the Mujib testifies for that (Fig. 9). Wadi Mujib is still deepening its course because uplift of its area and subsidence of the Dead Sea basin are still ongoing.

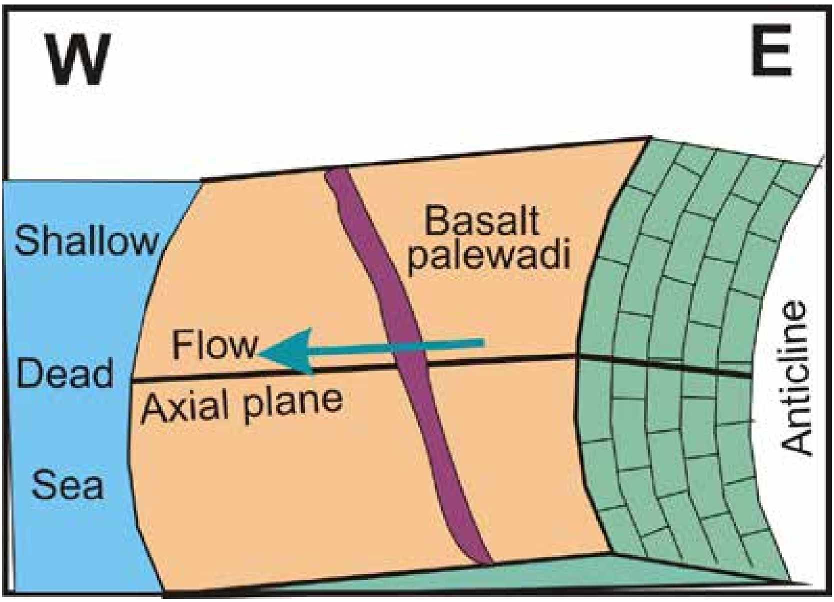


Figure 14: Thematic drawing of the Mujib anticline

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The biodiversity value of olive groves in Palestine

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ABSTRACT

Traditional olive groves and other forms of agriculture are a dominant feature of the Palestinian landscape. However, the biodiversity value of these areas needs to be better understood. This study compares the tree and bird richness of olive groves and field agricultural sites in Beit Sahour of Bethlehem, Palestine. A total of sixteen bird species were recorded, with fourteen species observed in olive groves and¬ six species observed in the field agricultural sites. Olive groves had significantly higher tree and bird richness than field agricultural sites. Our results corroborate other studies that suggest olive groves have biodiversity value as a cultural landscape.

Key words: Agriculture, Birds, Cultural landscapes, Olive groves, Palestine.

INTRODUCTION

Cultural landscapes have the potential to contribute to biodiversity conservation, as most of the world's biodiversity exists outside of nature preserves and protected areas (Farina, 2000; Dudley et al, 2005). Cultural landscapes are areas of cultural and heritage importance that have a long-term history of human interactions with the environment, which has dictated species distribution and assemblages (Farina, 2000; UNESCO, 2011). Traditional, low-impact agriculture is often the major activity in cultural landscapes that shapes the environment, energy flow, and habitat structure (Farina, 2000; Harrop, 2007). In contrast to other forms of agriculture, areas of traditional agriculture may mimic some aspects of more natural habitats by acting as corridors between natural areas and containing habitat structures that allow some wildlife to persist (Beaufoy, 2001; Chape et al, 2005; Dudley et al, 2005; Davy et al, 2007; Attum et al, 2011; Rey, 2011). The Mediterranean landscape, including historic Palestine, has a long history of human habitation and agriculture that have been sustained by cultural systems, which has resulted in a landscape that consists of a mosaic of natural and semi-modified landscapes (Naveh, 1975; Beaufoy, 2001; Biondi et al, 2007). Olive groves (*Olea europaea*) are dominant features of the Palestinian landscape and have evolved as a product of efficient use of energy, nutrients, and natural production cycles (Makhzoumi, 1997; Biondi et al, 2007).

Olive groves cover roughly 48% of the agricultural land in Palestine, with the majority of the trees found in the West Bank (UNDP, 2008). Olive trees are an important source of revenue, comprising 18% of the agricultural income, with most of the olive products consumed domestically (UNDP, 2008; United Nations, 2012). Olive trees, their fruits, and their harvest are symbolic and important features of Palestinian culture, history, and tradition (McLaughlin, 2006; Abufarha, 2008; UNDP, 2008). Given the widespread distribution of traditional olive groves and other forms of agriculture in Palestine, the biodiversity value of these areas needs to be better understood (Davy et al, 2007; Biondi et al, 2007; Rey, 2011).
This study compares the tree and bird richness of olive groves and field agricultural sites in Beit Sahour of Bethlehem, Palestine in order to better understand the biodiversity value of olive groves in comparison to other forms of agriculture. Birds were chosen as the focal species because birds are a valuable indicator of biodiversity, have an important role in ecological systems, and can be used in rapid assessment surveys (Martin et al, 2009).

MATERIALS AND METHODS

This study occurred in central and eastern suburbs of Beit Sahour in the Bethlehem district, which consists of rolling hills dominated by small-scale agriculture and surrounded by human housing. These rain fed groves are considered low-input traditional plantations with scattered trees, dominated by the olive tree, *Olea europaea* (Beaufoy, 2001). The olive groves were of different ages, ranging from fifty to several hundred years old, according to the local owners. The olive groves were harvested manually, without the use of machines or pesticides. The non-olive grove sites were field agricultural areas characterized by sparse tree density, in which crops such as wheat, barley, tomatoes, and striated cucumbers are planted. Tractors may be used for cultivation at these sites and vegetables are hand picked.

We sampled birds at randomly selected points in olive groves (n = 10, approximate mean area = 1.9 ha + SE 0.4) and field agricultural sites, (n = 15, approximate mean area = 2.5 ha + SE 0.7). Survey points were chosen by mapping potential sampling areas in Google Earth and then importing the polygons into GIS software to select random points. In order to not frighten the birds, we navigated to a location 50 m from each sampling point using a GPS unit, to observe birds using binoculars. Sampling points were separated by a minimum of 250 m (Rey 1993, 1995; Martin et al, 2009). We then recorded the number of individuals that were observed for each bird species within a thirty-meter radius of the original sampling point (Sensu Rey, 1995). We also recorded the species, canopy height, and maximum diameter of each tree within a 15 m radius of the original sampling point. Surveys occurred within two hours after sunrise for a duration of fifteen minutes in July 2010. We compared the bird and tree richness between olive groves and field agricultural sites through an ANOVA.

RESULTS

Six tree species, olive (*Olea europaea*), common almond (*Amygdalus communis*), fig (*Ficus carica*), spiny hawthorn (*Crataegus aronia*), Palestine Buckthorn (*Rhamnus palaestinus*), and Aleppo pine (*Pinus halepensis*), were recorded within our sampling points inside olive groves. The field agricultural sites contained two species of trees, olive and almond. A total of sixteen bird species were recorded, with fourteen species observed in olive groves and six species observed in the field agricultural sites (Table 1). There was a significant difference in species richness between olive groves and field agricultural sites (ANOVA: $F_{2,\ 22} = 46.05$, $P < 0.0001$). Olive groves had significantly higher tree (ANOVA: $F1,\ 25 = 40.51$, $P < 0.0001$) and bird richness (ANOVA: $F1,\ 25 = 9.68$, $P = 0.005$) than field agricultural sites (Fig 1).

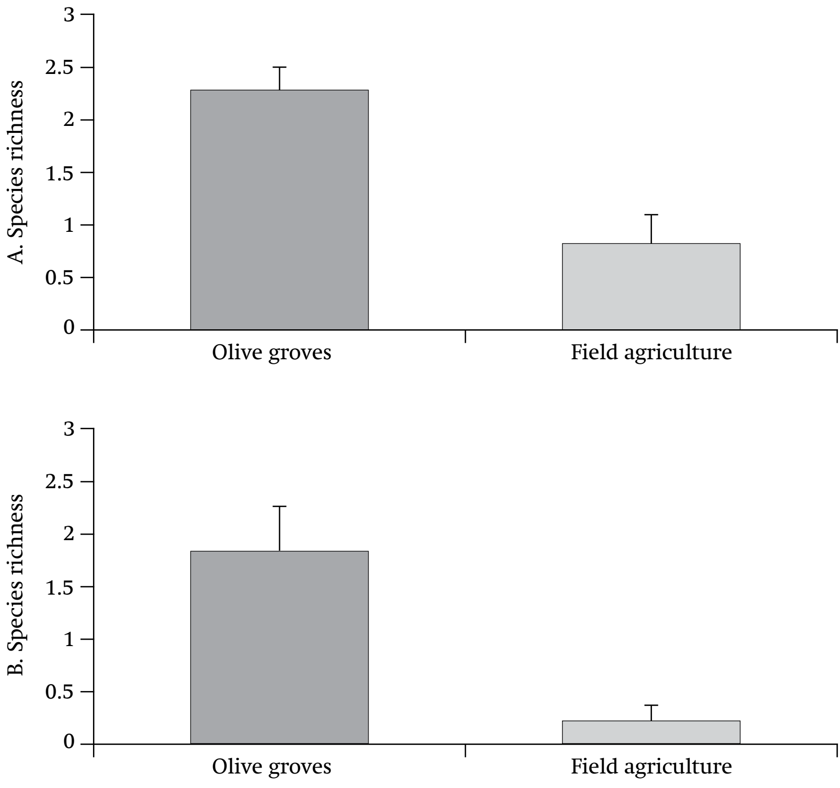

Figure 1. A comparison of bird (A) and tree (B) richness between olive groves and field agricultural sites.

DISCUSSION

Our results corroborate other studies that suggest olive groves have biodiversity value (Biondi et al, 2007; Carpio et al, 2015; Davy et al, 2007; Khoury et al, 2008; Rey 1993, 1995, 2011). Olive groves, like other forms of low-impact agriculture, may mimic some attributes of more natural systems and are associated with greater species diversity than other more intensive agricultural land uses (Beaufoy, 2001; Martin and Lopez, 2002; Dudley et al, 2005; Blondel, 2006; Davy et al, 2007; Rey, 2011). In addition, olive groves have a long history, often several hundred years or more, which allows species from neighboring natural habitats to colonize and utilize the semi-modified landscape (Rey, 1993, 1995, 2011; Davy et al, 2007; Khoury et al, 2008).

Species richness is often related to habitat heterogeneity and structural diversity, as more heterogeneous and structurally diverse habitats have more niches that could potentially be utilized by a greater variety of species for refuge, nesting, and foraging (MacArthur and MacArthur, 1961; Benton et al, 2003). The bird community observed in the olive groves included species found in disturbed and urban areas, Mediterranean forest, scrub, and open areas. The habitat heterogeneity of the olive groves was visually higher than the non-olive grove sites, as olive groves are an irregularly spaced tree community that included other agricultural and native tree species (Figure 1). The olive groves were found in areas in which trees were separated from one another by a matrix of open areas containing rock outcroppings, un-mowed grasses, and native shrubs. Short, irregular rock hedgerows used to delineate olive grove borders from neighboring orchards and minimize soil erosion, also contribute to the habitat heterogeneity (Beaufoy, 2001). The leaves of olive trees also provide leaf litter that are used by wildlife as a thermal and habitat refuge, which allows wildlife to persist in semi-modified landscapes (sensu Manning et al, 2006; Attum et al, 2011). Also, older olive trees have irregularly shaped trunks with numerous cavities, which contribute to the microhabitat heterogeneity.

In contrast, non-olive grove sites typically had lower observed species richness and a bird community that consisted of disturbance-tolerant and urban species. The non-olive groves consisted of a more homogenous and structurally simpler landscape consisting of few trees and a monoculture of crops, which usually lacked the habitat structures found in olive groves (Manning et al, 2006; Davy et al, 2007; Martin et al, 2009; Fischer et al, 2010). In addition, the spatial arrangement of crops in non-olive grove sites are often distributed in a uniform fashion, with the vegetation structure being present during growing season and absent from other times of the year, which further contributes to a simpler landscape than olive groves. The biodiversity value of olive groves and non-olive sites could also be related to factors that were not examined, which would explain the observation of the Palestine sunbird in the non-olive grove sites. For example, this study did not examine orchid age or size, habitat type of the neighboring patch, or pre-adaptive traits of the species community (Rey, 1993; 2011). Despite having presence-only data with no information on reproductive success, our results provide a meaningful comparison of biodiversity (Martin et al, 2009; Caula, 2010).

Our study suggests that olive groves in Palestine could be considered cultural landscapes or be designated as globally important agricultural systems because of the combination of their biodiversity, cultural, and economic values (Farina, 2000; Beaufoy, 2001; Biondi et al, 2007; Harrop, 2007). The biodiversity value of historic olive groves has been recognized in other parts of the Mediterranean, with some proposing these areas should receive protection because they are habitat used by some rare and threatened species and are important in maintaining regional biodiversity (Rey, 1995; Beaufoy, 2001; Biondi et al, 2007; Attum et al, 2011; Rey, 2011). The recognition and support for maintaining olive groves may assist in promoting biodiversity and support the local communities within Palestine, as occurs in other cultural landscapes (Farina, 2000; Beaufoy, 2001; Martin and Lopez, 2002; Harrop, 2007; Scherr and McNeely, 2008). Sustainable agricultural practices and some biodiversity conservation can be maintained when conservation objectives and local values are consistent (Farina, 2000; Beaufoy, 2001; Harrop, 2007; Martin et al, 2009). The designation of olive groves as cultural landscapes can be useful for educating the public and promoting tourist and local appreciation for the cultural, historical, and biological heritage of Palestine (Makhzoumi, 1997; Farina, 2000; Biondi et al, 2007).

However, olive groves in Palestine face numerous threats, which include destruction by the Israeli government and settlers to erase Palestinian cultural and ownership ties to the land, land confiscation, and the military occupation that prevents farmers from accessing their lands and disrupts cultural activities associated with the olive harvest season (Falah, 1996; Braverman, 2009; Oxfam, 2011; OCHA, 2012; UNDP, 2008). Strengthening traditional institutions and practices, such as community-based natural resource protection and the establishment of legal protection, may therefore likely preserve and maintain practices that allow biodiversity to exist in olive groves (Berkes, 2004; Davy et al, 2007; Harrop, 2007; Scherr and McNeely, 2008; Martin et al, 2009).

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Table 1. Species observed in olive groves (olive) and non-olive grove (non-olive) sites

Spec	Olive	on-olive
Alpine Swift, *Apus melba*		x
Black-eared Wheatear, *Oenanthe hispanica*	x	
(Eurasian) Collared Dove, *Streptopelia decaocto*		x
Graceful Prinia, *Prinia gracilis*	x	
Great Tit, *Parus major*	x	
(European) Green Finch, *Chloris chloris*	x	
(Eurasian) Hobby, *Falco subbuteo*	x	
Hooded Crow, *Corvus cornix*	x	x
House Sparrow, *Passer domesticus*	x	x
(Eurasian) Jay, *Garrulus glandarius*	x	
Masked Shrike, *Lanius nubicus*	x	
Orphean Warbler, *Sylvia hortensis*	x	
Palestine Sunbird, *Cinnyris osea*	x	x
Laughing Dove, *Streptopelia senegalensis*	x	x
Sardinian Warbler, *Sylvia melanocephala*	x	
White-spectacled Bulbul, *Pycnonotus xanthopygos*	x	

The birds diversity of the wetland habitats in the Fifa Nature Reserve, Jordan

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ABSTRACT

The diversity of the bird communities of wetland habitats in the Fifa Nature Reserve was studied during August 2017 to March 2018. The methods used were direct observation and spot counts. A total of 81 species of 31 families was recorded, including 52 Species of migrants. The largest number of birds was recorded in January and the lowest in March. Little Egret, Cattle Egret, Gray Heron, Spur-winged Lapwing, Black winged-Stilt, Moorhen, Teal and Garganey were the most abundant migrant species. Dead Sea Sparrow, Laughing Dove, Crested Lark, Reed Warbler, and White Wagtail were the most common resident species.

INTRODUCTION

Fifa Nature Reserve is a biodiversity-rich ecosystem that is one of the most important sites for migratory bird species in the Middle East (Ellis, 2017). The reserve was designated as the world's lowest elevation Ramsar Site, lying at 426 meters below sea level. It is considered an important habitat for several rare and endangered birds at the local and regional level, including Nubian Nightjar *Caprimulgus nubicus* and Dead Sea Sparrow *Passer moabiticus* (Fig. 1). Very large numbers of migrant birds pass through the area in the spring and autumn.

Wetland is widely recognized as a highly important ecosystem with diverse attributes including a distinctive avifauna (Burger, 1985). Birds are considered to be a good indicator of the degree of human disturbance in various ecosystems worldwide, as populations can vary considerably due to anthropogenic activities (Askins et al., 1990; Bock et al., 2001).

The aim of this study was to gather further baseline data on the diversity of birds in the wetland habitats of the reserve, including rare species, in order to update the relevant criteria for the Ramsar designation and inform habitat management. Such information has been difficult to gather in the past because the reserve lies on the Border between Jordan and Palestine.

Figure 1. Nubian Nightjar (A), and (B) the Dead Sea Sparrow both in Fifa Nature Reserve.

Materials and Methods

Site description

The Fifa Nature Reserve is located in the southwestern part of Jordan, about 33.5 km S-SE of the Dead Sea and 157 km north of the city of Aqaba [Coordinates for the centre of the reserve East 731366.653, North 3427479,77] (Fig. 2). The Fifa Nature Reserve is located within the Sudanian (Tropical) Bio-Geographical Zone, which is characterized by high temperatures with warm winters and hot summers, combined with low annual rainfall of about 50-100mm /year.

Two major vegetation types were recorded in the Fifa Protected Area, saline vegetation (19.9 km^2) and tropical vegetation (6.56 km^2 including 0.56 km^2on the included farms). The area is intersected by wadis and dominated by sparse vegetation of perennial grasses and woody plant such as: *Acasiatortilis, Phoenix dactylifera, Nitrariaretusa, Tamarixspp and Salvadorapersica* (RSCN 2011).

Methods

The survey was carried out from August 2017 to March 2018. Fourteen spot counts in the wetland habitats including the Sabkhat area and water channels within the Fifa Nature Reserve were chosen (Fig. 3). Bird counts were carried out between 06:30 and 10:00. Binoculars (8 x 42) and a telescope (72 x) were used for bird identification.

A total of 15 minutes was spent recording birds at each spot count to ensure that all birds present were observed and recorded. Each site was visited twice each week and the maximum number of each bird species recorded on each visit.

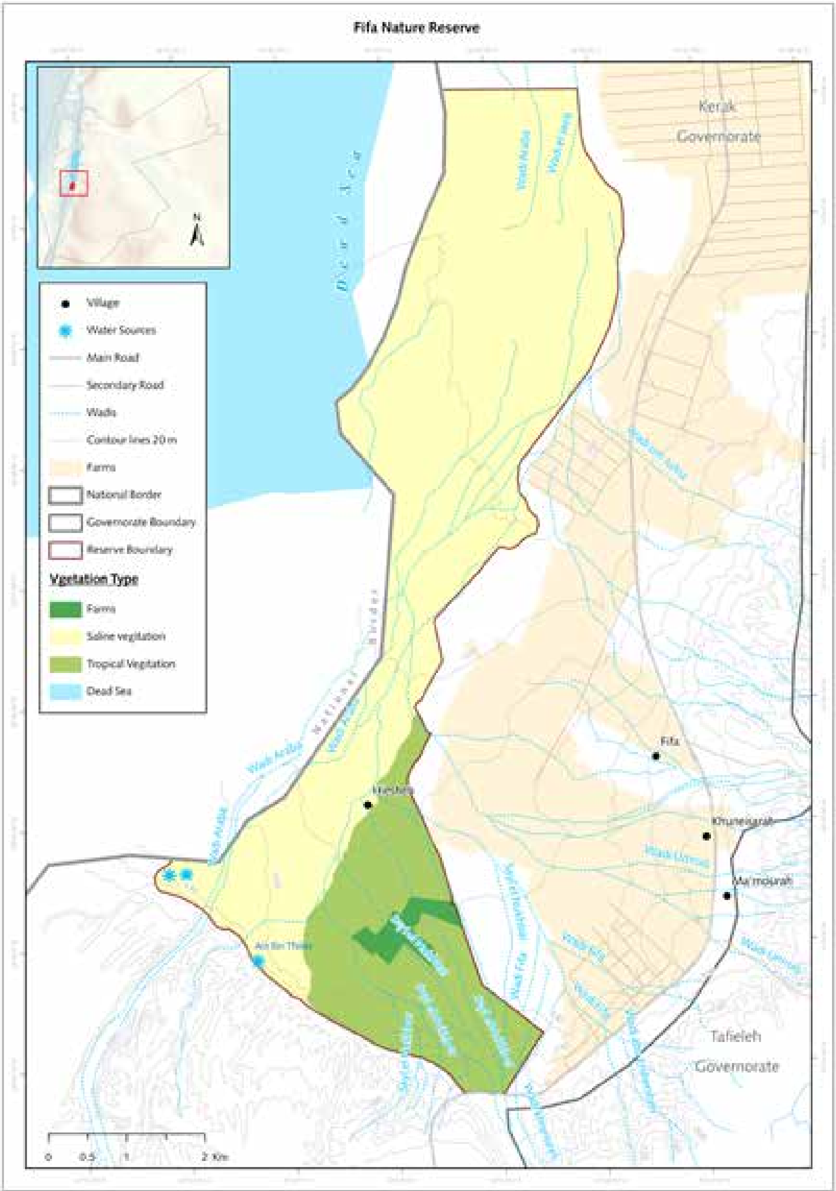

Figure 2: location and vegetation types of the Fifa Nature reserve

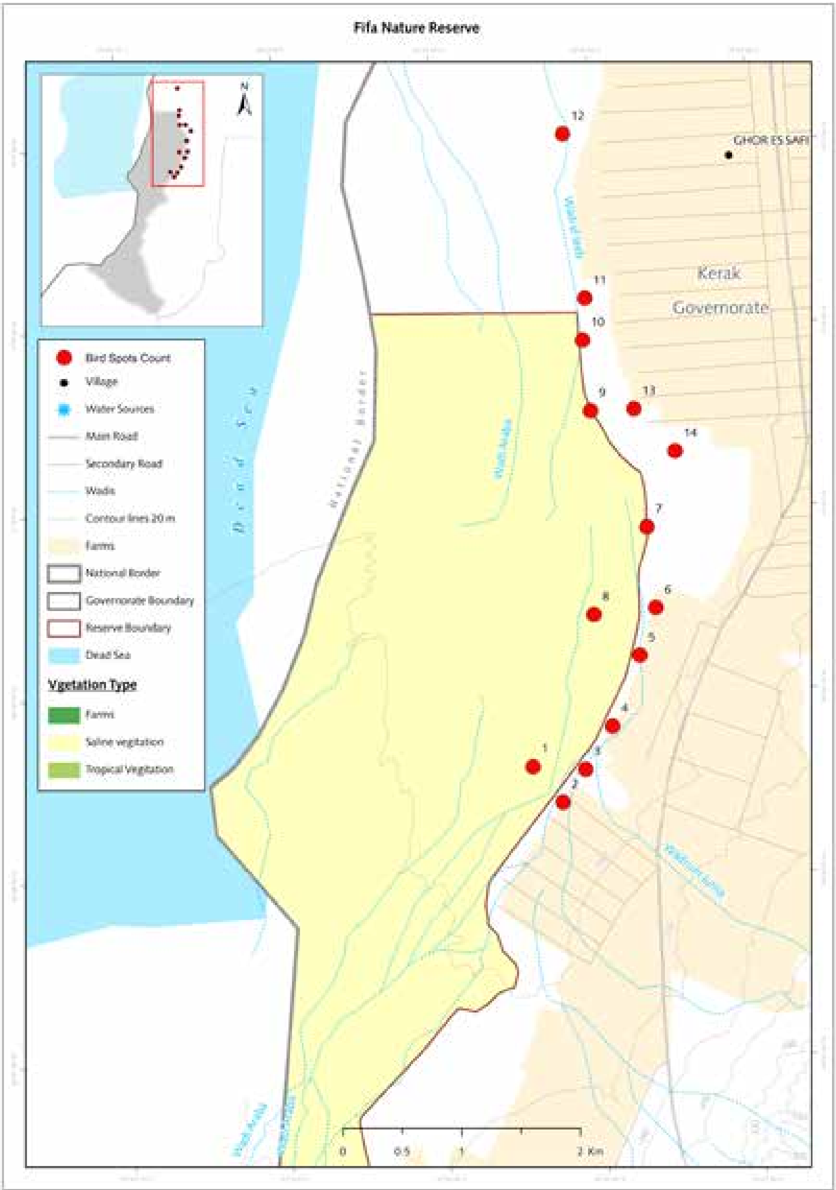

Figure (2): Sites of spot counts in the Fifa Nature Reserve

RESULTS

During the survey a total of 83 species of birds of 32 Families was recorded in the wetland habitats ofthe Fifa Nature Reserve (Table 1). A total of 52 species of migrants were recorded. Black-winged Stilt *Himantopus himantopus*, Spur-winged Plover *Vanellu sspinosus*, Moorhen *Gallinula chloropus*, Stone Curlew *Burhinus oedicnemus*, and Dead Sea Sparrow *Passer moabiticus* were common breeding species in the wetland areas of the reserve. Two species Hooded Crow and Glossy Ibis were recorded for the first time on the reserve.

The reserve also supports a considerable number of raptors and owls, including Bonelli's Eagle *Aquila fasciata*, Steppe Eagle *Aquila nipalensis*, Short-toed Eagle *Circaetus gallicus*, Booted Eagle *Hieraaetus pennatus*, Black Kite *Milvus migrans*, Black-shouldered Kite *Elanus caeruleus* Short-eared Owl *Asio flammeus*, Long-eared Owl *Asio otus*, Scops Owl *Otus scops* and Little Owl *Athene noctua*. The Fifa Nature Reserve is particularly important both nationally and internationally for its breeding populations of Nubian Nightjars and Dead Sea Sparrows, which are both endangered species at the local level.

DISCUSSION

In the present study 83 species of birds were observed, which indicates the richness of the avifauna of the Fifa Nature Reserve, especially during the migration season in the autumn. In addition, Spur-winged Lapwing and Stone Curlew were proved to breed on the reserve for the first time. The results of this study confirm that the Fifa Nature Reserve is an important habitat for several species, as well as large numbers of waders. Reed Warblers are considered to be a threatened species in Jordan and were recorded nesting in nationally and regionally important numbers on the reserve for the first time.

CONCLUSION

This study confirmed that the Fifa Nature Reserve is one of the most important sites in Jordan for migrant birds, especially during December to March, when water levels in the Sabkhat area were high. The protection of birds using the reserve can be greatly helped by the people of the village of Fifa. In order to achieve this, a programme is planned to raise awareness of the importance of the reserve in the local community.

ACKNOWLEDGEMENTS

The authors would like to thank Dr Nashat Hamidan (Head of Conservation Monitoring Centre at the Royal Society for the Conservation of Nature) for his kind assistance and support and valuable comments on the manuscript. Thanks also to Mr Ibrahim Mahasneh the site manager of Fifa Nature Reserve for his logistic and admin support.

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Table 1: List of bird species and numbers observed from August 2017 to March 2018, Fifa Nature Reserve, Jordan

Family	**Common name**	**Scientific name**	**Breed**
Podicipedidae	Little Greebe	*Tachybaptus ruficollis*	NBr
Anatidae	Egyptian Goose	*Alopochen aegyptiaca*	NBr
	Mallard	*Anas platyrhynchos*	NBr
	Teal	*Anas crecca*	NBr
	Garganey	*Anas querquedula*	NBr
Ardeidae	Great White Egret	*Casmerodius albus*	NBr
	Grey Heron	*Ardea cinerea*	NBr
	Purple Heron	*Ardea purpurea*	NBr
	Squacco Heron	*Ardea laralloides*	NBr
	Cattle Egret	*Bubulcus ibis*	BR
	Bittern	*Botaurus lentiginosus*	NBr
	Little Egret	*Egretta garzetta*	BR
Ciconiidae	White Stork	*Ciconi aciconia*	NBr
	Black Stork	*Ciconia nigra*	NBr
Phasianidae	Sand Partridge	*Ammoperdix heyi*	BR
Rallidae	Little Crake	*Porzana parva*	NBr
	Common Moorhen	*Gallinula chloropus*	BR
Accipitridae	Bonelli's Eagle	*Aquila fasciata*	NBr
	Steppe Eagle	*Aquila nipalensis*	NBr
	Short-toed Eagle	*Circaetus gallicus*	NBr
	Booted Eagle	*Hieraaetus pennatus*	NBr
	Black Kite	*Milvus migrans*	NBr
	Black-shouldered Kite	*Elanus caeruleus*	BR
Burhinidae	Stone Curlew	*Burhinus oedicnemus*	
Recurvirostridae	Black-winged Stilt	*Himantopus himantopus*	BR
Glareolidae	Collared Pratincole	*Glareola pratincola*	NBr
Charadriidae	Little Ringed Plover	*Charadrius dubius*	NBr
	Kentish Plover	*Charadrius alexandrinus*	NBr
	White-tailed Lapwing	*Vanellus leucurus*	NBr
	Spur-winged Lapwing	*Vanellus spinosus*	BR
	Lapwing	*Vanellus vanellus*	BR

Scolopacidae	Little Stint	*Calidris minuta*	NBr
	Common Sandpiper	*Actitis hypoleucos*	BR
	Wood Sandpiper	*Tringa glareola*	NBr
	Green Sandpiper	*Tringa ochropus*	BR
	Marsh Sandpiper	*Tringa stagnatilis*	NBr
	Common Snipe	*Gallinago gallinago*	BR
	Redshank	*Tringa totanus*	NBr
	Spotted Redshank	*Tringa erythropus*	NBr
Laridae	Common Tern	*Sterna hirundo*	NBr
Columbidae	Rock Dove	*Columba livia*	BR
	Laughing Dove	*Streptopelia senegalensis*	BR
	Namaqua Dove	*Oena capensis*	BR
	Collared Dove	*Streptopelia decaocto*	BR
Strigidae	Short-eared Owl	*Asio flammeus*	NBr
	Little Owl	*Athene noctua*	BR
	Long-eared owl	*Asio otus*	NBr
	Scops owl	*Otus scops*	NBr
Caprimulgidae	Nubian Nightjar	*Caprimulgus nubicus*	BR
Apodidae	Common Swift	*Apus apus*	NBr
	Pallid Swift	*Apus pallidus*	NBr
Upupidae	Common Hoopoe	*Upupa epops*	BR
Alcedinidae	Common Kingfisher	*Alcedo atthis*	BR
	Pied Kingfisher	*Ceryle rudis*	BR
	White-throated Kingfisher	*Halcyon gularis*	BR
Meropidae	Bee-eater	*Merops apiaster*	BR
	Little Green Bee-eater	*Merops pusillus*	BR
	Blue-cheeked Bee-eater	*Merops persicus*	NBr
Coraciidae	European Roller	*Coracias garrulus*	BR
Picidae	Eurasian Wryneck	*Jynx torquilla*	NBr
Alaudidae	Crested Lark	*Galerida cristata*	BR
	Short-toed lark	*Calandrella brachydactyla*	NBr
	Hoopoe lark	*Alaemon alaudipes*	NBr
Motacillidae	Water Pipit	*Anthus spinoletta*	NBr
	Red-throated Pipit	*Anthus cervinus*	NBr

Hirundinidae	Sand Martin	*Riparia riparia*	NBr
	House Martin	*Delichon urbicum*	BR
	Barn Swallow	*Hirundo rustica*	NBr
	Red-rumped Swallow	*Cecropis daurica*	BR
Passeridae	House sparrow	*Passer domesticus*	BR
	Spanish Sparrow	*Passer hispaniolensis*	BR
	Dead Sea Sparrow	*Passer moabiticus*	BR
Acrocephalidae	Common Reed-warbler	*Acrocephalus scirpaceus*	BR
	Clamorous Reed-warbler	*Acrocephalus stentoreus*	BR
	olivaceous warbler	*Iduna pallida*	BR
	Sedge Warbler	*Acrocephalus schoenobaenus*	BR
	Sardinian Warbler	*Sylvia melanocephala*	NBr
Sylviidae	common chiffchaff	*Phylloscopus collybita*	BR
Phylloscopidae	(Common Myna)	*Acridotheres tristis*	BR
Sturnidae	Tristarm's starling	*Onychognathus tristramii*	BR
Corvidae	House Crow	*Corvus splendens*	NBr
	Hooded Crow	*Corvus cornix*	NBr
Threskiornithidae	Glossy Ibis	*Plegadis falcinellus*	NBr

BR – Breeding record confirmed; NBr- Non Breeding

A zoogeographical analysis of rodent fauna of Jordan

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ABSTRACT

The rodent fauna of Jordan is highly heterogenous, totaling 28 species and originating from three zoogeographical affinities: Palaearctic, Afrotropical, and Oriental, in addition to several wide-ranging, Eastern Mediterranean and introduced species. The distribution of rodents in Jordan represents a reflection of their global distribution ranges and habitat preferences. For several species, Jordan lies at the edge of their distribution ranges (e.g. *Apodemus* sp., *Nannospalax ehrenberg*i), other have wide distribution (e.g. *Jaculus jaculus*), while some are represented by relict populations (e.g. *Eliomys melanurus* and *Acomys russatus lewisi*). Species associated with the temperate forest of northern Jordan includes *Sciurus anomalus* and two wood mice, *Apodemus mystacinus* and *A. flavicollis*, while non-forested areas are represented by *Nannospalax ehrenbergi* and *Microtus guentheri*. Strict sand dwellers include *Gerbillus cheesmani* and *G. gerbillus*. Petrophiles associated with sandstone or black lava deserts are exemplified by *Acomys russatus*, *A. r. lewsi, H. indica* and *S. calurus*. Others including: *Jaculus jaculus, G. nanus, G. henleyi, Meriones crassus*, and *M. libycus* are all desert-adapted species with a wide distribution occuring in areas of scarce vegetation, wadibeds, and marabs with clay, loess, or gravel surfaces. A single species, *Gerbillus dasyurus*, exhibits a wide range of distribution over diverse habitat types. Species composition is characterized by substantial variability of rodent assemblages due to habitat requirements and replacements of sibling species.

Key words: Habitat preference, Jordan, Rodents, Zoogeography.

INTRODUCTION

Jordan sits at the crossroads between three zoogeographical affinities: the Palaearctic, Oriental, and Sudanian Penetration. Despite its limited area, biodiversity in Jordan is remarkable due to the high habitat heterogeneity within several biogeographical regions (Amr, 2012). As the largest groups of mammals worldwide as well as in the Eastern Mediterranean region, rodents play an important role in establishing the ecosystem's biodiversity and food webs. Not only are they prey for avian and mammalian predators, but they are also consumers of seeds and green plants. Rodents are also able to alter the species composition of plant communities thereby altering the vegetation of an area by selective feeding (Chaline, 1977). Rodents are the most diversified group of mammals inhabiting temperate, arid and semi-arid habitats in North and East Africa, the Levant and the Arabian Peninsula (Harrison, 1972; Lay, 1983; Harrison & Bates, 1991; Wilson & Reeder, 2005; Granjon et al., 1999; Scott & Dunstone, 2000; Abu Baker & Amr, 2003b; 2004).

Our knowledge on rodent diversity in Jordan is a result of continuous efforts over the past 15 years. Several systematic accounts have been conducted yielding a great deal of data on the diversity, systematics and ecology (Abu Baker & Amr, 2003a; 2003b; 2004; 2008; Yousef & Amr, 2005; Amr et al., 2004; 2006; Amr, 2008; Atallah 1977; 1978; Harrison & Bates, 1991; Qumsiyeh, 1996; Amr, 2000; Benda et al., 2010; Amr, 2012; Amr et al., 2018). The rodents of Jordan are represented in eight families (Cricetidae, Dipodidae, Gliridae, Hystricidae, Muridae, Myocastoridae, Sciuridae, and Spalacidae) with 20 genera and 28 species. Species of this order are diverse, inhabiting a wide variety of habitats, ranging from extremely arid to mountainous and cold environments. The majority of rodents are nocturnal or crepuscular; however, some are strictly diurnal (e.g. squirrels). The diet of most rodents is primarily granivorous and herbivorous, but a few species feed on insects or land snails. Most of the rodents in Jordan are relatively small in size, with the exception of the Indian crested porcupine and the introduced coypu (Wilson et al., 2016).

This paper aims to summarize the diversity and ecology of the rodents of Jordan and zoogeographical affinities. The spatial patterns of distribution were analyzed based on past and updated records of all the rodents in Jordan.

MATERIALS AND METHODS

In Jordan, four biogeographical regions are identified: The Mediterranean region; which, has the highest rain fall and altitude and the most fertile soil. It includes the mountain ranges between Irbid in the north and Ra's an Naqb in the south. This region is dominated by oak, pine and pistachio trees. The Irano-Turanian region which surrounds the Mediterranean region, except in the north, is characterized by lower altitudes with poor soil and dominated by *Raetam* sp., *Anabasis* sp. and *Artimesia* sp. of vegetation. The Saharo-Arabian region comprises the majority of the total area of Jordan and has the lowest rain fall and poorest soils. Diversified subdivisions of vegetation types occur based upon habitat type such as hammada, saline, sandy and mud flat (Al-Eisawi, 1996). The Sudanian region is characterized by being the warmest region, occurring in the most southern and southwestern parts of the country, low rain fall and mostly saline or sandy soil. The dominant vegetation is *Acacia* sp. and *Haloxylon persicum* (Disi & Amr, 1998; Disi et al., 1999).

Rodent distribution by habitat type

The biogeographic zones were further subdivided into eight sub-regions based on the distinguished habitat aspects such as substrate types, land cover, and vegetation (Fig. 1, Table 1). These are:

Temperate Mediterranean forests

These include the Aleppo pine and evergreen and deciduous oak forests. The Aleppo pine forests (*Pinus halepensis*) covers small areas mainly in Dibbin forest, Ajlūn and Zai and is mainly associated with evergreen oak (*Q. calliprinos*), strawberry tree (*Arbutus andrachne*), Pistachio (*Pistaia palaestina*) and *Pyrus syriaca*. The soil is white calcareuos and/or Terra Rosa with average annual rainfall 500-700mm.

Non-forest Mediterranean region (including agricultural fields)

These areas may be classified as secondary (degraded) forests due to intense pressure of logging and deforestation for agriculture, urban development, and grazing over the years. These areas are not covered by forests, but contain some bushes and shrubs that are considered non-forest Mediterranean habitats and contains shrubs and bushes that are found in all Mediterranean regions.

Desert rocky slopes and boulders (including basaltic fields in the Lava Desert)

This habitat is represented by the rocky areas in Jordan including the mountains and boulders that support rock-dwelling species. This area lies mostly within the Saharo-Arabian region of the south where weathered sandstone and granite mountains and eastern regions of the country basaltic boulders originated from ancient volcanic activities.

Wadi beds, marab, and sabkha

These areas are represented by dry water courses (run-off), flat low land areas and depressions of land with high salty soil. The substrates may be of various origins, mostly calcareous, loess, or sandy. The vegetation cover is highly dependent on the season. Dominant plants include: *Artimesia* sp., *Origanum* sp., *Achillea fragrontissima*, *Nitraria retusa*, *Tamarix* sp., *Retama raetam*, and *Atriplix* sp.

Sand dunes and sandy sheets

These areas are composed of soft sand dunes and/or wind-blown sand that are stabilized by healthy vegetation cover of shrubs and bushes (sand dunes fixatives). The main species that characterize this type include *Haloxylon persicum, Retama raetam, Calligonum comosum, Neurada procumbens, Hammada scoparia* and *Seidlittzia rosmarinus.*

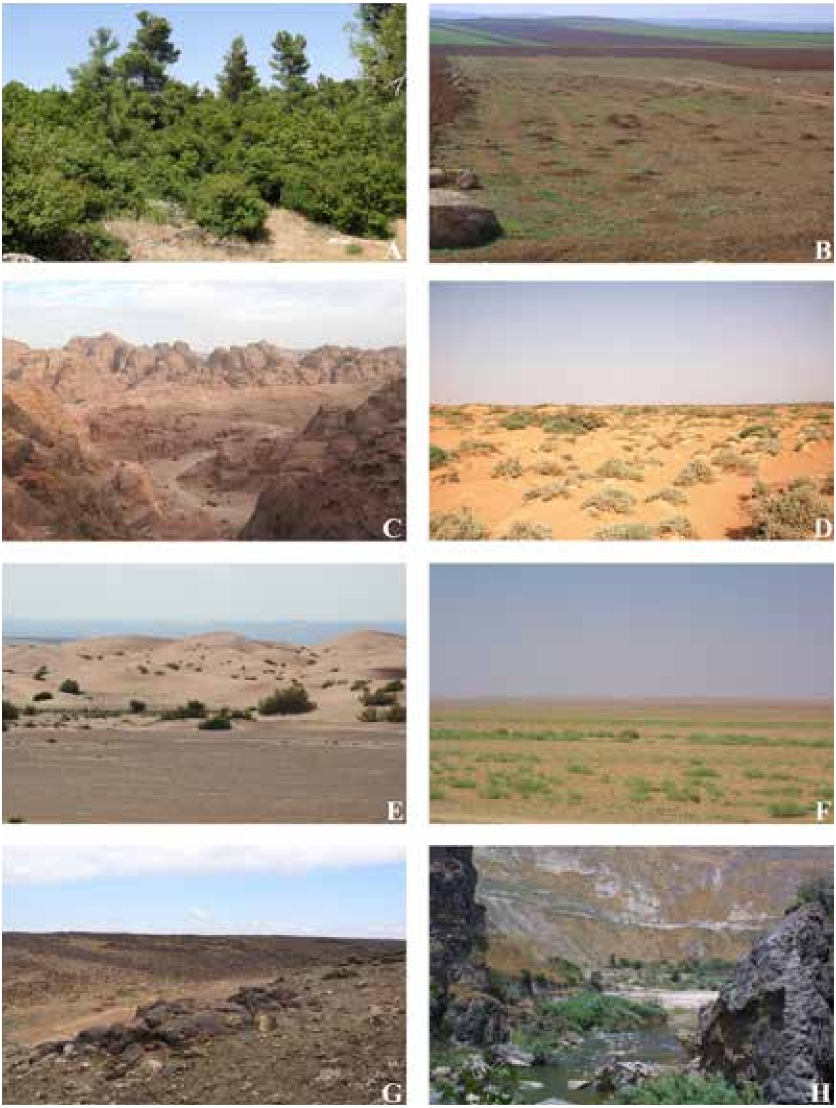

Figure 1: Habitat types: A: Temperate Mediterranean habitat with abundance of evergreen oak (*Quercus* sp.) and pine forests in northern Jordan. B: non- forest Mediterranean habitat with agricultural fields. C: Desert rocky slopes and sandstone mountains. D: Wadi-bids with silt dunes and loess substrates. E: Sand dunes with *Haloxylon shrubs* and Acacia trees in Wādī ʻAraba. F: Open Hamada in eastern Jordan with ample bushes of *Seidlitzia rosmarinus*. G: Bolders of black lava desert in eastern Jordan. H: The riparian habitat at the Yramouk River Basin in northern Jordan.

Open hammada desert: these are flat deserts of clayey loam covered by gravel. Vegetation is dominated by low shrubs of *Seidlittzia rosmarinus, Astragalus spinosus,* and some annual shrubs and succulent plants as; *Spergularia diandra, Herniaria hirsute* and *Anthemis deserti*.

Steppe and gravel/pebble vegetation: This is the largest vegetation type by area within Jordan. It is represented by the open shrubby and flat deserts covered with bare gravel and/or pebbles bordering the semi-temperate and true desert areas. The vegetation of the area is often poor and concentrated in water sheds and small wades with higher soil moisture. The main species of plants in this habitat type include: *Anabasis articulata, Retama raetam, Astragalus spinosus, Tamarix* sp., *Achillea fragrantissima, Artemisia sieberi* and *Zilla spinosa.*

Riparian/water vegetation: these habitats are confined to the limited temporary or permanent stream systems. These habitats and reed vegetation offers suitable habitats few aquatic mammals.

One hundred and thirty sites covering all vegetation types and habitats were visited during the past years and rodents and/or rodent remains were collected. Rodents were often trapped using Sherman folding live-traps (23 × 9 × 9 cm) during different seasons in which traps were baited with mixed oatmeal and pea nut butter, set in the late afternoon and checked in the following morning. Jerboas were spotted at night by the automobile lights and hand torches and caught with regular insect nets. Owl pellets were collected from different localities and analyzed for rodent's skull remains, they were identified to species level based on skull morphology and dental features. Species geographic ranges for the rodents of Jordan were obtained from Harrison & Bates (1991) and Osborne & Helmy (1980) with subsequent updates provided in Amr (2012). Eight main habitat types were recognized for the purpose of the similarity analysis.
The number of overlapping species between each pair of habitats was used to calculate the similarity index using the formula: $\frac{2C}{N1+N2}\times 100$, where C is the number of overlapping species between two habitats, N1 is the total number of species present in habitat 1 and N2 is the total number of species present in habitat 2 (Krebs, 1999). Species within 57 selected sites were classified based on similarity of rodent species composition using cluster-analysis (cosine similarity measure, UPGMA algorithm) using PAST 3.2, 2018 software.

RESULTS AND DISCUSSION

Zoogeographic origins and habitat preferences of rodents in Jordan

The distribution of rodents in Jordan represents, to a large extent, a reflection of their global distribution ranges and habitat preferences. The rodent fauna of Jordan (excluding the four introduced species: *Rattus rattus, R. norvegicus, M. msuculus,* and *Myocastor coypus*) consists of assemblages from different zoogeographical affinities and biogeographic ranges: Palaearctic (12 species), Oriental (5), Saharo-Arabian (10), and wide-Ranging. Nineteen of the recorded species occur in a single zoogeographic region, whereas, four species occurred in two regions, and only one species ranged widely over three regions. Nine, three, and seven species were restricted or had most of its range within the Mediterranean, Irano-Turanian, and Saharo Arabian region, respectively (Amr et al., 2018).

The eastern and southeastern parts of Jordan are largely arid and semi-arid with low productivity, yet, the local habitat heterogeneity have contributed to the relatively high species richness that includes two jerboas, four gerbils, three jirds, one dormouse and one species of spiny mice. Species associated with the temperate forest and non-forested areas of northern Jordan exhibited the highest species richness with a total of ten species, including a single species of squirrels (*Sciurus anomalus*), two wood mice, *Apodemus* sp., a single species of mole rat (*Nannospalax ehrenbergi*), one vole (*Microtus guentheri*), most of which are wide-ranging species toward the north of Jordan. The steppe areas contained nine species, followed by the sandy habitats with seven total species. The low species richness within the non-forest Mediterranean habitats (5 species) is likely in-part due to the agricultural activities and development associated with urban expansion. Strict sand dwellers include two hairy-footed psammophiles only found in the sand dunes are: the easterly-ranging *Gerbillus cheesmani* in the southeast and eastern Jordan is replaced by the westerly-ranging, Saharan *G. gerbillus* in Wādī ʻAraba. The two species are separated by the Sharah Mountains in southern Jordan. The riparian habitat ranked the lowest in terms of species richness with only one species (*Nesokia indica*) while the remaining habitats contained 5–6 species (Table 1).

Several species (Fig. 2) have confined distributions to preferred habitats including: petrophiles (*Acomys russatus, A. r. lewsi, H. indica* and *S. calurus*), psammophiles (*G. andersoni, G. gerbillus, and G. cheesmani*), and forest-dwellers (*S. anomalus, Apodemus mystacinus* and *A. flavicollis*). Other species including: *Jaculus jaculus, G. nanus, G. henleyi, Meriones crassus,* and *M. libycus* are all desert-adapted species with wider ranges of distributionin habitats of scarce vegetation, wadi beds, and marabs with clay, loess, or gravel surfaces provide foraging grounds and shelter (Scott & Dunstone, 2000; Abu Baker & Amr, 2003a; 2003b; 2004; 2008). A single species, *Gerbillus dasyurus*, exhibited a wide range of distribution over diverse habitat types (Table 1).

The similarity index analysis indicated that the highest average similarity was within the steppe and gravel/pebble areas (33.13%) which represent the transition zone bordering the temperate/semi temperate habitats from the west and the true desert areas from the east (Amr et al., 2018). The temperate forests ranked second in terms of overall similarity (26.21%), this area exhibited the highest species richness due to its high productivity and vegetation cover and the fact that it included several widely-distributed species. The lowest overall similarity occurred in the riparian vegetation which is confined to the limited water vegetation areas in Jordan with only one species recorded (Amr et al., 2018).

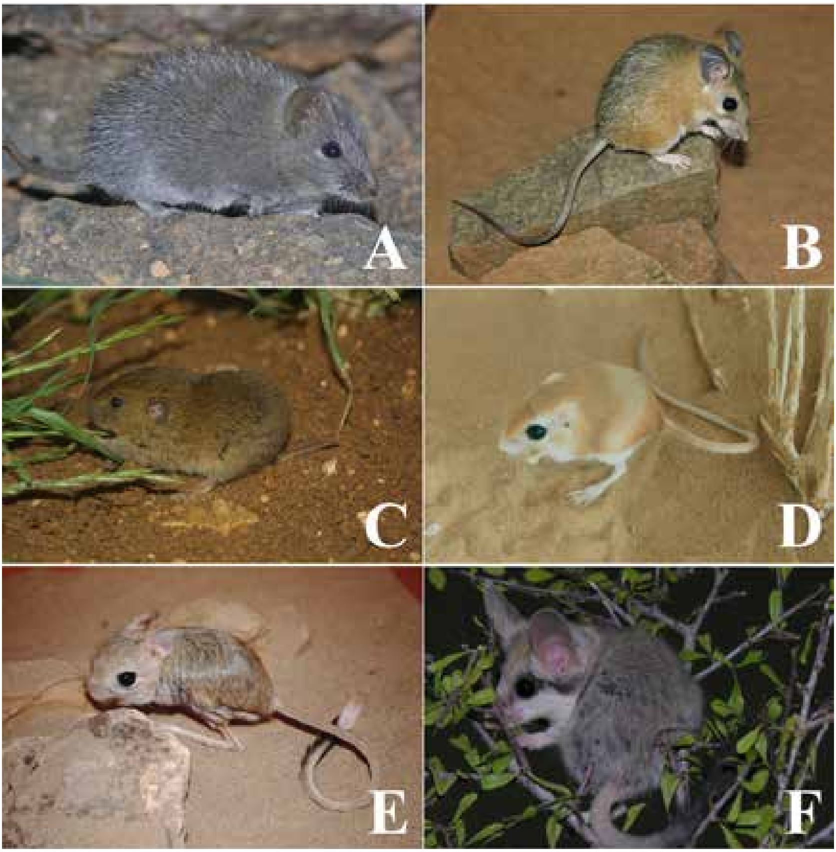

Figure 2: Representative rodents of Jordan: A: *Acomys russatus lewisi* from the rocky basaltic fields in Northeastern Jordan. B: *Acomys dimidiatus* from the rocky slopes and sandstone mountains. C: *Microtus guentheri*, an inhabitant of the agricultural fields and nonforest Mediterranean areas. D: *Gerbillus gerbillus*, from the sand dunes of Wādī ʻAraba. E: *Jaculus jaculus*, a generalist of the open deserts. F: *Eliomys melanurus*, an inhabitant of forested areas and a relict of vegetated wadis in the deserts of Jordan.

Species composition at the local scale

An analysis of 57 local assemblages throughout Jordan showed that species richness ranged from a lone species at 6 sites to 6 species at 2 sites. Mean species richness per site was 2.96, with a mode of 3. Approximately 11% of the sites had a single species, 61% had 2 or 3 species, and 28% supported 4-6 species (Fig. 3). The most abundant species were, *Gerbillus dasyurus* (at 21 sites), *Meriones crassus* (15), *Gebillus nanus* (14), *Jaculus* (13), and the least abundant were *Sekeetamys calurus* and *Allactaga euphratica*, each recorded at a single site. The results suggested that species incidence is highly dependent on habitat requirements.

Several assemblages of rodents were recognized among the study sites by their strict habitat preferences: sites within forested areas (*Sciurus anomalus* and *Apodemus* sp.), nonforest Mediterranean habitats and agricultural field (*Meriones tristrami* and *Microtus guentheri*, and *Nannospalax ehrenbergi*), rocky sites (*Gerbillus dasyurus, Acomys* spp.), sandy sites (*Gerbillus cheesmani*), densely vegetated wadis (*Psammomys obesus* and *Eliomys melanurus*), open gravel plains (*Jaculus* and *G. henleyi*), and in addition to species (*Meriones crassus* and *G. dasyurus*) that ranged over several habitat types. These assemblages were composed of species of similar zoogeographic origin and rarely included closely-related species.

Results of cluster-analysis of species composition indicated that three main groups with 6 assemblages were distinguished (Fig. 4). The distinguished assemblages at the 60% level of similarity represent a critical point where these assemblages can also be distinguished by the habitat types. These assembles are: 1.inhabitants of agricultural fields and non-forest Mediterranean, 2. forests, 3. steppe vegetation, 4. rocky areas, 5. open deserts, and 6. sandy areas (Fig. 3).

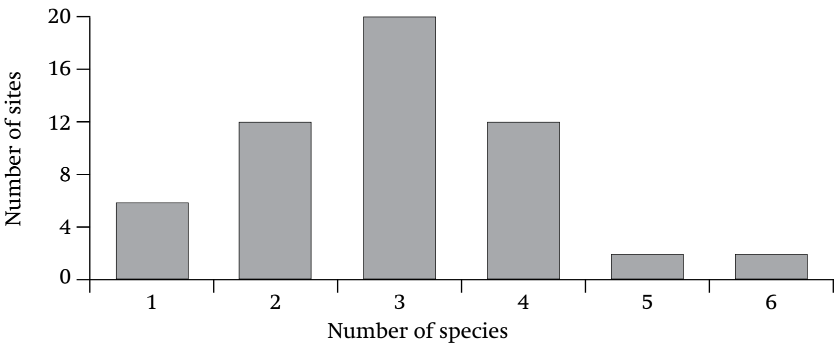

Figure 3. Frequency of coexisting species among 57 study sites.1 = agricultural fields and non-forest Mediterranean, 2 = forests, 3 = steppe vegetation 4 = rocky areas, 5= open deserts and 6 = sandy areas.

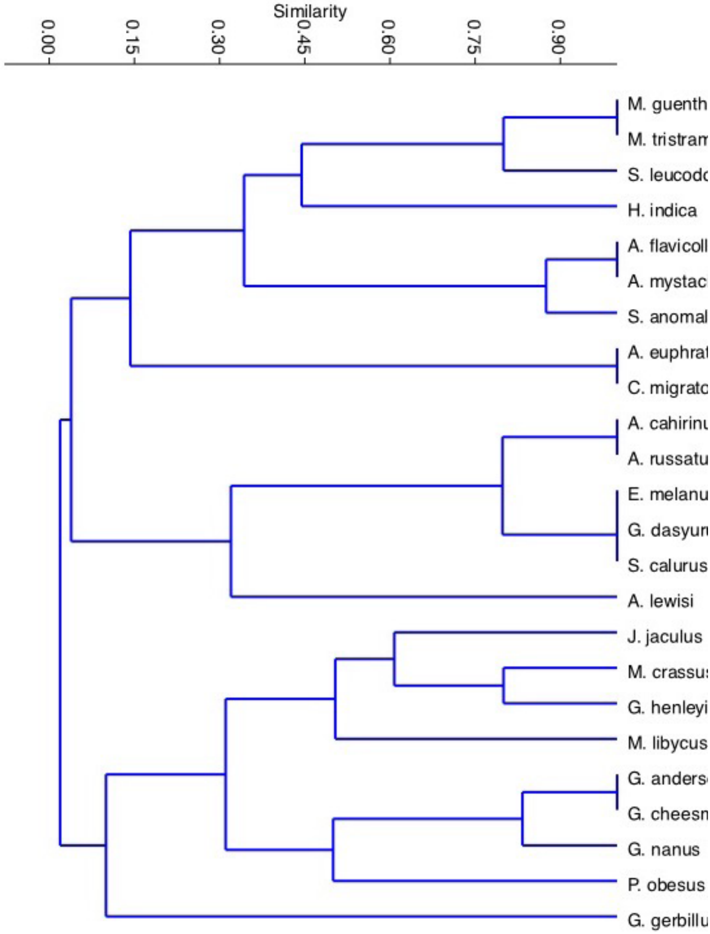

Figure 4: Cluster-analysis of rodent species within 57 sites based on their similarity.

Conclusion

The rodent diversity of Jordan is relatively high, consisting of 28 species. It is considered as mixture of three zoogeographical affinities (Palaearctic, Afrotropical, and Oriental), with some wide-ranging Eastern Mediterranean species. Jordan constitutes the most southern range of distribution for some rodents (e.g. *Apodemus mystacinus, A. flavicollis, Nannospalax ehrenbergi* and *Microtus guentheri*), while it represents the most northern distribution range for some Arabian and African forms (*e.g. S. calurus, Acomys russatus* and *G. gerbillus*).

TABLE 1. Species distribution, richness, percentage of rodents across the main habitats.

Biogeographic regions	**Mediterranean**			**Saharo-Arabian**			**Irano-Turanian**	
Habitat / Species	**Med. forest/forest fields**	**Non-forest Med. and agr. fields**	**Rocky slopes and boulders (including semiarid Med.)**	**Flat hammada deserts**	**Sandy areas and sand dunes**	**Wadi beds, marab, sabkha**	**Open gravel/pebble Steppe vegetation**	**Riparian/water veg.**
Sciurus anomalus	(+)							
Eliomys melanurus	+		+					
Allactaga euphratica							+	
Jaculus jaculus				+	+	+		
Cricetulus migratorius	+	+					+	
Microtus guentheri	+	+						
Acomys dimidiatus			+					
Acomys russatus russatus			+					
Acomys russatus lewisi			+				+	
Psammomys obesus					+		+	
Sekeetamys calurus			(+)					
Meriones crassus				+	+	+	+	
Meriones libycus				+	+	+		
Meriones tristrami	+	+					+	
Gerbillus andersoni					(+)			
Gerbillus cheesmani					(+)			
Gerbillus dasyurus	+		+	+		+	+	
Gerbillus					(+)			
Gerbillus henleyi				+				
Gerbillus nanus						+		
Apodemus mystacinus	(+)							
Apodemus flavicollis	(+)							
Nesokia indica								(+)
Hystrix indica	+	+	+				+	
Nannospalax ehrenbergi	+	+					+	
Species richness	**10**	**5**	**7**	**5**	**7**	**5**	**9**	**1**
% (out of 24 total species)	**41.67**	**20.83**	**29.17**	**20.83**	**29.17**	**20.83**	**37.5**	**4.17**

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Short Communication

Recent observations on snakes from Jordan

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The status and distribution of the snakes of Jordan have been extensively documented over the past three decades. However, additional distributional data are important to better understand the true distribution and ecological preference of snakes. Field notes are useful in that they provide anecdotal, needed information that can provide more insight to the biology of these animals. In this communication, we provide additional distributional and ecological observations for 18 species of snakes.

Family Colubridae

Dolichophis jugularis (Linnaeus, 1758)
Materials: Salt, 1.4.2018. Jawa (near Amman), 6.6.2018. Al Mazar Al Janoubi, 27.6.2018.
Remarks: A juvenile measuring 35 cm, Jawa, near Amman. An immature snake reaching up to 125 cm with the typical immature coloration was collected from Al Mazar Al Janoubi, while three other adult individuals were observed in a chicken farm. A 275 cm adult specimen was collected from Salt. The Syrian Black Snake is confined to the Mediterranean biotope, although specimens were also found in transitional areas between the Irano-Turanian and the Mediterranean biotopes (Amr & Disi, 2011).

Hemorrhois nummifer (Reuss, 1834)
Material: Wadi Al Hidan, 23.3.2018.
Remarks: The Coin Snake is usually found in shrubby and forested areas that extend along the mountainous range stretching from the north as far as Petra to the south (Amr & Disi, 2011). It was found in a cliff overlooking the water source.

Lytorhynchus diadema (Duméril, Bibron & Duméril, 1854) Fig 1A
Material: Al Atarat, 27.3.2018.
Remarks: The Diademed Sand Snake has been collected previously from southern Jordan. Al-Oran (2000) referred to a specimen collected from Al Jafer (in Southern or some other part of Jordan) similar to the individual we

collected as “forma ”*kennedyi*” Schmidt, 1939” in Al Atarat. The body colour was bright orange to reddish, with dark transverse spots on body and tail.

Malpolon insignitus (Geoffroy De St-Hilaire, 1809)
Material: Al Hashemeyah, near Zarqa, 3.1.2018.
Remarks: The Montpellier Snake typically inhabits the Mediterranean biotope in Jordan that is typically associated with vegetated areas. We collected an individual from arid regions within the Irano-Turanian biotope in the Al Hashemeyah area, near Zarqa. This snake was found hibernating under rocks in a construction site.

Platyceps collaris (Müller, 1878)
Material: Ain Al Bedah, Marka near Amman, 10.8.2017
Remarks: The Red Whip Snake is a strictly Mediterranean species. It is distributed along the mountain ranges that extend along northern Jordan to Petra in the south (Amr & Disi, 2011).

Platyceps rogersi (Anderson, 1893) Fig 1B
Material: Al Jizah, 20.5.2018.
Remarks: Roger’s Snake inhabits rocky or stony hills, hamada and steppes (Amr & Disi, 2011). It is more common in the eastern desert. Two specimens were found in a deserted house.

Platyceps sinai (Schmidt & Marx, 1956)
Material: Wadi Wadyeh (Ghor Al Karak), 19.8.2018.
Remarks: The Sinai Banded Snake was collected and observed previously from mouth of Wadi Al Mujib (Werner, 1998) and Wadi Ramm (Sindaco et al., 1995). This is a rare snake with limited known localities. It was found killed in the wadi.

Psammophis schokari (Forskål, 1775)
Material: Al Jizah, 20.5.2018.
Remarks: This is a common species in arid habitats, however, its distribution reaches the Mediterranean ecozone. It was observed during daytime under bushes on a black basalt wall at mid-day (Amr & Disi, 2011).

Rhagerhis moilensis (Reuss, 1834) Fig 2A
Material: Al Atarat, 13.5.2018.
Remarks: The Moila Snake is a common species in the Saharo-Arabian as well as some limited areas within the Irano-Turanian biotopes.

Figure 1: A. *Lytorhynchus diadema* from Al Atarat, B. *Rhagerhis moilensis* Al Atarat.

Telescopus dhara (Forskål, 1775) Fig 2B
Material: Al Kafrain, 30.3.2018.
Remarks: The Tree Cat Snake is distributed in the arid regions and rocky hills of the southern Jordan Valley, Wadi Araba and Wadi Ramm (Amr & Disi, 2011). This specimen was found in a banana planation within the Jordan Valley.

Telescopus nigriceps (Ahl, 1924)
Material: Sakhra, 3.7.2018.
Remarks: The Black-headed Cat Snake is characterized by two forms in Jordan. The true or typical form "*T. nigriceps*" and the form "*T. cf. nigriceps*". The first form is found in flat desert areas at low elevations, while the latter form is known from mountainous areas at high elevation (Disi et al., 2001). We collected one individual at one am near a pigeon coup.

Figure 2: A. *Platyceps rogersi* from Al Jizah. B. *Telescopus dhara* from Al Kafrain.

Family Atractaspididae

Micrelaps muelleri Boettger, 1880
Material: Kitim, 18.6.2018
Remarks: The Mueller's Ground Viper is a nocturnal and fossorial snake. This specimen was collected from a house.

Family Elapidae

Walterinnesia aegyptia Lataste, 1887
Material: Mahis, July 2017. Saroot, 14 August 2018.
Remarks: The black desert Cobra is from extreme desert habitats in the eastern desert and Wadi Araba to the mountain ranges near Al Karak and As Salt areas (Amr & Disi, 2011). We collected an individual from a mixed oak and pine forest in the Mediterranean zone.

Family Viperidae

Daboia palaestinae (Werner, 1938)
Material: Wadi Al Harmeyeh (Salt), 29.4.2018. Al Shajarah, 4.3.2018.
Remarks: The Palestine Viper is associated with oak and pine forested areas (Amr & Disi, 2011). The specimen from Wadi Al Harmeyeh was in ambush position under oak leaf letter around 11 am. We observed it striking a dove. This snake is considered the most dangerous viper in Jordan, causing the highest rate of fatalities (Amr & Disi, 2015).

Echis coloratus Günther, 1878
Material: Wadi Shaib, July 2017.
Remarks: The Arabian Saw-scaled Viper is an abundant and widespread snake that occurs in steep, dry rocky hillsides of mountains (Amr & Disi, 2011). This species is considered one of the most venomous vipers in Jordan (Amr & Disi, 2015).

Macrovipera lebetina obtusa (Dwigubsky, 1832) Fig 3A
Material: Karka (Tafilah), 6.7.2018.
Remarks: Al-Oran et al. (1998) recorded the Levantine Viper for the first time in Jordan from Sail El ʻAina and Al Ḩarīr. Two large specimens were caught by a farmer from Karka, where one was killed instantly, while the other individual was kept alive. The alive specimen regurgitated three house sparrows. Karka is close to Al Ḩarīr.

Pseudocerastes fieldi Schmidt, 1930 Fig 3B
Material: Azraq, 22.6.2018. Wadi Al Ghadaf, 9.8.2018.
Remarks: All previous specimens of the False Horn Viper recorded in Jordan have been the melanistic form from the eastern desert. Both of our specimens represent a new colour form for Jordan.

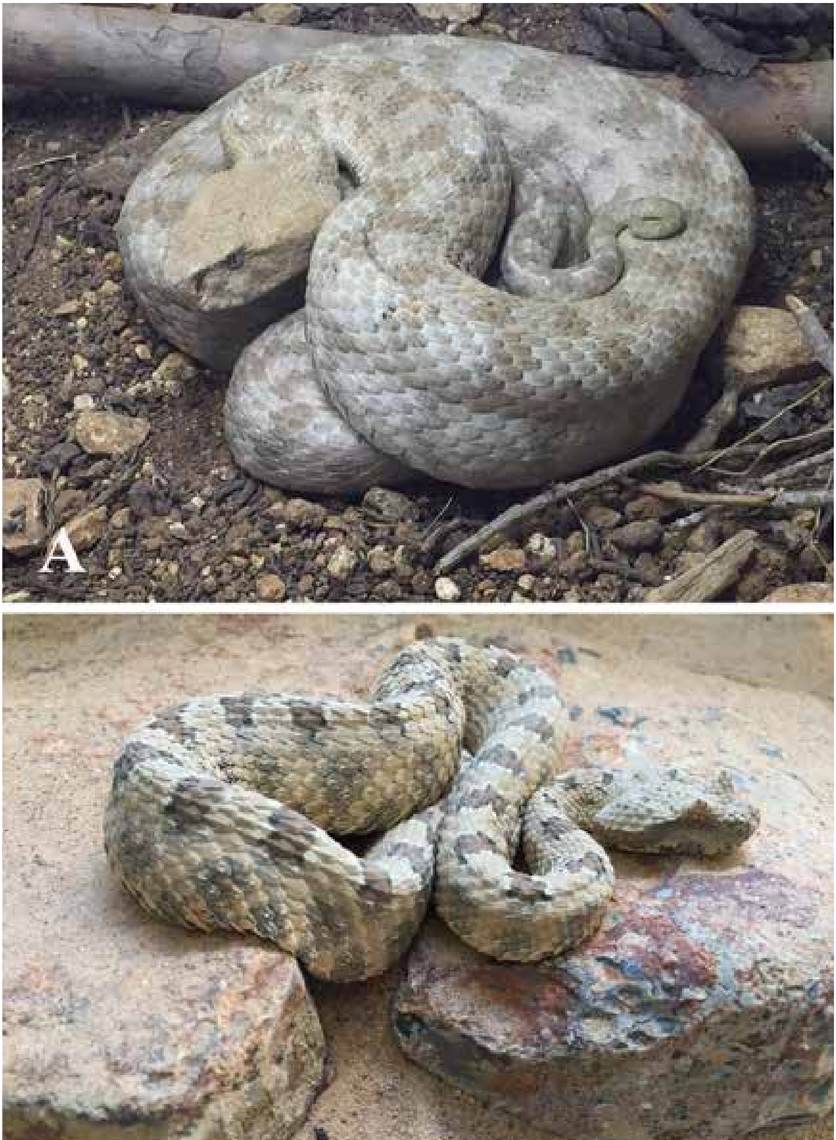

Figure 3: *A: Macrovipera lebetina obtusa* from Karka (Tafilah), B: *Pseudocerastes fieldi* from Wadi Al Ghadaf.

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Short Communication

First breeding record of Eurasian Sparrowhawk *Accipiter nisus* in northern Jordan

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The breeding distribution of the Eurasian Sparrowhawk *Accipiter nisus* extends over large areas of Eurasia, from Ireland (108W) to Kamchatka (1608 E) (Cramp and Simmons 1980, Ferguson-Lees and Christie, 2001). The Eurasian Sparrowhawk is the most abundant raptor species in Europe (BirdLife International 2018) with many northern populations migrating south to winter over a wide area including the Mediterranean, including Jordan and further south.

In Jordan, the species is a common winter visitor, and spring and autumn migrant (Andrews, 1995). It can usually be seen in Jordan from mid September to mid April, but there have been frequent records in May, and more recently, in late June near Tafeelah southern Jordan (El-moghrabi, pers. comm. 2017). The late summer records may indicate possible breeding in Jordan, especially as the Eurasian Sparrowhawk has been recorded breeding in a pine forest in north Palestine since 1989 (Frumkin and Adar, 1989).

On the 24th of June 2018, the Royal Society for the Conservation of Nature [RSCN] with the aid of the Royal Rangers [Environmental Police] followed up an online advertising five Eurasian Sparrowhawk chicks for sale (Fig. 1). The Royal Rangers confiscated these chicks and sent them to the RSCN, who reared them as orphan birds under a rehabilitation programme.

The authors tracked back the record and contacted the owner, who was helpful and showed the location and the nest used by the breeding birds. The birds had bred in Al-Se'enh village in the north of the country (Lat 32.521426°, Lon 35.741139), in a very narrow strip of pine forest at 400 metres elevation. The nest site was only 700 metres from a settlement (Fig. 2). The confiscated chicks were kept in captivity until the 12th September where they hacked back to the wild in similar habitats of pine forests near Amman.

This breeding record, together with those described by Frumkin and Adar (1989) in Palestine and the observations of El-moghrabi pers. comm. (2017) raises the possibility of further breeding in the forests of Jordan, especially pine forests like that at the Dibeen Forest Reserve, which is close to the recent breeding site.

Lehikoinen et al. (2010) studied the timing of migration (years 2007-1979), breeding phenology (2007-1979), and breeding success (2007-1973) of the Eurasian Sparrowhawk in Finland. Lehikoinen et al., (2010) concluded that the breeding success of Eurasian Sparrowhawks had increased significantly over the study period (2007-1973), but this was most likely caused by factors other than climate change, such as reduced exposure to organochlorine pollutants in Finland.

Figure 1: Five chicks of the Eurasian Sparrowhawk were offered for sale on the web.

In Jordan, the species could be a former breeder as suggested by Andrews (1995). It is not known if a former breeding population was affected by deforestation or habitat modification. A country-wide survey of potential breeding habitat is recommended, which should include the southern parts of the county indicated by the summer observations.

Figure 2: the small patch of pine forest where the Sparrowhawks bred successfully. The nest site is indicated by the black circle, and a close photo of the nest is inset.

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Short Communication

Further records of the Sand Cat, *Felis margarita*, from the eastern desert, Jordan

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The Sand Cat, *Felis margarita*, was recorded from Jordan based on an observation made by Mountfort (1965) in Wadi Rum during the Second Jordan International Expedition. Later, its presence was substantiated in Wadi Rum by finding a skull (Hemmer, 1978). Bunaian et al. (1998; 2001) reported a specimen around Qasr Burqu. It is currently considered rare, probably due to its largely nocturnal lifestyle and secretive habits, however it may well be more widespread than what records suggested.

Little is known about its habitat requirements and habits. The Sand Cat prefers sand deserts, inter-dune gravel flats, gravel/rocky and even volcanic lava fields and depressions without Acacia. It feeds primarily on small desert rodents, and to a lesser extent birds, reptiles and insects (Abbadi 1991; Bunaian et al. 1998; Cunningham, 2002). *Felis margarita* is a strictly nocturnal species; with most sightings between 00:00 and 06:00h (Ahmed et al., 2016). In Palestine, it was estimated that males have a territory of about 16 km² (Abbadi, 1991).

On 4.12.2016, while RSCN rangers were patrolling on a night shift near Abu Al Safa Dam (32.680393 N 38.115185 E), they encountered a Sand Cat at around 1 am (Fig. 1). The area enjoys lush vegetation with abundance of rodent burrows. Within the past two years, the Sand Cat was encountered by the RSCN rangers on several occasions around Burqu'a, east Al Rihsa, Lawrence Dam and Al Jua'baa N Burqu'a (Fig. 2).

It seems that the Sand Cat is common in the eastern desert of Jordan, and it coexists with other carnivores within the vicinity of Burqu'a including the Caracal, *Caracal caracal*, the Red Fox, *Vulpes vulpes*, the Sand Fox, *Vulpes rueppellii*, and the Striped Hyena, *Hyaena hyaena* (Amr, 2012).

The Sand Cat is listed as least concern in the in IUCN red list and in Appendix II of CITES. The Burq'a area is currently identified as a proposed protected area. The Sand Cat can be considered as a key species for this proposed protected area. Further monitoring should be conducted to explore more about the biology of this illusive species.

Figure 1. Sand Cat spotted in Abu Al Safa Dam © Nader Al-Gheiath

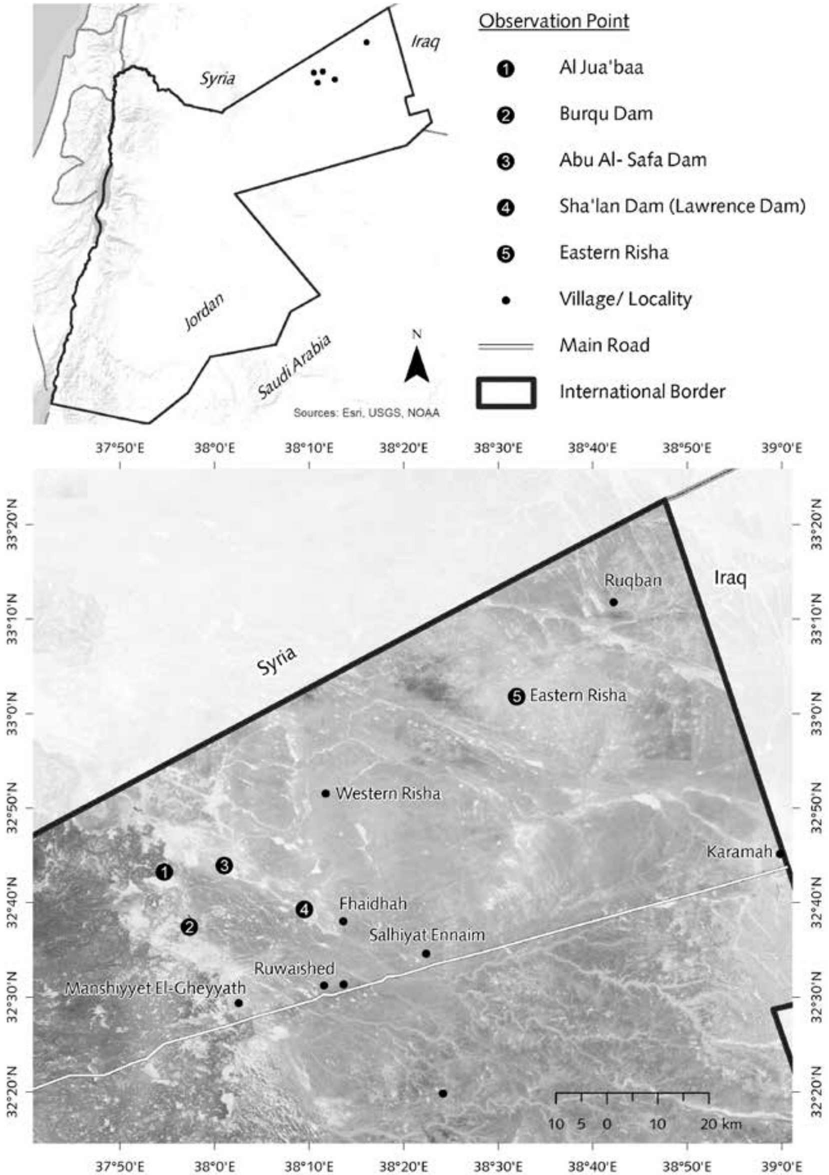

Figure 2. Sand Cat records at the eastern desert of Jordan.

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Is a national organization devoted to the conservation of Jordan's wildlife. It was founded in 1966 under the patronage of His Majesty the late King Hussein and has been given responsibility by the government to establish and manage protected areas and enforce environmental laws. As such, it is one of the few non-governmental organizations in the Middle East to be granted such a public service mandate.

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